

APPENDIX A
RESULTS OF ASSESSMENT ACTIVITIES

CONTAMINANTS IN THE GCR/IHC

Years of releases by the various industries that have used the river system for wastewater discharge and drainage have resulted in contamination of the resources of the GCR/IHC with a variety of contaminants of potential concern. The focus of the damage assessment has been on polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and metals.

Polychlorinated biphenyls (PCBs) are synthetic compounds that were produced commercially in the US between 1929 and 1977, at which time their production was banned. PCBs were widely used in commercial and industrial applications due to their favorable properties, including chemical stability, low flammability, and ability to serve as an electrical insulator. Their presence in the GCR/IHC is due at least in part to cutting and hydraulic oils (Erickson 1997). In addition, since PCBs are hydrophobic with low water solubility, they adsorb to materials such as organic matter in sediment. Higher trophic level organisms, such as fish and birds, may accumulate PCBs directly from the water column or sediment, or through the ingestion of contaminated food. PCBs are associated with a range of deleterious effects, including impaired reproductive ability in fish, mammals, and birds (Eisler 2000).

The term oil refers to a variety of complex mixtures of organic compounds and trace elements commonly associated with the petrochemical industry. Oil can be harmful to the environment as a result of both its physical and chemical properties. Aromatic hydrocarbons are one class of petroleum hydrocarbons, and a subcategory of this is a group known as polycyclic aromatic hydrocarbons, or PAHs. PAHs are a component of crude and refined oils.¹ PAHs can also form as products of incomplete combustion. PAHs of different molecular weight vary substantially in their behavior and distribution in the environment and in their biological effects. Simple, lower-molecular-weight PAHs have significant acute toxicity to some organisms, while some higher-molecular-weight PAHs are known or suspected carcinogens (Eisler 2000). Sixteen PAHs are classified as priority pollutants by the USEPA (MESL 2000).

Those metals commonly referred to as "heavy metals" are often associated with anthropogenic sources and are toxic to a wide range of organisms. This group includes metals known to be essential to organisms (*e.g.*, copper, iron, manganese, and zinc) as well as nonessential metals such as cadmium, lead, and mercury (Rainbow 1996). The presence of these metals in the GCR/IHC is likely related to steel making and metal finishing operations. Lead and mercury are two of the most toxic metals found in the GCR/IHC.

DISTRIBUTION OF CONTAMINATION

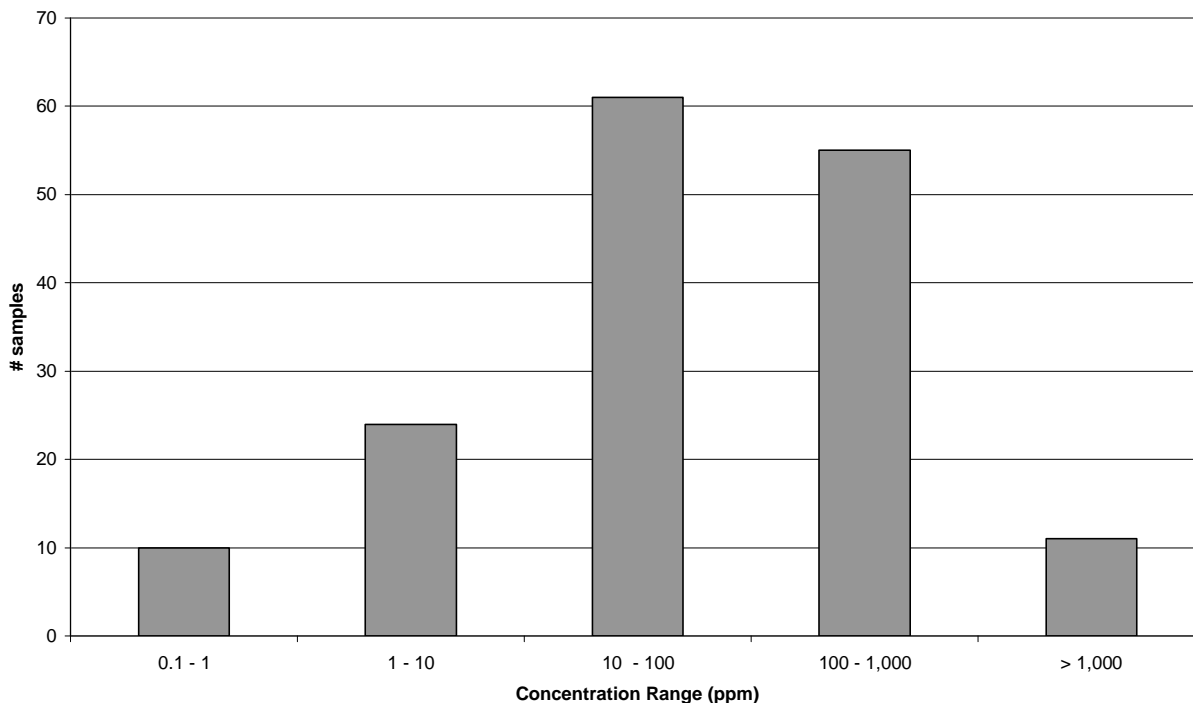
Sediment concentrations of PCBs, PAHs, lead and mercury vary greatly within reaches, with most reaches showing concentrations ranging over several orders of magnitude.² Due to

¹ Note that releases of oil to the environment are covered under the Oil Pollution Act (OPA) (33 U.S.C. 2701 *et seq.*), but mixtures of oil and hazardous substances such as are found in the GCR/IHC are covered by CERCLA (15 CFR §990.20(c)).

² The trustees note that in the GCR/IHC, areas with relatively 'low' concentrations compared with other areas of the GCR/IHC still contain elevated levels of contaminants in comparison with both uncontaminated areas

this variability, comparing the average sample concentration across reaches does not give an accurate picture of contaminant distribution. Instead, we construct histograms to describe the contaminant data. Due to the wide range in the data, we group the data into logarithmic ranges; each range is ten times as great as the previous one. As an example, Exhibit A-1 shows the histogram for the concentration of total PAHs in sediments in EBGCR I, which varies from less than 1 to over 10,000 ppm.

