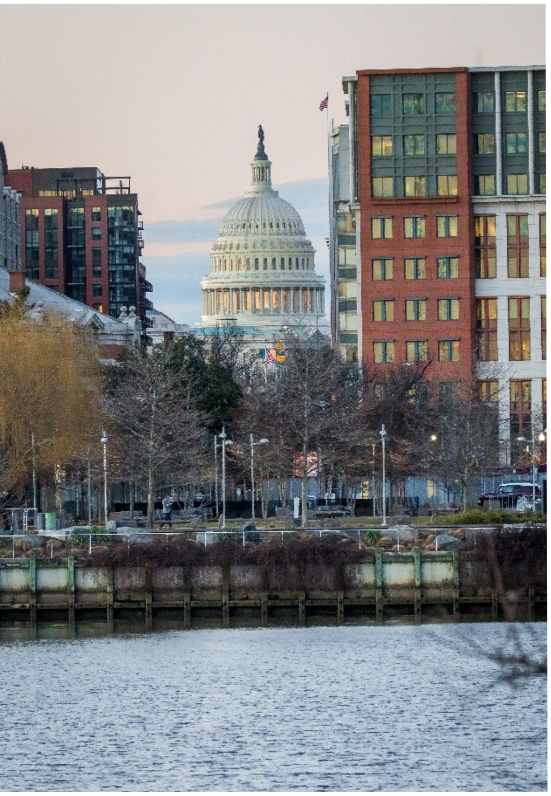
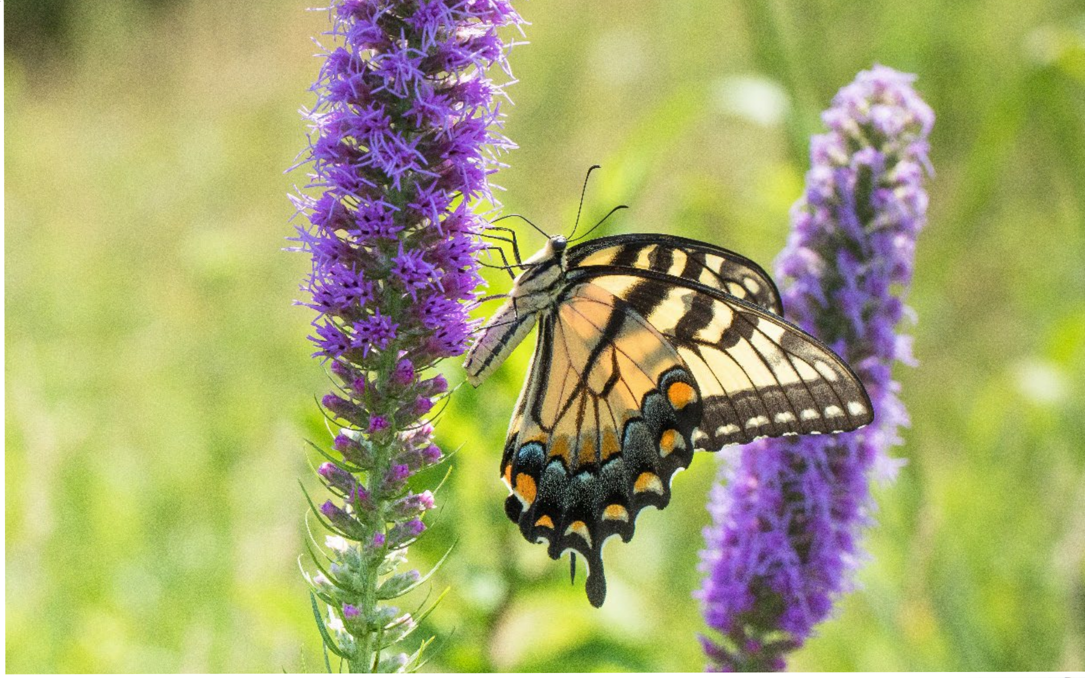
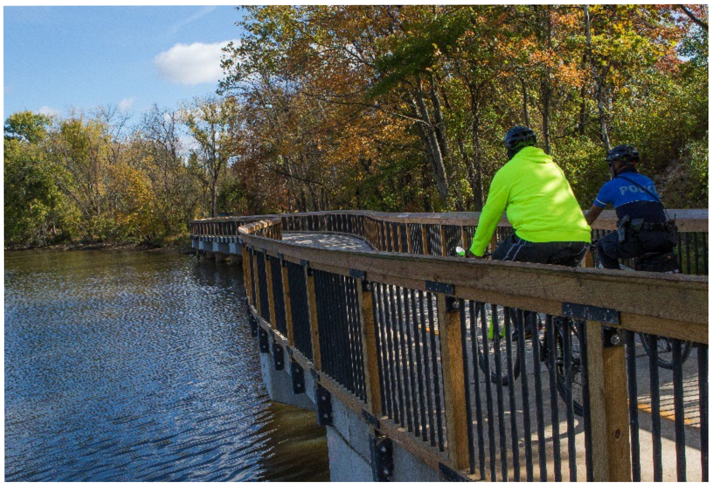






Photo credit © KristaSchlyer.com.

Anacostia River
Natural Resource Damage Assessment Plan

DRAFT | July 2023

prepared for:

Department of Energy and Environment
National Oceanic and Atmospheric Administration
National Park Service
United States Fish and Wildlife Service

prepared by:

Industrial Economics, Incorporated

ABOUT THE COVER:
These images of the Anacostia River watershed were created by Krista Schlyer for free use by those individuals and organizations actively working on ecological restoration of the Anacostia River watershed. The database was created through the Anacostia Project, with support from the Washington D. C. Department of Energy and Environment, and in collaboration with the Anacostia Waterfront Trust. More information on the photographic database is available at https://anacostiaphotos.photoshelter.com/.

TABLE OF CONTENTS

LIST OF EXHIBITS

LIST OF ACRONYMS

ARCRP	Anacostia River Corridor Restoration Plan
ARSP	Anacostia River Sediment Project
BEP	Bureau of Engraving and Printing
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Contaminant of Concern
CSOs	Combined Sewer Overflows
CVOC	Chlorinated Volatile Organic Compound
CWA	Clean Water Act
DAP	Damage Assessment Plan
DCMR	District of Columbia Municipal Regulations
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
District	District of Columbia
DOEE	Department of Energy and Environment
DOI	U.S. Department of the Interior
DRO	Diesel Range Organics
EJ	Environmental Justice
EPA	U.S. Environmental Protection Agency
FWS	Fish and Wildlife Service
GRO	Gasoline Range Organics
HaBREM	Habitat-Based Resource Equivalency Method
HEA	Habitat Equivalency Analysis
JBAB	Joint Base Anacostia-Bolling
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPS	National Park Service
NRDAR	Natural Resource Damage Assessment and Restoration
PAHs	Polycyclic Aromatic Hydrocarbons
PAS	Preassessment Screen

PCBs	Polychlorinated Biphenyls
PEC	Probable Effect Concentration
PECS	Potential Environmental Cleanup Site
Pepco	Potomac Electric Power Company
PI	Principal Investigator
PRP	Potentially Responsible Party
QA	Quality Assurance
QAP	Quality Assurance Plan
QAPP	Quality Assurance Project Plan
QC	Quality Control
RCDP	Restoration and Compensation Determination Plan
REA	Resource Equivalency Analysis
TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
TEC	Threshold Effect Concentration
TEF	Toxic Equivalency Factor
TEQ	Toxic Equivalent
TPH	Total Petroleum Hydrocarbons
VOC	Volatile Organic Compound
WGL	Washington Gas Light
WHO	World Health Organization

EXECUTIVE SUMMARY

This Draft Damage Assessment Plan (DAP) was created pursuant to the Federal regulations 43 C.F.R. Part 11 for conducting a natural resource damage assessment and restoration (NRDAR) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). It sets forth the manner in which the natural resource Trustees, including representatives from the District of Columbia, the U.S. Department of the Interior, and the U.S. Department of Commerce, will assess injuries to natural resources and resource services in the Anacostia River (River) stemming from releases of hazardous substances. The overall goal of the NRDAR is to identify and quantify such injuries, and to replace, restore, or acquire the equivalent of those injured natural resources and services as compensation on behalf of the public. Such compensation takes the form of environmental restoration projects, or monetary payments, which will be used by the Trustees to conduct environmental restoration.

