Special Publication SJ98-SP7

Environmental Risk Assessment of a Lake Apopka Muck Farm Wetlands Restoration

November 3, 1997

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Prepared for

St. Johns River Water Management District

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**Duda ecora.6*

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1 EXECUTIVE SUMMARY

This environmental risk assessment of the Duda Farms property was completed to evaluate potential ecological risks and describe how potential risks can be addressed through site management strategies. Characterization of the potential risks relating to past land uses at muck farms on Lake Apopka is of importance because one component of the current effort to restore the lake ecology involves acquisition of surrounding land to re-establish wetlands. Removal of land from agricultural production and the reclamation of wetlands around the edge of the lake has two major beneficial effects. First, these actions can serve to reduce the loading of nutrients and other agriculturally-related chemicals into the lake ecosystem. Second, is the return the lake ecosystem to one that is functionally more similar to the original ecology. In converting these properties back to wetlands, however, it is necessary to evaluate the potential risks relating to the existing chemicals that could be realized by the organisms (ecological receptors) that recolonize the site. While the general approach of assessing potential risks and describing available management strategies can be used as part of an area-wide strategy, the levels of risk and the chemicals of importance are specific to the particular properties being converted. This report focuses on the specific chemical concentrations and conditions at the Duda property in an effort to characterize the associated risks and describe how these risks can be affected by management strategies.

The risk assessment was carried out using a standard paradigm promoted by the USEPA and other regulatory agencies. The basic approach is to use conservative assumptions (i.e., over-estimations) of the extent of chemical exposure that could result for relevant ecological receptors, and to compare this to conservative representations of the toxicity of the pertinent chemicals. Where this model determines that exposures are insufficient to result in doses considered toxic under the intentionally conservative assumptions, it can be concluded with substantial certainty that the potential risks are not significant for the chemicals, receptors, and effects considered. Where the model suggests that exposures could produce unacceptable theoretical risks, a critical evaluation of the assumptions used (weight-of-evidence analysis) and a consideration of the available management strategies for precluding unacceptable exposure is used to characterize the potential for realizing the predicted risks.

There was only one receptor/chemical combination where the risk model predicted that exposures sufficient to produce significant risks could occur (exposure of piscivorous birds to total DDTs). This prediction was based upon conservative assumptions about the size and type of fish consumed by a great blue heron receptor and about the body burden of DDTs that could have accumulated within these fish. It is unlikely that birds would find such large fish available as their primary diet. There are available and feasible methods to control hydrologic conditions, promoting lush vegetative growth and encouraging high sedimentation rates. Thus exposure in the field can be controlled such that significant risks levels will not be reached. To verify the attenuation, methods to monitor sedimentation and bioaccumulation can be used. While monitoring is prudent to ensure that unacceptable or unexpected impacts do not occur, the reduction in risks anticipated through removing the site from agricultural production and preventing additional releases of the chemicals of concern is clear.

The overall conclusion of the evaluation of the Duda property is that there are no potential risks identified that could not be effectively controlled by the available management strategies, using natural attenuation as the contaminant remediation-method for the farm fields. More intensive remediation methods (e.g., soil removal) have already been applied at specific places on the property where handling or management of chemicals was a regular occurrence. A complete evaluation of remediation alternatives is always necessary prior to recommending a comprehensive solution, and this site is no exception. However, the benefits to the larger ecosystem projected to accrue from the restoration of this property to wetlands is high, particularly in conjunction with the risk reduction associated with the cessation of farming.

2 INTRODUCTION

The St. Johns River Water Management District (the "District", SJRWMD), under the authority of the Lake Apopka Agricultural Land Acquisition Project, has purchased the A. Duda & Sons Property as part of the restoration program for Lake Apopka and to eliminate a source of phosphorous to the lake. Pursuant to a contractual agreement with the U.S. Department of Agriculture, the District is required to perform an Environmental Risk Assessment (ERA) to address the concerns raised by the discovery of chlorinated pesticides in the soils of the Duda property. The presence of these chlorinated pesticides are of particular concern as the District plans to convert the Duda property and other properties that are purchased from agricultural fields to a functioning wetland by flooding the property. This activity will encourage the recruitment of wildlife indigenous to the area, and therefore result in their potential exposure to the chlorinated compounds. Thus, the focus of the ERA will be both to quantify current and future risks to the environment, and also develop information useful in developing risk management plans designed to provide a framework for wetland restoration efforts. This latter effort will include a quantitative evaluation of the natural recovery processes which are expected to occur over time as the re-claimed wetland undergoes various stages of progression into a more natural condition.

The Duda property represents a unique situation from which to develop a quantitative risk assessment. This property is currently an active agricultural enterprise, with the majority of the site still involved in the production of corn, carrots, celery and other crops (Earth Systems Engineering, 1997). Therefore, the site does not fit into the typical situation of an ERA, that is the assessment of an ecosystem currently being impacted by chemical stressors. Since the site is active farmland, there is no "natural" biological community (i.e., receptors) which is being adversely affected by the presence of certain chemical constituents. However, periodic flooding of the fields by the farmers for nematode and erosion control attracts a wide variety of wildlife to the raw flooded soils. Visiting organisms are exposed to the contaminated soils and prey items over the one to two month flooding periods. As the system returns to a more natural state, ecological receptors will permanently re-inhabit the flooded fields, increasing the potential chemical exposure conditions. As such, the ERA developed for this setting is an entirely prospective analysis, one focused on assessing the *re-creation* of the system. The ecological assessment will attempt to quantitatively and qualitatively assess the potential for the agricultural fields to evolve into a functional ecosystem.

The direct predictiveness of the risk assessment methodology for characterizing the Duda property is impacted by the fact that the ecosystem being characterized does not yet exist. Quantitative risk assessments are more typically carried out for existing ecosystems where community interactions, populations, and environmental components can be observed to identify critical factors and assumptions. The ecosystem characteristics used for analyzing risks in this assessment are theoretical assumptions based on the best available information about the neighboring ecosystems and previous situations where muck farms in the region have been converted to wetlands or surface water bodies. It should be kept clearly in mind that the potential for risks from chlorinated pesticides are being estimated for such a "theoretical" ecosystem and the extent to which they would eventually apply to the restored Duda property depends upon how closely conditions in the field and critical ecological factors have been matched.

Since the environmental conditions required to develop a functional wetland do not currently exist, the ERA cannot evaluate or quantify past or even current exposure (e.g., biomarkers, tissue residue) or effects (e.g., community structure metrics). For example, one cannot evaluate the effects of the various chemical constituents on food chain structure, since a highly altered (impacted) assemblage currently exists, independent of any chemical stressor. The explicit assumption considered in this ERA is that since there is no exposure, adverse ecological effects associated with the presence of the chlorinated pesticides are not currently occurring. Consequently, the ERA will focus on assessing only the *potential* risks to immigrant species as the former wetland recovers.

As the ERA is prospective in nature (i.e., evaluating an ecosystem that does not currently exist), the only measurement endpoints of future exposure are current soil constituent concentrations, and modeled values of environmental matrices once the wetland is flooded. Given the reliance on environmental models and assumptions regarding future site conditions, as well as the lack of empirical data on the site once it is flooded, the level of uncertainty of the ecological assessment could be high. However, data collected from former agricultural lands in the vicinity of the Duda property will be utilized whenever possible. Since these areas are of similar characteristics (i.e., soil types, climate, etc.), and are likely to have already recruited a biological community similar to ones expected at Duda (Marburger and Godwin, 1996), the development of a conceptual site model, including potential ecological receptors, can be done with an acceptable degree of certainty. The use of these surrogate ecosystems are preferential to applying "off the shelf" generic ecosystem models, even though the former may result in the development of more simplistic approaches to describing the environmental fate and potential risks associated with the chemicals of concern.

Finally, the potential ecological risks associated with chemical constituents found in the agricultural soils need to be placed into proper perspective. The Duda property is part of a larger marsh restoration plan for all muck farms in the basin and these new wetlands will eventually be reconnected to Lake Apopka, and become a functional component of that complex environment. However, Lake Apopka, like other areas of the immediate watershed, is not a pristine environment. Rather, the lake has experienced chemical and physical stressors for many years. Restoration efforts are attempting to alleviate many of the impacts, but this process is a long (and expensive) undertaking. The restoration of the Duda property is an important element of this program because it will reduce nutrient input to the lake. Lake Apopka and its surrounding environments are by no means restored to a natural state, and in fact contain many of these stressors which affect receptors common to this area. Thus, part of the ERA will evaluate the ecological conditions which will exist in the Duda wetland relative to the conditions found in the surrounding environment.

The development of the site-specific ecological risk assessment follows the general outline provided in USEPA's recently published *Proposed Guidelines for Ecological Risk Assessment* (1996a). The three primary phases of an ERA as outlined by USEPA (problem formulation, analysis, and risk characterization) are developed and outlined in the following sections. The intent of the USEPA guidelines is merely to provide a framework and not a roadmap (P. Cirone, personal communication), and given the unique nature of this project, there are modifications required to perform the ERA. However, these modifications were made without abdicating the primary goal of the ERA, which is to "evaluate the likelihood that adverse ecological effects may occur as a result of exposure to one or more stressors" (USEPA, 1996a).

2.1 Site Background

The following description of the Duda Property was taken from the Phase I and Phase II Site Assessment performed by Earth Systems Engineering, Inc. (1997). A. Duda & Sons' Lake Jem Farm is located on the northern shore of Lake Apopka in Lake Jem, Florida. Prior to the 1940s the land now used for cultivated fields was swamp and marsh land. Development of the cultivated fields through drainage began in the 1940s and continued through the 1980s. The first fields developed were those in the northeast portion of the property which were cultivated prior to 1947. Development of the fields progressed to the south and then west. By 1953, the southwest and central portion of the parcel had been developed as cultivated fields. By 1977, the last of the fields had been developed in the southeast corner of the parcel. The property consists of approximately 3,400 acres and is comprised of two individual non-contiguous parcels: the Old Celery Seed Bed parcel and the Main Farm parcel.

The Main Farm parcel contains the Redi Foods tract and the Main Farm tract. For the purpose of this report, the Redi Foods tract is considered that portion of the Main Farm parcel north of McDonald Canal and east of County Road 448A. This portion of the property is not scheduled to be part of the wetland restoration project, and therefore was not considered as part of the ERA for the site.

The Main Farm tract contains four areas based on current and former land use:

1) A Labor Housing Area, located at the northwest corner of the parcel;

2) The Current Airfield, located at the northern edge of the Main Farm tract east of the Headquarters Complex;

3) The Headquarters Complex, located directly south of the Redi Foods parcel; and

4) The Cultivated Fields, which comprise over 80% of the area to be flooded.

The property includes about 2,500 acres of muck lands, 200 acres of uplands, 400 acres of wetlands and 300 acres of potentially sovereign lands associated with Lake Apopka to the south.

The labor housing area contains 5 areas based on current and former land use:

1) a residential area includes the housing complex and recreational facilities;

2) a labor housing storage area, located on the corner of County Road 448A and the entrance to the cultivated fields;

3) a waste water treatment facility, located west of the residential area;

4) a solid waste disposal area, located west of the waste water treatment facility; and

5) a former mix/load site, located east and south of the storage area.

The current airfield consists of the current landing strip and the land to the north. Significant site features include the current mix/load area (that includes vehicle and aircraft mix/load sites), a former pesticide mix/load site, a suspected former pesticide mix/load site, the pesticide storage site, aircraft fuel above ground storage tank (AST), the former aircraft maintenance site, the vegetable disposal site, and a solid waste disposal area.

Significant site features within the Headquarters Complex include: the maintenance shop, the pesticide storage barn, the current solvent storage tank, the former solvent storage tank, the former pesticide storage building, the burn area, the pesticide application equipment cleaning area, the current fuel aboveground storage tanks (ASTs), the former fuel ASTs, the "bone" yard (obsolete equipment), the access road storage area, the processing facilities, and the farm offices.

The buildings at the Headquarters Complex include a former cold storage building, current cold storage building, the processing plant, the maintenance shop, and harvesting office. Four water supply wells are located at the Headquarters Complex.

The cultivated fields are located south of McDonald Canal and include about 2,500 acres. A series of lateral water management ditches cross the fields. Dirt roads are present next to the large ditches. Retention ponds, totaling about 300 acres were installed in the early 1990s along the southern property boundary, adjacent to Lake Apopka. These ponds were installed to mitigate phosphorous discharge to Lake Apopka.

2.2 Current and Past Uses of Adjoining Properties

Lake Apopka borders the southern end of the Main Farm parcel. Land use in the vicinity is predominantly agricultural. A large farm complex (Zellwin Farms, established in the 1940s) is located to the east and north of the portion of the property within Orange County. The District owns the property west of the site and the property north of the Labor Housing area. The large tract owned by the District west of the property is used for the Lake Apopka Marsh Restoration Project. This land (formerly called Clay Island Farm) was formerly owned by Duda and others and is located west of the Beauclair Canal. It was developed as a commercial farm in the 1950s.

North and east of the Redi Foods tract is Long & Scott Farm. West of the Redi Foods parcel is a fernery established in the 1950s. South of the Old Celery Seed Bed parcel is the Keene Ranch outparcel with single family homes, home-based businesses, and cattle grazing. The District owns the property west of the Old Celery Seed Bed parcel. Reportedly, a business on this property cleaned printing presses. East of the Old Celery Seed Bed parcel are rural residential tracts and north of the Old Celery Seed Bed parcel is Hurley Farm. A former cattle dip tank is located on this parcel.

3 PROBLEM FORMULATION

3.1 Management Goals

One purpose of the Land Acquisition Project is to eliminate a significant source of phosphorous loading to the lake. This will be accomplished by the conversion of agricultural land into wetlands. The conversion will not only reduce phosphorous inputs to the lake, but also eliminate a source of other agricultural associated chemicals (e.g., pesticides) which have historically entered the Lake Apopka ecosystem. A second effect of this restoration will be the expansion of ecologically desirable habitat and a recruitment of aquatic species onto the property. As a consequence of this effort, however, these organisms will be exposed, at least in the short term, to elevated levels of persistent chlorinated pesticides known to exist in the soil. The Duda ERA will address this latter issue.

For the purposes of this risk assessment, the source (soils) and characteristics (chlorinated pesticides) of the stressors evaluated in the ERA are known, although the site-specific data quantifying these stressors is rather limited.

The primary management goals of the Duda ERA are to:

1) quantify to the extent possible, the risks associated with exposure to chemical constituents found in agricultural soils to certain receptors once the property is returned to an aquatic ecosystem;

2) compare these risks (quantitatively or qualitatively) to those existing in the surrounding environments closely associated with the Duda property (e.g., Lake Apopka) ; and

3) determine the time frame and mechanisms of natural recovery which would be expected once the system is transformed from an agricultural (terrestrial) to aquatic environment.

3.2 Conceptual Site Model

The conceptual site model (CSM) is a written and visual representation of stressor source(s), exposure pathways and receptors specific to a specific site. The CSM for the Duda property is not intended to represent conditions as they currently exist, but rather it is a product of the assimilation of information used to develop a representation of conditions which will exist once the area is taken out of production and flooded. Since the CSM for the proposed wetland cannot describe existing conditions, it does not contain detailed descriptors of all ecological components, exposure pathways, or potential receptors (Figure 1). This lack of detail is simply a function of the reality that the ecosystem which is being evaluated in the ERA does not currently exist.

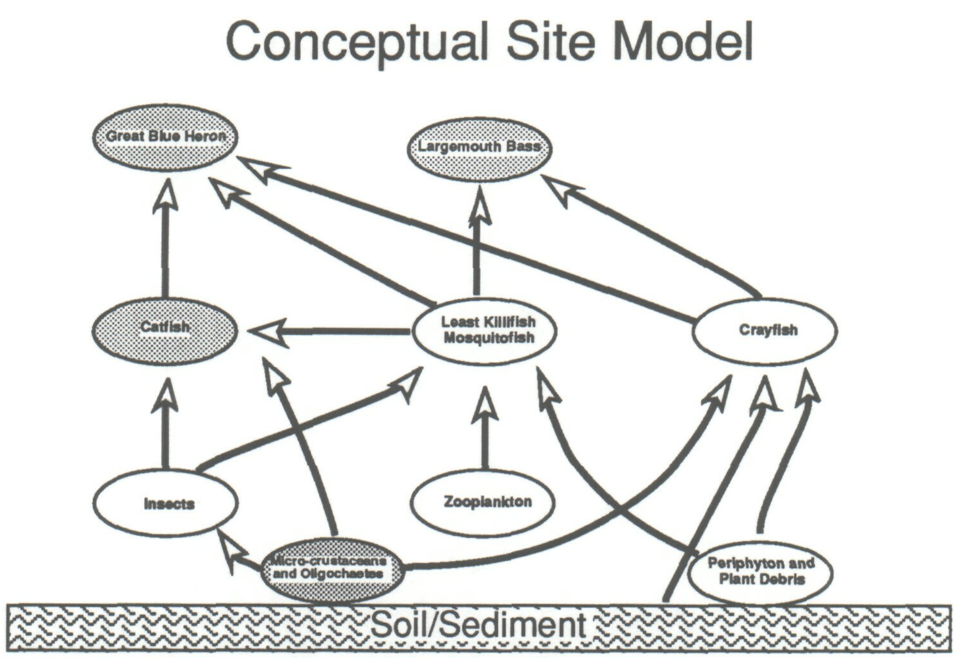


Figure 1. Conceptual Site Model for the Wetlands Anticipated to be Created at the Duda Property

Since the conceptual site model describes an ecosystem which will evolve and progress over time, certain assumptions were made as part of the problem formulation step. First, although it is not generally true in other aquatic systems, the soils of the Duda property are assumed to directly represent the sediment of the aquatic system. That is, the default assumption for the ERA is that the chemical and physical characteristics of the soil as determined by laboratory analysis will not change once they are flooded. Typically, surficial soils become components of aquatic systems through erosion or similar processes. As a result, the soils are mixed with already existing sediments, and therefore the soils' chemical concentrations and geophysical characteristics are altered by mixing with sediments. In the case of the Duda property, it is expected that little or no erosion will occur, rather the soils will remain in-place, relatively unaltered by the flooding process. Also, these fields are currently flooded on a periodic basis (as a form of pest control), and therefore the restoration process will not represent a unique event. Indeed, these soils have already been sediments before, and so the above assumption is not an unreasonable one.

A second assumption adopted for the ERA is that the soils/sediments are the direct and *only* source of chemical stressors. That is, it is assumed that source controls are in place (i.e., no additional applications to the fields), and the flooding waters do not contain quantitatively significant levels of any chemical of concern. Similarly, due to the lack of empirical data, the contribution of chemical constituents via atmospheric deposition (including dust from neighboring farmland) was not considered.

Finally, the model selected to quantify the transfer of compounds from the sediments to various trophic levels is the biota-sediment accumulation factor (BSAF). The BSAF is simply the ratio of the lipid normalized chemical concentration in fish tissue to the carbon normalized chemical concentration in sediments. The scientific rationale for this ratio is based on the fugacity principle which can be regarded as the "escaping tendency" of a chemical from one phase to another. Equilibrium is achieved when the escaping tendency from one phase exactly matches that from the other (Mackay and Paterson, 1981). In the case of lipophilic chemicals in aqueous environments, the phases are defined by the hydrophilicity, and the equilibrium a function of the lipophilic nature of the phase. The phases evaluated in the BSAF are biological tissue (normalized to their lipid content) and the organic matrix of the sediments (normalized to the organic carbon content).

The BSAF implicitly considers all routes of exposure without quantifying individual exposure pathways. For example, when a site-specific BSAF is calculated for a largemouth bass, it only considers the sediment concentration and tissue concentration of the fish. The model does not require incremental measurements of intermediate trophic levels to determine the accumulation from sediments into that particular species, even though sediments may not necessarily be a direct source for a specific fish species. Rather, the BSAF integrates all of the exposure routes (food species, water, sediment ingestion, etc.) by simply quantifying the direct accumulation by the species of concern. The use of the BSAF is particularly advantageous in this instance, since the ecosystem which eventually will develop is not yet present at the site, it is impossible to construct a stylized food web which is required in order to use some of the more sophisticated accumulation models.

3.3 Assessment Endpoints

While management goals state the overall goals to which an ecological risk evaluation is expected to relate, assessment endpoints serve as a link between the overall goals and the specific features that can be measured or estimated in some way as representations of risk. Assessment endpoints must incorporate some valued ecological entity (e.g., shallow lake fish species) and the identification of some feature(s) related to the entity that are considered important to protect (e.g., survival and reproductive success).