**Exhibit A-1
Total PAHs, EBGCR I Sediment**



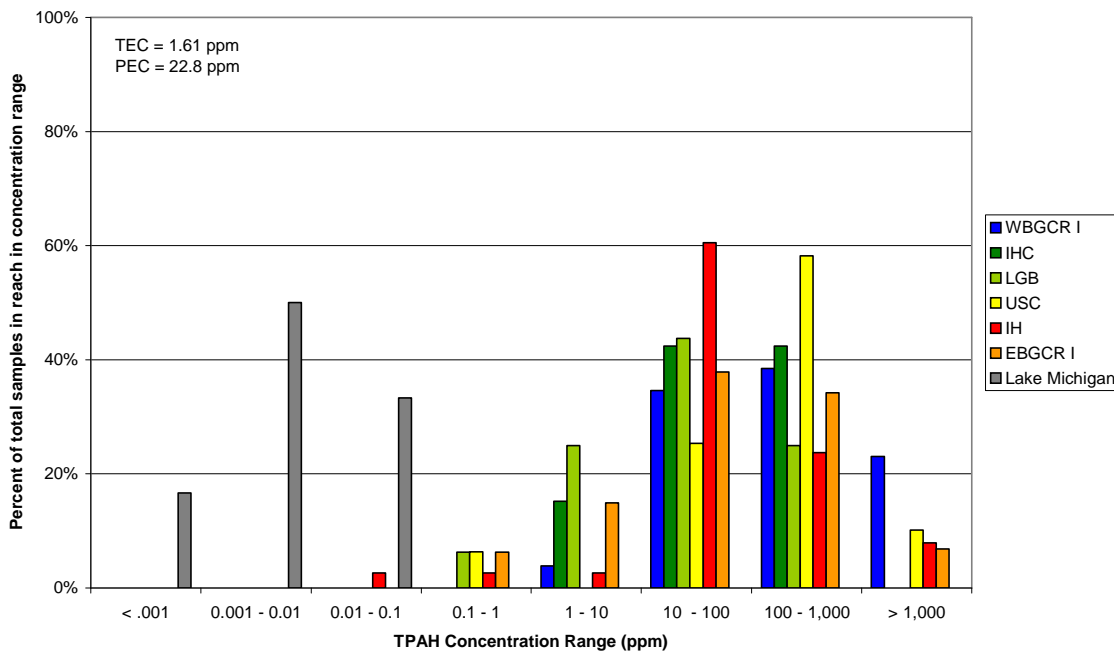
To compare the data across reaches, we account for differences in the number of samples collected by presenting the *percentage* of samples from the data set in each concentration range, rather than the *number* of samples as in the example above. Exhibit A-2 presents the histogram for total PAH concentrations in each of the six reaches in the project area plus Lake Michigan (LM). Although some areas of LM contain elevated levels of contaminants, particularly near the entrance to Indiana Harbor (IH), it provides a useful comparison between the GCR/IHC and an area not directly receiving discharges and releases of oil and hazardous substances. Also noted on Exhibit A-2 are the Threshold Effects Concentration (TEC) and Probable Effects Concentration (PEC) published by MacDonald *et al.* (2000a). The TEC is the concentration below which an adverse effect on sediment-dwelling organisms is unlikely to occur. Conversely, the PEC is the concentration above which it is more likely than not that an adverse effect is likely

and guidelines or benchmarks for protection of the environment. Please refer to Exhibits A-2 through A-5 and the discussion under "Injury and Lost Services."

to occur. For more information, please refer to MacDonald *et al.* (2000a) and the description of injury assessment using sediment chemistry below.

Exhibits A-3 through A-5 contain the same presentation of the sediment concentration data for PCBs, lead, and mercury.³ The relevant TECs and PECs are noted on these exhibits as well. Further interpretation of these data in terms of injury to natural resources will be described in the following section under the heading "Sediment Chemistry," but it is clear that concentrations of hazardous substances in the GCR/IHC are several orders of magnitude above levels sufficient to harm natural resources.

Exhibit A-2
Total PAHs Frequency Distribution by Reach



³ Note that there are no data for lead and mercury in southern Lake Michigan sediments.

