Final Report

Task 1
Search and Review of Existing Information

For Project Entitled

Technical Assistance in Review and Analysis of Existing Data for Evaluation of Legacy Phosphorus in the Lake Okeechobee Watershed

Prepared for

South Florida Water Management District

by

Soil and Water Engineering Technology, Inc.

In association with

JGH Engineering

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Technical Assistance in Review and Analysis of Existing Data for Evaluation of Legacy Phosphorus in the Lake Okeechobee Watershed

Task 1: Search and Review of Existing Information

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1.0 INTRODUCTION

This is the initial report for the above referenced project to evaluate the legacy phosphorus (P) within the northern Lake Okeechobee watershed (Figure 1). Legacy P, as used in this study, is defined as any phosphorus within the watershed that is present as the result of anthropogenic activities and has a transport potential to the lake. The objective of this report is to document the issue associated with legacy P and to search and review available information on the subject. The literature and data search was focused on both spatially quantifying the legacy P within the watershed and understanding the transport mechanisms that influence its delivery to the lake. The methodology used for the literature and data search and a listing of the information found are presented. The data and information identified during this task will be further evaluated during Task 2 to determine if the current legacy P knowledge base is sufficient to identify abatement strategies or if additional information is needed. Depending on the Task 2 findings either a research or P abatement plan will be developed.

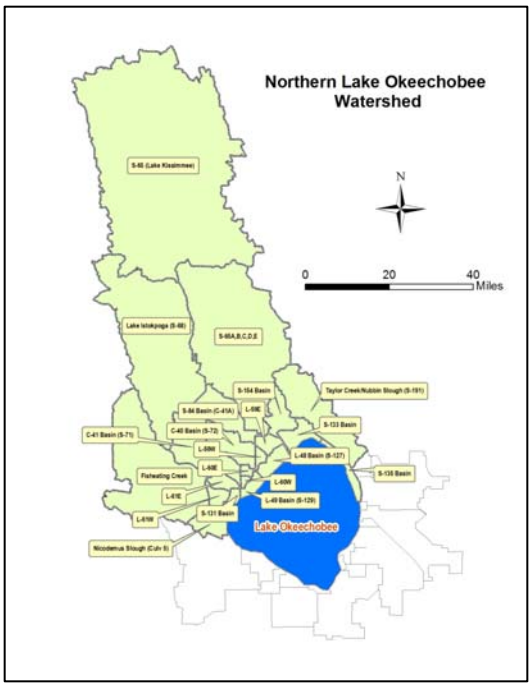

Figure 1. Project Basins in Northern Lake Okeechobee Watershed

1.1 DISCUSSION OF THE LEGACY P ISSUE

For several decades, Lake Okeechobee has experienced accelerated eutrophication due to excessive phosphorus loads from an agriculturally dominated watershed. This process encourages the formation of algal blooms, resulting in harm to other organisms. Lake Okeechobee's northern drainage area consists of 21 summary basins encompassing over 4,100 square miles (Figure 1). The majority of the phosphorus (P) loads are contributed from this northern drainage area (SFWMD, 2007) prompting the establishment by the Florida Department of Environmental Protection (FDEP, 2001) of a Total Maximum Daily Load (TMDL) target of 140 metric tons per year, which is well below the average measured load of 549 metric tons per year (1991 to 2005).

Current P loadings to the lake and P concentrations in the watershed north of the lake remain high despite voluntary and regulatory efforts to reduce P discharges from upland land uses. A better understanding of the fate and transport of P in the uplands, wetlands, ditches, and streams of the watershed is required in order that sufficient management strategies can be developed to lower P loadings sufficiently to meet the TMDL target by 2015.

Based on previous P budget studies in the watershed, a significant amount of imported P is retained in the soils and surface water sediments as a result of previous and current agricultural practices. It is possible and even likely that this P is migrating via ground water or re-suspension into the surface waters that lead directly to the lake. In order to accurately assess transport of P throughout the watershed and eventually into Lake Okeechobee, it is imperative to understand the storage and release properties of legacy P under unique soil and hydrologic conditions in the watershed. The remainder of this section will attempt to describe the issues and understanding of the legacy P pools and transport mechanisms in greater detail.

The legacy P within the Okeechobee basin was primarily sourced from animal feeds, fertilizers, domestic products, e.g. detergents, and human wastes (sewage and solid) that are either generated locally or imported. These sources ultimately manifest themselves in various storage pools of legacy P throughout the basin. For example, animal feed is a major input of P, but manifests itself in the watershed as animal manure deposition that then enters the various soil phosphorus pools. Fertilizer applications, either urban or agricultural, directly enter the various soil pools, while much of the urban, residential, and industrial wastes are be treated prior to being discharged or are placed in long-term storage facilities, such as landfills. Imported biosolids from waste treatment facilities and solid wastes from outside of the basin have also been significant sources of legacy P.

Figure 2 provides a generalization of how the P sources/pools are distributed among the major land categories within the basin. The relative scale/units of the plot is in terms of total mass of legacy P across the basin. Quantification of these pools is the primary focus of this project. As seen in Figure 2, the majority of the legacy P is stored in the upland soils as the result of direct deposits of fertilizer and manure and the fact that this component makes up the majority of the land area of the basin. To better track legacy P it has been referenced by its source and not by its final application form. The best example of this distinction would be for beef pastures where fertilizer is the primary source of legacy P and not the beef cattle manure deposition itself, i.e. the majority of the P within the beef manure is sourced from native soil and fertilizer P, not imported feed. Dairy cattle would be the opposite of beef cattle in that most of the P in their manure is sourced from imported feed versus fertilizer. The biosolids would primarily consist of imported municipal sludge that have been spread on pastureland around the basin. There is also a significant amount of P that would be trapped in the soils immediately around septic tank drain lines. The amount of septic drainfield sourced P reaching wetlands and streams would be minimal due to soil adsorption except for failed systems.

Over the years P from the uplands has washed into downstream ditches, wetlands, and streams. Significantly less P would be expected in these downstream systems than in the uplands because of the low fraction of P that can be washed out of upland soils on a yearly basis. The exception might be the isolated wetlands that dairies once used for cooling ponds/bogs. These highly impacted wetlands are the reason there are likely more feed/manure sourced legacy P in wetlands than fertilizer sourced P. Figure 2 also shows significant amounts of legacy P in containments, such as waste storage ponds on dairies, septic tanks, and landfills. Though these containment pools of P would not be considered legacy P by our definition because they have little or no direct transport potential to Lake Okeechobee, they can be a source of P that can be later

transferred to active legacy P pools that do have transport potential. Landfills are hopefully exceptions to this rule, but some of the older landfills could have existing transport potential.

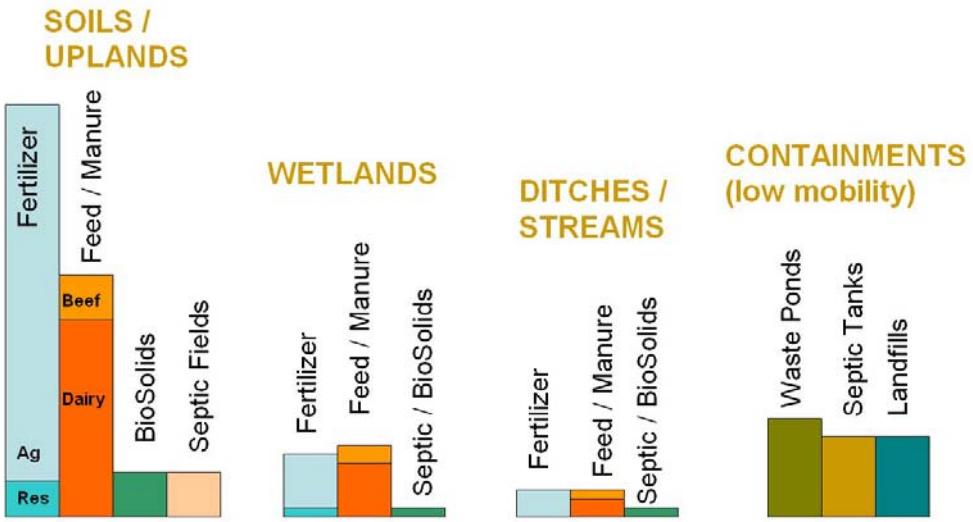

Figure 2. Conceptual View of Sources and Location of Legacy P

Figure 3 provides the primary forms and relative amounts on a per unit mass basis of P that are expected to be present in the profiles of the three major landscape categories in the basin for native/antecedent conditions versus the impacted condition with legacy P. The distribution shown is for the upper most layer of the soil or wetland system, but similar distribution could be developed for each layer of the soil. It is anticipated, though, that legacy P in these lower layers would only be important for moderate to well drained soils that have downward and lateral groundwater movement as shown in Figure 4. It is also anticipated that a majority of the P in the upland soils will be P adsorbed or bonded to soil particles where as the organic fraction of P is more important in the wetlands and water soluble P in the open streams. The adsorbed P will partition between the soil water and the particles at a ratio known as the "partitioning coefficient" in a rapid kinetic fashion where as the transformations between the other pools as shown in Figure 5 will be much slower. However, because the "partitioning coefficients" are relatively high (10 to 500), the adsorbed P can maintain high soil water P level for a long time because as the soil water P is flushed from the soil during drainage events it will be quickly replenished by the weakly adsorbed P, i.e. it could take many years to slowly reduce the adsorbed P levels, which is required to reduce P levels in runoff to native P levels unless the "partitioning coefficient" is altered by chemical means. The crop, temperature, pH, water and nutrient content, soil amendments, and redox potential all influence the transformation processes and, therefore, any land use practice causing a change in any of these factors will directly influence the P transformations and P pools, which in turn affects the mobility of P.

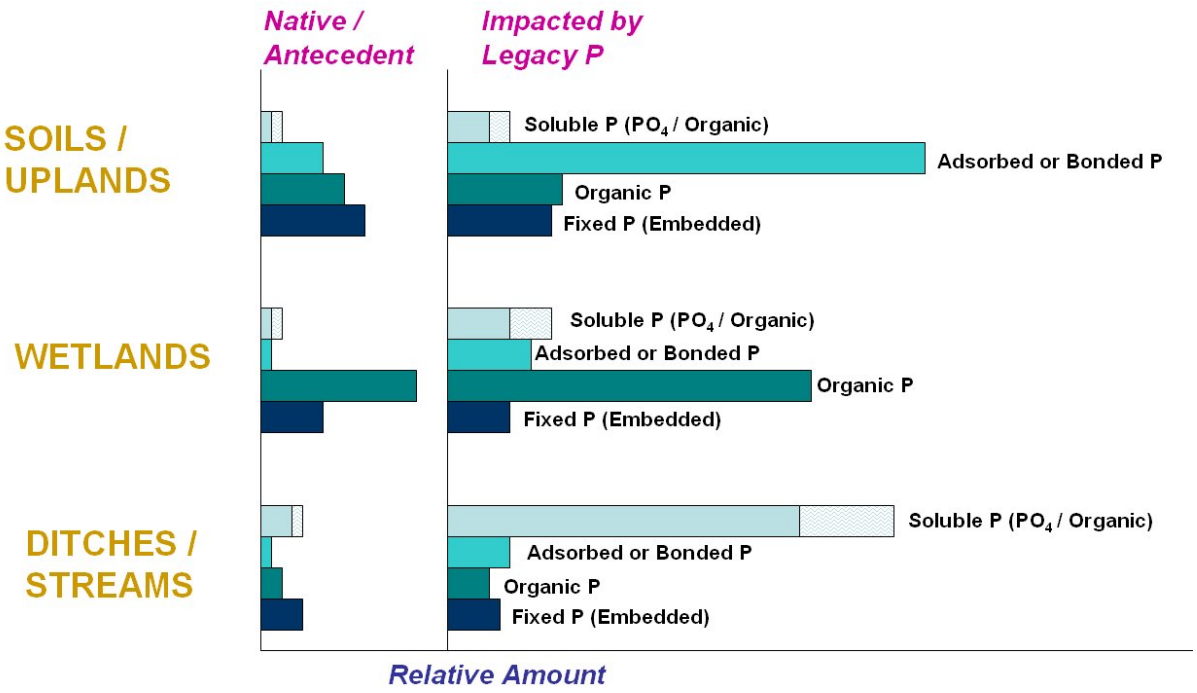

Figure 3. Relative Quantities of Legacy and Native P by Form and Landscape Feature

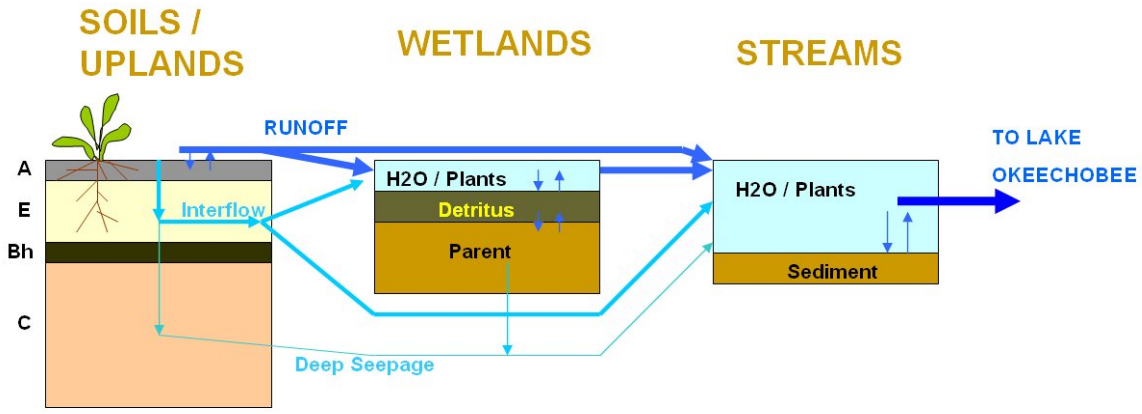

Figure 4. Flow Diagram of P Transport from Upland Soils to Lake Okeechobee via Wetland and Streams

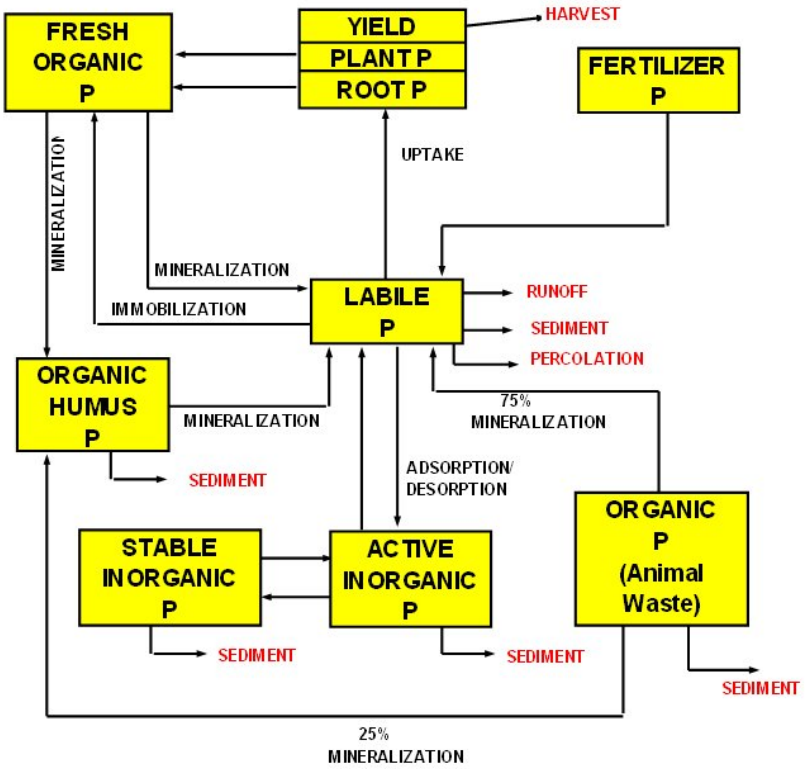

Figure 5. Phosphorus Pools and Transformations between Pools for a Soil/Plant System

As seen in Figure 4, the majority of the P transport from the upland soils and wetlands occur through surface runoff and therefore the P status in the upper most soil layer will have the greatest influence on P transport. For the few deeper more well drained soils, which proportionally have more infiltration and interflow/groundwater flow to neighboring streams or wetlands, the importance of the legacy P in deeper soil horizons is somewhat higher, but would have a relatively low impact on downstream loadings due to adsorption processes. Only the upper most soils zones are important for wetlands and streams.

Figure 4 also shows that a portion of the upland runoff will enter wetlands where its P can be taken up by the wetland plants and algae or can interact with the bottom sediment/detritus materials as it passes through. The P taken up by plants will eventually become organic detritus sediment as the plants die. The P transformation processes and pools, as shown in Figure 5, will determine the resulting balances between inflow and outflow P levels and the internal P pools. For example, if a wetland has been heavily loaded with P, then its detritus sediment may act as a P source as the P levels in the inflow waters are reduced. Similar processes are also present in the ditches, streams, sloughs, and canals, but will likely be less important than those in the upland soils and wetlands due to lower spatial extent and smaller detention times within these systems.

1.2 LIST OF P STUDIES/DOCUMENTS REVIEWED

The District has posed several important questions regarding legacy P in the Northern Lake Okeechobee watershed to be used as a basis of review and evaluation of existing literature on the topic. These questions are as follows:

1. What constitutes legacy P and how is it distributed within the different ecosystems (i.e. uplands, wetlands, ditches, streams) of the northern Lake Okeechobee watershed?
2. How is legacy P influenced by land use changes and landscape characteristics?
3. What are the sources and quantities of P imported annually into the northern watershed that influence the forms and spatial distribution of legacy P in Okeechobee soils?
4. What are the biogeochemical processes and soil parameters regulating storage and transport of legacy P within an ecosystem and between ecosystems (i.e. from uplands to wetlands to ditches/streams) in the watershed?
5. How do different landscape components differ in their ability to retain and release phosphorus? What are the soil properties, management practices, and environmental conditions that will control retention and release of P to drainage water?
6. What are the flow paths between uplands, wetlands, ditches and streams associated with surface and subsurface flows? What existing hydrologic/water quality models can be used to accurately predict the magnitude and rate of P loss via these transport processes?
7. How long will legacy P last as external P loads are reduced?
8. Given the timeframe it would take for P currently stored in the watershed to leach out, what management and predictive tools can be used for rapid implementation of practices to reduce P loads into Lake Okeechobee?

To find answers to these questions several sources were accessed including universities, journal databases, State agencies, environmental organizations and other experts in the field. Previous studies, peer reviewed publications and other relevant data were included in the search. Journal databases such as Cambridge Scientific Abstracts (CSA), National Center for Biological Information (NCBI) and ScienceDirect provided published papers of scientific research. A typical search query consisted of the following format and context:

Title = (phosphorus OR nutrient) AND Abstract(water OR sediment) AND (budget OR (mass balance) OR cumulative OR residual OR legacy OR leaching OR bmp OR abatement OR attenuation OR assimilation OR transport OR mobility OR losses)

In some of the larger national databases, additional criteria such as "AND Florida" and "Not mangrove" were applied to narrow the search results. The resulting titles were then reviewed to eliminate duplicates and documents with subjects that would not apply (such as marine systems). The results were downloaded via email or directly depending on the provisions of the source web site. Over 290 potential document references were obtained in this manner.

Since the references were obtained from various sources, it is possible that the same references exist in different source lists. Considering the total number of references obtained, it was

decided that a single database would be created to search for duplicates and to also expedite future evaluation of the references. The source lists were manipulated and formatted to provide a consistent set of database fields (Title, Source, Authors, Abstract, etc.). The abstracts/summaries were reviewed at this time to further narrow down the list of relevant documents. For example, some documents that appeared applicable based on their title, were found to be focused on other geographic regions with different environmental characteristics.

If readily available, the full text versions of the references were obtained. The file name (or an http location) was entered into the database to provide ready access to the full documents. Additional sources were found by reviewing the reference sections of several of the documents. Over 30 additional documents were found in this manner. Some of the documents were only available in hard copy format. This was noted in the database and summary information was manually entered. In all, over 150 records are included in the database (Appendix A).

Because of the scientific nature of this topic, the dominant source of information came from the University of Florida's Department of Soil and Water Sciences. Collectively, more than half of the documents, including dissertations, can be traced back to the faculty or students of this department. Many of the professors in the department, including Dr. Ramesh Reddy, Dr. Jack Rechcigl, Dr. Donald Graetz, Dr. Willie Harris, Dr. Vimala Nair and Dr. Rao S. Mylavarapu were contacted directly.

Previous studies provided insight into the hydrologic flow patterns and anthropogenic land use activities that characterize the watershed. Sediment and phosphorus budget studies represent important sources of information needed to begin understanding legacy P in the watershed. Available data were also identified that may be of use in answering the District's questions.

Brief descriptions of the types of literature and data found are provided below in relation to each question posed by the District. It is not the intent to answer these questions at this stage of the project, but simply to identify the informational resources. An overall evaluation of the information obtained will be conducted in the next task of the project where it will be determined if the questions can be answered.

1.2.1 Question 1

What constitutes legacy P and how is it distributed within the different ecosystems (i.e. uplands, wetlands, ditches, streams) of the northern Lake Okeechobee watershed?

The term "legacy P" is used in very few documents or publications. A paper written regarding an impoundment on the Illinois River (Haggard, et al. 2006) considered legacy P to be "sediments deposited over many years." The Audubon Society referred to it as the portion of P that was imported into the basin that stayed on the land, or at least, did not make it to the lake. They cited the first P budget conducted for the region (Boggess, 1995) which used the terminology, "net P import." The District used the term in their recent evaluation report for the Lake Okeechobee Protection Plan (SFWMD, 2007) in conjunction with "residual." There are several publications that use the terminology, "residual phosphorus," when referring to soil content. Though it is not clearly defined, the term is implied to mean the P in the soil that is not used by the plant.

For the purpose of this project, legacy P is considered to represent the phosphorus within the watershed that is present as the result of anthropogenic activities and has transport potential to Lake Okeechobee.

A valuable source of information regarding how legacy P, in terms of net P import, is potentially distributed within the watershed can be found in the P budget studies (Hiscock, et al. 2003) that were previously conducted. These studies include surveys of land use practices (as they relate to P import), which were used to develop net P import coefficients (e.g. kg/ha/yr). These coefficients were spatially applied to land use to quantify the annual mass of P remaining in the watershed. The methodology used for the distribution of P throughout the watershed is illustrated in Figure 2. It should be noted that the quantitative results from these studies were based on informational surveys averaged over land use and were not derived from any direct measurements of P in the soils or water body sediments.

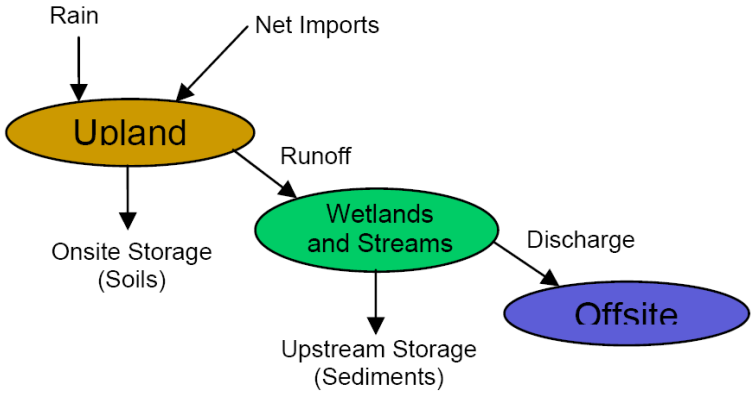

Figure 6. P Budget Distribution

In the early 1990's a P budget study was conducted for the northern Lake Okeechobee watershed (Boggess, et al. 1995). In 2002, an update of this study was conducted (Hiscock, et al. 2003). This update included the development of a graphical user interface (GUI), known as P-Budget, written in ArcView™ (Version 3.2a) Avenue™. This interface allows a user to select one or more (or all) basins of the watershed within a Geographical Information System (GIS) environment and apply phosphorus controls to specified land uses to assess the effects on phosphorus import, export and net import.

In 2003, a similar phosphorus budget analysis was conducted of the basins located within the Lake Istokpoga and Upper Chain of Lakes watersheds (Mock-Roos, et al. 2003). These watersheds were added to the P-Budget interface. The interface was updated at this time to include the phosphorus runoff results from the public domain WAMView model to replace the Event Mean Concentration (EMC) approach used in the northern Lake Okeechobee watershed. WAMView is a physical-based model that uses site-specific information such as soils, rainfall, fertilization practices, and location within the watershed to estimate phosphorus concentrations of both direct runoff and attenuated discharge to the lake. In 2005, the analysis was expanded to include the entire Lake Okeechobee Protection Plan (LOPP) area (JGH, et al., 2005) and the previous GUI was upgraded for ArcGIS™ and Visual Basic for Application (VBA).

Wetlands and streams were combined in the P budget analyses, but could potentially be separated using information from a study conducted in the mid 1990's to assess the feasibility of P removal in the tributaries to the lake (Mock-Roos, et al. 1997). This study included sampling of sediments in streams.

1.2.2 Question 2

How is legacy P influenced by land use changes and landscape characteristics?

The influence of land use activities on net P import is covered extensively in the previous P budget studies as discussed above. Changes in the annual net P import would be directly affected by the changes in land use. The effect of land use change on accumulated P is less clear with very few studies specifically addressing this issue. The studies (EWR, et al., 2003, SWET, et al., 2001) do produce a good indication of legacy P impacts on dairies that were converted to other land uses, such as beef pastures or row crop. These studies clearly found that the rate of accumulation or reduction of legacy P changes as land use changes. In general, legacy P changes slowly over time and therefore as land uses change no dramatic changes in legacy P are expected, depending on hydrology and soils of the area. However, these studies did indicate that changes in drainage and cropping patterns will influence the rate of P transport from the land as associated with the legacy P.

Numerous studies associate landscape characteristics, such as soil type, crop and drainage patterns, presence of wetlands, etc. These will be evaluated based on these characteristics influence on transport processes.

1.2.3 Question 3

What are the sources and quantities of P imported annually into the northern watershed that influence the forms and spatial distribution of legacy P in Okeechobee soils?

The P budget studies, as discussed above, include surveys of land use practices (as they relate to P import), which were used to develop net P import coefficients. These coefficients were spatially applied to land use to quantify the annual net P in the watershed. The studies identify the sources of P import (fertilizer, feed, etc.) and spatially quantify the annual amount of net P import.

Quantification of accumulated legacy P could be estimated based on the annual imports applied to temporal land use. GIS land use coverages are only available dating back to 1988 in the watershed. However, staff at FDACS are knowledgeable of changes that have occurred over the years before 1988 including locations of old dairies and row crops.

Verification of the forms and quantities of legacy P can be performed by comparing soil tests to the P budget estimates. An extensive amount of soil testing has been performed by the University of Florida's soils laboratory throughout the watershed for various projects. Dr. Rao S. Mylavarapu, who heads the lab, has been contacted and has indicated that this information may be available.

1.2.4 Question 4

What are the biogeochemical processes and soil parameters regulating storage and transport of legacy P within an ecosystem and between ecosystems (i.e. from uplands to wetlands to ditches/streams) in the watershed?

There are several sources of information found in this regard. A series of study reports and research papers were developed under the major project funded by the SFWMD named Biogeochemical Behavior and Transport of Phosphorus in the Okeechobee Basins. The principle investigator was Dr. Campbell at the University of Florida, but several other professors have been involved. Hard copies of some of the project reports have been obtained (Graetz, et al. 1990). Much of the research has been published and obtained through our literature review. The study examined existing levels of water-soluble, double-acid (0.05 M HCl in 0.025 M H_2SO_4) extractable and total phosphorus in soils of selected dairies in the watershed.

A report titled "The importance of considering biological processes when setting total maximum daily loads (TMDL) for phosphorus in shallow lakes and reservoirs" (Havens, et al. 2001) considers how biological processes (including those related to algae, plants, invertebrates and fish) can influence the ability of water bodies to assimilate P. A publication titled "Phosphorus transport in Spodosols impacted by dairy waste" (Mansell, et al. 1995) examines the soil properties in relation to the transport of P.

"Assessing phosphorus 'change points' and leaching potential by isotope exchange and sequential fractionation" (Blake, et al. 2002) and "Development of an indicator for risk of phosphorus leaching" (Hesketh, et al. 2000) examine the influences on the Olsen-P concentration (usually termed the 'Change Point') at which the rate of P leaching from soil suddenly increases and poses a greater threat of eutrophication. Several publications focus specifically on dairy-impacted soils (Wang, et al. 1995; Nair, et al. 1995; Graetz, et al. 1995 & 1999; Villapando, et al. 2001 and Pant, et al. 2002). A paper titled "Associated Release of Magnesium and Phosphorus from Active and Abandoned Dairy Soils" compared the chemical characteristics of active and abandoned dairy manure-impacted soils and minimally impacted soils and to assess the continuous release of P.

Work in regard to P retention and saturation indexes has been performed by the University of Florida (Rhue, et al. 1994; Nair, et al. 1999, 2002, 2003 & 2004 and Chrysostome, et al. 2007) that relates the P adsorption capacity to soil properties.

The transport process of P in streams and wetlands is discussed in several documents (Reddy, et al. 1992 & 1996; Pant, et al. 2001; Mock-Roos, 1997 and Gathumbi, et al. 2005).

1.2.5 Question 5

How do different landscape components differ in their ability to retain and release phosphorus? What are the soil properties, management practices, and environmental conditions that will control retention and release of P to drainage water?

P uptake of various crops and grasses has been documented in the P budget studies discussed above. The dynamics of wetland vegetation in terms of P is discussed in several sources (Knight, et al. 2003; Moustafa, et al. 1998 and Pant, et al. 2003). A paper by Dr. Rechcigl and Dr. Bottcher examines the fate of phosphorus on bahiagrass pastures (Rechcigl, et al. 1995).

Several methods have been documented to control the retention and release of P in the sandy soils of the Lake Okeechobee watershed. Many papers discuss the use of constructed wetlands or agroforestry to remove P (Pant, et al. 2002 & 2003; Reddy, et al. 2004; Anbumozhi, et al. 2005 and Nair, et al. 2004 and 2007-in press).

Drinking water residuals or chemical amendments have also been examined (Ann, et al. 2000; Hall, et al. 2004; Miyittah-Kporgbe, et al. 2004 and Rew, 2006). Best management practices (BMPs) have been used and are well documented (Bottcher, et al. 1995; Gilliam, 1995; Rice, 1998; Zhang, et al. 2002). Typical BMPs deal with soil fertility (banding, split application, etc.) and manure management (fencing, composting, etc.). Other BMPs involve the use of wetlands, buffer strips and chemical "edge of farm" treatment. Several management practices were studied at the Buck Island cattle ranch (Campbell, et al. 2003; Zhang, et al. 2006) including animal density and detention.

1.2.6 Question 6

What are the flow paths between uplands, wetlands, ditches and streams associated with surface and subsurface flows? What existing hydrologic/water quality models can be used to accurately predict the magnitude and rate of P loss via these transport processes?

The surface flow paths are known as a result of previous modeling efforts in the watershed. It has been generally accepted in that the surface and subsurface flow occur in the same direction and that subsurface flow will enter the nearest stream, ditch or canal. The Field Hydrologic and Nutrient Transport Model (FHANTM) has been applied to the northern Lake Okeechobee watershed (Campbell, et al. 1995; Zhang, et al. 1996) along with the Lake Okeechobee Agricultural Decision Support System (LOADSS) model (Negahban, et al. 1995). The Watershed Assessment Model (WAM) has been used in the northern Lake Okeechobee, Lake Istokpoga and Upper Kissimmee watersheds (HDR, et al. 2003) and has been tied into the P-Budget model interface (JGH, et al. 2005). It also has been used at a farm-scale on individual dairies (SWET, 2003).

1.2.7 Question 7

How long will legacy P last as external P loads are reduced?

This is the perhaps the most important and challenging question to be addressed. Several of the soils studies reported in Question 6 may be useful in developing seepage rates. Most of the P leaching is occurring on active or abandoned farms where the subsurface flow does not have far to travel before emerging to a stream, ditch or canal.

Some papers have been written regarding the measurement of P seepage into existing water bodies including the use of seepage meters (Belanger, et al. 1985; Kang, et al. 2005). Models have been used to estimate P leaching. A retardation based transport model (Rhue, 2006) simulates P leaching through soil using soil bulk density, volumetric water content, solution P concentration, and column length as inputs.

1.2.8 Question 8

Given the timeframe it would take for P currently stored in the watershed to leach out, what management and predictive tools can be used for rapid implementation of practices to reduce P loads into Lake Okeechobee?

Many of the management practices discussed in Question 5 to control P retention could also apply to this question, particularly the use of chemical additive to bind P to the soils. Predictive modeling tools include P-Budget (JGH Engineering, et al. 2005), LOADSS (Negahban, et al. 1995), WAM (SWET, 2003) and GIDM (Fraisse, et al. 1996). P-Budget, LOADSS, and WAM each provide a means to change land use practices, but may require modifications to include new control techniques.

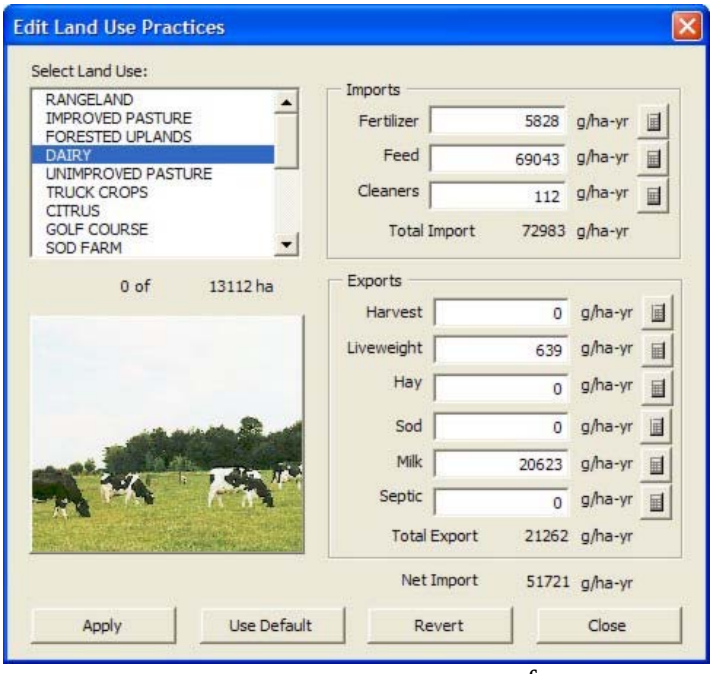

Figure 7. P-Budget Graphical User Interface

The graphical user interface for P-Budget provides the ability to create Phosphorus Control Plans (PCPs). After creating a new or opening an existing PCP, a form will appear for editing the phosphorus coefficients associated with a selected land use (Figure 3). Calculator buttons are provided for each import/export component. Each button opens a unique form designed to assist the user in applying changes (e.g., P content of fertilizer, application rates, etc.). P-Budget runs on ESRI™'s ArcGIS 9.1 GIS software.

LOADSS and WAM are similar in that they employ a GIS-based interface for users to select alternative land uses and land management practices for comparison. LOADSS was developed by the University of Florida IFAS in association with the District. It uses the CREAMS-WT water quality assimilation model to estimate average annual P runoff loads generated at the source, whereas, WAM uses GLEAMS and EAAMOD. Both programs include attenuation algorithms to simulate the effects of overland and stream flow. LOADSS includes an optimization model for users to evaluate tradeoffs between various environmental and economic issues. WAM includes time-series hydrologic modeling to assess long-term changes. LOADSS and WAM run on older unix versions of ESRI™'s ARC/INFO GIS software. WAM also runs on older PC versions of ESRI™'s ArcView GIS software, but is currently being updated to run on the latest version of ArcGIS.

GIDM (Generic Interactive Dairy Model) is another GIS-based model that was developed by the University of Florida specifically for dairy waste management analysis. GIDM is a tool for creating alternative field level dairy waste management plans and evaluating the effects of such plans on surface and ground water quality. GIDM employs the GLEAMS water quality model and runs on older unix versions of ARC/INFO (Figure 4). Although this model only addresses dairy land uses, dairies have been identified as a major source of net P import (Boggess, et al. 1995; Hiscock, et al. 2003) to the watershed.

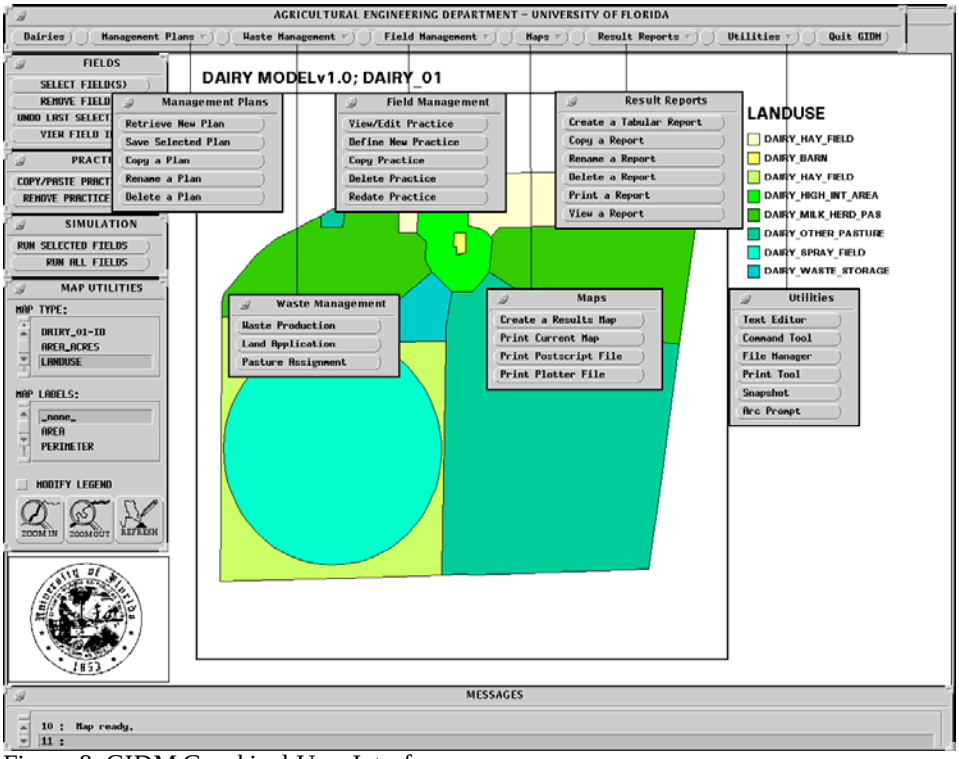

Figure 8. GIDM Graphical User Interface

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APPENDIX A

Documents Related to Legacy P

Title:	Phosphorus budget—land use relationships for the northern Lake Okeechobee watershed, Florida
Source:	Ecological Engineering, Volume 21, Issue 1, November 2003, Pages 63-74
Authors:	Hiscock, J.G., C.S. Thourot and J. Zhang
Document:	Hiscock P-Budget 2003.pdf
From:	ScienceDirect
District Question:	1,2,3
Abstract:	Phosphorus losses by surface runoff from agricultural lands have been of public concern due to increasing P contamination to surface waters. Five representative commercial citrus groves (C1–C5) located in South Florida were studied to evaluate the relationships between P fractions in soils, surface runoff P, and soil phosphatase activity. A modified Hedley P sequential fractionation procedure was employed to fractionate soil P. Soil P consisted of mainly organically- and Ca/Mg-bound P fractions. The organically-bound P (biological P, sum of organic P in the water, NaHCO3 and NaOH extracts) was dominant in the acidic sandy soils from the C2 and C3 sites (18% and 24% of total soil P), whereas the Ca/Mg-bound P (HCl-extractable P) accounted for 45–60% of soil total P in the neutral and alkaline soils (C1, C4 and C5 soils). Plant-available P (sum of water and NaHCO3 extractable P fractions) ranged from 27 to 61 mg P kgK1 and decreased in the order of C3>C4>C1>C2>C5. The mean total P concentrations (TP) in surface runoff water samples ranged from 0.51 to 2.64 mg LK1. Total P, total dissolved P (TDP), and PO4 3K-P in surface runoff were significantly correlated with soil biological P and plant-available P forms (p! 0.01), suggesting that surface runoff P was directly derived from soil available P pools, including H2O– and NaHCO3– extractable inorganic P, water-soluble organic P, and NaHCO3- and NaOH-extractable organic P fractions, which are readily mineralized by soil microorganisms and/or enzyme mediated processes. Soil neutral (55–190 mg phenol kgK1 3 hK1) and natural (measured at soil pH) phosphatase activities (77–295 mg phenol kgK1 3 hK1) were related to TP, TDP, and PO4 3K-P in surface runoff, and plant-available P and biological P forms in soils. These results indicate that there is a potential relationship between soil P availability and phosphatase activities, relating to P loss by surface runoff. Therefore, the neutral and natural phosphatase activities, especially the natural phosphatase activity, may serve as an index of surface runoff P loss potential and soil P availability.