Assessment endpoints should also be selected such that they effectively link feasible measures that can be used for risk estimation to management goals. In other words, where a management goal is to create a viable wetland ecosystem, a useful assessment endpoint would be one that identified a fish species for which survival was important and for which there was sufficient information on potential toxicity to estimate risks. In contrast, another possible, but not particularly useful assessment endpoint might be the maintenance of adequate nesting territory for a bird species. While this might be an important feature for a valued ecological entity, it would not provide a clear link between the chemical risk estimates that can be derived and overall goal of creating a viable wetland.

In light of the management goals discussed above for the Duda property and the available information that can be used to generate risk estimates, the following assessment endpoints are identified for this risk evaluation:

- Initially -- establishment of an aquatic environment and sediments that are not toxic to species expanding into the area and suitable for successful colonization.
- Eventually - development of a sustainable Florida wetland ecosystem with local reproducing populations of fish (including largemouth bass) and birds (including fish-eaters, e.g., great blue heron)

3.4 Selecting Relevant Measures of Potential Effect - Analysis Plan

Once assessment endpoints relating to overall management goals have been identified, relevant measures of specific potential effects that can be reasonably related to the assessment endpoints are characterized. These measures of effect are the features which can be directly analyzed with the available information (e.g., potential sediment toxicity to micro-crustaceans or potential for food source-related toxicity in great blue herons).

Measures of effect for a particular risk analysis must be selected with careful consideration of the information that is available and the expected sensitivity of the relevant effect. Many more measures of effect are conceptually possible than are practical to evaluate. The information available relating to environmental sampling data and ecosystem characteristics serves to focus efforts on the practical measures of effect. The environmental data that are pertinent to consider are the matrices which have been examined (soil, water, biological tissues), the number and types of samples which have been analyzed, and the concentrations of particular chemicals that have been identified.

With these considerations in mind, final measures of effect are selected by identifying species and endpoints that are expected to be sensitive indicators for the particular chemicals and exposures that are important for the particular site. This step is typically based upon evaluation of the local ecosystem characteristics, which is not possible because of the unique feature that the ecosystem being assessed does not yet exist. Likely ecosystem components were characterized on the basis of typical ecology for the area and the outcome of similar wetlands re-establishment efforts. For practical reasons, and to reduce uncertainty by focusing efforts, the goal is not to identify measures of effect by comprehensively characterizing the entire ecosystem, but to identify significant and sensitive indicators (species and effects) that are relevant for the most important chemicals and matrices.

For the Duda properties' evaluation, the most significant environmental matrices were determined to be the current soil and biological tissues. Since the evaluation considers the situation after flooding, exposure to sediments is obviously a primary source of exposure. Sediment is expected to be the most important source of exposure because the extremely high organic content and characteristics of the relevant chemicals (predominantly organochlorine pesticides) will strongly favor adsorption of these chemicals onto sediment particles. No pesticide compounds were found in water column samples collected over a 30 month period between 1990 and 1994 from a flooded muck farm area immediately adjacent to Jem Farm (SJRWMD, unpublished data). Levels of toxaphene and ΣDDT in soil sampled prior to flooding these fields were similar to levels obtained in Jem Farm fields (SJRWMD, unpublished data). Thus, on the basis of total contaminant load, partitioning to water is not expected to be as significant, and volatilization from water to air is expected to be a minor transfer pathway.

Because organochlorine pesticides often have significant potential to be retained and to accumulate within biological tissues, another important exposure pathway for consideration is transfer of contaminants along the food chain. The process of bioaccumulation can lead to magnifying levels of contaminants at each step along a food chain (as prey items end up with higher and higher body burdens) and top-level predators are frequently the most important receptor to consider. For evaluating exposures in the future ecosystem at the Duda property, the potential for bioaccumulation and ingestion of contaminants along with prey items is an alternative exposure pathway that is considered in developing measures of effects.

The following measures of effects were chosen to evaluate direct sediment exposure and bioaccumulation potential in organisms at the Duda property:

- Potential direct toxicity of sediment to benthic invertebrates
- Potential for foodchain transfers to produce toxicity in high-level predator fish and fish-eating birds

Potential toxic effects of concern for both invertebrates and higher trophic levels include both direct, acute lethality for individuals and compromised growth or reproduction that can lead to population-level effects. For the purposes of risk assessment, information on the most sensitive toxic endpoints available is used. Uncertainty factors (margins of safety) are increased for situations where results are only available for endpoints that are not considered particularly sensitive. Lab toxicity studies, especially for invertebrates, often focus on acute lethality. Field studies and collection surveys can address more sensitive endpoints such as growth, reproduction, and community health. Information from both of these types of studies was used in this assessment, and appropriate uncertainty factors were applied to help ensure that sensitive endpoints were accounted for conservatively.

Sufficient information is available for evaluating direct sediment exposure for benthic species, and invertebrates are a relevant and generally sensitive species for pesticides. This measure of effect is pertinent to both the assessment endpoint of initial concerns, providing a non-toxic aquatic/sediment environment suitable for colonization, and the assessment endpoint for eventual concern, development of a local ecosystem. Most of the data available for evaluating the Duda property is from soil sampling. This will be considered equivalent to sediment in the future flooded wetland and can be evaluated by comparing the concentrations found against toxicity levels identified through sediment toxicity tests with freshwater benthic invertebrates. Alternatively, equilibrium partitioning to water can be modeled to develop an estimated pore water concentration that can be compared against the results of water-borne toxicity tests.

Sufficient information is also available on local foodchain transfers. Predatory fish and piscivorous birds are reasonably anticipated to be at greatest risk from exposure through this pathway. This measure of effect is pertinent to the assessment endpoint for eventual concern (development of a local ecosystem), where predator populations may be resident on the site and deriving substantial prey from the associated waters and sediments. Sediment concentrations and related fish tissue concentrations are available from areas similar to the flooded Duda property. This allows the characterization of biota-sediment accumulation factors (BSAFs) relevant to the expected Duda ecosystem and specific for species and chemicals of interest. Compared to using default bioconcentration or bioaccumulation models, this local, measured data will provide an improved estimate of the actual risk potential and will reduce uncertainties related to contaminant transport through the food chain.

3.5 Problem Formulation Summary

Having identified, 1) management goals, 2) assessment endpoints that are pertinent for linking these goals to features that can be evaluated in the environment, and 3) measures of effects relevant to these features that can be directly analyzed, the problem formulation step is complete. The subsequent risk evaluation carried out on the basis of this plan is expected to outline a specific form of analysis that can serve as a useful tool for risk managers. This is optimized by having the specifics of the analysis selected on the basis of both overall management goals and practical considerations of what is feasible with the available information.

The specific environmental samples to be used for evaluating the expected ecosystem at the Duda property following flooding, along with the manner of analyzing the samples, the specific chemicals of potential concern, and the receptors to be evaluated can now be described, and the ways in which they fulfill the analysis plan highlighted.

4 ECOLOGICAL RISK ANALYSIS

4.1 Available Environmental Sampling Results

Data for the Duda property were provided to ATRA, Inc. by the District. Earth Systems (under contract with the District) collected 108 composite and soil samples from the Duda site during the Phase II investigation. Analyses were performed by Harbor Branch, Savannah Labs and Bionomics. Samples were collected from the areas identified as Area A - Celery Seed Beds, Area B - Redifarms, Area C - Labor Housing, Area D - Air Field, Area E - Headquarters Complex and Area F - Fields (see Figures 1 and 2 in Earth Systems Engineering, 1997). The areas to be flooded include areas C, D, E and F, as such these areas are the only ones considered in the assessment. At the request of the District, hot-spots in Area C, Area D and Area E have been remediated. Soil in the remediated areas was excavated to a depth of two feet and the areas were covered with clean fill. As a result, these areas are considered clean and samples collected in the remediated areas were not included in this assessment. A brief description of the samples collected from each area is included in Table 4-1, and a summary of the data (TOC normalized) is included in Appendix A.

The soil data utilized in this report is summarized in Table 5 of the *Phase I Environmental Site Assessment and Phase II Assessment Lake Jem Farm, Northern Shore of Lake Apopka, Lake Jem, Florida*, and in Table 1 of the *Phase III Assessment Lake Jem Farm, Northern Shore of Lake Apopka, Lake Jem, Florida* (Earth Systems Engineering, 1997).

For the purposes of this assessment Area F was handled as two sections, fields and canals. This was done because the seven samples (and two duplicate samples) from the cultivated field area were composite samples representing particular parcels of Area F, while the samples collected in the canals were discrete grab samples. Additionally, the analyses of the composite samples collected from the fields were noticeably different than the grab samples collected in the canals (e.g., toxaphene concentrations in the field range from 880 to 18,000 μg/kg, while toxaphene was never detected above the limit of detection in the canals). Two duplicate samples, analyzed by separate laboratories – 47A and 47A(D) and 53A and 53A(D) – were collected from the field area. Because of the composite nature of the samples collected from the cultivated field, inclusion of the duplicate as a separate data point would prejudice the data. As a result, only the analyses by Harbor Branch were retained. However, results for gamma chlordane, endrin ketone, ametryn, chloropropylate, chlorothanil, atrazine and metolachlor were not reported by Harbor Branch laboratories, so for completeness the data for these chemicals provided by Savannah Laboratories was retained.

Table 4-1
Summary of Samples Collected

	Number of Samples	
Areas	**Composites**	**Grab**
Area C	2	
Area D	4*	6
Area E	24	2
Area F (fields)	9**	
Area F (canals)		12

*One composite sample was collected during the Phase III investigation;
**Includes two duplicate sample

4.2 Characterization of Chemicals of Potential Concern (COPCs)

The maximum concentrations of the pesticides detected on the Duda site were compared to an appropriate screening value to determine which compounds pose the greatest toxicological concern. The high organic content of the muck soils at the site (48 – 52%) and the resulting high binding capacity of this material dictates the need to carbon normalize the data prior to screening. Because the Florida Sediment Quality Assurance Guidelines (MacDonald, 1994) are not carbon normalized, they are not the most appropriate screening tool. The Provincial Sediment Quality Guidelines for Organic Compounds Severe Effects Level (SEL) published by Ontario Ministry of the Environment (OME; Persaud et al., 1992) are carbon normalized and were therefore considered an appropriate screening criteria. At the SEL, however, adverse effects to the benthic community can be expected. To extrapolate to a more appropriate screening value, a safety factor of 15 was applied (USEPA, 1994a).

The maximum concentration for each chemical detected at the Duda site was carbon normalized and compared to the modified OME values (carbon normalized SEL divided by a safety factor of 15). If a chemical was not detected above the limit of detection for any sample collected in a nonremediated area, that chemical was eliminated (e.g., ametryn and endrin ketone). To carbon normalize the site data, the measured soil concentrations were divided by the organic carbon content of the soil (an organic carbon content of 50%, the average of the composite samples collected in the field, was assumed). The resulting comparison is presented in Table 4-2, and a summary of the data (TOC normalized) is included in Appendix A.

The nature of the restoration project indicates the area will be flooded resulting in the possible translocation of chemicals from soil to pore water. As a result pore water concentrations were calculated from the site soil data and compared to Ambient Water Quality Criteria (AWQC; USEPA, 1996b) values as an additional screening tool (Table 4-3). Pore water values were calculated, using the approach described in the USEPA *Briefing Report to the EPA Science Advisory Board on the Equilibrium Partitioning Approach to Generating Sediment Quality Criteria* (USEPA, 1989a):

$$\text{Pore Water } (\mu g/L_{oc}) =$$

$$\text{Carbon Normalized Soil } (\mu g/kg_{oc}) \div \text{Chemical Specific } K_{oc} \text{ (L/kg)}$$

Based on these two screening procedures the following chemicals have been eliminated as chemicals of potential concern: aldrin, alpha chlordane, dieldrin, and endrin.

Table 4-2
Comparison of Maximum Soil Concentration to Ontario Ministry of the Environment Sediment Quality Guidelines*

	Modified OME SELs** ($\mu g/kg_{oc}$)	Maximum Normalized Concentration ($\mu g/kg_{oc}$)	Retained#
Aldrin	533	54	No
Alpha chlordane	400 (value for chlordane)	136	No
Atrazine	ND	1,460	Yes^{ND}
Chloropropylate	ND	10,200	Yes^{ND}
Chlorothalonil	ND	1,880	Yes^{ND}
DDD	400	4,760	Yes
DDE	1,267	6,000	Yes
DDT	800	20,000	Yes
Dieldrin	6,067	760	No
Endrin	8,667	136	No
Gamma chlordane	400 (value for chlordane)	680	Yes
Heptachlor	ND	52	Yes^{ND}
Metolachlor	ND	800	Yes^{ND}
Toxaphene	ND	36,000	Yes^{ND}

* All concentrations included are reported in micrograms of chemical per kilogram of organic carbon
**Modified OME SEL = SEL (µg per kg of organic carbon) ÷ a safety factor of 15
"Yes" indicates chemicals were retained because the carbon normalized concentrations exceed the OME values; "Yes^{ND}" indicates chemicals were retained due to lack of toxicity information.

Table 4-3
Comparison of Maximum Calculated Pore Water Concentration to Ambient Water Quality Criteria (AWQC)

	AWQC (µg/L)	Maximum Calculated Pore Water Concentration (µg/L)	Retained*
Aldrin	ND	0.0011	Yes[ND]
Alpha chlordane	0.0043 (value for chlordane)	0.0027	No
Atrazine	ND	16.38	Yes[ND]
Chloropropylate	ND	8.50	Yes[ND]
Chlorothalonil	ND	3.27	Yes[ND]
DDD	ND	0.10	Yes[ND]
DDE	ND	0.07	Yes[ND]
DDT	0.001	0.03	Yes
Dieldrin	0.0019	0.03	Yes
Endrin	0.0023	0.01	Yes
Gamma chlordane	0.0043 (value for chlordane)	0.01	Yes
Heptachlor	0.0038	0.0055	Yes
Metolachlor	ND	Not calculated	Yes[ND]
Toxaphene	0.0002	0.38	Yes

*** "Yes" indicates chemicals were retained because the modeled pore water concentrations exceed the AWQC values; "Yes[ND]" indicates chemicals were retained due to lack of toxicity information.**

Final Selection of Chemicals of Potential Concern (COPCs)

- Final COPCs are: DDD, DDE, DDT, and toxaphene
- Atrazine, chloropropylate, chlorothanil, and metolachlor were retained through screening because of the lack of appropriate toxicity screening

values. However, of the 57 samples collected in non-remediated areas, atrazine, chloropropylate, chlorothanil, gamma chlordane and metolachlor were either not reported or not analyzed for consistently. Because of the lack of data for areas relevant to future exposure, these chemicals were dropped as COPCs.

- Heptachlor, although sampled adequately (57 times) was only detected above the limit of detection once (26 µg/kg in the Field F canal). Because of the lack of a significant number of detections and the fact that the one detection was not in the field (representative of the major areas of exposure), heptachlor was eliminated as a COPC.

Additionally, the chemicals retained as COPCs (DDD, DDE, DDT, and toxaphene) are among those with highest potential for toxicity. Therefore, basing the risk assessment upon these chemicals should provide evaluation of the most significant potential risk factors.

4.3 Receptor Characterization

Receptors selected for specific evaluation, especially quantitative risk estimation, in an environmental risk assessment should be demonstrably relevant in terms of both the ecosystem characteristics at the site under investigation and sensitivity to the chemicals of potential concern. Less sensitive species will be protected as a matter of course if adequate protection can be provided for the sensitive species.

A description of the relevant ecosystem that is expected to exist in the restored wetlands at the Duda property and species expected to use it serves as the first step in determining appropriate receptors. In addition, the presence of endangered or otherwise protected species should be noted. Subsequently, a list of receptors for risk estimation can be developed.

4.3.1 Ecosystem description and identification of species present

While the Duda property has been utilized as cultivated agricultural land, this evaluation considers the situation following permanent flooding of the land.

A number of similar areas are present on the north side of Lake Apopka to use as a basis for anticipating the ecosystem that will invade and develop at the Duda property (Figure 2a and 2b). As described in Section 2, it is anticipated that a fairly typical Florida wetland ecosystem, with shallow and deep areas, will result. While the property will be isolated from the rest of the Lake Apopka system by dikes for an extended period following flooding, it is anticipated that benthic species and some fish will invade. Also, it is anticipated that bird species will make extensive use of the flooded areas immediately as an opportunistic food source, and will begin establishing home ranges in the wetlands. These assumptions are also based on analogy to the situation occurring when the fields have been intermittently flooded as a part of agricultural practices in the past. Finally, when the Duda property is eventually connected to the Lake Apopka system, all of the local native species can be assumed to have access to this lake and wetlands. Once fully integrated, the ecosystem that will develop will be extremely similar to the existing lakes and wetlands on the north side of Lake Apopka.

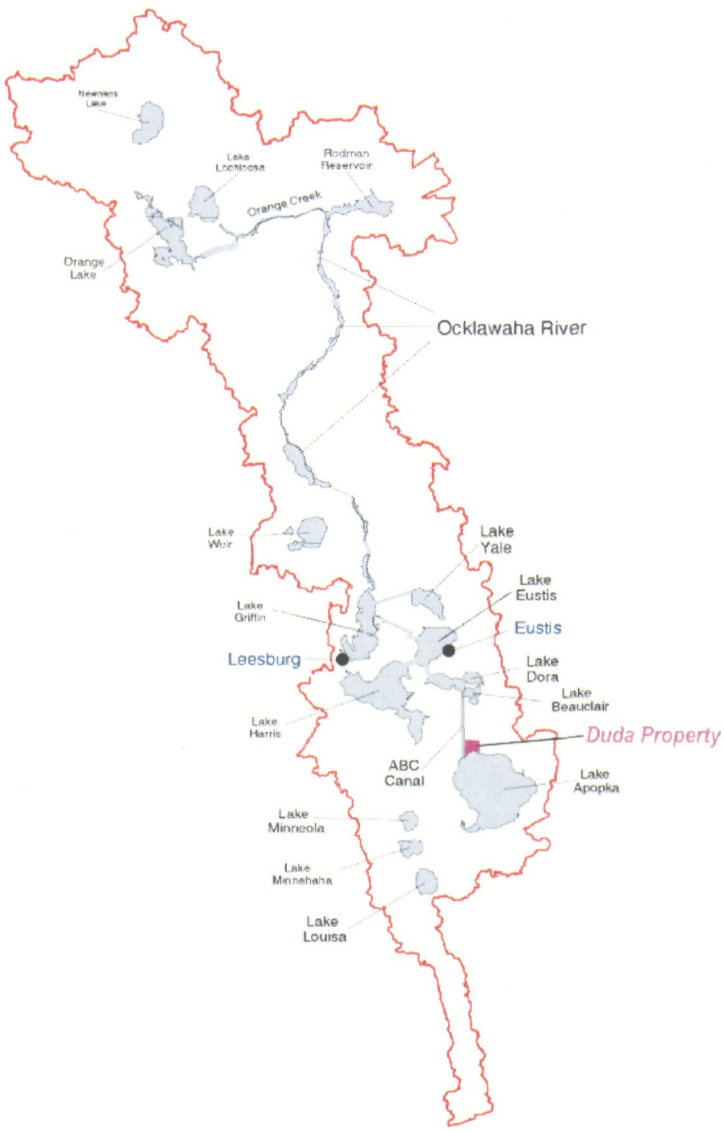
Species that are anticipated to use the Duda property can be assumed to be those observed at similar nearby sites. Field observations have been made at various locations. Examples of the fish and non-avian wildlife species observed around similar areas (uplands included) are listed in Table 4-4. Birds observed utilizing similar areas are listed in Table 4-5. Plants found in the area are listed in Table 4-6. While these observation lists do not represent a comprehensive index of all potential invading species, they provide a reasonable characterization of the expected ecosystem and serve as an adequate basis for identifying specific receptors of concern for the evaluation of the Duda property.

4.3.2 Threatened and endangered species

Because of special standards of protection afforded to federal and state listed species, the possible presence of these species must be considered in characterizing potential risks and determining management strategies. It is also necessary to determine whether any such species should be considered for direct analysis as potentially sensitive receptors. Listed species (threatened, endangered, or species of special concern) observed in similar environments around the Duda property are italicized and categorized in Tables 4-4 and 4-5. No listed species were selected as receptors for direct analysis of potential risks because they were either not considered likely to be among the most affected or most sensitive by the anticipated exposure pathways, or there was insufficient information available for developing relevant toxicity values.

