APPENDIX E

RISK ASSESSMENT

US Army Corps of Engineers
Buffalo District

CONTAMINANT MONITORING ASSESSMENT
CLEVELAND HARBOR
CONFINED DISPOSAL FACILITY 10B
CLEVELAND, OHIO

August 2007

CONTAMINANT MONITORING ASSESSMENT
CLEVELAND HARBOR
CONFINED DISPOSAL FACILITY 10B
CLEVELAND NY

EXECUTIVE SUMMARY

This contaminant monitoring assessment was completed in order to determine whether or not further management actions need to be taken at the dredged material confined disposal facilities (CDFs) under the jurisdiction of the Buffalo District of the US Army Corps of Engineers, in order to ensure protection of human health and the environment. This report followed guidance contained in the *Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities – Testing Manual* (UTM) (USACE 2003). The guidance contained within the UTM is technical and not regulatory in nature. It should be noted that the use of threshold levels such as criteria, guidelines, risk-based screening levels, etc. should not be mistaken for regulatory standards. This evaluation followed a tiered approach. Two tiers of evaluation were completed and are presented in this report. Based on this evaluation, it was determined that management actions are not necessary because contaminants in the Cleveland Harbor CDF 10B dredged material are not migrating into the environment outside the facility at levels that would pose a risk to human health or the environment.

The first Tier involved using a risk-based approach, in which potential contaminant migration pathways were identified. The migration pathways are routes by which contaminants or constituents of potential concern associated with dredged material contained in CDFs may move from the dredged material within the site into the environment outside the facility (USACE 2003). Secondly, environmental or human receptors outside of the CDF were identified. These receptors have the potential to be exposed to contaminants associated with the dredged material from within the CDF, once the contaminants migrate outside the facility. Thirdly, risk-based screening levels were identified that protected the identified receptors that could be exposed via the identified migration pathways. The levels of constituents measured in the dredged material were compared to the risk-based criteria in this Tier I evaluation.

This Tier I evaluation concluded that there is enough information to dismiss from further concern, some of the contaminants in the CDF. However, there is not enough information at this stage to eliminate the following potentially complete pathways and contaminants of plant bioaccumulation of cadmium, copper, and zinc; and animal bioaccumulation of DDT, DDE, and PCBs.

These pathways and constituents were carried forward to a Tier III evaluation, i.e., plant and earthworm bioassays were conducted on Cleveland Harbor CDF 10B dredged material and compared to reference area soils from the Cleveland Lakefront State Park. Plant uptake of metals by *Cyperus esculentus* grown in dredged material from the Cleveland Harbor CDF 10B did not exceed uptake from the Reference material. Since the availability of metals to plant uptake in the Cleveland Harbor CDF 10B was lower than from the Reference soil, there is no increased risk associated with the plant uptake of contaminants from the Cleveland Harbor CDF 10B. Earthworms exposed to Cleveland Harbor CDF 10B dredged material and Reference

material were analyzed for PCBs and DDT pesticides. While uptake of PCB (as Arochlor 1248) in the dredged material exceeded that of the Reference material, the concentrations were determined to be well below minimum dietary concentration posing adverse risks to higher animals. Earthworms exposed to dredged material showed higher concentrations of DDT, DDE and DDD compared to the Reference. However, these concentrations were 2 orders of magnitude less than minimum dietary concentrations causing adverse effects to higher animals.

The intended post-closure beneficial use of the CDF is for airport expansion. Federal Aviation Administration regulations will likely require a vegetative cover that reduces hazards for airport operations. This will likely require that vegetative cover be a turf-type that has little attraction for wildlife, particularly birds. Based on the results of this study, this beneficial use activity will not result in increased migration of contaminants outside the CDF. Uptake of cadmium by plants will be minimized by maintaining soil pH and limiting growth of woody species. Management in post-closure use should include the establishment of turf grass and management of soil pH between 7.5 and 6.5. Fine fescues are recommended but other turf species may be used as well.

CONTAMINANT MONITORING ASSESSMENT

CLEVELAND HARBOR
CONFINED DISPOSAL FACILITY 10B
CLEVELAND, OHIO

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ABBREVIATIONS AND ACRONYMS

BEHP	Bis(2-ethylhexyl)phthalate
BNAs	Base neutral and acid extractable compounds
CAA	Clean Air Act
CCC	Criteria Continuous Concentration
CDF	Confined Disposal Facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CMC	Criteria Maximum Concentration
COC	Constituent of Concern
DDT	Dichlorodiphyenyltrichloroethane
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
HTRW	Hazardous, Toxicological, Radiological Waste Sites
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFTA	Niagara Frontier Transportation Authority
NYSDEC	New York State Department of Environmental Conservation
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PEC	Probable Effects Concentrations
PL	Public Law
PPL	Priority Pollutant List
PRG	Preliminary Remediation Goal
SERA	Screening Ecological Risk Analysis
TEC	Threshold Effects Concentrations
TOC	Total Organic Carbon
UTM	Upland Confined Disposal Facilities – Testing Manual
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VOCs	Volatile Organic Compounds

1.0 INTRODUCTION

1.1 Objective

The objective of this evaluation is to determine whether or not further management actions need to be taken at the dredged material confined disposal facilities (CDFs) under the jurisdiction of the Buffalo District of the US Army Corps of Engineers, in order to ensure protection of human health and the environment. Management actions would be recommended if it is determined that contaminants are migrating from dredged material within the CDF into the environment outside the facility at levels that would pose a risk to human health or the environment. This report followed guidance contained in the *Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities – Testing Manual* (UTM), and follows a risk-based approach (USACE 2003). The guidance contained within the UTM is technical and not regulatory in nature. It should be noted that the use of threshold levels such as criteria, guidelines, risk-based screening levels, etc. should not be mistaken for regulatory standards. This evaluation followed a tiered approach, and concluded after the third tier.

1.2 History

Commercial navigation is a critical element of the national economy. Shipping channels and harbors require periodic dredging to maintain required depths. The US Army Corps of Engineers (USACE) dredges, relocates, and disposes of hundreds of millions of cubic yards of sediment annually. Over one hundred harbors and channels are presently maintained in the U.S. Great Lakes by the USACE, including several areas that the International Joint Commission has described as Areas of Concern due to, among other factors, contaminated sediments. The fate of these contaminated sediments has been a public health issue because of potential human exposure or contamination of biota.

Section 123 of Public Law (PL) 91-611 (1970) authorized the USACE to construct, operate, and maintain confined disposal facilities (CDFs) in Great Lakes harbors where dredged materials have been deemed to be unsuitable for open-lake disposal. A CDF is an engineered structure consisting of dikes or other structures that extend above any adjacent water surface and enclose a disposal area for containment of dredged material, isolating the dredged material from adjacent waters or land (USACE and USEPA 1992). Of the approximately four million cubic yards of sediments dredged annually from Federal navigation projects in the Great Lakes, about half are placed into existing CDFs. Disposal of dredged material in CDFs is one of the most commonly considered alternatives for such material. CDFs are also an option considered for disposal of contaminated sediments dredged for purposes of sediment remediation. They are used as temporary rehandling sites or for final disposal. CDFs are also used for the disposal of clean sediments where other disposal options are too costly or present additional environmental problems (USACE 2003).

Figure 1 illustrates the various categories of CDFs. CDFs may be constructed as upland sites, nearshore sites (partial on-shore/off-shore design), or as island containment areas (Figure 1). CDFs vary considerably in size, dike design, and method of filling. CDFs are typically designed

to retain solids while allowing water to be released through an overflow-weir and/or through semi-permeable dikes. CDFs are not solid waste landfills. They are designed and constructed specifically for disposal of dredged sediment, which has a high water content, and to return the flow of excess water as effluent to surface waters (USACE 2003). Over 30 CDFs now exist in the U.S. Great Lakes, with over twenty-five of these having been constructed with Federal funds.

CDFs constructed in water may become upland sites once the fill reaches elevations above the mean high water elevation. A true nearshore site will take advantage of the shoreline as a part of the containment structure for the site, with in-water dikes or other containment structures required only for the outer walls of the total enclosure. Island CDFs are similar to nearshore CDFs, except that they are constructed totally in water with no direct physical connection to the shore (USACE 2003).

Depending mostly on the elevation and frequency of dredged material disposal, dredged material in CDFs may develop into either aquatic, wetland or terrestrial-type habitats. A particular CDF may evolve through a succession of habitat types during its life. As sites are filled, aquatic habitat may be replaced by wetland and then terrestrial habitat. At any point in time, the portions of a single CDF near the inflow point may exhibit terrestrial habitat characteristics, which may shift to wetland habitat and then to aquatic habitat near the weir (USACE 2003).

A primary concern with CDFs is the potential for release of contaminants incorporated within the dredged material back into the environment. Potential pathways for contaminant release from CDFs include migration through or under the dikes, volatilization to the atmosphere, release with discharge water via the weir, and uptake by animals living or feeding in the facility. The purpose of this document is to evaluate the potential release pathways and to assess associated environmental and human health risks.

1.3 Dredged Material Management

The transport of dredged material to CDFs may be accomplished with hydraulic or mechanical means. Hydraulically dredged sediments may be conveyed to the facility with a pipeline from the hopper or cutterhead dredge. Mechanically dredged sediments may be transported to the facility and offloaded mechanically from a barge or the sediments may be converted to a slurry for hydraulic transfer to the disposal facility via pipeline.

Typically, CDFs are constructed with a designated off-loading site. With mechanically placed material, dredged sediment tends to accumulate near the offloading site. If the CDF is filled hydraulically, the discharge of the dredge slurry into the site is generally located away from the overflow weir and a sufficient amount of retention time allows for solids to settle, which translates into an acceptable effluent discharge. If the CDF is filled mechanically, the sediment is physically lifted and placed into the facility using a crane and clamshell bucket.

Early CDFs were designed to retain only solids and were not designed to be watertight. In some instances they were designed to be semi-permeable. CDFs were often constructed with gradations of stone in the dike walls. The outer face of the dike walls were required to have heavy armor stone to withstand forces created by wave action encountered on the Great Lakes. The interior face of the dike walls would also require some armoring to withstand wave action

generated from the water body within the CDF. Various designs were used, including gradations of smaller stone that allow water to move through the dike but trap fine sediment. The fine sediment would presumably clog the dike as the CDF was filled, preventing further release of water through the dike.

USACE policy regarding the flow of CDF return water through the overflow weir into nearby surface waters is that it is a discharge regulated under Section 404(b)(1) of the Clean Water Act. This mandates that unacceptable adverse effects on the aquatic environment be avoided during in-water disposal of dredged material. Therefore, a point source discharge permit under Section 402 of the Clean Water Act, called a National Pollutant Discharge Elimination System (NPDES) permit, is not required.

2.0 POLLUTANTS

Sediment, soil and water samples from the Cleveland Harbor CDF 10B were collected to evaluate the potential for release of contaminants associated with the dredged material back into the environment. Generally, pollutants in Great Lakes dredged material may be divided into three main categories: chlorinated organic compounds (pesticides/polychlorinated biphenyls [PCBs], and dioxin), polycyclic aromatic hydrocarbons (PAHs), and heavy metals. Volatile organic compounds (VOCs) have also been detected in Great Lakes dredged materials, however, to a lesser extent than the three categories cited above. While other physical and chemical constituents are important to water quality in the Great Lakes, these pollutants are not as critical when evaluating dredged material being placed in a CDF. Samples were analyzed for one or more parameter groups from the Federal Priority Pollutant List (PPL, Section 307 of the Clean Water Act) to ensure that the three major groups of pollutants were comprehensively investigated. The PPL includes 129 compounds/analytes analyzed as volatiles, semi-volatiles, pesticides/PCBs, heavy metals, and cyanide. PAHs are a sub-parameter group of the PPL semi-volatile group. The following discusses the most likely PPL compounds/analytes to be detected in material that is dredged from the Great Lakes watershed.

2.1 VOCs

VOCs in general are organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform. The loss of VOCs from sediments and dredged materials is a recognized environmental problem, and disposal and storage operations associated with dredged material placement in CDFs can result in VOC emissions.

Contaminant chemical properties such as Henry's Law Constant and vapor pressure are also very important in determining contaminant flux to air. Henry's Law states that chemicals with higher vapor pressures and low aqueous solubilities will tend to volatilize while chemicals with lower vapor pressures and higher aqueous solubilities will tend to dissolve in water. Environmental variables such as relative air humidity and temperature can also play a part in contributing to VOC loss. Volatile emissions pathways from CDFs can include releases from plant covered dredged material, exposed dredged material, ponded water, and from effluent released from the CDF.

The highest volatile contaminant transfer conditions are in the first few hours after the surface of the dredged material is exposed. After the initial drying of the surface occurs, the rate of volatile contaminant transfer is reduced to levels less than that for a ponded condition. Since ponded conditions can remain over dredged material in a CDF for considerable periods, the ponded condition is likely the most critical at most sites. Contaminant transport from in-situ dredged material to air is a relatively slow process because most contaminant should first be released to the water phase prior to reaching the air.

Currently, there are no known instances where volatiles from CDFs have posed a potential release sufficient enough to trigger the regulatory application of the Clean Air Act (CAA). Importantly, the CAA regulates volatile emissions from a point source (stack), and the CAA regulates only a few parameters such as particulates and carbon dioxide. Neither of these scenarios applies to CDFs. Nevertheless, there are occasions where workers can be exposed to volatile emissions while undertaking management actions at the CDF such as dike rehabilitation and dewatering activities.

2.2 Chlorinated Organic Compounds

2.2.1 PCBs

PCBs are mixtures of chlorine substituted biphenyl compounds. The structure of the compound consists of a biphenyl molecule with substitution of chlorine for the hydrogen on one to ten of the positions on the ring. Differing amounts of substitution and different positions of the chlorines leads to 209 possible compounds, termed congeners. If only the empirical formula is evaluated, the PCBs may be subdivided into ten PCB homologues. The different degrees of chlorination are noted by four-digit numbers after the trade name Aroclor, such as Aroclor 1242 or Aroclor 1260. With the exception of Aroclor 1016 (which is 41% chlorine), the last two digits of the four-digit term represent the percentage of chlorination by mass of the PCB mixtures. Homologous PCBs that only differ by position of the chlorine molecules are termed isomers.

PCBs in the aqueous phase may be sorbed to sediments or may be released to the atmosphere, depending on solubility, vapor pressure, mass transfer coefficients, and other congener specific characteristics. Solubility of PCBs is exceptionally low and this low aqueous solubility results in high partitioning coefficients to abiotic and biotic particles in sediments. Sorption is determined by the organic carbon content of the particles with the highest concentrations bound to organic carbon-rich, clay size particles (Eisenreich et al., 1989).

PCBs in soils will volatilize out of the soil depending on several properties, such as the organic content of the soil and nature of the surface. If water is not present, PCBs will move to the soil surface through simple diffusion. When water evaporates from the soil surface, an appreciable upward movement of water results through diffusion of water (Nottoli and Jacko, 1990).

Environmental PCBs are highly persistent, and quite resistant to biological or chemical degradation. Sediment-associated PCBs are usually quite bioavailable. Therefore, they tend to readily bioaccumulate in aquatic organisms and can biomagnify through the food web. They accumulate in fat tissue. The bioavailability of PCBs depends on factors such as the level and

origin of organic carbon, hydrophobicity (octanol-water partition coefficient, log Kow) and degree of chlorination. Since PCB congeners have differing hydrophobicities and chlorinations, their individual bioavailability can differ significantly.

2.2.2 Pesticides

Several organochlorine pesticides such as dichlorodiphyenyltrichloroethane (DDT), dieldrin, mirex (or dechlorane), toxaphene, and chlordane have been detected in the Great Lakes (Leland et al., 1973, Stevens and Nelson, 1989, Sullivan and Armstrong, 1985, Oliver et al., 1989). They are persistent and generally resistant to biological or chemical degradation. Several pesticides have been demonstrated to have high carcinogenic potency, especially dieldrin and chlordane, and pose the greatest human health risk associated with consumption of Great Lakes fish (Bro et al., 1987).

Sediment-associated pesticides can be quite bioavailable. Therefore, they can also readily bioaccumulate in aquatic organisms and can biomagnify through the food web. The bioavailability of pesticides such as DDT and mirex depends on factors such as the level and origin of organic carbon, and hydrophobicity.

2.3 PAHs

PAHs consist of multiple benzene rings fused together in various arrangements. PAHs are ubiquitous pollutants in Great Lakes sediments and concentrations remain high despite efforts to curb releases. Because many different PAH compounds exist and because of extreme variations in toxicity and carcinogenicity, it is often difficult to determine the impacts of PAHs in sediments. Point and non-point sources account for the high PAH concentrations often seen in dredged material. PAHs as a group are hydrophobic compounds, however there is wide variation in solubility, biodegradability, and toxicity within the group. The PAHs identified by the Environmental Protection Agency as priority pollutants are identified in Table 1. PAHs have higher water solubility than PCBs and their behavior in the water column appears to be dominated by solubility. Low molecular weight PAHs containing 2-3 benzene rings are highly susceptible to volatilization, photolysis, and biodegradation pathways and are rapidly removed from the water column.

When compared to PCBs and pesticides, PAHs can be degraded in the aquatic environment and are much less persistent. Sediment-associated PAHs are usually less bioavailable when compared to PCBs and pesticides, and show an overall relatively low potential to bioaccumulate. Nevertheless, they can bioaccumulate in aquatic organisms and are often metabolized into other compounds, some of which can be more toxic than the parent compound. PAHs usually do not biomagnify through the food web. Their bioavailability depends on factors such as the level and origin of organic carbon, and the hydrophobicity (octanol-water partition coefficient, log Kow) and molecular size of the compound. The bioavailability of PAH compounds can differ substantially.

2.4 Dioxins

Dioxins are classified as halogenated aromatic hydrocarbons. The most notably studied congener is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8- TCDD). As the most toxic congener, it is often referred to simply as dioxin and is the reference for a number of compounds that are similar structurally and have dioxin-like toxicity. Dioxins have no commercial usefulness by themselves, and are trace impurities formed during the manufacture, chlorination, or combustion of other organic compounds.

Dioxins are comprised of over 200 congeners. In general, dioxins have low water solubility and low vapor pressure, and many are very stable. Compounds in these families will have differing properties, depending on the number and position of chlorine atoms in the molecule.

Dioxins are ubiquitous and can be found in a wide range of environments and organisms, though normally in very low concentrations. The persistent and hydrophobic nature of dioxins causes them to accumulate in soils, sediments, organic matter and waste disposal sites. Disturbance of these sites (e.g. such as dredging) may re-release the dioxins. In some animals, dioxins are highly toxic, cause cancer, and alter reproductive development and immune function. They tend to be toxic at very low concentrations and the effects of exposure are often delayed. However, the toxicological effects of dioxins can vary dramatically from species to species. Dioxins are quite resistant to biological or chemical degradation. Sediment-associated dioxins are generally bioavailable and they tend to readily bioaccumulate in aquatic organisms. While dioxins are very slowly eliminated from organism tissues, evidence for biomagnification through the food web is limited. The bioavailability of sediment-associated dioxins depends on factors such as the level of total organic carbon and hydrophobicity. Since the congeners have differing hydrophobicities, their individual bioavailability can differ.

2.5 Metals

Concentrations of metals have been correlated with toxicity at several locations on the Great Lakes (Geisy, 1988) and metal induced toxicity was probably one of the main factors in the initiation of the CDF program. Several metals are included in the priority pollutant list (Table 2). In dredged material and soils metals are typically strongly bound to the soil particles and will resist release.

While metals can exert acute and chronic toxicity, they are generally regarded to be less or non-bioaccumulative. However, some metals such as cadmium and mercury, often do bioaccumulate, and mercury can even biomagnify in the food web. Methyl mercury is the most bioavailable form of mercury. There is no well-established relationship between the levels of metals in sediments and those which are bioaccumulated in aquatic organisms. Therefore, higher levels of metals in sediments are not necessary indicative of what could potentially bioaccumulate.

3.0 POTENTIAL CDF CONTAMINANT EXPOSURE PATHWAYS

Contaminant migration pathways are routes by which contaminants or constituents of concern (COCs) associated with dredged material contained in CDFs may move from the dredged material within the site into the environment outside the facility (USACE 2003). The possible pathways from an upland CDF are illustrated in Figure 2. These six pathways include:

1. Effluent discharges to surface water during filling operations and subsequent settling and dewatering.
2. Precipitation to surface runoff.
3. Leachate into ground water.
4. Volatilization to the atmosphere.
5. Direct uptake by plants growing on the dredged material (plant bioaccumulation).
6. Direct uptake by animals living on the dredged material and subsequent cycling through food webs (animal bioaccumulation).

Pathways for a **nearshore** CDF are illustrated in Figure 3. These routes include a number of pathways that are also considered for upland CDFs. However, the relative importance of pathways for a nearshore CDF differs from an upland CDF. A primary advantage of the nearshore CDF is that contaminated dredged material may remain within the saturated zone so that anaerobic conditions prevail and contaminant mobility is minimized. A disadvantage is that exterior water level fluctuations may cause a pumping action through the exterior dikes, which are generally constructed of permeable material. This pumping action increases the exchange of ponded water from the CDF and increases convection of soluble contaminants from the facility. Soluble contaminants are present in the ponded water by diffusion from the settled dredged material or by expulsion of contaminated pore water from consolidating dredged material. The pumping action may result in soluble convection through the dike in the partially saturated zone and soluble diffusion from the saturated zone through the dike. Pumping action, however, is experienced primarily in CDFs that contain large-grained sediments such as sands and gravels, and is less predominant in those CDFs that contain fine-grained materials such as clays, silts, and fine sands due to the low permeability of these materials.

Pathways for **island** CDFs would be similar to nearshore sites. That portion of a nearshore or island CDF raised to above the mean high water elevation will essentially function as an upland CDF.

Effects on surface water quality, ground water quality, air quality, plants and animals depend on the characteristics of the dredged material, management and operation of the site during and after filling, and the proximity of the CDF to potential contaminant receptors.

4.0 CLEVELAND HARBOR AND CDF 10B

4.1 Location

Cleveland Harbor is located in Cuyahoga County, Ohio at the mouth of the Cuyahoga River, on the south shore of Lake Erie, approximately 176 miles west of Buffalo, New York and 96 miles east of Toledo, Ohio. The Cleveland Harbor Dike CDF 10B is an in-water, nearshore facility. It is located in Cleveland Harbor, on the west side of the existing Dike 13 CDF, adjacent to the Burke Lakefront Municipal Airport (Figure 4).

4.2 Site Features and Characteristics

The City of Cleveland is located at the mouth of the Cuyahoga River as it enters Cleveland Harbor. Because of its location and transportation facilities, Cleveland has become an important center of industry and commerce. Commodities that move through the harbor include limestone, iron ore, cement, sand, gravel, salt, oil, grain, and general cargo. Land use in the Cleveland Harbor area is generally a mix of industrial, commercial, transportation, recreational, with some residential.

Federal navigation channels in Cleveland Harbor include those in the Outer Harbor, and the Old River and the Cuyahoga River Channels (Inner Harbor). The Cleveland Lakefront Harbor extends for a distance of approximately five miles along the shoreline and varies in width from approximately 1,600 to 2,400 feet. The Entrance Channel into the harbor is provided through either the dredged channel between the arrowhead breakwaters (the main or west entrance) or between the eastern end of the east breakwater and the shore (the east entrance). The Inner Harbor includes improved navigation channels on the lower 5.8 miles of the Cuyahoga River and about one mile of the Old River, the former outlet of the Cuyahoga River. Widths in the navigation channels vary from 100 to 325 feet, except at the river bends and in the existing turning basin in the Cuyahoga River where a width of 800 feet is available.