Title:	Long-term phosphorus removal in Florida aquatic systems dominated by submerged aquatic vegetation
Source:	Ecological Engineering, Volume 20, Issue 1, March 2003, Pages 45-63
Authors:	Knight, R.L., B. Gu, R.A. Clarke and J.M. Newman
Document:	Knight Long-term P removal 2003.pdf
From:	ScienceDirect
District Question:	5
Abstract:	Anthropogenic phosphorus (P) loads have been implicated in eutrophication of lakes and wetlands throughout Florida. One technology that holds considerable promise for controlling these loads in a cost-effective manner is the use of treatment wetlands. Preliminary research in south Florida on the use of submerged aquatic vegetation (SAV) as the dominant vegetation in these treatment wetlands is reporting higher P removal performance than wetlands dominated by rooted, emergent plants. This research has been based to-date primarily on relatively small-scale mesocosms (5–2000 m2) and on a larger scale treatment wetland (148 ha) that has been operated for about 7 years. Considering the magnitude of engineering decisions and project costs to implement P control in the Everglades Agricultural Area and elsewhere in Florida, it is prudent to look for additional confirmation of P removal performance from other existing SAV-dominated systems in Florida that have a longer operational period. This paper describes an analysis of existing data collected from a number of SAV-dominated, flow-through lakes and rivers in Florida with characteristics similar to the proposed SAV treatment systems. While these existing input–output data were not specifically collected for the purpose of preparing mass balances and P removal rate estimates, they can be judiciously applied to that analysis. The overall conclusion of this analysis is that SAV-dominated lakes and rivers do typically remove P from the water column. The likely long-term sink for this P is the newly accreted sediment. The long-term average P removal rate for 13 SAV-dominated lake and river systems in Florida was 1.2 g/m2 per year. This result compares favorably with an average net sediment P accumulation rate of 1.2 g/m2 per year reported by others for 11 SAV-dominated Florida lakes. These estimated long-term P removal rates are higher than those for full-scale wetlands dominated by emergent vegetation (Treatment Wetlands (1996); Wetlands Ecol. Mgmt. 4 (1997) 159). Average first-order P removal rate constants for SAV-dominated lakes (15 m/year) and rivers (46 m/year) are generally less than those estimated in SAV-dominated mesocosms (60–140 m/year) and similar to a large-scale SAV-dominated stormwater treatment area (STA) (40 m/year). P removals in all of these SAV-dominated systems are influenced by inlet P loading rates, with removal rates positively correlated to both P inlet concentration and hydraulic loading rate (HLR). Based on this analysis, caution is recommended when extrapolating the P removal results from relatively short-term or small-scale mesocosm studies to the design of full-scale, long-term operating SAV-dominated wetlands.

Title:	The importance of considering biological processes when setting total maximum daily loads (TMDL) for phosphorus in shallow lakes and reservoirs
Source:	Environmental Pollution, Volume 113, Issue 1, June 2001, Pages 1-9
Authors:	Havens, K.E., and C.L. Schelske
Document:	Havens Importance of considering biological 2001.pdf
From:	ScienceDirect
District Question:	4
Abstract:	Total maximum daily loads (TMDL) are required by the US Environmental Protection Agency for pollutants that have impaired the designated uses of surface waters in the nation. Setting an appropriate TMDL requires quantitative information on both the external pollutant inputs and the processes affecting pollutant dynamics within the ecosystem. Here we focus on phosphorus (P), a globally important pollutant of freshwater lakes. We consider how biological processes (including those related to algae, plants, invertebrates and fish) can influence the ability of lakes to assimilate P, and in turn the ability of managers to select appropriate TMDLs. The primary focus is on shallow eutrophic lakes, with Lake Okeechobee (Florida, USA) serving as a case study. The paper deals only with in-lake processes as they relate to setting the TMDL and not the subsequent issue of load allocation among pollution sources. The results indicate that the ability of a shallow lake to assimilate P is substantially reduced when surplus levels of P occur in the water column, the phytoplankton becomes dominated by cyanobacteria, the benthic invertebrate community becomes dominated by oligochaetes, and submerged plant biomass is low. If some of these biological changes can be reversed in a rehabilitation program then the lake may be able to support a higher TMDL.

Title:	A preliminary modeling analysis of water quality in Lake Okeechobee, Florida: Diagnostic and sensitivity analyses
Source:	Water Research, Volume 29, Issue 12, December 1995, Pages 2767-2775
Authors:	Bierman, V.J., and R.T James
Document:	Bierman Prelim modeling analysis 1995.pdf
From:	ScienceDirect
District Question:	6
Abstract:	A deterministic mass balance model for nutrient and phytoplankton dynamics was previously developed and calibrated to a comprehensive set of field data for Lake Okeechobee. In the present study, diagnostic and sensitivity analyses were conducted with the calibrated model to better understand factors controlling phytoplankton and load-response dynamics in the lake. Phytoplankton growth rate limitation due to underwater light attenuation appears to be substantially greater than growth rate limitation due to non-optimal phosphorus concentrations. Phytoplankton biomass appears strongly controlled by the supply rate of dissolved available phosphorus to the water column. The dynamics of total phosphorus and chlorophyll a concentrations in the lake are strongly influenced by sediment-water phosphorus fluxes. There is a wide range of uncertainty in responses of total phosphorus and cholorophyll a concentrations to changes in tributary phosphorus loadings. Much of this uncertainty is due to a lack of quantitative understanding of sediment responses to changes in tributary loadings. Other important factors are inter-annual variability in hydrometeorological conditions and the potential influence of wind-induced resuspension of particulate phosphorus. Responses of total phosphorus and chlorophyll a concentrations for a given change in tributary loading depend not only on the magnitide of the loading change, but also on the time frame after the loading change due to a lag in sediment response. Load-response predictions for Lake Okeechobee must take into account changes in available phosphorus loadings to the water column, and must be premised on assumptions for changes in internal phosphorus loadings from the sediments. Results from this preliminary modeling analysis are provisional in that they do not include potential nitrogen limitation, potential interactions between phosphorus and nitrogen, or phytoplankton responses to potential nitrogen fixation.

Title:	Phosphorus transport in Spodosols impacted by dairy waste
Source:	Ecological Engineering, Volume 5, Issues 2-3, November 1995, Pages 281-299
Authors:	Mansell, R.S, S.A. Bloom and P. Nkedi-Kizza
Document:	Mansell Phosphorus transport in Spodosols 1995.pdf
From:	ScienceDirect
District Question:	4
Abstract:	Deposition of P-laden dairy waste onto acid, sandy Spodosols located in the Lake Ocheechobee Basin in south Florida is commonly recognized to increase levels of P in soil profiles, groundwater, and local streamflow. In the soil profile, P accumulations occur in the surface A horizon, to a lesser extent in the E horizon, and to a much greater extent in the reactive Bh or spodic horizon. A one-dimensional mathematical model was used to demonstrate sorption and transport of P vertically through a 90-cm profile of an initially P-free Spodosol with A (0–15 cm), E (15–75 cm), and Bh (75–90 cm) horizons for conditions of steady, saturated water flow. Ten pore volumes (equivalent of 2.5 years of rainfall) of P-laden influent was applied before applying 40 volumes (equivalent of 10 years of rainfall) of P-free water. The loading of P in the influent was shown to greatly impact P transport during water flow in the soil. As expected, nonlinear sorption resulted in much greater retardation of P breakthrough in the soil effluent for the lowest influent concentration of 10 g m−3 than for either 100 or 1000 g m−3 concentrations. An underlying assumption in the model was that multi-dimensional water flow could be ignored. However, multi-dimensional flow under field conditions may well result in partial bypass of flow around highly consolidated Bh horizons.

Title:	Surface /subsurface hydrology and phosphorus transport in the Kissimmee River Basin, Florida
Source:	Ecological Engineering, Volume 5, Issues 2-3, November 1995, Pages 301-330
Authors:	Campbell, K.L., J.C. Capece and T.K. Tremwel
Document:	Campbell Surface-subsurface hydrology and P transport 1995.pdf
From:	ScienceDirect
District Question:	6
Abstract:	A comprehensive research program was conducted to enhance understanding of the hydrologic and phosphorus movement relationships of flat, sandy, high-water-table soils pervasive in the Kissimmee River Basin Region of Florida which drains into Lake Okeechobee. This region generates high phosphorus loads into the lake relative to other basins, causing environmental concerns. Field instrumentation and monitoring wells were installed at four experimental pasture sites in the Kissimmee River Basin to conduct research concerning water and phosphorus movement in flat, sandy, high-water-table soils. The focus was to obtain hydrologic /water quality data sufficient to determine surface /subsurface flow partitioning, and thus phosphorus flowpaths from the land phase to stream channels. A field-scale model was developed to simulate water and phosphorus movement from individual fields. This model, named FHANTM, is based on DRAINMOD with modifications to include simulation of phosphorus movement and routing of overland flow. The field monitoring data were used to calibrate and verify the modified model. This model was developed for use in predicting the effects on phosphorus movement to streams from application of management practices on the dairies.

Title:	Fate and transport of phosphorus in the Lake Okeechobee Basin, Florida
Source:	Ecological Engineering, Volume 5, Issues 2-3, November 1995, Pages 331-339
Authors:	C. T. Haan
Document:	Haan Fate and transport of P 1995.pdf
From:	ScienceDirect
District Question:	4,6
Abstract:	Recent water quality problems in Lake Okeechobee are thought to be related to agricultural activity in the drainage basins of the lake that introduce significant quantities of phosphorus into its hydrologic cycle. Under the sponsorship of the South Florida Water Management District, a large research program has been undertaken to identify the specific activities contributing phosphorus to the lake, quantify the magnitude of this contribution, gain an understanding of phosphorus behavior in the basin and quantify the fate and transport of phosphorus within the basin. This paper summarizes current understanding of the fate and transport of phosphorus in the Lake Okeechobee basin with specific reference to recently completed research.

Title:	Best management practices for water quality improvement in the Lake Okeechobee watershed
Source:	Ecological Engineering, Volume 5, Issues 2-3, November 1995, Pages 341-356
Authors:	Bottcher, A.B., T.K. Tremwel and K.L. Campbell
Document:	Boucher BMPs for WQ improvement in the Lake O 1995.pdf
From:	ScienceDirect
District Question:	5
Abstract:	A significant amount of work has been done in the Okeechobee/Everglades Dept., in south central Florida to understand and control the nutrient inputs to Lake Okeechobee, the Everglades, and surrounding estuaries. Phosphorus (P) control has been the primary focus of these studies because P has been found to be the limiting nutrient for the accelerated eutrophication of these aquatic systems. The watersheds of these systems are dominated by beef and dairy operations north of Lake Okeechobee and vegetables and sugarcane south of the Lake. As a result, most of the research activities have focused on agricultural transport processes and control practices (known as best management practices or BMPs) for P discharge. This paper focuses on the BMPs that have been developed for agricultural water quality control in south Florida. BMPs are discussed from the perspectives of conceptual operational theory and field evaluation data, as well as practical in-field design constraints. An itemized listing of the proposed BMPs is also presented, as well as a discussion of implementation strategies.

Title:	Groundwater seepage nutrient loading in a Florida Lake
Source:	Water Research, Volume 19, Issue 6, 1985, Pages 773-781
Authors:	Belanger, T.V., D.F. Mikutel and P.A. Churchill
Document:	
From:	ScienceDirect
District Question:	7
Abstract:	Twenty-five seepage meters were positioned in East Lake Tohopekaliga, Florida, to determine groundwater seepage contributions of water and nutrients to the lake in 1983. Seepage was found to be an important source of water to the lake, contributing 14.3% of the water sources, and rates decreased significantly ($P < 0.01$) with distance from shore. A comparison of the piezometer and seepage meter techniques for measuring nutrient loading to the lake indicates the direct seepage meter technique overestimated nutrient inputs due to the enclosure to the sediments, possibly resulting in anaerobic conditions and increased release rates of ammonium nitrogen and phosphate. These results suggest that past studies employing this technique may be in error. Nutrient loading, calculated from piezometer nutrient data and seepage meter flow data, show that the groundwater nutrient loading in the lake was significant, contributing 8.7 and 17.6% of the total phosphorus and total nitrogen inputs to the lake, respectively.

Title:	P-budget basin relationships for Lake Okeechobee tributary basins
Source:	Ecol. Eng. 5 (1995), pp. 143–162
Authors:	Boggess, C.F., E.G. Flaig and R.C. Fluck
Document:	Boggess P budget–basin relationships 1995.pdf
From:	ScienceDirect
District Question:	1,2,3
Abstract:	Accelerated cultural eutrophication of Lake Okeechobee, FL by excessive phosphorus (P) loading has generated a need to determine P sources and sinks in the watershed. Average annual P budgets were estimated for each of the 19 tributary basins in the northern Lake Okeechobee watershed for the period 1985-1989. Net P imports were estimated based on P usage by land use type, and land use area with a geographic information system (GIS) model. Off-site P losses, from uplands to wetlands, were estimated from literature values of P runoff concentrations for selected land use types. The P loads from each basin were measured at the discharge to the lake. For the north Okeechobee watershed, total net P imports were estimated at 2380 t P yr-t; rainfall P = 300 t P yr-l; off-site P load = 760 t P yr-~; and lake P load = 300 t P yr -t. An estimated 90% of imported P was retained in the basin. Of the P loaded to the streams and wetlands, 60% was retained. The intensity of phosphorus use, indicated by net P imports, explained 70% of the variability in basin P loads to the lake. Basin characteristics extracted from the GIS database, including: area of emergent wetlands; area of selected soil associations; area of developed land; and total length of canals were correlated significantly with tributary P loads. Other physical characteristics, such as basin shape, length, size, and distance to the lake, had no significant explanatory power.

Title:	A summary of landowners surveys and water quality data from improved pasture sites in the northern Lake Okeechobee watershed
Source:	Appl. Eng. Agric.15 2 (1999), pp. 121–127.
Authors:	S. Gornak and J. Zhang
Document:	Zhang A summary of landowners surveys 1999.pdf
From:	SFWMD
District Question:	1
Abstract:	In the last 25 years, Lake Okeechobee has experienced an accelerated rate of eutrophication due to agricultural practices ill the watershed. In response to this problem, a regulatory program was implemented to limit the total phosphorus (TP) concentrations in runoff. The TP in runoff from improved pasture areas was limited to 0.35 rng/L. To gain information about typical beef cattle management practices on improved pastures and the impact of these practices on water quality, a survey was conducted on ranches in the Lake Okeechobee watershed, and results from other studies were examined. Information from this survey indicated that the average stocking rate decreased from 1.25 animal unit/ha (0.51 animal unit/acre) in 1989 to 1.01 animal unit/ha (0.41 animal unit/acre) in 1996. The average stocking rate for the ranches surveyed for the 8 year period was 1.12 animal unit/ha (0.45 animal unit/acre). Historically, the stocking rates have varied from one animal unit per acre to one animal unit per four acres. The phosphorus fertilization rate ranged from 0 kg/ha-yr (0 lb P/acre-yr) to 29.87 kg/ha-yr (26.4 lb P/acre-yr). Ten of the eleven surveyed ranches feed their cattle a supplement for a couple months out of the year. The most common supplement type was rnolasses. Bahiagrass was the most common grass type grown on the ranches. In addition to the survey, water quality data from 69 improved pasture sites were analized. Although the seven year average TP concentration from the Works of the District (WOD) samples was 0.45 mg/L. and 37 of the 69 sites had period of record averages greater than the limit, 59% of the individual samples collected were less than the 0.35 mg/L limit. The median of the 2,663 samples collected was 0.29 mg/L and the mode was 0.09 mg/L. This indicates that the ranches have the potential to achieve the WOD limit. Additional analyses should be conducted on farms that are meeting the limit. The results could be used to help the ranchers with farms that are out of compliance to determine how to change their management practices to meet the limit.

Title:	Phosphorus budget update for the northern Lake Okeechobee watershed. Final Project Report to the South Florida Water Management District
Source:	SFWMD (South Florida Water Management District), West Palm Beach, FL, 2002
Authors:	Mock, Roos & Associates, Inc., Soil & Water Engineering Technology, Inc.
Document:	
From:	SFWMD
District Question:	1,2,3
Abstract:	Phosphorus losses by surface runoff from agricultural lands have been of public concern due to increasing P contamination to surface waters. Five representative commercial citrus groves (C1–C5) located in South Florida were studied to evaluate the relationships between P fractions in soils, surface runoff P, and soil phosphatase activity. A modified Hedley P sequential fractionation procedure was employed to fractionate soil P. Soil P consisted of mainly organically- and Ca/Mg-bound P fractions. The organically-bound P (biological P, sum of organic P in the water, NaHCO3 and NaOH extracts) was dominant in the acidic sandy soils from the C2 and C3 sites (18% and 24% of total soil P), whereas the Ca/Mg-bound P (HCl-extractable P) accounted for 45–60% of soil total P in the neutral and alkaline soils (C1, C4 and C5 soils). Plant-available P (sum of water and NaHCO3 extractable P fractions) ranged from 27 to 61 mg P kgK1 and decreased in the order of C3>C4>C1>C2>C5. The mean total P concentrations (TP) in surface runoff water samples ranged from 0.51 to 2.64 mg LK1. Total P, total dissolved P (TDP), and PO4 3K-P in surface runoff were significantly correlated with soil biological P and plant-available P forms (p! 0.01), suggesting that surface runoff P was directly derived from soil available P pools, including H2O– and NaHCO3– extractable inorganic P, water-soluble organic P, and NaHCO3- and NaOH-extractable organic P fractions, which are readily mineralized by soil microorganisms and/or enzyme mediated processes. Soil neutral (55–190 mg phenol kgK1 3 hK1) and natural (measured at soil pH) phosphatase activities (77–295 mg phenol kgK1 3 hK1) were related to TP, TDP, and PO4 3K-P in surface runoff, and plant-available P and biological P forms in soils. These results indicate that there is a potential relationship between soil P availability and phosphatase activities, relating to P loss by surface runoff. Therefore, the neutral and natural phosphatase activities, especially the natural phosphatase activity, may serve as an index of surface runoff P loss potential and soil P availability.

Title:	LOADSS: a GIS-based decision support system for regional environmental planning
Source:	Ecol. Eng. 5 (1995), pp. 391–404.
Authors:	Negahban B., C. Fonyo, W.G. Boggess, J.W. Jones, K.L. Campbell, G. Kiker, E. Flaig and H. Lal
Document:	Negahban LOADSS 1995.pdf
From:	ScienceDirect
District Question:	6,8
Abstract:	LOADSS (Lake Okeechobee Agricultural Decision Support System) was developed to help address problems created by phosphorus runoff into Lake Okeechobee. It was designed to allow regional planners to alter land uses and management practices in the Lake Okeechobee basin and then view the environmental and economic effects resulting from the changes. The Lake Okeechobee basin coverage incorporates information about land uses, soil associations, weather regions, management practices, hydrologic features and political boundaries for approximately 0.6 million ha of land and consists of close to 7000 polygons. The system has the capability to generate reports and maps concerning regional land attributes, call external hydrologic simulation models as well as display historical water quality and quantity sampling station data. LOADSS runs on SUN SPARC stations using the ARC/INFO GIS software and requires 80 mb of hard disk storage.

Title:	Evaluations of phosphorus load reduction alternatives from dairy sites in the Lake Okeechobee watershed
Source:	Proceedings of Decision Support Systems for Water Resources Management, 27–30 June 2001. American Water Resources Association, Snowbird, UT
Authors:	Ray, S.A.F., Zhang, J., 2001
Document:	
From:	SFWMD
District Question:	5
Abstract:	Review and improve existing programs to control phosphorus discharges in the watershed, to ensure that all regulated sources meet establish discharge concentration targets (Works of the District) or technology-based performance goals (FDEP Dairy Rule). Included under this strategy are: evaluation of the effectiveness of existing applied technologies and their management plans, evaluation of whether numeric discharge limits should be applied to Dairy operations, evaluation of whether existing numeric discharge limits should be modified, and re-evaluation of the methods whereby numeric discharge limits are established from loading targets and watershed assimilation coefficients.

Title:	Surface Water Improvement and Management (SWIM) Plan Update for Lake Okeechobee, 2002
Source:	SFWMD (South Florida Water Management District), West Palm Beach, FL, 2002
Authors:	South Florida Water Management District
Document:	SFWMD loSwimPlanJul2002.pdf
From:	SFWMD
District Question:	1
Abstract:	This document provides an overview of the activities and accomplishments that have been directed towards the restoration of Lake Okeechobee since adoption of the Surface Water Improvement and Management (SWIM) Plan - Update for Lake Okeechobee (SFWMD, 1997a). This update also describes the current and proposed activities through 2000. Lake Okeechobee and its watershed are key components of South Florida's Kissimmee-Okeechobee-Everglades ecosystem, which extends from the headwaters of the Kissimmee River in the north to Florida Bay in the south. The lake provides a number of ecological and societal values. It is home to one of the nation's prized bass and speckled perch fisheries, as well as an economically important commercial fishery. At the same time, it provides habitat for a wide variety of wading birds, migratory waterfowl, and the federally-endangered Everglades Snail Kite. Lake Okeechobee is also a source of drinking water for cities and towns along the lake, and can be a backup water supply for the communities of the lower east coast of Florida. The lake also supplies irrigation water for the expansive Everglades Agricultural Area, and is a critical supplemental water supply for the Everglades. The Lake Okeechobee SWIM planning area has been defined as the major basins that are direct tributaries to the lake, including those basins that are hydrologically upstream and/or from which water is presently released or pumped into the lake on a regular basis. Although the Lake Okeechobee SWIM planning area generally excludes basins that are hydrologically downstream and act primarily as receiving basins for water supply (Caloosahatchee and St. Lucie River), the conveyance of flood control discharges and the resulting potential associated environmental impacts make these basins a component of this plan.

Title:	Phosphorus in Lake Okeechobee: sources, sinks, and strategies
Source:	In: Reddy, K.R., O'Conner, G.A., Schelske, C.L. (Eds.), Phosphorus Biogeochemistry of Subtropical Ecosystems: Florida as a Case Example. CRC Press/Lewis Publisher, New York, pp.
Authors:	Steinman, A.D., Havens, K.E., Aumen, N.G., James, R.T., Jin, K.-R., Zhang, J., Rosen, B.
Document:	
From:	SFWMD
District Question:	5
Abstract:	Increased phosphoru load to Lakc Okeechobee, the large t lake in Florida, have resulted in higber total phosphorus concentrations in the sediments and water column of the lake's pelagic region since the mid-l900s . In this chapter, we examine the role of phosphorus (P) in this dynamic and heterogeneous ecosystem. The chapter is subdivided into six ections: (I) lake and watershed description, (2) phosphorus in lake sediments, (3) pelagic-littoraJ zone interaction , (4) phosphorus content in different pools, (5) modeling lake responses to watershed management of phosphorus, and (6) strategies for reducing phosphoru in the future. Given the large amount of phosphoru stored in the lake's sediments (2.87 x 10^7 kg) and its frequent resuspension, it may take a considerable period of time to measure noticeable reductions in P concentration in the lake's water column. However, the sooner P loads are reduced from sources in the watershed, the sooner recovery may begin. Progress has been made, in cooperation with the farmers and ranchers in the watershed, to reduce loads over the past two decades, but further reductions still are needed. In-lake P removal strategies, such as dredging, do not appear to be viable in Lake Okeechobee; both ecological and economic uncertainties restrict their utility and, at present, we discourage their implementation.

Title:	Lake Okeechobee Action Plan
Source:	USEPA and SFWMD, 1999
Authors:	Lake Okeechobee Issue Team for the South Florida Ecosystem Restoration Working Group.
Document:	SFWMD ACTIONPLAN 1999.pdf
From:	SFWMD
District Question:	1
Abstract:	The Lake Okeechobee Issue Team was formed in May 1998 by the South Florida Ecosystem Restoration Working Group. The charge given to the Issue Team is development of an Action Plan to protect and enhance the ecological and societal values of Lake Okeechobee. The primary focus of the Action Plan is on reducing in-lake concentrations of total phosphorus to 40 ppb, the goal of the SWIM Act. The Action Plan represents a consensus of federal, state, and local representatives involved in management of the lake, as well as representatives of regional municipalities, and concerned citizens. The Plan describes actions that could improve both water quality and lake ecosystem functions (e.g., fish and wildlife habitat). The major components of this plan were developed in the context of the following key factors: (a) Phosphorus loads to the lake greatly exceed the total maximum load considered acceptable by the scientific community for sustaining a healthy ecosystem. (b) The excessive phosphorus loads are attributable to human activities in the watershed, in particular animal agriculture. (c) If the sources of these loads are controlled, residual phosphorus in the watershed still may considerably delay reductions in tributary loads. (d) Substantial reductions in tributary loads will not result in reductions of phosphorus in the lake because of high internal loading from sediments.

Title:	Potential phosphorus load reductions under the Lake Okeechobee regulatory program
Source:	J. Am. Water Resour. Assoc. 38 6 (2002), pp. 1613–1624
Authors:	Zhang, J., S.A.F. Ray and A. Steinman
Document:	Zhang Potential Pload reductions 2002.pdf
From:	ScienceDirect
District Question:	5
Abstract:	Nutrient loading from beef pastures located within the northern Lake Okeechobee watershed in Florida, has been identified as a source of phosphorus contributing to the accelerated eutrophication of the lake. Since 1989 within the watershed, 557 agricultural drainage sites, mainly beef pasture, have been monitored for compliance under a regulatory program. Of those sites, 154 were actively monitored for phosphorus concentrations from October 1, 1998, to September 30, 1999. Of these 154 sites, 77 were considered to be out of compliance (OOC). An OOC site is defined as having runoff with a 12-month average phosphorus concentration exceeding the permitted discharge limit. The average annual phosphorous load from the 77 OOC sites for an eight-year study period from October 1, 1991, to September 30, 1999, was estimated using measured concentration values and simulated runoff obtained from an agricultural nonpoint source pollution model, CREAMS-WT. The 77 OOC sites produced an estimated average annual 46 metric tonnes of phosphorus load, of which an estimated 22 tonnes of phosphorus reached Lake Okeechobee on an average annual basis. The remaining estimated average annual 24 tonnes of phosphorus load was retained by streams and wetlands in the discharge transport system between the sites and the lake. The estimated average annual load reaching Lake Okeechobee from the OOC sites represented 11 percent of the phosphorus load above a five-year average annual target load for the lake. However, the OOC site drainage areas represented only 3 percent of the northern watershed that drains into the lake. Of the 77 OOC sites, 12 sites had an average annual phosphorus loading rate equal to or greater than 3.0 kg/ha and were placed on the priority list for the Critical Restoration Project in the Lake Okeechobee watershed. To estimate the possible phosphorus load reductions from the 77 sites, two scenarios were modeled. The first scenario reduced phosphorus concentrations in runoff to the permitted discharge limits under the Lake Okeechobee regulatory program. The second scenario changed current land uses to native rangeland with an estimated annual offsite total phosphorus areal loading rate of 0.114 kg/ha. These two scenarios are hypothetical with assumed concentration values and loading rate. Model results showed that the first management scenario reduced the average annual phosphorus load to the lake by an estimated 15 tonnes. The second scenario reduced the average annual phosphorus load to the lake by an estimated 21 tonnes

Title:	LAKE OKEECHOBEE PROTECTION PROGRAM: Lake Okeechobee Protection Plan
Source:	SFWMD (South Florida Water Management District), West Palm Beach, FL, 2004
Authors:	SFWMD
Document:	SFWMD LOPP Rpt.pdf
From:	SFWMD
District Question:	1
Abstract:	This is the first production of the Lake Okeechobee Protection Plan. As such, the recommendations included in this plan are based on best available information to date and are subject to modification as additional data and understanding of the dynamics of the watershed and lake are developed, thus allowing maximum flexibility to embrace new technologies, processes and procedures. The philosophies and programs described in the Plan reflect the collective efforts of the Interagency Team, representing federal, state, regional and local stakeholders from the public and private sectors. The performance goals and effectiveness estimates detailed in the plan are based on current data and best professional judgment. Program performance and effectiveness may vary from the originally established goals and estimates and will be revisited annually for current status and adjusted every three years as required by legislation to improve performance. Those who have participated in the development of this planning document are dedicated to the success of the Lake Okeechobee Protection Program. This plan is respectfully submitted in an effort to secure long-term support for the successful restoration and protection of Lake Okeechobee.

Title:	LAKE OKEECHOBEE PROTECTION PROGRAM: Lake Okeechobee Protection Plan Evaluation Report
Source:	SFWMD (South Florida Water Management District), West Palm Beach, FL, 2007
Authors:	SFWMD
Document:	SFWMD LOPP Eval Rpt 2007.pdf
From:	SFWMD
District Question:	1
Abstract:	This document provides an evaluation/update to the 2004 Lake Okeechobee Protection Plan (SFWMD et al., 2004), focusing on phosphorus (P) management activities, strategies, and associated costs. Results of recently completed projects are presented, as well as status updates for ongoing watershed and in-lake restoration projects. Project time lines, information about funding sources, and other aspects of project planning are also included. The recommendations included in this plan are based on best available information to date and are subject to modification as additional data and understanding of the dynamics of the watershed and lake are developed, thus allowing maximum flexibility to embrace new technologies, processes and procedures. The philosophies and programs described in the Plan reflect the collective efforts of the Interagency Team, representing federal, state, regional and local stakeholders from the public and private sectors. The performance goals and effectiveness estimates detailed in the plan are based on current data and best professional judgment. Program performance and effectiveness may vary from the originally established goals and estimates and will be revisited to determine whether any further reductions are necessary to achieve the TMDL. Those who have participated in the development of this planning document are dedicated to the success of the Lake Okeechobee Protection Program. This plan is respectfully submitted in an effort to secure long-term support for the successful restoration and protection of Lake Okeechobee.

Title:	Impact of riparian buffer zones on water quality and associated management considerations
Source:	Ecol. Eng. 24 (2005), pp. 517–523
Authors:	V. Anbumozhi, J. Radhakrishnan and E. Yamaji
Document:	Anbumozhi Impact of riparian buffer zones 2005.pdf
From:	ScienceDirect
District Question:	5

Abstract: Recent attention has focused on riparian forest buffer systems for filtering sediment, nutrients, and pesticides entering from upland agricultural fields. This paper summarizes the results of a field monitoring study done in Tokachikawa watershed in Hokkaido, Japan, Cisadane, Cianten and Citamyang sub-watersheds in Indonesia and Cauvery watershed, India to quantify the impact of riparian buffer zones on changes in stream water quality. A watershed approach was used to compare land use indicators – uplands, forests, riparian forest, livestock areas – to a wide range of surface water physical and chemical properties. Stream water physical property values increased from upstream to the confluence point, influenced by the upland and livestock land use activities. The greatest reduction in impairment of water quality was observed in buffer zones located along higher order streams where the gradient is very low, leading to slow groundwater movement. The lower stream water temperature in riparian buffer zones suggests that the shading effect is most pronounced in this area of the watershed. The results demonstrate the positive impact of forest buffer zones in reducing the influence of agricultural nutrients and chemicals on surface stream waters. Design and management considerations for establishing riparian zone land use are discussed.

Title:	Assessing phosphorus “change points” and leaching potential by isotope exchange and sequential fractionation
Source:	Soil Use Manage. 18 (2002), pp. 199–207
Authors:	Blake, L., N. Hesketh, S. Fortune and P.C. Brookes
Document:	
From:	Scopus
District Question:	4
Abstract:	There is increasing evidence that phosphorus (P) can be transferred to surface waters by leaching as well as by erosion and surface runoff. Recently it has been suggested that P soluble in 0.01 M CaCl2 may be a good indicator of the specific Olsen-P concentration (usually termed the 'Change Point') at which the rate of P leaching from soil suddenly increases and poses a greater threat of eutrophication to standing waters. We know that these 'Change Points' vary from soil to soil but, so far, we do not fully understand the mechanism(s) involved. Here, we combine methods for assessing isotopically exchangeable P and P sequential fractionation to gain an insight into the processes which cause this sudden increase in P solubilization. We suggest that Change-Points simply define the asymtote of rapid desorption isotherms relating to that P which is most readily isotopically exchangeable (i.e at 24h - 33P24) with the soil solution. This involves ligand exchange at hydroxyl sites associated with Fe and AI cations, which is kinetically governed by the concentration of surface complexes on soil minerals. Individual Change-Points reflect the mineralogy and surface chemistry of different soil types. Laboratory and field measurements of the Olsen-P Change-Point reflect these surface phenomena and are similar. Olsen-P extracts the portion of the exchangeable pool that most readily controls solution P, and the Olsen-P/33P24 ratio is linearly related to Olsen-P Change-Points. This may provide a method for estimating P Change-Points where gradients of soil P are not available

Title:	The long-term effects of manures and fertilizers on soil productivity and quality
Source:	Nutr. Cycl. Agroecosyst. 66 (2003), pp. 165–180
Authors:	D.C. Edmeades
Document:	Edmeades Long-term effects of manures 2003.pdf
From:	ScienceDirect
District Question:	4
Abstract:	The results from 14 field trials comparing the long-term (20 to 120 years) effects of fertilisers and manures (farmyard manure, slurry, and green manure) on crop production and soil properties are reviewed. In total there were 24 paired comparisons of the effects of manure and fertiliser. Some of the trials also contained a control (no nutrient inputs) treatment. The input of nutrients as either fertilisers or manures had very large effects (150–1000%) on soil productivity as measured by crop yields. Manured soils had higher contents of organic matter and numbers of microfauna than fertilised soils, and were more enriched in P, K, Ca and Mg in topsoils and nitrate N, Ca and Mg in subsoils. Manured soils also had lower bulk density and higher porosity, hydraulic conductivity and aggregate stability, relative to fertilised soils. However, there was no significant difference ($P < 0.05$) between fertilisers and manures in their long-term effects on crop production. In the context of this set of international trials, the recent evidence from the Rothamsted classical long-term trials appears to be exceptional, due to the larger inputs of manures and larger accumulation of soil OM in these trials. It is suggested therefore that manures may only have a benefit on soil productivity, over and above their nutrient content, when large inputs are applied over many years. The evidence from these trials also shows that, because the ratio of nutrients in manures is different from the ratio of nutrients removed by common crops, excessive accumulation of some nutrients, and particularly P and N, can arise from the long-term use of manures, relative to the use of fertilisers. Under these conditions greater runoff of P, and leaching of N may result, and for soils with low P retention and/or in situations where organic P is leached, greater P leaching losses may occur. The use of manures, relative to fertilisers, may also contribute to poor water quality by increasing its chemical oxygen demand. It is concluded therefore that it cannot generally be assumed that the long-term use of manures will enhance soil quality – defined in terms of productivity and potential to adversely affect water quality – in the long term, relative to applying the same amounts of nutrients as fertiliser.

Title:	Development of an indicator for risk of phosphorus leaching
Source:	J. Environ. Qual. 29 (2000), pp. 105–110
Authors:	Hesketh, N. and P.C. Brookes
Document:	
From:	Scopus
District Question:	4
Abstract:	Previous work showed that at soil P concentrations below 57 mg 0.5 M NaHCO3-extractable P (Olsen P) kg-1 soil, little P was found in drainage waters collected from tile drains set 65 cm below the soil surface in soils from the Broadbalk Continuous Wheat Experiment. Above this soil P concentration (termed the Change-Point) both total P and molybdate-reactive P (MRP) in drainage waters were linearly related to soil Olsen P concentrations. We now need to know if the Change-Point measured on Broadbalk occurs on other soils, and if so, whether a common value applies or if it varies depending upon soil type, management, and site hydrology. We investigated the possibility of 0.01 M CaCl2-extractable P being an indicator of the Change-Point. In all the soils studied, we found that the dynamics of P solubility in CaCl2 closely resembled the dynamics of P solubility in drainage waters of Broadbalk, since very distinct Change-Points occurred under both conditions. However, Change-Points measured following extraction with CaCl2 varied widely between soils, from 10 to 119 mg Olsen P kg-1 soil. Lysimeter studies showed, with some exceptions, good agreement between Change-Points measured in drainage water and in 0.01 M CaCl2. We therefore suggest that this approach may provide a valid indicator of the soil Olsen P concentration at which significant amounts of P begin to leach from soil to water, provided preferential pathways exist in the subsoil to permit P leaching down the soil profile in drainage water.