Exhibit A-3
Total PCBs Frequency Distribution by Reach

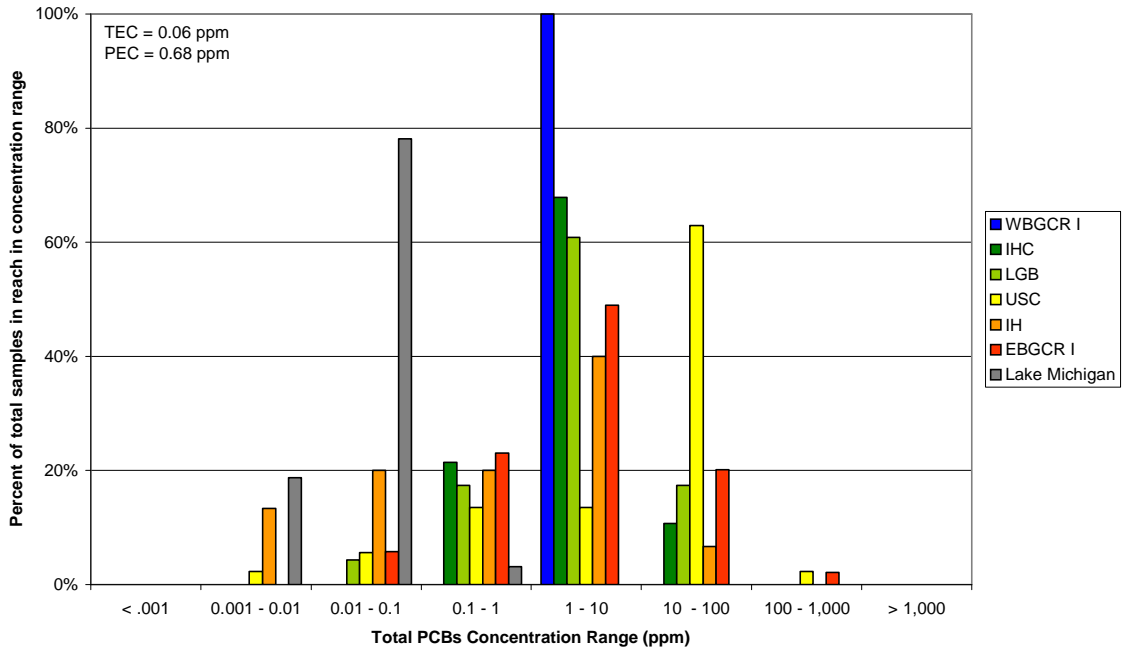
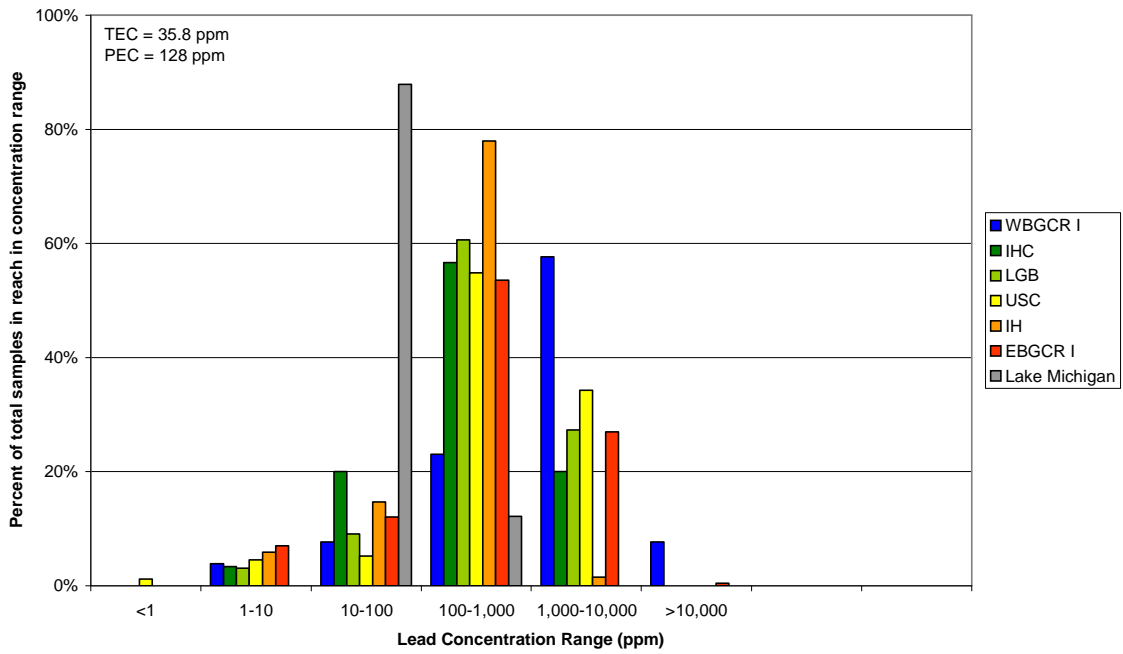
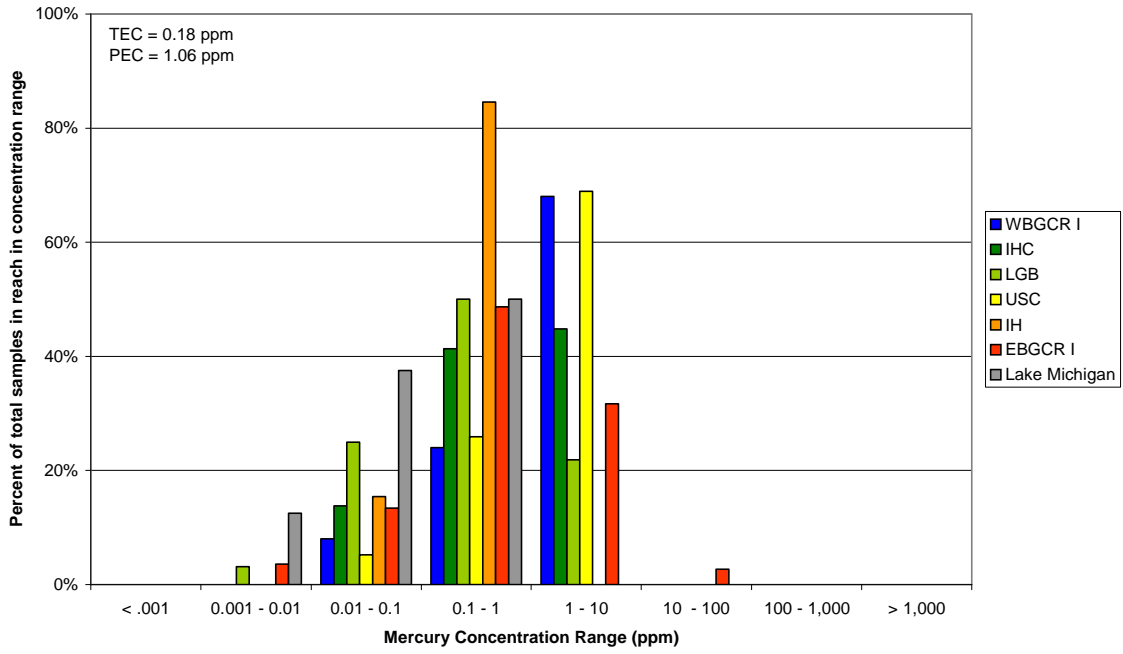


Exhibit A-4
Lead Frequency Distribution by Reach



**Exhibit A-5
Mercury Frequency Distribution by Reach**



INJURY AND LOST SERVICES

The trustees have undertaken several studies to define the nature and extent of injury to natural resources in the GCR/IHC system.⁴ Sediment injury determination and quantification is complete and is described in a sediment injury report authored by MESL (2000). The following sections summarize the results of the sediment injury report and some key results from on-going studies of birds and fish.