The Cleveland Harbor CDF 10B was constructed in 1998 at a cost of $32,900,000. An Environmental Impact Statement (EIS) dated March 1994 discussed the environmental effects of the project and weighed CDF construction alternatives. The dike design consists of a graded stone core with layered coverstone protection. Navigation projects served by the CDF are dredging of the Federal navigation channels of Cleveland Harbor, as well as dredging by some non-Federal interests. In order to maintain authorized depths in the Federal navigation channels, the USACE must conduct periodic dredging within the Cuyahoga River and Cleveland Harbor. Dredged quantities vary each year but have averaged approximately 300,000 cubic yards per year. The facility occupies an area of approximately 68 acres and has a total capacity of 3,840,000 cubic yards (USACE and USEPA 2003).

Transport of dredged material to the CDF may be accomplished with hydraulic or mechanical techniques. Hydraulically dredged sediments may be conveyed to the CDF with a pipeline from the dredge hopper while mechanically dredged sediments may be transported to the facility and offloaded mechanically or may be converted to a slurry for transfer to the facility by pipeline. Dewatering of the dredged material is accomplished by seepage through the dike walls and by

discharge through an overflow weir into Lake Erie. Treatment of the effluent is achieved through primary settling and filtration through the dike wall. No water quality monitoring is required. The intended post-closure use of the CDF is for expansion of the Burke Lakefront Municipal Airport.

Buffalo District USACE personnel conducted a site visit of the CDF in May of 2004. During this visit, visible evidence of waterfowl, and other avian species was observed on site. However, due the proximity of the Cleveland Harbor CDF 10B to the Burke Lakefront Airport, an aggressive wildlife control program is continuously ongoing at this facility. The presence of terrestrial and avian wildlife species in the area can be detrimental to the operation of the airport, particularly the take-off and landing activities of aircraft. Habitat types dominating the CDF include open-water, emergent wetland, and old-field.

4.3 Initial Identification of Receptors of Concern

Receptors of concern are considered to be ecological receptors, and/or humans outside of the CDF, who might be exposed to contaminants associated with the dredged material. One consideration in determining receptors of concern is current and potential future land use, including surrounding land use. Receptors of concern identified for Cleveland Harbor CDF 10B include dredging workers, wildlife control workers, and various wildlife, primarily waterfowl and other avian species.

The CDF does not constitute a unique fishery resource, nor is it an important fish spawning ground. No potential presence of Federally threatened and/or endangered (T&E) species or their critical habitat is expected in the CDF based on the current habitat present at the site and the distribution of known T&E species in Ohio.

5.0 TIER I - IDENTIFICATION OF POTENTIAL CONSTITUENTS OF CONCERN AND POTENTIAL RECEPTORS AND EXPOSURE PATHWAYS OF CONCERN

5.1 Methodology

Constituent screening evaluations have been conducted on media (soil, sediment and water) contained within and around Cleveland Harbor CDF 10B, to determine its potential toxicity, and determine the potential level of risk it may pose to off-site receptors such as humans, and terrestrial and aquatic biota. For the purposes of this screening, it was determined that the use of Federal screening levels or, where applicable, reference area sediment, soil, or water concentrations, would be the most appropriate approach. The choice of screening values depends on the nature of the constituents of potential concern, the receptors of potential concern, as well as the exposure pathway(s).

5.2 Available Data

Samples were collected from Cleveland Harbor CDF 10B media in 2004 and analyzed for organic and inorganic constituents, including VOCs, PAHs, PCBs, pesticides, metals, base neutral and acid extractable compounds (BNAs), cyanide, and dioxin, to complete the analysis of CDF media according to the priority pollutant list. Media sampled included soils and sediments (and corresponding leachate), ponded water within the dike, water just outside the dike, and lake water. Results of these analyses are found in Appendix A.

Only those analytes found on the priority pollutant list are considered in this evaluation. For example, we have results for metals such as aluminum, barium, and calcium. Since these analytes are not part of the priority pollutant list, they will not be presented here.

5.3 Exposure Pathways

A preliminary conceptual site model for a Tier I evaluation of Cleveland Harbor CDF 10B, identifying the source of contaminants, migration and exposure pathways, and receptors and standards, is shown in Figure 5. This conceptual site model is based upon the six pathways of concern identified in the USACE *Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities – Testing Manual* (UTM), which are listed and described in Section 3 (USACE 2003). The complete exposure pathways to be examined in this Tier 1 analysis are: (1) volatilization from sediments and soils to air, and inhalation by workers or people visiting the site for recreational purposes, (2) rainfall, partitioning to water and surface water accumulation in an interior pond, with subsequent exposure to aquatic organisms within the pond, (3) bioaccumulation of constituents within the pond by fish, and consumption by piscivore birds who visit the CDF, (4) bioaccumulation of constituents from sediments and ponded water by waterfowl, and consumption by people hunting at the CDF, (5) bioaccumulation of constituents from soils by soil invertebrates, and consumption by birds and small mammals at the CDF, (6) root uptake of metals from the soils and sediments, and ingestion of the plants by rabbits, deer, and people hunting at or near the CDF, and (7) direct contact of contaminated soils by people who work at the CDF.

Complete exposure pathways which link the source of constituents with receptors of concern include inhalation of volatiles, surface water runoff to an interior pond, plant uptake of metals, animal uptake of organic constituents, and direct contact with constituents in the soils and sediments. The remaining two pathways, release of discharge of water via the weir, and migration of constituents through or under the CDF dikes, are being eliminated from further consideration for the following reasons: (1) Discharge of effluent water is not a current concern, since the dredged sediment ponds are currently contained by the dike. In the future, when the dredged sediments reach the dike level and release of effluent may be necessary through the overflow weir, then this exposure pathway will have to be re-examined to ensure that surface water quality standards are not exceeded; and (2) Leaching of constituents through or under the dike to the lake is not a concern for this in-water CDF. As stated in section 6.1 of the UTM, leachate that passes through dredged material and directly enters surface waters is not generally a concern with regard to water column impacts, since the rate of flow of leachate is so low and the leachate would be mixed and diluted to background levels almost immediately. Leachate reaching groundwater and then rising to surface water is not addressed in this UTM (USACE 2003).

Five main categories were developed for the purposes of the screening, which encompass all of the exposure pathways identified on the conceptual site model (Figure 5).

a. *Comparison with Reference or Background Levels* – Since the main objective of this evaluation is to determine whether or not constituents from the CDF are being released into the environment at levels that could pose an unacceptable risk to outside receptors, it is appropriate to distinguish concentrations of constituents within the CDF from ambient levels of constituents. The background level of constituents is typically considered at USACE hazardous, toxicological, radiological waste sites (HTRW), which use the USEPA's Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and related documents, such as the National Oil and Hazardous Substances Contingency Plan (NCP), as guidance for investigations, risk assessments, and remedial actions. Although CERCLA does not apply to these CDF evaluations, the USEPA guidance document, "Role of Background in the CERCLA Cleanup Policy" (USEPA 2002a) may be helpful in deciding whether or not background should be considered when risk management concerns are considered for the CDFs. For example, the following definition of background is offered (USEPA 2002a):

> *Background refers to constituents or locations that are not influenced by the releases from a site, and is usually described as naturally occurring or anthropogenic. Anthropogenic refers to natural and man-made substances present in the environment as a result of human activities (not specifically related to the CERCLA release in question). Naturally occurring refers to substances present in the environment in forms that have not been influenced by human activity.*

Although the USEPA recommends that background levels of constituents be accounted for in the risk characterization of a site, it is acknowledged that where background concentrations are high relative to the concentrations of released hazardous pollutants, a comparison of site and background concentrations may help risk managers make decisions concerning appropriate remedial actions (USEPA 2002a). Furthermore, the

NCP outlines criteria for determining whether or not a substance has been released into the environment, which is a determination that needs to be made as part of these CDF evaluations (NCP 1990).

> *The minimum standard to establish an observed release by chemical analysis is analytical evidence of a hazardous substance in the media significantly above the background level. Further, some portion of the release must be attributable to the site.*

In 1997 and 2004, constituents were measured in the water ponded within the dike, just outside the dike, and at lake reference areas. These concentrations were compared to one another to determine whether or not the constituents may be leaking through the dike at elevated amounts, or, whether or not the constituents in the ponded water within the dike are elevated relative to reference lake levels (Table 3). In addition, comparisons were made to concentrations of constituents in background soils or sediments, whenever appropriate data was available (Table 4). Concentrations of PAHs and metals in lake reference sediments, measured in 2002, were compared to concentrations of PAHs and metals in sediments within the CDF (Table 5).

b. *Direct Human Contact with Soils/Sediments* – For direct human contact with the soils and sediments, USEPA Region IX Preliminary Remediation Goals (PRGs) have been used to screen the sediment and soil sample results (USEPA Region IX 2002). The PRGs are risk-based concentrations, developed by the USEPA, Region IX, and are used routinely during site inspections of hazardous wastes sites by USACE risk assessors. These PRGs were developed to address two different types of human receptors: residents and workers. As stated earlier, potential human receptors at CDF 10B include workers. When soil or sediment sample results exceed both the residential and the industrial PRGs, then further evaluation is warranted (Table 6).

This comparison to PRGs includes a consideration of inhalation of VOCs from soils and sediments. The exposure assumptions used to develop the PRGs are more conservative and protective of human health for this situation, than the assumptions used in developing the OSHA air standards. Therefore, an additional comparison to OSHA air standards is not necessary.

c. *Uptake by Biota* – To determine if the material in the CDF might pose the potential for risk to humans or wildlife due to biota uptake, concentrations of constituents in the soils and sediments were compared to biosolids criteria found in USEPA Rule 503 (Federal Register 1997) (Table 7). Biosolids are the nutrient-rich organic materials resulting from the treatment of sewage sludge (the name for the solid, semisolid or liquid untreated residue generated during the treatment of domestic sewage in a treatment facility). When treated and processed, sewage sludge becomes biosolids, which can be safely recycled and applied as fertilizer to sustainably improve and maintain productive soils, and stimulate plant growth. The biosolids rule established pollutant limits in biosolids when the biosolid is applied to agricultural lands, as well as the resulting soil concentration. This comparison is appropriate because the biosolids limits were established as a result of a risk assessment that included ingestion of crops grown in the biosolid-amended soil (which is relevant for exposure to metals), as well as ingestion of animals that have direct

ingestion of biosolid-amended soils (which is relevant for exposure to organic compounds). The most limiting exposure pathway was used to set the criteria concentrations (USEPA 1993).

d. *Aquatic Organism Exposure* – The presence of the ponded surface water at Cleveland Harbor CDF 10B necessitates a screen for protection of aquatic organisms. This was achieved by screening sediment concentrations against consensus threshold effects concentrations (TEC) and probable effects concentrations (PEC) listed in Table 8 (USEPA 2002b), as well as screening concentrations of constituents in ponded water, against national water quality criteria (USEPA 2004), which are listed in Table 9.

The consensus TECs were developed to represent concentrations of individual constituents, below which the constituent was considered to be non-toxic in the sediment. The consensus PECs were developed to represent concentrations of individual constituents, above which the constituent was considered to be toxic. The consensus effects concentrations were validated with toxicity tests (USEPA 2002b). These studies indicated that most of the TECs provide an accurate basis for predicting the absence of sediment toxicity. Similarly, most of the PECs provide an accurate basis for predicting sediment toxicity. The use of these consensus based sediment quality guidelines in a Tier I screen to identify contaminants which may be subject to higher tier effects-based testing is consistent with earlier recommendations by the USACE (USACE 1998). These sediment quality guidelines should not be the sole source of information used in making decisions regarding management of dredged material.

Aquatic life water quality criteria, from the National Recommended Water Quality Criteria (Section 304[a]), contain two criteria; a criteria maximum concentration (CMC), and a criteria continuous concentration (CCC) (USEPA 2004). The CMC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. The CCC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. Because 304(a) aquatic life criteria are national guidance, they are intended to be protective of the vast majority of the aquatic communities in the United States.

e. *Human Consumption of Aquatic* Organisms – Although the CDF is posted and fishing and hunting are not allowed or encouraged from or within the CDF, trespassing still occurs and people may consume fish or aquatic birds that live or feed within the CDF. Humans may hunt waterfowl that feed within the CDF. The USEPA, in its National Recommended Water Quality Criteria (Section 304[a]), has also developed guideline concentrations to protect humans who may consume organisms from surface water, as well as the surface water itself (USEPA 2004). Since municipal water supplies are readily available in the area of the CDF, it is assumed that the CDF water is not used as a source of drinking water. Therefore, the water quality criteria used for this evaluation are not those that are protective for people consuming both the water and organisms from the water; they are protective for people consuming aquatic organisms only. Although consumption of waterfowl is not directly assessed in the development of the water quality

criteria, comparison with these criteria may give an indication of the potential for unacceptable risk to humans who may hunt and consume waterfowl from this CDF. The comparison between concentrations of constituents in ponded water in Cleveland Harbor CDF 10B and the human health water quality criteria is made in Table 10.

5.4 Constituent Specific Screening

Details on the results of screening the data are discussed below.

5.4.1 VOCs:

a. *Comparison to Background* - Five VOCs (1,4-dichlorobenzene, benzene, chlorobenzene, ethylbenzene, and toluene) were detected in soil and sediment samples taken in the CDF, but no VOCs were detected in Cleveland Harbor CDF 10B surface water (Appendix A). VOCs are not expected to exist in background soils and sediments, so any VOCs detected would be considered elevated above background. In general, the sediment concentrations of VOCs are greater than the concentrations of VOCs in soils, so the presence of surface water in CDF 10B may be inhibiting volatilization from dredged material in the facility. Although dredged material is placed into the CDF on a yearly basis, it is not clear why the VOCs would persist in soils and sediments if they originated from the dredged sediments. These VOCs did not appear in Cleveland Harbor Dike14 CDF 1997 sample analysis, although PCE, methylene chloride, and xylene were detected in the 1997 soil samples. The presence of BTEX compounds in the Cleveland Harbor CDF 10B suggests a nearby source, such as aviation fuel from the nearby airport. (Xylene is not part of the priority pollutant list, so it was not analysed for during the 2004 sampling and analysis event.)

b. *Direct Human Contact with Soils/Sediments* – None of the five VOCs detected in CDF 10B soils and sediments are at concentrations that exceed their respective PRGs (Table 6). Therefore, these five VOCs would not pose an unacceptable risk via direct human contact with soils or sediments in Cleveland Harbor CDF 10B.

c. *Uptake by Biota* – Because of their physical properties, VOCs are typically not a bioaccumulation concern. No biosolids criteria (USEPA Rule 503) have been developed for VOCs.

d. *Aquatic Organism Exposure* – No National Recommended Water Quality Criteria for the protection of freshwater aquatic organisms have been developed for VOCs[1]. No sediment consensus effects concentrations have been developed for VOCs. However, secondary surface water quality criteria do exist for VOCs, which, along with equilibrium partitioning calculations, may be used to screen these sediment concentrations of 1,4-dichlorobenzene, benzene, chlorobenzene, ethylbenzene, and toluene. The Tier II

[1] For most organic constituents (other than pesticides), the EPA has not developed water quality criteria for the protection of aquatic life. The water quality criteria established for these organics is only aimed at protection of humans.

chronic values for protection of aquatic life were converted to a sediment quality criterion, using octanol-water partitioning (Suter and Tsao 1996). These were normalized against organic carbon content, to develop a site-specific sediment screening criteria for Cleveland Harbor CDF 10B that would be protective of aquatic life potentially exposed to the CDF sediments. As seen in Table 8a, the derived sediment quality criteria are greater than maximum detected concentrations of all the VOCs detected in Cleveland Harbor CDF 10B sediments. Therefore, it is concluded that VOCs in CDF 10B sediments are not present in levels that could pose a risk to aquatic organisms.

e. *Human Consumption of Aquatic Organisms* – No VOCs were detected in ponded water in Cleveland Harbor CDF 10B. The detection limits reported by the laboratory for the five VOCs that were detected in soils and sediments are less than the water quality criteria for human consumption of aquatic organisms (Table 10). Therefore, VOCs do not pose a risk to humans that may consume aquatic organisms from Cleveland Harbor CDF 10B waters.

f. *Conclusions for VOCs*: Although five VOCs were detected in Cleveland Harbor CDF 10B soils and sediments, they are not present in concentrations that would pose a risk to human health or ecological receptors, for any of the complete exposure pathways identified for this CDF. No further evaluation of VOCs is necessary.

5.4.2 Metals:

a. *Comparison to Background* – To determine whether or not metals exist at elevated concentrations within the CDF, a comparison of average CDF metal concentrations with concentrations of metals from reference areas was made (Table 4). These sediment reference values were published by the Ohio EPA (OEPA, February 2003). The concentrations of most metals in Cleveland Harbor CDF 10B sediments were above the Ohio sediment reference values. The average sediment concentrations of cadmium, copper, and zinc were all over twice the Ohio sediment reference values.

Many sediment metal concentrations were also above lake reference sediment concentrations (Table 5), but the level of exceedances was in general not as great as the exceedances of the Ohio sediment reference concentrations (Table 4).

The concentrations of most metals in the ponded water in the CDF are also higher than corresponding metal concentrations in lake background water (Table 3). The concentration of lead is almost 10 times higher in the ponded water than in the lake water.

b. *Direct Human Contact to Soils/Sediments* – The levels of arsenic in both soils and sediments exceeded both the residential and the industrial PRG (Table 6); however, arsenic was one of the few metals that did not exceed Ohio sediment reference values (Table 4). No other metal concentrations exceed their respective PRGs. Therefore, metals are not a direct contact hazard for humans.

c. *Uptake by Biota* – To determine whether or not these metals might pose a risk to humans or wildlife due to the plant uptake pathway, concentrations of metals in the soils and sediments were compared to biosolids criteria found in USEPA Rule 503. The soil and sediment concentrations of all metals are below biosolids criteria, with the exception of arsenic (Table 7). Although the concentration of arsenic in soil is below the biosolids criteria, the sediment concentrations of arsenic are above the biosolids criteria. However, the arsenic a biosolids criterion was developed based on direct consumption of biosolids by a child, not via plant or animal uptake and subsequent human exposure. The risk assessment used to develop the biosolids criteria also looked at plant and animal uptake for arsenic. If these pathways were used to set the biosolids criteria (rather than the limiting pathway of direct ingestion), then the biosolids criteria would be much higher than the sediment concentrations of arsenic (USEPA 1993). Nevertheless, the biosolids rule does not assess environmental effects of the presence of metals; rather, it focused on exposures to people. Therefore, comparison of metal concentrations to the biosolids limits would not indicate whether or not the plants themselves, or herbivores that visit the CDF, would be at risk due to metal concentrations in the soils or sediments. As several metals were identified as being significantly above background or reference values, further evaluation of this pathway is warranted, since there is currently not enough information available to eliminate this pathway from concern.

d. *Aquatic Organism Exposure* – The maximum and average sediment concentrations of several metals exceed the consensus TECs (Table 8). However, none of the sediment metal concentrations exceed the consensus PECs. Therefore, based on this screening, it is unlikely that metal concentrations in the Cleveland Harbor CDF 10B sediments have the potential to pose an unacceptable risk to aquatic organisms.

Surface water concentrations from within the CDF were also compared to the National Recommended Water Quality Criteria, for protection of freshwater aquatic organisms (Table 9). Only lead in CDF 10B ponded water exceeded the CCC water quality criteria for aquatic life. However, the concentration of lead in ponded water did not exceed the CMC. Therefore, based on this screening, it is unlikely that the metal concentrations in Cleveland Harbor CDF 10B ponded water have the potential to pose an unacceptable risk to aquatic organisms.

e. *Human Consumption of Aquatic Organisms* – Water quality criteria for the protection of human health have only been developed for a few metals (Table 10, USEPA 2004). The only metal that exceeded its respective water quality criteria was arsenic. However, the water quality criterion for arsenic was established at a cancer risk level of one in one million (10^{-6}) excess incremental lifetime cancers. The upper threshold for an acceptable cancer risk is one in ten thousand (1E-04) (NCP 1990). USEPA and USACE use an acceptable cancer risk range of 1 in 1 million to 1 in ten thousand for their HTRW sites. As noted in USEPA 2002c, footnote to the arsenic criterion, "Alternate [cancer] risk levels may be obtained by moving the decimal point (e.g., for a risk level of 10^{-5} move the decimal point in the recommended criterion one place to the right." The concentration of arsenic in ponded water does not exceed 100 times the arsenic criterion,

so the level of arsenic in ponded water would not likely an unacceptable risk via the fish ingestion pathway.

The potentially complete exposure pathway of concern is human consumption of waterfowl that feed at the CDF. Consumption of waterfowl is not directly assessed in the development of the water quality criteria. However, due the proximity of the CDF to the Burke Lakefront Airport, an aggressive wildlife control program is continuously ongoing at this facility. It is unlikely then that a robust waterfowl population would be sustained at CDF. Because arsenic does not have a high potential for bioaccumulation, and because this is only a marginally complete exposure pathway, no further evaluation of this pathway is warranted.

f. *Conclusions for Metals* – Several metals may be elevated relative to background or reference sediment values. Although these metals are not elevated enough to act as potential constituents of concern for some of the relevant exposure pathways (direct human contact, aquatic organism exposure, or human consumption of aquatic organisms), there is not enough information to eliminate the biota uptake pathways from further consideration. Therefore, additional evaluation of metal bioaccumulation, especially via plant uptake, is warranted.

5.4.3 PAHs:

a. *Comparison to Reference or Background* – Levels of PAHs from Cleveland Harbor CDF 10B sediments were compared to PAH concentrations in lake reference sediments, as measured during a 2002 sampling event of river, harbor, and lake reference sediments. As can be seen in Table 5, most PAHs within CDF sediments are greater than lake reference sediments.

b. *Direct Human Contact* - The soil and sediment concentrations of most PAHs are below their respective PRGs (Table 6). The soil concentration of benzo (a) pyrene exceeds the residential PRG, but not the industrial PRG. The maximum and average concentrations of benzo(a)pyrene in the sediments exceed both the residential and industrial PRG for benzo(a)pyrene. However, the PRGs were developed based on extensive direct exposure to soils, not sediments. Because the industrial PRG for benzo(a)pyrene is not exceeded in soil (only in sediments, which would not have as much exposure in an industrial land-use), and the most likely future use of Cleveland Harbor CDF 10B is for industrial use (airport expansion), PAHs in soils do not pose a hazard via direct human contact.

c. *Uptake by Biota* – As non-polar organics, PAHs may have the potential to bioaccumulate, although probably not to the same extent as chlorinated hydrocarbons. This is due to the ability of most organisms to at least partially metabolize PAHs and excrete some of the PAH residues.

To evaluate the potential for PAHs to bioaccumulate, the concentrations of PAHs were compared to criteria established in the biosolids USEPA Rule 503. As seen in Table 7, a biosolids limit of 15 ppm has been established for benzo(a)pyrene. This limit is greater

than the maximum detected concentration of benzo(a)pyrene in Cleveland Harbor CDF 10B soils or sediments. No corresponding soils concentration limit has been established. The 15 ppm limit was established based on the limiting exposure pathway in the biosolids risk assessment, which, for benzo(a)pyrene, was determined to be direct ingestion of biosolids by a child (USEPA 1993). No limit for benzo(a)pyrene was established based on plant to animal uptake, or direct animal uptake from contaminated soils, because these pathways were determined to have minimal risk during a screening, or hazard ranking, phase of the risk assessment (USEPA 1993).

Dredged sediment and the resulting consolidated soils would have significantly less organic carbon content than biosolid-amended soils, which should make organic contaminants more bioavailable (and hence more toxic) from dredged sediments than biosolid-amended soils. Therefore, comparison to the USEPA Rule 503 limits alone may not be enough information to conclude that PAHs do not pose the potential for unacceptable risk due to the animal uptake pathway.