Title:	Stability of phosphorus forms in dairy-impacted soils under simulated leaching
Source:	Ecol. Eng. 5 (1995), pp. 209–227
Authors:	Wang, H.D., W.G. Harris, K.R. Reddy and E.G. Flaig
Document:	Wang Stability of P forms 1995.pdf
From:	ScienceDirect
District Question:	4
Abstract:	Dairy manure has been linked to elevated phosphorus (P) levels in surface waters of Lake Okeechobee basin. Prevalent soils of the basin (Aquods) retain little P in sandy, quartz-dominated upper horizons, and lateral P transport is favored by high water tables. The stability of manure-derived P forms is thus an important factor in the Okeechobee basin and other regions where soil and hydrologic factors are unfavorable for P retention. The objectives of this study were to determine (1) the forms of P in four dairy impacted soils and one associated stream sediment, (2) the forms lost most readily following disturbance and simulated leaching, and (3) the effect of residence time prior to a leaching event on the relative amount of P released. Samples included four Ap horizons from holding areas and a stream sediment from one of the dairy sites. All samples (500 g) were packed in columns and leached with synthetic rainwater at 0.4 ml/min for 6 h weekly. Concentrations of P, Ca, Mg, Al, and Fe in the leachate, along with pH and electrical conductivity (EC) were determined. The form of solution P for selected leachates was also evaluated using 31P NMR spectroscopy. Samples before and after leaching were subjected to P fractionation. Results of P-fractionation, solution speciation, and 31P NMR indicated that P lost from surface horizons during leaching was dominantly in inorganic forms associated with Ca and Mg. Leachates of soil horizons contained much higher levels of P than did those of the sediment, despite comparable total-P levels. Recalcitrance of the sediment P probably relates to its dominant form, determined in a related study to be a poorly-crystalline apatite-like mineral; soil horizons contained no detectable crystalline P. However, speciation modelling indicated that leachates were supersaturated with respect to hydroxyapatite, and in most cases to metastable Ca---P forms. Lack of crystalline Ca---P could be related to kinetics, or to a poisoning effect of components such as Mg, Si and organic acids in the dairy soil system. Elimination of the “barrier” to Ca---P crystallization could reduce the leaching of P from dairy systems.

Title:	Stormwater BMP Modeling for Okeechobee Dairies Using WAM
Source:	Florida Department of Agriculture and Consumers Services. FDACS Contract No. 008156, 2003
Authors:	SWET (Soil and Water Engineering Technology, Inc.)
Document:	FDACS SW BMP modeling 2003.pdf
From:	Soil and Water Engineering Technology, Inc.
District Question:	6,8
Abstract:	A previous modeling effort included an evaluation of Best Management Practices (BMPs) for nineteen dairies within the Lake Okeechobee watershed using WAM. Two BMP scenarios were assessed – 1) land use modifications designed to achieve a nutrient balance and 2) the same land use modifications with a storm retention BMP added. A storm retention BMP was not evaluated separately. The purpose of this project was to use the WAM model to estimate the stormwater management BMP only.

Title:	Agricultural Nutrient Management Plans for Dairies in the Lake Okeechobee Watershed
Source:	Florida Department of Agriculture and Consumers Services. FDACS Contract No. 008156, 2003
Authors:	EWR (Engineering & Water Resources, Inc.), Royal Consulting Services, Inc., Soil and Water Engineering Technology, Inc. and Mock, Roos & Associates, Inc.
Document:	EWR (Engineering & Water Resources, Inc.), Royal Consulting Services, Inc.
From:	EWR
District Question:	1, 3
Abstract:	In November 2002, FDACS hired Engineering & Water Resources, Inc. to prepare agricultural nutrient management plans (AgNMPs) for 19 barn complexes that make up 12 existing dairies within the Lake Okeechobee basin. The AgNMP provides additional detail to justify and delineate improvements, actions, processes, facilities and best management practices needed to bring the dairy into phosphorus balance at the field level. The AgNMP also address whole farm phosphorus budgeting and other actions needed to achieve the water quality targets set forth in the statement of work. In Section 1 of the AgNMP report, the existing dairy operation and facilities were described along with prevalent hydrologic conditions. In Section 2, the status of phosphorus movement into, out of and within the dairy were quantized along with estimates of phosphorus that is stored on the farm. Based on the data collected in Section 2, the effectiveness of existing BMPs in managing phosphorus at both the whole farm and field level was assessed. Estimates were also made regarding the amount of phosphorus that leaves the farm as surface and groundwater discharge. In Section 3, problem areas were specifically identified and a “toolbox” of candidate best management practices (CMPs) to correct those problems was presented. For the purpose of this report a BMP is defined as a management practice, facility or technology that the dairy can afford to implement, whereas, CMPs are those practices, facilities or technologies that have the potential to achieve the project goals. In Section 4, final candidate best management practices were selected to address the AgNMP goals and BMPs the dairy selected were summarized. For each group of CMPs and BMPs final capital costs were estimated and phosphorus concentration/load reductions were simulated using the WAMView water quality model.

Title:	Development of a Graphical User Interface for Analyzing Phosphorus Load and Import/Export in the Lake Okeechobee Protection Plan Area
Source:	South Florida Water Management District (SFWMD), 2005
Authors:	JGH (JGH Engineering), Soil and Water Engineering Technologies, Inc. and HDR Engineering, Inc.
Document:	SFWMD Dev of a GUI for analyzing P 2005.pdf
From:	SFWMD
District Question:	1,2,3
Abstract:	The overall objective of this project is to develop an ArcGIS based graphical user interface for the entire Lake Okeechobee Protection Plan Area (Figure 1). The enhancement includes adding the ability to select a user defined area as opposed to being limited to selecting entire basins. This will provide the ability to assess specific changes within the watershed. The results of these changes need to be viewed at the selected area, the lake and at any location along the flow path to the lake. JGH Engineering was authorized by the District to accomplish the project objective by performing the following three tasks within a twelve month period: Task 1: Upgrade the graphical user interface from ArcView™ to ArcGIS™. Convert the relevant AvenueTM scripts and forms from the previous interface to Visual Basic for ApplicationsTM (VBA) and add enhancements. Task 2: Perform hydrological and water quality modeling for the remaining basins in the LOPP area where WAM has not been previously applied. Incorporate these basins into the upgraded graphical user interface. Add a graphical user interface feature to obtain the total drainage area for a site selected and compute the total phosphorus load in surface runoff from the drainage area to the site (including assimilation). Task 3: Write final documentation that describes the work performed and includes technical data and analyses. Present the work and the graphical user interface to the District staff during a four hour training class.

Title:	Lake Okeechobee Watershed Project – Section 6.0, Hydrologic / Water Quality Characterization of the Watershed, Part II – Modeling Report
Source:	USACOE, SFWMD, 2003
Authors:	HDR (HDR Engineering, Inc.)
Document:	
From:	SFWMD
District Question:	6
Abstract:	The purposes of this project are to reduce phosphorus loading to Lake Okeechobee; attenuate peak flows from the watershed; provide more natural water level fluctuations in the lake; and restore wetland habitat. These goals will be accomplished by: 1) a 17,500 acre reservoir in the lower Kissimmee Basin; 2) a 5,000 acre reservoir and a 5,000 STA in the Taylor Creek/Nubbin Slough Basin; 3) smaller RASTAs and restoration of isolated wetlands; and 4) removal of 150 tons of phosphorus from 10 miles of primary tributary canals. As a first step in development of the PIR, a Watershed Assessment Report was prepared in June 2003 to better define water quality and hydrologic problems in the watershed. The Watershed Assessment Model (WAM) was used to simulate water quantity and quality from the 1,440 sq. mile watershed.

Title:	Phosphorus Budget and Loading Analysis for Lake Istokpoga/Upper Chain of Lakes Basin Phosphorus Source Control – Task 4 Report
Source:	South Florida Water Management District (SFWMD), 2003
Authors:	Mock-Roos (Mock, Roos & Associates, Inc.), Berryman & Henigar, Inc., Soil & Water Engineering Technology, Inc.
Document:	
From:	SFWMD
District Question:	1,2,3,8
Abstract:	A phosphorus budget analysis for all land uses within watershed will be performed. This study will use the most recent three years of land use, phosphorus import and export data (fertilization, feed, cleaners, harvest, liveweight, milk, sod, hay and septic), as well as data on sludge application, poultry manure, and estimated values on phosphorus discharges via surface and subsurface flow. Relationships between the net import and basin characteristics will be examined to determine what sources are particularly problematic. This will allow the District to target those problem sources and determine effective means to control them. The following tasks, as specified in the District's Request for Proposals (RFP), will be performed to accomplish the project objective: Task 1: Data Acquisition and Assessment Task 2. Phosphorus Budget and Loading Analysis Task 3. Establish Relationships between Basin Characteristics and Net P Imports Task 4. Final Documentation and Presentation

Title:	Development of Phosphorus Retention Assimilation Algorithms for the Lake Okeechobee Watershed
Source:	SFWMD, West Palm Beach, Florida, 2001
Authors:	SWET (Soil & Water Engineering Technology, Inc.), K. Remesh Reddy, Mock, Roos & Associates, Inc., Entel Environmental Companies, Inc.
Document:	
From:	SFWMD
District Question:	6
Abstract:	The objective was to develop phosphorus assimilation coefficients/algorithms for use in water quality models to demonstrate the effectiveness of isolated and constructed wetlands to store P; and (v) to communicate the utility and effectiveness of isolated wetlands in phosphorus assimilation storage to dairy farmers and beef cattle ranchers through extension publications or other appropriate mechanisms.

Title:	Sediment Removal Feasibility Study or Tributaries to Lake Okeechobee
Source:	SFWMD, West Palm Beach, Florida, 1997
Authors:	Mock-Roos (Mock, Roos & Associates, Inc.), Soil & Water Engineering Technology, Inc., J. Stuck, A.J. Mehta, R.D. Rhue
Document:	Hard copies
From:	SFWMD
District Question:	1,4
Abstract:	Series of reports including: Analysis of Existing Data Report Pilot Sampling Program Design Report Results of Pilot Sampling Program Summary Final Sampling Program Design Report Quantification of P-enriched Tributary Sediments Report Mobility and Circumstances for Sedimentary P Transport Report Potential Management Strategies Report A study was conducted to determine the feasibility of removing sediments from the streams and canals in the northern Okeechobee basin to reduce the Pdelivery to Lake Okeechobee. The study profiled 85 stream reaches throughout the basin for sediment transport properties. These transport properties and local dredging and hauling costs were used to rank several alternative management strategies for removing and/or controlling these sediments. A general conclusion of the project is that sediment removal will reduce Ploads to Lake Okeechobee. The TP reduction using sediment control practices,however, will be limited by the fraction of the TP that is in the particulate form. Observed data indicates that the PP in the incoming water to the lake is about 25% of the TP or about 63Mt/yr (69 tons/yr). Based on the sediment mobility analysis presented in Deliverable 8,it is estimated that about 5 to 25%of the PP entering the lake could be removed by removing bottom sediment. This PP removal rate translates into a1to 6%or about 3 to 16 Mt/yr (3.3 to 17 tons/yr)of the TP being prevented from entering the lake. The large range for the potential PP removal reflects the uncertainty of the analysis which is primarily due to not having actual settling velocities for the suspended particulate matter moving through the streams. Other alternatives were evaluated for control of P loads. Of the abatement programs that were evaluated, enlargement of the primary canals/streams was found to be best the alternative. Vegetation removal and in-stream alum injection were also found to be slightly better alternatives than direct sediment removal. The study also identified several knowledge and data gaps that limited the quantification of the different alternatives, Further studies are needed to better estimate the benefits of sediment dredging.

Title:	Impacts of agricultural phosphorus use in catchments on shallow lake water quality: About buffers, time delays and equilibria
Source:	Science of The Total Environment, Volume 369, Issues 1-3, 1 October 2006, Pages 280-294
Authors:	Peter Schippers, Hendrika van de Weerd, Jeroen de Klein, Barend de Jong and Marten Scheffer
Document:	Schippers Impacts of ag P 2006.pdf
From:	ScienceDirect
District Question:	6,7
Abstract:	Phosphorus (P) losses caused by intensive agriculture are known to have potentially large negative effects on the water quality of lakes. However, due to the buffering capacity of soils and lake ecosystems, such effects may appear long after intensive agriculture started. Here we present the study of a coupled shallow lake catchment model, which allows a glimpse of the magnitude of these buffer-related time delays. Results show that the buffering capacity of the lake water was negligible whereas buffering in the lake sediment postponed the final lake equilibrium for several decades. The surface soil layer in contact with runoff water was accountable for a delay of 5–50 years. The most important buffer, however, was the percolation soil layer that may cause a delay of 150–1700 years depending on agricultural P surplus levels. Although the buffers could postpone final lake equilibria for a considerable time, current and target agricultural surplus levels eventually led to very turbid conditions with total P concentrations of 2.0 and 0.6 mg L− 1 respectively. To secure permanent clear water states the current agricultural P surplus of 15 kg P ha− 1 yr− 1 should drop to 0.7 kg P ha− 1 yr− 1. We present several simple equations that can be used to estimate the sustainable P surplus levels, buffer related time delays and equilibrium P concentrations in other catchment–lake systems.

Title:	Phosphorus control strategies
Source:	Ecological Engineering, Volume 5, Issues 2-3, November 1995, Pages 405-414
Authors:	Gilliam, J.W.
Document:	Gilliam P control strategies 1995.pdf
From:	ScienceDirect
District Question:	5
Abstract:	There are many recognized water quality problems resulting from nonpoint entry of P into surface waters. It has only been in the last decade that P applied to land as animal waste has been recognized as a large potential problem. This problem is a result of the concentration of animals into a small area to the extend that so much waste is applied to land that the P fixing capacity of the soil is exceeded. One of the first areas where this problem was recognized was in the Lake Okeechobee drainage basin. When the sources of P in the lake were identified, regulators took action to have best management practices (BMP) implemented on dairies which were a primary source of P and also several research projects were initiated to determine if better BMP could be developed. One of the most successful BMPs thus far implemented is improvement of collection of waste in high intensity areas and routing this waste to improved lagoons. Preliminary data indicate that up to 90% of the P entering a lagoon system remains there in the sludge. A project to remove the P with a combination of chemical and biological reactions has also been successful thus far. It has been shown that aquatic macrophytes can be utilized to reduce the P moving from secondary lagoons toward the drainage canals. There is, however, a problem of what to do with the plants. The model LOADSS has been successful in predicting the effect of various management options in the watershed on amount of P which will enter the lake. If the management options described in this special issue of Ecological Engineering are not successful in reducing the P loads in the lake to acceptable limits, it may mean that large animal units should not be concentrated in many watersheds of the U.S. because of the probability of encountering P problems.

Title:	Phosphorus Dynamics in Selected Wetland/Stream Systems of South Florida
Source:	SFWMD, West Palm Beach, Florida, 1992
Authors:	Reddy, K. R., O. Diaz, M. Agami, L. Scinto and L. LaClaire
Document:	Hard copy
From:	SFWMD
District Question:	4
Abstract:	The results presented in this report provide a comprehensive characterization of stream sediments and wetlands at two sites, with respect to labile and non-labile pools of P. Laboratory experiments provided information on relative rates of selected processes related to P retention by wetlands and sediments. It is very clear from these results that P cycling processes are dynamic and highly variable both at spatial and temporal scales. It should be recognized that relative rates of many of the processes measured were based on laboratory experiments. Results summarized in this report provide some answers to questions (see section 1.1) frequently posed to the researchers. However, these results are based on two sites which were plagued with drought conditions during the course of this study. The results presented in this report do provide a good understanding of the soil/sediment processes and their relative importance to the overlying water quality. However, the challenge remains to transfer this to other sites and predict their behavior with respect to impact on water quality. Based on the results presented in this report and our current understanding of P dynamics in the wetlands and streams, we have identified several .gaps' to address the questions raised at the beginning of the study.

Title:	Biogeochemical behavior and transport of phosphorus in the Lake Okeechobee basin
Source:	IFAS, University of Florida, Gainesville, FL, 1990
Authors:	Graetz, D.A., V.D. Nair, R. Voss, C. Mathews, R.R. Villapando, T.L. Yaun
Document:	Hard copy
From:	SFWMD
District Question:	4
Abstract:	The objective of this study was to determine existing levels of water-soluble, double-acid (0.05 M HCl in 0.025 M H2SO4) extractable and total phosphorus in soils of selected dairies in the watershed. Water-soluble phosphorus was extracted using a 1:4 soil:water ratio by shaking for 1 hour. Double-acid extractable (0.05 M HCl in 0.025 M H2SO4) phosphorus was extracted using a 1:4 soil:double-acid ratio by shaking for 15 minutes. Total phosphorus was determined by digestion with 3 ml concentrated H2SO4 containing 1 gm of 9:1 K2SO4:CuSO4 catalyst. Soluble reactive phosphorus was determined in all extracts using the ascorbic acid method of Murphy and Riley (Anal. Chim. Acta. 27:31-36). GENERAL CONCLUSIONS 1. Levels of water- soluble phosphorus in the A horizon of the native areas were less than 1 mg/kg compared to an average of 4, 13, 68 and 89 mg/kg in the forage, pasture, holding and intensive areas, respectively. 2. Double-acid extractable phosphorus levels in the A horizon of the native areas were less than 2 mg/kg compared to 10, 31, 575 and 557 mg/kg in the forage, pasture, holding and intensive areas, respectively. A similar trend was observed with total phosphorus levels in the A horizon. 3. The E horizon is a white, sandy horizon with little phosphorus retention capacity. It contained considerably less of all 3 forms of phosphorus than the A horizon. However, the trend between components was similar to the A horizon. 4. The Bh (spodic) horizon retained higher levels of the 3 forms of phosphorus than the E horizon. The trend of phosphorus levels between components was agains imi lar to the A and E horizons, i. e., native <forage < pasture < holding < intensive areas. 5. There was some indication that phosphorus had moved through the Bh horizon, particularly in the intensive, holding and pasture areas. 6. Water-soluble phosphorus was generally 5 to 10% of total phosphorus. Double-acid extractable phosphorus was generally 50% or greater of total phosphorus in the intensive areas and 15 to 25% in the forage and pasture areas. 7. The 3-year old dairy generally had lower levels of all 3 forms of phosphorus in the Ahorizon than the 8-, 20- and 32-year old dairies. The two older dairies had similar levels of phosphorus in all horizons. 8. In the pasture areas, dairy age had variable effects on the 3 forms of phosphorus in the A, E, and Bw horizons. However, the two older dairies appeared to be accumulating phosphorus in the Bh horizon.

Title:	A Soil-Based Phosphorus Retention Index for Animal waste Disposal on Sandy Soil
Source:	Florida Department of Envjronmental Protection, Contract No. WM459 , QAPP #920232R,1994
Authors:	Rhue, R.D., W.G. Harris, G. Kidder, and R.B. Brown
Document:	Hard copy
From:	SFWMD
District Question:	4
Abstract:	Sandy soils occur extensively throughout Florida and many are characterized by low phosphorus retention. The Suwannee River Basin is experiencing the development of intensive dairy and poultry operations which generate large quantities of wastewater and manure. Since land application is the primary method of disposal, the potential exists for significant movement of P to ground and surface waters at these sites. The purpose of this study was to develop a P retention index that relates the P adsorption capacity of these materials to their taxonomic and morphological properties. Ninety-six soil samples representing the three major taxonomic great groups found in Florida, Alaquods, Quartzipsamments, and Paleudults, were screened for relative P adsorption capacity. The relative P adsorption (RPA) ranged from 0 to 100% and was highly correlated with clay content. A discrete variable that served as a distinguishing criteria for P retention was color which signals the existence of highly reactive clay and oxide coatings on sand grains. A scheme for indexing P retention places soil materials in one of three categories: Group I materials exhibit the greatest P retention and are considered to pose minimal risk of P leaching; Group III materials exhibit the least P retention and pose the greatest risk of P leaching. Group II materials are intermediate and exhibit a wide range in P retention. Generalization of these results to soils in the landscape may be possible since the soil materials used were randomly selected from a pool of commonly occurring soils. However, the calculation of specific P loading rates from the index will require field validation and calibration.

Title:	Phosphorus Retention and Storage by Isolated and Constructed Wetlands in the Okeechobee Drainage Basin - Annual Report
Source:	Florida Department of Agriculture and Consumer Services, Office of Water Policy, Tallahassee, FL, 2004
Authors:	Reddy, K. R., M. Clark, J. Jawitz, T. DeBusk, M. Annable, W. Wise, S. Grunwald
Document:	Hard copy
From:	SFWMD
District Question:	5
Abstract:	The objectives of this interdisciplinary project are: 1. To demonstrate the efficacy of isolated wetlands to retain and store P. These wetlands will be located in land areas currently used for cow-calf operations. 2. To design and optimize on farm or edge-of-field treatment wetlands to maximize P removal performance (both mass removal per unit area basis, and effluent concentration basis) on land areas used for cow-calf operations. 3. Review current hydrologic and P models for adaptation to the Okeechobee Basin wetland systems and to predict P assimilation capacity of the four priority basins. 4. To develop P assimilation coefficients/algorithms for use in water quality models to demonstrate the effectiveness of isolated and constructed wetlands to store and retain P. 5. To communicate the utility and effectiveness of isolated wetlands in P storage and retention to dairy farmers and beef cattle ranchers through extension publications or other appropriate mechanisms. This project represents a 5 year joint effort among several agencies including agencies including: the University of Florida -Institute of Food and Agricultural Sciences (UFIFAS), FLDACS, FLDEP, SFWMD, DB Environmental Lab Inc., and dairy farmers and ranchers. Specific research and monitoring tasks are described separately for each of these systems.

Title:	Phosphorus assimilation by stream sediments - Final Report
Source:	University of Florida, Institute of Food and Agricultural Services, Soil & Water Science Department, Gainesville, FL, 1992
Authors:	K. R. Reddy, L. J. Scinto, T. A. DeBusk, J. E. Peterson, E. Flaig
Document:	Hard copy
From:	SFWMD
District Question:	4
Abstract:	From October 1990 through June 1991, several experiments designed to elucidate stream P assimilation rates were conducted at a research facility adjacent to Otter Creek in Okeechobee County, Florida. This facility consists of four 24 m2 fiberglass raceways, two of which contain a sandy, "low organic" sediment (LaM), and two that contain a sediment with a higher organic matter content (HOM). These raceways are utilized to evaluate the effects of various experimental parameters (e.g., hydraulic retention time, flooding and drying, presence ofperiphyton or macrophytes) on stream water quality and sediment chemistry. Sediment oxidation-reduction potential (Eh) generally increased during a "drydown" period (October 1990 - January 1991) in which no stream water was supplied to the raceways. Sediment Eh values fluctuated, however, as a result of periodic flooding from rain events. Sediment Eh values generally were lower in raceways equipped with shade structures, since this reduced evaporation rates and resulted in "wetter" sediments. Terrestrial plants colonized the unshaded raceways during the "drydown" period, with the HOM system developing a greater plant standing crop than the LOM system (25.1 vs. 108.6 g/m2, respectively). The raceways were reflooded with stream water during February 1991. All raceways exported a moderate amount of total phosphorus (P) (0.2 - 1.0 mg/L) and total kjeldahl nitrogen (TKN) (1.0 - 2.0 mg/L) for 48 hours after reflooding. During the reflooding and subsequent HRT studies, however, wide temporal swings in Otter Creek stream water P (0.2 - 3.5 mg total P/L) and N (1.5 - 21.0 mg TKN/L) concentrations made interpretation of raceway nutrient fluxes difficult. Following a reflooding period during which raceways received streamwater at a 48 hr HRT, a simulated storm event was provided, in which the raceway HRT was varied from 4 to 96 hours. General observations on the performance of the systems during these experiments are as follows. Unshaded raceways typically provided lower effluent N and P concentrations than did the shaded systems. Unshaded systems consistently had a greater standing crop of algae (periphyton and fJlamentous algae) and higher water column pH and DO levels. Hence, the superior N and P removal of the unshaded systems likely is related directly (nutrient uptake) or indirectly (p precipitation, NH.-N volatilization) to algal activity. Lowest effluent N and P concentrations (relative to influent concentrations) were achieved when the stream water fed to the raceways contained high concentrations of N and P. Additionally, effluent N and P concentrations generally exceeded influent concentrations at streamwater HRTs of from 4 to 16 hours. At longer HRTs (32-96 hrs), raceway effluent N and P

Title:	Final Report of the Buck Island Cattle Ranching BMP Optimization Project
Source:	FL Department of Environmental Protection, Tallahassee, FL, 2003
Authors:	Campbell, K.L., D.A. Graetz, K.M. Portier, J.C. Capece, P.J. Bohlen
Document:	Hard copy
From:	SFWMD
District Question:	5
Abstract:	In 1994, three organizations (Archbold Biological Station, University of Florida Institute of Food and Agricultural Sciences and South Florida Water Management District) initiated a multi-disciplinary BMP development program, at the Buck Island Ranch, near Lake Placid, Florida. The goal of the partnership was monitoring of water quality, wildlife biology, and landscape ecology in relation to agriculture practices. This document is relative to the third phase of this multi-step project. The opening step (started in 1996) initiated planning for a demonstration project to document water quality BMPs for south Florida's cattle ranches. The current plan seeks to develop BMPs that will help reduce phosphorus loadings into Lake Okeechobee, while maintaining the economic viability of Florida cattle ranches. After the conception/feasibility phase set up to launch the project and allow the transition effects to dissipate, a third phase of which this document is relative started in winter 2000 and was run until the end of summer 2002. This phase utilizes the infrastructure installed in the previous phases consisting of multiple, field-scale plots that are realistic in size and are instrumented so that all surface water runoff can be captured and analyzed. The design of the project consist of two arrays (Summer and Winter) experimented with a completely randomized block employing four stocking rates BMPs on eight pastures. Except the differences in cow/calf density (higher density for Summer plots presenting more biomass production potential), the two blocks are similar in design and instrumentation. Measurements included runoff flow rates and water quality trough TP, ortho-P, NH4, Nox and TKN parameters. Samples were taken by both manual grab techniques and automatic water samplers. Investigations of this period yield a more reliable and complete dataset with more consistency in the measurements. This phase also incorporates the development of a groundwater monitoring system instigated in September 2000. This allows the understanding of the relationships and interactions between the surface and groundwater systems. However, because of the limited collected data, the effect of the stocking rate on the water quality is inconclusive.

Title:	Reducing nutrient loss from farms through silvopastoral practices in coarse-textured soils of Florida, USA
Source:	Ecological Engineering, Volume 29, Issue 2, 1 February 2007, Pages 192-199
Authors:	V.D. Nair, P.K.R. Nair, R.S. Kalmbacher and I.V. Ezenwa
Document:	Nair Reducing Nutrient Losses.pdf
From:	ScienceDirect
District Question:	5
Abstract:	Trees integrated into the range- and pasturelands of Florida could remove nutrients from deeper soil profiles that would otherwise be transported to water dies cause pollution. Soil nitrogen (N) and phosphorus (P) concentrations were monitored in three pastures:a treeless pasture of bahiagrass (Paspalum notatum); a pasture of bahiagrass under 20-year old slash pine (Pinus elliotti) trees (silvopasture); and a pasture of native vegetation underpine trees (native silvopasture). Soil analysis from 10 profiles within each pasture showed that P concentrations were higher in treeless pasture (mean: 9.11mgkg−1 in the surface to 0.23mgkg−1 at 1.0mdepth) compared to silvopastures (mean: 2.51 and 0.087mgkg−1,respectively), and ammonium–N and nitrate–N concentrations were higher in the surface horizon of treeless pasture. The more extensive rooting zones of the combined stand of tree + forage may have caused higher nutrient uptake from silvopastures than treeless system.Further, compared to treeless system, soils under silvopasture showed higher P storage capacity. The results suggest that, compared to treeless pasture, silvopastoral association enhances nutrient retention in the system and thus reduces chances for nutrient transportto surface water. The study reflects the scope for applying ecological-engineering and ecosystem-restoration principles to silvopastoral-system design.

Title:	Potential internal loading of phosphorus in a wetland constructed in agricultural land
Source:	Water Research, Volume 37, Issue 5, March 2003, Pages 965-972
Authors:	Pant, H. K. and K. R. Reddy
Document:	Pant Potential internal loading of P.pdf
From:	ScienceDirect
District Question:	4
Abstract:	Wetland construction on agricultural or dairy lands could result in solubilization of phosphorus (P) stored in soils and release to the water column. To study the extent of P flux during the start-up period of a constructed wetland, intact soil-cores from areas used for dairy operations, in Okeechobee, Florida, USA were obtained and flooded with adjacent creek water. In the first 28-day hydraulic-retention period, P concentration in the water column increased several fold due to rapid P flux from impacted soils. A continuous decrease in P flux to the water column until the third hydraulic retention cycle (initial influent P concentration 0.2 mg L−1), and constant thereafter suggest that the effect of initial influent P upon long-term P flux from soils could be limited. The initial release maybe due to high concentration of labile P in impacted soils; however, slow dissolution of relatively stable P pools could maintain a steady flux, well above of that observed from non-impacted soils. Water soluble P along with double acid-extractable magnesium explained 76% of the variability in cumulative P flux to the water column. Apparently, co-occurrence of active adsorption–desorption phenomena due to independent maintenance of equilibrium by individual P compounds regulates P dynamics of the water column. The results indicated that equilibrium P concentration of the water column of the wetland would be above 1.3 mg L−1, which is well above the targeted P level in the water column of the Lake Okeechobee, one of the main water bodies in the area (0.04 mg P L−1). This suggests construction of wetlands in agricultural lands could result to substantial internal P loading. However, preventative measures including chemical amendments, establishment of vegetative communities or flushing the initially released P may potentially stabilize the system, and maintain P removal efficiency.

Title:	Water table effects on phosphorus reactivity and mobility in a dairy manure-impacted spodosol
Source:	Ecological Engineering, Volume 18, Issue 1, October 2001, Pages 77-89
Authors:	Villapando, R.R. and D.A. Graetz
Document:	Villapando Water Table Effects Ecol. Eng. 2001.pdf
From:	Dr. Graetz
District Question:	4
Abstract:	Many Florida soils present a unique situation for management of P in animal wastes due to fluctuating water table and predominantly sandy soils with low P retention capacity. These conditions may lead to significant P leaching, which can contaminate both surface and groundwaters. A column study was conducted to determine the fate of dairy manure-derived P under high and low water table conditions. Intact soil cores from low-impact (forage) and high-impact (intensive) areas of Dry Lake Dairy near Okeechobee, FL, were used in this study. Soluble reactive P (SRP) concentrations in the soil columns were monitored periodically to assess P leaching. The forms and distribution of P in the columns were determined to examine the nature and extent of P transformations in the soil. Aintaining the water table above (flooded) or below (drained) the Bh horizon resulted in substantial movement of P in the soil columns. High potential for surface water contamination with P was associated with the spodosol from heavily manure-impacted areas. Assuming a: bull,<: density of 1.33 g cm - 3 and an average thickness of 20 cm, with 61% of the total P in the labile pool, the intensive component would have over 3000 kg P ha - I in the surface horizon that could potentially be available for transport. The intensive soil columns maintained high porewater SRP concentrations in the A and E horizons during the entire course of the study. This suggests low P sorption in the overlying horizons and high potential for lateral movement of P above the Bh horizon. Most of the labile P (NH4CI-P) that leached into the Bh horizon was transformed into AI/Fe-P, which accounted for about 65% of the total P in the Bh horizon of soil from the intensive component. The Bh horizon under flooded and drained conditions provided storage for P but at a limited capacity.

Title:	Phosphorus accumulation in manure-impacted Spodosols of Florida
Source:	Agriculture, Ecosystems & Environment, Volume 75, Issues 1-2, August 1999, Pages 31-40
Authors:	Graetz, D.A., V.D. Nair, K.M. Portier and R.L. Voss
Document:	Graetz P Accumulation Ecol. Eng. 1999.pdf
From:	ScienceDirect
District Question:	4
Abstract:	Accumulation of phosphorus (P) in soils receiving long-term application of manure has been linked with degradation of water quality in nearby streams and lakes. The objective of this research was to determine the amounts and depth distribution of phosphorus (P) in Florida Spodosols used for dairies and beef ranches, and to relate them to various soil chemical parameters. Land areas of both active and abandoned dairies were sampled based on estimated cattle density. High cattle-density areas of both the active and abandoned dairies, i.e., the intensive and holding areas, had mean total phosphorus (TP) concentrations in the surface horizon (A) of 2500 mg kg−1 and 750 mg kg−1, respectively compared to 30 mg kg−1 in the native area, i.e., an area largely unimpacted by animals and humans. The dairy and beef cattle pastures and the forage areas (low cattle density areas) had a mean TP concentration of 114 mg kg−1. Concentrations of TP in the E, Bh, and Bw soil horizons were also greater in the high cattle density areas than in the low cattle density areas or in the native areas. Water-soluble P concentrations (WSP) were higher in all soil horizons of the high cattle density areas compared to the low cattle density areas and the native areas. Water-soluble P concentrations in the surface horizons of the high cattle density areas averaged 3.4% of TP which suggests that a substantial amount of P could be transported either vertically or laterally with subsurface drainage. Double acid-extractable P (DAP) concentrations, which could be used as an indicator of potentially leachable P, were considerably higher than WSP concentrations and averaged (over all land-uses) 42, 44, 57 and 31% of TP for the A, E, Bh, and Bw horizons, respectively. The association of WSP, DAP, and TP with the soil chemical parameters measured in this study showed a varied relationship with double acid-extractable Ca and Mg and oxalate-extractable Fe and Al. Overall, these results show the accumulation of large amounts of P in high cattle density areas. Significant amounts of this P were in forms that are potentially leachable, i.e., WSP and DAP. Higher concentrations of all P forms in the subsurface horizons (E, Bh, Bw) of high cattle density areas confirm the downward transport of P in these manure-laden Spodosols.

Title:	Fate of phosphorus in the Lake Okeechobee watershed, Florida, USA: overview and recommendations
Source:	Ecological Engineering, Volume 5, Issues 2-3, November 1995, Pages 127-142
Authors:	E. G. Flaig and K. R. Reddy
Document:	Flaig Fate of P in Lake O watershed.pdf
From:	ScienceDirect
District Question:	4
Abstract:	Lake Okeechobee, Florida, USA, currently is threatened by phosphorus (P) loading from the adjacent watershed north of the lake. The primary land uses in the watershed are beef cattle ranching and dairy farming for which there is a high net P import. The upland soils are predominantly poorly-drained, sandy Spodosols. Although the soils have low P retention capacity, about 80% of the applied P has remained in the soil in either unstable or stable forms. Phosphorus transport from the soil is controlled by relief, local drainage, and depth to the spodic horizon. Phosphorus in off-site runoff is partially assimilated in wetland and stream sediments, which have substantial long-term P retention capacities. Over the last 15 years, best management practices have been implemented to reduce P loads from agriculture. However, implementation has not been sufficient to meet P load reduction goals. Additional P control practices are needed to meet the target reduction goals. Several research and demonstration studies, have been conducted during the past decade to improve our understanding of the fate and transport of P. The results of the research were reviewed at a workshop held in West Palm Beach, Florida, USA, in June 1993, and are presented in this special issue of Ecological Engineering.

Title:	Fate of phosphorus in Florida Spodosols contaminated with cattle manure
Source:	Ecological Engineering, Volume 5, Issues 2-3, November 1995, Pages 163-181
Authors:	Graetz, D.A., and V.D. Nair
Document:	Graetz Nair Fate of P Ecol Eng 1995.pdf
From:	Dr. Graetz
District Question:	4
Abstract:	Phosphorus loading from dairies and beef ranches in the Lake Okeechobee watershed and the subsequent movement of the P into the drainage waters is a major factor influencing the eutrophication of Lake Okeechobee. The soils of this area are mainly Spodosols with the watertable lying between surface and spodic horizons for extended periods each year. In this study, the quantity of total P (TP) within the soil profile (A, E, Bh and Bw horizons) of dairies and beef ranches in the Lake Okeechobee basin was determined to evaluate the magnitude of P loading in these soils. The effect of cattle density was evident in TP concentrations throughout the soil profile. In the A horizon, mean TP concentrations were 1680, 165, and 34 kg P ha−1 for high, low, and nonimpacted areas, respectively. The same trend, although at lower concentrations, was evident in the E, Bh, and Bw horizons. The quantity of P considered to be potentially mobile under leaching conditions (water-soluble P, Mehlich I extractable or NH4Cl extractable), also followed similar trends as the TP concentrations. Based on chemical fractionation data, nearly 80% of TP in the A horizon of the highly impacted soils may be considered leachable. We calculated hat about 4000 kg P ha−1 would be available for leaching in the soil profile of the high intensity areas immediately adjacent to the dairy barns. This “labile P” appears to be solubilized slowly over a long period of time (likely several years). There seems to be no natural mechanism whereby the P is stabilized through the formation of minerals, and even if such processes do take place, a vast amount of P still remains in a form in which it is readily transported along with the drainage water. The A and E horizons had poor P retention capacities while the retention capacity of the Bh horizon varied with the soil type, Myakka ≥ Immokalee > Pomello. Due to the Low P-retention capacity in the upper horizons of these soils, there is potential for significant subsurface lateral P transport.

Title:	Fate of phosphorus on bahiagrass (Paspalum notatum) pastures
Source:	Ecological Engineering, Volume 5, Issues 2-3, November 1995, Pages 247-259
Authors:	Rechcigl, J. E. And A. B. Bottcher
Document:	Rechcigl Fate of P on bahiagrass.pdf
From:	ScienceDirect
District Question:	5
Abstract:	Phosphorus is considered to be the major factor causing eutrophication of Lake Okeechobee and other waterways in Florida. An important source of P for Lake Okeechobee is runoff of soluble P fertilizer applied to bahiagrass (Paspalum notatum Flugge) pastures. The present study was conducted to ascertain whether P application levels could be reduced below current agronomic recommendations without affecting pasture yields or quality and to determine the effects of P application on surface water quality. A field study was conducted on a bahiagrass pasture to assess the yield response of bahiagrass to five annual rates of P (0, 6, 12, 24 and 48 kg ha−1) and two application times (dry season and wet season). Fertilizer treatments were arranged in a randomized complete block design with four replications on an Immokalee fine sand (sandy, siliceous, hyperthermic Arenic Haplaquods). Results indicate that P fertilization rates could be reduced from 48 to 24 kg P ha−1 without affecting yields or quality of bahiagrass. Yields in 1989 averaged 11.4, 14.7 and 10.4 Mg ha−1 for the 48, 24 and 0 kg P ha−1 treatment, repectively. Time of P application had no effect on yields or quality of bahiagrass. There was a linear increase in Mehlich I extractable P in the A and E horizons and a quadratic increase to P in the Bh horizon in 1989. Extractable P ranged from 3.8 to 22.5, 1.3 to 2.5, and 21 to 55 mg P kg−1 for the A, E and Bh horizons, respectively. Phosphorus concentrations in surface water runoff was reduced from 33 to 60% as P application rates were decreased from 48 to 12 kg P ha−1 while total P loss was reduced from 17 to 78%, respectively. Recommended reductions in P application should result in substantial cost savings to producers and also reduce P inputs into surface water.

