

**ORGANOCHLORINE PESTICIDE RESIDUES IN INACTIVE  
CRANBERRY BOGS OF THE  
EDWIN B. FORSYTHE NATIONAL WILDLIFE REFUGE**

DEC ID# 199950002.1



U.S. Fish & Wildlife Service  
New Jersey Field Office

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## **EXECUTIVE SUMMARY**

A 1996 Baseline Contaminants Investigation of the U.S. Fish & Wildlife Service's (Service) Edwin B. Forsythe National Wildlife Refuge (EBFNWR) revealed elevated sediment organochlorine pesticide residues down-gradient of abandoned cranberry bogs on Four-mile Branch and Ballinger Creek (USFWS 1998). The purpose of this investigation was to determine if the abandoned bogs, now under U.S. Fish & Wildlife Service (Service) ownership, were a potential source of pesticide residues. Sediment samples were collected from within two bogs on the Oxycocus Property in Stafford Township, Ocean County, New Jersey, for organochlorine analysis. The results of that analysis indicate that the abandoned cranberry bogs sediments contain organochlorine pesticide residues, especially DDT and related breakdown analogs, DDD and DDE. The high organochlorine pesticide concentrations correlate with severe adverse impacts to benthic macroinvertebrates. In response to initial sediment results from this study, the Service initiated a Cleanup Project in 2003 to further address and eliminate bog sediments as a source of down-gradient contamination, and to develop a hydrodynamic model of bog effluent flow, which could transport re-suspended bog sediments during high flow events. Further work under the Cleanup Study is being undertaken to address fish contamination from organochlorine pesticides associated with the Oxycocus Property bogs to address ecological and human health risks in downstream Manahawkin Lake. There are similar needs that are currently unmet at other bog related locations.

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## INTRODUCTION

A 1996 Baseline Contaminants Investigation of the U.S. Fish & Wildlife Service's (Service) Edwin B. Forsythe National Wildlife Refuge (EBFNWR) revealed elevated sediment DDT (1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane) residues down-gradient of abandoned cranberry bogs on Four-mile Branch and Ballinger Creek (USFWS 1998). The Four-mile Branch sample also contained elevated levels of DDD (1,1-dichloro-2,2-bis(p-chlorophenyl)ethane), DDE (1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene), PCBs (polychlorinated biphenyls), lead, and copper; the Ballinger Creek sample contained elevated level of DDD, DDE, arsenic, copper, mercury, nickel, and lead.

Subsequently, this investigation was originally designed to delineate organochlorine contamination in fish and sediments associated with the Ballinger Creek and Four-mile Branch bogs. Repeated fish sampling between 1999 and 2001, using a variety of sampling gear (*e.g.*, seines, nets, electroshocker, and minnow traps), did not yield any specimens. Reconnaissance of the Ballinger Creek bog in late 2001 indicated that sediment sampling would require more logistical support than was originally planned. Access to the bog interior was impeded by obstructive vegetation in the water course, dense shoreline vegetation, unstable muck soils, and the need to acquire trespass rights through private property. Moreover, the thick vegetative cover, which included stands of *Phragmites* obscured the boundaries of the bog (personal observations Stern and Fannin 31 Oct. 2001; Stern and Solberg 6 Nov. 2001). The determination was made to move sediment sampling efforts to the bogs within the Oxycocus Property, namely the Four-mile Branch and Mill Creek bogs. The original investigation was modified to achieve the following objective:

- Initial characterization of bog sediment/soil organochlorine concentrations within the Oxycocus Property of the EBFNWR - Barnegat Division.

The Oxycocus Property of the EBFNWR - Barnegat Division consists of three parcels totaling 184 acres of a 328-acre natural area located in Stafford Township, Ocean County, New Jersey. Originally, the parcels were slated for the proposed Waterford and Deer Lake Heights property development projects. The parcels were deeded to the Service on 22 December 1994 (Trust for Public lands -New Jersey Tracts [2001 Ac], 67.87 acres), 23 May 1995 (Trust for Public lands - New Jersey Tracts [2001 Ag], 79.79 acres) and 16 May 1996 (Stafford Township Tracts [850s], 36 acres). Vegetative cover on the Oxycocus Property is primarily a mosaic of mixed upland temperate forest, pitch pine (*Pinus rigida*) lowland forest, upland shrub-scrub and Atlantic white-cedar (*Chamaecyparis thyoides*) bog/swamp habitats hemmed in by major roads, and commercial and residential developments. The Oxycocus Property is flanked by the Garden State Parkway (GSP), State Highway 72, and increasing residential and commercial development. The recent history of public use at the Oxycocus Property since acquisition by the Service includes illegal trespass via off-road vehicles (*i.e.*, all-terrain vehicles (ATV) and motorcycles), unauthorized uses (consumption of alcoholic beverages on site, bon-fires and associated littering) and pedestrian access (*i.e.*, fall / spring training by a local high school track / cross-country teams, strolling and dog-walking by local neighbors). These uses continue despite the fact that the entire tract and all access points to the area are posted with “**Unauthorized Entry Prohibited**” signs.

With a probable origin in the late 19th century, cranberry cultivation at the Oxycocus Property is believed to have persisted until *circa* 1959, when large operations put many of the smaller growers out of business. Remnants of two abandoned cranberry bogs, one associated with the Mill Creek, the other with the Four-mile Branch, still exist within the Oxycocus Property. The approximate surface areas of the Mill Creek and Four-mile Creek bogs are  $16.3\pm$  acres and  $14.3\pm$  acres, respectively. Remnants of up-gradient water storage reservoirs associated with each bog still remain. The effluents of both bogs merge approximately 200 meters down-gradient as Mill Creek forming the primary feeder stream to Manahawkin Lake. Mill Creek emerges from Manahawkin Lake, passing under Route 9 and later passes through Service lands draining into Barnegat Bay.

## METHODS

### Sample Collection

Sediment/soil sample sites were chosen using an intentionally biased approach to select depositional areas most likely to be contaminated. As such, results can be interpreted as being representative of the study area's most contaminated areas. Site-specific sampling location narrative descriptions can be found in Table 1.