Another line of evidence which may be used to determine whether or not levels of PAHs in Cleveland Harbor CDF 10B soils and sediments would bioaccumulate to adverse levels in wildlife visiting the site, is the comparison of PAH concentrations at the CDF, with PAH concentrations at Times Beach CDF. The Times Beach CDF has been extensively studied in the past, and conclusions may be inferred by making use of the data collected at this Lake Erie CDF (Stafford et al 1991, USACE-LRB 2003). A comparison of the concentrations of PAHs at Times Beach and CDF 10B can be seen in Tables 11 – 12. In addition, the concentration of total organic carbon (TOC) at the two sites was also compared, since TOC may affect the bioavailability of PAHs.

As can be seen in Table 11, average PAH levels in Times Beach oxidized soils are approximately 10 times higher than PAH levels in Cleveland Harbor CDF 10B oxidized soils. Average TOC levels at Times Beach are only approximately 2 times higher than TOC levels at CDF 10B. Therefore, it is likely that PAHs are less bioavailable from the CDF oxidized soils than Times Beach oxidized soils.

The levels of PAHs were measured in tissues of animals and birds caught at Times Beach (Stafford et al. 1991). The levels of PAHs in the Times Beach tissues were all below detection limits, between 0.3 to 1 ppm wet weight. (Although, this study of tissue levels of contaminants did not include an examination of insectivores, such as woodcocks, robins, or shrews, which would have the most direct contact to earthworms.) Most bird and animal species at Times Beach appear to be thriving.

As seen in Table 12, average levels of PAHs in reduced soils at Times Beach are about 10 times higher than PAHs in Cleveland Harbor CDF 10B reduced soils. Average TOC levels in reduced soils at Times Beach are approximately the same as average TOC levels from reduced soils at CDF 10B.

Since PAH levels at Times Beach were not apparently causing overt risk to ecological populations at Times Beach (USACE-LRB 2003), it is unlikely that the much lower

levels of PAHs in Cleveland Harbor CDF 10B have potential for causing adverse ecological risks either.

d. *Aquatic Organism Exposure* – In the Cleveland Harbor CDF 10B sediments, four PAHs had maximum sediment concentrations that exceeded the consensus TEC (Table 8). The average concentration of benzo(a)pyrene also exceeded its consensus TEC. None of the consensus PECs were exceeded. Furthermore, none of the PAHs were detected in ponded water in CDF 10B. Therefore, it is unlikely that Cleveland Harbor CDF 10B ponded water contains PAHs at levels that would have the potential to pose an unacceptable risk to aquatic organisms.

e. *Human Consumption of Aquatic Organisms.* Water quality criteria have been developed for the protection of human health (via consumption of aquatic organisms) for PAHs, and are presented in Table 10. No PAHs were detected in ponded water in CDF 10B, at detection limits that exceed the water quality criteria for many PAHs (Table 10). Therefore, the water quality criteria cannot be directly compared to water concentrations of PAHs. Rather, equilibrium partitioning was performed, using published octanol-water partitioning coefficients (Kow) and measured fraction organic carbon in Cleveland Harbor CDF 10B sediments, to estimate the water concentrations that would exist above sediment concentrations of PAHs. As seen in Table 10a, the estimated water concentrations of these PAHs are all below water quality criteria for PAHs, with the exception of chrysene.

The potentially complete exposure pathway of concern is human consumption of waterfowl that feed at the CDF. However, due the proximity of the Cleveland Harbor CDF 10B to the Burke Lakefront Airport, an aggressive wildlife control program is continuously ongoing at this facility. It is unlikely then that a robust waterfowl population would be sustained at CDF. Because most PAHs passed the screen (particularly the more toxic PAHs such as benzo(a)pyrene, benzo(a)anthracene, and benzo(b)flouranthene), and because this is only a marginally complete exposure pathway, no further evaluation of this pathway is warranted.

f. *Conclusions for PAHs.* Several PAHs are elevated above lake reference concentrations. However, these PAHs are not elevated enough to act as potential constituents of concern for any of the potentially complete exposure pathways at this CDF. Therefore, no further evaluation of PAHs is warranted.

5.4.4 Pesticides

a. *Comparison to Reference or Background* – A comparison of DDT/DDD/DDE in Cleveland Harbor CDF 10B sediments to lake reference concentrations of sediments indicates that the detection limits for these compounds was comparable for samples from both locations. Although DDT/DDD/DDE were not detected in CDF sediments, they were measured above detection limits in soil samples taken from the CDF. However, the total levels of DDT/DDD/DDE in CDF soils are comparable to the total levels of these

pesticides detected in lake reference sediments. Therefore, as the CDF concentrations are not above a lake background, no further evaluation of DDT/DDD/DDE for aquatic pathways from CDF 10B is warranted.

b. *Direct Human Contact* – The levels of DDT and DDE detected in Cleveland Harbor CDF 10B sediment are below residential PRGs (Table 6). Therefore, pesticides do not pose a risk via direct human contact with sediments.

c. *Uptake by Biota* – To evaluate the potential for pesticides to bioaccumulate, the concentrations of pesticides were compared to criteria established in the biosolids USEPA Rule 503. As seen in Table 7, the levels of pesticides in Cleveland Harbor CDF 10B sediments are less than the biosolids rule for these pesticides.

Dredged sediment and the resulting consolidated soils would have significantly less organic carbon content than biosolid-amended soils, which should make organic contaminants more bioavailable (and hence potentially more toxic) from dredged sediments than biosolid-amended soils. Therefore, comparison to the USEPA Rule 503 limits alone may not be enough information to conclude that pesticides do not pose the potential for unacceptable risk due to the animal uptake pathway. Furthermore, the limiting pathway in the risk assessment used to establish the biosolids limit for DDT and DDE was via fish ingestion, not animal bioaccumulation directly from soils. Therefore, there is not enough information to eliminate the animal bioaccumulation pathway for pesticides at Cleveland Harbor CDF 10B. Further evaluation of this pathway may be warranted.

d. *Aquatic Organism Exposure* – The maximum and average sediment concentration of DDT in CDF 10B exceeds the sediment consensus TEC, but not the sediment consensus PEC (Table 8). The sediment concentrations of DDE are lower than the sediment consensus TEC.

The concentration of DDE and DDT in ponded water at CDF 10B are below the limits of detection. The detection limits for DDT in water are greater than the CCC, but not the CMC (Table 9). Therefore, it is unlikely that concentrations of pesticides in Cleveland Harbor CDF 10B pose a risk to aquatic organisms. No further evaluation of this pathway is warranted.

e. *Human Consumption of Aquatic Organisms.* The detection limits for DDE and DDT in ponded water in Cleveland Harbor CDF 10B are greater than the water quality criteria for human health (Table 10). When equilibrium partitioning is used to estimate water concentrations of these pesticides from their maximum sediment concentrations, the calculated water concentration for DDE is lower than its water quality criterion (Table 10a). The estimated water concentration of DDT slightly exceeds its water quality criterion. However, all the reported results for DDT in sediment were below laboratory analytical detection limits. The actual concentration of DDT in sediments is likely to be lower than these detection limits. Because the estimated water concentration of DDT

only slightly exceeds its water quality criteria, and because this is only a marginally complete exposure pathway, no further evaluation of this pathway is warranted.

f. *Conclusions for pesticides.* The pesticide DDT and its degradation product, DDE, were detected in CDF 10B soils. The levels detected are not enough to pose a risk to humans via direct contactor consumption of aquatic organisms, or to aquatic organisms themselves. However, there is not enough information to eliminate the potentially complete pathway of animal bioaccumulation from further consideration. This pathway should be evaluated further for pesticides.

5.4.5 PCBs

a. *Comparison to Reference or Background* – Sediment concentrations of PCBs at the nearest available lake reference location (Rocky River Harbor lake reference area just west of Cleveland) were all below the lower detection limit, with detection limits ranging from 18.5 to 21 ppb. The PCB concentrations detected in Cleveland Harbor CDF 10B are above these lake reference levels, so it is concluded that PCBs are present in elevated levels in this CDF.

b. *Direct Human Contact* – Four different PCB mixtures (Aroclor 1242, Aroclor 1248, Aroclor 1254, and Aroclor 1260) were detected in CDF 10B soils and sediments. The only exceedance of the PRGs was for Aroclor 1242, which exceeded the residential PRG, in sediments only (Table 6). The soil concentration of Aroclor 1242 was less than the residential PRG. The industrial PRG was not exceeded for any of the PCBs detected. Therefore, no further evaluation of this pathway is warranted.

c. *Uptake by Biota* – To evaluate the potential for PCBs to bioaccumulate, the concentrations of PCBs were compared to criteria established in the biosolids USEPA Rule 503. As seen in Table 7, the maximum and average PCBs results from soils collected from the CDF were below the associated biosolid limit. The critical exposure pathway for the PCB biosolid limit was an adult eating animal product, in which the animals were eating the biosolid. As this pathway considered bioaccumulation, the potential for human health risks from animal uptake of PCBs is low. Although the biosolids rule limit does not consider if the bioaccumulation of PCBs is potentially harmful to the animals themselves, the measured concentrations of PCBs at the site are all below 1 ppm, which is considered a threshold for protection of terrestrial ecosystems (USEPA 2001).

d. *Aquatic Organism Exposure* – In the Cleveland Harbor CDF 10B sediments, the maximum concentration of total PCBs detected exceeded the sediment consensus TEC, but not the sediment consensus PEC (Table 8). The average concentration of total PCBs detected was below the sediment consensus TEC.

Although no PCBs were detected in ponded water in Cleveland Harbor CDF 10B, the detection limits for PCBs were above the CCC for protection of aquatic organisms (Table 9). Therefore, equilibrium partitioning was used to estimate the water concentration from the maximum detected PCB concentration (Table 9a). The calculated water

concentration is still greater than the CCC, so further evaluation of this pathway is warranted.

e. *Human Consumption of Aquatic Organisms.* The detection limits for PCBs in water are greater than the water quality criterion for human health (Table 10). When equilibrium partitioning is used to estimate water concentrations of total PCBs detected from their maximum sediment concentration, the calculated water concentration is still above the water quality criterion for PCBs, for protection of human health (Table 10a). Therefore, further evaluation of this pathway may be warranted if these pathways continue to be complete under future site use.

f. *Conclusions for PCBs* – The levels of PCBs detected in Cleveland Harbor CDF 10B media would not pose a risk via direct human contact. In addition, the levels of PCBs are well below 1 ppm, and so would not be a concern to ecological receptors in a terrestrial setting. However, there is not enough information to eliminate PCB exposure to aquatic organisms, or human consumption of aquatic organisms as pathways of concern. Further evaluation of these pathways may be warranted.

5.4.6 BNAs:

The only BNAs detected in Cleveland Harbor CDF 10B media, aside from the PAHs mentioned above, was bis(2-ethylhexyl) phthalate (BEHP). This BNA is a common laboratory contaminant, and the concentrations detected in the media from the CDF are typical concentrations that can be attributable to laboratory contamination. Therefore, no further evaluation of BNAs is necessary.

5.4.7 Cyanide:

There are very few evaluation criteria to compare the cyanide results to. There are no background levels, biosolids criteria, or consensus PEC or TEC values relative to cyanide. However, residential and industrial PRG criteria do exist for cyanide. The cyanide concentrations reported for the soils and sediments from the Cleveland Harbor CDF 10B were well below the USEPA PRG criteria (both residential and industrial) (Table 6). As such, it is unlikely that the cyanide concentrations in the CDF soils and sediments pose a risk to human health or the environment.

5.4.8 Dioxin:

One soil sample was selected for dioxin analysis from the three sediment samples collected in May 2004. The one sediment sample was chosen for dioxin analysis because it had the highest concentrations of PAHs and an elevated TOC concentration relative to the other two samples; thus increasing the potential for a bias in dioxin results.

The USEPA has decided that it is not necessary to regulate dioxin in land-applied sewage sludge (USEPA 2003). As part of their decision, the USEPA performed a Screening

Ecological Risk Analysis (SERA) on the risks to wildlife due to exposure to dioxins from land-applied sewage sludge. While the estimates are not without some uncertainty, the SERA indicates that wildlife should not be significantly impacted as a result of exposure to dioxins in land-applied sewage sludge.

No sediment effects concentrations have been established for dioxin (USEPA 2002b). As for PAHs and VOCs, no National Recommended Water Quality Criteria for the protection of freshwater aquatic organisms have been developed for dioxin[1] (USEPA 2002b).

The measured concentration of dioxin from the selected soil sample from Cleveland Harbor CDF 10B was below the residential and industrial USEPA PRG values (Table 6). Therefore dioxin is not a direct contact hazard for humans at the site. Additionally, due to its low aqueous solubility, dioxin is not expected to be present at detectable concentrations in the ponded water in Cleveland Harbor CDF 10B.

Based on the evaluation above, dioxin does not appear to be an environmental concern at Cleveland Harbor CDF 10B, and therefore, no further evaluation of dioxin is warranted.

5.4.9 Explosives:

No explosives were detected in any samples taken at Cleveland Harbor CDF 10B. In addition, based on surrounding land use as well as sampling of pre-dredged sediments, these constituents are not expected to be present in appreciable levels in the CDF. Therefore, explosives are eliminated from further evaluation.

5.5 Tier I Conclusions and Recommendations

The following conclusions about contaminant releases and contaminant-related environmental effects from Cleveland Harbor CDF 10B can be made. These Tier I conclusions are based upon a review of information that currently exists on the CDF, focusing on the 2004 results of sampling and analysis of CDF soils, sediments, and water. It is assumed that sediments that are currently being placed into the facility, as well as sediments to be dredged from these same areas in the future, are and will continue to be, less contaminated than the sediments placed in the CDF in the past.

1) *Conclusions for VOCs*: Although five VOCs were detected in Cleveland Harbor CDF 10B soils and sediments, they are not present in concentrations that would pose a risk to human health or ecological receptors, for any of the complete exposure pathways identified for this CDF. No further evaluation of VOCs is necessary.

2) *Conclusions for Metals.* Several metals may be elevated relative to background or reference sediment values (i.e., cadmium, copper, and zinc). Although these metals are not elevated enough to act as potential constituents of concern for some of the relevant exposure pathways (direct human contact, aquatic organism exposure, or human consumption of aquatic organisms), there is not enough information to eliminate the biota uptake pathways from further consideration. Additional

evaluation of metal bioaccumulation (for cadmium, copper, and zinc), especially via plant uptake, is warranted.

3) *Conclusions for PAHs.* Several PAHs are elevated above lake reference concentrations. Although these PAHs are not elevated enough to act as potential constituents of concern for any of the potentially complete exposure pathways at this CDF. No further evaluation of PAHs is warranted.

4) *Conclusions for pesticides.* The pesticide DDT and its degradation product, DDE, were detected in Cleveland Harbor CDF 10B soils. The levels detected are not enough to pose a risk to humans via direct contact or consumption of aquatic organisms, or to aquatic organisms themselves. However, there is not enough information to eliminate the potentially complete pathway of animal bioaccumulation from further consideration. This pathway should be evaluated further for pesticides.

5) *Conclusions for PCBs* – The levels of PCBs detected in Cleveland Harbor CDF 10B media would not pose a risk via direct human contact. In addition, the levels of PCBs are well below 1 ppm, and so would not be a concern to ecological receptors in a terrestrial setting. However, there is not enough information to eliminate PCB exposure to aquatic organisms, or human consumption of aquatic organisms as pathways of concern. Further evaluation of these pathways would be warranted only if surface water ponds on the site that would serve as habitat for fish. As the CDF become filled, surface water ponding would be eliminated, so this pathway would remain incomplete and would not be a concern. Furthermore, future use of the CDF for airport expansion would preclude the presence of surface water and fish on site.

6) *Conclusion for BNAs, Cyanide, Dioxin, and Explosives.* Based on the analyses conducted, these constituents are not expected to be an environmental concern for Dike 10B CDF. Therefore, these constituents are eliminated from further evaluation.

7) Leaching of Cleveland Harbor CDF 10B constituents is not a concern due to the placement of the facility in open water, as well as absence of a groundwater aquifer for drinking water purposes at this site. No further evaluation of the leaching pathway is warranted.

5) Because of the remaining capacity of the CDF, discharge of effluent into Lake Erie is not currently a concern. This pathway should be re-evaluated when the CDF nears capacity in the future.

This Tier I evaluation concluded that there is enough information to dismiss from further concern, some of the contaminants in the CDF. However, there is not enough information at this stage to eliminate the following potentially complete pathways and contaminants: (1) Plant bioaccumulation of cadmium, copper, and zinc, (2) Animal bioaccumulation of DDT and DDE, (3) Aquatic organism exposure to PCBs, and (4) Human consumption of aquatic organisms which have bioaccumulated PCBs. Before any decision regarding need for management actions in this CDF are made, these potentially complete exposure pathways and contaminants should be

evaluated in subsequent Tier evaluations, as recommended in the UTM. For evaluation of metals via plant bioaccumulation, the UTM recommends that the potential for plant uptake be estimated by the extraction of metals from the dredged material using diethylenetriaminepentaacetic acid (DTPA), in conjunction with a computerized plant uptake program (Tier II). If further evaluation is still needed after this, then plant bioaccumulation studies may be conducted (Tier III). For animal bioaccumulation of pesticides, the UTM recommends performing earthworm uptake studies (Tier III). For evaluation of whether or not PCBs could pose a risk to aquatic organisms, the UTM recommends repeating the water quality screen with a consideration of mixing effects (Tier II), and then if needed, complete water quality toxicity tests (Tier III). Finally, in order to evaluate whether or not the pesticides DDT and DDE, as well as PCBs could pose a risk to human health via consumption of aquatic organisms, the UTM recommends repeating the water quality screen with a consideration of mixing effects (Tier II), and then if needed, analyse fish tissues for the constituents of potential concern (Tier III).

The ponding of surface water on the CDF is assumed to be a transient condition. Once the CDF has been filled to capacity with dredged material, the final grading should preclude the presence of ponded surface water on the CDF. Therefore, the surface water pathways will not be complete in the future, especially under final land use of airport expansion, and so will not be evaluated further. Only the terrestrial exposure pathways (i.e., animal bioaccumulation) warrant further evaluation.

6.0 TIER II EVALUATION

6.1 Tier II Prediction of Plant Bioaccumulation Potential

The Tier I evaluation determined plant and animal uptake were contaminant pathways of concern and further testing was necessary to evaluate the potential for uptake by plants and animals exposed to dredged material in the Cleveland Harbor CDF 10B. The UTM (USACE, 2003) suggests proceeding to Tier II testing if a decision cannot be reached in Tier I. The procedures for predicting plant bioaccumulation potential under Tier II includes (1) chemical analysis of plant tissues growing in the CDF and comparison to like tissues growing in a reference or background area and/or (2) the chemical extraction of dredged material using a chelating agent diethylenetriaminepentaacetic acid (DTPA) and comparison to chemical extraction of a reference soil.

The comparison of contaminant concentrations in plant materials collected from a CDF and reference site requires that the same plant species must exist on both sites. This can sometimes be a difficult proposition and comparison between dissimilar species may not be valid as uptake potential varies by species. The DTPA procedure has been used in a number of studies to successfully predict plant bioaccumulation from dredged material placed in terrestrial (wetland and upland) environments (Lee, Folsom, and Engler 1982; Lee, Folsom, and Bates 1983; U.S. Army Engineer Waterways Experiment Station, 1987) and compared well with actual concentrations of metals in leaves of bioassay plants. However, actual plant exposures tend to be a more reliable method of evaluating plant response to contaminant exposures *in situ*.

For the reasons described above it was recommended by the developers of the UTM at the US Army Engineer Research and Development Center, Vicksburg, MS (ERDC-Vicksburg) to skip the Tier II testing and proceed directly to the more quantitative Tier III bioassay test procedure.

6.2 Tier II Theoretical Bioaccumulation Potential

The Tier II animal screen suggests the use of theoretical bioaccumulation potential (TBP) for predicting bioaccumulation of nonpolar organics. This includes the chlorinated hydrocarbon pesticides, many other halogenated hydrocarbons, PCBs, many PAHs including all the priority pollutant PAHs, dioxins, and furans. However, the TBP been used mainly for calculating bioaccumulation of nonpolar organics in aquatic animals and its utility for predicting bioaccumulation in soil invertebrates has not been confirmed to date. Again, UTM developers at the ERDC-Vicksburg suggested proceeding directly to the Tier III bioassay procedure.

6.3 Soil Screening Levels for Beneficial Use

Beneficial use of dredged material includes the use of the CDF and material within once the CDF is filled and no longer used for dredged material placement. The Great Lakes Commission developed a regional testing manual (Beneficial Use Upland Testing and Evaluation Project Management Team, 2004a and b) for the upland beneficial use of dredged material in the Great Lakes Area. State guidance and regulatory criteria for contaminant limitations appropriate for this project are provided in the manual http://www.glc.org/upland/download/UplandFramework_2.pdf and is summarized in Table 1 for the contaminants of interest. While criteria are not available for all contaminants of interest, many are and may be used to determine suitability of dredged material for specific purposes. For the State of Ohio, soil criteria for residential cover and unrestricted fill are adapted from Canadian Soil Quality Guidelines (Canadian Council of Ministers of the Environment, 2006 http://www.ccme.ca/assets/pdf/ceqg_soil_summary_table_v6_e.pdf). Ohio criteria for industrial use is based on Ohio sewage sludge rules (Ohio Administrative Code 3745-40) http://www.epa.state.oh.us/dsw/rules/3745-40.html. The monthly average concentrations are shown in Figure 1. The Canadian Soil Quality Guidelines are provided in Figure 2.

7.0 TIER III EVALUATION

7.1 Tier III Plant and Animal Bioaccumulation Tests

The purpose of Tier III plant and animal bioaccumulation test is to determine the potential migration of contaminants from the CDF through the food-chain. The bioavailability of contaminants to plants and animals exposed to dredged material in the CDF is a means of determining the potential risks to these receptors outside the CDF. For most contaminants, there is not a linear relationship between the concentration in dredged material and bioavailability to plants and soil invertebrates; thus, actual biological exposures to the dredged material in question must be conducted. The UTM recommends conducting bioassays on the dredged material in question as well as on a reference sediment or soil. Actual bioaccumulation in tissues exposed to dredged material and reference soil contaminants determines the potential risks posed to food webs in comparison to local conditions.

The Tier III procedure for plants determines the potential bioaccumulation of contaminants of any contaminant under freshwater terrestrial conditions by *Cyperus esculentus*, a representative plant species found in both wetland and upland soil conditions. The plant bioassay provides information on (1) ability of the dredged material to support plant survival and growth, (2) bioavailability and mobility of contaminants from soil to the above-ground plant tissues and (3) the potential for contaminant movement to higher organisms (e.g., birds, mammals, amphibians, reptiles) from off the site linked to plants in the food web.

The Tier III procedure for animals determines the potential bioaccumulation of any contaminant under freshwater terrestrial conditions by earthworms, a representative soil invertebrate known to accumulate a wide variety of contaminants from the soil in which it lives. This standardized test procedure has been published as ASTM Standard Procedure SE-1676 (ASTM 1997). The bioaccumulation assay provides information on (1) bioavailability and mobility of contaminants from soil to soil-dwelling earthworms, and (2) the potential for contaminant movement to higher organisms (e.g., birds, mammals, amphibians, reptiles) from off the site that are linked to earthworms in the food web.