- Chapter 1 provides introductory information about the NRDAR legislative basis and process, the Trustees and the laws that give them the authority to conduct NRDAR, coordination with parties potentially responsible for the hazardous substance releases, the public review process for this document, and the overall restoration-focused approach the Trustees plan to take in the NRDAR.
- Chapter 2 provides information on the geographic area of the Anacostia River that is the focus of the NRDAR, industrial activities that have resulted in releases of hazardous substances, and the specific suite of hazardous substances that are the focus of the NRDAR.
- Chapter 3 describes the natural resources that are the focus of the NRDAR, including surface water (and sediment), geological (soil), groundwater, and biological resources. It also describes some of the important services that ecosystems and humans derive from these natural resources. For example, the services habitats provide for resident biota such as the provision of food and shelter; as well as the ability for people to recreate in and enjoy the environment, participating in activities such as recreational fishing.
- Chapter 4 details the specific approaches and methods the Trustees anticipate using to assess injuries to natural resources within the Anacostia River assessment area and determine what kind and how much restoration is needed to make the public whole.
- Chapter 5 describes the approaches the Trustees anticipate using to estimate damages—the amount of money potentially responsible parties will be required to contribute to the cost of planning and implementing ecological restoration projects to make the public whole for the injuries caused by their releases of hazardous substances. It also outlines Trustee priorities and considerations for specific restoration project types that may be used as compensation.
- Appendices for this document provide supplementary information. A quality assurance plan (QAP) to guide the Trustees in the NRDAR and to ensure that decisions made in the NRDAR process are based on information of which the quality is well understood and which is scientifically valid for its intended use.

The Trustees are seeking public comment on this DAP. After this document has gone through public review and comment it will be revised, as needed, and finalized, and will serve to guide the Trustees as they implement the NRDAR. Public comments received will also be appended to the final DAP.

CHAPTER 1 | INTRODUCTION

1.1 PURPOSE AND OVERVIEW OF THE ASSESSMENT PLAN

U.S. Federal and District of Columbia representatives, serving as trustees of public natural resources, are conducting a natural resource damage assessment and restoration (NRDAR) process to identify and quantify natural resource injuries and service losses stemming from historical and ongoing releases of hazardous substances in the Anacostia River. The designated trustee organizations include:

- the Department of the Interior (DOI) acting through the U.S. Fish and Wildlife Service (FWS) and National Park Service (NPS), which serves as the Federal Lead Administrative Trustee to coordinate assessment and other activities for Federal agencies and provide technical support to the Lead Administrative Trustee;
- the Department of Commerce acting through the National Oceanic and Atmospheric Administration (NOAA); and
- the Government of the District of Columbia (District) acting through the Department of Energy and Environment (DOEE), which serves as the Lead Administrative Trustee.

Together, the representatives from these entities constitute the Anacostia River Trustee Council and are referred to as "the Trustees" herein. The decision to conduct a NRDAR was detailed previously in the 2021 Pre-Assessment Screen Determination (District of Columbia et al. 2021). In response to that decision, the Trustees began the formal NRDAR planning process. This Draft Damage Assessment Plan (DAP) sets forth the manner in which the Trustees will conduct the NRDAR. Specifically, it documents the methods and approaches the Trustees anticipate taking to complete the NRDAR and provides the public the opportunity to review and provide comment on that approach.

Natural Resource Trustees are Federal, state, or Tribal government representatives authorized to act on behalf of the public to: (1) assess injuries to natural resources resulting from hazardous substance releases, and (2) identify and plan restoration projects to compensate the public for those injuries.

1.2 AUTHORITY TO CONDUCT A NRDAR

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended (42 U.S.C. § 9601, *et seq.*), the National Oil and Hazardous Substances Contingency Plan (43 C.F.R. § 300, *et seq.*), the Federal Water Pollution Control Act (the "Clean Water Act" (CWA)), as amended (33 U.S.C § 1251, *et seq.*), the Oil Pollution Act (33 U.S.C. § 2701, *et seq.*), the District of Columbia Department of the Environment Establishment Act, D.C. Code § 8-151.08, the District of Columbia Brownfield Revitalization Amendment Act (D.C. Code §§ 8-631.01, *et seq.*), and the District of Columbia Water Pollution Control Act, §§ 8-103.03, authorize Federal, state, and Tribal officials to act on behalf of the public as trustees for natural resources.[1] In this role, trustees may assess and recover damages for natural resource injuries resulting from releases of hazardous substances or oil to the environment.[2]

Regulations have been promulgated to guide trustees in the assessment of natural resources injuries and damages. In 1987, under the authority of CERCLA and CWA, DOI issued regulations (43 C.F.R. Part 11; hereafter "CERCLA NRDAR regulations") for conducting NRDAR following the discharge of oil and/or the release of hazardous substances. The purpose of the regulations is "to provide standardized and cost-effective procedures for assessing natural resources damages" (43 C.F.R. § 11.11). When trustees complete an assessment according to these procedures, the results "shall be accorded the evidentiary status of a rebuttable presumption" (43 C.F.R. § 11.11). It is the Trustees' intent to pursue the damage assessment described in this DAP in accordance with the regulations at 43 C.F.R. Part 11.

KEY DEFINITIONS FROM THE NRDAR REGULATIONS AT 43 C.F.R. PART 11

Natural resources … *means land, fish, wildlife, biota, air, water, ground water, drinking water supplies, and other such resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States…, any State or local government, any foreign government…. These natural resources have been categorized into the following five groups: Surface water resources, ground water resources, air resources, geologic resources, and biological resources.* (43 C.F.R. § 11.14(z))

Injury *means a measurable adverse change, either long- or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a discharge of oil or release of a hazardous substance, or exposure to a product of reactions resulting from the discharge of oil or release of a hazardous substance.* (43 C.F.R. § 11.14(v))

Damages *means the amount of money sought by the natural resource trustee as compensation for injury, destruction, or loss of natural resources.* (43 C.F.R. § 11.14(l))

1.3 ASSESSMENT AREA

The assessment area for this DAP includes all locations where hazardous substances have come to be located within the tidal Anacostia River, Kingman Lake, and the Washington Channel, as well as adjacent tributary, tidal, terrestrial, and upland areas, including groundwater, associated with potential environmental cleanup sites. The assessment area is discussed in greater detail in Chapter 2.

[1] In accordance with section 101(27) of CERCLA, 42 U.S.C. § 9601(27), and the NCP, 40 C.F.R. § 300.5, for the purposes of this document, the term "state" includes the District of Columbia. Tribal trustees are Federally-recognized Indian Tribes (see: 40 C.F.R. § 300.5).

[2] In the District, D.C. Code § 10-102 confirms fee title in the United States to, inter alia, the Anacostia Riverbed. However, the District has the rights and the duties to regulate river uses (*see* 5 U.S.C.—Appendix, Reorganization Plan No. 3 of 1967, Part IV (Transfer of Functions to the D.C. Council), Section 9 (Public Buildings and Grounds); and *Anacostia Riverkeeper v. Jackson*, 798 F. Supp. 2d 210, 213 (D.C.D.C. July 25, 2011), citing 33 U.S.C. § 1251(b)). Additionally, the District and the Federal Trustees share trustee interests in the Anacostia River sediments and subsurface sediment, and the benthic invertebrates living within or on top of the sediment.

1.4 INTENT TO PERFORM A TYPE B ASSESSMENT

The CERCLA NRDAR regulations at 43 C.F.R Part 11 describe two processes by which trustees may conduct a NRDAR: Type A and Type B processes. The Trustees intend to conduct a Type B assessment.[3] The Type B process includes the three phases shown in Exhibit 1-1 and described below. Consistent with 43 C.F.R. § 11.31(c)(4), the Trustees have not included a Restoration and Compensation Determination Plan (RCDP) in this DAP but may develop an RCDP as part of the assessment or post-assessment process, if necessary.

1.4.1 PREASSESSMENT PHASE

During the Preassessment Phase, which has already been completed, the Trustees reviewed readily available information and existing data related to releases of hazardous substances and the potential impacts of those substances on natural resources. The review led to the Trustees' determination that there is sufficient evidence to support claims for natural resource damages against parties responsible for releasing the hazardous substances to the environment. Documentation of the Trustees' determination that further investigation and assessments are warranted (i.e., that a NRDAR could and should be performed) was published in the 2021 Pre-Assessment Screen Determination (District of Columbia et al. 2021). This phase is a prerequisite to conducting a formal assessment pursuant to 43 C.F.R. § 11.31(c)(4).

1.4.2 ASSESSMENT PHASE

The various stages of drafting a DAP and conducting the NRDAR include:

- Assessment Planning, which includes the development of this DAP.
- Injury Determination, which encompasses documentation that natural resource injuries have occurred.
- Injury Quantification, wherein the magnitude of injuries and service losses are quantified.
- Damage Determination, which involves monetizing quantified injuries, most often through the identification, scaling, and costing of restoration projects.

In addition, the Trustees may identify early restoration opportunities—that is, chances to commence with a restoration project before the assessment has proceeded completely through the NRDAR phases. Early restoration undertaken or funded by a potentially responsible party (PRP; see Section 1.5) may result in settlement of some or all of the PRP's natural resource damage (NRD) liability but not fully resolve all NRD liability, or it may generate a credit towards future settlement of NRD liabilities. Since these opportunities may be short-lived in duration, or there may be a benefit to earlier implementation (e.g., restoration of natural resources earlier than may otherwise be achieved), the Trustees may agree to pursue them. To allow for such opportunities, the Trustees may engage in early restoration planning as part of the Assessment Phase. Early restoration planning can include the development of a programmatic Restoration Plan or components of the RCDP that describe Trustee priorities regarding identification and selection of

[3] Type A assessments are "standard procedures for simplified assessments requiring minimal field observation to determine damages as specified in section 301(c)(2)(A) of CERCLA." (43 C.F.R. § 11.14(ss)). Type B assessments are "alternative methodologies for conducting assessments in individual cases to determine the type and extent of short- and long-term injury and damages, as specified in section 301(c)(2)(B) of CERCLA." (43 C.F.R. § 11.14(tt)).

projects. This could include efforts to estimate restoration credits for early restoration projects and identify offsets against future quantification of natural resources damages.