Sediments

For purposes of NRDA under CERCLA, sediments are considered to be part of surface water resources. Injury to sediments (and therefore surface water resources) can be demonstrated in several ways. One is to demonstrate the presence of concentrations of substances sufficient to cause injury to biological resources. Injury to biological resources can in turn be demonstrated by showing that the resource has undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, mutations, physiological malfunctions, or physical deformations (43 CFR §11.62). Therefore, demonstrating one or more of these effects on sediment-dwelling organisms demonstrates injury to sediments and surface water resources. MESL use four primary indicators to demonstrate or predict these effects:

- Whole sediment chemistry – Assessed by comparing the concentration of contaminants in whole sediment with previously-published benchmarks (described in more detail below.)
- Pore water chemistry – This metric compares the concentration of contaminants in the pore water of sediments with published toxicity thresholds.
- Sediment toxicity – This metric is assessed by conducting laboratory tests to determine the extent to which sediments are toxic (based on a variety of endpoints such as survival and reproduction) to benthic organisms under controlled exposure conditions, including use of control groups.
- Benthic invertebrate community structure – Uses the number of species present and the relative abundance of each to evaluate whether or not the benthic community is statistically different from that which would be expected in a particular ecosystem.

Due to the size of the project area, the trustees determine injury for each reach separately. In all six reaches of the project area, all four indicators show injury to sediment-dwelling organisms, as summarized in Exhibit A-6. The findings based on sediment chemistry and sediment toxicity are described in more detail below. Detailed results of the pore water chemistry and benthic invertebrate community structure assessments are found in MESL (2000).

⁴ Injury is defined as a measurable adverse change in the chemical or physical quality or the viability of a natural resource (43 CFR §11.14(v)).

Exhibit A-6
Summary of assessment of sediment injury to sediment-dwelling organisms

Reach	Indicator of Injury to Sediment-Dwelling Organisms ¹				Number of Lines of Evidence for Demonstrating Injury to Sediment-Dwelling Organisms
	Sediment Chemistry ²	Pore Water Chemistry ³	Sediment Toxicity ⁴	Benthic Community ⁵	
East Branch Grand Calumet River-I	83% (n=269)*	55% (n=20)*	73% (n=44)*	100% (n=14)*	4
West Branch Grand Calumet River-I	90% (n=31)*	100% (n=2)*	100% (n=2)*	100% (n=3)*	4
Indiana Harbor Canal	89% (n=36)*	60% (n=5)*	80% (n=5)*	100% (n=6)*	4
Lake George Branch	82% (n=33)*	83% (n=6)*	57% (n=7)*	100% (n=4)*	4
US Canal	89% (n=215)*	67% (n=3)*	80% (n=90)*	96% (n=25)*	4
Indiana Harbor	86% (n=78)*	100% (n=3)*	81% (n=32)*	81% (n=16)*	4
Overall	86% (n=662)*	67% (n=39)*	78% (n=180)*	94% (n=68)*	4
Lake Michigan ⁶	3% (n=33)	ID (n=0)	33% (n=6)*	43% (n=56)*	2

¹ For each line of evidence, sediment injury is indicated if two or more samples have conditions sufficient to cause or substantially contribute to sediment injury.

Evidence of sediment injury is denoted with an asterisk (*).

² Percent of sediment samples with mean PEC-Qs of ≥ 0.7 .

³ Percent of pore water samples with chemical concentration > published toxicity thresholds.

⁴ Percent of sediment samples that are toxic to aquatic organisms in laboratory tests.

⁵ Percent of samples with altered benthic invertebrate community structure.

⁶ Provided for comparison purposes only. Lake Michigan is not part of the restoration project area.

ID = insufficient data; n = number of samples.

Sediment Chemistry

Sediment chemistry data were assessed using a sediment quality guideline approach (Swartz 1999, MacDonald *et al.* 2000a, 2000b). This method allows the user to combine chemistry data for a number of contaminants in a sediment sample into a single quantitative measure indicating the probability that the sediment would cause adverse effects to biological resources. The process begins with development of consensus-based probable effect concentrations (PECs) for each contaminant. This is the concentration of the contaminant above which an adverse effect is likely to occur, based on an analysis of many individual studies reported in the literature.⁵

To assess the potential for a given sample to cause injury, the concentration of each contaminant in the sample is divided by the corresponding contaminant-specific PEC. These ratios are termed PEC-quotients, or PEC-Qs. Within each class of contaminant (e.g., PCBs, PAHs, or metals), the PEC-Qs of the individual contaminants are averaged to get an average PEC-Q for that class. For example, the PEC-Qs for arsenic, cadmium, chromium, and other metals in a sample are averaged to derive an average PEC-Q for metals for that sample. The overall mean PEC-Q for the sample is the average of the three average PEC-Qs (i.e., PCBs, PAHs, and metals). Injury is defined as a mean PEC-Q greater than 0.7.

In the six reaches of the project area, approximately 80 percent of samples exceed this criterion (please refer to Exhibit A-6, first column). Over the entire assessment area for which data exists, this figure is 70 percent. Based on sediment chemistry, sediments throughout the GCR/IHC are injured.

Sediment Toxicity

The results of toxicity tests conducted using whole sediments, pore waters, and/or elutriates (i.e., agitated mixtures of sediment and water) represent important indicators for assessing sediment injury and for determining the areal extent of sediment injury. The results of sediment toxicity tests provide quantitative information for discriminating between toxic and non-toxic sediments. They are an empirical demonstration of the effects of the sediment on actual organisms.