Title:	Potential internal loading of phosphorus in a wetland constructed in agricultural land
Source:	Water Research [Water Res.]. Vol. 37, no. 5, pp. 965-972. Mar 2003.
Authors:	Pant, HK; Reddy, KR
Document:	Pant Potential internal loading of P.pdf
From:	ScienceDirect
District Question:	5
Abstract:	Wetland construction on agricultural or dairy lands could result in solubilization of phosphorus (P) stored in soils and release to the water column. To study the extent of P flux during the start-up period of a constructed wetland, intact soil-cores from areas used for dairy operations, in Okeechobee, Florida, USA were obtained and flooded with adjacent creek water. In the first 28-day hydraulic-retention period, P concentration in the water column increased several fold due to rapid P flux from impacted soils. A continuous decrease in P flux to the water column until the third hydraulic retention cycle (initial influent P concentration 0.2 mg L−1), and constant thereafter suggest that the effect of initial influent P upon long-term P flux from soils could be limited. The initial release maybe due to high concentration of labile P in impacted soils; however, slow dissolution of relatively stable P pools could maintain a steady flux, well above of that observed from non-impacted soils. Water soluble P along with double acid-extractable magnesium explained 76% of the variability in cumulative P flux to the water column. Apparently, co-occurrence of active adsorption–desorption phenomena due to independent maintenance of equilibrium by individual P compounds regulates P dynamics of the water column. The results indicated that equilibrium P concentration of the water column of the wetland would be above 1.3 mg L−1, which is well above the targeted P level in the water column of the Lake Okeechobee, one of the main water bodies in the area (0.04 mg P L−1). This suggests construction of wetlands in agricultural lands could result to substantial internal P loading. However, preventative measures including chemical amendments, establishment of vegetative communities or flushing the initially released P may potentially stabilize the system, and maintain P removal efficiency.

Title:	Hydrologic influence on stability of organic phosphorus in wetland detritus.
Source:	Journal of environmental quality, 2001 Mar-Apr, 30(2):668-74
Authors:	Pant, H.K., K.R. Reddy
Document:	
From:	CSA
District Question:	4
Abstract:	Accretion of organic matter in wetlands provides long-term storage for nutrients and other contaminants. Water-table fluctuations and resulting alternate flooded and drained conditions may substantially alter the stability of stored materials including phosphorus (P). To study the effects of hydrologic fluctuation on P mobilization in wetlands, recently accreted detrial material (derived primarily from Typha spp.) was collected from the Everglades Nutrient Removal Project (ENRP), a constructed wetland used to treat agricultural drainage water in the northern Everglades. The detrital material was subjected to different periods of drawdown and consecutive reflooding under laboratory conditions. The 31P nuclear magnetic resonance (31P NMR) spectroscopy analysis revealed that sugar phosphate, glycerophosphate, polynucleotides, and phospholipids (glycerophosphoethanolamine and glycerophosphocholine) were the major forms of P in the detrital material. After 30 d of drawdown, polynucleotides were reduced to trace levels, whereas sugar phosphate, glycerophosphate, and phospholipids remained the major fractions of organic P. Microorganisms seemed to preferentially utilize nucleic acid P, perhaps to obtain associated nutrients including carbon and nitrogen. At the end of the 30-d reflooding period, cumulative P flux from detritus to water column accounted for 3% of the total P (< or = 15 d of drawdown) and further decreased to 2% at 30 d of drawdown, but increased to 8% at 60 d of drawdown. The drawdown (< or = 30 d) not only reduced P flux to the water column, but also increased the humification and microbial immobilization of P. Excessive drawdown (60 d), however, triggered the release of P into the water column as the water content of detritus decreased from 95 to 11%.

Title:	Phosphorus retention in soils from a prospective constructed wetland site: Environmental implications
Source:	Soil Science [Soil Sci.]. Vol. 167, no. 9, pp. 607-615. Sep 2002.
Authors:	Pant, HK; Reddy, KR; Spechler, RM
Document:	
From:	CSA
District Question:	5
Abstract:	The phosphorus (P) retention characteristics of soil layers are critical for predicting the effectiveness of a constructed wetland, built in high water table soils, in reducing P transport to the receiving water body. Soil samples were collected from surface and subsurface horizons for P sorption and mineralogical studies directed to the assessment of a proposed site for stormwater treatment area (STA) construction in the Okeechobee Basin, Florida. The P sorption maxima were positively correlated with oxalate-extractable aluminum (ox-Al) and citrate dithionite bicarbonate-extractable aluminum (CDB-Al) under anaerobic conditions, but there was no significant correlation with either ox- or CDB-extractable iron (Fe). The ox/CDB ratio for extractable Fe was relatively high (>0.5), indicating that most of the Fe was in noncrystalline form, i.e., highly reactive and prone to rapid dissolution under reducing conditions. The X-ray Diffraction (XRD) patterns indicated that smectite was the dominant mineral in the clay-size fraction. The permanent negative charge of smectite limits contribution to P sorption. The equilibrium P concentrations (EPC sub(0)) of the soils were significantly correlated to CDB-Al but not to CDB-Fe, suggesting that Al-associated P is involved primarily in elevating EPC sub(0) in these soils. Both P sorption capacity and EPC sub(0) were fairly low for soils from most locations, indicating that the proposed STA cannot remove P from the rerouted water to a significant extent under ambient conditions and would not also cause significant P loading to the water table aquifer. Thus, alternatives for effective P sequestration, such as establishment of vegetative communities or chemical amendment, would be required.

Title:	Influence of Flooding on Phosphorus Mobility in Manure-Impacted Soil
Source:	Journal of Environmental Quality [J. Environ. Qual.]. Vol. 31, no. 4, pp. 1399-1405. Jul-Aug 2002.
Authors:	Pant, H.K., V.D. Nair, K.R. Reddy, D.A. Graetz, R.R. Villapando
Document:	Pant Phosphorus Mobility JEQ 02.pdf
From:	Dr. Graetz
District Question:	4
Abstract:	Agricultural lands are often used for constructing stormwater treatment areas (STAs) to abate nutrient loading to adjacent aquatic systems. Flooding agricultural lands to create STAs could stimulate a significant release of phosphorus (P) from soil to the water column. To assess the suitability of agricultural lands, specifically those impacted by animal operations, for the construction of STAs, soils from different components of the New Palm-Newcomer dairies (Nubbin Slough Basin, Okeechobee, Florida, USA) were collected by horizon and their P retention and release capacities estimated. In general, P released from A-horizon soil under flooded (anaerobic) conditions was greater than under drained (aerobic) conditions due to redox effect on iron (Fe) and consequent P releases. However, the P released from Bh-horizon soil was greater under aerobic conditions than under anaerobic conditions, possibly due to excessive aluminum (Al) content in the horizon. Double acid-extractable calcium (Ca), magnesium (Mg), Al, and P explained 87% of the variability in P release under aerobic conditions, and 80% of that under anaerobic conditions. The P release maxima indicated a high solubility of P in A-horizon soil from both active and abandoned dairies (13 and 8% of the total P, respectively), suggesting that these soils could function as potential sources of P to the overlying water column when used in STA construction. Preestablishment of vegetative communities or chemical amendment, however, could ameliorate high P flux from soil to the water column.

Title:	Influence of chemical amendments on phosphorus immobilization in soils from a constructed wetland
Source:	Ecological Engineering [Ecol. Eng.]. Vol. 14, no. 1-2, pp. 157-167. Jan 2000.
Authors:	Ann, Y; Reddy, KR; Delfino, JJ
Document:	Ann Influence of chemical amendments.pdf
From:	ScienceDirect
District Question:	5
Abstract:	Soils previously used for agriculture are currently being converted to wetlands with the goal that they will function as sinks for nutrients. However, residual fertilizer nutrients, especially phosphorus (P) are rapidly released upon flooding. The objective of this study was to evaluate the efficacy of selected chemical amendments in immobilizing the soluble soil P. Soil used in the study was an organic soil, obtained from a 3-month old constructed wetland created on an agricultural land in Lake Apopka Basin, central Florida. Chemical amendments used were: CaCO sub(3), (calcite), Ca(OH) sub(2), CaMg(CO sub(3)) sub(2) (dolomite), Al sub(2)(SO sub(4)) (alum), FeCl sub(3) and mixtures of selected amendments. The effective amounts required for each chemical amendment to minimize P release from soil to overlying floodwater were 7-15 g kg super(-1) for CaCO sub(3) and Ca(OH) sub(2), 12 g kg super(-1) for alum, and 1-2 g kg super(-1) for FeCl sub(3). Based on P flux, the order of effectiveness in immobilizing soluble P was as follows: FeCl sub(3)>alum>Ca(OH) sub(2)>calcite>dolomite. High rates of chemical amendments are needed to reduce P levels, because of complexation of P binding cations (Ca, Fe and Al) with organic matter.

Title:	Phosphorus assimilation in a stream system of the Lake Okeechobee basin
Source:	Water Resources Bulletin. Vol. 32, no. 5, pp. 901-915. 1996.
Authors:	Reddy, K.R., E. Flaig, L.J. Scinto, O. Diaz, T.A. DeBusk
Document:	
From:	CSA
District Question:	4
Abstract:	The ability to predict how streams and wetlands retain phosphorus (P) is critical to the management of watersheds that contribute nutrients to adjacent aquatic systems such as lakes. Field and laboratory experiments were conducted to determine the P assimilatory capacity of a stream (Otter Creek) in the Taylor Creek/Nubbin Slough Basin located north of Lake Okeechobee, Florida. Dominant soils in this basin are sandy Spodosols; landuse is primarily dairy farms and beef cattle pastures. Estimates of P assimilation show that sediments assimilate approximately 5 percent of the P load. Phosphorus assimilation rates in the stream were estimated using first-order relationships based on the total P concentration of the water column as a function of distance from the primary source. This method assumes minimal lateral inputs. Stream lengths required for one turnover in P assimilation were estimated to be in the range of 3-16 km. Laboratory studies using intact sediment cores indicated a P assimilation rate of 0.025 m/day, and equilibrium P concentration of 0.16 plus or minus 0.03 mg/L in the water column. Dissolved P concentration gradients in the sediments showed upward flux of P at water column P concentration of <0.16 mg/L. Approximately 56-77 percent of the P assimilated in the above-ground vegetation during active growth was released or translocated within six months of senescence, suggesting short-term storage in above-ground vegetation. Bottom sediments and recalcitrant detrital plant tissue provide for long-term P assimilation in the creek. Although stream sediments have the potential to adsorb P, high flow rate and low contact period between water and sediment limits this process

Title:	Nitrogen and Phosphorus Fluxes From a Flooded Organic Soil
Source:	Soil Science Vol. 136, No. 5, p 300-307, 1983. 5 Fig, 14 Ref.
Authors:	Reddy, KR; Rao, PSC
Document:	
From:	CSA
District Question:	4
Abstract:	Florida has approximately 1.5 million hectares of organic soils, which were formed by the accumulation of the decayed remains of sawgrass and related wetland plants over the last 5000 years. Under laboratory conditions the anaerobic soil layer ammonification was functioning at a rate of 0.11 g N/sq m-day, and NH4+ flux from the anaerobic soil layer to the floodwater and to the aerobic soil layer was 0.045 g N/sq m-day. The sequential N processes functioning in a flooded organic soil include: ammonification in the anaerobic soil layer, upward diffusion of NH4+ from the anaerobic soil layer to the floodwater, nitrification in the floodwater, downward diffusion into the anaerobic soil layer and denitrification in the anaerobic soil layer. Losses due to these processes accounted for about 35% of the mineralized NH4+-N in the 21-cm organic soil column. The ammonification and NH4+ diffusion functioning at a slower rate probably are the limiting processes in N loss from a flooded organic soil. The results also showed that the rate of soluble P production in the anaerobic soil layer was 0.016 g P/sq m-day, and the flux of P, as a result of diffusion, was about 0.0098 g P/sq m-day. Major processes functioning in the anaerobic layer were mineralization of organic P, adsorption-desorption of P, and diffusion from underlying sediment to the overlying water. Losses of P due to these processes accounted for about 53% of the solubilized P in the 21-cm organic soil column

Title:	Use of Shallow Reservoir and Flooded Organic Soil Systems for Waste Water Treatment: Nitrogen and Phosphorus Transformations
Source:	Journal of Environmental Quality Vol 10, No 1, p 113-119, January-March, 1981. 6 Fig, 4 Tab, 19 Ref.
Authors:	Reddy, KR; Graetz, DA
Document:	
From:	CSA
District Question:	5
Abstract:	This study was conducted to evaluate the relative rates of NH4-N , NO3-N, and PO4-P removal from aerobic and anaerobic water columns with an underlying soil column, to determine the effect of residence time of the waste water above a soil column on inorganic N and PO4-P removal, to determine the significance of nitrification and NH3 volatilization in the water column, and to evaluate the P adsorption-desorption characteristics of the anaerobic reservoir sediments and flooded organic soils. The waste water used was obtained from drainage canals surrounding organic soils planted to vegetable crops located in Zellwood, Florida. The study demonstrated that flooded soils and shallow reservoirs can be effectively used for inorganic N levels of waste waters. Both aerobic and anaerobic water columns with an underlying anaerobic soil functioned as an effective treatment system for inorganic N removal. Aerating the water with carbon dioxide-free air resulted in increased losses of NH4-N through nitrification as compared to NH3 volatilization. It was concluded that shallow reservoirs with marly clay loam bottoms may be effectively used for reducing ortho-P levels of waste waters. (Baker-FRC

Title:	An environmental threshold for degree of phosphorus saturation in sandy soils
Source:	Journal of environmental quality., vol. 33, no. 1, pp. 107-113, Jan-Feb 2004
Authors:	Nair, V.D., K.M. Portier, D.A. Graetz, M.L. Walker
Document:	Nair DPS Environmental Threshold JEQ 2004.pdf
From:	Dr. Graetz
District Question:	4
Abstract:	There is critical need for a practical indicator to assess the potential for phosphorus (P) movement from a given site to surface waters, either via surface runoff or subsurface drainage. The degree of phosphorus saturation (DPS), which relates a measure of P already adsorbed by a soil to its P adsorption capacity, could be a good indicator of that soil's P release capability. Our primary objective was to find a suitable analytical protocol for determining DPS and to examine the possibility of defining a threshold DPS value for Florida's sandy soils. Four farmer-owned dairy sprayfields were selected within the Suwannee River basin and soil profiles were randomly obtained from each site, as well as from adjacent unimpacted sites. The soil samples were divided either by horizon or depth, and DPS was determined for each soil sample using ammonium-oxalate (DPS(Ox)), Mehlich-1 (DPS(M1)), and Mehlich-3 (DPS(M3)) extracts. All methods of DPS calculations were linearly related to one another (r2 > 0.94). Relationships between water-soluble P and DPS indicate that the respective change points are: DPS(Ox) = 20%, DPS(M1) = 20%, and DPS(M3) = 16%. These relationships include samples from Ap, E, and Bt horizons, and various combinations thereof, suggesting that DPS values can be used as predictors of P loss from a soil irrespective of the depth of the soil within a profile. Taking into consideration the change points, confidence intervals, agronomic soil test values, and DPS values from other studies, we suggest replacing Mehlich-1 P values in the Florida P Index with the three DPS categories (DPS(M1) = <30, 30-60, and >60%) to assign different P loss ratings in the P Index.

Title:	Phosphorus saturation in spodosols impacted by manure
Source:	Journal of environmental quality, 2002 Jul-Aug, 31(4):1279-85
Authors:	Nair, V.D., D.A. Graetz
Document:	Nair Phosphorus Saturation Spodosols JEQ 02.pdf
From:	CSA
District Question:	4
Abstract:	Significant amounts of phosphorus (P) accumulate in soils receiving animal manures that could eventually result in unacceptable concentrations of dissolved P loss through surface runoff or subsurface leaching. The degree of phosphorus saturation (DPS) relates a soil's extractable P to its P sorbing capacity, and is reportedly a predictor of the P likely to be mobilized from a system. A DPS value (DPS-1) was derived that expressed the percentage of Mehlich 1-extractable P to the sorbing capacity of a Spodosol (expressed as the sum of oxalate-extractable Fe and Al). Values of DPS-1 were determined in various horizons of soil in current and abandoned dairy systems in South Florida's Lake Okeechobee watershed to assess P release potential. Land use within the dairies was classified as highly impacted by cattle (intensive and holding), and minimally impacted by cattle (pasture, forage, or native) areas. The A and E horizon of soils in heavily manure-impacted intensive and holding areas for both active and abandoned dairies generally had higher DPS-1 values than the pasture, forage, and native area soils, which were minimally impacted by manure. Degree of P saturation was also calculated as a percentage of Mehlich 1-extractable P to the sum of Mehlich 1-extractable Fe and Al (DPS-2). Both DPS-1 and DPS-2 were shown to be significantly (P = 0.0001) related to water-extractable P for all soil horizons, suggesting that either index can be used as an indicator for P loss potential from a soil

Title:	Forms of phosphorus in soil profiles for dairies of south Florida
Source:	Soil Science Society of America journal., vol. 59, no. 5, pp. 1244-1249, Sept 1995-Oct 1995
Authors:	Nair, V.D., D.A. Graetz, K.M. Portier
Document:	Nair P Dairy Soils SSSAJ 1995.pdf
From:	CSA
District Question:	4
Abstract:	Soil P fractions of current and abandoned dairy systems in South Florida's Lake Okeechobee watershed were evaluated to develop an understanding of the stability of P in this basin. Land use within the dairies was classified as intensive (high cattle impacted) and pasture, forage, or native (low cattle impacted) areas All soils (Spodosols) were characterized for labile P (1 M NH4Cl), Fe-Al-associated P (0.1 M NaOH), Ca-Mg-associated P (0.5 M HCl), residual P, and organic P in the NaOH fraction The A horizons of the intensive areas had = 9% of total P as labile P, though most of the Ca-Mg-associated P (approximately 70% of total P) in these particular systems could also be removed by sequential NH4Cl extractions Therefore, almost 80% of the P in the surface horizons of the high cattle impacted areas had the potential to move eventually with drainage water into the lake The P in the E horizons of the intensive areas consisted primarily of labile P and Ca-Mg-associated P forms as well, though the total P in these horizons was < 5% of that for the A horizons About 80% of the total P in the spodic (Bh) horizons was extractable by NaOH, of which only 4 to 18% was associated with organic matter. The total P contents for all horizons of the soil profiles from the low cattle impacted areas were considerably less than those from the high cattle impacted areas. There were apparently no major shifts of P to more stable P forms, with time, for soils of high cattle impacted areas. Therefore, the possibility of P release from high cattle impacted soils, even after dairies were abandoned for more than 12 yr, cannot be ruled out.

Title:	A retardation-based model for phosphorus transport in sandy soil
Source:	Soil Science [Soil Sci.]. Vol. 171, no. 4, pp. 293-304. Apr 2006.
Authors:	Rhue, R.D., W.G. Harris, V.D. Nair
Document:	Rhue P Transport Model Sandy Soil.pdf
From:	CSA
District Question:	6
Abstract:	Animal-based agricultural is practiced in many areas of the world on sandy soils in which leaching is the major transport process for phosphorus (P). Disposing of large quantities of animal wastes on these soils can overload their P retention capacity and lead to elevated concentrations of P in ground and surface water. Subsurface zones may represent sizeable reserves for storing P, but to effectively utilize these zones, a way of predicting how much P will be adsorbed before solution P concentrations exceed acceptable limits must be known. This article describes a simple transport model that simulates P leaching through soil that uses soil bulk density, volumetric water content, solution P concentration, and column length as inputs. Phosphorus is partitioned between soil and solution phases using Freundlich equations whose parameters are calculated from a single-point adsorption measurement. The model was used to simulate P leaching from 40 columns containing samples of A, E, or Bt horizons of soil from the Suwannee River basin of Florida and Georgia, in the United States; some of which had been loaded with P from dairy and poultry manure applications. The degree of P saturation, DPS, based on acid ammonium oxalate-extractable P, Fe, and Al, ranged from 4% to 140% for these soils. No soil with a DPS of <50% had an initial column leachate P concentration that exceeded 0.10 mg L-1. The relationship between measured and simulated retardation of P for soils with a DPS of <50% was good (R2 = 0.873), but the measured retardation exceeded simulated retardation by about 30%. This was attributed to the fact that the Freundlich parameters were based on a 24-h equilibration between soil and solution, whereas the column studies covered a period of about 2.5 years. The relationship for soils with a DPS of >50% was not as good (R2 = 0.333) but could be improved considerably (R2 = 0.661) by setting the initially adsorbed P in the model equal to the oxalate-extractable P and adjusting the desorption exponent in the Freundlich equation to allow for greater desorption of P. The model was able to capture several important aspects of P retention in sandy soil despite its simplicity and small number of inputs

Title:	Phosphorus retention as related to morphology of sandy coastal plain soil materials.
Source:	Soil Science Society of America journal., vol. 60, no. 5, pp. 1513-1521, Sept 1996-Oct 1996
Authors:	Harris, W.G.; Rhue, R.D.; Kidder, G.; Brown, R.B.; Littell, R.
Document:	
From:	CSA
District Question:	4
Abstract:	Phosphorus retention in sandy coastal plain soils can be low enough that surface water quality is jeopardized by agricultural P loadings. Objectives of this study were to: (i) determine if discrete morphological characteristics could effectively differentiate sandy soils with respect to P retention and (ii) test the efficacy of a rapid chemical assessment of relative P adsorption (single-point isotherm) for sandy materials. Soil samples from 96 surface and subsurface horizons of randomly selected Alaquod, Quartzipsamment, and Paleudult pedons were used. These pedons had previously been described. sampled, and characterized as part of the Florida Cooperative Soil Survey Program. Two groups of uncoated Quartzipsamments (<5% silt plus clay) were distinguished: those having "clean" (coating-free) and "slightly coated" grains. Eluvial horizons from Alaquods were also designated as clean because of a dominance of coating-free sand grains. Single-point P adsorption isotherms were obtained for all samples, and multipoint adsorption and desorption isotherms for 21 of the 96 samples. Single-point isotherms effectively arrayed sandy material with respect to relative P adsorption. Sand-grain coatings significantly enhanced P adsorption and resistance to desorption. All clean samples readily desorbed P regardless of origin or amount adsorbed. Thus clean sands pose a greater hazard for P leaching than sands with grain coatings. Clay content was closely related to P adsorption, but silt content was not. The P-retention distinction between clean and other Quartzipsamments is more marked than the "uncoated vs. coated" USDA family criterion, the latter being confounded by the inclusion of silt content

Title:	Effects of phosphorus and potassium on forage nutritive value and quantity: Environmental implications
Source:	Agronomy Journal, 96 (5) pp. 1299-1305, 2004
Authors:	Pant, HK; Mislevy, P; Rechcigl, JE
Document:	
From:	CSA
District Question:	4
Abstract:	Management practices minimizing P application in agricultural catchments ultimately reduce P export to waters. To determine stargrass (Cynodon nlemfuensis Vanderyst var. nlemfuensis) response to P and K, eight rates of P and K were applied on experimental units located on Pomona fine sand (sandy, siliceous, hyperthermia Ultic Alaquods) Spodosols, and arranged in a randomized complete block design with four replicates. The forage yield was less from 39:0 (P/K; kg ha⁻¹ yr⁻¹) treatment than the experimental units supplied with 93 kg K ha⁻¹ yr⁻¹ and low P (10 and 20 kg ha⁻¹ yr⁻¹) in all years with exception in 1998 (i.e., the year of grass establishment), indicating efficient P utilization due to K applications. No significant differences were obtained in in-vitro organic matter digestibility (IVOMD) from the applications of 10 kg P ha⁻¹ yr⁻¹ and 93 kg K ha⁻¹ yr⁻¹. The applications of 10 and 93 kg ha⁻¹ yr⁻¹ of P and K, respectively, provided efficient P utilization. Phosphorus mass balance showed that stargrass receiving 10 and 93 kg ha⁻¹ yr⁻¹ of P and K, respectively, removed maximum P (161% of the applied P) by uptake from soils. This may indicate the capability of stargrass to mine P from subsoils if sufficient K is supplied, and also suggests that stargrass may be useful for crop phytoremediation on P-impacted sites. In general, this study indicates that applications of 10 kg P ha⁻¹ yr⁻¹ in combination with 93 kg K ha⁻¹ yr⁻¹ will maintain forage nutritive value and quantity, and maximize P removals by stargrass. Moreover, the supply of sufficient K appears to be crucial for efficient P utilization by forages, reducing potential adverse effects of P over-fertilization on water quality.

Title:	Dairy Manure Influences on Phosphorus Retention Capacity of Spodosols
Source:	J. Environ. Qual. 27:522-527 (1998).
Authors:	V. D. Nair, D. A. Graetz, and K. R. Reddy
Document:	Nair P Retention Capacity JEQ 1998.pdf
From:	Dr. Graetz
District Question:	4
Abstract:	Land areas used for dairy farming can result in accumulation of manure on soils that could produce nutrient-rich surface and subsurface runoff and cause accelerated lake eutrophication. This research was conducted on Spodosols that were differentially impacted by manure; the study included sites with different levels of total P (TP), from 2300 nig kg ' in the soil highly impacted by intensive dairy farming to 18 mg kg J in an unimpacted area. The P retention characteristics of these soils were determined by using both single-point (1000 mg P kg'1 or 100 mg P I. ') and traditional Langmuir isotherms. Phosphorus sorption values using a single high P solution had approximately a 1:1 relationship with values obtained for the maximum retention capacity, Snlal, obtained from Langmuir isotherms (r2 = 0.98). The surface A and E horizons of manure-impacted soils had essentially no sorbing capacity while the Bh (spodic) and Bw horizons had mean Smax values 430 and 385 mg kg"1, respectively. The P sorbing capacity of the Bh and Bw horizons were attributed to high Al concentrations in these horizons. Higher P concentrations in the surface A horizon resulted in greater P concentrations in solutions equilibrated with the Bh- and Bw- horizon materials, which suggests a potential for vertical P movement through the soil profile. The spodic horizon of the lessimpacted soils may not have been exposed to sufficiently high solution P concentrations to accumulate significant P in the soluble fraction.

Title:	Laboratory validation of soil phosphorus storage capacity predictions for use in risk assessment
Source:	Soil Science Society of America Journal. doi:10.2136/sssaj2006.0094, 2007
Authors:	Chrysostome, M., V.D. Nair, W.G. Harris, and R.D. Rhue. 2007
Document:	
From:	Dr. Nair
District Question:	4
Abstract:	Soil P concentrations in agricultural soils have increased over the years, increasing concerns about eutrophication of surface waters. Sandy soils are particularly prone to P leaching due to limited P retention capacity. This study tested the validity of a measure of soil P storage capacity (SPSC) for sandy soils amended with dairy and poultry manure by evaluation of SPSC response to P gain or loss under controlled laboratory conditions. Forty soil samples representing A, E, and Bt horizons were collected from two dairy and two poultry operations within the Suwannee River Basin. Soils were packed into 1.5-cm-diameter columns and 0.05 M KCl solution was passed through the column using unsaturated flow at pore water velocities of approximately 1 cm d–1. Then the soils were leached with known quantities of P. Several P addition and leaching cycles followed and the whole experiment lasted approximately 30 mo. Phosphorus in the leachate was measured after each P addition. The P saturation ratio (PSR) was calculated from oxalate P, Al, and Fe extracts analyzed before and after the study. The SPSC of the soils was calculated based on a threshold PSR of 0.15 for the oxalate solutions. Changes in SPSC due to repeated P additions corresponded to predicted values calculated from P loading amounts, taking into consideration the P concentration before additional P loading. Results support the validity of SPSC as a means of estimating P loading rates that pose low environmental risk for specific sandy soils.

Title:	Phosphorus Retention Capacity of the Spodic Horizon under Varying Environmental Conditions
Source:	J. Environ. Qual. 28:1308-1313 (1999).
Authors:	Nair, V.D., R.R. Villapando, and D.A. Graetz
Document:	Nair P Retention spodic 1999.pdf
From:	Dr. Graetz
District Question:	4
Abstract:	The spodic (Bh) horizon of Spodosols with AI, Fe, and C accumulations usually has a high P sorption capacity. However, the Bh horizon of prevalent Spodosols in the Lake Okeechobee basin of Florida is subject to a fluctuating watertable that could change the dynamics of P in these soils under alternating aerobic and anaerobic conditions. Further, the Bh horizon of this basin is often impacted by P moving vertically following heavy surface application of dairy manure. Our objectives were to relate the P retention capacity of the Bh horizons of the LakeO keechobeeb asin to other soil parameters,a nd to evaluate P retention of manure-impactedB h horizons under aerobic and anaerobic conditions. High watertable decreased the P retention capacity for the majority of the soils in this study. High manure-impacteadr eas have Bh horizons with high P concentrations as a result of P movement from the surface A horizon through the eluted E horizon. The P appeared to be temporarily retained and could be released upon prolonged contact with water. This P is likely to move horizontally above the Bh horizon to drainage ditches and eventually into the lake, causing eutrophication. The equilibrium P concentrations and water soluble P concentrations of Bh horizon soils that did not receive high rates of manurea pplication (native soils and pasture soils) are low and it is unlikely that P would move laterally out of such systems, above the Bh horizon.

Title:	Silvopastoral agroforestry for reducing phosphorus loss from subtropical sandy soils. Plant and Soil
Source:	in press, 2007
Authors:	Nair, V. D., S. Haile, G.A. Michel, and P.K. Nair
Document:	
From:	Dr. Nair
District Question:	5
Abstract:	Phosphorus (P) losses from sandy soils that are predominant in the 1.4 million ha of pastureland in Florida are a major cause of water pollution. We hypothesized that soil P loss would be lower from silvopastoral systems than from treeless pastures because soil P removal by a combined stand of trees and pasture would be more than that of treeless pasture. Four slash pine (Pinus elliottii Engelm.) + bahiagrass (Paspalum notatum Flüggé) silvopastoral systems located in Alachua, Suwannee, Manatee, and Osceola counties in Florida were selected for the study. The former two sites are on Ultisols, and the latter two on Spodosols. Soil samples were collected at different depth increments. Soil P storage capacity (SPSC), the maximum amount of P that can be safely applied to a soil before it becomes an environmental concern, was calculated. Water-soluble P concentrations in the 0–5 cm soil layer ranged from 4 to 11 mg kg−1 for the silvopasture sites and 10 to 23 mg kg−1 in the treeless pasture sites, with higher P concentrations in the treeless pasture at each location. Total SPSC in the upper 1 m depth ranged from 342 to 657 kg ha−1 in the silvopasture sites and −60 to 926 kg ha−1 in the treeless pasture sites (a negative value indicates that the soil is a P source). The results suggest that P buildup within the soil profile and therefore the chances for loss of P from soil to water bodies were less from silvopastures than from treeless pastures. Thus, silvopasture systems can be expected to provide greater environmental service in regard to water quality protection compared to treeless pastures under comparable ecological settings

Title:	A capacity factor as an alternative to soil test phosphorus in phosphorus risk assessment
Source:	A04074; Online publication date 15 December 2004
Authors:	Nair, V.D., W. G. Harris
Document:	Niar P Capacity factor 2004.pdf
From:	Dr. Graetz
District Question:	4
Abstract:	Soil test phosphorus (P) concentrations (STP) are often used as measures of environmental P risk. However, a low STP is not valid justification for further P application because P sorption capacity may be low and P added could be lost to surface waters. The degree of P saturation (DPS) normalises extractable P using extractable Al and Fe as a surrogate for P sorption capacity, but like STP, fails to convey a magnitude of capacity. We propose the use of a DPS-based prediction of the remaining soil P storage capacity (SPSC) that would capture risks arising from previous loading as well as inherently low P sorption capacity. The SPSC is a direct estimate of the amount of P a soil can sorb before exceeding a threshold soil equilibrium concentration. In this paper, we demonstrate the applicability of the SPSC for a variety of sandy soils impacted by dairy and poultry manure additions. The SPSC provides a means to assess the capacity of a soil to retain additional P and hence is a more useful indicator of P-related environmental risk than STP or DPS measures alone.

Title:	Phosphorus Sorption and Desorption Properties of the Spodic Horizon from Selected Florida Spodosols
Source:	Soil Science Society of America journal. 65:331-339 (2001)
Authors:	R. R. Villapando and D. A. Graetz
Document:	Villapndo P Sorption Spodic SSSAJ 2001.pdf
From:	Dr. Graetz
District Question:	4
Abstract:	The chemistry of P in the spodic (Bh) horizon of Florida Spodosols has generated considerable interest in recent years, particularly where depending on the soil series. Below the E horizon is the water quality problems have been reported. Early studies suggested that the Bh horizon can function as a sorption sink for P moving Al) have accumulated (Soil Survey Staff, 1996). This through nonretentive sands. However, the conditions under which P can be retained in or released from the Bh horizon have not been for the propensity of the Bh horizon to sorb P. Phosphoadequately investigated. This study evaluated the P sorption and desorption properties of the Bh horizon from 16 Florida Spodosols. The samples exhibited P sorption capacities that were reflective of their citrate-dithionite-bicarbonate (CDB)-extractable Al contents. Mean Langmuir sorption maximum (Smax) values of 7.55, 11.08, and 17.49 mmol P kg21 were obtained for low-, medium-, and high-Al soils, respectively. The CuCl2 extractable Al (organic matter bound) was the single most important chemical property contributing to P retention accounting for >60% of the variability in P sorption. Though anaerobic incubation altered P sorption and release, the effect was generally small and inconsistent. Such treatment reduced P sorption by low-Al soils and slightly increased that of high-Al soils. The lack of response to anaerobic incubation was attributed to generally low levels of reducible Fe in the soils. The samples also exhibited varying degrees of P sorption desorption hysteresis. Irreversibility was most pronounced for high-Al soils, where .70% of the added P remained sorbed after nine successive extractions. The relationships between Al contents and P sorption capacities should be useful in formulating site criteria for control and management of wastewater from dairy and other agricultural operations located on Florida Spodosols.

Title:	Nutrient Enrichment of Wetland Vegetation and Sediments in Subtropical Pastures
Source:	Soil Sci. Soc. Am. J. 69:539-548 (2005)
Authors:	Gathumbi, S.M., P.J. Bohlen, and D.A. Graetz
Document:	2005_Gathumbi&Bohlen_SSSJ.pdf
From:	Dr. Bohlen
District Question:	4
Abstract:	Land use practices exert a major influence on plant productivity, soil and plant nutrient content, and within-stand nutrient cycling in wetlands in agricultural landscapes.Weexamined differences between improved and seminative pastures in plant and soil nutrient characteristics in seasonally flooded wetlands in subtropical grazing land of south central Florida. The wetlands were embedded within either grazed improved pastures with a long-term history of fertilizer applica- or seminative pastures with no history of previous fertilizer applition cation. Soil nutrient concentrations decreased with soil depth for both land use types. Total C, N, and P were significantly greater ($P < 0.05$) in the 0- to 15-cm mineral layer compared with the deeper layers (15–30, 30–45 cm) for both improved and seminative pasture wetland soils. Improved pasture wetlands had greater amounts of total P (22.3 kg P ha┐1) in the upper 0- to 15-cm soil layer than did the seminative pasture wetlands (15.7 kg P ha┐1). Plant and soil (0–15 cm) N/P and C/P ratios were lower in improved pasture wetlands com- pared with seminative pasture wetlands, suggesting greater P enrich- ment in improved pasture wetlands. Microbial biomass C and N de- creased with soil depth in both pasture types. Soil microbial biomass C/total C ratios decreased with soil depth and were similar for both improved and seminative pasture wetlands. Our results suggest that plant and soil nutrient enrichment and storage in temporary wetlands may be impacted by adjacent land use practices, which potentially leads to the alteration of the structure and functions of these wet- land ecosystems.

Title:	Soil Phosphorus, Cattle Stocking Rates, and Water Quality in Subtropical Pastures in Florida, USA
Source:	Rangeland Ecol Manage 60:19-30 | January 2007
Authors:	J. C. Capece, K. L. Campbell, P. J. Bohlen, D. A. Graetz, and K. M. Portier
Document:	2007_capece_et_al_REM.pdf
From:	Dr. Bohlen
District Question:	1,2
Abstract:	Minimizing nonpoint source nutrient pollution is important to the sustainability of grazing lands. Increased nutrient loads have reduced water quality in Lake Okeechobee in south Florida, prompting establishment of a Total Maximum Daily Load (TMDL) that will require large reductions in phosphorus (P) runoff into the lake. A significant portion of this reduction must come from beef cattle ranches, the major land use in the region. A large-scale research project, consisting of a 420-ha array of 8 improved summer and 8 semi-improved winter pastures, was established from 1998–2003 to investigate the influence of beef cattle stocking rate on nutrient loads in surface runoff. Each pasture type had two replicates of four different cattle stocking rates including a control with no cattle and stocked pastures with low, medium, and high stocking rates (1.3, 1.0, 0.6 ha AU┐1 [animal unit] in summer pastures; 2.1, 1.6, and 0.9 ha AU┐1 in winter pastures). Cattle stocking rate did not affect nutrient concentrations or loads in surface runoff during the study period. Average annual P discharges were 1.71 kg ha┐1 from summer pastures and 0.25 kg ha┐1 from winter pastures. Average total P concentrations in runoff were 0.63 mg L┐1 for summer pastures and 0.15 mg L┐1 for winte pastures. Differences in runoff P were related to differences in soil P test results, a difference believed to be due to prior fertilization practices. Our findings show that reducing cattle stocking rates on beef cattle pastures is not an effective practice for reducing nutrient loads, and that accumulation of P in soil from historical fertilization has an overriding influence on P loads in surface runoff. Results indicate that reducing the overall volume of surface discharges would be a more effective strategy than altering cattle stocking practices to reduce nonpoint runoff of P from cattle pastures in this region.

Title:	Associated Release of Magnesium and Phosphorus from Active and Abandoned Dairy Soils
Source:	J. Environ. Qual. 34:184-191 (2005)
Authors:	M. S. Josan, V. D. Nair, W. G. Harris, and D. Herrera
Document:	Josan Release of Mag 2005.pdf
From:	Dr. Nair
District Question:	4
Abstract:	Dairy manure application to soils can result in phosphorus (P)-related degradation of water quality. The P in these manure-impacted soils can be labile even years after abandonment and under conditions normally associated vith high P stability. Failure of P to stabilize with time compounds the environmental consequences of dairy manure disposal, especially on sandy soils. The objectives of this study were to compare chemical characteristics of active and abandoned dairy manure-impacted soils and minimally impacted soils and to assess the continuous release of P in relation to sparingly soluble salts using repeated water extractions, X-ray diffraction, and speciation modeling of column leachates. Soil samples from Ap horizons were collected from nine highly manure-impacted (total P > 1000 mg P kg-' soil) areas on four active and five abandoned dairies and four minimally impacted soils (total P < 200 mg P kg-' soil). Soil extracts were analyzed for electrical conductivity (EC), soluble reactive phosphorus (SRP), Ca, Mg, Na, and K. The EC of the soil solutions decreased as active dairy > abandoned dairy > minimally impacted soils. Release of Mg and SRP were significantly correlated (r' = 0.68) and did not decline after abandonment; Ca release was not correlated with SRP (r2 = 0.01), and declined significantly ($p < 0.05$) after abandonment. Speciation data from column leachates suggested that Mg-P phases and/or the most soluble Ca-P phases could control P solution activities. An implication of this study is that P stabilization via crystallization of calcium phosphates (even at nearneutral pH) may be preempted by Mg-P association. Thus, mechanisms to minimize P release may require P-retaining soil amendments or management of animal rations to eliminate Mg-P formation.

