Report to Congress for Future Water Resources Development (WRRDA 7001) Submission Package

Proposal Name: Lake Apopka Phosphorus Removal

Submission Date: 08/10/2017

Proposal ID Number: c3e28697-1ab6-4a68-a0c8-171a19967d19

Purpose of Proposal: The multiple synergistic purposes of the Lake Apopka Phosphorus Removal project a re to improve environmental conditions both in Lake Apopka and surrounding wetland communities. Re moving nutrient dense muck and flocculent sediments from the lake will provide recreational and navigatio nal benefits. Placing those sediments from the lake onto adjacent former agricultural wetlands at the Nort h Shore will provide a beneficial use by reducing the exposure to OCP contaminated soils and expediting t he restoration of wildlife habitat and recreational opportunities. Restoring sediment to open water system s that subsided from decades of drainage for agricultural use will restore wetland communities from those a quatic systems. This project will support federal goals for navigation, recreation, environmental restoratio n, ecosystem restoration, environmental dredging, sediment management and water quality.

1. Administrative Details

Proposal Name: Lake Apopka Phosphorus Removal

by Agency: St. Johns River Water Management District

Locations: FL

Date Submitted: 08/10/2017

Confirmation Number: c3e28697-1ab6-4a68-a0c8-171a19967d19

Supporting Documents

File Name	Date Uploaded
Lake Apopka Soil Remediation Project.pdf	08/10/2017
Biological Assessment Phases 3458.pdf	08/10/2017
Coveney 2016 Water Quality Lake Apopka SJRWMD TechMemo56.pdf	08/10/2017
Pesticide Studies and Risk Assessments on the Lake Apopka North Shore.pdf	08/10/2017
KHankin ltr to USACE Lake Apopka Restoration support August 9 2017.pdf	08/10/2017
Lake Apopka Map.pdf	08/10/2017

2. Provide the name of the primary sponsor and all non-Federal interests that have contributed or are expected to contribute toward the non-Federal share of the proposed feasibility study or modification.

Sponsor	**Letter of Support**
St. Johns River Water Management D istrict(Primary)	The St. Johns River Water Management District (SJRW MD) supports the proposal to remove nutrient rich muck and flocculent sediment from Lake Apopka to restore the l ake by improving water quality, navigation, recreational v alue. The material from the lake will be used to expedite ultimate restoration of wetlands adjacent to the lake that were formerly used for intensive agriculture. This benefic ial use will reduce exposure to organochlorine pesticides (OCPs) in the wetland soils by thin layer placement of the lake sediment material. Additional beneficial use of the s ediment removed from the lake will be to re-establish grou nd elevations in subsided historic agricultural areas to rest ore open water communities to wetland systems.

3. State if this proposal is for a feasibility study, a modification to an authorized USACE feasibility study or a modification to an authorized USACE project. If it is a proposal for a modification, provide the authorized water resources development feasibility study or project name.

[x] Feasibility Study

4. Clearly articulate the specific project purpose(s) of the proposed study or modification. Demonstrate that the proposal is related to USACE mission and authorities and specifically address why additional or new authorization is needed.

The multiple synergistic purposes of the Lake Apopka Phosphorus Removal project are to improve environ mental conditions both in Lake Apopka and surrounding wetland communities. Removing nutrient dense muck and flocculent sediments from the lake will provide recreational and navigational benefits. Placing t hose sediments from the lake onto adjacent former agricultural wetlands at the North Shore will provide a beneficial use by reducing the exposure to OCP contaminated soils and expediting the restoration of wildlif e habitat and recreational opportunities. Restoring sediment to open water systems that subsided from de cades of drainage for agricultural use will restore wetland communities from those aquatic systems. This p roject will support federal goals for navigation, recreation, environmental restoration, ecosystem restoratio n, environmental dredging, sediment management and water quality.

5. To the extent practicable, provide an estimate of the total cost, and the Federal and non-Federal share of those costs, of the proposed study and, separately, an estimate of the cost of construction or modification.

	Federal	**Non-Federal**	**Total**
Study	$500,000	$500,000	$1,000,000
Construction	$9,000,000	$20,000,000	$29,000,000

Explanation (if necessary)

6. To the extent practicable, describe the anticipated monetary and nonmonetary benefits of the proposal including benefits to the protection of human life and property; improvement to transportation; the national economy; the environment; or the national security interests of the United States.

The proposed project will continue to improve the water quality in Lake Apopka, as well as facilitate other wetland restoration activities with the beneficial use of the material removed from the lake. Lake Apopka is a headwater for the Ocklawaha River Basin and the improved water quality will have benefits both in L ake Apopka and the downstream systems. This entire watershed is used intensively for recreation and nav igation, both of which will be enhanced by the proposed project. Recreational uses including fishing, hunti ng, ecotourism, etc. will benefit from improved water quality in Lake Apopka. Removal of sediments will improve navigation in this shallow lake and protect boat motors from fouling with suspended flocculent sol ids. The beneficial use of the sediment will expedite ongoing wetland restoration activities in the surround ing areas that were converted from sawgrass marsh to agriculture in the mid 20th century.

7. Does local support exist? If 'Yes', describe the local support for the proposal.

[x] Yes

Local Support Description

Local support for this project includes local state legislators and local non-governmental organizations, suc h as the Friends of Lake Apopka (FOLA).

8. Does the primary sponsor named in (2.) above have the financial ability to provide for the required cost share?

[x] Yes

Additional Proposal Information

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Lake Apopka Soil Remediation Project.pdf

PROFESSIONAL PAPER SJ2016-PP1

LAKE APOPKA SOIL REMEDIATION PROJECT

2016

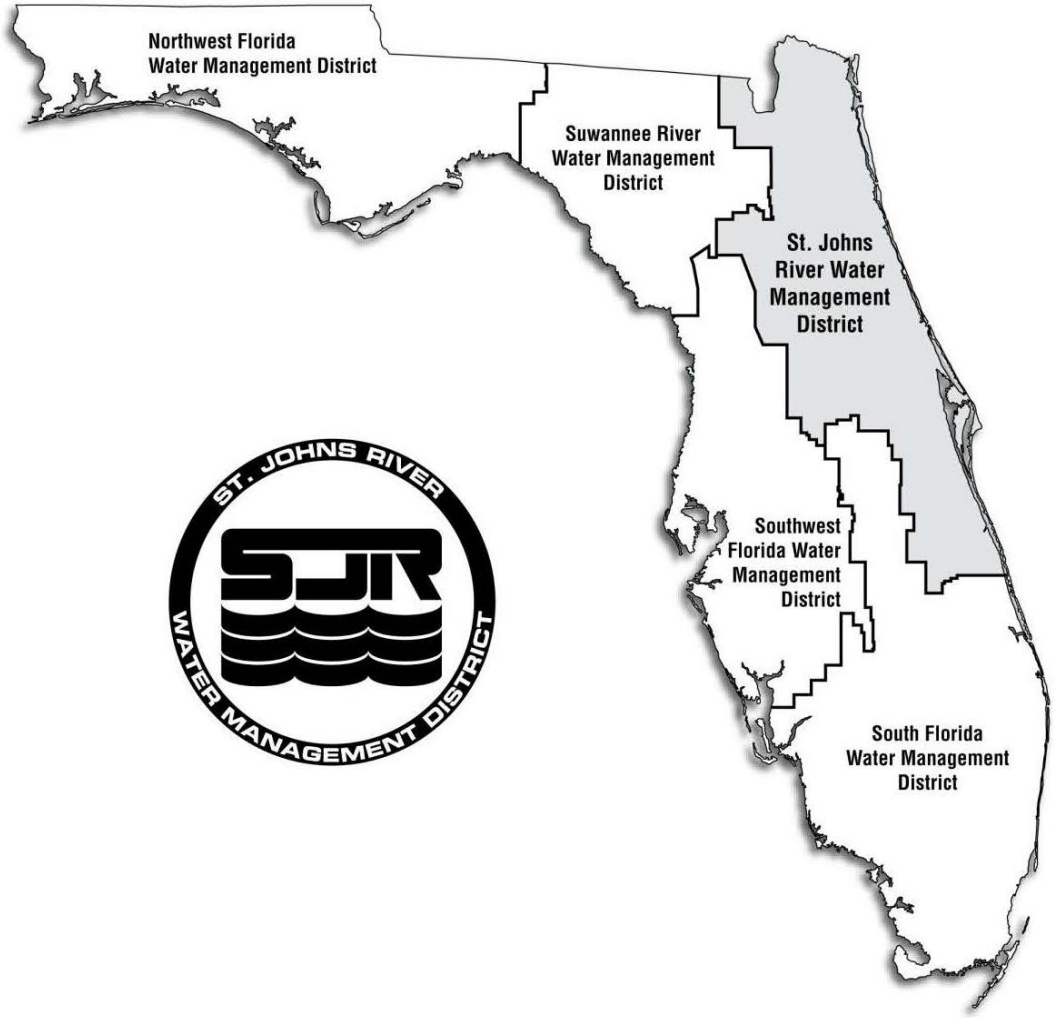
Professional Paper SJ2016-PP1

LAKE APOPKA SOIL REMEDIATION PROJECT

Tom Bartol, P.E.
Carol Brown, P.E.

St. Johns River Water Management District
Palatka, Florida

September 18, 2012



The St. Johns River Water Management District was created in 1972 by passage of the Florida Water Resources Act, which created five regional water management districts. The St. Johns District includes all or part of 18 counties in northeast and east-central Florida. Its mission is to preserve and manage the region's water resources, focusing on core missions of water supply, flood protection, water quality and natural systems protection and improvement. In its daily operations, the district conducts research, collects data, manages land, restores and protects water above and below the ground, and preserves natural areas.

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Professional Paper SJ2016-PP1

LAKE APOPKA SOIL REMEDIATION PROJECT

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St. Johns River Water Management District, Palatka, Florida

ABSTRACT

In fall 1998, the North Shore Restoration Area (NSRA) at Lake Apopka became shallowly flooded due to the termination of pumping of the fields and rainfall after the St. Johns River Water Management District (District) took possession of these properties. Unfortunately, fish-eating birds associated with the NSRA died in significant numbers during fall 1998 and winter 1999. The United States Fish and Wildlife Service (USFWS) released a statement in February 1999 indicating its opinion that the cause of the bird deaths was organochlorine pesticide (OCP) poisoning. Initial cost estimates to excavate the OCP impacted areas were $800,000,000 ($100,000/acre). The District proceeded with an investigation into alternative remediation techniques to reduce the exposure of avian species to OCPs within an approximately 8,000-acre area that would eventually be restored to a wetland habitat. Several other alternatives were evaluated, including capping, blending, land-farming, incineration and inversion. The most feasible remedial option was an inversion technique that uses four 52-inch disk blades on a Baker Plow to invert the top 10 inches of OCP contaminated soil into a ~3.5 ft furrow, ultimately creating an in-situ capping. Inversion of approximately 4,000 acres was completed in May 2009. Reductions of OCPs within the inverted fields averaged 68%. The final cost for this project was approximately $10,000,000.

INTRODUCTION

In 1996, the Florida Legislature enacted the Lake Apopka Restoration Act, Section 373.461, *Florida Statutes*, to provide that the St. Johns River Water Management District (District) accelerate the restoration of the Lake Apopka Basin by acquiring certain agricultural lands impacting Lake Apopka, along with their related facilities. The District closed on the 3,000-acre Duda property in 1997 and purchased essentially all parcels in the 6,000-acre Zellwood Drainage and Water Control District (ZDWCD) Unit 2 area in 1998. Acquisition continued with an additional 2,000 acres in Unit 1. Currently the District owns approximately 20,000 acres in the Lake Apopka Basin. The U.S. Natural Resources Conservation Service (NRCS) provided federal funding for part of the acquisition.

As part of the due diligence process during the acquisition of these properties, Phase I Environmental Site Assessments (ESA) were conducted on all 32 properties in accordance with the current ASTM 1527 standard. Twenty-six of these Phase I ESAs resulted in Phase II ESAs to investigate possible contamination. Eighteen of these Phase II ESAs confirmed contamination and were followed by Phase III Remedial Action Plans and Phase IV Remedial Action Reports. The subsequent remediation

activities removed approximately 24,000 tons of contaminated soil from former petroleum storage areas and mix / load sites and 20,000 tons of solid waste.

In 1997, concurrently with the ESA process, an Environmental Risk Assessment (ERA) was conducted to examine the risk to wildlife posed by restoration of the former agricultural areas. Approximately 400 soil samples were collected and analyzed for organochlorine pesticides (OCP) as part of the risk assessment. The ERA concluded that soil pesticide residues did not present an acute toxicity risk to wetland fish and wildlife (ATRA 1998). However, there was concern for potential long-term, sub-lethal effects of DDT residuals on growth or reproduction of top-level predatory birds. The reports recommended, and District staff concurred, that long-term monitoring of the site was necessary when the restoration flooding commenced. In 1998, the ERA Addendum evaluated the Site Remedial Action Levels (SRAL) proposed by the District. The Addendum concluded the remediation of any "hot spots" to these levels would result in overall averages in OCPs that would fall below the Ecological Protection Values (EPV) determined by the 1997 report. The Florida Department of Environmental Protection (FDEP) concurred with the ERA and provided oversight for the due diligence process during the acquisition of the NSRA properties.

In fall 1998, the North Shore Restoration Area (NSRA) became shallowly flooded due to rainfall and the termination of pumping of the fields. The area was not drained in order to prevent soil oxidation and the growth of vegetation. The diversity of habitats presented by the NSRA resulted in an enormous response by bird populations. Unfortunately, fish-eating birds associated with the NSRA died in significant numbers during fall 1998 and winter 1999. The species most affected was the American white pelican. The U.S. Fish and Wildlife Service (USFWS) released a statement in February 1999 indicating its opinion that the cause of the bird deaths was organochlorine pesticide poisoning.

With the support from a 13-agency Technical Advisory Group, NRCS and the District proceeded with an investigation into the cause of the bird mortality. Other objectives of this investigation were to further evaluate the background OCP levels in the soils and/or canals of the NSRA, attempt to locate any "hot spots" that may have contributed to the bird mortality, and evaluate implications for future restoration planning.

In summer 1999, a large-scale soil sampling project began at the NSRA. Soil samples were collected from approximately 1,500 locations and analyzed for OCPs by EPA Method 8081, RCRA 8 Metals plus Copper and Total Organic Carbon (TOC). A stratified, random sampling grid was designed with weighting determined by prior data for the areas. The former Duda farm, the western part of the NSRA, was sampled at the lowest density and Unit 2, the southern part of the NSRA, was sampled at the highest density. The former Duda Farms has historically had lower OCP levels than the eastern part of the NSRA. This background sampling was completed in 2001. The results of this investigation produced better definition of OCP concentrations within the fields of the NSRA. Table 1 includes a summary of these sample results compared to FDEP guidance levels.

Table 1. Summary of Sample Results Compared to FDEP Guidance Levels

Units: mg/kg	Residential SCTL	SQAG TEC	SQAG PEC	Average	Max
4,4'-DDD	4.2	0.0049	0.028	**0.816**	**8.8**
4,4'-DDE	2.9	0.0032	0.031	**1.842**	**16**
4,4'-DDT	2.9	0.0042	0.063	**1.398**	**62**
Dieldrin	0.06	0.0019	0.062	**0.423**	**3.3**
Toxaphene	0.9	0.0001	0.032	**14.268**	**150**

SCTL: Soil Cleanup Target Level
SQAG: Sediment Quality Assessment Guidelines
TEC: Threshold Effects Concentration
PEC: Probable Effects Concentration

Concurrently with the large-scale soil sampling project, the District's Division of Environmental Sciences (ES) researched appropriate Bio-Sediment Accumulation Factors (BSAF) for the high TOC content typical of the NSRA. Due to the uncertainty of the rate of bioaccumulation of weathered OCPs from soils/sediment through the food chain to fish and then birds, three additional phases of study were initiated during spring 2001. These three additional phases were: 1) laboratory microcosms, 2) field-scale mesocosms, and 3) bird feeding studies. "Safe levels" of OCPs in the soil were determined by these studies and used as guidance for eventual remedial activities at the NSRA. Two Expert Review Groups were convened to review and critique specific aspects of the study. The Expert Review Group comments were incorporated and the Safe Levels have been adjusted according to these comments and according to more current data from the field-scale mesocosm studies.

Remediation Plan

Preparation of a viable Remediation Plan for the NSRA was contingent on discovering a remedial option that was capable of reducing the OCP concentrations in the top foot of soil (exposure zone), and was cost effective as well as achievable within a reasonable amount of time. MACTEC Engineering & Consulting, Inc. (MACTEC) produced a Feasibility Study in January 2005 to compare remedial alternatives for the NSRA.

MACTEC used the 1999–2001 data to address site specific requirements for remedial options. The best estimate target levels (BETL) were calculated from trigger values in fish tissue provided to the District by USFWS in its consultation on the former Duda Farms. Conservative target levels (CTL) are one half of the BETL. These values are expressed as TOC normalized values in order to account for the transference of the OCPs from the TOC content of the soil to the lipid content of the fish.

MACTEC divided the 8,000 acres of Unit 1 and 2 into 70 distinct fields based upon previous land ownership and some natural boundaries such as ditches or canals. The percent reductions of OCP concentrations required to meet the BETLs and CTLs were calculated for each field. A list of 23

potential remedial options were evaluated and reduced to 12 remedial alternatives that would best reduce or remove exposure to OCPs. These 12 remedial action alternatives were screened against Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) based criteria and cost estimates were developed for each alternative. Each alternative was also assigned a percentage reduction in OCPs that could be expected. Remedial options assessed ranged from the "No Action Alternative" to "Excavation and Off-site Disposal." The result of this Feasibility Study was a menu of options to explore for remedial alternatives for specific fields.

Following the production of the Feasibility Study, it was determined that the 1999–2001 data was insufficient to adequately address the requirements for remediation of the individual fields. A resampling effort commenced during spring 2007. Sample densities within the MACTEC field designations were standardized based on size and on an existing agreement with the USFWS. Fields 50 acres or less had five soil samples collected. Fields with more than 50 acres and 200 acres or less had 10 soil samples collected. Fields larger than 200 acres had 15 samples collected. Sample points from the 1999–2001 data set were used, with additional points added spatially as needed. During this sampling event, the depth of the muck layer was also determined by continuing the soil boring to the end of the muck layer or 4 feet, whichever came first. If the end of the muck layer was found, then the soil type beneath the muck was documented. This information was useful in the success of the final remediation option.

Pilot studies were conducted for several of these remedial options. A reduction in DDE was the determining factor for the most effective remedial option. ES studies indicated that DDE has a chronic toxicity and bio-accumulates at a higher rate than the other OCPs. A 50% or greater reduction of the average DDE concentration was used as the indicator of success in the following pilot studies.

Pilot Studies

Fiscal Year (FY) 2003/2004

The first pilot study compared DDE reduction using two different pieces of normal farming equipment. Three one-acre plots were prepared (mowed). Twelve soil samples were collected from within each plot and analyzed for OCPs by EPA Method 8081. Soil samples were collected at the same locations and analyzed for OCPs subsequent to the project activities. The southern most plot acted as the Control plot, no mechanical manipulation of the soil occurred in this plot. The northernmost plot was tilled by District Operations staff on a weekly basis for a six-month period. The weekly tilling was accomplished using a Case 7230 tractor pulling a 12-inch wide 24-inch Rome disc for a tilling depth of approximately 10 to 12 inches. The middle plot was inverted to a depth of 18–24 inches by Allen Machines & Equipment of Roscoe, Texas using a 36-inch Square Bottom switchblade plow (Figure 1).

Figure 1: 36-inch Square Bottom switchblade plow

Soil samples were collected in the inverted plot immediately after inversion. Soil samples were collected from the tilled plot after three months of tilling and again at the end of the six-month project. The control plot was sampled at the end of the six-month period. Average results for DDE for each plot were compared for samples collected at the beginning of the project to samples collected at the end of the project. (Figure 2). The inversion plot showed the biggest reduction in average DDE concentration and the control plot showed an increase in average DDE concentration. The increase in average DDE concentration in the control plot may be a result of a decrease in the moisture content in the soil. A Moisture Study conducted by the District in 2005 has demonstrated that OCP concentrations in these high organic muck soils can be influenced by the moisture content of the soil, with the greatest concentrations occurring around a moisture content of 45%. Graphing moisture content versus OCP concentration developed a bell shaped curve with the apex around 45-48%. The average moisture content in the control plot changed from 69.5% to 52%, which may have skewed the DDE results in the final samples. The other two plots did not show as significant a change in moisture content and remained in the 60 percentiles. One of the biggest challenges for the inversion project was the very wet field conditions at the time of the inversion.

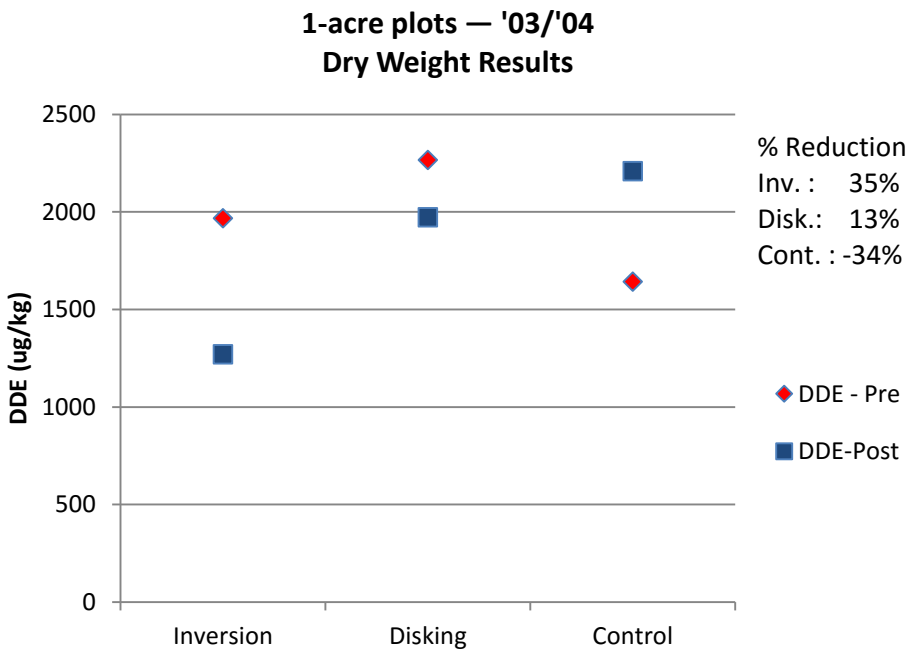

Figure 2. 1-acre plots — '03/'04, dry weight results

FY 2005/2006

Following the completion of the MACTEC Feasibility Study, a second pilot study was conducted to compare the inversion efficiency to a blending technique. A Mobile Injection Treatment Unit — Large Volume Remediator (MITU-LVR) (Figure 3) was used to vertically blend contaminated soil with underlying uncontaminated soil to a depth of 3–4 feet for this project. For this project, Allen Machines modified its plow and used a bi-directional moldboard plow (Figure 4) to invert the top 2–3 feet of soil. Three five-acre plots were prepared for this pilot study and 12 soil samples were collected from within each plot and analyzed for OCPs by EPA Method 8081 and Total Organic Carbon (TOC). Soil samples were collected at the same locations and analyzed for OCPs and TOC subsequent to the project activities. TOC was analyzed for each sample in order to calculate a carbon normalized result. In order to carbon normalize the data, the dry weight laboratory results are divided by the percentage of TOC. The northernmost plot was blended to a depth of approximately 3.5 feet. The blending was limited to a two-day period, and only 1.5 acres were completed of the 5-acre plot. The southern most plot acted as the Control plot, no mechanical manipulation of the soil occurred in this plot. The middle plot was inverted to a depth of approximately 2.5 feet.

Figure 3: MITU- LVR

Figure 4: Bi-directional moldboard plow

Soil samples were collected in the three plots after the inversion and blending were complete. Average results for DDE for each plot were compared for samples collected at the beginning of the project to samples collected at the end of the project. (Figure 5) Carbon normalized sample results were also compared (Figure 6). The blending plot showed the biggest reduction in average DDE concentration in the dry weight results and the inversion plot showed the biggest reduction in the carbon normalized results. The control plot showed a slight increase in average DDE concentration for both dry weight and carbon normalized results. Both machines had some difficulty with wet conditions. The blending machine was more successful in lower TOC areas, but these are not typical to the NSRA. At optimum field conditions, the MITU-LVR could complete one acre per day. Allen Machines expressed interest in further modifying its plow and performing additional field prep in order to get a more successful inversion. Under optimal field conditions, Allen Machines estimated inversion of at least 10 acres per day.

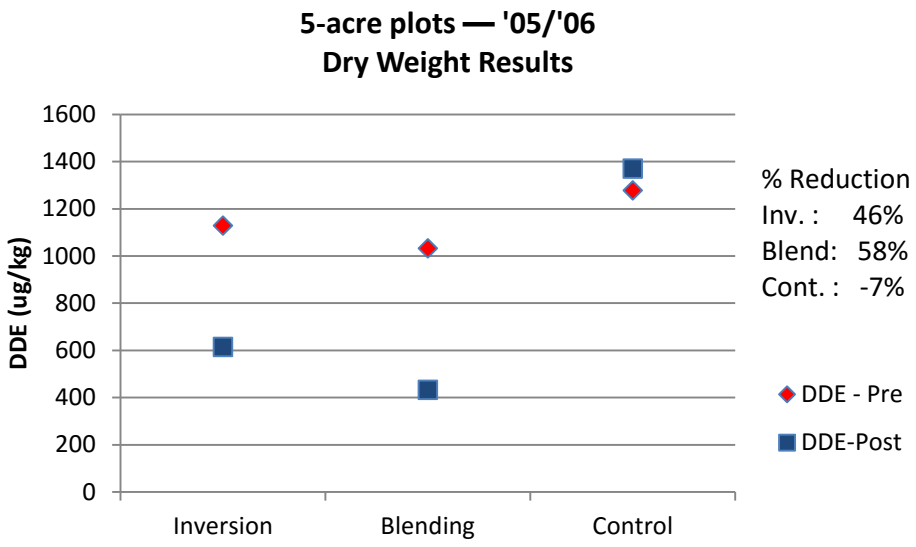

Figure 5. 5-acre plots – '05/'06 dry weight results

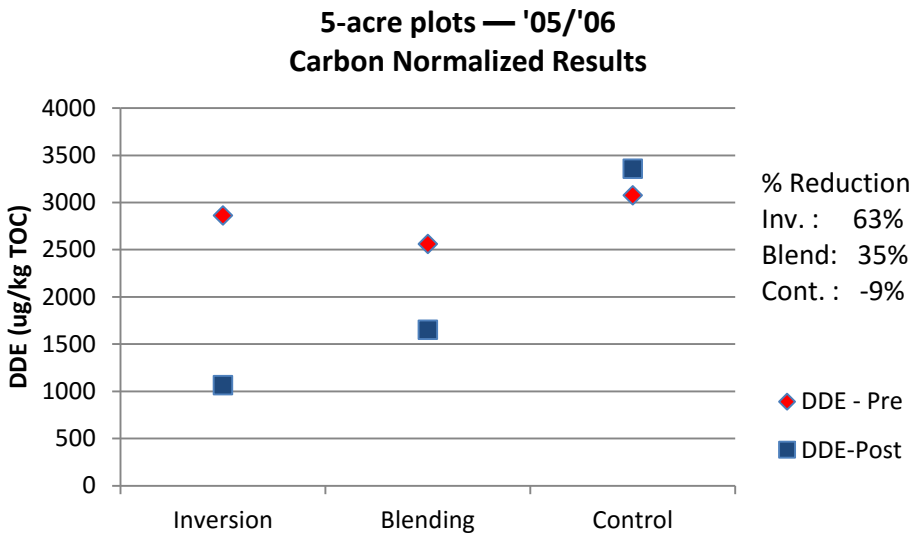

Figure 6. 5-acre plots – '05/'06 carbon normalized results

FY2006/2007

Pilot projects assessing two different remedial options were implemented with very limited success. These techniques were not further assessed due to difficulty in implementation and a relatively higher cost

compared to the other successful remedial options.

The first project consisted of applying a muck cap layer over the contaminated soil. A local trucking company involved in hauling excavated material from construction sites contacted the District to offer the fill material at a reasonable cost. Unfortunately, by the time the District analyzed the fill material for suitability, the material was not available. After several attempts, this project was not pursued further. Although the cap material was at a nominal cost, the cost to spread the material was prohibitive to use on a large scale project.

For the second project, a District contractor leased a CAT RM300 (Figure 7), a rotary trenching machine capable of mixing to a depth of 20 inches, to test the feasibility of using it for mixing the contaminated soil with the underlying clean soil. A 36-acre plot was prepared for this pilot study and 10 soil samples were collected and analyzed for OCPs and TOC. The CAT was leased for one week. The machine had difficulty getting stuck in wet muck and some vegetation managed to break the hydraulic line. By the end of the week, the Contractor only mixed the areas where six of the soil samples were taken. Reduction of DDE was significant, but the cost in time and equipment failure was prohibitive for use on a large scale. Modifications would need to be made for the machine to run more efficiently at this site.

Figure 7. CAT RM300

Allen Machines returned in spring 2007 for a 300-acre pilot project. Samples collected during the 2007 sampling event were used for the pre-inversion samples. In addition, the information on the subsurface conditions obtained during the 2007 sampling was used to select fields with varying subsurface conditions — muck, clay, sand and/or rock.

Five different fields were identified for this project to test the redesigned four-bottom bi-direction plow with 52-inch disks (Figure 8). Allen Machines was responsible for all field prep.

Figure 8. Four-bottom bi-direction plow with 52-inch disks

Figure 9. Fields 5 and 8 — post inversion

The percent reduction of DDE in the individual fields ranged from 54%–98% for the dry weight results (Figure 10) and from 13%–94% for the carbon normalized results (Figure 11). The 13% reduction in carbon normalized results for Field 5 (Figure 9) was attributed to the very low TOC resulting from inverting the rocky subsurface. The other field carbon normalized reductions were above 50%. Based on these results, a performance-based contract was awarded to Allen Machines for a large scale remediation project at the Lake Apopka NSRA.

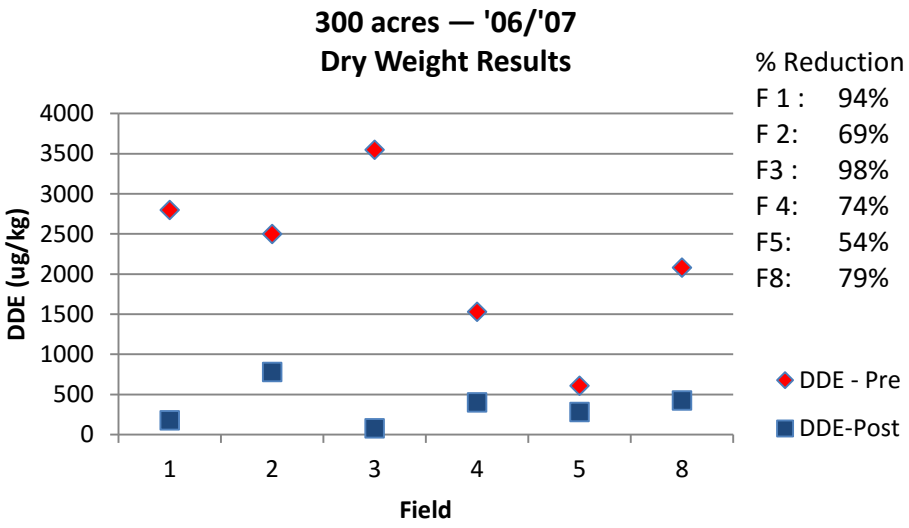

Figure 10. 300 acres — '06/'07 dry weight results

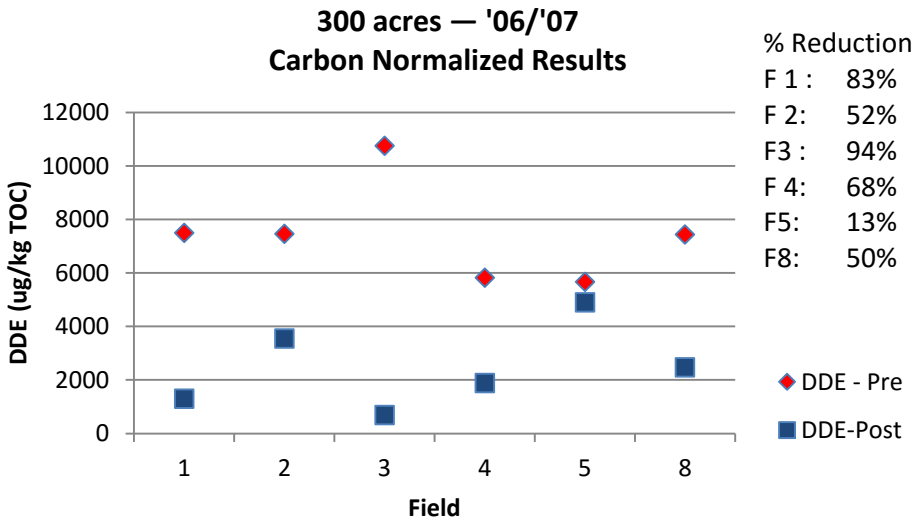

Figure 11. 300 acres – '06/'07 carbon normalized results

FY 2007/2008

A pilot project to assess the potential for bioremediation of the OCP contaminated soil was implemented by a District consultant and subcontractor. This pilot project consisted of the application of a protein factor amendment to the soil that would assist the existing microbes in dechlorinating the OCPs. The District considered this alternative for low TOC areas where the inversion had not shown to be as successful. The protein factor amendment was added to the soil and the areas were disked every two weeks for the five months of the project. Two 1.5-acre plots were prepared for application of the amendment, TA1 and TA2 (twice the rate of TA1) (Figure 12). One-acre plot was designated as the control, which would be disked, but have no amendment added.

Another one-acre plot was designated as background, where no activity occurred. Eight soil samples were collected from each of the treatment plots and five soil samples were collected from the control and background plots before the application, and at two and five months after the application. All soil samples were analyzed for OCPs and TOC. The consultant also monitored moisture and pH every two weeks and the plots were watered if necessary. TA2 showed the most reduction in DDE in dry weight (60%) (Figure 13) and carbon normalized results (43%) (Figure 14), but the Control plot had similar results (52% and 40%). It was unclear how much of the reduction could be attributed to the addition of the amendment. The cost of this alternative was also significantly higher, so further assessment of this alternative was not pursued.

Figure 12. Treatment areas and control area

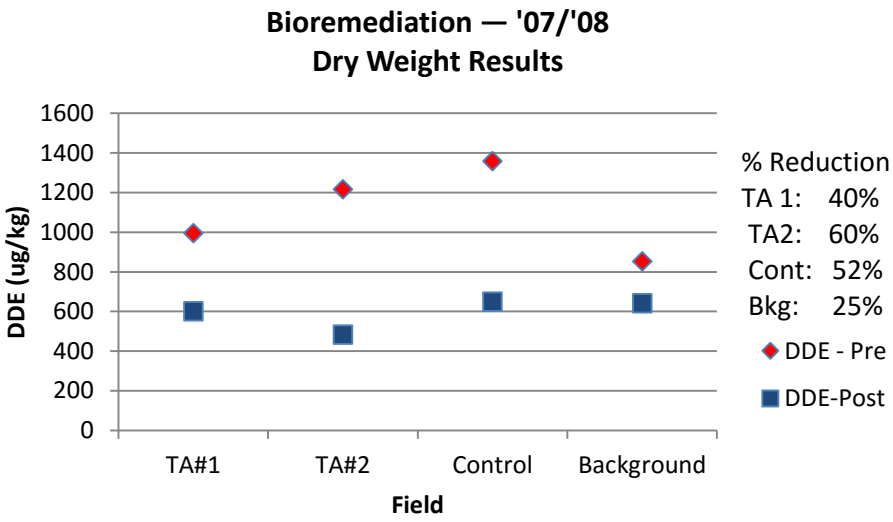

Figure 13. Bioremediation — '07/'08 dry weight results

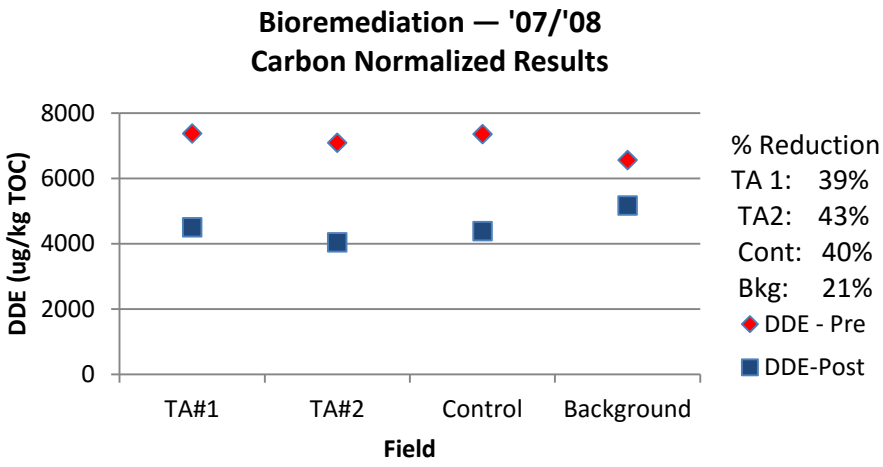

Figure 14. Bioremediation — '07/'08 carbon normalized results

Table 2 summarizes the results of the Pilot Studies and estimates the cost and duration for each technique over the presumed 8,000 acres requiring remediation. Inversion proves to be the most successful in terms of cost and duration. Full scale remediation began using inversion. The next challenge was to reduce the cost further by reducing the number of acres requiring remediation.

Table 2. Summary of Pilot Studies

				8,000 acres	
Project	% Reduction DDE	Rate: Acre/Day	Cost: $/Acre	Total Time (Days)	Total Cost
Inversion	79	15	$2,500	533	$20,000,000
Blending	58	1	$2,700	8,000	$21,600,000
Bio-remediation	50	NA	$31,839	NA	$254,712,000
Excavation and disposal	100	0.25	$100,000	32,000	$800,000,000

Full Scale Remediation

Remediation Strategy

Early in the project, DDE concentrations were the driving force in determining remediation requirements. Data from the 2007 sampling event were compared to ES's Safe Levels to decide which fields required remediation. Requirements were further refined by evaluating DDE concentrations spatially within the fields. Within fields, there were areas that exhibited DDE concentrations lower than Safe Levels. A Remediation Strategy was developed to standardize the method for determining how much of a field would be remediated. The steps are outlined below followed by an example.

<u>Step 1: Determination of fields requiring remediation:</u>

The results of the 2007 data set have been carbon normalized and the 95% Upper Confidence Limits (UCL 95) of the field averages have been determined and compared to proposed "Safe Levels"

concentrations for DDE (5,275 ug/kg TOC). Fields that have a UCL 95 above the Safe Levels are targeted for remediation.

Step 2: Determination of specific blocks within fields requiring remediation:

Individual points within each field are evaluated against the Safe Level for DDE. Smaller fields (defined by canal or ditch boundaries) within these fields are targeted for remediation based on the presence of individual sample points with concentrations above Safe Levels. The smaller fields are combined to create a block. The total acreage for the block of smaller fields will be at least 25% of the total acreage of the field. The block is delineated on an aerial map and the locations are confirmed in the fields for Allen Machines to complete the inversion.

The UCL 95 is also calculated for the proposed non-inverted portion of the field. Sample density within the non-inverted portion must follow the same sample density used for the 2007 sampling effort. The UCL 95 for the proposed non-inverted portion must be less than the Safe Level.

Step 3: Post-inversion sampling of the block:

Once the inversion has been completed, the block is resampled at the locations that were previously sampled. These new sample results replace the pre-remediation 2007 sample results to determine a new UCL 95 for the total field.

Example: Field 4 (152 acres)

Step 1: Determination of fields requiring remediation:

Figure 15 shows that the UCL 95 for DDE in Field 4 is above the Safe Level.

	DDE (ug/kg TOC)
UCL 95	6,327
Safe Level	5,275

Figure 15. DDE in Field 4

Step 2: Determination of specific blocks within fields requiring remediation:

Three individual farm fields are identified with three points with the highest concentrations of DDE. These fields are defined as a block for remediation. This block consists of 45.4 acres or 30% of the total acreage of Field 4. Allen Machines inverts the block.

The proposed non-inverted portion of the field is 106.6 acres, which would require 10 sampling locations based on the 2007 sampling density. Only five points are within the proposed non-inverted portion, so an additional five points are sampled within the proposed non-inverted portion. The UCL 95 for DDE is calculated using all 10 points and Figure 16 shows that it is below the Safe Level.

	DDE (ug/kg TOC)
UCL 95 – non-inverted portion	4,162
Safe Level	5,275

Figure 16. DDE in non- inverted portions of the field

Step 3: Post-inversion sampling of the block:

The new UCL 95 for the entire Field 4 is below the Safe Levels (Figure 17).

	DDE (ug/kg TOC)
UCL 95 — post-inversion	4,136
Safe Level	5,275

Figure 17. UCL 95 for entire Field 4

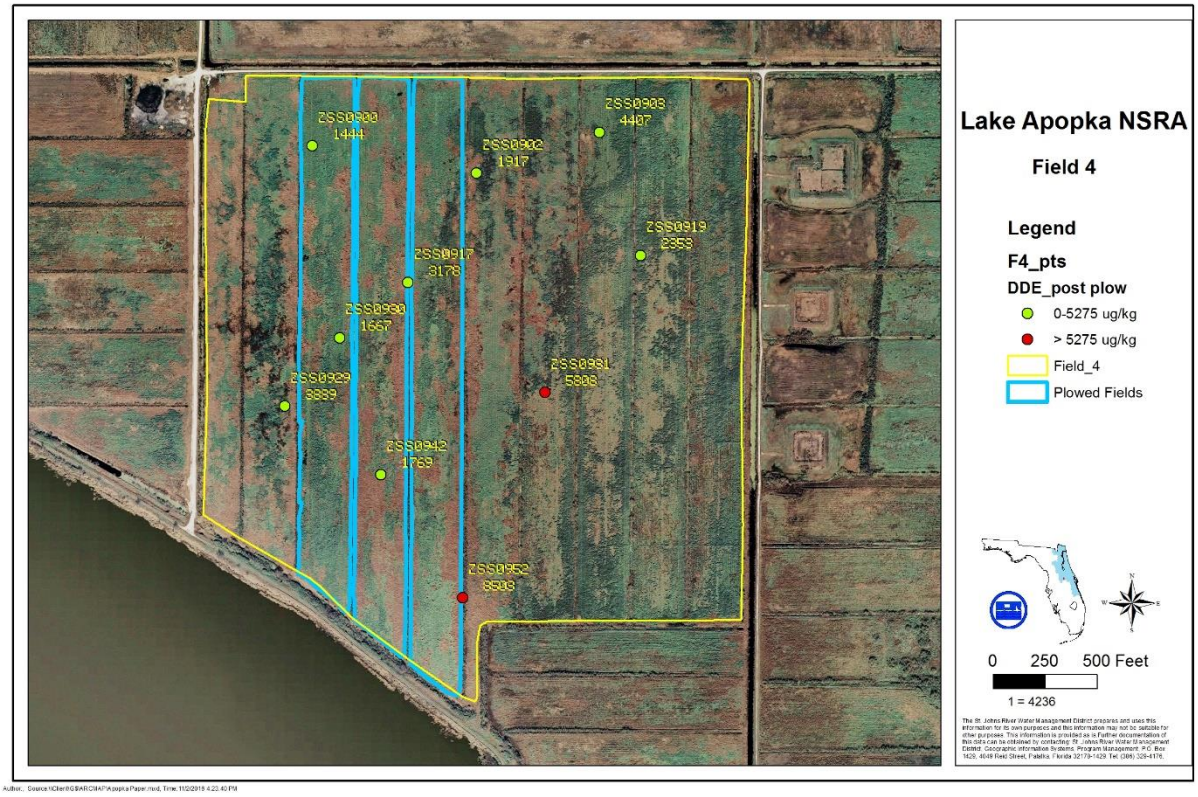

Figure 18. Field 4 of the Example

Implementation of Remediation Strategy

The steps described in the Remediation Strategy are applied to each field. Blocks for remediation are defined within each field. The FY 07/08 contract with Allen Machines originally specified 1,000 acres to be inverted. Due to the success of the inversion early in the fiscal year, another 500 acres were added to the contract. Also, due to the continued success of the inversion on reducing all OCPs within the fields, the Remediation Strategy was altered to include the Hazard Index (HI) as the driving force

for the determination of the necessity for remediation within the individual fields. The HI considers the cumulative effects of toxaphene, DDT and its metabolites DDE and DDD, dieldrin, and seven chlordane compounds on potential avian receptors. Some additional acreage was targeted for inversion after evaluation using the HI in addition to the DDE concentrations in the fields. The FY 08/09 Allen Machines contract specified 2,200 acres to be inverted. Four thousand acres were ultimately designated for inversion in the three-year contract.

Inversion process

In order to successfully invert the soil, approximately 10 to 12 passes were necessary across each field. Prior to the inversion, several steps were necessary to prepare the fields. Roller chopping (Figure 20) and shredding the fields (Figure 21) would break up the vegetation to prevent slippage from the vegetation becoming tangled in the disks. After the vegetation was managed, the fields were disked (Figure 22) to a depth of approximately 10 inches to break up the surface material. Rock or other subsurface conditions could necessitate the use of a chisel plow (Figure 23) to break up the subsurface to assist the inversion process. Following each of the field prep techniques, the fields were rolled (Figure 24) to provide a smoother, more compact surface. Once the field was prepped, the Baker plow (Figure 25) would invert the field. The Baker plow created a 2.5–3.5-foot furrow (Figure 19) in which the top one foot of contaminated soil was rolled into and capped with the less contaminated underlying soil. Following inversion, several more passes with the offset disk and roller were necessary to provide a final smooth, more compact surface.

Figure 19. Furrow created by Baker plow

Figure 20. Chopper

Figure 21. Shredder

Figure 22. Offset disk

Figure 23. Ripper / chisel plow

Figure 24. Soil packer / roller

Figure 25. Baker plow with 52” disks

Tractors pulling the Baker plow were equipped with a GPS navigation system. The navigation system aided the operators in guiding the large tractors to the edge of the previous furrow for a more complete inversion. An onboard computer system recorded fuel consumption, depth of

furrow and acreage completed (Figure 26). Figure 27 shows a view of the plow from inside the tractor.

Figure 26. Screen for onboard computer system

Figure 27. View from the tractor

Challenges for the inversion process

The greatest challenge for the inversion process was the height of the water table on the site. This area is historic s and can be as much as 6 feet lower in elevation than the surface level of Lake Apopka. Keeping the water table at least 4 feet below land surface (BLS) required vigilant attention to water levels in the canals and rainfall data. Large pumps were available at several locations within the NSRA and smaller portable pumps were moved around as needed. Rainfall of more than one inch a day would shut down the project until the water levels could be managed. Fortunately, the full scale project began after a drought period for the area so the water table was lower than usual. Inversion was scheduled for the winter months that are typically drier. The project was completed by the time that normal rainfall returned to the site.

A second challenge for the inversion process was low TOC soils. These soils typically had much lower dry weight OCP concentration. TOC soils of less than 5% resulted in very high carbon normalized results. One 300-acre field (Field 57) was not inverted due to TOC less than 3% and dry weight OCP concentrations less than FDEP Residential Soil Cleanup Target Levels (SCTLs).

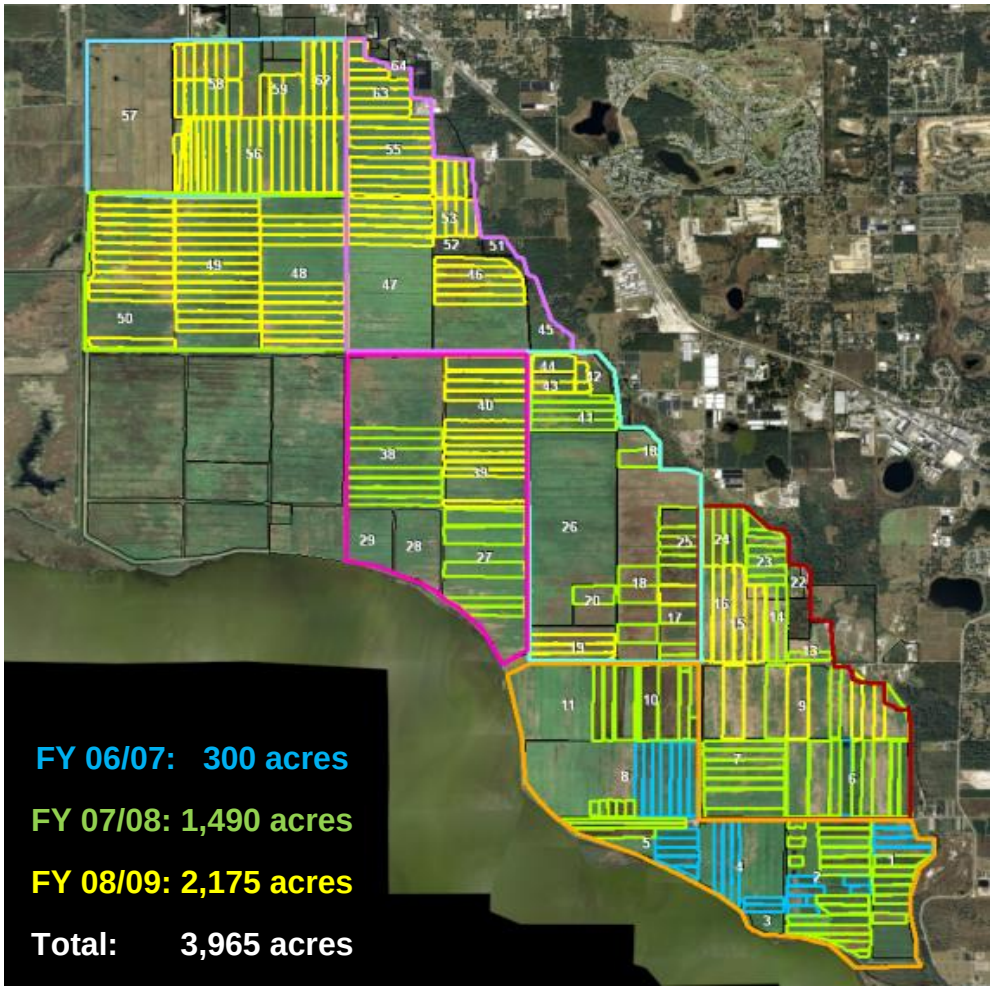

Figure 28. 3,965 acres completed

Project Results

The inversion of 3,965 acres (Figure 28) was completed in spring 2009. By summer 2012, all properties targeted for remediation were scheduled for wetland restoration. As part of the phased flooding, fish are routinely monitored for OCP levels for a year. To date, after the first year of flooding, measured OCP levels in fish were below predicted values. As management goals change from dense wetland vegetation to other options that include open water areas, representative fish species will be sampled and analyzed to verify that OCPs remain at ecologically safe levels. There have been no documented adverse impacts to avian species from exposure to OCPs within the remediated site.

BIBLIOGRAPHY

ATRA, Inc. Occupational and Environmental Services, *Environmental Risk Assessment of a Lake Apopka Muck Farm Wetlands Restoration*, November 3, 1997 – (District Special Publication SJ98-SP7)

ATRA, Inc. Occupational and Environmental Services, *Environmental Risk Assessment of a Lake Apopka Muck Farm Wetlands Restoration - Addendum*, 1998

Additional Proposal Information

(This is as uploaded, a blank page will show if nothing was submitted)

Biological Assessment Phases 3458.pdf

United States Department of the Interior

U. S. FISH AND WILDLIFE SERVICE

7915 BAYMEADOWS WAY, SUITE 200
JACKSONVILLE, FLORIDA 32256-7517

IN REPLY REFER TO:
FWS Log No. 04EF1000 -2016-I-0062

November 2, 2015

Lori McCloud
St. Johns River Water Management District
P.O. Box 1429
Palatka, FL 32178-1429

Re: Biological Assessment for District Properties within the Ocklawaha Chain-of-Lakes – Modification

Dear Ms. McCloud:

Reference is given to email correspondence and attachments that we received October 22, 2015 from the St. Johns River Water Management District (SJRWMD) requesting informal consultation regarding modifications to the Biological Assessment for District Properties within the Ocklawaha Chain-of-Lakes as outlined within your letter.

The District is requesting concurrence from the Service for a minor modification to this BA that will terminate aerial and ground-based avian surveys and vegetation monitoring in areas that have had a minimum of quarterly fish sampling for one year post-project completion and no avian mortality events associated with these properties attributed to contaminants since project completion.

In accordance with the Endangered Species Act of 1973, (ESA) as amended (16 U.S.C. 1531 *et seq.*), the U.S. Fish and Wildlife Service (Service) has reviewed the modifications proposed within the letter titled Blanket Modification for Biological Assessments on District Properties within the Ocklawaha Chain-of-Lakes. The Service concurs with your determination that the proposed modifications to the project may affect, but is not likely to adversely affect federally listed species. If you have any questions or concerns about this consultation, please feel free to contact Erin M. Gawera of my staff at 904-731-3121.

Sincerely,

for Jay B. Herrington
Field Supervisor

St. Johns River
Water Management District
Ann B. Shortelle, Ph.D., Executive Director

4049 Reid Street • P.O. Box 1429 • Palatka, FL 32178-1429 • (386) 329-4500
On the Internet at floridaswater.com.

September 22, 2015

Erin Gawera
U.S. Fish & Wildlife Service
North Florida Ecological Services Office
7915 Baymeadows Way, Suite 200
Jacksonville, FL 32256-7517

Subject: Blanket Modification for Biological Assessments on District Properties within the Ocklawaha Chain-of-Lakes

Erin:

This letter proposes modifications to several Biological Assessments (BAs) for properties within the Ocklawaha Chain-of-Lakes. The project plans included within these BAs were submitted with no end-date for proposed monitoring; we are proposing to terminate that monitoring at this time. Specific monitoring activities addressed: aerial and ground-based avian surveys and vegetation monitoring. A list of impacted properties follows:

<u>Emeralda Marsh Conservation Area:</u>

Area 3
Project Completed: Infrastructure installation completed 2007
Proposed action: cease weekly bird surveys

Area 4 (Lowrie Brown)
Project Completed: Infrastructure repairs and flooding complete 2007
Proposed action: cease weekly bird surveys

Area 5 (Long Farm)
Project Completed: Infrastructure installation completed 2007
Proposed action: cease weekly bird surveys

Area 7 (Eustis Muck Farm)
Project Completed: Infrastructure installation completed 2008
Proposed action: cease weekly bird surveys

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Douglas Burnett ST. AUGUSTINE
Maryam H. Ghyabi ORMOND BEACH
Ron Howse COCOA
George W. Robbins JACKSONVILLE

Lake Apopka North Shore Restoration Area:

Phase 1

Project Completed: Reflooded in 2008
Proposed action: cease weekly bird surveys and vegetation monitoring

Phase 2

Project Completed: Reflooded in 2009
Proposed action: cease weekly bird surveys and vegetation monitoring

Phase 3

Project Completed: Reflooded in 2013
Proposed action: cease weekly bird surveys and vegetation monitoring

Phase 4

Project Completed: Reflooded in 2013
Proposed action: cease weekly bird surveys and vegetation monitoring

Phase 5

Project Completed: Reflooded in 2013
Proposed action: cease weekly bird surveys and vegetation monitoring

Phase 6

Project Completed: Reflooded in 2011
Proposed action: cease weekly bird surveys and vegetation monitoring

Phase 7

Project Completed: Reflooded in 2011
Proposed action: cease weekly bird surveys and vegetation monitoring

Phase 8

Project Completed: Reflooded in 2014
Proposed action: cease weekly bird surveys and vegetation monitoring

Duda

Project Completed: Reflooded in 2002
Proposed action: cease weekly bird surveys and vegetation monitoring

Marsh Flow-Way

Project Completed: Flooded in 2004
Proposed action: cease weekly bird surveys and vegetation monitoring

All properties listed had a minimum of quarterly fish sampling for one year post-project completion, which either ceased with mutual agreement from USFWS, or is near completion with no expected extensions based on data to date (Phase 4 and Phase 8). There have been no avian mortality events associated with these properties attributed to contaminants since project

completion. Please review the proposed modifications and provide feedback accordingly. If you have any additional questions, please feel free to contact me.

Sincerely,

Lori McCloud
Environmental Scientist V
St. Johns River Water Management District
Bureau of Environmental Sciences
lmccloud@sjrwmd.com
Office: (386) 329-4491

SJRWMD
MAY 01 2012
MAIL CENTER

United States Department of the Interior
U. S. FISH AND WILDLIFE SERVICE
7915 BAYMEADOWS WAY, SUITE 200
JACKSONVILLE, FLORIDA 32256-7517

IN REPLY REFER TO:

FWS Log No. 04EF1000-2012-I-0135

April 25, 2012

Tamy Dabu
Project Manager
U.S. Army Corps of Engineers
Cocoa Section
400 High Point Drive, Suite 600
Cocoa, FL 32926

Re: Re-hydration Plan for Phase 3, 4, 5 and 8 of the Lake Apopka Wetland Restoration project (FWS Log No. 04EF1000-2012-I-0135)

Dear Ms. Dabu:

Reference is given to email correspondence and attachments that we received April 17, 2012 from the St. Johns River Water Management District (SJRWMD) requesting informal consultation regarding the proposed re-hydration of Phases 3, 4, 5 and 8 of the Lake Apopka Wetland Restoration project, located at the north shore of Lake Apopka, Orange County, Florida. The SJRWMD determined that the project may affect, but is not likely to adversely affect federally listed species.

In accordance with the Endangered Species Act of 1973, (ESA) as amended (16 U.S.C. 1531 *et seq.*), the U.S. Fish and Wildlife Service (Service) reviewed the Biological Assessment (BA) entitled "*Lake Apopka North Shore Restoration Area –Biological Assessment Phases 3, 4, 5 and 8*" (received 17 April 2012). The Service concurs with your determination that the proposed project may affect, but is not likely to adversely affect federally listed species; provided implementation and monitoring are conducted as described in the BA.

This concludes section 7 consultation on the proposed re-hydration of the Phase 3, 4, 5 and 8 portion of the Lake Apopka Wetland Restoration project. If you have any questions or concerns about this consultation, please feel free to contact Erin M. Gawera of my staff at 904-731-3121.

Sincerely,

for David L. Hankla,
Field Supervisor

Cc: Roxanne Conrow, SJRWMD

Lake Apopka North Shore Restoration Area

Biological Assessment–Phases 3, 4, 5 and 8

April 2012

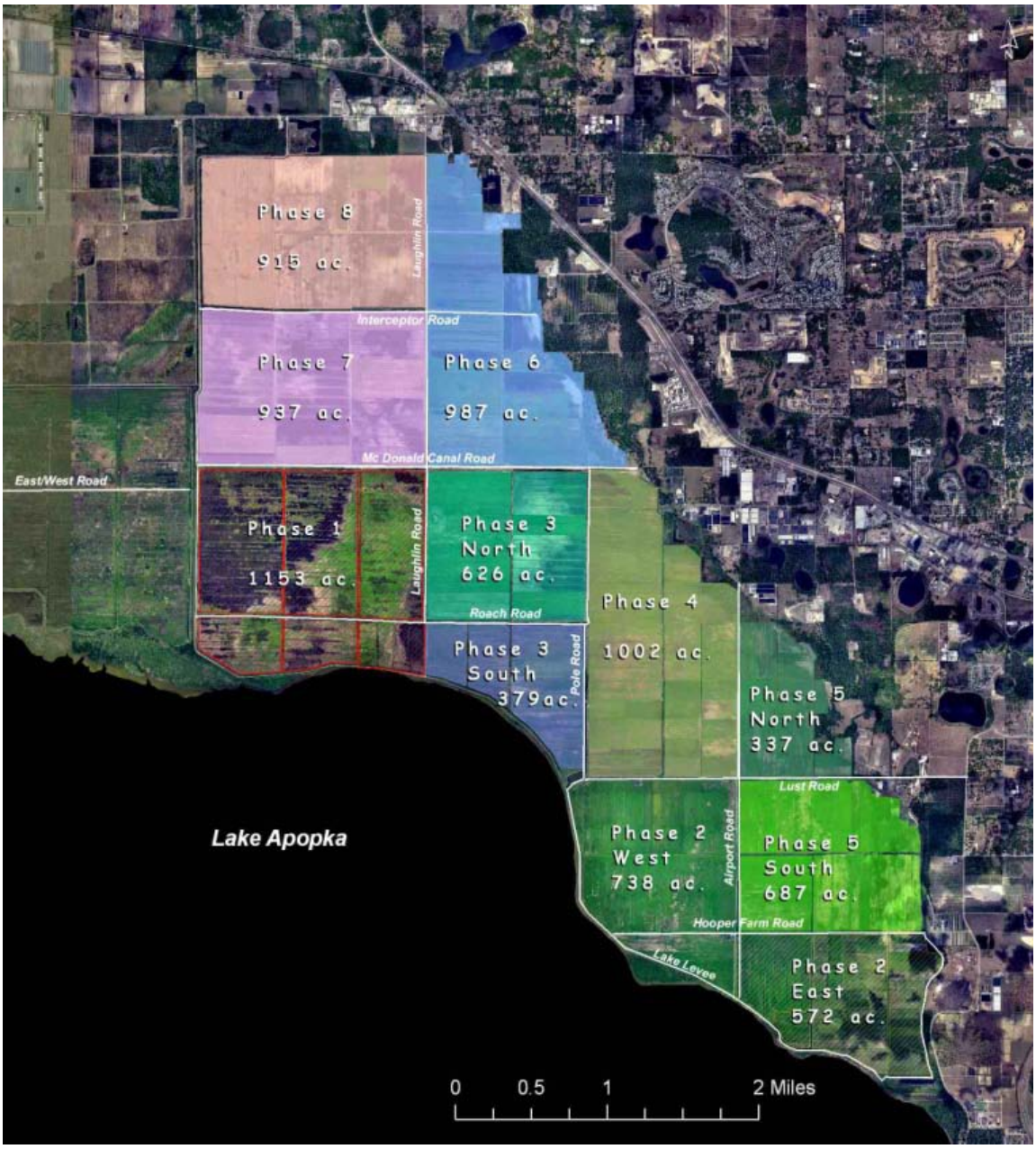
Addendum: Note that, since the finalization of this BA, the areas covered by the phases have changed. Phase 3 North and Phase 5 North have been consolidated together with Phase 4 into one hydrologic unit to make Phase 4 West, Middle, and East. Phase 3 (South) and Phase 5 (South) retain the same names that are used in this document.

5/20/2014 R. Conrow

Document author: Roxanne Conrow
Document location SJRWMD: H:\apopka\Biological Assessments\...Phases 3, 4, 5, 8

Executive Summary

Phases 3, 4, 5 and 8, totaling approximately 3,900 acres, are the final phases proposed for flooding in Units 1 and 2 of the North Shore Restoration Area.



Phases 3 and 5 each have north and south units. The north units are hydrologically connected with Phase 4, and those three units together will be maintained at a maximum flooding elevation of 60 ft NGVD 29. A large portion—roughly two-thirds—of Phase 5 North and the western half of Phase 3 North will remain dry, or barely saturated, under normal operating conditions.

Soil organochlorine pesticide (OCP) concentrations in the combined portions of Phase 3 North, Phase 4, and Phase 5 North present a low mortality risk to avian piscivores. The calculated hazard quotients (HQs) for all fields are < 1 (indicating low risk to fish-eating birds) for predicted fish concentrations of DDTr, dieldrin, toxaphene, and chlordanes. The calculated HQ level for DDE–for reproductive effects–is 1.24 in one field of Phase 5. The sum of the hazard quotients, or hazard index (HI), is < 1 for five of the field units but > 1 (1.20 and 1.46), for two fields. The overall acreage-weighted HI for the hydrologically-combined phases is 0.94.

Phase 3 South and Phase 5 South will be operated independently. Phase 3 South will be maintained at a maximum flooding elevation of 60 ft NGVD 29. Except for the edges bordering the lake and internal levees, the majority of Phase 3 South will be flooded under normal operating conditions. Maximum flooding elevations for Phase 5 South will be maintained at 61 ft NGVD 29. Under that criterion, the central portion of the property will be flooded or saturated, with a wide outer edge remaining unsaturated.

Soil OCP concentrations in all fields of Phase 3 South present a low mortality risk to fish-eating birds. Calculated HQs are < 1 for predicted fish concentrations of DDE, DDTr, dieldrin, toxaphene and chlordanes. The Hazard Index is <1 for two of the fields, but is 1.45 for the third. The overall acreage-weighted HI for the three fields in Phase 3 South is 1.26. For the three fields in Phase 5 South, the calculated HQs are <1 for predicted fish concentrations of DDTr, dieldrin, toxaphene and chlordanes. For DDE, all fields have an HQ >1, but less than 2. The HI for each of the fields is >1 but <2. The overall acreage-weighted HI for Phase 5 South is 1.53.

Phase 8 will be the last area flooded. Under normal operating conditions, with a maximum flooding elevation of 61 ft NGVD 29, one large field unit, formerly known as Bass Sod Farm, will remain dry. Discussions continue regarding how best to utilize that unflooded property—including possible cattle grazing. For completeness, the sod farm (Field ZIN-A) has been included in this risk assessment.

Soil OCP concentrations in Phase 8 are generally low. However, because of low soil carbon content, this phase presents some challenges. The HQ for all fields for predicted fish concentrations of DDE are >1, and indeed, are 4.1 and 4.3 for two fields and 1.48 and 2.79 for two fields. The HQs are < 1 for predicted fish concentrations of DDTr, toxaphene, and chlordanes. However, in two field units, the HQ for dieldrin is 1.46 and 1.24. The HI for three of the fields is >1 but <2. For one field, the HI is 4.23. The overall acreage-weighted HI for Phase 8 is 1.95; however, when the sod farm is removed from the calculations, the overall acreage-weighted HI for Phase 8 increases to 2.28.

Some practical considerations dictate the time frame for flooding the remaining NSRA phases. We have, prior to this document, completed assessments for a projected phase only after we have collected a year's worth of fish data from the previously flooded phase. With this biological assessment we seek approval to flood the remaining phases, over a time scale of approximately 1 to 2 years. At present, drought conditions would limit flooding for any new phases. In fact, flooding levels in much of the existing wetland areas are barely at saturation. Additionally, as discussed below, all new phases will have the same level of fish monitoring as has been performed in the past. Thus, new phases can be brought on line only after we are comfortable that our staff can handle the additional required monitoring.

As phases are flooded, monitoring of bird use will continue. Fish monitoring will occur quarterly, commencing 3 months after initial flooding. If fish trigger values are exceeded, or if unusual bird

mortality occurs, SJRWMD will coordinate with USACOE and USFWS to determine whether dewatering of the system is prudent. A network of field ditches and canals are in place that facilitates dewatering of the fields. If it is necessary to drain any of the project areas, the main pump station has three diesel pumps (each with 35,000 gpm capacity), and one electric pump (50,000 gpm capacity). By around mid-2012, a pump located at Interceptor and Lake Level Canal will be capable of pumping 30,000 gpm.

As each phase is flooded, monitoring of whole fish for OCPs will continue for 4 quarters. After one year of data results, routine monitoring will cease unless the project team, consisting of staff from USACOE, USFWS and SJRWMD determine otherwise.

Table of Contents

Executive Summary 2
List of Acronyms 6
1.0 Introduction 7
1.1 Location 9
1.2 Purpose 9
1.3 History 9
1.4 Project description 11
1.5 Consultation history with USFWS 26
2.0 Phases 3, 4, 5, and 8 Organochlorine Pesticides 28
2.1 Sampling and analysis 28
2.2 Prediction of OCP levels in fish and comparison to trigger values 31
2.3 Inspection of data 39
2.4 Summary of risk 40
3.0 Species Accounts 43
3.1 Orange County federally listed species 43
3.2 Site-specific listed species 44
3.3 Management plan and minimization of impacts to listed species of concern 54
4.0 Conclusions 56
5.0 References Cited 57
Appendix 1. Soil sampling locations at NSRA Phases 3, 4, 5, and 8 collected in 2007-2008. 62
Appendix 2. Raw data for Phases 3, 4, 5, and 8 soil samples. Data qualifier codes are defined at end of tables. 66

List of Acronyms

ASTM	American Society for Testing and Materials
BETL	Best estimate target level
BSAF	Biota sediment accumulation factor
DDTx	Sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT
DDTr	DDT equivalents: DDTr=(DDD/5)+(DDE/15)+ DDT, after Stickel et al. (1970)
dw	dry weight
ESA	Environmental site assessment
FDEP	Florida Department of Environmental Protection
gpm	Gallons per minute
HI	Hazard index
HQ	Hazard quotient
NGVD 29	National Geodetic Vertical Datum 1929
NRCS	Natural Resources Conservation Service
NSRA	North Shore Restoration Area
OCP	Organochlorine pesticide
SJRWMD	St. Johns River Water Management District
TOC	Total organic carbon
TRV	Toxicity reference value
USACOE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service (Service)
ww	wet weight
ZDWCD	Zellwood Drainage and Water Control District

1.0 Introduction

Lake Apopka is a 31,000-acre (12,500 ha) lake in central Florida about 15 miles northwest of the Orlando metropolitan area. The fourth largest lake, and formerly the most polluted large lake in Florida, Lake Apopka is the headwater for the Ocklawaha Chain of Lakes (Figure 1). The St. Johns River Water Management District (SJRWMD) proposes to flood the remaining 3,900 acres (1,580 ha), designated as *Phases 3, 4, 5, and 8,* located on the north shore of Lake Apopka (Figure 2).

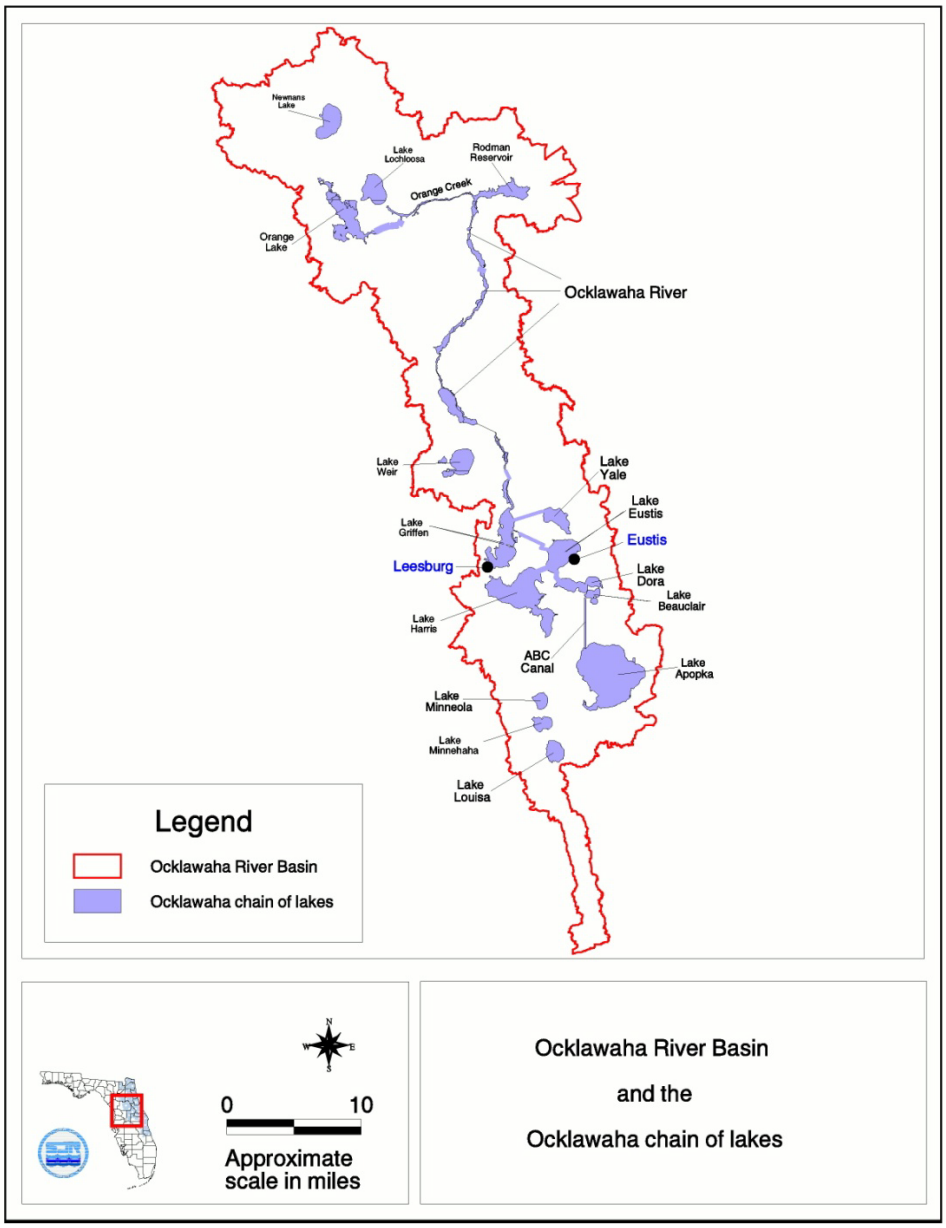


Figure 1. Overview of Lake Apopka and the Ocklawaha Basin.