⁵ The term *sediment quality guidelines* (SQGs) is used to describe previously published benchmarks for assessing the biological significance of contaminant concentrations in whole sediments (e.g., threshold and probable effect levels - Smith *et al.* 1996; no effect concentrations - Ingersoll *et al.* 1996). By comparison, the term *consensus-based sediment effect concentrations* (SECs) is used to describe the benchmarks that provide an estimate of the central tendency of the published SQGs (Ingersoll and MacDonald 1999; MacDonald *et al.* 2000a; USEPA 2000). The consensus-based SECs are intended to define the concentrations of sediment-associated contaminants that would be sufficient to cause or substantially contribute to injury to sediment-dwelling organisms, including infaunal (i.e., those species that live in the sediments) and epibenthic (i.e., those species that live on the sediments) organisms. In this report, the term probable effects concentration (PEC) refers to an SEC above which an adverse effect is more likely than not (i.e., 51 percent) to occur. Please refer to MESL (2000) for a more detailed description of this methodology.

The results of sediment toxicity testing in the project area are summarized in MESL (2000). The percentage of samples found to be toxic to sediment-dwelling organisms ranged from 57 percent in LGB to 100 percent in WBGCR I (please refer to Exhibit A-6, third column). Based on sediment toxicity, sediments in all reaches of the project area are injured.

Biological Resources

While it is difficult to measure the overall health of any ecosystem, biologists have developed metrics to assess the health of individual components of an ecosystem. If the health of these components is compromised, the ecosystem itself is likely to be impaired, and there may be a loss of ecosystem services. For example, a reduced food base due to altered benthic community structure would likely reduce fish abundance, which could in turn affect piscivorous wildlife. Therefore, one might infer potential effects on wildlife by assessing the degree and type of alteration to benthic community structure. To date, the trustees have assessed ecosystem impairment in the GCR/IHC by evaluating five indicators or metrics of effects on fish and wildlife resources that are associated with sediment contamination. These are described briefly below.

- Toxicity to fish - This metric is assessed by conducting laboratory tests to determine the extent to which sediments are toxic (based on a variety of endpoints) to fish under controlled exposure conditions, including use of control groups.
- Fish health - This metric measures the incidence of deformities, fin erosion, lesions, and tumors (known collectively as DELT abnormalities) in fish collected from the area of interest.
- Fish community structure - An Index of Biotic Integrity (IBI) is used to assess impairment of fish community structure. The index is based on the number of species present and the relative abundance of these species, compared to an unimpaired reference community.
- Whole sediment chemistry - Measured concentrations of bioaccumulative substances in the sediment are compared to bioaccumulation-based sediment quality guidelines (SQGs) for the protection of wildlife.
- Tissue chemistry - Similar to the above metric, concentrations of contaminants in fish and invertebrates are compared to tissue residue guidelines (TRGs).

In the sections below, we discuss the available data for fish and birds in more detail. While the data presented below is focused on evaluating injury to sediments, the trustees note that reports demonstrating injury to invertebrate and fish communities and to birds are forthcoming.

Metrics to Assess Effects of Sediment on Fish

Contaminated sediments do more than affect organisms that live in the sediment. Fish are exposed to contaminants through direct contact with sediment, contact with water overlying the sediments and carrying contaminants, or ingestion of other contaminated organisms. Toxic effects can be acute or chronic, and result in both mortality and morbidity such as DELT abnormalities, as described above. Due to the lipophilic nature of many of the contaminants of concern in the GCR/IHC system, species that feed on sediment-dwelling organisms will accumulate the contaminants in their own tissues, a process known as bioaccumulation. In this way, predator fish can accumulate significant body-burdens of contaminants without any "direct" exposure to the sediment.

The trustees have assessed the effect of contaminated sediments on the fish of the GCR/IHC using the first three metrics described above (i.e., toxicity to fish, fish health, and fish community structure). These metrics indicate that contaminated sediments contribute to adverse acute or chronic effects to fish in four of the six reaches of the project area (please refer to Exhibit A-7). The trustees are preparing a separate report evaluating injury to fish in the assessment area which will consider these and other metrics such as toxicity to spawned eggs and larvae

The trustees also note that in addition to providing services to other resources (e.g., as prey for wildlife) fish provide human-use services, including the opportunity for recreational fishing. In the case of the GCR/IHC, fish consumption advisories have greatly diminished the recreational fishery since 1986⁶ (MESL 2003). These advisories are a *de facto* injury under the Department regulations (43 CFR § 11.62(f)). In the absence of contamination by oil and hazardous substances, the trustees believe that fishing pressure in the GCR would equal that observed at comparable warmwater fisheries in Indiana. This conclusion is supported by inferred existing fishing pressure at the nearby Little Calumet River and Salt Creek and the presence of a large, local population with easy access to the river. The trustees recently completed a report evaluating injury to fishery resources in the assessment (MESL 2003).

Metrics to Assess Effects of Sediment on Non-Aquatic Wildlife

Contaminants in the sediment of the GCR/IHC are available to non-aquatic wildlife (e.g., waterfowl) through both direct exposure and dietary uptake. Direct exposure is typically a problem associated with petroleum-based compounds, although difficult to assess quantitatively. Dietary transfer of contaminants occurs in much the same way as described above for fish. The trustees have assessed the effects of contaminated sediments on non-aquatic wildlife using two metrics, tissue chemistry and whole sediment chemistry.

Tissue residue guidelines (TRGs) reported in the literature specify limits of contaminants in fish that will protect predator species from acquiring a harmful amount of contaminants through bioaccumulation. These TRGs define the concentrations of contaminants in fish tissue

⁶ The advisory states that no fish from the GCR/IHC should be consumed, but it is possible that anglers either ignore the advisory or practice catch-and-release fishing for recreation.

which, if not exceeded, are likely to prevent carcinogenic or non-carcinogenic impacts on piscivorous wildlife, including birds and mammals. Similar limits have been developed for sediments (i.e., sediment quality guidelines, SQGs) (MESL 2000).