Title:	A quick field test for evaluating phosphorus movement in sandy soils
Source:	New Zealand J. of Agricultural Research, 2005, Vol. 48: 367-375
Authors:	R. D. Rhue, V. D Nair, W. G. Harris
Document:	044 - Rhue et al. PQT.pdf
From:	Dr. Nair
District Question:	4
Abstract:	Assessing the risk of phosphorus (P) leaching in sandy soils requires a valid and practical indicator of the depth to which applied P has moved in soil. This paper describes a rapid field test for soil P called the Phosphorus Quick Test (PQT) that is based on the phosphomolybdate blue procedure. One gram samples of soil taken from known depths within a soil profile were saturated with 0.10 M HCl on a porcelain spot plate and a few drops of the solution were treated with phosphomolybdate reagent to form a blue colour. The depth to which P has moved into the soil can be determined visually after only a few minutes. A comparison of the PQT results with soil (Mehlich-1 P) and water-soluble P tests showed that the PQT could accurately determine the depth of P movement in sandy soils. Results of the PQT at a field site that had received a single, heavy application of dairy lagoon effluent showed that considerable downward movement of P occurred in some areas of the field as a result of the effluent application.

Title:	Phosphorus release characteristics of manure and manure-impacted soils
Source:	Food, Agriculture & Environment Vol.1(2) : 217-223. 2003
Authors:	Nair, V.D., D.A. Graetz, and D.O. Dooley
Document:	Nair Graetz Dooley Manure P FAE 2003.pdf
From:	Dr. Nair
District Question:	4
Abstract:	Phosphorus (P) management for dairy and beef cattle operations can be improved by understanding P chemistry in manure and manure-impacted soils. This study characterizes the P forms in dairy and beef cattle manure, and evaluates P release characteristics of manure-impacted soils. Dairy and beef manure from 5 cattle was collected in two consecutive years and subjected to sequential P fractionation, using 1.0 M NH4Cl (labile P), 0.1 M NaOH (Fe/Al-P) and 0.5 M HCl (Ca/Mg-P) for 2, 17, and 24 h, respectively. In the second year, manure samples were also extracted repeatedly with 1.0 M NH4Cl until no more P was released. Phosphorus release was influenced primarily by Ca and Mg concentrations in the manure, and their P release potential varied with the manure source. The Ca:Mg ratios in the sequential water extracts of manure-impacted soils decreased from 1.0 in the first extract to 0.6 in the tenth extract for soils collected from active dairies with high rates of manure application. The ratio was a constant 2.0 for soils from abandoned dairies with high manure application rates. Ca:Mg ratios were even higher for beef pasture and forage soils. It also appears that Mg concentrations in the manure could have a detrimental effect on Ca-P stabilization in manure-impacted soils. To minimize the environmental impact of manure applications, it may be necessary to reduce the amount of Mg in the manure through diet or by pre-treatment prior to land application.

Title:	Agroforestry as an approach to minimizing nutrient loss from heavily fertilized soils: The Florida experience
Source:	Agroforestry Systems 61: 269-279, 2004
Authors:	V.D. Nair and D.A. Graetz
Document:	Nair & Graetz - Agroforestry.pdf
From:	Dr. Nair
District Question:	5
Abstract:	Nutrient buildup in the soil caused by increased animal manure and fertilizer use in agricultural and forestry practices may increase the potential for their loss from the soil, leading to groundwater contamination and nonpoint source pollution. Studies in the tropics have suggested that agroforestry practices can reduce such nutrient (especially nitrogen) losses because of enhanced nutrient uptake by tree and crop roots from varying soil depths, compared to more localized and shallow rooting depths of sole crop stands. In temperate systems, such benefits have been well documented for riparian forest buffer practices. Currently, other temperate agroforestry practices are also being considered for their potential to reduce runoff and leaching of chemicals and thereby improve environmental quality within the agricultural landscape. In this regard, the 'Florida P-Index,' which considers both phosphorus transport characteristics and management practices, may be a useful tool in the evaluation of nutrient management practices and environmental benefits of agroforestry. Preliminary results from an alleycropping site and a silvopastoral site on two different soil types in Florida suggest that both of these agroforestry practices will likely reduce nutrient loss compared to conventional agricultural practices. The primary aspects of P-Index include consideration of transport factors such as soil erosion, soil runoff class, leaching potential, and distance from a water body along with management factors such as soil test P, P application method, and source and rate of P application. P-Index evaluation of these studies indicates that both agroforestry sites can be on a nitrogen-based nutrient management program. The relevance of some management practices such as application of manure vs. inorganic fertilizer is also discussed in light of the P-Index and the two agroforestry practices.

Title:	Minimizing Confounding Factors in Phosphorus Leaching Assessment for Dairy-and Poultry-Manure-Amended Soils
Source:	Communications in Soil Science and Plant Analysis, 38: 975-987, 2007
Authors:	Chrysostome, M., V.D. Nair, W.G. Harris, and R.D. Rhue
Document:	Chrysostome et al. Communications.pdf
From:	Dr. Nair
District Question:	5
Abstract:	Soil phosphorus (P) concentrations have increased over the years, increasing P losses to surface waters. Phosphorus saturation ratios (PSR), used as environmental soil tests, have different relationships with conventional water-soluble-P (WSP) determinations for dairy and poultry-manure-amended soils. Objective was to develop a WSP procedure to characterize P leaching from manure-amended soils. Soil samples were collected from dairy and poultry sites. WSP was determined using 1:10 and 5:1 soil–water ratios. Soils in columns were leached using unsaturated flow. Results showed that relationships between PSR and WSP 5:1 were consistent for all soils. The 5:1 ratio, closer to field moisture conditions, could be a good indicator of P leaching. There was good correlation between the WSP 1:10, 5:1, and column leachate, and a paired t test showed no difference between the last two. Thus, a single 5:1 extraction could be as useful in P leaching assessments as laborious column studies.

Title:	Phosphorus leaching potential from compost amendments in a carbonatic soi
Source:	Soil Science [Soil Sci.]. Vol. 171, no. 11, pp. 865-873. Nov 2006.
Authors:	Reed, S; Shinde, D; Konomi, K; Jayachandran, K; Nkedi-Kizza, P; Reza Savabi, M
Document:	
From:	CSA
District Question:	4
Abstract:	Composts are applied to carbonatic soils in south Florida to improve their physical characteristics and increase water retention. Blends of biosolids and municipal waste are often combined to increase the nutrient content of the compost. However, the high P content of some compost has led to concerns about the potential for P movement into shallow groundwater. Studies were conducted to determine the potential for P leaching in soil amended with biosolids, clean organic waste, and Bedminster composts. Bedminster was the most suitable of the composts used in terms of a lower potential for P leaching as a result of P sorption in the amended soil. Each compost-amended soil demonstrated a slight decrease in P leaching at 1 pore volume after simulated rainfall (21 cm). Pore volume was defined as the total volume in a column less the volume of solids. The high P content of the composts made it unlikely that additions of these materials to soil would improve P sorption capacity. However, Bedminster and clean organic waste did not significantly increase P leaching above that of the soil. Caution should be exercised when applying these composts because materials themselves contain an enormous amount of P that could be eventually transported into the groundwater.

Title:	Phosphorus concentrations and loads in runoff water under crop production
Source:	Soil Science Society of America Journal, vol.70, no.5, pp.1807-1816, Oct 2006
Authors:	He, Z L; Zhang, M K; Stoffella, P J; Yang, X E; Banks, D J
Document:	
From:	CSA
District Question:	4
Abstract:	Transport of phosphorus (P) through surface runoff from agriculture is suspected to contribute to the eutrophication of surface waters in South Florida and elsewhere. There is minimal quantitative information on the concentrations and loads of various P forms in surface runoff water on a field-scale. The objective of this study was to evaluate the annual loads of various P forms in runoff water from citrus and vegetable crop production systems in sandy soil regions in Florida and their relations to soil P status, fertilizer P input, and environmental conditions. Eleven field sites (four on vegetable farms and seven in citrus groves) were selected for this monitoring study over a 2-yr period. The concentrations of total P (TP) in the runoff water samples varied widely from 0.01 to 22.74 mg L (super -1) , with approximately half of the samples having the TP over 1 mg L (super -1) . Eighty-three percent of the samples had orthophosphate (PO (sub 4) -P) higher than 0.02 mg L (super -1) . The mean proportion of total dissolved P (TDP) in the TP was higher than that of the total particulate P (TPP). The TDP constituted the major proportion of P in runoff water from most of the sites. The PO (sub 4) -P accounted for approximately 64% of the TDP. The annual median concentrations of various P forms in the runoff water varied spatially and temporally and were correlated with total and labile P in the soils (water-P, Olsen-P, Mehlich 1-P, and Mehlich 3-P) as well as fertilizer P rate. The vegetable farms had higher concentrations of P in the runoff water than citrus groves due to their more severe soil erosion and higher fertilizer P input, which resulted in higher soil P accumulation and availability. The annual loads of TP, TDP, and PO (sub 4) -P varied among the field sites and between the 2 yr. The TP loads were significantly correlated with soil labile P estimated by the four extraction procedures, but the Olsen-P was best related to runoff P. Runoff P concentrations and the annual discharge rate accounted for 55 to 64% of the variance in the annual P loads. These results indicate that P transport through surface runoff from agriculture is affected by soil P status and water management, and merits attention in the development of best management practices.

Title:	Surface runoff phosphorus (P) loss in relation to phosphatase activity and soil P fractions in Florida sandy soils under citrus production
Source:	Soil Biology and Biochemistry [Soil Biol. Biochem.]. Vol. 38, no. 3, pp. 619-628. Mar 2006.
Authors:	Yu, S; He, ZL; Stoffella, PJ; Calvert, DV; Yang, XE; Banks, DJ; Baligar, VC
Document:	
From:	CSA
District Question:	5
Abstract:	Phosphorus losses by surface runoff from agricultural lands have been of public concern due to increasing P contamination to surface waters. Five representative commercial citrus groves (C1-C5) located in South Florida were studied to evaluate the relationships between P fractions in soils, surface runoff P, and soil phosphatase activity. A modified Hedley P sequential fractionation procedure was employed to fractionate soil P. Soil P consisted of mainly organically- and Ca/Mg-bound P fractions. The organically-bound P (biological P, sum of organic P in the water, NaHCO sub(3) and NaOH extracts) was dominant in the acidic sandy soils from the C2 and C3 sites (18% and 24% of total soil P), whereas the Ca/Mg-bound P (HCl-extractable P) accounted for 45- 60% of soil total P in the neutral and alkaline soils (C1, C4 and C5 soils). Plant-available P (sum of water and NaHCO sub(3) extractable P fractions) ranged from 27 to 61 mg P kg super(-1) and decreased in the order of C3>C4>C1>C2>C5. The mean total P concentrations (TP) in surface runoff water samples ranged from 0.51 to 2.64 mg L super(-1). Total P, total dissolved P (TDP), and PO sub(4) super(3-)-P in surface runoff were significantly correlated with soil biological P and plant-available P forms (p-0.01), suggesting that surface runoff P was directly derived from soil available P pools, including H sub(2)O- and NaHCO sub(3)- extractable inorganic P, water-soluble organic P, and NaHCO sub(3)- and NaOH- extractable organic P fractions, which are readily mineralized by soil microorganisms and/or enzyme mediated processes. Soil neutral (55-190 mg phenol kg super(-1) 3 h super(-1)) and natural (measured at soil pH) phosphatase activities (77-295 mg phenol kg super(-1) 3 h super(-1)) were related to TP, TDP, and PO sub(4) super(3-)-P in surface runoff, and plant-available P and biological P forms in soils. These results indicate that there is a potential relationship between soil P availability and phosphatase activities, relating to P loss by surface runoff. Therefore, the neutral and natural phosphatase activities, especially the natural phosphatase activity, may serve as an index of surface runoff P loss potential and soil P availability.

Title:	Use of dolomite phosphate rock (DPR) fertilizers to reduce phosphorus leaching from sandy soil
Source:	Environmental Pollution [Environ. Pollut.]. Vol. 139, no. 1, pp. 176-182. Jan 2006.
Authors:	Chen, GC; He, ZL; Stoffella, PJ; Yang, XE; Yu, S; Calvert, D
Document:	
From:	CSA
District Question:	5
Abstract:	There is increasing concern over P leaching from sandy soils applied with water-soluble P fertilizers. Laboratory column leaching experiments were conducted to evaluate P leaching from a typical acidic sandy soil in Florida amended with DPR fertilizers developed from dolomite phosphate rock (DPR) and N- Viro soil. ten leaching events were carried out at an interval of 7 days, with a total leaching volume of 1183 mm equivalent to the mean annual rainfall of this region during the period of 2001-2003. Leachates were collected and analyzed for total P and inorganic P. Phosphorus in the leachate was dominantly reactive, accounting for 67.7-99.9% of total P leached. Phosphorus leaching loss mainly occurred in the first three leaching events, accounting for 62.0-98.8% of the total P leached over the whole period. The percentage of P leached (in the total P added) from the soil amended with water-soluble P fertilizer was higher than those receiving the DPR fertilizers. The former was up to 96.6%, whereas the latter ranged from 0.3% to 3.8%. These results indicate that the use of N-Viro-based DPR fertilizers can reduce P leaching from sandy soils. Fertilizers developed from dolomite phosphate rock (DPR) reduce phosphorus leaching from sandy soil.

Title:	Surface runoff phosphorus (P) loss in relation to phosphatase activity and soil P fractions in Florida sandy soils under citrus production
Source:	Soil Biology and Biochemistry, 38 (3) pp. 619-628, 2006
Authors:	Yu, S; He, ZL; Stoffella, PJ; Calvert, DV; Yang, XE; Banks, DJ; Baligar, VC
Document:	
From:	CSA
District Question:	5
Abstract:	Phosphorus losses by surface runoff from agricultural lands have been of public concern due to increasing P contamination to surface waters. Five representative commercial citrus groves (C1-C5) located in South Florida were studied to evaluate the relationships between P fractions in soils, surface runoff P, and soil phosphatase activity. A modified Hedley P sequential fractionation procedure was employed to fractionate soil P. Soil P consisted of mainly organically- and Ca/Mg-bound P fractions. The organically-bound P (biological P, sum of organic P in the water, NaHCO<inf>3</inf> and NaOH extracts) was dominant in the acidic sandy soils from the C2 and C3 sites (18% and 24% of total soil P), whereas the Ca/Mg-bound P (HCl-extractable P) accounted for 45-60% of soil total P in the neutral and alkaline soils (C1, C4 and C5 soils). Plant-available P (sum of water and NaHCO<inf>3</inf> extractable P fractions) ranged from 27 to 61 mg P kg⁻¹ and decreased in the order of C3>C4>C1>C2>C5. The mean total P concentrations (TP) in surface runoff water samples ranged from 0.51 to 2.64 mg L⁻¹. Total P, total dissolved P (TDP), and PO<inf>4</inf>³⁻-P in surface runoff were significantly correlated with soil biological P and plant-available P forms ($p<0.01$), suggesting that surface runoff P was directly derived from soil available P pools, including H<inf>2</inf>O- and NaHCO<inf>3</inf>- extractable inorganic P, water-soluble organic P, and NaHCO<inf>3</inf>- and NaOH-extractable organic P fractions, which are readily mineralized by soil microorganisms and/or enzyme mediated processes. Soil neutral (55-190 mg phenol kg⁻¹ 3 h⁻¹) and natural (measured at soil pH) phosphatase activities (77-295 mg phenol kg⁻¹ 3 h⁻¹) were related to TP, TDP, and PO<inf>4</inf>³⁻-P in surface runoff, and plant-available P and biological P forms in soils. These results indicate that there is a potential relationship between soil P availability and phosphatase activities, relating to P loss by surface runoff. Therefore, the neutral and natural phosphatase activities, especially the natural phosphatase activity, may serve as an index of surface runoff P loss potential and soil P availability.

Title:	Three-Dimensional Modeling of Sediment and Phosphorus Dynamics in Lake Okeechobee, Florida: Spring 1989 Simulation
Source:	Journal of Environmental Engineering [J. Environ. Eng.]. Vol. 131, no. 3, pp. 359-374. Mar 2005.
Authors:	Chen, XinJian; Sheng, YP
Document:	
From:	CSA
District Question:	6
Abstract:	Lake Okeechobee is a large and shallow freshwater body in south Florida. Due to the shallowness of Lake Okeechobee, the nutrient dynamics are strongly influenced by hydrodynamic processes (circulation and wind-induced waves) and sediment transport processes. To study water quality and the effects of hydrodynamic and sediment transport processes on nutrient dynamics in the lake, a three-dimensional simulation system that closely couples hydrodynamic and sediment transport processes with nutrient dynamics was developed and used. In this paper, we present a three-dimensional, coupled hydrodynamics-sediment-nutrient model for Lake Okeechobee. The coupled model was used to simulate a four-week survey conducted in spring 1989 in Lake Okeechobee. By comparing model results to measured field data, it is shown that the coupled model system is able to simulate weekly sediment and phosphorus dynamics in Lake Okeechobee. Model applications demonstrated that the resuspension flux of phosphorus from the lake bottom is significantly higher than the molecular flux during resuspension events and can cause increases of phosphorus concentrations in the water column. Sensitivity runs of the model show that both the advective/diffusive transport and the algal uptake promote the release of phosphorus from suspended sediments and thus affect the phosphorus budget in the lake and the net resuspension flux of phosphorus from the lake bottom.

Title:	Groundwater inflow and associated transport of phosphorus to a hypereutrophic lake
Source:	Environmental Geology [Environ. Geol.]. Vol. 47, no. 4, pp. 565-575. Mar 2005.
Authors:	Kang, W-J; K.V. Kolasa, M.W. Rials
Document:	
From:	CSA
District Question:	7
Abstract:	Hydrogeochemical data from lake, sediment pore, and well waters were used to quantify groundwater seepage and the associated transport of phosphorus to Lake Persimmon, Florida, USA. The data show that lake chloride concentrations vary as a function of lake elevations that are controlled by groundwater inflow. A whole-lake average seepage rate, estimated using a simple one dimensional advection-diffusion model fitted to the lake chloride profile, currently averages 2.3 plus or minus 0.3 cm yr super(-1) and is in reasonable agreement with the rate of advective flow obtained from the pore water chloride profile. The ratios of nutrient regeneration versus sulfate consumption indicate that the phosphorus enrichment in deeper portions of sediment pore water is most likely a result of groundwater phosphorus transport through sediment. Thus, the net inputs of groundwater phosphorus to the lake, calculated using the deep pore water phosphorus concentration, are about 7.4 plus or minus 4.3 mg P m super(-2) yr super(-1) and comparable with recent in situ estimates from seepage meters. This study provides a simple hydrogeochemical method for estimating hydrologic and phosphorus inputs via groundwater to the lake, thereby supporting current efforts for lake management.

Title:	Nutrient distribution and sampling for leaf analysis in St. Augustinegrass.
Source:	Communications in soil science and plant analysis., vol. 35, no. 15-16, pp. 2357-2367, 2004
Authors:	Broschat, T.K.; Elliott, M.L.
Document:	
From:	CSA
District Question:	4
Abstract:	Leaf nutrient analysis for turfgrass is typically performed on clipping samples. However, since clippings of St. Augustingrass used in lawns consist primarily of the youngest leaves, they may not be the best material to sample, especially for mobile elements. This study examined the concentration gradients of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), and zinc (Zn) among leaves of various ages to determine their relative mobility within St. Augustingrass [Stenotaphrum secondatum (Walt.) O. Kuntze] plants, and to determine which age of leaves were the best indicators of plant nutritional status for each element. To provide varying levels of fertility on a Hallandale fine sand soil in southern Florida, a landscape area of "Floratam" St. Augustingrass was either not fertilized or fertilized with 4.9 g N m-2 every 3 months from either a mostly water soluble 16-4-8 (N-P2O5-K2O) fertilizer blend or an 8-4-12-4 Mg (N-P2O5-K2O-Mg) controlled-release fertilizer blend containing micronutrients. Leaf samples were obtained twice for analysis, once during the cooler winter months and once during the warmer summer months. About 50 shoots were sampled from each plot, and the leaves were separated according to their position on the shoot axis. Leaf samples were analyzed for N, P, K, Ca, Mg, Fe, Mn, and Zn content. Concentrations of each element in each leaf and fertilizer plot were used to determine which leaf position provided the best indicator of plant nutrient status for each element. Nitrogen, P, K, and Mn showed decreasing leaf elemental concentrations with increasing leaf age, as is typical for mobile elements, while Ca, Mg, and Zn had higher concentrations in the older leaves and were considered immobile in this species. Leaf Fe concentrations were not correlated with either fertilizer treatment or leaf position. Leaf 3, which is the oldest leaf, followed by Leaf 2, was found to be the best indicator of plant nutrient status for all elements, regardless of their mobility. Leaf 1, which is the primary component of turfgrass clippings, was generally the poorest indicator of plant nutritional status and is not recommended for leaf nutrient analysis.

Title:	Phosphorus soil tests for environmental assessment in subtropical soils.
Source:	Communications in soil science and plant analysis., vol. 35, no. 11-12, pp. 1485-1503, 2004
Authors:	Sotomayor-Ramirez, D.; Martinez, G.A.; Mylavarapu, R.S.; Santana, O.; Guzman, J.L.
Document:	Sotomayor-Ramirez P soil tests.pdf
From:	CSA/ScienceDirect
District Question:	4
Abstract:	Soil test phosphorus (P) is used to evaluate the nutritional status of a soil in relation to a crop's yield response. Recently, there is interest to calibrate agronomic soil tests to predict risk of P transport in runoff. An experiment was conducted to evaluate the relationships among three agronomic soil test P extraction methods (Olsen, Bray1, Mehlich3) and dissolved P in water (0.01 M CaCl2 extractable P) in five representative soils of tropical and subtropical areas in Puerto Rico and Florida. The soils were of the series Astatula (Entisol), San Anton (Mollisol), Caguabo (Inceptisol), Corozal (Ultisol), and Bayamon (Oxisol). Soils were amended with three inorganic P levels as triple super phosphate, three organic P levels as broiler litter, and their combinations in an incomplete factorial design for a total of 11 treatments. Soils were sampled during 46 weeks and soil test P was measured. Exploratory statistics were used to evaluate relationships among the variables. Relationships using the Astatula soil were studied separately as inherently high soil test P values influenced regressions greatly. A near 1:1 relationship between soil test P extracted using Bray1 and Mehlich3, and Mehlich3 and Olsen extractants was obtained. In general, improved relationships were obtained using individual soils as soil pH and mineralogy influenced the amount of P extracted. Critical soil test concentrations to reach dissolved P concentrations of 1 mg P L(-1) were (95% confidence intervals in parenthesis) 179 (174-185), 197 (190-207), and 252 (243-266) ppm for Olsen, Bray1, and Mehlich3 extractants, respectively for all soils combined excluding Astatula. The critical values obtained in combination with soil-landscape information can be used to establish guidelines for P management in agricultural soils.

Title:	Distribution and Fractionation of Phosphorus, Cadmium, Nickel, and Lead in Calcareous Soils Amended with Composts
Source:	J. Environmental Science and Health, Part B: Pesticides, Food Contaminants and Agricultural Wastes [J. Environ. Sci. Health, Pt. B: Pestic., Food Contam., Agric. Wastes]. Vol. B39, no. 1, pp.
Authors:	Zinati, GM; Li, Yuncong; Bryan, HH; Mylavarapu, RS; Codallo, M
Document:	
From:	CSA
District Question:	5
Abstract:	Composts improve organic carbon content and nutrients of calcareous soils but the accumulation and distribution of phosphorus and heavy metals among various fractions in soil may vary under the south Florida conditions. The accumulation of P, Cd, Ni, and Pb with depth and the distribution of water soluble, exchangeable, carbonate, Fe-Mn oxides, organic and residual forms of each element were investigated in soils amended with municipal solid waste (MSW) compost, co-compost and biosolids compost and inorganic fertilizer (as control). Total concentrations of P, Cd, Ni and Pb were higher in the 0-22 cm soil layers and decreased considerably in the rock layers. These elements were in the decreasing order of P >> Pb > Ni > Cd. Amounts of water soluble and exchangeable forms of P, Cd, Ni and Pb were negligible at 0-22 cm soil depths except for Cd in the 10-22 cm depth. Amending calcareous soil with either organic or inorganic amendments rendered phosphorus, nickle and lead in the residual form followed by Fe-Mn oxides form in the 0-10 and 10-22 cm soil layers. Cadmium was predominantly in the Fe-Mn oxides fraction followed by the residual and carbonate forms in both soil layers. A significant positive correlation was found between various organic carbon fractions and organic forms of P, Cd and Pb in the surface soil layer. Soil amended with MSW compost had higher concentration of Cd in the organic fraction whereas, co-compost and MSW compost amended soil had higher concentrations of organic Ni fraction in the 0-10 cm soil layer.

Title:	Modeling Phosphorus Dynamics in a Shallow Lake During an Episodic Event
Source:	Lake and Reservoir Management [Lake Reserv. Manage.]. Vol. 19, no. 4, pp. 323-340. Dec 2003.
Authors:	Chen, XinJian; Sheng, YP
Document:	
From:	CSA
District Question:	6
Abstract:	Wind, current, suspended sediment, dissolved oxygen (DO), pH and phosphorus data were collected in Lake Okeechobee, a shallow lake in south Florida, during a storm event in early 1993. Measured field data indicate that wind and wind-generated waves are major factors responsible for sediment resuspension in the lake. Data also show that soluble reactive phosphorus (SRP) and total dissolved phosphorus (TDP) were inversely-correlated with the DO concentration in the water column. This paper focuses on the use of a vertical one-dimensional model coupling phosphorus dynamics with hydrodynamics and sediment transport processes to simulate the observed episodic event. Model simulations confirmed that resuspension of sediments occurred during the episodic event, with the subsequent increases in phosphorus concentrations. Model results suggest that release of SRP from suspended sediment particles increases as the DO concentration in the water column decreases. By fitting simulated results with field data, an empirical formula describing the effect of the DO concentration on the release of inorganic phosphorus from resuspended sediments has been obtained. Further research to elucidate the detailed mechanism is recommended.

Title:	The role of periphyton in phosphorus retention in shallow freshwater aquatic systems
Source:	Journal of Phycology [J. Phycol.]. Vol. 39, no. 5, pp. 840-849. Oct 2003.
Authors:	Dodds, WK
Document:	
From:	CSA
District Question:	5
Abstract:	Eutrophication caused by phosphorus (P) leads to water quality problems in aquatic systems, particularly freshwaters, worldwide. Processing of nutrients in shallow habitats removes P from water naturally and periphyton influences P removal from the water column in flowing waters and wetlands. Periphyton plays several roles in removing P from the water column, including P uptake and deposition, filtering particulate P from the water, and attenuating flow, which decreases advective transport of particulate and dissolved P from sediments. Furthermore, periphyton photosynthesis locally increases pH by up to 1 unit, which can lead to increased precipitation of calcium phosphate, concurrent deposition of carbonate-phosphate complexes, and long-term burial of P. Actively photosynthesizing periphyton can cause super-saturated O sub(2) concentrations near the sediment surface encouraging deposition of metal phosphates. However, anoxia associated with periphyton respiration at night may offset this effect. Linking the small-scale functional role of periphyton to ecosystem-level P retention will require more detailed studies in a variety of ecosystems or large mesocosms. A case study from the Everglades illustrates the importance of considering the role of periphyton in P removal from wetlands. In general, periphyton tends to increase P retention and deposition. In pilot-scale constructed periphyton-dominated wetlands in South Florida, about half of the inflowing total P was removed.

Title:	Phosphorus and heavy metal attachment and release in sandy soil aggregate fractions
Source:	Soil Science Society of America Journal, vol.67, no.4, pp.1158-1167, Aug 2003
Authors:	Zhang, M K; He, Z L; Calvert, D V; Stoffella, P J; Yang, X E; Li, Y C
Document:	
From:	CSA
District Question:	4
Abstract:	The presence of P and heavy metals in different forms or in association with different size fractions influences availability and discharge of these elements from watersheds. Understanding the association of P and heavy metals with size fractions can improve evaluation of leaching potential of P and heavy metals from soils. In this study, five aggregate-size fractions, ranged from 1.00 to 0.50 to <0.053 mm, were separated from seven Florida sandy soils by dry sieving. Each aggregate fraction was characterized by phosphate sorption, sequential fractionation of P, total, water- and Mehlich III-extractable concentrations of P and heavy metals. Size differences in sand, silt, and clay aggregates influence the amount and strength of element binding. Elemental attachment (particularly heavy metals) increased with decreasing aggregate sizes. Phosphorus and heavy metals in the sandy soils are readily transported to surface waters with suspended fine particles. Higher percentages of water-extractable, Mehlich III-extractable P, and heavy metals were found in both the 0.50- to 0.25- and 0.25- to 0.125-mm aggregate fractions, suggesting that P and heavy metals in these two fractions had higher release potential. The sequential fractionation of P suggested that the 1.00- to 0.50-mm fraction contained a larger percentage of Ca-bound P, whereas the 0.50- to 0.25-, 0.25- to 0.125-, and 0.125- to 0.053-mm fractions had higher ratios of labile P (H (sub 2) O-P and NaHCO (sub 3) -P). Phosphorus release from smaller aggregate fractions is faster with a higher P (sub 1) /P (sub 168) ratio than from larger aggregate fractions because of larger amounts of water soluble P attached in the smaller aggregate fractions.

Title:	Nutrient removal from eutrophic lake water by wetland filtration
Source:	Ecological Engineering [Ecol. Eng.]. Vol. 19, no. 2, pp. 141-159. Aug 2002.
Authors:	Coveney, MF; Stites, DL; Lowe, EF; Battoe, LE; Conrow, R
Document:	Coveney Nutrient removal 2002.pdf
From:	CSA/ScienceDirect
District Question:	5
Abstract:	Lake Apopka is a large (125 km super(2)), shallow (mean depth 1.6 m) lake in Florida, USA. The lake was made hypereutrophic by phosphorus loading from floodplain farms and has high levels of nutrients, phytoplankton (Chl a 80 mu g l super(-1)), and suspended matter. The restoration plan developed by the St. Johns River Water Management District encompasses the biomanipulation concept in which the critical step for large shallow lakes is increasing the transparency of the water to allow the re-establishment of submerged macrophytes. Restoration includes operation of a treatment wetland, reduction in external P loading, harvest of fish, fluctuation of lake levels, and littoral planting. The District constructed a 2-km super(2) pilot-scale treatment wetland to test nutrient-removal and hydraulic performance. Lake water was recirculated for 29 months, and the removal of suspended solids and particle-bound nutrients was assessed. Hydraulic loading rate varied from 6.5 to 65 m year super(-1) with a mean hydraulic residence time of about 7 days. The inflow contained 40-180 mg l super(-1) TSS, 80-380 mu g l super(-1) TP (mostly particulate organic), and 3-9 mg l super(-1) TN (mostly dissolved and particulate organic). Overall, particulate matter was removed (> 90%) by the wetland, and soluble organic compounds were unaffected. Soluble inorganic compounds such as nitrate, ammonia, and soluble reactive phosphate (SRP) were low in the lake water but increased during passage through the wetland. Particulate matter at the outlet was enriched in both N (2-fold) and P (5-fold) compared to particles in the inflow. Mass removal efficiencies were 89-99 (TSS), 30-67 (TP), and 30-52% (TN), but efficiency fell when hydraulic short-circuiting occurred. First-order removal coefficients were 107 (TSS), 63 m year super(-1) (TP) and 98 m year super(-1) (particulate N). Areal particulate removal rates were 5.4 g dry matter m super(-2) day super(-1), 0.18 g PON m super(-2) day super(-1), and 0.006 g POP m super(-2) day super(-1). The ratio of N:P removal was 28:1. Total sedimentation rate was 0.4 mm day super(-1) of very light matter (4.4 g dw l super(-1)). About 40% of the dry matter and nitrogen removed and about 80% of the phosphorus was found in the new sediments. Relative to the inflow of lake water, evapotranspiration (4.3%), seepage (2.6%), and rainfall (2.8%) were low. Major problems were initial leaching of SRP, but not ammonia, from native organic soils and vegetation when this former farmland was flooded; hydraulic short-circuiting via former drainage ditches; and low inflows under drought conditions. After 6 months SRP release declined, and initial SRP leaching could be prevented with soil treatment. Hydraulic short-circuiting occurred only after modifications were made. Low gravity flows were augmented with pumped inflows. With these improvements P-removal should increase from the measured 0.48 to at least 3 g P m super(-2) year super(-1). Based on the pilot project results, the first phase of an improved 14-km super(2) wetland filter has been constructed.

Title:	Model Prediction of the Effects of Changing Phosphorus Loads on the Everglades Protection Area
Source:	Water, Air, & Soil Pollution [Water, Air, Soil Pollut.]. Vol. 134, no. 1-4, pp. 255-272. Feb 2002.
Authors:	Munson, RK; Roy, SB*; Gherini, SA; MacNeill, AL; Hudson, RJ; Blette, VL
Document:	
From:	CSA
District Question:	6,8
Abstract:	The Everglades Phosphorus and Hydrology (EPH) model was developed to simulate water movement and phosphorus transport in the Everglades Protection Area which is comprised of the Everglades National Park (ENP) and surrounding wetlands known as the Water Conservation Areas (WCAs). Water flows from the Everglades Agricultural Area (EAA) through the WCAs into Everglades National Park (ENP). The model is designed to represent the system as a series of cells in which water flows from one cell to the next. The code allows for pumped inputs and pumped outputs of water as well as sorption and removal of phosphorus through peat accretion. Model application involved dividing the system into twenty cells representing different segments of the WCAs. Inputs to each cell consisted of water pumped from the EAA (where appropriate), flow from upgradient cells, and precipitation. Outputs included pumped outputs and flow out of each cell. Using data collected by the South Florida Water Management District, the model was calibrated by matching simulated and observed flows, water elevations, and phosphorus (P) concentrations for the period 1980-1988. The model was then validated for the 1988-1992 period using the same model parameters derived from the calibration process and comparing simulated and observed values. Reasonable agreement between simulated and observed values was attained for both the calibration and validation periods. The calibrated and validated model was used to simulate the impacts on annual average total P concentrations in each cell resulting from the implementation of the management plan mandated by the Everglades Forever Act. This plan calls for the construction of six Stormwater Treatment Areas (STAs) to treat discharges from the EAA, hydrologic modifications of the system to promote sheet flow, and the implementation of Best Management Practices to reduce P runoff from individual farms. In addition, the model was used to evaluate the impact of not building one of the STAs (STA 3/4), and sensitivity analyses were conducted to determine the effects of changing STA outlet P concentrations throughout the system. Model results indicate that phosphorus concentration reductions will occur in areas near EAA discharges in response to reductions in input P concentrations. However these measures will have little impact on phosphorus concentrations for 85% of the area of the WCAs and on the water entering Everglades National Park. The scenario analyses also indicate that phosphorus concentrations throughout most of the WCAs are similar with or without the construction of STA-3/4.

Title:	Release potential of phosphorus in Florida sandy soils in relation to phosphorus fractions and adsorption capacity.
Source:	Journal of environmental science and health. Part A, Toxic/hazardous substances & environmental engineering, 2002, 37(5):793-809
Authors:	Zhang, M K; He, Z L; Calvert, D V; Stoffella, P J; Li, Y C; Lamb, E M
Document:	
From:	CSA
District Question:	4
Abstract:	Information on P release potential in relation to labile P and P fractions in sandy soils is limited. In this study, P release potential was determined by leaching, and labile P, soil P fractionation, and P adsorption capacity were measured in the laboratory using 96 Florida sandy soil samples to evaluate the relationship between P release in water and soil P status. The sandy soils had a very low P adsorption capacity. The adsorption maximum, as calculated from the Langmuir equation, averaged 40.4 mg P kg(-1). More than 10% of the soil P was water soluble, indicating a high risk of P leaching from soil to water. Successive leaching using deionized water released, on average, 7.7% of total P (144.5 mg kg(-1)) in different soils, whereas labile P recovered by successive water extraction accounted for 39.2% of the total P. Variation in release potential among the different soils could be explained more by the difference in amounts of extractable P than the adsorption capacity. Total amounts of P released by successive leaching were significantly correlated with all labile P indices measured by different methods and all soil P fractions except for residual P. The correlation coefficients (r) were 0.97** for water-soluble P, 0.96** for 0.01 M CaCl2-P, 0.94** for Olsen P, 0.86** for Mehlich 1-P, 0.77*** for Mehlich 3-P, and 0.64*** for Bray 1-P. There were no obvious turning points in the relationships between Olsen-P, water-soluble P, or CaCl2-P and the amounts of P released from the sandy soils. The release of P from the sandy soils appeared to be controlled by a precipitation-dissolution reaction rather than a P sorption-desorption process. Furthermore, the sequential extraction of soils using deionized water indicated that P released was not limited to the labile P (H2O-P, NaHCO3-IP) and potentially labile P (NaOH-P) pools, but also from the HCl-P, indicating that all of P fractions except for residual P in the sandy soils can contribute to P release.

Title:	Division S-8 - Nutrient management & soil & plant analysis: Estimation of nitrate leaching in an entisol under optimum citrus production
Source:	Soil Science Society of America Journal, 65 (3) pp. 914-921, 2001
Authors:	Paramasivam, S; Alva, AK; Fares, A; Sajwan, KS
Document:	
From:	CSA
District Question:	5
Abstract:	Leaching of fertilizer nutrients and widespread NO<inf>3</inf>-N contamination of drinking water wells in proximity to citrus growing regions of central Florida are a serious concern. We evaluated NO<inf>3</inf>-N distribution in soil solution at various depths in the vadose zone, and N leaching below the root zone for two cropping seasons under the canopy of 21-yr-old Hamlin orange [Citrus sinensis (L.) Osbeck] trees on Cleopatra mandarin (Citrus reticulata Blanco) rootstock, on an entisol of central Florida. The treatments included 112, 168, 224, and 280 kg N ha⁻¹ yr⁻¹ as either dry granular fertilizer (DGF; broadcast, in 4 equal doses) or fertigation (FRT; 15 applications yr⁻¹), and 56, 112, and 168 N kg ha⁻¹ yr⁻¹ as controlled-release fertilizer (CRF; single application yr⁻¹). Irrigation was scheduled using recommended tensiometer set points as guidelines, with a target wetting depth of 90 cm. The NO<inf>3</inf>-N was measured in soil solutions bi-weekly at 60-, 120-, and 240-cm depths using suction lysimeters (SLs) installed under the tree canopy. The 240-cm depth sample represented soil solution below the rooting depth of the trees, and the NO<inf>3</inf>-N at this depth could contaminate groundwater. At the 60- or 120-cm depths, the NO<inf>3</inf>-N concentrations occasionally peaked at 12 to 100 mg L⁻¹, but at 240 cm NO<inf>3</inf>-N concentrations mostly remained below 10 mg L⁻¹. The careful irrigation management, split fertilizer application, and timing of application contributed to the low leaching of NO<inf>3</inf>-N below the root zone. Calculated NO<inf>3</inf>-N leaching losses below the rooting depth increased with increasing rate of N application and the amount of water drained, and accounted for 1 to 16% of applied fertilizer N.