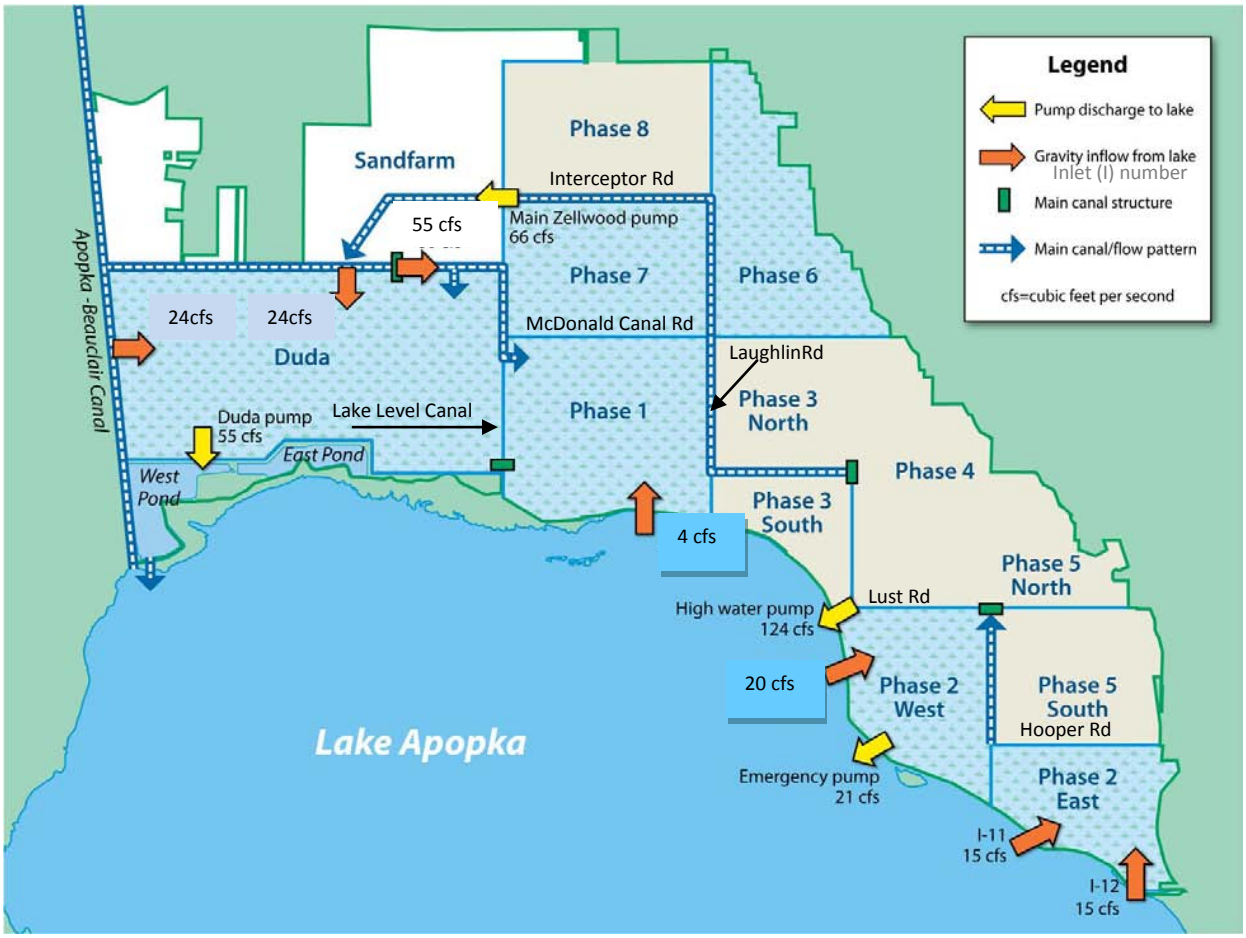


Figure 2. North Shore Restoration Area.

Lake Apopka once was bordered on the north by a floodplain marsh. Until 1946, the lake was clear and had extensive submersed plant beds in which game fish flourished (Clugston 1963). The polluted condition of Lake Apopka resulted from excessive phosphorus loading, primarily from a large (about 20,000 acres (8,000 ha)) farming area created on the floodplain marsh (Battoe et al. 1999; Lowe et al. 1999; Schelske et al. 2000). Degradation of the 50,000-acre (20,000 ha) Lake Apopka ecosystem persisted for more than 50 years.

Restoration efforts for Lake Apopka began in 1985 with passage of the Lake Apopka Restoration Act (Chapter 85, Laws of Florida) and were continued by listing Lake Apopka as a priority water body in the 1987 Surface Water Improvement and Management Act (SWIM Act) (Chapter 373.461, Laws of Florida). Both acts directed SJRWMD to develop and implement a plan to restore and preserve the lake and its environment.

Cessation of farming and restoration of wetland and aquatic habitat was recognized by the Florida legislature as the most effective and equitable means of achieving the first, and most essential, step in the lake's restoration: reduction of phosphorus loading. Acquisition of 5,300 acres (2,144 ha) of farms on the west side of the Apopka Beauclair Canal began through legislative appropriation ($15 million) in 1988 and was completed in 1992. A portion of that property was used for the Lake Apopka Marsh Flow-

Way Project, and the majority of the remainder is wetland, fluctuating with the level of water in the lake.

Acquisition of the farms on the east side of the canal was initiated by the 1996 Lake Apopka Restoration Act which provided $20 million to acquire farmland. An additional $26 million was authorized in 1997 from the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) as matching funds for farm purchase. An additional $56 million from the state allowed completion of the farm purchases. By August 1998, SJRWMD, in partnership with the NRCS, had purchased most of the farms east of the Apopka-Beauclair Canal.

1.1 Location

The portion of the North Shore Restoration Area (NSRA) that is located east of the Apopka-Beauclair Canal encompasses two former farming properties, Jem Farm (hereafter called Duda), and Units 1 and 2 of the former Zellwood Drainage and Water Control District (ZDWCD). In addition, the NSRA also includes Zellwin Sand Farm (Figure 2).

Restoration of the NSRA began in 2002-2003 with flooding of the 3,000-acre (1,214 ha) Duda property. In March 2008, flooding of a portion of Unit 2, Unit 2 West (Phase 1), began the restoration of the former farms to a productive wetland and aquatic system. In April 2009, Phase 2 (East and West) was flooded. In January 2011, flooding of Phase 6 began, followed by flooding of Phase 7 in April 2011.

1.2 Purpose

There are several substantial benefits to flooding the remaining phases: 1) Wetland and aquatic habitat will be created that will benefit many species of wildlife. 2) Pollution of Lake Apopka by phosphorus (P) will be reduced because the volume of drainage water will decline and the area of soil subject to oxidative release of P will be reduced. 3) Natural attenuation of organochlorine pesticide (OCP) levels can begin at an accelerated rate due to sedimentation and establishment of anaerobic conditions (ATRA 1997). 4) Data from soil and wildlife monitoring of the remaining phases will be combined with existing data from Duda and Phases 1, 2, 6 and 7 to more accurately define risks posed by flooding moderately contaminated areas. It appears that these benefits can be gained without significant identifiable risk to the health of wildlife using the site.

1.3 History

As the farm properties were purchased in 1998, the farmers were asked to leave their fields shallowly flooded following their final crop harvest in the summer of 1998. Shallow flooding for 4-6 weeks was standard farming practice at the end of each year's growing season, in order to minimize soil subsidence and erosion, and to control nematodes. Over the past fifty years, migratory shorebirds have used Florida's flooded farm fields during July, August, and September (Stevenson 1972; Sykes and Hunter 1978; Kale et al. 1990). After SJRWMD gained ownership of the farmlands in August and September 1998, the fields remained flooded in order to minimize discharge of phosphorus-rich water to the lake and to inhibit growth of terrestrial vegetation. The fields were to be drained during the winter and treated with a soil amendment (alum residual) to prevent phosphorus release when restoration flooding

commenced. Following the initial shallow flooding by the farmers, water levels increased due to significant rainfall during the summer of 1998. In November 1998, the flooded Duda farm was drained in order to apply the soil amendment.

As water levels in the Unit 2 farm fields began to rise with seepage and rainfall, and as more migratory waterbirds arrived, the situation became unique and unprecedented. In December 1998 the population of American white pelicans (*Pelecanus erythrorhynchos*) on the NSRA rose to over 3,500 in one day's count and, also that month, the first of many mortalities was recorded. Over the next four months more than 400 American white pelicans, 28 wood storks (*Mycteria americana*), 24 great egrets (*Casmerodius albus*), 20 great blue herons (*Ardea herodias*) and smaller numbers of 10 other bird species died on the Unit 2 portion of the NSRA.

In February 1999, the U. S. Fish and Wildlife Service (USFWS; Service) released preliminary findings attributing the deaths to OCP poisoning. By the first week of March 1999, the entire NSRA farm field area had been drained, and the mortality ceased. With the exception of agreed progressive flooding in Duda, Sand Farm, Unit 2 West (Phase 1), Phase 2, and Phases 6 and 7 properties, the NSRA fields have been kept dry and have become vegetated with upland herbaceous and shrub communities.

In March 1999, SJRWMD and the NRCS, with support from a 13-agency Technical Advisory Group, launched a $1.5 million project to investigate the cause of the bird mortality and to determine how to proceed with restoration.

In May 2001, SJRWMD and NRCS submitted to USFWS a biological assessment and interim restoration plan for three fields (~680 acres) in the eastern portion of the Duda property. A Biological Opinion (USFWS 2002) was issued by the Service in April 2002 and flooding was initiated two months later. After over a year of vigorous monitoring of bird use and fish OCP levels, the three agencies agreed to flood the remaining Duda fields, except for a small 38-acre (15 ha) field in the north, near the boat-launch site. Monitoring continued and quarterly fish samples from each of the field units were collected and analyzed for OCPs.

In October 2003, SJRWMD entered into a Memorandum of Understanding with the United States Government. The agreement was the result of a collaborative effort among SJRWMD, Department of Justice and the USFWS and resolved all of the legal issues relating to the bird deaths as they pertained to the District.

In November 2004, a biological analysis and restoration plan for the Sand Farm South property was completed and accepted by the Service. Two consecutive years of fish monitoring resulted in fish OCP levels that were less than, or equal to, one-half the trigger levels provided in the biological opinion (USFWS 2002) for the Duda property. Annual sampling was halted in 2006 in accordance with the *Biological analysis and restoration plan for the Sand Farm South,* submitted to the Service in November 2004.

In July 2006, the Service reviewed the biological assessment and monitoring plan for Unit 2 West (Phase 1) and concurred with the NRCS that the project may affect, but is not likely to adversely affect Federally listed species. However, despite approval to commence restoration flooding, drought conditions prevented restoration efforts until March 2008, when the District decided to use water from Lake Apopka to flood the fields. Because of extensive bird activity in the delivery canals after initial flooding, in April 2008, staff collected fish from the canals and recently flooded fields for OCP analysis. All data

were well below established trigger values. The first planned quarterly fish sampling occurred in July 2008 and, after one year of sampling, monitoring was curtailed for most of the fields and reduced to a spring/fall fish sampling schedule for two of the fields, ZSWC and Beall. While actual fish OCP levels in those two fields were near or below predicted levels, mean values of 4,4' DDE (1,043, and 1,400 µ/kg wet wt, respectively) were near the toxicity reference value (TRV) of 1,500 µ/kg wet wt, indicating possible sub-lethal reproductive effects such as eggshell thinning. Accordingly, samples were collected at those two sites through the fall of 2010 with mean results (946 and 245 µ/kg ww, respectively) well below the TRV for reproductive effects.

In December 2008, the Service reviewed the biological assessment and monitoring plan for Phase 2 and concurred with the NRCS that the project may affect, but is not likely to adversely affect Federally listed species. After one year of quarterly fish samples the hazard index (HI) was less than the HI calculated in the biological assessment. After one year of fish data we halted sampling on all but one field unit, and continued sampling that unit for an additional quarter to verify that values were below the TRVs.

In January 2011, the Service reviewed the biological assessment and monitoring plan for Phases 6 and 7 and concurred that the project may affect, but is not likely to adversely affect federally listed species. Flooding commenced immediately that same month on Phase 6 and three months later on Phase 7. However, because of generally low rainfall in the central Florida area, only two of four fields in Phase 6 have been maintained under flooded/saturated conditions and two of three fields in Phase 7 have remained wet. All fish OCP data from the flooded field units are well below the TRVs.

1.4 Project description

Infrastructure

A major retrofit of the entire NSRA water management infrastructure will be completed in 2012. The retrofit connects all phases with the Duda property by plugging and isolating the southern portion of Lake Level Canal from the lake to allow hydrologic connection from Duda through Phase 1, and back to Duda through the Sand Farm (Figure 2).

Phase 3 North, Phase 4, and Phase 5 North consist of seven field units, all functioning as one hydrologic unit . The combined phases connect to a main trunk canal system by way of gated culverts and two main canal structures (Figure 2). An internal pump, located at the southwest corner of Phase 4 North allows discharge into Laughlin/Roach Canal. Phase 3 South and Phase 5 South will be operated independently and are each connected to the main trunk system (Figure 2). Phase 8 consists of three field units, one of which, because of its higher elevation, will not be flooded. Water inflow and outflow is through a series of culverts with risers, similar to those for Phase 7 (Figure 4). A staff gauge for monitoring water elevation is located along Interceptor Canal, approximately half-way between the two cells of Phase 8 that will be flooded (Figure 4). Five staff gauges will be used to monitor water levels in the remainder of the proposed project: two along Roach Canal (one on the Phase 3 North side, and one on the Phase 3 South side); three at the main canal structure at Lust Canal (two on the north side split between Phase 4 and Phase 5 North, and one on the south side at Phase 5 South (Figure 3)).

In each unit a series of lateral field ditches are connected to feeder canals which can move water away from the fields through culverts with risers. To facilitate drainage through the culverts, water levels in the main canals can be lowered by the main pump station at the end of Lust Rd or by pumped discharge

into Lake Level Canal at the NW corner of Phase 7. There are three diesel pumps (each with 35,000 gpm capacity) and one electric pump (50,000 gpm capacity) at the main pump station. By around mid-2012, a pump located at Interceptor and Lake Level Canal will be capable of pumping 30,000 gpm.

Elevation contours based on recent survey information indicate elevation differences ranging from around 57 ft to 64 ft National Geodetic Vertical Datum 1929 (NGVD 29) (Figure 5a-i). Operational water levels are targeted at 60.0 ft NGVD 29 for Phase 3, Phase 4, and Phase 5 North and at 61.0 ft NGVD 29 for Phase 5 South and Phase 8. Perhaps as much as 40 percent of the large hydrologic unit, consisting of Phase 3 North, Phase 4 and Phase 5 North, will remain dry/saturated during initial flooding for wetland restoration. The remaining phases will have 20 to 25 percent of their area remaining dry/saturated. Wetland-tolerant tree species may be planted in suitable areas. Species that have been planted at similar high elevations in the NSRA include bald and pond cypress (*Taxodium* sp), sweetgum (*Liquidambar styraciflua*), blackgum (*Nyssa sylvatica*), and pop ash (*Fraxinus caroliniana*).

Legend

Flow into and out of Phase

Culvert

Staff gauge

Pump

Figure 3. Water control structures and road/canal system for Phases 3, 4, and 5.

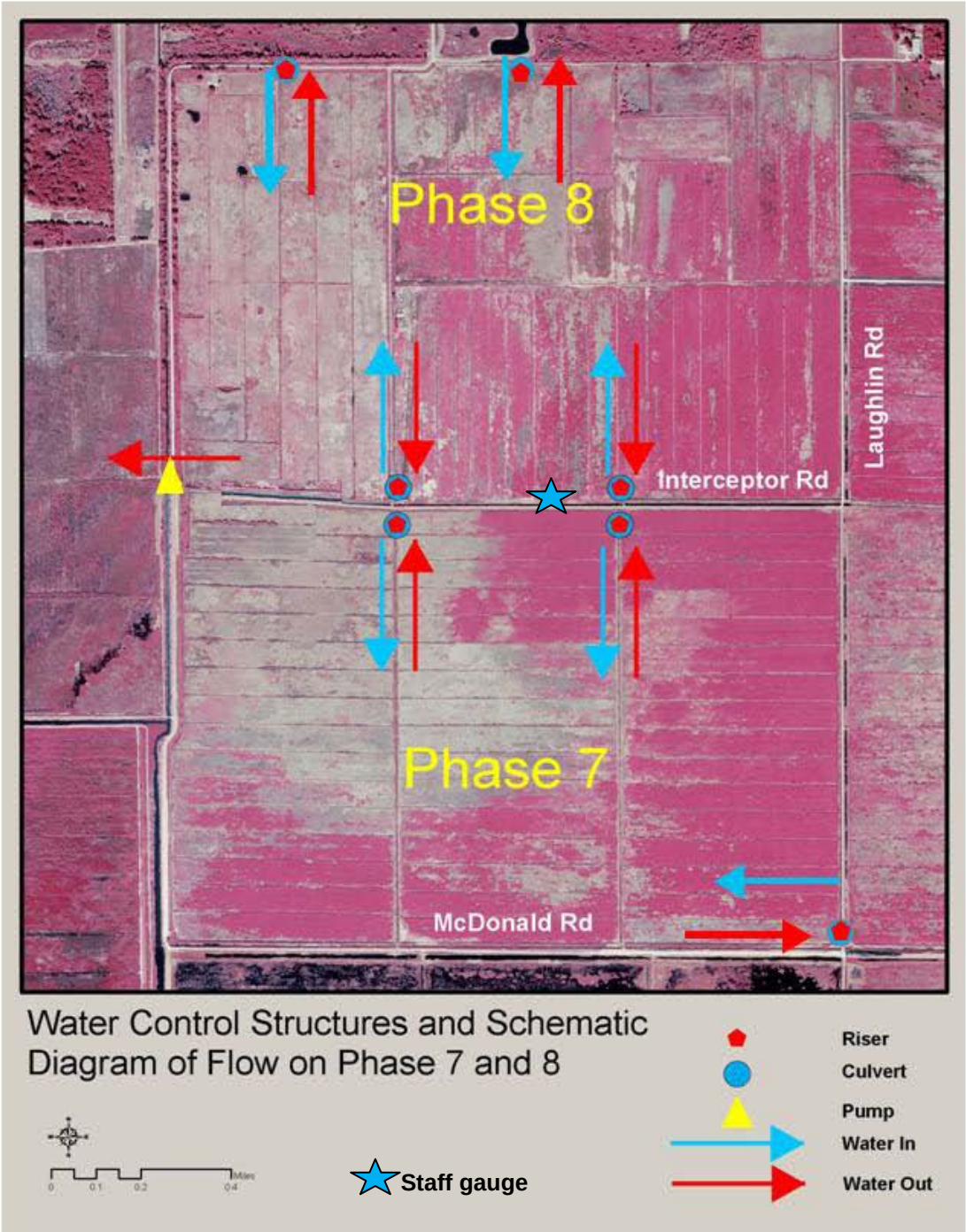


Figure 4. Water control structures and road/canal system for Phase 8.

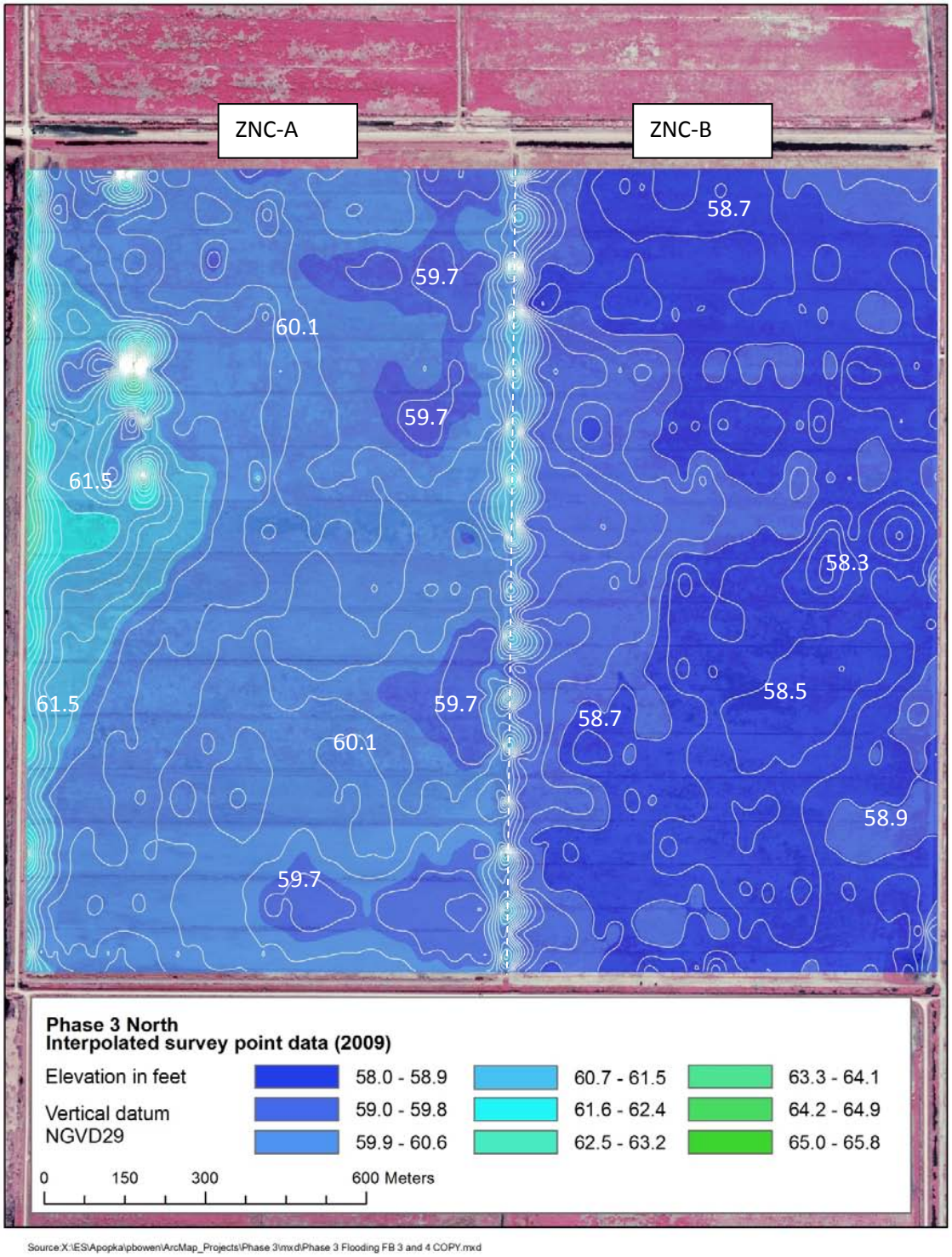


Figure 5a. Elevation contours for Phase 3 North. Maximum flooding elevation will be 60 ft NGVD 29.

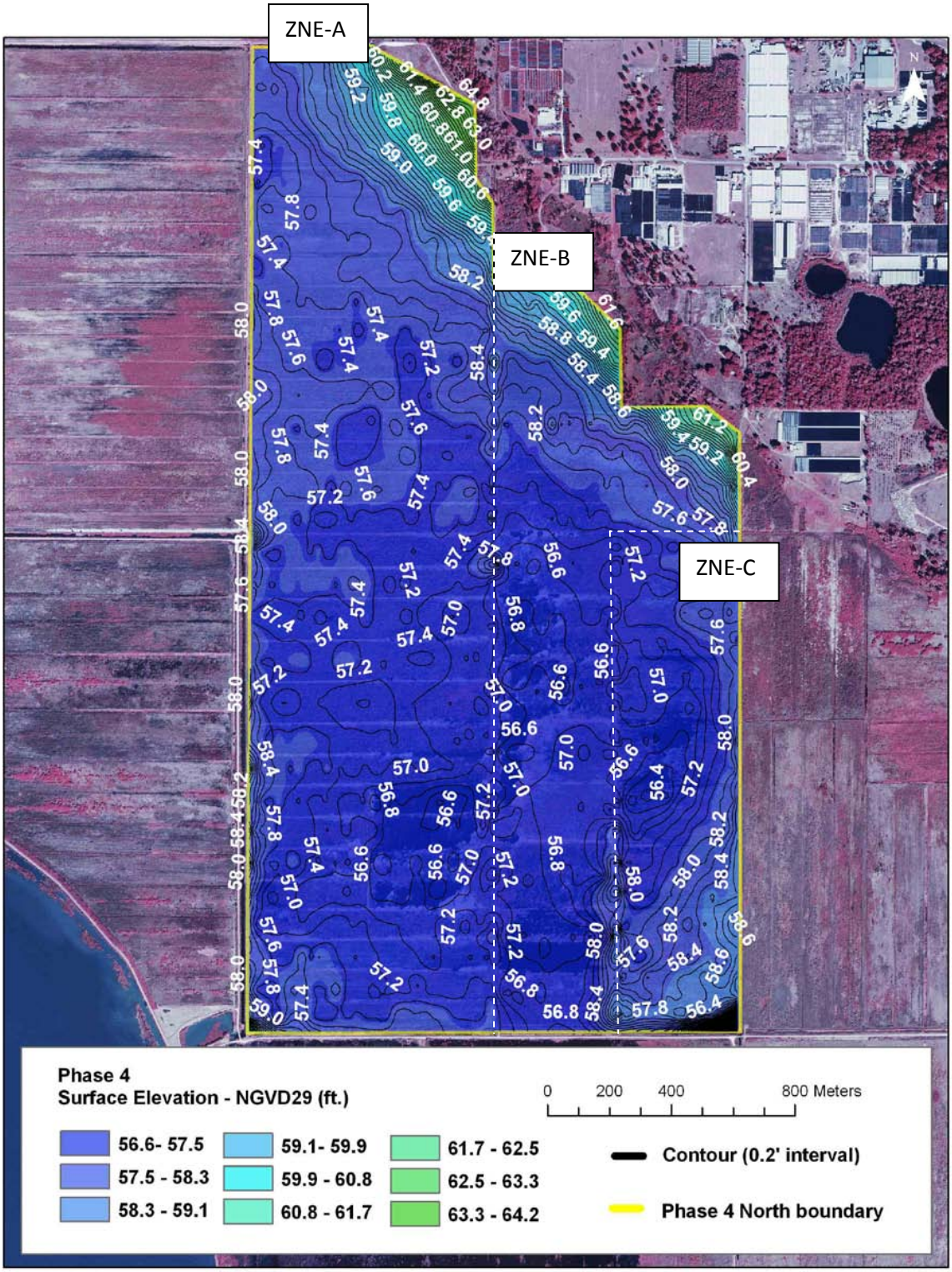


Figure 5b. Elevation contours for Phase 4. Maximum flooding elevation will be 60 ft NGVD 29.

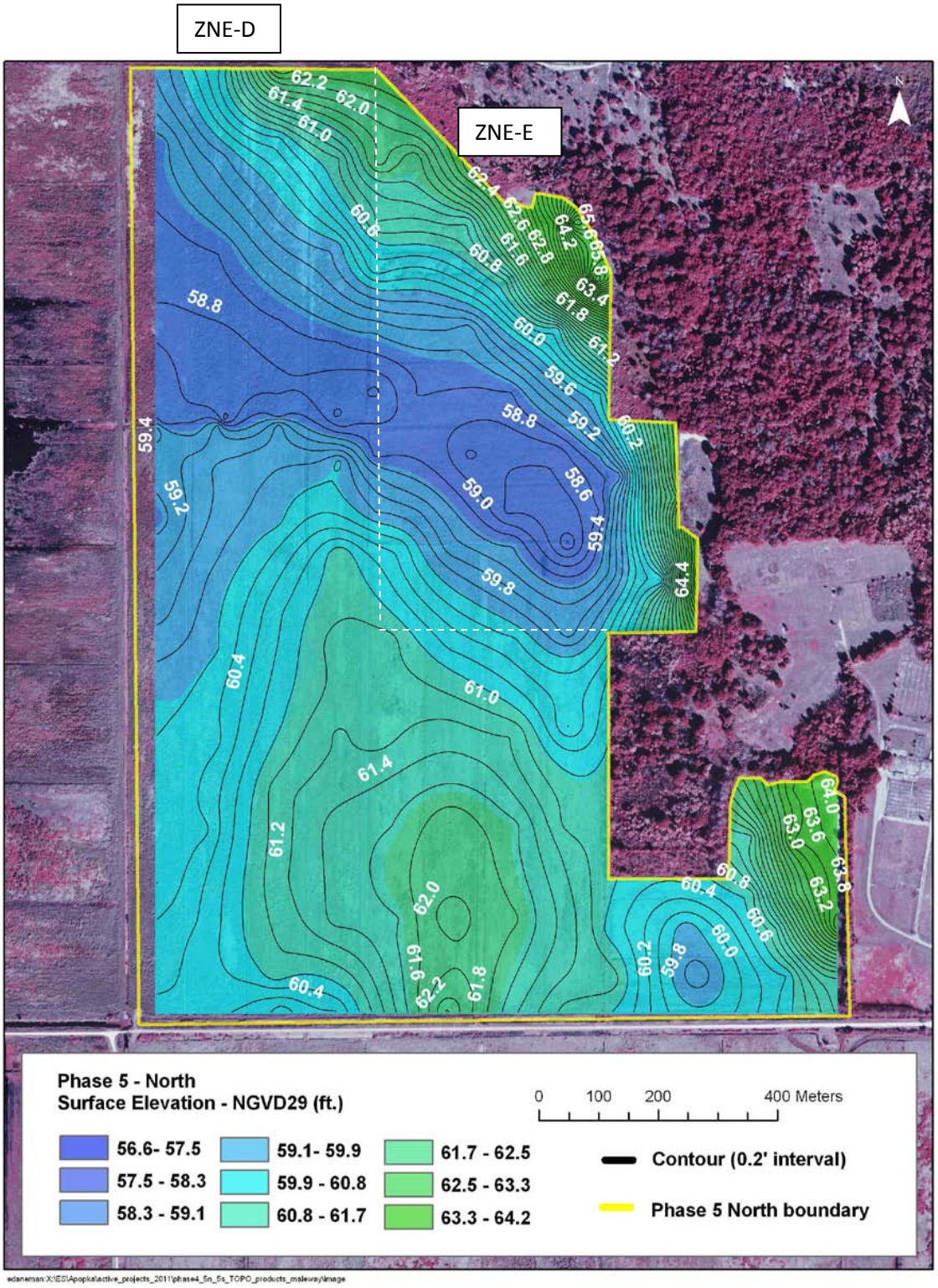


Figure 5c. Elevation contours for Phase 5 North. Maximum flooding elevation will be 60 ft NGVD 29.

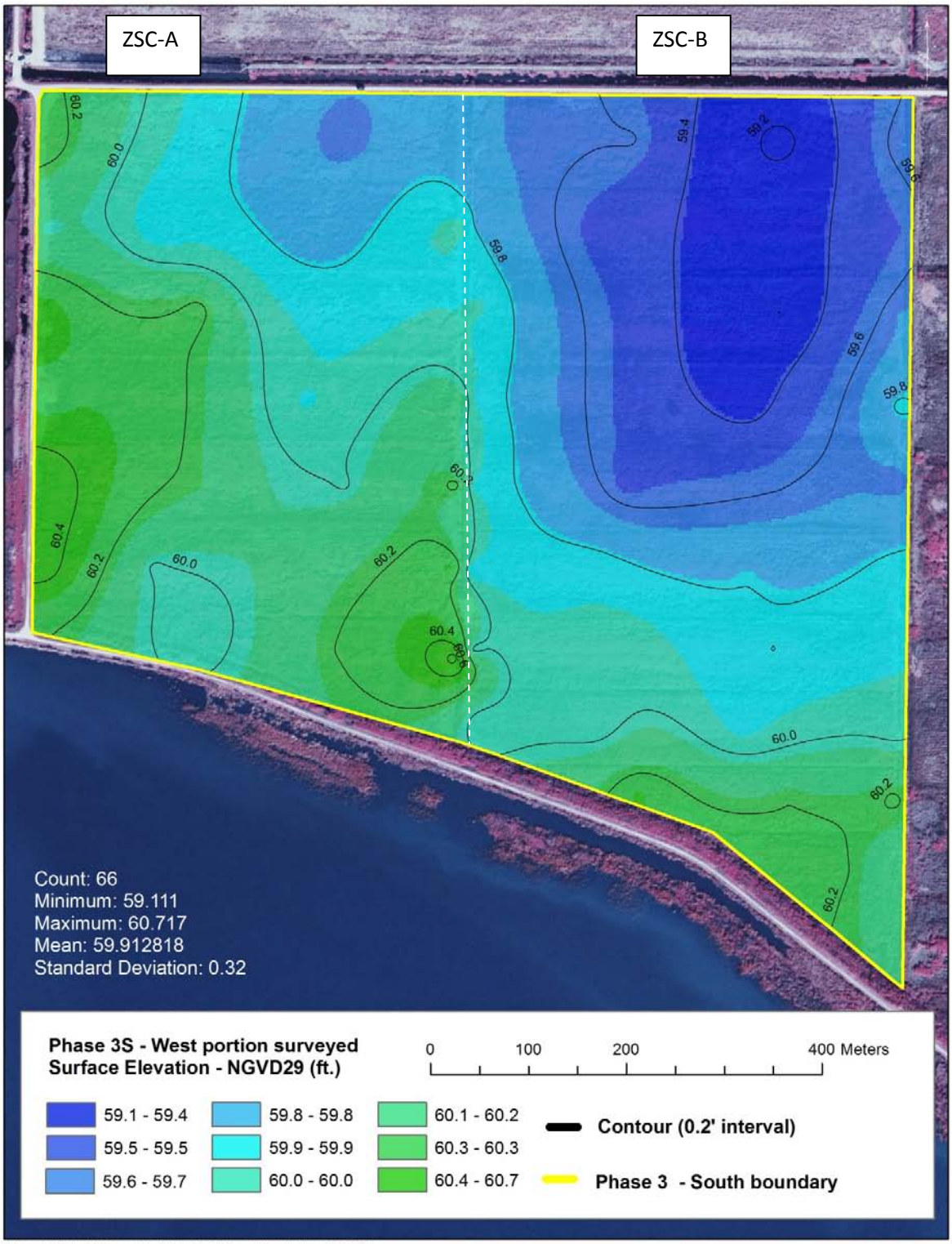


Figure 5d. Elevation contours for Phase 3 South – west side. Maximum flooding elevation will be 60 ft NGVD 29.

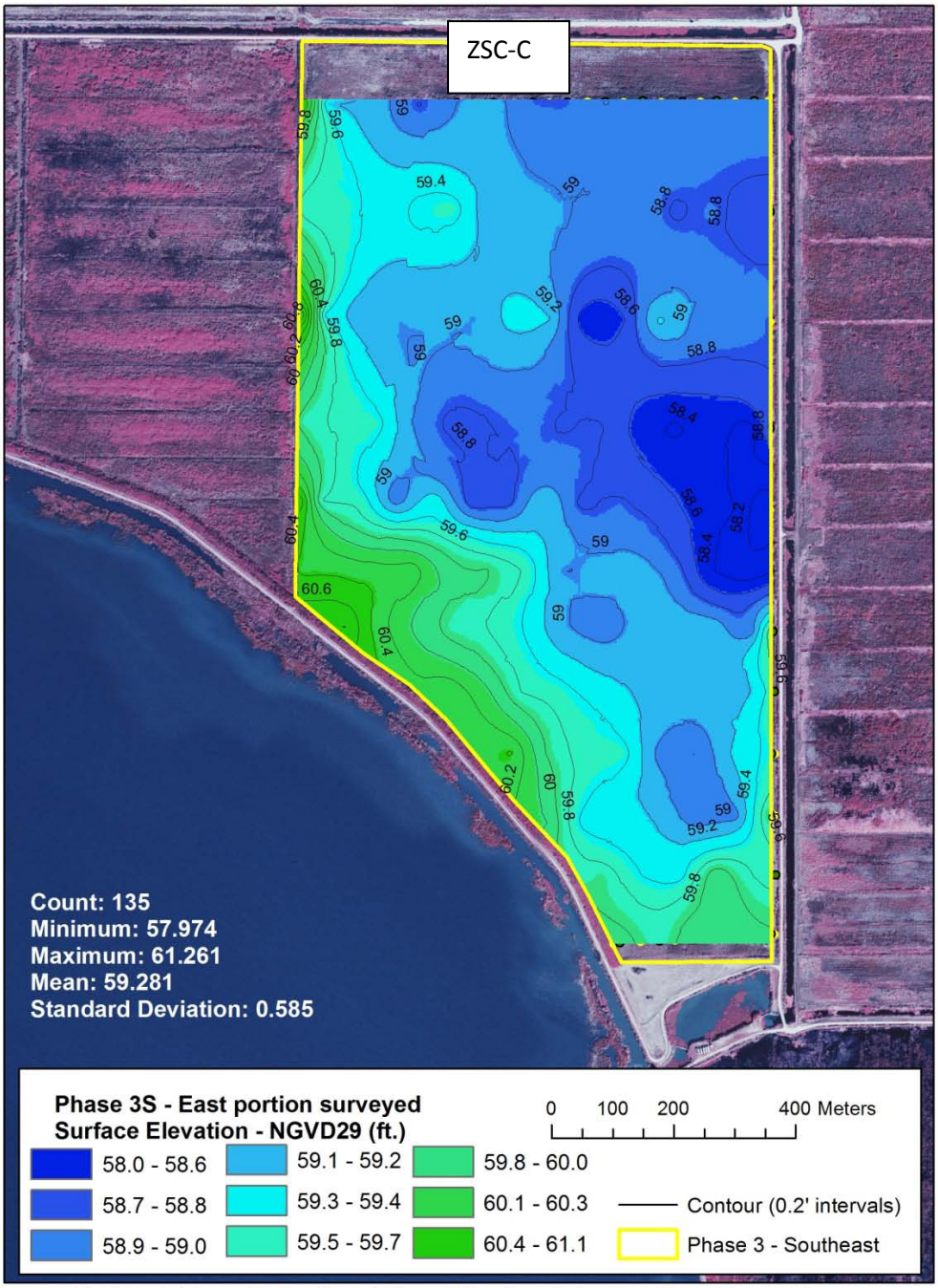


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Figure 5e. Elevation contours for Phase 3 South – east side. Maximum flooding elevation will be 60 ft NGVD 29.

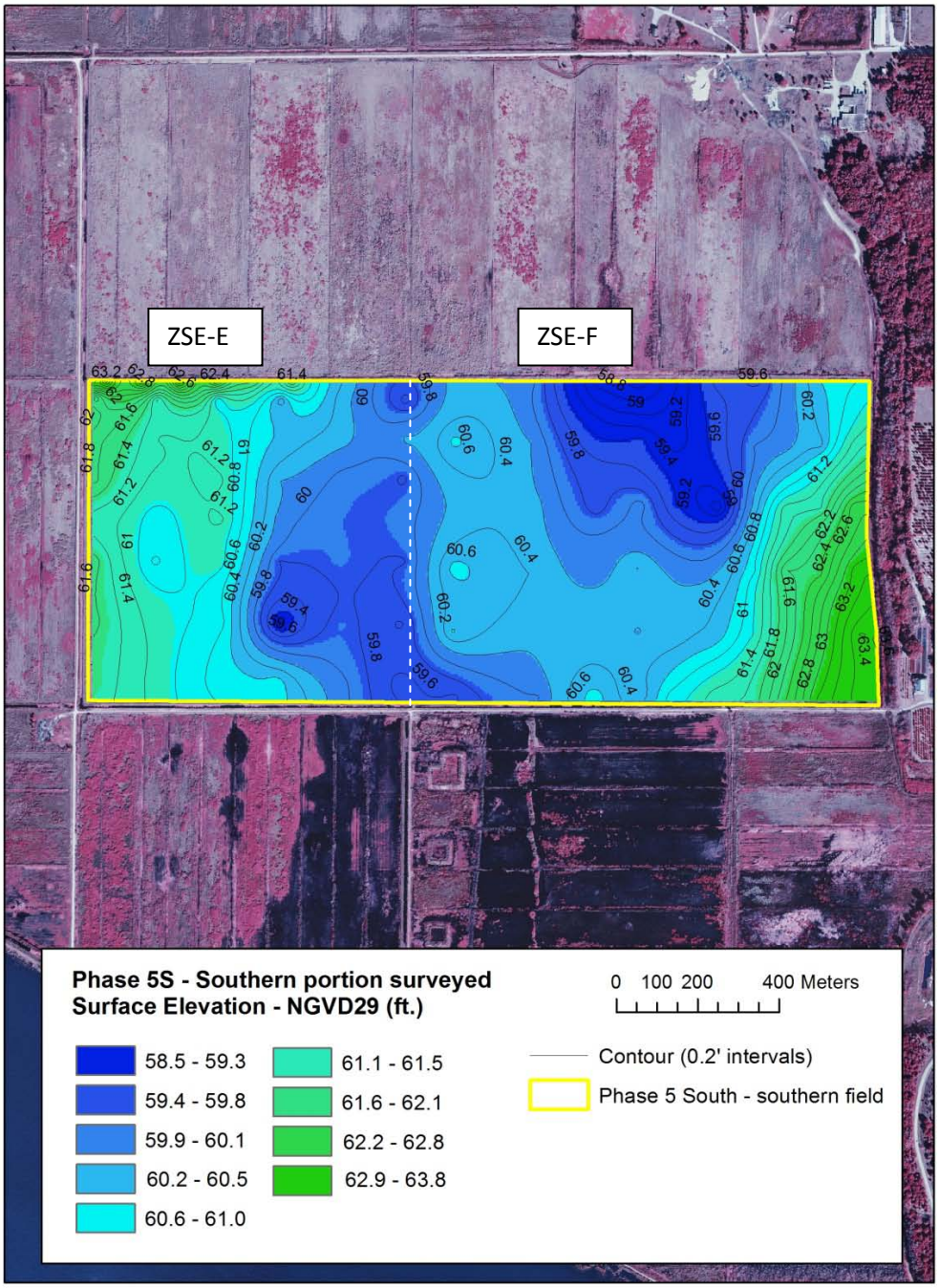

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Figure 5f. Elevation contours for Phase 5 South – south side . Maximum flooding elevation will be 61 ft NGVD 29.

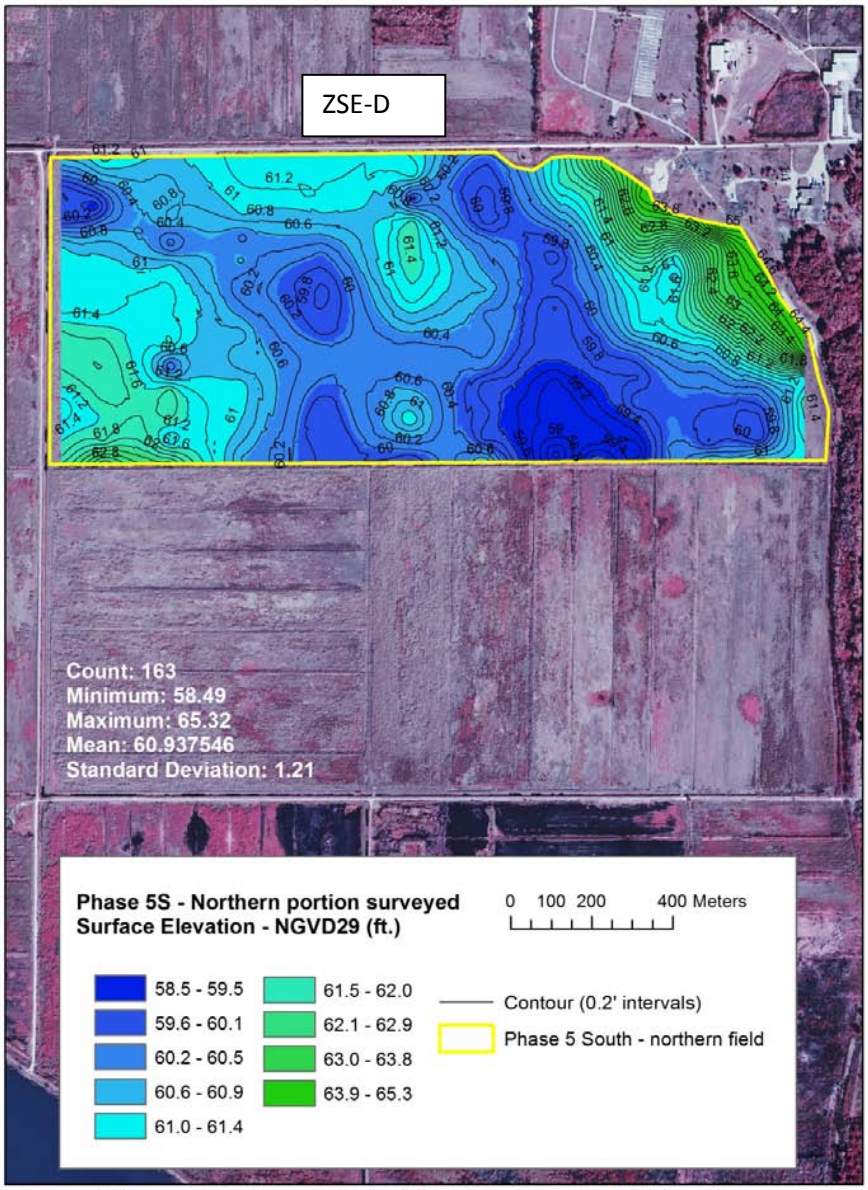

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Figure 5g. Elevation contours for Phase 5 South – north side. Maximum flooding elevation will be 61 ft NGVD 29.

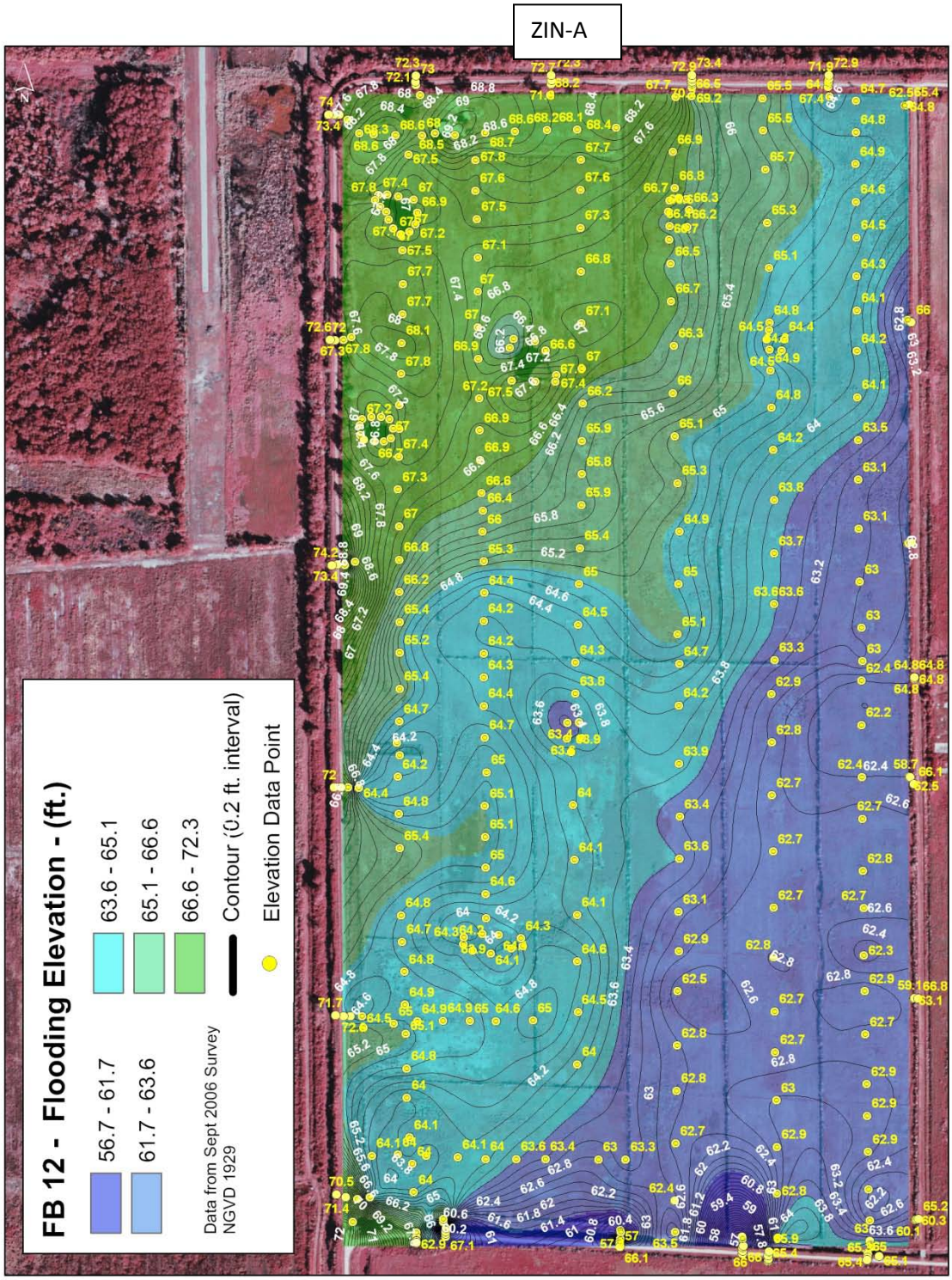


Figure 5h. Elevation contours for Phase 8 – Bass Sod Farm. Maximum flooding elevation will be 61 ft NGVD 29.

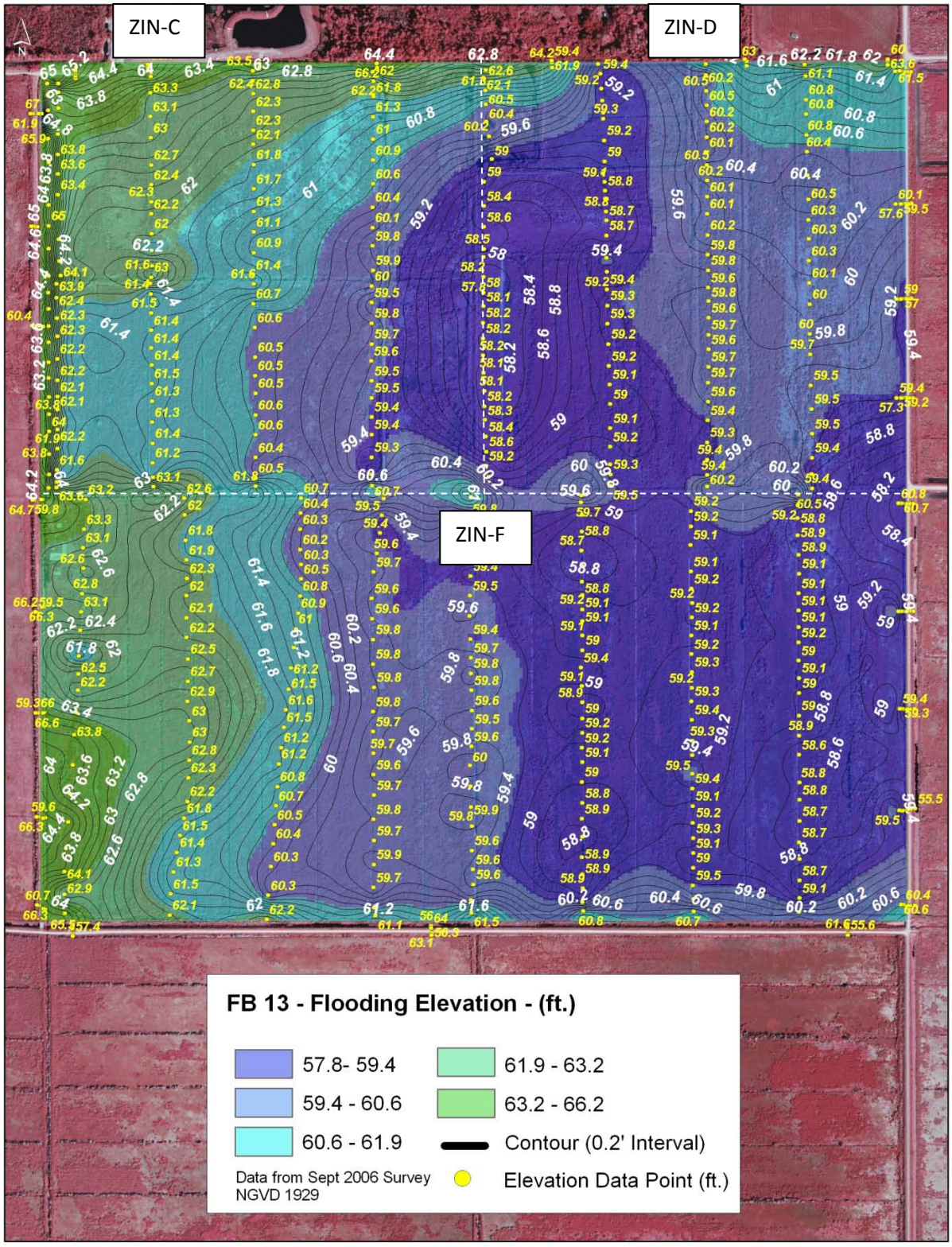


Figure 5i. Elevation contours for Phase 8 – Field units ZIN-C, D, F. Maximum flooding elevation will be 61 ft NGVD 29.

Summary of relevant scientific investigations on the NSRA

As part of the NSRA acquisition process all properties received an Environmental Site Assessment (ESA) in accordance with the American Society for Testing and Materials (ASTM) Standard E1527. The ESAs were reviewed by SJRWMD and Florida Department of Environmental Protection (FDEP) staff throughout the process. An ESA consists of up to four phases. The first phase is an in-depth review of the documents available concerning historical land use and what potential contamination issues might be present, as well as a site reconnaissance and interviews with property owners. The second phase implements sampling based upon the recommendations made in the first phase. Phase III involves the delineation and formulation of a remediation plan for contamination found during Phase II, and Phase IV requires confirmation sampling to verify sufficient site cleanup. All recognized environmental conditions verified in Phase II were addressed in further Phase III and IV investigations and approved by FDEP.

As a consequence of the 1998-1999 bird mortality on the flooded NSRA property, an extensive investigation was undertaken by SJRWMD and NRCS in an effort to determine whether OCPs had killed the birds, and to reassess the risks to wildlife posed by OCPs. The Technical Advisory Group reviewed sampling design, analytical methods and a work plan for data analysis. A total of 920 soil samples were collected in 1999 from 709 locations and analyzed at En Chem (now called Pace Analytical Services, Inc. (Pace)), a laboratory chosen for its extensive experience with OCPs, especially toxaphene.

In addition to the soil samples, 158 tissue samples from 34 birds and 36 whole fish (6 species) were analyzed for OCP levels by the same laboratory. All data on soils and sediments, birds, and fish were provided to Exponent Inc., a consulting firm based in Bellevue, WA. Their analysis of the data and report on the mortality event and on restoration issues was completed August 2003 (Exponent 2003). The report provides soil concentration thresholds for sublethal effects for the OCPs toxaphene, dieldrin, and the sum of DDT and its metabolites (DDD, DDE) expressed as DDT equivalents (DDTr) *sensu* Stickel et al. (1970). These thresholds were used to segregate the NSRA into areas of higher and lower risks to wildlife from residual OCPs.

In 2003, BEM Systems, Inc. completed a report for NRCS that provided a screening level ecological risk evaluation for the remainder of the Duda property based on soil data collected and analyzed in 1999 and 11 additional samples collected by them for total organic carbon analysis.

MACTEC Engineering and Consulting Inc. further summarized the nature and extent of contamination and risks posed by OCPs in soil within Units 1 and 2 of the NSRA (MACTEC 2005). For each of the field units a best estimate and a conservative estimate of the carbon-normalized concentrations of each of the contaminants of potential concern were calculated. The best estimate target levels (BETLs) were calculated from trigger values in fish tissue provided in the USFWS Biological Opinion for the Duda property (USFWS 2002). The conservative target levels are one-half of the BETLs and incorporate potential uncertainties that MACTEC recognized could be resolved by further research.

Beginning in May 2001, the District collaborated with the University of Florida and the United States Geological Survey (USGS) for a Bioaccumulation Study. The study measured uptake of OCPs from NSRA soils into fish and crayfish using lab-based microcosms (Sepúlveda et al. 2005) as well as mesocosms constructed on-site at the NSRA. Data collected from open-water fishponds and vegetated mesocosms were used to calculate biota sediment accumulation factors (BSAFs) for fish and crayfish. Finally, fish

grown in the fishponds, with high background levels of soil OCPs, were fed to great egrets in a controlled experiment. Accumulations of OCPs in tissues of the birds were measured (Gross et al. 2006).

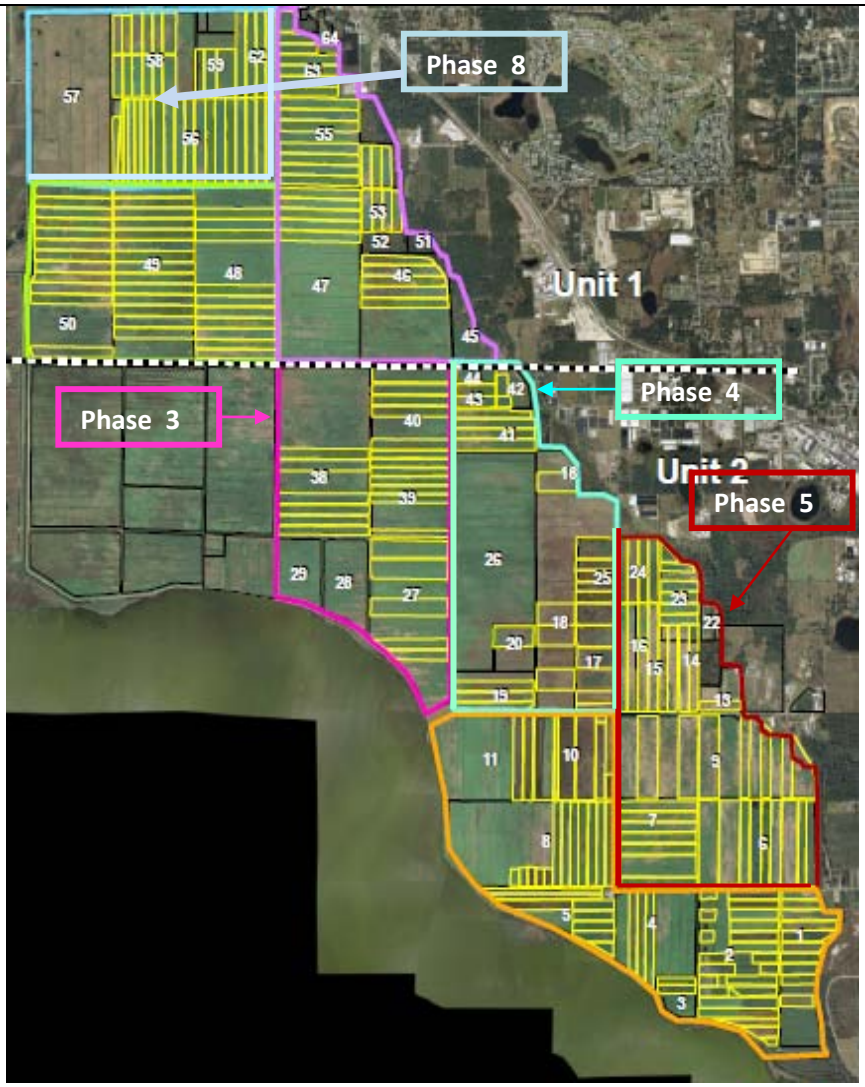
In 2006, the District conducted a pilot project to determine the effectiveness of two different types of equipment to reduce soil OCP concentrations in selected fields of the NSRA. Both methods–vertically blending soil to a depth of 3 or 4 ft (0.91-1.2 m), and deep plowing by covering the top foot (30 cm) of contaminated soil with deeper, cleaner soil–resulted in double-digit percent reduction of OCPs (Table 1). However, deep plowing was a much faster process, and thus, a more cost-effective remedial alternative.

In 2007, the original soil sites sampled in 1999, plus additional sites, were again sampled and analyzed by Pace for OCPs, and by D.B. Labs for total organic carbon content. These data were used to identify areas for remediation by deep plowing. However, because the fields have remained dry and fallow since 1999, the property had to be prepared for plowing. Preparation included mowing, roller chopping and, in areas where woody vegetation dominated, cutting with a special piece of equipment called a Brontosaurus. Once the final preparation work and plowing were completed, a soil amendment was applied. The amendment, consisting of alum residual from the City of Melbourne Water Treatment Plant, is a byproduct of the process used to clarify drinking water. The soil amendment applied to the fields is expected to reduce the amount of phosphorus released into the water column when the soils are inundated (Hoge et al. 2003). After site preparation, the fields were surveyed to provide elevation data within a vertical accuracy of +/- 5 cm at a 95% confidence interval. Plowed fields were sampled again to quantify the change in OCP levels (Table 1). The most recent data from the 2007-2008 soil collections are used in this biological assessment (Appendices 1 and 2).

The cumulative research has shown that soil OCP levels vary greatly in units of the NSRA. The lowest areas of contamination – the Duda property and the Sand Farm – have been flooded for up to ten years. Monitoring programs have shown that mean concentrations of OCPs in fish tissue are well below the trigger values provided in the biological opinion for Duda sub-East (USFWS 2002) or for the updated trigger levels used in the Phase 2, 6, and 7 biological assessments. Results of fish analyses from Phase 1 and Phase 2 also indicate OCP levels are generally well below trigger levels. However, data from the bioaccumulation studies indicate an increase in fish levels of OCPs is possible for up to two years after initial stocking and data from the flooded phases show that levels of OCPs, particularly DDE, can continue to increase in fish for more than a year.

Table 1. Percent reduction of 4,4'-DDE and TOC after plowing, compared to pre-plowed soil values. Sections that underwent remediation plowing are shown as enclosed yellow strips.

Phases 3-5, 8	% reduction	
Unit (field #)	**DDE**	**TOC**
ZNC-A (38)	60	69
ZNC-B (40)	68	76
ZNC-B (39)	60	58
ZSC-A (29)	0	0
ZSC-B (28)	0	0
ZSC-C (27)	57	59
ZNE-A (44)	77	64
ZNE-A (42)	58	44
ZNE-A (43)	50	54
ZNE-A (26)	0	0
ZNE-A (19,20)	83	79
ZNE-B (18)	73	75
ZNE-B (16)	74	50
ZNE-B (17)	66	58
ZNE-B (25)	52	61
ZNE-D (15)	83	48
ZNE-D (16)	74	50
ZNE-D (13,14)	84	59
ZNE-F (22,23)	75	74
ZNE-F (24)	66	68
ZSE-D (9)	57	34
ZSE-E (7)	63	60
ZSE-F (6)	77	49
ZIN-C (58)	88	57
ZIN-D (53)	85	73
ZIN-D (62)	73	48
ZIN-F (56)	66	43



1.5 Consultation history with USFWS

- On February 9, 2004, USFWS and SJRWMD met to discuss guidelines for sediment/soil sampling. A follow-up letter summarizing the discussion was sent (by SJRWMD to Ms. Karen Benjamin) on March 9, 2004.

- On August 30, 2005, USFWS, NRCS and SJRWMD convened their annual meeting to discuss collected data from the Duda wetlands, as well as results from egg monitoring. In addition, the group discussed future plans to flood Unit 2 West.
- On November 29, 2005, SJRWMD presented a briefing to USFWS and NRCS on the NSRA Safe Levels Project. At this meeting an overview was presented regarding how the District intended to calculate Biota Sediment Accumulation Factors (BSAFs) using data from the Bioaccumulation study; how the scientific literature was being explored to determine the best Toxicity Reference Values (TRVs); how the NSRA soil dataset was being organized to provide flexibility to easily incorporate BSAFs, TRVs, and other components to calculate Hazard Quotients (HQ) and Hazard Indices (HI) for individual field units or groups of units.
- On January 31, 2006, USFWS and SJRWMD met for an update of the Safe Levels Project. Because of the importance of the project to future restoration decisions, the group decided to delay for further consideration the TRVs for the OCPs of concern and, in particular, the various chlordane constituents. In the interim, SJRWMD and NRCS would use OCP trigger levels provided in the biological opinion for the Duda property in evaluating the Unit 2 West project.
- In April 11-13 2006, USFWS and SJRWMD met with a team of three professional ecotoxicologists to discuss the draft report "*Analysis of risks to piscivorous birds from pesticide residues in soils and fish on the North Shore Restoration Area at Lake Apopka*".
- On May 30, 2007, USFWS and SJRWMD met for an update on progress with the pilot study for soil inversion as a remediation method, preliminary results of the NSRA soil resampling, an engineering update and hydrologic questions, and to discuss the Conceptual Remediation Plan. Jay Herrington requested that, with the new soil data, we compare calculations of risk using the "old" (Duda Biological Opinion) TRVs with our current TRVs. This requested information was transmitted by email on 6/11/07. The HQs calculated using the new TRVs are typically higher than HQs calculated with the old values. However, in the Duda BO the Service provided a chlordane TRV for all congeners combined (285 ug/kg wet weight (ww)). The updated TRVs take into account that some chlordane congeners present a greater risk than others, and each congener is assigned its own TRV value. As a result, the HQ for Total Chlordane is less using the new reference values.
- In June 2009, USFWS and SJRWMD agreed to reduce monitoring in Phase 1.
- In September 2010, after one year of sampling in Phase 2, USFWS and SJRWMD agreed to reduce monitoring to twice a year fish sampling in field ZSE-J. Two more quarterly fish sample results for all OCPs of concern were less than trigger levels, and sampling was halted.
- In January 2011, USFWS, USACOE and SJRWMD staff toured the project area to discuss progress and future flooding plans. The biological assessment for Phases 6 & 7 was approved by USFWS shortly thereafter.
- In February 2012, USFWS, USACOE and SJRWMD staff met on site to view construction changes to infrastructure and to discuss hydrologic plans and future phases.

2.0 Phases 3, 4, 5, and 8 Organochlorine Pesticides

2.1 Sampling and analysis

The soil OCP data for this assessment are based upon samples collected in 2007-2008 by BEM under contract to the District, and many were collected at the same locations as the first sampling event in 1999-2000. Those earlier sample collection locations were determined as part of a large sampling effort for all of the former Zellwood Drainage and Water Control District Unit 2 and the former Duda Farm. A stratified random grid approach using the District's GIS (Geographic Information System) was employed to locate sample sites on the former fields. The entire sample area was gridded in 10-acre (4-ha) squares, and the actual sample location was randomly selected from within the square. At all locations the top one foot (30 cm) of soil was collected, mixed thoroughly, and a subsample was analyzed for OCPs. In the recent sampling, additional locations were added to ensure a minimum number of samples for a given acreage.

A small 35-ac parcel, located in Phase 5 South, may be used by the City of Apopka as a wetland to remove suspended solids from lake water prior to that water entering the City's reclaimed water system. Additional soil samples were collected and analyzed from this parcel to allow for a separate risk analysis. Thus, in the tables below, the potential flow-way is evaluated as a separate component of Phase 5 South. It is also included in the risk analysis for the overall Phase 5 South.

See Appendices 1 and 2 for sample locations and OCP results for each of the Phases 3, 4, 5, and 8 soil samples.

Analyses of the soil data demonstrated that an important predictor of relative OCP concentrations was the previous ownership of the fields. Within fields under the same ownership, OCP concentrations appeared to be uniform. Variation among ownership field units could be great. This type of variation has lent itself to analysis using standard statistics rather than geostatistical approaches.

The analytical laboratory, Pace, which conducted all OCP analyses discussed in this document, lacked the specialized equipment to measure the high organic carbon content of the muck soils. As a result, a portion of each collected soil sample was sent to DB Environmental Laboratories, Inc., Rockledge, FL for total organic carbon (TOC) analysis.

Carbon-normalized concentrations were calculated for each of the collected soil samples. Because soil OCP concentrations within fields from the same ownership were relatively uniform, the 95% upper confidence limit of the mean was calculated for each field and OCP (Table 2). In calculations, when laboratory reported values were less than the method detection limit, the instrument output value was used.

Table 2a. Phase 3 North, Phase 4 and Phase 5 North carbon normalized soil OCP concentrations (µg/kg OC dry weight (dw)) expressed as the 95 percent upper confidence level for the mean.

Site	ZNC-A (18)*	ZNC-B (24)	ZNE-A (59)	ZNE-B(15)	ZNE-C(20)	ZNE-D (30)	ZNE-E (12)
	Phase 3 North		**Phase 4**			**Phase 5 North**	
Acres	**333**	**293**	**617**	**264**	**149**	**251**	**84**
4,4'-DDD	498	693	1,995	1,152	1,514	1,762	1,742
4,4'-DDE	3,355	2,117	3,526	3,139	3,244	4,886	3,206
4,4'-DDT	338	351	3,252	2,413	1,354	3,355	2,738
4,4'-DDTr***	661	631	3,886	2,853	1,873	4,033	3,300
4,4'-DDTx **	4,191	3,161	8,773	6,704	6,112	10,003	7,686
Dieldrin	1,318	1,317	700	581	690	1,212	428
Toxaphene	19,175	8,927	16,024	18,884	12,834	34,132	23,798
alpha-Chlordane	393	214	228	326	334	524	291
cis-Nonachlor	173	105	178	234	226	350	306
gamma-Chlordane	236	140	112	258	157	283	130
Heptachlor	4	6	7	11	3	7	5
Heptachlor epoxide	134	57	51	57	84	174	91
Oxychlordane	65	26	54	96	62	106	81
trans-Nonachlor	173	163	180	294	242	286	224
Total Chlordane	1,248	698	793	1,196	1,088	1,701	1,061

* Number of samples collected are in parenthesis
** DDTx is the sum of DDD, DDE and DDT
*** After Stickel et al. (1970): DDT equivalents = DDTr = (DDD/5) + (DDE/15) + DDT

Table 2b. Phase 3 South and Phase 5 South carbon normalized soil OCP concentrations (µg/kg OC dry weight (dw)) expressed as the 95 percent upper confidence level for the mean.

Site	ZSC-A (10)*	ZSC-B(10)	ZSC-C(18)	ZSE-D (21)#	City of Apopka (10)	ZSE-E (10)	ZSE-F (22)
	Phase 3 South			**Phase 5 South**			
Acres	**62**	**78**	**239**	**316**	**35**	**148**	**223**
4,4'-DDD	369	253	349	954	1,811	731	1,387
4,4'-DDE	3,198	2,560	2,579	3,996	6,674	5,436	6,649
4,4'-DDT	369	650	1,711	2,763	8,481	1,874	5,984
4,4'-DDTr***	656	1,934	1,953	3,220	9,288	2,383	6,705
4,4'-DDTx **	3,936	3,463	4,639	7,713	16,966	8,041	14,020
Dieldrin	1,047	1,411	1,714	1,063	1,143	1,624	1,455
Toxaphene	11,472	8,550	19,031	33,452	54,037	16,381	41,835
alpha-Chlordane	238	191	494	567	803	352	664
cis-Nonachlor	160	117	142	363	573	196	536
gamma-Chlordane	198	137	310	320	388	197	422
Heptachlor	4	4	3	4	2	2	4
Heptachlor epoxide	4	12	110	128	115	114	143
Oxychlordane	19	13	43	81	29	64	115
trans-Nonachlor	202	149	384	413	500	273	513
Total Chlordane	809	607	1,455	1,832	2,363	1,168	2,372

* Number of samples collected are in parenthesis
** DDTx is the sum of DDD, DDE and DDT
*** After Stickel et al. (1970): DDT equivalents = DDTr = (DDD/5) + (DDE/15) + DDT
# These data also include the City of Apopka data points.

Table 2d. Phase 8 carbon normalized soil OCP concentrations (µg/kg OC dry weight (dw)) expressed as the 95 percent upper confidence level for the mean.

Site	ZIN-A (15)*	ZIN-C (10)	ZIN-D (20)	ZIN-F (15)
	Phase 8			
Acres	**305**	**156**	**150**	**307**
4,4'-DDD	2,500	8,641	2,331	2,164
4,4'-DDE	16,263	16,844	5,856	11,025
4,4'-DDT	2,237	20,225	3,374	4,402
4,4'-DDTr***	3,821	23,076	4,230	5,570
4,4'-DDTx **	21,000	45,710	11,561	17,591
Dieldrin	738	2,946	803	2,507
Toxaphene	6,429	102,353	39,123	133,770
alpha-Chlordane	452	1,659	869	857
cis-Nonachlor	168	1,051	385	496
gamma-Chlordane	583	933	534	502
Heptachlor	13	25	8	15
Heptachlor epoxide	210	308	182	240
Oxychlordane	63	158	99	125
trans-Nonachlor	357	980	438	504
Total Chlordane	1,767	5,085	2,500	2,674

* Number of samples collected are in parenthesis
** DDTx is the sum of DDD, DDE and DDT
*** After Stickel et al. (1970): DDT equivalents = DDTr = (DDD/5) + (DDE/15) + DDT

2.2 Prediction of OCP levels in fish and comparison to trigger values

An important component of a risk assessment is a quantitative measure of the toxicity of a chemical to the animal of concern, in this case, fish-eating birds. This measure is referred to as a toxicity reference value (TRV) (USACHPPM 2000). Phases 3, 4, 5 and 8 are currently dry so it is not possible to measure directly OCPs in fish from the site. Therefore, we must predict what fish OCP concentrations will be when the project is flooded, and evaluate those predicted concentrations against the TRVs. In portions of Phase 8 with low surface elevations, rainwater sometimes collects long enough for fish to briefly colonize, and fish samples collected from those areas will be discussed later.

Based on a comprehensive search of the primary scientific literature we identified the lowest dietary concentrations associated with toxic effects in birds. We considered two types of effects. The first, mortality, was used to derive TRVs where the endpoint was death of an individual or physiological harm that could lead to increased mortality. The second endpoint, for DDE only, was reduction in reproductive success due to thinning and breakage of eggshells and loss of embryos. To provide an additional margin of safety, we applied a "fasting factor" to those TRVs that were evaluated against a mortality threshold (i.e. everything but DDE). In the bird-feeding studies (Gross et al. 2006), great egret brain concentrations of several OCPs increased when food was withheld. Therefore, a fasting factor of two is included in our risk analyses.

Fish concentration is estimated using the biota-sediment accumulation factor (BSAF) model. The BSAF describes the ability of an OCP to accumulate in the biota's lipids relative to the abundance of the OCP in the carbon fraction of the soil.

Equation 1.
$$\mathrm{BSAF} = \frac{\dfrac{[\mathrm{Fish\ (ww)}]_{\mathrm{OCP}}}{[\mathrm{Fish}]_{\mathrm{Lipid}}}}{\dfrac{[\mathrm{Soil\ (dw)}]_{\mathrm{OCP}}}{\mathrm{Soil}_{\mathrm{TOC}}}}$$

A BSAF equal to one means the lipid-normalized OCP concentration in the fish is equal to the carbon-normalized concentration in the soil. Though a robust predictor across a broad range of soil types and fish species, the most accurate BSAF values are those that are derived from fish collected under conditions that mimic as closely as possible those of the anticipated project. In this case, mesocosm ponds were located on undisturbed soil in fields of the NSRA that possess soil TOC and OCP conditions that include what will be expected on the project site. Vegetation and fish in the mesocosms also reflect the species that we expect to find in all restoration phases. Thus, BSAFs (Table 3) based on a large number of mesocosm fish and soil data likely are very reliable.

Table 3. Median BSAFs for fish from mesocosms located on NSRA representing flooded conditions with wetland vegetation. The BSAFs for the chlordanes are ratios of each chlordane congener in fish to the total of the chlordane congeners in the soil.

	4,4'-DDD	**4,4'-DDE**	**4,4'-DDT**	**Dieldrin**	**Toxaphene**	***trans*-Nonachlor**
BSAF	2.71 (229)*	8.06 (314)	0.32 (229)	1.47 (314)	0.77 (314)	0.69 (314)
	***alpha*-Chlordane**	***cis*-Nonachlor**	***gamma*-Chlordane**	**Heptachlor**	**Heptachlor epoxide**	**Oxychlordane**
BSAF	0.31 (314)	0.32 (314)	0.16 (314)	0.017 (314)	0.042 (314)	0.14 (314)

*Number of fish samples used in the calculation is shown in parenthesis

The BSAF equation can be mathematically rearranged and used to predict fish OCP concentrations.

Equation 2. $$\frac{[\text{Soil (dw)}_{\text{OCP}}]}{\text{Soil}_{\text{TOC}}} \times [\text{Fish}]_{\text{Lipid}} \times \text{BSAF} = [\text{Fish (ww)}_{\text{OCP}}]$$

The carbon-normalized soil concentrations (Table 2) were multiplied by the BSAF (Table 3) and a fish lipid concentration of 4.71%. The fish lipid value was derived from fish collected from the existing Duda marsh and represents the median value of 190 measurements.