7.2 Regulatory Guidance

Chapter 1 of the UTM (USACE, 2003) discusses the regulatory authorities governing placement of dredged material in CDFs. The direct uptake or bioaccumulation of contaminants by wetland and terrestrial plants and animals is not directly governed by any specific regulations. The plant and animal uptake pathways for CDFs receiving dredged material are unique in that dredged material is not sewage sludge, solid waste, or an industrial byproduct and therefore the regulatory authorities over those materials cannot be applied to dredged material in a CDF. Once dredged material is placed in a CDF it is essentially a soil and since it is generally from the adjacent waterway it may contain low levels of contaminants from various anthropogenic sources. Statutory or regulatory regimes used for land application of sludge or industrial waste products were developed based on the risks posed by the use of those materials and are not applicable for CDF placement of dredged material. The general mandate under NEPA requires evaluations of the uptake pathways, since uptake and subsequent movement of contaminants into food webs may result in impacts outside the CDF. In the UTM, the potential uptake of contaminants into plant and animal tissue is compared to that for a reference material representative of soils in the vicinity of the CDF. Generally, if the dredged material uptake exceeds that for the reference, the potential environmental impact of the plant or animal uptake pathway outside of the CDF is evaluated in the context of a risk assessment.

For beneficial uses of dredged material there is little guidance for determining suitability of dredged material for any given use based on its contaminant concentrations. The soil screening levels described in section 6.3 above can be used to determine suitability of dredged material for beneficial purposes. Some states use various soil quality criteria derived form a number of sources including USEPA 503 Rule sewage sludge limitations, ecological/human health soil screening levels, remediation or cleanup goals for superfund sites, etc. The use of these varies in regulatory application by states and some are applied with a pass (suitable) or fail (not suitable) philosophy. In the testing protocols under the UTM, a Tier II screening level should determine whether suitability can be determined at the Tier II level or whether further testing under Tier III is required to make that decision. In that context, soil criteria based on protection of ecological

or human health should be sufficient to determine if a dredged material is suitable for specific beneficial uses and to determine if additional testing is required.

7.3 Methods and Materials

7.3.1 Sample Collection and Preparation

Samples of dredged material and reference soils were collected by USACE-LRB personnel during the month of April, 2006. A 13-liter polyethylene bucket was filled from three locations within Cleveland Harbor CDF 10B and the Cleveland Lakefront State Park for a total of three buckets from each site. The buckets were sealed and shipped to the ERDC-Vicksburg. Upon sample receipt the three buckets from each site were mixed to form one composite sample each for Cleveland Harbor CDF 10B and the Cleveland Lakefront State Park.

7.3.2 Plant and Earthworm Bioassays

The plant and earthworm bioassays were conducted on both reference soils and dredged materials following the methods in the UTM (USACE, 2003). The plant bioassay followed Section H.3 Tier III – Laboratory Plant Bioaccumulation Procedures in Appendix H of the UTM. After completion of the plant bioassay, the soil materials were remixed within each bioassay unit and the earthworm bioassay was conducted on that same material following procedures in Section G.3 Tier III - Terrestrial Animal Bioaccumulation Test, found in Appendix G of the UTM. Both tests were conducted in the ERDC-Vicksburg facilities.

7.3.3 Evaluation Parameters

Samples of each composite were analyzed for metals, PCBs (as Arochlors), and total organic carbon (TOC). Results of chemical analysis were compared to soil criteria described in Section 6.3. At the end of the bioassay period, plant biomass was determined on the above-ground portion of the plant. Above-ground plant tissues were dried, ground and analyzed for arsenic, silver, cadmium, chromium, copper, mercury, nickel, lead and zinc. Earthworms were collected at the end of the bioassay period, counted and weighed to determine effects on survival and growth. Earthworm tissues were ground and analyzed for PCBs. Tissue concentrations of contaminants in both plants and earthworms exposed to CDF dredged material was compared to reference soil tissues. For determination of means, values below the method detection limit (MDL) were set at the MDL numerical value.

7.4 Results and Discussion

7.4.1 Physical and Chemical Soil Characteristics

Characteristics of the Cleveland Harbor CDF 10B and Reference site are shown in Table 2. The Reference soil consisted of considerably more sand than the CDF dredged

material and had a lower pH response. Total organic carbon (TOC) was also higher in the Cleveland Harbor CDF 10B dredged material. Results of chemical analysis of the Cleveland Harbor CDF 10B and Cleveland Reference soils are shown in Table 3. Concentrations of all metals, except Ag, were shown to be higher in the CDF dredged material than in the Reference soil. Ag was not detected in either material. Results of analysis for PCBs (as Arochlors) and DDT and breakdown products DDE and DDD indicate detectable levels of Arochlor 1248 in dredged material only. DDT was not detected in either the CDF dredged material or Reference material while the breakdown product DDE was detected in both and DDD was only detected in the CDF dredged material. Detectable contaminants in the CDF dredged material were generally higher than contaminants in the Reference material. However, the increased concentration alone does not result in increased bioaccumulation by organisms. Other soil properties influence the availability of contaminants through various contaminant pathways which is why bioassays are valuable in determining actual uptake of contaminants due to exposure.

Contaminant concentrations of the CDF dredged material was compared to soil criteria in section 6.3. All contaminants, except arsenic, in Cleveland Harbor CDF 10B dredged material were below the Ohio criteria for unrestricted fill or the Canadian Soil Quality Guidelines for residential/parkland use (Figure 1 and 3). Arsenic concentration in Cleveland Harbor CDF 10B dredged material was 13 mg kg^{-1} while the criteria for residential or unrestricted fill is 12 mg kg^{-1}. With replicate analysis and statistical comparison, the dredged material arsenic my not statistically exceed the criterion. Assuming all stakeholders and regulatory authorities would agree with the screening level comparison to determine suitability, the Cleveland Harbor CDF 10B dredged material would be considered suitable for residential, parkland or unrestricted fill. However, agreement to this approach is not widely held by many states and additional testing is generally required for such determination.

7.4.2 Plant Growth and Uptake of Metals

Total above-ground plant biomass after 45 days of growth is shown in Table 16. The dredged material from Cleveland Harbor CDF 10B (Figure 8) was found to produce more robust plant growth compared to the Reference soil (Figure 9). The fresh weight biomass of 118.2 grams was nearly twice the biomass produced in the Reference soil. The results from chemical analysis, shown in Table 17, demonstrate that while the concentrations of metals were higher in the CDF dredged material, plant tissue concentrations were not. None of the metals analyzed in tissue of *Cyperus esculentus* grown in Cleveland Harbor CDF 10B dredged material exceeded concentrations in tissues grown in the Reference site soil. While the reference site soil had lower concentrations of metals, bioavailability of these metals to plants was actually higher. This is probably due to the lower pH of 5.7 and possibly to the lower TOC while other properties, such as variations in essential nutrients, may also contribute.

While there are no specific regulatory limitations on ecological plant tissue contaminants there are some guidelines that can be made useful. The European Commission (EU) has

set action levels contaminants in foodstuffs (http://eur-lex.europa.eu/LexUriServ/site/en/consleg/2001/R/02001R0466-20051129-en.pdf) which can be compared to plant tissue levels. Action levels for lead and cadmium in leafy vegetables (wet weight), is 0.3 and 0.2 mg kg^{-1}, respectively. Converting for the wet weight concentration, the CDF plant tissue lead and cadmium would be 0.77 and 0.27 mg kg^{-1}, respectively. While CDF plant tissues may exceed the EU action levels for leafy vegetables, plant tissue lead and cadmium in the Reference material is higher and due to the industrial history of the Cleveland area, other vegetated soils in the area would be expected to produce similar results.

7.4.3 Earthworm Growth and Uptake of Organic Contaminants

Initial (Day 0) and 28-day earthworm weights and counts are shown in Table 18. Mean lipid content of earthworms at the start of the test procedure was 19.3 mg kg^{-1}. Overall, recovered worms and recovered weight was less in the CDF dredged material compared to the Reference and control. Loss of earthworms in all test materials can be explained by death and decomposition but cause of death is uncertain. Stress or injury during handling and transfer to test media or competition for food are possible explanations. The 28-day exposure of earthworms to test materials did result in uptake of PCBs and DDT pesticides as shown in Table 19. Arochlor 1248 was the only PCB compound detected in earthworm tissues from both the CDF dredged material and the Reference material. Pesticides DDT, DDE and DDD were all detectable in earthworms exposed to CDF dredged material while only DDE was detected in Reference material earthworms. Concentrations of PCB and DDT pesticides were higher in dredged material earthworms compared to Reference material earthworms but are not considered elevated. Eisler (1986) suggests a level of <0.64 mg PCBs/kg fresh weight of diet for mink (very sensitive to PCBs) and <3.0 mg PCBs/kg fresh weight of diet for birds (more resistant to PCBs). Concentrations of PCBs in earthworms exposed to CDF dredged material were 0.041 mg kg-1, below the dietary concentration suggested by Eisler (1986) as protective for more sensitive species.

DDT uptake by earthworms is of concern due to the high level of tolerance to the compound by earthworms. Earthworms have been shown to be unaffected by DDT at levels of 2000 mg kg^{-1} soil (Goffart, 1949). However, bioaccumulation of DDT by earthworms can result in adverse effects to other species in the food chain. WHO (1989) summarizes the environmental aspects of DDT and its derivatives. Effects on birds are mostly associated with thinning of eggshells and WHO found the lowest reported dietary concentration of DDT reported to cause shell thinning experimentally was 0.6 mg kg^{-1} for the black duck. Earthworms exposed to CDF dredged material contained concentrations of DDT and its derivatives 2 orders of magnitude below this.

7.5 TIER III Conclusion

Contaminants in the Cleveland Harbor CDF 10B dredged material are below numerical criteria deemed suitable for beneficial uses. However, at this time the suitability for beneficial uses may not be determined acceptable by such comparisons alone. Tier III plant and earthworm bioassays were conducted on Cleveland Harbor CDF 10B dredged material and compared to the Cleveland Lakefront State Park (Reference). Plant uptake of metals by *Cyperus esculentus* grown in dredged material from the Cleveland Harbor CDF 10B did not exceed uptake from the Reference material. Since the availability of metals to plant uptake in the Cleveland Harbor CDF 10B was lower than from the Reference soil, there is no increased risk associated with the plant uptake of contaminants from the Cleveland Harbor CDF 10B. Other plant species, such as trees, may increase the uptake of some metals while some species, such as fine fescues, can minimize uptake of metals (Palazzo 2003). A lowering of pH over time may also increase metal uptake by plants. Management options to ensure conditions attributable to higher plant uptake of metals may include establishment of grasses, such as fine fescues, and monitoring of pH and subsequent liming to maintain pH levels above 6.5.

Earthworms exposed to Cleveland Harbor CDF 10B dredged material and Reference material were analyzed for PCBs and DDT pesticides. While uptake of PCB (as Arochlor 1248) in the dredged material exceeded that of the Reference material, the concentrations were determined to be well below minimum dietary concentration posing adverse risks to higher animals. DDT, DDE and DDD were also higher earthworms exposed to dredged material compared to the Reference but these concentrations were 2 orders of magnitude less than minimum dietary concentrations causing adverse effects to higher animals.

8.0 Recommendations for CDF Beneficial Use and Management

The intended post-closure beneficial use of the CDF is for airport expansion. Federal Aviation Administration regulations will likely require a vegetative cover that reduces hazards for airport operations. This will likely require that vegetative cover be a turf-type that has little attraction for wildlife, particularly birds. Based on the results of this study, this beneficial use activity will not result in increased migration of contaminants outside the CDF. Uptake of cadmium by plants will be minimized by maintaining soil pH and limiting growth of woody species. Management in post-closure use should include the establishment of turf grass and management of soil pH between 7.5 and 6.5. Fine fescues are recommended but other turf species may be used as well.

REFERENCES

American Society of Testing and Materials (ASTM). (1997). "Standard guide for conducting laboratory soil toxicity of bioaccumulation tests with the lumbricated earthworm *Eisenia Fetida*," Designation ASTM E 1676-97, West Conshohocken, PA.

Beneficial Use Upland Testing and Evaluation Project Management Team. (2004a). "Testing and Evaluating Dredged Material for Upland Beneficial Uses: A Regional Framework for the Great Lakes," 2nd Ed., Great Lakes Commission, Ann Arbor, MI. (This report is available online via the Great Lakes Dredging Team website at http://www.glc.org/dredging/publications).

Beneficial Use Upland Testing and Evaluation Project Management Team. (2004b). "Upland Beneficial Use of Dredged Material Testing and Evaluation Annotated Bibliography," 2nd Ed., Great Lakes Commission, Ann Arbor, MI. (This report is available online via the Great Lakes Dredging Team website at http://www.glc.org/dredging/publications

Bro, K.M., Sonzongi, W.C. and M.E. Hanson. 1987. *Relative Cancer Risks of Chemical Contaminants in the Great Lakes*. Environ. Manage. 11(4): 495-505.

Eisenreich, S.J., Capel, P.D., Robbins, J.A., and R. Bourbonniere. 1989. *Accumulation and Diagenesis of Chlorinated Hydrocarbons in Lacustrine Sediments*. Environ. Sci. and Tech. 23: 1116-1126.

Eisler, R. 1986. Polychlorinated biphenyl hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85(1.7).

Environmental Laboratory. (1987). "Disposal alternatives for PCB contaminated sediments from Indiana Harbor, Indiana; Volume II," Miscellaneous Paper EL-87-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Federal Register. 1997. *The Standards for the Use or Disposal of Sewage Sludge* (Title 40 of the Code of Federal Regulations [CFR], Part 503).

Giesy, J.P., Ludwig, J.P., and D.E. Tillit. 1994. *Deformities in Birds of the Great Lakes Region: Assigning Causality*. Environ. Sci. and Tech. 28(3): 128A-135A.

Goffart, H. 1949. [The effect of new kinds of insecticides on earthworms.] *Anz. Schadlingskd. (Berlin)* , **22:** 72-74 (in German).

Marquenie, J. M., Simmers, J. W., and S. H. Kay. 1987. *Preliminary Assessment of Bioaccumulation of Metals and Organic Contaminants at the Times Beach Confined Disposal Site, Buffalo New York.* Miscellaneous Paper EL-87-6. US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, C.R., Folsom, B. L., Jr., and Engler, R. M. (1982) "Availability and Plant Uptake of Heavy Metals from Contaminated Dredged Material Placed in Flooded and Upland Disposal Environments," *Environment International* 7: 65-71

Lee, C.R., Folsom, B. L., Bates, D. J. (1983) "Prediction of Plant Uptake of Toxic Metals Using a Modified DTPA Soil Extractant," *The Science of the Total Environment* 28: 191-202

Leland, H.V., Bruce, W.N., and N.F. Shimp. 1973. *Chlorinated Hydrocarbon Insecticides in Sediments of Southern Lake Michigan*. Environ. Sci. and Tech. 7(9): 833-838.

Nottoli, J.A. and R.B. Jacko. 1990. *Atmospheric PCB Flux Rate Determination Following a Localized Soil Spill*. Hydrocarbon Processing Symposium. 1990. Presented at the Thirteenth Annual Energy-Sources Technology Conference and Exhibition. New Orleans. 28: 1-5.

NCP. 1990. National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 CFR Part 300, 55 Federal Register 8666, March 8, 1990.

NYSDEC. 1994. *Technical and Administrative Guidance Memorandum #4046: Determination of Soil Cleanup Objectives and Cleanup Levels.*

Ohio EPA Division of Emergency and Remedial Response. 1993. Guidance for Conducting Ecological Risk Assessments. DERR - 00 - RR – 031. February 2003. http://www.epa.state.oh.us/derr/rules/RR-031.pdf

Palazzo, AJ, Cary, TJ, Hardy, SE and Lee, CR. 2003. "*Root Growth and Metal Uptake in Four Grasses Grown on Zinc Contaminated Soils*", Journ. of Environ. Qual. 32:834-840.

Oliver, B.G., Charlton, M.N. and R.W. Durham. 1989. *Distribution, Redistribution, and Geochronology of Polychlorinated Biphenyl Congeners and Other Chlorinated Hydrocarbons in Lake Ontario Sediments*. Environ. Sci. and Tech. 23: 200-208.

Roper, J.M., Cherry, D.S., Simmers, J.W., Tatem, H.E. 1996. *Bioaccumulation of toxicants in the zebra mussel, Dreissena polymorpha, at the Times Beach Confined Disposal Facility, Buffalo, New York.* Environmental Pollution; 94:117-129.

Stafford, E. A., J. W. Simmers, G. R. Rhett, and C. P. Brown. 1991. *Interim Report: Collation and Interpretation of Data for Times Beach Confined Disposal Facility, Buffalo, New York.* Miscellaneous Paper D-91-17, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Stevens, R.J. and M.A. Nelson. 1989. *Inter- and Intra-Lake Distributions of Trace Organic Contaminants in Surface Waters of the Great Lakes.* J. Great Lakes Res. 15(3): 377-393.

Sullivan, J.R. and D.E. Armstrong. 1985. *Toxaphene Status in the Great Lakes*. University of Wisconsin Sea Grant Institute - Priority Pollutants Status Report No. 2. : 37 pp.

Suter, G.W. II, and C.L. Tsao. 1996. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision*. ES/ER/TM 96/R2. Lockheed Martin Energy Systems, Oak Ridge National Laboratory, Oak Ridge, Tenn.

USACE. 2001 (August). *Project Report: Sediment Sampling for Chemical Analysis at Times Beach, New York.* Prepared by Engineering and Environment, Inc., for the Buffalo District United States Army Corps of Engineers.

USACE. 1998. *Use of Sediment Quality Guidelines (SQGs) in Dredged Material Management*. Dredging Research Technical Note EEDP-04-29. Vicksburg, Mississippi: USAERDC-WES

USACE. 2003. Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities – Testing Manual. (UTM). January 2003. USACE Engineer Research and Development Center, Vicksburg, MS. ERDC/EL TR-03-1

USACE-LRB. 2003. *Memorandum for File: Ecological Risk Assessment For Times Beach, New York.* Karen Keil, Risk Assessor, Buffalo District Office, Technical Services Division, Environmental Health Section.

USACE and USEPA. 1992. *Evaluating Environmental Effects of Dredged Material Management Alternatives – A Technical Framework.* EPA 842-B-92-008, Office of Water, Washington, DC.

USACE and USEPA. 2003. Great Lakes Confined Disposal Facilities. Appendix B: Fact Sheets. April 2003.

USEPA. 1993. A Guide to the Biosolids Risk Assessments for the EPA Part 503 Rule. EPA832-B-93-005. http://www.epa.gov/owm/mtb/biosolids/503rule/index.htm

USEPA. 2001. 40 Code of Federal Regulations Part 761, Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions.

USEPA. 2002a. Role of Background in the CERCLA Cleanup Program. OSWER 9285.6-07P.

USEPA. 2002b. A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems Volume III - Interpretation of the Results of Sediment Quality Investigations. EPA-905-B02-001-C United States Great Lakes National Program Office.

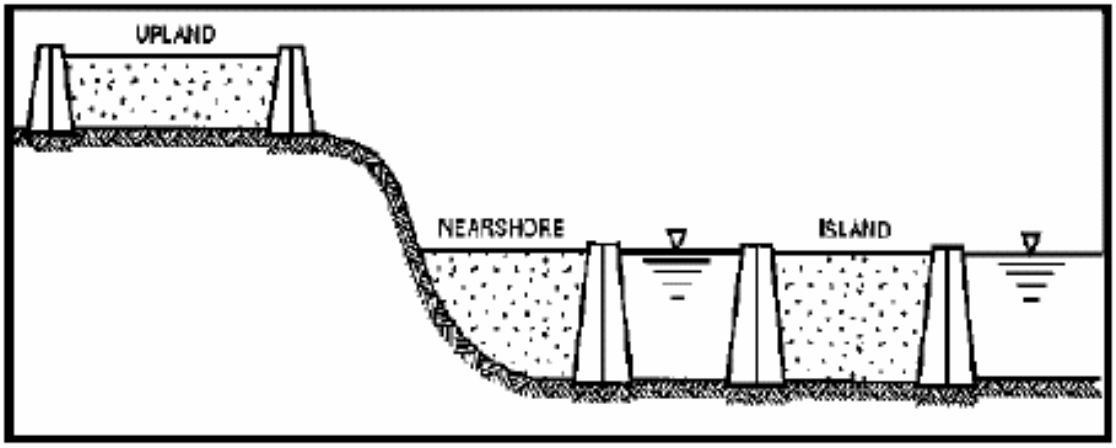
USEPA. Region IX. 2002. Preliminary Remediation Goals. http://www.epa.gov/region09/waste/sfund/prg/

USEPA. 2003. Agency Final Action Not to Regulate Dioxins in Land-Applied Sewage Sludge. Office of Water 4304T EPA-822-F-03-007 http://www.epa.gov/waterscience/biosolids/dioxinfs.html

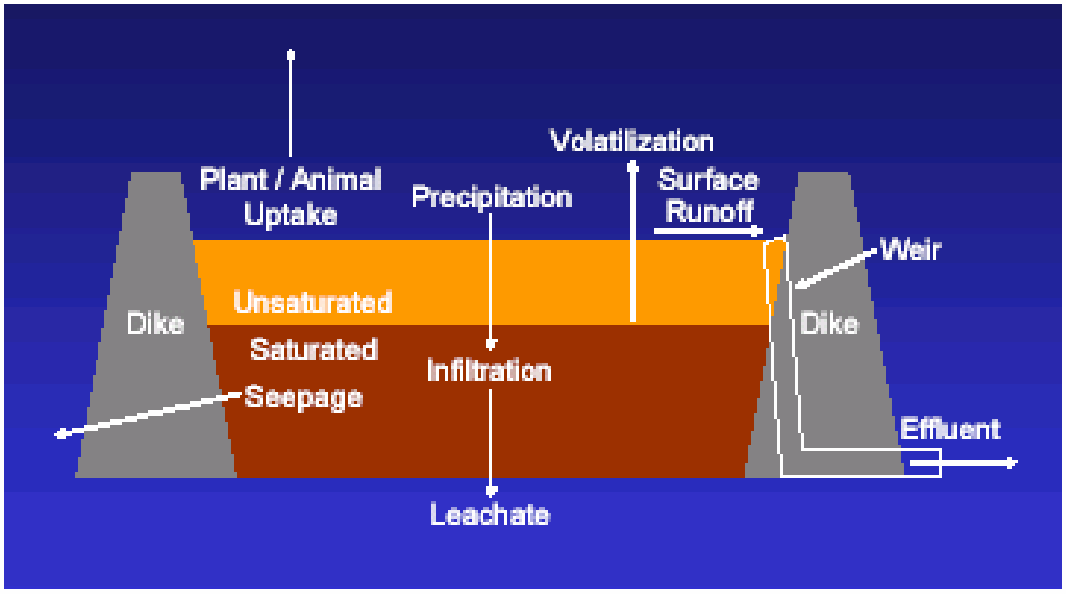
USEPA. 2004. Recommended Water Quality Criteria, for protection of freshwater aquatic organisms. United States Environmental Protection Agency Office of Water 4304 T EPA 822-Z-99-001. http://www.epa.gov/waterscience/criteria/wqcriteria.html

World Health Organization. 1989. Environmental Health Criteria 83 DDT and its Derivatives - Environmental Aspects, Geneva, International Programme on Chemical Safety, 98 pp. 1989, http://www.inchem.org/documents/ehc/ehc/ehc83.htm#SubSectionNumber:6.2.1

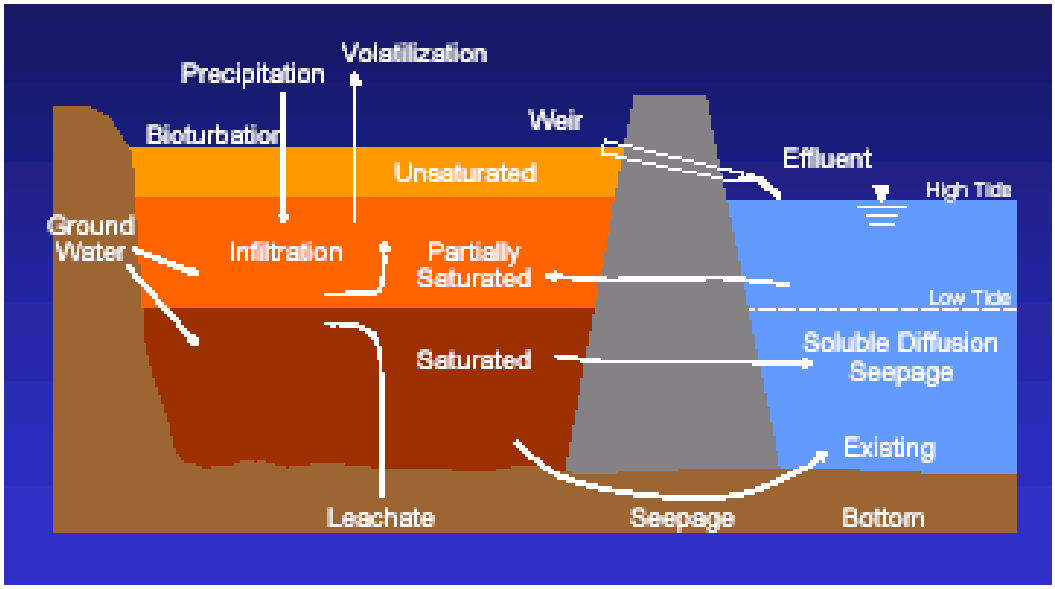
FIGURES



<u>Figure 1</u>: Schematic of upland, nearshore and island CDFs (after USACE/EPA 1992)



<u>Figure 2</u>: Schematic of contaminant migration pathways for upland CDFs (USACE 2003).