Title:	Hydrological and nutrient budgets of freshwater and estuarine wetlands of Taylor Slough in southern Everglades, Florida (USA)
Source:	Biogeochemistry (Dordrecht), vol.56, no.3, pp.287-310, 2001
Authors:	Sutula, M; Day, J W; Cable, J; Rudnick, D
Document:	
From:	CSA
District Question:	6
Abstract:	Hydrological restoration of the Southern Everglades will result in increased freshwater flow to the freshwater and estuarine wetlands bordering Florida Bay. We evaluated the contribution of surface freshwater runoff versus atmospheric deposition and ground water on the water and nutrient budgets of these wetlands. These estimates were used to assess the importance of hydrologic inputs and losses relative to sediment burial, denitrification, and nitrogen fixation. We calculated seasonal inputs and outputs of water, total phosphorus (TP) and total nitrogen (TN) from surface water, precipitation, and evapotranspiration in the Taylor Slough/C-111 basin wetlands for 1.5 years. Atmospheric deposition was the dominant source of water and TP for these oligotrophic, phosphorus-limited wetlands. Surface water was the major TN source of during the wet season, but on an annual basis was equal to the atmospheric TN deposition. We calculated a net annual import of 31.4 mg m (super -2) yr (super -1) P and 694 mg m (super -2) yr (super -1) N into the wetland from hydrologic sources. Hydrologic import of P was within range of estimates of sediment P burial (33-70 mg m (super -2) yr (super -1) P), while sediment burial of N (1890-4027 mg m (super -2) yr (super -1) N) greatly exceeded estimated hydrologic N import. High nitrogen fixation rates or an underestimation of groundwater N flux may explain the discrepancy between estimates of hydrologic N import and sediment N burial rates.

Title:	Agricultural Best Management Practices and the Decline in Surface Water Total Phosphorus Concentrations in an Impounded Everglades Marsh
Source:	Lake and Reservoir Management [Lake Reserv. Manage.]. Vol. 16, no. 3, pp. 235-247. Sep 2000.
Authors:	Maceina, MJ
Document:	
From:	CSA
District Question:	5
Abstract:	Agricultural Best Management Practices (BMPs) in the 290,000 ha Everglades Agricultural Area (EAA) resulted in a 55% reduction in phosphorus loading to the remnant Florida Everglades in 1996-98, exceeding the 25% load reduction mandated by law. Consonant with this, discharge total phosphorus concentrations (TP) declined from 173 ug times L super(-1) in the 1980s to 103 ug times L super(-1) during 1996-98. Although not mandatory until 1995, BMP activity started in the EAA in the mid-1980s. I analyzed 3,798 surface water TP samples collected from 1980 to 1999 in a 54,700 ha impounded Everglades marsh that received surface water inflows from the EAA to examine temporal changes in TP. A gradient of high (> 100 ug times L super(-1)) to low (about 10 ug times L super(-1)) TP existed from northern regions that received EAA discharge south to interior regions of the marsh. During the 1980s, higher TP concentrations extended further south into the marsh, but that process reversed in the 1990s. During the 1990s, wet climatic conditions occurred and TP was inversely correlated to water levels throughout the marsh. However in nearly all regions, TP declined between 1980 and 1999 after accounting for the effects of water levels. Marsh TP was correlated to inflow TP in the regions nearest to the discharge gates, and inflow TP declined from about 150 to 50 ug times L super(-1) with the implementation of BMPs. In addition, this marsh was kept essentially flooded for 18 years to increase water supply, but a more normal "wet-dry" regulation schedule went into effect in late 1980 that permitted drying of the marsh. Three droughts followed by reflooding occurred during the 1980s that caused short-term "TP spikes" in the surface water. Lower inflow TP and possible stabilization of phosphorus between the sediment and the water in the marsh after being kept artificially flooded for so long appeared related to the decline in TP. The establishment of BMPs in the EAA have been successful to help in part to achieve phosphorus reduction goals throughout the remaining Everglades.

Title:	Hydrologic balance for a subtropical treatment wetland constructed for nutrient removal
Source:	Ecological Engineering [Ecol. Eng.]. Vol. 12, no. 3-4, pp. 315-337. Feb 1999.
Authors:	Guardo, M
Document:	Guardo Hydrologic balance 1999.pdf
From:	CSA/ScienceDirect
District Question:	5
Abstract:	This paper reports on an analysis of a water budget for the Everglades Nutrient Removal (ENR) Project in South Florida, USA, for the first 2 years of operation. Estimates of nominal hydraulic retention time (HRT) based on average monthly values are compared with HRT obtained from steady-state two-dimensional hydrodynamic simulations, and show good agreement. Statistical analysis is performed to develop stage- and depth-duration curves for the ENR Project. The ENR Project was constructed south of Lake Okeechobee by the South Florida Water Management District to begin the process of removing nutrients (especially phosphorus) from agricultural drainage and stormwater run-off before entering the Everglades. The State of Florida's Everglades Forever Act of 1994 mandates, among other things, completion of stormwater treatment areas (STAs), and research to optimize phosphorus retention capacity, and to define threshold phosphorus concentrations that lead to an imbalance of biota. The ENR Project, a 1544-ha wetland, was designed and constructed as a pilot project to gain experience on design, construction, and operation of the STAs. It began operation in August 1994. For the 732 days analyzed (19 August 1994-19 August 1996), the average water inputs into the project were as follows: 86.2% from the inflow pumps, 11.2% from rainfall, and 2.6% as emerging measured and estimated seepage from an adjacent area with higher stages (Water Conservation Area 1). The average water outputs from the project consisted of 85.1% from the outflow pumps, 8.9% as evapotranspiration, and 6.0% as a net seepage and groundwater component. This net component accounts for elements of the surface/subsurface water interaction, either entering or leaving the project, which are unknown at this time. Considering monthly average values, there were only 3 months within the study period with positive values of this net component. These months were June 1995, and March and July 1996. The two most important elements included in the net seepage and groundwater component are expected to be the surficial aquifer recharge (outflow), and the unmeasured seepage (inflow) from Water Conservation Area 1 (subsurface seepage). The unmeasured subsurface seepage has recently been determined from computer model simulations.

Title:	Reactivity of Inorganic Phosphorus in the Spodic Horizon
Source:	Dissertation Abstracts International Part B: Science and Engineering [Diss. Abst. Int. Pt. B - Sci. & Eng.]. Vol. 58, no. 7, p. 3402. Jan 1998.
Authors:	Villapando, R
Document:	
From:	CSA
District Question:	4
Abstract:	The reactivity of phosphorus (P) in the spodic (Bh) horizon has drawn increased attention in recent years, in large part due to the growing public concern over accelerated eutrophication of many lakes and streams. Considerable evidence exists that the Bh horizon can function as a sorption sink for P. However, the soil factors and environmental conditions under which P can be retained or released by the Bh horizon are not well understood. This research was conducted (i) to provide a quantitative description of the surface charge properties of Bh horizons from selected Florida Spodosols, (ii) to evaluate their P sorption and release properties under aerobic and anaerobic conditions, (iii) to determine the rate and extent of P sorption and desorption reactions in the Bh horizon as influenced by pH, and (iv) to study the effect of water table manipulations on P leaching from a Spodosol differentially impacted with animal wastes.

Title:	The response of a freshwater wetland to long-term 'low level' nutrient loads: nutrients and water budget
Source:	Hydrobiologia [Hydrobiologia]. Vol. 364, no. 1, pt., pp. 41-53. 1997 - 1998.
Authors:	Moustafa, M.Z, T.D. Fontaine, M. Guardo, R.T. James
Document:	Moustafa The response of a freshwater wetland 1998.pdf
From:	CSA/ScienceDirect
District Question:	4, 5
Abstract:	Boney Marsh is a small constructed freshwater wetland located along the floodplain of the Kissimmee River in south Florida, USA. River water, with average Tot-P concentrations of 0.052 mg l super(-1), Tot-N of 1.70 mg l super(-1), and Cl super(-) of 15.95 mg l super(-1), was diverted through the marsh to quantify mass retention and fate. Comprehensive mass balance budgets for Tot-P, Tot-N, and Cl super(-) were developed based on input (inflow, precipitation) and output (outflow, evapotranspiration, seepage). Cl super(-), as well as Na super(+), budgets indicated that groundwater accounted for approximately 7% of the total water budget. Annual mass loadings to Boney Marsh were 0.5, 15.7, and 147.9 g m super(-2) year super(-1) for Tot-P, Tot-N, and Cl super(-), respectively. Mean annual nutrient removal was estimated at 72% for Tot-P and 34% for Tot-N, and P-assimilation capacity remained high and unchanged for the period of record. The subtropical marsh system accumulated Tot-P at a much higher rate than Tot-N, with averaged net sedimentation rates of 20.4 and 8.3 year super(-1), respectively. Boney Marsh net sedimentation coefficients were higher than lakes with similar depths. The N:P mass ratio in the wetland water column increased during the period of record, and was primarily due to a high P-sedimentation rate and a declining N-sedimentation rate.

Title:	A critical evaluation of phosphorus management goals for Lake Okeechobee, Florida, USA
Source:	Lake and Reservoir Management [Lake Reserv. Manage.]. Vol. 13, no. 4, pp. 292-301. Dec 1997.
Authors:	Havens, KE; James, RT
Document:	
From:	CSA
District Question:	6
Abstract:	An empirical phosphorus (P) loading model modified from the original Vollenweider formulation has been used since the late 1970s to track progress toward a legally mandated P loading target for Lake Okeechobee, Florida. The loading target is designed to achieve, as an annual average for the pelagic region, a total P (TP) concentration of 40 mu g L super(-1). This TP goal is not based on historic data from the lake, nor on how certain levels of TP might cause use-impairment or ecological harm. Nevertheless, our retrospective analyses indicate that the goal falls within a range of TP concentrations (26 to 92 mu g L super(-1)) derived from historical data, pelagic TP-algal bloom relationships, pelagic TP-chlorophyll a relationships, and a Florida lake regression model. When first applied to Lake Okeechobee, the modified Vollenweider model gave accurate estimates of pelagic TP, but now it under-predicts TP by nearly 50 percent. This may reflect time lags in lake responses to recent reductions in P loads, an increase in the relative magnitude of internal vs. external P loads, or a change of in-lake processing of P. The lake's P budget shows a decline over time in the net sedimentation of P. The Vollenweider model estimates P sedimentation based on a fixed empirical relationship using water residence time (tau sub(w)), a parameter that has not displayed a significant historical trend. Given these issues, it is important to consider whether the existing model is an effective management tool for Lake Okeechobee. Our results indicate that the modified Vollenweider model may suffice as a coarse-scale tool for tracking progress in the eutrophication management program, with a major caveat: model predictions of pelagic TP at any given external loading rate may reflect what is potentially attainable, if internal loading rates decrease to their previous lower levels. A more complex dynamic model is being developed, which accounts for sediment-water P exchanges. The new model should provide more accurate estimates of pelagic TP, as well as estimates of recovery time and predictions of short-term responses to management actions.

Title:	Experiments on water-sediment nutrient partitioning under turbulent, shear and diffusive conditions
Source:	Water, Air, & Soil Pollution [WATER, AIR, SOIL POLLUT.]. Vol. 99, no. 1-4, pp. 411-425. Oct 1997.
Authors:	Scarlatos, PD
Document:	
From:	CSA
District Question:	4
Abstract:	Cultural eutrophication from excessive input of nutrients is a major problem for many water bodies around the world. Phosphorus and to a lesser degree nitrogen constitute the limiting elements for growth of plankton cells. Mobility, speciation and partition of nutrients in aquatic ecosystems depend on a number of physicochemical parameters. Experiments have been conducted for quantification of nutrient partition between ambient water and cohesive sediments. The experiments included nitrate and soluble phosphorus (superphosphate - 46% P sub(2)O sub(5) fertilizer) partitioned between tap water and sediment slurries. The slurries involved kaolinite and bentonite as well as natural organic mud from, Lake Okeechobee, Florida. The nutrient exchange was promoted by sediment resuspension. Resuspension was induced either under homogeneous turbulent conditions in an oscillating-grid tank or by shear flow in a lock-exchange flume. The effects of phosphorus or nitrogen concentration, sediment concentration, water temperature, pH and salinity on nutrient partition were quantified. The results obtained through this study appear to be in agreement with data from other similar laboratory or field studies.

Title:	Evaluation of uncertainty in estimated flow and phosphorus loads by FHANTM.
Source:	Applied engineering in agriculture., vol. 12, no. 6, pp. 663-669, Nov 1996
Authors:	Zhang, J., Haan, C.T.
Document:	
From:	CSA
District Question:	6
Abstract:	The South Florida Water Management District uses a computer model, the Field Hydrologic and Nutrient Transport Model (FHANTM), to estimate flow (runoff and subsurface lateral flow) and phosphorus (P) loads leaving agricultural fields in the Lake Okeechobee watershed. Uncertain knowledge of FHANTM parameter values leads to uncertainty in model estimates. This study used First Order Analysis (FOA) and Monte Carlo Simulation (MCS) to quantify uncertainty in model outputs. A sensitivity analysis was conducted to identify parameters that have the greatest effect on model output. Six parameters significantly affected model output and were used in the uncertainty analysis. In the case of surface runoff, FACTOR (monthly potential evapotranspiration factor) accounted for 64% of the uncertainty in terms of variance. For P concentrations in surface runoff, PADD (the mass of phosphorus added by animals each day) accounted for 79% of the uncertainty in terms of variance. Thus, improving knowledge of these parameters has a significant impact on reducing the uncertainty in the predicted runoff and phosphorus loads.

Title:	The response of a freshwater wetland to long-term "low level" nutrient loads -- marsh efficiency
Source:	Ecological Engineering. Vol. 7, no. 1, pp. 15-33. Sep 1996.
Authors:	Moustafa, MZ; Chimney, MJ; Fontaine, TD; Shih, G; Davis, S
Document:	
From:	CSA
District Question:	4
Abstract:	Total phosphorus (TP) and nitrogen (TN) mass balances were calculated for Boney Marsh, a subtropical constructed freshwater wetland located along the floodplain of the Kissimmee River in south Florida, USA. River water was diverted through the marsh for a 9-year period (1978-1986). Monthly mean retention rates were 0.03 and 0.41 g m super(-2) month super(-1) for TP and TN, respectively, for the period of record. Nutrient retention rates and nutrient loading rates were strongly correlated for TP but not for TN. Total phosphorus removal efficiencies were consistently higher than TN removal efficiencies at all times, and remained relatively unchanged during the entire study period. The subtropical marsh was a net positive sink for TP year-round but not for TN. Boney Marsh nutrient assimilation capacity remained high and invariable for the period of record for TP but not for TN. Our analysis showed that studies which derive nutrient removal estimates from reductions in surface water concentrations, rather than mass balances, may under-represent mass retention by as much as 50 and 100% for TP and TN, respectively. Rainfall contributions to Boney Marsh nutrient budgets could be as high as 99 and 94% for TP and TN, respectively, depending on the season. An apparent net settling velocity for total phosphorus of 9.93 m year super(-1) provided independent confirmation of settling rates previously estimated for the Water Conservation Areas of southern Florida.

Title:	A basin scale phosphorus transport model for south Florida.
Source:	Applied engineering in agriculture., vol. 12, no. 3, pp. 321-327, May 1996
Authors:	Zhang, J.; Tisdale, T.S.; Wagner, R.A.
Document:	
From:	CSA
District Question:	6
Abstract:	Florida's Lake Okeeckobee is currently experiencing accelerated eutrophication due to excessive phosphorus (P) loadings from agricultural activities in its drainage basin. As a part of a P management program, the South Florida Water Management District has developed a computer modeling framework to simulate P transport processes in watersheds that drain into Lake Okeechobee. The overall framework consists of a land-based model (CREAMS-WT), a P transport model, and a set of computer programs that transform output from the land-based model into a form usable by the P transport model. The transport model is a modified version of the QUAL2E model that accounts for P assimilation in both stream channels and wetlands. Results from model simulations were compared with measured data at sites located in the Taylor Creek basin for the period of May 1981 through October 1985. Comparisons indicate that the model provides reasonable estimates of flow and P loadings on a seasonal basis. Phosphorus assimilation within the transport system also was analyzed using the transport model, and estimates of P assimilation compared favorably with values taken from previous studies.

Title:	Nutrient-loss trends for vegetable and citrus fields in west-central Florida. I. Nitrate.
Source:	Journal of environmental quality., vol. 24, no. 1, pp. 95-100, Jan 1995-Feb 1995
Authors:	McNeal, B.L.; Stanley, C.D.; Graham, W.D.; Gilreath, P.R.; Downey, D.; Creighton, J.F.
Document:	
From:	CSA
District Question:	5
Abstract:	Vegetable and citrus production in west-central Florida is reportedly of considerable eutrophication hazard to local groundwater and surface-water bodies, including a 33 000-ha drinking-water supply reservoir (Lake Manatee) near the coast of the Gulf of Mexico. Nitrate-N levels were assessed for three vegetable-production seasons during 1990 and 1991 using a combination of multilevel samplers into the shallow (surficial) aquifer beneath selected vegetable fields and citrus groves, coupled with piezometric wells around each field's periphery to assess direction and rate of groundwater How. The NO3(-)N concentrations beneath vegetable sites showed sizeable spikes (up to 130 mg L -1 NO3(-)N), especially early in the season and at season's end, though almost exclusively at <1-m depth. These concentrations did not persist, however, with the overwhelming majority of samples from most vegetable sites evidencing NO3(-)N concentrations below 1 mg L-1. At citrus sites from the same area, NO3(-)N concentrations in the surficial water table (located 2-4 m below the soil surface in this case) have evidenced high (20-40 mg NO3(-)N L-1) and persistent levels throughout the entire sampling period. This zone of NO3(-)N enrichment commonly extends 2 to 3 m into the surficial aquifer before NO3(-)N concentrations decline to <10 mg L-1 once more. Rates of lateral movement off-site averaged 20 to 40 m yr-1 for the vegetable sites and 200 to 400 m yr-1 for the more undulating citrus sites. It is postulated that gaseous denitrification losses naturally remediate the periodic spikes in NO3(-)N concentrations beneath the vegetable sites because of the high water tables maintained at such locations, whereas denitrification in the deep sands beneath typical citrus sites proceeds much more slowly due to such limitations as a soluble-C energy source and/or a suitable microbial population. The results have implication with respect to shallow water table vs. deeply rooted crop-production systems from the same geographic area, wherever such pairings may occur.

Title:	The response of a freshwater wetland to longterm, low level nutrient loads
Source:	Lake and Reservoir Management. Vol. 11, no. 2, pp. 173. 1995
Authors:	South Florida Water Manage. District
Document:	
From:	CSA
District Question:	4
Abstract:	Nutrient mass balances were calculated for a small constructed subtropical wetland located along the floodplain of the Kissimmee River in south Florida. River water (average TP = 0.07 and TN = 1.70 mg L-1) was diverted through the marsh for a nine year period (1978-1986). Rainfall contributed 7% and 3% of the total TP and TN budget, respectively, while pumped river water provided the balance of TP and TN supplied to the marsh. Unlike wetlands at temperate latitudes, Boney Marsh was a net positive sink for TP year-round but not for TN. Boney Marsh mean annual TP removal efficiency of 72% was comparable to nutrient removal efficiency data from other wetlands. Total phosphorus removal efficiencies were consistently high and remained relatively unchanged during the entire study period. Cumulative TP mass retained and mass loading were positively correlated, indicating that Boney Marsh nutrient assimilation capacity remained high and invariable for the period of record. Our analysis showed that studies which derive nutrient removal estimates from reductions in surface water concentrations alone may under-represent mass retention by as much as 50% and 100% for TP and TN, respectively. Properly managed wetlands, through careful selection of inflow loading rate, can be very effective at removing nutrients from inflowing water for an extended period of time.

Title:	Nutrient retention in a restored wetland used for lakewater filtration.
Source:	ASLO/SWS, (USA). vp. 1993.
Authors:	Coveney, MF; Stites, DL; Battoe, LE; Lowe, EF
Document:	
From:	CSA
District Question:	4
Abstract:	A demonstration project at Lake Apopka, Florida filters hypertrophic lake water through a 2.4 km super(2) restored wetland to remove particle-bound nutrients. Water was pumped through two wetland cells in series and returned to the lake. Water flow varied from 0.4 to 1.0 m super(3)/s, and mean depths ranged from 0.35 to 0.75 m. Hydraulic residence time in each cell varied between 3 and 12 d. Net retention of particulate matter was > 90% in the first cell. Between 30 and 50% of total N was removed in the first cell, with little additional change in the second. Because of P leached from organic soils, each cell initially had negative P removal. As soil leaching declined, P removal efficiencies improved to between 30 and 50%. Leaching declined more rapidly in soils which had been fallow and hydrated. Data on forms of N and P and not areal N and P retention in the wetlands are presented.

Title:	Aquatic Weed Removal as a Nutrient Export Mechanism in Lake Okeechobee, Florida
Source:	Environmental Restoration: Science and Strategies for Restoring the Earth. Island Press, Covelo, California. 1990. p 203-211
Authors:	Mericas, D; Gremillion, P; Terczak, E
Document:	
From:	CSA
District Question:	5
Abstract:	Lake Okeechobee is the heart of south Florida's water-supply and flood-control system, and has a large surface area, though its mean depth is only 3 m. Eutrophication has occurred as a result of nutrient loading from surrounding agricultural watersheds. A demonstration was undertaken to assess the efficacy of operational-scale macrophyte harvesting as a nutrient-export strategy. Harvesting operations are being conducted in a 202-ha study area using specially modified harvesting machinery. The bulk (i.e., over 95%) of the macrophytes harvested are Hydrilla verticillata. Harvesting strategies emphasize selective harvesting to maximize nutrient yield per unit effort. Preliminary estimates of daily exports are 12 kg of phosphorus and 80 kg of nitrogen per harvester. Phosphorus data from the literature suggest that rates in excess of 20 kg may be attainable. The economic practicality of mechanical harvesting as a mitigative strategy for eutrophication is dependent on a variety of situation-specific factors, such as plant nutrient content, lake nutrient budget, machinery and operating costs, economic benefits provided, and available alternatives. Future analyses of the data collected during this study will quantify the costs involved in implementing a harvesting program at this scale. The potential for cost recovery associated with reuse of the harvested plant material is also being investigated as part of this effort.

Title:	Use of Seepage Meters to Estimate Groundwater Nutrient Loading to Lakes
Source:	Water Resources Bulletin Vol. 21, No. 2, p 265-272, April, 1985
Authors:	Belanger, TV; Mikutel, DF
Document:	
From:	CSA
District Question:	7
Abstract:	Data from a study on East Lake Tohopekaliga, Florida, indicate that the seepage meter measurement method may often overestimate nutrient contributions to lakes. Nutrient loading data from this method and a method employing lakeside piezometer nutrient data and seepage meter flows were not comparable. Seepage nutrient loading from the meter and piezometer methods comprised 39 and 18% of the nitrogen budget and 38 and 9% of the phosphorus budget, respectively, for East Lake Tohopekaliga. In terms of water, groundwater seepage accounted for only 14% of the total input to the lake. It is felt that some of the past studies using the seepage meter method to estimate nutrient loading may be in error due to reasons related to the enclosure of lake sediments by the meter and the accompanying anaerobic conditions which quickly result.

Title:	The Effects of Secondary Sewage Effluent on the Water Quality, Nutrient Cycles and Mass Balances, and Accumulation of Soil Organic Matter in Cypress Domes
Source:	PhD Dissertation 1980. 324 p, 67 Fig, 38 Tab, 267 Ref, 3 Append. University Microfilms International, Ann Arbor, MI; Order No GAX81-05570.
Authors:	Dierberg, FE
Document:	
From:	CSA
District Question:	5
Abstract:	The capability of cypress domes to act as efficient nutrient traps has been demonstrated for a natural and sewage-enriched cypress dome. Mass balance models indicated that 87% of the nitrogen and 92% of the phosphorus loadings were retained within a cypress dome receiving secondary sewage effluent, removal efficiencies that are among the highest reported for any wetland ecosystem receiving treated sewage. Thus, cypress domes seem to be effective natural tertiary treatment systems. Field data and laboratory investigations demonstrated that denitrification was a major nitrogen sink in both natural and sewage-enriched domes. Bulk precipitation was the most important factor in supplying new minerals and nutrients (except nitrogen) to the natural cypress dome. Analyses of standing waters of natural and sewage-enriched cypress domes near Gainesville, Florida, over a 4.5-year period showed that discharge of secondary sewage effluent altered the soft, acid water found in natural domes to a neutral, moderately hard condition. Furthermore, the absence of dissolved oxygen, high levels of phosphorus, nitrogen, biochemical oxygen demand, and the presence of hydrogen sulfide mean that treated sewage effluent has a substantial impact on water quality. Water samples from shallow wells, ceramic soil moisture tubes, and laboratory percolation columns indicated that the underlying organic matter and sands were serving as an effective barrier to the transport of sewage pollutants to the shallow aquifer immediately below. (Sinha-OEIS)

Title:	Nutrient-uptake model in marsh ecosystems
Source:	Proc. Am. Soc. Civ. Eng., J. Tech. Councils, 105(TC1), 177-196, (1979)
Authors:	Burns,L.A.; Taylor,R.B.
Document:	
From:	CSA
District Question:	4
Abstract:	Mechanistic models of nutrient dynamics in natural wetlands were developed and applied in a study of Kissimmee R. (Florida) flood-plain marshes. The models describe hydrodynamics and transport diffusion in wetland basins; and the ecological processes of nutrient uptake, conversion to organic forms, and release from the marsh to a receiving water body. Results of computer simulations suggested that more than 50% of dissolved phosphorus loadings could be permanently captured by the marsh ecosystem, at least up to a loading rate of 5 g /mSUP-2 /yr. In addition, 80% to 90% of the phosphorus exported from the marsh would be transformed from dissolved to detrital forms, and would therefore be relatively unavailable to nuisance algae. The simulations suggested that consolidated peat would be laid down at a rate of approx 0.5 cm/yr, giving a useful life of the marsh of perhaps 50 yr to 100 yr.

Title:	Transport characteristics of phosphorus in channelized and meandering streams
Source:	Water Resour. Bull., 14(5), 1227-1238, (1978)
Authors:	Rosendahl,P.C.; Waite,T.D.
Document:	
From:	CSA
District Question:	6
Abstract:	Comparisons were made between rates of movement of orthophosphate in a canal and a meandering stream of the Kissimmee River, Florida. The meander system had greater algal and macrophyte phosphate uptake rates, and lower plankton and sediment release rates compared to the canal. Chemical precipitation and direct rainfall influences on orthophosphate movement were insignificant relative to other terms. The major source of phosphorus to both systems was from upland runoff. The impact of this source was greater on the meandering system due to the smaller channel volume. When secondary effects of meandering were considered such as marsh inundation, the net orthophosphate movement within the meandering channel was less than that for the canal; due to the lower concentrations of phosphorus in marsh effluent waters. Field experiments were conducted to compare the longitudinal dispersion coefficient between a canal and meandering river system; the meandering stream had a dispersion coefficient over 17 times that measured for the canal. Rates of orthophosphate movement were combined into a single mass transport equation, and a numerical solution was obtained. Internal river and canal channel processes were overshadowed by external point source loadings.

Title:	SYSTEMS MODELS FOR PHOSPHORUS MANAGEMENT IN FLORIDA
Source:	PROCEEDINGS OF A SYMPOSIUM 'MINERAL CYCLING IN SOUTHEASTERN ECOSYSTEMS' 1975, (CONF-740513), P. 179-208. 7 FIG, 2 TAB, 38 REF. NOAA SG R/EA-3
Authors:	GILLILAND, MW
Document:	
From:	CSA
District Question:	6
Abstract:	THE PERCENT EFFECT ON THE OVERALL GEOCHEMICAL CYCLE OF THE PHOSPHORUS FLOWS IN PENINSULAR FLORIDA WAS DETERMINED BY EVALUATING AN OVERALL STATE PHOSPHORUS BUDGET MODEL. THROUGH MINING, FLORIDA IS DRAINING ITS PHOSPHORUS SUPPLY 125 TIMES AS FAST AS IT IS REPLACED. PHOSPHORUS MOBILIZED BY MINING WAS THREE ORDERS OF MAGNITUDE HIGHER THAN THE PHOSPHORUS CYCLING THROUGH ITS WATERWAYS. DIGITAL COMPUTER SIMULATION OF THE PHOSPHORUS FLUX IN THE PEACE RIVER ESTUARY SHOWED THE RELATIVE IMPORTANCE OF PROJECTED CHANGES IN MINING AND POPULATION. TOTAL PHOSPHORUS IN THE SYSTEM RANGED FROM 0.3 TO 1.0 MG/1. SIMULATIONS INDICATED THAT DAILY MINING-WATER DISCHARGES HAD LITTLE EFFECT ON TOTAL P CONCENTRATIONS AND THAT PERIODIC SPILLS FROM SLIME PONDS IN THE MINING DISTRICT ELEVATED P LEVELS FOR MANY YEARS. ANALOG COMPUTER SIMULATIONS OF A PRODUCTIVITY MODEL FOR THE PEACE RIVER MOUTH (CHARLOTTE HARBOR) INDICATED THAT HIGH PHOSPHORUS LEVELS KEEP NITROGEN LEVELS LOW (LESS THAN 0.1 MG/1), WHICH LIMITS PRODUCTIVITY; IF THIS CONCLUSION IS VALID COULD THE EXTREME EXCESS OF ONE NUTRIENT MAKE AN AQUATIC SYSTEM MORE OLIGOTROPHIC. THE OTHER QUESTION POSITED IS WHETHER WATER QUALITY CONTROL BASED ON THE PERCENT EFFECT OF A GIVEN FLOW ON THE OVERALL CHEMICAL CYCLE MAY BE MORE EFFECTIVE THAN EFFLUENT STANDARDS BASED ON CONCENTRATIONS. THE RESEARCH IMPLIES SEVERAL P MANAGEMENT CONTINGENCIES IN FLORIDA. (SEE ALSO W76-10266)

Title:	Water budgets, water quality, and analysis of nutrient loading of the Winter Park chain of lakes, central Florida, 1989-92
Source:	USGS, EARTH SCIENCE INFORMATION CENTER, OPEN-FILE REPORTS SECTION, BOX 25286, MS 517, DENVER, CO 80225 (USA). [nd].
Authors:	Phelps, GG; German, ER; Beckage, B; Gain, WS
Document:	
From:	CSA
District Question:	1
Abstract:	The Winter Park chain of lakes (Lakes Maitland, Virginia, Osceola, and Mizell) has a combined area of about 900 acres, an immediate drainage area of about 3,100 acres, and mean depths ranging from 11 to 15 feet. The lakes are an important recreational resource for the surrounding communities, but there is concern about the possible effects of stormwater runoff and seepage of nutrient-enriched ground water on the quality of water in the lakes. The lakes receive water from several sources: rainfall on lake surfaces, inflow from other surface-water bodies, stormflow that enters the lakes through storm drains or by direct runoff from land adjacent to the lakes and ground-water seepage. Water leaves the lakes by evaporation, surface outflow, and ground-water outflow. Of the three, only surface outflow can be measured directly. Rainfall, surface inflow and outflow, and lake-stage data were collected from October 1, 1989, to September 30, 1992. Stormflow, evaporation and ground-water inflow and outflow were estimated for the 3 years of the study. Ground-water outflow was calculated by evaluating the rate of lake-stage decline during dry periods. Estimated ground-water outflow was compared to downward leakage rates estimated by ground-water flow models. Lateral ground-water inflow from surficial sediments was calculated as the residual of the flow budget. Flow budgets were calculated for the 3 years of the study. In water year 1992 (a year with about average rainfall), inflow consisted of rainfall, 48 inches; stormflow, 15 inches; surface inflow, 67 inches; and ground water, 40 inches. The calculated outflows were evaporation, 47 inches; surface outflow, 90 inches; and ground water, 33 inches. Water-quality data also were used to calculate nutrient budgets for the lakes. Bimonthly water samples were collected from the lakes and at surface inflow and outflow sites, and were analyzed for physical characteristics, dissolved oxygen, pH, specific conductance, major ions, the nutrients nitrogen and phosphorus, and chlorophyll (collected at lake sites only). Specific conductance ranged from about 190 to 230 microsiemens per centimeter at 25 degrees Celsius in Lakes Maitland, Virginia and Osceola and from about 226 to 260 microsiemens per centimeter at 25 degrees Celsius in Lake Mizell. The median concentrations of total ammonia-plus-organic nitrogen in all the lakes ranged from 0.79 to 0.99 milligrams per liter. Median total phosphorus concentrations ranged from less than 0.02 to 0.20 milligrams per liter. Stormwater samples were collected for 17 storms at one storm-drain site and 16 storms at another storm-drain site on Lake Osceola. Median total nitrogen concentrations at the sites were 2.23 and 3.06 milligrams per liter and median total phosphorus concentrations were 0.34 and 0.40 milligrams per liter. The water quality in the Winter Park lakes generally is fair to good, based on a trophic-state index used by the Florida Department of Environmental Protection for assessing the tropic state of Florida lakes.

Title:	Hydraulic characteristics and nutrient transport and transformation beneath a rapid infiltration basin, Reedy Creek Improvement District, Orange County, Florida
Source:	U.S. GEOL. SURVEY, EARTH SCIENCE INFORMATION CENTER, OPEN FILE REPORTS SECTION, BOX 25286, MS 517, DENVER, CO 80225 (USA). [nd].
Authors:	Sumner, DM; Bradner, LA
Document:	
From:	CSA
District Question:	4
Abstract:	The Reedy Creek Improvement District disposes of about 7.5 million gallons per day (1992) of reclaimed water through 85 1-acre rapid infiltration basins within a 1,000-acre area of sandy soils in Orange County, Florida. The U.S. Geological Survey conducted field experiments in 1992 at an individual basin to examine and better understand the hydraulic characteristics and nutrient transport and transformation of reclaimed water beneath a rapid infiltration basin. At the time, concentrations of total nitrogen and total phosphorus in reclaimed water were about 3 and 0.25 milligrams per liter, respectively. A two-dimensional, radial, unsaturated /saturated numerical flow model was applied to describe the flow system beneath a rapid infiltration basin under current and hypothetical basin loading scenarios and to estimate the hydraulic properties of the soil and sediment beneath a basin. The thicknesses of the unsaturated and saturated parts of the surficial aquifer system at the basin investigated were about 37 and 52 feet, respectively. The model successfully replicated the field-monitored infiltration rate (about 5.5 feet per day during the daily flooding periods of about 17 hours) and ground-water mounding response during basin operation. Horizontal and vertical hydraulic conductivity of the saturated part of the surficial aquifer system were estimated to be 150 and 45 feet per day, respectively. The field-saturated vertical hydraulic conductivity of the shallow soil, estimated to be about 5.1 feet per day, was considered to have been less than the full-saturation value because of the effects of air entrapment. Specific yield of the surficial aquifer was estimated to be 0.41. The upper 20 feet of the basin subsurface profile probably served as a system control on infiltration because of the relatively low field-saturated, vertical hydraulic conductivity of the sediments within this layer. The flow model indicates that, in the vicinity of the basin, flow in the deeper, saturated zone was relatively slow compared to the more vigorous flow in the shallow saturated zone. The large radial component of flow below the water table in the vicinity of the basin implies that reclaimed water moves preferentially in the shallow part of the saturated zone upon reaching the water table. Therefore, there may be some vertical stratification in the saturated zone, with recently infiltrated water overlying ambient water. The infiltration capacity at the basin would be unaffected by a small (less than 10 feet) increase in background water-table altitude, because the water table would remain below the system control on infiltration. However, water-table rises of 15 and 20 feet were estimated to reduce the infiltration capacity of the basin by 8 and 25 percent, respectively.

Title:	Aluminum water treatment residuals for reducing phosphorus loss from manure-impacted, high-watertable soils
Source:	[Gainesville, Fla.] : University of Florida, 2006.
Authors:	Rew, T.J.
Document:	Full text: http://purl.fcla.edu/fcla/etd/UFE0017880
From:	UF Online Dissertations See Link to Connect LD1780 2006
District Question:	5
Abstract:	Dairy and beef operations in the Lake Okeechobee watershed in Florida and across the nation are receiving attention as a result of their contribution of phosphorus (P) to surficial water bodies. Numerous efforts are being made to support the agricultural industry by reducing P losses from the soil. One such effort involves the addition of water treatment residuals (WTRs) to the soil. Prior research has shown that Al-WTRs are capable of binding P and therefore reducing P loss through runoff and leaching. The objective of this research was to evaluate the effect of Al-WTR on P loss from a manure-impacted soil obtained from a dairy sprayfield using a rainfall simulation protocol. Soil was removed from the field site as 0 10 and 10 20 cm depths. Both depths contained high concentrations of water-soluble P and Mehlich-1 P; approximately 18 and 950 mg P kg^{-1}, respectively. After air drying and sieving, the soil was placed in rainfall simulation boxes (100 cm x 30 cm x 20 cm) designed to collect runoff, subsurface flow, and leachate. An Al-WTR was either surface applied or incorporated to 10 or 20 cm depths at a rate of 2.5% of soil dry weight. The soil was then sprigged with stargrass (Cynodon nlemfuensis). Rainfall simulations were run six times at 3 wk intervals. Runoff was collected for 30 min after initial runoff began. Subsurface flow and leachate were collected (depths of 10 and 20 cm, respectively) after runoff ceased. When Al-WTR was surface-applied, the SP concentration in runoff was reduced by approximately 75% compared to untreated soil; however, SP concentrations in subsurface flow and leachate did not decrease. When Al-WTR was incorporated into the soil at depths of 0-10 or 0- 20 cm, runoff SP concentrations were reduced by approximately 45%. Incorporation of Al-WTR to a depth of 10 cm decreased SP concentrations in subsurface flow and leachate by 37 and 11%, respectively. However, with incorporation of Al-WTR to a depth of 20 cm, both subsurface flow and leachate SP concentrations were reduced by approximately 90%. The incorporated Al-WTR reduced soil water-extractable P (WEP) by approximately 70%. However, Mehlich-1 P concentrations were not affected by the incorporation of Al-WTR in the soil. Care must be taken to ensure complete incorporation of Al-WTR throughout the P-impacted layer, as Al-WTR is only effective in reducing SP concentrations when it is in contact with the impacted soil. Shoot and root growth of stargrass were not adversely affected by the Al-WTR applied at a rate of 2.5% of soil weight.