An example calculation using Equation 2 to predict fish concentration is shown below. Using carbon-normalized soil data for dieldrin in field ZNC-A (Table 2), and the BSAF value for dieldrin (Table 3) we get:

(1,318 ug/kg OC dieldrin) $(.0471)_{\text{lipid}}$ $(1.47)_{\text{BSAF}}$ = 91.2 µg/kg $_{\text{ww}}$ dieldrin in fish

Similar calculations to predict fish OCP concentrations once the project is flooded were made for each of the individual fields of Phases 3, 4, 5 and 8 (Table 4a-c). The predicted fish OCP concentration (ww) from Table 4 were then compared to the TRVs (Tables 5 and 6).

Table 4a. Predicted fish OCP concentrations (µg/kg ww) for Phase 3 North, Phase 4, and Phase 5 North.

Site	**ZNC-A**	**ZNC-B**	**ZNE-A**	**ZNE-B**	**ZNE-C**	**ZNE-D**	**ZNE-E**
Chemical	**Phase 3 North**		**Phase 4**			**Phase 5 North**	
4,4'-DDD	64	88	255	147	193	225	222
4,4'-DDE	1,274	804	1,339	1,192	1,231	**1,855**	1,217
4,4'-DDT	5	5	49	36	20	51	41
DDTr	103	77	189	145	141	219	167
Dieldrin	91	91	48	40	48	84	30
Toxaphene	695	324	581	685	465	1,238	863
alpha-Chlordane	18	10	12	17	16	25	15
cis-Nonachlor	19	11	12	18	16	26	16
gamma-Chlordane	9	5	6	9	8	13	8
Heptachlor	1	1	1	1	1	1	1
Heptachlor epoxide	2	1	2	2	2	3	2
Oxychlordane	8	5	5	8	7	11	7
trans-Nonachlor	41	23	26	39	35	55	34
Total chlordanes	98	56	64	94	85	134	83

Table 4b. Predicted fish OCP concentrations (µg/kg ww) for Phase 3 South and Phase 5 South.

Site	ZSC-A	ZSC-B	ZSC-C	ZSE-D*	City of Apopka	ZSE-E	ZSE-F
Chemical	**Phase 3 South**			**Phase 5 South**			
4,4'-DDD	47	32	45	122	231	93	177
4,4'-DDE	1,214	979	979	**1,517**	**2,534**	**2,064**	**2,524**
4,4'-DDT	6	10	26	42	128	28	90
DDTr	96	81	100	167	343	184	294
Dieldrin	73	98	119	74	79	112	101
Toxaphene	416	310	690	1,213	1,960	594	1,517
alpha-Chlordane	12	9	21	27	34	17	35
cis-Nonachlor	12	9	22	28	36	18	36
gamma-Chlordane	6	5	11	14	18	9	18
Heptachlor	1	0	1	2	2	1	2
Heptachlor epoxide	2	1	3	4	5	2	5
Oxychlordane	5	4	10	12	16	8	16
trans-Nonachlor	26	20	47	60	77	38	77
Total chlordanes	64	48	115	147	188	93	189

*These data also include the City of Apopka data.

Table 4c. Predicted fish OCP concentrations (µg/kg ww) for Phase 8

Site	ZIN-A	ZIN-C	ZIN-D	ZIN-F
	Phase 8			
4,4'-DDD	320	1,103	298	276
4,4'-DDE	**6,174**	**6,394**	**2,223**	**4,185**
4,4'-DDT	34	305	51	66
4,4'-DDTr	509	951	259	401
Dieldrin	51	**204**	56	174
Toxaphene	233	3,712	1,419	4,851
alpha-Chlordane	26	74	37	39
cis-Nonachlor	27	77	38	40
gamma-Chlordane	13	38	19	20
Heptachlor	1	4	2	2
Heptachlor epoxide	5	10	5	5
Oxychlordane	12	34	16	18
trans-Nonachlor	57	165	81	87
Total Chlordane	141	402	198	211

Table 5. Toxicity Reference Values (TRVs) and fasting factors

	Toxicity Reference Values (TRV) for fish prey (ug/kg ww)	Fasting Factor	Adjusted TRV (ug/kg ww)	TRVs from Duda BO
4,4'-DDE	1,500	0	1,500	
DDTX				3,600
DDTr	3,000	2	1,500	
Dieldrin	280	2	140	690
Toxaphene	10,000	2	5,000	4,300
***cis*-Nonachlor**	1,100	2	550	
***gamma*-Chlordane**	2,000	2	1,000	
Heptachlor	800	2	400	
Heptachlor epoxide	200	2	100	
Oxychlordane	100	2	50	
***trans*-Nonachlor**	900	2	450	
***alpha*-Chlordane**	2,000	2	1,000	
total-Chlordane				285

The ratio of an estimated fish OCP concentration to the TRV is defined as a hazard quotient.

$$HQ_{OCP} = \frac{[\text{Predicted Prey}_{OCP}]}{\text{Toxicity Reference Value}_{OCP}}$$

For example, the predicted fish OCP concentration for dieldrin in field ZNC-A is 91 µg/kg ww (Table 4). The adjusted TRV for dieldrin is 140 ug/kg ww (Table 5). Thus, the calculated hazard quotient for field ZSE-A would be:

$$HQ_{dieldrin} = \frac{[91\,\text{ug/kg ww}]}{140\,\text{ug/kg ww}}$$

$HQ_{dieldrin}$ = 0.65.

An HQ less than 1 results when the fish concentration is less than the TRV and suggests the risk associated with the OCP is low and acceptable. To assess the additive impact, the HQs for each OCP (except DDE) are summed to create a hazard index, HI (Table 6).

$$HI = \Sigma HQ_{OCP}$$

Table 6a. Hazard quotients (HQ) and hazard indices (HI) for Phases 3, 4, and 5.

	Phase 3 North HQ		**Phase 4 HQ**			**Phase 5 North HQ**	
Chemical	**ZNC-A**	**ZNC-B**	**ZNE-A**	**ZNE-B**	**ZNE-C**	**ZNE-D**	**ZNE-E**
4,4'-DDE	0.85	0.54	0.89	0.79	0.82	**1.24**	0.81
DDTr	0.07	0.05	0.13	0.10	0.09	0.15	0.11
Dieldrin	0.65	0.65	0.35	0.29	0.34	0.60	0.21
Toxaphene	0.14	0.06	0.12	0.14	0.09	0.25	0.17
alpha-Chlordane	0.02	0.01	0.01	0.02	0.02	0.02	0.02
cis-Nonachlor	0.03	0.02	0.02	0.03	0.03	0.05	0.03
gamma-Chlordane	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Heptachlor	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptachlor epoxide	0.02	0.01	0.02	0.02	0.02	0.03	0.02
Oxychlordane	0.16	0.09	0.10	0.16	0.14	0.22	0.14
trans-Nonachlor	0.09	0.05	0.06	0.09	0.08	0.12	0.08
Summed HQ (HI)	**1.20**	0.96	0.81	0.85	0.83	**1.46**	0.79

Table 6b. Hazard quotients (HQ) and hazard indices (HI) for Phase 3 South and Phase 5 South.

	Phase 3 South HQ			Phase 5 South HQ			
Chemical	**ZSC-A**	**ZSC-B**	**ZSC-C**	**ZSE-D***	**City of Apopka**	**ZSE-E**	**ZSE-F**
4,4'-DDE	0.81	0.65	0.65	1.01	**1.69**	**1.38**	**1.68**
DDTr	0.06	0.05	0.07	0.11	0.23	0.12	0.20
Dieldrin	0.52	0.70	0.85	0.53	0.57	0.80	0.72
Toxaphene	0.08	0.06	0.14	0.24	0.39	0.12	0.30
alpha-Chlordane	0.01	0.01	0.02	0.03	0.03	0.02	0.03
cis-Nonachlor	0.02	0.02	0.04	0.05	0.06	0.03	0.07
gamma-Chlordane	0.01	0.01	0.01	0.01	0.02	0.01	0.02
Heptachlor	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptachlor epoxide	0.02	0.01	0.03	0.04	0.05	0.02	0.05
Oxychlordane	0.11	0.08	0.19	0.24	0.31	0.14	0.31
trans-Nonachlor	0.06	0.04	0.11	0.13	0.17	0.08	0.17
Summed HQ (HI)	0.89	0.98	**1.45**	**1.38**	**1.84**	**1.37**	**1.87**

*These data also include the City of Apopka data.

Table 6c. Hazard quotients (HQ) and hazard indices (HI) for Phase 8.

	Phase 8 HQ			
Chemical	**ZIN-A**	**ZIN-C**	**ZIN-D**	**ZIN-F**
4,4'-DDE	**4.12**	**4.26**	**1.48**	**2.79**
DDTr	0.34	0.63	0.17	0.27
Dieldrin	0.36	**1.46**	0.40	**1.24**
Toxaphene	0.05	0.74	0.28	0.97
alpha-Chlordane	0.03	0.07	0.04	0.04
cis-Nonachlor	0.05	0.14	0.07	0.07
gamma-Chlordane	0.01	0.04	0.02	0.02
Heptachlor	0.00	0.01	0.01	0.01
Heptachlor epoxide	0.03	0.10	0.05	0.05
Oxychlordane	0.23	0.67	0.33	0.35
trans-Nonachlor	0.13	0.37	0.18	0.19
Summed HQ (HI)	**1.24**	**4.23**	**1.54**	**3.21**

Weighting the HIs of the individual field units by their acreage yields HIs for Phase 3 North, Phase 4 and Phase 5 North of 1.08, 0.83 and 1.29, respectively (Table 7a). These three phases comprise one hydrologic unit, with a combined acreage-weighted HI of 0.94 (Table 7b).

For Phase 3 South, Phase 5 South and Phase 8, the acreage-weighted HIs (1.26, 1.53 and 1.95, respectively; Tables 7c, 7d), indicate that some caution is warranted and further inspection of the data are necessary. Of particular need for data inspection is Phase 8 with three of four fields having HIs for DDE near 2 or above, and with two fields possessing overall HIs higher than 3 (Tables 6c and 7d).

Table 7a. Hazard Indices (HI), adjusted for acreage of each phase.

	ZNC-A	ZNC-B		ZNE-A	ZNE-B	ZNE-C		ZNE-D	ZNE-E	
	Phase 3 North		**TOTAL acres**	**Phase 4**			**TOTAL acres**	**Phase 5 North**		**TOTAL acres**
Acres	333	307	640	617	264	149	1,030	251	84	335
Acre ratio to total	0.52	0.48	1	0.60	0.26	0.14	1	0.75	0.25	1
HI	1.20	0.96		0.81	0.85	0.83		1.46	0.79	
Size adjustment (HI*ac-ratio)	0.62	0.46	**Acreage-weighted HI 1.08**	0.49	0.22	0.12	**Acreage-weighted HI 0.83**	1.09	0.20	**Acreage-weighted HI 1.29**

Table 7b. Hazard Indices, adjusted for acreage of combined phases.

	ZNC-A	ZNC-B	ZNE-A	ZNE-B	ZNE-C	ZNE-D	ZNE-E	
	Phase 3 North		**Phase 4**			**Phase 5 North**		**Total acres**
Acres	333	307	617	264	149	251	84	2,005
Acre ratio to total	0.17	0.15	0.31	0.13	0.04	0.12	0.04	1
HI	1.20	0.96	0.81	0.85	0.83	1.46	0.79	
Size adjustment (HI*ac-ratio)	0.20	0.14	0.25	0.11	0.03	0.18	0.03	**Acreage-weighted HI 0.94**

Table 7c. Hazard Indices, adjusted for acreage in Phase 3 South and Phase 5 South.

	ZSC-A	ZSC-B	ZSC-C		ZSE-D*	ZSE-E	ZSE-F	
	Phase 3 South			**TOTAL acres**	**Phase 5 South**			**TOTAL acres**
Acres	62	79	242	383	316	148	223	687
Acre ratio to total	0.16	0.21	0.63	1	0.46	0.22	0.32	1
HI	0.89	0.98	1.45		1.38	1.37	1.87	
Size adjustment (HI*ac-ratio)	0.14	0.20	0.92	Acreage-weighted **HI 1.26**	0.63	0.30	0.60	Acreage-weighted **HI 1.53**

*These data include the City of Apopka data points.

Table 7d. Hazard Index, adjusted for acreage of Phase 8.

	ZIN-A	ZIN-C	ZIN-D	ZIN-F	
	Phase 8				**TOTAL acres**
Acres	305	156	150	307	918
Acre ratio to total	0.33	0.17	0.16	0.33	1
HI	1.24	4.23	1.54	1.71	
Size adjustment (HI*ac-ratio)	0.41	0.72	0.25	0.57	Acreage-weighted **HI 1.95**

2.3 Inspection of data

Phase 3 North, Phase 4 and Phase 5 North comprise one hydrologic unit, with an overall acreage-weighted HI of 0.97. However, because they will be flooded as one unit to a maximum elevation of 60 ft NGVD 29, large areas of Phase 4 may at times be between 2 and 3 ft deep, or slightly above optimal conditions for rooted vegetation.

In Phase 3 South, only one field, ZSC-C, has an HI (1.45) above one. Dieldrin contributes the highest hazard quotient value (0.85) to the HI score, and is slightly higher than for the other two fields (Table 6b). Of the 18 soil samples collected from ZSC-C, two have dieldrin levels that are approximately 3 times higher than the mean of the remaining 16 samples. The two sample locations are in a portion of the field that will be flooded under normal operating conditions.

An inspection of the data for Phase 5 South shows several samples with low TOC (<10%). Even when actual soil OCP values are small, a low TOC can result in a high projected fish tissue concentration. Six of those sandy sites are located in sections that will be above the flooding/saturation zone. However, even with those data removed from the calculations, the acreage-weighted HI value decreases by only a small amount, to 1.50. The 35-ac parcel that may be used by the City of Apopka has an HI of 1.84. However,

its small size and expected use as a vegetated flow-way suggest there would be minimal risk to wading birds.

In Phase 8, field ZIN-A, with the lowest HI, will not be flooded under normal operating conditions. This field, formerly known as the Bass Sod Farm has TOC values ranging from 1.5–7.7 percent. If that field is removed from the calculations, the acreage-weighted HI for Phase 8 increases to 2.28 (Table 7e).

Table 7e. Phase 8 Hazard Indices, adjusted for acreage of each phase that will be flooded under normal operating conditions.

	ZIN-C	ZIN-D	ZIN-F	TOTAL acres
Acres	156	150	307	613
Acre ratio to total	0.25	0.24	0.50	1
HI	4.23	1.54	1.71	
Size adjustment (HI*ac-ratio)	1.06	0.37	0.86	Acreage-weighted **HI** **2.28**

Under normal flooding conditions, the majority of the three fields will be inundated. Based on the HI calculations, the field that poses the largest apparent risk is ZIN-C. An inspection of the soil data indicates that all three fields have low mean TOC values, compared with the majority of the NSRA, and ZIN-C has the lowest mean percent TOC of the three. It also has the lowest mean soil values of all OCPs. Table 8 shows how the low percent carbon content in field ZIN-C affects the HI calculation, using 4,4'-DDE as an example. Although the mean percent TOC and the DDE levels in field ZIN-C are roughly 3 to 4 times *smaller* than in the other two fields, the calculated carbon normalized DDE is 7 to 8 times *greater*. Our past bioaccumulation experiments indicate that the BSAF model is robust under low TOC conditions (Sepúlveda et al. 2005), thus an HI of 4.23 warrants caution.

Table 8. Example of how low soil carbon affects carbon normalized DDE content.

Chemical	ZIN-C	ZIN-D	ZIN-F
TOC (%)	6	22	17
4,4'-DDE µg/kg dw	192	825	768
4,4'-DDE µg/kg oc dw	**32,000**	**3,750**	**4,518**

2.4 Summary of risk

The hydrologic unit that consists of Phase 3 North, Phase 4 and Phase 5 North has an overall HI < 1. At the maximum desirable flooding elevation, the majority of Phase 4 will have water levels slightly higher than optimal conditions for rooted vegetation. Care will be taken to ensure slow, shallow initial flooding to promote dense wetland vegetation coverage, and to ensure that vegetation remains rooted during high rain years.

Phases 3 South and 5 South have acreage-adjusted HIs (1.3 and 1.5, respectively) similar to those predicted for Phase 2. The predicted HIs for Phase 2 East and West were 1.5 and 1.2 (Conrow 2008).

Fish from all field units of Phase 2 were analyzed for at least a year and OCP results did not trigger any concern.

Predicted fish 4,4'-DDE levels (6,394 µg/kg ww) in Phase 8 are the highest we have seen thus far in the NSRA restoration process. The Phase 8 predicted fish level of dieldrin (204 µg/kg ww) is also the highest seen thus far. However, data from actual fish samples collected in Phase 2 suggest that our approach to DDE prediction is conservative, with actual values ranging from 20 to 50 percent of the predicted value (Table 9). Actual fish levels of dieldrin were from 5 to 27 percent of the predicted value (Table 9). Thus, if we use our past data to adjust our calculated levels of DDE and dieldrin in Phase 8 fish, we might expect to see DDE levels ranging from 1,279 to 3,197 µg/kg ww, and dieldrin levels of 10 to 55 µg/kg ww.

Table 9. Phase 2 fish data after one year of flooding. Measured (Msr) values are means of three composite samples. Predicted (Pred) values are from the Biological Assessment for Phase 2, and were developed using the same equations as in this document. The toxicity reference values (TRV) are provided for comparison.

Field	**A**		**B**		**C**		**D**		**E**		**F**		
	Pred	**Msr**	**Pred**	**Msr**	**Pred**	**Msr**	**Pred**	**Msr**	**Pred**	**Msr**	**Pred**	**Msr**	**TRV**
4,4'-DDE	1,188	249	1,666	341	1,912	959	1,447	400	1,252	429	1,285	591	**1500**
Ratio msr : pred		0.21		0.20		0.50		0.28		0.34		0.46	
Dieldrin	105	10	80	4.3	132	10	72	7	118	27	102	28	**140**
Ratio msr : pred		0.09		0.05		0.08		0.10		0.23		0.27	

Fortunately, we have the luxury of some real, but limited, fish data from Phase 8. At surface elevations of 58 to 59 ft NGVD 29, the east side of Field ZIN-C, and the west side of ZIN-D frequently hold water during the summer rainy season. Although the District makes every effort to drain water from that portion of the project, there are often periods ranging up to a month, when there have been patches of shallow water on the fields, and much longer periods of time when the field ditches are full. Because of this cyclical flooding, typical wetland vegetation, such as cattail (*Typha* spp) and alligator weed (*Alternanthera philoxeroides*) dot small portions of the landscape (Figure 6). After one of the rain events in May 2011, we collected fish at two field locations. Composite samples of tadpoles and water beetles also were collected. Results (Table 11) indicate that OCP levels are low and acceptable. Clearly, however, these results only provide an indication of tissue burdens after brief—albeit, perhaps, repeated— contact with flooded field sediments.

Figure 6. Shallowly flooded section of Phase 8 ZIN-C. May 19, 2011, SJRWMD.

Table 10. Select OCP concentrations (µg/kg ww) of fish and other aquatic organisms collected from Phase 8 field unit ZIN-C. Samples obtained May 19, 2011.

	Composite fish #1	Composite fish #2	Composite fish #3	Composite tadpole	Composite water beetle
4,4'-DDE	90.3	91.8	83.6	18.6	12.0
Dieldrin	4.6	4.8	4.9	4.2	6.3
Toxaphene	78.8	67.9	53.9	40.1	60.5
alpha-Chlordane	3.1	4.7	2.0	6.5	7.1
cis-Nonachlor	1.9	2.1	2.3	2.6	1.8
gamma-Chlordane	1.7	2.8	1.8	1.9	2.4
Heptachlor	1.3	1.1	1.4	1.2	1.8
Heptachlor epoxide	3.6	5.3	2.6	2.3	3.4
Oxychlordane	2.0	1.1	2.2	1.0	1.5
trans-Nonachlor	6.2	6.0	4.0	4.5	2.1

3.0 Species Accounts

3.1 Orange County federally listed species

Five birds, three reptiles, one amphibian, and seven plants are federally-listed threatened or endangered species in Orange County, Florida (Table 11). The gopher tortoise and the striped newt, have been added to the species list, as candidates for listing, since the last biological assessment was completed.

At a January 31, 2001 meeting in Jacksonville regarding the Biological Assessment for the Duda sub-East Project, it was agreed that, for the Orange County list, all seven plant species, the Florida scrub-jay, red-cockaded woodpecker and sand skink are upland species and, due to lack of suitable habitat, would not be found on the project area. Similarly, the gopher tortoise is an upland species, and is not expected to be found on the project site. Striped newts are found in longleaf pine-dominated savanna, scrub, or sandhill habitats, and they breed in shallow, isolated temporary ponds and are not expected on the project site (http://www.fws.gov/northflorida/Releases-11/20110607_nr_Striped-newt_12%20month_Finding_news_release.htm). Audubon's crested caracara and eastern indigo snake were not included in the Biological Opinion for Duda sub-East and the letter of concurrence for Unit 2 West (USFWS 2002, 2006) and they will not be included here.

Table 11. Orange County Federally Listed Species
(http://www.fws.gov/northflorida/CountyList/Orange.htm)

The following table lists those federally-listed species known to be present in the county. Code Key: E = Endangered, T = Threatened, P = Proposed, C = Candidate, CH = Critical Habitat

Category	Species Common Name	Species Scientific Name	Code
Birds	Audubon's Crested Caracara	*Polyborus plancus audubinii*	T
	Everglade Snail Kite	*Charadrius melodus*	E
	Florida Scrub-jay	*Aphelocoma coeruluscens*	T
	Wood Stork	*Mycteria americana*	E
	Red-cockaded Woodpecker	*Picoides borealis*	E
Reptiles	Gopher Tortoise	*Gopherus polyphemus*	C
	Sand Skink	*Neoseps reynoldsi*	T
	Eastern Indigo Snake	*Dymarchon corais couperi*	T
Amphibians	Striped Newt	*Notophthalmus perstriatus*	C
Plants	Britton's Beargrass	*Nolina brittoniana*	E
	Florida Bonamia	*Bonamia grandiflora*	T
	Scrub Lupine	*Lupinus aridorum*	E
	Beautiful Pawpaw	*Deeringothamnus pulchellus*	E
	Sandlace	*Polygonella myriophylla*	E
	Papery Whitlow-wort	*Paronychia chartacea = Nyachia pulvinata*	T
	Scrub Wild Buckwheat	*Eriogonum longifolium* var. *gnaphalifolium*	T

3.2 Site-specific listed species

One threatened and one endangered species have suitable habitat and are assumed to be present on the project site. These species are the snail kite, and the wood stork. Each of these species will be discussed in detail below.

Detailed information regarding the status of the above-mentioned species along with the biological and ecological information utilized by the Service in evaluating potential adverse effects was summarized in the Biological Opinion for Duda sub-East (USFWS 2002) and is duplicated below. The original source is the *South Florida Multi-Species Recovery Plan* (MSRP) (Service 1999). That document is incorporated here by reference.

Snail kite (*Rostrhamus sociabilis*)

The species was federally-listed as endangered in 1967 and critical habitat was determined in 1977 (FR 42(155): 40685-40688). That protection was continued under the Endangered Species Conservation Act of 1969 and the Endangered Species Act, as amended. The snail kite was listed because of its limited distribution and threats to its habitat posed by large-scale conversion of land in southern Florida to agricultural uses.

A. Distribution (snail kite)

The current distribution of the snail kite in Florida is limited to central and southern portions of the state. Six large freshwater systems generally encompass the current range of the species, although radio tracking of snail kites has revealed that the network of habitats used by the species also includes many other smaller widely dispersed wetlands within this overall range (Bennetts and Kitchens 1997).

B. Habitat (snail kite)

Snail kite habitat consists of fresh-water marshes and the shallow vegetated edges of lakes (natural and man-made) where apple snails (*Pomacea paludosa*) can be found. Suitable foraging habitat for the snail kite is typically a combination of low profile ($\leq$10 feet) marsh with a matrix of shallow (0.65 - 4.25 feet deep) open water, which is relatively clear and calm. Low trees and shrubs are also often interspersed with the marsh and open water. Snail kites require foraging areas to be relatively clear and open in order to visually search for apple snails, therefore, dense growth of herbaceous or woody vegetation is not conducive to efficient foraging. Nesting and roosting sites almost always occur over water, which deters predation. Nesting substrates include small trees (usually < 32.8 feet in height), but can also occur in herbaceous vegetation, such as sawgrass, cattail, bulrush, and reed (Service 1986). It is important to note that suitable nesting substrate must be close to suitable foraging habitat, so extensive areas of contiguous woody vegetation are generally unsuitable for nesting.

C. Critical Habitat (snail kite)

Critical habitat was designated for the snail kite in 1977 and, since then, has not been revised. Critical habitat includes the Water Conservation Areas (WCA), portions of Everglades National Park, western portions of Lake Okeechobee, the Strazzulla and Cloud Lake reservoirs in St. Lucie County, Loxahatchee National Wildlife Refuge, and portions of the St. Johns marsh in Indian River County. A complete description of the critical habitat is available in 50 CFR §17.95, and 42 FR 47840 47845.

Although the critical habitat that was designated for the snail kite did not include constituent elements, water level management is required to maintain favorable habitat conditions that are considered necessary to ensure the species survival.

D. Reproduction (snail kite)

Copulation can occur from early stages of nest construction, through egg-laying, and during early incubation if the clutch is not complete. Egg laying begins soon after completion of the nest. In Florida, the incubation period lasts 24-30 days (Sykes 1987).

Hatching success is variable from year to year and between areas. In nests where more than one egg hatched, hatching success averaged 2.3 chicks/nest. The most successful months for hatching are February (19 percent), March (31 percent), and April (23 percent) (Sykes 1987). The breeding season varies widely from year to year in relation to rainfall and water levels. Ninety-eight percent of the nesting attempts are initiated from December through July, while 89 percent are initiated from January through June (Sykes 1987, Beissinger 1988).

E. Foraging (snail kite)

The snail kite feeds almost exclusively on apple snails in Florida. Apple snails although primarily herbivores, are not very selective in their food choice and eat almost everything available in their environment. In general they prefer soft and digestible vegetation, but also tougher plants, incidental sediment, and algae are consumed as long as they are able to grasp pieces with their radula (rasp tongue). Snail kites spend between 25 to 50 percent of the time foraging while nesting and 31 to 68 percent of the time foraging during pre- and post-nest desertion periods. Feeding perches include living and dead woody-stemmed plants, blades of sawgrass and cattails, and fence posts.

F. Movements (snail kite)

Snail kites in Florida are not migratory in the strict sense and they are restricted to South and Central Florida. Snail kites are nomadic in response to water depths, hydroperiod, food availability, nutrient loads, and other habitat changes (Bennetts *et al.* 1994). Radio-tracking and sighting of marked individuals have revealed that nonbreeding individuals disperse widely on a frequent basis (Bennetts *et al.* 1994). Shifts in distribution can be short-term, seasonal, or long-term, and can take place between areas among years (Rodgers *et al.* 1988), between areas within a given nesting season (Beissinger 1986), within areas in a given nesting season, and within or between areas for several days to a few weeks (Bennetts *et al.* 1988). Sykes (1983a) noted that during colder winters, snail kites will shift their distribution to the southern part of their range.

G. Status and Trends (snail kite)

Several authors (Nicholson 1926, Howell 1932, Bent 1937) indicated that the snail kite was numerous in central and south Florida marshes during the early 1900s, with groups of up to 100 birds. Sprunt (1945) estimated the population to be between 50 to 100 individuals. The snail kite apparently plummeted to its lowest population between 1950 and 1965. By 1954, the population was estimated at no more than 50 to 75 birds (Sprunt 1954). Stieglitz and Thompson (1967) reported eight birds in 1963 at the Loxahatchee National Wildlife Refuge, 17 on the refuge and two at Lake Okeechobee in 1964, eight in WCA 2A and two at Lake Okeechobee in 1965, and 21 in WCA 2A in 1966.

The snail kite has apparently experienced population fluctuations associated with hydrologic influences, both man-induced and natural (Sykes 1983b, Beissinger 1986), but the amount of fluctuation is debated. The abundance of its prey, apple snails, is closely linked to water regime (Sykes 1979, 1983b). Drainage of Florida's interior wetlands has reduced the extent and quality of habitat for both the apple snail and the kite (Sykes 1983a). The kite nests over water, and nests become accessible to predators in the event of unseasonal drying (Beissinger 1986, Sykes 1987). In dry years, the kite depends on water bodies that normally are suboptimal for feeding, such as canals, impoundments, or small marsh areas, remote from regularly used sites (Bennetts *et al.* 1988). These secondary or refuge habitats are vital to the continued survival of this species in Florida.

H. Recovery Plan Objective (snail kite)

Pursuant to the Florida Snail Kite Recovery Plan (Service 1986), to achieve downlisting the following criteria must be met:

> The recovery goal for the population is the existence of a significant number of kites so that the species will have a 95 percent probability of surviving 3 to 4 successive drought years of no reproduction and high mortality, while remaining reproductively viable. In the absence of adequate data, upon which to establish a specific population goal, the interim goal is an annual average of 650 birds for a ten-year period with annual population declines of less than 10 percent of the average.

I. Project Effects (snail kite)

Direct effects

It is not expected, based on bird surveys conducted on the NSRA over the past several years, that the snail kite will utilize the project site. Their almost exclusive prey organism, the apple snail (*Pomacea paludosa*), is not expected to populate the project area in numbers sufficient for foraging birds for several years (Darby et al. 1997). It is unlikely that snail kites would exhibit direct effects from foraging on the project site, because projected OCP levels in fish are generally below the HQs for the contaminants of concern and near one for HIs, and we expect that, due to their diet, snails would have lower OCP levels than fish; because the size of the potential foraging area is small relative to their feeding range; and the dense vegetation expected on the site is not a preferred condition for foraging activity.

Indirect effects

It is not expected, based on bird surveys conducted on the NSRA over the past several years, that snail kites would be seen on the project area. It is unlikely that the snail kite would exhibit indirect effects, such as long term reproductive impacts, from foraging on the project site because the size of the

potential foraging area is small relative to their territory; the projected OCP levels in fish are generally below the HQs for the contaminants of concern and near one for HIs, and we expect that, due to their diet, snails would have lower OCP levels than fish; establishment of a suitable apple snail population would require numerous years; and the dense vegetation existing on the site is not a preferred condition for foraging activity.

Cumulative effects

It is possible that snail kites, a highly mobile species, might move into the Lake Apopka area in response to regional hydrologic conditions. Within a short radius of the site are numerous natural water bodies as well as other state-owned former farm properties in the Upper Ocklawaha River Basin that are presently under various stages of wetland restoration. In addition, as more acreage is restored to wetlands on the NSRA, suitable conditions may develop. There were single sightings on the NSRA by Harry Robinson of snail kites on July 16, 1999, August 20, 2000, August 14, 2002 and September 4, 2011. According to Mr. Robinson, it is likely that these were all immatures, and there were no adult males. In November 2007, a snail kite was observed at Area 3 of the Emeralda Marsh Conservation Area, and its leg band number was provided to FFWCC. A lone snail kite was observed flying over Area 7 February 2012.

J. Conservation plan/minimization of impacts

A conservation plan/minimization of impacts for all site-specific listed avian species is provided in detail in Section 3.3 below.

Wood Stork (*Mycteria americana*)

The United States population of the wood stork was listed as endangered in 1984 because it had declined by more than 75 percent since the 1930s (49 FR 7335). At the time, the Service believed that the United States breeding population would be extirpated by the turn of the century if it continued to decline at the same rate. The original listing recognized the relationship between the declining wood stork population, the loss of suitable foraging habitat and colony nesting failures, particularly in the breeding colonies in South Florida where human actions have reduced wetland areas by about 35 percent (Ogden and Nesbitt 1979), influenced the hydrologic regime, and altered the prey base. No critical habitat has been designated for this species.

A. Distribution (wood stork)

In the United States, the wood stork has been reported both as a casual and regular visitor, ranging from southern California and southern Arizona, the Gulf of Mexico north to Canada; from Maine, southern New Brunswick, Canada, and New York, south to its breeding range in Florida, Georgia, and South Carolina. It is suspected that most wood storks sighted in Arkansas, Louisiana, Texas, and points farther west are birds that have dispersed from colonies in Mexico. During the non-breeding season (July to October), wood storks are much less common in South Florida.

B. Habitat (wood stork)

The wood stork is primarily associated with freshwater habitats for nesting, roosting, foraging, and rearing young. Wood storks typically construct their nests in medium to tall trees that occur in stands located either in swamps or on islands surrounded by relatively broad expanses of open water (Ogden 1991). During the non-breeding season or while foraging, wood storks occur in a wide variety of wetland and other aquatic habitats. Typical foraging sites for the wood stork include freshwater marshes and stock ponds, shallow, seasonally flooded roadside or agricultural ditches, narrow tidal creeks or shallow tidal pools, managed impoundments, and depressions in cypress heads and swamp sloughs. Because of their specialized feeding behavior, wood storks forage most effectively in shallow-water areas with highly concentrated prey (Ogden *et al*. 1978, Browder 1984, Coulter 1987). In South Florida, low, dry-season water levels are often necessary to concentrate fish to densities suitable for effective foraging by wood storks (Kushlan *et al*. 1975). As a result, wood storks will forage in many different shallow wetland depressions where fish become concentrated, either due to local reproduction by fishes, or as a consequence of seasonal drying.

C. Reproduction (wood stork)

Wood storks tend to use the same colony sites over many years, as long as the sites remain undisturbed and sufficient feeding habitat remains in the surrounding wetlands. Traditional wetland sites may be abandoned by storks once local or regional drainage schemes remove surface water from beneath the colony trees. As a result of such drainage, many storks have shifted colony sites from natural to managed or impounded wetlands. Ogden (1991) has suggested that recent increases in the number of colonies in north and central Florida have occurred as a result of an increase in the availability of altered or artificial wetlands.

Times of nest initiation for wood storks varies geographically. In Florida, wood storks lay eggs as early as October and as late as June (Rodgers 1990). In general, earlier nest initiation occurs in the southern portion of the state (below 27°N). Storks nesting in the Everglades and Big Cypress basins, under pre-drainage conditions, are known to form colonies between November and January (December in most years), regardless of annual rainfall and water level conditions (Ogden 1994). In response to deteriorating habitat conditions in South Florida, wood storks in these two regions have delayed the initiation of nesting to February or March in most years since the 1970s. This shift in the timing of nesting is believed to be responsible for the increased frequencies of nest failures and colony abandonment in these regions over the last 20 years; colonies that start after January in South Florida risk having young in the nests when May-June rains flood marshes and disperse fish.

Female wood storks lay a single clutch of eggs per breeding season. However, they will lay a second clutch if their nests fail early in the breeding season. Wood storks lay two to five (usually three) eggs depending on environmental conditions; the average clutch size may increase during years with favorable water levels and food resources. Once an egg has been laid in a nest, the breeding pair do not leave the nest unguarded, unless disturbed. Both parents are responsible for incubation and foraging (Palmer 1962). Incubation takes approximately 30 days, and begins after the first one or two eggs are laid.

The production of wood stork colonies varies considerably between years and locations, apparently in response to differences in food availability; colonies that are limited by food resources may fledge an average of 0.5-1.0 young per active nest; colonies that are not limited by food resources may fledge between 2.0 and 3.0 young per active nest (Ogden 1996).

D. Foraging (wood stork)

The natural hydrologic regime in Florida involves seasonal flooding of extensive areas of the flat, low-lying peninsula, followed by drying events that confine water to ponds and sloughs. Fish populations reach high numbers during the wet season, but become concentrated into smaller areas as drying occurs. Consumers, such as the wood stork, are able to exploit high concentrations of fish in drying pools and sloughs. In the pre-drainage Everglades, the dry season of South Florida provided wood storks with ideal foraging conditions over a wide area.

Storks forage in a wide variety of shallow wetlands, wherever prey reach high enough densities, and in water that is shallow and open enough for the birds to be successful in their hunting efforts (Ogden *et al*. 1978, Browder 1984, Coulter 1987). Good feeding conditions usually occur in relatively calm water, where depths are between 4 to 10 inches, and where the water column is uncluttered by dense patches of aquatic vegetation (Coulter and Bryan 1993). In South Florida, dropping water levels are often necessary to concentrate fish to suitable densities (Kushlan *et al*. 1975). Typical foraging sites throughout the wood stork's range include freshwater marshes and stock ponds; shallow, seasonally flooded roadside or agricultural ditches; narrow tidal creeks or shallow tidal pools; managed impoundments; and depressions in cypress heads and swamp sloughs. Almost any shallow wetland depression that concentrates fish, either through local reproduction or the consequences of area drying, may be used as feeding habitat.

E. Movements (wood stork)

During the non-breeding season (late summer and early fall), juvenile wood storks from South Florida colonies have been located throughout the Florida peninsula, southern Georgia, coastal South Carolina, central Alabama, and east-central Mississippi. Additionally, banded individuals from a colony in east-central Georgia were found in the central Everglades during the winter (Ogden 1996). This information suggests that a single population of wood storks in the southeast is responding behaviorally to changing environmental conditions through temporal relocation. Although the majority of nesting by the southeastern wood stork population no longer occurs in south Florida, excluding the Corkscrew rookery, the wetlands in the Everglades remain an important feeding area for large numbers of storks during the dry season (winter-spring) (Bancroft *et al.* 1992).

F. Status and Trends (wood stork)

Although we cannot accurately estimate the size of the North American breeding population prior to the late-1950s, there are reliable estimates of the size of some breeding colonies. Historically, larger breeding colonies at areas like Corkscrew Swamp, Okaloacoochee Slough, and the southern Everglades contained 5,000 to 15,000 pairs of wood storks (Palmer 1962, Ogden 1996). Most authors also agree that, since the late 1930s, the number of wood storks in the United States declined by more than 90 percent; additionally, the rate of decline in south Florida accelerated in the 1960s and 1970s (Palmer 1962, Ogden 1994).

Between 1957 and 1960, the Florida and National Audubon Societies conducted a series of statewide aerial wood stork surveys of all known or suspected stork nesting colonies. In 1974, statewide aerial surveys were initiated and repeated, annually, until 1986. In 1959, 14 breeding colonies supported an estimated 7,657 pairs of wood storks in Florida; in 1960, 15 breeding colonies supported an estimated

10,060 breeding pairs. By 1975, 15 breeding colonies supported an estimated 5,382 breeding pairs; in 1976, 17 breeding colonies supported an estimated 5,110 breeding pairs. Since 1983, the United States breeding population of wood storks has fluctuated between 5,500 and 6,500 pairs.

While the number of wood storks breeding in south Florida has substantially decreased in the 1970s, in north Florida, Georgia, and South Carolina, the number of breeding wood storks has significantly increased (Ogden *et al*. 1987). From 1958-1960, 80 to 88 percent of wood stork nesting pairs were located at six sites in South Florida. Surveys from 1976 showed a decline to 68 percent, with a further decline to 13 percent in 1986. Since the late 1970s, a majority of wood storks have nested in central and north Florida, and an increasing number have nested in coastal colonies in Georgia and South Carolina. Between 1965 and 1995, the number of wood storks nesting in Georgia increased from four pairs to 1,501 pairs; between 1981 and 1995, the number of wood storks nesting in South Carolina increased from 11 pairs to 829 pairs. After the 1970s, associated with this shift to the north, the southeast wood stork population appeared to be gradually increasing, from a low of 3,000-4,000 pairs in the late 1970s, to over 6,000 pairs in the mid-1990s.

A five-year review, completed in 2007, is a mandated Endangered Species Act process to ensure that the listing classification of a species as either threatened or endangered is still accurate. Three-year averages from nesting data (2002-2006) indicate that the total nesting pair population has averaged from 7,400 to over 8,700—consistently above the 6,000 nesting pairs threshold for reclassification (USFWS 2007). As a result of the review, the Service recommended that the wood stork's status on the federal list of threatened and endangered species be upgraded to threatened (USFWS 2007).

In May 2009, the Service received a petition from the Florida Home Builders Association requesting that the U.S. breeding population of the wood stork be reclassified from endangered to threatened under the Endangered Species Act. The Service found that the information provided in the petition did provide substantial scientific or commercial information indicating that reclassifying the wood stork’s status under the Act may be warranted. The Service is initiating a status review to determine whether reclassification of the U.S. breeding population of wood storks is warranted. The results of the status review will be published as part of a 12-month finding (USFWS 2010).

G. Recovery Plan Objective (wood stork)

Pursuant to the wood stork Recovery Plan (Service 1996), to achieve recovery the following criteria must be met:

> To down list: An average of 6,000 nesting pairs and annual regional productivity greater than 1.5 chicks per nest year, calculated over 3 years.
>
> To delist: An average of 10,000 nesting pairs calculated over 5 years beginning at time of reclassification, annual regional productivity greater than 1.5 chicks per nest per year (also calculated over a 5-year average). As a subset of the 10,000 pairs, a minimum of 2,500 successful nesting pairs must occur in the Everglades and Big Cypress systems.

H. Project effects (wood stork)

Numerous wood stork colonies have been documented in central Florida during the past decade. Based on 2006 colony data, the two nearest colonies to Phases 6 & 7 are located approximately 30 miles to the northeast. Two concentric circles illustrate which colonies might conservatively be expected to contribute breeding and non-breeding birds foraging on the project (Figure 7a). The Service also maintains a database of wood stork colonies and maps regional core foraging areas for colony locations in the state (Figure 7b).

Direct effects

Based on bird surveys conducted on the NSRA over the past several years, it is likely that wood storks will sometimes occur on the project site. And, if feeding conditions become optimal, wood storks may quickly congregate in large numbers. It is unlikely that wood storks would exhibit direct effects from foraging on the project site, because projected OCP levels in fish are generally below the HQs for the contaminants of concern and near one for HIs; because the dense vegetation, primarily cattail, is not a preferred condition for foraging activity; and the limited areas that might be used for foraging are small in size relative to their feeding range.

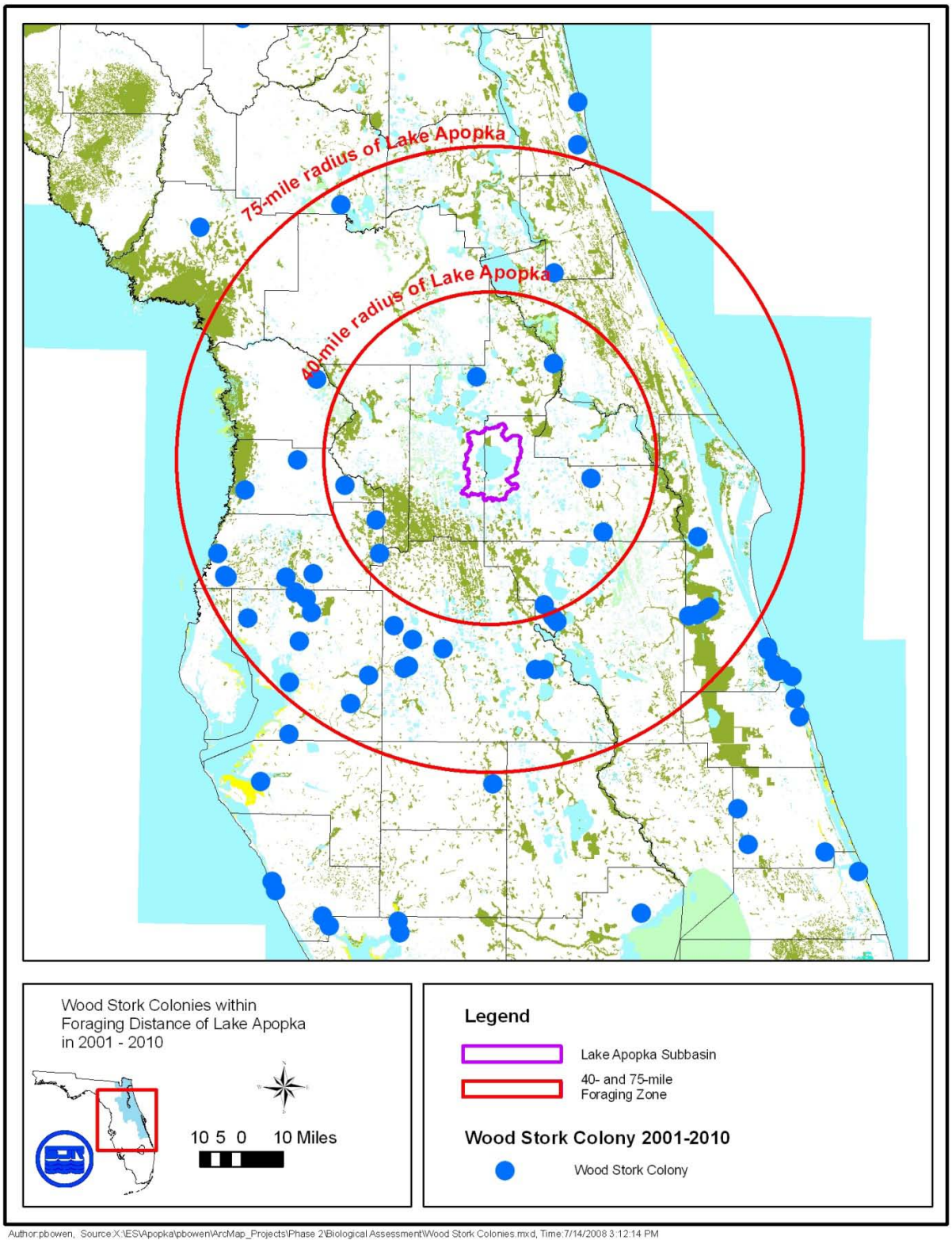


Figure 7a. The location of wood stork colonies in 2001- 2010 in relation to Lake Apopka and central Florida.

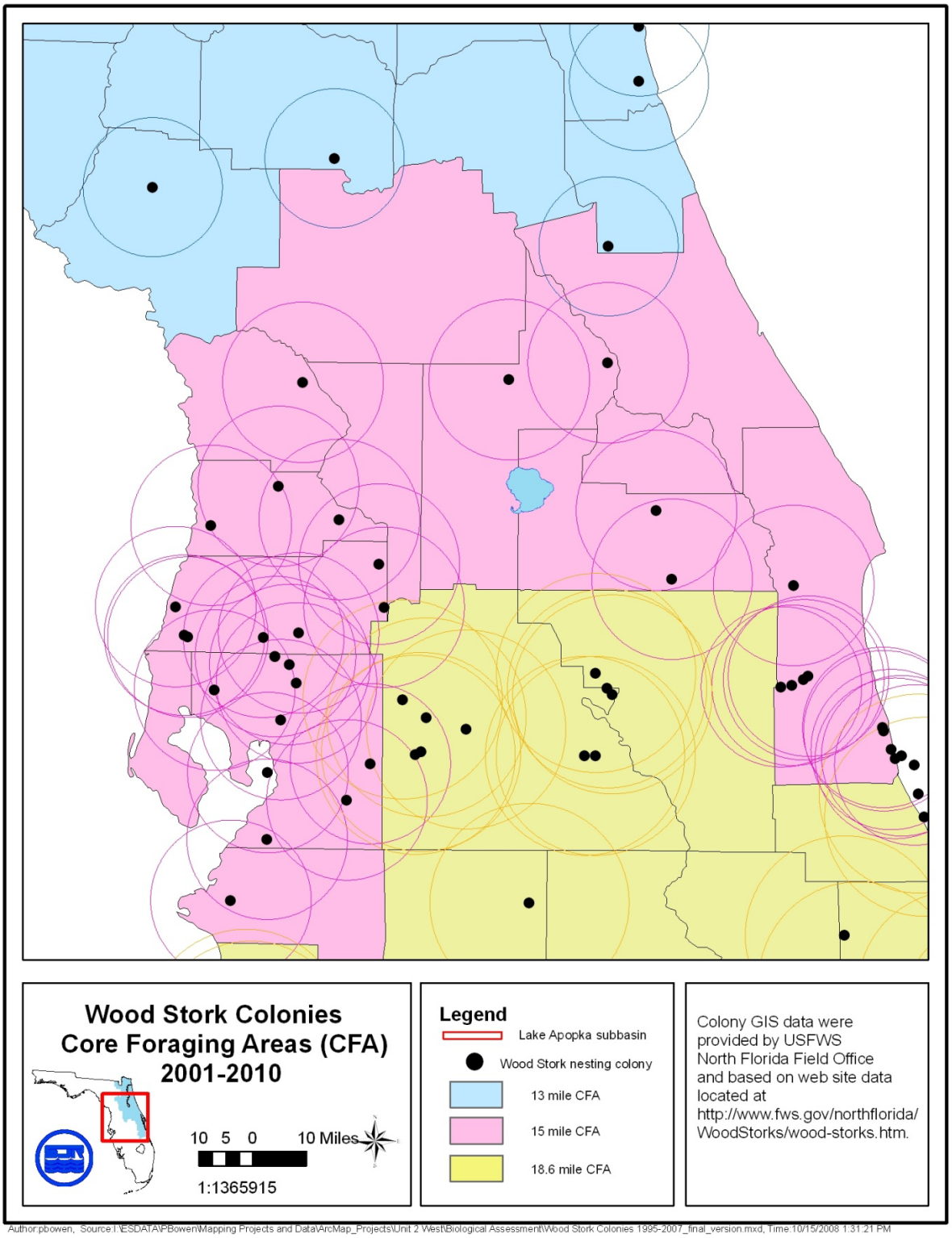


Figure 7b. All wood stork nesting colony locations from 2001-2010. Each colony was populated at least once in the 10-year time period, but may not be present in 2010.

Indirect effects

It is likely that wood storks sometimes will occur on the project site. And, if feeding conditions become optimal, wood storks may quickly congregate in large numbers. It is unlikely that wood storks would exhibit indirect effects from foraging on the project site, because projected OCP levels in fish are generally below the HQs for the contaminants of concern and near one for HIs; because the dense vegetation, primarily cattail, is not a preferred condition for foraging activity; and the limited areas that might be used for foraging are small in size relative to their feeding range.

Cumulative effects

It is possible that wood storks, a highly mobile species, might move into the Lake Apopka area in response to suitable regional hydrologic conditions. Within a short radius of the site are numerous natural water bodies as well as other state-owned former farm properties in the Upper Ocklawaha River Basin that are presently under various stages of wetland restoration.

I. Conservation plan/minimization of impacts (wood stork)

A conservation plan/minimization of impacts for all site-specific listed species is provided in detail in Section 3.3 below.

3.3 Management plan and minimization of impacts to listed species of concern

Actions taken to minimize impacts - hydrology

It is expected that dense plant growth will act as a physical barrier to many fish-eating birds, and limit use of the site by species, such as snail kites, that prefer open water conditions. Over time, we expect bird use to shift from wetland to oldfield habitat guilds (Hapner et al. 2011). In addition, abundant plant cover will maximize sediment accrual rates, thus minimizing as quickly as possible any exposure of biota to the existing soil. Cattail, a native wetland species, is very competitive, has a high rate of growth and one of the highest leaf litter rates (Lee et al. 1996; Davis 1984), and currently dominates the flooded portions of the NSRA property, serving as a ready seed source.

Soil surface elevations are an important component when planning flooding scenarios. Based on elevation maps (Figure 4), there is as much as a 7-ft elevation gradient across the project. Perhaps as much as 40 percent of the large hydrologic unit, consisting of Phase 3 North, Phase 4 and Phase 5 North, will remain dry/saturated during initial flooding for wetland restoration. The remaining phases will have 20 to 25 percent of their area remaining dry/saturated. Wetland-tolerant tree species may be planted in suitable areas. Species that have been planted at higher elevations at the NSRA include bald and pond cypress (*Taxodium* sp), sweetgum (*Liquidambar styraciflua*), blackgum (*Nyssa sylvatica*), and pop ash (*Fraxinus caroliniana*).

Timing of first flooding dictates the possible management scenarios to best encourage rapid colonization by wetland species. Optimally the soil in Phase 3 North, Phase 4 and Phase 5 North will be saturated by

late spring 2012. Flooding of the remaining phases will proceed as conditions allow. As seedlings germinate and grow, water levels will be raised to an operating depth of approximately 1.5 to 2 ft. Wetlands function best when water levels fluctuate over a range of conditions and we expect to allow water levels to fall with the typical winter-spring pattern, allowing additional seed germination over time. Ideally, our target water depth will fluctuate around an average of 12-30 inches in the rainy months, and lower in the dry season.

Monitoring

Monitoring of bird use is ongoing and will continue once a week on transects along the perimeter of the project. In addition, when weather conditions are acceptable, weekly aerial survey flights over SJRWMD property in the Upper Ocklawaha River Basin provide a broad overview of avian activity in the area as well as a visual check of any large-bird mortality.

Hydrologic monitoring will include at least weekly staff gauge readings. Samples for water chemistry will be collected at discharge locations. Vegetation communities on the site will be monitored through aerial photography and photo-interpretation, and onsite ground-truthing (ongoing).

Tissue contaminant levels of resident fish and other collected organisms will be monitored. Our experience to date is that it takes approximately three months for fish to colonize the newly flooded fields. At the three-month mark, quarterly sampling of each of the newly-flooded field units will commence. A composite fish sample of the available species from each of the flooded field units will be analyzed for OCPs on a quarterly basis. Fish samples will be collected and analyzed in accordance with the methodology established in the BO issued for the Duda sub-East project. Fish tissue trigger levels (wet weight) for each of the primary OCPs of concern are: toxaphene, 5 mg/kg; dieldrin, 0.14 mg/kg; DDTr, 1.5 mg/kg; DDE, 1.5 mg/kg; *alpha*-chlordane, 1 mg/kg; *cis*-nonachlor, 0.55 mg/kg; *gamma*-chlordane, 1 mg/kg; heptachlor, 0.4 mg/kg; heptachlor epoxide, 0.1 mg/kg; oxychlordane, 0.05 mg/kg. If analyses results exceed the trigger values, SJRWMD will immediately contact USFWS. After one year of data results, routine monitoring will cease unless the project team, consisting of staff from USACOE, USFWS and SJRWMD determine otherwise.

Contingency plan for dewatering

If fish trigger values are exceeded, or if unusual bird mortality occurs, SJRWMD will coordinate with USACOE and USFWS to determine whether dewatering of the system is prudent. A network of field ditches and canals are in place that facilitates dewatering of the fields. If it is necessary to drain any of the project areas, the main pump station has three diesel pumps (each with 35,000 gpm capacity), and one electric pump (50,000 gpm capacity). By around mid-2012, a pump located at Interceptor and Lake Level Canal will be capable of pumping 30,000 gpm.

Hazing Plan

If fish trigger values are exceeded, or if unusual bird mortality occurs, SJRWMD will coordinate with USACOE and USFWS to determine whether bird hazing is necessary. If it is necessary to discourage bird use of the site, SJRWMD has contracted with personnel from the USDA who possess the necessary federal permits to haze migratory and endangered birds. Alternatively, raising or lowering water levels may be sufficient action to cause species of concern to leave the site.

4.0 Conclusions

NSRA Phases 3, 4, 5, and 8 comprise approximately 3,900 acres located in the former Zellwood Drainage and Water Control District property. Soil organochlorine pesticide (OCP) concentrations in the hydrologically-connected field units of Phase 3 North, Phase 4, and Phase 5 North present a low mortality risk to avian piscivores. The calculated hazard quotients (HQs) for all fields are below 1 (indicating low risk to fish-eating birds) for predicted fish concentrations of DDTr, dieldrin, toxaphene, and chlordanes. The calculated HQ level for DDE–for reproductive effects–is 1.24 in one field of Phase 5, but is <1 for all other fields. The overall acreage-weighted HI for the combined phases is 0.94. This suggests that risk of avian mortality is low.

Soil OCP concentrations in all three fields of Phase 3 South present a low mortality risk to fish-eating birds. Calculated HQs are below 1 for predicted fish concentrations of DDE, DDTr, dieldrin, toxaphene and chlordanes. The overall acreage-weighted HI for the three hydrologically-connected fields is 1.26.

Soil OCP concentrations in all fields of Phase 5 South present a low mortality risk to fish-eating birds. The HQ for DDE, representing reproductive effects, ranges from 1.0 to 1.7. The overall acreage-weighted HI for Phase 5 South is 1.53.

Phase 8 will be the last area flooded. Under normal operating conditions, with a maximum flooding elevation of 61 ft NGVD29, one large field unit, formerly known as Bass Sod Farm, will remain dry. Soil OCP concentrations in Phase 8 are generally low. However, this phase presents challenges . The HQ for all fields for predicted fish concentrations of DDE are >1, and indeed, are 4.1 and 4.3 for two fields and 1.48 and 2.79 for the remaining two fields. The HQs are below 1 for predicted fish concentrations of DDTr, toxaphene, and chlordanes. However, in two field units, the HQ for dieldrin is 1.46 and 1.24. The HI for three of the fields is >1 but <2. For one field, the HI is 4.23. The overall acreage-weighted HI for Phase 8 is 1.95; however, when the sod farm is removed from the calculation, the overall acreage-weighted HI for Phase 8 increases to 2.28.

Routine monitoring of whole fish for OCPs will stop after one year of data collection unless the project team determines that continued monitoring is necessary.

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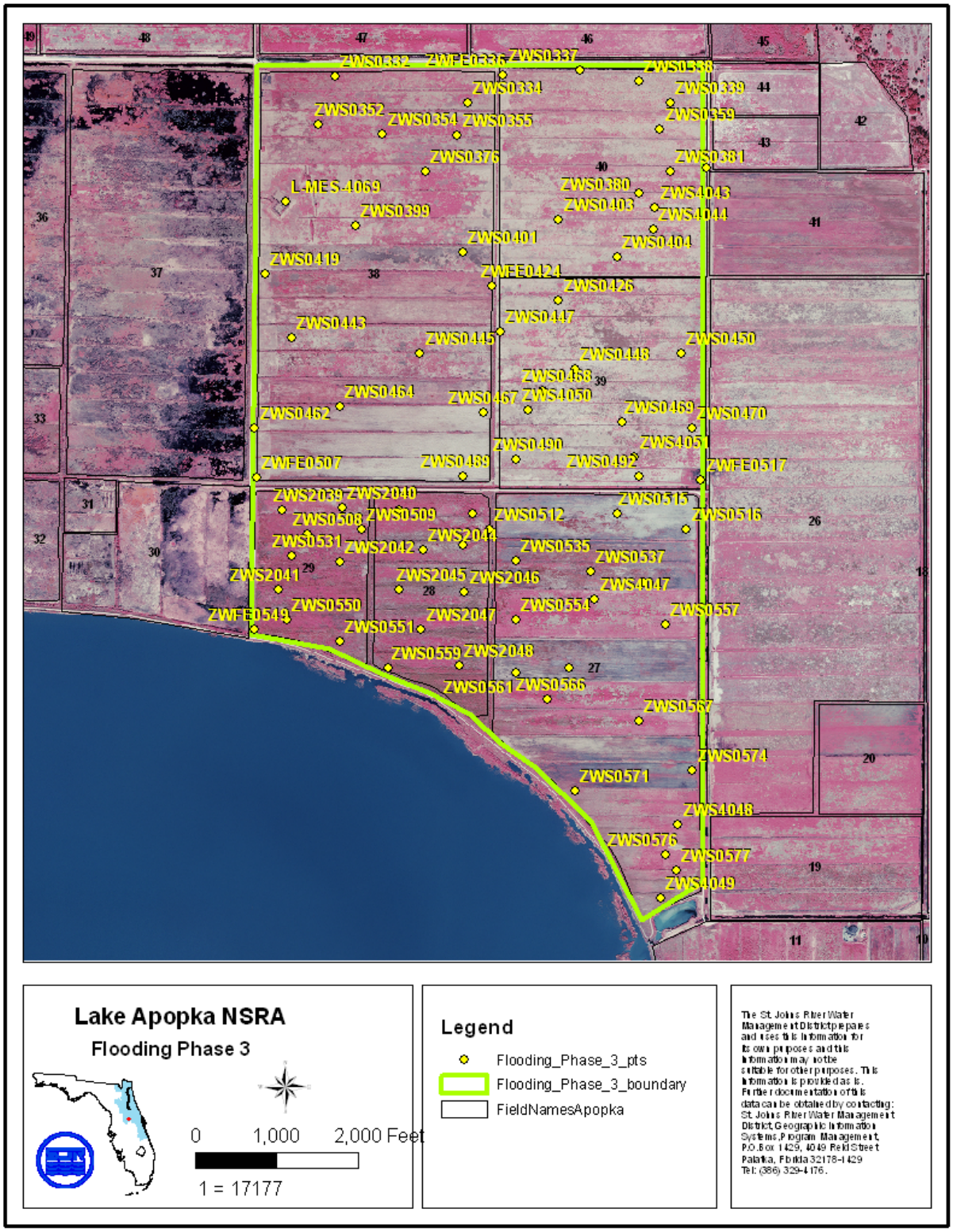
Appendix 1. Soil sampling locations at NSRA Phases 3, 4, 5, and 8 collected in 2007-2008.



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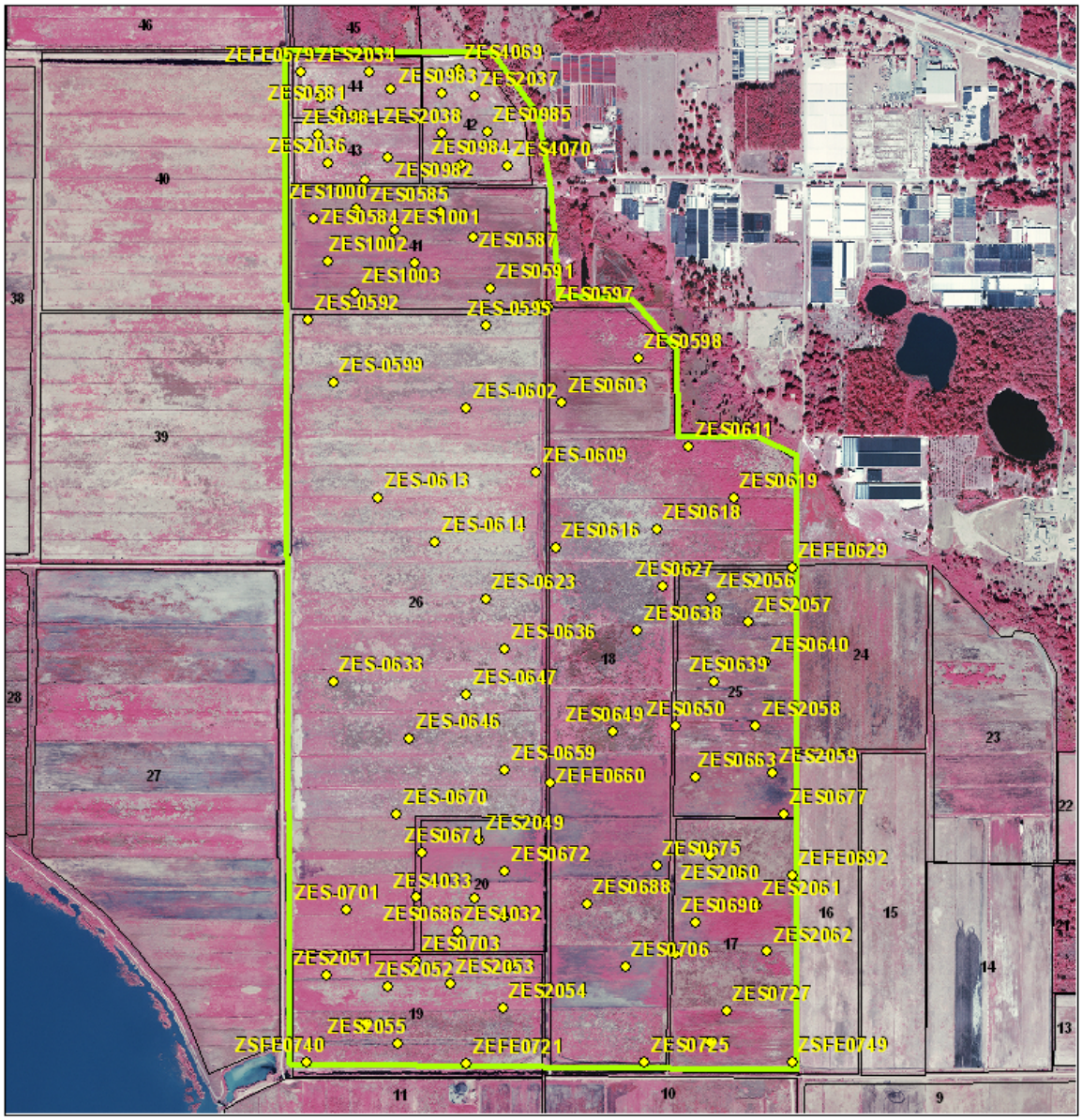


Lake Apopka NSRA

Flooding Phase 4

0 1,000 2,000 Feet

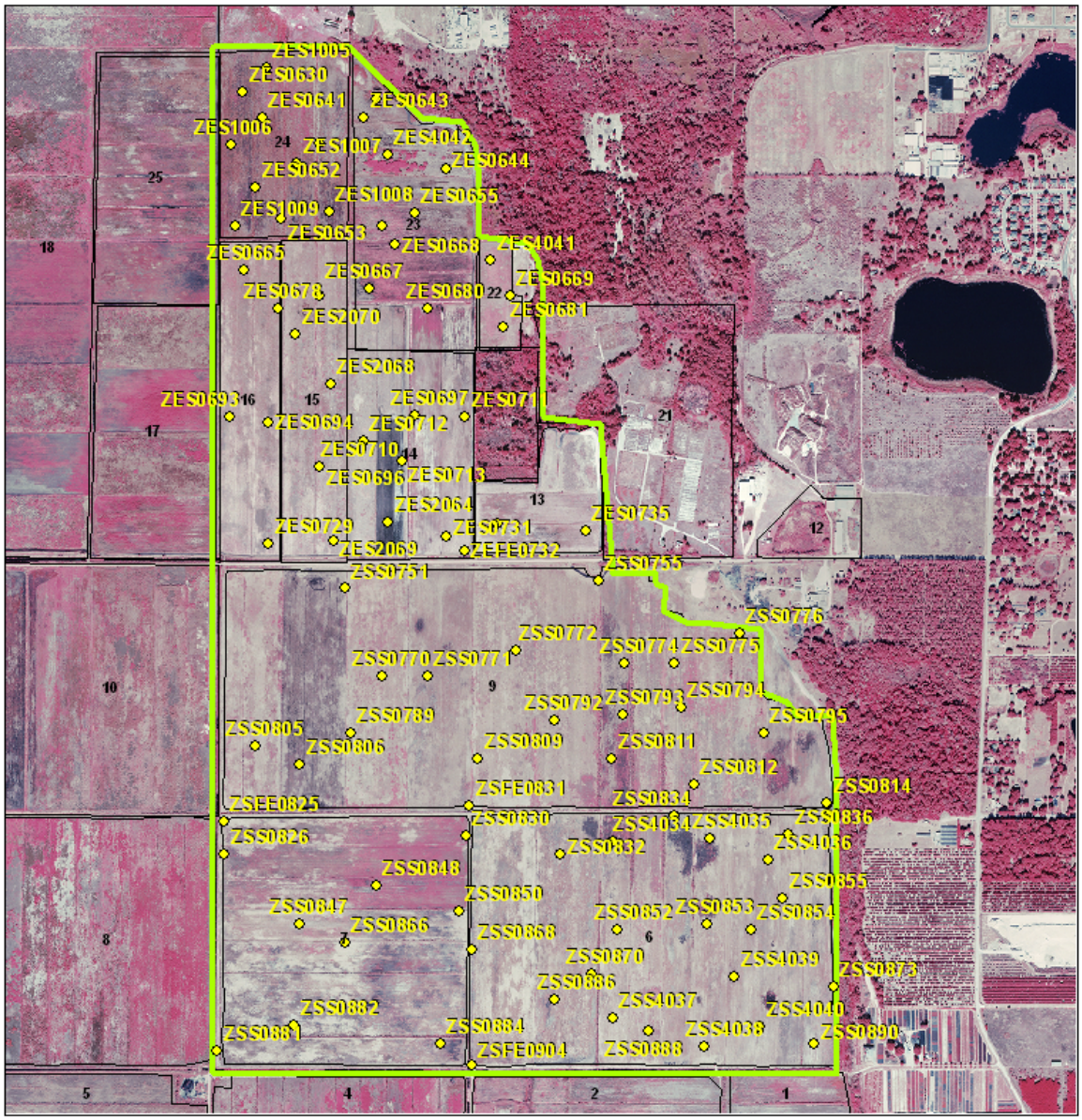
1 = 17056

Legend

- Flooding_Phase_4_pts
- Flooding_Phase_4_boundary
- FieldNamesApopka

The St. Johns River Water Management District prepares and uses this information for its own purposes and this information may not be suitable for other purposes. This information is provided as is. Further documentation of this data can be obtained by contacting: St. Johns River Water Management District, Geographic Information Systems, Program Management, P.O. Box 1429, 4049 Reid Street Palatka, Florida 32178-1429 Tel: (386) 329-4176.

Author:cgbrown , Source:G:\ARCMAP\NSRA flooding phases.mxd, Time:7/15/2009 9:20:17 AM



Lake Apopka NSRA

Flooding Phase 5

0 1,000 2,000 Feet

1 = 17056

Legend

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- Flooding_Phase_5_boundary
- FieldNamesApopka

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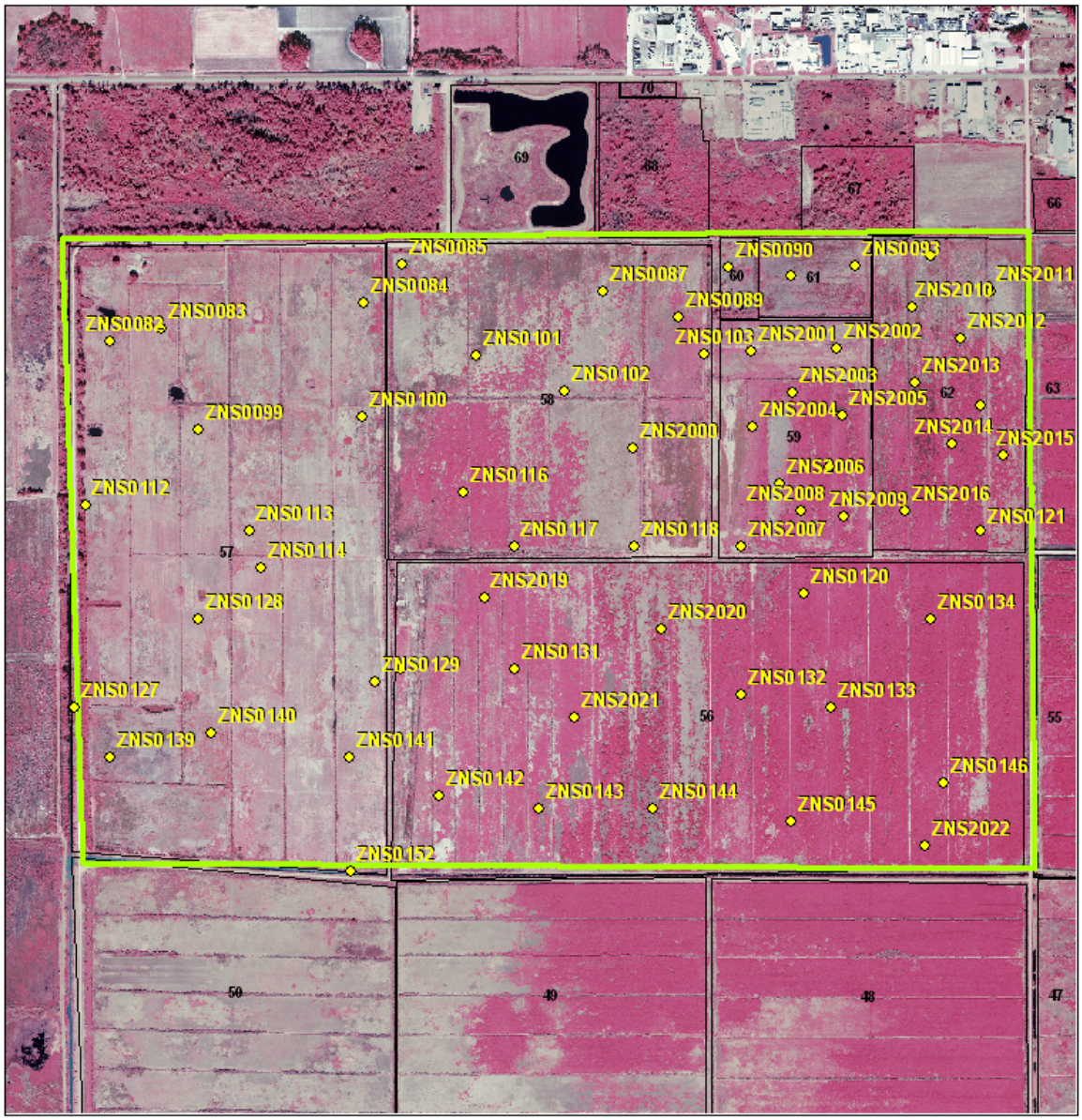
Author:cgbrown , Source:G:\ARCMAP\NSRA flooding phases.mxd, Time:7/15/2009 9:20:17 AM



Lake Apopka NSRA

Flooding Phase 8

0 750 1,500 Feet

1 = 13571

Legend

- Flooding_Phase_8_pts
- Flooding_Phase_8_boundary
- FieldNamesApopka

The St. Johns River Water Management District prepares and uses this information for its own purposes and this information may not be suitable for other purposes. This information is provided as is. Further documentation of this data can be obtained by contacting: St. Johns River Water Management District, Geographic Information Systems, Program Management, P.O. Box 1429, 4049 Reid Street Palatka, Florida 32178-1429 Tel: (386) 329-4176.

Author:cgbrown , Source:G:\ARCMAP\NSRA flooding phases.mxd, Time:7/15/2009 9:20:17 AM

Appendix 2. Raw data for Phases 3, 4, 5, and 8 soil samples. Data qualifier codes are defined at end of tables.

DDTr represents DDT equivalents *sensu* Stickel et al. (1970), where DDTr=(DDD/5)+(DDE/15)+DDT. DDTX is the sum of DDD+DDE+DDT.