<u>Figure 3</u>: Schematic of contaminant migration pathways for nearshore CDFs (USACE 2003).

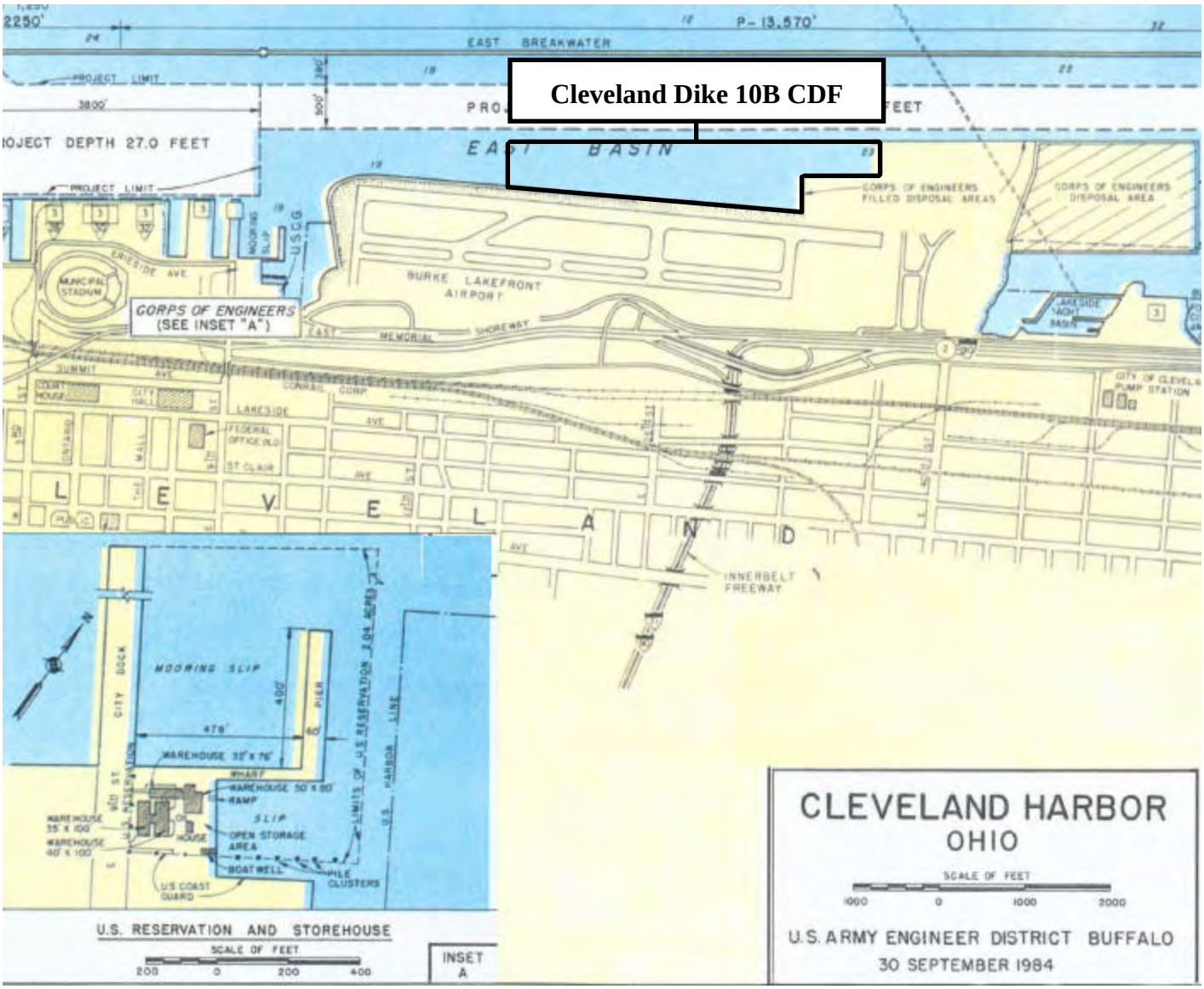
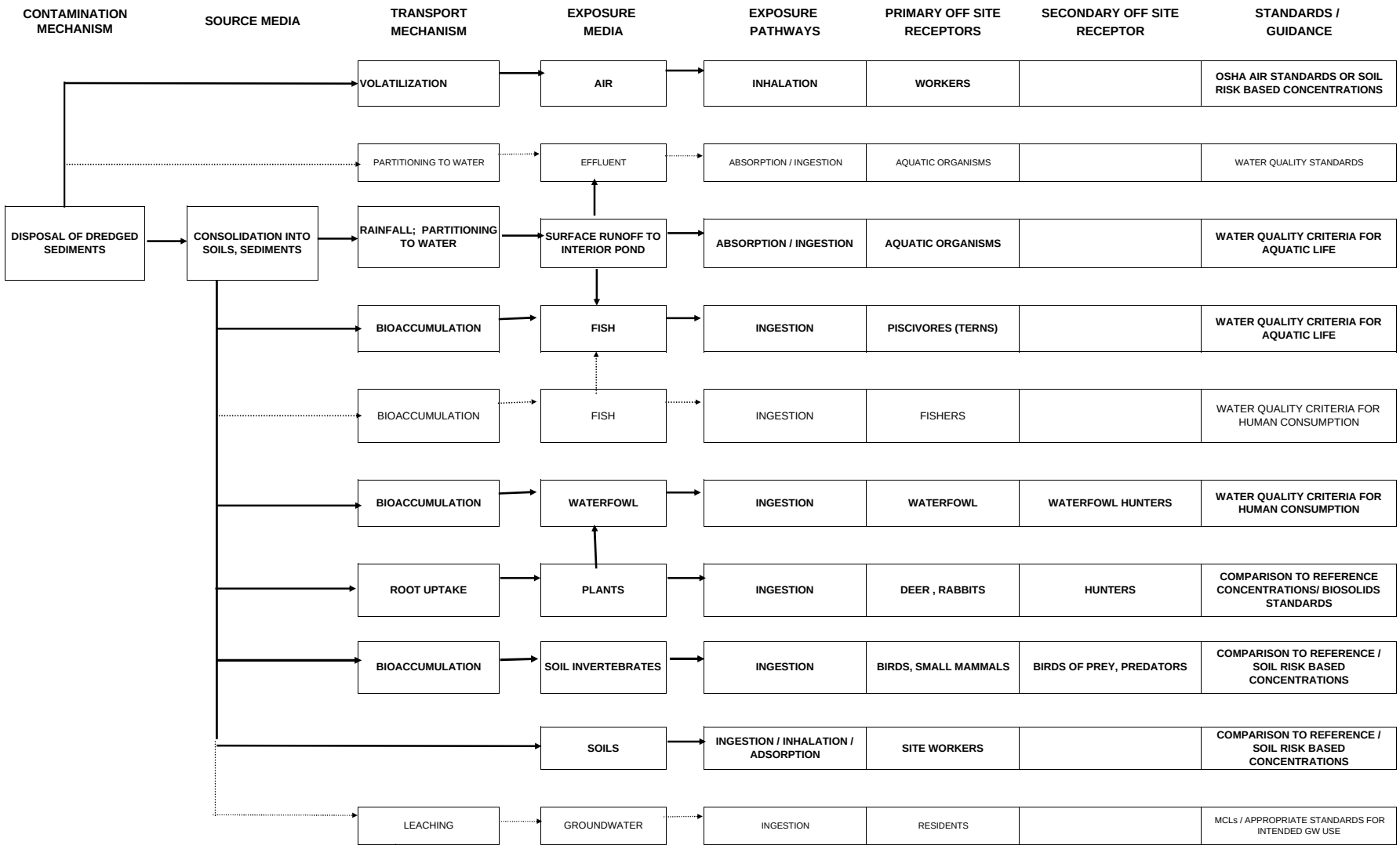


Figure 4: Cleveland Harbor Dike 10B CDF Site Map

Figure 5. TIER 1 GRAPHIC CONCEPTUAL SITE MODEL ~ PATHWAYS FOR INITIAL EVALUATION OF CLEVELAND HARBOR CONFINED DISPOSAL FACILITY 10B



Notes:
Bold indicates the pathway is complete and should be evaluated for this CDF
Regular font and dashed arrows indicates that this pathway is incomplete and does not have to be evaluated for this CDF.

Pollutant	Monthly average concentration (milligrams per kilogram dry weight basis)
Arsenic	41
Cadmium	39
Copper	1,500
Lead	300
Mercury	17
Nickel	420
Selenium	100
Zinc	2,800

Figure 6. State of Ohio land application restrictions for sewage sludge (monthly average) http://www.epa.state.oh.us/dsw/rules/40-05.pdf.

Figure 7. Canadian Soil Quality Guidelines (CSQG) from:
http://www.ccme.ca/assets/pdf/ceqg_soil_summary_table_v6_e.pdf

Substance	Year revised/ released[a]	Land Use and Soil Texture							
		Agricultural*		Residential/ parkland*		Commercial*		Industrial*	
		Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Arsenic (inorganic)	1997	12[b]		12[b]		12[b]		12[b]	
Barium	2003	750[c]		500[c]		2000[c]		2000[c]	
Benzene									
Surface[y]	2004	0.030[u, t]	0.0068[u, t]	0.030[u, t]	0.0068[u, t]	0.030[u, t]	0.0068[u, t]	0.030[u, t]	0.0068[u, t]
Subsoil[y]	2004	0.030[u, t]	0.0068[u, t]	0.030[u, t]	0.0068[u, t]	0.030[u, t]	0.0068[u, t]	0.030[u, t]	0.0068 [u, t]
Surface[x]	2004	0.0095[u, t]	0.0068[u, t]	0.0095[u, t]	0.0068[u, t]	0.030[u, t]	0.0068[u, t]	0.030[u, t]	0.0068 [u, t]
Subsoil[x]	2004	0.01[u, t]	0.0068[u, t]	0.011[u, t]	0.0068[u, t]	0.030[u, t]	0.0068[u, t]	0.030[u, t]	0.0068 [u, t]
Benzo*(a)*pyrene	1997	0.1[e]		0.7[f]		0.7[f]		0.7[f]	
Cadmium	1999	1.4[b]		10[g]		22[b]		22[b]	
Chromium									
Total chromium	1997	64[b]		64[b]		87[b]		87[b]	
Hexavalent chromium (VI)	1999	0.4[h]		0.4[h]		1.4[h]		1.4[h]	
Copper	1999	63[b]		63[b]		91[b]		91[b]	
Cyanide (free)	1997	0.9[b]		0.9[b]		8.0[b]		8.0[b]	
DDT (total)	1999	0.7[i]		0.7[i]		12[i, j]		12[i, j]	
Diisopropanolamine (DIPA)	2006	180[b]		180[b]		180[b]		180[b]	
Ethylbenzene									
Surface	2004	0.082[t]	0.018[u, t]	0.082[t]	0.018[u, t]	0.082[t]	0.018[u, t]	0.082[t]	0.018[u, t]
Subsoil	2004	0.082[t]	0.018[u, t]	0.082[t]	0.018[u, t]	0.082[t]	0.018[u, t]	0.082[t]	0.018[u, t]
Ethylene glycol	1999	960[k]		960[k]		960[k]		960[k]	
Lead	1999	70[b]		140[b]		260[b]		600[b]	
Mercury (inorganic)	1999	6.6[b]		6.6[b]		24[b]		50[b]	
Naphthalene	1997	0.1[d]		0.6[h]		22[h]		22[h]	
Nickel	1999	50[l]		50[l]		50[l]		50[l]	
Nonylphenol (and its ethyloxylates)	2002	5.7[p]		5.7[p]		14[p]		14[p]	
Pentachlorophenol	1997	7.6[b]		7.6[b]		7.6[b]		7.6[b]	
Phenol	1997	3.8[b]		3.8[b]		3.8[b]		3.8[b]	
Polychlorinated biphenyls (PCBs)	1999	0.5[m]		1.3[l]		33[l, j]		33[l, j]	
Polychlorinated dibenzo-*p*-dioxins/ dibenzofurans (PCDD/Fs)	2002	4 ng TEQ·kg^{-1} [q]		4 ng TEQ·kg^{-1} [q]		4 ng TEQ·kg^{-1} [r]		4 ng TEQ·kg^{-1} [s]	
Propylene glycol	2006	Insufficient information[v]		Insufficient information[v]		Insufficient information[v]		Insufficient information[v]	
Selenium	2002	1[b]		1[b]		3.9[b]		3.9[b]	

Continued

Figure 7. Concluded.

Sulfolane	2006	0.8[b]		0.8[b]		0.8[b]		0.8[b]	
Tetrachloroethylene	1997	0.1[e]		0.2[f]		0.5[f]		0.6[f]	
Thallium	1999	1[n]		1[o]		1[o]		1[o]	
Toluene									
Surface	2004	0.37[t]	0.08[t]	0.37[t]	0.08[t]	0.37[t]	0.08[t]	0.37[t]	0.08[t]
Subsoil	2004	0.37[t]	0.08[t]	0.37[t]	0.08[t]	0.37[t]	0.08[t]	0.37[t]	0.08[t]
Trichloroethylene	2006	0.01[b,u]		0.01[b,u]		0.01[b,u]		0.01[b,u]	
Vanadium	1997	130[l]		130[l]		130[i]		130[i]	
Xylenes									
Surface	2004	11[t]	2.4[t]	11[t]	2.4[t]	11[t]	2.4[t]	11[t]	2.4[t]
Subsoil	2004	11[t]	2.4[t]	11[t]	2.4[t]	11[t]	2.4[t]	11[t]	2.4[t]
Zinc	1999	200[l]		200[l]		360[l]		360[l]	

Notes: SQG_E = soil quality guideline for environmental health; SQG_{HH} = soil quality guideline for human health.

* For guidelines derived prior to 2004, differentiation between soil texture (coarse/fine) is not applicable.

[a]Guidelines released in 1997 were originally published in the working document entitled "Recommended Canadian Soil Quality Guidelines" (CCME 1997) and have been revised, edited, and reprinted here. Guidelines revised/released in 1999 are published here for the first time (see Table 2).
[b]Data are sufficient and adequate to calculate an SQG_{HH} and an SQG_E. Therefore the soil quality guideline is the lower of the two and represents a fully integrated de novo guideline for this land use, derived in accordance with the soil protocol (CCME 1996). The corresponding interim soil quality criterion (CCME 1991) is superseded by the soil quality guideline.
[c]Data are insufficient/inadequate to calculate an SQG_{HH}, a provisional SQG_{HH}, an SQG_E, or a provisional SQG_E. Therefore the interim soil quality criterion (CCME 1991) is retained as the soil quality guideline for this land use.
[d]Data are sufficient and adequate to calculate only a provisional SQG_E. It is greater than the corresponding interim soil quality criterion (CCME 1991). Therefore, in consideration of receptors and/or pathways not examined, the interim soil quality criterion is retained as the soil quality guideline for this land use.
[e]Data are sufficient and adequate to calculate an SQG_{HH} and a provisional SQG_E. Both are greater than the corresponding interim soil quality criterion (CCME 1991). Therefore, in consideration of receptors and/or pathways not examined, the interim soil quality criterion is retained as the soil quality guideline for this land use.
[f]Data are sufficient and adequate to calculate an SQG_{HH} and a provisional SQG_E. Both are less than corresponding interim soil quality criterion (CCME 1991). Therefore the soil quality guideline supersedes the interim soil quality criterion for this land use.
[g]The soil–plant–human pathway was not considered in the guideline derivation. If produce gardens are present or planned, a site-specific objective must be derived to take into account the bioaccumulation potential (e.g., adopt the agricultural guideline as objective). The off-site migration check should be recalculated accordingly.
[h]Data are sufficient and adequate to calculate only a provisional SQG_E, which is less than the existing interim soil quality criterion (CCME 1991). Therefore the soil quality guideline supersedes the interim soil quality criterion for this land use.
[i]Data are sufficient and adequate to calculate only an SQG_E. An interim soil quality criterion (CCME 1991) was not established for this land use, therefore the SQG_E becomes the soil quality guideline.
[j]In site-specific situations where the size and/or the location of commercial and industrial land uses may impact primary, secondary, or tertiary consumers, the soil and food ingestion guideline is recommended as the SQG_E.
[k]Data are sufficient and adequate to calculate only a provisional SQG_E.
[l]Data are sufficient and adequate to calculate only an SQG_E, which is less than the interim soil quality criterion (CCME 1991) for this land use. Therefore the SQG_E becomes the soil quality guideline, which supersedes the interim soil quality criterion for this land use.
[m]Data are sufficient and adequate to calculate only an SQG_E, which is greater than the interim soil quality criterion (CCME 1991) for this land use. Therefore the interim soil quality criterion (CCME 1991) is retained as the soil quality guideline for this land use.
[n]Data are sufficient and adequate to calculate a provisional SQG_{HH} and an SQG_E. The provisional SQG_{HH} is equal to the SQG_E and to the existing interim soil quality criterion (CCME 1991) and thus becomes the soil quality guideline, which supersedes the interim soil quality criterion for this land use.
[o]Data are sufficient and adequate to calculate a provisional SQG_{HH} and an SQG_E. The provisional SQG_{HH} is less than the SQG_E and thus becomes the soil quality guideline for this land use.
[p]Data are sufficient and adequate to calculate only an SQG_E. An interim soil quality criterion (CCME 1991) was not established for these substances, therefore, the SQG_E becomes the soil quality guideline.
[q]Data are sufficient and adequate to calculate only a provisional SQG_{HH}, which is less than the existing interim soil quality criterion (CCME 1991). Thus the provisional SQG_{HH} becomes the soil quality guideline, which supersedes the interim soil quality criterion for this land use.
[r]Data are sufficient and adequate to calculate only a provisional SQG_{HH}. An interim soil quality criterion (CCME 1991) was not established for this land use, therefore the provisional SQG_{HH} becomes the soil quality guideline.
[s]Data are sufficient and adequate to calculate only an SQG_{HH}. An interim soil quality criterion (CCME 1991) was not established for this land use, therefore the SQG_{HH} becomes the soil quality guideline.
[t]Data are sufficient and adequate to calculate an SQG_{HH} and an SQG_E. Therefore the soil quality guideline is the lower of the two and represents a fully

Figure 8. *Cyperus esculentus* in Cleveland Harbor CDF 10B dredged material.

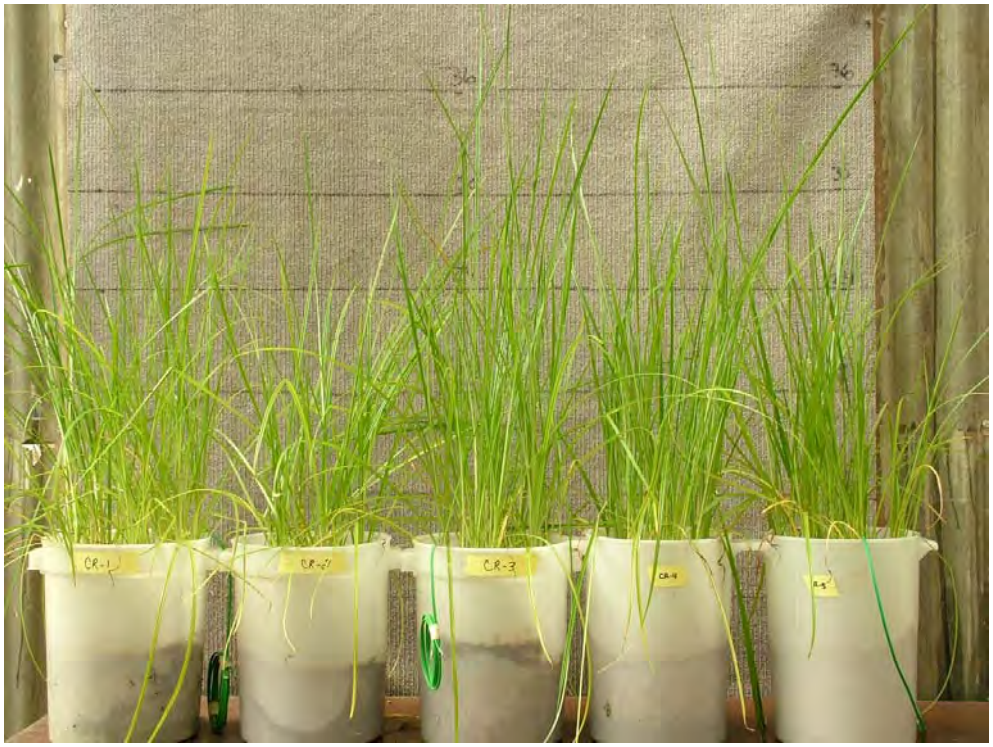


Figure 9. *Cyperus esculentus* in the Cleveland Lakefront Park Reference.