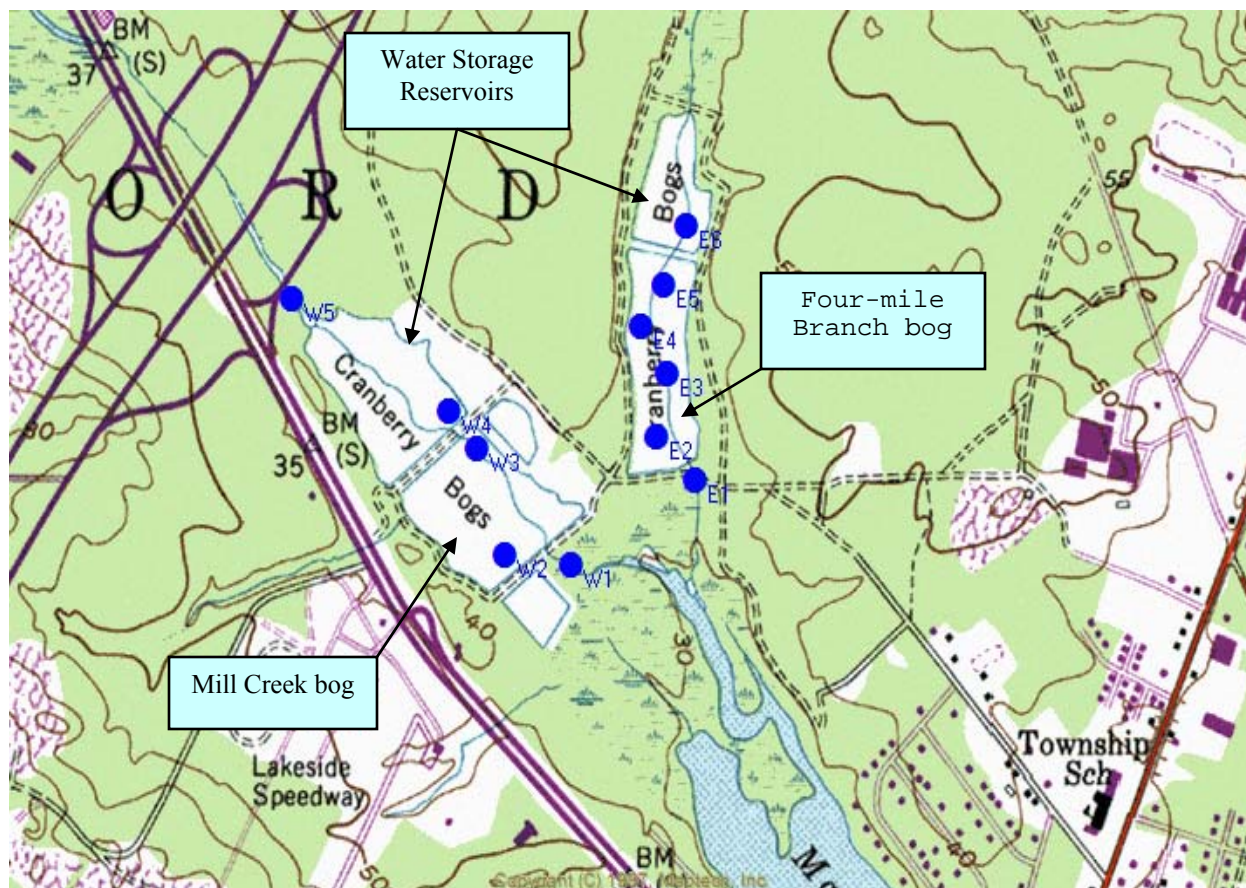
Figure 1 identifies the location of the general study area, Mill Creek and Four-mile Creek bogs as well as sampling locations. Sampling was conducted during the first week of December 2001. Soil/sediment samples were collected by either pre-cleaned ponar grab or with pre-cleaned stainless-steel trowels. When necessary, the overlying vegetative carpet (usually sphagnum or grasses/sedges) was removed prior to collecting the sample. Soil/sediment samples were collected to a depth of 0-8 centimeters. Each sample consisted of three sub-samples taken approximately 3-5 meters apart as site-specific conditions dictated and were thoroughly mixed in a pre-cleaned stainless steel bucket. For the

Table 1. Sampling Coordinates and Sample Location Descriptions		
Site	Coordinates (NAD-83)	Description
<b>Four-mile Creek Bog [East/Echo (E)]</b>		
<b>E1</b>	N 39°, 42.437' W 74°, 16.010'	Effluent stream; 0-15 meters down-gradient of Oxycocus Road bridge; water depth ~0.5-1.0 meters.
<b>E2</b>	N 39°, 42.462' W 74°, 16.032'	Depositional area adjacent to a stand of dead cedar in the flooded southwestern portion of the bog; water depth ~0.25 – 0.5 meters.
<b>E3</b>	N 39°, 42.523' W 74°, 16.070'	Depositional area on the main channel east-bank; water depth ~0.25 – 0.5 meters.
<b>E4</b>	N 39°, 42.595' W 74°, 16.101'	Water-saturated sedge/hummock forested area ~20 meters west of the main channel.
<b>E5</b>	N 39°, 42.653' W 74°, 16.078'	Water-saturated sedge/hummock forested area east of the main channel.
<b>E6</b>	N 39°, 42.734' W 74°, 16.027'	Eastern stream bank ~30 – 50 meters up-gradient of the dike-road crossing.
<b>Mill Creek Bog [West/Whiskey (W)]</b>		
<b>W1</b>	N 39°, 42.355' W 74°, 16.210'	Depositional area on main channel west-bank ~ 50 meters down-gradient of dike-road and former bridge/water control structure.
<b>W2</b>	N 39°, 42.363' W 74°, 16.308'	Water-saturated area ~30 – 50 meters up-gradient of dike-road, dominated by sphagnum and sapling/pole stage cedars.
<b>W3</b>	N 39°, 42.492' W 74°, 16.366'	Drainage ditch on the western shore of the main channel ~50 meters down-gradient of center dike-road.
<b>W4</b>	N 39°, 42.512' W 74°, 16.396'	Shallow depression area ~30 – 50 meters up-gradient of the center dike-road; east of the main channel.
<b>W5</b>	N 39°, 42.628' W 74°, 16.635'	Mill Creek ~50 meters down-gradient of SH72 (west) north-bound GSP entrance ramp; water depth < 0.25 meter.

purpose of the investigation, the Four-mile Branch bog samples are identified as “Echo” (a/k/a: E or east), the Mill Creek bog samples are identified as “Whiskey” (a/k/a west or W), followed by the designated station number. An aliquot was transferred to 500 ml pre-cleaned I-Chem jars with Teflon-lined lids for the organochlorine analysis (these samples may be identified in the raw data by their station name followed by the letter "a"[i.e., E1a]). A second aliquot of the composite was transferred to a 125 ml pre-cleaned I-Chem jars with teflon-lined lids for grain size and total organic carbon (TOC) analysis (these samples may be identified in the raw data by



**Figure 1. Sampling Locations**



their station number followed by the letter "b"). Samples were immediately placed in a cooler on blue ice. Upon return from the field, the organochlorine samples were stored at -20°C until shipment to the laboratory on dry ice; the grain size/TOC samples were stored at +4°C until shipment to the laboratory on wet ice.

### **Equipment Decontamination**

Sampling equipment preparation and decontamination consisted of an ambient (or tap) water rinse, followed by scrubbing with a Liqui-Nox<sup>®</sup> 1% solution, a deionized water rinse, an acetone rinse, a methanol rinse, and 3 deionized water rinses. Equipment was allowed to air dry and then wrapped in aluminum foil until ready for use for each sample.

### **Quality Control**

Additionally the following samples were also submitted for analysis: one sediment sample as a blind duplicate; deionized water from New Jersey Field Office Environmental Contaminants Laboratory on-demand Type I reagent grade water tap was used as a reagent blank; and the final rinsate from the equipment decontamination procedure as a validation of the field decontamination procedure.

## Analytical Methods

Organic analyses, grain size, and TOC analyses were performed at the Service's Patuxent Analytical Control Facility (PACF), Laurel, Maryland. A list of analytes contained in the organochlorine scan can be found Table 2.