Phase 3:

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)	alpha-BHC (ug/kg)
L-MES-4069	161.0	618.0	43.3 JN, P	116.7 JN, P	822.3 JN, P	2.8 IJN, P	0.0 U
ZEFE0583	83.1 JN, P	969.0 J	46.8 JN, P	128.0 JN, PJJN, P	1098.9 JJN, PJN, PJJN, P	0.6 UJN, P	0.0 UJN, P
ZWFE0336	14.4 IJN, P	492.0 J	51.8 JN, P	87.5 IJN, PJJN, P	558.2 JJN, PIJN, PJJN, P	0.9 UJN, P	0.1 UJN
ZWFE0424	67.2 J, JN, P	668.0 J	31.2 JN, P	89.2 J, JN, PJJN, P	766.4 J, JN, PJJN, P	4.0 IJN, P	0.0 U
ZWFE0507	101.0 P	663.0	55.4 P	119.8 PP	819.4 PP	2.3 IJN, P	0.0 U
ZWFE0517	37.0	219.0 J	20.7	42.7 J	276.7 JJ	1.9 IJN, P	0.2 UJN
ZWFE0549	17.0 JV	470.0	32.0 JV	66.7 JVJV	519.0 JVJV	1.3 IJN	0.0 U
ZWS0332	180.0	1200.0	47.0 JNP	163.0 JNP	1427.0 JNP	3.2 UJNP	0.0 U
ZWS0334	209.0 JN, P	993.0	443.0	551.0 JN, P	1645.0 JN, P	4.6 JN, P	0.0 U
ZWS0337	0.9 UP	18.0 V	7.9	9.3 UPV	26.8 UPV	0.1 UJNP	0.0 U
ZWS0338	315.0	604.0 J	111.0 JN, P	214.3 JJN, P	1030.0 JJN, PJJN, P	0.5 UJN, P	0.0 U
ZWS0339	263.0	443.0 J	123.0	205.1 J	829.0 JJ	0.2 UJN, P	0.0 U
ZWS0352	250.0	1200.0	100.0 JNP	230.0 JNP	1550.0 JNP	3.6 UJNP	0.0 U
ZWS0354	86.0 JN, P	980.0	39.8 JN, P	122.3 JN, PJN, P	1105.8 JN, PJN, P	2.0 IJN, P	0.2 UJN, P
ZWS0355	130.0	1200.0	57.0 JNP	163.0 JNP	1387.0 JNP	1.7 UJNP	0.0 U
ZWS0359	344.0	640.0 J	117.0 JN, P	228.5 JJN, P	1101.0 JJN, PJJN, P	1.5 UJN, P	0.0 U
ZWS0376	210.0	1200.0	62.0 JNP	184.0 JNP	1472.0 JNP	1.8 UJNP	0.0 U
ZWS0380	73.0	730.0	46.0 P	109.3 P	849.0 P	0.9 UJNP	0.0 U
ZWS0381	118.0 P	516.0 J	86.9 JN, P	144.9 PJJN, P	720.9 JJN, PPJJN, P	0.3 UJN, P	0.0 UJN, P
ZWS0399	300.0	2000.0	110.0 JNP	303.3 JNP	2410.0 JNP	2.5 UJNP	0.0 U

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)	alpha-BHC (ug/kg)
ZWS0401	110.0	1100.0	44.0 JNP	139.3 JNP	1254.0 JNP	2.2 IJNP	0.0 U
ZWS0403	41.0	780.0	180.0	240.2	1001.0	0.9 UJNP	0.6 UJNP
ZWS0404	14.5 JN, P	127.0 J	13.0 JN, P	24.4 JN, PJJN, P	154.5 JJN, PJN, PJJN, P	0.3 UJN, P	0.0 U
ZWS0419	7.7 P	76.4	5.1 IP	11.7 PIP	89.2 PIP	0.6 UJN	0.0 U
ZWS0426	17.2 JN, P	217.0 J	27.8	45.7 JN, PJ	262.0 JJN, PJ	0.9 U	0.0 UJN, P
ZWS0443	380.0 P	1700.0	210.0 P	399.3 PP	2290.0 PP	4.4 IJNP	0.0 U
ZWS0445	91.0	1500.0	54.0 P	172.2 P	1645.0 P	3.7 IJNP	0.0 U
ZWS0447	69.0 JN, P	885.0 J	184.0	256.8 JN, PJ	1138.0 JJN, PJ	4.1 IJN, P	0.0 U
ZWS0448	174.0	611.0 J	113.0	188.5 J	898.0 JJ	2.6 IJN, P	0.0 UJN, P
ZWS0450	1650.0	2080.0 J	351.0	819.7 J	4081.0 JJ	20.5 JN	0.0 U
ZWS0462	46.7 JN, P	433.0	34.2 JN, P	72.4 JN, PJN, P	513.9 JN, PJN, P	5.1	0.0 U
ZWS0464	60.0 JN, P	501.0	33.1 JN, P	78.5 JN, PJN, P	594.1 JN, PJN, P	4.6	0.0 U
ZWS0467	55.3 JN, P	501.0	22.5 JN, P	67.0 JN, PJN, P	578.8 JN, PJN, P	3.0 I	0.0 U
ZWS0468	66.7 JN, P	682.0 J	101.0	159.8 JN, PJ	849.7 JJN, PJ	3.6 IJN, P	0.0 U
ZWS0469	300.0	850.0	170.0	286.7	1320.0	9.3 I	0.0 U
ZWS0470	79.0	470.0	61.0	108.1	610.0	4.3 I	0.0 U
ZWS0489	55.4 JN, P	425.0	97.1	136.5 JN, P	577.5 JN, P	4.4 I	0.0 U
ZWS0490	52.0	560.0	66.0	113.7	678.0	4.3 I	0.0 U
ZWS0492	121.0	649.0 J	87.2	154.7 J	857.2 JJ	5.3 IJN, P	0.0 UJN, P
ZWS0508	56.0	360.0	61.0	96.2	477.0	0.9 UJN	0.0 U
ZWS0509	84.0	730.0	56.0 P	121.5 P	870.0 P	1.4 IJN	0.0 U
ZWS0511	67.0	520.0	41.0 P	89.1 P	628.0 P	5.2 IJN	0.3 UJNP
ZWS0512	65.0	540.0	52.0 P	101.0 P	657.0 P	1.3 IJNP	0.3 UJNP
ZWS0515	242.0 P	1160.0	240.0	365.7 P	1642.0 P	15.6 JN	0.4 UJN, P
ZWS0516	116.0 P	1000.0	105.0 IJN, P	194.9 PIJN, P	1221.0 PIJN, P	8.5 JN, P	0.6 UJN, P
ZWS0531	98.0	610.0	96.0	156.3	804.0	1.5 IJN	0.0 U
ZWS0534	27.0 P	360.0	33.0 P	62.4 PP	420.0 PP	1.1 UJN	0.5 UJNP
ZWS0535	85.9 JN, P	728.0	154.0	219.7 JN, P	967.9 JN, P	3.5 IJN, P	0.5 UJN, P
ZWS0537	136.0 JN, P	505.0	157.0	217.9 JN, P	798.0 JN, P	3.3 IJN, P	0.3 UJN, P
ZWS0538	99.6 JN, P	553.0	121.0	177.8 JN, P	773.6 JN, P	2.8 IJN, P	0.4 UJN, P
ZWS0550	48.0 P	670.0	81.0 P	135.3 PP	799.0 PP	1.5 IJNP	0.0 U

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)	alpha-BHC (ug/kg)
ZWS0551	23.0 PV	680.0	92.0 V	141.9 PVV	795.0 PVV	0.7 UJNP	0.4 UJNP
ZWS0554	210.0	1200.0	2600.0	2722.0	4010.0	6.4 IJNP	0.0 U
ZWS0557	170.0	890.0	81.0 P	174.3 P	1141.0 P	5.1 IJNP	0.0 U
ZWS0559	15.0 I	270.0	18.0 I	39.0 II	303.0 II	0.6 UJNP	0.0 U
ZWS0561	0.0 U	364.0	79.2 JN, P	103.5 UJN, P	443.2 UJN, P	5.1 I	0.1 UJN, P
ZWS0562	75.5 JN, P	521.0	141.0	190.8 JN, P	737.5 JN, P	3.5 IJN, P	0.0 U
ZWS0566	86.0 JNP	850.0	91.0 P	164.9 JNPP	1027.0 JNPP	5.3 IJNP	0.0 U
ZWS0567	210.0 I	1500.0	89.0 IP	231.0 IIP	1799.0 IIP	9.5 JNP	0.0 U
ZWS0571	37.0	650.0	19.0 IJNP	69.7 IJNP	706.0 IJNP	4.1 IJNP	0.0 U
ZWS0574	72.2 JN, P	1090.0	124.0 JN, P	211.1 JN, PJN, P	1286.2 JN, PJN, P	5.0 IJN, P	0.0 U
ZWS0576	92.0	850.0	47.0 P	122.1 P	989.0 P	2.1 IJNP	0.0 U
ZWS0577	29.0	540.0	24.0 P	65.8 P	593.0 P	4.1 I	0.0 UJNP
ZWS2039	120.0	740.0	100.0	173.3	960.0	1.9 IJN	0.0 U
ZWS2040	120.0	750.0	120.0	194.0	990.0	1.9 IJNP	0.0 U
ZWS2041	68.0	670.0	94.0	152.3	832.0	1.1 UJN	0.0 U
ZWS2042	19.0	300.0	41.0	64.8	360.0	0.5 UJN	0.0 U
ZWS2043	40.0	290.0	28.0 P	55.3 P	358.0 P	1.5 IJN	0.1 UJNP
ZWS2044	46.0	420.0	71.0	108.2	537.0	1.3 IJNP	1.0 UJNP
ZWS2045	79.0	1100.0	94.0	183.1	1273.0	1.8 IJN	0.0 U
ZWS2046	100.0	670.0	490.0	554.7	1260.0	2.4 IJN	0.0 U
ZWS2047	20.0 P	530.0	55.0	94.3 P	605.0 P	1.3 IJNP	0.0 U
ZWS2048	28.0 P	440.0	87.0	121.9 P	555.0 P	1.3 UJN	0.0 U
ZWS4043	182.0 C2	764.0	70.2 C2, JN	157.5 C2C2, JN	1016.2 C2C2, JN	4.5 IC2, JN	0.7 UC2, JN
ZWS4044	113.0 C2	661.0	90.5 C2, JN	157.2 C2C2, JN	864.5 C2C2, JN	2.7 UC2, JN	0.0 U
ZWS4047	211.0 JN, P	1310.0	363.0	492.5 JN, P	1884.0 JN, P	9.2 IJN, P	0.0 U
ZWS4048	47.1 JN, P	1060.0	191.0 JN, P	271.1 JN, PJN, P	1298.1 JN, PJN, P	5.3 IJN, P	0.2 UJN, P
ZWS4049	53.5	469.0	745.0	787.0	1267.5	1.0 I	0.0 U
ZWS4050	98.5	652.0	80.5	143.7	831.0	6.1 I	0.0 U
ZWS4051	210.0	763.0	130.0	222.9	1103.0	9.2 IJN, P	0.0 U

Site Name	alpha-Chlordane (ug/kg)	beta-BHC (ug/kg)	cis-Nonachlor (ug/kg)	delta-BHC (ug/kg)	Dieldrin (ug/kg)	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)
L-MES-4069	23.7 P	1.2 UJN, P	35.0 JN, P	0.7 UJN, P	99.2 P	15.2 IJN, P	111.0 JN, P	11.2 JN
ZEFE0583	95.5	0.2 UJN, P	29.9 JN, P	2.1 UJN, P	166.0 P	37.0 JN, P	116.0 J, JN, P	4.1 UJN, P
ZWFE0336	34.5	0.0 U	14.7 JN, P	0.5 UJN, P	71.1 P	14.5 JN, P	50.2 J, JN, P	1.6 UJN, P
ZWFE0424	65.4 J	0.0 U	21.4 IJN, P	0.0 U	355.0 J	9.8 JN, P	73.6 J, JN, P	4.7 UJN, P
ZWFE0507	113.0	0.0 U	55.5	0.0 U	381.0	14.8 JN, P	172.0 JN	10.7 IJN, P
ZWFE0517	19.1	0.1 UJN, P	9.1	0.3 UJN, P	163.0	3.3 JN, P	13.5 J, JN, P	0.5 UJN, P
ZWFE0549	14.0	0.0 U	19.0	0.0 UJ	46.0 P	0.0 UJ	0.0 UJ	0.0 UJ
ZWS0332	190.0	0.0 U	51.0 IJNP	0.0 U	250.0 P	18.0 UJNP	330.0 JNP	0.0 U
ZWS0334	63.0 P	0.0 U	83.3 JN, P	0.7 UJN, P	221.0 P	30.6 IJN, P	196.0 JN, P	0.0 U
ZWS0337	0.0 U	0.0 U	0.1 UJNP	0.3 UJNP	0.4 UP	0.0 UJNP	0.2 UJNP	0.0 U
ZWS0338	73.8	0.8 UJN, P	38.1 JN, P	1.7 UJN, P	212.0	0.0 U	163.0 J, JN	7.7 UJN
ZWS0339	55.3	0.8 UJN, P	24.9 JN, P	1.4 UJN, P	182.0	18.3 JN, P	111.0 J, JN	4.8 UJN
ZWS0352	170.0	0.5 UJNP	92.0 IJNP	0.0 U	360.0	13.0 UJNP	540.0 JN	46.0 JN
ZWS0354	57.4 P	0.0 U	42.5 JN, P	0.0 U	139.0 P	10.5 UJN, P	144.0 JN, P	11.8 JN, P
ZWS0355	93.0 P	0.0 U	61.0 IJNP	0.0 U	250.0 P	15.0 UJNP	230.0 JNP	0.0 U
ZWS0359	73.1	1.9 UJN, P	41.3 JN	1.3 UJN, P	212.0	33.0 JN, P	171.0 J, JN	6.5 UJN, P
ZWS0376	160.0	0.0 U	52.0 IJNP	0.0 U	380.0	13.0 UJNP	330.0 JNP	24.0 IJNP
ZWS0380	23.0	0.0 U	15.0 JNP	1.7 UJNP	70.0 P	2.0 UJNP	51.0 JNP	0.0 U
ZWS0381	83.8	0.8 UJN, P	29.8 JN, P	1.3 UJN, P	139.0 P	23.3 JN, P	130.0 J, JN, P	6.3 UJN
ZWS0399	280.0	0.0 U	110.0 JNP	0.0 U	440.0	21.0 UJNP	530.0 JN	38.0 JN
ZWS0401	130.0	0.0 U	60.0 JNP	0.0 U	220.0 P	12.0 UJNP	190.0 JNP	0.0 U
ZWS0403	24.0	0.5 UJNP	26.0	0.0 U	61.0 P	3.5 IJNP	34.0 JN	0.0 U
ZWS0404	15.7	0.3 UJN, P	6.1 JN, P	0.4 UJN, P	35.5 P	4.2 IJN, P	23.9 J, JN, P	1.1 UJN
ZWS0419	13.7	0.0 U	7.6	0.0 U	54.4	1.2 IJN, P	11.7 JN, P	0.5 UJN, P
ZWS0426	24.8	0.0 U	7.6 JN, P	0.2 UJN, P	225.0	3.9 IJN, P	17.0 J, JN, P	0.8 UJN, P
ZWS0443	270.0	0.4 UJNP	120.0 JNP	0.0 U	910.0	24.0 UJNP	490.0 JN	35.0 JN
ZWS0445	120.0	0.0 U	43.0 IJNP	0.0 U	720.0	6.5 UJNP	150.0 IJNP	0.0 U
ZWS0447	98.3	0.0 U	50.3	0.3 UJN, P	732.0	20.7 JN, P	73.9 J, JN, P	3.3 UJN, P
ZWS0448	90.8	0.4 UJN, P	47.0	0.5 UJN, P	640.0	19.5 JN, P	76.9 J, JN, P	3.5 UJN, P
ZWS0450	186.0	5.7 UJN	71.9	0.8 UJN, P	775.0	41.6 JN, P	137.0 J, JN, P	8.8 UJN, P
ZWS0462	32.7 P	0.0 U	21.8 JN, P	0.0 U	212.0	4.8 UJN, P	67.6 JN, P	8.5 JN
ZWS0464	54.5	0.0 U	21.3 JN, P	0.0 U	164.0 P	5.9 JN, P	56.2 JN, P	5.4 IJN, P
ZWS0467	51.9	0.0 U	13.8	0.0 U	263.0	6.4 JN, P	37.7 JN, P	0.0 U
ZWS0468	94.6	0.2 UJN, P	53.5	0.3 UJN, P	819.0	17.3 JN, P	72.7 J, JN, P	3.3 UJN, P
ZWS0469	57.0 JNP	0.0 U	49.0	1.3 UJNP	580.0	0.0 U	0.0 U	0.0 U
ZWS0470	29.0 P	0.0 U	21.0	0.3 UJNP	310.0	0.0 U	0.0 U	0.0 U
ZWS0489	55.5	0.0 U	20.6	0.0 U	252.0	6.0 JN, P	33.7 JN, P	0.0 U

Site Name	alpha-Chlordane (ug/kg)	beta-BHC (ug/kg)	cis-Nonachlor (ug/kg)	delta-BHC (ug/kg)	Dieldrin (ug/kg)	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)
ZWS0490	51.0	0.0 U	25.0	0.0 U	380.0	0.0 U	0.0 U	0.0 U
ZWS0492	80.4	0.2 UJN, P	40.2	0.7 UJN, P	669.0	14.8 JN, P	59.0 J, JN, P	1.7 UJN, P
ZWS0508	36.0	0.0 U	18.0 P	0.0 U	170.0	0.0 U	33.0 JNP	0.0 U
ZWS0509	69.0	7.4 JNP	50.0	0.0 U	320.0	0.0 U	52.0 JNP	0.0 U
ZWS0511	59.0	0.0 U	39.0	0.0 U	350.0	0.0 U	24.0 JNP	0.0 U
ZWS0512	58.0	0.0 U	30.0 P	0.0 U	350.0	0.0 U	30.0 JNP	0.0 U
ZWS0515	274.0	0.8 UJN, P	80.4 JN, P	0.0 U	1310.0	36.1 IJN, P	264.0 JN, P	0.0 U
ZWS0516	161.0	0.0 U	74.7	0.0 U	534.0 P	23.9 IJN, P	113.0 IJN, P	0.0 U
ZWS0531	35.0	0.0 U	23.0 P	0.0 U	250.0	0.0 U	62.0 JNP	0.0 U
ZWS0534	45.0	0.0 U	22.0 P	0.0 U	250.0	0.0 U	19.0 JNP	0.0 U
ZWS0535	165.0	0.0 U	49.6 JN, P	0.0 U	684.0	10.4 JN, P	179.0 JN	11.6 IJN
ZWS0537	126.0	0.0 U	39.0 JN, P	0.0 U	405.0	11.9 JN, P	163.0 JN	11.1 IJN
ZWS0538	122.0	0.0 U	37.9 JN, P	0.0 U	420.0	8.9 JN, P	115.0 JN, P	8.6 IJN
ZWS0550	53.0	0.0 U	44.0 P	0.0 U	270.0	0.0 U	84.0 JNP	0.0 U
ZWS0551	44.0 P	0.0 U	42.0	0.0 U	63.0 P	9.3 JN	0.0 U	0.0 U
ZWS0554	190.0	0.0 U	34.0 UJNP	0.0 U	910.0	12.0 IJNP	320.0 JN	0.0 U
ZWS0557	150.0	0.0 U	22.0 IJNP	0.0 U	600.0	12.0 UJNP	150.0 JNP	0.0 U
ZWS0559	3.4 I	0.0 U	3.0 IP	0.0 U	35.0 P	0.0 U	5.2 IJNP	0.1 UJNP
ZWS0561	105.0	0.0 U	36.3 JN, P	0.6 UJN, P	372.0	0.0 U	99.2 JN, P	5.2 UJN, P
ZWS0562	159.0	0.0 U	49.0 JN, P	1.0 UJN, P	497.0	0.0 U	160.0 JN	12.1 IJN
ZWS0566	220.0	0.0 U	34.0 IJNP	0.0 U	630.0	7.3 UJNP	290.0 JNP	0.0 U
ZWS0567	320.0	0.0 U	32.0 IJNP	0.0 U	830.0	18.0 UJNP	320.0 JNP	0.0 U
ZWS0571	62.0	0.0 U	8.5 IJNP	0.0 U	90.0 P	3.1 UJNP	51.0 JNP	0.0 U
ZWS0574	227.0	0.0 U	58.0 JN, P	0.8 UJN, P	588.0	18.2 IJN, P	190.0 JN, P	11.1 JN, P
ZWS0576	82.0	0.0 U	15.0 JNP	0.0 U	100.0 IP	3.2 IJNP	58.0 JNP	0.0 U
ZWS0577	46.0	0.0 U	8.8 IJNP	0.0 U	120.0 P	1.4 UJNP	29.0 JNP	0.0 U
ZWS2039	84.0	1.8 UJN	42.0 P	0.0 U	290.0	0.0 U	76.0 JNP	0.0 U
ZWS2040	91.0	0.0 U	43.0 P	0.0 U	310.0	0.0 U	68.0 JNP	0.0 U
ZWS2041	38.0	0.4 UJNP	33.0 P	0.0 U	240.0	0.0 U	63.0 JNP	0.0 U
ZWS2042	11.0	0.1 UJNP	9.8	0.0 U	90.0	0.0 U	13.0 IJNP	0.0 U
ZWS2043	32.0	0.0 U	16.0 P	0.0 U	210.0	0.0 U	16.0 JNP	0.0 U
ZWS2044	50.0	0.0 U	28.0 P	0.0 U	260.0	0.0 U	25.0 JNP	0.0 U
ZWS2045	45.0	0.1 UJNP	36.0 P	0.0 U	420.0	0.0 U	85.0 JNP	0.0 U
ZWS2046	42.0	0.0 U	29.0 P	0.0 U	430.0	0.0 U	74.0 JNP	2.7 IJNP
ZWS2047	24.0	0.0 U	19.0 P	0.0 U	310.0	0.0 U	32.0 JNP	5.1 IJN
ZWS2048	9.1	0.1 UJNP	13.0 P	0.0 U	300.0	0.0 U	29.0 JNP	0.0 U
ZWS4043	106.0	0.2 UC2, JN	41.2 C2	0.0 U	165.0 C2	21.0 C2, JN	140.0 C2, JN	7.5 UC2, JN

Site Name	alpha-Chlordane (ug/kg)	beta-BHC (ug/kg)	cis-Nonachlor (ug/kg)	delta-BHC (ug/kg)	Dieldrin (ug/kg)	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)
ZWS4044	92.1	0.0 U	42.6 C2	0.0 U	158.0 C2	10.3 IC2, JN	134.0 C2, JN	7.6 UC2, JN
ZWS4047	295.0	0.8 UJN, P	128.0	1.3 UJN, P	1300.0	20.6 UJN, P	414.0 JN	26.9 JN, P
ZWS4048	192.0	0.0 U	70.9 JN, P	0.0 U	280.0 P	9.3 JN, P	115.0 IJN, P	6.1 UJN, P
ZWS4049	32.8	0.0 U	13.1 P	0.1 UJN, P	16.6 IP	1.3 IJN, P	6.6 JN, P	2.7 IJN
ZWS4050	84.3	0.0 U	43.6	0.0 U	768.0	8.0 IJN, P	58.5 JN, P	3.8 UJN, P
ZWS4051	126.0	0.2 UJN, P	56.1	0.0 U	824.0	12.5 JN, P	92.7 JN, P	4.7 UJN, P

Site Name	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)
L-MES-4069	0.0 U	101.0 JN, P	15.4 JN, P	1.0 UJN, P	32.9	1.4 IJN, P	28.7 JN	38.0 IJN, P
ZEFE0583	9.1 IJN, P	75.8 UJN, P	3.3 UJN, P	0.2 UJN, P	26.6 JN, P	1.4 UJN	40.1 JN	16.3 UJN, P
ZWFE0336	1.2 UJN, P	28.1 JN, P	0.9 UJN, P	0.1 UJN, P	12.7 JN	0.7 UJN, P	11.6 JN, P	11.8 UJN, P
ZWFE0424	0.0 UJ	0.0 UJ	10.4 J, JN, P	0.0 U	45.8 J	0.5 UJN	22.5 JN	22.5 IJN, P
ZWFE0507	0.0 U	52.6 UJN, P	12.8 IJN	0.4 UJN, P	61.4	1.4 UJN, P	29.5 JN	23.1 UJN, P
ZWFE0517	0.6 UJN, P	9.3 JN, P	1.0 UJN, P	0.0 UJN, P	14.2	0.9 IJN	3.6 JN, P	4.3 UJN
ZWFE0549	0.0 UJ	0.0 UJ	4.5 IJN	0.0 UJ	9.9 JNP	0.7 IJN	0.0 UJ	0.0 UJ
ZWS0332	0.0 U	0.0 U	37.0 JNP	0.5 UJNP	46.0	1.8 UJNP	68.0 JN	110.0 IJNP
ZWS0334	0.0 U	150.0 JN, P	39.4 JN	0.3 UJN, P	89.0	0.7 UJN, P	57.2 JN	51.9 JN, P
ZWS0337	0.5 UJNP	1.2 UJN	0.8 UJN	0.1 UJNP	0.0 U	0.2 UJNP	0.0 U	1.1 UJNP
ZWS0338	14.3 IJN, P	97.1 JN, P	11.7 IJN	0.0 UJN, P	25.4 JN, P	0.8 UJN, P	28.3 JN	21.0 UJN, P
ZWS0339	7.4 IJN, P	64.3 JN, P	8.1 IJN	0.1 UJN, P	19.7 JN	2.3 UJN	22.7 JN	23.6 UJN, P
ZWS0352	0.0 U	0.0 U	58.0 JNP	0.5 UJNP	44.0	1.3 UJNP	62.0 JNP	200.0 JNP
ZWS0354	0.0 U	122.0 JN, P	18.1 JN, P	0.0 U	33.5	0.3 UJN, P	37.7 JN	29.1 IJN, P
ZWS0355	0.0 U	0.0 U	29.0 JNP	0.1 UJNP	59.0	1.2 UJNP	48.0 JN	85.0 JNP
ZWS0359	13.1 IJN, P	104.0 JN, P	8.9 IJN, P	0.3 UJN, P	31.5 JN	1.3 UJN, P	29.1 JN, P	21.2 UJN, P
ZWS0376	0.0 U	0.0 U	35.0 JNP	0.1 UJNP	75.0	1.3 UJNP	60.0 JN	120.0 IJNP
ZWS0380	42.0 JN	0.0 U	8.9 IJN	0.4 UJNP	6.5 IJNP	0.0 U	16.0 JN	27.0 UJNP
ZWS0381	9.8 IJN, P	87.4 JN, P	4.7 UJN, P	0.2 UJN, P	16.4 JN, P	1.3 UJN	23.7 JN	18.2 UJN, P
ZWS0399	0.0 U	0.0 U	40.0 JNP	1.2 UJNP	110.0	0.0 U	76.0 JN	170.0 JNP
ZWS0401	77.0 IJNP	0.0 U	26.0 JNP	0.2 UJNP	92.0	0.0 U	39.0 JN	73.0 JNP

Site Name	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)
ZWS0403	0.0 U	0.0 U	8.3 IJN	0.0 U	18.0	2.4 IJNP	0.0 U	34.0 IJN
ZWS0404	1.1 UJN, P	17.2 JN, P	1.1 UJN, P	0.1 UJN, P	2.8 IJN	1.0 UJN	4.1 IJN, P	9.2 UJN
ZWS0419	0.0 U	5.9 IJN, P	2.2 IJN	0.1 UJN	9.0	0.6 UJN, P	3.0 IJN	0.0 U
ZWS0426	0.8 UJN, P	12.5 JN, P	0.9 UJN, P	0.1 UJN, P	22.8	1.3 UJN	4.7 IJN, P	5.8 UJN, P
ZWS0443	0.0 U	0.0 U	37.0 JNP	1.2 UJNP	160.0	3.2 UJNP	70.0 JN	180.0 JNP
ZWS0445	48.0 JNP	0.0 U	21.0 JNP	0.1 UJNP	100.0 I	0.8 UJNP	45.0	74.0 JNP
ZWS0447	5.8 IJN, P	55.5 JN, P	5.2 IJN, P	0.1 UJN, P	92.5	1.4 UJN	21.0 JN	9.9 UJN, P
ZWS0448	7.0 IJN, P	55.3 JN, P	6.7 IJN, P	0.0 UJN, P	53.0	1.5 UJN	26.0 JN	14.0 UJN, P
ZWS0450	19.8 IJN, P	80.1 JN, P	16.4 IJN	0.5 UJN, P	117.0	2.1 UJN, P	51.7 JN, P	12.5 UJN, P
ZWS0462	0.0 U	0.0 U	12.4 JN, P	0.3 UJN, P	42.0	0.4 UJN, P	20.4 JN	26.6 IJN, P
ZWS0464	0.0 U	0.0 U	11.2 JN	0.2 UJN, P	38.5	0.9 UJN	15.7 JN	19.3 IJN, P
ZWS0467	0.0 U	0.0 U	5.6 IJN, P	0.0 U	42.5	0.5 UJN, P	15.1 JN	13.1 UJN, P
ZWS0468	6.9 IJN, P	56.6 JN, P	6.5 IJN, P	0.1 UJN, P	73.0	2.2 I	17.1 JN, P	12.1 UJN, P
ZWS0469	0.0 U	0.0 U	8.9 IJN	0.0 U	58.0	1.5 IJN	0.0 U	40.0 IJNP
ZWS0470	0.0 U	0.0 U	5.5 IJN	0.0 U	29.0	0.7 UJNP	0.0 U	30.0 IJN
ZWS0489	0.0 U	0.0 U	4.5 IJN, P	0.0 U	43.5	0.6 UJN, P	14.2 JN	9.2 UJN, P
ZWS0490	0.0 U	0.0 U	4.1 IJN	0.0 U	50.0	0.6 UJNP	0.0 U	21.0 IJNP
ZWS0492	2.6 UJN, P	44.3 JN, P	3.8 UJN, P	0.0 UJN, P	57.1	2.8 IJN	15.8 JN, P	13.1 UJN
ZWS0508	13.0 JNP	44.0 JNP	4.8 IJNP	0.1 UJNP	26.0	0.0 U	0.0 U	19.0 IJN
ZWS0509	22.0 JNP	48.0 JNP	7.0 IJN	0.0 U	62.0	0.0 U	0.0 U	31.0 IJN
ZWS0511	15.0 IJNP	12.0 IJNP	5.7 IJN	0.0 U	46.0	2.3 IJNP	0.0 U	26.0 IJNP
ZWS0512	21.0 JNP	18.0 JNP	7.3 IJN	0.0 U	46.0	0.5 UJNP	0.0 U	31.0 IJNP
ZWS0515	0.0 U	0.0 U	43.3 JN, P	0.6 UJN, P	124.0	0.9 UJN, P	58.5 JN, P	0.0 U
ZWS0516	9.1 IJN, P	0.0 U	21.5 JN	0.9 UJN	85.1	0.8 UJN, P	46.1 JN	0.0 U
ZWS0531	18.0 JNP	62.0 JNP	9.8 IJN	0.1 UJNP	27.0	0.0 U	0.0 U	36.0 IJN
ZWS0534	12.0 IJNP	41.0 JNP	4.7 IJNP	0.0 U	30.0	1.0 IJN	0.0 U	23.0 IJNP
ZWS0535	0.0 U	198.0 JN, P	24.4 JN, P, V	0.4 UJN, P	56.5	0.5 UJN	32.0 JN	58.5 IJN, P
ZWS0537	0.0 U	127.0 JN, P	19.7 JN, P, V	0.4 UJN, P	43.6	0.1 UJN, P	26.9 JN	57.3 IJN
ZWS0538	0.0 U	111.0 JN, P	18.0 JN, P, V	0.0 U	53.4	0.1 UJN, P	29.0 JN	40.5 IJN, P
ZWS0550	27.0 JNP	93.0 JNP	8.2 IJNP	0.0 U	34.0 JNP	3.4 IJN	0.0 U	57.0 IJNP
ZWS0551	0.0 U	0.0 U	8.2 IJN	0.0 U	30.0	2.3 IJNP	0.0 U	22.0 IJNP

Site Name	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)
ZWS0554	0.0 U	0.0 U	32.0 JNP	0.0 U	130.0	2.5 UJNP	57.0 JN	120.0 IJNP
ZWS0557	0.0 U	0.0 U	20.0 JNP	0.1 UJNP	94.0	0.7 UJNP	43.0 JN	59.0 IJNP
ZWS0559	2.1 UJNP	7.7 IJNP	0.4 UJNP	0.0 U	2.1 IJNPV	0.0 U	2.5 IJNP	7.0 UJN
ZWS0561	0.0 U	105.0 JN, P	16.8 JN, V	0.6 UJN	93.9	0.7 UJN	20.4 JN	10.0 UJN, P
ZWS0562	0.0 U	148.0 JN, P	19.0 JN, P, V	0.3 UJN, P	140.0	0.4 UJN, P	29.9 JN	53.7 IJN, P
ZWS0566	0.0 U	0.0 U	33.0 JNP	0.4 UJNP	140.0	0.0 U	44.0 JNP	120.0 JNP
ZWS0567	0.0 U	0.0 U	37.0 JNP	0.5 UJNP	160.0 P	0.0 U	65.0 JN	130.0 JNP
ZWS0571	0.0 U	0.0 U	7.7 UJN	0.0 U	51.0	1.8 UJN	12.0 IJNP	31.0 UJNP
ZWS0574	0.0 U	182.0 JN, P	22.6 JN, P, V	0.4 UJN, P	176.0	0.4 UJN, P	49.5 JN	53.6 JN, P
ZWS0576	0.0 U	0.0 U	9.8 IJN	0.0 U	96.0	0.3 UJNP	16.0 JNP	24.0 UJNP
ZWS0577	0.0 U	0.0 U	4.0 UJNP	0.0 U	42.0	2.2 UJNP	12.0 JN	24.0 UJNP
ZWS2039	25.0 JNP	73.0 JNP	9.4 IJN	0.2 UJNP	75.0	0.0 U	0.0 U	39.0 IJN
ZWS2040	28.0 JNP	55.0 JNP	9.1 IJN	0.0 U	70.0	0.9 IJNP	0.0 U	39.0 IJN
ZWS2041	14.0 IJNP	55.0 JNP	8.6 IJN	0.0 U	26.0 JNPV	0.4 UJNP	0.0 U	39.0 IJNP
ZWS2042	3.0 IJNP	28.0 JN	0.6 UJNP	0.2 UJNP	7.7 IJNPV	0.1 UJNP	2.9 IJNP	6.5 UJNP
ZWS2043	9.3 IJNP	4.6 IJNP	5.2 IJN	0.0 U	21.0 V	0.3 UJNP	0.0 U	8.8 UJNP
ZWS2044	12.0 IJNP	11.0 IJNP	7.7 IJNP	0.0 U	32.0	0.0 U	0.0 U	37.0 IJNP
ZWS2045	20.0 JNP	85.0 JNP	11.0 IJNP	0.0 U	29.0 JNP	0.6 UJNP	0.0 U	52.0 IJNP
ZWS2046	20.0 JNP	60.0 JNP	8.1 IJNP	0.0 U	29.0 PV	1.0 IJN	0.0 U	38.0 IJNP
ZWS2047	2.4 IJNP	44.0 JNP	3.5 IJNP	0.0 U	14.0 JNPV	0.6 UJNP	7.1 IJN	18.0 IJN
ZWS2048	2.4 IJNP	40.0 JNP	3.5 IJNP	0.2 UJNP	5.1 IJNPV	0.0 U	5.6 IJN	23.0 IJN
ZWS4043	0.0 U	14.0 UC2, JN	21.7 IC2, JN	0.2 UC2, JN	30.5 C2, JN	3.8 UC2, JN	33.5 C2	54.9 IJN
ZWS4044	0.0 U	22.9 IC2, JN, Z2	17.9 IC2, JN	0.0 U	20.6	2.2 UC2, JN	24.0	49.3 IJN
ZWS4047	0.0 U	253.0 JN, P	56.8 JN, P	0.6 UJN	163.0	0.9 UJN, P	65.2	147.0 JN
ZWS4048	9.5 IJN, P	90.7 IJN, P	19.7 JN	0.0 U	119.0	0.0 U	40.9 JN	47.2 IJN
ZWS4049	0.0 U	13.9 JN, P	3.2 IJN, P	0.0 U	30.7	0.4 UJN, P	1.6 IJN, P	13.3 IJN
ZWS4050	4.1 UJN, P	15.3 IJN, P	10.3 IJN	0.0 U	51.4	2.7 UJN	25.7	28.0 UJN
ZWS4051	0.0 U	16.1 IJN, P	18.2 IJN, P	0.0 U	76.0	2.1 UJN	35.9	41.8 UJN

Site Name	Moisture, Percent (%)	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZWS0332	58.5	33.0 JNP	89.8	420000	509.8 IJNPUJNPJNJNP	9700.0	120.0
ZWS0352	72.9	47.0 JNP	79.2	466000	516.3 IJNPUJNPJNPJNPIP	12000.0	100.0 IP
ZWS0355	71.2	19.0 UJNP	81.0	441000	353.2 PIJNPUJNPJNUJNPIP	8300.0	72.0 IP
ZWS0376	67.9	32.0 JNP	67.8	458000 A	490.3 IJNPUJNPJNJNPI	11000.0	110.0 I
ZWS0399	79.8	38.0 JNP	70.2	401000	794.0 JNPUJNJNP	11000.0	180.0
ZWS0401	70.5	18.0 IJNP	73.1	391000	431.0 JNPUJNIJNP	7700.0	92.0
ZWS0443	73.3	32.0 JNP	66.8	416000	805.2 JNPUJNPJNJNP	10000.0	150.0
ZWS0445	67.8	17.0 UJNP	44.6	307000	407.8 IJNPIUJNPUJNPI	6100.0	82.0 I
ZWS0337	70.6	0.1 UJNP	38.8	22400 I	0.6 UUJNPUUJNPUUJNP UJNP	0.0 U	0.3 UJNP
ZWS0380	65.6	8.0 IJNP	34.4	391000	84.5 JNPIJNPUJNIJNPP	2200.0	16.0 P
ZWS0403	73.3	6.4 JNP	39.1	240000	95.8 IJNPUJNPP	1900.0	19.0 P
ZWS0469	80.7	6.9 IJNP	49.6	471000	225.4 JNPIJNUIJNP	4000.0	53.0
ZWS0470	77.0	4.8 IJNP	42.8	371000	110.5 PUJNPUIJNPP	1700.0	26.0 P
ZWS0490	72.4	4.7 IJNP	49.2	320000	174.3 UJNPUIJNP	1800.0	43.0
ZWFE0549	67.5	1.5 IJNP	39.8	93300	63.1 JNPIJNUJIJNP	1000.0	18.0
ZWS0508	70.3	0.8 UJNP	25.1	231000	108.8 PUUUJNP	1600.0	28.0
ZWS0509	77.4	2.9 IJNP	61.7	239000	238.9 UUIJNP	2900.0	55.0
ZWS0531	83.6	1.9 IJNP	45.2	176000	114.9 PUUIJNP	2600.0	28.0
ZWS0550	77.9	5.1 IJNP	44.5	449000	185.5 PJNPIJNUIJNP	3200.0	46.0
ZWS0551	0.0	8.6 I	58.5	394000	183.9 PIJNPUI	1800.0	57.0
ZWS2039	0.0	7.2 JNP	52.4	225000	274.2 PUUJNP	3300.0	66.0
ZWS2040	0.0	6.7 IJNP	56.1	384000	285.6 PIJNPUIJNP	3600.0	74.0

Site Name	Moisture, Percent (%)	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZWS2041	0.0	3.4 IJNP	39.3	425000	132.8 PJNPVUJNPUIJNP	2600.0	32.0
ZWS2042	0.0	1.4 UJNP	35.6	242000	44.9 IJNPVUJNPIJNPUJNP	780.0	12.0
ZWS0511	60.1	2.7 IJNP	38.6	261000 A	199.0 IJNPUIJNP	2200.0	50.0
ZWS0512	0.0	4.4 IJNP	26.4	237000	184.9 PUJNPUIJNP	2700.0	46.0
ZWS0534	61.3	0.6 UJNP	27.2	229000	130.6 PIJNUUJNP	1800.0	32.0
ZWS0559	33.5	1.0 UJN	42.1	351000	14.6 IIPIJNPVUIJNPUJNUP	420.0 I	2.6 UP
ZWS2043	0.0	2.1 IJNP	34.2	198000	91.4 PVUJNPUIJNP	1400.0	20.0
ZWS2044	0.0	4.3 IJNP	27.9	333000	149.3 PUUIJNP	2000.0	35.0
ZWS2045	0.0	3.2 IJNP	30.9	253000	152.8 PJNPUJNPUIJNP	1300.0	39.0
ZWS2046	0.0	3.6 IJNP	30.6	292000	135.6 PPVIJNUIJNP	3100.0	31.0
ZWS2047	66.3	0.5 UJNP	39.6	317000	88.2 PJNPVUJNPIJNUJNP	1400.0	23.0
ZWS2048	46.1	1.9 UJNP	31.2	221000	40.8 PIJNPVUIJNUJNPIP	910.0	6.1 IP
ZWS0554	37.4	21.0 JNP	24.3	401000	614.5 UJNPUJNPJNJNP	11000.0	180.0
ZWS0557	51.3	17.0 JNP	37.2	423000	476.7 IJNPUJNPJNJNP	8100.0	150.0
ZWS0566	0.0	20.0 UJNP	30.7	441000	648.0 IJNPUJNPUJNP	10000.0	190.0
ZWS0567	69.1	21.0 UJNP	33.1	422000 A	868.0 IJNPPUJNUJNP	12000.0	270.0
ZWS0571	77.3	8.1 IJNP	31.3	395000	227.4 IJNPUJNIJNPIJNP	2100.0	84.0
ZWS0576	67.3	7.4 JNP	31.6	359000	316.7 JNPUJNPJNPJNP	3200.0	100.0
ZWS0577	72.2	7.5 IJNP	27.9	349000	174.5 IJNPUJNPJNIJNP	1500.0	56.0
L-MES-4069	23.3	15.0 JN, P	36.6	241000	202.3 PJN, PIJN, PJNJN, P	3940.0	65.6

Site Name	Moisture, Percent (%)	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZWFE0424	5.1	7.9 JN, P	24.6	156000 A	205.9 JIJN, PJUJNJNJN, P	2260.0	42.4
ZWFE0507	0.0	17.2 JN, P	52.0	377000 A	355.0 UJN, PJNJN, P	3380.0	77.0
ZWS0334	11.1	28.5 IJN, P	60.4	437000	424.7 PJN, PUJN, PJNIJN, P	5640.0	103.0
ZWS0354	26.3	15.0 JN, P	65.0	389000	221.4 PJN, PUJN, PJNJN, PIP	4500.0	35.0 IP
ZWS0419	11.7	1.7 IJN, P	72.5	128000 A	46.5 UJN, PIJNIJN, P	374.0	10.9
ZWS0462	0.0	8.0 JN, P	63.1	210000	162.2 PJN, PUJN, PJNJN, P	1970.0	36.9
ZWS0464	42.6	6.7 JN, P	38.5	163000	173.3 JN, PUJNJNJN, P	1810.0	35.7
ZWS0467	0.0	6.2 JN, P	51.5	186000	171.2 UJN, PJNJN, P	1280.0	41.2
ZWS0489	43.6	6.7 JN, P	45.5	244000	185.3 UJN, PJNJN, P	1410.0	44.2
ZEFE0583	66.5	14.4 JN, P	40.5	443000 0	271.1 JN, PJN, PUJNJNJN, P	5340.0	63.2
ZWFE0336	76.2	6.6 IJN, P	41.9	438000 0	116.5 JN, PJNUJN, PJN, PIJN, P	2080.0	35.7
ZWFE0517	67.3	1.3 IJN, P	48.6	76900 A	64.0 IJNJN, PIJN, P	632.0	15.8
ZWS0338	74.0	15.7 JN, P	46.3	493000 0	219.7 JN, PJN, PUJN, PJNJN, P	5140.0	37.6
ZWS0339	69.1	9.4 IJN, P	49.0	511000 0	160.6 JN, PJNUJNJNIJN, P	3710.0	26.3
ZWS0359	14.6	17.5 JN, P	45.9	492000 0	234.1 JNJNUJN, PJN, PJN, P	5560.0	40.3
ZWS0381	35.3	10.8 JN, P	35.5	488000 0	213.1 JN, PJN, PUJNJNJN, P	4400.0	47.3
ZWS0404	37.5	2.1 IJN, P	21.1	226000 0	42.1 JN, PIJNUJNIJN, PIJN, P	885.0	10.3
ZWS0426	21.3	1.5 UJN, P	18.9	219000 0	80.6 JN, PUJNIJN, PUJN, P	814.0	17.9
ZWS0447	0.0	7.5 IJN, P	64.1	253000 0	343.5 UJNJNIJN, P	2810.0	72.5

Site Name	Moisture, Percent (%)	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZWS0448	0.0	7.8 JN, P	19.9	404000 0	291.7 UJNJNJN, P	3400.0	65.6
ZWS0450	0.0	21.9 JN, P	16.7	485000 0	604.6 UJN, PJN, PJN, P	5940.0	154.0
ZWS0468	0.0	5.5 JN, P	20.7	335000 0	323.4 IJN, PJN, P	3120.0	77.5
ZWS0492	0.0	6.3 IJN, P	20.5	417000 0	269.0 IJNJN, PIJN, P	2670.0	66.4
ZWS4043	0.0	19.9 C2	31.7	465000	313.6 C2C2, JNUC2, JNC2C2	4520.0	78.7
ZWS4044	0.0	13.6 C2	30.1	474000	258.0 C2UC2, JNC2	4090.0	62.9
ZWS4050	0.0	7.9 IJN, P	41.5	395000	287.6 UJNIJN, P	2300.0	72.0
ZWS4051	0.0	11.2 IJN, P	27.1	462000	405.4 UJNIJN, P	4860.0	98.1
ZWS0515	31.1	26.6 JN, P	28.8	428000	771.4 JN, PUJN, PJN, PJN, P	8600.0	207.0
ZWS0516	54.8	14.3 JN, P	32.1	386000	513.0 UJN, PJNJN, P	4420.0	131.0
ZWS0535	25.1	13.5 JN, P	20.2	368000	402.3 JN, PUJNJNJN, P	6150.0	85.2
ZWS0537	58.5	13.4 JN, P	34.4	511000	334.8 JN, PUJN, PJNJN, P	5070.0	85.8
ZWS0538	50.7	8.2 JN, P	26.7	465000 A	322.9 JN, PUJN, PJNJN, P	4780.0	72.3
ZWS0561	55.5	7.3 JN, P	19.3	307000	321.3 JN, PUJNJNJN, P	3610.0	57.7
ZWS0562	6.0	9.6 JN, P	23.0	454000	466.7 JN, PUJN, PJNJN, P	5180.0	78.8
ZWS0574	32.7	15.3 JN, P	27.6	323000	662.2 JN, PUJN, PJNJN, P	6970.0	136.0
ZWS4047	29.8	29.8 JN, P	26.9	464000	879.9 UJN, PJN, P	12600.0	198.0
ZWS4048	51.8	17.2 JN, P	22.7	411000	613.0 JN, PUJNJN, P	6230.0	173.0
ZWS4049	37.6	3.6	32.0	155000	113.4 PUJN, PIJN, P	866.0	31.2

Phase 4:

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)
ZEFE0579	112.0	985.0	79.3	167.4	1176.3	0.5 UJN, P
ZEFE0596	2840.0 J	6070.0 J	8460.0 J	9432.7 JJJ	17370.0 JJJ	7.5 UJN, P
ZEFE0629	921.0	1630.0 J	2160.0	2452.9 J	4711.0 J	1.7 UJN, P
ZEFE0660	231.0	1320.0	53.9 P	188.1 P	1604.9 P	7.9 JN
ZEFE0692	62.0	710.0	43.0	102.7	815.0	5.1 IJN
ZEFE0721	79.4 JN, P	2080.0 J	48.9 JN, P	203.4 JN, PJJN, P	2208.3 JJN, PJN, PJJN, P	2.9 UJN, P
ZES0580	559.0	1030.0	524.0	704.5	2113.0	0.8 UJN, P
ZES0581	1700.0	2170.0	1130.0	1614.7	5000.0	2.0 UJN, P
ZES0582	530.0	1470.0	418.0	622.0	2418.0	1.4 UJN, P
ZES0584	55.1	160.0	40.8	62.5	255.9	0.7 UJN, P
ZES0585	320.0 P	931.0	214.0	340.1 P	1465.0 P	2.2 IJN, P
ZES0586	555.0	955.0	1600.0	1774.7	3110.0	0.6 UJN, P
ZES0587	1410.0	3150.0	7770.0	8262.0	12330.0	2.5 UJN, P
ZES0590	810.0	739.0	618.0	829.3	2167.0	1.2 UJN, P
ZES0591	1180.0	2070.0	4280.0	4654.0	7530.0	1.0 UJN, P
ZES0592	310.0	880.0	170.0	290.7	1360.0	5.0 IJN
ZES0595	2500.0	2700.0	4800.0	5480.0	10000.0	7.4 I
ZES0597	400.0	1900.0 V	1900.0	2106.7 V	4200.0 V	1.0 UP
ZES0598	90.0 Q	1400.0 Q	2700.0 Q	2811.3 QQQ	4190.0 QQQ	0.5 UJNPQ
ZES0599	680.0	1100.0	440.0 JN	649.3 JN	2220.0 JN	4.3 IJNP
ZES0602	810.0	850.0	430.0	648.7	2090.0	8.2 IJN
ZES0603	284.0	1040.0	159.0	285.1	1483.0	2.1 UJN, P
ZES0609	750.0	1600.0	460.0	716.7	2810.0	7.0 IJN
ZES0611	410.0	1500.0	3100.0	3282.0	5010.0	2.1 UJNP
ZES0613	340.0	680.0	240.0	353.3	1260.0	3.5 IJN
ZES0614	2800.0	2600.0	1400.0	2133.3	6800.0	12.0 JN
ZES0616	380.0	1500.0 V	80.0 JNP	256.0 VJNP	1960.0 VJNP	13.0 IJN
ZES0618	910.0	1000.0	220.0 P	468.7 P	2130.0 P	13.0 JNP

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)
ZES0619	590.0	790.0	560.0	730.7	1940.0	0.8 UJNP
ZES0623	870.0	1300.0	530.0	790.7	2700.0	5.5 IJNP
ZES0627	790.0	1200.0 V	280.0	518.0 V	2270.0 V	11.0 P
ZES0633	270.0	750.0	280.0	384.0	1300.0	5.7 IJN
ZES0636	260.0	700.0	160.0	258.7	1120.0	4.4 IJN
ZES0638	380.0	590.0 V	94.0 P	209.3 VP	1064.0 VP	1.9 UP
ZES0639	735.0	835.0	313.0	515.7	1883.0	3.1 IJN, P
ZES0640	736.0	1160.0	493.0	717.5	2389.0	3.0 UJN, P
ZES0646	610.0	760.0	290.0	462.7	1660.0	5.9 IJN
ZES0647	430.0	850.0	310.0	452.7	1590.0	6.3 IJN
ZES0649	530.0	810.0 V	160.0 P	320.0 VP	1500.0 VP	2.8 UP
ZES0650	126.0	222.0	177.0	217.0	525.0	1.4 UJN, P
ZES0659	570.0	1000.0	180.0	360.7	1750.0	6.9 IJN
ZES0663	500.0	764.0	242.0	392.9	1506.0	2.7 UJN, P
ZES0670	210.0	770.0	66.0 P	159.3 P	1046.0 P	2.3 IJN
ZES0671	178.0	456.0	83.5	149.5	717.5	1.2 UJN, P
ZES0672	163.0	455.0	74.6	137.5	692.6	0.8 UJN, P
ZES0675	61.9	207.0	19.4 IP	45.6 IP	288.3 IP	1.0 UJN, P
ZES0676	41.8	237.0	15.1 P	39.3 P	293.9 PP	0.8 UJN, P
ZES0677	95.4	271.0	44.1	81.2	410.5	0.4 UJN, P
ZES0686	1300.0	1800.0	530.0	910.0	3630.0	20.0 JNP
ZES0688	390.0	1300.0	87.0 P	251.7 P	1777.0 P	13.0 JN
ZES0690	150.0 P	595.0	47.5 P	117.2 PP	792.5 PP	2.2 IJN, P
ZES0701	270.0 I	1000.0	110.0 PJ	230.7 IPJ	1380.0 IPJ	2.5 IJN
ZES0703	1200.0	1200.0	460.0	780.0	2860.0	13.0 JN
ZES0704	750.0	1200.0	540.0	770.0	2490.0	5.8 IJNP
ZES0706	229.0	377.0	102.0	172.9	708.0	2.7 IJN, P
ZES0707	110.0	980.0	56.0	143.3	1146.0	2.2 IJNP
ZES0719	450.0 J, P	1530.0 J	369.0 J	561.0 J, PJJ	2349.0 JJJ, PJJ	5.3 IJN, P
ZES0725	270.0 P	1100.0	120.0 P	247.3 PP	1490.0 PP	3.2 UP
ZES0727	46.9	366.0	18.7 P	52.5 P	431.6 P	0.7 UJN, P

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)
ZES0981	510.0 P	1530.0	224.0 P	428.0 PP	2264.0 PPP	3.8 IJN, P
ZES0982	1050.0	1970.0	2160.0	2501.3	5180.0	3.1 UJN, P
ZES0983	169.0	721.0	842.0	923.9	1732.0	0.4 UJN, P
ZES0984	102.0	487.0	436.0	488.9	1025.0	0.6 UJN
ZES0985	180.0	460.0	720.0	786.7	1360.0	0.9 IJN
ZES1000	1490.0	1500.0	473.0	871.0	3463.0	5.8 UJN, P
ZES1001	4440.0	3410.0	3020.0	4135.3	10870.0	10.3 IJN
ZES1002	253.0	621.0	154.0	246.0	1028.0	2.4 UJN, P
ZES1003	1360.0	1580.0	1010.0	1387.3	3950.0	6.6 IJN, P
ZES2034	67.5	273.0	542.0	573.7	882.5	0.1 UJN, P
ZES2035	402.0	1810.0	3400.0	3601.1	5612.0	0.6 UJN, P
ZES2036	365.0 P	1060.0	249.0	392.7 P	1674.0 P	2.3 UJN, P
ZES2037	23.0	110.0	130.0	141.9	263.0	0.0 U
ZES2038	435.0	1920.0	2140.0	2355.0	4495.0	1.1 UJN, P
ZES2049	290.0 Q	480.0 Q	110.0 Q	200.0 QQQ	880.0 QQQ	2.8 Q
ZES2050	1600.0	2100.0	470.0	930.0	4170.0	17.0 JNP
ZES2051	150.0	930.0	95.0 V	187.0 V	1175.0 V	1.9 IJNP
ZES2052	1080.0	1360.0	397.0	703.7	2837.0	3.8 UJN, P
ZES2053	939.0	988.0	288.0	541.7	2215.0	4.6 IJN, P
ZES2054	166.0 P	950.0	120.0	216.5 P	1236.0 P	3.7 IJN, P
ZES2055	314.0	1240.0 J	107.0 IJN, P	252.5 JIJN, P	1661.0 JIJN, PJIJN, P	1.6 UJN
ZES2056	317.0	324.0	182.0	267.0	823.0	1.1 UJN, P
ZES2057	2770.0	3810.0	1650.0	2458.0	8230.0	6.7 UJN, P
ZES2058	212.0	332.0	135.0	199.5	679.0	1.6 UJN, P
ZES2059	698.0	1020.0	396.0	603.6	2114.0	3.9 IJN, P
ZES2060	131.0 IP	949.0	78.0 P	167.5 IPP	1158.0 PIPP	3.8 IJN, P
ZES2061	429.0	944.0	121.0 P	269.7 P	1494.0 P	4.1 IJN, P
ZES2062	33.0	280.0	18.0	43.3	331.0	0.7 IJNP
ZES2063	127.0	324.0	30.3 P	77.3 P	481.3 P	1.1 IJN, P
ZES4032	963.0	1430.0	378.0	665.9	2771.0	7.9 IJN
ZES4033	954.0	1460.0	318.0	606.1	2732.0	9.9 JN

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)
ZES4069	0.2 U	10.0	3.7 I	4.3 UI	12.9 UI	0.0 UJN, P
ZES4070	162.0	468.0	660.0	723.6	1290.0	0.6 UJN, P
ZSFE0740	87.9 JN, P	2010.0 J	62.2 JN, P	213.8 JN, PJJN, P	2160.1 JJN, PJN, PJJN, P	0.1 UJN, P
ZSFE0749	85.5 P	1580.0	554.0	676.4 P	2219.5 P	2.2 UJN, P

Site Name	alpha-BHC (ug/kg)	alpha-Chlordane (ug/kg)	beta-BHC (ug/kg)	cis-Nonachlor (ug/kg)	delta-BHC (ug/kg)	Dieldrin (ug/kg)
ZEFE0579	0.5 UJN, P	28.0	0.1 UJN, P	10.9 JN, P	0.8 UJN	47.1 P
ZEFE0596	0.0 U	170.0 J	4.9 UJN, P	91.2 JN, P	0.0 U	459.0 J
ZEFE0629	0.3 UJN, P	70.4	0.0 U	112.0 JN, P	1.3 UJN, P	112.0
ZEFE0660	0.0 U	152.0	2.8 IJN, P	48.6	0.0 U	350.0
ZEFE0692	0.0 U	65.0	0.0 U	56.0 P	0.0 U	160.0
ZEFE0721	0.0 U	92.9	0.2 UJN, P	31.7 JN, P	0.5 UJN, P	165.0 P
ZES0580	0.7 UJN, P	63.3	0.0 U	31.1 JN	0.0 U	114.0
ZES0581	1.2 UJN, P	114.0	1.2 UJN, P	68.7 JN	0.0 U	195.0
ZES0582	0.8 UJN, P	52.3	0.4 UJN, P	34.9 JN	1.1 UJN, P	158.0
ZES0584	0.0 U	14.3	0.0 U	7.4 I	0.0 U	49.4
ZES0585	0.5 UJN	62.1	1.0 UJN, P	17.4 JN, P	0.8 UJN, P	234.0
ZES0586	0.0 U	20.0 P	0.0 U	21.9 JN, P	0.0 U	50.8
ZES0587	0.0 U	49.2	1.4 UJN	81.0 JN, P	1.4 UJN	146.0
ZES0590	0.0 U	36.2	0.0 U	22.6 JN, P	0.0 U	105.0
ZES0591	0.0 U	27.6	0.0 U	34.5 JN, P	0.0 U	85.1
ZES0592	0.0 U	63.0 P	0.0 U	45.0 P	1.9 IJN	330.0
ZES0595	0.0 U	75.0 P	0.0 U	110.0 P	0.0 U	350.0
ZES0597	0.0 U	100.0	0.0 U	130.0 PV	0.0 U	210.0
ZES0598	0.0 UQ	110.0 Q	0.0 UQ	300.0 Q	0.0 UQ	160.0 Q
ZES0599	0.0 U	140.0 IP	0.0 U	120.0 IP	0.5 UJNP	450.0
ZES0602	0.3 UJNP	76.0	4.5 IJNP	51.0 P	0.0 U	340.0
ZES0603	0.0 U	86.2	2.5 UJN, P	37.0	0.0 U	122.0
ZES0609	0.0 U	140.0	0.0 U	110.0 P	0.0 U	710.0

Site Name	alpha-BHC (ug/kg)	alpha-Chlordane (ug/kg)	beta-BHC (ug/kg)	cis-Nonachlor (ug/kg)	delta-BHC (ug/kg)	Dieldrin (ug/kg)
ZES0611	0.0 U	140.0	0.0 U	150.0 JNP	0.0 U	230.0 J
ZES0613	0.5 UJNP	43.0 P	0.0 U	33.0 P	4.0 IJNP	260.0
ZES0614	0.0 U	140.0 IP	4.8 IJNP	170.0 P	0.0 U	680.0
ZES0616	0.0 U	140.0	17.0 JN	59.0 JNPV	0.0 U	170.0 P
ZES0618	0.0 U	140.0 P	7.3 IJNP	58.0 IJNP	0.0 U	260.0
ZES0619	0.0 U	67.0	0.0 U	54.0 JNP	0.0 U	100.0
ZES0623	0.0 U	74.0 P	1.6 UJN	63.0 P	0.0 U	440.0
ZES0627	0.0 U	190.0	9.9 JN	73.0 IPV	0.0 U	290.0
ZES0633	0.0 U	84.0	0.2 UJNP	65.0 P	1.9 IJNP	450.0
ZES0636	0.0 U	64.0 P	0.1 UJNP	49.0 P	0.0 U	280.0
ZES0638	0.0 U	100.0	3.0 UJNP	50.0 PV	0.0 U	120.0 P
ZES0639	0.0 U	137.0	2.3 UJN, P	50.2	1.7 UJN, P	191.0
ZES0640	0.0 U	97.5 P	0.0 U	58.7	6.1 UJN	187.0
ZES0646	0.3 UJNP	79.0	5.6 IJN	61.0 P	1.8 IJNP	260.0
ZES0647	0.3 UJNP	87.0	1.5 UJN	62.0 IP	6.2 IJN	370.0
ZES0649	0.0 U	110.0	1.8 UJNP	50.0 PV	0.0 U	260.0
ZES0650	0.0 U	35.6	0.0 U	10.1 IJN, P	1.9 UJN	86.0
ZES0659	0.5 UJNP	100.0 P	2.9 UJNP	82.0 P	2.1 IJN	240.0
ZES0663	0.0 U	116.0	0.0 U	57.8	2.8 UJN	257.0
ZES0670	0.2 UJNP	100.0 P	1.0 UJNP	68.0 P	0.7 UJN	220.0
ZES0671	0.0 U	39.9	0.0 U	27.9	0.0 U	77.2
ZES0672	0.0 U	44.0	0.0 U	23.6	0.0 U	76.7
ZES0675	0.0 U	30.6	0.0 U	16.9	0.0 U	42.3 P
ZES0676	0.3 UJN, P	34.5	0.0 U	15.2 JN	0.6 UJN	78.6
ZES0677	0.0 U	16.3	0.0 U	8.2	0.5 UJN	36.6
ZES0686	1.3 IJNP	260.0 P	11.0 JNP	320.0	11.0 JN	450.0
ZES0688	0.0 U	220.0	3.8 UJN	96.0 IJNP	0.0 U	360.0 P
ZES0690	0.0 U	109.0	0.5 UJN, P	44.8	0.0 U	218.0
ZES0701	0.3 UJNP	130.0 IP	1.0 UJN	70.0 P	0.0 UJ	240.0 J
ZES0703	0.0 U	88.0 IP	18.0 JN	99.0 IP	0.0 U	500.0
ZES0704	0.4 UJNP	95.0	2.7 UJNP	97.0 P	2.4 IJN	570.0

Site Name	alpha-BHC (ug/kg)	alpha-Chlordane (ug/kg)	beta-BHC (ug/kg)	cis-Nonachlor (ug/kg)	delta-BHC (ug/kg)	Dieldrin (ug/kg)
ZES0706	0.0 U	42.4	0.8 UJN, P	30.3	0.0 U	97.9
ZES0707	0.0 U	72.0	0.0 U	45.0 JNP	1.6 IJNP	230.0
ZES0719	0.8 UJN, P	180.0 J	0.5 UJN, P	90.0	1.7 UJN	516.0 J
ZES0725	0.0 U	110.0 JN	0.0 U	52.0 JNP	3.7 IJNP	250.0
ZES0727	0.0 U	31.9	0.0 U	18.7	0.0 U	69.0
ZES0981	0.7 UJN, P	128.0	0.9 UJN, P	35.4 JN, P	5.8 IJN	475.0
ZES0982	1.0 UJN, P	102.0	1.7 UJN, P	88.1 IJN	0.0 U	304.0
ZES0983	0.3 UJN, P	32.9	0.6 UJN, P	39.3 JN, P	0.4 UJN, P	66.9
ZES0984	0.5 UJN, P	14.9	0.0 U	25.8 JN	0.0 U	40.6
ZES0985	0.7 IJNP	29.0	0.4 UJNP	50.0 JNP	0.0 U	59.0 JN
ZES1000	0.0 U	101.0	2.6 UJN, P	51.2	0.0 U	313.0
ZES1001	0.0 U	94.6	0.0 U	115.0 IJN, P	0.0 U	520.0
ZES1002	0.0 U	82.6	0.0 U	35.2	0.0 U	234.0
ZES1003	0.0 U	219.0	4.7 IJN	137.0 JN, P	0.0 U	636.0
ZES2034	0.0 UJN, P	5.3	0.0 U	6.5 JN, P	0.0 U	11.2
ZES2035	0.4 UJN, P	38.4	0.0 U	43.6 JN, P	0.0 U	76.5
ZES2036	1.5 UJN, P	101.0	1.5 UJN, P	34.5 IJN, P	1.7 UJN, P	335.0
ZES2037	0.2 UJNP	4.8	0.4 UJN	9.8 JNP	0.0 U	11.0
ZES2038	0.4 UJN, P	73.1	2.1 UJN, P	127.0	0.0 U	230.0
ZES2049	0.1 UJNPQ	39.0 PQ	1.7 IJNPQ	27.0 JNPQ	1.8 IQ	79.0 Q
ZES2050	0.6 UJNP	290.0 P	9.3 IJNP	290.0 JNP	9.0 IJN	600.0
ZES2051	0.4 UJNP	52.0	0.0 U	37.0 P	0.0 U	290.0
ZES2052	0.8 UJN, P	141.0	3.3 UJN, P	74.9	0.8 UJN, P	450.0
ZES2053	0.8 UJN, P	115.0	4.7 IJN, P	55.1	1.8 IJN, P	401.0
ZES2054	0.3 UJN, P	74.8	0.0 U	28.7 JN, P	0.5 UJN	187.0 P
ZES2055	0.0 U	127.0	0.0 U	50.9 JN	1.4 UJN, P	370.0
ZES2056	0.0 U	27.3	3.3 UJN, P	14.0	0.0 U	65.2
ZES2057	5.0 UJN, P	188.0	0.0 U	93.9	6.2 UJN	483.0
ZES2058	0.0 U	30.3	0.6 UJN, P	9.7 JN, P	0.0 U	60.2
ZES2059	0.0 U	83.4	2.5 UJN	32.6	0.0 U	195.0
ZES2060	0.6 UJN, P	190.0	0.4 UJN, P	93.3 JN	1.6 UJN, P	470.0

Site Name	alpha-BHC (ug/kg)	alpha-Chlordane (ug/kg)	beta-BHC (ug/kg)	cis-Nonachlor (ug/kg)	delta-BHC (ug/kg)	Dieldrin (ug/kg)
ZES2061	0.0 U	164.0	1.3 UJN, P	76.5	0.0 U	337.0
ZES2062	0.0 U	27.0	0.0 U	21.0 P	0.4 UJNP	56.0
ZES2063	0.0 U	60.1	0.5 UJN	23.6 I	0.0 U	72.5
ZES4032	0.0 U	161.0	8.3 IJN	58.1	0.0 U	186.0
ZES4033	0.4 UJN, P	234.0	9.5 JN	73.2	0.0 U	223.0
ZES4069	0.0 U	0.3 U	0.0 U	0.4 UJN, P	0.0 U	0.9 U
ZES4070	0.0 U	25.7	0.9 UJN, P	33.1 JN, P	0.0 U	45.0
ZSFE0740	0.0 U	111.0	0.2 UJN, P	57.5 JN	0.8 UJN, P	399.0
ZSFE0749	0.0 U	151.0	0.0 U	176.0 JN, P	0.0 U	273.0

Site Name	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)
ZEFE0579	4.8 IJN, P	54.6 JN, P	2.8 UJN, P	0.0 U	0.0 U	6.2 IJN
ZEFE0596	63.6 J, JN, P	362.0 J, JN	0.0 UJ	0.0 UJ	0.0 U	73.4 JN
ZEFE0629	0.0 U	136.0 J, JN	26.8 J, JN, P	0.0 U	125.0 JN, P	26.0 JN, P
ZEFE0660	24.5 JN, P	121.0 JN	0.0 U	0.0 U	0.0 U	11.7 JN
ZEFE0692	0.0 U	0.0 U	6.5 IJNP	0.0 U	0.0 U	9.1 IJN
ZEFE0721	32.1 JN, P	149.0 J, JN	6.1 UJN, P	11.2 IJN, P	88.6 JN, P	7.3 UJN, P
ZES0580	9.9 JN, P	133.0 JN	16.7 JN	0.0 U	0.0 U	15.3 JN, P
ZES0581	22.6 JN, P	233.0 JN	30.6 JN	0.0 U	0.0 U	27.6 IJN, P
ZES0582	8.7 JN, P	120.0 JN	14.2 JN	0.0 U	0.0 U	17.5 JN, P
ZES0584	0.7 UJN, P	26.7 J, JN	1.1 UJN, P	0.0 U	0.0 U	2.8 UJN, P
ZES0585	8.0 JN, P	141.0 JN, P	15.3 JN	0.0 U	0.0 U	20.2 JN, P
ZES0586	0.0 U	46.2 JN	0.0 U	0.0 U	0.0 U	10.9 IJN, P
ZES0587	0.0 U	143.0 J, JN	0.0 U	0.0 U	0.0 U	41.5 JN
ZES0590	0.0 U	68.4 J, JN	8.0 UJN, P	0.0 U	0.0 U	21.7 IJN, P
ZES0591	0.0 U	68.0 J, JN	0.0 U	0.0 U	0.0 U	18.9 IJN, P
ZES0592	19.0 JNP	130.0 JNP	12.0 IJN	16.0 JNP	97.0 JNP	16.0 JNP

Site Name	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)
ZES0595	28.0 IJNP	280.0 JN	98.0 JN	67.0 IJNP	210.0 JNP	100.0 JNP
ZES0597	0.0 U	0.0 U	50.0 JNP	0.0 U	0.0 U	42.0 JNP
ZES0598	0.0 UQ	0.0 UQ	0.0 UQ	0.0 UQ	0.0 UQ	93.0 JNPQ
ZES0599	27.0 JNP	400.0 JN	23.0 JN	32.0 JNP	210.0 IJNP	33.0 JNP
ZES0602	76.0 JN	96.0 JNP	6.6 IJNP	0.0 U	130.0 JNP	41.0 JNP
ZES0603	11.2 IJN, P	127.0 J, JN	0.0 U	0.0 U	0.0 U	10.2 UJN, P
ZES0609	0.0 U	330.0 JN	38.0 IJN	33.0 IJNP	190.0 JNP	49.0 IJNP
ZES0611	0.0 UJ	320.0 JNP	0.0 UJ	0.0 U	0.0 U	99.0 JN
ZES0613	36.0 JN	52.0 JNP	0.0 U	33.0 JN	31.0 JNP	20.0 JN
ZES0614	80.0 IJNP	590.0 JN	0.0 U	45.0 IJNP	350.0 JNP	110.0 JN
ZES0616	0.0 U	170.0 JNP	16.0 IJNP	0.0 U	0.0 U	13.0 IJNP
ZES0618	0.0 U	0.0 U	0.0 U	0.0 U	0.0 U	34.0 JN
ZES0619	0.0 U	150.0 JN	0.0 U	0.0 U	0.0 U	39.0 JN
ZES0623	33.0 JNP	200.0 JN	0.0 U	20.0 JNP	0.0 U	40.0 JN
ZES0627	32.0 IJNP	0.0 U	0.0 U	0.0 U	0.0 U	24.0 JNP
ZES0633	24.0 JNP	150.0 JNP	0.0 U	14.0 IJNP	0.0 U	31.0 JN
ZES0636	18.0 JN	120.0 JNP	0.0 U	11.0 IJNP	0.0 U	23.0 JN
ZES0638	18.0 JNP	0.0 U	0.0 U	0.0 U	0.0 U	12.0 IJNP
ZES0639	0.0 U	163.0 J, JN	12.2 IJN, P	20.7 JN, P	105.0 JN, P	21.4 JN
ZES0640	0.0 U	172.0 J, JN	20.6 UJN, P	33.8 IJN, P	154.0 JN, P	30.2 IJN, P
ZES0646	27.0 JNP	170.0 JN	0.0 U	22.0 JNP	0.0 U	36.0 JN
ZES0647	24.0 JNP	180.0 JN	0.0 U	19.0 JNP	0.0 U	34.0 JN
ZES0649	0.0 U	0.0 U	0.0 U	0.0 U	0.0 U	11.0 IJNP

Site Name	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)
ZES0650	0.0 U	41.9 J, JN	2.4 UJN	4.2 UJN, P	35.7 JN, P	5.9 UJN
ZES0659	26.0 IJNP	240.0 JN	0.0 U	28.0 JNP	0.0 U	29.0 JNP
ZES0663	0.0 U	166.0 J, JN	8.1 UJN	16.5 UJN, P	116.0 JN, P	21.7 IJN
ZES0670	18.0 JNP	140.0 JNP	0.0 U	0.0 U	0.0 U	23.0 JN
ZES0671	6.4 IJN, P	81.0 JN	6.7 UJN, P	0.0 U	0.0 U	7.4 IJN
ZES0672	0.0 U	59.4 JN	0.0 U	0.0 U	0.0 U	6.4 IP
ZES0675	3.6 IJN, P	38.1 JN	0.0 U	0.0 U	21.2 JN, P	3.2 UJN
ZES0676	2.5 IJN, P	38.5 JN, P	2.2 UJ, JN, P	3.2 IJN, P	36.6 JN, P	4.8 IJN, P
ZES0677	0.0 U	25.9 J, JN	2.1 UJN	3.1 IJN, P	45.0 JN	2.8 IJN, P
ZES0686	0.0 U	470.0 JN	43.0 JN	0.0 U	0.0 U	43.0 JN
ZES0688	0.0 U	0.0 U	0.0 U	0.0 U	0.0 U	48.0 JN
ZES0690	9.0 JN, P	195.0 JN	9.0 JN, P	0.0 U	0.0 U	9.4 JN
ZES0701	13.0 JNP	150.0 JNP	0.0 U	0.0 U	0.0 U	23.0 JNP
ZES0703	0.0 U	0.0 U	0.0 U	0.0 U	0.0 U	78.0 JN
ZES0704	0.0 U	0.0 U	19.0 JN	0.0 U	0.0 U	49.0 JN
ZES0706	9.2 JN, P	93.1 JN	9.7 IJN	0.0 U	0.0 U	9.3 IJN
ZES0707	0.0 U	0.0 U	7.7 IJN	0.0 U	0.0 U	7.5 IJN
ZES0719	20.4 JN, P	376.0 J	31.2 JN	0.0 U	0.0 U	33.0 JN, P
ZES0725	18.0 JNP	160.0 JN	0.0 U	0.0 U	110.0 JNP	14.0 IJNP
ZES0727	3.9 JN, P	46.6 JN	3.0 IJN, P	0.0 U	0.0 U	5.5 JN, P
ZES0981	9.8 UJN, P	278.0 JN	25.3 JN	0.0 U	0.0 U	36.1 JN, P
ZES0982	26.3 JN, P	288.0 JN	75.6 JN, P	0.0 U	0.0 U	60.3 JN
ZES0983	0.0 U	116.0 JN	78.5 JN	0.0 U	0.0 U	24.1 JN
ZES0984	0.0 U	65.9 JN	45.2 JN, P	0.0 U	0.0 U	14.6 JN
ZES0985	17.0 JNP	110.0 JN	0.0 U	0.0 U	0.0 U	21.0 JNP