While some listed piscivorous and wetlands bird species are expected to utilize the restored ecosystem, this will not represent completely new exposure potential. Such species have been observed making opportunistic use of the property during periods when it has been flooded as a part of agricultural practice. Thus, they have been realizing exposure to contaminants in the flooded soil while there have been continuing sources of chemical input and agricultural uses. Analogous exposures can be expected for some species immediately after the flooding of the property for wetlands restoration. Over time, however, precluding new soil tilling and inputs of chemicals, degradation and persistent sedimentation are expected to produce a net reduction in the potential for exposure among colonizing species (including listed species). Thus, overall it is anticipated that the restoration strategy will reduce potential risks to listed species.

Also, maintaining a flooded state in the former fields for an extended period, and not having routine cycles of flooding and draining is expected to reduce use of the area by species that opportunistically feed on the disturbed benthic organisms during these cycles.



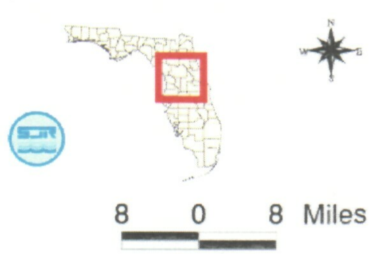


Figure 2a
Lakes in the Upper Ocklawaha Basin including the Duda Property

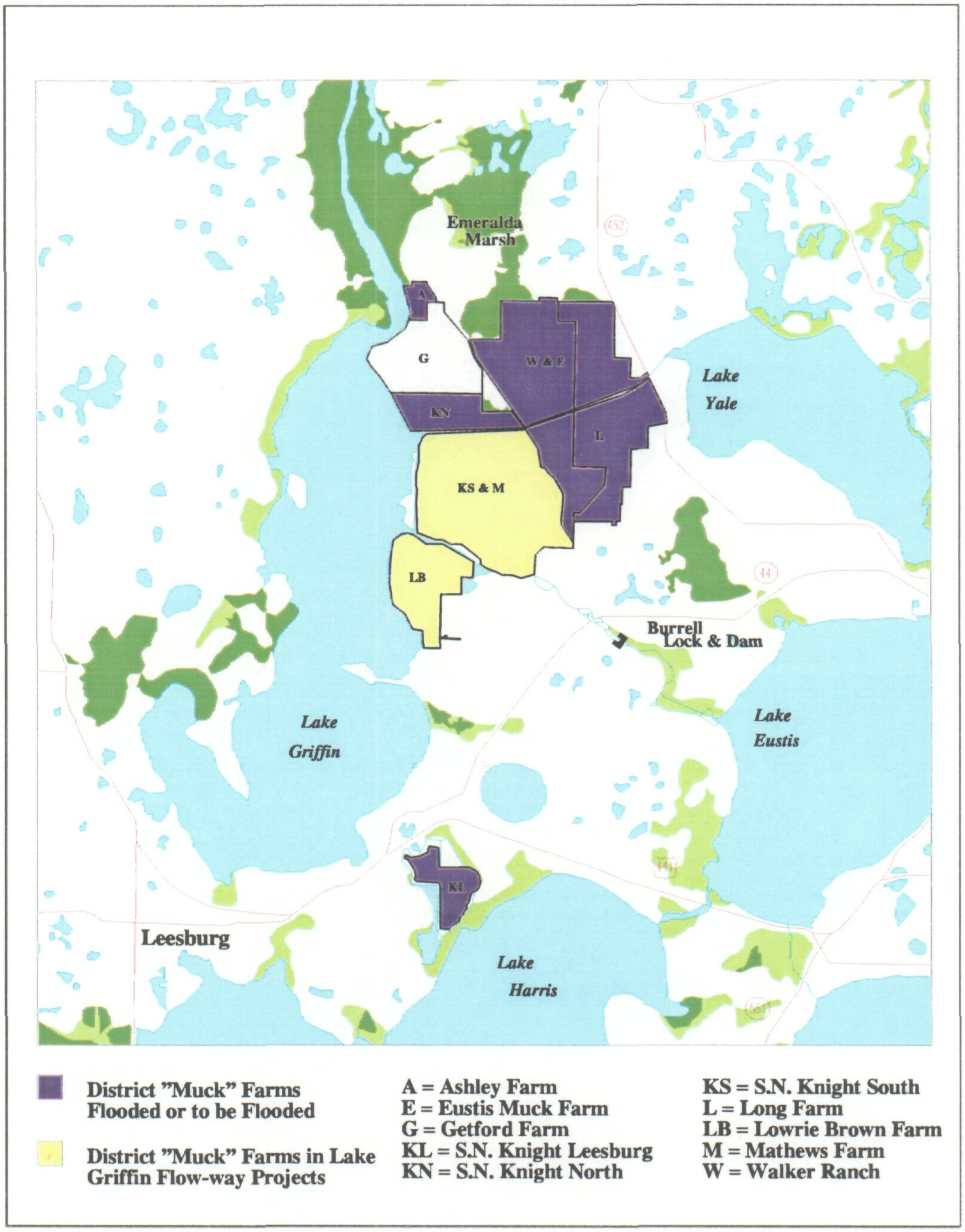


Figure 2b

SJRWMD "Muck Farms" that are currently part of the wetland restoration program.

Table 4-4
Fish and Non-Avian Wildlife Species Observed in the Lake Apopka Marsh Restoration Project (Stenberg et al., 1997)

Fish	
Blue tilapia	Largemouth bass
Bluegill	Least killifish
Bowfin	Red-ear sunfish
Brown bullhead	Sailfin molly
Eastern mosquitofish	Seminole killifish
Florida gar	Warmouth
Mammals	
Armadillo	Mouse
Bobcat	Opossum
Florida water rat	Otter
Marsh rabbit	Raccoon
Reptiles	
Alligator snapping turtle	Brown water snake
Florida box turtle	Common garter snake
Florida red-bellied slider	Coral snake
Florida soft shell turtle	Corn snake
Map turtle	Crayfish snake
Peninsula cooter	Eastern diamondback rattlesnake
Snapping turtle	*Eastern indigo snake -- Fed, St. Threat.*
Southern painted turtle	Florida black snake
Stinkpot turtle	Florida cottonmouth
Stripe-necked musk turtle	*Florida pine snake -- SSC*
Striped mud turtle	Green water snake
American alligator --SSC	Rough green snake
Brown anole	Scarlet king snake
Five-lined skink	Southern ring-neck snake
Green anole	Yellow rat snake
Amphibians	
Bullfrog	Pig frog
Chorus frog	Southern leopard frog
Cricket frog	Southern toad
Eastern narrow-mouth toad	Spring peeper
Green tree frog	Greater/lesser siren
Green frog	Two-toed amphiuma

SSC = Species of Special Concern *Fed/ St. Threat. = Federal and State Threatened Species*

Table 4-5
Bird Species Observed in Restored Wetlands of the Upper Ocklawah River Basin

American bittern	Bobwhite
American coot	Bonaparte's gull
Am. white pelican	Brown thrasher
Anhinga	Cape May warbler
Black-crowned night heron	Carolina wren
Black-necked stilt	Caspian tern
Cattle egret	Cedar waxwing
Common moorhen	Chimney swift
Double-crested cormorant	Chipping sparrow
Glossy ibis	Chuck-will's widow
Great blue heron (Great white heron)	Common ground dove
Great egret	Common nighthawk
Green heron	Common snipe
King rail	Common yellowthroat
Least bittern	Downy woodpecker
Limpkin	Dunlin
Little blue heron -- SSC	Eastern bluebird
Mottled duck	Eastern kingbird
Purple gallinule	Eastern meadowlark
Roseate spoonbill -- SSC	Eastern phoebe
Sandhill crane -- St. Threat.	European starling
Scarlet ibis	Field sparrow
Snowy egret -- SSC	Fish crow
Sora	Forester's tern
Tricolored heron -- SSC	Gray catbird
Virginia rail	Great crested flycatcher
White ibis -- SSC	Greater yellowlegs
Whooping crane -- SSC, Fed. Threat.	Hairy woodpecker
Wood stork -- Fed/St. Endang.	Herring gull
Yellow-crowned night heron	House sparrow
	House wren
Am. kestrel	Indigo bunting
American swallow-tailed kite	Killdeer
Bald eagle -- Fed/St. Threat.	Le Conte's sparrow
Barn owl	Least sandpiper
Barred owl	Lesser yellowlegs
Black vulture	Loggerhead shrike
Burrowing owl	Long-billed dowitcher
Cooper's hawk	Louisiana waterthrush
Eastern screech owl	Magnolia warbler
Great horned owl	Marsh wren
Merlin	Mourning dove
Northern harrier	N. cardinal
Osprey	N. mockingbird

SSC = Species of Special Concern   Fed/St. Endang. = Federal and State Endangered Species
Fed.and/or St. Threat. = Federal and/or State Threatened Species

Table 4-5 (continued)
Bird Species Observed in Restored Wetlands of the Upper Ocklawah River Basin

Peregrine falcon	N. parula
Red-shouldered hawk	N. rough-winged swallow
Red-tailed hawk	Northern flicker
Sharp-shinned hawk	Orange-crowned warbler
Turkey vulture	Orchard oriole
	Ovenbird
Am. black duck	Painted bunting
Am. widgeon	Palm warbler
Blue-winged teal	Pileated woodpecker
Bufflehead	Prairie warbler
Canada goose	Purple martin
Canvasback	Red-bellied woodpecker
Common loon	Red-eyed vireo
Fulvous whistling duck	Red-headed woodpecker
Gadwall	Red-winged blackbird
Green-winged teal	Ring-billed gull
Hooded merganser	Royal tern
Lesser scaup	Rufous-sided towhee
Mallard	Savannah sparrow
N. pintail	Scrub jay
N. shoveller	Sedge wren
Pied-billed grebe	Semipalmated plover
Ring-necked duck	Semipalmated sandpiper
Ruddy duck	Short-billed dowitcher
Wood duck	Solitary sandpiper
American crow	Solitary vireo
American goldfinch	Song sparrow
American pipit	Spotted sandpiper
American redstart	Summer tanager
American robin	Swamp sparrow
Bank swallow	Tree swallow
Barn swallow	Tufted titmouse
Belted kingfisher	Western sandpiper
Black skimmer -- SSC	Whip-poor-will
Black&white warbler	White-eyed vireo
Black-throated blue warbler	Willet
Black-throated green warbler	Wood thrush
Blackpoll warbler	Woodcock
Blue grosbeak	Yellow warbler
Blue jay	Yellow-bellied sapsucker
Blue-gray gnatcatcher	Yellow-billed cuckoo
Boat-tailed grackle	Yellow-rumped warbler
Bobolink	Yellow-throated warbler

SSC = Species of Special Concern *Fed/St. Endang. = Federal and State Endangered Species*
Fed.and/or St. Threat. = Federal and/or State Threatened Species

Table 4-6
Plant Species Observed in the Lake Apopka Marsh Restoration Project (Stenberg et al., 1997)

Acer rubrum	Ludwigia peruviana
Alternanthera philoxeroides	Ludwigia spp.
Amaranthus australis	Lythrum alatum
Ambrosia artemisifolia	Melothria pendula
Andropogon	Mikania scandens
Apiaceae	Myrica cerifera
Aster subulatus	Najas sp.
Azolla caroliniana	Nitella sp.
Baccharis halimifolia	Nuphar lutea
Bacopa caroliniana	Nymphaea mexicana
Bidens laevis	Nymphaea odorata
Bohemeria cylindrica	Panicum hemitomon
Carex sp.	Panicum sp.
Cardamine sp.	Paspalum sp.
Cassia spp.	Peltandra virginica
Cephalanthus occidentalis	Physalis sp.
Cladium jamaicense	Pluchea odorata
Commelina diffusa	Pluchea rosa
Conyze canadensis	Polygonum densiflorum
Cynadon dactylon	Polygonum hydropiperoides
Cyperus spp.	Polygonum punctatum
Decodon verticellatus	Polygonum sp.
Digitaria sp.	Pontederia cordata
Echinochloa spp.	Rhynchospora sp.
Eclipta alba	Rumex sp.
Eichhornia crassipes	Saccioplepis striata
Eleocharis sp.	Sagittaria latifolia
Eleocharis vivipara	Sagittaria lancifolia
Eleusine indica	Salix caroliniana
Eriocaulon sp.	Salvinia
Eupatorium capillifolium	Salvinia rotundifolia
Fuirena spp.	Sambucus canadensis
Gallium tinctorium	Saururus cernuus
Gnaphalium sp.	Scirpus californicus
Hydrocotyle spp.	Scirpus cubensis
Hydrocotyle umbellata	Scirpus spp.
Ipomoea spp.	Senecio gabellus
Juncus effusus	Setaria magna
Juncus spp.	Solanum spp.
Kosteletskya virginica	Solidago spp.
Lachnanthes caroliniana	Spirodela polyrhiza
Leersia hexandra	Typha domingensis
Lemna sp.	Typha latifolia
Limnobium spongia	Utricularia spp.
Ludwigia alata	Websteria conforvoides
Ludwigia leptocarpa	Wolfiella spp.
Ludwigia octovalvis	Woodwardia virginica

4.3.3 Selected receptor species

Receptors selected for risk evaluation should be selected to account for the major potential pathways of exposure, and potentially sensitive species. Practical considerations regarding which species may be adequately represented by extrapolations of the available toxicity data are also of concern. Species for which direct toxicity tests have been reported involving the relevant environmental matrix and exposure pathway are the most appropriate. When this is not available, the closest taxonomic relationship that is possible and the most similar type of exposure are used as the basis of determining suitable receptor species.

The primary source of contaminant anticipated in the restored wetlands at the Duda property is the soils that have been turned into sediment. One of the major exposure pathways is through direct contact of benthic organisms with this substrate. Benthic species will have direct contact with both sediment particles and the interstitial pore water surrounding them. Various benthic invertebrates ingest, excavate and/or form chambers from sediments. This varied potential for direct contact makes benthic invertebrates among the most highly exposed organisms to sediment-associated contaminants.

While the primary source of contaminant at the Duda property will be sediments, the exposure pathway anticipated to be the most significant toxicologically involves biotic transfers from the primary source up the foodchain with concomitant biomagnification. The anticipated significance of this exposure pathway is due to the chemical-specific bioaccumulative potential of many of the chemicals involved. The chemical properties of many of the organochlorine compounds favors their association with lipids in biological tissues and subsequent storage. This potential means that the highest levels of exposure can occur at the top of the foodchain. Multiple steps of contaminant storage and concentration may have occurred prior to the consumption of prey organisms by top-level predators. Thus, top-level predators, including fish such as the brown bullhead catfish and largemouth bass and fish-eating birds such as the great blue heron, are also important receptors for consideration.

The species selected for evaluation as potential receptors at the Duda property are summarized in the following table and discussed below.

Species	Rationale
Benthic invertebrates	*Direct contact with sediments*
Brown bullhead	*Both high-level predator and benthic opportunist*
Largemouth bass	*Top-level predator*
Great blue heron	*Piscivorous bird*

4.3.3.1 Benthic Invertebrates

To evaluate this exposure pathway, a generic sediment-dwelling invertebrate is considered as a receptor. The particular benthic species that will occur at the restored wetlands are difficult to predict, but on the basis of their ubiquitousness it is clear that insects, larvae, amphipods, and various types of worms will move in and make use of the shallow water and sediment. Rather than attempt to predict toxicity for a particular species at the Duda property, the benthic invertebrate species (epifauna or infauna) associated with the most relevant and sensitive toxicity testing results for each chemical of concern was assumed to be present. In other words, the Duda property sediments were evaluated to determine if the concentrations present were high enough to result in toxicity for a relatively well-studied, sensitive benthic species. It is assumed that if this species is adequately protected, then the actually occurring species at the site are also protected. The species utilized as receptors for each chemical are identified in Section 4.5 along with the specific toxicity values.

4.3.3.2 Brown Bullhead

The brown bullhead catfish (*Ameiurus nebulosus*) was selected as a receptor because it is a high-level predator as well as a benthic opportunist and there is a relatively large database of both local exposure and toxicity information to use in estimating potential risks. Bullhead catfish are opportunistic feeders, are known to prey upon second and third trophic level fishes, and frequently stay at the bottom of water bodies. These characteristics make it likely that they will consume substantial amounts of prey items that have high potential for contact with sediment-associated contamination and for foodchain accumulation of contaminants. Brown bullheads are found in the Lake Apopka system, and it is reasonable to assume that they will utilize the restored wetlands at the Duda property.

Species-specific biota-sediment accumulation factors (BSAFs) for the brown bullhead could be derived for chemicals of potential concern at the Duda property using both fish tissue concentrations and sediment concentrations obtained from nearby areas with similar sediment characteristics. This means that current, analogous, and directly measured associations between sediment concentrations and brown bullhead tissue concentrations can be used as the basis for evaluating the potential exposure at the Duda property.

Also, toxicity testing results are available for a number of bullhead catfish species, including channel catfish and black bullheads. The availability of results from several catfish species allows sensitive endpoints and toxicity values to be used as the basis for deriving toxicity reference values (TRVs).

4.3.3.3 Largemouth Bass

The largemouth bass (*Micropterus salmoides*) is a top-level predator in many Florida lake systems and is also a species of interest for resource and fisheries management. Its feeding habits provide the largemouth bass with substantial potential for exposure to contaminant concentrations magnified up the foodchain. Largemouth bass are found in the Lake Apopka system, and it is reasonable to assume that they will either colonize or be stocked in the restored wetlands at the Duda property. Also, largemouth bass spawn in shallow wetlands, so it is reasonable to assume that they will eventually use the restored wetlands at the Duda property for reproduction.

Species-specific BSAFs for the largemouth bass could also be derived for chemicals of potential concern at the Duda property using both fish tissue concentrations and sediment concentrations obtained from nearby areas with similar sediment characteristics (Marburger et al., 1997). This means that current, analogous, and directly measured associations between sediment concentrations and largemouth bass tissue concentrations can be used as the basis for evaluating the potential exposure at the Duda property.

Also, toxicity testing results for largemouth bass are available for a number of the chemicals of potential concern, and studies have been carried out using larval, juvenile, and adult bass. The availability of results from this species allowed sensitive endpoints and toxicity values to be used as the basis for deriving toxicity reference values (TRVs) for the largemouth bass.

4.3.3.4 Great Blue Heron

The great blue heron (*Ardea herodias*) is the largest piscivorous wetlands bird that is expected to utilize the restored wetlands at the Duda property. Great blue herons consume a relatively large amount of fish and fish make up a very large proportion of their diet (USEPA, 1993a). In addition, because of their size, great blue herons can consume the larger size classes of fish. Larger fish from high on the foodchain have the most potential for bioaccumulation of contaminants. Great blue herons do not have strictly adhered to territories in their feeding areas, however they feed over a range of from around 6 to 20 acres (USEPA, 1993a). Given the size of the Duda property, this small feeding range suggests that herons using the restored wetlands would be likely to obtain all of their diet from within the property. Thus, in comparison to other piscivorous and wading birds, even other heron species, it is reasonable to assume that the great blue heron has the highest potential for exposure to contaminants through the foodchain and thus serves as the sensitive species for determining the potential risks to piscivorous birds using the Duda property. For this reason it was assumed that 100% of the fish diet was from Duda property.

Local estimates of food intake and other exposure related parameters are not available for great blue herons in the Lake Apopka area. However, the species has been relatively well studied and preferred factors for estimating exposure have been identified in the USEPA's *Wildlife Exposure Factors Handbook* (USEPA, 1993a). These values are used in estimating the exposure potentially realized by great blue herons through consuming fish with bioaccumulated contaminant concentrations. The concentrations in the fish are derived using the same BSAF methodology outlined above to estimate transfer from sediment to fish. The highest tissue level estimated among the largemouth bass or brown bullhead for each chemical was assumed to be the concentration present in all the fish consumed by the heron. This is a conservative assumption since it is not likely that large, maximally impacted fish make up the entire diet of the birds.

Direct toxicity testing results for dietary exposure in great blue herons are also not available. However, conservative extrapolations of the potential for toxicity can be derived from feeding studies with other birds. These results are adjusted downward to account for potential species sensitivity differences using uncertainty factors specified by USEPA Region VIII (USEPA, 1994a). The derivation of toxicity values for each individual chemical of concern is discussed in Section 4.5, below.