<b>Table 2. Target Organochlorines</b>	
<b>Target Group</b>	<b>Specific Targets</b>
Hexachlorocyclohexane (HCH)	Hexachlorobenzene (HCB) Benzene hexachloride (BHC) <i>alpha, beta, and gamma isomers</i>
Cyclodienes	Dieldrin Endrin Chlordane <i>alpha</i> chlordane <i>gamma</i> chlordane heptachlor epoxide oxychlordane <i>cis</i> -nonachlor <i>tran</i> -nonachlor
DDT and its analogs	<i>o,p'</i> - and <i>p,p'</i> -DDD <i>o,p'</i> - and <i>p,p'</i> -DDE <i>o,p'</i> - and <i>p,p'</i> -DDT
Toxaphene	Toxaphene
Mirex	Mirex
Polychlorinated Biphenyls (PCBs)	PCBs - Total

### Organochlorines in Sediment

The Soxhlet extraction procedure was a modified version of the one described by Cromartie et al. (1975). Ten gram aliquots of moist soil were mixed together in activated florisil and ignited sea sand. The samples were then placed into a glass extraction thimble and extracted eight hours via Soxhlet extraction using an 8/1/1 hexane - acetone - methanol solution. The extracts were then extracted three times with water and the organic layers were then combined and cleaned up with florisil (Cromartie *et. al.*, 1975). The pesticides were separated from the PCBs using silica gel column chromatography as described by the above reference except that two fractions were used instead of three (Pesticide and PCB). Samples were quantified by a gas-liquid chromatograph (GLC), equipped with a <sup>63</sup>Ni electron capture detector. The GLC column used was a 30m MEGABORE coated with a 1.0 micron film of 7% cyanopropyl 7% phenyl polysiloxane. Residues were confirmed in one of the samples by gas chromatography/mass spectrometry (GC/MS). Method Code: 005.

### Total Organic Carbon

Total Organic Carbon (TOC) is determined by chemical oxidation of the organic carbon of a sample in an ampule. The sample is acidified, persulfate is added and the sample is purged of Total Inorganic Carbon (TIC). The ampule is sealed and placed in a oven or water bath. The strong oxidant quickly reacts with organic carbon at 100 C to CO<sub>2</sub>. When the oxidation is complete, the ampule is broken and the CO<sub>2</sub> is purged, concentrated by trapping, desorbed, and carried into a non- dispersive infrared detector (NDIR). The measured mass of CO<sub>2</sub> is equal to the mass of TOC in the sample. Method Code: 024.

### Grain Size Analysis

A 15 to 20 gram homogenized sample is placed in a large glass jar. The sample is treated with 50 to 100 ml of Hydrogen Peroxide to oxidize organic matter. The sample is washed with distilled water to remove soluble salts. 400 ml of Sodium Hexametaphosphate (5.5g/L) is added to disperse the sample. The sample is shaken for 24 hours. After shaking, the sample is filtered through a 62.5 micron screen into a 1000 ml graduated cylinder. The sample is rinsed with dispersant in order that all fine-grain sediment is washed into the cylinder. This separates the gravel sand fraction (on the screen) from the silt/clay fraction (in the cylinder). The coarse fraction is washed into a pre-weighed beaker with distilled water and placed in a 100 degree oven for 24 hours. The sample is allowed to cool. The sample is weighed and weights recorded on the data sheets.

The silt/clay size material is determined by settling. A graduated cylinder is filled to exactly 1 liter. The sample is stirred and left to stand for one day. The sample is stirred vigorously. After removing the stirring rod, a 20 ml aliquot is taken from a depth of 20 cm after 20 seconds. This is the 4 phi aliquot and the total weight of the silt + clay fraction. The aliquot is placed in a pre-weighed beaker. At the 2 hour and 3 minute time another 20 ml aliquot is taken at the 10 cm depth. This is the 8 phi aliquot. Pipette the suspension into a different pre-weighed beaker. The beakers are dried overnight and cooled. The beakers are weighed, and the percent sand, silt, and clay fractions are determined. Method Code: 025.

### **Data Analysis**

In addition to reporting analyte-specific minimum, maximum, and geometric mean concentrations, sediment analyte concentrations are compared to the New Jersey Department of Environmental Protection (NJDEP) criteria contained within the *Guidance for Sediment Quality Evaluations* (NJDEP 1998). For freshwater environs the NJDEP *Guidance for Sediment Quality Evaluations* are drawn from Persaud, *et al.*, (1993), utilizing the Lowest Effects Level (LEL) criteria which indicates concentrations at which adverse impacts to benthic organisms may begin to occur (a level tolerated by most benthic organisms). An exceedence of the LEL indicates a **potential** risk (adverse impact) to the benthic community and need for further investigations to reduce uncertainty and better characterize risk and natural resource injury. The NJDEP *Guidance for Sediment Quality Evaluations* also includes the Severe Effects Level (SEL) criterion. Analyte-specific SELs are based on the correlation of severe benthic impacts in 95 percent of the studies reviewed (Persaud, *et al.*, 1993). For non-polar organics, the SEL is

calculated as a function of TOC content. Sediment analyte concentrations were also compared to consensus-based sediment quality guidelines (MacDonald, *et al.*, 2000). The consensus-based sediment quality guidelines use the Toxic Effect Concentration (TEC) defined as the concentration below which harmful effects to benthic organisms are unlikely to be observed, and the Probable Effects Concentration (PEC) defined as the concentration above which harmful effects are likely to be observed. The LEL, SEL, TEC, and PEC are screening values, not enforceable cleanup standards.

## **Data Reporting**

Organochlorine concentrations are reported as ug/kg-dry weight (dw). Ten percent (10%) TOC was the upper limit used for SEL and PEC calculations. One to 10 percent represents the average range over which the TOC normalization approach for generation of the SEL has been examined (USEPA 1988). The PEC was derived from field-collected samples using the assumption of 1 percent TOC. The SELs were calculated assuming 1 percent TOC. Accordingly, for comparison to the PEC and SEL, reported dry weight contaminant concentrations were divided by the sample-specific percent-TOC (*i.e.*, 6.1 percent as a whole number). As with organic carbon-normalization, dry weight-normalization of planar halogenated and non-halogenated organics can be used as an indication of relative bioavailability. The dry weight-normalized values demonstrate good correlation with observed toxic effects when sample-specific TOCs exceed 1-2 percent, and predict sediment toxicity as well or better than organic carbon-normalized criterion in field-collected sediments (Ingersoll, personal communication, August 2005). Dry weight-normalized values to 1 percent organic carbon are reported as ug/kg<sub>oc</sub>.

With the exception of Table 4, when a reported value was less than the Method Detection Limit (MDL) it was assigned a value of zero (*e.g.*, not detected [ND]). The MDL is the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero, and is determined from analysis of a sample in a given matrix containing the analyte (40 CFR part 136, Appendix B, rev.1.11). It is assumed that because a substance was detected at a concentration equal to or greater than the MDL, that substance is 99 percent likely to be present and the quantified value is the "best available estimate" of the true value. The MDL is statistically derived more so than it is analytically.

## **Raw Data**

Raw data in a customized format may be retrieved from the Environmental Conservation Online System (ECOS) web site through the Environmental Contaminants Data Monitoring System (ECDMS) – Catalog 5040068, and has not been included with this report. Spreadsheets used to interpret the raw data are electronically filed at the New Jersey Field Office and are available upon request.

## RESULTS

### Quality Control Samples

Analytical results for the blind duplicate sample (labeled Echo 7) were comparable ( $\log[\text{duplicate}] \pm 25$  percent) to its duplicate (Echo 3). Therefore, the mean analyte values were used for Echo 3 (data not shown). All reagent and field blank analyte values were below method detection limits indicating that sample cross-contamination was unlikely.