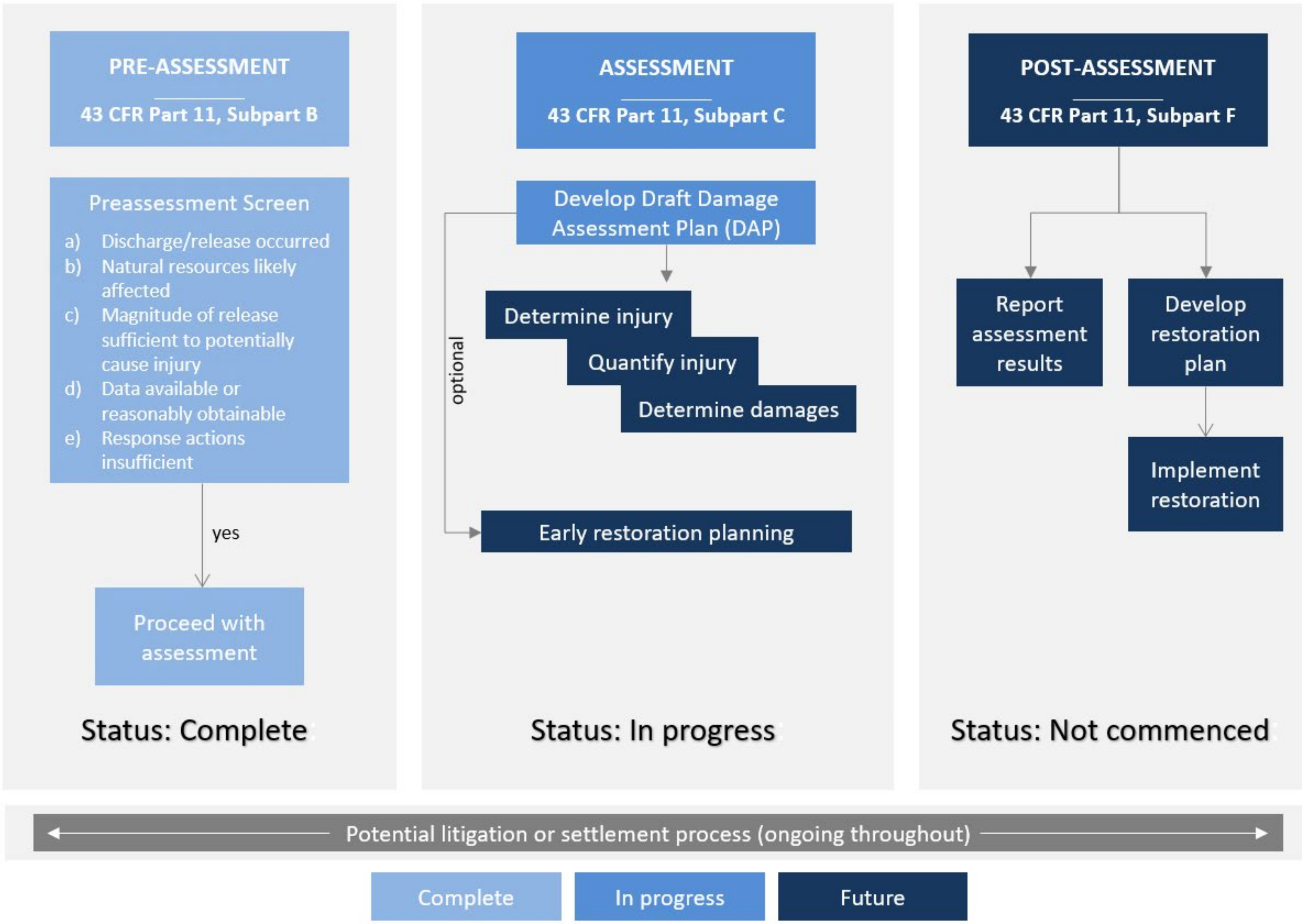
1.4.3 POST-ASSESSMENT PHASE

The Post-assessment Phase involves implementation of restoration and has a reporting component. If not completed sooner, the RCDP may be completed during the Post-assessment Phase. The RCDP will undergo public review and comment at that time (see Section 5.4 for more information on restoration planning; see Section 1.6 for more information on public participation). The Post-assessment Phase may also include a Report of Assessment and project-specific Restoration Plan(s) if the assessment proceeds to that stage. The former describes the results of the Assessment Phase and includes all the documentation supporting determinations made in the Preassessment and Assessment Phases (e.g., the Pre-Assessment Screen Determination; the Final DAP and documentation used in the Injury Determination, Quantification, and Damage Determination phases; and the RCDP and/or project-specific Restoration Plan(s)).

REMEDIATION VERSUS RESTORATION UNDER CERCLA

"**Remediation**" and "**restoration**" represent two related, but distinct processes under CERCLA. Remediation is intended to address human health and ecological risks associated with contamination and is part of the response action taken to prevent or minimize the release of hazardous substances. Restoration via the NRDAR process compensates the public for injuries to natural resources and associated service losses that are caused by the contamination or by the remediation itself. Restoration includes "… actions undertaken to return an injured resource to its baseline condition, as measured in terms of the injured resource's physical, chemical, or biological properties or the services it previously provided, when such actions are in addition to response actions…and…exceed the level of response actions determined appropriate…" (43 C.F.R. § 11.14(ll)). NRDAR also takes into consideration the time period over which the natural resources are injured until such time as the remedy or restoration returns those resources, and the services they provide, to their baseline condition.

EXHIBIT 1-1. DIAGRAM OF THE NRDAR PROCESS



1.5 COOPERATION WITH THE POTENTIALLY RESPONSIBLE PARTIES

The CERCLA NRDAR regulations at 43 C.F.R. § 11.32(a)(2)(ii) direct trustees to "use reasonable efforts to proceed against most known PRPs or at least against all those potentially responsible parties responsible for significant portions of the potential injury." 43 C.F.R. § 11.32(a)(2)(iii)(A) requires trustees to send a Notice of Intent to Perform a NRDAR (NOI) to all identified PRPs, which invites the PRPs to participate in the assessment and restoration process. The Trustees sent the NOI letters in 2021 to the same list of PRPs who were invited to participate in the remedial action:

> **Potentially Responsible Parties (or PRPs)** are the entities responsible for releases of hazardous substances. The intent of the NRDAR is to hold these entities responsible for the natural resource injuries caused by their releases. PRPs are responsible for paying natural resource damages, which may take the form of restoration actions or monetary payments that are used by trustees to plan and implement natural resource restoration actions.

- Amtrak;
- Blake Construction Co., Inc.;
- CSX Transportation;
- District of Columbia Water and Sewer Authority;
- Hess Corporation;
- Jemal's Buzzard Point, LLC;
- Joseph Smith & Sons, Inc.;
- Maryland-National Capital Park and Planning Commission;
- Potomac Electric Power Company (Pepco);
- Prince George's County;
- Steuart Investment Company;
- Washington Gas Light Company;
- Washington Metropolitan Transit Authority;
- Washington Suburban Sanitary Commission;
- U.S. Architect of the Capital;
- U.S. Army Corps of Engineers;
- U.S. Bureau of Engraving and Printing;
- U.S. General Services Administration;
- U.S. National Park Service; and
- U.S. Navy.

Other parties not listed above may be considered PRPs if additional information evidencing their status as a PRP is obtained during the assessment.

As indicated in Exhibit 1-1 above, although the NRDAR process is systematic and comprised of discrete steps, ultimately liability of PRPs is typically determined through litigation or by reaching settlement with PRPs. Thus, litigation preparation occurs simultaneously while the assessment proceeds and damages claims may be settled at any time.

1.6 PUBLIC PARTICIPATION

Public participation and review are an integral part of the assessment planning process and are required by the CERCLA NRDAR regulations (e.g., 43 C.F.R. § 11.32(c)). To facilitate public involvement in the NRDAR planning process, the Trustees encourage the public to review and comment on this Draft DAP. The review period is for 30 days (in accordance with 43 C.F.R. § 11.32(c)(1)) from the date of public release of the Draft DAP. Following comment submittal by the public, the Trustees will address any questions and recommendations, as well as provide a list of the comments received in an appendix of the Final DAP.

This document is available for review online at:

- https://restoretheanacostiariver.com/library,
- https://www.diver.orr.noaa.gov/web/guest/diver-admin-record/6231,
- https://www.nps.gov/anac/learn/management/anacostia-river-natural-resource-damage-assessment-and-restoration.htm, and
- https://parkplanning.nps.gov/AnacostiaDAP.