Site Name	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)
ZES1000	18.3 IJN, P	235.0 J, JN	15.7 UJN, P	0.0 U	0.0 U	27.3 IJN
ZES1001	0.0 U	264.0 J, JN	0.0 U	0.0 U	0.0 U	43.8 JN, P
ZES1002	0.0 U	122.0 J, JN	8.3 IJN, P	0.0 U	0.0 U	15.2 IJN
ZES1003	0.0 U	253.0 J, JN	0.0 U	0.0 U	0.0 U	64.9 JN
ZES2034	0.0 U	17.9 JN	6.8 JN	0.0 U	0.0 U	3.1 IJN, P
ZES2035	0.0 U	116.0 JN	45.5 JN	0.0 U	0.0 U	19.0 IJN, P
ZES2036	13.5 JN, P	204.0 JN, P	19.4 JN	0.0 U	0.0 U	27.6 JN, P
ZES2037	0.0 U	20.0 JN	0.0 U	0.0 U	0.0 U	4.5 IJNP
ZES2038	0.0 U	112.0 J, JN, P	0.0 U	0.0 U	366.0 JN, P	90.3 JN, P
ZES2049	15.0 JNPQ	0.0 UQ	13.0 JNQ	0.0 UQ	0.0 UQ	13.0 JNQ
ZES2050	0.0 U	710.0 JN	62.0 JN	0.0 U	0.0 U	60.0 JNP
ZES2051	0.0 U	0.0 U	0.0 U	0.0 U	0.0 U	9.9 IJNP
ZES2052	20.2 JN, P	219.0 JN	20.4 IJN	0.0 U	0.0 U	28.2 JN, P
ZES2053	8.9 UJN, P	183.0 JN	16.7 JN	0.0 U	0.0 U	25.9 JN, P
ZES2054	8.2 JN, P	94.2 JN, P	11.1 IJN	4.8 IJN, P	0.0 U	11.6 IJN, P
ZES2055	0.0 U	244.0 J, JN	7.9 IJN, P	15.6 JN, P	98.1 IJN, P	16.4 JN
ZES2056	4.2 UJN, P	52.2 JN	5.5 UJN	10.7 IJN, P	46.6 JN, P	8.9 IJN, P
ZES2057	32.0 IJN, P	425.0	26.0 U	0.0 U	264.0 JN, P	41.4 UJN, P
ZES2058	4.5 IJN, P	46.2 JN	3.3 UJN	5.3 UJN, P	34.9 JN, P	5.8 UJN, P
ZES2059	16.1 JN, P	143.0 JN	13.3 JN, P	19.8 JN, P	104.0 IJN, P	20.4 JN, P
ZES2060	7.9 UJN, P	148.0 JN, P	29.7 J, JN	0.0 U	34.4 UJN, P	22.6 JN, P
ZES2061	17.9 UJN, P	357.0 JN	21.3 JN, P	0.0 U	0.0 U	25.8 JN
ZES2062	0.0 U	0.0 U	2.5 IJNP	0.0 U	0.0 U	4.6 IJN

Site Name	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)
ZES2063	5.1 JN, P	58.8 JN	4.5 IJN, P	0.0 U	0.0 U	6.0 JN
ZES4032	0.0 U	212.0 JN	19.7 JN, P	34.9 JN, P	132.0 IJN, P	24.6 JN, P
ZES4033	0.0 U	241.0 JN	0.0 U	35.3 JN, P	143.0 IJN, P	25.7 JN
ZES4069	0.2 UJN, P	0.7 UJN	0.0 U	0.0 U	6.1 JN	0.9 UJN, P
ZES4070	4.3 IJN, P	89.4 JN	0.0 U	0.0 U	0.0 U	22.9 JN
ZSFE0740	0.0 U	256.0 J, JN	11.2 IJN	17.5 IJN, P	148.0 JN, P	20.3 IJN
ZSFE0749	24.5 JN, P	240.0 JN	0.0 U	0.0 U	0.0 U	25.6 JN, P

Site Name	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)	Moisture, Percent (%)
ZEFE0579	0.1 UJN, P	11.6 JN, P	0.3 UJN, P	7.8 JN, P	29.2 IJN	46.9
ZEFE0596	0.6 UJN, P	36.4 J, JN, P	5.5 UJN, P	63.9 J, JN, P	302.0 J, JN	62.2
ZEFE0629	0.3 UJN, P	33.7 P	0.0 U	24.2 JN, P	146.0 JN	19.1
ZEFE0660	0.8 UJN, P	51.5	2.1 IJN, P	41.0 JN	34.0 IJN, P	19.7
ZEFE0692	0.1 UJNP	46.0	0.0 U	0.0 U	54.0 IJNP	73.8
ZEFE0721	0.1 UJN, P	43.3 JN	0.9 UJN, P	26.3 JN, P	18.2 UJN, P	65.7
ZES0580	0.1 UJN, P	20.9 JN, P	1.3 UJN	18.9 JN, P	66.4 JN, P	22.3
ZES0581	0.0 U	28.5 JN, P	2.0 UJN	42.3 JN, P	73.5 IJN, P	65.5
ZES0582	0.0 U	13.8 JN, P	1.4 UJN	10.2 JN, P	73.5 JN	36.5
ZES0584	0.1 UJN, P	5.5 I	0.0 U	3.7 IJN	0.0 U	39.7
ZES0585	0.1 UJN, P	11.5 JN, P	1.1 UJN, P	13.1 JN, P	61.5 JN	53.0
ZES0586	0.1 UJN, P	8.5 JN, P	0.0 U	5.7 IJN, P	0.0 U	57.6
ZES0587	0.4 UJN, P	21.2 JN, P	0.0 U	17.0 IJN, P	179.0 J, JN, P	43.6
ZES0590	0.2 UJN, P	9.8 IJN, P	0.8 UJN, P	10.5 IJN, P	0.0 U	50.4
ZES0591	0.2 UJN, P	12.0 IJN, P	0.0 U	8.3 IJN, P	0.0 U	23.4
ZES0592	0.5 UJNP	47.0	1.9 IJNP	0.0 U	0.0 U	73.1

Site Name	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)	Moisture, Percent (%)
ZES0595	0.7 UJNP	32.0 IP	1.5 UJNP	49.0 JN	140.0 IJNP	77.3
ZES0597	0.0 U	74.0	1.3 UJNP	18.0 JN	290.0 JN	46.6
ZES0598	0.0 UQ	80.0 JNQ	0.0 UQ	11.0 JNPQ	550.0 JNPQ	71.5
ZES0599	0.5 UJNP	88.0	1.1 IJNP	28.0 JNP	74.0 IJNP	68.0
ZES0602	0.0 U	43.0	0.0 U	13.0 JNP	65.0 IJNP	64.1
ZES0603	1.1 UJN, P	38.9	1.1 UJN, P	25.7 JN, P	88.4 IJN	13.5
ZES0609	0.6 UJNP	76.0	1.8 UJNP	48.0 JN	110.0 IJN	58.0
ZES0611	0.0 U	83.0	0.0 U	28.0 JN	370.0 JN	83.7
ZES0613	0.7 UJNP	23.0 P	0.5 UJNP	0.0 U	40.0 IJNP	34.6
ZES0614	0.6 UJNP	64.0 P	13.0 JN	35.0 JNP	200.0 JN	67.7
ZES0616	1.1 UJNP	110.0	12.0 IJN	27.0 JNP	71.0 IJNP	69.8
ZES0618	1.0 UJNP	100.0	11.0 JN	0.0 U	130.0 JNP	71.3
ZES0619	0.0 U	43.0	0.0 U	0.0 U	110.0 JN	79.1
ZES0623	0.5 UJNP	31.0 P	1.7 IJNP	0.0 U	58.0 IJNP	64.4
ZES0627	0.0 U	210.0	0.0 U	0.0 U	0.0 U	27.9
ZES0633	0.5 UJNP	51.0	1.8 IJNP	7.6 IJNP	31.0 IJN	73.5
ZES0636	0.4 UJNP	37.0	3.4 IJN	0.0 U	29.0 IJN	71.9
ZES0638	0.0 U	120.0	0.0 U	0.0 U	0.0 U	51.5
ZES0639	1.3 UJN, P	36.2 JN, P	0.7 UJN, P	36.6 JN	97.5 JN	14.9
ZES0640	4.6 UJN	49.8	0.0 U	24.5 IJN, P	93.3 UJN, P	29.8
ZES0646	0.2 UJNP	49.0	4.9 IJN	13.0 JNP	49.0 IJN	76.9
ZES0647	0.3 UJNP	53.0	1.7 IJN	0.0 U	49.0 IJN	73.9
ZES0649	0.0 U	92.0	0.0 U	24.0 JNP	0.0 U	80.1
ZES0650	0.5 UJN, P	12.6	0.5 UJN, P	10.4 IJN	18.9 UJN	23.8
ZES0659	0.3 UJNP	54.0	3.7 IJNP	16.0 JNP	62.0 IJN	80.8
ZES0663	2.8 UJN	40.2	1.1 UJN, P	32.7 JN	22.9 UJN, P	49.0
ZES0670	0.5 UJNP	56.0	0.8 UJNP	0.0 U	66.0 IJNP	68.7
ZES0671	0.5 UJN, P	18.2	0.3 UJN, P	16.0 JN	0.0 U	23.8
ZES0672	0.5 UJN	25.1	0.0 U	14.3 JN	43.7 IP	29.3
ZES0675	0.6 UJN, P	20.7	0.0 U	9.6 IJN	0.0 U	28.3

Site Name	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)	Moisture, Percent (%)
ZES0676	0.0 U	17.8	0.5 UJN, P	7.9 JN	26.2 IJN, P	21.0
ZES0677	0.4 UJN, P	5.1 JN, P	0.3 UJN, P	4.8 JN, P	14.0 IJN	35.8
ZES0686	1.6 UJNP	180.0 P	19.0 JN	0.0 U	190.0 JNP	76.1
ZES0688	1.1 UJNP	180.0	4.1 IJNP	0.0 U	100.0 IJNP	62.0
ZES0690	0.5 UJN	41.7	0.0 U	20.1 JN	37.6 IJN, P	33.1
ZES0701	0.0 UJ	53.0	1.3 IJNP	0.0 UJ	80.0 IJNP	75.1
ZES0703	0.6 UJNP	95.0	8.8 JN	35.0 JNP	0.0 U	79.8
ZES0704	0.6 UJNP	87.0	3.7 IJNP	0.0 U	99.0 JNP	83.4
ZES0706	0.3 UJN, P	23.3	1.6 UJN	19.0 JN	0.0 U	37.3
ZES0707	0.0 U	58.0	2.0 IJN	0.0 U	31.0 IJNP	74.7
ZES0719	0.2 UJN, P	71.7 J, JN, P	1.4 UJN, P	30.6 J, JN, P	96.7 IJN, P	28.5
ZES0725	0.9 UJNP	63.0	0.9 UJNP	38.0 JN	76.0 IJNP	73.8
ZES0727	0.1 UJN, P	20.5	0.5 UJN	8.6 JN	10.1 IJN, P	67.2
ZES0981	0.4 UJN, P	22.3 JN, P	1.0 UJN, P	28.9 JN, P	65.4 IJN, P	48.0
ZES0982	0.2 UJN, P	24.5 JN, P	2.2 UJN, P	36.3 JN, P	178.0 JN, P	26.5
ZES0983	0.2 UJN, P	21.8	0.6 UJN, P	9.1 JN, P	199.0 JN	12.7
ZES0984	0.0 U	7.6 JN, P	0.0 U	3.2 IJN, P	65.0 JN, P	53.7
ZES0985	0.0 U	11.0 JNP	1.4 IJNP	0.0 U	0.0 U	76.7
ZES1000	1.3 UJN, P	41.8 JN, P	2.6 UJN, P	39.3 JN, P	0.0 U	23.4
ZES1001	0.0 U	38.2 JN, P	5.2 IJN, P	60.9 JN, P	203.0 J, JN	25.4
ZES1002	0.2 UJN, P	24.0	0.0 U	19.4 JN	0.0 U	23.5
ZES1003	0.5 UJN, P	39.1 JN, P	0.0 U	46.2 JN	156.0 J, JN, P	10.4
ZES2034	0.1 UJN, P	2.5 JN, P	0.1 UJN, P	1.4 IJN, P	13.5 IJN, P	17.7
ZES2035	0.1 UJN, P	18.0 JN, P	0.6 UJN	8.7 IJN, P	104.0 JN, P	28.3
ZES2036	0.2 UJN, P	15.4 JN, P	0.7 UJN, P	21.4 JN, P	77.8 IJN, P	19.4
ZES2037	0.0 U	2.3 IJNP	0.0 UJNP	0.0 U	0.0 U	74.5
ZES2038	0.7 UJN, P	38.2	2.1 UJN, P	23.1 JN, P	147.0 IJN, P	13.2
ZES2049	0.2 UJNPQ	26.0 Q	1.8 IQ	9.1 JNPQ	49.0 JNPQ	71.9
ZES2050	1.2 UJNP	210.0	12.0 JN	0.0 U	250.0 JNP	76.2
ZES2051	0.0 U	51.0 JN	1.3 IJNP	0.0 U	0.0 U	72.4

Site Name	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)	Moisture, Percent (%)
ZES2052	0.3 UJN, P	56.9 JN, P	0.5 UJN, P	30.9 JN, P	84.1 IJN, P	30.0
ZES2053	0.3 UJN, P	49.1 JN, P	0.7 UJN, P	38.8 JN	70.4 JN	3.0
ZES2054	0.1 UJN, P	36.1	0.3 UJN, P	17.1 JN, P	43.6 IJN	63.0
ZES2055	0.2 UJN, P	52.0 JN	1.1 UJN, P	34.0 JN	14.4 UJN, P	58.6
ZES2056	0.8 UJN, P	12.1 IJN, P	2.4 UJN, P	10.7 IJN, P	26.1 UJN, P	43.9
ZES2057	5.0 UJN	67.2 IJN, P	1.7 UJN, P	60.7 IJN, P	111.0 UJN, P	58.5
ZES2058	1.0 UJN	9.6 IJN, P	1.7 UJN	9.8 JN, P	25.0 UJN	63.4
ZES2059	0.3 UJN, P	26.3 JN, P	0.9 UJN	29.3 JN, P	12.6 UJN, P	46.1
ZES2060	0.6 UJN, P	98.7	2.0 UJN	54.0 JN	89.7 IJN, P	63.8
ZES2061	0.7 UJN, P	65.6	0.0 U	45.1 JN	97.6 J, JN, P	34.1
ZES2062	1.9 IJN	20.0	0.3 UJNP	0.0 U	23.0 IJNP	70.2
ZES2063	0.1 UJN, P	21.6	0.3 UJN, P	11.8 JN	8.3 UJN, P	62.2
ZES4032	1.6 UJN, P	63.2	2.8 UJN, P	53.3 JN	36.1 IJN, P	44.7
ZES4033	0.7 UJN, P	79.9	6.3 IJN, P	62.7 JN	25.6 UJN, P	27.3
ZES4069	0.0 UJN, P	0.1 UJN, P	0.0 U	0.1 UJN, P	3.5 UJN, P	50.3
ZES4070	0.2 UJN, P	9.4 JN, P	2.0 UJN	9.8	103.0 JN, P	27.9
ZSFE0740	0.1 UJN, P	57.7 JN	0.6 UJN, P	32.1 JN	22.9 UJN, P	26.3
ZSFE0749	0.2 UJN, P	84.4	0.0 U	39.5 JN	147.0 J, JN, P	57.3

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZEFE0579	2.6 IJN, P	35.9	340000 0	71.6 JN, PJN, PUJN, PJN, PIJN, P	2030.0	10.4
ZEFE0596	46.0	42.0	470000 A	662.0 JJN, PJ, JN, PUJN, PJ, JN, P	8060.0	249.0
ZEFE0629	18.9	23.7	449000	312.5 JN, PPUJN, P	4480.0	53.3
ZEFE0660	19.9 JN, P	29.7	389000	385.8 IJN, PJNJN, P	4940.0	70.7
ZEFE0692	10.0 JNP	29.9	328000	247.0 PUUJNP	3200.0	70.0
ZEFE0721	10.1 IJN, P	65.4	387000 0	269.8 JN, PJNUJN, PJN, PIJN, P	4360.0	64.6

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZES0580	11.4 JN, P	32.3	496000 0	167.3 JNJN, PUJNJN, PJN, P	3970.0	20.4
ZES0581	19.8 JN, P	26.5	492000 0	327.1 JNJN, PUJNJN, PJN, P	7390.0	51.8
ZES0582	8.6 JN, P	28.1	477000 0	137.3 JNJN, PUJNJN, PJN, P	3610.0	16.1
ZES0584	1.7 UJN, P	23.1	486000	41.4 IIUIJNUJN, P	822.0	8.8
ZES0585	10.9 JN, P	26.1	426000 0	130.8 JN, PJN, PUJN, PJN, PJN, P	4460.0	14.7
ZES0586	4.5 I	19.2	487000	67.3 PJN, PJN, PUIJN, PII	1490.0 I	6.7 I
ZES0587	8.7 I	31.3	508000	261.9 JN, PJN, PUIJN, PI	4970.0	84.8
ZES0590	7.2 I	23.9	502000	112.7 JN, PIJN, PUJN, PIJN, PIP	2030.0 I	25.6 P
ZES0591	5.0 IJN	24.9	509000	103.9 JN, PIJN, PUIJN, PIJNP	2490.0 I	16.5 P
ZES0592	16.0 JNP	46.1	404000	222.9 PPIJNPUJNPP	6700.0	50.0 P
ZES0595	24.0 IJN	69.2	509000	358.5 PPIPUJNPJNIJNP	11000.0	67.0 P
ZES0597	33.0 JN	32.3	337000	440.3 PVUJNPJNJN	8000.0	84.0
ZES0598	5.2 IJNPQ	27.0	650000	636.2 QQJNQUQJNPQIJNPQQ	15000.0 Q	130.0 Q
ZES0599	28.0 JNP	26.9	465000	475.1 IPIPIJNPJNPJNPIP	9000.0	70.0 IP
ZES0602	25.0 JN	40.0	498000	257.0 PUJNPJNP	6700.0	49.0 P
ZES0603	15.2 IJN, P	22.6	458000	258.8 UJN, PJN, PIJN, P	4190.0	54.7
ZES0609	39.0 JN	26.8	473000	534.8 PUJNPJNJNP	10000.0	120.0 P
ZES0611	32.0 JN	54.6	504000 A	543.0 JNPUJNJN	15000.0	110.0
ZES0613	15.0 JN	33.8	463000	148.5 PPPUJNPUJNP	3700.0	34.0 P
ZES0614	40.0 JN	33.9	495000	582.0 IPPPJNJNPJNIP	16000.0	120.0 IP
ZES0616	59.0 IJNP	90.3	349000	537.0 JNPVIJNJNPIJNPI	6400.0	130.0 I
ZES0618	20.0 UJNP	28.4	475000	479.0 PIJNPJNUUJNP	8600.0	150.0
ZES0619	14.0 JNP	24.4	489000	229.0 JNPUUJNP	4000.0	51.0
ZES0623	24.0 JN	33.4	463000	253.7 PPPIJNPUJNIP	7300.0	60.0 IP

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZES0627	81.0 IJNP	23.1	520000 A	754.0 IPVUUIJNP	8100.0	200.0
ZES0633	20.0 JNP	34.3	469000	295.4 PIJNPIJNPJNP	5900.0	66.0
ZES0636	14.0 JNP	31.0	465000	218.4 PPIJNUJNP	5800.0	51.0
ZES0638	47.0 JNP	38.5	339000	410.0 PVUUJNP	4700.0	93.0
ZES0639	16.9 JN, P	25.0	496000	343.7 JN, PUJN, PJNJN, PP	3910.0	66.1 P
ZES0640	14.5 IJN, P	30.7	473000	312.7 PUIJN, PIJN, PP	4110.0	67.7 P
ZES0646	20.0 JNP	29.4	483000	292.9 PIJNJNPJNPP	6200.0	66.0 P
ZES0647	23.0 JNP	33.0	464000	298.7 IPIJNUJNPP	7200.0	72.0 P
ZES0649	50.0 JNP	29.2	453000	401.0 PVUJNPJNPP	4900.0	75.0 P
ZES0650	4.1 IJN, P	16.7	508000	98.3 IJN, PUJN, PIJNIJN, P	1350.0	25.0
ZES0659	30.0 JNP	28.3	475000	379.7 PPIJNPJNPJNPP	9000.0	94.0 P
ZES0663	13.2 IJN, P	26.0	501000	343.4 UJN, PJNIJN, P	1700.0	82.4
ZES0670	18.0 JNP	31.8	458000	320.8 PPUJNPUJNP	6200.0	78.0
ZES0671	8.4 JN, P	20.2	349000	151.8 UJN, PJNJN, P	2490.0	41.1
ZES0672	6.7 JN, P	16.6	436000	153.9 UJNJN, P	2040.0	40.2
ZES0675	11.6	16.4	466000	122.4 UIJN	1300.0	33.0
ZES0676	2.6 IJN, P	39.9	255000 A	102.5 JNUJN, PJNIJN, P	1500.0	24.0
ZES0677	2.0 IJN, P	63.0	114000	47.4 JN, PUJN, PJN, PIJN, P	1040.0	10.7
ZES0686	100.0	28.7	492000	1159.0 PPJNUP	19000.0 Q	280.0 P
ZES0688	27.0 UJNP	33.5	448000	757.1 IJNPIJNPUUJNPP	9800.0	230.0 P
ZES0690	13.7 JN, P	38.7	249000	315.4 UJNJN, P	3530.0	86.1
ZES0701	19.0 JNP	27.9	464000 A	356.3 IPPIJNPUJJNP	6700.0	83.0
ZES0703	56.0	25.2	484000	455.8 IPIPJNJNPIP	8400.0	74.0 IP
ZES0704	25.0 JNP	30.0	470000	399.7 PIJNPUJNP	6900.0	92.0
ZES0706	11.4 JN, P	22.1	401000	177.6 UJNJNJN, P	2990.0	49.6
ZES0707	11.0 JNP	25.2	385000	256.0 JNPIJNUJNPP	3300.0	68.0 P
ZES0719	24.9 JN, P	23.3	457000 0	472.3 JJ, JN, PUJN, PJ, JN, PJN, P	9460.0	73.7
ZES0725	18.0 JNP	35.3	401000 A	355.9 JNJNPUJNPJNJNPP	5000.0	74.0 P
ZES0727	5.0 JN, P	66.5	229000	116.9 UJNJNJN, P	1420.0	31.7

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZES0981	25.5 JN, P	25.5	463000 0	271.7 JN, PJN, PUJN, PJN, PJN, P	8720.0	30.6
ZES0982	27.0 JN	28.1	488000 0	296.7 IJNJN, PUJN, PJN, PJN	10000.0	16.6
ZES0983	3.8 JN, P	23.8	222000 0	139.1 JN, PUJN, PJN, PJN, P	4690.0	31.6
ZES0984	1.2 UJN, P	27.6	460000 0	62.3 JNJN, PUIJN, PUJN, P	2810.0	9.6
ZES0985	4.4 IJN	29.8	188000	114.8	3400.0	19.0
ZES1000	18.9 IJN, P	53.4	494000	343.9 JN, PUJN, PJN, PIJN, P	6250.0	89.1
ZES1001	42.4	28.5	489000 A	499.3 IJN, PJN, PIJN, PJN, PIP	8240.0	143.0 IP
ZES1002	10.7 JN, P	16.3	473000	216.9 UJNJN, PP	3430.0	45.0 P
ZES1003	38.2	30.2	473000	606.5 JN, PJN, PUJNP	6910.0	127.0 P
ZES2034	1.2 IJN	28.7	86200 0	20.0 JN, PJN, PUJN, PIJN, PIJN	608.0	3.0
ZES2035	7.4 IJN	20.9	224000 0	139.7 JN, PJN, PUJNIJN, PIJN	4180.0	23.0
ZES2036	17.7 JN, P	72.1	480000 0	213.7 IJN, PJN, PUJN, PJN, PJN, P	6830.0	23.0
ZES2037	0.0 U	31.1	69900	20.4 JNPIJNPUJNPUU	640.0	3.5
ZES2038	7.3 IJN, P	48.5	493000 0	321.1 UJN, PJN, PIJN, P	13000.0	50.3
ZES2049	0.0 UQ	30.6	474000	144.9 PQJNPQQIQJNPQUQQ	13000.0 Q	42.0 Q
ZES2050	120.0	28.2	489000 A	1242.0 PJNPJNUP	9500.0 Q	320.0 P
ZES2051	8.2 IJNP	31.0	403000	194.5 PJNIJNPUIJNPP	3500.0	45.0 P
ZES2052	18.9 JN, P	19.9	488000 0	375.2 JN, PUJN, PJN, PJN, P	7400.0	52.1
ZES2053	17.5 JN, P	38.0	461000 0	318.7 JN, PUJN, PJNJN, P	6390.0	42.5
ZES2054	7.6 JN, P	26.2	435000 A	195.6 JN, PUJN, PJN, PJN, P	3890.0	31.0

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZES2055	13.9 JN, P	26.2	429000 0	361.8 JNJNUJN, PJNJN, P	5770.0	82.9
ZES2056	5.2 IJN, P	19.5	504000	100.4 IJN, PUJN, PIJN, PIJN, P	1090.0	28.7
ZES2057	26.7 IJN, P	19.2	517000	561.2 IJN, PUJN, PIJN, PIJN, P	4160.0	123.0
ZES2058	4.1 IJN, P	20.1	456000 A	85.7 JN, PIJN, PUJNJN, PIJN, P	1220.0	20.5
ZES2059	15.4 JN, P	30.7	454000	247.7 JN, PUJNJN, PJN, P	3150.0	59.8
ZES2060	62.7 JN	33.7	389000 0	631.7 JNUJNJNJN	8500.0	131.0
ZES2061	28.4 JN, P	53.9	274000	508.6 UJNJN, P	5860.0	129.0
ZES2062	6.2 JNP	27.8	129000	98.5 PUJNPUJNPP	1400.0	24.0 P
ZES2063	7.0 JN, P	62.6	150000	159.1 IUJN, PJNJN, P	1700.0	34.7
ZES4032	26.7 JN, P	25.3	485000	472.1 UJN, PJNJN, P	10000.0	107.0
ZES4033	29.5 JN, P	29.8	492000	697.6 IJN, PJNJN, P	6640.0	212.0
ZES4069	0.2 U	37.2	6860	1.7 UUJN, PUJN, PUUJN, PUU	70.8 I	0.7 U
ZES4070	6.6 I	35.8	361000	104.8 JN, PJN, PUJNI	3990.0	18.2
ZSFE0740	11.0 JN, P	32.5	370000 0	353.6 JNJNUJN, PJNJN, P	5870.0	83.7
ZSFE0749	29.2	48.7	241000	582.1 JN, PUJN	6470.0	102.0

Phase 5:

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)
ZEFE0732	370.0	1200.0	470.0	624.0	2040.0	2.4 IJNP
ZES0630	120.0	1000.0	1200.0	1290.7	2320.0	2.9 IJNP
ZES0632	460.0	1600.0	2300.0	2498.7	4360.0	1.0 UJNP
ZES0641	1100.0	1800.0	480.0	820.0	3380.0	5.0 IJNP
ZES0642	65.0	640.0	460.0	515.7	1165.0	2.2 IJN
ZES0643	160.0 IP	910.0	380.0	472.7 IP	1450.0 IP	3.2 IJNP
ZES0644	71.0 P	420.0	55.0 P	97.2 PP	546.0 PP	0.7 UJNP
ZES0652	210.0	520.0	200.0	276.7	930.0	1.6 IJNP
ZES0653	130.0 P	620.0	170.0	237.3 P	920.0 P	1.8 IJNP
ZES0654	12.3 P	147.0	34.1	46.4 P	193.4 P	0.1 UJN, P
ZES0655	1300.0	2100.0	907.0	1307.0	4307.0	2.4 IJN, P

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)
ZES0665	527.0	763.0	329.0	485.3	1619.0	0.9 UJN, P
ZES0666	479.0	1340.0	1460.0	1645.1	3279.0	0.8 UJN, P
ZES0667	366.0	678.0	244.0 J	362.4 J	1288.0 J	1.7 UJN, P
ZES0668	136.0	241.0	106.0 J	149.3 J	483.0 J	0.7 UJN, P
ZES0669	938.0	1910.0	431.0	745.9	3279.0	10.4 JN, P
ZES0678	118.0	504.0	148.0	205.2	770.0	1.2 UJN, P
ZES0680	184.0	476.0	184.0	252.5	844.0	1.1 UJN, P
ZES0681	39.4 IP	325.0	66.6	96.1 IP	431.0 IP	1.2 IJN, P
ZES0693	80.7 P	293.0	167.0	202.7 P	540.7 P	0.8 IJN, P
ZES0694	13.0	39.2	29.2	34.4	81.4	0.0 UJN, P
ZES0696	305.0	553.0	209.0	306.9	1067.0	1.6 UJN, P
ZES0697	9.4 P	88.3	32.8	40.6 P	130.5 P	0.2 UJN, P
ZES0710	189.0 P	754.0	640.0	728.1 P	1583.0 P	3.5 IJN, P
ZES0711	78.4 P	567.0	522.0	575.5 P	1167.4 P	1.5 IJN, P
ZES0712	137.0	335.0 J	120.0	169.7 J	592.0 J	0.5 UJN, P
ZES0713	190.0 P	1070.0	266.0	375.3 P	1526.0 P	3.6 IJN, P
ZES0729	29.3	197.0	69.5	88.5	295.8	0.2 UJN, P
ZES0731	223.0	732.0	1190.0	1283.4	2145.0	0.9 UJN, P
ZES0733	2830.0	3930.0	4010.0 J	4838.0 J	10770.0 J	2.1 UJN, P
ZES0735	329.0	498.0	158.0 J	257.0 J	985.0 J	1.3 UJN, P
ZES1005	1810.0	2510.0	1340.0 J	1869.3 J	5660.0 J	3.2 IJN, P
ZES1006	124.0	183.0	83.2 J	120.2 J	390.2 J	0.4 UJN, P
ZES1007	481.0	819.0	336.0 J	486.8 J	1636.0 J	2.9 IJN, P
ZES1008	54.5 P	208.0	182.0	206.8 P	444.5 P	0.9 IJN, P
ZES1009	336.0	1540.0	964.0	1133.9	2840.0	1.8 UJN, P
ZES2064	75.2 P	486.0	142.0	189.4 P	703.2 P	0.9 UJN, P
ZES2068	63.1	269.0	134.0	164.6	466.1	0.4 UJN, P
ZES2069	58.6	197.0	184.0	208.9	439.6	0.4 UJN, P
ZES2070	128.0	399.0	337.0	389.2	864.0	0.3 UJN, P
ZES4041	427.0	640.0 J	179.0	307.1 J	1246.0 J	2.9 IJN, P
ZES4042	784.0	1050.0	452.0	678.8	2286.0	1.9 UJN, P
ZSFE0825	499.0	1150.0	641.0	817.5	2290.0	2.9 UJN, P
ZSFE0831	296.0	474.0	117.0	207.8	887.0	2.5 UJN, P
ZSFE0837	391.0	927.0	317.0	457.0	1635.0	4.6 JN, P
ZSFE0904	1410.0	1810.0	1460.0	1862.7	4680.0	3.2 UJN, P
ZSS0751	271.0	1130.0	837.0	966.5	2238.0	1.7 IJN, P
ZSS0755	9.5 P	180.0	19.2 JN, P	33.1 PJN, P	208.7 PJN, P	0.5 UJN

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)
ZSS0770	489.0	1750.0	629.0	843.5	2868.0	5.2 JN, P
ZSS0771	5.5	21.6	7.8	10.3	34.9	0.3 UJN, P
ZSS0772	305.0 P	1180.0	648.0	787.7 P	2133.0 P	3.2 IJN, P
ZSS0774	73.0	138.0	56.0	79.8	267.0	0.3 UJN, P
ZSS0775	381.0	919.0	1140.0	1277.5	2440.0	1.5 UJN, P
ZSS0776	29.7 P	190.0	166.0	184.6 P	385.7 P	0.2 UJN, P
ZSS0789	133.0 P	732.0	403.0	478.4 P	1268.0 P	2.1 IJN, P
ZSS0791	3.1 IJN, P	15.7	4.5 I	6.2 IJN, PI	23.3 IJN, PI	0.1 UJN, P
ZSS0792	573.0 P	2000.0	1730.0	1977.9 P	4303.0 P	4.5 IJN, P
ZSS0793	284.0	1240.0	1380.0	1519.5	2904.0	1.9 IJN, P
ZSS0794	340.0	1030.0	284.0	420.7	1654.0	2.6 IJN, P
ZSS0795	390.0	1610.0	341.0	526.3	2341.0	6.9 IJN, P
ZSS0805	48.3 JN, P	181.0	59.0	80.7 JN, P	288.3 JN, P	0.7 UJN, P
ZSS0806	35.7 P	196.0	19.2 P	39.4 PP	250.9 PPP	0.3 UJN, P
ZSS0809	195.0	474.0	407.0	477.6	1076.0	0.5 UJN, P
ZSS0811	159.0	1160.0	137.0	246.1	1456.0	2.2 UJN, P
ZSS0812	200.0	1070.0	231.0	342.3	1501.0	1.3 UJN, P
ZSS0814	124.0 P	774.0	392.0	468.4 P	1290.0 P	1.0 UJN, P
ZSS0826	295.0	3220.0	1810.0	2083.7	5325.0	12.0
ZSS0830	37.6	176.0	45.3	64.6	258.9	0.4 UJN, P
ZSS0832	151.0	1350.0	138.0	258.2	1639.0	6.7
ZSS0834	15.9	115.0	42.7	53.5	173.6	0.1 UJN, P
ZSS0836	17.5 JN, P	143.0 J	48.7 J	61.7 JN, PJJ	209.2 JN, PJJ	0.0 U
ZSS0847	23.7 JN, P	153.0	45.2	60.1 JN, P	221.9 JN, P	0.0 U
ZSS0848	66.2 IJN, P	750.0	65.1 IJN, P	128.3 IJN, PIJN, P	881.3 IJN, PIJN, P	3.1 IJN, P
ZSS0850	373.0	911.0	750.0	885.3	2034.0	3.0 IJN, P
ZSS0852	24.7 JN, P	174.0	14.5 JN, P	31.0 JN, PJN, P	213.2 JN, PJN, P	0.4 UJN, P
ZSS0853	29.4 P	191.0	46.6	65.2 P	267.0 P	0.4 UJN, P
ZSS0854	578.0	1320.0	424.0	627.6	2322.0	5.1 IJN, P
ZSS0855	208.0	496.0	381.0	455.7	1085.0	1.9 IJN, P
ZSS0866	41.9 JN, P	213.0	36.8 JN, P	59.4 JN, PJN, P	291.7 JN, PJN, P	0.8 IJN, P
ZSS0868	52.5	103.0	44.2	61.6	199.7	0.8 I
ZSS0870	10.0	25.8	9.4	13.1	45.2	0.1 UJN, P
ZSS0873	189.0	424.0	286.0	352.1	899.0	1.4 IJN, P
ZSS0881	26.8 JN, P	304.0	27.2 JN, P	52.8 JN, PJN, P	358.0 JN, PJN, P	1.2 IJN, P
ZSS0882	23.2 P	264.0	47.3	69.5 P	334.5 P	0.8 IJN, P
ZSS0884	166.0 JN, P	1220.0	1200.0	1314.5 JN, P	2586.0 JN, P	1.9 UJN, P

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)
ZSS0886	28.3 P	309.0	54.5	80.8 P	391.8 P	1.1 IJN, P
ZSS0888	28.0 JNP	130.0	34.0 JNP	48.3 JNPJNP	192.0 JNPJNP	0.6 UJNP
ZSS0890	9.0 JN, P	107.0	132.0	140.9 JN, P	248.0 JN, P	0.2 UJN, P
ZSS4034	387.0 JN, P	1450.0	354.0 P	528.1 JN, PP	2191.0 JN, PP	7.4 JN, P
ZSS4035	815.0	1510.0	792.0	1055.7	3117.0	5.5 JN, P
ZSS4036	268.0	613.0	322.0	416.5	1203.0	1.7 IJN, P
ZSS4037	4.7 JN, P	32.3	5.4 JN, P	8.5 JN, PJN, P	42.4 JN, PJN, P	0.2 UJN, P
ZSS4038	231.0 JN, P	787.0	484.0	582.7 JN, P	1502.0 JN, P	2.8 IJN, P
ZSS4039	115.0 JN, P	429.0	276.0	327.6 JN, P	820.0 JN, P	1.2 IJN, P
ZSS4040	293.0	710.0	658.0	763.9	1661.0	1.9 IJN, P

Site Name	alpha-BHC (ug/kg)	alpha-Chlordane (ug/kg)	beta-BHC (ug/kg)	cis-Nonachlor (ug/kg)	delta-BHC (ug/kg)	Dieldrin (ug/kg)
ZEFE0732	0.1 UJNP	86.0	0.0 U	83.0 JNP	0.2 UJNP	210.0
ZES0630	0.0 U	110.0	0.0 U	220.0	0.0 U	150.0
ZES0632	0.0 U	94.0	0.0 U	190.0 JN	0.0 U	140.0
ZES0641	0.0 U	140.0 P	0.0 U	100.0 JNP	0.0 U	220.0
ZES0642	0.0 U	96.0	0.0 U	24.0 IJNP	0.0 U	120.0 P
ZES0643	0.0 U	140.0	0.1 UJNP	51.0 IJN	0.0 U	230.0
ZES0644	0.0 U	71.0	0.0 U	28.0 IJN	0.0 U	86.0
ZES0652	0.0 U	120.0	0.0 U	58.0 JNP	0.0 U	180.0
ZES0653	0.0 U	170.0	0.2 UJNP	69.0 JNP	0.0 U	180.0
ZES0654	0.1 UJN, P	13.3	0.0 U	5.8	0.1 UJN, P	11.6
ZES0655	0.0 U	132.0	2.6 UJN, P	70.9 IJN, P	1.3 UJN, P	273.0
ZES0665	0.0 U	52.9	1.5 UJN, P	25.5 JN, P	0.9 UJN, P	108.0
ZES0666	0.0 U	44.5	1.4 UJN, P	35.4 IJN, P	0.7 UJN, P	135.0
ZES0667	0.2 UJN, P	56.7	0.2 UJN, P	27.9 JN, P	1.1 UJN, P	115.0
ZES0668	1.0 UJN, P	22.6	0.0 U	10.5 JN, P	0.6 UJN, P	41.4
ZES0669	0.0 U	273.0	0.0 U	143.0	0.0 U	625.0
ZES0678	0.0 U	39.0	0.0 U	25.9	0.0 U	73.8
ZES0680	0.0 U	61.8	0.3 UJN, P	39.3	0.0 U	120.0
ZES0681	0.0 U	51.4	0.0 U	30.3	0.0 U	140.0
ZES0693	0.0 U	44.1	0.3 UJN, P	22.7	0.0 U	91.8
ZES0694	0.0 U	3.8	0.0 UJN, P	4.6 JN, P	0.0 U	5.9
ZES0696	0.0 U	84.5	0.7 UJN, P	45.8	2.1 IJN, P	114.0
ZES0697	0.0 U	8.0	0.0 U	5.0	0.0 U	17.4

Site Name	alpha-BHC (ug/kg)	alpha-Chlordane (ug/kg)	beta-BHC (ug/kg)	cis-Nonachlor (ug/kg)	delta-BHC (ug/kg)	Dieldrin (ug/kg)
ZES0710	0.0 U	118.0	1.8 UJN, P	76.3	0.0 U	350.0
ZES0711	0.0 U	63.3	1.0 UJN, P	41.4 JN, P	0.0 U	205.0
ZES0712	0.0 U	52.5	0.0 U	19.7 IJN, P	0.0 U	43.5
ZES0713	0.0 U	184.0	0.9 UJN, P	87.7	0.0 U	404.0
ZES0729	0.2 UJN	17.3	0.0 U	9.6	0.4 UJN	14.0
ZES0731	0.0 U	57.0	0.0 U	60.5 JN, P	0.0 U	88.8
ZES0733	0.9 UJN, P	117.0	0.0 U	70.3 JN, P	0.9 UJN, P	234.0
ZES0735	0.8 UJN, P	45.0	0.0 U	19.5 JN, P	0.7 UJN, P	85.9
ZES1005	0.0 U	173.0	0.5 UJN, P	82.6 IJN, P	0.0 U	413.0
ZES1006	0.0 U	15.5	0.0 U	7.7 JN, P	0.0 U	41.8
ZES1007	0.0 U	110.0	0.7 UJN, P	47.9 IJN, P	0.0 U	218.0
ZES1008	0.0 U	33.6	0.4 UJN, P	17.0 JN, P	0.0 U	98.8
ZES1009	0.0 U	124.0	1.8 UJN, P	70.7 JN, P	0.0 U	224.0
ZES2064	0.0 U	67.2	0.0 U	36.2	0.0 U	130.0
ZES2068	0.2 UJN, P	22.5	0.2 UJN, P	16.8 IJN, P	0.0 U	40.5
ZES2069	0.0 U	15.9	0.0 U	19.6	0.6 UJN, P	24.0
ZES2070	0.3 UJN, P	20.4	0.0 U	20.9	1.0 UJN, P	34.3
ZES4041	0.0 U	98.5	2.1 UJN, P	40.1 IJN, P	1.0 UJN, P	132.0
ZES4042	2.9 UJN	136.0	2.9 UJN, P	68.7	3.6 UJN, P	182.0
ZSFE0825	0.0 U	95.7	0.0 U	72.2	1.3 UJN, P	228.0
ZSFE0831	0.0 U	61.9	2.0 UJN, P	25.5 JN, P	1.1 UJN, P	130.0
ZSFE0837	0.0 U	111.0	2.4 IJN	49.0	0.0 U	184.0
ZSFE0904	0.0 U	178.0	1.8 UJN	102.0	0.0 U	201.0
ZSS0751	0.0 U	100.0	0.0 U	136.0 JN, P	0.9 UJN, P	136.0
ZSS0755	0.0 U	26.8	0.0 U	16.0	0.0 U	28.5 JN, P
ZSS0770	0.6 UJN, P	250.0	0.9 UJN, P	174.0 JN, P	1.1 IJN, P	350.0
ZSS0771	0.1 UJN, P	3.0	0.0 U	1.8 IJN, P	0.0 UJN, P	5.7
ZSS0772	0.0 U	192.0	0.6 UJN, P	98.3 JN	0.0 U	401.0
ZSS0774	0.3 UJN, P	25.1	0.0 U	15.2 JN, P	0.3 UJN, P	40.2
ZSS0775	0.5 UJN, P	112.0	0.6 UJN, P	93.1 JN, P	0.0 U	230.0
ZSS0776	0.1 UJN, P	16.0	0.0 U	18.1 JN, P	0.0 U	37.1
ZSS0789	0.0 U	128.0	0.5 UJN, P	65.2 JN	0.0 U	282.0
ZSS0791	0.0 UJN, P	3.4	0.9 UJN	1.5 IJN, P	0.1 UJN, P	5.2
ZSS0792	0.0 U	302.0	0.0 U	223.0 JN, P	3.7 UJN, P	597.0
ZSS0793	0.4 UJN, P	79.5	3.2 JN	79.2 JN, P	1.7 IJN, P	155.0
ZSS0794	0.0 U	189.0	0.3 UJN, P	98.1	0.0 U	325.0
ZSS0795	0.0 U	270.0	0.0 U	169.0	2.9 IJN	734.0

Site Name	alpha-BHC (ug/kg)	alpha-Chlordane (ug/kg)	beta-BHC (ug/kg)	cis-Nonachlor (ug/kg)	delta-BHC (ug/kg)	Dieldrin (ug/kg)
ZSS0805	0.5 UJN, P	43.7	1.4 UJN, P	19.9 JN, P	0.9 UJN	69.5
ZSS0806	0.1 UJN, P	22.1	0.0 U	10.6 JN	0.3 UJN	28.3 P
ZSS0809	0.8 UJN, P	38.7	1.4 UJN, P	31.9 JN, P	1.1 UJN, P	76.5
ZSS0811	0.0 U	80.9	0.1 UJN, P	46.0	0.0 U	393.0
ZSS0812	0.0 U	82.6	0.5 UJN	41.7	0.0 U	373.0
ZSS0814	0.0 U	51.1	0.0 U	26.9	0.0 U	253.0
ZSS0826	0.5 UJN, P	139.0	1.4 UJN	89.1 IJN, P	0.4 UJN, P	778.0
ZSS0830	0.0 U	14.4	0.0 U	8.6	0.0 U	54.9
ZSS0832	0.2 UJN, P	76.7	0.3 UJN, P	38.1 IJN, P	0.1 UJN, P	371.0
ZSS0834	0.1 UJN, P	5.9	0.0 U	3.7 JN, P	0.1 UJN, P	22.3
ZSS0836	0.3 UJN, P	9.9	0.0 U	4.8 JN, P	0.1 UJN	26.8
ZSS0847	0.0 UJN, P	13.8	0.0 U	5.9 JN, P	0.1 UJN, P	53.7
ZSS0848	0.4 UJN, P	70.2	0.6 UJN	37.2 IJN, P	0.5 UJN, P	247.0
ZSS0850	0.3 UJN, P	135.0	1.2 UJN, P	84.9 JN, P	0.0 U	282.0
ZSS0852	0.2 UJN, P	24.9	0.0 U	13.6 JN, P	0.0 U	69.8
ZSS0853	0.0 UJN, P	24.8	0.3 UJN, P	14.8 JN, P	0.0 U	45.6
ZSS0854	0.6 UJN, P	215.0	3.5 UJN	109.0 JN, P	0.0 U	395.0
ZSS0855	0.1 UJN, P	83.7	0.8 UJN, P	52.8 JN, P	0.0 U	170.0
ZSS0866	0.0 U	39.5	0.0 U	22.2 JN, P	0.0 U	75.8
ZSS0868	0.0 U	14.4	0.0 U	11.0 JN, P	0.0 U	34.7
ZSS0870	0.0 UJN, P	2.2	0.0 U	2.5 JN, P	0.0 U	5.8
ZSS0873	0.1 UJN, P	76.0	1.2 IJN, P	44.3 JN, P	0.0 U	156.0
ZSS0881	0.1 UJN, P	36.0	0.0 U	23.0 JN, P	0.0 U	106.0
ZSS0882	0.1 UJN, P	42.3	0.6 UJN, P	20.9	0.0 U	87.0
ZSS0884	0.1 UJN, P	109.0	0.6 UJN	90.5 JN, P	0.0 U	216.0
ZSS0886	0.1 UJN, P	48.9	0.0 U	25.0	0.0 U	122.0
ZSS0888	0.1 UJNP	25.0	0.0 U	15.0 JNP	0.2 UJNP	60.0
ZSS0890	0.0 UJN, P	5.8	0.0 U	6.6 JN, P	0.0 U	15.2
ZSS4034	0.0 U	220.0	1.0 UJN, P	172.0 JN, P	1.0 UJN, P	549.0
ZSS4035	0.0 U	207.0	3.0 IJN	150.0 JN, P	0.0 U	453.0
ZSS4036	0.0 U	81.0	0.5 UJN	67.3 JN, P	0.0 U	157.0
ZSS4037	0.0 UJN, P	4.5	0.0 U	2.7 JN, P	0.0 U	10.9
ZSS4038	0.0 U	130.0	1.0 UJN, P	101.0 JN, P	0.0 U	276.0
ZSS4039	0.0 U	44.8	0.0 U	50.6 JN, P	0.0 U	104.0
ZSS4040	0.0 U	81.1	0.0 U	96.5 JN, P	0.0 U	162.0

Site Name	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)
ZEFE0732	0.0 U	210.0 JN	0.0 U	0.0 U	0.0 U	46.0 JN
ZES0630	0.0 U	0.0 U	0.0 U	0.0 U	0.0 U	90.0 JN
ZES0632	36.0 JNP	0.0 U	0.0 U	0.0 U	0.0 U	45.0 JNP
ZES0641	0.0 U	520.0 JN	0.0 U	0.0 U	0.0 U	45.0 JNP
ZES0642	0.0 U	60.0 JNP	0.0 U	0.0 U	0.0 U	1.6 UJNP
ZES0643	0.0 U	190.0 JN	0.0 U	0.0 U	0.0 U	25.0 JN
ZES0644	0.0 U	110.0 JN	0.0 U	0.0 U	0.0 U	11.0 JN
ZES0652	0.0 U	180.0 JN	0.0 U	0.0 U	0.0 U	21.0 JN
ZES0653	0.0 U	220.0 JN	0.0 U	0.0 U	0.0 U	20.0 JN
ZES0654	0.0 U	14.7 J, JN	0.6 UJN, P	2.4 IJN, P	12.2 JN, P	2.3 IJN
ZES0655	22.2 UJN, P	256.0 JN	18.0 JN, P	0.0 U	160.0 IJN, P	31.1 JN, P, V
ZES0665	7.9 JN, P	89.4 JN	5.1 UJN, P	0.0 U	75.9 JN, P	17.4 JN, V
ZES0666	9.8 JN, P	100.0 JN	18.7 JN	0.0 U	142.0 JN	24.2 JN, P, V
ZES0667	13.0 JN, P	94.5 JN	9.5 IJN	7.7 IJN, P	82.8 JN, P	14.3 JN, P
ZES0668	4.8 IJN, P	40.6 JN	1.1 UJN, P	2.5 UJN, P	36.5 JN, P	10.3 IJN
ZES0669	29.7 UJN, P	600.0 JN	0.0 U	0.0 U	0.0 U	51.6 JN
ZES0678	0.0 U	78.6 JN	0.0 U	0.0 U	0.0 U	9.5 JN, P
ZES0680	0.0 U	130.0 JN	0.0 U	0.0 U	0.0 U	15.5 JN
ZES0681	3.5 UJN, P	118.0 JN	0.0 U	0.0 U	0.0 U	8.4 JN
ZES0693	3.5 UJN, P	104.0 JN	0.0 U	0.0 U	0.0 U	12.3 JN, P
ZES0694	0.0 U	9.1 JN	0.0 U	0.0 U	0.0 U	1.3 IJN, P
ZES0696	10.7 JN, P	78.7 J, JN, P	14.5 JN, P	30.4 JN, P	116.0 JN, P	18.3 JN, P
ZES0697	0.0 U	20.1 JN	0.0 U	0.0 U	0.0 U	1.9 IJN, P
ZES0710	12.8 UJN, P	315.0 JN	0.0 U	0.0 U	0.0 U	56.7 JN, P
ZES0711	0.0 U	191.0 JN	0.0 U	0.0 U	0.0 U	35.4 JN, P
ZES0712	0.0 U	33.3 IJ, JN, P	0.0 UJ	0.0 U	58.7 JN, P	7.9 JN, P
ZES0713	16.3 UJN, P	403.0 JN	0.0 U	0.0 U	0.0 U	32.9 JN
ZES0729	0.0 U	10.9 J, JN, P	2.9 IJN, P	0.0 U	20.7 JN, P	3.7 IJN, P
ZES0731	11.1 JN, P	65.6 JN, P	40.8 JN	0.0 U	0.0 U	30.0 JN, V
ZES0733	29.7 JN, P	218.0 JN	27.7 IJN	43.9 JN	231.0 JN, P	40.5 JN, P
ZES0735	6.7 IJN, P	73.1 JN	4.6 UJN, P	6.5 IJN	59.4 JN, P	9.7 IJN, P
ZES1005	25.5 JN, P	133.0 IJN, P	26.6 JN	0.0 U	0.0 U	49.8 J, JN
ZES1006	1.5 UJN, P	13.9 JN, P	3.7 UJN	0.0 U	0.0 U	5.5 IJN, P
ZES1007	12.4 JN, P	91.6 IJN, P	11.6 JN, P	0.0 U	0.0 U	21.0 JN, P
ZES1008	0.0 U	85.0 JN	0.0 U	0.0 U	0.0 U	14.5 JN, P
ZES1009	0.0 U	274.0 JN	0.0 U	0.0 U	0.0 U	42.1 JN, P
ZES2064	6.1 JN, P	143.0 JN	0.0 U	0.0 U	0.0 U	13.4 JN, P

Site Name	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)
ZES2068	0.0 U	41.3 JN	6.7 J, JN	0.0 U	0.0 U	5.3 JN, P
ZES2069	0.0 U	49.8 J, JN	19.5 JN, P	14.3 JN, P	73.1 JN	15.4 JN, P
ZES2070	0.0 U	57.0 J, JN	17.7 JN, P	15.2 IJN, P	79.5 JN	13.0 IJN, P
ZES4041	11.8 JN, P	68.2 J, JN, P	12.8 IJ, JN	0.0 U	104.0 JN, P	15.0 IJN
ZES4042	0.0 U	245.0 J, JN	16.0 UJN	37.0 IJN, P	181.0 JN, P	24.3 UJN, P
ZSFE0825	0.0 U	285.0 J, JN	24.6 IJN, P	55.1 JN, P	223.0 JN, P	40.2 JN, P
ZSFE0831	0.0 U	95.4 J, JN	7.8 UJN	10.5 IJN, P	75.1 JN, P	8.4 IJN, P
ZSFE0837	0.0 U	203.0 J, JN	21.6 JN, P	22.4 UJN, P	148.0 JN, P	31.4 JN
ZSFE0904	0.0 U	354.0 JN	36.0 JN, P	76.4 JN, P	326.0 IJN, P	36.5 JN, P
ZSS0751	0.0 U	289.0 J, JN	98.9 JN	65.7 IJN, P	334.0 JN	28.5 UJN, P
ZSS0755	0.9 IJN, P	30.2 JN, P	0.0 U	0.0 U	0.0 U	1.4 UJN, P
ZSS0770	21.4 UJN, P	517.0 JN	53.9 JN, P	0.0 U	455.0 JN, P	42.7 UJN, P, V
ZSS0771	0.3 UJN, P	5.4 JN	0.3 UJN, P	0.0 U	5.5 JN, P	3.1 IJN, V
ZSS0772	11.2 UJN, P	387.0 JN	0.0 U	0.0 U	0.0 U	54.5 JN
ZSS0774	2.1 IJN, P	47.2 JN	3.4 UJN, P	0.0 U	41.3 JN, P	7.0 JN, V
ZSS0775	15.2 JN, P	134.0 JN, P	51.2 J, JN	0.0 U	141.0 IJN, P	29.5 JN, P
ZSS0776	0.0 U	39.9 JN	9.0 J, JN	0.0 U	30.5 IJN, P	3.9 JN, P
ZSS0789	6.9 UJN, P	270.0 JN	18.3 JN, P	0.0 U	0.0 U	38.8 JN, P
ZSS0791	0.0 U	6.0 JN	0.7 UJN	0.0 U	5.9 JN, P	1.7 IJN, V
ZSS0792	0.0 U	610.0 JN	113.0 J, JN	0.0 U	543.0 JN, P	68.9 JN, P
ZSS0793	8.5 UJN, P	196.0 JN	54.5 JN	0.0 U	256.0 JN	32.1 UJN, P, V
ZSS0794	10.0 UJN, P	391.0 JN	0.0 U	0.0 U	0.0 U	30.2 JN, P
ZSS0795	15.9 UJN, P	513.0 JN	0.0 U	0.0 U	0.0 U	48.0 JN
ZSS0805	3.5 IJN, P	70.2 JN	3.7 UJN, P	0.0 U	57.0 JN, P	8.2 IJN, V
ZSS0806	0.0 U	17.9 JN, P	0.0 UJ	0.0 U	0.0 U	2.6 IJN, P
ZSS0809	5.3 JN, P	86.0 JN	12.7 JN	0.0 U	97.4 JN, P	22.2 JN, P, V
ZSS0811	15.9 JN, P	166.0 JN	10.4 IJN, P	0.0 U	0.0 U	13.8 IJN
ZSS0812	0.0 U	165.0 JN	12.0 IJN, P	0.0 U	0.0 U	14.8 IJN
ZSS0814	7.3 JN, P	84.9 JN	6.2 IJN, P	0.0 U	0.0 U	5.8 IJN, P
ZSS0826	7.1 UJN, P	312.0 JN	37.2 JN, P	0.0 U	245.0 JN, P	74.4 JN, P, V
ZSS0830	0.0 U	31.6 JN	2.6 UJN, P	0.0 U	0.0 U	5.3 IJN, P
ZSS0832	2.7 UJN, P	165.0 JN	11.5 JN, P	0.0 U	118.0 IJN, P	19.1 JN, V
ZSS0834	0.3 UJN, P	12.7 JN	0.9 UJN, P	0.0 U	13.1 JN, P	4.5 JN, V
ZSS0836	0.9 IJN, P	17.4 JN	1.3 UJN, P	0.0 U	16.1 JN, P	2.5 IJN, P, V
ZSS0847	0.4 UJN, P	25.9 JN	2.5 IJN	0.0 U	26.8 JN, P	5.1 JN, V
ZSS0848	0.0 U	145.0 JN	12.7 JN	0.0 U	92.5 IJN, P	10.2 JN
ZSS0850	13.6 IJN, P	229.0 JN	0.0 U	0.0 U	0.0 U	43.2 JN

Site Name	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)
ZSS0852	2.2 IJN, P	32.9 JN, P	4.0 IJN	3.5 IJN, P	23.9 JN, P	3.9 IJN, P
ZSS0853	1.5 IJN, P	41.4 JN	0.0 U	0.0 U	0.0 U	5.6 JN, P
ZSS0854	21.7 UJN, P	381.0 JN	0.0 U	0.0 U	0.0 U	41.5 JN, P
ZSS0855	8.4 IJN, P	141.0 JN	0.0 U	0.0 U	0.0 U	29.6 JN
ZSS0866	0.0 U	68.1 JN	5.9 JN, P	0.0 U	52.5 JN, P	6.6 JN, P
ZSS0868	1.4 IJN, P	28.0 JN	3.6 IJN	0.0 U	26.1 JN, P	3.1 IJN, P
ZSS0870	0.0 U	7.5 JN	1.3 UJN	0.0 U	7.1 JN, P	1.2 IJN, P
ZSS0873	6.3 UJN, P	122.0 JN	0.0 U	0.0 U	0.0 U	22.9 JN
ZSS0881	0.0 U	68.1 JN	5.2 JN, P	0.0 U	45.7 JN, P	7.1 JN, P
ZSS0882	1.3 IJN, P	67.2 JN	0.0 U	0.0 U	0.0 U	8.6 JN, P
ZSS0884	14.7 JN, P	231.0 JN	0.0 U	0.0 U	0.0 U	44.5 JN
ZSS0886	0.0 U	78.2 JN	0.0 U	0.0 U	0.0 U	10.2
ZSS0888	2.4 IJNP	62.0 JN	1.9 UJNP	6.9 IJNP	29.0 JNP	4.5 IJNP
ZSS0890	0.9 IJN, P	15.3 JN	0.0 U	0.0 U	0.0 U	4.9 JN
ZSS4034	20.7 UJN, P	513.0 JN	53.3 JN	0.0 U	0.0 U	52.4 JN, P
ZSS4035	20.1 UJN, P	443.0 JN	50.0 JN	0.0 U	0.0 U	37.1 JN, P
ZSS4036	7.3 UJN, P	180.0 JN	29.1 JN	0.0 U	0.0 U	19.0 JN, P
ZSS4037	0.0 U	8.9 JN	0.8 UJN, P	0.0 U	0.0 U	1.1 UJN, P
ZSS4038	13.3 JN, P	257.0 JN	34.7 JN	0.0 U	0.0 U	24.9 JN, P
ZSS4039	7.6 JN, P	130.0 JN	25.4 JN	0.0 U	0.0 U	16.1 JN, P
ZSS4040	11.4 JN, P	226.0 JN	50.5 JN	0.0 U	0.0 U	25.5 JN, P

Site Name	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)	Moisture, Percent (%)
ZEFE0732	0.1 UJNP	51.0	0.0 U	0.0 U	120.0 JN	0.0
ZES0630	0.7 UJNP	54.0	0.0 U	14.0 JNP	340.0 JNP	0.0
ZES0632	0.5 UJNP	55.0	0.0 U	0.0 U	210.0 JN	9.7
ZES0641	0.8 UJNP	75.0	0.0 U	0.0 U	200.0 JNP	55.5
ZES0642	0.0 U	88.0	0.2 UJNP	15.0 JN	11.0 UJNP	76.5
ZES0643	0.0 U	97.0	0.0 U	27.0 JN	51.0 IJNP	64.4
ZES0644	0.0 U	43.0	0.0 U	13.0 JN	25.0 IJNP	59.9
ZES0652	0.0 U	47.0	0.0 U	14.0 JNP	49.0 JNP	28.2
ZES0653	0.1 UJNP	83.0	0.0 U	17.0 JNP	55.0 JNP	34.2
ZES0654	0.2 UJN	19.3	0.5 UJN	8.7 JN	3.6 UJN, P	71.6
ZES0655	0.1 UJN, P	52.5 JN, P	1.4 UJN	32.7 JN, P	19.2 UJN, P	27.4
ZES0665	0.3 UJN, P	25.9 JN, P	0.4 UJN, P	15.6 JN, P	12.9 UJN, P	33.3

Site Name	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)	Moisture, Percent (%)
ZES0666	0.1 UJN, P	23.1	0.4 UJN, P	10.3 JN, P	20.0 IJN, P	37.4
ZES0667	0.2 UJN, P	28.0	0.8 UJN, P	16.3 JN, P	13.7 UJN, P	68.6
ZES0668	0.0 UJN, P	10.7	0.1 UJN, P	9.4 JN	7.3 UJN, P	37.3
ZES0669	0.4 UJN, P	102.0	1.7 UJN, P	88.6 JN	140.0 JN	18.3
ZES0678	0.9 UJN, P	27.0	0.7 UJN, P	8.4 JN	15.9 IJN	18.3
ZES0680	0.2 UJN, P	52.1	0.8 UJN, P	23.6 JN	12.5 UJN, P	47.7
ZES0681	0.2 UJN, P	17.9	0.3 UJN, P	13.7 JN	26.0 JN, P	31.9
ZES0693	0.3 UJN, P	36.9	0.6 UJN, P	17.3 JN	12.3 IJN, P	53.1
ZES0694	0.1 UJN	1.6 IJN, P	0.0 U	1.2 IJN	0.0 U	18.6
ZES0696	0.2 UJN, P	38.7	1.1 UJN	29.0 JN	86.0 JN, P	34.1
ZES0697	0.1 UJN, P	4.9	0.3 UJN	1.9 JN	4.9 UJN, P	44.1
ZES0710	0.2 UJN, P	45.0	1.5 IJN, P	36.2 JN	42.5 IJN, P	35.9
ZES0711	0.2 UJN, P	23.3	0.8 UJN	21.0 JN	34.9 IJN, P	68.5
ZES0712	0.1 UJN, P	27.2	0.0 U	16.0 JN	40.0 JN	29.7
ZES0713	0.4 UJN, P	164.0	1.9 IJN, P	62.0 JN	30.0 IJN, P	27.6
ZES0729	0.1 UJN, P	19.2	0.2 UJN, P	12.2 JN	7.2 IJN, P	25.7
ZES0731	0.1 UJN, P	59.9	0.9 UJN, P	22.6 JN	28.5 UJN, P	70.0
ZES0733	0.0 U	69.3 JN, P	1.5 UJN	31.7 JN, P	18.9 UJN, P	66.5
ZES0735	0.3 UJN, P	19.9	0.4 UJN, P	15.3 JN	6.2 UJN, P	76.2
ZES1005	0.3 UJN, P	65.7	0.9 UJN, P	45.4 J, JN, P	26.6 UJN, P	67.3
ZES1006	0.0 U	8.8	0.0 U	4.7 IJN, P	8.9 UJN, P	74
ZES1007	0.1 UJN, P	42.7	1.3 UJN	31.8 JN	13.4 UJN, P	69.1
ZES1008	0.2 UJN, P	12.0	0.5 UJN	11.0 JN	13.5 IJN, P	85.4
ZES1009	0.5 UJN, P	54.4	2.1 UJN	37.6 JN	39.6 UJN, P	64.7
ZES2064	0.2 UJN, P	22.6	0.8 UJN	18.3 JN	14.2 UJN, P	62.5
ZES2068	0.0 U	10.4	0.4 UJN	6.6 JN	18.0 IJN, P	21.3
ZES2069	0.3 UJN, P	7.9	0.6 UJN	2.5 IJN	20.0 IJN, P	64.8
ZES2070	0.7 UJN	10.2	0.8 UJN, P	4.6 IJN, P	20.5 UJN, P	70.4
ZES4041	0.3 UJN, P	50.7	1.5 UJN	39.2 JN	77.8 IJN	80.3
ZES4042	2.9 UJN	75.9	2.9 UJN, P	54.4 JN	50.7 UJN, P	74.6
ZSFE0825	0.3 UJN, P	37.0 JN, P	2.2 UJN, P	57.7 JN	62.0 IJN, P	67.2
ZSFE0831	1.1 UJN, P	28.7	1.1 UJN, P	28.4 JN	47.8 IJN	75.7
ZSFE0837	0.5 UJN, P	32.6 IJN, P	3.3 IJN	44.1 JN	23.7 IJN, P	56.4
ZSFE0904	0.3 UJN, P	56.9 JN, P	3.2 UJN	60.8 JN	32.6 UJN, P	52.4
ZSS0751	0.6 UJN, P	36.2	1.3 UJN, P	24.6 JN	81.9 JN, P	54.5
ZSS0755	0.0 UJN, P	18.7	0.5 UJN, P	4.5 JN	5.8 UJN	68.9
ZSS0770	0.5 UJN, P	122.0	0.7 UJN, P	48.3 IJN	66.2 JN, P	54.8

Site Name	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)	Moisture, Percent (%)
ZSS0771	0.0 U	3.1	0.0 U	0.8 IJN	2.8 UJN	25.1
ZSS0772	0.3 UJN, P	128.0	1.7 UJN	49.1 JN	120.0 JN	41.5
ZSS0774	0.1 UJN, P	13.0	0.4 UJN, P	6.9 JN	4.5 UJN, P	50.7
ZSS0775	0.3 UJN, P	57.1	1.3 UJN, P	43.0 JN	131.0 JN, P	55.5
ZSS0776	0.0 U	7.7 JN, P	0.0 U	4.8 JN	23.8 JN, P	6
ZSS0789	0.3 UJN, P	88.8	0.9 UJN	30.3 JN	75.7 JN, P	67.3
ZSS0791	0.0 UJN, P	2.0 I	0.0 U	0.4 UJN	2.4 UJN	29.8
ZSS0792	0.8 UJN, P	50.6 JN, P	4.7 IJN	94.7 JN	464.0 JN	51.8
ZSS0793	0.4 UJN	49.4 I	1.7 IJN	20.4 JN, P	44.3 JN, P	37.6
ZSS0794	0.3 UJN, P	115.0	0.9 UJN	37.8 JN	26.3 IJN, P	53.1
ZSS0795	0.5 UJN, P	212.0	1.4 UJN, P	49.0 JN, P	109.0 JN, P	37.8
ZSS0805	0.6 UJN	22.5	0.3 UJN, P	11.0 JN	27.9 IJN	65.7
ZSS0806	0.0 U	11.2	0.3 UJN, P	5.4 JN	14.7 IJN	22.3
ZSS0809	0.5 UJN, P	17.3	0.8 UJN, P	10.6 JN, P	9.7 UJN, P	65.5
ZSS0811	0.1 UJN, P	26.6 JN, P	0.0 U	28.9 JN	0.0 U	36.5
ZSS0812	0.2 UJN, P	28.0 JN, P	0.0 U	27.1 JN	0.0 U	39.7
ZSS0814	0.1 UJN, P	22.2	0.0 U	15.0 JN	29.1 IJN, P	53
ZSS0826	0.0 U	82.1 I	1.5 UJN	31.6 JN, P	47.3 IJN, P	57.6
ZSS0830	0.0 UJN, P	11.1	0.0 U	4.5 JN	0.0 U	43.6
ZSS0832	0.1 UJN, P	52.4 I	0.3 UJN, P	26.2 JN	83.4 JN	50.4
ZSS0834	0.0 UJN, P	3.3	0.0 UJN, P	1.0 IJN, P	3.0 UJN, P	23.4
ZSS0836	0.1 UJN, P	8.7 J	0.0 U	2.9 JN	6.9 UJN, P	23.8
ZSS0847	0.1 UJN, P	0.0 U	0.0 U	5.6 JN, P	9.4 IJN, P	29.3
ZSS0848	0.0 U	68.3	1.1 UJN	23.7 JN	34.4 IJN, P	28.5
ZSS0850	0.1 UJN, P	71.3	0.9 UJN, P	37.9 JN	30.3 IJN, P, V	48
ZSS0852	0.0 U	19.0	0.1 UJN, P	7.0 JN	10.6 IJN, P	26.5
ZSS0853	0.2 UJN, P	13.4	0.0 U	5.9 JN	4.0 UJN, P, V	12.7
ZSS0854	1.2 UJN, P	95.5	1.1 UJN, P	60.4 JN	26.0 UJN, P, V	53.7
ZSS0855	0.5 UJN, P	48.0	1.4 IJN, P	24.1 JN	19.8 IJN, P, V	23.4
ZSS0866	0.0 UJN, P	20.3	0.0 U	8.0 JN, P	21.6 IJN, P	25.4
ZSS0868	0.0 UJN, P	7.1	0.0 U	3.8 JN	10.4 IJN, P	23.5
ZSS0870	0.0 U	1.2 I	0.0 U	0.4 UJN	2.7 UJN, P	10.4
ZSS0873	0.5 UJN, P	42.8 P	0.8 IJN, P	19.5 JN	15.0 IJN, P, V	17.7
ZSS0881	0.0 U	26.0	0.0 U	9.5 JN	22.5 IJN, P	28.3
ZSS0882	0.2 UJN	25.0	0.3 UJN, P	7.3 JN	0.0 U	19.4
ZSS0884	0.2 UJN, P	82.1	0.6 UJN, P	19.4 JN, P	38.8 IJN, P, V	13.2
ZSS0886	0.1 UJN, P	28.2	0.3 UJN	10.3 JN	0.0 UJN, P	30

Site Name	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)	Moisture, Percent (%)
ZSS0888	0.1 UJNP	11.0	0.1 UJNP	0.0 U	11.0 UJNP	29.5
ZSS0890	0.1 UJN	4.6	0.0 U	0.7 IJN, P	6.6 IJN, P, V	3
ZSS4034	0.5 UJN, P	112.0	0.5 UJN, P	37.1 IJN, P	164.0 JN, P	63
ZSS4035	0.4 UJN, P	76.9 I	0.0 U	51.2 IJN	119.0 JN, P	58.6
ZSS4036	0.5 UJN, P	40.9	0.0 U	26.9 JN	72.4 JN, P	44.7
ZSS4037	0.1 UJN, P	2.5	0.0 U	0.7 UJN	1.9 UJN, P	27.3
ZSS4038	0.2 UJN, P	70.2	0.0 U	35.4 JN	92.4 JN, P	50.3
ZSS4039	0.1 UJN, P	30.2	0.0 U	16.9 JN	63.9 JN, P	27.9
ZSS4040	0.2 UJN, P	33.4 I	0.0 U	26.9 JN	118.0 JN, P	26.3

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZEFE0732	11.0 JNP	23.7	406000	286.0 JNPUUJNP	4000.0	55.0
ZES0630	23.0	22.2	402000	482.0 UJNP	15000.0	61.0
ZES0632	31.0	22.8	367000	433.0 JNUUIJNP	9100.0	63.0 IJNP
ZES0641	60.0	23.4	400000	485.0 PJNPUUP	12000.0	110.0 P
ZES0642	0.0 U	32.2	301000 A	319.2 IJNPUJNPJNU	2400.0	96.0
ZES0643	0.0 U	36.0	294000	415.0 IJNUJNU	6400.0	100.0
ZES0644	0.0 U	34.2	224000	197.0 IJNUJNU	3000.0	42.0
ZES0652	0.0 U	38.2	179000	305.0 JNPUJNPU	5400.0	66.0
ZES0653	0.0 U	19.5	210000	422.0 JNPUJNPU	6600.0	83.0
ZES0654	1.0 UJN, P	84.9	44900	57.0 UJNJNUJN, P	468.0	8.4
ZES0655	24.8	30.9	494000	406.7 IJN, PJN, PUJNJN, PI	5050.0	92.4 I
ZES0665	7.2 IJN, P	22.7	506000	179.7 JN, PJN, PUJN, PJN, PIJN, P	2350.0	52.2
ZES0666	6.2 JN, P	32.7	501000	146.0 IJN, PUJN, PJN, PJN, P	2920.0	26.1
ZES0667	9.0 JN, P	27.8	496000	178.0 JN, PUJN, PJN, PJN, P	2700.0	39.3
ZES0668	4.8 IJN	23.5	508000	81.4 JN, PUJN, PJNIJN	1160.0	23.3
ZES0669	45.5 JN, P	64.4	485000	916.8 UJN, PJNJN, P	14000.0	263.0
ZES0678	4.8 JN, P	59.9	363000	131.4 UJN, PJNJN, P	1990.0	25.6
ZES0680	11.6 JN, P	28.2	86100	218.3 UJN, PJNJN, P	3660.0	29.1

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZES0681	8.3 JN, P	34.2	138000	152.1 UJN, PJNJN, P	2690.0	30.2
ZES0693	13.0	23.3	92000	154.7 UJN, PJN	3110.0	20.1
ZES0694	0.9 I	94.9	3760 I	14.9 JN, PIJN, PUIJNI	224.0	2.8
ZES0696	15.7 JN, P	54.8	285000 A	282.1 UJNJNJN, P	3020.0	67.3
ZES0697	1.0 IJN, P	11.1	17000	26.2 UJNJNIJN, P	564.0	5.1
ZES0710	27.6 JN	26.3	126000	349.1 IJN, PJNJNI	8750.0	44.5 I
ZES0711	14.1 JN	11.7	60400	189.4 JN, PUJNJNJN	5900.0	25.5
ZES0712	7.3 JN, P	74.3	114000	152.8 IJN, PUJNJN, P	2170.0	30.1
ZES0713	31.5 JN, P	42.6	302000	605.3 IJN, PJNJN, P	9710.0	74.2
ZES0729	1.7 IJN, P	84.1	53700	70.9 UJN, PJNIJN, P	730.0	10.7
ZES0731	12.7	56.4	214000	223.6 JN, PUJN, PJN	4480.0	10.0
ZES0733	16.2 JN, P	33.5	500000	381.4 JN, PJN, PUJNJN, PJN, P	5670.0	75.4
ZES0735	7.3 JN	23.8	504000 A	148.8 JN, PUJN, PJNJN	2100.0	41.4
ZES1005	24.1 JN	32.7	502000	506.7 IJN, PUJN, PJ, JN, PJNI	6720.0	115.0 I
ZES1006	2.3 IJN, P	26.0	504000	48.7 JN, PUIJN, PIJN, P	904.0	9.7
ZES1007	24.6	30.9	487000	358.1 IJN, PUJNJN	4100.0	99.8
ZES1008	7.7 JN	14.6	29100	95.0 JN, PUJNJNJN	2500.0	13.2
ZES1009	23.5 JN	35.3	175000	372.4 JN, PUJNJNJN	8430.0	60.1
ZES2064	12.5 JN, P	37.5	133000	188.2 UJNJNJN, P	3930.0	30.6
ZES2068	6.3 JN, P	78.7	76900 0	75.4 IJN, PUJNJNJN, PP	1450.0	12.4 P
ZES2069	1.2 UJN, P	35.2	381000	57.8 UJNIJNUJN, P	2530.0	10.1
ZES2070	2.4 UJN, P	29.6	445000	72.1 UJN, PIJN, PUJN, P	2450.0	12.8
ZES4041	16.7 JN, P	19.7	506000	346.3 IJN, PUJNJNJN, P	4630.0	99.6
ZES4042	21.3 IJN, P	25.4	521000	444.9 UJN, PJNIJN, P	8280.0	85.7