4.3.3.5 Other Potential Receptor Species Considered

The selected receptor species were chosen because of their anticipated sensitivity to the exposure pathways of concern for the area and the availability of toxicity information relevant to the estimation of potential risks. These receptor species are intended to serve as sentinels, or surrogates for the collection of populations that might use the area. Other potential receptor species were considered based on experience with typical Florida ecosystems and discussions with field biologists familiar with the particular area. A brief discussion of the rationale for not using some obvious contenders for quantitative risk estimation is included.

Investigations of potentially chemical related impacts in Lake Apopka have focused on the American alligator (*Alligator mississippiensis*). Alligators are top level predators, opportunistic, and quick to colonize new areas. Based on observed pathologies, reproductive/developmental endpoints in alligators have been suggested as indicators of possible chemical toxicities (Guillette et al., 1994; Rice and Percival, 1996; Crain et al., 1997) . The potential for reproduction to represent an especially sensitive endpoint for exposure to chemicals that can modulate endocrine function has been suggested by several of these authors.

These endpoints are clearly of interest for analyzing potential risks, however, there is currently no quantitative data linking particular doses of the chemicals of concern for the Duda Property to particular effects. Without some way to quantify the dose/response relationship, there is no way to derive a value to use in estimating risks. In addition to the Lake Apopka literature, general toxicity testing literature was reviewed to identify any testing results that could be applied to an alligator receptor.

No usable testing results from any reptiles or amphibians were identified for the chemicals of concern at the Duda property. On this basis, reptile and amphibian species were eliminated as receptors for risk estimation because of the extent of uncertainty associated with the toxicity database. Further, studies evaluating reproduction and the development of fry were available for fish species and were considered. Therefore, it is reasonable to suggest that the potential for these effects was considered, and the best quantitative database for analyzing these effects were used. Fish are also considered to be sensitive to endocrine modulation, so this receptor is appropriate.

Other piscivorous bird species were also considered as possible receptors. Other heron species, such as egrets, and anhingas (cormorants) are common to Florida wetland ecosystems and feed on fish. However, the great blue heron was considered to represent the most sensitive potential receptor among the various species. As the largest species, great blue herons are expected to take larger size classes of fish that have the higher potential for bioaccumulation. Among the wading birds, great blue herons are also apparently among the most heavily reliant on fish for their diet (USEPA, 1993a; Niethammer et al., 1984). Finally, while they travel to and from their selected feeding grounds, great blue herons appear to have a relatively confined range within which they forage - up to around 20 acres (USEPA, 1993a). This suggests that great blue herons which establish a feeding ground within the restored Duda property are likely to get a large proportion of their diet from within the area.

The great blue heron has also been included as a receptor of concern for many of the studies of the Great Lakes region, so there is a relatively large database on its habits that has been used specifically for environmental risk assessment in the past (USEPA, 1993a).

4.4 Exposure Point Concentrations

The exposure point concentration is a conservative estimation of the concentration of chemicals of concern to which receptors are exposed through the relevant pathways. For this ecological risk assessment, the exposure point concentration can be sediment concentrations to which the benthic invertebrates are directly exposed. Additionally, the exposure point concentrations may be tissue concentrations in fish used as a food source by the great blue heron receptor. Tissue concentrations are also used to assess the impact to fish populations residing in the restored wetlands. Such concentrations in biological tissues can be estimated using biota sediment accumulation factors (BSAFs). These factors are representations of the observed relationship between a sediment contaminant concentration and a resulting tissue concentration.

4.4.1 Direct exposure to sediments

Exposure point concentrations were derived using the data described in Section 4.4. Results of the statistical analysis include frequency of detection, arithmetic mean concentration, 95% upper confidence limit (UCL) concentration, and the range of concentration values. Samples in which chemical concentrations were below the limit of detection were included in the analysis by substituting one-half of the analytical detection limit as the point estimate of concentration (USEPA, 1989b).

An arithmetic mean concentration indicates the central tendency of a given *normally* distributed data set. The 95% UCL value not only provides an indication of the "spread" or variability of the data, but also provides a very conservative estimate of a chemical's concentration since, by definition, there is a 95% chance that the UCL value is greater than or equal to the true mean chemical concentration. The 95% UCL values were calculated according to the following formula:

$$95\%\ \text{UCL} = \text{arithmetic mean} + \frac{t_{0.05} \times \text{standard deviation}}{\sqrt{\text{number of values}}}$$

The sessile nature of the benthic receptors being considered in this assessment, allows exposure point concentrations to be calculated assuming each area identified for sampling purposes (Area C, Area D, Area E, Area F-fields and Area F-canals) represents a discrete area of exposure. As a result, consistent with USEPA guidance (USEPA, 1992), the 95% upper confidence limit of the arithmetic mean for each area was calculated and used as the exposure point concentration for benthic species. However, if the 95% UCL concentrations exceed the maximum concentration, the maximum detected value was used to estimate exposure concentrations as recommended by USEPA (1989b).

The derivation of the toxicity reference value (TRV) could be most confidently derived for total DDT (ΣDDT) (Section 4.5). As a result, to assess the toxicity of DDT and metabolites, ΣDDT (the sum of DDD + DDE + DDT) was used. In summing DDD, DDE and DDT, in cases where concentrations were less than the limit of detection, one-half the analytical detection limit was used as the point estimate of concentration. Concentrations are reported in Table 4-7.

Table 4-7
Summary of ΣDDT Carbon Normalized Exposure Point Concentrations*

Area	Maximum Concentration ($\mu g/kg_{OC}$)	95% UCL Concentration ($\mu g/kg_{OC}$)
Area C	**11,536**	28,837
Area D	6,432	**3,151**
Area E	25,640	**7,247**
Area F-Field	4,944	**4,031**
Area F-Canal	6,030	**1,819**

* The values used as exposure point concentrations are indicated in **bold**.

For toxaphene, because of toxicity data limitations, pore water concentrations based on the 95% UCL were derived for use as exposure point concentrations (Table 4-8). Pore water values were calculated as follows, using the approach described in the USEPA *Briefing Report to the EPA Science Advisory Board on the Equilibrium Partitioning Approach to Generating Sediment Quality Criteria* (USEPA, 1989b):

Pore Water ($\mu g/L_{oc}$) = Carbon Normalized Soil ($\mu g/kg_{oc}$) + Toxaphene K_{oc} (L/kg)

Where:

toxaphene Koc = 9.58E+04 L/kg (USEPA, 1996c).

Table 4-8
Summary of Total Toxaphene Exposure Point Concentrations*
(Calculated Pore Water Concentration)

	Maximum Concentration		95% UCL Concentration	
Area	**Soil ($\mu g/kg_{OC}$)**	**Calculated Pore Water ($\mu g/L$)**	**Soil ($\mu g/kg_{OC}$)**	**Calculated Pore Water ($\mu g/L$)**
Area C	ND	--	ND	--
Area D	ND	--	ND	--
Area E	36,000	0.38	**7,222**	**0.075**
Area F-Field	36,000	0.38	**28,978**	**0.30**
Area F-Canal	ND	--	ND	--

ND = Toxaphene was not reported above the limit of detection for these areas;
* The values used as exposure point concentrations are indicated in **bold**.

4.4.2 Area weighted averages

The mobility of the organisms in higher trophic levels (i.e., largemouth bass, catfish, blue heron) being considered in this assessment, necessitate that the exposure point concentration be based on an "area-wide" assessment. By using an "area-wide" exposure point concentration, it is assumed the organisms are exposed equally to all areas of the restored wetlands (i.e., the heron consumes fish that freely migrate throughout the restored areas). The variability in the size of each area being considered, along with inconsistencies in the data collected from each area precludes a straight average or 95% UCL being used as the exposure point concentration. Because the chemical concentration the high-end consumers will be exposed to is directly related to the aerial distribution of that chemical, an area weighted average was calculated for use as the exposure point concentration (Table 4-9). When the distribution of chemical concentrations is distinctly heterogeneous, the surface area weighted average provides the most reasonable approximation of the total exposure.

As such, the arithmetic average was used in the calculation of the area weighted average. The area weighted site average was calculated as illustrated below, using the data included in Table 4-9.

$$\text{Area Weighted Exposure Point Concentration} = \frac{(C \times A_C) + (D \times A_D) + (E \times A_E) + (F_{field} \times A_{Ffield}) + (F_{canal} \times A_{Fcanal})}{\text{Total Area of Reclaimed Area}}$$

Where:

$C, D, E, F_{field}, F_{canal}$ are the arithmetic average concentrations for Area C, Area D, Area E, Area F-field and Area F-canal respectively, and

$A_C, A_D, A_E, A_{Ffield}$, and A_{Fcanal} are the number of acres in Area C, Area D, Area E, Area F-field and Area F-canal respectively.

For example, the area weighted average for ΣDDT is calculated as follows:

$$\frac{(10{,}058x9.0)+(1{,}745x16.5)+(4{,}550x46.3)+(2{,}168x2499.2)+(744x66.8)}{2637.8}$$

$$= 2.2E{+}03\ \mu g/kg_{oc}$$

And the area weighted average for toxaphene is calculated as follows:

$$\frac{(655x9.0)+(1{,}249x16.5)+(4{,}253x46.3)+(15{,}877x2499.2)+(278x66.8)}{2637.8}$$

$$= 1.5E{+}04\ \mu g/kg_{oc}$$

Table 4-9
Normalized Arithmetic Averages, and Acreages for Areas within the Duda Property Used to Calculate Weighted Averages

Area	Average ΣDDT ($\mu g/kg_{OC}$)	Average Toxaphene ($\mu g/kg_{OC}$)	Acres*
Area C	10,058	655**	9.0
Area D	1,745	1,249**	16.5
Area E	4,550	4,253	46.3
Area F-Field	2,168	15,877	2,499.2
Area F-Canal	744	278**	66.8
Weighted Average:	2,200	15,100	

* Information provided by the District

** For the areas indicated toxaphene was never detected above the limit of detection, in order to be conservative one-half the limit of detection was used to derive the concentrations reported.

4.4.3 Derivation of BSAF (biota-sediment accumulation factor)

In order to determine the potential toxicity of the ΣDDT and toxaphene the body burdens of the higher trophic level organisms need to be compared to applicable toxicity reference values. Because the area of concern has not yet been flooded, and is not expected to support a fish population for years, surrogate data must be used to derive body burdens in the receptor species. Using data from nearby marsh restoration areas supplied by the District and Florida Game and Freshwater Fish Commission, BSAF values were calculated using the following algorithm:

$$BASF = \frac{\text{Lipid Normalized Fish Tissue } (\mu g/kg_{oc})}{\text{Carbon Normalized Sediment } (\mu g/kg_{oc})}$$

To calculate a BSAF, fish tissue and sediment data were required. Ideally these data should be temporally and spatially related (i.e., fish samples should be collected from the same location and at the same time the sediment samples are collected). However, although the data being used in this assessment were collected during roughly the same time period (1995-1996), their collection is not coincidental. Fish tissue data from Long Farm provided by Florida Game and Freshwater Fish Commission (Bill Johnson) were used in the final analyses because it appears to be the most complete dataset and the data validation appears to meet typical data quality objectives for risk assessment purposes. These data were collected in July and November of 1995. The July 1995 samples were collected by the Florida Game and Freshwater Fish Commission and were analyzed by Triangle Labs at the request of the District. These data consist of three (3) largemouth bass samples and two (2) brown bullhead samples, all fillets, analyzed for toxaphene, DDD, DDE and DDT. The November 1995 data are all whole fish; six (6) largemouth bass samples analyzed only for toxaphene. These samples were collected by Florida Game and Freshwater Fish Commission and analyzed by Florida Department of Environmental Protection. Lastly, the DDT, DDD, DDE analysis of fish tissue samples (fillet only, brown bullhead and largemouth bass) collected in March of 1996 provided by the District (personal communication, Joy Marburger) were used in the calculation of the BSAF for ΣDDT. These data are summarized in Appendix B.

The fish tissue concentrations used to calculate the BSAF must be lipid normalized (fish tissue concentration ÷ % lipid). For the July 1995 fish tissue samples, lipid analysis was performed for each fillet sample. This information was used to point normalize the fish tissue ΣDDT and toxaphene concentrations. No lipid data were provided with the November 1995 whole-fish chemical analysis, nor the March 1996 fillet analysis. To normalize the whole fish data, whole fish lipid values were calculated from values presented by Winger et al. (1984). Upper and lower Apalachicola River data were presented for three size groups of female, male and eggs of largemouth bass and catfish. The average lipid content of the largest size group of male and female fish was calculated for samples collected in the upper river for largemouth bass (8.6%) and catfish (10.6%). To lipid normalize the fillet data the average percent lipid in the edible portions of fish were used per Sullivan and Otwel, 1992 (1.3% for largemouth bass and 2.7% for catfish). A summary of the fish tissue normalized data used to calculate the BSAF values are presented in Table 4-10.

Sediment data used in the derivation of the BSAF were provided by the District (personal communication, Joy Marburger), collected in September of 1996; and the Florida Game and Freshwater Fish Commission (Bill Johnson), collected in the spring of 1995. The sediment data used to calculate the BSAF must be organic carbon normalized (sediment concentration ÷ % TOC). Because sample-specific organic carbon analyses was not performed for the sediment samples used, total organic carbon (TOC) data collected in May and June of 1995 were used for normalization. Three samples and one duplicate were collected for the site, and these data were averaged. The resulting arithmetic mean organic carbon concentration was used to normalize sediment data. A TOC value of 44.25% was used to normalize sediment data collected from Long Farm. A summary of the sediment normalized data used to calculate the BSAF values are presented in Table 4-10.

Table 4-10
Summary of BSAF Calculations for Long Farm
(Lipid Normalized Fish Tissue and TOC Normalized Sediment)

Chemical	Normalized Fish Tissue ($\mu g/kg_{OC}$)	Normalized Sediment ($\mu g/kg_{OC}$)	BSAF (for Long Farm)
ΣDDT-BBC	5,270	4,668	1.13
ΣDDT-LMB	15,548	4,668	3.33
Toxaphene-BBC	36,391	28,839	1.26
Toxaphene-LMB	91,002	28,839	3.16

BBC = Brown Bullhead Catfish; LMB = Largemouth Bass
BSAF = Normalized Fish Tissue Conc. ÷ Normalized Sediment Conc.

4.4.4 Derivation of fish tissue levels

The BSAF values modeled for Long Farm were used to derive body burdens in fish species potentially residing at the Duda site after flooding (Table 4-11).

To derive these body burdens it is assumed the present soil pesticide concentration will exist as sediment pesticide concentrations.

Lipid Normalized Fish Tissue (µg/kg_{oc})

= BSAF x Carbon Normalized Sediment (µg/kg_{oc})

Fish Tissue (µg/kg)

= Carbon Normalized Fish Tissue (µg/kg_{oc}) x % Fish Lipid

The sediment (or soil) is carbon normalized using site-specific values. The muck soil composite in the fields has a TOC value of 48% and 52%, an average of these values was used (50%) to normalize the Duda property soil data. In order to determine potential ecological impact, the chemical concentration in the whole fish must be determined. It is necessary to examine the whole fish rather than edible fillets, because wildlife receptors consume the total fish, not just the portions humans consider edible. Whole fish lipid values were calculated from values presented by Winger et al. (1984). Upper and lower Apalachicola River data were presented for three size groups of female, male and eggs of largemouth bass (8.6%) and catfish (10.6%) The average lipid content of the largest group of male and female fish was calculated for samples collected in the upper river. These are conservative assumptions since these result in the highest lipid content, which in turn result in an estimate of high bioaccumulation.

A sample calculation for brown bullhead catfish is as follows:

Lipid Normalized Fish Tissue – BBC (2,486 µg/kg_{oc})

= BSAF (1.13) x Carbon Normalized Sediment (2,200 µg/kg_{oc})

Fish Tissue – BBC (260 µg/kg)

= Carbon Normalized Fish Tissue (2,486 µg/kg_{oc}) x 10.6% Fish Lipid

Table 4-11
Predicted Duda Property Fish Tissue Concentrations Derived from the BSAF Values

Chemical	BSAF	Normalized Sediment (μg/kg_{OC})	Fish Tissue (μg/kg)
ΣDDT-BBC	1.13	2,200	260
ΣDDT-LMB	3.33	2,200	630
Toxaphene-BBC	1.26	15,100	2,000
Toxaphene-LMB	3.16	15,100	4,100

4.5 Derivation of Toxicity Reference Values and Profiles of Primary Chemicals of Concern

The basic approach for evaluating the potential for toxicity from a particular compound in a particular receptor is to compare conservatively derived doses or concentrations associated with the toxicity (or more correctly the lack of toxicity) of the compound to the expected exposure of the receptor. Where the exposure is not anticipated to reach the toxicity reference value (TRV) it may be concluded that there is not a strong potential for risk relating to such toxicity. When the exposure exceeds the TRV, more refined analysis and determination of the relative conservatism, i.e., protectiveness, of the toxicity and exposure estimates is in order to determine if there is a realistic risk of toxic effects.

TRVs are derived based on the most sensitive endpoints and toxicity values that are available and relevant to the exposure pathways and receptors used in an environmental risk assessment. In selecting the toxicity study results to use, the scientific literature, and compendia and databases collected by the USEPA and other relevant agencies are examined. Preferred studies involve doses at which non-lethal endpoints that are reasonably assumed to represent sensitive indicators are analyzed. First priority is given to studies that identify a "no-observable-adverse-effects level" (NOAEL) for a sensitive endpoint following long-term exposure. To generate a NOAEL, there must be information available for multiple doses, at least one of which leads to an observable effect. The NOAEL is the highest of the dose levels which does not produce any effect. Because of the extent of the interest in chlorinated pesticides, there was an atypically large amount of information available for non-lethal endpoints, including reproductive and developmental endpoints for the chemicals of concern for the Duda property and these results were considered and used.

For direct exposure of receptors to environmental media such as sediment or water, TRVs can be readily estimated as concentrations of the chemical in question within the appropriate medium that are expected not to cause toxic responses. This is referred to as an applied dose of the chemical. TRVs as media concentrations are most confidently estimated using the results of toxicity tests with the appropriate medium and the target species, or a species as similar as possible. In order to account for differences in species sensitivity, the duration of the study from which the results were drawn (chronic vs. acute), and the extrapolation from doses shown to cause toxic responses to a "no-effects level," the testing results may be adjusted downward by dividing them by a series of uncertainty factors.

$$\text{TRV} = \frac{\text{Observed Toxicity Test Result}}{\text{Uncertainty Factors (species x duration x effect)}}$$

Such uncertainty factors are clearly arbitrary and intended to be protective, not precise estimates of the toxic potential to the receptor species. A reasonably up-to-date default approach for determining such uncertainty factors is presented by USEPA Region VIII (USEPA, 1994a). It is possible to generate more refined extrapolation models for particular species and chemicals using the scientific literature, however, this effort is typically only justified when the intentional conservatism of the default method produces risk estimates that are unacceptably biased.

TRVs can also be converted from applied doses to body burdens (tissue doses) using bioconcentration factors that are available from some toxicity tests. The conservatism associated with the derivation of the TRV is retained, and bioconcentration factors should also be selected in a conservative manner.

This approach can be useful for generating an estimate of the tissue pesticide levels in the receptor species that are expected not to produce a toxic response. Where tissue sampling and BSAFs are available for estimating tissue levels associated with exposure to the receptors (such as at the Duda property), a toxicity value converted to tissue dose provides a means for directly comparing expected exposure and toxicity. This method was used for deriving tissue level TRVs for the largemouth bass and the bullhead receptors.

Toxicity test results are frequently available for feeding studies on birds. In this case, the exposure to chemicals is via ingestion and the concentrations of the test chemical in the diet fed to the subjects can be used as the basis for deriving a dietary TRV. The concentration in the food source is divided by uncertainty factors to develop a dietary concentration anticipated not to cause toxic effects. When chemical concentrations in the food sources for receptors in a risk evaluation can be estimated (as through the BSAF approach), these concentrations can be compared to dietary TRVs to determine the potential risks associated with consumption of that food source. Since relatively reliable local BSAFs can be estimated for the restored wetlands at the Duda property, this approach is used to estimate the chemical concentrations in the higher trophic level fish that the great blue heron is assumed to ingest. These exposure estimates can be compared to dietary TRVs derived for the great blue heron.