Interested parties can review a hard copy of this Draft DAP at the following locations:

- Francis A. Gregory Neighborhood Library
  3660 Alabama Avenue SE, Washington, DC 20020
- Rosedale Neighborhood Library
  1701 Gales Street NE, Washington, DC 20002
- Anacostia Park Headquarters
  1900 Anacostia Drive, SE, Washington, DC 20020

Comments may be submitted in writing:

- Online at the following website: https://parkplanning.nps.gov/AnacostiaDAP (preferred), or
- Via e-mail to: WASO_Anacostia_River_NRDAR_Case@nps.gov.

As the Trustees move forward with the NRDAR, there will be additional opportunities for public participation. Examples include reviewing any significant changes to the DAP, any restoration plans, and any proposed settlements.

1.7 ASSESSMENT TIMELINE

The Trustees do not have a fixed timeline for the completion of the NRDAR process. As called for in the CERCLA NRDAR regulations, the Trustees intend, where possible, to coordinate the assessment with the remedial processes, ensuring any changes in natural resource services and their services due to implementation of remedial actions within the assessment area are appropriately considered in the

NRDAR. The timeline of the assessment will also be adjusted to accommodate public participation and environmental conditions, if relevant (e.g., assessment of resources, including any field studies, may be limited by weather, seasons, and/or other factors).

1.8 ASSESSMENT APPROACH

The overarching goal of a NRDAR is to restore, replace, or acquire the equivalent of natural resources and resource services injured or lost as a result of a release of hazardous substances. Specifically, the CERCLA NRDAR regulations describe damages as the restoration costs required to return the injured natural resources to their baseline condition plus, at the Trustees' discretion, the compensable value of all, or a portion of, the services lost to the public for the time period from the release until the attainment of the restoration, replacement, and/or acquisition of equivalent of baseline (43 C.F.R. §§ 11.13(e)(3), 11.83, *et seq.*). In addition, the reasonable costs of performing the assessment are recoverable from PRPs (43 C.F.R. § 11.15(3)). Of note, individual and commercial losses (e.g., losses experienced by businesses) are not included in the definition of damages, so are not compensable through the NRDAR process. Natural resource services are defined as the "physical and biological functions performed by the resource, including the human uses of those functions" (43 C.F.R. § 11.14(nn)).[4]

Compensable value for interim losses therefore includes both past losses and losses that will occur until the injured resources and services are returned to baseline. The CERCLA NRDAR regulations provide trustees with a range of alternative approaches to determine the compensable value, including restoration cost-based approaches for compensating for interim losses as well as economic valuation approaches used to estimate public use and nonuse values (43 C.F.R. § 11.83(c)). While the specific approaches for injury and damages determination are detailed in the remainder of this report, for this case the Trustees intend to use both restoration cost-based approaches and valuation approaches in the assessment. That is, through a mix of habitat and resource equivalency and economic valuation approaches, the Trustees will identify and scale restoration projects in appropriate types and amounts to compensate the public for quantified losses in natural resources and resource services. When practicable, this will include use of existing information—potentially supplemented by new, focused site-specific data collection efforts (e.g., primary interviews, discussions, and/or meetings)—to assess compensable values for interim losses in the assessment area. All recovered damages will be used by the Trustees for restoration of natural resources and natural resource services.

1.9 ORGANIZATION OF THIS PLAN

The remainder of the DAP is organized as follows:

- **Chapter 2** provides the geographic and temporal scope of this assessment and a history of activities in the assessment area.
- **Chapter 3** addresses the natural resources and resource services that are the focus of the NRDAR.

[4] Natural resources, resource services, and baseline are discussed in greater detail in Chapter 3.

- **Chapter 4** describes the methods and approaches the Trustees anticipate using to document and evaluate the nature and degree of injuries to natural resources and resource services resulting from historical and ongoing releases of hazardous substances in the assessment area.
- **Chapter 5** describes the approach for determining damages, including the Trustees' approach to, and priorities for, natural resource restoration.

CHAPTER 2 | HISTORY AND DESCRIPTION OF THE ASSESSMENT AREA

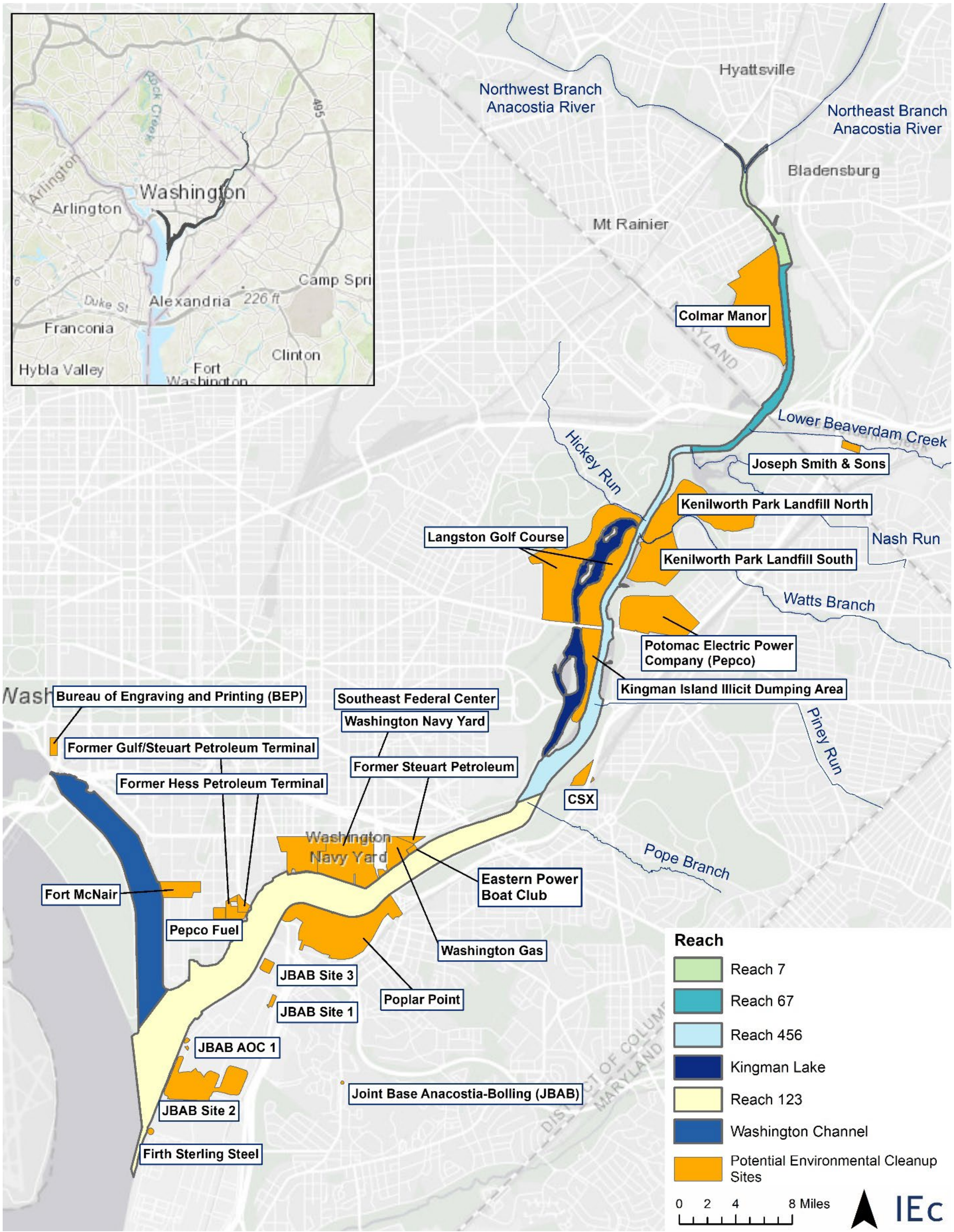
2.1 GEOGRAPHIC AND TEMPORAL SCOPE

The assessment area is defined in the CERCLA NRDAR regulations as: "the area or areas within which natural resources have been affected directly or indirectly by the discharge of oil or release of a hazardous substance and that serves as the geographic basis for the injury assessment" (43 C.F.R. § 11.14(c)). In this case, the geographic scope of this assessment encompasses the tidal Anacostia River (i.e., downstream of the confluence of the Northwest and Northeast Branches of the Anacostia River in Maryland, near Bladensburg, to its confluence with the Potomac River in Washington, DC), Kingman Lake, and the Washington Channel. It also includes tributaries to the Anacostia River, and limited terrestrial areas and groundwater contaminated by releases from potential environmental cleanup sites (PECSs). A map of the assessment area is presented in Exhibit 2-1, which includes labels for the established names of geographic areas and Anacostia River reaches used conventionally for environmental projects including the remedial investigation (Tetra Tech 2019a; DOEE 2020). As the assessment proceeds, the Trustees reserve the right to expand or further constrain its geographic scope.

The temporal scope of this assessment is based on the duration of injury to natural resources and corresponding damages. Due to the industrial history of the Anacostia River assessment area, natural resources likely have been exposed to and injured by hazardous substance releases since at least the early 1900s. The re-release and remobilization of contamination and associated injuries are expected to continue into the future. The NRDAR will therefore consider the full scope of these injuries.