### Geophysical Characteristics

Grain size analysis indicates that the sediment/soil samples were principally composed of sand and silt, consistent with soils types along the New Jersey coastal plain. Cranberry bog soils consist of alternating layers of sand and organic matter. While in normal cranberry production, decaying plant material was allowed to accumulate within the bog over time and 0.5 to 2-inches of sand was added to the bog's bed surface every 2-5 years to encourage upright plant production and maintain productivity. Moreover, cranberry soil requires no tilling, and therefore remains undisturbed with minimal mixing of sand and organic matter. The high percentage of fine particulates (sand and silt) in the samples as seen in Table 3 is indicative of depositional areas. The TOC ranged from 1.6 percent to 14.8 percent with a geometric mean of 8.4 percent. The TOC is a useful qualitative indicator of contaminant bioavailability: generally the lower the TOC the more readily a contaminant may be taken up by an organism. Surface water pH in both bogs ranged from 5.5 to 5.8 (data not shown).

### Organochlorines

Dry-weight sediment concentrations of target analytes are found in Table 4 (when the reported value was less than the MDL, the MDL was used and italicized). Table 5 presents analysis of contaminant data by chemical group. All quantifiable analytes exceeded their respective TECs and LELs, indicating a **potential** risk (adverse impact) to the benthic community. Quantifiable organochlorine residues are compared to their respective SELs in Table 6 and PECs in Table 7. PEC-Hazard Quotients (PEC-HQ) were calculated and may be found in Table 8. A PEC-HQ (the dry-weight normalized to 1 percent organic carbon contaminant concentration divided by the analyte-specific PEC) greater than 1 indicates a probabilistic risk of adverse affects to benthic macroinvertebrate; the higher the PEC-HQ over 1, the higher the relative probability of adverse impacts to benthic organisms. Interestingly Station

**Table 3. Sample Site Sediment Characteristics (Percent)**

	Moisture	Grain (particle) Size			Total Organic Carbon
		Clay	Silt	Sand	
E1	42.7	5.61	9	86	1.58
E2	77.4	11	38	51	7.56
E3	84.4	15.6	78	7	12.3
E4	72	12.7	26	61	8.67
E5	77.7	8.35	31	61	6.25
E6	80.6	16.2	38	45	9.56
W1	71.8	10.2	20	70	2.81
W2	85.5	14.7	44	41	14.8
W3	60.7	9.15	30	61	9.83
W4	76.7	8.95	31	60	7.35
W5	76.9	30.8	42	27	11.8
Min	42.7	5.61	9	7	1.58
Mean	73.3	13.0	35.2	51.8	8.4
Max	85.5	16.2	78	86	14.8

W4, the water storage/supply reservoir for the Mill Creek bog, is the only sample station with a mean PEC-HQ of less than unity ( $< 1$ ), which is consistent with the former land use. The data also suggest that used bog waters were not recycled into the up-gradient storage reservoir. If bog waters were recycled, they did not carry significant suspended sediments from the bog. Nominal pesticide residues at W4 are likely a function of drift from historical applications.

#### HCb/ $\alpha$ , $\beta$ , and $\gamma$ BHC

HCB and BHC isomers were not detected above the MDL (17.4 ug/kg-68.9 ug/kg) at any of the eleven sample stations.

#### Cyclodienes

Dieldrin: Quantifiable levels of dieldrin were detected at 3 of 11 (27 percent) sample stations; E1 (27.3 ug/kg), E3 (83 ug/kg) and W2 (110 ug/kg). These three concentrations exceeded the dieldrin TEC (1.90 ug/kg) and LEL (2 ug/kg). When dry-weight normalized to 1 percent organic carbon, residues did not exceed the dieldrin SEL (910 ug/kg<sub>oc</sub>) or PEC (61.8 ug/kg<sub>oc</sub>).

Endrin: Quantifiable levels of endrin were detected at all eleven sampling stations (range = 94.9 ug/kg to 1,280 ug/kg; geometric mean = 423 ug/kg). All eleven endrin detections exceeded the endrin TEC (2.22 ug/kg) and LEL (3 ug/kg). When dry-weight normalized to 1 percent organic carbon, station E5 (205 ug/kg<sub>oc</sub>) approximated the endrin PEC (207 ug/kg<sub>oc</sub>), while station W1 (402 ug/kg<sub>oc</sub>) was approximately twice the endrin PEC, but did not exceed the SEL (1,300 ug/kg<sub>oc</sub>). Based on these results, endrin is a secondary driver of benthic macroinvertebrate toxicity relative to total DDT (see below) found in this investigation. Once endrin is absorbed in mammals, it is converted to endrin ketone, a metabolite far more toxic than the parent compound. The sediment quality criteria used herein were not derived to address mammalian toxicity.

Chlordane: Chlordane components were detected at several stations. Quantifiable levels of  $\gamma$  chlordane were detected at 2 of 11 (18 percent) stations, E4 (53.8 ug/kg) and W2 (88.3 ug/kg). Heptachlor epoxide (82.3 ug/kg), oxychlordane (111.2 ug/kg), and *trans*-nonachlor (94 ug/kg) were detected at station E3. Station E3 was the only station (1 of 11 [9.1 percent]) whereas heptachlor epoxide or oxychlordane were quantifiable. *Trans*-nonachlor also was quantifiable at E2 (49.6 ug/kg), a second of 11 stations (18 percent) with detectable *trans*-nonachlor. For sample E2, the quantifiable chlordane component exceeded the  $\Sigma$ -chlordane TEC (3.24 ug/kg) and LEL (7 ug/kg). When dry-weight normalized to 1 percent organic carbon, none of the stations with quantifiable chlordane components (29 ug/kg<sub>oc</sub>) exceeded the  $\Sigma$ -chlordane PEC (17.6 ug/kg<sub>oc</sub>) but not the SEL (60 ug/kg<sub>oc</sub>). The remaining chlordane components targeted in this investigation,  $\alpha$  chlordane and *cis*-chlordane, were not detected above their sample-specific MDLs.

#### DDT and its analogs

DDD: Quantifiable levels of *o,p'*-DDD were detected at 10 of 11 (percent) stations ranging from 43 ug/kg to 831 ug/kg (geometric mean = 165 ug/kg). Quantifiable levels of *p,p'*-DDD were



detected at all 11 sampling stations, ranging from 266 ug/kg to 5,980 ug/kg (geometric mean = 1,730 ug/kg). The  $\Sigma$ -DDD (*o,p'*-DDD + *p,p'*-DDD) ranged from 297 ug/kg to 6,562 ug/kg (geometric mean = 1,899 ug/kg). When dry-weight normalized to 1 percent organic carbon, all sample stations exceeded the  $\Sigma$ -DDD-PEC (28 ug/kg<sub>oc</sub>), and all stations, except W4, exceeded the  $\Sigma$ -DDD-SEL (60 ug/kg<sub>oc</sub>).

DDE: Quantifiable levels of *o,p'*-DDE were detected at 10 of 11 (percent) stations ranging from 43 ug/kg to 831 ug/kg (geometric mean = 165 ug/kg). Quantifiable levels of *p,p'*-DDE were detected at all 11 sampling stations, ranging from 266 ug/kg to 5,980 ug/kg (geometric mean = 1,730 ug/kg). The  $\Sigma$ -DDE (*o,p'*-DDE + *p,p'*-DDE) ranged from Not Detected (ND) to 2,067 ug/kg (geometric mean of quantifiable values = 438 ug/kg). When dry-weight normalized to 1 percent organic carbon, only stations E3 (207 ug/kg<sub>oc</sub>) and E5 (270 ug/kg<sub>oc</sub>) exceeded the  $\Sigma$ -DDE-SEL (190 ug/kg<sub>oc</sub>). However, all sampling station in the Four-mile Branch (E1-E6) and W1 exceed the  $\Sigma$ -DDE-PEC (31.3 ug/kg<sub>oc</sub>).