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZSFE0825	29.8 JN, P	32.8	471000	411.6 JN, PUJN, PJNJN, P	9060.0	117.0
ZSFE0831	10.5 IJN, P	24.3	509000	205.7 JN, PUJN, PJNIJN, P	2390.0	49.6
ZSFE0837	37.2	43.6	392000	356.8 IJN, PIJNJN	5360.0	79.6
ZSFE0904	34.7 JN, P	47.6	395000	574.6 JN, PUJNJNJN, P	10400.0	139.0
ZSS0751	19.3 JN, P	45.5	467000	379.1 JN, PUJN, PJNJN, P	9900.0	61.7
ZSS0755	2.3 IJN, P	31.1	118000	87.9 UJN, PJNIJN, P	1150.0	19.1
ZSS0770	35.7 IJN, P	45.2	469000	880.7 JN, PUJN, PIJNIJN, P	12400.0	250.0
ZSS0771	0.7 I	74.9	30000	11.4 IJN, PUIJNII	119.0 I	2.0 I
ZSS0772	27.2 JN, P	58.5	320000 A	611.3 JNUJNJNJN, PJN, P	16600.0	115.0 JN, P
ZSS0774	3.4 JN, P	49.3	149000	81.2 JN, PUJN, PJNJN, P	1110.0	17.2
ZSS0775	27.4 JN, P	44.5	361000 0	400.3 JN, PUJN, PJNJN, P	8370.0	66.4
ZSS0776	4.2 JN, P	94.0	21100 0	62.0 JN, PJN, PUJNJN, P	1460.0	11.2
ZSS0789	17.9 JN, P	32.7	151000	425.8 JNUJNJNJN, P	7020.0	94.7
ZSS0791	0.5 U	70.2	59600	10.2 IJN, PIUUJNUI	123.0 I	2.3 I
ZSS0792	54.1 JN, P	48.2	345000 0	901.1 JN, PJN, PIJNJNJN, P	21400.0	172.0
ZSS0793	21.1	62.4	202000	298.9 JN, PIIJNJN, PI	5210.0	47.6 I
ZSS0794	25.3 JN, P	46.9	244000	582.1 UJNJNJN, P	9640.0	116.0
ZSS0795	29.5 JN, P	62.2	399000	1087.9 UJN, PJN, PJN, P	11900.0	357.0
ZSS0805	6.1 JN, P	34.3	365000	134.1 JN, PUJN, PJNJN, P	1460.0	30.6
ZSS0806	6.7 JN	77.7	77300 0	72.5 JNUJN, PJNJN	1120.0	16.2
ZSS0809	6.2 JN, P	34.5	374000	128.8 JN, PUJN, PJN, PJN, P	2100.0	23.3
ZSS0811	14.2 JN, P	63.5	152000	247.8 JN, PUJNJN, P	3730.0	51.2

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZSS0812	14.7 JN, P	60.3	187000	282.4 JN, PUJNJN, P	3900.0	88.3
ZSS0814	7.2 JN, P	47.0	246000	157.2 UJNJN, P	2870.0	34.8
ZSS0826	18.5 JN, P	42.4	439000	454.2 IJN, PIUJNJN, PJN, P	5910.0	92.4
ZSS0830	1.9 IJN, P	56.4	132000	50.9 UJNIJN, P	837.0	10.4
ZSS0832	9.7 JN, P	49.6	371000	254.8 IJN, PIUJN, PJNJN, PI	3370.0	51.4 I
ZSS0834	0.5 UJN, P	76.6	26400 A	18.1 JN, PUJN, PIJN, PUJN, P	298.0	3.6
ZSS0836	0.7 IJN, P	76.2	63000	33.7 JN, PJUJNIJN, P	470.0	6.7
ZSS0847	2.1 IJN, P	70.7	199000	36.9 JN, PUUJN, PIJN, P	766.0	9.5
ZSS0848	19.6 JN, P	71.5	202000	270.8 IJN, PUJNJNJN, P	3080.0	50.7
ZSS0850	26.5	52.0	227000	467.5 JN, PUJN, PJN	6770.0	111.0
ZSS0852	2.8 JN, P	73.5	129000	89.6 JN, PUJN, PJNJN, P	975.0	22.2
ZSS0853	2.9 JN, P	87.3	93900	84.7 JN, PUJNJN, P	1230.0	22.9
ZSS0854	32.4 JN, P	46.3	471000	758.4 JN, PUJN, PJNJN, P	10800.0	245.0
ZSS0855	15.9	76.6	153000	284.6 JN, PIJN, PJN	4780.0	58.7
ZSS0866	5.9 JN, P	74.6	86700	119.9 JN, PUJN, PJN, P	1790.0	24.0
ZSS0868	2.5 JN	76.5	53800	50.1 JN, PUJNJN	814.0	11.3
ZSS0870	0.6 I	89.6	5720	8.8 JN, PIUUJNI	268.0	1.9
ZSS0873	13.9	82.3	68100	246.9 JN, PPIJN, PJN	3640.0	49.6
ZSS0881	5.3 JN, P	71.7	114000	132.1 JN, PUJNJN, P	1720.0	32.3
ZSS0882	3.2 JN, P	80.6	95800	123.7 UJN, PJNJN, P	1590.0	24.7
ZSS0884	16.8	86.8	64300 A	418.4 JN, PUJN, PJN, P	6720.0	100.0
ZSS0886	4.1 JN, P	70.0	122000	147.7 UJNJNJN, P	1970.0	30.9
ZSS0888	3.0 IJNP	70.5	52700	65.1 JNPUJNPUIJNP	1200.0	11.0

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZSS0890	0.5 U	97.0	5010 U A	22.2 JN, PUIJN, PU	534.0	4.0
ZSS4034	52.0 I	37.0	461000	754.6 JN, PUJN, PIJN, PI	10900.0	161.0
ZSS4035	50.9	41.4	478000	653.0 JN, PIUIJNP	10000.0	117.0 P
ZSS4036	23.7	55.3	280000	281.7 JN, PUJN	4910.0	41.9
ZSS4037	0.7 UJN, P	72.7	41200	13.9 JN, PUUJNUJN, P	240.0	2.8
ZSS4038	32.0	49.7	371000	466.2 JN, PUJN	6300.0	97.6
ZSS4039	17.1	72.1	147000	190.5 JN, PUJN	3370.0	30.9
ZSS4040	25.3	73.7	154000	322.2 JN, PIUJN	6500.0	59.0

Phase 8:

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)
ZNS0082	0.5 UP	15.0 V	4.2 I	5.3 UPVI	19.7 UPVI	0.1 UJNP
ZNS0083	6.0	39.0	0.9 UP	4.7 UP	45.9 UP	0.2 UJNP
ZNS0084	68.0	270.0	23.0	54.6	361.0	0.0 U
ZNS0085	2.5 I	21.0	0.9 U	2.8 IU	24.4 IU	0.1 UJNP
ZNS0087	240.0	740.0	200.0	297.3	1180.0	0.1 UJNP
ZNS0089	0.4 UP	13.0	2.3 I	3.2 UPI	15.7 UPI	0.0 U
ZNS0094	12.0	350.0	31.0	56.7	393.0	0.0 U
ZNS0099	2.8 I	130.0	11.0	20.2 I	143.8 I	0.0 U
ZNS0100	33.0	300.0	34.0	60.6	367.0	0.0 U
ZNS0101	2.5 I	40.0	1.8 I	5.0 II	44.3 II	0.1 U
ZNS0102	23.0	560.0	110.0	151.9	693.0	0.2 UJN
ZNS0103	29.0	370.0	14.0	44.5	413.0	0.0 U
ZNS0104	33.0	410.0	42.0	75.9	485.0	0.1 UJNP
ZNS0105	3.1 I	67.0	8.5	13.6 I	78.6 I	0.0 U
ZNS0112	17.0	350.0	20.0	46.7	387.0	0.3 UJN
ZNS0113	10.0	230.0	40.0	57.3	280.0	0.0 U
ZNS0114	1.3 I	6.9 I	3.3 I	4.0 III	11.5 III	0.0 U
ZNS0116	5.3 I	59.0	4.1 I	9.1 II	68.4 II	0.0 U
ZNS0117	13.0	160.0	13.0	26.3	186.0	0.0 U
ZNS0118	65.5	124.0	157.0	178.4	346.5	0.2 UJN, P
ZNS0120	91.4	168.0	202.0	231.5	461.4	0.0 U
ZNS0121	133.0	323.0	434.0	482.1	890.0	0.4 UJN, P

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)
ZNS0127	204.0	318.0	299.0	361.0	821.0	0.6 UJN, P
ZNS0128	208.0	412.0	277.0	346.1	897.0	1.5 IJN, P
ZNS0129	50.8	114.0	30.9	48.7	195.7	0.4 UJN, P
ZNS0130	64.7	185.0	39.6	64.9	289.3	0.5 UJN, P
ZNS0131	18.4	41.3	16.2	22.6	75.9	0.1 UJN, P
ZNS0132	128.0	313.0	239.0	285.5	680.0	0.3 UJN, P
ZNS0133	114.0	297.0	195.0	237.6	606.0	0.3 UJN, P
ZNS0134	94.7	303.0	44.7 JN, P	83.8 JN, P	442.4 JN, P	0.9 IJN, P
ZNS0139	43.5	150.0	6.6 JN, P	25.3 JN, P	200.1 JN, P	0.3 UJN, P
ZNS0140	245.0	988.0	358.0	472.9	1591.0	0.8 UJN, P
ZNS0141	264.0	728.0	105.0	206.3	1097.0	0.9 UJN, P
ZNS0142	516.0	929.0	783.0	948.1	2228.0	2.0 UJN, P
ZNS0143	507.0	1180.0	1610.0	1790.1	3297.0	0.7 UJN, P
ZNS0144	74.0	679.0	32.8	92.9	785.8	0.2 UJN, P
ZNS0145	845.0	1870.0	492.0	785.7	3207.0	1.5 UJN, P
ZNS0146	120.0	222.0	183.0	221.8	525.0	0.3 UJN, P
ZNS0152	788.0	2580.0	1600.0	1929.6	4968.0	1.1 UJN, P
ZNS2000	903.0	2750.0	3400.0	3763.9	7053.0	3.3 UJN, P
ZNS2001	567.0	1440.0	1120.0	1329.4	3127.0	2.1 UJN, P
ZNS2002	298.0	462.0	175.0	265.4	935.0	1.0 IJN, P
ZNS2003	46.0 JN, P	205.0	16.4 JN, P	39.3 JN, PJN, P	267.4 JN, PJN, P	0.4 UJN, P
ZNS2004	202.0 J	460.0 J	61.1 J, JN, P	132.2 JJJ, JN, P	723.1 JJJ, JN, P	1.5 IJN, P
ZNS2005	341.0	733.0	47.8 UJN, P	164.9 UJN, P	1121.8 UJN, P	2.9 IJN, P
ZNS2006	36.0 P	71.7	7.1 P	19.1 PP	114.8 PP	0.5 UJN
ZNS2007	52.2 P	676.0	167.0	222.5 P	895.2 P	0.8 UJN
ZNS2008	153.0	600.0	568.0	638.6	1321.0	1.5 IJN, P
ZNS2009	701.0	1550.0	180.0 IP	423.5 IP	2431.0 IP	6.4 IJN, P
ZNS2010	32.8 IP	147.0	6.6 P	23.0 IPP	186.4 IPP	0.7 IJN, P
ZNS2011	159.0	275.0	47.5 IP	97.6 IP	481.5 IP	1.7 IJN
ZNS2012	135.0 P	1090.0	394.0	493.7 P	1619.0 P	1.3 UJN, P
ZNS2013	3.3 I	9.4	4.6 I	5.9 II	17.3 II	0.2 UJN, P
ZNS2014	112.0	223.0	211.0	248.3	546.0	1.7 IJN, P
ZNS2015	162.0 P	737.0	26.2 P	107.7 PP	925.2 PP	5.1 IJN, P
ZNS2016	2010.0 P	4610.0	502.0 P	1211.3 PP	7122.0 PP	43.8 UJN, P
ZNS2019	49.2 P	233.0	111.0	136.4 P	393.2 P	0.3 UJN, P
ZNS2020	121.0	211.0	176.0	214.3	508.0	1.0 IJN, P
ZNS2021	75.7 P	249.0	282.0	313.7 P	606.7 P	1.1 IJN

Site Name	4,4'-DDD (ug/kg)	4,4'-DDE (ug/kg)	4,4'-DDT (ug/kg)	4,4'-DDTr (ug/kg)	4,4'-DDTx (ug/kg)	Aldrin (ug/kg)
ZNS2022	292.0 P	834.0	103.0 JN, P	217.0 PJN, P	1229.0 PJN, P	5.4 IJN, P

Site Name	alpha-BHC (ug/kg)	alpha-Chlordane (ug/kg)	beta-BHC (ug/kg)	cis-Nonachlor (ug/kg)	delta-BHC (ug/kg)	Dieldrin (ug/kg)
ZNS0082	0.0 U	0.5 I	0.0 U	1.0 IJNP	0.0 U	6.2
ZNS0083	0.0 U	15.0	0.0 U	2.5 IJNP	0.1 UJNP	22.0
ZNS0084	0.0 U	5.6	0.0 U	2.2 IJNP	0.1 UJNP	18.0
ZNS0085	0.0 U	0.6 I	0.0 U	2.2 IJN	0.0 U	2.5 I
ZNS0087	0.0 U	24.0	0.0 U	7.5 JNP	0.1 UJN	42.0
ZNS0089	0.0 U	0.7 I	0.0 U	0.9 IJN	0.0 U	1.8 I
ZNS0094	0.0 U	1.9 I	0.0 U	0.0 U	0.0 U	2.2 I
ZNS0099	0.0 U	1.6 I	0.0 U	1.6 I	0.0 U	0.9 IP
ZNS0100	0.0 U	29.0	0.0 U	25.0	1.2 IJN	0.0 U
ZNS0101	0.0 U	0.7 I	0.0 U	0.0 U	0.1 UJNP	0.0 U
ZNS0102	0.0 U	7.9	0.0 U	3.5 JNP	0.1 UJNP	20.0
ZNS0103	0.0 U	3.3	0.0 U	3.3	0.0 U	12.0
ZNS0104	0.0 U	9.1	0.0 U	0.0 U	0.1 UJNP	9.5
ZNS0105	0.0 U	1.4 I	0.0 U	0.4 UJNP	0.0 U	0.7 UJNP
ZNS0112	0.0 U	12.0	0.1 UJNP	5.3	0.0 U	6.1 IP
ZNS0113	0.0 U	1.8 I	0.9 UJNP	1.9 IJNP	0.0 U	6.0 I
ZNS0114	0.0 U	0.3 U	0.1 UJNP	0.4 U	0.0 U	0.0 U
ZNS0116	0.0 U	2.4 I	0.0 U	1.0 IP	0.0 U	1.3 IJNP
ZNS0117	0.0 U	8.5	0.0 U	3.0 IP	0.0 U	4.7 IJNP
ZNS0118	0.0 U	10.6 JN, P	0.0 U	6.9 JN, P	0.0 U	17.9
ZNS0120	0.0 U	11.3	0.2 UJN, P	13.1 JN, P	0.0 U	20.8
ZNS0121	0.3 UJN, P	44.0	0.0 U	22.8 IJN, P	0.0 U	57.3
ZNS0127	0.0 U	31.4	0.0 U	24.7 IJN, P	0.0 U	58.0
ZNS0128	0.0 UJN, P	82.2	0.1 UJN, P	36.4	0.2 UJN, P	203.0
ZNS0129	0.0 U	15.0	0.0 U	8.4	0.3 UJN, P	34.1
ZNS0130	0.1 U	20.4	0.1 UJN, P	11.3	0.1 UJN, P	46.7
ZNS0131	0.1 UJN, P	5.5	0.0 U	3.1	0.1 UJN, P	11.6
ZNS0132	0.0 U	20.8	0.2 UJN	14.3 IJN, P	0.1 UJN, P	46.2
ZNS0133	0.0 U	43.3	0.2 UJN, P	20.8 IJN, P	0.1 UJN, P	32.7
ZNS0134	0.0 U	42.6	0.2 UJN	22.3	0.2 UJN, P	71.8
ZNS0139	0.0 U	30.0	0.2 UJN, P	12.4	0.0 U	26.9 JN, P
ZNS0140	0.2 UJN, P	79.3	0.0 U	42.2 JN, P	0.8 UJN, P	43.4 JN, P
ZNS0141	0.1 UJN, P	62.3	0.7 UJN	18.9	0.4 UJN, P	22.9 JN, P

Site Name	alpha-BHC (ug/kg)	alpha-Chlordane (ug/kg)	beta-BHC (ug/kg)	cis-Nonachlor (ug/kg)	delta-BHC (ug/kg)	Dieldrin (ug/kg)
ZNS0142	0.5 UJN, P	132.0	1.7 UJN	65.5 IJN, P	0.5 UJN, P	96.7
ZNS0143	0.0 U	138.0	1.1 UJN	79.5 JN, P	0.7 UJN, P	98.7
ZNS0144	0.0 U	24.5	0.1 UJN, P	8.7	0.0 U	10.6 JN, P
ZNS0145	0.7 UJN, P	249.0	1.1 UJN, P	92.5 JN, P	1.5 UJN	133.0 JN, P
ZNS0146	0.2 UJN, P	35.3	0.5 UJN	15.9 IJN, P	0.2 UJN, P	27.9
ZNS0152	0.2 UJN, P	148.0	0.5 UJN, P	128.0 JN, P	1.6 UJN	350.0
ZNS2000	0.0 U	402.0	1.4 UJN	194.0 IJN, P	0.5 UJN, P	316.0
ZNS2001	0.2 UJN, P	253.0 JN, P	0.5 UJN, P	128.0 JN, P	0.0 U	244.0
ZNS2002	0.0 U	67.0	0.5 U	36.7 JN, P	0.3 UJN, P	81.1
ZNS2003	0.0 U	30.6	0.3 UJN	16.0	0.0 U	52.4
ZNS2004	0.6 UJN, P	116.0 J	0.8 UJN, P	43.2 J	0.0 U	150.0 J
ZNS2005	0.2 UJN, P	232.0	1.3 UJN, P	66.4 JN, P	1.1 UJN, P	262.0
ZNS2006	0.3 UJN, P	12.2	0.2 UJN, P	5.5	0.7 UJN	27.4
ZNS2007	0.1 UJN, P	18.6	0.0 U	18.1	0.8 UJN, P	102.0
ZNS2008	0.1 UJN, P	46.9	0.2 UJN, P	43.4	1.4 UJN	217.0
ZNS2009	0.5 UJN, P	324.0	1.0 UJN	140.0	1.3 UJN	680.0
ZNS2010	0.2 UJN, P	21.7	0.0 U	11.1	0.8 UJN, P	47.5
ZNS2011	0.5 UJN, P	71.7	0.4 UJN, P	24.9	1.7 IJN, P	90.4
ZNS2012	0.3 UJN	47.6	0.0 U	40.4	0.3 UJN, P	191.0
ZNS2013	0.4 UJN, P	1.1 I	0.0 U	0.6 U	0.0 U	3.6 I
ZNS2014	0.4 UJN, P	36.7	1.8 UJN	0.0 U	1.2 IJN, P	114.0
ZNS2015	0.1 UJN	115.0	0.5 UJN, P	41.8 P	1.4 UJN	225.0 JN, P
ZNS2016	12.0 UJN, P	867.0	0.0 U	326.0	58.6 UJN, P	1430.0
ZNS2019	0.3 UJN, P	13.6	0.0 U	9.8	0.5 UJN	58.9
ZNS2020	0.3 UJN, P	29.1	0.4 UJN, P	0.0 U	1.6 IJN	80.7
ZNS2021	0.3 UJN, P	24.9	0.9 UJN, P	21.1	1.1 IJN	89.8
ZNS2022	0.4 UJN, P	200.0	0.7 UJN, P	55.4 JN, P	4.5 IJN	333.0

Site Name	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)
ZNS0082	0.0 U	0.0 U	0.0 U	0.0 U	0.1 UJNP	0.2 UJN
ZNS0083	0.0 U	0.0 U	0.0 U	0.0 U	0.4 UJNP	0.1 UJNP
ZNS0084	0.0 U	2.9 IJN	1.1 IJN	0.0 U	0.0 U	1.2 IJN
ZNS0085	0.0 U	0.0 U	0.0 U	0.0 U	0.2 UJNP	0.2 U
ZNS0087	0.0 U	13.0 JN	4.0 I	0.0 U	0.0 U	1.7 IJNP
ZNS0089	0.0 U	0.0 U	0.0 U	0.0 U	0.7 UJNP	0.5 U

Site Name	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)
ZNS0094	0.0 U	0.0 U	0.0 U	0.0 U	0.5 UJNP	0.6 UJNP
ZNS0099	0.0 U	1.2 IJN	0.0 U	0.0 U	0.4 UJNP	0.6 UJNP
ZNS0100	0.0 U	4.9 IJN	8.7 JNP	0.0 U	0.0 U	3.2 IJN
ZNS0101	0.0 U	0.4 UJN	0.0 U	0.0 U	0.4 UJNP	0.2 UJNP
ZNS0102	0.0 U	12.0 JNP	0.0 U	0.0 U	0.0 U	2.5 IJNP
ZNS0103	0.0 U	1.1 UJNP	0.0 U	0.0 U	2.7 UJN	0.4 UJNP
ZNS0104	0.0 U	5.1 IJNP	0.0 U	0.0 U	0.0 U	1.2 IJNP
ZNS0105	0.0 U	1.5 IJN	0.0 U	0.0 U	0.0 U	0.6 UJNP
ZNS0112	0.0 U	1.4 IJNP	0.0 U	0.0 U	0.0 U	1.6 IJNP
ZNS0113	0.0 U	3.2 IJNP	0.4 UJNP	0.0 U	0.0 U	0.0 U
ZNS0114	0.0 U	0.4 UJNP	0.0 U	0.0 U	0.0 U	0.2 UJNP
ZNS0116	0.0 U	1.7 IJNP	0.1 UJNP	0.0 U	0.0 U	0.3 UJNP
ZNS0117	0.0 U	5.5 IJNP	0.7 UJN	0.0 U	0.0 U	0.2 UJNP
ZNS0118	1.5 IJN, P	17.0 JN	2.5 IJN, P	0.0 U	14.0 JN, P	2.3 IJN, P
ZNS0120	0.0 U	36.0 JN	4.8 IJN	0.0 U	35.4 JN, P	3.6 IJN, P
ZNS0121	4.0 IJN, P	67.4 JN	9.6 JN, P	0.0 U	68.9 JN, P	7.5 IJN, P
ZNS0127	3.4 JN, P	71.2 JN	9.1 JN	0.0 U	60.9 JN, P	7.9 JN, P
ZNS0128	6.8 JN, P	124.0	0.0 U	0.0 U	76.5 IJN, P	14.3 JN, P
ZNS0129	1.1 IJN, P	27.6 JN	1.3 IJN, P	0.0 U	20.1 JN, P	2.8 IJN
ZNS0130	1.4 IJN, P	37.2 JN	1.9 IJN, P	0.0 U	27.3 JN, P	3.7 IJN
ZNS0131	0.3 UJN, P	10.5 JN	0.4 UJN, P	0.0 U	6.7 JN, P	1.1 UJN
ZNS0132	0.0 U	52.5 JN	10.0 JN	0.0 U	51.0 JN, P	5.9 IJN, P
ZNS0133	0.0 U	54.1 JN	10.9 JN	0.0 U	45.8 JN, P	5.6 JN, P
ZNS0134	0.0 U	81.0 JN	6.2 JN, P	0.0 U	54.3 JN, P	7.0 JN
ZNS0139	0.0 U	24.1 JN, P	1.6 IJN	0.0 U	17.6 JN, P	2.6 IJN
ZNS0140	0.0 U	110.0 JN	21.7 IJN	0.0 U	76.2 JN, P	10.6 UJN, P
ZNS0141	2.9 IJN, P	54.6 JN	5.4 IJN	0.0 U	32.3 JN, P	7.3 IJN
ZNS0142	0.0 U	181.0 JN	40.8 JN	0.0 U	127.0 IJN, P	20.2 JN, P
ZNS0143	0.0 U	178.0 JN	46.2 JN, P	0.0 U	170.0 JN, P	20.9 IJN, P
ZNS0144	1.3 IJN, P	19.3 JN	1.9 IJN	0.0 U	15.8 JN, P	2.2 UJN, P
ZNS0145	0.0 U	284.0 JN	30.3 IJN	0.0 U	175.0 JN, P	20.1 IJN, P
ZNS0146	0.0 U	49.5 JN	14.9 JN	0.0 U	38.5 JN, P	5.7 JN, P
ZNS0152	0.0 U	338.0 JN	43.9 IJN, P	0.0 U	319.0 JN, P	31.8 IJN, P
ZNS2000	0.0 U	470.0	110.0 JN	0.0 U	549.0 JN	53.4 JN, P
ZNS2001	0.0 U	374.0 JN	66.6 JN	0.0 U	288.0 JN, P	32.0 JN, P
ZNS2002	0.0 U	128.0 JN	11.3 JN	15.7 IJN, P	89.8 JN, P	10.0 JN, P
ZNS2003	0.0 U	43.8 JN	4.7 IJN	0.0 U	28.7 JN, P	4.1 IJN

Site Name	Endosulfan I (ug/kg)	Endosulfan II (ug/kg)	Endosulfan sulfate (ug/kg)	Endrin (ug/kg)	Endrin aldehyde (ug/kg)	Endrin ketone (ug/kg)
ZNS2004	7.0 JN	158.0 J, JN	9.1 JN, P	0.0 U	109.0 J, JN, P	13.8 J, JN
ZNS2005	0.0 U	242.0 JN	14.9 JN, P	0.0 U	170.0 JN, P	15.6 JN
ZNS2006	1.1 IJN, P	18.0 JN	0.8 UJN, P	0.0 U	0.0 U	1.7 UJN
ZNS2007	0.0 U	57.2 JN	15.0 IJN	0.0 U	0.0 U	7.8 IJN, P
ZNS2008	8.9 JN, P	123.0 JN	37.1 JN	0.0 U	0.0 U	29.2 JN
ZNS2009	26.9 JN, P	521.0 JN	28.2 JN, P	0.0 U	0.0 U	34.3 JN
ZNS2010	2.5 JN, P	27.4 JN	1.3 IJN, P	0.0 U	0.0 U	1.7 UJN, P
ZNS2011	6.7 JN, P	73.5 JN	5.7 IJN, P	0.0 U	0.0 U	8.8 JN
ZNS2012	0.0 U	114.0 JN	27.8 JN	0.0 U	0.0 U	19.3 JN, P
ZNS2013	0.1 UJN, P	2.2 IJN	0.3 UJN	0.0 U	0.0 U	0.4 UJN
ZNS2014	5.3 JN, P	69.8 JN	10.2 JN, P	0.0 U	0.0 U	15.2 JN
ZNS2015	15.0 JN, P	116.0 JN, P	6.0 IJN, P	0.0 U	0.0 U	17.8 JN
ZNS2016	82.7 IJN, P	1050.0 JN	54.6 UJN, P	0.0 U	0.0 U	75.9 UJN
ZNS2019	0.0 U	37.2 JN	6.2 IJN	0.0 U	0.0 U	5.7 IJN, P
ZNS2020	3.8 JN, P	57.6 JN	8.0 JN, P	0.0 U	0.0 U	9.1 JN, P
ZNS2021	4.6 JN, P	61.7 JN	14.8 JN	0.0 U	0.0 U	14.9 JN
ZNS2022	23.3 JN, P	168.0 JN	10.0 IJN, P	0.0 U	0.0 U	10.4 IJN, P

Site Name	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)	Moisture, Percent (%)
ZNS0082	0.0 U	0.0 U	0.0 U	0.2 U	1.0 UJNP	61.5
ZNS0083	0.0 U	7.3	0.0 U	0.4 U	0.0 U	48.5
ZNS0084	0.0 U	4.2 JNP	0.0 U	1.2 IJNP	5.2 UJNP	54.5
ZNS0085	0.0 U	0.5 IJN	0.1 UJNP	0.0 UJNP	0.0 U	59.5
ZNS0087	0.1 UJNP	62.0	1.1 IJN	26.0	15.0 IJNP	58.1
ZNS0089	0.0 U	0.0 U	0.0 U	0.0 U	1.4 UJNP	51.4
ZNS0094	0.0 U	1.0 IP	0.0 U	0.7 UJNP	3.9 UJNP	53.7
ZNS0099	0.1 UJNP	1.4 IJNP	0.0 U	1.0 IP	1.5 UJN	51.0
ZNS0100	0.0 U	38.0	0.0 U	0.0 U	7.4 IJN	54.1
ZNS0101	0.0 U	0.3 U	0.4 IJNP	0.2 UJNP	0.9 UJN	64.5
ZNS0102	0.0 U	3.5 P	0.4 IJN	1.7 IJN	13.0 IJNP	78.9
ZNS0103	0.1 UJNP	0.9 U	0.0 UJNP	0.3 UJNP	4.7 UJN	81.1
ZNS0104	0.0 U	7.1 JN	0.0 U	2.4 IJN	6.7 IJN	35.9
ZNS0105	0.0 U	0.7 I	0.3 UJNP	0.3 UJNP	0.2 UJNP	80.1
ZNS0112	0.0 U	9.1	0.4 IJN	0.0 U	4.7 UJN	83.3
ZNS0113	0.2 UJNP	1.4 IJNP	0.4 UJNP	0.0 U	0.0 U	79.3

Site Name	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)	Moisture, Percent (%)
ZNS0114	0.2 UJNP	0.1 UJNP	0.1 UJNP	0.0 U	0.3 UJNP	79.5
ZNS0116	0.1 UJNP	1.6 I	0.0 U	0.0 U	0.0 U	68.3
ZNS0117	0.1 UJNP	5.4	0.3 UJNP	0.0 U	0.0 U	69.9
ZNS0118	0.0 UJN	6.5	0.2 UJN, P	2.0 IJN, P	15.8 IJN	80.3
ZNS0120	0.1 UJN	5.1 JN, P	0.0 U	3.2 JN, P	31.1 JN	86.5
ZNS0121	0.2 UJN, P	22.3	0.5 UJN, P	4.6 JN, P	37.5 IJN, P	71.7
ZNS0127	0.1 UJN, P	14.5 JN, P	0.0 U	6.0 JN, P	31.2 JN, P	62.7
ZNS0128	0.2 UJN, P	39.0	0.6 UJN, P	16.6	26.3 IJN, P	80.9
ZNS0129	0.1 UJN, P	8.5 JN	0.3 UJN, P	3.9 JN	6.6 IJN	85.1
ZNS0130	0.0 UJN, P	14.9	0.5 UJN	5.3 JN	10.5 IJN	70.2
ZNS0131	0.1 UJN, P	3.6	0.4 UJN	1.3 IJN	2.1 UJN, P	76.2
ZNS0132	0.1 UJN, P	10.9 JN, P	0.4 UJN, P	5.2 JN, P	31.3 IJN	51
ZNS0133	0.0 UJN, P	32.2	0.6 UJN	7.1 JN, P	21.6 JN, P	79
ZNS0134	0.1 UJN, P	22.5 JN, P	0.5 UJN	12.5 JN	22.9 IJN, P	64.2
ZNS0139	0.2 UJN, P	17.8	0.0 U	7.8 JN	12.5 IJN	66.9
ZNS0140	0.0 U	57.8	1.6 UJN, P	11.5 IJN, P	44.9 UJN, P	32.8
ZNS0141	0.1 UJN, P	35.3	2.0 UJN	6.9 JN, P	33.0 IJN	56.1
ZNS0142	0.1 UJN, P	103.0	1.7 UJN	29.7 JN, P	76.5 IJN, P	41.5
ZNS0143	0.2 UJN, P	96.1	1.0 UJN, P	21.4 JN, P	123.0 IJN, P	36.6
ZNS0144	0.1 UJN	18.6	0.5 UJN, P	2.7 IJN, P	16.2 IJN	53.9
ZNS0145	0.2 UJN, P	159.0	2.1 UJN	41.5 JN, P	108.0 IJN, P	36.2
ZNS0146	0.0 UJN, P	26.3	0.4 UJN, P	7.5 JN	18.4 IJN, P	65.9
ZNS0152	0.0 U	42.5 JN, P	1.1 UJN, P	36.0 JN, P	123.0 IJN, P	37.8
ZNS2000	0.4 UJN	221.0	1.4 UJN, P	63.1 JN, P	247.0 JN, P	42.7
ZNS2001	0.1 UJN, P	129.0	1.4 UJN	35.9 JN, P	139.0 JN, P	28.4
ZNS2002	0.1 UJN, P	28.7 P	0.4 UJN, P	12.4 JN, P	33.9 JN, P	72.6
ZNS2003	0.1 UJN, P	15.6	0.4 UJN	8.0 JN	23.4 IJN	66.7
ZNS2004	0.2 UJN, P	66.2 J	0.0 U	22.8 J, JN	41.9 J, JN, P	62.6
ZNS2005	0.1 UJN, P	106.0	1.1 UJN, P	39.4 JN	59.9 JN, P	31.4
ZNS2006	0.2 UJN, P	5.1	0.7 UJN	2.3 IJN, P	6.0 UJN	62.7
ZNS2007	0.0 U	24.3	0.8 UJN	11.2 JN	25.5 IJN	81.7
ZNS2008	0.1 UJN, P	16.6	0.7 UJN, P	17.0 JN	36.0 IJN, P	81.7
ZNS2009	0.2 UJN, P	138.0	2.8 UJN, P	53.6 JN, P	19.8 UJN, P	52.3
ZNS2010	0.0 UJN, P	10.5	1.0 IJN	3.9 JN, P	10.0 IJN	68.1
ZNS2011	0.3 UJN, P	52.5	1.4 IJN	12.3 JN	21.4 IJN	46.9
ZNS2012	0.1 UJN, P	23.1	0.7 UJN, P	16.6 JN	31.4 IJN, P	81.4
ZNS2013	0.1 UJN, P	0.5 U	0.4 UJN, P	0.4 UJN	0.8 UJN, P	65.9

Site Name	gamma-BHC (Lindane) (ug/kg)	gamma-Chlordane (ug/kg)	Heptachlor (ug/kg)	Heptachlor epoxide (ug/kg)	Methoxychlor (ug/kg)	Moisture, Percent (%)
ZNS2014	0.0 UJN, P	12.0	1.6 IJN, P	9.4 JN	21.1 IJN, P	55.9
ZNS2015	0.5 UJN, P	59.8	0.9 UJN	26.0 JN, P	8.9 UJN, P	64.1
ZNS2016	8.0 UJN, P	493.0	0.0 U	164.0 IJN, P	318.0 UJN, P	31.5
ZNS2019	0.0 UJN, P	3.5 IJN, P	0.1 UJN, P	5.0 JN	13.7 UJN	70.3
ZNS2020	0.2 UJN, P	8.3	0.7 UJN, P	8.0 JN	20.2 IJN, P	72.4
ZNS2021	0.1 UJN, P	7.6 P	0.7 UJN, P	8.0 JN	22.8 JN, P	74.3
ZNS2022	0.7 UJN, P	110.0	2.9 UJN	38.7 JN, P	32.0 UJN, P	30

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZNS0082	0.1 U	30.5	14900 U	4.6 IIJNPUUUUI	19.0 U	2.7 I
ZNS0083	0.5 U	27.7	14900 U	33.1 IJNPUUU	32.0 U	7.4
ZNS0084	0.5 UJNP	33.2	16000 I	18.0 IJNPJNPUIJNPUJNP	100.0 I	4.3
ZNS0085	0.0 U	30.4	14900 U	4.4 IIJNIJNUJNPUJNPUI	23.0 U	1.0 I
ZNS0087	5.4	36.6	28500 I	143.0 JNPIJN	340.0	17.0
ZNS0089	0.0 U	91.3	14900 U	3.3 IIJNUUUUI	14.0 U	1.7 I
ZNS0094	0.4 U	46.5	15000 I	7.8 IUIPUUJNPU	66.0 I	3.9
ZNS0099	0.7 U	83.6	14900 U	10.0 IIIJNPUIPU	41.0 U	3.7
ZNS0100	3.8 JN	86.6	77000	130.8 UUJN	390.0	35.0
ZNS0101	0.0 UJNP	84.5	14900 U	3.8 IUUIJNPUJNPUJNPI	28.0 U	2.2 I
ZNS0102	0.9 UJNP	85.5	44300 I	28.8 JNPPIJNIJNUJNP	320.0	11.0
ZNS0103	0.6 U	86.0	14900 UA	13.0 UUJNPUJNPU	38.0 U	4.6
ZNS0104	1.3 IJNP	94.5	14900 U	26.0 UJNUIJNIJNP	180.0	6.1
ZNS0105	0.0 U	82.3	15900 I	4.8 IUJNPIUJNPUJNPUI	44.0 U	1.7 I
ZNS0112	1.4 IJN	84.0	31500 I	37.2 IJNUIJN	200.0	9.0
ZNS0113	0.0 U	70.5	231000	8.8 IIJNPIJNPUJNPUUI	200.0 I	3.3 I
ZNS0114	0.0 UJNP	82.6	41100	1.7 UUUJNPUJNPUUJNPU	32.0 U	0.7 U
ZNS0116	0.2 UJNP	77.9	71200	6.1 IIPIUUUJNPUP	95.0 I	0.9 UP
ZNS0117	0.9 U	94.6	84300	22.5 IPUJNPUU	320.0	4.4
ZNS0118	0.9 UJN, P	19.7	3030 U	33.7 JN, PJN, PUJN, PIJN, PUJN, P	665.0	6.6
ZNS0120	1.1 UJN, P	13.5	12200	37.9 JN, PJN, PUJN, PUJN, P	1220.0	4.1

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZNS0121	4.3 IJN, P	28.3	21400 A	123.1 IJN, PUJN, PJN, PIJN, P	2260.0	24.6
ZNS0127	3.7 JN, P	37.3	66300	91.9 IJN, PJN, PUJN, PJN, P	2610.0	11.6
ZNS0128	10.4 JN, P	19.1	51500	233.2 UJN, PJN, P	4020.0	48.0
ZNS0129	1.7 IJN, P	14.9	21600	48.3 JNUJN, PJNIJN, P	759.0	10.5
ZNS0130	2.1 IJN, P	29.8	77900	66.9 UJNJNIJN, P	905.0	12.4
ZNS0131	0.6 UJN, P	23.8	61700	18.1 UJNIJNUJN, P	304.0	3.6
ZNS0132	1.9 IJN, P	49.0	88400	62.9 IJN, PJN, PUJN, PJN, PIJN, P	2080.0	9.4
ZNS0133	6.7	21.0	63000	132.1 IJN, PUJNJN, P	2060.0	21.4
ZNS0134	5.4 JN, P	35.8	127000	119.5 JN, PUJNJNJN, P	2380.0	13.7
ZNS0139	2.0 IJN, P	33.1	12900	87.9 UJNIJN, P	1160.0	17.9
ZNS0140	10.6 U	67.2	404000	248.2 JN, PUJN, PIJN, PU	3280.0	45.2
ZNS0141	3.1 UJN, P	43.9	103000	165.0 UJNJN, PUJN, P	1930.0	36.5
ZNS0142	21.5	58.5	361000	422.4 IJN, PUJNJN, P	5640.0	69.0
ZNS0143	14.5 IJN	63.4	405000	415.5 JN, PUJN, PJN, PIJN	6730.0	65.0
ZNS0144	0.7 UJN, P	46.1	449000	73.6 UJN, PIJN, PUJN, P	808.0	17.9
ZNS0145	35.5	63.8	205000	686.6 JN, PUJNJN, P	8260.0	107.0
ZNS0146	5.0	34.1	21300	108.3 IJN, PUJN, PJN	2000.0	17.9
ZNS0152	18.2 IJN, P	62.2	352000	436.8 JN, PJN, PUJN, PJN, PIJN, P	10900.0	63.0
ZNS2000	49.6	57.3	368000	1143.1 IJN, PUJN, PJN, P	16300.0	212.0
ZNS2001	46.8	71.6	482000	725.1 JN, PJN, PUJNJN, P	11200.0	131.0
ZNS2002	11.4 JN, P	27.4	133000	173.8 JN, PPUJN, PJN, PJN, P	4290.0	17.2
ZNS2003	2.9 JN, P	33.3	127000	83.1 UJNJNJN, P	1570.0	9.6
ZNS2004	12.2 J, JN, P	37.4	152000 A	294.7 JJJUJ, JNJ, JN, PJ	4920.0	34.3 J
ZNS2005	21.3 JN, P	68.6	362000	532.5 JN, PUJN, PJNJN, P	8480.0	66.3
ZNS2006	1.3 UJN, P	37.3	155000	33.8 UJNIJN, PUJN, P	594.0	6.7

Site Name	Oxychlordane (ug/kg)	Solids, Percent (%)	TOC (mg/kg)	Total Chlordane (ug/kg)	Toxaphene (ug/kg)	trans-Nonachlor (ug/kg)
ZNS2007	2.8 UJN, P	18.3	22300	88.1 UJNJNUJN, P	2170.0	12.3
ZNS2008	12.0	18.3	48800	154.3 UJN, PJNI	4720.0	17.7 I
ZNS2009	34.7 JN, P	47.7	252000	860.1 UJN, PJN, PJN, P	12200.0	167.0
ZNS2010	2.6 JN, P	31.9	123000	64.1 IJNJN, PJN, P	884.0	13.3
ZNS2011	7.0 JN, P	53.1	259000	212.5 IJNJNJN, P	2450.0	42.7
ZNS2012	10.2	18.6	55200	168.7 UJN, PJN	3790.0	30.1
ZNS2013	0.1 UJN, P	34.1	17300	4.4 IUUUJN, PUJNUJN, PI	74.3 I	1.4 I
ZNS2014	8.8	44.1	261000	84.5 UIJN, PJN	2350.0	16.0
ZNS2015	10.9 JN, P	35.9	248000	327.2 PUJNJN, PJN, P	4650.0	72.8
ZNS2016	77.1 UJN, P	68.5	417000 A	2442.1 UIJN, PUJN, P	30600.0	515.0
ZNS2019	3.0 I	29.7	38500	50.4 IJN, PUJN, PJNI	1260.0	15.4
ZNS2020	8.3	27.6	103000	82.2 UUJN, PJN	1820.0	27.8
ZNS2021	6.1	25.7	60700	78.8 PUJN, PJN	2380.0	10.4
ZNS2022	14.9 JN, P	70.0	467000	536.9 JN, PUJNJN, PJN, P	240000.0	115.0

Definition of data qualifier/comment codes

Comment Code Definitions

U - Indicates that the compound was analyzed for but not detected. This shall be used to indicate that the specified component was not detected. The value associated with the qualifier shall be the instrument output value.
I - The value is between the laboratory method detection limit and the laboratory practical quantitation limit. The value associated with the qualifier shall be the instrument output value.
D - Value resulted from a dilution greater than what was used for the other compounds
P - Presumptive evidence of presence of material. This qualifier shall be used if:

1. the component has been tentatively identified based on mass spectral library search;
2. there is an indication that the analyte is present, but quality control requirements for confirmation were not met (i.e. presence of analyte was not confirmed by alternate procedures).

J - Estimated value; value not accurate. This code shall be used in the following instances:

1. surrogate recovery limits have been exceeded;
2. no known quality control criteria exists for the component;
3. the reported value failed to meet the established quality control criteria for either precision or accuracy;
4. the sample matrix interfered with the ability to make any accurate determination; or
5. if the data is questionable because of improper laboratory or field protocols (e.g. composite sample was collected instead of a grab sample).

Note: a "J" value shall be accompanied by justification for its use. A "J" value shall not be used if another code applies (e.g., K, L, M, T, V, Y, PQL)

JN - If a satisfactory pattern match is not possible, Toxaphene quantitation results shall be reported with the "JN" comment code.
JNP - Presumptive evidence of presence of material. This qualifier shall be used if:

1. the component has been tentatively identified based on mass spectral library search;

there is an indication that the analyte is present, but quality control requirements for confirmation were not met (i.e. presence of analyte was not confirmed by alternate procedures).

Additional Proposal Information

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Technical Memorandum 56

WATER QUALITY CHANGES IN LAKE APOPKA, FLORIDA, AND THE ST. JOHNS RIVER WATER MANAGEMENT DISTRICT'S RESTORATION PROGRAM

by

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St. Johns River Water Management District
Division of Water and Land Resources
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Palatka, Florida
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SUMMARY

The primary step in the St. Johns River Water Management District's comprehensive restoration program for Lake Apopka is a substantial reduction in external phosphorus (P) loading. This step largely has been achieved through progressive restoration of former farms on the Lake Apopka North Shore (LANS) to wetlands after remediation of residual pesticides in soils to ecologically safe levels. Drainage infrastructure in the LANS was modified to impound rainwater and to treat any necessary discharges to the lake with alum.

To date, P loading to Lake Apopka has met the total maximum daily load (TMDL) target P loading (15.9 metric tons per year) in years during or following droughts when little rainwater was discharged from the LANS. Further improvements to water management and P treatment infrastructure will be needed to ensure that the current loading limit can be met in normal to wet years and that lower loading limits can be met, if necessary, during low water periods to prevent hypereutrophic water quality conditions. Achieving the target P loading for Lake Apopka should result in meeting the target total phosphorus (TP) concentration (0.055 mg P/L) as well if lake levels remain within a normal fluctuation range.

Long-term (1987 to present) changes in water quality in Lake Apopka largely are explained by three factors, which are 1) improving trends due to reduced P loading and P removal, 2) cyclical oscillations since 2000 due to alternating periods of extremely low and normal lake levels, and 3) seasonal cycles.

The restoration program has reduced annual P loading to Lake Apopka from about 62 metric tons to an average of 11 metric tons during 2010 – 2014. Reduction in external P loading and removal of P from lake water resulted in improvements in key water quality indicators TP, chlorophyll-*a* (Chl-*a*), and Secchi transparency. Despite worsened conditions at low lake levels during recent droughts, water quality improved since the late 1980s in Lake Apopka in response to restoration efforts.

Calculated using total water column mass to reduce the confounding effects of smaller lake volume during droughts, TP averaged over the past five years was 50% lower than pre-restoration (1987 – 1992) values. Algal chlorophyll-*a* declined 43%, and Secchi transparency increased 24% over this same period. Long-term improvements persisted despite short-term wind effects caused by multiple hurricanes in 2004, which is evidence for a controlling role of external loading rather than wind resuspension or P recycling for long-term lake water TP concentration.

Since 2000, recurring low lake stage during droughts at 5 to 6-yr intervals resulted in periodic degradation of all water quality indicators. TP, total suspended solids (TSS), total nitrogen (TN), and Chl-*a* concentrations increased greatly at low lake levels because their lake water masses were concentrated in a smaller volume and because the normal net sedimentation of TP to sediments was interrupted.

Secchi transparency worsened until 1993 but then followed the same general pattern as TP, TSS, and TN – long-term improvements from 1993 through 2000 followed by temporarily worsened conditions during subsequent periods of low lake level.

Mass of TP in Lake Apopka declined in parallel with concentration from 1987 until 2000 and subsequently maintained a low and quasi-stable level. In contrast, lake water masses of TSS and TN declined initially but then trended upwards from 2000 through 2015. Mass of particulate N increased proportionally to TSS, but particulate P did not. Therefore, suspended matter in Lake Apopka, increasing since 2000, maintained a similar N content but a lower P content than in prior years.

Annual mean Chl-*a* concentration in Lake Apopka showed a strong linear relationship with TP concentration. Continued reduction in TP concentrations should translate to continued reduction in phytoplankton biomass. Annual mean concentration of Chl-*a* also varied linearly with TSS concentration. Most of the TSS was not living algal biomass but may consist of algal detritus.

We predicted that the restoration program in Lake Apopka would produce a cascade of ecological changes. Reduced external P loading would lead to reduced TP concentrations in lake water and lower algal levels. Lower algal biomass would lead to improved water transparency that would allow submersed aquatic vegetation (SAV) to recolonize the bottom. Re-growth of submersed plants would provide improved habitat, and game fish populations would increase to levels that allow successful recreational fishing.

External P loading to Lake Apopka has been reduced, although the only years to date that P loading met the restoration (TMDL) target were years during or immediately following droughts. All steps in the cascade of restoration effects, down to colonization by submersed plants, currently are operating in Lake Apopka. Native submersed aquatic vegetation (SAV) began to grow in the littoral zone of Lake Apopka in 1995 but almost was eliminated in subsequent droughts. By 2012, SAV had expanded to about 23 ha (57 acres). SAV declined during the most recent (2012 – 2014) drought as well, but losses were much less than previously, which showed greater resilience by the SAV community. As littoral plants continue to expand, other monitoring will be necessary to determine whether game fish populations also respond.

During extreme low-water periods, TP concentrations in lake water were decoupled from external loading and increased despite low loading. Chl-*a* increased proportionally, and Secchi transparency decreased. SAV either disappeared or decreased in total area. It is clear that under current conditions, sustained improvements in TP, algal Chl-*a* transparency, and SAV will require sustained periods without the extreme low lake levels typical of the past fifteen years.

Contents

Summary ii
Introduction 1
Restoration Program 3
Phosphorus Loading 4
Water Quality Indicators 6
  Total Phosphorus 8
  Total Suspended Solids, Total Nitrogen, Chlorophyll-*a*, Secchi Transparency 9
Ecological Changes in Lake Apopka 16
Conclusions 21
Acknowledgements 22
References 22
Appendix A. Seasonal TP Patterns in Lake Apopka 25

INTRODUCTION

Lake restoration work worldwide provides evidence that eutrophication of lakes can be reversed by reduction in external nutrient loading (Jeppesen et al. 2005). Large shallow lakes are especially important case studies, because the close contact between water and sediments promotes the recycling of sediment nutrients that might delay recovery. The St. Johns River Water Management District (District) developed and is implementing a restoration program for Lake Apopka, a shallow, 125 km^2 (31,000 acre), eutrophic lake in the Upper Ocklawaha River Basin near Orlando, Florida (Hoge et al. 2003).

Prior to the 1940s, Lake Apopka had abundant submersed, rooted vegetation and was nationally famous for its clear water and abundant game fish (Clugston 1963; Lowe et al. 1999). Large-scale draining for agriculture of about 80 km^2 of mostly floodplain marshes at the north end of Lake Apopka began in the 1940s. Drainage and farming of the peat ("muck") soils increased nutrient loading, water color, and lake stage, and precipitated a shift in the primary producer community from submersed macrophytes to phytoplankton (Schelske et al. 2010). Submersed macrophytes declined rapidly and almost disappeared by the 1950s. Drainage water discharges from farm lands increased phosphorus (P) loading sevenfold from 0.08 to about 0.56 g P m^{-2} yr^{-1} and were the primary cause of eutrophication (Battoe et al. 1999, Lowe et al. 1999). Because of oxidation of the drained muck soils, surface elevations in the farm areas subsided up to 1.8 m (6 ft) below lake level.

Legislation passed in 1985 and 1987 directed the District to restore Lake Apopka to Class III water quality. The District began diagnostic and feasibility studies for the lake under the 1985 Lake Apopka Restoration Act, and the 1987 Surface Water Improvement and Management (SWIM) Act included the lake as a priority water body for restoration. The 1996 Lake Apopka Improvement and Management Act authorized the District to set a P concentration target for the lake and provided funding to initiate a mandated buyout of the remaining floodplain muck farms on the north shore of the lake. The District adopted the P concentration target by rule in 1996 and completed buyout of most of the farms by 1999 using both state and federal funds.

The District established a restoration P loading target for Lake Apopka of 15.9 metric tons P per year (0.13 g P m^{-2} yr^{-1}) (Coveney et al. 2005). This loading target was derived through input-output modeling to meet a restoration goal for total phosphorus (TP) concentration in lake water of 0.055 mg/L (Coveney 2000). We set this concentration goal through a weight-of-evidence approach that estimated TP levels prior to large-scale farming (Lowe et al. 1999).

The 15.9 metric tons P annual loading target represented a 74% reduction from baseline loadings measured in a six-year P budget (Fig. 1). Pumped discharges from the farms made up about 86% of baseline P loading (Fig. 1). Because we do not have direct control over many sources of P (e.g. atmospheric deposition and spring input), loading from the farm/former farm areas needed to be decreased by almost 90%. At the target P loadings for restoration, the former farm area

(Lake Apopka North Shore – LANS), the atmosphere, and other sources would contribute approximately equal shares (Fig. 1).

The Florida Department of Environmental Protection (FDEP) and the United States Environmental Protection Agency (EPA) adopted the District's loading limit as a Total Maximum Daily Load (TMDL) for P (Magley 2003). FDEP formed a Basin Working Group and adopted a Basin Management Action Plan for the Upper Ocklawaha River Basin, including Lake Apopka (FDEP 2014). Through the Basin Working Group, local stakeholders are involved with the District and FDEP in the efforts to improve Lake Apopka and downstream lakes.

This report summarizes the changes in important water quality indicators in Lake Apopka during 29 years of District restoration activities from 1987 through 2015. P loading calculations are included from 1989 through 2014.

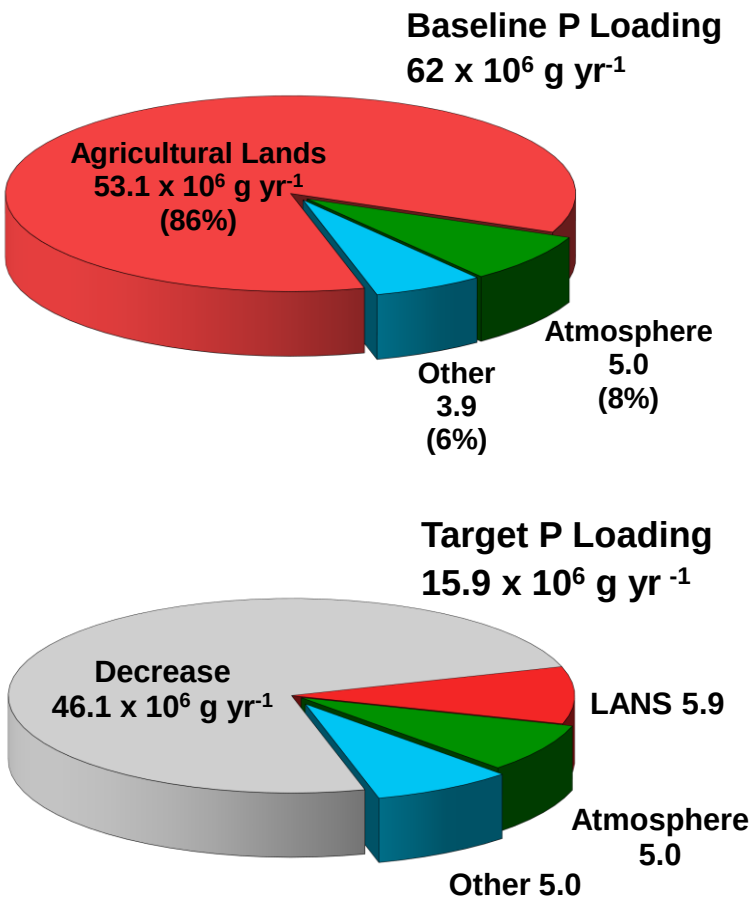

Figure 1. Top: Distribution of P loading from all sources to Lake Apopka measured for a baseline period (1989-94). Bottom: Projected P loading to meet the restoration (TMDL) target. The necessary reduction in P loading (46.1×10^6 g yr^{-1}) must come from discharges from the LANS (former agricultural lands) because other sources either are not subject to regulation (e.g. atmospheric loading) or are expected to remain level (e.g. watershed runoff). Derivation of target P loading found in Coveney (2000).

RESTORATION PROGRAM

Background information on Lake Apopka and details about the restoration plan, the early diagnostic and feasibility studies, and the land acquisition program are found in the Lake Apopka SWIM Plan (Hoge et al. 2003).

The primary step in the comprehensive restoration of Lake Apopka was a large reduction in external P loading through gradual restoration of wetlands on about 60 km^2 (14,800 acres) of the former agricultural lands. Wetland restoration was done of necessity behind intact lake-shore levees because soil subsidence left much of the former farm lands well below lake level. High mortality of fish-eating birds occurred during the initial phases of reflooding in winter 1998 – 1999. These deaths were attributed to organochlorine pesticide (OCP) residues bound to the organic, peat soils (USFWS 2004). The District along with federal and state partners began a decade-long project to study the distribution and bioaccumulation of weathered OCP residues in muck soils and to remediate these contaminants to ecologically safe levels before re-initiating large-scale reflooding (Conrow et al. 2011, Coveney et al. 2008).

Approximately 1,610 ha (3,970 acres) of contaminated soil were remediated by inverting soil layers to bury the top 30 cm (12 inches) under about 60 cm (24 inches) of deeper, cleaner soil (Bartol and Brown 2012). Remediation was completed in 2009. Controlled reflooding began in 2002 on the former Duda property where no remediation was needed. Reflooding progressed in stages to other areas. We monitored OCP levels in fish at each step to confirm our predictions and to ensure safe conditions. Concurrently, drainage works over this 80 km^2 wetlands and uplands area were reconfigured to impound rainwater in the restored marshes and route any necessary discharge water through alum treatment and settling systems. Treated water now is discharged by pumps both to the Apopka-Beauclair Canal (primary) and to Lake Apopka (secondary). Rebuilding the drainage and treatment structures and shallow reflooding of the last parts of the entire 60 km^2 wetland restoration area were completed in 2014. Management of the reflooded marshes as well as the surrounding upland areas (the LANS) is described in the current Lake Apopka North Shore Land Management Plan (SJRWMD 2013).

In addition to projects to reduce P loading, the District's restoration program for Lake Apopka includes wetland treatment and rough-fish harvest projects that remove P from the nutrient-rich lake water.

The Lake Apopka Marsh Flow-Way is a 310-ha (766 acre) treatment wetland with four wetland cells. The project was constructed on a part of the former farmlands and has operated in phases beginning in 1990 to remove suspended particles and nutrients from recirculating lake water (Coveney et al. 2002; Dunne et al. 2012). Median P removal efficiency from lake water was about 30%, and median removal of P has been 2.5 metric tons (5,500 lb) annually. In addition to

P, the Marsh Flow-Way removes nitrogen and is an effective filter for suspended particles. The wetland treats about 40% of the lake volume per year.

A second long-term District project is the large-scale removal of rough fish, primarily gizzard shad (*Dorosoma cepedianum*) from Lake Apopka. This project started in 1993 and has removed from 125 to 880 metric tons (0.28 to 2.0 million lb) of fish per year. The project removes P in the fish biomass and reduces P recycling caused by gizzard shad feeding in bottom sediments (Schaus et al. 2010). Rough-fish removal relies upon a cooperative agreement between governmental agencies (Florida Fish and Wildlife Conservation Commission and the District) and is a public-private partnership funded partly through private profits. The direct removal of P in fish biomass varies with catch and has ranged from 1 to 7 metric tons P with median 3.8 metric tons P (8,360 lb) removed annually.

The Florida Fish and Wildlife Conservation Commission (FWC) has worked to accelerate development of shallow-water habitat by planting more than 500,000 emergent and floating-leaved plants (giant bulrush, *Schoenoplectus californicus* and spatterdock, *Nuphar luteum*) over 182 ha (450 acres) of the littoral zone of Lake Apopka in 2012 – 2014.

Additional projects are planned or underway in Lake Apopka funded by the Florida Legislature and conducted by FDEP, FWC, and the District. These projects include removal of flocculent sediment for near-shore habitat improvement, excavation of sumps to trap sediments, and improvements to navigation. Further, several pilot projects are testing innovative advanced technologies to remove nutrients from lake water and sediments.

PHOSPHORUS LOADING

External P loading to Lake Apopka from the watershed has been reduced significantly (Fig. 2). Beginning with the initial purchases of some farmlands by the District in the late 1980s and continuing with regulatory efforts and then complete acquisition of the farms by 1999, the restoration program has reduced annual P loading to Lake Apopka from about 62 metric tons to an average of 11 metric tons during the last five years with complete data (2010 – 2014) (Fig. 2). Watershed modifications to reduce loading began in 1993 during the farming period with construction of retention ponds and are ongoing as rainwater is impounded in restored marshes on the LANS, and any water discharges are treated with alum.

However, P loading from the watershed is controlled in part by rainfall, and the decline in loading has not been monotonic. The increase in P loading to Lake Apopka in 2008 resulted in part from the need to keep large portions of the former farms dry to operate heavy equipment to remediate soil pesticide residues. To date, P loading has met the TMDL target (15.9 metric tons P per yr) only for years during or following droughts (2000 – 2001, 2006 – 2007, 2011 – 2014) when very little rainwater was discharged from the LANS (Fig. 2). Further improvements to water management and P treatment infrastructure on the LANS will be needed to ensure that current loading limits for Lake Apopka will be met in normal to wet years and that lower loading

limits can be met, if necessary, during low water periods to prevent hypereutrophic water quality conditions.

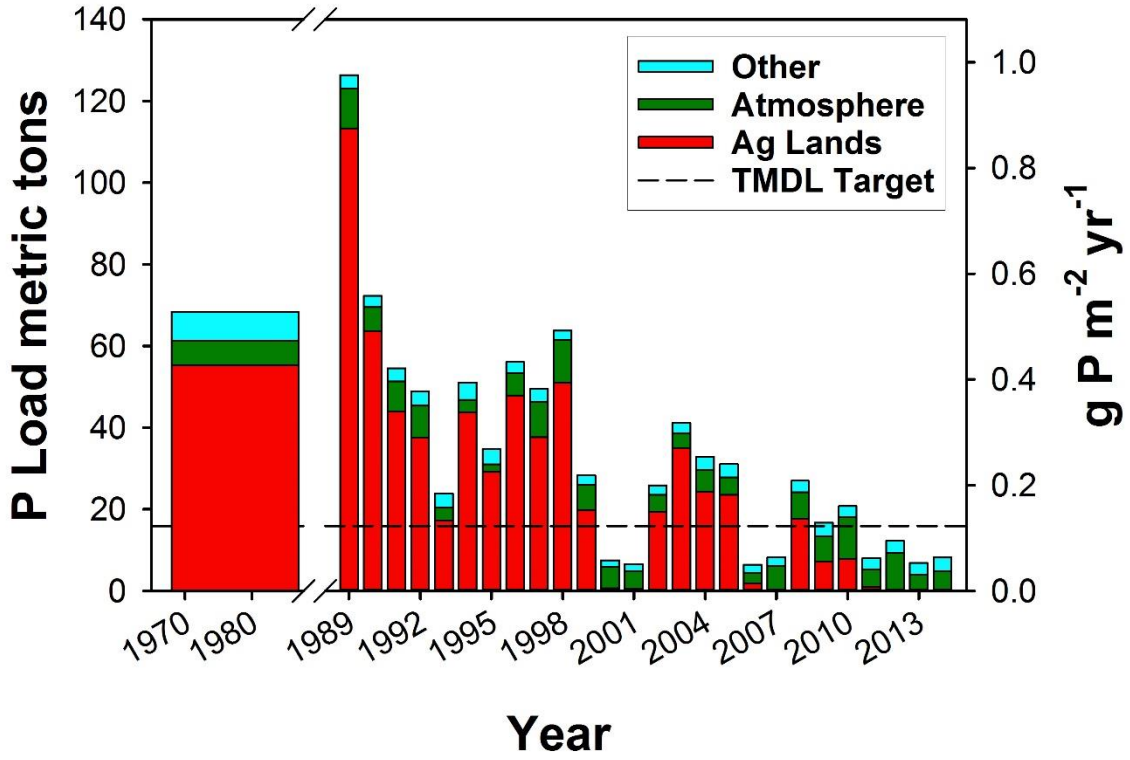

Figure 2. Annual phosphorus loading from all sources to Lake Apopka. "Agricultural Lands" are the Lake Apopka North Shore. Land use in that area shifted from mostly agriculture prior to 1996 to mostly reflooded wetlands by 2013. The TMDL target for P loading is 15.9 metric tons P per yr. Mean loading for 1968-87 was derived through analyses of sediment stratigraphy (Coveney 2000). P loading was measured directly beginning in 1989. Loading sources included discharges from agricultural lands, wet and dry atmospheric deposition, basin runoff, Apopka Spring, Winter Garden wastewater treatment, and groundwater exchange through the lake bottom.

Although TP in lake water declined in response to reduced loading (Fig. 3), annual TP concentration was not closely related to annual P loading (Coveney et al. 2005). Because of relatively long residence times for water and for P in Lake Apopka, loading and TP concentrations must be averaged over multiple years to establish even an approximate relationship. Furthermore, hydrologic characteristics (e.g. lake volume and hydraulic residence time) change through time and especially during drought years. These changes must be considered to compare properly the effects of various P loading rates.

In the long run, steady state models predict that Lake Apopka will meet the target TP concentration (0.055 mg/L) when loading meets the TMDL target (Coveney 2000). In the short run, many other variables affect the relationship between P loading and TP concentration. For example, low loading during drought years coincided with high rather than low TP concentrations because of reduced lake volume, evaporative concentration, and reduced net P sedimentation.

Nitrogen (N) loading to Lake Apopka was not calculated for most of the 26-yr reporting period. However, reductions in water discharges from the farms to target P loading likely reduced N loading as well.

WATER QUALITY INDICATORS

Long-term changes in water quality in Lake Apopka largely can be attributed to three drivers:

1. An improving trend due to reduced P loading and P removal achieved by the restoration program
2. Cyclical oscillations in water quality since 2000 due to alternating periods of extremely low and normal lake levels
3. Seasonal cycles in water quality

To summarize overall changes in water quality, we compared "Pre", the period prior to start of watershed restoration, 1987 – 1992; and "Post", the most recent five-year period, January 2011 – December 2015 (Fig. 3). For water constituents, we based the comparison on total water column masses to minimize the confounding effects of changes in lake volume during droughts.

Reduction in external P loading to Lake Apopka and P removal projects resulted in long-term improvements in the key water quality indicators TP, chlorophyll-*a* (Chl-*a*), and Secchi transparency compared with pre-restoration conditions. TP showed the greatest (50%), and TSS showed the least (11%), improvement. TN, Secchi transparency, and Chl-*a* were intermediate with improvements from 24% to 43% (Fig. 3). Neither internal recycling of sediment P nor wind-driven resuspension of sediments prevented improvements in these water quality measures in this shallow, eutrophic lake (Coveney et al. 2005).

However, it is important to note that since 2000, recurring low lake stage during droughts resulted in degradation of all water quality indicators but especially total nitrogen (TN) and total suspended solids (TSS). Droughts and low lake stages recurred at 5 to 6-yr intervals (e.g. Fig. 4). The low lake stages reached at the end of each of these droughts were the lowest lake levels in the entire data record (start 1936) for Lake Apopka. At the lowest point in 2002, the lake had lost 72% of its mean volume. Maximal loss of volume was about 50% in 2008 and in 2012. These low lake stages and long durations exceeded the low end of the range of fluctuation in lake level that is beneficial to develop and sustain healthy littoral plant communities.

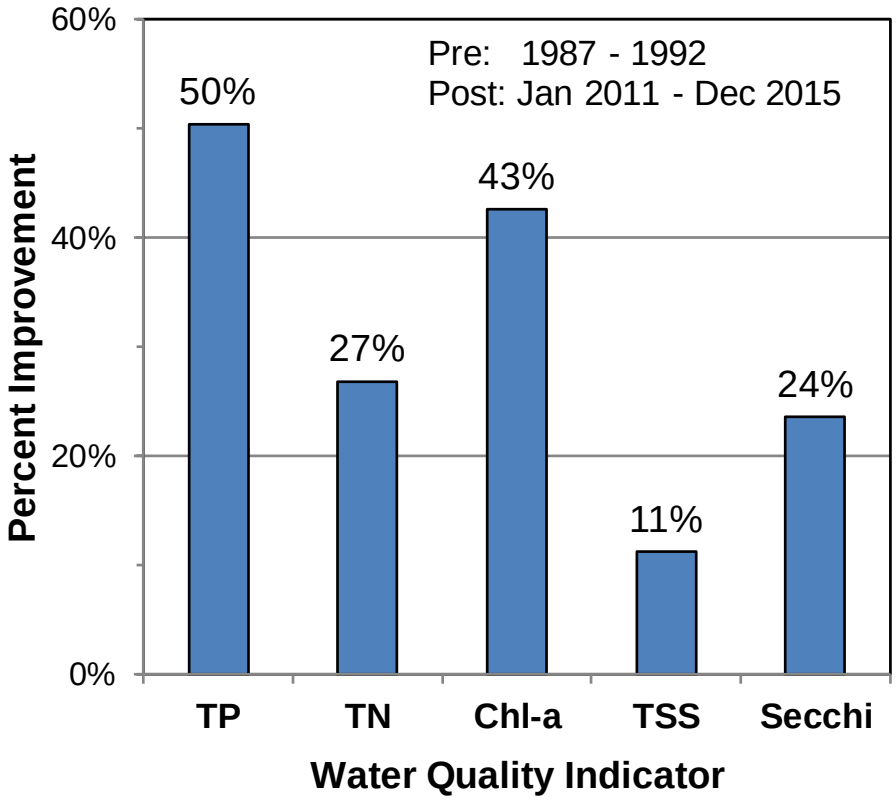

Figure 3. Percent improvements to date in mass of TP, TN, Chl-*a*, and TSS, and in Secchi transparency in Lake Apopka during the restoration program. Improvements were decreases in TP, TN, Chl-*a*, and TSS and an increase in Secchi transparency. Because water quality conditions are variable, we calculated improvements by comparison of the most recent five years with the period 1987 – 1992, prior to the start of watershed restoration. Except for Secchi transparency, we based percentages on water column masses to reduce the confounding effects of changing lake volume.

A seasonal pattern in water quality was evident in Lake Apopka in most but not all years. This pattern consisted of worsening water quality in the winter/spring and improvements in the summer/fall. This seasonality appeared to be due, in part, to slower P sedimentation and possible sediment resuspension during winter because of wind mixing from frontal events (Coveney et al. 2005). The analyses in this report were based on mean annual constituent values so seasonal patterns will not be discussed. These patterns are illustrated, however, in the six-year monthly data set for TP presented in Appendix A.

TOTAL PHOSPHORUS

A detailed examination of changes in TP through time will serve as an example for other water quality constituents. The time series of TP masses, as well as concentrations, reveals important dynamics of the changes in nutrient levels during drought conditions.

The average composition of TP in Lake Apopka for 1987 – 2015 was 91% particulate P (PP), 5% dissolved organic P, and 4% dissolved inorganic P (soluble reactive P, SRP). Accordingly, virtually all dynamics in TP reflected changes in concentration or mass of the particulate fraction.

TP concentrations in lake water (Fig. 4, top) declined along with reductions in P loading (Fig. 2) until 2000. A marked exception to this trend was 1993, where TP concentrations were elevated considerably despite relatively low loading. This increase in TP corresponded with the "Storm of the Century" in March 1993 with high winds and numerous tornados in central Florida. Lake water ammonium (NH_4) increased greatly in Lake Apopka at the same time (data not shown). We interpret this sudden increase in NH_4 as a marker for strong disturbance of the sediments that also recycled dissolved and particulate P to the water column. Elevated TP concentrations in 1993 occurred at normal water levels and reflected increased TP mass in the water column (Fig. 4, bottom). Annual P budget calculations for 1993 showed a net flux of P from the sediments to the water (data not shown).

From 2000 until 2015, TP concentrations oscillated greatly, associated with multi-year cycles of dry and wet conditions. TP concentrations increased during each period of low lake stage only to decrease again as lake stage recovered to a normal range (Fig. 4, top).

Mass of TP in Lake Apopka declined in parallel with lake water concentration until TP mass reached a low and quasi-stable level about 2000 (Fig. 4, bottom). Both the period of decline in TP mass (1987-2000) and the subsequent fluctuations around the new reduced mass level were similar to patterns of TP loading (Fig. 2). In addition to changes in external loading, other mechanisms might have contributed to increases in water column TP mass during droughts. These factors included increased sediment-water exchange, release of P through oxidation or erosion of exposed sediments, and low net sedimentation of P during low water periods (Coveney et al. 2005).

Whereas TP concentration increased sharply at low lake stage in 2001 – 2002, TP mass increased only slightly (Fig. 4). This increase in TP concentration at a constant TP mass is consistent with a concentrating effect of declining lake volume. Similar increases were evident during low lake levels in 2007-2008 and again in 2012-2014, where TP concentration increased greatly, while TP mass increased only modestly (Fig. 4). Pumping from LANS needed to keep large portions of the former farms dry for mechanical remediation of soil pesticides was responsible for most of the increase in TP mass in 2008.

This apparently conservative behavior of TP mass in Lake Apopka during drought, where concentrations varied inversely with lake stage, was unexpected. A concentration of TP through

evaporation of water from the lake followed by dilution upon refill of the lake appeared to explain in part both the rapid increase in TP concentration at low lake stage and the decrease in TP concentration as the lake refilled to normal level in 2003 (Fig. 4).

Loss of TP from lake water in Lake Apopka occurs mainly through sedimentation. Net sedimentation of TP can be described by the sedimentation coefficient, which is the proportion of mean annual TP mass that sediments each year (Coveney et al. 2005) and is calculated from TP mass budgets. Annual sedimentation coefficients declined almost to zero during each period of low lake level (data not shown). In other words, lake water TP concentrations increased greatly at low lake levels both because lake water TP mass was concentrated in a smaller volume and because the normal net sedimentation of TP from lake water to sediments was interrupted. Net sedimentation is the difference between sedimentation (downward flux) and recycling from sediments due to diffusion and resuspension (upward flux). Whether low net sedimentation was due to decreased sedimentation or increased recycling cannot be determined from TP mass balance data.

Annual TP concentrations in 2004 – 2006 and again in 2010 – 2011 were under 0.1 mg P/L, and some monthly values approached the TMDL target of 0.055 mg/L (Fig. 4; Appendix A). These long-term improvements persisted despite short-term wind effects caused by multiple hurricanes affecting central Florida in 2004. This pattern was evidence for a primary controlling role of external loading rather than wind resuspension on long-term lake water TP concentration at normal water levels.

TOTAL SUSPENDED SOLIDS, TOTAL NITROGEN, CHLOROPHYLL-*A*, SECCHI TRANSPARENCY

Lake water concentrations and masses of TSS and TN in Lake Apopka showed changes since 1987 similar to those described above for TP, including elevated values during periods with low lake stage caused by drought. However, the behavior of these constituents showed important differences as well.

Temporary increases in TSS and TN concentrations and masses were evident in 1993 and likely were initiated by storm disturbance as described above for TP (Figs. 5 & 6). Concentrations, and particularly masses, declined from 1993 through 2000. Lake water concentrations of both TSS and TN increased during the subsequent three periods of low lake levels (2001 – 2002, 2007 – 2008 and 2012 – 2014) (Figs. 5 & 6). As discussed above for TP, these increases appeared to be due in part to the concentrating effects of declining lake volume. However, an important difference was that lake water masses of TN and, in particular, TSS increased during periods of low water (Figs. 5 & 6, bottom). Increases in mass contributed to the sharp increases in concentration. Further, lake water masses of TSS and TN trended upwards from 2000 through 2015, but mass of TP did not (ordinary least squares linear regression, significance criterion $p < 0.05$) (Figs. 4 - 6).