However, in accordance with the promulgation of CERCLA in December of 1980, when injuries pre- and post-CERCLA are distinguishable, damages will be calculated based on injuries and service losses occurring after the enactment of CERCLA. When injuries are indistinguishable prior to and after the enactment of CERCLA, damages will be calculated beginning at the start of injury. Damages calculations will include losses through the reasonable expected recovery of the injured natural resources and their services. Therefore, emphasis will be placed on information on natural resource injuries and service losses beginning in 1981 and into the future. The rate of recovery will be based upon best available information on proposed or implemented remedial and restoration activities, natural attenuation, and expected resource recoverability. If a resource is not expected to fully recover, the injuries will be considered permanent.

EXHIBIT 2-1. ANACOSTIA RIVER ASSESSMENT AREA



2.2 INDUSTRIAL ACTIVITIES WITHIN THE ASSESSMENT AREA

Numerous contaminated sites that may have released hazardous substances to the Anacostia River have been identified in the Anacostia River watershed. Exhibit 2-2 lists and describes these potential environmental cleanup sites. Neither the list of sites below, the list of hazardous substances, nor the potentially responsible parties identified, are considered exhaustive and do not reflect all potential sources of contamination to the Anacostia River.

EXHIBIT 2-2. POTENTIAL ENVIRONMENTAL CLEANUP SITES (PECSs) WITHIN THE ASSESSMENT AREA

SITE NAME	HIGHLIGHTS OF OPERATIONS, INDUSTRIAL FACILITIES, AND ACTIVITIES	HAZARDOUS SUBSTANCES
Colmar Manor Landfill	1955-1970: Operated by the Washington Suburban Sanitary Commission as a permitted landfill 1970: Redeveloped by Maryland-National Capital Park and Planning Commission as a recreational park	PAHs, Pesticides, Lead, Arsenic
Joseph Smith and Sons, Inc.*	Active scrap processing site	PCBs
Kenilworth Park Landfill	1942-1970: Operational landfill	PAHs, PCBs, Pesticides, Metals, VOCs
Pepco Benning Road Facility	1906-2012: Operated by Pepco as a coal-fired, then oil-fired, electric generating station; demolished in 2015 (Tetra Tech 2019b) 2015-present: Used by Pepco to manage operations and maintain equipment associated with their electrical distribution system	PCBs, Dioxins, Metals, PAHs, VOCs, CVOCs
CSX Benning Yard	Active railroad switching yard	TPH-GRO, Arsenic, PAHs, PCBs, Lead
Langston Golf Course (Kingman Island / Kingman Lake)	1910s-1920s: Kingman Lake, Kingman Island, and Heritage Island were constructed by the U.S. Army Corps of Engineers using dredge spoil from the Anacostia River and adjacent mudflats (Tetra Tech 2019b) 1930-1937: Refuse disposal/burning on Kingman Island 1937-present: Kingman Island reclaimed as the nine-hole Langston Golf Course 1930-1955: Refuse disposal/burning on the western (landside) shore of Kingman Lake 1955-present: Kingman Lake dump was covered and redeveloped as the second nine holes of Langston Golf Course	Aluminum, Arsenic, Lead, TPH-DRO, PCBs
Kingman Island Illicit Dumping Area	1940s: Used as an illicit dumping site	PCBs, PAHs, TPH-DRO, Metals

SITE NAME	HIGHLIGHTS OF OPERATIONS, INDUSTRIAL FACILITIES, AND ACTIVITIES	HAZARDOUS SUBSTANCES
Washington Gas Light (WGL) East Station Site	1888-1948: Manufactured gas plant operated by Washington Gas Light (WGL) 1948-1983: The plant was operated only for peaking purposes or once a year to check equipment operation 1986: Plant was demolished	PAHs, VOCs (including benzene), CVOCs, Metals
Former Steuart Petroleum Company (adjacent to WGL East Station)	1966-1982: Bulk oil distribution facility operated by Steuart Petroleum Company 1992: ~51,000 gallons of #4 fuel oil spilled from an above-ground storage tank; ~2,000 gallons of product drained into a storm drain flowing into the Anacostia Present: Mostly demolished	VOCs, TPH-DRO, Metals
Eastern Power Boat Club/District Yacht Club	Adjacent to WGL and Steuart Petroleum	PAHs, Metals, VOCs (including benzene)
Poplar Point	1927-1993: Plant nurseries operated intermittently by the Architect of the Capitol 1942-1960s: Naval Receiving Station	PCBs, PAHs, Pesticides, Metals, TPH-DRO, TPH-GRO, VOCs
Washington Navy Yard	1799-present: Shipyard operated by the United States; operations have included shipbuilding, ordnance research and production, naval gun manufacturing, and administrative activities	PCBs, PAHs, Metals, VOCs, CVOCs
Southeast Federal Center	Prior to 1963: Part of Navy Yard included manufacturing of ordnance and medium to large caliber guns 1963-present: Owned by the U.S. and used for administrative offices, warehouses, laboratories, and light industrial operations	PCBs, PAHs, Metals, VOCs, CVOCs (including TCE)
Joint Base Anacostia-Bolling (JBAB)	1917-1962: Military airfield and testing facility operated by the United States Present: Used for administrative purposes	VOCs, PAHs, Dioxins, Metals
Former Hess Oil Corporation Petroleum Terminal	1920-1985: Bulk oil facility operated by Hess	PAHs, VOCs, TPH, Metals
Former Steuart Petroleum Company/Gulf Oil Company Petroleum Terminal	1930-1969: Bulk gasoline and fuel oil terminal operated by Gulf Oil 1969-1989: Bulk gasoline and fuel oil terminal operated by Steuart Petroleum Company	PAHs, VOCs, TPH
Fort McNair	1794-present: Army facility, which has included a Federal penitentiary, a general hospital, and a training facility	PAHs, Metals, TPH
Bureau of Engraving and Printing (BEP)	1880s-present: Printing facility for U.S. paper currency and other security documents	PCBs, Lead

Abbreviations: PCBs: Polychlorinated Biphenyls, PAHs: Polycyclic Aromatic Hydrocarbons, VOCs: Volatile Organic Compounds, CVOCs: Chlorinated Volatile Organic Compounds, TPH: Total Petroleum Hydrocarbons, GRO: Gasoline Range Organics, DRO: Diesel Range Organics, TCE: Trichloroethylene

Source: Pre-Assessment Screen Determination (District of Columbia et al. 2021)

*The Joseph Smith and Sons, Inc. site was identified as a PECS after the publication of the Pre-Assessment Screen Determination (District of Columbia et al. 2021)

2.3 HAZARDOUS SUBSTANCES IN THE ASSESSMENT AREA

A variety of hazardous substances have been released into the assessment area (District of Columbia et al. 2021; Tetra Tech 2019b). As part of the development of this DAP, the Trustees reviewed existing information on contaminants of concern (COCs) described in remedial investigation and risk assessment documents relevant to the assessment area to guide the assessment going forward. Beginning with the list of contaminants identified as being of concern in these existing documents[5], the Trustees then performed a screening analysis of the available environmental sampling data within the assessment area.

The analysis focused on the extensive quantity of sediment data from the Anacostia River available to the Trustees and screened those data against the threshold effect consensus-based sediment quality guidelines from MacDonald et al. (2000). The exception to this was the contaminant dioxin. Dioxin and a number of PCBs with co-planar chemical orientation exhibit similar toxic effects and are more toxic to higher trophic-level organisms, such as birds and mammals which are exposed primarily through consumption of contaminated fish, than they are to sediment-dwelling infauna. As such, to screen for potential adverse effects of dioxin and dioxin-like PCB congeners to natural resources, concentrations of PCBs and dioxins in fish tissues collected from the Anacostia River were screened using the toxic equivalency quotient approach described in Van den Berg et al. (1998) using screening thresholds from EPA (1993).

> **CONSENSUS-BASED SEDIMENT QUALITY GUIDELINES**
>
> Numerical sediment quality guidelines have been developed by regulatory agencies, resource managers, and academics to evaluate contaminants in freshwater and marine sediments for a variety of purposes, including but not limited to conducting ecological risk assessment, conducting NRDAR, identifying contaminants of concern, and setting clean-up goals. Two commonly utilized criteria in the field of NRDAR are the threshold effect concentration (TEC) and probable effect concentration (PEC) developed by MacDonald et al. (2000).
>
> The TEC is considered a threshold ***below*** which adverse effects to sediment-dwelling infauna are not expected to occur. The PEC is a threshold ***above*** which such adverse effects would be expected to occur. MacDonald et al.'s guidelines were derived as the geometric mean of numerous similar published sediment quality guidelines, so therefore are characterized as "consensus-based" thresholds.

The Trustees then evaluated the magnitude, spatial scope, and temporal trends of observed threshold exceedances. A summary of the exceedances in the evaluated sampling data for selected COCs is presented in Exhibit 2-3. Each of these hazardous substances exhibit a consistent pattern of increasing numbers of exceedances, as well as a larger proportion of exceedances, when moving from upstream to downstream.