To assess the potential for adverse effects to non-aquatic wildlife in the GCR/IHC system, sediment chemistry data and fish tissue chemistry data were compared with established SQGs and TRGs, respectively. In five of the six project reaches, both sets of these guidelines are exceeded (see Exhibit A-7). In the LGB, prey species tissue data are insufficient to compare with TRGs, but available whole sediment chemistry data exceed the SQGs in 83 percent of the samples (MESL 2000). This indicates that contaminated sediments in the GCR/IHC have an adverse effect on non-aquatic wildlife.

The trustees are preparing a separate report evaluating injury to non-aquatic wildlife in the assessment area which will consider these and other metrics such as effects on reproductive success.

Exhibit A-7
Metrics indicating adverse effect to fish and wildlife

Indicator of Effects on Fish and Wildlife Resources¹

Reach	Indicator of Effects on Fish and Wildlife Resources ¹					Number of Lines of Evidence for Demonstrating Ecosystem Impacts
	Toxicity to Fish ²	Fish Health ³	Fish Community ⁴	Whole Sediment Chemistry ⁵	Tissue Chemistry ⁶	
East Branch Grand Calumet River-I	57% (n=23)*	40% (n=10)*	100% (n=29)*	74% (n=110)*	100% (n=22)*	5
West Branch Grand Calumet River-I	ID (n=0)	100% (n=3)*	100% (n=12)*	29% (n=7)*	100% (n=7)*	4
Indiana Harbor Canal	ID (n=0)	33% (n=3)	100% (n=4)*	93% (n=15)*	100% (n=7)*	3
Lake George Branch	ID (n=0)	50% (n=2)	50% (n=2)	83% (n=29)*	ID (n=0)	1
US Canal	ID (n=0)	50% (n=2)	100% (n=8)*	84% (n=37)*	100% (n=18)*	3
Indiana Harbor	ID (n=0)	ID (n=1)	ID (n=1)	67% (n=6)*	94% (n=17)*	2
Overall	57% (n=23)*	48% (n=21)*	96% (n=56)*	77% (n=198)*	100% (n=54)*	
Lake Michigan ⁷	ID (n=0)	ID (n=0)	ID (n=0)	93% (n=27)*	50% (n=4)*	2

1 For each line of evidence, adverse effect is indicated if two or more samples demonstrate conditions sufficient to indicate adverse effects. Evidence of adverse effect is denoted with an asterisk (*).

2 Percent of sediment samples that were toxic to fish in laboratory tests.

3 Percent of fish samples with > 1.3% DELT abnormalities.

4 Percent of fish samples with IBI scores of ≤34 (i.e., poor, very poor, or no fish).

5 Percent of sediment samples with one or more chemical concentrations in excess of the bioaccumulation SQGs for wildlife.

6 Percent of fish and invertebrate tissue samples with one or more chemical concentrations in excess of the TRGs for wildlife.

7 Provided for comparison purposes only. Lake Michigan is not part of the restoration project area.

ID = insufficient data; n = number of samples.

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APPENDIX B

PRELIMINARY SCREENING OF RESTORATION ALTERNATIVES

ON-SITE RESTORATION ALTERNATIVES

This appendix describes the trustees' process to identify and evaluation options for on-site restoration of the GCR/IHC

To develop restoration alternatives, the trustees first evaluate a range of sediment management technologies. Restoration alternatives are then developed from those technologies judged to be appropriate for this site, as described below. The information this Appendix is a summary of the work presented in the Final Restoration Alternatives Development and Evaluation Report prepared by Foster Wheeler Environmental Corporation, dated December 2000 (Foster Wheeler 2000).

Sediment Management Technologies

The trustees follow a multi-step process to identify a range of sediment remediation alternatives and to evaluate these alternatives against relevant criteria. The first step is the identification of available technologies for management of contaminated sediments. They are:

- Dredging technologies (of various kinds);
- Sediment disposal (in conjunction with dredging);
- Sediment treatment (various kinds, including mechanical, chemical, and thermal treatments); and
- In-place capping (both "thick" and "thin").

These options are "pre-screened" using the criteria of effectiveness, implementability, and order-of-magnitude costs. At this stage, the screen consists simply of "retain" or "eliminate."

Dredging Technologies

Dredging is a remediation technique used to remove material with contaminant concentrations in excess of remediation goals. When dredging, several site-specific characteristics must be considered, including the depth of the water column, volume of material to be removed, width and depth of the dredge cut, firmness of the sediment, and the presence of debris. There are three types of dredging technologies: hydraulic dredging, mechanical dredging, and hybrid or specialty dredging. The key differences lie in the mechanism for removing and transporting the dredged material. In hydraulic dredging, material is removed via suction created by a pump. The resulting slurry can be conveyed via pipeline some distance. In addition, some hydraulic dredging equipment is small enough to be used in confined waterways such as the GCR/IHC. Mechanical dredging involves using a bucket or shovel to excavate material and raise it to the surface for disposal. Hybrid dredging technologies incorporate some features of the two (e.g., a dredge with a mechanical "cutter head" that removes sediment to a controlled depth, and then pumps it to the surface as would a hydraulic dredge). Hydraulic dredging is retained by the

trustees for further consideration because of its operational flexibility, which is necessary under the difficult site constraints of the GCR/IHC. Hybrid dredging technologies are also retained. Mechanical dredging does not have this flexibility and thus is eliminated.

Sediment Disposal Options

If dredging is deemed the best alternative for remediation of the contaminated sediment, a site(s) must be chosen for disposal of the dredged material. Consideration must be given to the available geographic alternatives as well as the characteristics of the contaminated sediment when choosing a disposal site. Three options for confined disposal are considered in the following subsections: upland or off-site confined disposal, nearshore confined disposal, and confined aquatic disposal (CAD).