TABLES

Table 1: Sixteen Priority Pollutant PAHs

Acenaphthene	Acenaphthylene
Anthracene	Benzo(a)anthracene
Benzo(a)pyrene	Benzo(b)fluoranthene
Benzo(ghi)perylene	Benzo(k)fluoranthene
Chrysene	Dibenzo(a,h)anthracene
Fluoranthene	Fluorene
Indeno(1,2,3-cd)pyrene	Naphthalene
Phenanthrene	Pyrene

Table 2: Priority Pollutant Metals

Antimony	Arsenic
Beryllium	Cadmium
Chromium	Copper
Iron	Lead
Mercury	Nickel
Selenium	Silver
Thallium	Zinc

Table 3: Comparison of Average Concentrations of Constituents In Diked Pond Water with Concentrations Outside of the Dike

Constituent	Average Pond Water Concentration	Average Concentration of Background Lake Water
VOCs	µg/L	µg/L
1,4-Dichlorobenzene	<2.50E-01	<2.50E-01
Chlorobenzene	<3.20E-01	<3.20E-01
Benzene	<3.30E-01	<3.30E-01
Ethylbenzene	<2.10E-01	<2.10E-01
Toluene	<3.90E-01	<3.90E-01
B/N/A		
Acenaphthene	<4.90E-01	<4.81E-01
Anthracene	<4.90E-01	<4.81E-01
Benzo(a)anthracene	<4.90E-01	<4.81E-01
Benzo(a)pyrene	<4.90E-01	<4.81E-01
Benzo(b)fluoranthene	<4.90E-01	<4.81E-01
Benzo(ghi)perylene	<4.90E-01	<4.81E-01
Chrysene	<4.90E-01	<4.81E-01
Fluoranthene	<4.90E-01	<4.81E-01
Fluorene	<4.90E-01	<4.81E-01
Indeno(1,2,3-cd)pyrene	<4.90E-01	<4.81E-01
Phenanthrene	<4.90E-01	<4.81E-01
Pyrene	<4.90E-01	<4.81E-01
bis(2-Ethylhexyl)phthalate	<1.27E+00	<1.25E+00
Metals		
Antimony	1.40E+00	3.00E-01
Arsenic	3.90E+00	1.17E+00
Beryllium	<1.00E-01	<5.00E-2
Cadmium	1.33E-01	<4.00E-02
Chromium	2.20E+00	1.10E+00
Copper	5.87E+00	1.50E+00
Lead	4.70E+00	5.00E-01
Mercury	<5.00E-02	<5.00E-02
Nickel	7.47E+00	1.57E+00
Selenium	<6.00E-01	<6.00E-01
Silver	<4.00E-02	<4.00E-02
Thallium	<2.00E-02	<2.00E-02
Zinc	1.79E+01	2.93E+00

Pond water concentration exceeds Lake water concentration

Table 4. Comparison of Average Metal Concentrations with Ohio EPA Reference Sediment Concentrations

All units are in ppm

Metals	Average Concentration in Soils	Average Concentration in Sediments	Ohio EPA Reference Values EOLP	Ohio EPA Statewide Reference Values
Antimony	1.13E-01	2.17E-01	1.30E+00	
Arsenic	7.30E+00	2.13E+01	2.50E+01	
Beryllium	3.31E-01	9.42E-01		8.00E-01
Cadmium	8.35E-01	2.59E+00	7.90E-01	
Chromium	1.32E+01	3.74E+01	2.90E+01	
Copper	2.79E+01	6.80E+01	3.20E+01	
Lead	3.52E+01	7.99E+01		4.70E+01
Mercury	1.08E-01	1.62E-01		1.20E-01
Nickel	2.30E+01	5.01E+01	3.30E+01	
Silver	1.62E-01	7.00E-01		4.30E-01
Thallium	1.75E-01	5.61E-01		4.70E+00
Vanadium	1.08E+01	3.11E+01		4.00E+01
Zinc	1.53E+02	3.60E+02	1.60E+02	

EOLP Erie/Ontario Lake Plains area of Ohio sediment reference value.

Exceeds Ohio EOLP reference value.

Exceeds Ohio Statewide reference value.

Table 5. Comparison of CDF sediment concentrations with lake reference sediment concentrations

	2002 Average Lake Reference Sediment, mg/kg	2002 Maximum Lake Reference Sediment, mg/kg	Maximum Concentration in Sediments mg/kg	Average Concentration in Sediments mg/kg
VOCs				
1,4-Dichlorobenzene	NA	NA	7.02E-03	3.92E-03
Chlorobenzene	NA	NA	2.68E-03	1.61E-03
Benzene	NA	NA	4.01E-03	3.26E-03
Ethylbenzene	NA	NA	3.44E-03	2.70E-03
Toluene	NA	NA	5.05E-02	3.84E-02
B/N/A				
Acenaphthene	<1.52E-02	1.60E-02	1.85E-02	<1.790E-02
Anthracene	1.90E-02	2.40E-02	3.86E-02	<3.733E-02
Benzo(a)anthracene	6.70E-02	8.70E-02	1.35E-01	1.06E-01
Benzo(a)pyrene	7.60E-02	1.00E-01	2.97E-01	2.65E-01
Benzo(b)fluoranthene	1.06E-01	1.40E-01	2.87E-01	1.97E-01
Benzo(ghi)perylene	7.60E-02	1.20E-01	2.48E-01	2.21E-01
Chrysene	7.30E-02	9.30E-02	1.94E-01	1.28E-01
Fluoranthene	1.26E-01	1.50E-01	3.23E-01	2.32E-01
Fluorene	1.20E-02	1.80E-02	1.61E-02	1.19E-02
Indeno(1,2,3-cd)pyrene	6.40E-02	9.50E-02	2.89E-01	2.66E-01
Phenanthrene	5.80E-02	6.90E-02	1.39E-01	1.10E-01
Pyrene	1.24E-01	1.50E-01	2.41E-01	1.65E-01
bis(2-Ethylhexyl)phthalate	NA	NA	4.10E-01	3.21E-01
Metals				
Antimony	9.50E-01	1.40E+00	2.41E-01	2.17E-01
Arsenic	9.50E+00	1.05E+01	2.25E+01	2.13E+01
Beryllium	1.40E+00	1.60E+00	9.65E-01	9.42E-01
Cadmium	2.30E+00	2.90E+00	2.84E+00	2.59E+00
Chromium	6.00E+01	7.08E+01	3.78E+01	3.74E+01
Copper	5.90E+01	6.83E+01	6.97E+01	6.80E+01
Lead	6.30E+01	7.28E+01	8.20E+01	7.99E+01
Mercury	4.00E-01	4.10E-01	2.09E-01	1.62E-01
Nickel	6.26E+01	7.48E+01	5.11E+01	5.01E+01
Selenium	2.40E+00	3.60E+00	1.44E+00	1.36E+00
Silver	5.20E-01	8.10E-01	7.16E-01	7.00E-01
Thallium	6.30E-01	8.30E-01	5.93E-01	5.61E-01
Zinc	2.26E+02	2.71E+02	3.66E+02	3.60E+02

Exceeds average reference concentrations

NA Not Analysed

Table 6: Comparison of detected constituents with USEPA Region IX Preliminary Remediation Goals

All units are ppm Constituent	USEPA Region IX PRG Residential	USEPA Region IX PRG Industrial	Maximum Detection Soils	Maximum Detection Sediment	Average Concentration Soils	Average Concentration Sediments
VOCs						
1,4-Dichlorobenzene	3.40E+00	7.90E+00	1.10E-03	7.02E-03	4.86E-04	3.92E-03
Chlorobenzene	1.50E+02	5.30E+02	4.53E-04	2.68E-03	<4.01E-04	1.61E-03
Benzene	6.00E-01	1.30E+00	3.11E-03	4.01E-03	2.19E-03	3.26E-03
Ethylbenzene	8.90E+00	2.00E+01	1.58E-03	3.44E-03	1.04E-03	2.70E-03
Toluene	5.20E+02	5.20E+02	8.93E-03	5.05E-02	6.19E-03	3.84E-02
PAHs						
Acenaphthene	3.70E+03	2.90E+04	2.09E-02	1.85E-02	1.03E-02	<1.790E-02
Acenaphthylene			2.16E-02	3.86E-02	<1.983E-02	<3.733E-02
Anthracene	2.19E+04	1.00E+05	3.65E-02	3.86E-02	2.36E-02	<3.733E-02
Benzo(a)anthracene	6.21E-01	2.10E+00	9.30E-02	1.35E-01	7.53E-02	1.06E-01
Benzo(a)pyrene	6.21E-02	2.10E-01	1.69E-01	2.97E-01	1.57E-01	2.65E-01
Benzo(b)flouranthene	6.21E-01	2.10E+00	1.53E-01	2.87E-01	1.27E-01	1.97E-01
Benzo(k)flouranthene	6.20E+00	2.10E+01	2.16E-02	3.86E-02	<1.983E-02	<3.733E-02
Benzo (g,h,I)perylene			1.44E-01	2.48E-01	1.28E-01	2.21E-01
Chrysene	6.21E+01	2.10E+02	1.06E-01	1.94E-01	9.21E-02	1.28E-01
Flouranthene	2.29E+03	2.20E+04	1.93E-01	3.23E-01	1.53E-01	2.32E-01
Fluorene	2.70E+03	2.60E+04	2.35E-02	1.61E-02	1.38E-02	1.19E-02
Indeno(1,2,3-cd)Pyrene	6.21E-01	2.10E+00	1.64E-01	2.89E-01	1.49E-01	2.66E-01
Naphthalene	5.60E+01	1.90E+02	2.16E-02	3.86E-02	<1.983E-02	<3.700E-02
Phenanthrene			1.28E-01	1.39E-01	8.68E-02	1.10E-01
Pyrene	2.32E+03	2.90E+04	1.55E-01	2.41E-01	1.19E-01	1.65E-01
BNAs						
bis(2-ethylhexyl)phthalate	3.5E+01	1.2E+02	1.32E-01	4.10E-01	1.04E-01	3.21E-01
Pesticides/PCBs						
4,4'-DDE	1.7E+00	7.0E+00	2.64E-03	<4.17E-03	1.39E-03	<4.03E-03
4,4'-DDT	1.7E+00	7.0E+00	1.59E-02	<8.81E-03	7.04E-03	<8.51E-03
Aroclor-1242	2.2E-01	7.4E-01	1.00E-01	3.49E-01	3.63E-02	2.86E-01
Aroclor-1248	2.2E-01	7.4E-01	2.73E-02	<2.32E-03	9.46E-03	<2.24E-03
Aroclor-1254	2.2E-01	7.4E-01	6.19E-02	1.86E-01	2.60E-02	1.68E-01
Aroclor-1260	2.2E-01	7.4E-01	1.63E-02	7.41E-02	9.50E-03	6.25E-02
Total PCBs				6.09E-01		5.17E-01
Metals						
Antimony	3.10E+01	4.10E+02	1.67E-01	2.41E-01	1.13E-01	2.17E-01
Arsenic	3.90E-01	1.60E+00	9.06E+00	2.25E+01	7.30E+00	2.13E+01
Beryllium	1.50E+02	1.90E+03	4.27E-01	9.65E-01	3.31E-01	9.42E-01
Cadmium	3.70E+01	4.50E+02	1.32E+00	2.84E+00	8.35E-01	2.59E+00
Chromium	2.10E+02	4.50E+02	2.15E+01	3.78E+01	1.32E+01	3.74E+01
Copper	3.10E+03	4.10E+04	4.35E+01	6.97E+01	2.79E+01	6.80E+01
Lead	4.00E+02	7.50E+02	7.29E+01	8.20E+01	3.52E+01	7.99E+01
Mercury	2.30E+01	3.10E+02	2.52E-01	2.09E-01	1.08E-01	1.62E-01
Nickel	1.60E+03	2.00E+04	2.85E+01	5.11E+01	2.30E+01	5.01E+01
Selenium	3.90E+02	5.11E+03	4.32E-01	1.44E+00	3.20E-01	1.36E+00
Silver	3.91E+02	5.11E+03	3.49E-01	7.16E-01	1.62E-01	7.00E-01
Thallium	5.20E+00	6.70E+01	2.65E-01	5.93E-01	1.75E-01	5.61E-01
Zinc	2.30E+04	1.00E+05	2.65E+02	3.66E+02	1.53E+02	3.60E+02
Other						
Dioxin (2,3,7,8-TCDD)	3.9E-06	1.6E-05		2.10E-07		2.10E-07
Cyanide	1.1E+01	3.5E+01	1.03E+00	2.19E+00	5.16E-01	1.73E+00
	Exceeds residential PRG					
	Exceeds industrial PRG					

Table 7: Comparison of detected constituents with USEPA Biosolids Rule 503

All units are ppm

Constituent	Biosolids Limits	Soil Concentration Limits	Maximum Detection, Soils	Maximum Detection, Sediment
PAHs		NE		
Anthracene	NE	NE	3.65E-02	3.86E-02
Benzo(a)anthracene	NE	NE	9.30E-02	1.35E-01
Benzo(a)pyrene	1.50E+01	NE	1.69E-01	2.97E-01
Benzo(b)flouranthene	NE	NE	1.53E-01	2.87E-01
Chrysene	NE	NE	1.06E-01	1.94E-01
Flouranthene	NE	NE	1.93E-01	3.23E-01
Indeno(1,2,3-cd)Pyrene	NE	NE	1.64E-01	2.89E-01
Phenanthrene	NE	NE	1.28E-01	1.39E-01
Pyrene	NE	NE	1.55E-01	2.41E-01
Pesticides/PCBs				
4,4'-DDE	1.20E+00	NE	2.64E-03	<4.17E-03
4,4'-DDT	1.20E+00	NE	1.59E-02	<8.81E-03
Aroclor-1242	4.60E+00	NE	1.00E-01	3.49E-01
Aroclor-1248	4.60E+00	NE	2.73E-02	<2.32E-03
Aroclor-1254	4.60E+00	NE	6.19E-02	1.86E-01
Aroclor-1260	4.60E+00	NE	1.63E-02	7.41E-02
Metals				
Antimony	NE	NE	1.67E-01	2.41E-01
Arsenic	4.10E+01	2.05E+01	9.06E+00	2.25E+01
Beryllium	NE	NE	4.27E-01	9.65E-01
Cadmium	NE	1.95E+01	1.32E+00	2.84E+00
Chromium	NE	NE	2.15E+01	3.78E+01
Copper	1.50E+03	7.50E+02	4.35E+01	6.97E+01
Lead	3.00E+02	1.50E+02	7.29E+01	8.20E+01
Mercury	1.70E+01	8.50E+00	2.52E-01	2.09E-01
Nickel	4.20E+02	2.10E+02	2.85E+01	5.11E+01
Selenium	1.00E+02	5.00E+01	4.32E-01	1.44E+00
Silver	NE	NE	3.49E-01	7.16E-01
Thallium	NE	NE	2.65E-01	5.93E-01
Zinc	2.80E+03	1.40E+03	2.65E+02	3.66E+02
NE Not Established				
	Exceeds criteria			

Table 7a: Comparison of detected constituents with USEPA Ecological Soil Screening Levels (protection of terrestrial ecosystems)

All units are ppm

Constituent	USEPA Eco SSL	Maximum Detection, Soils	Maximum Detection, Sediment	Average Concentration Soils	Average Concentration Sediments
PAHs					
Anthracene	NE	3.65E-02	3.86E-02	2.36E-02	<3.733E-02
Benzo(a)anthracene	NE	9.30E-02	1.35E-01	7.53E-02	1.06E-01
Benzo(a)pyrene	NE	1.69E-01	2.97E-01	1.57E-01	2.65E-01
Benzo(b)flouranthen	NE	1.53E-01	2.87E-01	1.27E-01	1.97E-01
Chrysene	NE	1.06E-01	1.94E-01	9.21E-02	1.28E-01
Flouranthene	NE	1.93E-01	3.23E-01	1.53E-01	2.32E-01
Indeno(1,2,3-	NE	1.64E-01	2.89E-01	1.49E-01	2.66E-01
Phenanthrene	NE	1.28E-01	1.39E-01	8.68E-02	1.10E-01
Pyrene	NE	1.55E-01	2.41E-01	1.19E-01	1.65E-01
Pesticides/PCBs					
4,4'-DDE	1.20E+00	2.64E-03	<4.17E-03	1.39E-03	<4.03E-03
4,4'-DDT	1.20E+00	1.59E-02	<8.81E-03	7.04E-03	<8.51E-03
Aroclor-1242	4.60E+00	1.00E-01	3.49E-01	3.63E-02	2.86E-01
Aroclor-1248	4.60E+00	2.73E-02	<2.32E-03	9.46E-03	<2.24E-03
Aroclor-1254	4.60E+00	6.19E-02	1.86E-01	2.60E-02	1.68E-01
Aroclor-1260	4.60E+00	1.63E-02	7.41E-02	9.50E-03	6.25E-02
Metals					
Antimony	2.90E-01	1.67E-01	2.41E-01	1.13E-01	2.17E-01
Arsenic	NE	9.06E+00	2.25E+01	7.30E+00	2.13E+01
Beryllium	3.60E+01	4.27E-01	9.65E-01	3.31E-01	9.42E-01
Cadmium	3.80E-01	1.32E+00	2.84E+00	8.35E-01	2.59E+00
Chromium	NE	2.15E+01	3.78E+01	1.32E+01	3.74E+01
Copper	NE	4.35E+01	6.97E+01	2.79E+01	6.80E+01
Lead	1.60E+01	7.29E+01	8.20E+01	3.52E+01	7.99E+01
Mercury	NE	2.52E-01	2.09E-01	1.08E-01	1.62E-01
Nickel	NE	2.85E+01	5.11E+01	2.30E+01	5.01E+01
Selenium	NE	4.32E-01	1.44E+00	3.20E-01	1.36E+00
Silver	NE	3.49E-01	7.16E-01	1.62E-01	7.00E-01
Thallium	NE	2.65E-01	5.93E-01	1.75E-01	5.61E-01
Zinc	NE	2.65E+02	3.66E+02	1.53E+02	3.60E+02
NE Not Established					
	Exceeds criteria				

Table 8: Comparison of Sediment Concentrations with Consensus Threshold and Probable Effects Concentrations

Constituent	Consensus TEC (ppm DW)	Consensus PEC (ppm DW)	Maximum Sediment Detection (ppm)	Average Sediment Concentration (ppm)
Metals				
Antimony	NA	NA	2.41E-01	2.17E-01
Arsenic	9.79E+00	3.30E+01	2.25E+01	2.13E+01
Beryllium	NA	NA	9.65E-01	9.42E-01
Cadmium	9.90E-01	4.98E+00	2.84E+00	2.59E+00
Chromium	4.34E+01	1.11E+02	3.78E+01	3.74E+01
Copper	3.16E+01	1.49E+02	6.97E+01	6.80E+01
Lead	3.58E+01	1.28E+02	8.20E+01	7.99E+01
Mercury	1.80E-01	1.06E+00	2.09E-01	1.62E-01
Nickel	2.27E+01	4.86E+01	5.11E+01	5.01E+01
Selenium	NA	NA	1.44E+00	1.36E+00
Silver	NA	NA	7.16E-01	7.00E-01
Thallium	NA	NA	5.93E-01	5.61E-01
Zinc	1.21E+02	4.59E+02	3.66E+02	3.60E+02
Pesticides/PCBs				
4,4'-DDE	3.16E-03	3.13E-02	<4.17E-03	<4.03E-03
4,4'-DDT	5.28E-03	5.72E-01	<8.81E-03	<8.51E-03
Aroclor-1242	see value for total PCBs		3.49E-01	2.86E-01
Aroclor-1248	see value for total PCBs		<2.32E-03	<2.24E-03
Aroclor-1254	see value for total PCBs		1.86E-01	1.68E-01
Aroclor-1260	see value for total PCBs		7.41E-02	6.25E-02
Total PCBs	5.98E-02	6.76E-01	6.09E-01	5.17E-01
BNAs				
bis (2-ethyl hexyl) phthalate	NA	NA	4.10E-01	3.21E-01
PAHs				
Acenaphthene	NA	NA	1.85E-02	<1.79E-02
Acenaphthylene	NA	NA	3.86E-02	<3.73E-02
Anthracene	5.72E-02	8.45E-01	3.86E-02	<3.73E-02
Benzo(a)anthracene	1.08E-01	1.05E+00	1.35E-01	1.06E-01
Benzo(a)pyrene	1.50E-01	1.45E+00	2.97E-01	2.65E-01
Benzo(b)flouranthene	NA	NA	2.87E-01	1.97E-01
Benzo(k)flouranthene	NA	NA	3.86E-02	<3.73E-02
Benzo(g,h,I) perylene	NA	NA	2.48E-01	2.21E-01
Chrysene	1.66E-01	1.29E+00	1.94E-01	1.28E-01
Flouranthene	4.23E-01	2.23E+00	3.23E-01	2.32E-01
Fluorene	7.74E-02	5.36E-01	1.61E-02	1.19E-02
Naphthalene	1.76E-01	5.61E-01	3.86E-02	<3.70E-02
Indeno(1,2,3-cd)Pyrene	NA	NA	2.89E-01	2.66E-01
Phenanthrene	2.04E-01	1.17E+00	1.39E-01	1.10E-01
Pyrene	1.95E-01	1.52E+00	2.41E-01	1.65E-01
Total PAHs	1.61E+00	2.28E+01	2.34E+00	
Dioxin (2,3,7,8-TCDD)	NA	NA	2.10E-07	2.10E-07
Cyanide	NA	NA	2.19E+00	1.73E+00
NA	No sediment effects concentration available			
	Exceeds Threshold Effect Concentration			
	Exceeds Probable Effect Concentration			

Table 8a: Use of secondary water quality criteria and equilibrium partitioning, to estimate sediment concentrations protective of aquatic life for Organics

Constituent	Water Quality Criteria (μg/L)	Kow L/kg	Koc** L/kg	Sediment quality criteria, derived using equilibrium partitioning (μg per g OC)	Sediment quality criteria for Cleveland 10B, assuming 3.1% organic carbon content	Maximum Detection Sediment, mg/kg	Average Concentration Sediments, mg/kg
VOCs							
1,4-Dichlorobenzene	15	3311	2086	3.13E+01	9.70E-01	7.02E-03	3.92E-03
Chlorobenzene	64	6.9E+02	436	2.79E+01	8.65E-01	2.68E-03	1.61E-03
Benzene	130	1.3E+02	85	1.10E+01	3.42E-01	4.01E-03	3.26E-03
Ethylbenzene	7.3	1.4E+03	890	6.50E+00	2.01E-01	3.44E-03	2.70E-03
Toluene	9.8	6.2E+02	388	3.81E+00	1.18E-01	5.05E-02	3.84E-02
** Koc = Kow*0.63							

Table 9: Comparison of Pond Water Concentratons with EPA Environmental Water Quality Criteria for Aquatic Organisms

	CCC	CMC	Maximum Pond Water Detection	Average Pond Water Concentration
Constituent	**µg/L**	**µg/L**	**µg/L**	**µg/L**
Metals				
Antimony	NA	NA	1.40E+00	1.40E+00
Arsenic	1.50E+02	3.40E+02	4.50E+00	3.90E+00
Beryllium	NA	NA	1.00E-01	<1.000E-01
Cadmium	2.50E-01	2.00E+00	2.00E-01	1.33E-01
Chromium	7.40E+01	5.70E+02	2.40E+00	2.20E+00
Copper	9.00E+00	1.30E+01	7.30E+00	5.87E+00
Lead	2.50E+00	6.50E+01	7.30E+00	4.70E+00
Mercury	7.70E-01	1.40E+00	5.00E-02	<5.000E-02
Nickel	5.20E+01	4.70E+02	7.80E+00	7.47E+00
Selenium	5.00E+00	NA	6.00E-01	<6.000E-01
Silver	NA	3.20E+00	4.00E-02	<4.000E-02
Thallium	NA	NA	2.00E-02	<2.000E-02
Zinc	1.20E+02	1.20E+02	2.54E+01	1.79E+01
VOCs				
1,4-Dichlorobenzene	*	*	<2.50E-01	<2.50E-01
Chlorobenzene	*	*	<3.20E-01	<3.20E-01
Benzene	*	*	<3.30E-01	<3.30E-01
Ethylbenzene	*	*	<2.10E-01	<2.10E-01
Toluene	*	*	<3.90E-01	<3.90E-01
Pesticides/PCBs				
4,4'-DDE	*	*	<2.14E-02	<2.14E-02
4,4'-DDT	1.00E-03	1.10E+00	<5.29E-02	<5.29E-02
Aroclor-1242	1.40E-02	NA	<5.77E-02	<5.77E-02
Aroclor-1248	1.40E-02	NA	<4.81E-02	<4.81E-02
Aroclor-1254	1.40E-02	NA	<4.81E-02	<4.81E-02
Aroclor-1260	1.40E-02	NA	<4.81E-02	<4.81E-02
Cyanide	5.2	22	1.72E+00	<1.72E+00

CMC-criteria maximum concentration; National Recommended Water Quality Criteria (Section 304(a))

CCC-criteria continuous concentration; National Recommended Water Quality Criteria (Section 304(a))

*	Only human health surface water quality criteria exist, but not established for protection of aquatic life
NA	Criteria not available.
	Exceeds CMC Criteria.
	Exceeds CCC Criteria.