Based on this analysis, the hazardous substances that will be the initial focus of the ecological injury assessment include:

- polycyclic aromatic hydrocarbons (PAHs),
- polychlorinated biphenyls (PCBs),
- dichlorodiphenyltrichloroethane (DDT; and its breakdown products, measured as total DDT),
- chlordane (including various isomers and breakdown products, measured as total chlordane),

[5] This included a variety of organic contaminants including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT; and its breakdown products), chlordane (including its various isomers and breakdown products), dieldrin, endrin, and heptachlor epoxide, as well as metals including arsenic, cadmium, copper, lead, mercury, nickel, and zinc.

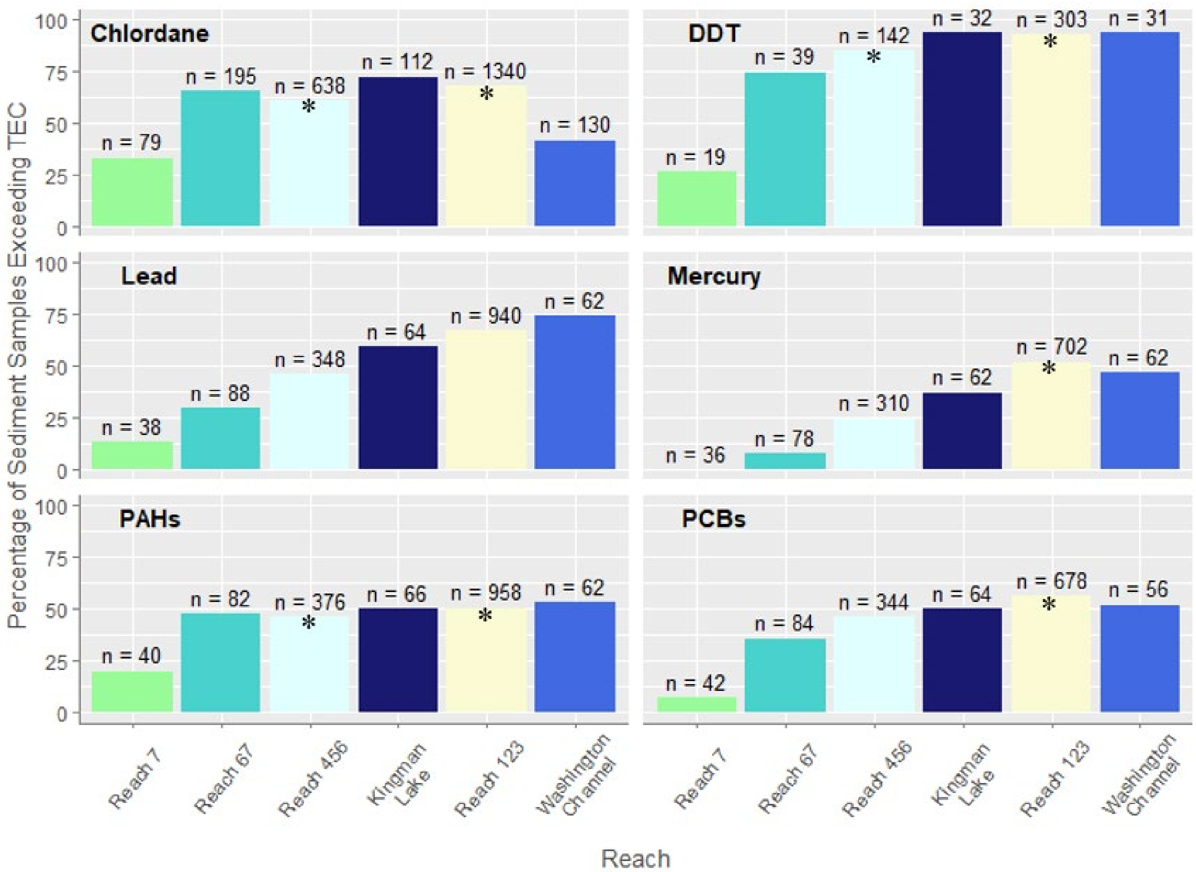
- lead, and
- mercury.

In addition to these COCs, the District anticipates assessing injuries to groundwater from volatile organic compounds (VOCs) and chlorinated volatile organic compounds (CVOCs), as well as other inorganic and organic contaminants.

The COCs discussed above are not intended to constitute an exhaustive list, but rather reflect the priorities the Trustees will place on their review of relevant information in the assessment. The Trustees reserve the right to expand or reduce the number of COCs that are the focus of the assessment based on information reviewed and analyses performed during the assessment.

Additional information on each of these COCs of initial ecological focus is provided in Appendix B. For each contaminant, general information—such as global sources, characteristics, and environmental behavior—is provided. Then, toxicity information related to human health (for context) and ecological receptors (e.g., toxicological effects on aquatic invertebrates, fish, birds, and mammals) is briefly summarized.

EXHIBIT 2-3. SUMMARY OF THRESHOLD EFFECT CONCENTRATION (TEC) EXCEEDANCES IN THE SCREENING ANALYSIS FOR THE SELECTED HAZARDOUS SUBSTANCES (MACDONALD ET AL. 2000)



* Analytical records flagged as "non-detect" are included in this exhibit. "Non-detect" records are records for which the contaminant of concern (COC) being analyzed was not detected analytically in the sample. Detection limits are specific to the COC, laboratory method, and instrumentation used. Since detection limits vary, and the inability to measure a COC at a level below the detection limit does not preclude the presence of the COC in the sample, "non-detect" records are typically treated in screening analyses as containing a COC concentration equal to the detection limit. A total of 166 records in the dataset had records flagged as "non-detect" for which the reported concentration (i.e., the detection limit) was higher than the TEC. These 166 records exist in eight different COC and reach combinations, designated with an asterisk. In most instances, TEC exceedances flagged as "non-detect" records were less than one percent of the total exceedances. The maximum percentage of TEC exceedances flagged as "non-detect" records occurred for DDT in Reach 123, at 15.5 percent of the exceeding records.

CHAPTER 3 | NATURAL RESOURCES AND RESOURCE SERVICES

This chapter provides information on the natural resources present within the assessment area and the types of services those natural resources provide, which will be the focus of the NRDAR.

3.1 NATURAL RESOURCES

Under the CERCLA NRDAR regulations, natural resources include the land, fish, wildlife, biota, air, water, groundwater, drinking water supplies, and other resources that belong to, are managed by, or held in trust by, appertaining to, or otherwise controlled by the United States, state or local governments, foreign governments, or Tribes (43 C.F.R. § 11.14(z)). These resources are organized into five categories: surface water (including sediments), groundwater, air, geological (including soil), and biological resources.

The Trustees intend to focus assessment efforts on surface water, groundwater, geological, and biological resources in the assessment area. At this time, the Trustees do not plan on quantifying distinct injuries to air resources. Rather, air will be considered as one pathway through which hazardous substances may have come to be located within the assessment area.

3.1.1 SURFACE WATER AND SEDIMENT RESOURCES

Surface water resources are defined in the CERCLA NRDAR regulations as:

> *The waters of the United States, including the sediments suspended in water or lying on the bank, bed, or shoreline and sediments in or transported through coastal and marine areas* (43 C.F.R. § 11.14(pp).

Waters of the District or District waters are defined as:

> *. . . Flowing and still bodies of water, whether artificial or natural, whether underground or on land, so long as in the District of Columbia, but excludes water on private property prevented from reaching underground or land watercourses, and also excludes water in closed collection or distribution systems.* (21 DCMR 1199.1).

Surface water resources in the assessment area include the Anacostia River waters, Kingman Lake, and the Washington Channel. Sediment in the Anacostia River is typically composed of silt deposits in the top 10 feet, often underlain by sandy sediments between 5 and 10 feet below surface (AECOM 2020). The Anacostia River Sediment Project (ARSP) surface water model, developed as part of the remedial investigation process, indicated a range of sedimentation rates in the Anacostia River, from 0 to 5.5 cm/yr in Reach 123 up through 0-18 cm/yr in Reach 67 (Tetra Tech 2019c).

The District classifies both the current uses of the Anacostia River and the future uses to which the waters will be restored. The current uses include secondary contact recreation and aesthetic enjoyment; protection and propagation of fish, shellfish, and wildlife; protection of human health related to consumption of fish and shellfish; and navigation. The future uses (or "designated uses") of the Anacostia River include all the current uses in addition to primary contact recreation (District of Columbia Municipal Regulations (DCMR) 21-1101.1). Maryland designates the waters of Anacostia River as "Use I" (water contact recreation and protection of nontidal warmwater aquatic life). Maryland also designates the tidally influenced portion of the Anacostia River as "Use II" (tidal waters: support of estuarine and marine aquatic life and shellfish harvesting).

3.1.2 GROUNDWATER RESOURCES

Groundwater resources are defined in the CERCLA NRDAR regulations as:

> *Water in a saturated zone or stratum beneath the surface of land or water and the rocks or sediments through which ground water moves. It includes ground water resources that meet the definition of drinking water supplies* (43 C.F.R. § 11.14(t)).