For upland or off-site confined disposal facilities (CDFs), contaminated sediment is transported to an adjoining upland site or a permitted off-site disposal area. The goal of off-site disposal is to eliminate contact between contaminated sediment and the water body. Confinement may be accomplished through construction of dikes or low structural walls, with either a clay or geofabric liner to prevent contaminant migration. Water released from the sediment as it consolidates (supernatant) must usually be treated before discharge. Nearshore CDFs are similar to upland CDFs in most respects, differing mainly in that they are constructed near the dredging location, extending into the water. CAD differs in that disposal occurs below the water line, either directly on the bottom, or in a shallow pit. The material is then capped using a method such as described for capping, above. CDFs, while expensive, are considered viable alternatives, and are retained by the trustees. CADs may result in adverse impacts to aquatic ecosystems, including the risk of future releases of hazardous substances, and are therefore eliminated.

Sediment Treatment

A variety of methods can be used to treat contaminated sediments. The method chosen depends on the characteristics of the sediment, the contaminants that are present, and the concentrations of the contaminants. Potential sediment treatment technologies and process options are the same as those used for upland solid waste such as soil or sludge. The main difference between river sediment and upland soil is that river sediments have a much higher initial water content than upland soil. Before treating the sediment for specific contaminants, dredged material often must be modified by mechanical treatments such as screening, dewatering, and consolidation.

Many treatment technologies were investigated in connection with the disposal of potential dredged materials from Indiana Harbor as part of the Final Feasibility Report and Environmental Impact Statement conducted for the IHC (USACE 1995). Four were selected as having greatest potential for application to the IHC sediments: solidification/stabilization, solvent extraction, incineration, and wet air oxidation. The effectiveness of these technologies, however, is low because none would treat both organic and inorganic contaminants as are found in the GCR/IHC. Only the mechanical technologies (e.g., dewatering) are retained to facilitate disposal.

In-place Capping

In-place capping is generally the most straightforward and least intrusive sediment remediation technique (other than natural recovery). The technique involves placing clean sediments, generally consisting of silty to gravelly sand, over the areas of contaminated sediment. This prevents resuspension of contaminated sediment and reduces the risk of human or biotic contact with contaminated material. The issues generally associated with in-place capping include obtaining appropriate cap thickness over the entire area of contaminated sediment, placing the capping material without displacing the contaminated sediment, and maintaining long-term cap integrity.

There are two approaches to capping: thick and thin. Thick capping isolates areas of contaminated sediment and establishes conditions for the creation of a new benthic habitat. Cap thickness is on the order of three feet to prevent bioturbation into the underlying contaminated sediments. Thin capping (cap thickness approximately one foot) may be used as a way of enhancing natural recovery processes. This allows for mixing of the clean and contaminated sediment, but at a rate such that release of contaminants to the system is slowed. Thick capping is retained by the trustees as an option for the GCR/IHC, but thin capping is unlikely to be effective given the high contamination levels at this site, and is therefore eliminated.

Restoration Alternatives

The trustees next develop several restoration options which incorporate one or more of the technologies retained in the pre-screening step. Multiple technologies may be used in combination to effect a "complete" alternative. The restoration options are:

- Dredging with on-site CDF disposal - Sediment would be removed such that remaining contaminant concentrations resulted in mean PEC-Q values of <0.7. Disposal would be in the Corps CDR.
- Dredging with off-site landfill disposal - Sediment removed as above, with disposal at a commercial landfill.
- Thick Capping - Three feet of clean sediment would be placed over the contaminated sediments to isolate them from the environment.
- Shallow dredging with on-site disposal, followed by thick capping - The top three feet of sediment would be removed, after which a three-foot cap of clean sediment would be placed. Disposal would be in the Corps CDF.
- Shallow dredging with off-site disposal, followed by thick capping - The top three feet of sediment would be removed, after which a three-foot cap of clean sediment would be placed. Disposal would be at a commercial landfill.

The trustees' evaluation of these options is presented in the next section.

EVALUATION OF RESTORATION ALTERNATIVES

The Department regulations describe ten criteria for use in evaluating restoration alternatives (43 CFR § 11.82(d)). To ensure that the evaluation of alternative restoration projects will remain focused on the key considerations for projects that seek to actively address contaminated sediments, the trustees developed criteria specific to this assessment that are intended to include and go beyond those listed in the Department regulations. The Initial RCDP presents two sets of criteria specific to alternatives for management of contaminated sediments, designated as "threshold" and "ranking" criteria (IDEM 1998). Threshold criteria represent the requirements the trustees must satisfy, due to statutory mandates, or choose to satisfy, due to state and federal policies, procedures, or other factors. Ranking criteria represent metrics by which the trustees can compare restoration alternatives than meet the threshold criteria.

Threshold Criteria

The first step in evaluating the restoration alternatives is to assess each against the three threshold criteria. If an alternative fails to meet one or more of the criteria, it is eliminated from further consideration. The threshold criteria for the sediment management restoration alternatives are:

- Does the project clearly address injuries to natural resources or losses of natural resource services?
- Does the project comply with applicable federal and state laws and regulations?
- Is there general public support for the implementation of the project?

The trustees' evaluation of the sediment management restoration alternatives is presented in Exhibit B-1. Thick capping, while potentially able to reduce the effects of contaminated sediment on the environment, would result in unacceptable changes to the hydrology of the GCR/IHC due to changes in bottom profile and elevation of the water surface. It is therefore eliminated from further consideration. Only those alternatives which incorporate removal of contaminated sediment by dredging meet all of the threshold criteria. These four alternatives are retained for further evaluation using the ranking criteria.

Exhibit B-1
Evaluation of sediment management restoration alternatives using threshold criteria

Alternative	Addresses injuries?	Complies with laws?	Public support?	Retain for further evaluation?
Dredging with on-site disposal	Y	Y	Y	Y
Dredging with off-site disposal	Y	Y	Y	Y
Thick capping	N	Y	N	N
Dredging, on-site disposal, & thick capping	Y	Y	Y	Y
Dredging, off-site disposal, & thick capping	Y	Y	Y	Y

Ranking Criteria

The four alternatives that meet the threshold criteria are similar in that they all begin with dredging of contaminated sediments from the GCR/IHC. Therefore, further evaluation is focused on the two components that vary among the alternatives: first, the location of sediment disposal (locally in a CDF or off-site in a commercial landfill); and second, the depth of dredging (and therefore whether or not a thick cap is subsequently placed). Exhibit B-2 presents the trustees' evaluation of these two components using the ranking criteria developed in the Initial RCDP. The criteria are:

- Is the project technically feasible?
- Will the project cause "collateral injuries" or other undesirable short-term impacts?
- Can the project provide the desired habitat improvements within a reasonable timeframe?
- Are the resource-based "benefits" of the project reasonable relative to the project's cost?
- Is the project consistent or compatible with ongoing or planned response activities?
- Will the project simultaneously achieve one or more of the objectives defined under a comparable "restoration" effort (e.g., development and implementation of the Remedial Action Plan for the International Joint Commission's Grand Calumet Area of Concern)?