Table 9a: Use of equilibrium partitioning to estimate water concentrations from sediment concentrations of organics

Constituent	**Water Quality Criteria for Aquatic Life (μg/L)**	**Maximum Detected Sediment Concentration (mg/kg)**	**Kow L/kg**	**Kp** L/kg**	**Calculated Water Concentration (μg/L)**
Total PCBs	1.40E-02	6.09E-01	1.10E+06	2.1E+04	2.84E-02
	Exceeds water quality criteria				

Table 10: Comparison of Pond Water Concentratons with EPA Environmental Water Quality Criteria for Human Health

	Human Health - Consumption of Organisms only	Maximum Pond Water Detection	Average Pond Water Concentration
Constituent	**µg/L**	**µg/L**	**µg/L**
Metals			
Antimony	6.40E+02	1.40E+00	1.40E+00
Arsenic	1.40E-01	4.50E+00	3.90E+00
Beryllium	NA	<1.00E-01	<1.00E-01
Cadmium	NA	2.00E-01	1.33E-01
Chromium	NA	2.40E+00	2.20E+00
Copper	NA	7.30E+00	5.87E+00
Lead	NA	7.30E+00	4.70E+00
Mercury	NA	<5.00E-02	<5.00E-02
Nickel	4.60E+03	7.80E+00	7.47E+00
Selenium	4.20E+03	<6.00E-01	<6.00E-01
Silver	NA	4.00E-02	<4.00E-02
Thallium	4.70E-01	<2.00E-02	<2.00E-02
Zinc	2.60E+04	2.54E+01	1.79E+01
PAHs			
Anthracene	4.00E+04	<4.90E-01	<4.90E-01
Benzo(a)anthracene	1.80E-02	<4.90E-01	<4.90E-01
Benzo(a)pyrene	1.80E-02	<4.90E-01	<4.90E-01
Benzo(b)flouranthene	1.80E-02	<4.90E-01	<4.90E-01
Chrysene	1.80E-02	<4.90E-01	<4.90E-01
Flouranthene	1.40E+02	<4.90E-01	<4.90E-01
Indeno(1,2,3-cd)Pyrene	1.80E-02	<4.90E-01	<4.90E-01
Phenanthrene	NA	<4.90E-01	<4.90E-01
Pyrene	4.00E+03	<4.90E-01	<4.90E-01
VOCs			
1,4-Dichlorobenzene	1.90E+02	<2.50E-01	<2.50E-01
Chlorobenzene	1.60E+03	<3.20E-01	<3.20E-01
Benzene	5.10E+01	<3.30E-01	<3.30E-01
Ethylbenzene	2.10E+03	<2.10E-01	<2.10E-01
Toluene	1.50E+04	<3.90E-01	<3.90E-01
Pesticides/PCBs			
4,4'-DDE	2.20E-04	<2.14E-02	<2.14E-02
4,4'-DDT	2.20E-04	<5.29E-02	<5.29E-02
Aroclor-1242	6.40E-05	<5.77E-02	<5.77E-02
Aroclor-1248	6.40E-05	<4.81E-02	<4.81E-02
Aroclor-1254	6.40E-05	<4.81E-02	<4.81E-02
Aroclor-1260	6.40E-05	<4.81E-02	<4.81E-02
NA	Criteria not available.		
	Exceeds Human Health Consumption Criteria.		

Table 10a: Use of equilibrium partitioning to estimate water concentrations from sediment concentrations of organics

Constituent	Water Quality Criteria for Human Health (µg/L)	Maximum Detected Sediment Concentration (mg/kg)	Kow L/kg	Kp** L/kg	Calculated Water Concentration (µg/L)	Measured Water Concentration (µg/L)
Benzo(a)anthracene	1.80E-02	1.35E-01	5.01E+05	9.8E+03	1.38E-02	<4.90E-01
Benzo(a)pyrene	1.80E-02	2.97E-01	1.10E+06	2.1E+04	1.39E-02	<4.90E-01
Benzo(b)flouranthene	1.80E-02	2.87E-01	1.58E+06	3.1E+04	9.27E-03	<4.90E-01
Chrysene	1.80E-02	1.94E-01	5.01E+05	9.8E+03	1.98E-02	<4.90E-01
4,4'-DDE	2.20E-04	4.17E-03	1.00E+06	2.0E+04	2.14E-04	<2.14E-02
4,4'-DDT	2.20E-04	8.81E-03	1.55E+06	3.0E+04	2.91E-04	<5.29E-02
Total PCBs	6.40E-05	6.09E-01	1.10E+06	2.1E+04	2.84E-02	<4.81E-02
	Exceeds water quality criteria					

Table 11 **Times Beach Oxidized Soil vs. Cleveland Harbor CDF 10B Oxidized Soil PAH Results**

Times Beach 2001 Oxidized Soil Testing Results (units are in ppm)

Parameter	T-1 0-28	T-2 0-15	T-3 0-18	T-4 0-18	T-5 0-18	T-6 0-12
Naphthalene	0.73	0.83	0.56	0.22	1.33	0.98
Acenaphthylene	0.20	0.20	0.16	0.25	0.28	0.50
Acenaphthene	0.08	0.15	0.12	0.55	0.31	0.34
Fluorene	0.22	0.10	0.79	0.25	0.27	0.30
Phenanthrene	0.55	0.96	0.61	0.52	1.30	1.66
Anthracene	0.32	0.39	0.30	0.35	0.56	0.90
Fluoranthene	0.73	1.18	0.72	0.63	1.04	2.71
Pyrene	0.64	0.95	0.56	0.53	0.63	1.90
Benzo(a)Anthracene	0.71	0.81	0.58	0.43	0.71	2.24
Chrysene	0.73	0.79	0.56	0.38	0.71	1.91
Benzo(b)Fluoranthene	1.08	1.16	0.90	0.57	1.57	3.05
Benzo(k)Fluoranthene	0.43	0.39	0.32	0.21	0.44	1.25
Benzo(a)Pyrene	0.86	1.02	0.74	0.52	1.30	2.79
Indeno(1,2,3-cd)Pyrene	0.70	0.69	0.47	0.28	0.83	1.61
Dibenzo(a,h)Anthracene	0.22	0.23	0.24	0.09	0.34	0.29
Benzo(ghi)Perylene	0.84	0.81	0.52	0.31	0.82	1.71
Total PAH (ppm)	9.02	10.66	8.14	6.07	12.44	24.13
TOC	20,700	15,000	11,500	15,700	40,900	33,100

PAH min	PAH max	PAH average
6.07	24.13	11.74

TOC min	TOC max	TOC average
11,500	40,900	22,817

Cleveland CDF 10B 2004 Oxidized Soil Testing Results (units are in ppm)

	CCDF-1 Soil mg/kg	CCDF-2 Soil mg/kg	CCDF-3 Soil mg/kg
Acenaphthene	0.005	0.005	0.021
Acenaphthylene	0.010	0.011	0.009
Anthracene	0.024	0.011	0.037
Benzo(a)anthracene	0.080	0.053	0.093
Benzo(a)pyrene	0.169	0.148	0.153
Benzo(b)fluoranthene	0.153	0.094	0.135
Benzo(ghi)perylene	0.144	0.116	0.123
Benzo(k)fluoranthene	0.010	0.011	0.009
Chrysene	0.099	0.072	0.106
Dibenzo(a,h)anthracene	0.010	0.011	0.009
Fluoranthene	0.155	0.112	0.193
Fluorene	0.011	0.007	0.024
Indeno(1,2,3-cd)pyrene	0.164	0.145	0.137
Naphthalene	0.010	0.011	0.009
Phenanthrene	0.087	0.045	0.128
Pyrene	0.111	0.092	0.155
Total PAH (ppm)	1.24	0.94	1.34
TOC (ppm)	21,700	10,900	3,180

PAH min	PAH max	PAH average
0.94	1.34	1.17

TOC min	TOC max	TOC average
3,180	21,700	11,927

Table 12 **Times Beach Reduced Soil vs. Cleveland Harbor CDF10B Sediment PAH Results**

Times Beach 2001 Sediment Testing Results (units are in ppm [dry weight])

Parameter	T-9 0-24	T-10 4-30	T-11 0-8	T-11 8-30	T-12	T-13	T-14
Naphthalene	0.46	11.30	0.76	1.74	0.30	0.41	0.29
Acenaphthylene	0.22	0.26	0.24	0.32	0.42	0.56	0.49
Acenaphthene	0.66	1.01	0.17	1.20	0.42	0.56	0.49
Fluorene	0.62	0.51	0.08	0.64	0.42	0.56	0.49
Phenanthrene	2.55	2.54	0.57	2.16	0.39	0.33	0.24
Anthracene	1.79	2.83	0.52	2.18	0.26	0.25	0.21
Fluoranthene	2.49	1.03	0.55	1.31	0.52	0.42	0.31
Pyrene	1.86	0.79	0.71	1.00	0.39	0.33	0.28
Benzo(a)Anthracene	1.15	0.85	0.45	0.47	0.28	0.24	0.20
Chrysene	0.95	0.73	0.44	0.48	0.28	0.24	0.22
Benzo(b)Fluoranthene	1.04	0.91	0.64	0.34	0.41	0.35	0.37
Benzo(k)Fluoranthene	0.44	0.37	0.20	0.13	0.14	0.56	0.49
Benzo(a)Pyrene	0.84	0.81	0.57	0.27	0.29	0.24	0.23
Indeno(1,2,3-cd)Pyrene	0.39	0.41	0.35	0.13	0.17	0.56	0.49
Dibenzo(a,h)Anthracene	0.13	0.26	0.24	0.32	0.42	0.56	0.49
Benzo(ghi)Perylene	0.42	0.43	0.37	0.14	0.21	0.56	0.49
Total PAH (ppm)	16.00	25.04	6.85	12.82	5.30	6.68	5.76
TOC (ppm)	20,600	23,900	23,800	46,700	31,400	33,000	32,900

PAH		
min	max	average
5.30	25.04	11.21

TOC		
min	max	average
20,600	46,700	30,329

Cleveland CDF 10B 2004 Sediment Testing Results (units are in ppm)

PAHs	CCDF-4 Sediment mg/kg	CCDF-5 Sediment mg/kg	CCDF-6 Sediment mg/kg
Acenaphthene	0.009	0.009	0.009
Acenaphthylene	0.018	0.019	0.019
Anthracene	0.018	0.019	0.019
Benzo(a)anthracene	0.135	0.098	0.085
Benzo(a)pyrene	0.297	0.249	0.250
Benzo(b)fluoranthene	0.287	0.156	0.147
Benzo(ghi)perylene	0.248	0.214	0.201
Benzo(k)fluoranthene	0.018	0.019	0.019
Chrysene	0.194	0.095	0.095
Dibenzo(a,h)anthracene	0.018	0.019	0.019
Fluoranthene	0.323	0.197	0.176
Fluorene	0.015	0.004	0.016
Indeno(1,2,3-cd)pyrene	0.289	0.255	0.254
Naphthalene	0.018	0.019	0.019
Phenanthrene	0.139	0.098	0.093
Pyrene	0.241	0.125	0.129
Total PAH (ppm)	2.27	1.59	1.55
TOC (ppm)	34,000	30,400	30,400

PAH		
min	max	average
1.55	2.27	1.80

TOC		
min	max	average
30,400	34,000	31,600

Table 13. State of Ohio criteria for beneficial use of dredged material (from GLC, 2004).

Contaminant	Cover for Residential Use	Cover for Industrial Use	Fill, Unrestrictive
Arsenic	12[a]	41	12
Lead	140	300	70
Zinc	200	2800	200
PCBs	1.3	--	0.5
Benzo(a)pyrene	0.7	--	0.1
Benzene	0.5	--	0.05
Criteria Source	CEQG[b]	Sludge Rules[c]	CEQG[d]

a: All values are in mg kg^{-1} and applicable for the use classification.
b: Adapted from Canadian Environmental Quality Guidelines for residential soil.
c: Based on monthly average limits contained in Ohio's sewage sludge rules.
d: Adapted from Canadian Environmental Quality Guidelines for soil based on the most stringent value.

Table 14. Physical soil characteristics.

Sample	Field Moisture %	pH	Particle Size Analysis (%)			TOC
			Sand	Silt	Clay	
CDF 10B	23.6	6.8	35.8	55.0	9.2	7,500
Reference	14.9	5.7	78.3	14.2	7.5	4,500

Table 15. Soil contaminant concentrations, mg kg^{-1} dry weight.

Metals	CDF 10B	Reference	Criteria	PCB/Pest[a]	CDF 10B	Reference
As	13	6.4	12 – 41*	**1016**	<0.011	<0.0095
Cd	2.6	0.99	10 - 22**	**1221**	<0.011	<0.0095
Cr	20	7.8	218**	**1232**	<0.011	<0.0095
Cu	39	10	1127**	**1272**	<0.011	<0.0095
Hg	0.071	0.038	6.6 – 50**	**1248**	0.0805	<0.0095
Ni	28	9.3	50**	**1254**	<0.011	<0.0095
Pb	34	24	70 – 300*	**1260**	<0.011	<0.0095
Ag	<1	<1	--	**DDT**	<0.0011	<0.00095
Zn	186	47	200 – 2800*	**DDE**	0.00958	0.00077
				DDD	0.00304	<0.00095

* State of Ohio criteria for unrestricted fill (most restrictive) to cover for industrial use.
** From Canadian Environmental Quality Guidelines (2006) for residential/park – industrial.
a: State of Ohio criteria for PCBs is 0.5 mg kg^{-1} for unrestricted fill, 1.3 mg kg^{-1} for residential cover (GLC, 2004). CEQG criteria for DDT is 0.7 mg kg^{-1} for residential/park and 12.0 mg kg^{-1} for industrial.

Table 16. Plant biomass properties after 45 days of growth.

		Fresh wt. (g)	Dry wt (g)	% moisture
CDF 10B	mean	118.2	24.9	79.0
	max	139.1	31.6	80.6
	min	106.6	20.7	77.3
Reference	mean	67.2	15.6	76.8
	max	86.7	20.5	77.4
	min	51.0	11.6	76.3

Table 17. Plant tissue concentrations of metals, mg kg^{-1} dry weight.

	Replicate	As	Cd	Cr	Cu	Pb	Hg	Ni	Ag	Zn
CDF 10B	1	<0.5	1.18	<0.5	7.95	4.53	0.004	0.87	<0.5	58.65
CDF 10B	2	<0.5	1.36	<0.5	7.57	1.01	0.0042	0.91	<0.5	56.44
CDF 10B	3	<0.5	1.34	0.77	8.87	5.38	0.0057	1.35	<0.5	69.39
	Mean	**<0.50**	**1.29**	**0.07**	**8.13**	**3.64**	**0.005**	**1.04**	**<0.50**	**61.49**
Reference*	1	<0.5	3.27	<0.5	6.6	8.83	0.0037	0.92	<0.5	68.95
Reference	2	1.75	4.77	5.14	12.66	81.06	0.0036	5.12	<0.5	103.7
Reference	3	<0.5	2.97	1.07	9.82	16.02	0.0117	1.91	<0.5	74.57
	Mean	**0.25**	**3.67**	**1.90**	**9.69**	**35.30**	**0.01**	**2.65**	**<0.50**	**82.41**

Table 18. Earthworm survival and growth.

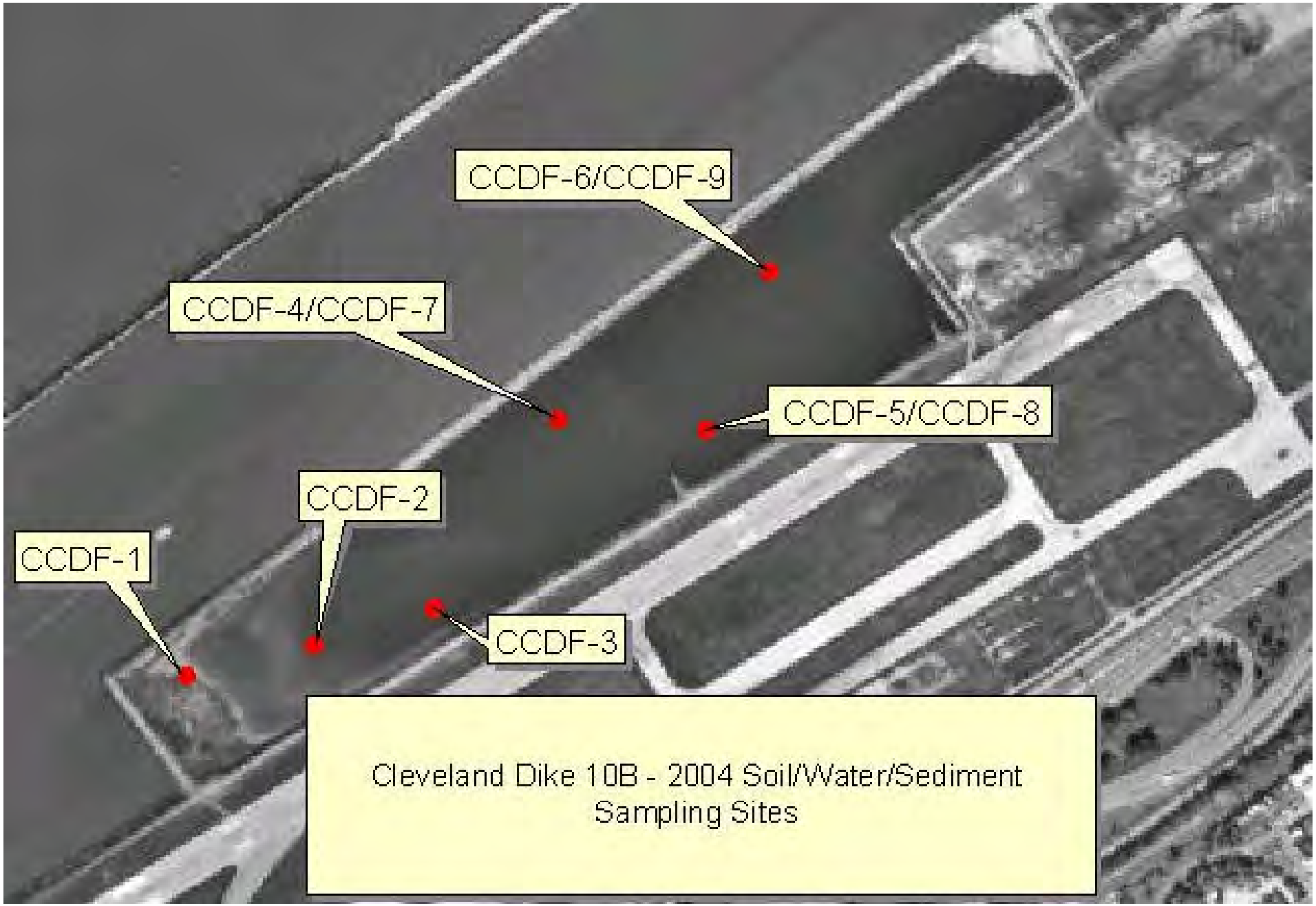
		Day 0 Count	Day 0 wt. (g)	Day 28 Count	Day 28 wt. (g)
CDF 10B	**mean**	**75**	**24.5**	**60.6**	**13.3**
	max		25.8	71	16.1
	min		23.8	52	9.8
Reference	**mean**	**75**	**23.7**	**70.8**	**15.5**
	max		25.5	74	16.8
	min		22.4	67	14.3
Control	**mean**	**75**	**24.5**	**65.6**	**15.4**
	max		26.3	74	20.8
	min		22.2	49	12.2

Table 19. PCB uptake by earthworms, mg kg^{-1}.

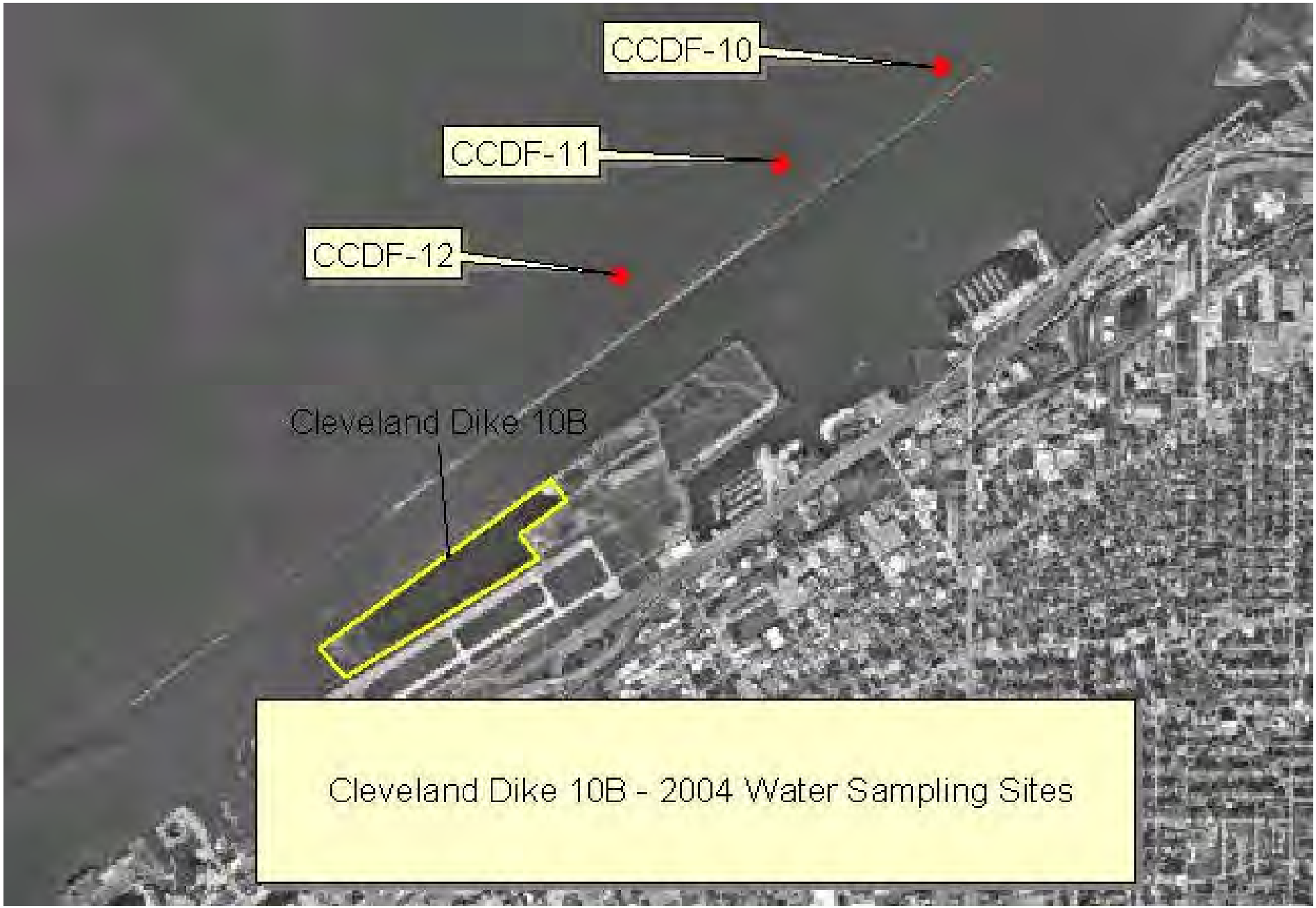
PCB/Pest	CDF 10B	Reference	Day 0 Blank
1016	<0.00777	<0.00803	<0.00793
1232	<0.00777	<0.00803	<0.00793
1248	0.041	0.0208	<0.00793
1254	<0.00777	<0.00803	<0.00793
1260	<0.00777	<0.00803	<0.00793
DDT*	0.00772	<0.0008	<0.00079
DDE	0.00474	0.00222	<0.00079
DDD	0.00339	<0.0031	<0.00079