The determination of chemicals of concern for which quantitative risk evaluation was necessary was described in Section 4.2, above. The chemicals identified as the likely risk-driving compounds, toxaphene and ΣDDT are relatively well studied which allowed reasonably confident determination of TRVs for these chemicals for each of the receptors. This means that data was available from a number of toxicity studies, and results directly related to the receptors, or closely related species, in the appropriate medium, could generally be used. A brief profile of each chemical and discussion of the individual TRVs is provided.

4.5.1 Toxaphene

Toxaphene is a variable mixture of polychlorinated camphene compounds used extensively as a pesticide on cotton, vegetable, grain and fruit crops prior to the 1980s. It was frequently used concomitantly with DDT, lindane and other insecticides. By the mid-1970s, toxaphene was one of the most heavily used insecticides in the U.S. These general use patterns appear to apply to toxaphene use in the muck farms around Lake Apopka. Toxaphene was also used as a fish control agent in lakes to remove existing species and clear the way for restocking efforts.

There are currently no permitted uses of toxaphene in the U.S., however, its persistence in aerobic soils has provided a continuing source for contaminant transfer. Transfer from soil through runoff, leaching and resuspension continue to provide mechanisms for water and air contamination. Continuing disturbance of agricultural land through tilling and cultivation is expected to maintain the accessibility of soil sources to runoff and limit the anaerobic degradation of toxaphene. When conditions become anaerobic, experimental toxaphene degradation half-lives have been accelerated from numbers of years to numbers of months or shorter (ATSDR, 1996).

Toxaphene is recognized to be extremely potent in its toxicity to terrestrial insects and fishes. This is consistent with its primary uses. Compared with other chlorinated pesticides, however, toxaphene is not particularly potent in its toxicity to aquatic invertebrates, birds, or mammals (Saleh, 1991). There is still clearly a concern for toxicity among these types of organisms, but this characterization suggests that fish are the organisms that are most at risk and should be considered most closely due to their sensitivity.

Toxaphene is also of particular concern to organisms near the top of the food chain because of its capacity to bioaccumulate. Like many of the organochlorine pesticides, toxaphene is highly lipophilic, allowing it to be stored in fatty tissues of biota. Its persistence and slow metabolism permit body burdens to increase over time and its partitioning to the fatty tissues slows depuration or removal. Thus, at subsequent steps up the food chain, effective doses of toxaphene may be increased to the predator because the prey item has concentrated toxaphene levels from its food sources lower down the food chain.

4.5.1.1 Toxaphene Water TRV for Benthic Invertebrate Receptor

A TRV was estimated for the benthic invertebrate receptor on the basis of toxicity testing results on water-borne exposures of the freshwater amphipod *Gammarus pseudolimnaeus*. No sediment toxicity test results for freshwater invertebrates could be identified. Of the aquatic toxicity tests reported on freshwater benthic invertebrates for toxaphene, the most sensitive chronic test result was obtained for *G. pseuedolimnaeus* (USEPA, 1980). The value reported was 0.18 µg/l. Since this value was from a lifecycle test using a sensitive freshwater amphipod species, the uncertainty factor was set at 1.

$$TRV = \frac{\text{Observed Toxicity Test Result (0.18 µg/l)}}{\text{Uncertainty Factor (1)}}$$

Toxaphene benthic $TRV_{(water)}$ = 0.18 µg/l

Potential risk to benthic invertebrates in the sediments of the restored wetlands at the Duda property can be characterized by comparing this TRV to the pore water concentration estimated to result from the sediment contaminant levels. Derivation of this pore water concentration using the conservative USEPA equilibrium approach was described along with the screening process in Section 4.2.

4.5.1.2 Toxaphene Tissue-Level TRVs for Bullhead and Largemouth Bass

Tissue-level TRVs were estimated for the bullhead catfish and largemouth bass using aquatic toxicity tests results for these species and a bioconcentration factor reported from analogous types of tests. The aquatic toxicity value used for the bullhead was 0.003 mg/l. This was the mean acute LC_{50} (lethal concentration to 50% of the test subjects) value reported for tests with the black bullhead (USEPA, 1980). Following the USEPA Region VIII recommendations (USEPA, 1994a), an uncertainty factor of 10 was assigned since the test involved acute exposure and a factor of 15 was assigned to extrapolate from an LC_{50} to a no-adverse effects level (total uncertainty factor = 150). The uncertainty value is a divisor used to reduce the reference level and thus provide a margin of protectiveness.

For the largemouth bass, the TRV was based on a non-lethal, developmental endpoint to a sensitive lifestage. The aquatic toxicity value used for the largemouth bass was 0.0002 mg/l. This concentration produced developmental effects on the proper formation of backbone structure following exposure of largemouth bass throughout the larval period (Pollack and Kilgore, 1978). Following USEPA Region VIII recommendations (USEPA, 1994a), an uncertainty factor of 10 was applied to account for extrapolation from a non-lethal frank effects level (level at which clearly toxic endpoints were observed) to a no-effects level. This was considered a chronic test with the appropriate species, so no other uncertainty factors were used.

The bioconcentration factor (BCF) used to relate the concentrations in water to tissue levels in the fish was 50,000 for both the bullhead and the largemouth bass. In other words, the tissue concentration associated with the toxic effect in the exposed fish was assumed to be 50,000 times higher than the water concentration. This BCF value was calculated from aquatic toxicity experiments with channel catfish (*Ictalurus punctatus*) analogous to those used to generate the toxicity values (Saleh, 1991). This species was clearly the closest relative to the bullhead for which a specific experimental value was available. No experimental value was available for the largemouth bass or a closely related species, but a range of 10,000 to 69,000 was reported for the only other freshwater species studied, fathead minnow (*Pimephales promelas*). This suggests the catfish value of 50,000 is probably a reasonable default assumption for the largemouth bass, as well.

Bullhead

$$\text{TRV(tissue)} = \text{BCF (50,000) X} \frac{\text{Observed Toxicity Test Result (0.003 mg/l)}}{\text{Uncertainty Factor (150)}}$$

Toxaphene bullhead $TRV_{(tissue)}$ = 1.0 mg/kg

Largemouth Bass

$$\text{TRV(tissue)} = \text{BCF (50,000) X} \frac{\text{Observed Toxicity Test Result (0.0002 mg/l)}}{\text{Uncertainty Factor (10)}}$$

Toxaphene largemouth bass $TRV_{(tissue)}$ = 1.0 mg/kg

Potential risk to bullhead catfish and largemouth bass in the restored wetlands at the Duda property can be characterized by comparing these tissue-level TRVs to the concentrations estimated to result from the sediment contaminant levels using the locally determined BSAFs. Estimating the expected tissue concentration with a BSAF that has been locally validated with actual sediment and fish tissue levels provides the most confident measure of exposure. These tissue levels due to exposure can be directly compared to the derived no-effects levels based on toxicity testing.

4.5.1.3 Toxaphene Dietary TRV for Great Blue Heron

The TRV developed for the great blue heron used a study on sensitive, non-lethal endpoints -- growth and reproduction endpoints for black ducks. A dietary TRV was estimated for the great blue heron on the basis of toxicity testing results in feeding studies with black ducks. There were no results available for wading or piscivorous birds. The value reported was a concentration in the diet of 10 ppm as a chronic no observable adverse effect level (NOAEL) in a two-year study including evaluation of growth and reproduction endpoints (Haseltine et al., 1980). Multiplying this feed concentration by an ingestion rate of 0.162 kg/kg-day for juvenile captive ducks (USEPA, 1993a) yields a chronic daily dietary dose of 1.62 mg/kg-day. Following the USEPA Region VIII recommendations (USEPA, 1994a) , an uncertainty factor of 7 was assigned to account for the extrapolation of results from a species in a different taxonomic family. Since the source study was both chronic and identified a NOAEL, no other uncertainty factors were used.

$$\text{TRV} = \frac{\text{Observed Toxicity Test Result (1.62 mg/kg-day)}}{\text{Uncertainty Factor (7)}}$$

Toxaphene great blue heron $\text{TRV}_{(\text{diet})}$ = 0.231 mg/kg-day

Potential risk to great blue herons in the restored wetlands at the Duda property can be characterized by comparing this dietary TRV to the dose that great blue herons would be expected to receive through consumption of fish from the restored wetlands at the Duda property.

Dividing the daily dose TRV (0.231 mg/kg-day) by an estimated feeding rate for great blue herons (0.18 kg/kg-day -- USEPA, 1993a) yields an estimate of the concentration in the food source that would produce the TRV (1.28 mg/kg). In other words, when the concentration of toxaphene in the fish consumed by great blue herons is less than 1.28 mg/kg, the herons would not be expected to receive a dose equivalent to the conservatively derived TRV. The concentrations in the fish can be estimated using the BSAF approach.

4.5.2 DDT/DDE/DDD

DDT is a variable mixture of polychlorinated biphenyl compounds used extensively for mosquito control and as a pesticide on cotton, soybean, peanut, and other crops up until the early 1970s. Technical mixtures of DDT were among the first widely used organochlorine pesticides and usage peaked in the late 1950s to early 1960s. DDE and DDD are among the most significant metabolites of DDT. DDD was also manufactured for use as a pesticide. DDT and DDE are extremely persistent and recognition of this feature along with their potential for bioaccumulation lead to elimination of DDT use in the U.S.

There are currently no permitted uses of DDT, DDE, or DDD in the U.S., however, its persistence in soil has provided a continuing source for contaminant transfer. Transfers from soil through runoff, leaching and resuspension continue to provide mechanisms for water and air contamination. Continuing disturbance of agricultural land through tilling and cultivation is expected to maintain the accessibility of soil sources to runoff and limit the degradation of DDT. The rate of degradation of DDT is enhanced under flooded conditions which causes the soils to become anaerobic (Samuel and Pillai, 1990).

DDT is considered to be intermediate among organochlorine pesticides in its potency to fish and aquatic organisms. It is not as potent a threat to aquatic organisms as toxaphene. However, the persistence and bioaccumulative potential of DDT are recognized as the basis for concerns about organisms high up the food chain. DDT was first recognized as a problematic environmental toxicant through reproductive failures among birds, eventually ascribed to eggshell thinning.

Therefore, with regard to the restored wetlands ecosystem expected at the Duda property, the potential risks from DDT to piscivorous birds (represented by the great blue heron) are a major factor to consider. There is also toxicity information available for DDT effects on benthic organisms and fish, and these are also evaluated.

Most of the available toxicity tests relating to DDT, DDD, and DDE were carried out with either technical-grade mixtures of DDT, or unspecified mixtures of the compounds. These values are generally most analogous to ΣDDT in the environment (the sum of DDT and its major metabolites). There are clearly proportional differences among the metabolites between the parent pesticide and what is found aged in the environment. However, it is preferable to sum the related compounds and compare that sum to conservatively derived toxicity values from the most extensive database -- technical DDT mixtures. This results in less uncertainty than using the limited information on DDD and DDE and attempting to treat each concentration separately.

4.5.2.1 ΣDDT Sediment TRV for Benthic Invertebrate Receptor

The TRV was based on a sensitive endpoint related to successful reproduction and survival (population counts) for benthic populations. A TRV was estimated for the benthic invertebrate, chironomid (*Chironomus tentans*) on the basis of toxicity assessments for DDT and metabolite contaminated sediment. Following a series of laboratory tests, a concentration of total DDTs of 3000 mg/kg was estimated as the no-effects threshold for chironomid population decline using field collected sediments from a stream system in Alabama (West et al., 1994). The uncertainty factor was set to 1 since this was a comprehensive test on field contaminated sediments using a relevant benthic species. These results are considered to be the most appropriate for determining the potential for benthic toxicity from sediments in the restored wetlands at the Duda property.

$$\text{TRV} = \frac{\text{Observed Toxicity Test Results (3000 mg/kg)}}{\text{Uncertainty Factor (1)}}$$

$$\Sigma\text{DDT benthic TRV}_{(\text{sediment})} = 3000 \text{ mg/kg}$$

Potential risk to benthic invertebrates in the sediments of the restored wetlands at the Duda property can be characterized by comparing this TRV directly to the soil/sediments concentration measured at the Duda property.

4.5.2.2 ΣDDT Tissue-Level TRVs for Bullhead and Largemouth Bass

Tissue-level TRVs were estimated for the bullhead catfish and largemouth bass using aquatic toxicity test results for these species and bioconcentration factors reported from analogous types of tests. The aquatic toxicity value used for the bullhead was 0.018 mg/l. This was the mean acute LC_{50} value reported for the black bullhead (USEPA, 1980). Following the USEPA Region VIII recommendations (USEPA, 1994a), an uncertainty factor of 10 was assigned since the test involved acute exposure and a factor of 15 was assigned to extrapolate from an LC_{50} to a no-adverse effects level (total uncertainty factor = 150).

The aquatic toxicity value used for the largemouth bass was 0.0014 mg/l. This was the mean acute LC_{50} value reported for the largemouth bass (USEPA, 1980). Following the USEPA Region VIII recommendations (USEPA, 1994a), an uncertainty factor of 10 was assigned since the test involved acute exposure and a factor of 15 was assigned to extrapolate from an LC_{50} to a no-adverse effects level (total uncertainty factor = 150).

The bioconcentration factor used to relate the concentrations in water to tissue levels in the bullhead was 99,000 and in the largemouth bass was 317,000. This BCF value for the bass was calculated from aquatic toxicity experiments with largemouth bass analogous to those used to generate the toxicity values (USEPA, 1980). The value used for the bullhead was estimated from toxicity tests with fathead minnows (*Pimephales promelas*). This species was used since it has a lipid content very similar to the bullhead catfish and the value is more conservative than using the value estimated for the bass (lower BCF produces lower tissue-level TRV)

Bullhead

$$\text{TRV(tissue)} = \text{BCF (99,000)} \times \frac{\text{Observed Toxicity Test Result (0.018 mg/l)}}{\text{Uncertainty Factor (150)}}$$

ΣDDT bullhead $TRV_{(tissue)}$ = 11.88 mg/kg

Largemouth Bass

$$TRV(tissue) = BCF\ (317{,}000) \times \frac{\text{Observed Toxicity Test Result } (0.0014\ mg/l)}{\text{Uncertainty Factor } (150)}$$

ΣDDT largemouth bass $TRV_{(tissue)} = 2.96$ mg/kg

Potential risk to bullhead catfish and largemouth bass in the restored wetlands at the Duda property can be characterized by comparing these tissue-level TRVs to the concentrations estimated to result from the sediment contaminant levels using the locally determined BSAFs. Estimating the expected tissue concentration with a BSAF that has been locally validated with actual sediment and fish tissue levels provides the most confident measure of exposure. These tissue levels due to exposure can be directly compared to the derived no-effects levels based on toxicity testing.

4.5.2.3 ΣDDT Dietary TRV for Great Blue Heron

This TRV is based on a sensitive ecological endpoint related to reproductive success- fledging success in field exposed pelicans. A dietary TRV was estimated for the great blue heron on the basis of results from a field study on pelican reproduction. The pelican is a piscivorous bird and the daily dose received at the lowest observable effects level (fledging success) was estimated at 0.027 mg/kg-day from anchovies containing DDT and metabolites (USEPA, 1995). The uncertainty factors recommended by USEPA (USEPA, 1995) for adjusting this value are 3, to extrapolate to a no-effects level, and 1 for other piscivorous large birds (total uncertainty factor = 3).

$$TRV = \frac{\text{Observed Toxicity Test Result } (0.027\ mg/kg\text{-}day)}{\text{Uncertainty Factor } (3)}$$

ΣDDT great blue heron $TRV_{(diet)} = 0.009$ mg/kg-day

Potential risk to great blue herons in the restored wetlands at the Duda property can be characterized by comparing this dietary TRV to the dose that great blue herons would be expected to receive through consumption of fish from the restored wetlands at the Duda property.

Dividing the daily dose TRV (0.009 mg/kg-day) by an estimated feeding rate for great blue herons (0.18 kg/kg-day -- USEPA, 1993a) yields an estimate of the concentration in the food source that would produce the TRV (0.05 mg/kg). In other words, when the concentration of DDT in the fish consumed by great blue herons is less than 0.05 mg/kg, the herons would not be expected to receive a dose equivalent to the conservatively derived TRV. The concentrations in the fish can be estimated using the BSAF approach.

5 RISK CHARACTERIZATION

Risk characterization is the estimation and interpretation of the potential risks relating to the exposure and toxicity characteristics outlined in Section 5. Comparisons between the anticipated, site-related exposure and the potential toxicity of given exposure levels are made. The principal form of comparison used in ecological risk assessment is characterizing the ratio between the estimated exposure at the site and an analogous exposure estimate that is conservatively related to a minimum toxicity threshold (TRV). This ratio is termed the ecological quotient (EQ), and when the quotient is less than one, the site-related exposure is estimated to be less than that associated with the TRV. In other words, it may be conservatively concluded that the potential for realizing toxicity among the receptors is not significant.

$$EQ = \frac{\text{Estimated exposure}}{\text{TRV (Toxicity Related Value)}}$$

When the site-related exposure is higher than that associated with the TRV, the EQ will be greater than one. This type of result suggests that site conditions could result in exposures for which there is a significant potential for toxicity. Clearly, because of the intentionally conservative assumptions and extrapolations, including in the TRV an EQ in excess of 1 does not support a definitive conclusion that toxic impacts would be expected. The conservatism incorporated into the exposure estimate and TRV maximizes the likelihood that toxic effects will not be realized.

When an EQ exceeds 1, determining the realistic potential for toxicity typically is evaluated further using a weight of evidence analysis. This analysis considers critically the basis for the toxicity and exposure estimates, along with associated uncertainties, for the pertinent chemical/exposure pathway/receptor combinations.

5.1 Characterizing Estimated Risks for Duda Property Receptors

Ecological quotients were estimated for the exposure of each receptor to toxaphene and ΣDDT associated with the sediments to be created upon flooding of the Duda property. Direct sediment or interstitial water contact was considered for the benthic invertebrate receptors. Bioaccumulation through foodchain transfers was considered for the bullhead catfish and largemouth bass using local BSAFs. Consumption of fish that were assumed to have bioaccumulated contaminants was considered for the great blue heron.

5.1.1 Ecological quotients for benthic invertebrates

Ecological quotients for the benthic invertebrate receptor based on TRVs for water exposure and the estimation of interstitial water concentrations from sediment concentrations (see 4.2) were calculated for toxaphene (Table 5-1).

Toxaphene was not identified in the sediments from Areas C, D, and F-Canal so no EQ was calculated and it can be concluded that the potential for risk to benthic invertebrates in these areas is not significant.

For Area E, an EQ of 0.42 was estimated. This result suggests that toxaphene exposure for benthic invertebrates in Area E would be substantially below that associated with a no-effects level TRV.

For Area F-Field, an EQ in excess of 1 (1.7) was estimated. This result suggests that toxaphene exposure of benthic invertebrates in the field area could exceed that associated with the no-effects level TRV if exposure similar to the assumed levels (95% UCL of the mean value) was actually realized.

Ecological quotients for the benthic invertebrate receptor based on TRVs for direct sediment exposure to ΣDDT were calculated and presented in Table 5-2.

Concentrations of summed DDT, DDE, and DDD were available for each of the areas considered and these were all substantially below the TRV, yielding EQ estimates that were all well below 1. This result suggests that potential for risk to benthic invertebrates exposed to ΣDDT is not significant.

Table 5-1
Ecological Quotient for Benthic Organisms Exposed to Toxaphene-Containing Sediments (as interstitial water)

	TRV (µg/L)	Duda Pore Water Concentration* (µg/L)	Benthic Ecological Quotient** – Interstitial Water
Area C	0.18	ND	--
Area D	0.18	ND	--
Area E	0.18	0.075	0.42
Area F-Field	0.18	0.3	**1.7**
Area F-Canal	0.18	ND	--

ND = Not detected above the limit of detection; TRV = Toxicity reference value;
*Calculated based on 95% UCL concentration in soils;
**Ecological Quotient = [Pore Water] + TRV.

Table 5-2
Ecological Quotient for Benthic Organisms Exposed to ΣDDT Containing Sediments

	TRV (mg/kg$_{oc}$)	Duda Soil Concentration* (mg/kg$_{oc}$)	Benthic Ecological Quotient** – Sediments
Area C	3000	12	0.004
Area D	3000	3.2	0.001
Area E	3000	7.2	0.002
Area F-Field	3000	4.0	0.001
Area F-Canal	3000	1.8	0.001

TRV = Toxicity reference value;
*Calculated based on 95% UCL concentrations in soils;
**Ecological Quotient = [Sediment] + TRV.