DDT: Quantifiable levels of *o,p'*-DDT were detected at 10 of 11 (percent) sampling stations, ranging from 43 ug/kg to 831 ug/kg (geometric mean = 165 ug/kg). Quantifiable levels of *p,p'*-DDT were detected at all 11 ranging from 266 ug/kg to 5,980 ug/kg (geometric mean = 1,730 ug/kg). The  $\Sigma$ -DDT (*o,p'*-DDT + *p,p'*-DDT) ranged from ND to 3,210 ug/kg (geometric mean of quantifiable values = 712 ug/kg). When dry-weight normalized to 1 percent organic carbon, only station W1 (1142 ug/kg<sub>oc</sub>) exceeded the  $\Sigma$ -DDT-SEL (710 ug/kg<sub>oc</sub>). Moreover, stations E1 (303 ug/kg<sub>oc</sub>), E4 (360 ug/kg<sub>oc</sub>), E5 (306 ug/kg<sub>oc</sub>), W1 (1142 ug/kg<sub>oc</sub>), and W3 (318 ug/kg<sub>oc</sub>) exceeded the  $\Sigma$ -DDT-PEC (62.9 ug/kg<sub>oc</sub>).

Technical grade DDT is generally considered a mixture of three forms, *p,p'*-DDT (85%), *o,p'*-DDT (15%), and *o,o'*-DDT (trace amounts), and may be contaminated with DDD and DDE. DDT was a widely used to control insects on agricultural crops and insects that carry diseases like malaria and typhus. Most DDT in the environment is a result of past use; DDD was also used as a pesticide to a limited extent in the past and interestingly *o,p'*-DDD has been used to treat cancer of the adrenal gland. DDE is only found in the environment as a result of contamination or breakdown of DDT. Generally, once in the environmental DDT slowly breaks down to DDD under anaerobic conditions and in areas consistently flooded. In contrast, under aerobic environmental conditions DDT slowly breaks down to DDE, a compound considered far more toxic than its parent compound. Given the limited sampling in this investigation, an average of 79 percent of the total DDT (the sum of the six isomers [DDTr]) was composed of DDD and DDE. This indicates that the parent DDT represents a historic source and that a recent or continuous release (*e.g.*, buried drums) is unlikely. Assuming that DDD was not applied as a direct product for insect control, environmental conditions at the Oxycocus Property appear to preferentially favor the degradation of DDT to DDD. In the Four-mile Branch samples, 56 percent of the DDTr was accounted for by DDD, whereas DDE accounted for 22 percent. Interestingly, in the Mill Creek samples, DDD and DDE accounted for 75 percent and 4.5 percent, respectively, of the DDTr residues.

### Toxaphene

Toxaphene: Quantifiable levels of toxaphene were not detected above the MDL (87.2 ug/kg-345 ug/kg) at any of the eleven sample stations.

### Mirex

Mirex: Mirex was detected at 4 of 11 (36 percent) sample stations, all in the Four-mile Creek bog; (E1 (29.3 ug/kg), E2 (116 ug/kg), E3 (133 ug/kg), and E5 (47.2 ug/kg). All four concentrations exceeded the mirex LEL (7 ug/kg). When dry-weight normalized to 1 percent organic carbon, no samples exceeded the mirex SEL (1,300 ug/kg<sub>oc</sub>) (there is not a TEC or PEC for mirex).

### PCBs

Total PCBs were not detected above the MDL (87.2 ug/kg-345 ug/kg) at any of the eleven sample stations.



**Table 4. Sediment Organochlorine Pesticide Concentrations (ug/kg dw)**

Station	Dieldrin	Endrin	<i>gamma</i> Chlordane	Heptachlor epoxide	Oxychlordane	<i>trans</i> - nonachlor	Mirex	<i>o,p'</i> - DDD	<i>p,p'</i> - DDD	<i>o,p'</i> - DDE	<i>p,p'</i> - DDE	<i>o,p'</i> - DDT	<i>p,p'</i> - DDT
E1	27.3	131	17.4	17.4	17.4	17.4	29.2	42.5	266	57.8	109	17.4	478
E2	44.2	172	44.2	44.2	44.2	49.6	116	68.8	543	294	117	44.2	44.2
E3	83	750	66	82	111	94	133	267	5557	587	1480	77	151
E4	35.7	529	53.8	35.7	35.7	35.7	35.7	157	2300	66.9	799	47.5	3070
E5	44.8	1280	44.8	44.8	44.8	44.8	47.2	582	5980	149	1540	104	1810
E6	51.6	284	51.6	51.6	51.6	51.6	51.6	101	1900	71.9	506	51.6	248
min	27.3	131	17.4	17.4	17.4	17.4	29.2	42.5	266	57.8	109	17.4	44.2
geo mean	45	385	43	42	44	43	58	139	1661	139	477	50	405
max	83	1280	66	82	111	94	133	582	5980	587	1540	104	3070
W1	35.4	1130	35.4	35.4	35.4	35.4	35.4	831	2720	52.8	193	35.4	3210
W2	110	808	88.3	68.8	68.8	68.8	68.8	255	3790	68.8	289	68.8	528
W3	25.4	828	25.4	25.4	25.4	25.4	25.4	370	2780	66.4	224	25.4	3130
W4	43	94.9	43	43	43	43	43	43	297	43	43	43	43
W5	43.2	334	43.2	43.2	43.2	43.2	43.2	102	2330	43.2	105	43.2	55
min	25.4	94.9	25.4	25.4	25.4	25.4	25.4	43	297	43	43	25.4	43
geo mean	45	474	43	41	41	41	41	203	1817	54	141	41	417
max	110	1130	88.3	68.8	68.8	68.8	68.8	831	3790	68.8	289	68.8	3210
<b>All Stations</b>													
min	25.4	94.9	17.4	17.4	17.4	17.4	25.4	42.5	266	43	43	17.4	43
geo mean	45	423	43	41	42	42	50	165	1730	90	274	46	410
max	110	1280	88.3	82	111	94	133	831	5980	587	1540	104	3210

When the report value was less than the MDL, the MDL was used and italicized.