Title:	Coupled simulation modeling of flatwoods hydrology, and nutrient and vegetation dynamids
Source:	[Gainesville, Fla.] : University of Florida, 2006.
Authors:	Yang, Lei
Document:	Full text: http://purl.fcla.edu/fcla/etd/UFE0013090
From:	UF Online Dissertations See Link to Connect LD1780 2006
District Question:	6
Abstract:	Lake Okeechobee, located at the center of the Kissimmee-Okeechobee-Everglades aquatic ecosystem in south Florida, is experiencing water quality degradation. Non-point agricultural runoff from dairies and cow-calf operations in the northern watershed of the lake is considered to be the primary source of excess phosphorus (P) loading discharged into the lake. In order to evaluate alternative land management practices that result in reduced P loading from the watershed to the lake, a coupled modeling system integrating hydrology, nutrient and vegetation dynamics simulation was developed. The coupled modeling system was developed within the Java-based, object-oriented framework of the ACRU2000 modeling system by adding new hydrologic and nutrient components and a vegetation model to enable multi-directional spatial simulation of hydrological, chemical, and biological processes simultaneously in a daily time step. The coupled model was tested for accuracy by comparing performance with well-accepted models including MIKE SHE and MODFLOW. Results indicate that the coupled model is capable of simulating, with reasonable accuracy, hydrological and solute transport processes for the hypothetical scenarios. Additionally, the model was tested in the Kissimmee River Basin and Lake Okeechobee Basin by comparing with the FHANTM model and against measured data. These applications demonstrated that the coupled model is statistically close to the performance of FHANTM with respect to hydrologic response in the Kissimmee River Basin, but much better than FHANTM with regard to hydrologic and nutrient responses in the Lake Okeechobee Basin. From the testing, it was concluded that the model is able to continuously simulate the surface runoff and groundwater tables with adequate accuracy. However the model?s capacity to simulate nutrient loading needs further testing after sufficient reliable nutrient data becomes available. The vegetation model, coupled with the hydrologic and nutrient models, was tested for a hypothetical scenario based on the conditions in the Lake Okeechobee Basin. The test results show that the temporal and spatial vegetation composition pattern can be an indicator of the ecohydrological impacts of alternative land management practices. However, for actual application of this model, further testing is required when more vegetation data are available. Recommended future research includes further development of the coupled model to enable a user-friendly pre- and post-processing graphical interface, an option for sub-daily time steps, beef-cattle roaming simulation, and plant competition. Further testing of the coupled model should be conducted at larger watershed scales and for the nutrient and vegetation simulations when additional data are available.

Title:	Nutrient release patterns of coated fertilizers used for citrus production and their effect on fruit yield and foliar nutrition
Source:	[Gainesville, Fla.] : University of Florida, 2006.
Authors:	Medina, Carolina.
Document:	Full text: http://purl.fcla.edu/fcla/etd/UFE0014281
From:	UF Online Dissertations See Link to Connect LD1780 2006
District Question:	5
Abstract:	Citrus trees require nitrogen (N) fertilizer to maintain optimum levels of fruit quality and productivity. Farmers have relied for many years on water-soluble fertilizers as the main method to provide N to Florida citrus trees. However, leaching of NO-N from excessive use of N containing water-soluble fertilizers can potentially contribute to contamination of groundwater, which supplies more than half of the total fresh water used in Florida. Controlled-release fertilizers (CRFs) have the potential to gradually release nutrients to coincide with the nutrient demand for crop growth, thereby maximizing N uptake efficiency while minimizing leaching losses. A laboratory study was conducted to investigate the effect of various coated fertilizers (CitriBlenregistered trademark; Agrocoteregistered trademark Type A; Agrocoteregistered trademark Type C(D) and Agrocoteregistered trademark Poly-Sregistered trademark) on nitrogen (N), phosphorus (P) and potassium (K) leaching using a soil incubation and leaching technique. The quantity of N, P and K released depended on composition and thickness of the coating. Release of N, P and K was delayed with CRF applications compared with water-soluble fertilizers. A 1-year field study in a mature citrus tree environment was used to estimate N release characteristics of the same CRFs and a water-soluble formulation. Similar studies were simultaneously conducted in central and southwest Florida. Mesh bags containing 3.5 g of elemental N from each source were placed on the soil surface within the irrigated zone under the tree canopy and were retrieved from the field on a given. Despite differences in total amount of N released between locations, N release rates at both locations followed the same order: Water-soluble formulation > Agrocoteregistered trademark Type A > CitriBlenregistered trademark > Agrocoteregistered trademark Poly-Sregistered trademark > Agrocoteregistered trademark Type C (D). Quantity and frequency of irrigation and rainfall and orchard orientation were determined as potential factors affecting these differences. N release patterns coincided with the citrus fertilization strategy recommended as a Best Management Practice (BMP). Four commercial citrus orchards located in southwest and central Florida were used to compare the effects of CitriBlenregistered trademark and a conventional water-soluble fertilizer program on mature citrus production and nutrition. Leaf tissue was sampled at each orchard in August 2004 and 2005. Results suggested that CitriBlenregistered trademark applied only once per year at half the water-soluble N rate has the potential to produce leaf nutrient concentrations within the optimum range according to guidelines. An economic analysis compared costs and benefits between the two fertilization programs. A reduction in net income indicated that using CitriBlenregistered trademark exclusively for citrus production is economically unfeasible due to its high cost. The implementation of a CRF program would not be attractive to citrus

Title:	Effects of dietary aluminum from water treatment residuals on phosphorus status and bone density in growing lambs [electronic resource] / by Rachel Van Alstyne.
Source:	[Gainesville, Fla.] : University of Florida, 2005.
Authors:	Van Alstyne, Rachel
Document:	Full text: http://purl.fcla.edu/fcla/etd/UFE0011627
From:	UF Online Dissertations See Link to Connect LD1780 2005
District Question:	5
Abstract:	Experiments using growing feeder lambs were conducted to gather data on 1) the safety of a Al-water treatment residual (WTR) ingested in amounts to provide between 2,000 and 8,000 ppm Al, and 2) the bioavailability of Al in WTR when compared to a control (910 ppm Al from sand) and a diet containing a known bioavailable form of Al from AlCl. The study was conducted to examine changes in performance (ADG, BW, and feed intake), tissue mineral concentrations, plasma P concentrations, bone mineral content (BMC), bone density, and apparent P absorption. At experimental termination, samples of brain, liver, kidney, heart, and bone were collected and analyzed for concentrations of Ca, P, Mg, Cu, Fe, Mn, Se, and Zn. Thirty-two wether and ten female lambs were assigned to six dietary treatments: 1) control (10% sand), 2) (9.7% sand and 0.3% AlCl), 3) (2.5% WTR and 7.5% sand), 4) (5% WTR and 5% sand), 5) (10% WTR and 0% sand), and 6) (10% WTR, 0% sand, plus double the quantities of the mineral-vitamin premix, and 1.29% dicalcium phosphate). Treatments 1-5 contained P at 0.25% and concentrations of Al were 910, 2000, 4000, 8000 and 8000 ppm, respectively for the six diets. Compared to the control, ADG, BW, and intakes were unaffected by dietary levels of WTR ($P > 0.05$); however lambs fed 2,000 ppm Al from AlCl had reduced body weights and lower ADG ($P < 0.05$). The control, most often, had the highest plasma P concentrations and the WTR treatments generally had higher P concentrations than lambs given AlCl during wk 6, plasma P concentrations declined for all animals but steadily increased thereafter. Kidney P differed; control lambs had larger deposits of P than lambs given 8,000 ppm Al from WTR ($P < 0.05$). Iron deposits were highest in livers from lambs fed 8,000 ppm Al from WTR and lowest in the controls ($P < 0.05$). Brain Al was highest for animals receiving 2,000 ppm Al from AlCl and lowest for lambs given 2,000 ppm Al from WTR ($P < 0.05$). Brain Al concentrations increased when Al from WTR was given in amounts above 2,000 ppm. Apparent P absorption did not differ among WTR treatments and the control (range from 11 to 32 %), but lambs fed 2,000 Al via AlCl had a negative (-13%) apparent absorption of P. Values of BMC and bone density did not vary with treatments; this is likely due to the short duration of the study. This study found no evidence of health related defects because of the administration of the WTR. The Al as AlCl was more bioavailable with regard to plasma P levels and performance, than Al via WTR; animals which were given the AlCl were negatively affected.

Title:	Management strategies to improve nutrient cycling in grazed Pensacola bahiagrass pastures [electronic resource] / by Jose Carlos B. Dubeux.
Source:	[Gainesville, Fla.] : University of Florida, 2005.
Authors:	Dubeux, Jose Carlos B.
Document:	Full text: http://purl.fcla.edu/fcla/etd/UFE0011202
From:	UF Online Dissertations See Link to Connect LD1780 2005
District Question:	5
Abstract:	Efficient nutrient cycling plays a major role in pasture sustainability in low-input systems and in preservation of the environment in high-input systems. In this work, we studied the effect of a range of management practices on aspects of nutrient return to pastures via animal excreta and plant litter. There were two grazing experiments. In Experiment 1, bahiagrass pastures were continuously stocked and the treatments were three management intensities: Low (40 kg N ha^{-1} and 1.4 AU [animal units] ha^{-1}), Moderate (120 kg N ha^{-1} and 2.8 AU ha^{-1}), and High (360 kg N ha^{-1} and 4.2 AU ha^{-1}). Patterns of excreta deposition, changes in soil nutrient concentration, and herbage responses were measured. Litter production and decomposition rates were also assessed. In Experiment 2, rotational and continuous stocking methods were compared in terms of their effect on animal grazing behavior, uniformity of excreta distribution in the pasture, changes in soil nutrient concentration, and herbage responses. Finally, the effect of management intensity and grazing method on soil organic matter (SOM) was determined. Based on the herbage responses to N fertilizer it is concluded that under continuous stocking the use of more than 120 kg N ha^{-1} yr^{-1} is not justified for Pensacola bahiagrass in North Central Florida. In terms of stocking methods, rotational stocking promoted greater herbage accumulation (70 kg DM ha^{-1} d^{-1}) than continuous stocking (40 kg DM ha^{-1} d^{-1}). Soil nutrient concentration was greater closer to shade and water, but rotational stocking with short grazing periods promoted a more uniform excreta distribution across the pasture. The litter results showed that the above-ground plant litter pool does not supply a large amount of nutrients for plant and microbial growth, but it does act as a buffering pool reducing potential N losses to the environment, particularly in more intensive systems. Finally, the SOM results demonstrated that increasing management intensity increased C and N accumulation in grazed pastures. These data aid in assessing potential environmental impacts and nutrient-use efficiency of various grazing management practices as well as providing data needed for modeling nutrient cycling in forage-livestock systems.

Title:	Utilizing in-situ benthic mesocosms to quantify phosphorus and nitrogen fluxes in south florida agricultural canals [electronic resource] / by Steven D Collins.
Source:	[Gainesville, Fla.] : University of Florida, 2005.
Authors:	Collins, Steven D.
Document:	Full text: http://purl.fcla.edu/fcla/etd/UFE0011800 private 2006-02-28
From:	UF Online Dissertations See Link to Connect LD1780 2005
District Question:	5
Abstract:	Improved pastures in the Lake Okeechobee Basin, Florida contain extensive surface drainage networks. The water and nutrients they transport eventually discharges to Lake Okeechobee. In addition to facilitating drainage for agricultural production, these drainage networks provide a means to reduce phosphorus (P) loading from pastures through biological and chemical retention. The effect of storing water in drainage ditches under varying runoff P concentrations was investigated using in-situ benthic mesocosms. Nutrient concentrations of the water inside the mesocosms were altered to promote P flux across the sediment-water interface. Four treatments (representing four P concentrations levels) were tested in triplicate across two drainage ditches on a 620 ha commercial cattle ranch. Nutrient concentrations in the water-column were monitored over 7 days. Ammonium-N was added when Phosphate-P was added, to maintain the N:P ratio. Both nitrogen (N) and P were monitored, though results indicated that N transformation processes could not be identified conclusively. Results indicate that drainage ditch sediments possess a high P-retention capacity, closely related to sediment aluminum and iron contents. Soluble reactive phosphorus (SRP) retention over 7 days varied from 13 to 55% of the starting water-column concentration. Results indicated that P uptake is greater and releases more rapidly in drainage ditches with organic sediment and emergent macrophytes compared to ditches with mostly mineral sediment and without macrophytes. Phosphorus retention over time is rate-limited by diffusion and sediment porewater exchange. The applicability of five kinetic models and six net P flux models was tested with the data. Using those models that best represented the data, empirical models were derived to predict P retention based on known water-column SRP concentrations and hydraulic residence times. Results show that retaining ditch water for at least 4 days can be an effective BMP for reducing net discharge of P from cow-calf operations.

Title:	Long-term stability of sorbed phosphorus by drinking-water treatment residuals [electronic resource] : mechanisms and implications
Source:	[Gainesville, Fla.] : University of Florida, 2004.
Authors:	Hall, W.L., W.P. Robarge
Document:	Full text: http://purl.fcla.edu/fcla/etd/UFE0006635
From:	UF Online Dissertations See Link to Connect LD1780 2004
District Question:	5
Abstract:	Drinking-water treatment residuals (WTRs) are amorphous metal hydroxides with significant phosphorus (P) retention capacities, and offer significant potential to cost-effectively control soluble P losses in P-impacted sandy soils. The long-term stability of WTR-immobilized P, however, is unknown and is of major concern to regulatory agencies. We studied the sorption/desorption capacities, kinetics, and mechanisms involved in the reaction of P with three Fe-based and four Al-based WTRs. Three approaches to "compress" long-term effects and simulate them experimentally, were used: a) monitor the longevity of the WTR effect on soil P extractability (5.5 years after WTR application) at two sites (Holland, MI); b) study the physical nature of the WTRs, because micropores may severely restrict P desorption; and c) use heat incubations at elevated temperatures (46, 70C) to hasten reactions that occur over decades in the field. Phosphorus sorption capacities of the WTRs were a function of oxalate-extractable Fe and Al, % C, and porosity, as expressed by the ratio of specific surface areas measured with N and CO. Phosphorus desorption from the WTRs was minimal. Intraparticle diffusion in micropores of WTRs was the main mechanism of P sorption as inferred by multiple lines of solid-state and chemical assessments for two P-loaded WTRs, which is consistent with the minimum P desorption. In effect, P diffuses to the interior of particles where it is retained tenaciously. Monitoring of soil P levels with time in two WTR-amended soils showed that P extractability did not significantly increase 5.5 years after WTR application. In parallel, 2 years of heat incubation suggested that P sorbed on WTRs was not released with time, or with increasing incubation temperature. Field and heat incubation data coupled with the fact that intraparticle P diffusion in micropores was the main mechanism, were consistent with irreversible P sorption and imply that WTR-immobilized P is stable in the long term.

Title:	Phosphorus immobilization in manure-impacted soil with aluminum-based drinking water treatment residual
Source:	[Gainesville, Fla.] : University of Florida, 2004.
Authors:	Miyittah-Kporgbe, M.
Document:	Full text: http://purl.fcla.edu/fcla/etd/UFE0008946
From:	UF Online Dissertations See Link to Connect LD1780 2004
District Question:	5
Abstract:	Phosphorus pollution has attracted attention in recent times due to continuing trends of rising P levels in manure-amended soils, exceeding P removal by plants. Manure-impacted Spodosols retain phosphorus poorly and can contaminate surrounding water bodies leading to eutrophication. Previous work showed water treatment residuals (WTRs) can reduce P losses, but questions remain regarding the necessary WTR rates and methods of application/utilization. We examined the impacts of Al-WTR rates (0, 2.5, 5.0 and 10 % by wt.), depths of incorporation (mixed throughout or partially incorporated), and mixing of impacted soil A-horizon with unimpacted soil (E horizon) on P leaching in a column study. Soil columns representing each treatment were leached weekly to yield a total of 15 pore volumes of drainage. Thoroughly mixing Al-WTR with the entire soil column (15 cm) was much more effective than mixing WTR with only the top 7.5 cm of soil. Leaching losses of P were reduced by 87 to 99.7% when WTR was thoroughly mixed compared with 40 to 58% reduction in partially incorporated treatments, and reductions increased with increasing WTR rate. We also examined the impacts of Al-WTR rates and incorporation with depth (surface or thoroughly mixed) on runoff and leaching using rainfall simulation. Simulation runoff data suggest that WTR is most effective when surface applied. Leaching data, however, suggest that thorough mixing is more effective than surface application. Soluble P in runoff meets a critical threshold of < 0.03 mg L-1 when WTR was surface applied; however, the soluble P in leachate far exceeds the critical value because of limited contact between soluble P and WTR amendment. Mixing various amounts of A and E horizons improved WTR efficiency, probably due to dilution of soluble organics from manure in the A horizon that can block P sorption sites on WTR. Increased WTR rates can largely overcome soluble organics impacts and negate the need for massive soil horizon mixing. Al-WTR can be an effective soil amendment to reduce P loss from manure-impacted soil when the WTR is made to contact soluble P in the soil profile. Soluble P not in direct contact with the WTR is unaffected by WTR and is subject to leaching loss.

Title:	Vertical mobility and dynamics of phosphorus from fertilizer and manure in sandy soils
Source:	[Gainesville, Fla.] : University of Florida, 2004.
Authors:	Walker, Leighton Croft.
Document:	Full text http://purl.fcla.edu/fcla/etd/UFE0004917
From:	UF Online Dissertations See Link to Connect LD1780 2004
District Question:	4,7
Abstract:	Animal manures from intensive livestock operations are rich sources of nutrients such as phosphorus (P) which are vital for plant growth. Increased amounts of P in water bodies may lead to unwanted environmental and aesthetic damages to these aquatic ecosystems. Some types of land-applied animal manures may release P even more easily than commercial P fertilizers when in contact with rainwater. The coarse textured sandy soils of Florida are prone to losing P both by surface runoff and leaching down through the soil profile. A column leaching study was conducted on coarse textured sandy soils with different nutrient management histories (high and low impact by manures) from two commercial dairy farms. Soil columns were treated with three P sources (dairy storage pond effluent, inorganic fertilizer and broiler litter compost), each applied at a rate equivalent to 40 kg P ha±. The objective of this study was to compare the leaching potential of the three P sources applied to low and highly manure-impacted sandy soils, and also to evaluate the effects of an aluminum based water treatment residual (WTR) on P leaching. Soil columns (25cm L * 7.5 cm I.D.) were leached with simulated rainfall over a 19 week period. Leachate was collected at each leaching event, and at the end of the study, the soil was sectioned into three depth increments to evaluate the movement of P within the column. The low manure impacted soil leached overall approximately five times less P than the highly impacted soil. The dairy storage pond effluent treated soils leached P more easily and in greater amounts than the remaining soil treatments. Leachates of dairy storage pond effluent treated soils had higher electrical conductivity (EC) and pH values than the leachates of the remaining treatments. The Al-WTR reduced the quantities of P leached within P source treatments of the low manure impacted soil by 18-33% and from the high impact soil P source treatments (excluding the control) by 16-22%. It was, however, less effective at reducing the quantities of P leached from dairy effluent treated soil columns when compared to the remaining P sources. The soil columns containing the added Al-WTR had significantly (P = 0.05) greater quantities of soil P stored as the stable iron (Fe) and aluminum Al bound P.

Title:	Phosphorus removal and soil stability within emergent and submerged vegetation communities in treatment wetlands
Source:	[Gainesville, Fla.] : University of Florida, 2003.
Authors:	Grace, Kevin.
Document:	Full text http://purl.fcla.edu/fcla/etd/UFE0001219
From:	UF Online Dissertations See Link to Connect LD1780 2003
District Question:	4
Abstract:	Phosphorus (P) removal by treatment wetlands is an integral part of Everglades protection and restoration. The effects of water column shading on P cycling and retention were explored in emergent (Typha spp.) and submerged (Najas guadalupensis) vegetation communities within a Stormwater Treatment Area (STA-1W) wetland in south Florida. The physicochemical aquatic environments within these two vegetation communities were hypothesized to differentially affect community metabolism, which in turn would affect biological P uptake rates and P stability in accrued soils. Muck soils beneath emergent aquatic vegetation (EAV) were P-depleted over 8 years of operation in STA-1W, while the muck soils beneath submerged aquatic vegetation (SAV) beds were P-enriched. The stability of P within newly accrued soils was dependent on macrophyte community type, and was likely increased through water column $CaCO_3$ precipitation. Soils (0-4 cm layer) in SAV communities contained significantly more P in residual, Ca/Mg-bound and fulvic/humic acid-bound pools than soils in EAV. Because of similar pools of exchangeable and Al/Fe-bound P, the two soil types each released P to an oxygenated water column at similar flux rates. Typha litter and associated microbial biomass retained P mineralized from soils under oxic water column conditions, but retention was lower under anoxic conditions. Dense EAV stands accumulate oxygen demand, reduce light penetration and may have little microbial P uptake and retention capacity due to anoxic conditions. While Typha biomass persists as leaf litter and detritus to a greater extent than Najas tissues, the extensive Typha root system has the potential to hinder long-term storage by mobilizing P from enriched soils. Community metabolism was influenced by water column shading, which reduced $CaCO_3$ precipitation and Ca-bound P pools; and reduced oxygen supply to microorganisms in EAV communities. Managing for SAV and eliminating dense EAV stands from treatment wetlands may reduce surface water TP concentrations. Phosphorus-enriched areas within the northern Everglades may also be contained or restored by increasing light penetration to the water column, in order to enhance soil P sorption capacity through $CaCO_3$ precipitation and increase photosynthetic oxygen supply to the aquatic microbial communities.

Abstract: With less than four years of monitoring data, researchers and water managers are challenged to assess the effectiveness of farm-level P-reduction BMPs in south Florida. Straight comparisons between baseline and BMP period UAL data are inadequate because calendar time frames and rainfall distributions differ for the two monitoring periods. Meaningful comparisons require some measure of hydrologic adjustment to UAL data.Three methods for comparing water quality monitoring data were discussed. The first method minimizes rainfall differences (which influence drainage pumping) across monitoring periods by comparing baseline period total UAL to rainfall (UAL:R) ratios to those for the BMP period. The second method involved the re-expression of water quality databases into cumulative UAL and cumulative rainfall values. These cumulative databases are plotted to assess differences in baseline and BMP UAL discharge trends over incremental rainfall.

Linear regression applied to these distributions allows differences to be quantified through slope comparisons. Finally, the application of a hydrologic model (developed for P discharge regulatory compliance assessments) to farm UAL data allows the calculation of rainfall-adjusted UALs (AUALs) for different water year (WY) periods. Subsequent AUAL comparisons across different WYs serves to quantify P discharge trends over time.Although not specifically addressed in this publication, it may be instructive to briefly summarize water quality trends recorded at 10 EAA research farm sites from late-1992 through April 1996 (Izuno and Rice, 1997). Using the UAL:R ratio comparison method, BMP data for six of 10 sites reflected P reductions of 3 to 33%. Using cumulative databases, the BMP distribution slope magnitudes for six sites were 6 to 35% lower than for baseline, evidence of long-term P load reductions under BMP strategies.

Eight of 10 sites reflected reductions after omitting nonrepresentative UAL data collected under flooded conditions caused by a 3-day tropical storm. Applying the hydrologic adjustment model, average AUALs for eight sites declined by 73% over a 3-year period. Across all three analytical exercises, two sites consistently demonstrated declining water quality trends as a consequence of large cropping system modifications in the absence of adequate hydraulic BMP technologies. Despite short baseline monitoring periods and less than four years of data collected under conditions of highly variable rainfall, analytical methods discussed herein consistently verify BMP reductions for a wide range of agricultural cropping systems.

Title:	Sediment flux modeling
Source:	New York : Wiley, c2001.
Authors:	Di Toro, Dominic M.
Document:	
From:	Science Library TD370 .D527 2000 Regular Loan
District Question:	4

Abstract:

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Title:	Transformations of nutrients in natural and constructed wetlands
Source:	Leiden : Bachhuys, 2001.
Authors:	Vymazal, Jan., Botanický ústav (Ceskoslovenská akademie ved)
Document:	
From:	Science Library QH541.5.M3 T72x 2001 In Transit to Home Location
District Question:	4
Abstract:	Table of Contents Preface Table of Contents Types of Constructed Wetlands for Wastewater Treatment: Their Potential for Nutrient Removal, by Jan Vymazal -- Page 1 Table of Contents Ecological Functional Assessment (EFA): A New Approach to Determining Wetland Health, by Curtis J. Richardson, by Kevin Nunnery -- Page 95 Table of Contents Functional and Structural Trajectory (FAST) Model to Predict Wetland Ecosystem Development: A Case Study Using Constructed Salt Marshes, by Christopher B. Craft -- Page 113 Table of Contents Restoration of Spoil Heaps in Northwestern Bohemia Using Wetlands, by Emilie Pecharova, by Tomas Hezina, by Jan Prochazka, by [et al.] -- Page 129 Table of Contents Effect of Different Management Practices on Vegetation Development, Losses of Soluble Matter and Solar Energy Dissipation in Three Small Sub-Mountain Catchments, by Jan Prochazka, by Pavlina Hakrova, by Jan Pokorny, by [et al.] -- Page 143 Table of Contents Effect of Secondary Sewage Sludge on Retention of Nitrogen and Phosphorus in Phragmites australis Growing in Constructed Wetlands, by Teresa Ozimek, by Hanna Obarska-Pempkowiak, by Stanislaw Cytawa -- Page 177 Table of Contents Nitrogen and Phosphorus Removal in a Wetland Treating Sludge Dewatering Effluent, by Karin Sundblad Tonderski, by Anna Berggren -- Page 187 Table of Contents Wastewater Purification Efficiency in Experimental Treatment Wetlands in Estonia, by Ulo Mander, by Valdo Kuusemets, by Mart Oovel, by [et al.] -- Page 201 Table of Contents Reed Dominated Intermittent Lake Cerknisko Jezero as a Sink for Nutrients, by Alenka Gaberscik, by Olga Urbanc-Bercic -- Page 225 Table of Contents Wastewater Treatment, With Emphasis On Nitrogen Removal, in a Constructed Wetland Planted with Phragmites australis and Glyceria maxima, by Lada Felberova, by Ota Rauch, by Jan Kvet -- Page 235 Table of Contents Impact of Flow Pattern on Purification Efficiencies of Terrestrial Ecosystems Planted with Ligneous Species in the MHEA System, by Marie Nemcova, by Didier Cadelli, by Michel Radoux -- Page 243 Table of Contents Nitrification and Denitrification in Hybrid Constructed Wetlands Systems, by Paul Cooper -- Page 257 Table of Contents Constructed Wetlands for Wastewater Treatment in Portugal: a Global Overview, by Verissimo N. Dias, by Patricia M. Pacheco -- Page 271 Table of Contents Removal of Organics in Czech Constructed Wetlands with Horizontal Sub-Surface Flow, by Jan Vymazal -- Page 305

Title:	Water quality modeling for wasteload allocations and TMDLs
Source:	New York : Wiley, c2001.
Authors:	Lung, Wu-Seng.
Document:	
From:	Science Library TD370 .L86 2001 Regular Loan
District Question:	6
Abstract:	"Water Quality Modeling for Wasteload Allocations and TMDLs is an essential resource for state and federal water quality agencies, consulting engineering firms, publicly owned treatment works, environmental biologists and chemists, and public health officials involved with pollution control."--BOOK JACKET. Preface Acknowledgments 1 : Introduction -- Page 1 - 1.1 : Using a More Robust Model -- Page 2 - 1.2 : Developing the Stream Reaeration Coefficient -- Page 4 - 1.3 : Post Auditing the Water Quality Response - A Bigger Picture -- Page 4 - 1.4 : New Horizon in Water Quality Modeling -- Page 6 - 1.5 : It Is the Modeling Skills and Data, Not the Model, That Matters -- Page 7 2 : Total Maximum Daily Loads (TMDLs) -- Page 8 - 2.1 : Evolution of Water Quality Modeling in Water Pollution Control -- Page 8 - 2.2 : What Is a TMDL? -- Page 9 - 2.3 : Water Quality Endpoints for TMDLs -- Page 11 - 2.4 : Water Quality Modeling for TMDL -- Page 13 - 2.5 : TMDL Modeling Study -- Page 15 3 : Derivation of Mass Transport Coefficients -- Page 21 - 3.1 : One-Dimensional Advective Transport in Streams, Rivers, and Estuaries -- Page 22 - 3.2 : One-Dimensional Longitudinal Dispersion Coefficient -- Page 30 - 3.3 : Lateral Dispersion Coefficient in Rivers and Estuaries -- Page 34 - 3.4 : Vertical Diffusion Coefficient -- Page 36 - 3.5 : Two-Dimensional Vertically Integrated Mass Transport -- Page 43 - 3.6 : Two-Dimensional Longitudinal/Vertical Mass Transport -- Page 44 - 3.7 : Need a Hydrodynamic Model? -- Page 61 - 3.8 : Linking a Hydrodynamic Model with a Water Quality Model -- Page 68 4 : Derivation of Kenetic Coefficients -- Page 71 - 4.1 : Biochemical Oxygen Demand and CBOD[subscript u] to CBOD[subscript 5] Ratio -- Page 72 - 4.2 : Nitrification in Wastewater and Receiving Water -- Page 84 - 4.3 : Reaeration Coefficient -- Page 89 - 4.4 : Saturation Dissolved Oxygen Level -- Page 98 - 4.5 : Sediment Oxygen Demand -- Page 99

Title:	Phosphorus biogeochemistry in subtropical ecosystems
Source:	Boca Raton, Fla. : Lewis Publishers, 1999.
Authors:	edited by K.R. Reddy, G.A. O'Connor, C.L. Schelske.
Document:	
From:	Science Library QH344 .P5 1999 Regular Loan
District Question:	4
Abstract:	Based on papers from a symposium held in Clearwater, Fla., July 14-16, 1997. "The first thorough study of the role of phosphorus in ecological health and metabolism ever published. Because of its vast and extensively studied ecosystems, Florida has often served as a national laboratory on current and future trends in ecosystem management. The reader will find studies at all levels of biological organization, from the cellular to entire ecological communities. The book is a definitive study of the role and behavior of phosphorus deposition in the upland, wetland/aquatic environments."--BOOK JACKET. Symposium Overview and Synthesis, by K. R. Reddy, by G. A. O'Connor, by C. L. Schelske -- Page 3 Ch. 1 : Global Issues of Phosphorus in Terrestrial Ecosystems, by A. N. Sharpley -- Page 15 Ch. 2 : Role of Wetlands in Storage, Release, and Cycling of Phosphorus on the Landscape: A 25-Year Retrospective, by C. J. Richardson -- Page 47 Ch. 3 : Phosphorus Chemistry and Cycling in Florida Lakes: Global Issues and Local Perspectives, by P. L. Brezonik, by C. D. Pollman -- Page 69 Ch. 4 : Phosphorus in Florida's Ecosystems: Analysis of Current Issues, by K. R. Reddy, by E. Lowe, by T. Fontaine -- Page 111 Ch. 5 : Introduction to Soils of Subtropical Florida, by W. Harris, by W. Hurt -- Page 143 Ch. 6 : Inorganic Forms of Phosphorus in Soils and Sediments, by D. A. Graetz, by V. D. Nair -- Page 171 Ch. 7 : Phosphorus Sorption/Desorption Reactions in Soils and Sediments, by R. D. Rhue, by W. G. Harris -- Page 187 Ch. 8 : Forms of Organic Phosphorus in Water, Soils, and Sediments, by S. Newman, by J. S. Robinson -- Page 207 Ch. 9 : Organic Phosphorus Mineralization in Soils and Sediments, by R. G. Wetzel -- Page 225 Ch. 10 : Influence of Phosphorus Loading on Microbial Processes in the Soil and Water Column of Wetlands, by K. R. Reddy, by J. R. White, by A. L. Wright -- Page 249 Ch. 11 : Effects of Phosphorus Enrichment on Structure and Function of Sawgrass and Cattail Communities in the Everglades, by S. L. Miao, by W. F. DeBusk -- Page 275 Ch. 12 : Influence of Phosphorus Loading on Wetlands Periphyton Assemblages: A Case Study from the Everglades, by P. V. McCormick, by L. J. Scinto -- Page 301 Ch. 13 : Assessing Nutrient Limitation and Trophic State in Florida Lakes, by C. L. Schelske, by F. J. Aldridge, by W. F. Kenney -- Page 321 Ch. 14 : Hydrologic Processes Influencing Phosphorus Transport, by K. L. Campbell, by J. C. Capece -- Page 343

Title:	Phosphorus loss from soil to water
Source:	Wallingford, OX ; New York : CAB International, c1997.
Authors:	edited by H. Tunney ... [et al.].
Document:	
From:	Science Library QH96.8.E9 P48 1997 Regular Loan
District Question:	4
Abstract:	1 : Phosphorus in Agriculture and Its Environmental Implications, by A. N. Sharpley, by S. Rekolainen -- Page 1 2 : Estimating the Contribution from Agriculture to the Phosphorus Load in Surface Water, by S. D. Lennox, by R. H. Foy, by R. V. Smith -- Page 55 3 : Phosphorus Losses from Agriculture to Surface Waters in the Nordic Countries, by S. Rekolainen, by P. Ekholm, by B. Ulen -- Page 77 4 : Reconstructing Historical Phosphorus Concentrations in Rural Lakes Using Diatom Models, by N. J. Anderson -- Page 95 5 : Dynamics of Phosphorus in Freshwater and Marine Environments, by C. E. Gibson -- Page 119 6 : Behaviour of Soil and Fertilizer Phosphorus, by M. A. Morgan -- Page 137 7 : Setting and Justifying Upper Critical Limits for Phosphorus in Soils, by E. Sibbesen, by A. N. Sharpley -- Page 151 8 : Phosphorus Fertilizer Strategies: Present and Future, by H. Tunney, by A. Breeuwsma, by P. J. A. Withers -- Page 177 9 : Sources and Pathways of Phosphorus Loss from Agriculture, by A. L. Healthwaite -- Page 205 10 : Hydrological and Chemical Controls on Phosphorus Loss from Catchments, by H. B. Pionke, by W. J. Gburek, by A. N. Sharpley -- Page 225 11 : Movement of Phosphorus from Agricultural Soil to Water, by B. Pommel, by J. M. Dorioz -- Page 243 12 : Losses of Phosphorus in Drainage Water, by P. C. Brookes, by G. Heckrath, by J. De Smet -- Page 253 13 : Sustainable Phosphorus Management in Agriculture, by G. Bertilsson, by C. Forsberg -- Page 273 14 : Phosphorus Requirements for Animal Production, by P. B. Lynch, by P. J. Caffrey -- Page 283 15 : Nutrient-Management Planning, by T. C. Daniel, by O. T. Carton, by W. L. Magette -- Page 297 16 : European Fertilizer Industry View on Phosphorus Retention and Loss from Agricultural Soils, by I. Steen -- Page 311 17 : European Perspective on Phosphorus and Agriculture, by F. Marien -- Page 329 18 : Views on Phosphorus and Agriculture - Paris Commission, by S. Sadowski -- Page 339 19 : Phosphorus Loss in Runoff, Leaching and Erosion - 19.1 : Phosphorus Fractionation in Grassland Hill-Slope Hydrological Pathways, by R. M. Dils,

Title:	Surface water-quality modeling / Steven C. Chapra.
Source:	New York : Mcgraw-Hill, 1997.
Authors:	Chapra, Steven C.
Document:	
From:	Science Library TD365 .C48 1997 Regular Loan
District Question:	6
Abstract:	"Surface Water-Quality Modeling presents the wealth of knowledge that Dr. Chapra has acquired through his extensive study and scholarship on surface water quality. The book provides both a thorough introduction to modeling fundamentals along with in-depth descriptions of how a variety of pollutants move and react with a variety of water bodies." "Effectively written in a "user-friendly" format, the text facilitates independent learning while balancing traditional analytical models with more recent computer-oriented approaches."--BOOK JACKET.

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- Lecture 23 : Nitrogen -- Page 419

Title:	Animal waste and the land-water interface / edited by Kenneth Steele.
Source:	Boca Raton : Lewis Publishers, c1995.
Authors:	Steele, Kenneth F.
Document:	
From:	Science Library TD930 .A55 1995 Regular Loan
District Question:	4
Abstract:	Based on a conference held in Fayetteville, Arkansas,July 16-19, 1995. Characteristics of Animal Wastes and Waste-Amended Soils: An Overview of the Agricultural and Environmental Issues, by J. Thomas Sims -- Page 1 Waste-Amended Soils: Methods of Analysis and Considerations in Interpretation of Analytical Results, by S. M. Combs, by L. G. Bundy -- Page 15 Nitrogen Transformations in Soil Amended with Poultry Litter Under Aerobic Conditions Followed by Anaerobic Periods, by W. F. Johnson, Jr., by D. C. Wolf -- Page 27 Phosphorus Retention in Selected Indiana Soils Using Short-Term Sorption Isotherms and Long-Term Aerobic Incubations, by T. L. Provin, by B. C. Joern, by D. P. Franzmeier, by A. L. Sutton -- Page 35 Effect of Animal Manure Applications on the Forms of Soil Phosphorus, by J. S. Robinson, by Andrew N. Sharpley, by S. J. Smith -- Page 43 Characteristics of Animal Wastes and Waste-Amended Soils: Nutrient Management Planning Beyond the Farm Boundary, by Joseph P. Zublena -- Page 49 Animal Waste Management and Edge of Field Losses, by Robert L. Mikkelsen, by J. Wendell Gilliam -- Page 57 Nitrate Loss Via Ground Water Flow, Coastal Sussex County, Delaware, by A. Scott Andres -- Page 69 Fecal Bacteria in Surface Runoff from Poultry-Manured Fields, by M. S. Coyne, by R. L. Blevins -- Page 77 Edge-Of-Field Losses of Surface-Applied Animal Manure, by T. C. Daniel, by D. R. Edwards, by D. J. Nichols -- Page 89 Dairy Lagoon Effluent Irrigation: Effects of Runoff Quality, Soil Chemistry, and Forage Yield, by J. M. Sweeten, by M. L. Wolfe, by E. S. Chasteen, by M. Sanderson, by B. A. Auvermann, by G. D. Alston -- Page 99 Livestock and Pasture Land Effects on the Water Quality of Chesapeake Bay Watershed Streams, by David L. Correll, by Thomas E. Jordan, by Donald E. Weller -- Page 107 Stream Impacts Due to Feedlot Runoff, by E. O. Ackerman, by A. G. Taylor -- Page 119 Using Riparian Buffers to Treat Animal Waste, by R. K. Hubbard, by G. Vellidis, by R. Lowrance, by J. G. Davis, by G. L. Newton -- Page 127 Stream Bioassessment and Contrasting Land Uses in the Tennessee Valley, by Billie L. Kerans, by Steven A. Ahlstedt, by Thomas A. McDonough, by Frank J. Sagona, by Charles F. Saylor -- Page 135 Effects of Open-Range Livestock Grazing on Stream Communities, by Christopher T. Robinson,

Title:	The effect of nutrient fluxing between bottom sediments and overlying water on the nutrient budget of wetland detention/retention areas : final report
Source:	Gainesville, Fla. : Soil Science Department and Agricultural Engineering Department, University of Florida, 1981.
Authors:	Graetz, D. A. (Donald Alvin); Campbell, K. L.
Document:	
From:	Science Library TD224.F6 G721 1981 Regular Loan
District Question:	4
Abstract:	Water quality -- Florida. Wetlands -- Florida. Organic water pollutants -- Florida.