5.1.2 Ecological quotients for high trophic level fish

Ecological quotients for the bullhead catfish and largemouth bass based on tissue-level TRVs and estimated tissue levels from locally validated BSAFs were calculated for toxaphene and ΣDDT (Table 5-3).

Estimated tissue concentrations of toxaphene exceeded the relevant no-effects TRV for both fish. The estimated EQs were 2.0 for the bullhead and 4.1 for largemouth bass. This result suggest that based on the conservative assumptions used in deriving the TRV and the exposure through bioaccumulation, there is some potential for significant body burdens of toxaphene to be realized by the fish. A weight-of-evidence analysis is needed to characterize how realistic is the potential for toxaphene risks through the food chain.

Estimated tissue concentrations of ΣDDT were substantially less than the derived no-effects TRV for both fish, yielding EQ estimates well below 1. This result suggests that potential for risk to higher trophic level fish through bioaccumulation of toxaphene and ΣDDT is not significant.

Table 5-3
Ecological Quotient for Fish Exposed to Sediments (as fish tissue)

	Derived NOAEL Tissue Level (mg/kg)	Predicted Duda Fish Tissue Concentration (mg/kg)	Fish Tissue Ecological Quotient**
Toxaphene			
Brown Bullhead Catfish	1.0	2.0	**2.0**
Largemouth Bass	1.0	4.1	**4.1**
ΣDDT			
Brown Bullhead Catfish	11.88	0.26	0.02
Largemouth Bass	2.96	0.63	0.21

TRV = Toxicity reference value;
**Ecological Quotient = [Fish Tissue] ÷ TRV.

5.1.3 Ecological quotients for great blue heron

Ecological quotients for the great blue heron based on dietary TRVs and levels estimated in their food source using locally validated BSAFs were calculated for toxaphene and ΣDDT (Table 5-4). As described in Section 4.5, dietary TRVs were converted to an associated critical concentration in the food source using a standard feeding rate for great blue herons.

The concentration of toxaphene estimated in the food source fish tissue was above the critical concentration associated with the great blue heron TRV, yielding an EQ greater than 1 (3.2). Based on the conservative assumptions used to predict fish concentrations that could be realized at the Duda property, this result suggests that there is some potential for toxaphene-related risks to the great blue heron associated with ingestion of fish from the restored wetlands. A weight-of-evidence analysis is needed to characterize how realistic is the potential for toxaphene risks through the food chain to piscivorous birds.

The concentration of ΣDDT estimated in the food source fish tissue was above the critical concentration associated with a no-effects TRV for the great blue heron, yielding an EQ of 12.5. This result suggests that ΣDDT exposure of herons consuming fish that had bioaccumulated ΣDDT from the sediments could exceed that associated with the no-effects level TRV if the stated exposure assumptions were actually realized. A weight-of-evidence analysis is needed to characterize how realistic is the potential for toxaphene risks through the food chain to piscivorous birds.

5.2 Weight-of-evidence Evaluation

Using the ecological quotient approach, there was no indication of a significant potential for DDT-related risks to the benthic organisms, bullhead catfish, or largemouth bass receptors. A discussion of the uncertainties associated with these risk estimates is provided (Section 5.3), however, no detailed weight-of-evidence analysis is necessary for these receptors since the EQ method did not identify a significant potential for exposure to exceed conservatively protective levels. For the remaining receptor/chemical combinations, EQ's greater than 1 (one) were estimated, indicating the need for a weight-of-evidence analysis to characterize the potential for risks to be realized.

Table 5-4
Ecological Quotient for Great Blue Heron Consuming Fish Tissue

	Critical Concentration in Food (mg/kg)	Predicted Duda Fish Tissue Concentration (mg/kg)	Dietary Ecological Quotient[a]
Toxaphene			
Blue Heron	1.29	4.1*	**3.2**
ΣDDT			
Blue Heron	0.05	0.63*	**12.5**

TRV = Toxicity reference value;
*Fish tissue value for the largemouth bass;
[a]Ecological Quotient = [Fish Tissue] ÷ TRV.

5.2.1 Toxaphene and benthic invertebrate receptors

For the benthic invertebrate receptor exposure to toxaphene, an EQ of 1.7 was estimated, indicating the need for more critical analysis. Estimated EQs in this range are not typically considered to indicate a strong likelihood for toxic effects to be realized because of the intentional bias introduced into both exposure and toxicity estimates in quantitative risk assessment. In addition, for this benthic invertebrate/toxaphene EQ there is a particular source of conservatism that suggests there is still a substantial degree of protectiveness in the EQ.

The available toxicity data for benthic species exposure to toxaphene included only aquatic toxicity tests, not sediment tests. Therefore a water-based TRV was derived and compared to estimated interstitial water concentrations. The simple equilibrium partitioning model recommended by the USEPA and used in this assessment to estimate interstitial water concentration from bulk sediment (Section 4.4) generally provides an overestimate of the water concentration, primarily because matrix geometry factors that affect adsorption to sediment particles are not considered. This overestimation is likely exacerbated when the sediment used as the basis of the model contains unusually high levels of organic matter for adsorption (e.g., Duda property sediments). Also, the model relies upon estimates of the partitioning coefficient (K_{oc}) that were derived based on sediments with much lower organic carbon content than found at the Duda property. Assuming the K_{oc} responds linearly at extremely high levels of organic carbon is a conservative assumption. Based on these factors, it is likely that the estimated interstitial water concentration used in calculating the EQ is higher than will actually be experienced by benthic organisms in the Duda property sediments.

Coupled with the barely significant EQ, the conservative overestimation of the interstitial water concentration suggests that the actual potential for toxaphene-related risks to benthic invertebrates is very limited. The conclusion of the weight-of-evidence analysis is that it is unlikely that toxaphene represents a significant risk to benthic invertebrates even if current soil levels are directly converted to sediment levels.

5.2.2 Toxaphene and the fish receptors

Estimated toxaphene EQs ranged from approximately 2-4 for the fish receptors. Quotients in this range are generally not considered to represent a realistic threat of toxicity because of the conservativeness built into the risk estimation. Results in this range are often interpreted as an indication to revisit the safety factors used to see how much protectiveness has been incorporated and to consider the biological relevance of the various assumptions that have been made. Where such considerations indicate that a degree of safety was built into the estimation that is substantially larger than the exceedance of the EQs, it is reasonable to conclude that the estimated theoretical risks are not likely to be realized. In cases where such considerations indicate that there are biologically relevant indications that the estimated risks are realistic, further analysis of conditions in the field and an examination to see whether the predicted effects are actually occurring would be reasonable.

For the Duda property assessment, review of the derivation of both the exposure estimates and toxicity values used for toxaphene with the fish receptors indicates that there is substantial protectiveness retained in the estimation and that it is unlikely that toxic effects would be realized by these receptors. For both fish, the exposure concentration was predicted using the BSAF approach with sediment and fish tissue levels from other areas. In other words, the predicted levels are not measured directly from the Duda property. An uncertainty factor of 150 was used in conjunction with the bullhead TRV and an uncertainty factor of 10 was used with the largemouth bass TRV. For both TRVs, it was assumed that fish tissue concentrated the toxaphene 50,000 times. This combination of conservative assumptions leads to a reasonable conclusion that exposures exceeding the TRV in the range of 2-4-fold are not likely to represent a realistic risk for the bullhead and largemouth bass receptors for toxaphene.

5.2.3 Toxaphene, DDT and the great blue heron receptor

For exposure of the great blue heron to toxaphene from dietary sources, an EQ of 3.2 was estimated. This estimate represents a relatively modest exceedance of the TRV and analysis of the intentional conservatism incorporated into the risk calculation suggests that this value is unlikely to correspond to a realistic risk to great blue herons. The dietary concentration generating this risk estimate comes from fish tissue predictions based on the BSAF. Again, the BSAF is not directly linked to the Duda property, and the risk calculation assumes that the heron would have consumed its entire dietary intake from fish that had reached this body burden of toxaphene.

In order to estimate the highest potential levels of pesticides in fish tissue that might result from bioaccumulation, the fish were assumed to be large and have correspondingly high proportions of lipid. This conservative estimation was made in order to be protective in considering the fish that the heron might feed upon, and also to allow conservative estimation of the fish tissue levels used in evaluating risks directly to the bullhead and largemouth bass receptors. The lipid proportions play a major role in the potential for retention of organochlorine pesticides and the assumed levels were the highest values (from the largest size classes) for catfish and largemouth bass analyzed in the Apalachicola River system (see Section 4.4).

In estimating exposure for the heron, it was assumed that fish in this size class made up 100% of the heron diet. This is clearly a conservative assumption since great blue herons, like other piscivorous birds, can be observed to be opportunistic about the size of fish they eat, and they clearly do not restrict their foraging to large bass or catfish. Smaller, leaner fish with lower levels of accumulated pesticides and other food sources (frogs, lizards, snakes, small mammals) probably make up the actual bulk of the heron diet, suggesting that the exposure estimate used is a conservative overestimate.

The derivation of the critical dietary concentration for toxaphene assumes that the receptor birds are consuming the specified level of contaminant each day on a chronic basis. It is unlikely that the actual receptors would consume their entire diet from fish containing the predicted levels of toxaphene on a chronic basis.

In addition, the derivation of the TRV and critical dietary concentration is based on a solid no-effects level for endpoints expected to be sensitive (growth and reproduction). In other words exposure at this level was demonstrated not to have an effect. The level at which effects are actually observable is higher than this, possibly as much as 5-times higher according to the original study (Haseltine et al., 1980). In accordance with USEPA Region IV guidance however, the "no-effects" level is the preferred basis for risk estimation when it is available. Finally, there is a 7-fold uncertainty factor built in. This provides an additional margin of safety, and combined with the conservative assumptions about dietary intake, suggests that a risk estimate in the calculated range for toxaphene is not likely to represent a realistic threat to piscivorous receptors.

For exposure of the great blue heron to ΣDDT from dietary sources, an EQ of 12.5 was estimated, indicating the need for more critical analysis. Estimated EQs in this range warrant careful consideration to determine whether the safety margin built into the risk calculations has been significantly compromised. Where there are clear model uncertainties or biological reasons that suggest there is still substantial protectiveness, an EQ in this range does not necessarily indicate a realistic threat to the modeled receptor. However, where there are not identifiable factors contributing substantial conservatism, an EQ in this range would typically warrant efforts in the field to "ground-truth" the potential for effects to be realized. This particular assessment is complicated by the lack of an existing ecosystem to analyze.

Review of the toxicity values and exposure estimates for the blue heron and ΣDDT suggests that there is not a clear rationale to suggest that substantial conservatism exists to ensure protectiveness at an EQ of 12.5. There are factors suggesting that the risks are overestimated by the calculations, but it is not clear that this overestimation is substantially larger than the estimated EQ.

The overestimation of the likely dietary intake of pesticides by herons was discussed above. This argument applies for ΣDDT as well as for toxaphene. In addition, using the ΣDDT provides for additional overestimation since the concentrations of DDT, DDE, and DDD are added directly to generate the BSAFs. This incorporates the assumption that the toxicities of the various DDT-related compound are directly additive and affect the same toxic endpoints. So, there is reason to expect that there is substantial overestimation of the dietary intake of toxic equivalents of DDT.

The critical dietary concentration and TRV for ΣDDT was derived, however, on the basis of a very relevant field study and does not incorporate a large uncertainty factor. Based on the known toxicity of DDT, the endpoint of this study -- fledging success in pelicans, is clearly relevant to estimating the potential risks to a piscivorous bird receptor such as the great blue heron. An uncertainty factor of 3 was applied in conjunction with this study for deriving the TRV. In other words, the safety margin is relatively limited and the potential effect is clearly relevant. On this basis, it is not clear that there is conservatism substantially in excess of the factor of 12.5 predicted by the EQ.

There is too much uncertainty to conclude that there is not some realistic potential for the estimated risks to be realized if the exposure conditions modeled here were met and remained on a chronic basis. It is clear, however, that exposure conditions will change over time at the Duda property and it is reasonable to conclude that exposure concentrations will be reduced as sedimentation and anaerobic degradation reduce the source reservoirs of pesticides. This suggests that whatever the risks to the piscivorous bird receptors, they will be declining over time.

5.2.4 Weight-of-evidence summary

The estimated risks to benthic organisms from toxaphene, the estimated risks to the fish receptors from toxaphene and ΣDDT, and the estimated risks to the great blue heron receptor from toxaphene can be eliminated as realistic risk concerns on the basis of the weight-of-evidence analysis. For all of these cases, there is substantial, identifiable conservatism built into the risk model that is not significantly compromised by the modestly elevated EQs estimated.

For the potential risks to the great blue heron receptor from ΣDDT, it is not clear that there is sufficient identifiable conservatism to ensure that there is no realistic risk if exposures were to occur as modeled. There are clearly factors providing conservatism, but the estimated EQ is large enough that it is not clear that there is adequate overestimation of the potential for risk. This finding suggests that ensuring exposures remain below those predicted by the risk model may be necessary to confidently rule out any potential risk to this type of receptor. Since the risk model includes conservative estimates of the ΣDDT concentration at the site and there are risk management strategies available to both monitor and control exposure (Section 6), it is reasonable to conclude that potential risks can be effectively managed to preclude the assumptions of the risk model being met.

5.3 Sources and Extent of Uncertainty

Uncertainty in an ecological risk assessment can be defined as the lack of information and understanding (ignorance) of the system being analyzed, a phenomenon which can often be reduced by further measurements and study. This is substantially different than variability - a fact of nature that cannot be reduced by further study. Although the variability inherent in the Duda ERA is likely to be high given the prospective nature of the analysis and large numbers of plant and animal species which could potentially inhabit this new environment, the following discussion is limited to the uncertainty in the ERA resulting from assumptions made in formulating and carrying out the analysis. While the ability to reduce uncertainty in the Duda ERA is limited given practical and cost limitations for expanding the database, identification of the major sources of uncertainty can be used to determine the overall strength of the conclusions drawn from the risk analysis and to develop data collection/analysis plans for future restoration projects.

The major sources of uncertainty in the Duda ERA are:

1. Limited analytical database.

As previously stated, a default assumption for the ERA was that the soils of the properties constitute the sole source of chemicals of concern. The area planned for restoration is in excess of 3,000 acres, and the majority of this land was agricultural fields. In fact, the fields constitute approximately 80% of the total surface area of the restoration site. Although roughly 59 discrete and composite soil samples were collected and analyzed for chemical constituents, chlorinated pesticide levels in the agricultural fields were only available from 7 composite samples. Each composite represented 9 individual grab samples, but no information was available on either the location or characteristics of these individual samples.

The use of this limited database to characterize the chemical composition of the site incorporated a certain degree of uncertainty. However, data from the surrounding environment, the homogeneous nature of the fields, and the consistent and widespread application practices, and the consistency in the levels of pesticides reported for the 7 field samples, suggests that these data provided an adequate measure of site characteristics. Also, the limited nature of the data prevented the use of a number of statistical approaches (e.g., krieging, Monte Carlo analysis). As a result, the level of uncertainty inherent in site characterization and in estimating risks is increased.

2. Expected Ecosystem Does Not Exist

Since the intention of the restoration activity is to re-establish a wetland environment, the focus of the ERA (i.e., an aquatic ecosystem) does not yet exist at the site. As a result, the system could not be directly evaluated. That is, community structure, chemical tissue levels, and bioindicators could not be determined and assessed at this site. Similarly, receptors appropriate for evaluation in the ERA could not be directly determined. Therefore, much of the information used to develop quantitative estimates of future risk was developed from environments similar to that expected to exist once the Duda property is flooded. The fact that there exist locations with a high degree of similarity to the Duda property tends to reduce the uncertainty inherent in using this procedure. However, any further reduction in uncertainty associated with attempting to predict future risks when the community is not yet established will be a difficult task.

3. Estimating Bioaccumulation

Associated with the absence of the aquatic ecosystem, the degree of bioaccumulation expected at this site could not be directly determined. This component of the ERA is perhaps the most critical since it determined the magnitude of the movement of the chemicals from sediment to sensitive receptors at higher trophic levels. Also, the lack of an established ecosystem limited the models which could be used to predict bioaccumulation. Successional wetlands of the type likely to be found once Duda is flooded are not clearly understood. Thus, attempts to construct a hypothetical food web with sufficient confidence to be used in the available food web bioaccumulation models could not be performed. As a result, a rather simplistic model, the BSAF, was used for the ERA. While the BSAF was developed using regional data, and from sites with similar physical characteristics, it was not site specific and therefore introduced a degree of uncertainty. That is, at locations where the BSAF can be directly developed (i.e., fish tissue and sediment concentrations concurrently collected at the site), the confidence in the predicted bioaccumulation as the site conditions change is enhanced. This is because, as previously explained, the BSAF integrates the nuances and characteristics of the site by assessing the source (sediments) and the organism of interest.

4. Characterizing Potential Toxicity

Thorough consideration of the toxicity information on the chemicals of potential concern in both the primary scientific literature and regulatory program documents was completed prior to selecting the values used for quantitative risk estimation. Conservative determinations making use of the most sensitive relevant findings were made to help ensure that potential risks were not underestimated. However, identifying toxicity-related values, especially those that can be used for quantitative risk analysis, is necessarily limited to considering results pertaining to toxic effects that have been well studied.

In general, the organochlorine pesticides are a heavily studied group of compounds and their acute toxicity and some of the reproductive effects are relatively well known. In selecting results to use as the basis of deriving TRVs, toxicity tests evaluating various endpoints, including reproductive ones, were available and considered. In some cases (i.e., DDT effects on pelican fledging rate and toxaphene effects on amphipod populations), reproductive endpoints were the most sensitive relevant indicator available and were used. In other cases, direct mortality (with additional uncertainty factors) or developmental endpoints (fish backbone development effects from toxaphene) were used. The endpoints selected were based on the best available current data.

However, over the last several years, there has been growing interest in the potential for many of the organochlorine compounds to interfere with endocrine signaling pathways – endocrine modulation. There is a mechanistic basis for this type of effect, and it can be demonstrated to operate under experimental conditions. There is still no clear evidence or scientific consensus regarding the expression of similar effects at typical environmental contamination levels, however, there are indications of endocrine disruptive effects occurring in the field associated with extreme concentrations such as spills or accidental releases.

Because of the intensive agricultural use and associated organochlorine contamination in the area surrounding Lake Apopka and an accidental spill occurring in 1980, the Lake Apopka system has been a focus of investigations into the potential for environmental expression of endocrine disruption (Guillette et al., 1994; Rice and Percival, 1996; Crain et al., 1997). While there are indications of possible hormonal profile alterations in both alligators and bass from the Lake Apopka system, the ecological significance of these observations is not clear. There are plausible mechanisms by which such alterations could affect populations and clear indications of population-level impacts following intense acute exposure, however there is not yet a clear link between potential population effects and low-level chronic exposure. Thus, it is currently not clear how to incorporate such considerations into quantitative risk analysis. There are currently no data including a dose-response relationship for such endocrine modulation events to use as the basis for deriving a toxicity value for quantitative risk assessment. The available field studies do not provide a dose-response association between a particular exposure level and a particular adverse effect. There are plenty of quantitative laboratory studies on cellular, microbial, and other experimental systems, but there is no relationship for extrapolating these type of results to levels pertinent for ecological receptors in the field.

Specifically significant in terms of carrying out the ecological risk analysis for the Duda property, there are no data available that establish a dose-response relationship for endocrine disruption and exposure to toxaphene or ΣDDT in sediments or overlying water. Thus, there is no way to derive a TRV based on endocrine disruption endpoints and no way to quantitatively estimate a related potential for risk to the receptors. With currently available data, consideration of such potential effects must be limited to qualitative discussion as a potential source of uncertainty.

Based on the expectation that source loading of additional chemicals and soil tilling will be stopped and anaerobic degradation will progress following the flooding of the Duda property, concentrations are expected to decline much more rapidly than for agricultural land. True breakdown (as opposed to contaminant transfer) will be increased. Given the currently available toxicity information and incorporation of the most sensitive available endpoints (including studies on population growth and reproduction and fledging success), the subsequent identification of alternative toxicity endpoints such as endocrine disruption would not likely change the overall conclusions of the risk analysis. This area of research should be monitored, however, and future wetlands restoration projects should be planned using any additional developments in the scientific knowledge base.