<b>Table 5. Sediment Contaminants Concentrations by Structural Group (ug/kg)</b>								
	<b>Cyclodienes</b>			<b>Mirex</b>	<b>DDT and its analogs</b>			
<b>Station</b>	<b>Dieldrin</b>	<b>Endrin</b>	<b>Σ-Chlordane</b>	<b>Mirex</b>	<b>Σ-DDD</b>	<b>Σ-DDE</b>	<b>Σ-DDT</b>	<b>Total DDT</b>
E1	27.3	131	ND	29.2	308.5	166.8	478	953.3
E2	ND	172	49.6	116	611.8	411	ND	1022.8
E3	83	750	287	133	5824	2067	228	8119
E4	ND	529	53.8	ND	2457	865.9	3117.5	6440.4
E5	ND	1280	ND	47.2	6562	1689	1914	10165
E6	ND	284	ND	51.6	2001	577.9	248	2826.9
min	27.3	131	53.8	29.2	308.5	166.8	228	953.3
geo mean	48	385	91	64	1813	702	694	3370
max	83	1280	287	133	6562	2067	3117.5	10165
W1	ND	1130	ND	ND	3551	245.8	3210	7006.8
W2	110	808	88.3	ND	4045	289	528	4862
W3	ND	828	ND	ND	3150	290.4	3130	6570.4
W4	ND	94.9	86	ND	297	ND	ND	297
W5	ND	334	ND	ND	2432	105	55	2592
min	110	94.9	86		297	105	55	297
geo mean	110	474	87		2008	216	735	2801
max	110	1130	88.3		4045	290.4	3210	7006.8
<b>All Stations</b>								
min	27.3	94.9	ND	ND	297	105	55	297
geo mean	63	423	90	64	1899	438	712	3098
max	110	1280	287	133	6562	2067	3210	10165

<b>Table 6. Sediment Organochlorine Pesticides vs. SELs</b>								
	<b>% TOC</b>	<b>Deldrin</b>	<b>Endrin</b>	<b>ΣChlordane</b>	<b>Mirex</b>	<b>Σ-DDD</b>	<b>Σ-DDE</b>	<b>Σ-DDT</b>
E1	1.58	17	83		18	195	106	303
E2	7.56		23	7	15	81	54	ND
E3	10	8	75	29	13	582	207	23
E4	8.67		61	6		283	100	360
E5	6.25		205		8	1050	270	306
E6	9.56		30		5	209	60	26
W1	2.81		402			1264	87	1142
W2	10	11	81	9		405	29	53
W3	9.83		84			320	30	318
W4	7.35		13	12		40		
W5	10		33			243	11	6
<b>SEL</b>		<b>910</b>	<b>1300</b>	<b>60</b>	<b>1300</b>	<b>60</b>	<b>190</b>	<b>710</b>

When a value exceeds its SEL, the cell is shaded.

**Table 7. Sediment Organochlorine Pesticides vs. PECs**

Station	% TOC	Dieldrin	Endrin	ΣChlordane	Σ-DDD	Σ-DDE	Σ-DDT
E1	1.58	17	83		195	106	303
E2	7.56		23	7	81	54	
E3	10	8	75	29	582	207	23
E4	8.67		61	6	283	100	360
E5	6.25		205		1050	270	306
E6	9.56		30		209	60	26
W1	2.81		402		1264	87	1142
W2	10	11	81	9	405	29	53
W3	9.83		84		320	30	318
W4	7.35		13	12	40		
W5	10		33		243	11	6
<b>PEC</b>		<b>61.8</b>	<b>207</b>	<b>17.6</b>	<b>28.0</b>	<b>31.3</b>	<b>62.9</b>

When a value exceeds its SEL, the cell is shaded.

**Table 8. Contaminant PEC Hazard Quotients**

Station	Dieldrin	Endrin	ΣChlordane	ΣDDD	ΣDDE	ΣDDT	mean PEC HQ
E1	0.28	0.40		6.97	3.37	4.81	3.2
E2		0.11	0.37	2.89	1.74		1.3
E3	0.13	0.36	1.63	20.80	6.60	0.36	5.0
E4		0.29	0.35	10.12	3.19	5.72	3.9
E5		0.99		37.50	8.63	4.87	13.0
E6		0.14		7.48	1.93	0.41	2.5
W1		1.94		45.13	2.79	18.16	17.0
W2	0.18	0.39	0.50	14.45	0.92	0.84	2.9
W3		0.41		11.44	0.94	5.06	4.5
W4		0.06	0.66	1.44			0.7
W5		0.16		8.69	0.34	0.09	2.3
<b>PEC</b>	<b>61.8</b>	<b>207.0</b>	<b>17.6</b>	<b>28.0</b>	<b>31.3</b>	<b>62.9</b>	
Min	0.13	0.06	0.35	1.44	0.34	0.09	0.7
Max	0.28	1.94	1.63	45.13	8.63	18.16	17.0

When a PEC Hazard Quotient is greater than 1, the cell is shaded.

## DISCUSSION

### Study Results

As was done in this investigation, the TEC, LEL, PEC, and SEL criteria are often used to predict potential adverse impacts to benthic organisms. The consensus-based criteria (TEC and PEC), which with rare exception are more stringent than the LEL and SEL, reflect correlative effects and can be used to identify factors that are causing or substantially contributing risk via sediment toxicity. The utility of the TEC is that it can identify sediments which are probabilistically not toxic. In contrast, the PEC should be used to identify sediments that are likely toxic to sediment-dwelling organisms. As such, the TEC and PEC can be used to identify hot spots with respect to sediment contamination, determine the potential for and spatial extent of injury to benthic organisms, and evaluate the need for sediment remediation (MacDonald *et al.*, 2000). However, none of these criteria have demonstrable relevance for direct adverse effects of sediment toxicity to humans, higher trophic-level aquatic life, or aquatic-dependent wildlife such as mink (*Mustela vison*) or birds. Therefore, if interpreted beyond their intended purpose, these criteria may underestimate the risks higher trophic organisms. Additionally, these criteria were not derived to account for bioaccumulative characteristics of substances such as DDE, PCBs and mercury. Nevertheless, when interpreted within their intended purposes, these criteria are useful indicators of potential adverse impacts to benthic organisms, which are an important component of the aquatic food chain.

The contaminants of concern detected in this investigation are the organochlorine pesticides (OCPs) DDT and its analogs, and to a lesser extent, the cyclodiene endrin. The registrations of all OCPs examined in this investigation have been cancelled by the United States Environmental Protection Agency (USEPA). DDT and endrin are highly toxic to aquatic insects and fish. Short-term exposure to DDT at concentrations less than 1 ppb (part per billion) in water has been reported to elicit toxic responses in freshwater and marine fish (USEPA 1980). Endrin produced mortality in a variety of aquatic insects at levels below 1 ppb in water (USEPA 2005). Uptake and translocation of DDT or endrin into plants is not generally efficient and usually does not represent a significant exposure pathway to sensitive ecological receptors (ATSDR 2002).

As a group, OCPs are neuroactive agents; the modes of action include ion permeability (DDT) or effects as blocking or binding agents for nerve receptors (cyclodienes). They can adversely affect reproductive success, thyroid secretion, adrenal function, migratory condition, estrogenic activity, calcium metabolism, and the immune system (Blus 2003). Although varying dramatically according to physical, chemical, and biological conditions, OCP residues may persist in environment for decades, possibly centuries (ATSDR 2002, Blus 2003). Moreover, OCPs have an inherent propensity to bioaccumulate. Bioaccumulation includes bioconcentration (*i.e.*, directly from water through the gills or skin) and biomagnification (*i.e.*, the food chain effect across trophic levels and abiotic matrices). The OCPs are highly soluble in lipids, thus can be stored in an organism's fat deposits. During periods of stress, which can be described by starvation, other weight loss causes or egg production, pesticide residues may be liberated from the fat deposits and transported to the brain or tissues where they may induce mortality or serious sublethal effects (Blus 2003).