Exhibit B-2

Evaluation of sediment management restoration alternatives using Ranking Criteria

Criterion	On-site CDF vs. Off-site Landfill	Shallow dredging with cap vs. "Maximum" dredging
Technically feasible?	Equal	Capping adds a potentially difficult technical component to the shallow dredging option.
Collateral injuries?	Additional local impacts if new CDF is sited.	Capping could result in additional short-term impacts to the water column and stream-side areas used for staging, stockpiling, and access. On the other hand, some contamination will remain.
Reasonable timeframe?	Siting and construction of new CDF could delay implementation.	Provision of a clean substrate after shallow dredging may restore baseline conditions in the GCR/IHC sooner and provide additional protection for the ecosystem.
Benefit-cost reasonableness?	Off-site disposal is significantly more expensive with few additional benefits compared to utilizing Corps CDF.	If disposal will be off-site, maximum dredging is substantially more expensive but unlikely to provide substantially larger ecological benefit. If disposal is in Corps CDF, maximum dredging is less expensive.
Consistent with other response activities?	N/A ¹	N/A ¹
Achieve other objectives?	Equal	Because it is likely to bring additional environmental benefits, capping may also achieve other objectives for the restoration of the GCR/IHC environment.

¹ No other response activities are contemplated at this time.

The trustees note the possibility of selecting different dredging depths for different reaches of the GCR/IHC. For example, in areas where contaminated sediments is relatively deep, shallow dredging followed by placement of a cap may result in cost savings compared to removal of all contaminated sediment. Nevertheless, evaluation and selection of the alternatives for implementation on a reach-by-reach basis is not feasible at this time. A more detailed consideration of the river characteristics and restoration specifics at the reach level is left for the Restoration Planning phase, when preliminary engineering design occurs.

COST ASSESSMENT

To fully evaluate the range of restoration alternatives, the trustees must consider the costs of implementing each alternative. This section presents the trustees' cost-estimating methodology and preliminary cost estimates for the four retained alternatives.

Cost Estimating Methodology

First, the trustees conducted a survey of the river to develop accurate measurements of the channel cross section at a large number of sites. Using these cross-sections, the trustees estimated the amount of sediment needing removal under various management alternatives. Volume estimates were made for two dredging scenarios in the "trustee project area" (i.e., WBGCR I, IHC, LGB, EBGCR I) and one dredging scenario in the "federal project area" (i.e., USC, IH).

To estimate costs, dredging and capping alternatives are broken into component actions (e.g., dredging, de-watering, and shipment to disposal site) and cost estimates developed using a unit-cost approach. The cost of each component action of an alternative is estimated based on the predicted amount of work required and the unit cost. For example, dredging sediment and pumping it to a de-watering area is estimated to cost \$5 per cubic yard. Therefore, the estimated cost of dredging one million cubic yards is \$5 million. The unit costs developed for the various operations are collected from a variety of sources and based on professional experience (Foster Wheeler 2000).

Cost Estimates for Alternatives Carried Forward

Cost estimates for the four restoration alternatives are presented in Exhibit B-3. These estimates are developed using the data provided in the Final Restoration Alternatives Development and Evaluation Report (Foster Wheeler 2000). The cost estimates for the on-site disposal option assume that disposal of contaminated sediments will be in the Corps' CDF at the ECI site. Separate estimates are developed for the trustee project area and the federal project area. Estimates for the trustee project area are further refined by considering two dredging scenarios. The first would entail dredging to a uniform depth of three feet, followed by capping with clean sediment. The second would involve dredging to a variable depth depending on the results of sediment chemistry. That is, dredging would occur until all sediment with a mean PEC-Q > 0.7 is removed. This would represent the maximum dredging effort for the GCR/IHC. The cost estimates for the federal project area assume that additional dredging beyond that required for navigation will be necessary to remove residual contamination. In the event that additional dredging is not necessary, the cost estimates for the federal project area will be limited to the costs of capping, if any. All cost estimates include 20 percent markup to cover design, management, and contingency.

Exhibit B-3
Estimated Restoration Costs

Restoration Alternative	Trustee Project Area	Federal Project Area
Maximum dredging and on-site disposal	\$53,000,000	N/A
Maximum dredging and off-site disposal	\$252,000,000	N/A
Shallow dredging, on-site disposal, and capping	\$69,000,000	\$15,000,000
Shallow dredging, off-site disposal, and capping	\$173,000,000	\$53,000,000

REFERENCES

Foster Wheeler. 2000. Final Restoration Alternatives Development and Evaluation Report, Grand Calumet River/Indiana Harbor Canal, Indiana. December.

IDEM. 1998. Initial Restoration and Compensation Determination Plan for the Grand Calumet River, Indiana Harbor Ship Canal, Indiana Harbor, and Associated Lake Michigan Environments: Part I, Restoration Criteria. Prepared by IDEM, IDNR, FWS, NPS, and NOAA. 8 October.

USACE. 1998. Indiana Harbor and Canal Maintenance Dredging and Disposal Activities Comprehensive Management Plan: Final Feasibility Report and Environmental Impact Statement. Vol. 1.

USACE. 1995. Indiana Harbor and Canal Maintenance Dredging and Disposal Activities Comprehensive Management Plan: Feasibility Report and Draft Environmental Impact Statement. Vol. 1.