The District's Water Pollution Control Act (D.C. Law 5- 188) defines groundwater as "underground water, but excludes water in pipes, tanks, and other containers created or set up by people."

The groundwater aquifers underlying the assessment area have not been fully characterized. In collaboration with the United States Geological Survey (USGS), DOEE investigated the hydrology of the Anacostia River watershed (Raffensperger et al., 2021) and identified three main hydrostratigraphic units based on a review of available information:

1. **The Surficial Aquifer** consists of unconsolidated clays, silts, sands, and gravels and is the main source of recharge to deeper confined aquifers. The surficial aquifer also provides the primary source of groundwater flow to local streams within the District.
2. **The Coastal Plain Aquifers and Confining Units** consist of the Aquia, the Magothy, the Upper Patapsco, the Patapsco, the Lower Patapsco, and the Patuxent aquifers. These deeper units are potential sources of drinking or other water supplies for the general region.
3. **The Piedmont** comprises three distinct geologic areas (carbonate, siliciclastic, and igneous and metamorphic crystalline rocks). Groundwater flow within the associated bedrock occurs via secondary porosity associated with fractures and joints.

Additional details describing the geologic characteristics of each unit are available in Raffensperger et al., 2021 and references therein.

3.1.3 GEOLOGIC RESOURCES

Geologic resources are defined in CERCLA NRDAR regulations as:

> *Those elements of the Earth's crust such as soils, sediments, rocks, and minerals, including petroleum and natural gas, that are not included in the definitions of ground and surface water resources* (43 C.F.R. § 11.14(s)).

The Anacostia River assessment area is located within the Coastal Plain Physiographic Province, which consists of a wedge-shaped sequence of mixed sedimentary rocks and deposits originating from the Cretaceous Period. These rocks and deposits include sandstones, clay beds, gravel deposits, and silts (Walsh et al. 2016). The Anacostia River assessment area has undergone major changes to its soil composition in the past 150+ years, particularly as urban development has progressed. Beginning in the

1920s, the U.S. Army Corps of Engineers left fill materials (udorthents soils) along much of the riparian buffer in the District portion of the Anacostia River (DOI 2014).

3.1.4 BIOLOGICAL RESOURCES

Biological resources are defined in the CERCLA NRDAR regulations as:

> *Those* natural resources *referred to in section 101(16) of* CERCLA *as fish and wildlife and other biota. Fish and wildlife include marine and freshwater aquatic and terrestrial species; game, nongame, and commercial species; and threatened, endangered, and State sensitive species. Other biota encompass shellfish, terrestrial and aquatic plants, and other living organisms not otherwise listed in this definition* (43 C.F.R. § 11.14(f)).

The Anacostia River area supports a diversity of fish, aquatic invertebrates, plants, mammals, reptiles, and amphibians.[6] For example, the following organisms occur in the assessment area:

- There have been 32 **benthic invertebrate** taxa documented in the tidal Anacostia River (McGee and Pinkney 2002). However, the benthic macroinvertebrate communities present in the Anacostia River are dominated by pollution-tolerant oligochaetes (segmented aquatic worms) and chironomids (non-biting midge larvae) (DOI 2014).
- A total of sixty species of **fish** have been identified in the Anacostia Watershed, including the Federally listed endangered short-nosed sturgeon (*Acepinser brevirostrum)* and Atlantic sturgeon (*Acipenser oxyrhynchus*) (District of Columbia et al. 2021). Commonly observed fish in the Anacostia River include anadromous fish such as shad species or striped bass, and catadromous fish such as the American eel (NOAA 2007). However, the resident fish species assemblage is dominated by killifish (*Fundulidae*) and minnows (*Cyprinidae*) at the lowest trophic level, sunfishes (*Lepomis* spp.) at the mid-level, and catfishes (*Ictaluridae*) and largemouth and smallmouth bass (*Micropterus* spp.) at the highest trophic level (Tetra Tech 2019b).
- Ten **freshwater mussel** species occur in the Anacostia Watershed (District of Columbia et al. 2021), including the Eastern elliptio (*Elliptio complanata*) and Eastern floater mussel (*Pyganodon cataracta*), which are both commonly found throughout the Anacostia River (Tetra Tech 2019b). Two **crayfish** species, native spinycheek crayfish (*Orconectes limosus*) and invasive nonindigenous red swamp crayfish (*Procambarus clarkii*), are both well-established in the Anacostia River (District of Columbia et al. 2021, Tetra Tech 2019b). Fifteen **damselfly and dragonfly**

Bluet damselfly. Photo credit: © KristaSchlyer.com.

[6] Species of greatest conservation need in the District of Columbia are listed in Appendix C.

species are known or expected to occur in the Anacostia Watershed, including pond damsels (*Coenagrionidae*), darners (*Aeshnidae*), emeralds (*Corduliidae*), and skimmers (*Libellulidae*) (District of Columbia et al. 2021).

- A total of 148 species of **non-aquatic birds** have been identified in the Anacostia Watershed (District of Columbia et al. 2021). Non-aquatic birds within the Anacostia Watershed include year-round residents such as bobwhite quail (*Colinus virginianus)* and European starling (*Sturnus vulgaris),* local breeding populations of woodthrush (*Hylocichla mustelina),* and migratory species such as warbling vireo (*Vireo gilvus)* and common yellowthroat *(Geothlypis trichas)* (DOI 2014).
- Seventy-six species of **aquatic birds** have been identified in the Anacostia Watershed, including 35 waterfowl species, 35 shorebird species, two blackbird species, and four other species (District of Columbia et al. 2021). The most common aquatic birds are ducks and geese (*Anatidae*), loons (*Gaviidae*), grebes (*Podicipedidae*), and coots and rails *(Rallidae*) (DOI 2014).
- At least 21 **mammal** species occur in the Anacostia Watershed, including the Federally listed endangered northern long-eared bat (*Myotis septentrionalis*) (District of Columbia et al. 2021). Some of the most commonly observed mammals in the aquatic or riparian environment are beavers (*Castor canadensis*), river otters (*Lutra canadensis*), muskrats (*Ondatra zibethicus*), and racoons (*Procyon lotor*). Foxes (*Vulpes* spp.), squirrels (*Sciurus* spp.), and opossums (*Didelphis* spp.) are common in the surrounding woodland habitats (DOI 2014).

North American beaver. Photo credit © KristaSchlyer.com.

- At least 15 **amphibian** species and 21 **reptile** species are present in the Anacostia Watershed (District of Columbia et al. 2021). Common turtle species found in the Anacostia River or surrounding wetland areas include the common snapping turtle (*Chelydra serpentina*), eastern painted turtle (*Chrysemys picta picta),* red-bellied turtle (*Pseudemys rubriventris*), eastern mud turtle (*Kinosternum subrubrum),* and the common musk turtle (*Sternotherus odoratus*). The spotted turtle (*Clemmys guttata*), which is included in the International Union for Conservation of Nature Red List, has been observed at Kenilworth Park and Aquatic Gardens and Piscataway Park (Walsh et al. 2016).

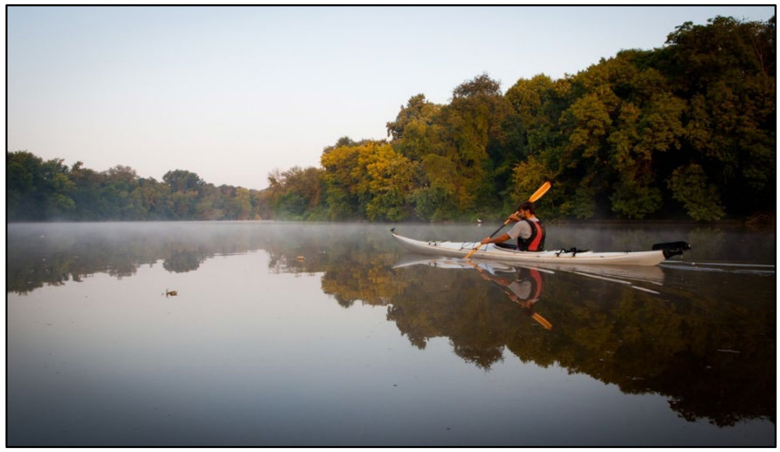
3.2 NATURAL RESOURCE SERVICES

Natural resource services are the physical and biological functions performed by the natural resources, including the human uses of those functions, and are a result of the quality of the resource (43 C.F.R. § 11.14 (nn)). Hazardous substances have potentially adversely affected natural resource services in the assessment area, including surface water and sediment services, groundwater services, geologic resource services, and biological resource services.

3.2.1 SURFACE WATER (AND SEDIMENT) SERVICES

Surface water in the assessment area provides habitat for aquatic animals and plants and serves as a source of drinking water for biological resources. Sediment provides habitat and prey resources for fish, invertebrates, birds, and mammals.

Anacostia River surface waters also provide a variety of recreational opportunities, including boating, swimming, and wildlife observation. A DOEE Anacostia River Use survey found that survey respondents participated in fishing, kayaking/canoeing, other boating (sailing etc.), rowing, and using the trails and visiting parks along the Anacostia River (DOEE 2022b).