*data for CDF 10B and Reference are questionable, calculated concentration is >40% difference between primary and secondary columns

APPENDIX A Summary tables of 2004 sampling results



Cleveland Dike 10B - 2004 Soil/Water/Sediment Sampling Sites



Cleveland Dike 10B - 2004 Water Sampling Sites

CLEVELAND CDF 10B
2004
B/N/A
SOILS/SEDIMENT DATA

B/N/A	CCDF-1 Soil ug/kg	CCDF-2 Soil ug/kg	CCDF-3 Soil ug/kg	CCDF-4 Sediment ug/kg	CCDF-5 Sediment ug/kg	CCDF-6 Sediment ug/kg
1,2,4-Trichlorobenzene	<14.8	<16.4	<14.0	<27.4	<28.3	<29.4
1,2-Dichlorobenzene	<11.7	<12.9	<11.0	<21.7	<22.4	<23.2
1,2-Diphenylhydrazine	<30.4	<33.6	<28.7	<56.3	<58.2	<60.3
1,3-Dichlorobenzene	<13.3	<14.7	<12.5	<24.5	<25.3	<26.3
1,4-Dichlorobenzene	<18.3	<20.3	<17.3	<33.9	<35.0	<36.3
2,4,6-Trichlorophenol	<32.0	<35.4	<30.2	<59.2	<61.1	<63.4
2,4-Dichlorophenol	<24.2	<26.7	<22.8	<44.8	<46.2	<47.9
2,4-Dimethylphenol	<195	<216	<184	<361	<373	<386
2,4-Dinitrophenol	<195	<216	<184	<361	<373	<386
2,4-Dinitrotoluene	<29.7	<32.8	<28.0	<54.9	<56.7	<58.7
2,6-Dinitrotolune	<39.0	<43.1	<36.8	<72.2	<74.6	<77.3
2-Chloronaphthalene	<16.0	<17.7	<15.1	<29.6	<30.6	<31.7
2-Chlorophenol	<18.0	<19.8	<16.9	<33.2	<34.3	<35.5
2-Methyl-4,6-dinitrophenol	<195	<216	<184	<361	<373	<386
2-Nitrophenol	<19.9	<22.0	<18.8	<36.8	<38.0	<39.4
3,3'-Dichlorobenzidine	<195	<216	<184	<361	<373	<386
4-Bromophenylphenylether	<39.8	<44.0	<37.6	<73.6	<76.0	<78.8
4-Chloro-3-methylphenol	<195	<216	<184	<361	<373	<386
4-Chlorophenylphenylether	<23.0	<25.4	<21.7	<42.6	<44.0	<45.6
4-Nitrophenol	<195	<216	<184	<361	<373	<386
Acenaphthene	<9.37	<10.4	20.9	<17.3	<17.9	<18.5
Acenaphthylene	<19.5	<21.6	<18.4	<36.1	<37.3	<38.6
Anthracene	23.6	<21.6	36.5	<36.1	<37.3	<38.6
Benzidine	<195	<216	<184	<361	<373	<386
Benzo(a)anthracene	80.1	52.9	93.0	135	98.1	85.3
Benzo(a)pyrene	169	148	153	297	249	250
Benzo(b)fluoranthene	153	93.8	135	287	156	147
Benzo(ghi)perylene	144	116	123	248	214	201
Benzo(k)fluoranthene	<19.5	<21.6	<18.4	<36.1	<37.3	<38.6
Butylbenzylphthalate	<33.6	<37.1	<31.7	<62.1	<64.1	<66.5

CLEVELAND CDF 10B
2004
B/N/A
WATER DATA

B/N/A	CCDF-7 Pond ug/l	CCDF-10 Background ug/l
1,2,4-Trichlorobenzene	<0.696	<0.683
1,2-Dichlorobenzene	<0.402	<0.394
1,2-Diphenylhydrazine	<0.843	<0.837
1,3-Dichlorobenzene	<0.402	<0.394
1,4-Dichlorobenzene	<0.304	<0.298
2,4,6-Trichlorophenol	<0.382	<0.375
2,4-Dichlorophenol	<0.461	<0.452
2,4-Dimethylphenol	<0.461	<0.452
2,4-Dinitrophenol	<4.90	<4.81
2,4-Dinitrotoluene	<0.686	<0.673
2,6-Dinitrotolune	<0.490	<0.481
2-Chloronaphthalene	<0.392	<0.385
2-Chlorophenol	<0.402	<0.394
2-Methyl-4,6-dinitrophenol	<0.980	<0.962
2-Nitrophenol	<0.578	<0.567
3,3'-Dichlorobenzidine	<0.500	<0.490
4-Bromophenylphenylether	<1.20	<1.17
4-Chloro-3-methylphenol	<0.676	<0.663
4-Chlorophenylphenylether	<0.824	<0.808
4-Nitrophenol	<4.90	<4.81
Acenaphthene	<0.490	<0.481
Acenaphthylene	<0.490	<0.481
Anthracene	<0.490	<0.481
Benzidine	<4.90	<4.81
Benzo(a)anthracene	<0.490	<0.481
Benzo(a)pyrene	<0.490	<0.481
Benzo(b)fluoranthene	<0.490	<0.481
Benzo(ghi)perylene	<0.490	<0.481
Benzo(k)fluoranthene	<0.490	<0.481
Butylbenzylphthalate	<0.667	<0.654

CLEVELAND CDF 10B
2004
B/N/A
SOILS/SEDIMENT DATA

B/N/As	CCDF-1 Soil ug/kg	CCDF-2 Soil ug/kg	CCDF-3 Soil ug/kg	CCDF-4 Sediment ug/kg	CCDF-5 Sediment ug/kg	CCDF-6 Sediment ug/kg
Chrysene	98.5	71.7	106	194	95.3	95.0
Di-n-butylphthalate	<28.1	<31.1	<26.5	<52.0	<53.7	<55.6
Di-n-octylphthalate	<35.5	<39.2	<33.5	<65.7	<67.8	<70.3
Dibenzo(a,h)anthracene	<19.5	<21.6	<18.4	<36.1	<37.3	<38.6
Diethylphthalate	<20.7	<22.9	<19.5	<38.3	<39.5	<41.0
Dimethylphthalate	<21.5	<23.7	<20.3	<39.7	<41.0	<42.5
Diphenylamine	<26.2	<28.9	<24.7	<48.4	<49.9	<51.8
Fluoranthene	155	112	193	323	197	176
Fluorene	11.2	6.80	23.5	15.0	<8.95	16.1
Hexachlorobenzene	<23.4	<25.9	<22.1	<43.3	<44.7	<46.4
Hexachlorobutadiene	<14.8	<16.4	<14.0	<27.4	<28.3	<29.4
Hexachlorocyclopentadiene	<195	<216	<184	<361	<373	<386
Hexachloroethane	<25.8	<28.5	<24.3	<47.6	<49.2	<51.0
Indeno(1,2,3-cd)pyrene	164	145	137	289	255	254
Isophorone	<18.7	<20.7	<17.7	<34.6	<35.8	<37.1
N-Nitrosodipropylamine	<26.5	<29.3	<25.0	<49.1	<50.7	<52.5
Naphthalene	<19.5	<21.6	<18.4	<36.1	<37.3	<38.6
Nitrobenzene	<23.8	<26.3	<22.5	<44.0	<45.5	<47.1
Pentachlorophenol	<195	<216	<184	<361	<373	<386
Phenanthrene	87.3	45.1	128	139	98.4	93.4
Phenol	<14.8	<16.4	<14.0	<27.4	<28.3	<29.4
Pyrene	111	92.1	155	241	125	129
bis(2-Chloroethoxy)methane	<14.4	<16.0	<13.6	<26.7	<27.6	<28.6
bis(2-Chloroethyl)ether	<43.7	<48.3	<41.2	<80.8	<83.5	<86.5
bis(2-Chloroisopropyl)ether	<12.9	<14.2	<12.2	<23.8	<24.6	<25.5
bis(2-Ethylhexyl)phthalate	89.6	132	89.3	410	271	283

CLEVELAND CDF 10B
2004
B/N/A
SOILS/SEDIMENT DATA

B/N/As	CCDF-7 Pond ug/l	CCDF-10 Background ug/l
Chrysene	<0.490	<0.481
Di-n-butylphthalate	<0.980	1.20
Di-n-octylphthalate	<0.853	<0.837
Dibenzo(a,h)anthracene	<0.490	<0.481
Diethylphthalate	<0.873	<0.856
Dimethylphthalate	<0.520	<0.510
Diphenylamine	<0.775	<0.760
Fluoranthene	<0.490	<0.481
Fluorene	<0.490	<0.481
Hexachlorobenzene	<0.637	<0.625
Hexachlorobutadiene	<0.314	<0.308
Hexachlorocyclopentadiene	<0.980	<0.962
Hexachloroethane	<0.422	<0.413
Indeno(1,2,3-cd)pyrene	<0.490	<0.481
Isophorone	<0.578	<0.567
N-Nitrosodipropylamine	<0.735	<0.721
Naphthalene	<0.108	<0.106
Nitrobenzene	<0.618	<0.606
Pentachlorophenol	<4.90	<4.81
Phenanthrene	<0.490	<0.481
Phenol	<0.294	<0.288
Pyrene	<0.490	<0.481
bis(2-Chloroethoxy)methane	<0.471	<0.462
bis(2-Chloroethyl)ether	<1.34	<1.32
bis(2-Chloroisopropyl)ether	<0.784	<0.769
bis(2-Ethylhexyl)phthalate	<1.27	<1.25

CLEVELAND CDF 10B
2004
METALS
SOIL/SEDIMENT DATA

Metals	CCDF-1 Soil mg/kg	CCDF-2 Soil mg/kg	CCDF-3 Soil mg/kg	CCDF-4 Sediment mg/kg	CCDF-5 Sediment mg/kg	CCDF-6 Sediment mg/kg
Aluminum	6500	3870	3700	16900	1630	15200
Antimony	0.167	0.088	0.084	0.188	0.241	0.222
Arsenic	9.06	5.63	7.20	20.7	22.5	20.8
Barium	59.0	29.4	21.7	119	119	115
Beryllium	0.427	0.284	0.283	0.959	0.965	0.903
Cadmium	1.32	0.771	0.414	2.31	2.61	2.84
Calcium	37200	7710	3310	14800	16000	15000
Chromium	21.5	9.99	8.12	37.2	37.8	37.1
Cobalt	6.79	4.62	4.58	15.4	16.2	15.6
Copper	43.5	24.1	16.2	66.2	69.7	68.1
Iron	21500	12900	14900	40000	41800	40100
Lead	72.9	21.4	11.3	77.3	82.0	80.5
Magnesium	8200	2550	1420	6630	7110	6500
Manganese	437	240	171	869	895	872
Mercury	0.252	0.061	0.012	0.126	0.152	0.209
Nickel	23.6	16.9	28.5	49.3	51.1	49.8
Potassium	1200	891	746	3120	3220	2790
Selenium	0.432	0.260	0.269	1.20	1.43	1.44
Silver	0.349	0.086	0.050	0.691	0.716	0.693
Sodium	81.8	63.4	35.5	197	195	182
Thallium	0.265	0.144	0.116	0.549	0.593	0.540
Vanadium	13.7	8.97	9.72	31.3	32.6	29.5
Zinc	265	103	90.0	356	359	366

CLEVELAND CDF 10B
2004
METALS
WATER DATA

Metals	CCDF-7 Pond ug/l	CCDF-8 Pond ug/l	CCDF-9 Pond ug/l	CCDF-10 Background ug/l	CCDF-11 Background ug/l	CCDF-12 Background ug/l
Aluminum	349	836	674	73.6	79.7	63.3
Antimony	1.4	1.4	1.4	<0.3	<0.3	<0.3
Arsenic	4.5	3.0	4.20	1.4	<1.0	1.6
Barium	49.6	44.7	45.5	17.0	17.0	17.6
Beryllium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	0.2	0.1	0.1	<0.04	<0.04	<0.04
Calcium	62600	59400	59200	32700	32100	33200
Chromium	2.2	2.4	2.0	1.0	1.1	1.2
Cobalt	1.2	1.0	0.9	0.1	0.1	0.1
Copper	7.3	5.2	5.1	1.5	1.5	1.5
Iron	1540	1510	1370	197	214	217
Lead	7.3	3.2	3.6	0.7	0.2	0.6
Magnesium	17500	17000	16500	9690	10500	10200
Manganese	196	152	154	4.6	5.0	5.2
Mercury	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel	7.8	7.5	7.1	1.5	1.6	1.6
Potassium	6180	6160	6770	1500	1390	1550
Selenium	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Silver	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Sodium	45400	45300	43500	13600	13400	14800
Thallium	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Vanadium	<5.4	<5.4	<5.4	<5.4	<5.4	<5.4
Zinc	25.4	14.1	14.3	3.5	2.4	2.9

CLEVELAND CDF 10B
2004
VOLATILES
SOILS/SEDIMENT DATA

Volatiles	CCDF-1 Soil ug/kg	CCDF-2 Soil ug/kg	CCDF-3 Soil ug/kg	CCDF-4 Sediment ug/kg	CCDF-5 Sediment ug/kg	CCDF-6 Sediment ug/kg
1,1,1-Trichloroethane	<0.435	<0.533	<0.586	<0.751	<1.37	<1.63
1,1,2,2-Tetrachloroethane	<0.747	<0.916	<1.01	<1.29	<2.35	<2.80
1,1,2-Trichloroethane	<0.443	<0.543	<0.597	<0.765	<1.39	<1.66
1,1-Dichloroethane	<0.386	<0.473	<0.520	<0.666	<1.21	<1.45
1,1-Dichloroethylene	<0.410	<0.503	<0.553	<0.708	<1.29	<1.54
1,2-Dichlorobenzene	<0.369	<0.453	<0.497	<0.637	<1.16	<1.39
1,2-Dichloroethane	<0.353	<0.433	<0.475	<0.609	<1.11	<1.32
1,2-Dichloropropane	<0.394	<0.483	<0.531	<0.680	<1.24	<1.48
1,3-Dichlorobenzene	<0.254	<0.312	<0.343	<0.439	<0.800	<0.955
1,4-Dichlorobenzene	<0.304	1.10	<0.409	<0.524	4.47	7.02
2-Chloroethylvinyl ether	<1.76	<2.15	<2.37	<0.3.03	<5.53	<6.59
Acrolein	<3.28	<4.03	<4.42	<5.67	<10.3	<12.3
Acrylonitrile	<2.29	<2.81	<3.08	<3.95	<7.20	<8.60
Benzene	3.11	2.43	1.02	2.00	3.76	4.01
Bromodichloromethane	<0.402	<0.493	<0.542	<0.694	<1.27	<1.51
Bromoform	<0.402	<0.493	<0.542	<0.694	<1.27	<1.51
Bromomethane	<0.410	<0.503	<0.553	<0.708	<1.29	<1.54
Carbon tetrachloride	<0.402	<0.493	<0.542	<0.694	<1.27	<1,51
Chlorobenzene	<0.336	<0.413	<0.453	1.61	<1.06	2.68
Chloroethane	<0.665	<0.815	<0.895	<1.15	<2.09	<2.50
Chloroform	<0.427	<0.523	<0.575	<0.737	<1.34	<1.60
Chloromethane	<0.304	<0.372	<0.409	<0.524	<0.955	<1.14
Dibromochloromethane	<0.410	<0.503	<0.553	<0.708	<1.29	<1.54
Ethylbenzene	1.34	1.58	<0.420	1.60	3.05	3.44
Methylene chloride	<1.11	<1.36	<1.49	<1.91	<3.49	<4.16
Tetrachloroethene	<0.312	<0.382	<0.420	<0.538	<0.981	<1.17
Toluene	8.47	8.93	1.16	16.4	50.5	48.4
Trichloroethene	<0.369	<0.453	<0.497	<0.637	<1.16	<1.39
Vinyl chloride	<0.460	<0.564	<0.619	<0.793	<1.45	<1.73
cis-1,2-Dichloropropylene	<0.353	<0.433	<0.475	<0.609	<1.11	<1.32
trans-1,2-Dichloroethylene	<0.435	<0.533	<0.586	<0.751	<1.37	<1.63
trans-1,2-Dichloropropylene	<0.205	<0.252	<0.276	<0.354	<0.646	<0.770

CLEVELAND CDF 10B
2004
VOLATILES
WATER DATA

Volatiles	CCDF-7 Pond ug/l	CCDF-10 Background ug/l
1,1,1-Trichloroethane	<0.340	<0.340
1,1,2,2-Tetrachloroethane	<0.490	<0.490
1,1,2-Trichloroethane	<0.440	<0.440
1,1-Dichloroethane	<0.410	<0.410
1,1-Dichloroethylene	<0.410	<0.410
1,2-Dichlorobenzene	<0.360	<0.360
1,2-Dichloroethane	<0.290	<0.290
1,2-Dichloropropane	<0.250	<0.250
1,3-Dichlorobenzene	<0.330	<0.330
1,4-Dichlorobenzene	<0.250	<0.250
2-Chloroethylvinyl ether	<1.25	<1.25
Acrolein	<4.06	<4.06
Acrylonitrile	<2.00	<2.00
Benzene	<0.330	<0.330
Bromodichloromethane	<0.380	<0.380
Bromoform	<0.500	<0.500
Bromomethane	<0.500	<0.500
Carbon tetrachloride	<0.290	<0.290
Chlorobenzene	<0.320	<0.320
Chloroethane	<0.500	<0.500
Chloroform	<0.360	<0.360
Chloromethane	<0.500	<0.500
Dibromochloromethane	<0.290	<0.290
Dichlorodifluoromethane	<0.430	<0.430
Ethylbenzene	<0.210	<0.210
Methylene chloride	<1.90	<1.90
Tetrachloroethene	<0.330	<0.330
Toluene	<0.390	<0.390
Trichloroethylene	<0.360	<0.360
Trichlorofluoromethane	<0.500	<0.500
Vinyl chloride	<0.550	<0.550
cis-1,2-Dichloropropylene	<0.300	<0.300
trans-1,2-Dichloroethylene	<0.370	<0.370
trans-1,2-Dichloropropylene	<0.290	<0.290

CLEVELAND CDF 10B
2004
PESTICIDES
SOILS/SEDIMENT DATA

Pesticides	CCDF-1 Soil ug/kg	CCDF-2 Soil ug/kg	CCDF-3 Soil ug/kg	CCDF-4 Sediment ug/kg	CCDF-5 Sediment ug/kg	CCDF-6 Sediment ug/kg
4,4'-DDD	<1.23	<1.36	<2.32	<4.55	<4.70	<4.87
4,4'-DDE	<1.05	2.64	<1.99	<3.90	<4.03	<4.17
4,4-DDT	<2.23	15.9	<4.20	<8.23	<8.50	<8.81
Aldrin	<1.01	<1.11	<1.90	<3.72	<3.84	<3.98
alpha-BHC	<0.676	<0.747	<1.28	<2.50	<2.58	<2.68
beta-BHC	<0.555	<0.614	<1.05	<2.05	<2.12	<2.20
Chlordane	<38.9	<43.0	<73.5	<144	<149	<154
delta-BHC	<0.555	<0.614	<1.05	<2.05	<2.12	<2.20
Dieldrin	<1.01	<1.11	<1.90	<3.72	<3.84	<3.98
Endosulfan I	<0.469	<0.519	<0.886	<1.74	<1.79	<1.86
Endosulfan II	<0.906	<1.00	<1.71	<3.35	<3.46	<3.59
Endosulfan sulfate	<1.07	<1.19	<2.03	<3.97	<4.10	<4.25
Endrin	<1.18	<1.30	<2.23	<4.37	<4.51	<4.68
Endrin aldehyde	<1.18	<1.30	<2.23	<4.37	<4.51	<4.68
gamma-BHC (Lindane)	<0.487	<0.539	<0.919	<1.80	<1.86	<1.93
Heptachlor	<0.621	<0.686	<1.17	<2.30	<2.37	<2.46
Heptachlor epoxide	<0.526	<0.581	<0.992	<1.95	<2.01	<2.08
Toxaphene	<73.2	<80.9	<138	<271	<280	<290

CLEVELAND CDF 10B
2004
PESTICIDES
WATER DATA

Pesticides	CCDF-7 Pond ug/l	CCDF-10 Background ug/l
4,4'-DDD	<0.0267	<0.00505
4,4'-DDE	<0.0214	<0.00404
4,4-DDT	<0.0529	<0.010
Aldrin	<0.0255	<0.00482
alpha-BHC	<0.00704	<0.00133
beta-BHC	<0.0138	<0.00261
Chlordane	<0.752	<0.132
delta-BHC	<0.0133	<0.00252
Dieldrin	<0.0187	<0.00353
Endosulfan I	<0.0299	<0.00564
Endosulfan II	<0.0575	<0.0109
Endosulfan sulfate	<0.0226	<0.00427
Endrin	<0.0184	<0.00349
Endrin aldehyde	<0.0337	<0.00638
gamma-BHC (Lindane)	<0.0102	<0.00193
Heptachlor	<0.0284	<0.00537
Heptachlor epoxide	<0.0146	<0.00275
Toxaphene	<0.510	<0.0963

CLEVELAND CDF 10B
2004
PCB
SOILS/SEDIMENT DATA

PCBs	CCDF-1 Soil ug/kg	CCDF-2 Soil ug/kg	CCDF-3 Soil ug/kg	CCDF-4 Sediment ug/kg	CCDF-5 Sediment ug/kg	CCDF-6 Sediment ug/kg
Aroclor 1016	<1.17	<1.29	<1.10	<2.17	<2.24	<2.32
Aroclor 1221	<3.30	<3.65	<3.12	<6.11	<6.31	<6.54
Aroclor 1232	<1.95	<2.16	<1.84	<3.61	<3.73	<3.86
Aroclor 1242	8.20	<1.29	100	324	184	349
Aroclor 1248	<1.17	27.3	<1.10	<2.17	<2.24	<2.32
Aroclor 1254	3.40	12.8	61.9	163	156	186
Aroclor 1260	6.70	5.50	16.3	60.7	52.8	74.1

CLEVELAND CDF 10B
2004
PCB
WATER DATA

PCBs	CCDF-7 Pond ug/l	CCDF-10 Background ug/l
Aroclor 1016	<0.0481	<0.0481
Aroclor 1221	<0.0801	<0.0801
Aroclor 1232	<0.0481	<0.0481
Aroclor 1242	<0.0577	<0.0577
Aroclor 1248	<0.0481	<0.0481
Aroclor 1254	<0.0481	<0.0481
Aroclor 1260	<0.0481	<0.0481

CLEVELAND CDF 10B

2004

TOTAL ORGANIC CARBON

SOILS/SEDIMENT DATA

Total Organic Carbon	CCDF-1 Soil	CCDF-2 Soil	CCDF-3 Soil	CCDF-4 Sediment	CCDF-5 Sediment	CCDF-6 Sediment
mg/kg	21,700	10,900	3,180	34,000	30,400	30,400

CLEVELAND CDF 10B

2004

TOTAL CYANIDE

SOILS/SEDIMENT DATA

Total Cyanide	CCDF-1 Soil	CCDF-2 Soil	CCDF-3 Soil	CCDF-4 Sediment	CCDF-5 Sediment	CCDF-6 Sediment
ug/kg	1,030	186	331	1,990	2,190	1,020

CLEVELAND CDF 10B
2004
TOTAL CYANIDE
WATER DATA

Total Cyanide	CCDF-7 Pond	CCDF-8 Pond	CCDF-9 Pond	CCDF-10 Background	CCDF-10 Background	CCDF-10 Background
ug/l	<1.72	<1.72	<1.72	<1.72	<1.72	<1.72

CLEVELAND CDF 10B
2004
DIOXIN
SOILS/SEDIMENT DATA

2,3,7,8-TCDD	CCDF-4 Sediment
pg/g	0.210