Other OCPs detected in this investigation include mirex and the cyclodienes dieldrin and chlordane; however, the concentrations of these compounds were relatively low compared to the levels of DDT. Although levels of dieldrin and chlordane were relatively low, cyclodienes are the most toxic OCPs relative to acute poisoning, with endrin being the considered the most acutely toxic OCP ever used in the United States. Accordingly, additional sampling of the cranberry bogs' abiotic and biotic matrices to reduce uncertainty and better inform EBFNWR management of ecological risk and potential management actions is warranted. The need for additional sampling is underscored by the OCP analysis of eastern mud minnows (*Umbra pygmaea*) collected down-gradient of the Ballinger Creek bog in 1988 (USFWS 1988). These fish had whole body DDT residues of 7.41 ppm (parts per million), more than 10 times the USEPA's most stringent (none [ $<0.5$ ] fish meals/month) monthly fish consumption limit for carcinogenic endpoints (0.55 ppm) (USEPA 2000). The State of New Jersey does not have a DDT fish consumption advisory (NJDEP 2005).

### Water Quality Status Considerations

Mill Creek and Four-mile Branch are perennial streams. The State designated use of each waterbody is "Aquatic Life Use." Moreover, both streams are designated as Freshwater 2- Non-Trout, Category 1 (FW2-NT (C1)). The FW2 designations means the general surface-water classification applied to those fresh waters that are not designated as FW1 or Pinelands Waters. Further, all FW2 waters have a designated use which provides for maintenance, migration and propagation of the natural and established biota (7:9B-1.12(c)1) which includes wildlife. The C1 designation refers to those waters listed in the tables in N.J.A.C. 7:9B- 1.15(c) through (h), for purposes of implementing the antidegradation policies set forth at N.J.A.C. 7:9B-1.5(d), for protection from **measurable changes** in water quality characteristics because of their clarity, color, scenic setting, other characteristics of aesthetic value, exceptional ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resource(s). These waters may include, but are not limited to:..."*waters originating wholly within Federal, interstate, State, county, or municipal parks, forests, fish and wildlife lands, and other special holdings that have not been designated as FW1 at N.J.A.C. 7:9B-1.15(h) Table 6...[and]... other waters and their tributaries that flow through, or border, Federal, State, county, or municipal parks, forests, fish and wildlife lands, and other special holdings.*" Additionally, as defined in N.J.A.C. 7:9B, **measurable change** "*means changes measured or determined by a biological, chemical, physical, or analytical method, conducted in accordance with [U.S. Environmental Protection Agency (USEPA)] approved methods as identified in 40 C.F.R. 136 or other analytical methods (for example, mathematical models, ecological indices) approved by the Department, that might adversely impact a water use (including, but not limited to, aesthetics).*"

Even though Mill Creek is classified as C1, it was on the 2002 303(d) list as "Biology Moderately Impaired" (Site ID: AN0555 - down-gradient of Manahawkin Lake at State Highway 72). Four-mile Branch was not included in the 2002 303(d) list. The State uses benthic macroinvertebrate monitoring based on Barbour, *et al.*, (1999) for water quality evaluations (*e.g.*, to determine the presence or absence of "impairment," but not the cause(s) of the impairment) pursuant to the 303(d) list. In 2004 the State prepared, under USEPA guidance, a combined report which presents the extent to which waters of the State are attaining water

quality standards (pursuant to section 305(b)) and identifies waters that are impaired and need a parameter-specific Total Maximum Daily Load (TMDL) established as required under section 303(d) of the Clean Water Act (CWA) of 1972, as amended (33 U.S.C. 1251 *et seq.*). The Integrated Report describes attainment of designated uses specified in New Jersey's Surface-water Quality Standards (SWQS) which includes: aquatic life, recreation, drinking water, fish and shellfish consumption, industrial and agricultural. In addition, ongoing and planned strategies to maintain and improve water quality statewide are described. The Integrated Report contains the Integrated List that consists of five categories or lists (New Jersey terms them sublists). All assessed waterbodies are placed on a sublist based upon:

1. the degree of support of designated uses;
2. how much is known about the waterway's water quality status; and
3. the type of impairment preventing use support.

Four-mile Branch and Mill Creek are listed in the 2004 Integrated Report as follows.

**Four-mile Branch** at Oxycocus Street, Stafford Township, New Jersey (Site ID: AN0554)

- *Sublist 1. Attaining the water quality standard and no use is threatened.* Threatened is defined as currently supporting uses but information suggests that such uses will not be met within the next two years. Waterways are listed in this sublist if there are data and information that meet the requirements of the State's assessment and listing methodology and support a determination that the water quality standard is attained and no use is threatened.

The Oxycocus Street sampling point (AN0554) and sampling station E1 are at the same location on Four-mile Branch. The data contained herein indicate that Four-mile Branch's water quality standard cannot likely be attained and should be placed on Sublist 5. Moreover, Four-mile Branch's attainment of the water quality standard for support of Aquatic Life Use is likely impacted by the increasing suburbanization in Stafford Township. The combined threats of elevated OCP sediment concentrations and the potential adverse effects of suburban runoff warrants continued long-term monitoring to establish defensible water quality trends and to insure the early detection and cessation of no measurable water quality degradation.

**Mill Creek:** Route 72, Stafford Township, New Jersey (Station ID: AN0555)

- *Sublist 5. The water quality standard is not attained. The waterway is impaired or threatened for one or more designated uses by a pollutant(s), and requires a TMDL.* This sublist constitutes the Section 303(d) list of waters impaired or threatened by a pollutant(s) for which one or more TMDL(s) are needed. A waterway should be listed on this sublist if it is determined, in accordance with the State's assessment and listing methodology that a pollutant has caused, is suspected of causing, or is projected to cause impairment. Where more than one pollutant is associated with the impairment of a single waterway, the waterway will remain on sublist 5 until TMDLs for all pollutants have been completed and approved by USEPA.

The limited sampling in this investigation cannot support or refute that a potential causal factor of benthic macroinvertebrate impairment in Mill Creek at the Route 72 sampling station is

related to up-gradient contaminated bog sediments within the Oxycocus Property. Further evaluation is needed to determine the factors that are causing or significantly contributing to conditions not consistent with the attainment of the Mill Creek's existing or designated uses throughout its entire course. Future investigations of the Oxycocus property bogs will need to include, but should not be limited to, sediment toxicity testing, bioaccumulation studies using fish or mussels, and bird egg contaminant characterizations.

Future analytical characterizations in bog sediments, and possibly biota, need to include heavy metals. Like many small fruiting plants, cranberry vines are susceptible to a variety of fungal-induced rots. To preserve and protect their crop, cranberry farms historically used copper based fungal treatments (Bordeux mixture) several times a year (Oudemans *et al.*, 1998) to combat fungal rot. This would be consistent with the findings of elevated sediment copper concentrations found in the 1996 sampling effort at the effluents of Four-mile Branch bog and the Ballinger Creek bog (USFWS 1998). Moreover, elevated levels of arsenic and mercury, common metals used in fungicidal solutions, were also detected at the Ballinger Creek bog effluent. Like OCPs, heavy metals can elicit adverse toxic effect to aquatic organisms.