5.4 Summary of Risk Characterization

The conclusions of the characterization of the quantitative risk estimates (EQ) and the weight-of-evidence analyses suggest that there would not be significant potential for risks to the benthic and fish receptors from the chemicals of concern following flooding and wetlands restoration at the Duda property. The conclusions likewise suggest that there would not be significant risk to the bird receptor from toxaphene. The results relating to the bird receptor and ∑DDT exposure did not rule out the possibility of potential risks if the exposure conditions used in the assessment are met on a chronic basis. There are factors suggesting that the likelihood of risks being actually realized by this receptor is limited.

The overall conclusion of the risk characterization is that there are not clear indications of realistic risks to benthic organisms or to fish and there is a modestly elevated risk estimated for the great blue heron from ∑DDT that cannot be explained on the basis of known conservatism in the model.

For toxaphene, elevated EQs were calculated for all of the receptors. The weight-of-evidence analysis presented clear reasons why the EQ incorporates conservative overestimation of the potential exposure and concluded that for the endpoints that could be quantitatively evaluated, there are not likely to be significant realistic risks to any of the receptors from toxaphene.

For ΣDDT, the only elevated EQ was calculated for the great blue heron. The weight-of-evidence analysis showed that the conservative assumption that the heron diet is made up of 100% of large fish with maximal potential for bioaccumulation, provides for an overestimation of the exposure likely realized by the heron. However, based on the strength of the available toxicity information, limited uncertainty factors were incorporated into the derivation of the toxicity value for this receptor. The magnitude of the risk estimate was such that it cannot be confidently concluded that substantial conservativeness remains if the exposure conditions are met for this receptor. Environmental levels are anticipated to decline over time and the likelihood of chronic exposure at the predicted level is expected to be limited.

Overall, the discussion of the factors contributing uncertainty to the estimations of exposure and derivation of toxicity values pointed out areas for potential further consideration and identified potential toxic endpoints that could not be considered quantitatively at this time due to limited knowledge about dose-response characteristics. The available risk estimates coupled with the expectation that these chemicals will undergo substantial burial/degradation once the land is flooded provide a strong argument for the lack of significant identifiable risks. The areas and degree of uncertainty are not adequate to alter this overall conclusion.

6 RISK MANAGEMENT RECOMMENDATIONS

Risk management is a formalized process which integrates the results of a risk assessment along with other factors (i.e., legal or economic concerns) to derive environmental decisions. For the Duda property, the management decisions are primarily a function of the predicted timeframe to "recovery" of the former wetland habitat. That is, the wetland restoration program is not reliant upon a remedial or removal action, and therefore the ability of the natural system to repair itself is the primary risk mitigation option for the Duda property. The EPA has termed this process "natural recovery" (or natural attenuation) and considers this an important component to be considered when selecting techniques for remediating sediments (USEPA, 1991):

> *No action is an option because natural sedimentation can bury and contain pollutants. . . The natural degradation and solution process can sometimes reduce contaminant loads. . . The no-action option is appropriate when the pollutant discharge source has been halted, burial or dilution processes are rapid, sediment will not be remobilized by human activities, and environmental effects of cleanup are more damaging than allowing the sediments to remain in place.*

For this site, the cause of risk to ecological receptors are chemical constituents and to some extent, the lack of suitable habitat. Though the quantitative evaluation of the absolute potential risks is complicated by the fact that the ecosystem under evaluation does not yet exist, from a comparative risk standpoint, there are major factors pointing toward improvements in risk associated with the restoration of the wetlands. The land is being converted from an active agricultural facility that utilizes a relatively intense form of farming. The management goal is to allow the site to develop into a wetland typical for the region. Under its current use, the physical stressors of minimal and disturbed habitat would remain. In addition, it is reasonable to expect that chemical stressor loads would remain or increase. This relates to both specific toxic chemicals such as pesticides and to nutrient loading of the area water bodies due to fertilizer runoff.

Whatever the current chemical stressors mean in terms of projected risks to a restored wetlands ecosystem, such a restoration would begin the process of decreasing chemical loads and re-establishing a more diverse and dynamic ecosystem. Restoration to wetlands will clearly yield an overall reduction in potential long-term risks to the immediate area of the Duda property and to the comprehensive Lake Apopka ecosystem. Conversely, failing to limit additional chemical loading and turning of the soils will result in continued additions to the overall potential risks.

The ERA addressed only those risks associated with chemical exposure, since it is assumed that the flooding procedures will be performed in such a manner as to encourage the establishment of the preliminary stages of successive habitat development. As previously mentioned, the soils of the property were assumed to be the sole source of the chemical stressors to the established ecosystem. The fate of the chemical constituents in these soils is the specific focus of the evaluation of the effectiveness of natural recovery processes.

6.1 Natural Recovery and Sediment Half-Life

There are two main categories of sediment natural recovery. The reduction in the effective concentration of a particular compound in sediments results from the breakdown of the chemical constituent by biological ("biodegradation"), physical, or chemical activity or the dilution of the chemical in sediments by the addition of clean material (i.e., sedimentation). The former mechanism results in mass reduction, while the latter results in exposure reduction. That is, while the mass of the chemical in the system does not decrease as a result of sedimentation, the effective concentration at the point of exposure does decrease. This reduction in exposure carries with it a concomitant reduction in toxicity. The consideration of the effect of sedimentation on the risks from chemicals in surficial soil has been used by the USEPA at a number of Superfund sites. In fact, this process has been part of selected remedial strategies at other sites involving contaminated sediments (USEPA, 1994b). The decline in the concentration of many bioaccumulative chemicals in fish populations of the Great Lakes has been attributed to the natural sedimentation processes occurring system-wide (USEPA, 1993b; Smith, 1995).

Using empirical data collected from similar ecosystems, the effect of sedimentation on constituent concentrations can be quantified for the Duda property. An algorithm has been derived which expresses the sedimentation half-life (the length of time required to reduce the chemical concentration by 50%) as a function of the rate of deposition and the mixing zone where the new and old materials are assimilated (Manchester-Neesvig et al., 1996).

$$X^Y = 0.5$$

where:

X = 1 - [deposition rate (cm/yr)/mixing zone(cm)]

Y = sedimentation half-life (yrs)

Data from environments similar in character to that expected to occur, at least for the initial stages, are available. Reddy et al. (1993) reported sediment accretion rates in areas dominated by cattails was 1.13 cm/yr. Brenner and Schelske (1995) reported similar recent sediment accumulation rates at ten marsh sites reflecting increased organic production (i.e., similar to cattail environments). Since a cattail dominated environment is expected to exist on the Duda property for several years after the initiation of flooding (the District, personal communication), the sedimentation rate reported by Reddy and co-workers was used in the above calculation.

The mixing zone component of the calculation is intended to reflect the specific zone of surficial sediments which combine with the newly deposited material. That is, the entire sediment column does not mix with the new sediment, rather only a small fraction is available for physical mixing. The extent of this mixing zone is site specific and is dependent upon a variety of physical and biological factors. For rivers or coastal environments, areas which can experience periods of high hydrodynamic energy, the mixing layer can be quite extensive (Eadies et al., 1991). However, forces of this magnitude would not be expected in the environment of the flooded agricultural land. In fact, for the purposes of calculating a mixing zone, it was assumed that biological, rather than hydrodynamic forces would be the most important factor. As such, the mixing zone for this system was assumed to be equivalent to the bioturbation zone.

Infaunal macrobenthos can mix the sediments in which they live by either their feeding or burrowing activities (McCall and Tevesz, 1982). In freshwater system, tubificid oliogochaetes are considered the most quantitatively significant organism in terms of "reworking" sediment material (Fisher, 1982). Other macrobenthos, such as crayfish and bivalves, may move greater amounts of materials, but their "patchy" population densities are significantly less than oligochaetes (McCall and Tevesz, 1982), and consequently, their contribution to the total amount of mixing is significantly less important. McCall and Fisher (1980) state that for the Great Lakes, the maximum tubificid feeding and burrowing determines that the depth of biogenic sediment mixing. These investigators reported that maximum feeding zone for the tubificid population occurs somewhere between 3 and 6 cm. The sediment mixing zone of amphipods is restricted to the top 2 cm (Robbins, 1982; McCall and Tevesz, 1982). In the Everglades, Reddy reported a maximum bioturbation zone of 8 cm (Reddy et al., 1993). These data are consistent with the sediment profiles reported by Reddy and co-workers for the Everglades marshes. At cattail dominated locations, the Cs-137 profile exhibited very limited disruption, particularly in the more surficial sediments (Reddy et al. 1993). This evidence suggests that the vertical component of the mixing profile was very small in these systems.

Thus, for the purposes of our calculation, we used the maximum mixing depth reported by Reddy et al. (1993) of 8 cm. To calculate a sedimentation half-life:

$$1 - [\text{deposition rate (cm/yr)/mixing zone(cm)}]^{Y} = 0.5$$

or

$$1 - [1.13 \text{ cm yr}^{-1} / 8 \text{ cm}]^{Y} = 0.5$$

$$0.859^{Y} = 0.5$$

Thus, Y = 4.5 years

The results of this calculation suggest that if the bioturbation zone of the Duda sediments were 8 cm, and new (i.e., clean) sediments are deposited at a rate of 1.13 cm per year, the concentration of the chemicals in the surficial sediments will decrease by 50% every 4.5 years. If a smaller mixing zone was assumed in the calculation, for example if the community was dominated by amphipods and a 2 cm mixing zone was considered, the sedimentation half-life would be 0.8 years.

This consideration has important implications for determining the recovery and re-establishment process of the Duda property. Based on the progression observed at other properties located in the Everglades Water Management areas, the establishment of emergent vegetation, initially dominated by cattails, would proceed without any inhibition associated with the chemicals found in the Duda soil. If there is a significant lag time between the flooding of the property and the establishment of a benthic community, little or no mixing of the "new" sediment originating from the decay of dead vegetative material would occur. Alternatively, if the area is quickly inhabited by either amphipods or tubificid oliogochaetes, mixing of the surficial sediment would proceed. Thus, assuming a benthic community becomes established concurrent with the plant community, a prediction of the rate of decline in surficial sediment chemical concentrations could be conservatively estimated considering the two half-lives developed in the above calculation as bounding estimates.[1] The quantitative effect on the exposure concentration of the various chemical constituents is illustrated in Figure 3.

[1] Note: This estimation is considered conservative since it assumes that a benthic community is immediately established (i.e., from t = 0.)

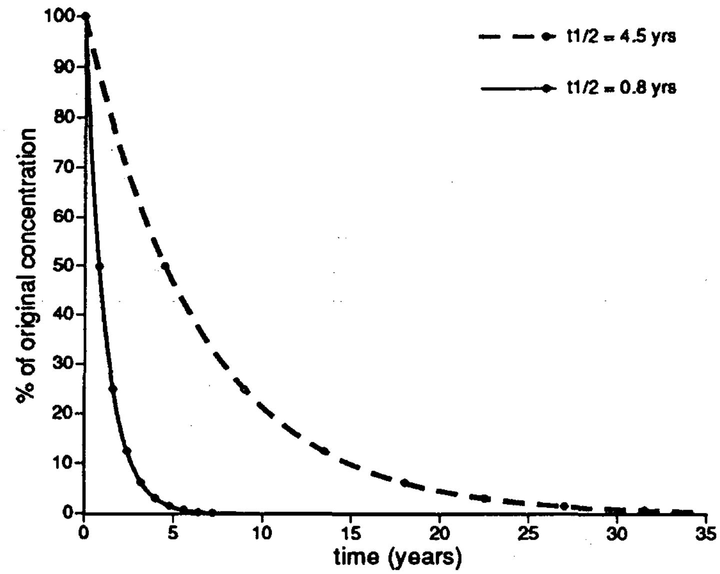


Figure 3. Projected Degradation Profile for Duda Property Sediments.

6.2 Risk Implications of Natural Recovery

These natural processes have important risk management implications. Since there is an explicit assumption in the ERA of a linear relationship between sediment concentrations and constituent levels in the food web, a reduction in the former would be reflected in the higher trophic levels. It follows that the reduction in the effective dose of the chemical would result in a significant and commensurate reduction in chemical-associated risks. This risk reduction would occur without the need for any remedial activity. For example, based on the assumption that amphipods were the dominant species "working" the sediments of the Duda property, after 7 years less than 1% of the original concentration will be in the surficial sediment. This reduction in effective chemical concentration of roughly two orders of magnitude would be reflected in all other environmental components, including sensitive and sentinel species.

Even a minor decrease in the exposure concentration will have a significant impact on the risk management decisions concerning the future chemical associated risks to the successional ecosystem. The results of the quantitative portion of the ERA indicate that there is only modest potential for risk to the receptors assuming current conditions and the exposures assumed in the risk estimation are met (See Section 4.4). Thus, any reduction in chemical concentration (either through sedimentation or biodegradation) would provide an additional level of safety and confidence in concluding that, over time, natural recovery is an acceptable alternative to reduce the level of chemical associated risk to future populations.

The quantification of any actual risk reduction is highly dependent upon the two descriptors used in the above calculation, that is sedimentation rates and mixing zones. Since natural attenuation will be the primary restoration mechanism at work at this site, at least in terms of chemical risk reduction, a carefully designed monitoring plan should be developed to assess and quantify the recovery process. Monitoring programs addressing the impact of sedimentation on bioaccumulation have been designed for other areas (e.g., Lake Hartwell, South Carolina (USEPA, 1994b)), and would provide information critical to the risk evaluations for other lands targeted for inclusion in the wetland restoration program.

Monitoring efforts of this type will assist the decision maker on the appropriate time to reconnect the new marsh to Lake Apopka. As previously stated, wading birds are likely to invade the reclaimed wetland almost immediately, since they continually visit the site during periods of flooding. The species selected to represent wading birds, the blue heron, was the only receptor for which the ecological quotient exceeded 10. Reduction in soil/sediment concentrations would reduce the estimated risks relatively quickly. Based on the sedimentation model developed in this report, a 90% reduction in surficial sediment concentration could be expected after less than 3 years and at most 15 years could be required (Figure 3). A monitoring program which would accurately quantify the natural recovery process could verify the time required to reduce the risks.

6.3 Biodegradation of Chlorinated Hydrocarbons

Biodegradation, while potentially important, may not be as quantitatively significant a component of natural recovery as sedimentation. The biodegradation of persistent chlorinated hydrocarbons has been reported to occur, particularly in anaerobic sediments. For example, a number of investigators have reported on the occurrence of dechlorination of PCB congeners under aerobic and anaerobic conditions in marine and freshwater sediments. Half-lives for a number of these highly chlorinated congeners in environmental samples were calculated by Lake et al. (1991) and range from only a few years (4.4 for 2,3,3',4,4'-PCB) to almost twenty years (18.8 for 2,2',4,4',5,5'-HCB) at extensively contaminated sites. Quensen et al. (1990) reported that experimentally, after 16 weeks, 53% of the total chlorine was removed from 700 ppm Aroclor 1242 by anaerobic bacteria isolated from Hudson River sediments. Brown and Wagner (1990) were able to calculate the clearance rate of various PCB congeners based on dechlorination-resistent peaks found in Aroclor 1242 and Aroclor 1254 and industry records of contamination histories. The half-time removal for the main toxic congeners (3,3',4,4'-TCB and 2,3,3',4,4'-PCB) in the environment was 8 $\pm$ 2 years.

Similar degradation half-lives have been reported for DDT and its metabolites. Biodegradation may occur under both aerobic and anaerobic conditions in the presence of certain soil and sediment microorganisms. Estimation of the environmental half-life for DDT biodegradation in soil range from 2 to 15 years (ATSDR,1994). The average half-life in anaerobic soils was 692 days (1.9 years) (Montgomery, 1997). However, Parr and Smith (1974) reported that in Everglades muck p,p'-DDT was only slowly converted to p,p'-DDD and p,p'-DDE. Although the breakdown of toxaphene has been reported in artificial systems, review of the literature failed to identify any environmental half-lives for toxaphene.

Given the lack of quantitative data, the development of a predicted decay rate for the chemicals of concern at the Duda property would have an unacceptably high level of uncertainty. However, this may be a significant mechanism of risk reduction, once the soils are converted to an anaerobic environment. Since the degradation of the chlorinated pesticides could augment the risk reduction expected from sedimentation and mixing, it is recommended that this process be investigated at this location. The most effective method would be to develop laboratory studies of the ability of muck soils in anaerobic environments to degrade these chlorinated compounds. Since there is a paucity of information on the fate of these chemicals in muck environments, any data gleaned for the Duda property would provide a valuable tool for the evaluation of other land considered for the restoration program.

6.4 Risk Management Summary

The area of the Duda property scheduled for restoration has an extremely unusual characteristic which significantly affects the potential ecological risks posed by chemicals detected in the soil. The extremely high level of organic carbon in the matrix of the muck soils found on the Duda property retard the movement of lipophilic chemicals (e.g., persistent chlorinated pesticides detected on-site) into aquatic environments. This characteristic has resulted in the estimation that only modest risks are posed to receptors expected to immigrate to this area following flooding. Subsequently, natural recovery processes which have been demonstrated to be effective in other ecosystems will provide a reduction in these estimated risk levels over a reasonable period of time. Given the high probability that natural attenuation can proceed at a rate estimated in this report, no other action would seem to be required. However, as much of the information used to quantify the natural recovery process was taken from other areas, it is recommended that a monitoring program be established with the specific intent of quantifying the progression of the system recovery and ensuring that adverse effects are not observed in colonizing populations. In essence, following completion of this growing season, this portion of the Lake Apopka environment will begin the recovery process. The opportunity to monitor this recovery, and obtain quantitative and descriptive data on this process, useful for future projects, should not be lost.

Natural attenuation of contaminants in the Duda property soils is intended to serve as the model for the larger Lake Apopka muck farm area. However, the choice of natural attenuation for remediation of the Apopka area or any other site should be considered in the context of the site-specific conditions and of any larger restoration plan. First, the selection of any particular remedition method should always be prefaced with as complete a consideration of alternatives as possible. Natural attenuation was found here to be a reasonable and prudent approach after the intensive cleanup of specific areas on the property that were in need of targeted of remediation. Second, natural attenuation does not mean abdication of management responsibilities at the site. For the Lake Apopka muck farm area it is expected that active water management and other efforts will promote the development of the wetland system at the rate and toward the goal intended in the conceptual restoration plan for the site (personal communication, David Stites). Third, attenuation (or any remediation choice) and system development should be followed by careful and effective monitoring as discussed above. In the case of Lake Apopka monitoring is necessary because the attenuation of these contaminants is not well quantified in organic soils. In addition, presently unknown conditions or factors in the larger area may still cause the need for some additional remedial activity or management approach.

The ecological benefit provided by the natural attenuation process must be viewed in the context of overall risk reduction which is a product of the restoration program. A significant risk reduction will be afforded by simply removing this tract of land from active farming operations. The net result of eliminating fertilizer and pesticide application will be a dramatic reduction in pollutant loading to the system. These "source controls" are perhaps the most significant risk management programs resulting from the Lake Apopka Restoration Agricultural Land Acquisition Project. The ecological benefit provided by this step alone cannot be minimized, and needs to be considered when determining the "acceptable" level of risk resulting from the restoration program. Assuming that recovery processes will occur, combined with elimination of future applications, the acceptability of this approach by all interested parties should be high.