The average composition of TN in Lake Apopka for 1987 – 2015 was 60% particulate N (PN), 38% dissolved organic N (DON), and 2% dissolved inorganic N (DIN). Changes in mass of the PN fraction accounted for virtually all of the dynamics in TN, including the increase in lake water mass since 2000 (Fig. 7). The DON fraction declined slowly over most of the period, and DIN was a small part of the whole. The increase in mass of PN from 2000 to 2015 was proportional to the increase in mass of TSS. Mean mass ratios of PN:TSS during 2000/01 and 2014/15 were practically identical at 0.038 and 0.036, respectively.

In summary, concentration and mass of TSS in Lake Apopka mostly decreased from 1987 to 2000 and then increased significantly during periods of low lake levels in 2007 – 2008 and 2012 – 2014. Additionally, TSS mass showed a general increase from 2000 through 2015. This increase in TSS was accompanied by proportional increases in particulate N but not particulate P. Therefore, suspended matter in Lake Apopka, increasing since 2000, had similar N content but a lower P content than in prior years.

Changes in lake water concentrations of Chl-*a* in Lake Apopka (Fig. 8) were almost identical to changes in TP (Fig. 4) – long-term improvements from 1987 through 2000 followed by worsened conditions during subsequent periods of low lake level.

Secchi transparency worsened somewhat from 1987 to 1993 but then followed the same general pattern as TP, TSS, and TN – improvements through 2000 and temporarily, but significantly, worsened conditions during subsequent periods of low lake level (Fig. 8). It is notable that, whereas TSS showed an increasing trend post 2000 (Fig. 5), Secchi transparency showed no significant trend but fluctuated about a median of 0.30 m (ordinary least squares linear regression, significance criterion $p < 0.05$) (Fig. 8).

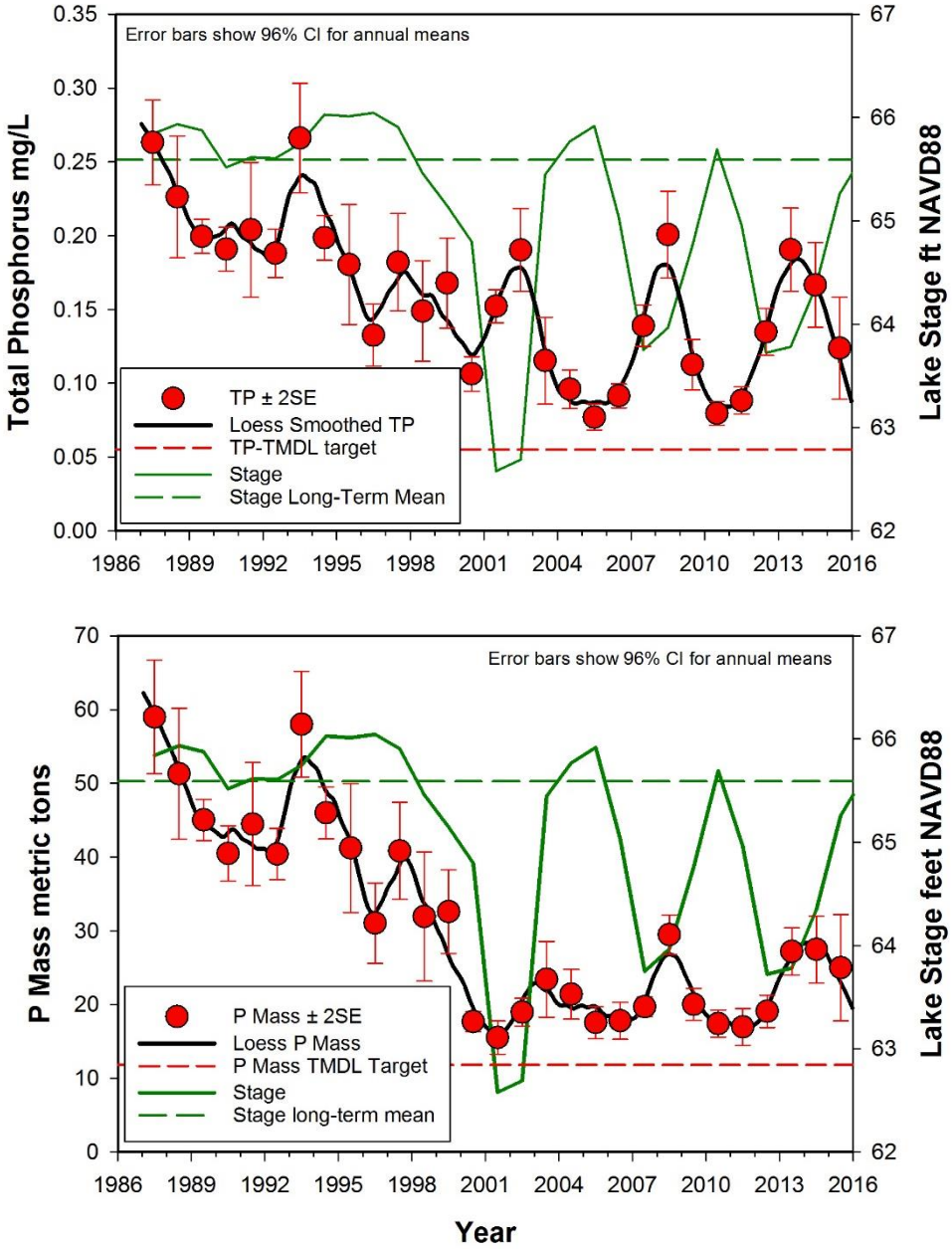

Figure 4. Mean annual values for total phosphorus (TP) concentration (top) and TP mass (bottom) in Lake Apopka for the period (1987-2015) of District monitoring. Local polynomial regression (LOESS) smooth curves were fit to mean monthly values. Mean annual lake stage, long-term mean stage (1960 – 1990), and the TMDL target concentration for P are included. Error bars are 96% confidence limits around means (±2SE).

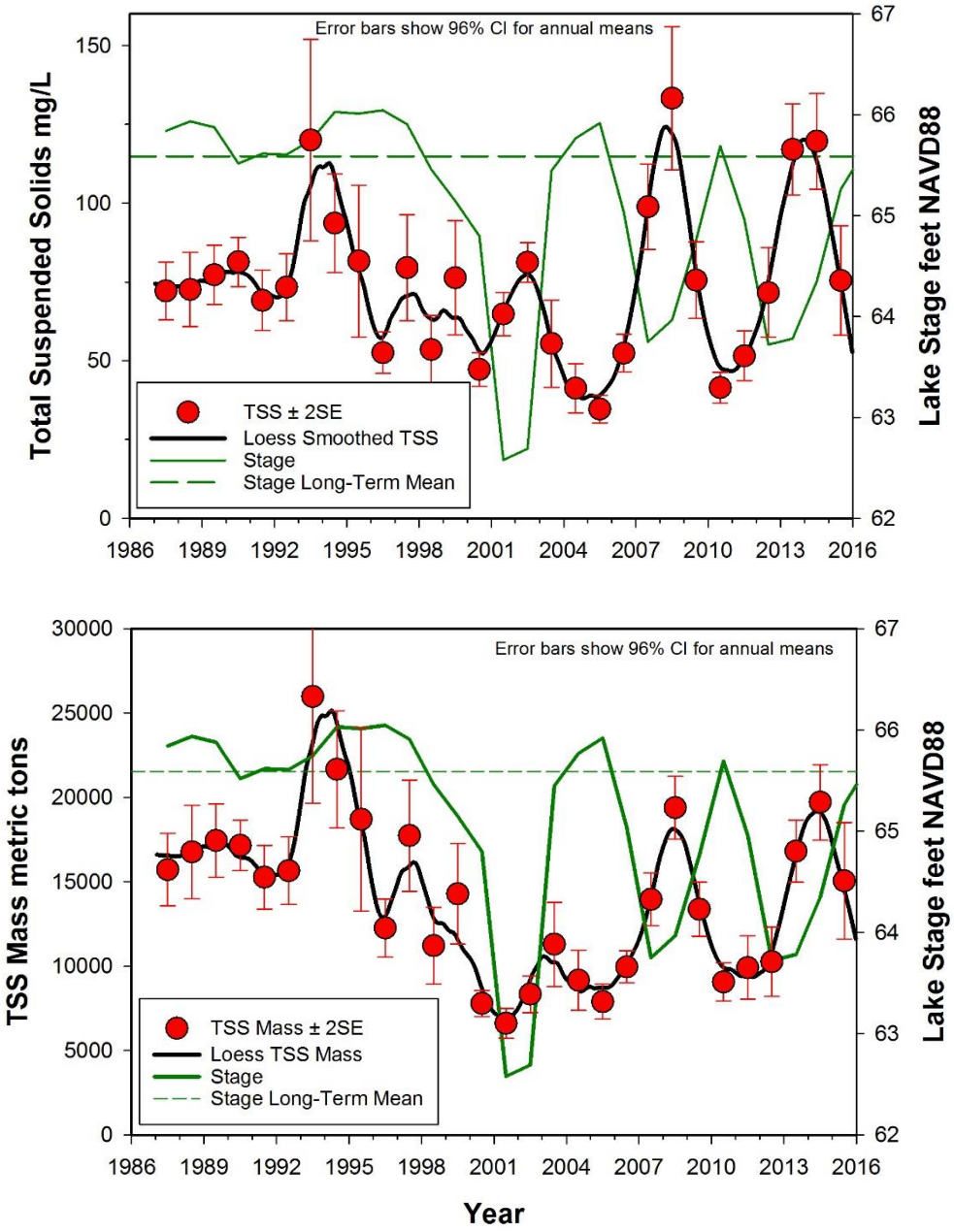

Figure 5. Mean annual values for total suspended solids (TSS) concentration (top) and TSS mass (bottom) in Lake Apopka for the period (1987-2015) of District monitoring. Local polynomial regression (LOESS) smooth curves were fit to mean monthly values. Mean annual lake stage and long-term mean stage (1960 – 1990) are included. Error bars are 96% confidence limits around means (±2SE).

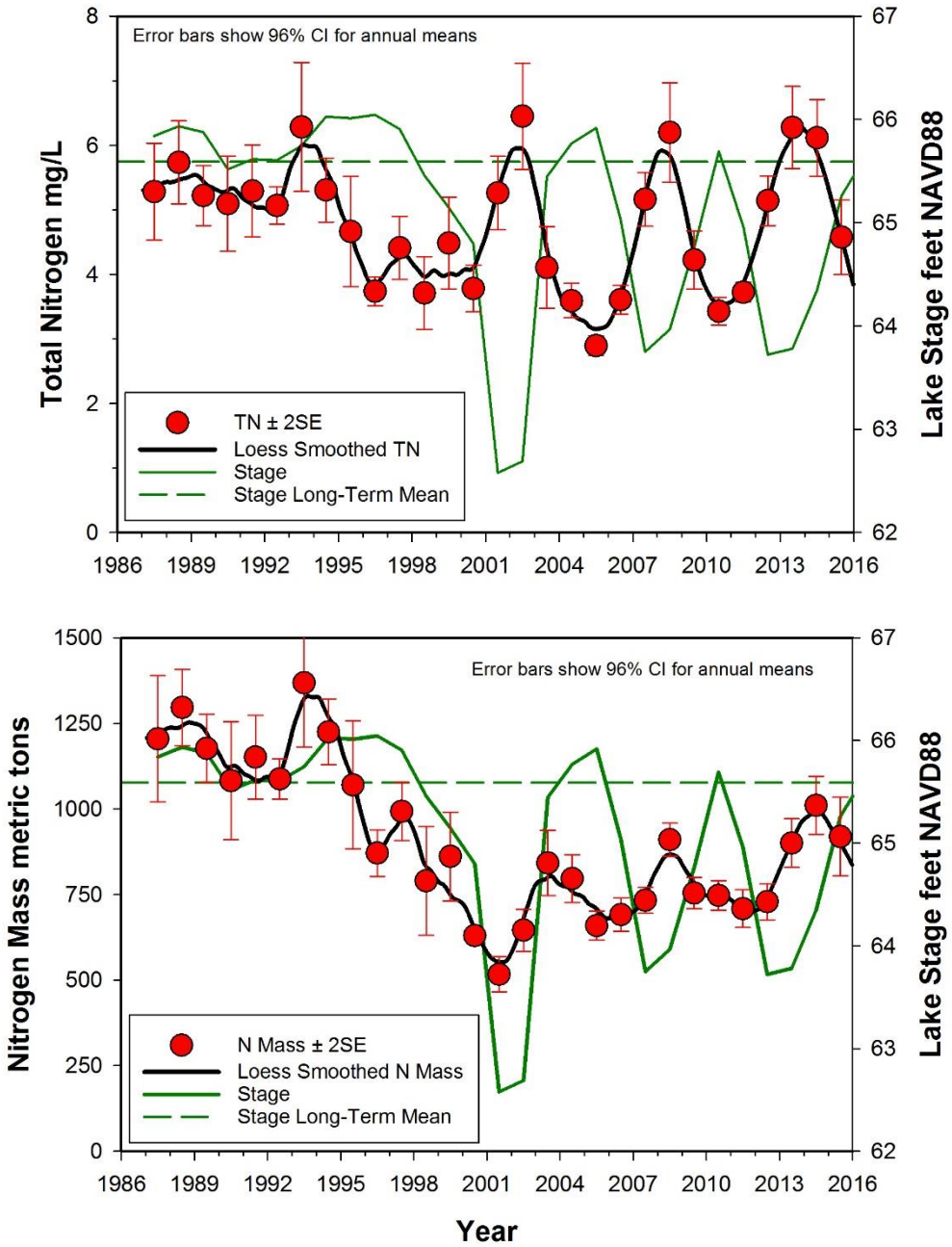

Figure 6. Mean annual values for total nitrogen (TN) concentration (top) and TN mass (bottom) in Lake Apopka for the period (1987-2015) of District monitoring. Local polynomial regression (LOESS) smooth curves were fit to mean monthly values. Mean annual lake stage and long-term mean stage (1960 – 1990) are included. Error bars are 96% confidence limits around means (±2SE).

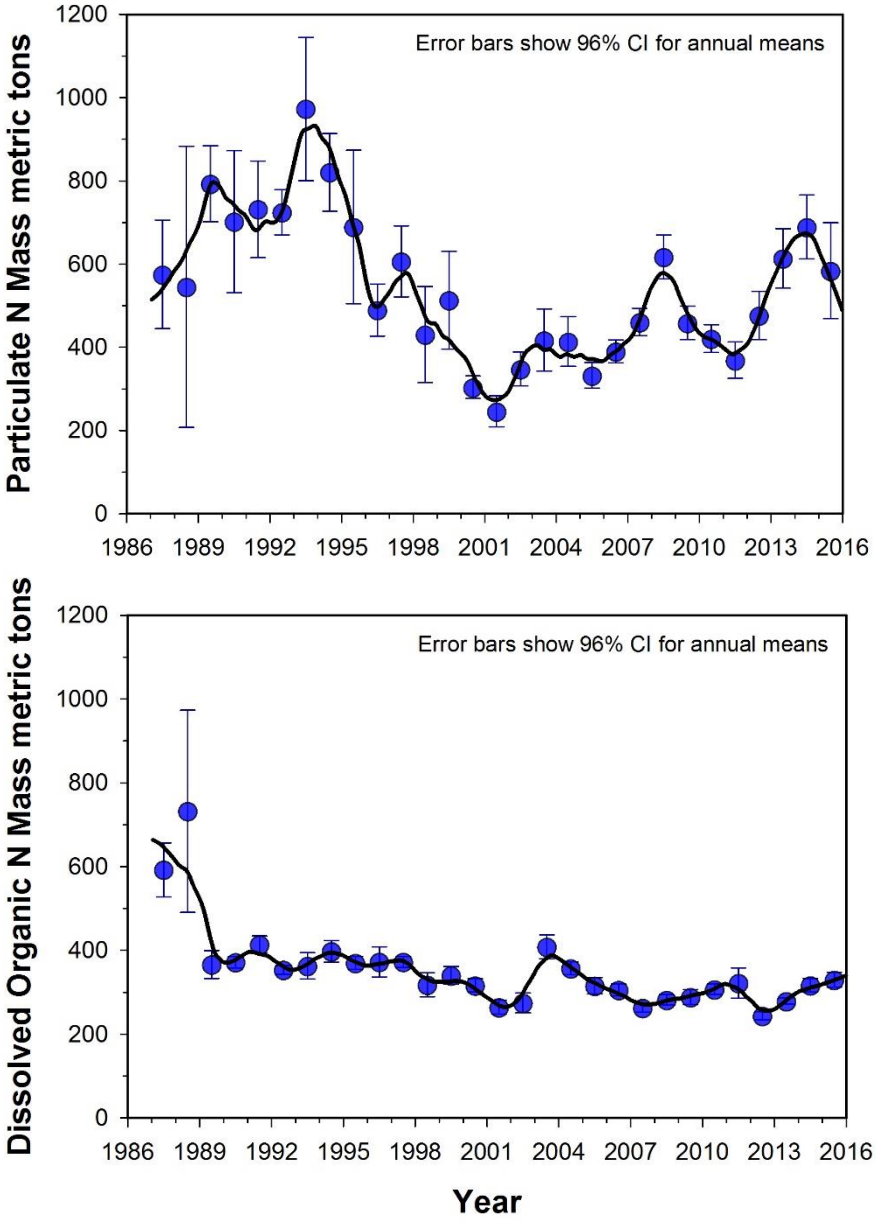

Figure 7. Mean annual values for particulate N mass (top) and dissolved organic N mass (bottom) in Lake Apopka for the period (1987-2015) of District monitoring. Local polynomial regression (LOESS) smooth curves were fit to mean monthly values. Error bars are 96% confidence limits around means (±2SE).

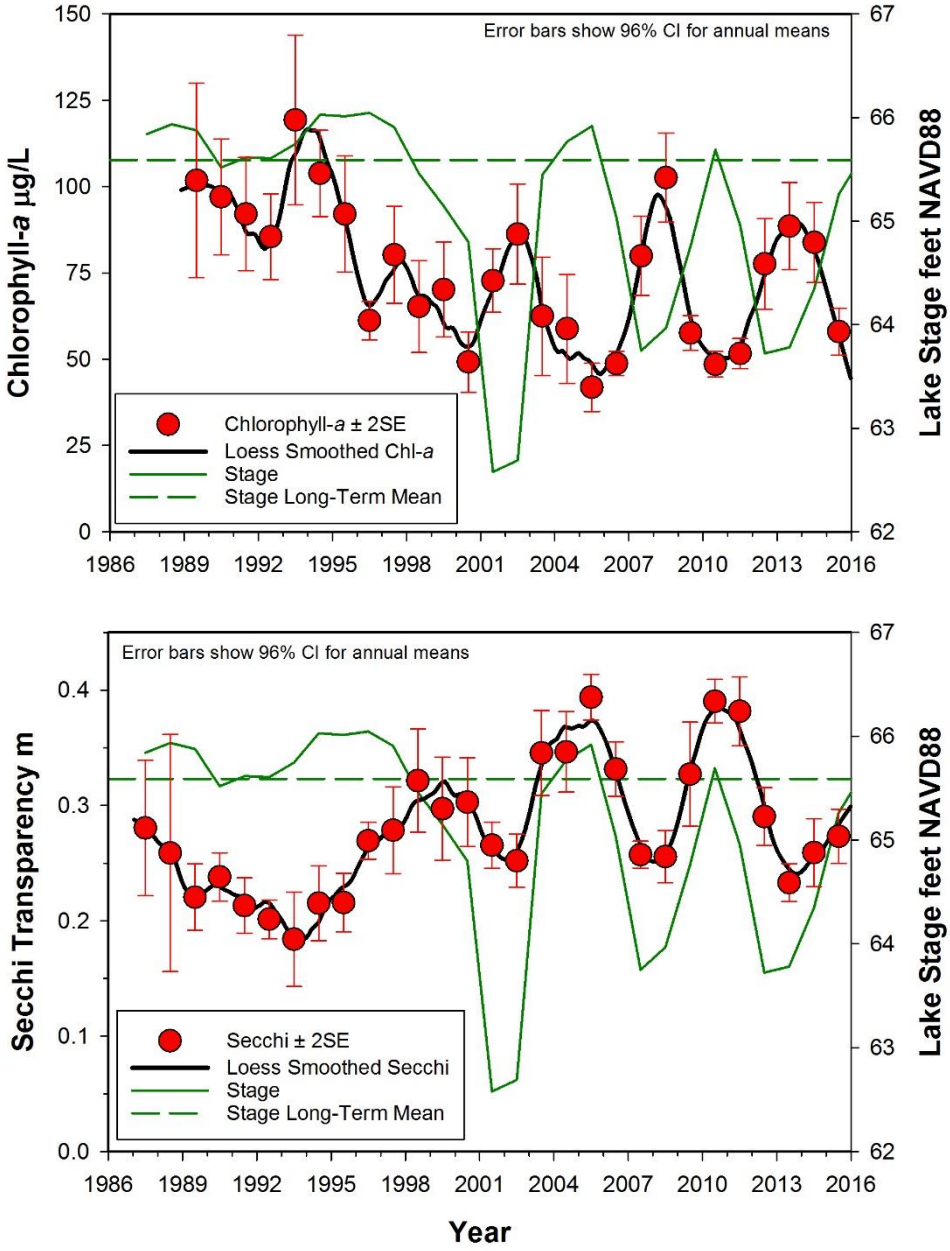

Figure 8. Mean annual values for chlorophyll-*a* concentration (top) and Secchi transparency (bottom) in Lake Apopka for the period (1987-2015) of District monitoring. Local polynomial regression (LOESS) smooth curves were fit to mean monthly values. Mean annual lake stage and long-term mean stage (1960 – 1990) are included. Error bars are 96% confidence limits around means (±2SE).

ECOLOGICAL CHANGES IN LAKE APOPKA

We predicted that the restoration program in Lake Apopka would produce a cascade of ecological changes (Fig. 9). Reduced external P loading would lead to reduced TP concentrations in lake water and lower algal levels. Lower algal biomass would lead to improved water transparency that would allow submersed aquatic vegetation (SAV) to recolonize the bottom. Re-growth of submersed plants would provide improved habitat, and game fish populations would increase to levels needed for successful recreational fishing (Battoe et al. 1999).

External P loading to Lake Apopka was reduced, although the only years to date when P loading met the restoration (TMDL) target were years during or immediately following droughts (Fig. 2). All steps in the cascade of restoration effects (Fig. 9), down to increased colonization by submersed plants, currently are operating in Lake Apopka. As littoral plant areas expand, monitoring will be necessary to determine whether game fish populations also respond.

However, the linear trophic cascade (Fig. 9) in Lake Apopka was severely impacted, and even reversed, during periods of extremely low lake levels due to drought. During these periods, TP concentrations in lake water were decoupled from external loading and increased despite low loading (Fig. 4). Chl-*a* increased proportionally, and Secchi transparency decreased (Fig. 8). Volunteer patches of SAV either disappeared or decreased in size (Fig. 11) due primarily to exposure and desiccation. It is clear that under current conditions, sustained improvements in TP, transparency, and SAV will require sustained periods without the extreme low lake levels typical of the past fifteen years.

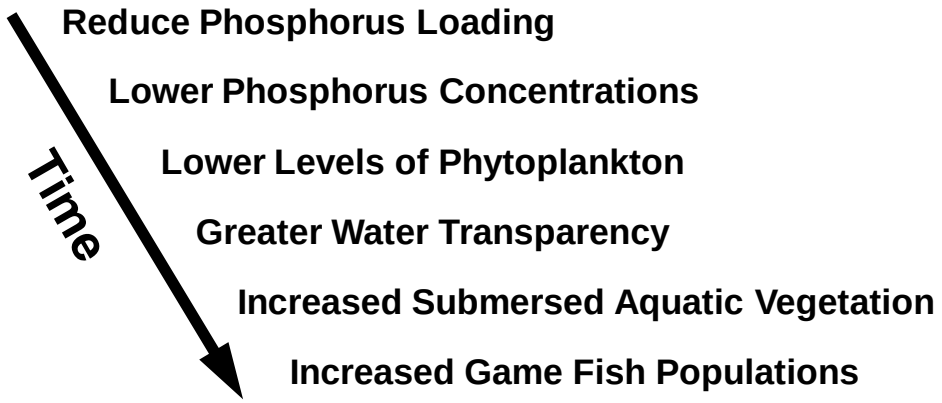

Figure 9. Conceptual cascade of events that we predicted to follow from reduction in P loading to Lake Apopka. These events describe both a reduction in trophic state (lower nutrients) and important ecological changes (e.g. shift in primary producer community structure from phytoplankton to aquatic macrophytes).

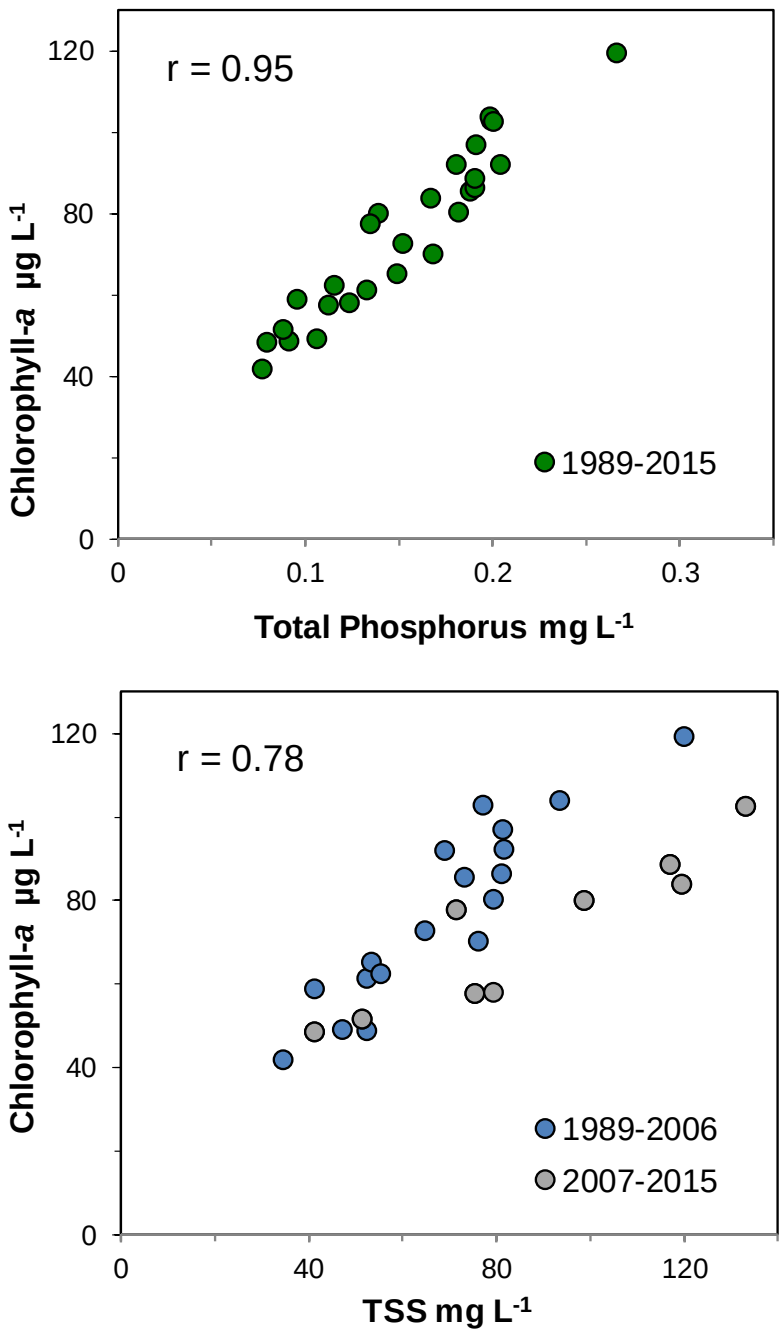

Figure 10. Top: Relationship between mean annual chlorophyll-*a* and mean annual TP in Lake Apopka. Bottom: Relationship between mean annual chlorophyll-*a* and mean annual TSS in Lake Apopka. For both data sets, Pearson's r indicates good linear correlation. Correlations are significant at $p < 0.001$.

We found a strong linear relationship between annual mean TP concentration and Chl-*a* concentration in Lake Apopka (Pearson's $r = 0.95$, $p < 0.001$) (Fig. 10, top). Declines and increases in TP over this 27-y data set were accompanied by similar changes in Chl-*a* without exception. This relationship supported our conclusion that continued reduction in TP concentrations will translate to continued reduction in phytoplankton biomass.

The Chl-*a*:TP ratio in Lake Apopka was lower and varied less with trophic state (e.g. TP concentration) than in downstream lakes in the Upper Ocklawaha River Basin (Table 1). For Lake Apopka, Chl-*a*:TP ranged from 0.47 to 0.58 for a range in TP concentrations. This same ratio ranged from 1.2 to 1.8 for a range in TP concentrations in downstream lakes (Table 1).

Much speculation has occurred about resuspension of sediments in Lake Apopka as a primary source of turbidity that is separate from phytoplankton biomass and that will not decline even as phytoplankton biomass declines. However, the data supported the opposite conclusion. The annual mean concentration of Chl-*a* varied more-or-less linearly with the concentration of TSS over a three-fold range in both variables (Pearson's $r = 0.78$, $p < 0.001$) (Fig. 10, bottom). Although the overall linear relationship is good, differences exist between earlier and later, drought years that show less Chl-*a* in relation to TSS (Fig. 10, bottom). This decline in the Chl-*a* content of TSS likely was related to the decline in TP content of TSS noted above, since Chl-*a* and TP covary closely (Fig. 10, top).

Cyanobacteria have dominated the phytoplankton in Lake Apopka based on biovolume since the start of District analyses in 1989, and *Planktolyngbya* has been the major genus (Fulton, unpublished). Phytoplankton vary in Chl-*a* content with a range for all taxa of about 0.5 – 2.0 % of dry weight (Reynolds 1984). For cyanobacteria, Reynolds (1984) included data for four taxa that averaged 1.2 %. Overall, Chl-*a* in Lake Apopka ranged from 0.07% to 0.14% of TSS. Even with the assumption that phytoplankton in Lake Apopka had low Chl-*a* content (0.5% of dry weight), phytoplankton would account for a minority (14% - 28%, median 22%) of TSS. Thus, Chl-*a* and TSS covary in Lake Apopka, but living algal biomass as represented by Chl-*a* does not appear to make up most of the TSS. One hypothesis that is consistent with these data is that much of the remaining TSS in Lake Apopka is algal detritus. In this scenario, TP reductions lower algal biomass (Fig. 10), and both the living algal biomass and algal detrital components of TSS decline, perhaps on different time scales. Declines in both algal biomass and other, possibly detrital, TSS will be important to produce improved light conditions for submersed vegetation. Here, the Marsh Flow-Way will play an important role due to its high efficiency for removal of TSS from inflowing lake water (Dunne et al. 2012).

TP*	Lake Apopka		Upper Ocklawaha lakes	
	Pred Chl-*a**	**Chl-*a*:TP**	**Pred Chl-*a****	**Chl-*a*:TP**
50	NA	NA	61	1.2
75	43	0.58	116	1.6
100	54	0.54	183	1.8
200	95	0.47	NA	NA

* Concentration units µg/L

Table 1. Predicted Chl-*a* concentrations and Chl-*a*:TP ratios for a range of TP concentrations in Lake Apopka and downstream lakes. Linear (Lake Apopka, Fig. 10) and log-log (Upper Ocklawaha, Fulton & Smith 2008) equations fitted to annual mean Chl-*a* and TP values were used for predictions. NA: TP concentration outside range of prediction equation.

Beginning in 1995, small patches of native SAV, primarily eelgrass (*Vallisneria americana*) and muskgrass (*Chara* sp.), began to grow in the littoral zone of Lake Apopka after being almost absent for several decades (Fig. 11). Recovery was slowed by drought in 2001 – 2002, when many of these patches were exposed and damaged by low water levels. Submersed vegetation was limited again by low water and worsening water quality during drought in 2007 – 2008 but again recovered when water levels increased. By the time water levels declined in 2012, SAV had expanded to about 23 ha (57 acres) and was present in patches along much of the perimeter of the lake. SAV declined in area during this drought as well but showed greater resilience than previously. Declines were on the order of 40%, and SAV area expanded again with higher water levels in 2015 (Fig. 11).

District scientists have found SAV species colonizing all types of sediments in Lake Apopka including the soft, organic “muck” sediments that some have argued would preclude the establishment of rooted plants (Dobberfuhl et al. 2015). If lake levels remain within the typical fluctuation range, then we expect continued reduction in TP concentrations to approach the TMDL target of 0.055 mg P/L. Based on data to date, lower TP should result in lower phytoplankton Chl-*a* (Fig. 10), continued increases in Secchi transparency (Fig. 8), and further expansion of SAV.

Expanded SAV beds will provide improved habitat for fish and wildlife. At some point, expanded SAV will help to stabilize shallow sediments and reduce sediment-water nutrient

recycling, which should increase net P sedimentation. SAV also will compete with phytoplankton for nutrients. All of these effects will provide positive feedback for further improvements in water quality and habitat conditions in Lake Apopka.

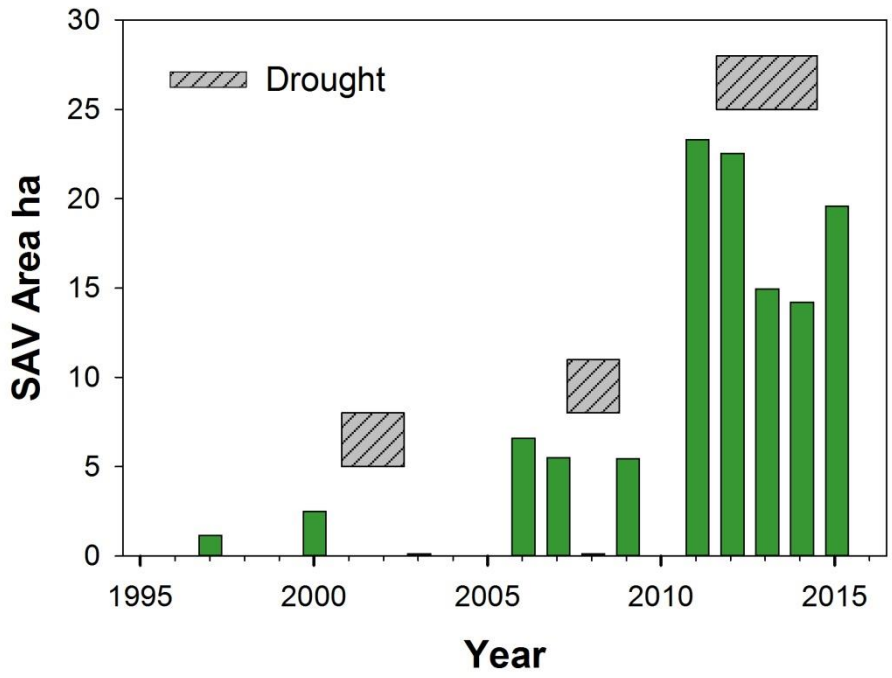

Figure 11. Colonization of littoral areas of Lake Apopka by native submersed aquatic vegetation (SAV). SAV in Lake Apopka consists mostly of eelgrass (*Vallisneria americana*) with some muskgrass (*Chara sp.*). Patches of Vallisneria were noticed first in 1995, and monitoring began in 1997. SAV area was negligible in 2003 and 2008 during or after droughts.

CONCLUSIONS

- The District's restoration program for Lake Apopka has reduced annual P loading to the lake from about 62 metric tons to an average of 11 metric tons for 2010 – 2014. P loading to Lake Apopka has met the total maximum daily load (TMDL) target (15.9 metric tons per year) in years during or following droughts. Further improvements to water management and P treatment on the Lake Apopka North Shore are needed to ensure that loading targets can be met in normal to wet years and that loading can be reduced further during low water periods to prevent hypereutrophic water quality. Steady-state models predict that Lake Apopka will meet the target TP concentration (0.055 mg P/L) when loading meets the TMDL target – if lake levels remain within normal ranges.
- Reduction in external P loading to Lake Apopka and removal of P from lake water resulted in improvements in key water quality indicators TP, Chl-*a*, and Secchi transparency. Neither internal recycling of sediment P nor wind-driven resuspension of sediments prevented improvements in these water quality metrics.
- Long-term changes in water quality in Lake Apopka largely are explained by three drivers: 1) improving trends due to reduced P loading and P removal, 2) cyclical oscillations since 2000 due to alternate periods of low and normal lake levels (and volumes), and 3) seasonal cycles.
- Calculation of water column masses of chemical constituents in addition to concentrations helped to minimize the confounding effects in analyses of changes in lake volume during droughts.
- TP and Chl-*a* concentrations in lake water declined along with reductions in P loading until 2000. Mass of TP in Lake Apopka declined in parallel with concentration until TP mass reached a low and quasi-stable level about 2000.
- Since 2000, extremely low lake stage during three droughts at 5 to 6-yr intervals resulted in periodic degradation of all water quality indicators. TP, TSS, TN, and Chl-*a* concentrations increased greatly at low lake levels both because their lake water masses were concentrated in a smaller volume and because the normal net sedimentation of TP to sediments was interrupted.
- Lake water masses of TSS and TN declined initially but then trended upwards from 2000 through 2015. Mass of particulate N increased proportionally to TSS, but particulate P did not. Therefore, suspended matter in Lake Apopka, increasing since 2000, maintained a similar N content but a lower P content than in prior years.
- Secchi transparency followed the same general pattern as TP, TSS, and TN – long-term improvements through 2000 and temporarily worsened conditions during subsequent periods of low lake level.

- Chl-*a* concentration in Lake Apopka showed a strong linear relationship with TP concentration. Continued reduction in TP concentrations should translate to continued reduction in phytoplankton biomass.
- Chl-*a* varied linearly with TSS concentration, although this relationship differed between earlier and later years. Most of the TSS was not living algal biomass, which suggests that algal detritus may be an important component.
- Native SAV began to recolonize the littoral zone of Lake Apopka in 1995 but almost was eliminated in subsequent droughts. By 2012, SAV had expanded to about 23 ha (57 acres). SAV declined during the most recent drought as well, but showed greater resilience than previously.
- Under current conditions, sustained improvements in TP, algal Chl-*a* transparency, and SAV will require sustained periods without the extreme low lake levels typical of the past fifteen years.

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APPENDIX A. SEASONAL TP PATTERNS IN LAKE APOPKA

A seasonal pattern in water quality has been evident in Lake Apopka in most but not all years of District monitoring. This pattern is illustrated with six years of TP data through one drought cycle (Fig. A-1). Generally, water quality tended to worsen in the winter/spring and improve in the summer/fall. This seasonality appeared to be due, in part, to lower net P sedimentation and possible sediment resuspension during winter/spring because of wind mixing from frontal events. However, the negative relationship between wind velocity and net P sedimentation was stronger in early years (1987 – 1995) than in later years (1996 – 2002) (Coveney et al. 2005).

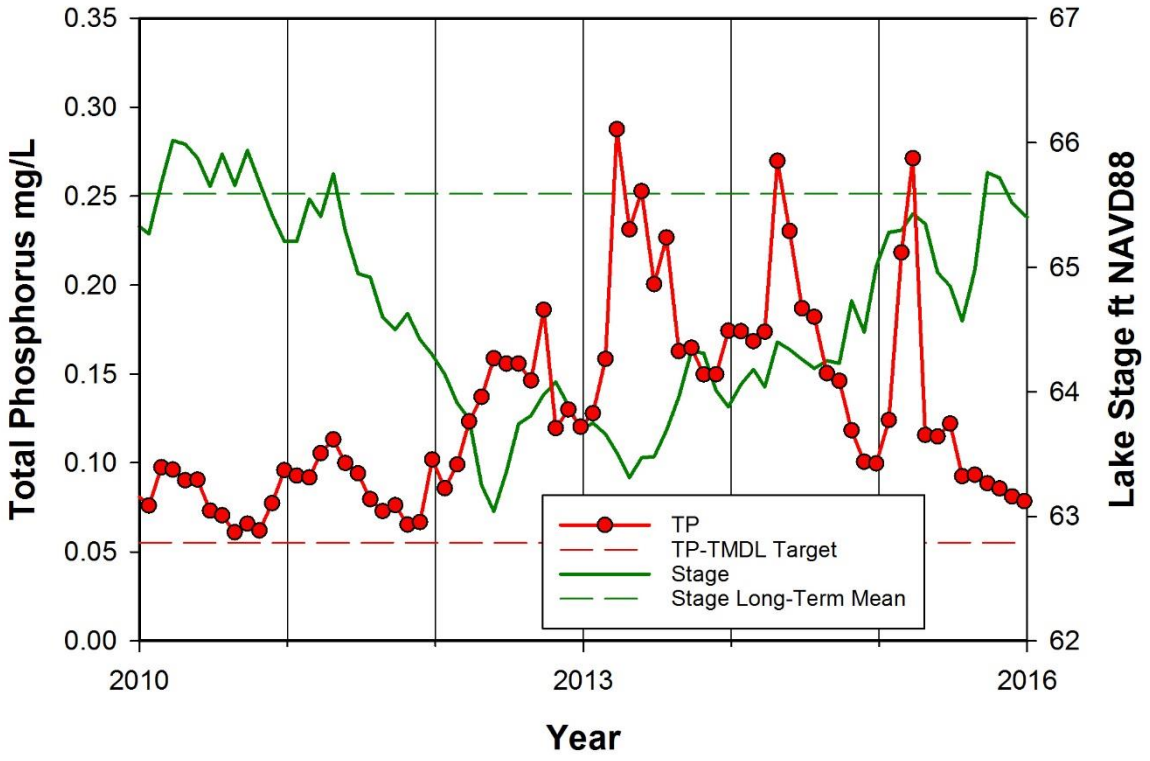

Figure A-1. Mean monthly values for total phosphorus (TP) concentration in Lake Apopka for the period 2010 – 2015. Mean monthly lake stage, long-term mean stage (1960 – 1990), and the TMDL target concentration for P are included.

Additional Proposal Information

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Pesticide Studies and Risk Assessments on the Lake Apopka North Shore.pdf

Technical Memorandum 57

PESTICIDE STUDIES AND RISK ASSESSMENTS ON THE LAKE APOPKA NORTH SHORE

by

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Palatka, Florida

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Preface

The Lake Apopka North Shore (LANS) was the site of a large and unanticipated bird mortality event during winter 1998/1999 that was linked to organochlorine pesticide (OCP) residues in the soils. In response to the bird deaths, the District and the Natural Resources Conservation Service launched the Lake Apopka Pesticide Study. The study included applied research to analyze potential causes of the mortality and to fill gaps in our understanding of bioaccumulation and avian toxicity of OCPs in organic soils. Our goal was to provide sufficient data for prospective risk assessments and for remediation so the District could move ahead safely with restoration of wetlands on the former agricultural lands.

The pace of the work was rapid, and the priorities were to answer important questions and to move forward. Components of this project were presented to the Technical Advisory Group for the study and to two Expert Review Groups as well as to national conferences. Although the work was reviewed and vetted thoroughly in this process, most of the results of the study were not published. Our goal in writing this report was to summarize important but largely unpublished data and information from the Lake Apopka Pesticide Study by District staff and outside collaborators. Our focus was on those portions of the study that subsequently were used by District staff in prospective risk assessments, Biological Assessments, and remediation planning.

We gratefully acknowledge the many contributions of District colleagues in the Lake Apopka Pesticide Study, including E. Lowe, E. Marzolf, S. Richter, E. Mace, J. Peterson, P. Bowen, C. Brown, and J. Marburger. We thank J. Peterson, P. Ek, and other staff at the Apopka Field Station for their hard work and dedication in maintaining field mesocosms to measure bioaccumulation. P. Bowen, R. Fulton, and L. McCloud reviewed and commented on a draft of this report.

Contents

Preface ii

Overview 1

Soil and Tissue Sampling and Organochlorine Pesticide Analyses 3

Analytical Methods 3

Soil Sampling 5

Soil OCPs – Results and Discussion 5

Forensic Analysis of Soil and Tissue Data and Bird Mortality Information 6

Bioaccumulation Study 7

Definition of the Biota Sediment Accumulation Factor (BSAF) 8

Microcosm Study – Proof of Concept for BSAF Model 8

Results and Discussion 9

Mesocosm Study 11

Results and Discussion – BSAF Values 13

Results and Discussion – Attenuation Rate Constants for OCPs in Soil and Fish 19

Bird Feeding Study 20

Abstract 20

Results and Discussion 21

Toxicity Reference Values (TRVs) to Characterize Risk to Piscivorous Birds from OCP Residues in Fish 25

Summary of TRV Values 26

Dieldrin 27

Toxaphene 27

DDT 28

DDE 29

Heptachlor Epoxide 30

Oxychlordane, *alpha*-Chlordane, *cis*-Nonachlor, *gamma*-Chlordane, Heptachlor, *trans*-Nonachlor 30

Risk Analyses 31

Remediation 33

References 34

Appendix A. Technical and Expert Review Groups for the Lake Apopka Pesticide Study 38

Overview

Lake Apopka has been the focus of comprehensive restoration efforts by the St. Johns River Water Management District (District) (Coveney 2016). To prevent excessive phosphorus loading to the lake, the District used state and federal funding (Natural Resources Conservation Service, NRCS) to purchase farms constructed in former floodplain wetlands to form the Lake Apopka North Shore (LANS). The intent was to stop agricultural discharges and to impound rain water in restored wetlands to prevent further oxidation of organic soils and to restore habitat.

During winter 1998/99, a significant bird mortality event occurred after initial flooding of portions of the LANS. The District and the US Fish and Wildlife Service (USFWS) linked this mortality to toxicosis from organochlorine pesticides (OCPs), although risk assessments prior to flooding failed to indicate a significant risk for mortality from OCP residues in soils (ATRA Inc. 1997 & 1998). The OCPs of concern on the LANS were toxaphene, DDT and its metabolites DDE and DDD, dieldrin, and seven chlordane compounds.

Conrow et al. (2011) presented an overview of the degradation and restoration of the LANS, the bird mortality event, and subsequent interagency efforts to put restoration back on track. Potential criminal and civil legal issues between the United States Department of Justice and the District stemming from the bird mortality event were resolved with a memorandum of understanding in 2003 (Conrow et al. 2011).

In response to the bird deaths, the District and the NRCS launched the Lake Apopka Pesticide Study. One goal of the study was to set concentration targets for OCP residues in soils on the LANS that would allow safe re-flooding of the lands for restoration of wetlands and other aquatic habitat. Data needed to set these target concentrations also would be used in prospective risk assessments and in planning and implementing necessary remediation. The District and the NRCS assembled a large, multi-agency Technical Advisory Group that met at intervals to discuss the Pesticide Study. Furthermore, the District convened two Expert Review Groups to review and critique specific aspects of the study. Appendix A shows the makeup of each of these groups.

The focus of this report is the Lake Apopka Pesticide Study and subsequent remediation of the LANS. This work had the following main components:

- Soil OCP sampling and analyses
    - Extensive sampling of soils on the LANS in 1999 - 2001 to characterize the concentrations, depth, and spatial distribution of weathered OCP residues
    - Spatial analysis of soil pesticide concentrations
    - Resampling of soil in 2007 for former Zellwood Drainage and Water Control District (ZDWCD) Units 1 and 2 to update the soil OCP database prior to remediation and further sampling after remediation
- Contracted (Exponent) forensic analysis of soil and tissue data and bird mortality information

- Bioaccumulation study and estimation of biota sediment accumulation factors (BSAFs)
    - Large, laboratory microcosms to evaluate the BSAF model for bioaccumulation of weathered OCPs from soil to fish with highly-organic soils
    - Field-scale mesocosms to determine site-specific BSAFs and to measure rates *in situ* of natural attenuation of weathered OCPs in flooded soils on the LANS
    - Bird feeding studies to measure the bioaccumulation from fish to birds of weathered OCPs from the LANS
- Development of toxicity reference values to characterize risk to piscivorous birds from weathered OCP residues in fish
- Risk Analyses
- Remediation
    - Contracted (Mactec) desktop feasibility study of possible soil remediation techniques
    - Refinement of soil inversion, the chosen remediation technique, in field-scale testing
    - Remediation by soil inversion of almost 4,000 acres in former Zellwood Drainage and Water Control District Units 1 and 2

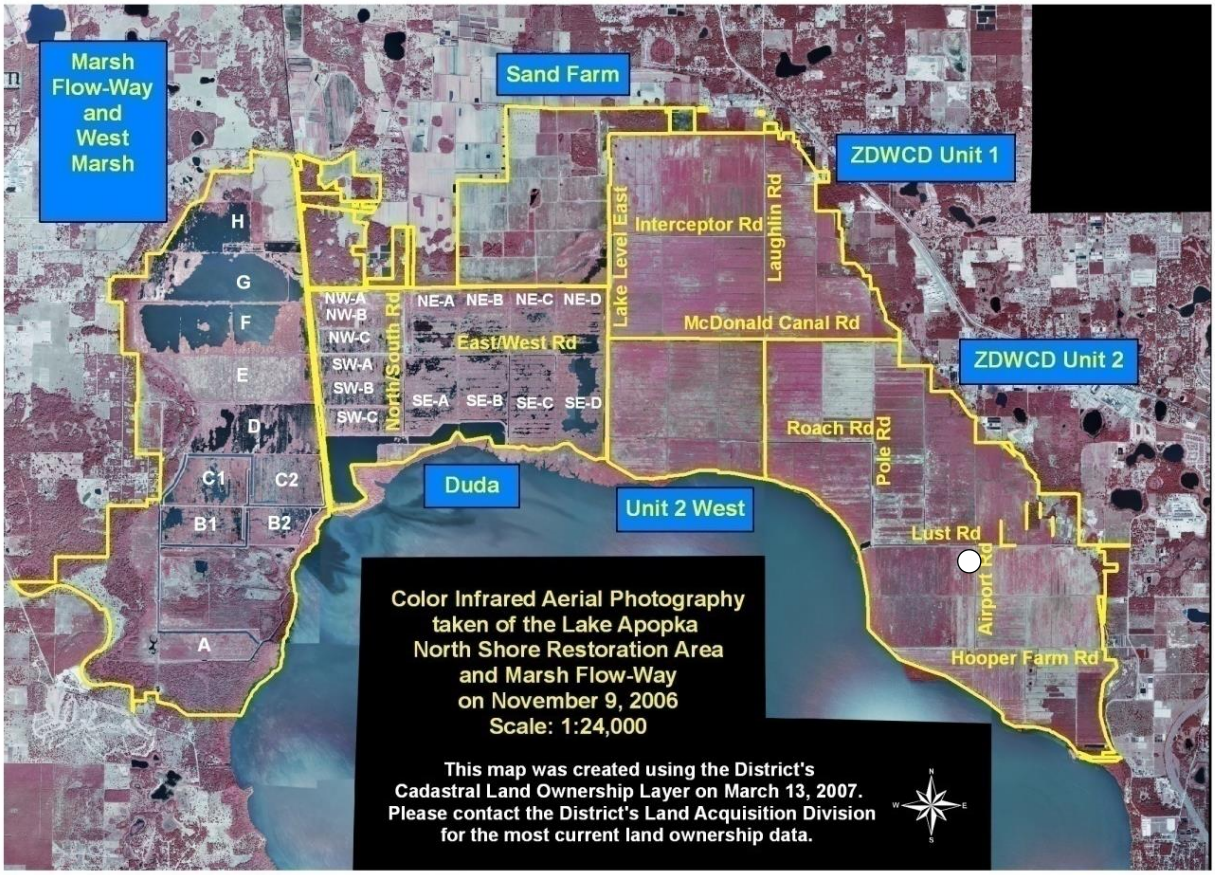

Fig. 1. Areas on the Lake Apopka North Shore (LANS) restoration area referenced in this report by their former ownership: Duda, and Zellwood Drainage and Water Control District (ZDWCD) Units 1 and 2. Examples of individual field identifiers are shown for Duda. The white dot south of Lust Road shows the location of the Lust Farm "hot spot" where extremely high soil concentrations of pesticide residues were measured (see text).

Soil and Tissue Sampling and Organochlorine Pesticide Analyses

Analytical Methods

To provide a consistent set of laboratory analyses, the District contracted with Pace Analytical Services Inc. (formerly En Chem Inc.), Madison, WI to perform all OCP analyses for the duration of the District's pesticide studies on the LANS. This decision was prompted by early comparison of split bird tissue samples analyzed by various laboratories that showed large inter-lab differences, especially for toxaphene. Pace developed a variation of USEPA Method 8081A for weathered toxaphene for this project that they cited as the "Apopka method".

Samples were screened for up to 24 OCPs, including 4,4'-DDT and its metabolites, dieldrin, toxaphene, *alpha*-chlordane, *gamma*-chlordane, heptachlor, and heptachlor epoxide.

Oxychlordane, *cis*-nonachlor, and *trans*-nonachlor were added to the analyte list in 2002. Concentrations of these missing chlordane congeners were estimated for older samples by single or multiple linear regression using data from later samples where all congeners had been measured. The regressions used the potential prediction variables *alpha*-chlordane, *gamma*-chlordane, heptachlor epoxide and toxaphene, and Y-intercepts were fixed at zero. R^2 values for these regressions ranged from 0.39 to 0.86.

For soils, a 20 g sample was homogenized by hand mixing and mixed with 60 g anhydrous sodium sulfate. The sample was extracted with methylene chloride/acetone by sonication for a total of 15 min (SW846 Method 3550B). An aliquot of the extract was cleaned up by gel permeation chromatography (GPC). After GPC clean-up, the solvent was exchanged to hexane and concentrated.

We determined total organic carbon (TOC) in a subset of soil samples by high-temperature combustion and direct assay of CO_2 and measured loss on ignition at 550 ± 50 C. The resulting linear relationship between soil TOC and loss on ignition ($R^2 = 0.98$) was used to derive TOC values for remaining samples.

For tissues, approximately 20 g of tissue (e.g. homogenized whole fish, dissected bird tissues, whole bird carcasses) was frozen with liquid nitrogen and then mixed with 40 g of anhydrous sodium sulfate. Samples were extracted with methylene chloride for a minimum of 16 h in a Soxhlet extractor. A portion of the Soxhlet extract was analyzed for lipid content, and the rest was cleaned up by GPC (SW846 Method 3640A). After GPC clean-up, the solvent was exchanged to hexane and concentrated.

For soils and tissues, the GPC extract was further cleaned up by the Florisil method (SW846 Method 3620B), and another portion underwent sulfuric acid clean-up (SW846 Method 3665A). The Florisil-cleaned extract was analyzed for OCP content with a gas chromatograph (GC) equipped with an electron capture detector (ECD). The sulfuric acid extract was analyzed for toxaphene by GC using five calibration standards (Restek, Bellefonte, PA). Toxaphene was identified by matching at least four peaks with the toxaphene standard pattern based on both retention time and relative peak height. To maximize the recovery of weathered forms, toxaphene was quantified using the total area under the curve above a straight base line procedure as described in Method 8081A, Section7.6.1.3.2. The areas of large single peaks not matching the toxaphene pattern (e.g. chlordane and the DDT-series) were subtracted.

OCP concentrations were reported as µg/kg (ppb) wet weight for tissues and dry weight for soils. In some instances, these concentrations also were presented as lipid or carbon (TOC) normalized values by multiplication of the wet or dry weight OCP concentration by the factor 100 ÷ % lipid or %TOC, respectively.

Early in these studies, OCPs analyzed as not-detected were reported by Pace as the PQL (Practical Quantitation Limit). Later, Pace reported non-detects as the MDL (Method Detection Limit) and subsequently added the actual machine output value. Because sample weight was included in calculation of detection limits, each sample had a unique PQL or MDL. In the Microcosm Study, we omitted non-detects from analyses. In the Mesocosm Study, we substituted either ½MDL (½PQL if no MDL) or MDL (PQL if no MDL) for censored data in derivations of BSAFs. Details are shown below.

All soil and tissue OCP data, both historic and recent, currently are stored in an ACCESS database curated by the Bureau of Water Resource Information.

Soil Sampling

Extensive resampling of soils for OCP and TOC analyses was conducted in 1999 - 2001 and again in 2007. Samples were taken as single soil cores. We aggregated the top 30 cm (12 in) for most samples, but cores were sectioned and sampled at multiple intervals at a subset of sites. The 1999 - 2001 soil sampling followed a stratified random grid design with each sample representing from 13 to 25 acres. The sampling program in 2007 on ZDWCD Units 1 and 2 followed a protocol that was developed jointly by the District and the USFWS. This protocol called for 5 soil samples in fields 50 acres or less, 10 samples in fields between 50 and 200 acres, and 15 samples in fields larger than 200 acres.

Approximately 1,700 sites were sampled in 1999 - 2001 in Duda and Units 1 and 2, and about 590 sites were sampled in 2007 in Units 1 and 2.

Sampling sites for all soil OCP data were spatially located in approximately 70 different fields east of the Apopka-Beauclair Canal with potentially different past ownerships and farming history. Locations of fields on the LANS were identified in Marzolf et al. (2003) and numerous other reports by the "intersection of field and ownership" or "owner and alum blocks". This nomenclature used individual field identifiers that were developed previously to plan spreading of alum residuals to bind phosphorus in soils.

Soil OCPs – Results and Discussion

Bowen (2001) prepared a map book with spatial graphics illustrating most features of the 1999 – 2001 soil sampling program. These features included previous parcel owners, alum block IDs, sampling sites, and analytical results for TOC, dieldrin, toxaphene, and the DDT family.

NewFields, Inc. (2000) did spatial statistical analyses on soil data from 1999 – 2000 that revealed no significant correlations for OCPs but showed important differences in OCP concentrations among fields. Generally, OCP concentrations were lower in Duda and increased across Units 1 and 2 along two gradients: west to east and south to north.

TOC concentrations in the fields were uniformly high. About 60% of the area of Units 1 and 2 showed soil TOC concentrations greater than 30% of dry weight, and TOC values ranged as high as 50%.

Marzolf et al. (2003) presented an overview of the extensive 1999 – 2001 round of soil sampling on the LANS. Using toxaphene and DDE as examples, they discussed the vertical and spatial distribution of OCPs in soil and the relationship between OCP concentrations and soil organic content. They found the most consistent pattern for OCP concentrations across the LANS to be similar concentrations within single fields with sometimes abrupt changes in the next field, even for fields with the same owner. This pattern existed because agricultural practices including pesticide applications were consistent within fields, and fields changed ownership through the years. Note that the data presented by Marzolf et al. (2003) do not represent data from the later (2007) soil sampling, nor do they represent soil OCP concentrations after subsequent soil remediation.

Richter and Schell (2003) compared OCP extraction by sonication as used in this study with Soxhlet extraction. They found the Soxhlet procedure to extract about 3-fold more OCPs from

wet soils. However, they discussed that rigorous Soxhlet extraction may remove OCPs that would not be bioavailable. All soil analyses described here for the LANS and elsewhere on District properties have been extracted by sonication and therefore are internally consistent. Comparisons with soil analyses done with other procedures should be made with caution.

One benefit of the stratified random soil sampling in 1999 – 2001 was the discovery of one sample with extremely high soil OCP concentrations. This site was close but not immediately adjacent to a crop-dusting airstrip on the former Lust Farm (Fig. 1). Subsequent delineation around this single sample revealed about 6 acres of highly-contaminated soil with toxaphene present up to 11,000 mg/kg dwt. This area ultimately was excavated, and soil was transported to an approved landfill. The area was back-filled with 2 ft of clean soil. In all, about 9,000 tons of soil were removed at a cost of about $600,000. Soil from this site (Lust Farm "hotspot") subsequently was included as part of the Microcosm Study. The District resampled an additional 9 former airstrips on the LANS after discovery of the Lust hotspot without finding similarly high OCP concentrations.

Although fields on both sides of the Lust hotspot area were flooded in 1998 (Bowen 2001), we were unable to determine from oblique aerial photographs after the fact whether the actual hotspot soil area had standing water. Therefore, the potential role of the hotspot in the bird mortality could not be established.

Forensic Analysis of Soil and Tissue Data and Bird Mortality Information

The District contracted with Exponent, Bellevue, WA, in 2000 to conduct a forensic analysis of all available data and information about the 1998-99 bird mortality event on the Lake Apopka North Shore (also referred to as the North Shore Restoration Area or NSRA). The primary objectives directed to Exponent were to

- Analyze the underlying causes of the bird mortality at the LANS
- Determine the concentrations of pesticides in muck soils that would be protective of birds, if pesticides were the cause of mortality
- Determine the most effective management options for preventing such mortality events from occurring in the future (Exponent 2003)

Most of their report addressed the first of these objectives. Exponent used a weight-of-evidence approach and an epidemiological structure in their analyses and evaluated causality using the following components (Exponent 2003):

- Avian population census and mortality data
- Food-web modeling to evaluate exposure of avian species to organochlorine pesticides
- Body residues of organochlorine pesticides in dead birds
- Etiology and pathology of the mortality event

In their conclusions, Exponent (2003, p. 6-4) was equivocal regarding the role of organochlorine pesticides in causing the bird mortality,

> "Overall, application of epidemiological criteria to the mortality event does not produce strong evidence either supporting or refuting the hypothesis that mortality was a result of exposure to organochlorine pesticides."

Although Exponent failed to conclude that the bird mortality was caused by organochlorine pesticides, they found evidence that pesticides were a contributing factor (Exponent 2003, p. 8.1). They used existing information in risk analyses to predict the threshold concentrations in soils above which organochlorine pesticides could have adverse affects on birds foraging on the Lake Apopka North Shore (Exponent 2003, Fig. 8-1).

Regarding management recommendations, Exponent (2003) found the following:

> "At this juncture, Exponent feels that such recommendations are premature because there is inconclusive evidence that the organochlorine pesticide contamination associated with the soils of the north shore of Lake Apopka was solely responsible for avian mortalities. Furthermore, there are data gaps, particularly with regard to bioavailability, that need to be understood before informed management recommendations can be made. … Therefore, Exponent's primary recommendation at this time is to fully characterize transport, fate, and biological uptake of organochlorines at the NSRA. … Furthermore, until the uptake and distribution within the food web of the organochlorine pesticides within the north shore of Lake Apopka are better understood, it would be prudent not to inundate the flooding blocks, potentially creating a situation similar to that which occurred in the winter of 1998−1999."

The Bioaccumulation Study funded by the District and the NRCS was designed to fill the data gaps identified by Exponent. Site-specific data on pesticide bioaccumulation would allow the District to complete risk analyses, plan and implement any necessary remediation of pesticide residues in soils, and continue ecologically-safe wetland restoration on the Lake Apopka North Shore.

Bioaccumulation Study

The Bioaccumulation Study was funded by the District and the NRCS and was conducted by District staff in collaboration with Dr. T. S. Gross (US Geological Survey – Center for Aquatic Resource Studies) and Dr. M. S. Sepúlveda (University of Florida). The bioaccumulation study had three components – microcosm study, mesocosm study, and bird feeding study. Each of these components is explained in more detail below.

Definition of the Biota Sediment Accumulation Factor (BSAF)

The BSAF is a simple environmental fate model that characterizes the bioaccumulation of lipophilic OCPs as a function of organic carbon in sediments and lipid in aquatic organisms. The BSAF is calculated from sediment and fish OCP concentrations, lipid content in fish, and TOC in sediments as follows:

$$\text{BSAF} = \frac{\text{OCP}_{\text{fish}}\ \mu\text{g/kg wet wt} \ / \ \text{lipid}_{\text{fish}}\ \text{kg/kg wet wt}}{\text{OCP}_{\text{sed}}\ \mu\text{g/kg dry wt} \ / \ \text{TOC}_{\text{sed}}\ \text{kg/kg dry wt}}$$

We calculated BSAFs for OCPs from three datasets: microcosms, emergent marsh mesocosms (shallow), and open water mesocosms (deep). In most cases, BSAFs are calculated from measurements of individual OCPs in organisms and in soil. One exception in our work was calculation of chlordane BSAFs in mesocosms where we used the congener concentration in organisms divided by total chlordane concentration in soil. We adopted this approach because we found individual chlordane congeners in fish that no longer were detected in soil during the course of the study. This situation could have developed through different breakdown rates in fish and in soils or because of biological conversion of one congener to another. In either case, using total chlordane concentrations in soils allowed us to calculate site-specific BSAFs for chlordane congeners. However, these BSAFs should not be used to predict a concentration of chlordane congener in fish from that congener's concentration in soil.

Microcosm Study – Proof of Concept for BSAF Model

The microcosm study provided "proof of concept" for the use of a BSAF model for bioaccumulation of OCPs from soil to fish. Sepúlveda et al. (2005) described the experimental design, set up, and sampling for the Microcosm Study in detail, and a brief summary follows here. We measured bioaccumulation by fish and crayfish under controlled outdoor conditions in thirty-nine 700-L tanks containing flooded soils collected from the LANS. Tanks contained thirteen soils and soil treatments in triplicate with varying OCP and TOC concentrations, as follows:

- Nine treatments made up a factorial design with three soil TOC concentrations (high, medium, low) and three OCP concentrations (high, medium, and low)
- Three control treatments contained uncontaminated soils with high, medium, and low TOC
- One treatment contained soil from the Lust hotspot site collected prior to remediation

In all, the soils contained a wide range of concentrations of TOC (22-fold) and OCPs (57-fold for toxaphene). Tanks were stocked with eastern mosquitofish, *Gambusia holbrooki*, and calico crayfish, *Orconectes immunis*, and bioaccumulation of OCPs was measured with repeated sampling over 16 weeks. Sampling and chemical analyses of sediments and fish in the microcosm study were analogous to methods described below for the mesocosm study.

For microcosms, we omitted from analyses any OCP values below detection limits. For each treatment, initial and final sediment OCP values were normalized for TOC and averaged across replicate tanks within treatments. Similarly, *Gambusia* OCP data shown here were normalized for lipid content, averaged for 4 to 16 weeks, and averaged across replicate tanks within each treatment. Division of the mean lipid-normalized fish concentration by the mean TOC-normalized soil concentration gave one BSAF value per OCP per treatment.

Eight of the original 13 soil treatments were used in final analyses. Fish in the three control treatments did not bioaccumulate OCPs, and fish did not survive in the Lust hotspot soil treatment. No area of the LANS contained a low TOC – high OCP soil (treatment g), so we mixed soil for this treatment using clean sand plus "hotspot" soil. Data from these tanks were anomalous in several ways and were omitted. Crayfish did not thrive in the microcosms. We collected and analyzed crayfish samples when possible but did not use the resulting BSAFs.

Results and Discussion

The microcosm study was reported in detail by Sepúlveda et al. (2005). The soils and soil mixtures for the microcosm study were chosen to cover a broad range of TOC and OCP concentrations. An important goal was to determine whether BSAF values for fish (e.g. *Gambusia*) would be sufficiently constant for use in the range of TOC and OCP concentrations encountered in the LANS. Soil OCP concentrations varied 44 to 95-fold in the final eight microcosm treatments, and TOC in soils varied from 2.2% to 48% or 22-fold. About 95% of the area of LANS Zellwood Drainage and Water Control District Units 1 and 2 had TOC concentrations between 20% and about 50% dwt.

Simple accumulation factors (OCP µg/kg wet wt in fish ÷ OCP µg/kg dry wt in soil) varied greatly across the range in soil TOC (Fig. 2). For example, the simple accumulation factor for toxaphene varied about 33-fold from 0.04 at high TOC to 1.5 at low TOC. In comparison, BSAF values for toxaphene varied less than 2-fold. For toxaphene, BSAF did not vary significantly across the TOC gradient (linear regression, F-test, $p > 0.05$) (Fig. 2). In contrast, BSAF values for both DDE and dieldrin varied significantly with soil TOC (linear regression, F-test, $p < 0.05$). However, even for DDE and dieldrin with higher BSAF at low TOC, BSAF values were sufficiently constant in the TOC range 10 to 48% dwt to support the use of a mean value in risk assessment.

None of the OCPs evaluated (DDE, dieldrin, toxaphene) showed significant variation in BSAF with OCP concentration in the soil (linear regression, F-test, $p > 0.05$).

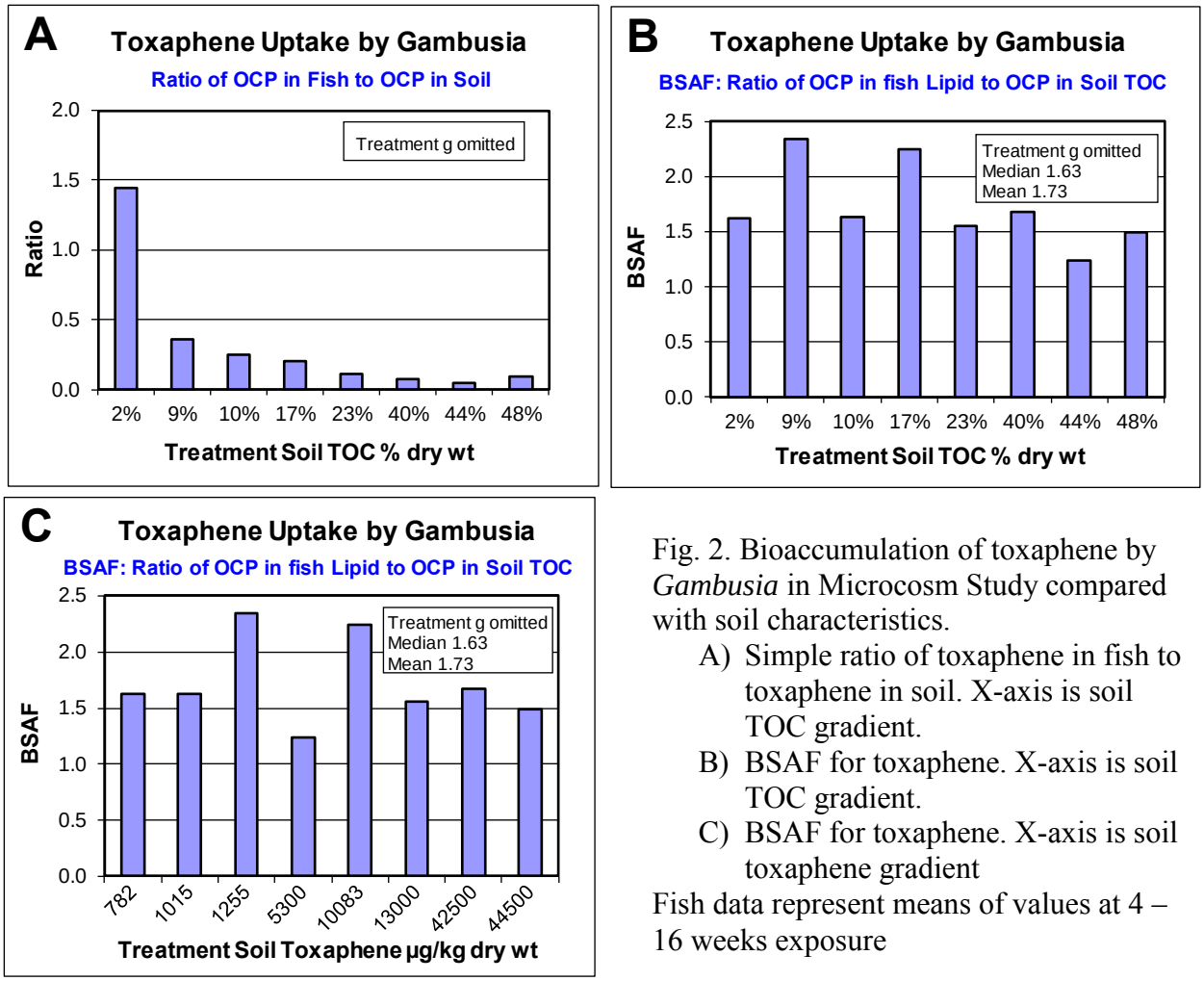

Fig. 2. Bioaccumulation of toxaphene by *Gambusia* in Microcosm Study compared with soil characteristics.

A) Simple ratio of toxaphene in fish to toxaphene in soil. X-axis is soil TOC gradient.
B) BSAF for toxaphene. X-axis is soil TOC gradient.
C) BSAF for toxaphene. X-axis is soil toxaphene gradient

Fish data represent means of values at 4 – 16 weeks exposure

We also used the time-course of accumulation of OCPs by *Gambusia* measured in microcosms to derive rate constants for elimination (k_2) assuming a first-order model (Coveney et al. 2003). The rate constant for elimination was of interest because elimination rate determines the time to equilibrium as well as the time course for depuration. Elimination rate constants varied from 0.027 d^{-1} (DDE) to 0.061 d^{-1} (dieldrin), equivalent to half-lives of 26 to 11 d. Values for k_2 were insensitive to the range of TOC and OCPs in the experimental soils. Elimination measured for *Gambusia* was similar to values predicted empirically from octanol/water partition coefficients. Consequently, the elimination rate constants measured here did not indicate an important role for metabolic processes for elimination compared to passive losses (Coveney et al. 2003).

Mesocosm Study

The mesocosm study measured site-specific BSAFs for bioaccumulation of weathered pesticide residues from soil to fish on the LANS. Data from the mesocosms also were used to measure natural attenuation of OCPs in soils and fish and to test effects of fluctuation in redox conditions on attenuation.

We constructed five 0.1 – 0.3 ha mesocosm ponds on former agricultural fields on the LANS (Fig. 3). The ponds were designed to simulate the wetland conditions that will develop in the LANS under shallow and deep flooding. Ponds had intact soils and were fenced and netted to exclude wildlife. Three shallow (emergent marsh) ponds were placed one on each site in fields with low (Duda), moderate (Laughlin), and high (Hooper) soil OCP concentrations (Fig. 3). Two deeper (open water) ponds were placed on the high OCP site. The undisturbed native soils in the ponds had representative soil TOC values for the LANS (marsh: 25.6% to 49.8% dwt, mean 39.3%; open water: 30.3% to 41.3% dwt, mean 34.7%). We stocked the ponds with blue tilapia (*Oreochromis aurea*), Eastern mosquitofish (*Gambusia holbrooki*), sunfish (*Lepomis spp*.), brown bullhead (*Ictalurus nebulosus*), and crayfish (*Procambarus clarkii*). Fish and crayfish foraged on naturally-occurring detritus, plants, and animals. We analyzed OCPs, lipids, organic carbon, and water content in fish, crayfish, and sediment.

Each of the three 0.3-ha marsh mesocosms was divided into three 0.1-ha sections with turbidity barrier fabric. The barriers allowed water level equilibration but prevented exchange of fish and most other large aquatic organisms. Each marsh mesocosm section was sampled separately. The marsh ponds were managed for fish (normal operation) from November 2002 until May 2005. Two of the three marsh ponds (Laughlin and Hooper) were drained once during that period (October 2003) because low DO caused by dense cover of duckweed (*Lemna minor* and *Spirodela polyrhiza*) did not allow fish to thrive. These mesocosms were refilled, and aeration was installed in the middle section of all three marsh mesocosms to maintain fish viability. Fish were restocked in Laughlin and Hooper in April – May 2004.