While different from metals being intentionally applied to bogs, the likelihood of PAHs in bog sediments is real and is related to the current land development trend towards increased suburbanization, rather than historic bog management practices. Increased suburbanization, as seen around Stafford Township and other part of the EBFNWR, alters the hydrologic response of a watershed or drainage area to rainfall events. The degree of this impact depends on the level of land use changes, the physical features of the watershed including soil characteristics, and the intensity and duration of precipitation. The results of the changes are as follows: the infiltration of precipitation is reduced, the rate of storm-water runoff is accelerated and the quality of storm-water runoff is degraded. In most cases, all three can be expected to occur, and storm-water management is necessary to mitigate the impacts. Among the more toxic constituents of suburban/urban runoff are PAHs which can adversely affect mammals, birds, fish, amphibians, invertebrates, and plants associated with the aquatic environment. The effects of PAHs on invertebrates include inhibited reproduction, delayed emergence, sediment avoidance, and mortality, and the effects on fish include fin erosion, liver abnormalities, cataracts, and immune system impairments (USEPA 2003). Accordingly, best management practices for storm-water management on and around the EBFNWR will be necessary and should be implemented to mitigate these impacts. To assess the impacts of local land use changes the physical features of the local watersheds should include, but not be limited to, soil characterization (*i.e.*, type, grain size, and organic content), storm drain locations and outfalls, storm-water drainage and infiltration areas, storm-water sediment load, and percent impervious cover. These features should be thoroughly delineated, cataloged and periodically (*i.e.*, a 5-year cycle) updated using GPS-GIS techniques.

A previously unidentified source of urban PAHs, parking lot sealcoat, may dominate loading of PAHs to urban water bodies in the United States. Particles in runoff from parking lots with coal-tar emulsion sealcoat had mean concentrations of PAHs of 3500 mg/kg, 65 times higher than the mean concentration from unsealed asphalt and cement surfaces (Mahler *et al.*, 2005). Coal-tar-based sealants are the most readily used sealant in the eastern United States. Moreover, through the combustion and distillation of petroleum in the production of coal-tar, toxic components are

concentrated. This further underscores the need for periodic monitoring of stream sediments entering the EBFNWR and sediments associated with road crossings within the EBFNWR. Moreover, the promotion of an ordinance with the local municipalities (Ocean County and Stafford Township) to limit or ban the use of coal-tar-based sealants, if used, would aid in the "no measurable change" intent of the C1 water designations and likely accelerate the improvement water quality where the biological impairment to benthic macroinvertebrates may be related to PAH sediment loading. The extensive impervious cover of commercial and retail structures along Route 72 adjacent to the southern border of the Oxycoccus Property, and of the high density residential development, Ocean Acres, northwest of the Oxycoccus Property will likely contribute to runoff-related pollutant (*i.e.*, metals, PAHs). Long-term and repetitive monitoring of Mill Creek and Four-mile Branch should be implemented to establish defensible trends in water quality changes on a parallel course with future OCP delineation.

A goal of the CWA is to "restore and maintain the chemical, physical and biological integrity of the Nation's waters." Although the Service and other federal agencies work with the states and USEPA to implement the applicable requirements of the CWA, further progress is needed both to prevent degradation of high quality waters and sensitive aquatic ecosystems and to accelerate the restoration of degraded water resources. The Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management (Federal Register, Vol. 65, No.202 pp. 62566-62572) (UFP), to which the Department of the Interior is signatory, provides a foundation to help ensure that federal land and resource management activities meet the CWA's goals and that the federal government serves as a model for water quality stewardship. The completion of this investigation is consistent with that policy in that it implements a science-based approach to watershed assessment and uses information from the assessment to identify management opportunities and priorities and to develop alternatives to protect or restore watersheds. But because many factors (*e.g.*, stream flow, season, sampling frequency) can induce sample variation, several years of data are needed to determine a trend in analyte concentrations at a specific sampling station. Therefore, environmental quality trends can only be determined at sites where long-term records exist. The implementation of a GIS contaminants database that captures long-term EBFNW contaminants data and contaminants data from other sources (*i.e.*, U.S. Geologic Survey, NJDEP, local watershed management committees) should be an EBFNWR and Service-wide priority. Accordingly, sufficient allocation of funds and manpower are prerequisite for the implementation of any environmental monitoring program. Also to be consistent with the UFP, an environmental quality-monitoring program must be robust, repetitive, and orchestrated with other federal, state and local monitoring programs. It is imperative that such a monitoring program is implemented as a standardized EBFNWR function with a specific and guaranteed annual commitment for contaminant monitoring.

### **Study Area Findings Relationship To EBFNWR Cleanup Investigation**

Preliminary examination of the raw data from this investigation in 2002 revealed concentrations of OCPs correlated with severe adverse effects to benthic macroinvertebrates. Clearly, further investigation of the nature and extent of OCP bog sediment contamination was warranted. Moreover, elevated sediment OCP concentrations detected down-gradient of the bogs indicated the potential for OCP contaminated sediments to migrate off Service lands and downstream. Manahawkin Lake, a recreational lake owned by Stafford Township is located approximately



200 meters down-gradient of the Oxycoccus Property bogs. The 1998 Baseline Contaminant Study of the Edwin B. Forsythe National Wildlife Refuge (USFWS 1998) also revealed elevated sediment levels of DDT and cyclodienes down-gradient of the 35-acre EBFNWR Commerce Bank Tract bog. This bog is less than 2 miles due south of the Oxycoccus Property.

A 2003 Refuge Cleanup Project was funded to further delineate OCP sediment contamination in the Oxycoccus Property bogs' influents and effluents, Manahawkin Lake, and to conduct initial sediment sampling within the Commerce Bank Tract bog. The Cleanup Project also targets the analysis of Manahawkin Lake whole fish and fish fillets for OCPs; however limited analytical funding precluded OCP analysis of fish downstream of the Commerce Bank Tract bog. As part of the Cleanup Project, and in concert with the Service's Division of Engineering, a hydrodynamic flow model for the Mill Creek bog effluent has been initiated. By running the model with flows ranging from an observed low flow to more than the 100-year flood flow, the model will define stream flows at which sediment erosion and transport is likely to occur. This will then allow preliminary quantification of contamination risk, since identified contaminants move with the sediment. If stream sediment is not shown to erode under 100-year flood flows, the risk of downstream contamination is low. If stream sediment begins to erode at 10-year flows, the risk can be much greater. This information will also be critical determining performance specifications of a water control structure if needed. Interpretation of flow model data will begin in October 2005. Upon completion of sediment, hydrodynamic flow modeling and fish data analysis, a final Cleanup Project report will be issued.

## RECOMMENDATIONS

- Conduct sediment toxicity testing, bioaccumulation studies using fish or mussels, and bird egg contaminant characterizations;
- Conduct further sampling of the Oxycocus bogs to horizontally and vertically delineate OCP sediment contamination;
- Analyze Oxycocus Property bog sediments for heavy metals and PAHs in the future;
- Inventory and prioritize all bogs on EBFNWR property for contaminant delineation and down-gradient fish sampling;
- Promote an ordinance with the local municipalities to limit or ban the use of coal-tar-based sealants, if used;
- Thoroughly delineate storm drain locations and outfalls, storm-water drainage and infiltration areas, as well as percent impervious cover up-gradient of the bogs using GPS-GIS techniques;
- Create a GIS contaminants database that captures long-term EBFNWR contaminants data and contaminants data from other sources;
- Implement a contaminants monitoring program as a standardized EBFNWR function with a specific and guaranteed annual commitment of funds and manpower;
- Continue the on-going Cleanup Project pertaining to the Oxycocus and Commerce Bank Tract bog; and
- Analyze fish down-gradient of the Commerce Bank Tract for metals and OCPs.

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### **Personal Communication**

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### **Field Observations**

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