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Appendices

Carbon Normalized Soil Analytical Results Lake Jem Farm - Post-remediation (µg/kg organic carbon)

Area	Site	Lab	Sample ID	DDD	DDE	DDT	Dieldrin	Endrin	Heptachlor	Aldrin	Toxaphene	Alpha chlordane	Gamma chlordane	Endrin ketone	Ametryn	Chloro-propylate	Chloro-thalonil	Atrazine	Metola-chlor
C	1	H	C1-D	780	3600	4200	<108.00	<116.00	<116.00	<160.00	<1,960.00	<134.00	–	–	–	–	–	–	–
C	4	H	SWDAW-1	4760	1096	5680	<66.00	<66.00	<33.00	<33.00	<660.00	80	131.2	–	–	–	–	–	–
D	4	H	CLSC-1	<280.00	<360.00	1400	<260.00	<280.00	<280.00	<380.00	<4,800.00	<360.00	–	–	–	–	–	–	–
D	5	H	CLSC-2	<280.00	540	2000	<260.00	<280.00	<280.00	<380.00	<4,800.00	<280.00	–	–	–	–	–	–	–
D	5	B	ESWDA-1	47.6	306	<66.00	<66.00	<66.00	<33.00	<33.00	<660.00	<33.00	–	–	–	–	–	–	–
D	5	B	L11FT	498	486	<660.00	<660.00	<660.00	<330.00	<330.00	<6,600.00	9.3	–	–	–	–	–	–	–
D	5	B	L1D1TH	6.8	13.8	9.22	<6.60	<6.60	<3.30	<3.30	<66.00	<3.30	–	–	–	–	–	–	–
D	5	B	L1TOP	826	630	1622	173.2	<66.00	<33.00	<33.00	<660.00	133.2	88.6	–	–	–	–	–	–
D	5	B	F1B3FT	29.6	128.8	61.6	<6.60	<6.60	<3.30	<3.30	<66.00	<3.30	–	–	–	–	–	–	–
D	5	B	B1B1FT	254	814	450	220	<66.00	<33.00	<33.00	<660.00	113.2	86.6	–	–	–	–	–	–
D	5	B	B1C2FT	15.12	51.6	<6.60	<6.60	<6.60	<3.30	<3.30	<66.00	<3.30	–	–	–	–	–	–	–
D	5	B	B1C2FT	992	2200	3240	<660.00	–	–	–	<6,600.00	–	–	–	–	–	–	–	–
E	2	S	SB-1	260	6000	142	<184.00	<184.00	<94.00	<94.00	<9,400.00	136	100	<24.00	–	1200	<380.00	–	–
E	4	H	E4-1	76	188	50	<58.00	<64.00	<64.00	<88.00	<1,080.00	<74.00	–	–	–	–	–	–	–
E	5	H	E5-A	36	164	114	<10.40	<11.20	<11.20	<156.00	<190.00	<13.00	–	–	–	–	–	–	–
E	5	H	E5-B	<40.00	380	132	<36.00	<40.00	<40.00	<56.00	<680.00	<46.00	–	–	–	–	–	–	–
E	5	H	E5-C	46	94	280	<32.00	<34.00	<34.00	<48.00	<580.00	<40.00	–	–	–	–	–	–	–
E	5	H	E5-D	54	220	34	<6.20	<6.60	<6.60	<9.20	<112.00	<7.80	–	–	–	–	–	–	–
E	5	H	E5-E	60	124	30	<5.80	<6.40	<6.40	<8.80	2000	<7.40	–	–	–	–	–	–	–
E	5	H	E5-F	2600	3400	4200	760	<320.00	<320.00	<460.00	<5,600.00	<380.00	–	–	–	–	–	–	–
E	6	H	E6-A	<58.00	540	<80.00	<54.00	<58.00	<58.00	<80.00	6200	<66.00	–	–	–	–	–	–	–
E	6	S	SB-2	112	340	162	44	<70.00	<36.00	<36.00	1440	<36.00	<36.00	<70.00	–	1800	<144.00	–	–
E	14	H	E14-A	90	170	840	<58.00	<64.00	<64.00	<88.00	<1,080.00	<74.00	–	–	–	–	–	–	–
E	14	H	E14-B	1620	3800	5200	420	<380.00	<380.00	<540.00	15600	<440.00	–	–	–	–	–	–	–
E	14	H	E14-C	1600	3000	13400	<720.00	<780.00	<780.00	<1,080.00	<13,200.00	<900.00	–	–	–	–	–	–	–
E	14	H	E14-D	880	3800	4200	540	<380.00	<380.00	<540.00	<6,600.00	<440.00	–	–	–	–	–	–	–
E	14	H	E14-E	460	2400	1580	<340.00	<360.00	<360.00	<500.00	<6,200.00	<420.00	–	–	–	–	–	–	–
E	14	H	E14-F	720	3600	3000	<440.00	<480.00	<480.00	<660.00	<8,200.00	<560.00	–	–	–	–	–	–	–
E	14	H	E14-G	1080	2800	11600	640	<600.00	<600.00	<840.00	<10,200.00	<700.00	–	–	–	–	–	–	–
E	14	H	E14-H	1840	3800	20000	<760.00	<820.00	<820.00	<1,140.00	<14,000.00	<960.00	–	–	–	–	–	–	–
E	14	H	E14-I	166	460	3000	<106.00	<116.00	<116.00	<160.00	<1,960.00	<134.00	–	–	–	–	–	–	–
E	14	H	E14-J	<6.00	14.8	<8.40	<5.60	<6.00	<6.00	<8.40	<102.00	<7.00	–	–	–	–	–	–	–
E	16	H	E4-B	182	320	1700	<74.00	<80.00	<80.00	<110.00	<1,360.00	<92.00	–	–	–	–	–	–	–
E	16	H	E7-A	54	128	24	<4.80	<5.20	<5.20	<7.20	960	<6.00	–	–	–	–	–	–	–
E	16	H	E7-B	<280.00	<360.00	<380.00	<240.00	<280.00	<280.00	<380.00	36000	<320.00	–	–	–	–	–	–	–

Data from Phase I and II Assessment Lake Jem Farm; Remediated site information provided by Donna Cline (SJRWMD); –=data not sampled or not reported

Carbon Normalized Soil Analytical Results Lake Jem Farm - Post-remediation (µg/kg organic carbon)

Area	Site	Lab	Sample ID	DDD	DDE	DDT	Dieldrin	Endrin	Heptachlor	Aldrin	Toxaphene	Alpha chlordane	Gamma chlordane	Endrin ketone	Ametryn	Chloro-propylate	Chloro-thalonil	Atrazine	Metola-chlor
E	16	H	E7-C	<44.00	<58.00	<60.00	<40.00	<44.00	<44.00	<60.00	6800	<50.00	--	--	--	--	--	--	--
E	16	H	E7-D	<50.00	122	<70.00	<46.00	<50.00	<50.00	<70.00	<860.00	<58.00	--	--	--	--	--	--	--
E	16	H	E8-A	<5.00	46	11.6	<4.60	<5.00	<5.00	<6.80	880	<5.80	--	--	--	--	--	--	--
F	1	H	47A	680	1260	2800	138	<8.00	<8.00	<11.00	13000	<9.20	680	<460.00	--	10200	1880	1460	800
F	1	H	47B	46	70	50	<7.40	<8.00	<8.00	<11.00	1760	<9.20	--	--	--	--	--	--	--
F	1	H	53A	780	1080	<132.00	38	<9.40	<9.40	<13.20	24000	<11.00	520	<500.00	--	8400	<1,000.00	900	580
F	1	H	53B	1140	<8.00	3800	260	<6.20	<6.20	<8.60	30000	<7.20	--	--	--	--	--	--	--
F	1	H	66A	88	700	<8.20	<5.40	<5.80	<5.80	<8.20	4600	<6.80	--	--	--	--	--	--	--
F	1	H	66B	1120	1300	<30.00	70	<22.00	<22.00	<30.00	36000	<26.00	--	--	--	--	--	--	--
F	1	H	85A	42	124	<20.00	<13.40	<14.60	<14.60	<20.00	1780	<16.80	--	--	--	--	--	--	--
F	1	H	Canal-1	420	580	<28.00	<18.20	22	<19.60	<28.00	<340.00	<22.00	--	--	--	--	--	--	--
F	1	H	Canal-2	<6.80	64	<9.40	6.6	<6.80	<6.80	<9.40	<116.00	<8.00	--	--	--	--	--	--	--
F	1	H	Canal-3	<6.00	22	400	110	136	52	54	<102.00	<7.00	--	--	--	--	--	--	--
F	1	H	Canal-4	118	220	300	<44.00	<48.00	<48.00	<66.00	<800.00	<54.00	--	--	--	--	--	--	--
F	1	H	Canal-5	44	26	<5.60	<3.60	<3.40	<3.40	<5.60	<68.00	<4.60	--	--	--	--	--	--	--
F	1	H	Canal-6	<11.80	56	<16.40	<11.00	<11.80	<11.80	<16.40	<200.00	<13.80	--	--	--	--	--	--	--
F	1	H	Canal-7	<4.40	5.6	<6.00	<4.00	<3.60	<3.60	<6.00	<72.00	<5.00	--	--	--	--	--	--	--
F	1	H	Canal-8	<4.80	<6.40	<6.60	<4.40	<4.80	<4.80	<6.60	<82.00	<5.60	--	--	--	--	--	--	--
F	1	H	Canal-9	280	<300.00	5600	<200.00	<220.00	<220.00	<300.00	<3,800.00	<260.00	--	--	--	--	--	--	--
F	1	H	Canal-10	60	158	38	<26.00	<30.00	<30.00	<40.00	<500.00	<34.00	--	--	--	--	--	--	--
F	1	H	Canal-11	100	116	<38.00	<26.00	<28.00	<28.00	<38.00	<480.00	<32.00	--	--	--	--	--	--	--
F	1	H	Canal-12	36	52	9.4	<5.40	<5.80	<5.80	<8.20	<100.00	<6.80	--	--	--	--	--	--	--

Data from Phase I and II Assessment Lake Jem Farm; Remediated site information provided by Donna Cline (SJRWMD); --=data not sampled or not reported

Toxaphene Fish Tissue Data Used in the Derivation of the BSAF
(Long Farm)

Largemouth Bass										
Field ID	Collection Date	Analytical Date	Chemical	Concentration	% Lipid	Lipid Normalized Toxaphene	Qualifiers	Units	Species	Field Comments
LF-95-14	7/26/95	8/17/95	Toxaphene	599.94	1.5%	39996.00	DX	ug/kg	LMB	Fillet
LF-95-15	7/26/95	8/17/95	Toxaphene	1973.1	2.7%	73077.78	DX	ug/kg	LMB	Fillet
LF-95-18	7/26/95	8/17/95	Toxaphene	2038.04	3.3%	61758.79	DX	ug/kg	LMB	Fillet
#1	11/2/95	2/12/96	Toxaphene	1.10E+04	8.6%	127906.98	J	ug/kg	LMB	Whole Fish
#2	11/2/95	2/12/96	Toxaphene	1.10E+04	8.6%	127906.98	J	ug/kg	LMB	Whole Fish
#3	11/2/95	2/12/96	Toxaphene	5.10E+03	8.6%	59302.33	J	ug/kg	LMB	Whole Fish
#4	11/2/95	2/12/96	Toxaphene	8.60E+03	8.6%	100000.00	J	ug/kg	LMB	Whole Fish
#5	11/2/95	2/12/96	Toxaphene	7.70E+03	8.6%	89534.88	J	ug/kg	LMB	Whole Fish
#6	11/2/95	2/12/96	Toxaphene	1.20E+04	8.6%	139534.88	J	ug/kg	LMB	Whole Fish
Brown Bullhead Catfish										
Field ID	Collection Date	Analytical Date	Chemical	Concentration	% Lipid	Lipid Normalized Toxaphene	Qualifiers	Units	Species	Field Comments
LF-95-16	7/26/95	8/17/95	Toxaphene	1304	2.8%	46571.43	DPX	ug/kg	BBC	Whole Fish
LF-95-17	7/26/95	8/17/95	Toxaphene	<314.53	0.6%	26210.83	UD	ug/kg	BBC	Whole Fish

Data provided by Bill Johnson, Florida Game and Freshwater Fish Commission
U=undetected; P=%D>25; D=diluted; X=%RSD>40; J=estimated value

DDT, DDE and DDD Fish Tissue Data Used in the Derivation of the BSAF
(Long Farm)

Brown Bullhead Catfish																	
Field ID	Collection Date	Analytical Date	Lipid %	DDD-p,p'	Qualifers	DDD-p,p' normalized	DDE-p,p'	Qualifers	DDE-p,p' normalized	DDT-p,p'	Qualifers	DDT-p,p' normalized	Total DDT	Total DDT Normalzed	Units	Species	Field Comments
1956-FILLE	3/4/96	4/19/96	2.7%	6.8		251.85	9.2		340.74	<1.8	U	33.33	16.9	625.92	μg/kg	BBC	Fillet
1962-FILLE	3/4/96	4/20/96	2.7%	26		962.96	74		2740.74	<3.1	U	57.41	101.55	3761.11	μg/kg	BBC	Fillet
1963-FILLE	3/4/96	4/20/96	2.7%	120		4444.44	160		5925.93	<3.3	U	61.11	281.65	10431.48	μg/kg	BBC	Fillet
514-FILLET	3/4/96	4/20/96	2.7%	52		1925.93	52		1925.93	<1.7	U	31.48	104.85	3883.34	μg/kg	BBC	Fillet
515-FILLET	3/4/96	4/20/96	2.7%	120		4444.44	110		4074.07	<1.8	U	33.33	230.9	8551.84	μg/kg	BBC	Fillet
LF-95-16	7/26/95	8/17/95	2.8%	<12.4	UD	221.43	<12.4	UD	221.43	34.6	D	1235.71	47	1678.57	μg/kg	BBC	Fillet
LF-95-17	7/26/95	8/17/95	0.6%	<6.29	UD	524.17	41.46	D	6910.00	<6.29	UD	524.17	47.75	7958.34	μg/kg	BBC	Fillet
Largemouth Bass																	
Field ID	Collection Date	Analytical Date	Lipid %	DDD-p,p'	Qualifers	DDD-p,p' normalized	DDE-p,p'	Qualifers	DDE-p,p' normalized	DDT-p,p'	Qualifers	DDT-p,p' normalized	Total DDT	Total DDT Normalzed		Species	Field Comments
1957-FILLE	3/4/96	4/19/96	1.3%	35		2692.31	42		3230.77	<1.7	U	65.38	77.85	5988.46	μg/kg	LMB	Fillet
1958-FILLE	3/4/96	4/19/96	1.3%	86		6615.38	99		7615.38	<2	U	76.92	186	14307.68	μg/kg	LMB	Fillet
1958-FILLE	3/4/96	4/19/96	1.3%	94		7230.77	120		9230.77	<2	U	76.92	215	16538.46	μg/kg	LMB	Fillet
1959-FILLE	3/4/96	4/19/96	1.3%	120		9230.77	110		8461.54	<1.7	U	65.38	230.85	17757.69	μg/kg	LMB	Fillet
1960-FILLE	3/4/96	4/19/96	1.3%	74		5692.31	96		7384.62	<1.6	U	61.54	170.8	13138.47	μg/kg	LMB	Fillet
1961-FILLE	3/4/96	4/20/96	1.3%	44		3384.62	54		4153.85	<1.6	U	61.54	98.8	7600.01	μg/kg	LMB	Fillet
LF-95-14	7/26/95	8/17/95	1.5%	158.55	EDP	10570.00	171.03	EDP	11402.00	<3.52	UD	117.33	331.34	22089.33	μg/kg	LMB	Fillet
LF-95-15	7/26/95	8/17/95	2.7%	302.01	EDP	11185.56	405	EDP	15000.00	<3.53	UD	65.37	708.775	26250.93	μg/kg	LMB	Fillet
LF-95-18	7/26/95	8/17/95	3.3%	267.81	EDP	8115.45	266.97	EDP	8090.00	<3.58	UD	54.24	536.57	16259.69	μg/kg	LMB	Fillet

Data provided by Bill Johnson (FGFWFC) and Joy Marburger (SJRWMD)
U=undetected; P=%D>25; E=exceeds calib.; D=diluted

Sediment Data Used in the Derivation of the BSAF
(Long Farm)

Sample ID	Collection Date	Analytical Date	Units	DDD-p,p'	Qualifiers	DDE-p,p'	Qualifiers	DDT-p,p'	Qualifiers	Total DDT	Qualifiers	Toxaphene	Qualifiers
LONG 134	9/12/96	10/28/96	µg/kg	2200		910		34	N	3144		5400	J
LONG 142	9/12/96	10/21/96	µg/kg	540		510		<1.9	U	1050.95		12000	J
LONG 147	9/12/96	10/28/96	µg/kg	1900		1400	J	95	N	3395		7700	J
LONG 171	9/12/96	10/28/96	µg/kg	2300		1400		160	N	3860		9100	J
LONG 187	9/12/96	10/28/96	µg/kg	2100		1800	J	210	N	4110		12000	J
LONG 196	9/12/96	10/28/96	µg/kg	4800		2300	J	160	N	7260		12000	J
LONG 196 D	9/12/96	10/28/96	µg/kg	3700		1600	J	180	N	5480		12000	J
LONG 212	9/17/96	10/11/96	µg/kg	140	J	270		37	N	447		1900	J
LONG 234	9/12/96	10/28/96	µg/kg	4900		2800	J	320	N	8020		16000	J
LONG 245	9/12/96	10/21/96	µg/kg	350		470	J	<2	U	821		10000	J
LONG 248	9/12/96	10/28/96	µg/kg	2700		2100	J	160	N	4960		9700	J
LONG 270	9/12/96	10/28/96	µg/kg	2100		1300	J	120	N	3520		6400	J
LONG 284	9/12/96	10/21/96	µg/kg	260		370	J	<1.9	U	630.95		4700	J
LONG 293	9/12/96	10/28/96	µg/kg	7700		2200	J	240	N	10140		13000	J
LONG 301	9/12/96	10/21/96	µg/kg	420		410		<2.1	U	831.05		9200	J
LONG 324	9/12/96	10/28/96	µg/kg	2800		2200	J	170	N	5170		9200	J
LONG 329	9/12/96	10/28/96	µg/kg	2900		1500	J	140	N	4540		12000	J
LONG 357	9/17/96	11/2/96	µg/kg	340		600		20	N	960		27000	J
LONG 362	9/17/96	11/2/96	µg/kg	1800		880		130	N	2810		27000	J
LONG 381	9/17/96	11/2/96	µg/kg	930		220	J	47	N	1197		11000	J
LONG 392	9/17/96	11/2/96	µg/kg	1800		940		54	N	2794		32000	J
LONG 419	9/17/96	11/2/96	µg/kg	270		310	J	13	N	593		20000	J
LONG 424	9/17/96	11/2/96	µg/kg	780		230	J	38	N	1048		11000	J
LONG 449	9/17/96	11/2/96	µg/kg	200		310		17	N	527		8200	J
LONG 454	9/17/96	10/11/96	µg/kg	21	I	12	I	11	N	44		<190	U
LONG 464	9/17/96	11/2/96	µg/kg	310		330	J	10	N	650		22000	J
LONG 471	9/17/96	11/2/96	µg/kg	140		230	J	<2.8	U	371.4		21000	J
LONG 488	9/17/96	10/11/96	µg/kg	51		44	J	<14	U	102		1600	J
LONG 494	9/17/96	11/2/96	µg/kg	150	J	160	J	<2.1	U	311.05		29000	J
LONG 515	9/17/96	11/2/96	µg/kg	100	J	130	J	<1.9	U	230.95		24000	J

Data provided by Joy Marburger (SJRWMD)

I=less than the minium quantitation limit and greater than or equal to the minium detection limit; J=estimated; N=presumptive evidence of the presence of material; U=undetected

Sediment Data Used in the Derivation of the BSAF
(Long Farm)

Sample ID	Collection Date	Analytical Date	Units	DDD-p,p'	Qualifiers	DDE-p,p'	Qualifiers	DDT-p,p'	Qualifiers	Total DDT	Qualifiers	Toxaphene	Qualifiers
LONG 519	9/17/96	10/11/96	µg/kg	5.3	I	5.8	I	<3.7	U	12.95		240	J
LONG 53	9/12/96	10/21/96	µg/kg	1100		840		49	N	1989		5000	J
LONG 540	9/17/96	11/2/96	µg/kg	180	J	170	J	<2	U	351		35000	J
LONG 540 D	9/17/96	11/2/96	µg/kg	180	J	170	J	<2.1	U	351.05		32000	J
LONG 549	9/17/96	11/2/96	µg/kg	140	J	140	J	<2.1	U	281.05		32000	J
LONG 566	9/17/96	10/11/96	µg/kg	<4.6	U	<4.6	U	<4.6	U	6.9		<160	U
LONG 589	9/17/96	10/11/96	µg/kg	10	I	9.6	I	<3.2	U	21.2		960	J
LONG 95	9/12/96	10/21/96	µg/kg	1000		1100		39	N	2139		4900	J
LONG 01	7/13/96		µg/kg	<170	U	<170	U	<170	U	255		<8400	U
LONG 02	7/14/96		µg/kg	<3.8	U	<3.8	U	<3.8	U	5.7		<190	U
LONG 03	7/15/96		µg/kg	1100		600	J	<920	U	2160		<45000	U
LONG 1S	7/16/96		µg/kg	<110	U	<110	U	<110	U	165		<5600	U

Data provided by Joy Marburger (SJRWMD)
I=less than the minium quantitation limit and greater than or equal to the minium detection limit; J=estimated; N=presumptive evidence of the presence of material; U=undetected