Title:	Sediment phosphorus release at a small impoundment on the Illinois River, Arkansas and Oklahoma, USA
Source:	Ecological Engineering Volume 28, Issue 3, 1 December 2006, Pages 280-287
Authors:	Haggard, B.E. and T.S. Soerens
Document:	Haggard Legacy P 2006.pdf
From:	ScienceDirect
District Question:	1
Abstract:	The Illinois River in northeast Oklahoma and northwest Arkansas has been the focal point of environmental, political and legal debate over elevated P concentrations and loads transported across the Arkansas and Oklahoma border. The Oklahoma Water Resources Board has adopted numeric total P criteria (0.037 mg P L−1) in Oklahoma's Scenic Rivers, including the Illinois River. The US Geological Survey has reported flow-weighted total P concentrations approximately an order of magnitude greater than the newly adopted criterion. Furthermore, elevated dissolved P concentrations have been traced over 45 river kilometers upstream to municipal wastewater discharges in the headwaters of the Illinois River. The point of regulation regarding the total P criteria will be where the Illinois River flows from Arkansas into Oklahoma; however, a small impoundment exists at the Arkansas and Oklahoma border and the states respectively monitor water quality upstream and downstream from this impoundment. The purpose of this study was to evaluate P release from sediments accumulated in this small impoundment. Sediment P release measured in laboratory incubations was as much as 4 mg P m−2 day−1 under aerobic conditions and approximately 15 mg P m−2 day−1 under anaerobic conditions. Sediment equilibrium P concentrations (EPC0) in laboratory equilibration studies were 0.05–0.20 mg P L−1, which is greater than the total P criteria for this river in Oklahoma. Thus, it is conceivable that P released from bottom sediments in this small impoundment may, in fact, increase dissolved P concentrations in the Illinois River. The effect of internal P cycling at Lake Frances on P concentration in the Illinois River downstream might be greatest in the near future, because municipal discharges have recently reduced effluent P concentrations.

Title:	Lake Okeechobee: A Synthesis of Information and Recommendations for its Restoration
Source:	Audubon of Florida, Miami, FL, 2005
Authors:	P. N. Gray, C. J. Farrell, M. L. Kraus, and A. H. Gromnicki
Document:	http://www.audubonofflorida.org/pubs_OkeechobeeReport.html
From:	Audubon of Florida
District Question:	1
Abstract:	Amidst all the complexity and confusion surrounding Lake Okeechobee's problems, there are three fundamental goals that must be achieved to put the lake on the path towards restoration. 1) Manage water levels for the ecological health of the lake's 100,000 acres of wetland habitats. 2) Achieve nutrient levels in the lake and its watershed that support the health of the lake and the downstream Everglades ecosystem. 3) Minimize or eliminate populations of invasive exotic species within the lake. Ideally, Lake Okeechobee should never rise above 15.5 feet and should drop to about 12 feet most dry seasons. Until alternative water storage and water supply projects are completed, water supply concerns will most likely preclude Lake Okeechobee from being managed to reach 12 feet each year. In the interim, management should strive to reach approximately 13 feet at the end of most dry seasons since this level results in minimal risk to water supply. Such a dryseason level would benefit the lake and help protect the estuaries from massive summer releases. Nutrient levels may take some time to correct fully, but there is much that can be done now to prevent the problem from worsening. The most important action that can be taken is to stop the importation of additional phosphorus into the watershed. At the same time that Comprehensive Everglades Restoration Plan (CERP) and the Lake Okeechobee Protection Plan (LOPP) are being designed to reduce phosphorus inflows to Lake Okeechobee by about 400 tons per year, at a cost nearing a billion dollars or more, an additional 5000 ons of phosphorus are imported to the watershed each year. The benefits from restoration programs ill not be sustainable with continued nutrient-loading of the watershed. There are several invasive exotic species within the lake that are major concerns. An integrated strategy of physical and chemical management along with the development of biological controls is necessary to minimize the extent and impact of invasive exotic species. Significant progress has been made on several species, including melaleuca, but a comprehensive program is required to maintain populations at low levels and prevent new species from becoming widespread problems. Torpedo grass is the largest single management concern today, forming thick stands over thousands of acres of wetland habitat. Techniques have been developed to control it, funding is needed to complete that control. A long-term combination of aggressive and wide-ranging programs is necessary to achieve the restoration of Lake Okeechobee. Restoring Lake Okeechobee is a necessary component of restoration and protection for the estuaries and the greater Everglades ecosystem. Current state and federal programs, including the CERP and the LOPP, are important components of these efforts. Additionally, the Governor recently announced a suite of strategies that is renewing and strengthening efforts to restore the lake. Though it is a daunting task, growing

Title:	Modeling Phosphorus Load Reductions of Agricultural Water Management Practices on a Beef Cattle Ranch
Source:	Written for presentation at the 2006 ASABE Annual International Meeting
Authors:	Zhang, J., J. G. Hiscock, A. B. Bottcher, B. M. Jacobson, P. J. Bohlen
Document:	Zhang_ASAE062010.pdf
From:	SFWMD
District Question:	5,6
Abstract:	The Watershed Assessment Model (WAM) was applied to Buck Island Ranch, location of the MacArthur Agro-ecology Research Center, near Lake Placid, Florida. This is a 4,200 ha cattle ranch and is operated at full commercial scale allowing researchers to investigate ecological interactions under the economic realities of a working agricultural operation. WAM is a physically based model that can be used to perform watershed-related hydrological and water quality analyses. It simulates surface and ground water quality based on land use, soil, weather and land management practices. The model uses Geographic Information System (GIS) functions to overlay land use, soils, and rain zones to create a list of unique combinations that are used to estimate the nutrient concentrations in the surface and groundwater flow leaving each source cell. The objective of this study was to determine the potential phosphorus load reduction under various water management alternatives for the most intensively managed portion of the ranch, where 39 proposed structures for on-site water detention are located. The average base load from the ranch is 1.87 mtons per year. It is recommended that a detention depth ranging from 0.25 to 0.5” for pastures should be used to achieve a ranch level phosphorus load reduction of 20%.

Title:	Surface Water Quality Monitoring Network Optimization: Comprehensive Report to the South Florida Water Management District
Source:	SFWMD, Work Order Number C-15968-WO04-11, 2006
Authors:	Carlton D. Hunt, Ph.D., Jennifer Field, M.S., Steve Rust, Ph.D., Patricia Burke, M.S.
Document:	Comp_WQ_Optimza_Rpt.pdf
From:	SFWMD
District Question:	1
Abstract:	The South Florida Water Management District (District) is continuously challenged with providing the resources needed to accommodate substantial and diverse water quality data needs. With over 1500 active monitoring sites, the District's surface water quality monitoring network spans a wide variety of ecosystems over a large geographic area. The network consists of several individual monitoring projects (groupings of monitoring station/sites) driven by a diverse set of mandates (i.e., laws, permits, agreements, etc.) and objectives. This monitoring must be accomplished under the constraint of priority initiatives being supported by limited financial resources and manpower. To ensure cost effective monitoring, improve service, and position the District to accommodate future monitoring requirements, the Environmental Resource Assessment Department conducted a detailed optimization of its non-permit driven water quality monitoring program. The findings of the optimization, as well as recommendations for evaluating future monitoring initiatives are reported in this document.

Title:	Phosphorus Model of Lake Eutrophication
Source:	Limnology and Oceanography, Vol 19, No 2, P 297-304, 1974. 2 Fig, 2 Tab, 14 Ref.
Authors:	Imboden, DM
Document:	
From:	CSA
District Question:	8
Abstract:	A two-box lake model is described with the subsystems epilimnion and hypolimnion and phosphorus as the limiting nutrient factor. The mean oxygen consumption in the hypolimnion as a function of p loading is calculated and critical p-loading figures above which the lake turns toward eutrophy are given for varying lake mean depths and hydraulic loading factors. Results agree with an empirical relation between lake mean depth and p loading as given by vollenweider. Also, p retention factors are calculated using the model and compared to measured values. The following qualitative conclusions concerning the memory and the rate of a lake's response to changes in nutrient input are drawn: a lake, oscillating between two annual states, each described by a different set of model parameters, reaches the corresponding steady states faster if its mean depth is small and its hydraulic loading factor is large. A deep lake may have a memory in its hypolimnion consisting of both slow approach to steady state and incomplete renewal of its oxygen reserves. Its persistence against increase of nutrient input may keep the lake oligotrophic for a time. Both shallow and deep lakes may also have an important and long lasting memory in the sediments. (jones-wisconsin)

Title:	Relationships between Extractable Soil Phosphorus and Phosphorus Saturation after Long Term Fertilizer or Manure Application
Source:	Soil Sci. Soc. Am. J. 70:454–463 (2006).
Authors:	Brett L. Allen and Antonio P. Mallarino
Document:	Allen Relationships between Extractable Soil P.pdf
From:	Blackwell Synergy
District Question:	4
Abstract:	Total soil P (TP), soil-test P (STP), and the degree of soil P saturation are affected by long-term P application but relationships between these measurements need to be established for grain production cropping systems to improve P management guidelines. This research studied these relationships from samples collected from 11 long-term (4–23 yr) Iowa P trials. Mean soil clay content and pH (0- to 15-cm depth) ranged from 171 to 375 g kg–1 and 6.1 to 6.8, respectively, and maximum cumulative P application was 192 to 1098 kg P ha–1. Soil was analyzed for Bray-P1 (BP), Mehlich-3 P (M3P), Olsen P (OP), TP, P sorption index (PSI), and P saturation by STP/PSI and Mehlich-3 extractable P, Al, and Fe (M3sat) indices. Soil-test P increased as P applied increased and declined when P was not applied. Total P increased linearly with increasing BP, M3P, and OP (r = 0.52–0.55), and increases were 1.8, 1.7, and 3.5 mg TP kg–1 per mg STP kg–1 for BP, M3P, and OP, respectively. Usually STP was linearly correlated to M3sat and STP/PSI (r = 0.80–0.94), and M3sat was linearly correlated to STP/PSI (r = 0.86–0.92). Results indicate that STP can approximately estimate long-term effects of P application on TP, and soil P saturation for conditions similar to those in this study, but TP estimates are improved by grouping similar soil series. Further research for a wider range of soils and STP would be useful to better describe relationships between these measurements.

Title:	Taxonomic and Geographic Distribution of Total Phosphorus in Florida Surface Soils
Source:	Soil Science Society of America Journal 65:1539-1547 (2001)
Authors:	Ming Chen, and Lena Q. Ma
Document:	Chen Taxonomic and Geographic Distribution of TP.pdf
From:	Blackwell Synergy
District Question:	4
Abstract:	Taxonomic and geographic distributions of background P concentrations are important in assessing whether a soil P level is influenced by anthropogenic activities. This study was conducted to establish an upper baseline concentration (UBC) of soil P, which is defined as 97.5% of the background concentration, using 448 geographically and pedogenically representative Florida surface soils (genetic horizon A, A1, Ap, O, O1 or Op) using total P as determined by the USEPA Method 3052 (HCl–HNO3–HF digestion). A significant difference existed in total P concentrations between disturbed (126 mg kg-1, n = 180) and undisturbed (60 mg kg-1, n = 268) soils. Geometric mean (GM) concentration of total P in the undisturbed soils decreased in the order of Histosols (350 mg kg-1) > Mollisols (171 mg kg-1), Inceptisols (140 mg kg-1) > Ultisols (88 mg kg-1) > Alfisols (54 mg kg-1), Entisols (53 mg kg-1) > Spodosols (24 mg kg-1). Aquic suborders tended to have greater P contents than the dry suborders, e.g., Aquents (92 mg kg-1) > Psamments (47 mg kg-1) and Aquods (27 mg kg-1) > Orthods (14 mg kg-1). Total P estimation based on digitized taxonomic soil maps suggested that native soil properties were primary factors in controlling total P in soils. The wide occurrence of P bearing parent materials resulted in many soils having high P concentrations. Twenty-four P-elevated samples from the disturbed soils were identified using the UBC of P for the undisturbed soils at suborder level as reference criterion. Anthropogenic P inputs were related to commercial PO4–fertilizer application and population growth as nonpoint sources.

Title:	Phosphorus management in balanced agricultural systems
Source:	Soil Use and Management, Volume 21, Issue s1, Page 94-101, Mar 2005
Authors:	F. Djodjic, L. Bergström C. Grant
Document:	Djodji P management in balanced ag systems.pdf
From:	Blackwell Synergy
District Question:	5
Abstract:	The practice of large phosphorus (P) additions to agricultural land has resulted in an increased depletion of limited mineable rock phosphate resources, P accumulation in soils with an increased risk for P losses, and intensified eutrophication and deterioration of water quality in recipient water bodies. A number of measures have been used to reach balance between P inputs and outputs in agricultual systems, with the goal of achieving improved P use efficiency, sustained high crop yields and reduced P losses. This paper discusses how this goal may be achieved. Results from a Swedish long-term fertility experiment combined with results of a P leaching study using a selection of soils from the fertility experiment are used to evaluate the effects of a balanced P system on yields, soil P levels and P leaching. Three P fertilizer application strategies are compared (zero P, replacement P, and a treatment where surplus P fertilization was used to achieve a rapid increase in the soil P status). The replacement P strategy appeared to be the most sustainable system but P fixation in this system must be accounted for. When surplus P rates were applied, increased crop yields were counterbalanced by poorer use efficiency and P accumulation in soil. Topsoil P content was a poor predictor of P leaching. Instead, balancing P inputs and outputs represents a first step in the management of P losses, but additional, sitespecific measures are required to counteract site-specific factors responsible for P losses.

Title:	Hydrologic Regime Controls Soil Phosphorus Fluxes in Restoration and Undisturbed Wetlands
Source:	Restoration Ecology, Volume 13, Issue 2, Page 341-347, Jun 2005
Authors:	Allison Aldous, Paul McCormick, Chad Ferguson, Sean Graham, and Chris Craft
Document:	
From:	Blackwell Synergy
District Question:	4
Abstract:	Many wetland restoration projects occur on former agricultural soils that have a history of disturbance and fertilization, making them prone to phosphorus (P) release upon flooding. To study the relationship between P release and hydrologic regime, we collected soil cores from three restoration wetlands and three undisturbed wetlands around Upper Klamath Lake in southern Oregon, U.S.A. Soil cores were subjected to one of three hydrologic regimes—flooded, moist, and dry—for 7.5 weeks, and P fluxes were measured upon reflooding. Soils from restoration wetlands released P upon reflooding regardless of the hydrologic regime, with the greatest releases coming from soils that had been flooded or dried. Undisturbed wetland soils released P only after drying. Patterns in P release can be explained by a combination of physical and biological processes, including the release of iron-bound P due to anoxia in the flooded treatment and the mineralization of organic P under aerobic conditions in the dry treatment. Higher rates of soil P release from restoration wetland soils, particularly under flooded conditions, were associated with higher total P concentrations compared with undisturbed wetland soils. We conclude that maintaining moist soil is the means to minimize P release from recently flooded wetland soils. Alternatively, prolonged flooding provides a means of liberating excess labile P from former agricultural soils while minimizing continued organic P mineralization and soil subsidence.

Title:	Redox reactions and phosphorus release in re-flooded soils of an altered wetland
Source:	European Journal of Soil Science, Volume 56, Issue 4, Page 515-525, Aug 2005
Authors:	M. Shenker, S. Seitelbach, S. Brand, A. Haim & M. I. Litaor
Document:	
From:	Blackwell Synergy
District Question:	4
Abstract:	Phosphorus loss from land can be a major factor affecting surface water quality. We studied P-release mechanisms in wetland soils that had been drained and cultivated for four decades and then re-flooded. We measured redox, pH and solution composition in two sites in the field and in four peat and calcareous soils incubated in biogeochemical microcosms. The redox and pH measurements during the 120 days of incubation and the resulting soil solution composition indicated that the main process leading to P release is reductive dissolution of ferric hydroxides on which P was adsorbed and in which P was occluded. The molar Fe:P ratio increased with period of reduction from below 1 in the first week of re-flooding to 15–60 after 120 days. This suggests an increased P-retention capacity upon reoxidation of the soil solution, whether within the soil profile or in the drainage canals. Prolonged flooding of the calcite-poor, gypsum-rich peat soils increased the oversaturation of soil solutions with respect to hydroxyapatite and occasionally β-Ca3(PO4)2(c), indicating that in spite of the large Ca concentration, the rate of Ca-P precipitation was insufficient to maintain the saturation status of the Ca-P system. In the calcareous soils the Ca-P system effectively controlled the P activity in soil solution throughout the incubation period. In both cases the precipitation of Ca-P minerals could be an important P-retention mechanism.

Title:	On The Use of Seepage Meters to Estimate Groundwater Nutrient Loading to Lakes
Source:	Journal of the American Water Resources Association, Volume 21, Issue 2, Page 265-272, Apr 1985
Authors:	Thomas V. Belanger Donald F. Mikutel
Document:	
From:	Blackwell Synergy
District Question:	7
Abstract:	Data from a study on East Lake Tohopekaliga, Florida, indicate that the seepage meter measurement method may often overestimate nutrient contributions to lakes. Nutrient loading data from this method and a method employing lakeside piezometer nutrient data and seepage meter flows were not comparable. Seepage nutrient loading from the meter and piezometer methods comprised 39 and 18 percent of the nitrogen budget and 38 and 9 percent of the phosphorus budget, respectively, for East Lake Tohopekaliga. In terms of water, groundwater seepage accounted for only 14 percent of the total input to the lake. It is felt that some of the past studies using the seepage meter method to estimate nutrient loading may be in error due to reasons related to the enclosure of lake sediments by the meter and the accompanying anaerobic conditions which quickly result.

Title:	Phosphorus Removal from Natural Waters Using Controlled Algal Production
Source:	Restoration Ecology, Volume 1, Issue 1, Page 29-39, Mar 1993
Authors:	W. Adey, C. Luckett, K Jensen
Document:	
From:	Blackwell Synergy
District Question:	8
Abstract:	A series of experiments designed to demonstrate the potential of using managed, attached algal production to permanently remove excess phosphorus from agricultural run-off is described. The experiments were carried out on a secondary canal in the New Hope South region of the Florida Everglades Agricultural Area from October, 1991, to May, 1992. Natural algal populations of periphyton, including species of the genera Cladophora, Spirogyra, Enteromorpha, Stigeoclonium, and a variety of filamentous diatoms such as Eunotia and Melosira, were grown on plastic screens in raceways, under a wave surge regime. Considerable biomass production of algae occurred, and the resulting algal canopy also trapped plankton and organic particulates from the water column. A seven- to eight-day harvest interval was determined to be optimal, and both hand harvesting and vacuum harvesting were employed. The vacuum device is applicable to large scale-up. In source water having total phosphorus concentrations of 0.012–0.148 ppm, mean macro-recovery dry biomass production levels of 15–27 g/m2/day were achieved. The lower rates occurred in the winter, the higher rates in the late spring. Two techniques were employed to reduce losses of fine material at harvest during the March to May period. Gravity sieving increased mean dry production levels to 33–39 g/m2/day. The mean phosphorus content of harvested biomass ranged from 0.34% to 0.43%. Total phosphorus removal rates during the spring period of average solar intensity and low nutrient supply, by methods demonstrated in this study, ranged from 104 to 139 mgTP/m2/day (380–507 kgP/ha/year). Over the incoming nutrient range studied, phosphorus removal was independent of concentration and was 16.3% of total phosphorus for 15 m of raceway. Up-stream-downstream studies of overflowing water chemistry (total P, total dissolved -P, orthophosphate -P) showed highly -significant reductions of all phosphorus species. Total phosphorus reduction closely correlated with phosphorus yield from biomass removal. Yearly, minimum phosphorus removal rates are predicted that are 100–250 times that achieved both experimentally and in long-term, large-area wetland systems. Engineering scale-up to systems of hundreds of acres is being studied.

Title:	Phosphorus cycling and partitioning in an oligotrophic Everglades wetland ecosystem: a radioisotope tracing study
Source:	Freshwater Biology, Volume 48, Issue 11, Page 1993-2008, Nov 2003
Authors:	Gregory B. Noe, Leonard J. Scinto, Jonathan Taylor, Daniel L. Childers and Ronald D. Jones
Document:	
From:	Blackwell Synergy
District Question:	4

Abstract:

1. Our goal was to quantify short-term phosphorus (P) partitioning and identify the ecosystem components important to P cycling in wetland ecosystems. To do this, we added P radiotracer to oligotrophic, P-limited Everglades marshes. 32PO4 was added to the water column in six 1-m2 enclosed mesocosms located in long-hydroperiod marshes of Shark River Slough, Everglades National Park. Ecosystem components were then repeatedly sampled over 18 days.

2. Water column particulates (>0.45 µm) incorporated radiotracer within the first minute after dosing and stored 95–99% of total water column 32P activity throughout the study. Soluble (<0.45 µm) 32P in the water column, in contrast, was always <5% of the 32P in surface water. Periphyton, both floating and attached to emergent macrophytes, had the highest specific activity of 32P (Bq g131P) among the different ecosystem components. Fish and aquatic macroinvertebrates also had high affinity for P, whereas emergent macrophytes, soil and flocculent detrital organic matter (floc) had the lowest specific activities of radiotracer.

3. Within the calcareous, floating periphyton mats, 81% of the initial 32P uptake was associated with Ca, but most of this 32P entered and remained within the organic pool (Ca-associated = 14% of total) after 1 day. In the floc layer, 32P rapidly entered the microbial pool and the labile fraction was negligible for most of the study.

4. Budgeting of the radiotracer indicated that 32P moved from particulates in the water column to periphyton and floc and then to the floc and soil over the course of the 18 day incubations. Floc (35% of total) and soil (27%) dominated 32P storage after 18 days, with floating periphyton (12%) and surface water (10%) holding smaller proportions of total ecosystem 32P.

5. To summarise, oligotrophic Everglades marshes exhibited rapid uptake and retention of labile 32P. Components dominated by microbes appear to control short-term P cycling in this oligotrophic ecosystem.

Title:	Do wetlands behave like shallow lakes in terms of phosphorus dynamics?
Source:	Journal of the American Water Resources Association, Volume 36, Issue 1, Page 43-54, Feb 2000
Authors:	M. Z. Moustafa
Document:	
From:	Blackwell Synergy
District Question:	4
Abstract:	The applicability of empirical relationships governing phosphorus (P) retention and nutrient assimilation in lakes and reservoirs was extended to include free surface water wetland treatment systems. Mixed reactor models have been used in lakes to predict steady state P concentration, characterize trophic state, compare P-dynamics, and predict permissible P-loading rates. Applying lake models to free surface water wetlands treatment systems, it was found that: sedimentation rates, loading rates, and settling velocity in these wetlands, and their typology are comparable to their lake counterparts. The analyses also suggest that phosphorus removal efficiency in a free surface water wetland treatment system is independent of trophic status, and similar to lakes, these wetlands can be classified according to their trophic state. Oligo-and eutrophic wetland treatment systems can be defined by low and high TP inflow concentrations, respectively. In this study, olig-otrophic status is defined as systems receiving inflow P-loading less than 0.10 g m-2 year-1, and their P inputs are mainly derived from agricultural and stormwater runoff. Eutrophic treatment systems, on the other hand, are defined as those receiving inflow P-loading higher than 0.20 g m2 year-1, and their inputs are mainly derived from industrial and municipal wastewater. The comparability found between lakes and free surface water wetlands treatment systems raises the question: should we consider these wetlands "shallow lakes?"

Title:	Response of a eutrophic, shallow subtropical lake to reduced nutrient loading
Source:	Freshwater Biology, Volume 50, Issue 10, Page 1718-1730, Oct 2005
Authors:	M. F. Coveney, E. F. Lowe, L. E. Battoe, E. R. Marzolf And R. Conrow
Document:	
From:	Blackwell Synergy
District Question:	7

Abstract:

1. Lake Apopka (FL, U.S.A.) was subjected to decades of high nutrient loading from farms developed in the 1940s on converted riparian wetlands. Consequences included perennially high densities of cyanobacteria, low water transparency, elimination of submerged vegetation, modified fish community, and deposition of nutrient-rich, flocculent sediments.
2. Initial steps were taken to reduce phosphorus (P) loading. Through strengthened regulation and purchase of farms for restoration, external P loading was reduced on average from 0.56 to 0.25 g P m2 year1 (55%) starting in 1993. The P loading target for the lake is 0.13 g P m2 year1.
3. For the first 6 years of P loading reduction the annual sedimentation coefficient (σ) averaged 13% less than the prior long-term value (0.97 versus 1.11 year1). The sedimentation coefficient, σ, was lower in the last 3 years of the study, but this period included extreme low-water conditions and may not be representative. Annual σ was negative (net P flux to the water column) only 1 year.
4. Wind velocity explained 43% of the variation in σ during the period before reductions in total phosphorus (TP) concentration of lake water, but this proportion dropped to 6% after TP reductions.
5. Annual mean TP concentrations differed considerably from values predicted from external loading and hydraulic retention time using the Vollenweider–Organization for Economic Co-operation and Development relationship. Reductions in lake water TP concentration fit model predictions better when multiyear (3-year) mean values were used.
6. Evidence available to date indicates that this shallow, eutrophic lake responded to the decrease in external P loading. Neither recycling of sediment P nor wind-driven resuspension of sediments prevented improvements in water quality. Reductions in TP concentration were evident about two TP-resident times (2 × 0.9 year) after programmes began to reduce P loading. Improvements in concentrations of chlorophyll a and total suspended solids as well as in Secchi transparency lagged changes in lake-water TP concentration but reached similar magnitudes during the study.

Title:	Relating soil phosphorus indices to potential phosphorus release to water
Source:	Journal of Environmental Quality, 29: 1166–1171. (2000)
Authors:	Hooda, P.S., Rendell, A.R., and Edwards, A.C.
Document:	Hooda Relating soil P indices.htm
From:	CSA
District Question:	4
Abstract:	Relationships between soil test phosphorus (STP) and release of P in surface and subsurface runoff are needed to help identify source areas for implementing management strategies to limit P loss to water. To determine whether soil P release could be predicted either by STP values, sorption-desorption indices, or the degree of soil saturation with phosphorus (DSSP), 11 sites with contrasting chemical properties and management histories were sampled from long-term field trials in the UK. Each site offered up to three treatments, resulting in a total of 29 soil samples. The results showed that the amount of P desorbed using a successive dilution procedure had no relationship with either total soil P content or P sorption capacity. The most significant property was the extent of P saturation. There was little desorption for DSSP values below 10%; above this point, the amount of P desorbed increased linearly with the DSSP. Five STP methods (Olsen, Mehlich-3, acidified ammonium oxalate-oxalic acid, Fe sub(2)O sub(3)-coated paper strip, and distilled water) were compared to predict their effectiveness in predicting potential P release to water. While STP values obtained using acidified ammonium oxalate proved to be least effective, those extracted with water correlated best with the amount of P desorbed, accounting for 96% of the variability in differential P release from the soils.

Title:	Using soil phosphorus profile data to assess phosphorus leaching potential in manured soils
Source:	Soil Science Society of America Journal, vol.67, no.1, pp.215-224, Feb 2003
Authors:	Kleinman, Peter J A; Needelman, Brian A; Sharpley, Andrew N; McDowell, Richard W
Document:	
From:	CSA
District Question:	4
Abstract:	Transport of P by subsurface flow pathways can be an important mechanism of P transfer from land to water, particularly in manured soils that are artificially drained. This study was conducted to determine whether detailed description and interpretation of soil P profile data provide adequate insight into P leaching potential. Evidence of P translocation within soil profiles of a tile-drained Buchanan (fine-loamy, mixed, semiactive, mesic Aquic Fragiudult)-Hartleton (loamy-skeletal, mixed, active, mesic Typic Hapludults) catena was assessed by measuring oxalate-extractable P, P sorption saturation, Mehlich-3 P, water-extractable P in bulk and clay film samples obtained from individual horizons. Tile-drain monitoring and column leaching experiments were conducted to evaluate interpretations derived from soil P profile data. Soil P fractions were not correlated with P losses in lysimeter studies, indicating the limited potential of using soil profile P data for quantitative prediction of leaching losses. Application of manure to the soil surface resulted in significant increases in leachate P concentrations from the lysimeters. Soil profile P data did, however, provide some evidence of long-term P leaching. While bulk horizon samples did not indicate significant long-term P translocation to soil depths corresponding with artificial drainage, some clay film samples had significantly elevated oxalate P, P sorption saturation and Mehlich-3 P at lower depths. Elevated P concentrations in clay films may be associated with preferential transport of P along soil macropores, although, not all clay films sampled in this study were necessarily associated with active macropores. Thus, soil P profile data appear to provide limited insight into P leaching potential.

Title:	Phosphorus Leaching in Relation to Soil Type and Soil Phosphorus Content
Source:	Journal of Environmental Quality [J. Environ. Qual.]. Vol. 33, no. 2, pp. 678-684. Mar-Apr 2004
Authors:	Djodjic, F; Boerling, K; Bergstroem, L
Document:	Djodjic P Leaching in Relation to Soil Type.pdf
From:	CSA
District Question:	4
Abstract:	Phosphorus losses from arable soils contribute to eutrophication of freshwater systems. In addition to losses through surface runoff, leaching has lately gained increased attention as an important P transport pathway. Increased P levels in arable soils have highlighted the necessity of establishing a relationship between actual P leaching and soil P levels. In this study, we measured leaching of total phosphorus (TP) and dissolved reactive phosphorus (DRP) during three years in undisturbed soil columns of five soils. The soils were collected at sites, established between 1957 and 1966, included in a long-term Swedish fertility experiment with four P fertilization levels at each site. Total P losses varied between 0.03 and 1.09 kg ha super(-1) yr super(-1), but no general correlation could be found between P concentrations and soil test P (Olsen P and phosphorus content in ammonium lactate extract [P-AL]) or P sorption indices (single-point phosphorus sorption index [PSI] and P sorption saturation) of the topsoil. Instead, water transport mechanism through the soil and subsoil properties seemed to be more important for P leaching than soil test P value in the topsoil. In one soil, where preferential flow was the dominant water transport pathway, water and P bypassed the high sorption capacity of the subsoil, resulting in high losses. On the other hand, P leaching from some soils was low in spite of high P applications due to high P sorption capacity in the subsoil. Therefore, site-specific factors may serve as indicators for P leaching losses, but a single, general indicator for all soil types was not found in this study.

Title:	GIDM: A GIS-BASED MODEL FOR DAIRY WASTE MANAGEMENT ANALYSIS
Source:	Proceedings: AWRA SYMPOSIUM ON GIS AND WATER RESOURCES Sept 22-26, 1996 Ft. Lauderdale, FL
Authors:	Fraisse, C.W., K.L. Campbell, J.W. Jones, and W.G. Boggess
Document:	http://www.awra.org/proceedings/gis32/fraisse/index.html
From:	Misc
District Question:	8
Abstract:	Recent evidence that agriculture in general, and animal waste in particular, may be an important factor in surface and ground water quality degradation has induced a strong interest in nutrient management research. The presence of nitrogen and phosphorus in surface water bodies and ground water aquifers is recognized as a significant water quality problem in many parts of the world. A Generic Interactive Dairy Model (GIDM) has been developed as a tool for creating alternative dairy waste management plans and evaluating the effects of such plans on surface and ground water quality degradation. GIDM utilizes a GIS-based interface to develop field level management plans, run the GLEAMS water quality model and analyze the results obtained by means of tabular reports and thematic maps. GIDM runs on SUN SPARC stations using the ARC/INFO GIS software.

Title:	A FRAMEWORK FOR PHOSPHORUS TRANSPORT MODELING IN THE LAKE OKEECHOBEE WATERSHED
Source:	Journal of the American Water Resources Association 32 (1), 57–73, 1996
Authors:	R. A. Wagner, T S. Tisdale, J. Zhang
Document:	
From:	Blackwell Synergy
District Question:	6
Abstract:	A modeling framework was developed to determine phosphorus loadings to Lake Okeechobee from watersheds located north of the lake. This framework consists of the land-based model CREAMS-WT, the in-stream transport model QUAL2E, and an interface procedure to format the land-based model output for use by the in-stream model. QUAL2E hydraulics and water quality routines were modified to account for flow routing and phosphorus retention in both wetlands and stream channels. Phosphorus loadings obtained from previous applications of CREAMS-WT were used by QUAL2E, and calibration and verification showed that QUAL2E accurately simulated seasonal and annual phosphorus loadings from a watershed. Sensitivity and uncertainty analyses indicated that the accuracy of monthly loadings can be improved by using better estimates of in-stream phosphorus decay rates, ground water phosphorus concentrations, and runoff phosphorus concentrations as input to QUAL2E.

Title:	Total Maximum Daily Load for Total Phosphorus Lake Okeechobee, Florida
Source:	FDEP (2001), Tallahassee, FL
Authors:	FDEP
Document:	FDEP Lake_O_TMDL_Final.pdf
From:	Misc
District Question:	1
Abstract:	Lake Okeechobee is a large, shallow eutrophic lake located in subtropical south central Florida that is designated a Class I water (potable water supply). It is a large multipurpose lake providing drinking water for urban areas, irrigation water for agricultural lands, recharge for aquifers, freshwater for the Everglades, habitat for fish and waterfowl, flood control, navigation, and many recreational opportunities. High phosphorus loadings resulting from man-induced hydrologic and land use modifications over the past 60 years have degraded the water quality of the lake. This TMDL proposes an annual load of 140 metric tons of phosphorus to Lake Okeechobee to achieve an in-lake target phosphorus concentration of 40 ppb in the pelagic zone of the lake. This restoration target will support a healthy lake system, restore the designated uses of Lake Okeechobee and allow the lake to meet applicable water quality standards. The annual load was determined using computer models developed with guidance from the Lake Okeechobee TMDL Technical Advisory Committee. The entire load is allocated to the sum of all nonpoint sources. Currently, there are no point sources discharging directly to Lake Okeechobee. The implementation of the TMDL will follow a phased approach consistent with Section 373.4595, Florida Statutes, Lake Okeechobee Protection Program, which addresses the restoration of Lake Okeechobee. Phase I includes immediately initiating activities within the Lake Okeechobee watershed to achieve the phosphorus load reductions as set forth in the South Florida Water Management District's Technical Pub 81-2. It is also the planning period for all activities to be implemented in Phase II. Phase II will include the implementation of additional phosphorus reductions in the watershed following management activities outlined in the Lake Okeechobee Protection Program to achieve the phosphorus TMDL for the lake of 140 metric tons. Phase III includes evaluating phosphorus reductions and monitoring up to this point and comparing the results to the water quality target.

Title:	Animal Nutrient Management Assessments of Daries in the Lake Okeechobee Basin
Source:	Florida Department of Agricultural and Consumer Services (FDACS), Tallahassee, FL, September 2001
Authors:	SWET (Soil and Water Engineering Technology, Inc), Causseaux & Ellington, Inc. and others
Document:	CMRucks.pdf (sample)
From:	SWET
District Question:	5
Abstract:	An animal nutrient management assessment (ANMA) has been completed for 12 dairy operations within the Lake Okeechobee basin. The focus of this ANMA was to describe the existing conditions and related phosphorus (P) balance on the dairy so that the most appropriate practices or technologies can be identified to further reduce phosphorus (P) discharges to the target goal of 150 ppb. High P source areas were identified and potential solutions proposed. The solutions, however, were only generally described in this report, because the contracting agency (DACS) wanted the results of the current Dairy Best Available Technologies (BAT) Study to be available and evaluated before making a final decision on solutions for the dairy. The Dairy BAT study funded by the South Florida Water Management District is being conducted by Soil and Water Engineering Technology, Inc. to evaluate the best available technologies for dairies in the Okeechobee basin. Preliminary results of the study have been submitted and final recommendations are expected to be available before the end of 2001. Once the final technologies are selected, a comprehensive design/engineering plan can be completed and included as part ofthis ANMA.

Title:	Dairy Best Available Technologies in the Okeechobee Basin
Source:	SFWMD Contract No. C-11652 (2001), West Palm Beach, FL
Authors:	SWET (Soil and Water Engineering Technology, Inc.), Mock, Roos & Associates, Inc., CH2M Hill, Inc., ENTEL, Inc.
Document:	https://my.sfwmd.gov/portal/page?_pageid=2294,5002341,2294_5002354&_dad=portal&_schema=PORTAL&project=1214&ou=440
From:	SFWMD
District Question:	5
Abstract:	The purpose of the Dairy Best Available Technology project is to identify, select, monitor, and oversee the implementation of best available technologies (BATs) that will significantly reduce the export of phosphorus (P) from dairy operations into Lake Okeechobee and its tributaries. The project goal statement provides a clear and unambiguous target for success: "This project will result in the unbiased identification, selection, implementation, and monitoring of Best Available Technologies (BATs) that will significantly reduce P export from dairy operations into Lake Okeechobee and its tributaries and bring about the most substantial improvements in water quality in the shortest amount of time possible, while minimizing project costs and detrimental socio-economic impacts to the local region." The selection of the best available technologies is being implemented through a decisionmaking process called value modeling. The value model provides a logical process to rank technologies. A value model was developed from the goal statement for the project. The model describes the set of objectives necessary to achieve the goals in the goal statement and measurable criteria for each objective. The five objectives for the Best Available Dairy Technologies Project are to: Maximize Engineering Feasibility Maximize Cost-Effectiveness Maximize Water Quality Benefit Maximize Ease of Implementation Minimize Environmental and Socio-Economic Impacts Performance criteria for each objective were then defined. While the performance of a technology with respect to a criterion may be measured quantitatively or qualitatively a single common scale was developed to standardize all criteria measurements. The standardized nature of criteria scales is balanced by criteria weighting. Weighting is a cooperative, consensus process to be conducted by the Technical Review Team (TRT), stakeholders, and possibly others. The group will collectively identify the relative importance of each objective and each criterion within an objective, and weight the criteria based on that importance. As technologies are evaluated they will be scored for their performance with respect to each criterion within each objective. By weighting the score that each technology receives on each criterion the relative importance of the performance of each technology will be fully defined within the value matrix. The total weighted score of each technology will then be calculated and the technologies can be ranked.