We halted normal operation of the emergent marsh mesocosms in May 2005 (2.7 yr post flooding). The Duda pond was decommissioned at that time. We continued to operate the Laughlin and Hooper marsh ponds until January 2008 (5.3 yr post flooding) with cycles of alternating drying for one month and flooding for one month. We continued to measure OCPs in soils during this time to assess whether fluctuation in sediment redox potential brought about by water level manipulation would accelerate the attenuation of soil OCPs.

Vegetative cover in the emergent marsh mesocosms varied and included dock (*Rumex crispus*), alligator weed (*Alternanthera philoxeroides*), cattail (*Typha latifolia* and *T. angustifolia*), and duckweed (*Lemna minor* and *Spirodela polyrhiza*). In the latter stages of the experiment we used mechanical harvest and herbicide treatments to maintain primarily a cattail (*Typha spp*) community. We favored cattail in the emergent mesocosms because *Typha* typically is the dominant plant genus when the nutrient-rich organic soils on the LANS are first flooded.

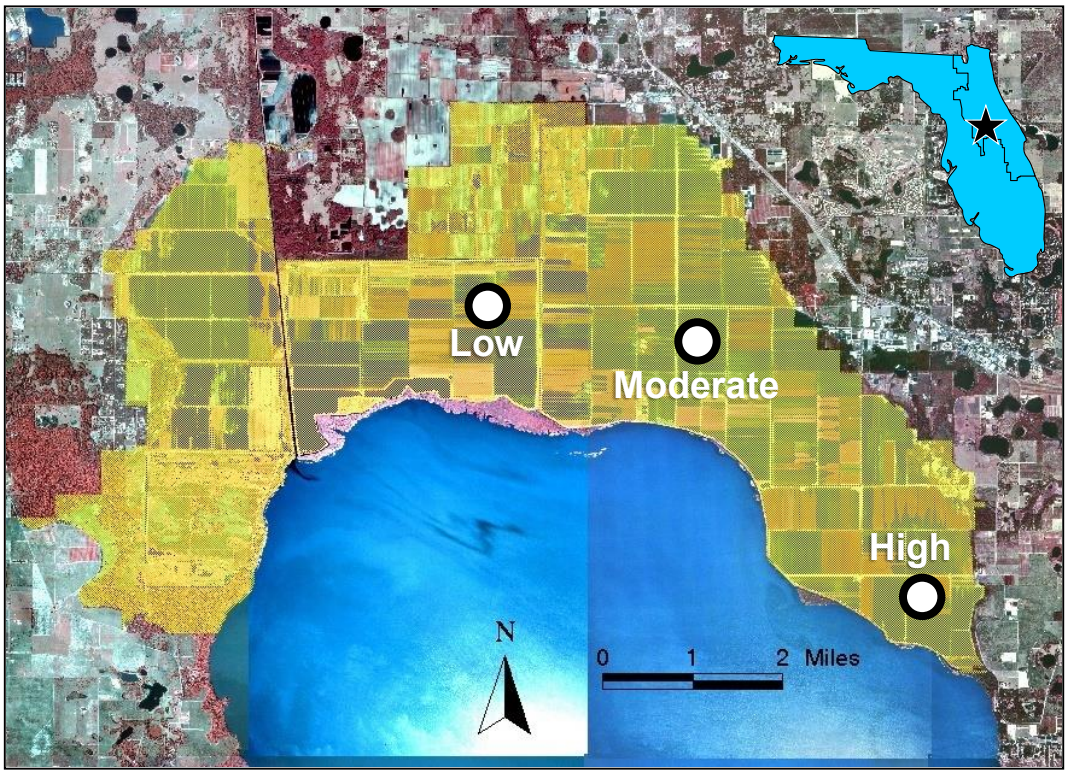

Fig. 3. Locations of mesocosms on the Lake Apopka North Shore restoration area. Sites had low (Duda), moderate (Laughlin), and high (Hooper) soil OCP concentrations.

The two deep (open water) mesocosms were used for bioaccumulation studies but also served to grow fish for the bird feeding experiment. The period of normal operation of the open water ponds for BSAF data was from February 2002 to September 2005 (3.5 yr post flooding). We continued to sample fish, mostly Gambusia, and soils in open water mesocosms for OCP analyses until April 2008 (6.1 yr post flooding) to estimate attenuation coefficients. Overgrowth by duckweed (*Lemna minor* and *Spirodela polyrhiza)* occasionally was a problem, and this was treated successfully with mechanical harvesting. Algal blooms occurred at intervals, and ponds were aerated as necessary.

It is possible that aeration of both marsh and open water mesocosms affected OCP attenuation rates compared to rates in these same habitats in their natural state. Occasional aeration was necessary to sustain fish in these experiments, however.

Loss of water through the bottom of both the marsh and open water mesocosms was substantial although variable, and makeup water from surrounding canals was pumped in as needed daily. The makeup water was filtered (0.15 mm) to avoid introducing exogenous particulate organic matter to the mesocosms. Mechanical failures in filtration were common over the first 14 months but less so subsequently.

Surficial (0 to 25 – 30 cm, 10 - 12 in) sediments in the marsh mesocosms were sampled periodically at 3 to 5 sites in each section, and sediments in the open water mesocosms were sampled periodically at 3 to 5 sites in each pond. Some samples consisted of replicate sediment

samples taken in clusters and pooled for analysis. Other samples were discrete. OCP and TOC analyses were handled as described for soil samples above.

Fish and crayfish in the mesocosms were sampled using seines, dip nets, cast nets, or traps. Sampling of open water ponds frequently occurred when fish were harvested by seine for the bird feeding study. Our goal was that each biota sample should consist of at least three individuals and a minimum of 20 g wet wt. However, this goal was not always attainable in the marsh mesocosms where fish were difficult to catch. OCPs and lipids were analyzed in fish samples as previously described for tissues.

For mesocosm soil data below reporting limits (non-detect, ND, censored, "less-than"), we substituted ½MDL or ½PQL as available for calculations. We made this substitution for soil data to allow calculation of a soil concentration on the date of each fish sample (below) to provide the denominator for BSAF calculation. For censored fish data, we used the MDL or PQL in the numerator for BSAF calculation but also marked records ND for later calculation of median BSAFs.

For all mesocosms, we used one-way ANOVA to test replicate sediment OCP data from multiple sample dates for a time effect. Where time was a significant factor ($p < 0.05$, generally DDT and toxaphene), we calculated linear trend lines (ordinary least squares) to estimate sediment OCP values on each fish sampling date. We used mean sediment values across time for all OCPs where a time effect was not significant. Because of frequent ND values for chlordanes in soils, we based BSAFs for chlordane congeners on congener concentration in fish divided by total chlordane concentration in soil (see section on BSAFs, above).

Because fish OCP concentrations in mesocosms increased appreciably over the first year of flooding, we began calculation of BSAFs at 1.1 yr post flooding. We continued BSAF calculations for the duration of normal operation of the marsh mesocosms (until 2.7 yr). For open water mesocosms, we calculated BSAFs from 1.1 to 3.5 yr post flooding. At that point, concentrations of most OCPs in fish lipids clearly were in decline. In all cases, one BSAF value was calculated for each fish sample.

BSAFs for some OCPs differed among fish species, although species differences were not consistent across OCPs (data not shown). For risk assessment, BSAFs were pooled across fish species for calculation of median values. We used median values for BSAFs to minimize the impact of NDs. In most cases for fish, the majority of NDs were below medians so calculation of median BSAFs were unaffected.

Results and Discussion – BSAF Values

Bioaccumulation data for fish in the mesocosms provided the BSAF values used in subsequent risk assessments for the LANS. A total of 114 BSAF values were calculated from the open water (deep) mesocosm dataset and 229 (DDD and DDT) or 314 (all other OCPs) BSAF values made up the emergent marsh (shallow) mesocosm data set. BSAF values and attenuation rates from the Mesocosm Study were presented previously by Coveney et al. (2008).

Here, we primarily use data for toxaphene and DDE to illustrate results, although we also analyzed DDT, DDD, dieldrin, and seven chlordane congeners.

Soil TOC was relatively stable in both the marsh and the open water mesocosms. (Fig. 4).

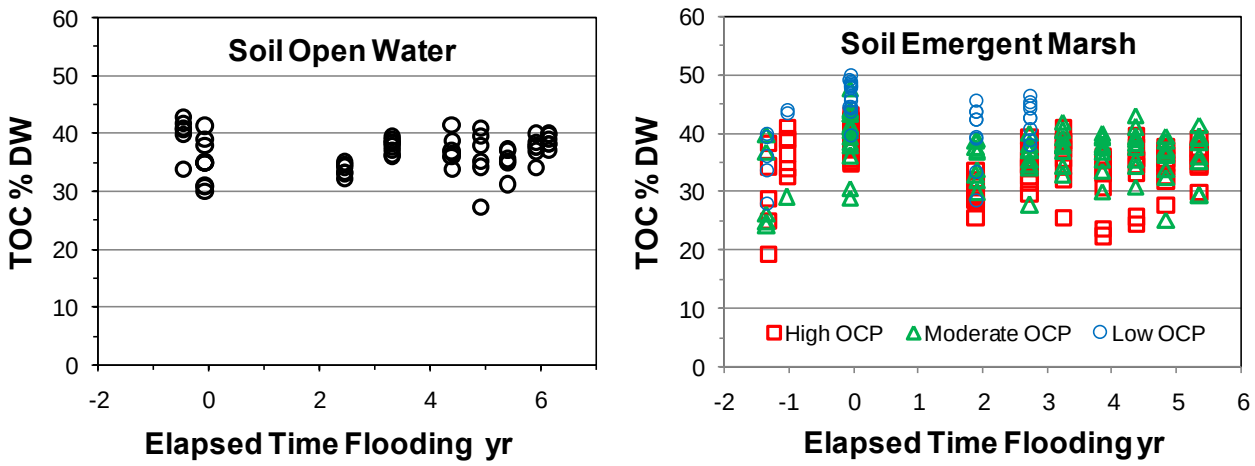

Fig. 4. Total organic carbon (TOC) in soils as percentage of dry weight in mesocosms with time of flooding. Negative elapsed time of flooding indicates samples taken prior to flooding.

OCP concentrations in soils and fish varied with flooding duration in both marsh and open water. Soil concentrations of toxaphene showed decline already for the first sampling after flooding. In contrast, OCPs other than toxaphene declined after a lag of about 2 yr (e.g. DDE, Fig. 5).

In fish, toxaphene and DDE reached maximal concentrations in 1 to 2 yr (Fig. 6). Toxaphene declined thereafter. In contrast, DDE declined only slightly over the remaining 4 yr of study. This slow increase in body burden of OCPs in fish in mesocosms was in stark contrast to the rapid accumulation found in the Microcosm Study. There, concentrations of OCPs in *Gambusia* reached at least 95% of equilibrium within 16 wks (Coveney et al. 2003).

A part of the difference could have stemmed from the large difference in body size of fish in the respective systems: *Gambusia* in microcosms vs mostly tilapia in mesocosms. However, we hypothesize that the major difference was that bioaccumulation of OCPs in mesocosms reflected bioaccumulation through developing food webs, whereas bioaccumulation in microcosms reflected mostly passive equilibration.

Bioaccumulation levels in marsh mesocosms coincided more closely with elapsed time of flooding (e.g. development of the ecosystem and/or food web) than by contact time for individual fish. For example, clean fish that were restocked into High OCP marsh mesocosms at 1.6 yr (Fig. 6, red bars) accumulated both toxaphene and DDE much more rapidly than fish stocked after initial flooding. Bioaccumulation in the restocked fish regained the same upwards trajectory that one would extrapolate for fish in the original stocking.

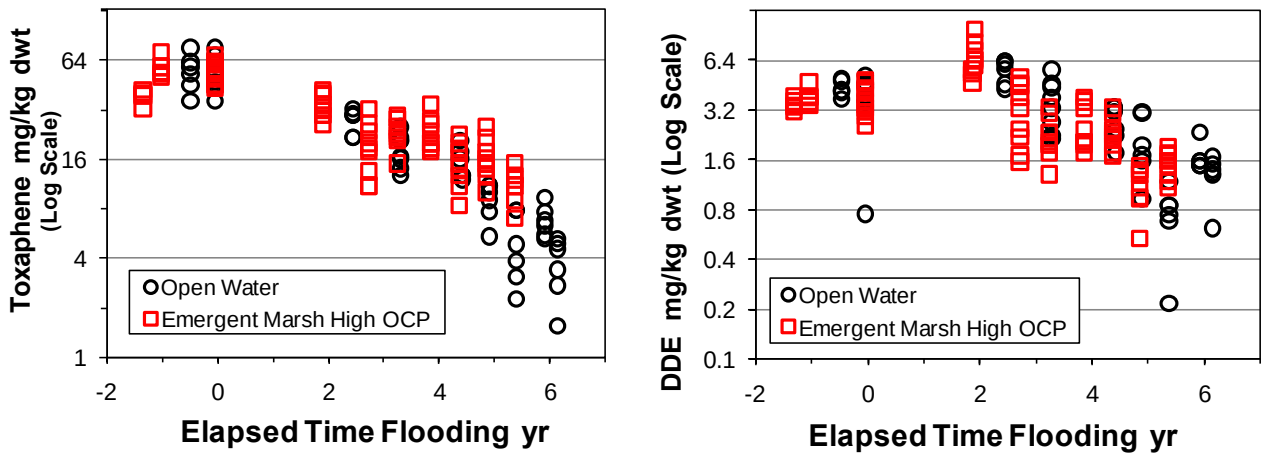

Fig. 5. Toxaphene and DDE in soils with duration of flooding in mesocosms located at the high (Hooper) OCP site. Negative elapsed time of flooding indicates samples taken prior to flooding.

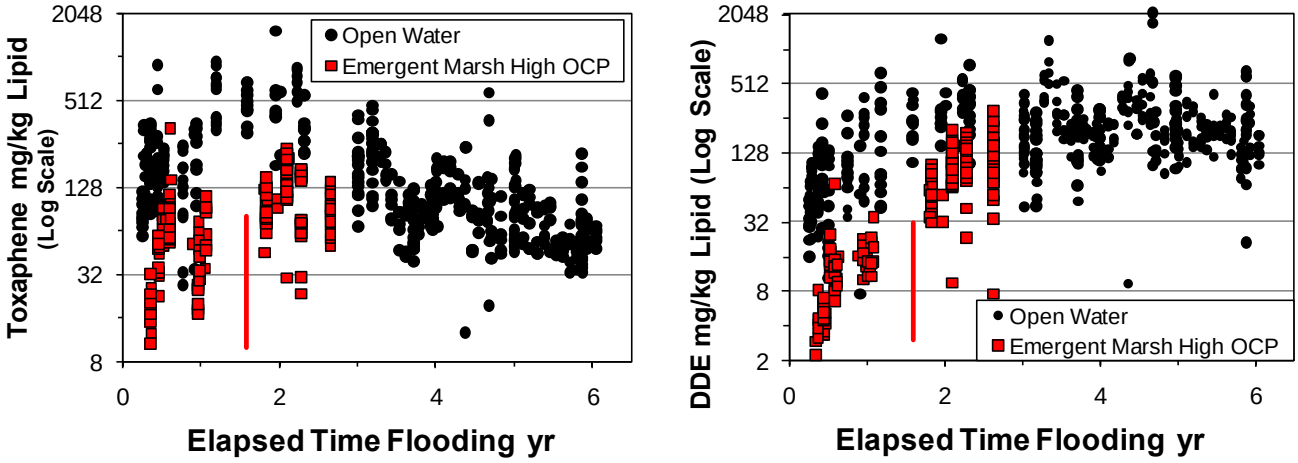

Fig. 6. Toxaphene and DDE in fish lipids with duration of flooding in mesocosms located at the high (Hooper) OCP site. Red bars indicate the elapsed time when the Laughlin and Hooper emergent marsh mesocosms were drained during the experiment, refilled, and restocked with clean fish at 1.6 yr.

For all fish sampled at >1 yr flooding, BSAFs for toxaphene in marsh mesocosms were elevated somewhat at the highest soil concentration, but BSAFs for DDE did not vary with soil concentration (Fig. 7)

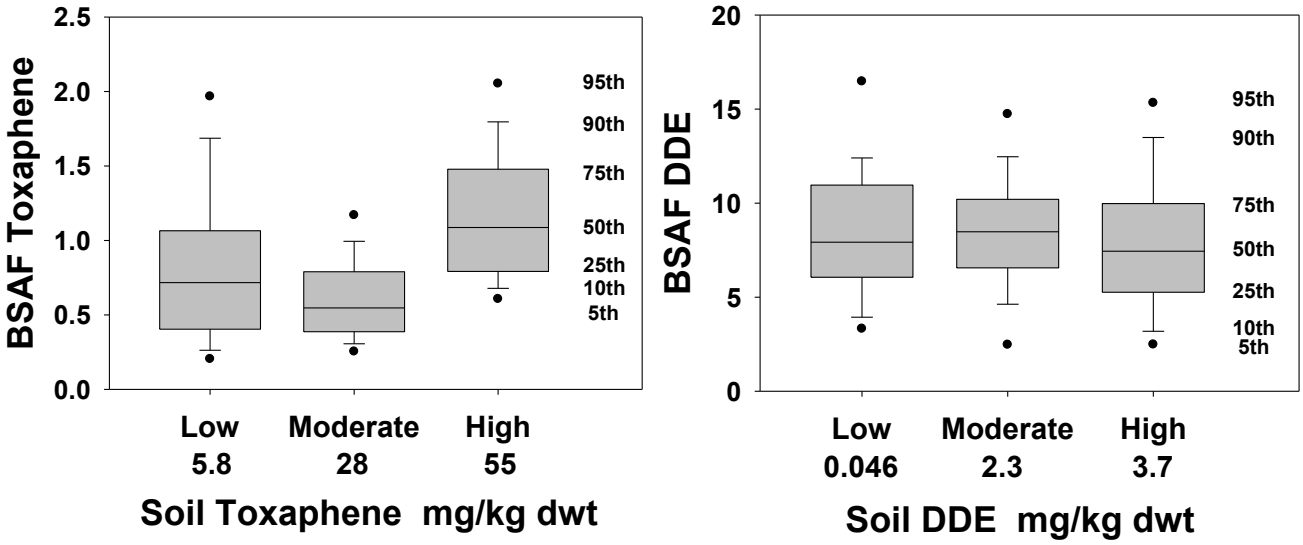

Fig. 7. BSAF values for Toxaphene and DDE in fish in emergent marsh mesocosms at three soil OCP concentrations. Soil concentrations are mean values for each mesocosm. The percentiles indicated by each feature of the box plots are shown to the right of each panel.

An important finding in the Mesocosm Study was that median BSAFs were two to five-fold greater for fish in open water mesocosms compared to marsh mesocosms for all OCPs measured (Table 1). For example, median BSAFs for toxaphene, DDE, and dieldrin, were 4.04, 19.2, and 4.56 in open water, and 0.77, 8.06, and 1.47 in emergent marsh, respectively. These differences in median BSAFs (e.g. toxaphene, DDE, and dieldrin) for fish were highly significant (Kruskal-Wallis test, $p < 0.0001$). Crayfish BSAFs tended to be lower and more uncertain due to frequent NDs than for fish species (Table 1) and were not used in risk assessments.

The different BSAF values for fish in the marsh and open water mesocosms likely had ecological causes and caused us to evaluate prospective risk for two different flooding habitat scenarios:

> Emergent marsh. Shallow flooding on the LANS should encourage establishment of emergent marsh. This habitat was represented by the marsh mesocosms, and we used marsh mesocosm BSAFs in risk evaluation.
>
> Open water. Open water on the LANS could result from water depths greater than that tolerated by emergent plants or from shallow but rapid flooding over bare soils. The open-water habitat was represented by the open water mesocosms, and open water BSAFs were used in risk evaluation for this scenario.

Table 1. Median BSAF values for fish (top) and crayfish (bottom) for both emergent marsh and open water mesocosms. We calculated medians to minimize the effects of ND values in organism samples. Also shown are the ratios (open water) ÷ (emergent marsh) for median BSAFs in those cases where values were unaffected or minimally affected by NDs. Fish data represented 1.1 - 2.7 yr after initial flooding for marsh and 1.1 - 3.5 yr for open water. Chlordane BSAFs were based on congener concentrations in organisms divided by total chlordane concentrations in soil. Number of values for fish was 229 (DDD, DDT) or 314 in marsh and 114 in open water. Crayfish data represented all sample dates. Number of values for crayfish was 23 (DDD, DDT) or 46 in marsh and 24 in open water.

FISH	4,4'-DDD	4,4'-DDE	4,4'-DDT	*alpha*-Chlordane	*cis*-nonachlor	Dieldrin	*gamma*-Chlordane	Heptachlor	Heptachlor epoxide	Oxychlordane	Toxaphene	*trans*-nonachlor
Emergent Marsh	2.71	8.06	0.32	0.31	0.32	1.47	0.16	0.02	0.04	0.14	0.77	0.69
Open Water	9.10	19.2	0.66	1.56	0.95	4.56	0.62	0.02	0.18	0.31	4.04	2.81
Ratio OW/EM	3.36	2.39	2.08	5.05	2.97	3.11	*	*	*	2.16	5.26	4.09

Slight risk that median is overestimated because some NDs > median
High risk that median is overestimated because many NDs > median
Values based primarily on NDs evaluated at the MDL

* Ratio not calculated due to high uncertainly (NDs)

CRAYFISH	4,4'-DDD	4,4'-DDE	4,4'-DDT	*alpha*-Chlordane	*cis*-nonachlor	Dieldrin	*gamma*-Chlordane	Heptachlor	Heptachlor epoxide	Oxychlordane	Toxaphene	*trans*-nonachlor
Emergent Marsh	0.30	2.72	0.12	0.038	0.084	0.33	0.11	0.049	0.046	0.063	0.13	0.19
Open Water	0.62	2.87	0.11	0.080	0.12	0.51	0.033	0.0052	0.013	0.081	0.12	0.41
Ratio OW/EM	2.1	1.1	*	*	*	*	*	*	*	*	*	2.1

We hypothesize that bioaccumulation of OCPs by fish was greater in the open water mesocosms because of the greater importance of benthic food webs based on original soil organic matter – e.g. organic matter with appreciable pesticide residues. In contrast, the emergent vegetation and periphytic primary producers in the marsh mesocosms provided more new organic matter and vertical structure to support food webs that were less dependent on sediment organic matter. These food webs likely had lower concentrations of pesticide residues than food webs based on the original soils.

If this hypothesis is correct, then the emergent marsh BSAFs may not be limited to areas with dense emergent vegetation. These BSAFs also might be applicable to areas with emergent and floating vegetation interspersed with open-water sloughs. Even in these open-water areas, we expect that food webs would be based substantially on the primary production of the surrounding marsh.

An alternate hypothesis is that the higher BSAFs in the open water mesocosms stemmed from the physical disturbance to sediments in these ponds during fish sampling and harvest. The seining procedures used to harvest fish resulted in substantial episodic resuspension of bottom materials. However, results from the microcosm study provide evidence against a physical disturbance hypothesis. In most cases, BSAFs in microcosms also were higher than BSAFs in mesocosms (Fig. 8), yet physical disturbances to sediments in the microcosms were practically nonexistent because tanks were set up and equilibrated for four weeks prior to addition of the test species.

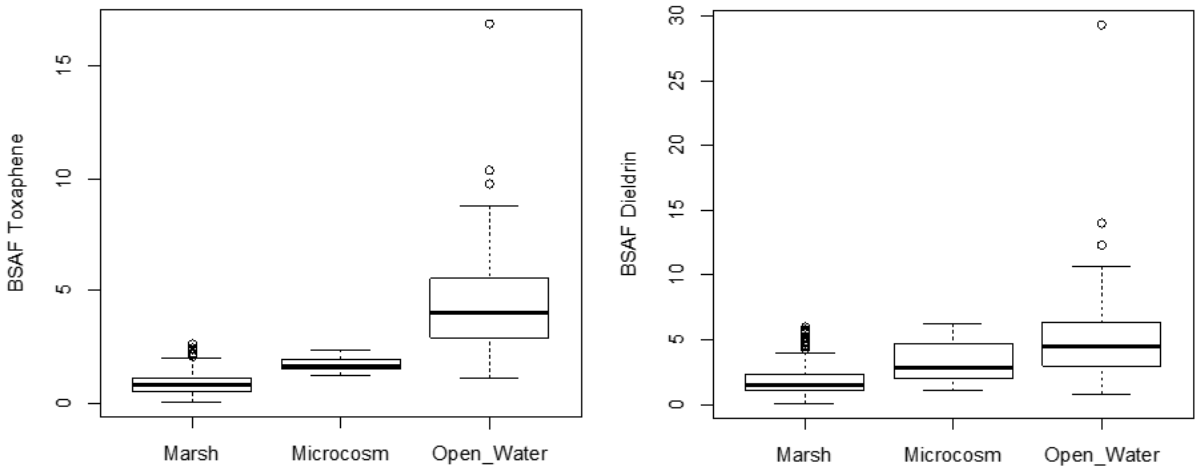

Fig. 8. Distribution of BSAF values for fish in emergent marsh mesocosms, microcosms, and open water mesocosms for toxaphene (left) and dieldrin (right). Values for marsh and open water mesocosms represent individual fish samples. Values for microcosms represent means for each treatment. Number of values (n) was 314 in marsh, 8 in microcosms, and 114 in open water. Horizontal lines are medians, and boxes indicate the interquartile range (IQR, 25th to 75th percentiles). "Whiskers" represent ± 1.5 × IQR or the range of observations, whichever is more extreme. Any points outside the whiskers are plotted individually.

Results and Discussion – Attenuation Rate Constants for OCPs in Soil and Fish

Toxaphene concentrations in soils in the mesocosms had declined by the first sampling after flooding. OCPs other than toxaphene declined after about a 2-yr lag (Fig. 9). For both toxaphene and DDE, soil concentrations attenuated at similar relative rates in emergent marsh mesocosms at different initial OCP concentrations. Initial soil concentrations of toxaphene in the high mesocosm were 2-fold higher than the moderate mesocosm, and DDE was 1.6-fold higher.

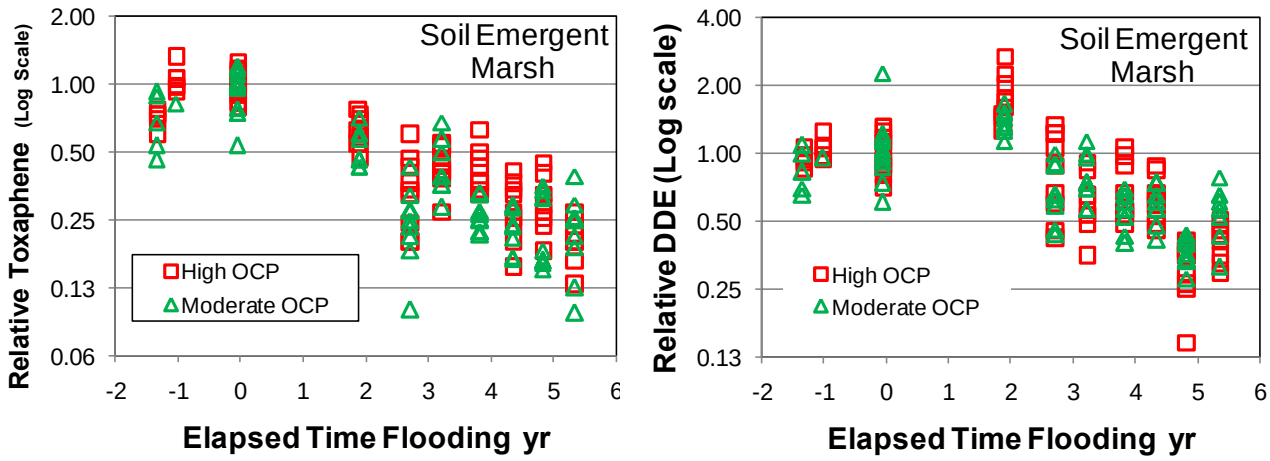

Fig. 9. Toxaphene and DDE in soils with duration of flooding in marsh mesocosms located at the high (Hooper) and the moderate (Laughlin) OCP sites. Negative elapsed time of flooding indicates samples taken prior to flooding. Here, we expressed OCP concentrations on relative scales because of differences between sites. The mean soil concentration for each site at time zero was set to 1, and values at other times were scaled accordingly.

We calculated first-order rate constants for attenuation of OCPs in mesocosm soils and in fish. In these calculations, we used data from 1.9 to 6.1 yr for open water soils, 1.9 to 5.3 yr for marsh soils, and 2.0 to 6.1 yr for open water fish.

First-order rate constants for attenuation in soil in open water mesocosms (0.43 – 0.63 yr^{-1}) were similar for different OCPs (Table 2). Attenuation rate constants for dieldrin and toxaphene (0.41, 0.49 yr^{-1}) in fish in open water systems were similar to soil rates, but rate constants for DDE were much lower (0.09 yr^{-1}) (Table 2).

Attenuation rate constants for OCPs in soil in marsh mesocosms were similar across OCPs but were lower than rate constants in open water mesocosms (Table 2). These differences may have been due to the fact that marsh mesocosms were alternately dried and flooded during the final 2.7 yr of the study. We had hypothesized that variation in microbial communities under alternating low and high redox conditions caused by flooding and drying would increase decomposition of OCPs. However, this was not the case, and attenuation of OCPs may have been slowed in the marsh soils compared to soils in open water systems that always were flooded.

Our results were consistent with conclusions by Ogram and Chen (2007) who measured degradation of toxaphene, DDT, and DDD in laboratory mesocosms with soils from the LANS. They found degradation of toxaphene and DDT only during flooded (anoxic) stages in their experiments and not during dry (oxic) stages. Furthermore, they found that addition of dried, ground cattail biomass as an electron donor enhanced degradation of OCPs. Their results support our recommendation that initial flooding of the LANS should be shallow and with dense emergent vegetation.

Table 2. First-order rate constants for attenuation of OCPs in mesocosm soil and fish. Calculated for 1.9 to 6.1 yr for open water soils, 1.9 to 5.3 yr for marsh soils, and 2.0 to 6.1 yr for open water fish.

First-Order Rate Constants for Attenuation yr^{-1}			
Component	**DDE**	**Dieldrin**	**Toxaphene**
Soil, Open Water	**0.43** $R^2 = 0.57$	**0.63** $R^2 = 0.57$	**0.52** $R^2 = 0.76$
Soil, Emergent Marsh	**0.34** $R^2 = 0.57$	**0.32** $R^2 = 0.43$	**0.25** $R^2 = 0.39$
Fish, Open Water	**0.09** $R^2 = 0.027$	**0.41** $R^2 = 0.47$	**0.49** $R^2 = 0.54$

Bird Feeding Study

Abstract

The following abstract was taken from Gross et al. (2009):

> "During 1998-1999, a significant mortality of several piscivorous bird species occurred on the former agricultural property on the north shore of Lake Apopka (North Shore Restoration Area, NSRA), Florida. Although this mortality was ultimately linked to organochlorine pesticide (OCP) toxicosis, there was very little understanding of the rate of bioaccumulation of OCPs by fish-eating birds feeding on these flooded sites. Studies were conducted in three phases during 2002 through 2004: Phase I - to determine the potential for bioaccumulation of organochlorine pesticides (OCP) in great egrets (*Casmerodius albus*) fed diets consisting of primarily blue tilapia (*Oreochromis aurea*) exposed to OCP-contaminated soils/sediments from the NSRA and evaluate health and growth effects; Phase II – to determine the potential for toxicosis from NSRA-derived

OCPs in great egrets; and Phase III – to evaluate the effects of fasting on tissue bioaccumulation and repartitioning of OCPs in great egrets. These feeding studies were conducted during the spring and summer of three consecutive years (2002 to 2004). For all years, egrets were collected as nestlings (< 4 weeks of age) from wild colonies located in either south or northcentral Florida and were raised in the laboratory to juvenile age (~ 2 months of age) prior to the start of OCP-fish dosing. Dosing was achieved by feeding egrets ground OCP-contaminated fish sausage in natural casings. During 2002 (Phase I), ten birds were fed a diet consisting of approximately 40% NSRA-OCP-contaminated tilapia sausage. Five birds were euthanized at 8 weeks and five at 11 weeks to evaluate bioaccumulation of OCPs. During 2003 (Phase 2), ten birds were dosed as follows: three controls and 7 treated (fed 100% NSRA-OCP-contaminated tilapia sausage for 8 weeks). Four treated egrets exhibited signs of poor health or potential toxicosis by 7 weeks and were euthanized (symptoms included lethargy, decreased food intake, tremors, inability to perch and poor mobility), and the remaining egrets were euthanized at 8 weeks as per the experimental design. During 2004 (Phase III), thirty birds were split into two groups and either fed/dosed with 100% diet of NSRA-OCP-contaminated fish (n=22) or control fish (n=8) for 18 to 20 weeks. NSRA-OCP fed birds were sacrificed at three week intervals (weeks 3, 6, 9, 12, 15 and 18) through week 18 to assess bioaccumulation over time. At the conclusion of week 18, the remaining birds (n=10) were maintained for two additional weeks and sacrificed as follows: n=3 NSRA-OCP birds maintained as treated (week 20 treated egrets); n=3 control birds maintained on control diets (week 20 control egrets); and n=4 NSRA-OCP birds which were starved (provided no food but water provided *ad libitum*; week 20 starved birds) to assess effects of fasting on tissue bioaccumulation and re-partitioning of OCPs in great egrets. Results demonstrated significant bioaccumulation of OCPs in egrets from dietary intake of NSRA-tilapia through 18 weeks. Results demonstrated that a 100% diet of NSRA tilapia was capable of a resultant toxicosis, which could, in part, explain the 1998-99 avian mortality event reported for the NSRA. Results also indicated that seasonal and/or health derived reductions in dietary intake would repartition OCPs and that this mechanism may be a critical component in the toxicosis of OCPs in wading birds."

Results and Discussion

The bird feeding study was conducted to measure the accumulation and distribution of weathered pesticides from LANS fish to a fish-eating bird, the great egret (*Ardea alba*, formerly known as *Casmerodius albus*). Primarily blue tilapia (*Oreochromis aurea*) with other fish were reared in two open-water mesocosms constructed on the high OCP site (Hooper) on the LANS (see Mesocosm Study, above). These ponds were constructed without disturbance to the soil internal to the berms. Ponds were fenced and netted over to exclude wildlife. Algal blooms occurred at intervals, and ponds were aerated as necessary to sustain the fish. Fish fed on naturally-occurring plants, animals, and detritus.

Whole fish were harvested at intervals, ground, and made into sausages. Great egrets captured as nestlings in the wild were reared to adult size on clean food and then were fed the OCP-laden sausages. Birds were sacrificed at intervals for necropsy and for histological and OCP analyses. Details about preparation of the fish sausages, collection and husbandry of the birds, and tabular results from each of the three phases of the experiments are found in Gross et al. (2009).

Important findings from these experiments included the following:

- A diet of 100% LANS tilapia was capable of a resultant toxicosis, which could, in part, explain the 1998-99 avian mortality event reported for the LANS (Gross et al. 2009).
- When birds were deprived of food, OCPs were mobilized from fat, and concentrations in brain tissue increased about 1.8-fold (Table 4).
- The half-lives of OCPs in birds were longer than previously assumed in models. A longer half-life would result in a higher accumulated body burden in feeding models if other variables are constant.
- OCP concentrations in birds showed constant ratios among organs. This relationship allows one to use measurements done with one tissue to estimate OCP concentrations in other tissues (Lowe et al. 2003).

Gross et al. (2009) concluded from the Phase 2 feeding experiments that some birds fed 100% LANS tilapia showed likely toxicosis. Especially for toxaphene and dieldrin, mean concentrations in fish sausages from Phase 2 (Gross et al. 2009, Table 12) greatly exceeded the adjusted toxicity reference values (TRV) derived by the District (Summary of TRV Values, below) (Table 3). The fact that the fish grown on LANS soil for this experiment accumulated substantial OCPs in excess of safe levels for birds supports the conclusion of toxicosis by Gross et al. (2009)

Table 3. Adjusted toxicity reference values (TRVs, Table 5) for dieldrin and toxaphene compiled from toxicological studies compared with fish fed to great egrets in the Phase 2 feeding study.

	Adjusted TRV (µg/kg wwt)	**Phase 2 Fish Sausages (µg/kg wwt)**
Dieldrin	140	1,525
Toxaphene	5,000	52,250

In their previous food-web modeling of the LANS mortality event, Exponent (2003) used a literature value of 3 d for the half-life of body burden of toxaphene based on a study with Japanese quail (2003, p. 4-10). We did not estimate values for half-lives for OCPs in our Phase 3

feeding studies with great egrets. However, substantially longer half-lives were evident from the time course of bioaccumulation. For example, half-lives for toxaphene would be measured in weeks to months for both body burden and brain concentration (Fig. 10).

Body fat in both wild and captive-fed birds showed especially high OCP concentrations compared to other tissues even after OCP concentrations were normalized for lipid content (Lowe et al. 2003). This fact underscored the significance of fat as a reservoir. Risk analyses needed to consider the latent dose to brain or other tissues represented by OCP depots in storage fats when those fats are metabolized.

The Phase 3 feeding experiments were particularly important in testing the hypothesis that physiologically important amounts of OCPs can be mobilized from fat reserves if birds are deprived of food. In this experiment, birds were fed LANS fish containing OCP residues for a total of 141 days and sacrificed at intervals for analyses. During the final 14 d (127 d to 141 d), one group continued to be fed OCP-fish while the second group received no food (fasting).

We assessed changes in OCP concentrations during fasting by comparing concentrations in fasting birds at 141 d with concentrations in fed birds (pooled) at 127 and 141 d (Mann-Whitney-Wilcoxon test). Total body burdens of OCPs did not change significantly ($p > 0.05$) from 127 to 141 d regardless of food status for the three OCPs evaluated (toxaphene, DDE, dieldrin) (Fig. 10).

In contrast, brain concentrations of OCPs increased in fasting birds, presumably due to mobilization of OCPs stored in fat reserves (Fig. 10). This increase was significant ($p < 0.05$) for both DDE and dieldrin and nearly significant ($p = 0.054$) for toxaphene.

We calculated "fasting factors" as the ratios of brain concentrations both between fasting birds and fed birds compared at 141 d and between fasting birds at 141 d compared with fed birds at 127 d. Fasting factors were similar for toxaphene, DDE, and dieldrin (Table 4). The median of the six ratios calculated was 1.8 (Table 4).

Although we could not test this idea, we hypothesized that the following sequence of events may have contributed to the mortality of birds at the LANS:

1. Birds fed on contaminated fish. Subsequently, sub-lethal effects of OCPs hindered their ability to hunt.
2. As birds consumed less food, metabolism of fat reserves mobilized OCPs to other, sensitive tissues such as brain.
3. Increasing toxic effects of mobilized OCPs further reduced feeding abilities, which increased fat metabolism in a feedback loop.
4. Birds succumbed to toxicosis.

Based on results from the Bird Feeding Study, the District incorporated a potential fasting effect into risk assessments by dividing toxicity reference values for acute effects by a rounded-up fasting factor of 2 (Table 5).

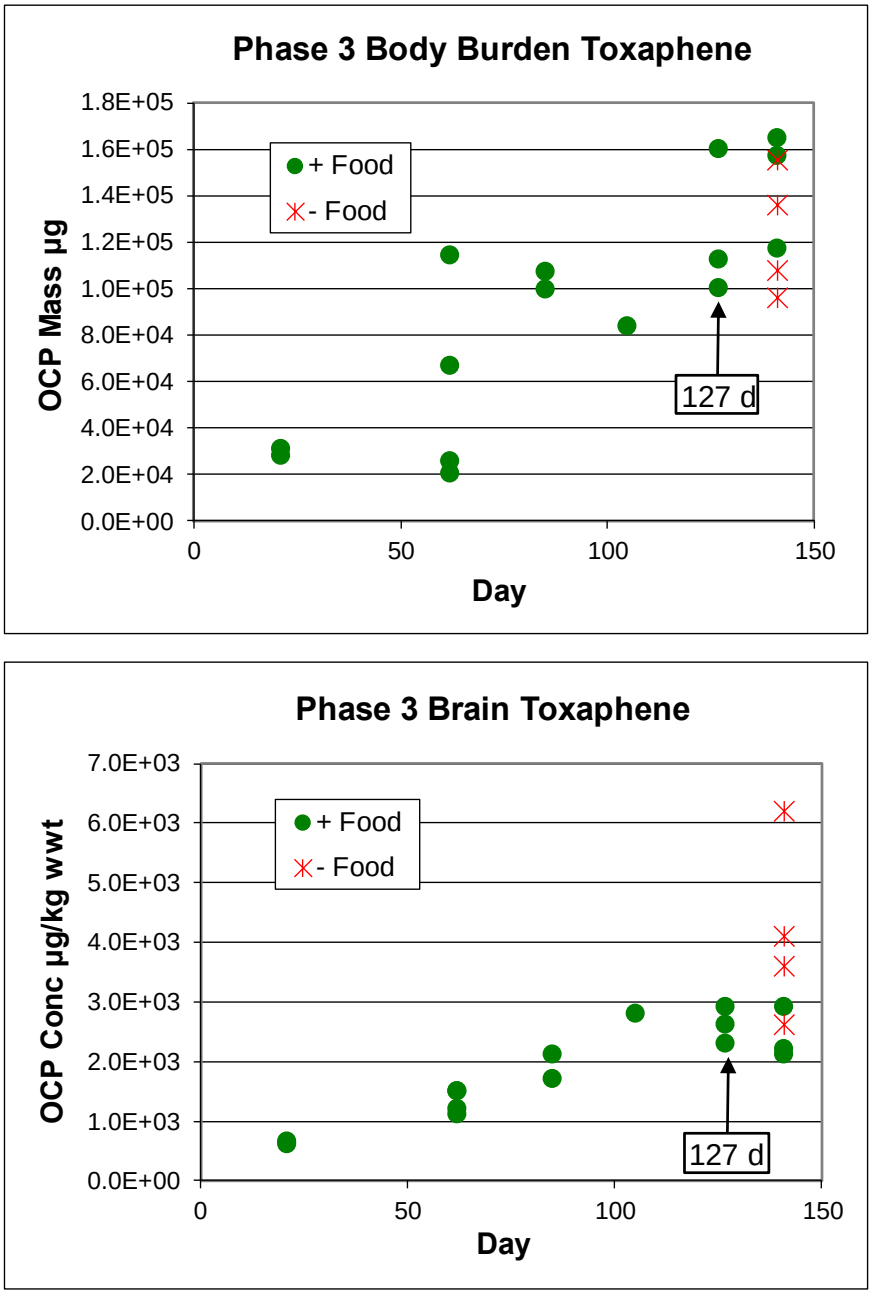

Fig. 10. Total body burden (top) and brain concentration (bottom) of toxaphene in two treatment groups of great egrets in Phase 3 feeding experiment. Birds were fed LANS fish containing OCP residues and sacrificed at intervals for analyses. During the final 14 d (127 d to 141 d), one group continued to be fed (+ Food) while the second group was fasted (- Food).

Table 4. Ratio of brain concentrations of OCPs in two treatment groups of great egrets in Phase 3 feeding experiment. Birds were fed LANS fish containing OCP residues and sacrificed at intervals for analyses. During the final 14 d (127 d to 141 d), one group of birds continued to be fed while the second group received no food (fasting). We calculated the increase in brain residue concentrations for fasting birds in two ways:

1) Mean OCP concentration in fasting birds at 141 d divided by mean concentration in fed birds at 141 d
2) Mean OCP concentration in fasting birds at 141 d divided by mean concentration in fed birds at 127 d.

	Ratio of Mean Brain Concentrations of Organochlorine Pesticides		
Conditions	**Toxaphene**	**DDE**	**Dieldrin**
Fasting at 141 d compared to fed at 141 d	1.72	1.82	1.78
Fasting at 141 d compared to fed at 127 d	1.59	1.78	1.76

Toxicity Reference Values (TRVs) to Characterize Risk to Piscivorous Birds from OCP Residues in Fish

We did a comprehensive search and review of the primary scientific literature to determine toxicity reference values (TRVs) to characterize the risk of OCP residues to piscivorous birds. We used the lowest dietary concentrations associated with toxic effects in birds as TRVs. To compile this information, we reviewed and extracted data from about 350 published papers. We summarized the information in tabular form for discussion and chose the most appropriate toxicity thresholds through professional judgment and consensus. We considered two types of effects. The first, mortality, was used to derive TRVs where the end point was death of an individual or physiological or developmental defects that could lead to increased population mortality. The second endpoint, for DDE only, was reduction in reproductive success due to thinning and breakage of eggshells and loss of embryos. We evaluated the risks separately for each of these endpoints.

We further adjusted most TRVs by dividing them by a “fasting factor” of 2. This step was prompted by our finding in the bird feeding studies that brain concentrations of several OCPs increased when food was withheld.

Summary of TRV Values

Table 5 summarizes the Toxicity Reference Values for food used in the risk assessments and the fasting factor. The final, adjusted value (TRV ÷ fasting factor) also is shown. A fasting factor was applied for all OCPs except DDE when it is used alone to assess the risk for reproductive effects. The background for each recommendation is discussed below.

Table 5. Toxicity Reference Values (TRVs) and fasting factors

	Toxicity Reference Values (TRV) for fish prey (µg/kg wwt)	Fasting Factor	Adjusted TRV (µg/kg wwt)
4,4'-DDE	1,500	1	1,500
DDTr*	3,000	2	1,500
Dieldrin	280	2	140
Toxaphene	10,000	2	5,000
***cis*-Nonachlor**	1,100	2	550
***gamma*-Chlordane**	2,000	2	1,000
Heptachlor	800	2	400
Heptachlor epoxide	200	2	100
Oxychlordane	100	2	50
***trans*-Nonachlor**	900	2	450
***alpha*-Chlordane**	2,000	2	1,000

*After Stickel et al. (1970): DDT equivalents = DDTr = (DDD/5) + (DDE/15) + DDT

Dieldrin

We used a dietary TRV for dieldrin of 0.28 mg/kg wet wt based on Wiemeyer et al. (1986). American kestrels were dosed with both DDT and dieldrin in combination. One bird died on the low dose, 0.28 mg/kg wet wt dieldrin in food, with a brain dieldrin concentration of 6.1 mg/kg wet wt.

> This was a complex, multi-tiered study. High treatment birds (13 pairs) received about 4.2 mg/kg wet wt DDT and 0.84 mg/kg wet wt dieldrin. Low-treatment birds (13 pairs) received 1.4 mg/kg wet wt DDT and 0.28 mg/kg wet wt dieldrin. There was also a control group (13 pairs). Offspring were maintained on the same dose as their parents. Birds were dosed from March 1966 until "spring" 1969. Wiemeyer et al. (1986) reported three periods of heavy stress-related mortality. The first, at the end of Aug 1966, involved 4 high-dosage birds – all died with >5 mg/kg wet wt dieldrin in their brains. This event followed a drop in minimum daily temperature. The second die-off occurred at the end of Sept/ beginning of Oct. 1967, also following a sharp decline in temperature, in the high-dose second-generation group. Five birds died, all with > 5 mg/kg wet wt dieldrin in their brains. The third incident was in May 1968 and involved low- and high-dosed DDE/dieldrin combination birds, and one bird from the DDE-only group. Eight birds died, four with >5 mg/kg wet wt dieldrin (one was from low DDT + dieldrin group) in their brains. No control birds died during any of the events. We note that this study dosed birds with both DDT and dieldrin in combination. However, the fact that a bird died on the low dose with a brain dieldrin concentration of 6.1 mg/kg wet wt caused us to select the 0.28 mg/kg wet wt value from this study to be more protective than the 0.58 mg/kg wet wt value from Mendenhall et al. 1983 (below).
>
> Another pertinent study was by Mendenhall et al. (1983). This two-year study was used as a NOAEL (no observed adverse effect level) reference by Exponent (2003) and by BBL (2004) for a Tier 1 assessment. In a long-term study, barn owls (13 pairs) were fed dieldrin (mean dose 0.58 mg/kg wet wt), DDE (13 pairs) (mean dose 2.83 mg/kg wet wt), or both doses (12 pairs). No difference in carcass storage of either toxicant was noted due to presence of the other. Three DDE birds, 3 dieldrin birds, 2 DDE + dieldrin birds, and no control birds died during the experiment. Dead dieldrin birds had low carcass lipid, and brain residues were 5.0 and 15 mg/kg wet wt. No significant changes in egg characteristics (i.e. weight and lipid) were noted with treatment in either year. Dieldrin did not reduce breeding success either alone or through interaction with DDE. Although eggshells were thinned severely by DDE, dieldrin caused only slight eggshell thinning that did not contribute to egg breakage. Dieldrin did not cause embryo mortality. The authors noted that, "Barn owl [was] among the most sensitive of tested species".

Toxaphene

We used a dietary TRV for toxaphene of 10 mg/kg wet wt based on Haseltine et al. (1980). This 19-month study fed 0, 10 or 50 mg/kg wet wt toxaphene to black ducks. Ducklings exhibited alteration in both collagen and mineral content of backbones.

> Black ducks (3 sets of 15 pairs each) were fed 0, 10 or 50 mg/kg wet wt toxaphene for 19 months. Adult survival was not affected by toxaphene ingestion. At the end of the second breeding season females had larger livers than controls. Drakes fed 50 mg/kg wet wt had

elevated brain weights. Breeding pairs on the 50 mg/kg wet wt diet appeared hyperactive. Several 50 mg/kg wet wt hens laid very late in the season. Toxaphene was not detected in the brain (at 0.1 mg/kg wet wt) at the 10 mg/kg wet wt dose using total area under the toxaphene profile. Eggshell thickness did not vary. No effect on duckling survival was noted. However, ducklings exhibited alteration in both collagen and mineral content of backbones (toxaphene-caused skeletal aberrations were also documented in fish (Mayer and Mehrle 1976, cited in Haseltine et al. 1980)). This study also was cited by Exponent (2003); however, they used 50 mg/kg wet wt as a NOAEL.

Another pertinent study to support a TRV at 10 mg/kg wet wt was Mehrle et al. (1979). Black ducks (3 sets of 15 pairs each) were fed 0, 10, and 50 mg/kg wet wt for 90 days prior to laying and through the reproductive season. Progeny were fed the same doses for 14 and 84 days. Toxaphene did not affect reproduction or survival but impaired backbone development in ducklings within 14 days after hatch based on levels of calcium (10 mg/kg wet wt and 50 mg/kg wet wt groups) and collagen (50 mg/kg wet wt group). After 84 days, they observed effects only in female ducklings fed 50 mg/kg wet wt.

DDT

We used a dietary TRV for DDT of 3 mg/kg wet wt for mortality, based on Stickel et al. (1966). Alaskan bald eagles were fed DDT in ground salmon for 120 days. Birds fed 5 mg/kg dry wt (3 mg/kg wet wt) were not visibly affected. In our assessments, we calculated a DDT equivalent (DDTr), which sums DDT, DDD, and DDE based on their relative acute toxicities (Stickel et al. 1970), and compared DDTr with the TRV for DDT.

Stickel et al. (1966) used dietary dosages of DDT at 5, 83, 414, and 2070 mg/kg dry wt (wet wt estimated at 3, 48, 240, 1200 mg/kg). Two birds were fed clean food for 112 days; two birds were fed at each of the 3 lowest dosages; and 3 birds were fed at the highest dosage. Food consumption varied from day to day. All eagles fed more than 240 mg/kg wet wt died in 2 months or less. Of the two fed about 48 mg/kg wet wt, one died in 71 days with pronounced tremors. The other survived 112 days but showed some tremors and jerking. The authors concluded that a dosage that would kill half the birds during a 3-4 mo period may be near 80 mg/kg dry wt (~48 mg/kg wet wt). Brain and liver concentrations were given for the two high-dosage groups where the cause of death almost certainly was DDT poisoning. Quantities of DDT + DDD in the brain ranged from 58 to 86 mg/kg wet wt and were similar to those associated with DDT-induced deaths in several other species of birds and mammals. This work was considered to support a NOAEL at 3 mg/kg wet wt by Newell et al. (1987) and, similarly, we chose 3 mg/kg wet wt as a NOAEL to be protective.

Another pertinent study supports an unbounded LOAEL (lowest observed adverse effect level) at 100 mg/kg wet wt in mash (90 mg/kg wet wt in total diet) (Genelly and Rudd 1956). Ring-necked pheasants were fed 50, 200, 400, and 600 mg/kg wet wt DDT in mash for 57, 90, 90, and 57 days in a pre-reproductive trial (10 birds in each). Birds also were fed 100 mg/kg wet wt (1 male, 10 females) and 400 mg/kg wet wt (4 males, 20 females) for 74 days in their reproductive period. No mortality was found at 50 or 100 mg/kg wet wt dosing. Weight loss was observed in the higher (400) dose, and all 4 males died (20 females survived). One female analyzed after 74 days of 90 mg/kg wet wt dosing had 1,095 mg/kg wet wt of DDT in fat. Survival of young was reduced by about 10% from controls. In risk assessments prepared for the District, BBL Sciences (e.g. BBL Sciences 2004) considered

90 mg/kg wet wt to be an unbounded LOAEL because of the decrease in chick survival. However, we also note that experiments with gallinaceous (i.e. chickens and pheasants) birds indicate that they may be considerably less susceptible than some other birds to effects of the DDT group (Edwards 1973)

DDE

We used a TRV for DDE of 1.5 mg/kg wet wt for reproductive effects based on Lincer (1975). A 15% decrease in eggshell thickness against control birds (26% against pre-DDT values) was measured in American kestrels at a dose of 3 mg/kg wet wt in food. There was no difference from the control for a 0.3 mg/kg wet wt treatment. The relationship between eggshell thickness and DDE concentration in food was nonlinear. Thickness declined steeply until approximately 3 mg/kg wet wt DDE in food, and the decline slowed at higher food concentrations. Lincer (1975) reported that eggshell breakage began at 22% thinning compared to pre-DDT values. We recommend dividing the 3 mg/kg wet wt value by a factor of two to derive 1.5 mg/kg wet wt as a NOAEL for egg breakage. We apply no fasting factor to this TRV because we evaluated a long-term, sublethal, reproductive end-point.

Lincer (1975) kept wild-trapped American kestrels in aviaries and fed 0.3, 3.0, 6.0 or 10.0 mg/kg wet wt DDE. Dosed feeding began in mid-March and continued through late Aug. Eggs were collected five days after the last egg of the clutch was laid. Wild eggs also were collected and analyzed, along with the aviary eggs, for OCPs and eggshell characteristics. A dose response relationship between dietary DDE and eggshell thinning was established. According to other data compiled by Lincer, no North American raptor population exhibiting 18% or more eggshell-thinning (against pre-DDT levels) has been able to maintain a stable population.

Other studies support the conclusion that long-term dosing in the range of 3 mg/kg wet wt in food results in adverse reproductive effects (Longcore et al. 1971 and Longcore and Samson 1973, black duck) (Mendenhall et al. 1983, barn owl).

Longcore et al. (1971, black duck) found that a concentration of 10 mg/kg DDE in dry mash (approximates 3 mg/kg wet wt in natural foods) adversely affected reproduction. Shell cracking was found in 11% of eggs in incubators. Survival of ducklings from dosed parents was 40-76 percent lower than survival of ducklings from undosed parents.

Longcore and Samson (1973, black duck) replicated the dosage (10 mg/kg DDE in dry mash, ~3 mg/kg wet wt) of birds from Longcore et al. (1971). Ducks were allowed to incubate the eggs themselves. Shell cracking was present in 58% of treatment eggs vs 14% of controls. Some cracked eggs were pushed from nests. Only 19% of dosed eggs hatched vs 86% of controls. Longcore and Samson (1973) concluded that mechanical incubation does not reveal the importance of shell thinning to reproductive failure.

Mendenhall et al. (1983, barn owl) dosed birds with DDE at 2.83 mg/kg wet wt with and without dieldrin. In DDE treatments, eggshells were thinned 20% against controls the first year and 28% against controls the second year. Egg breakage increased, and hatching was lower both years.

Heptachlor Epoxide

We used a TRV for heptachlor epoxide of 0.2 mg/kg wet wt based on Wolvin et al. (1969) as reported in WHO Environmental Health Criteria 38, Heptachlor (1984). The paper of origin was an industrial bio-test laboratory report to Velsicol Chemical Corporation.

> Heptachlor epoxide was fed to groups of 4 male and 20 female chickens at dietary concentrations of 0, 0.02, 0.1, or 0.2 mg/kg wet wt for 25 wks. Body weight increase was not affected. Mortality rates were low in all groups, and a slightly higher mortality rate for the group fed 0.2 was "of doubtful significance". No abnormal behavior was noted. Weekly egg production and mean egg weights were not affected. Hatchability was slightly decreased in eggs from the group fed 0.1 and 0.2 mg/kg wet wt, but the viability of hatched chicks was not affected.
>
> The lethal actions of heptachlor epoxide and oxychlordane appear to be additive based on Stickel et al. (1979).

Oxychlordane, *alpha*-Chlordane, *cis*-Nonachlor, *gamma*-Chlordane, Heptachlor, *trans*-Nonachlor

Of the numerous environmental and physiological degradation products of technical chlordane, heptachlor epoxide and oxychlordane "merit careful analysis". Both tend to accumulate in fat, and both are more toxic than the parent compounds (National Research Council Canada on technical chlordane, NRCC 1974). Other than heptachlor epoxide, we did not find sufficient data to develop independent TRVs for each of the seven chlordanes that we analyzed. However, we used published reports to relate the toxicity of oxychlordane to heptachlor epoxide and then to relate the toxicity of the remaining five chlordane components either to oxychlordane or to heptachlor epoxide. This approach allowed us to set TRVs for each chlordane component (Fig. 11).

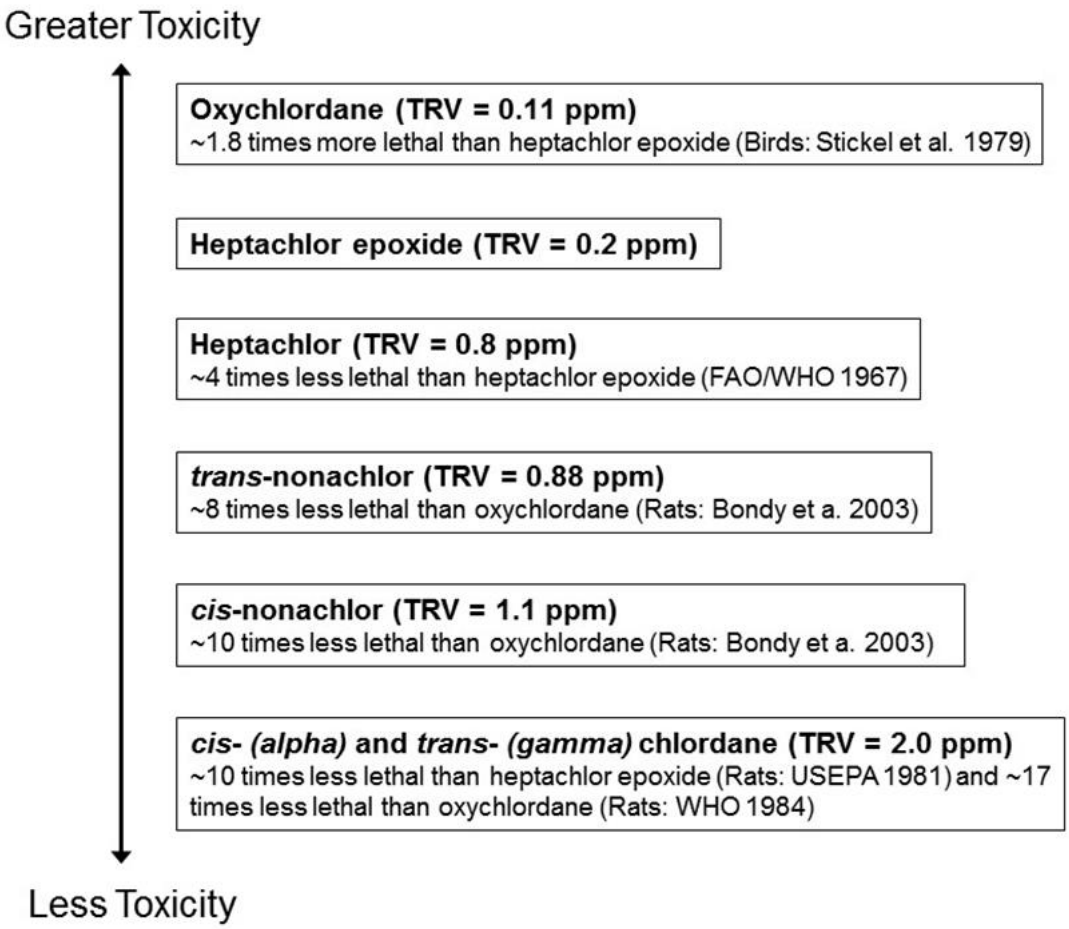

Fig. 11. Relative toxicity relationships used to set TRVs for chlordanes. We first derived a TRV for heptachlor epoxide (above). We used the publications cited above to relate the toxicity of oxychlordane to heptachlor epoxide and then to relate the toxicity of the remaining five chlordane components either to oxychlordane or to heptachlor epoxide. Citation "USEPA 1981" for toxicity of *cis*- and *trans*-chlordane is found in Stansley et al. 2001.

Risk Analyses

The Bioaccumulation Study figured prominently in subsequent risk assessment, remediation, and restoration planning. Our interim restoration goal for the former farms was dense emergent marsh rather than open water to minimize bioaccumulation of OCPs in fish and to reduce foraging value for wading birds.

We assessed risk in three steps:

1. We used the 95-percent upper confidence level (95%UCL) of the mean carbon-normalized value from the field sampling program as the soil concentration of each OCP in each field

2. We predicted the concentration of each OCP in fish for each field from the soil concentration and the appropriate BSAF from the emergent marsh mesocosm study
3. We calculated a hazard quotient for each OCP by dividing the predicted fish concentration by the dietary TRV value from our literature review. Values less than one represented minimal risk and values greater than one indicated increasing risk.

We assessed two types of risk to fish-eating birds, mortality and reproductive loss. The hazard quotient (HQ) for DDE was used alone to measure reproductive risk. We summed the HQs for all other OCPs to make a single hazard index (HI) to measure mortality risk.

Our soil remediation program was designed, wherever possible, to lower both the HQ and the HI close to or below one for each field.

Our risk assessment included several decisions and assumptions designed to provide a substantial margin of safety, including the following:

- We assumed that birds will find 100% of their food in each field. In fact, water depths will be too deep over most of the field areas for effective foraging by wading birds. The emergent vegetation that we will promote through controlled flooding will further discourage feeding.
- We assumed that birds will feed 100% on fish. In fact, fish production will be low in the heavy emergent vegetation that we will promote. Fish also may represent an unusually highly contaminated prey item. For example, bioaccumulation of OCPs into crayfish was less than for fish in our microcosms and mesocosms.
- Our calculation of a hazard index HI for mortality assumed additive toxic effects for all OCPs. We and our Expert Review Group consultants were unable to find information on combined effects of exposure to multiple OCPs. Little research has been done with these pesticides after they were banned from use in the U.S. We believe that the assumption of additive effects likely exaggerated the risk

Furthermore, we used several management techniques in addition to remediation to reduce risk in newly flooded areas. These include the following:

- Discourage feeding by wood storks and other wading birds by maintaining water levels too high and emergent vegetation too dense for tactile foraging
- Reduce the potential for piscivory by wood storks and other wading birds by maintaining marsh conditions that lead to low production of forage fish due to hypoxia stress
- Reduce bioaccumulation of OCPs by encouraging a highly productive, dense community of emergent vegetation
- Maintain the ability to pump water off areas should problems develop
- Monitor OCP concentrations in fish to detect problems quickly

Remediation

The District contracted with MACTEC Engineering and Consulting, Inc. for a feasibility study of the nature and extent of contamination and risks posed by OCPs in soil within Units 1 and 2 of the LANS and of remedial alternatives that would permit ecologically-safe restoration of wetlands. In Table 6-3 of their final report, MACTEC (2005) summarized cost estimates for twelve options. These options comprised two no-action alternatives, six isolation/containment alternatives, two *in situ* treatment alternatives, and two *ex situ* treatment alternatives. Estimated treatment costs for estimated 8,000 acres ranged from zero for no action to as much as $950M for excavation and transport to an off-site landfill. Of course, not all options would be equally effective in mitigating ecological risk over an acceptable time span.

The District built on the feasibility study by MACTEC to narrow the list of remedial options under consideration and to pilot test several alternatives on the LANS. This work and the final remediation was reported in detail by Bartol and Brown (2012). The most feasible remedial option proved to be the use of special plows with 52-inch disk blades to invert the soil. This was an *in situ* capping process that inverted the surficial soil containing most of the OCP contamination to the bottom of a 3.5-ft (approximately) furrow.

We calculated "safe" soil levels for individual OCPs from BSAFs and TRVs, and these safe levels were refined as the Pesticide Study progressed. The safe level is equal to the soil level of an OCP where fish exposed to that soil would bioaccumulate that OCP to a body burden equal to the TRV (hazard quotient = 1). The calculation uses the BSAF for emergent marsh, the TRV, and the predicted lipid value in fish and is shown below (wwt = wet weight).

$$\text{OCP soil safe level (µg OCP/kg TOC)} = \frac{\text{TRV (µg OCP/kg wwt)}}{\text{BSAF (µg OCP/kg lipid / µg OCP/kg TOC) X lipid}_{\text{fish}}\text{ (kg lipid/kg wwt)}}$$

For example, for DDE, the TRV was 1500 µg/kg wwt, and the emergent marsh BSAF was 8.06. Here, we assumed a fish lipid concentration of 3.5%, or 0.035 kg lipid/kg wwt. The resulting safe level is 5,317 µg DDE/kg TOC.

The fish lipid concentration for this calculation is that predicted for fish after the area is flooded. In the example above, we used a value similar to median values in fish sampled during early flooding of the Duda property and to median values in fish during the initial two years of operation of the mesocosms. Higher predicted lipid concentrations in fish would result in greater predicted bioaccumulation and lower safe level OCP concentrations in soils.

Bartol and Brown (2012) planned the initial soil remediation based on the percent reduction needed to achieve safe levels (HQ = 1) for DDE. They did this because DDE had a high BSAF (Table 1) and slow attenuation in biota (Table 2). Later in the project, they planned additional areas for remediation based on the hazard index (HI) for soil samples. For example, if the initial HI was 2, then remediation to achieve a 50% reduction in OCPs (to HI = 1) was necessary. This step provided protection against possible additive effects of multiple OCPs.

A resampling of soil OCPs across Units 1 and 2 in 2007 allowed refinements to the remediation plan that reduced the area for treatment from 8,000 to approximately 4,000 acres. Remediation

was completed in 2009 at a cost of about $10M. Reductions of OCPs within the treated fields averaged 68% (Bartol and Brown 2012).

The District funded research by three groups at the University of Florida on alternate approaches to remediation of contaminants on the LANS. Although soil inversion was chosen as the most cost-effective remediation method, this research demonstrated that management of the LANS under flooded conditions and with dense wetland plant cover should promote further reduction in OCP residues in soils. Brief summaries of some of this work follow, and the full reports by these groups are available at the District's Scientific Reference Center.

- Clark and Cheng focused on toxaphene and prepared several literature reviews and a summary of possible *in situ* remediation techniques including flushing with solvents and/or surfactants (Clark and Cheng 2004).
- Ogram and Chen used laboratory microcosms and mesocosms to study the effects of redox condition and supply of electron donors on the degradation of toxaphene, DDT, and DDD. Redox was controlled by flooding and drying, and electron donors tested included dried, ground cattail as a surrogate for naturally-occurring wetland plant residues. Addition of an electron donor increased degradation of all OCPs, and toxaphene and DDT were degraded only under flooded (anoxic) conditions (Ogram and Chen 2007).
- Thomas and colleagues investigated the potential to enhance both aerobic and anaerobic degradation of DDX (DDT, DDD, DDE) using fungal inocula and various amendments including surfactants, NaCl, organic compounds, and chelated trace metals. Among other findings, they concluded that a naturally-occurring wood-rot fungus (*Nectria* sp.) was as effective in aerobic degradation of DDX as were inoculations of other species. Degradation by the native species was enhanced by depletion of NO_3 concentrations in soils through frequent watering and by addition of yeast extract. Further, they found that DDX was degraded rapidly by naturally-occurring anaerobic bacteria after addition of a trace-metal solution and lactate. Addition of NaCl further enhanced degradation, presumably through increased solubility of dissolved organic matter and increased bioavailability of hydrophobic compounds including DDX (Thomas et al. 2010).

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Appendix A. Technical and Expert Review Groups for the Lake Apopka Pesticide Study

The Lake Apopka Pesticide Study Technical Advisory Group

U.S Fish & Wildlife Service U.S. Environmental Protection Agency Fl. Fish and Wildlife Conservation Commission Fl. Department of Health Fl. Department of Agriculture and Consumer Services Fl. Department of Environmental Protection	University of Florida U.S. Geological Survey Lake County Lake County Water Authority Orange County Audubon Society Friends of Lake Apopka

Expert review group for the first phase of the Lake Apopka Pesticide Study (soil sampling and analyses and Exponent project)

Michael Fry, Ph.D. University of California at Davis Ecological toxicology Michael Hooper, Ph.D. Texas Tech University Avian toxicology Thomas W. La Point, Ph.D. University of North Texas Avian toxicology	P. Suresh C. Rao, Ph.D. Purdue University Soil biogeochemistry Gary Rand, Ph.D. Florida International University Ecological toxicology James Sikarskie, D.V.M. Michigan State University Wildlife Veterinarian

Expert review group for the second phase of the Lake Apopka Pesticide Study (Bioaccumulation Study)

John D. Schell, Ph.D. BBL, Inc. Ecological toxicology Harry Ohlendorf CH2M Hill Avian toxicology	Michael J. Hooper, Ph.D. Texas Tech University Avian toxicology

Primary Sponsor Letter of Support

(As uploaded)

KHankin ltr to USACE Lake Apopka Restoration support August 9 2017.pdf

St. Johns River
Water Management District
Ann B. Shortelle, Ph.D., Executive Director

4049 Reid Street • P.O. Box 1429 • Palatka, FL 32178-1429 • 386-329-4500
On the internet at www.sjrwmd.com.

August 9, 2017

United States Army Corps of Engineers
Via Electronic Submittal
WRRDA7001Proposal@USACE.army.mil

RE: Lake Apopka Restoration - Future Water Resource Development Project

To Whom It May Concern:

The St. Johns River Water Management District (District) proposes to restore Lake Apopka by removing nutrient laden muck and flocculent sediment from the lake. This material will be beneficially used to expedite ultimate restoration of wetlands adjacent to the lake that are former agricultural lands. This will be accomplished by thin layer placement of the lake sediment material to reduce exposure to organochlorine pesticides in the wetland soils. In addition, sediment material removed from the lake will be used beneficially to re-establish ground elevation in subsided historic agricultural areas to restore open water to wetland systems.

Other non-federal interests that are expected to contribute to the non-Federal share of the proposed project include the Florida Department of Protection and the Florida Fish and Wildlife Conservation Commission. Other local government entities may also participate.

The District has had an excellent long-term working relationship with the United States Army Corps of Engineers (USACE) in the Upper Basin and we are interested in expanding that relationship into partnering opportunities associated with the restoration of Lake Apopka.

The District fully endorses and supports this proposed project. The District looks forward to continuing our relationship with USACE and developing additional award winning projects like the Upper Basin Project.

Sincerely,

for Karl E. Hankin, P.E., Director
Division of Projects

WILLIAM ABRAMS
GENERAL COUNSEL

C: Rebecca Trudeau

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Map Document

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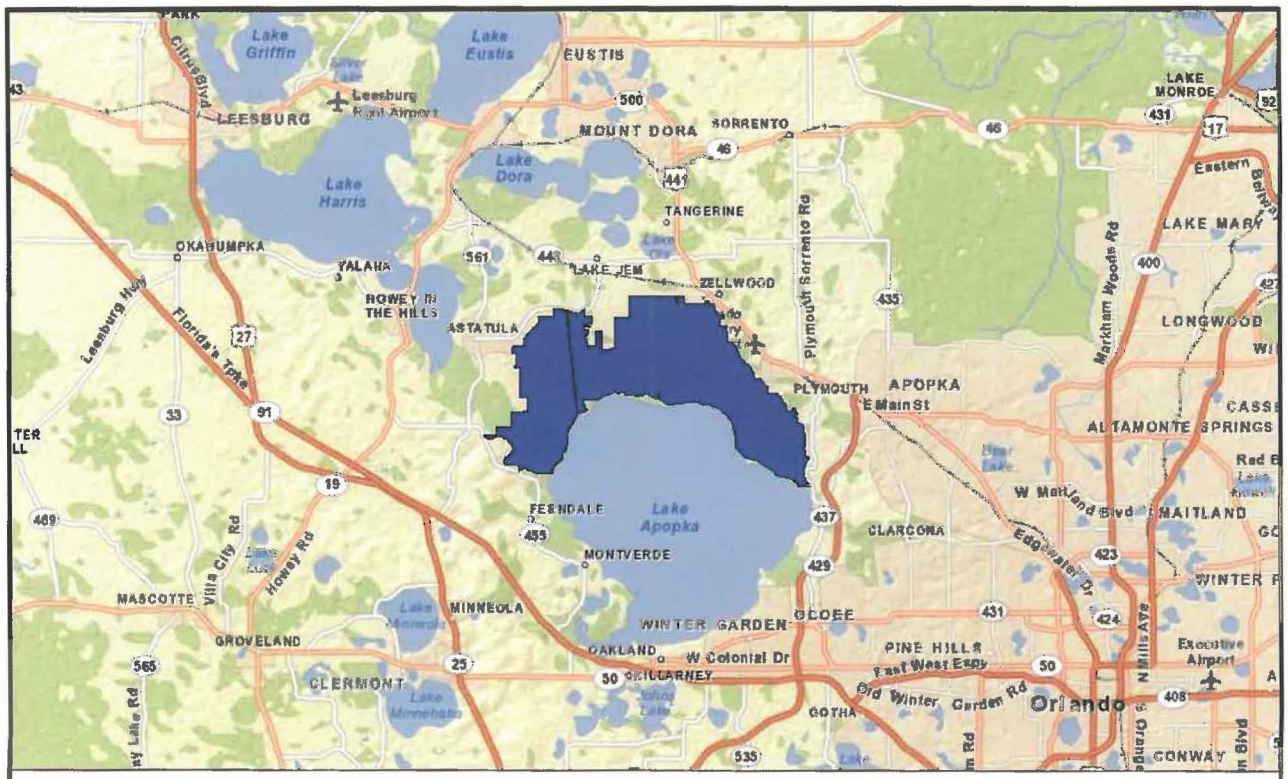
Lake Apopka Map.pdf



Lake Apopka North Shore

Figure 2 - Location Map

2 Miles

1 = 250000

North Shore

The St. Johns River Water Management District presents and uses this information for its own purposes and this information may not be suitable for other purposes. This information is provided as is. Further documentation of this data can be obtained by contacting St. Johns River Water Management District, Geographic Information Systems Program Management, P.O. Box 1429, 4049 Reid Street, Palatka, Florida 32178-1429 Tel: (386) 329-4125