Kayaker on the Anacostia River. Photo credit: Fred Pinkney.

3.2.2 GROUNDWATER SERVICES

The literature has documented a wide range of services that are provided by groundwater. These include services that can accrue to people (e.g., drinking water), as well as ecological services (both *in situ* services as well as those resulting from clean groundwater discharging to surface waters). For example, the National Research Council states:

> *The total economic value (TEV) of ground water is a summation of its values across all of its uses. Sources of values have been classified into use values (sometimes called direct use values) and nonuse values (also known as passive use values, existence values). The use values arise from the direct use of a good or asset by consuming it or its services. For ground water, these would include consumption of drinking water and other municipal or commercial uses. Nonuse values arise irrespective of such direct use. Thus in the economist's jargon the total economic value of a given resource asset includes the summation of its use and nonuse values across all service flows. The notion of total economic value is fundamental to ground water valuation and should enter into management decisions regarding use of water resources. Valuation is a useful tool if the values can help inform decision-makers. The relevant issue is how the TEV of ground water will change when a policy or management decision is implemented.* (NRC 1997, p. 48)

Other researchers (e.g., EPA 1995; Bergstrom et al. 1996) also have documented the range of services provided by groundwater, including both use and nonuse services. Additionally, published studies have demonstrated the economic value the public holds for these various services (e.g., Bergstrom et al. 2001). For example, the public likely holds an option value for groundwater that represents an individual's willingness-to-pay to reduce or eliminate uncertain future risks associated with groundwater resources. "Option price", which includes such option values, is well established in the economics literature generally (see Freeman 2003), and specifically with respect to groundwater protection (see Bergstrom et al. 2001; Sun et al., 1992). Option prices may reflect ecological, use, and nonuse values; that is, the option price an individual is willing to pay reflects all of the values that individual may hold for a groundwater resource.

Groundwater resources within the assessment area provide a source of recharge for surface water in the assessment area. Further, although groundwater in the District is not currently used for drinking water, District law requires that it be protected for beneficial uses that include drinking water in other jurisdictions as well as a potential future source of drinking water (21 DCMR 1150.2).

3.2.3 GEOLOGIC RESOURCE SERVICES

Geologic resources provide storage for groundwater and filter and clean surface water as it passes into the ground. Additionally, geologic resources provide a nutritive substrate for plant growth and shelter for burrowing animals, such as chipmunks. Geologic resources also preserve archeological resources in the assessment area. For example, archaeological studies within Anacostia Park have identified many prehistoric and historical archaeological sites within the past 125 years (DOI 2017).

3.2.4 BIOLOGICAL RESOURCE SERVICES

Biological resources provide a variety of ecological and human-use services. Forest, grassland, and wetland vegetation in the assessment area provides food; nutrient cycling; and breeding, loafing, and denning services for migratory birds, mammals, and other biota. For example, soil-dwelling invertebrates cycle nutrients and serve as food resources for mammals and small birds. Small mammals are prey for higher trophic level organisms. Fish contribute to nutrient cycling, control insect populations, and serve as a food resource for birds and mammals. Birds serve as pollinators, scavengers, and seed dispersers and some small birds serve as a food source for larger birds of prey.

Biological resources in the Anacostia River assessment area provide many opportunities for recreation, such as birding and wildlife observation and recreational fishing. The diverse wildlife, flora, and fauna found in the assessment area also provide educational opportunities for residents and visitors. For example, Kenilworth Park and Aquatic Gardens offers ranger-led school programs and the Anacostia Watershed Society and Anacostia Riverkeeper lead boat tours to educate the public about the Anacostia River Watershed.[7] Fish also serve as a food source for subsistence anglers, who most commonly harvest blue catfish, striped bass, yellow perch, and channel catfish (Fiske and Callaway 2019).

Anglers on the Anacostia River. Photo credit: © KristaSchlyer.com.

[7] See, for example: https://www.nps.gov/keaq/learn/education/index.htm; https://www.anacostiariverkeeper.org/anacostia-river-explorers/; and https://www.anacostiaws.org/events-and-recreation/signature-events/anacostia-river-discovery-series.html.

CHAPTER 4 | APPROACH TO INJURY DETERMINATION AND QUANTIFICATION

As noted in Chapter 1, the Trustees intend to perform a Type B assessment. The CERCLA NRDAR regulations stipulate that trustees must confirm that at least one of the natural resources identified as potentially injured in the Preassessment Screen has in fact been exposed to the released substance (43 C.F.R. § 11.37(a)). In this case, the 2021 Pre-Assessment Screen Determination included a wide variety of data evaluating pathways and confirming exposure and injury of natural resources including surface water, sediment, groundwater, and biological resources (aquatic invertebrates and fish). It also confirmed exposure and the potential for injury of additional biological resources including birds, mammals, and reptiles, and highlighted, for example, the presence of hazardous substance-based fish consumption advisories for the Anacostia River (District of Columbia et al. 2021, MDE 2023). Therefore, natural resources within the Anacostia River assessment area have been exposed and injured.

The CERCLA NRDAR regulations also stipulate that after completing the Injury Determination phase, for resource(s) found to be injured and for which the trustees anticipate pursuing damages, trustees should quantify injury and service losses relative to baseline (43 C.F.R. § 11.70). Thus, injury quantification should focus only on those resources documented to have been injured. This Chapter describes the methodologies, approaches, and objectives for (1) injury determination and (2) injury quantification. It also identifies some of the key information sources available to the Trustees for completing these steps and includes a list of planned or potential studies the Trustees may conduct to compile or generate the information necessary for injury determination and quantification, and ultimately, damages determination (Chapter 5).

4.1 INJURY DETERMINATION

Determination of injury to natural resources under the CERCLA NRDAR regulations is based on documentation that: (1) there is a pathway for the released hazardous substance from the point of release to a point at which natural resources are exposed to the released substance, and (2) injury of a natural resource of interest (i.e., surface water, sediment, soil, groundwater, biota) has occurred, as defined in 43 C.F.R. § 11.62.

Pathway is defined as: "The route or medium through which…a hazardous substance is or was transported from the source of the discharge or release to the injured resource" (43 C.F.R. § 11.14(dd)). Injury is defined as: "A measurable adverse change, either long- or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a…release of a hazardous substance" (43 C.F.R. § 11.14(v)).

For certain resource categories, the CERCLA NRDAR regulations provide more specific definitions for what constitutes injury to that particular resource, as well as specific considerations and acceptance criteria for documenting injury. For several resource categories, for example, exceedance of a Federally- or state-promulgated criterion (e.g., an ambient water quality criterion in the case of surface water or a maximum contaminant level based on the District standard set forth in 21 DCMR 21-1155 in the case of groundwater) is determined to be a *per se* injury.[8] Additionally, the presence of a governmental advisory limiting or banning consumption of fish or wildlife due to the presence of hazardous substances is also considered a *per se* injury. Readers are referred to 43 C.F.R. § 11.61, *et seq*. of the CERCLA NRDAR regulations for additional details in this regard.

The Anacostia River Trustees anticipate applying a variety of approaches to determine if an injury to a natural resource has occurred, including comparing observed hazardous contaminant concentrations to promulgated thresholds and identifying measurable adverse changes in resources attributable to hazardous substance exposure. As part of the assessment, the Trustees will decide upon appropriate adverse effects endpoints or criteria to use when quantifying service losses based on a variety of factors (e.g., nature of the contaminants, potentially exposed receptors, and review of available toxicity information). For example, to determine injury to sediment resources in the 2021 Pre-Assessment Screen Determination, the Trustees considered results of laboratory-based toxicity testing as well as hazardous substance concentrations in the context of consensus-based probable effect concentration thresholds (District of Columbia et al. 2021, MacDonald et al. 2000). Finally, the Trustees will also evaluate collateral injuries to natural resources caused by remedial actions (see 43 C.F.R. § 11.15(a)(1)).

4.1.1 INJURY DETERMINATION FOR BIOLOGICAL RESOURCES

As noted above, the 2021 Pre-Assessment Screen Determination determined injury to certain biological resources such as aquatic invertebrates and fish, and available information suggests the potential for injury to birds, mammals, and reptiles (e.g., Exhibit 2-3 and the Pre-Assessment Screen Determination (District of Columbia et al. 2021)). As part of the NRDAR, the Trustees anticipate further examination of available data for these resources to determine injury to these resources. The Trustees will consider the guidance provided in 43 C.F.R. § 11.62(f) in this regard. Consistent with the CERCLA NRDAR regulations, the Trustees anticipate focusing on adverse changes in viability, the potential exceedance of Food, Drug and Cosmetic Act (21 U.S.C. § 242) action or tolerance levels, or applicable consumption advisory levels to determine if injuries to these resources have occurred.

4.2 INJURY QUANTIFICATION

The CERCLA NRDAR regulations state: “In the Quantification phase, the extent of the injury shall be measured, the baseline condition of the injured resource shall be estimated, the baseline services shall be identified, the recoverability of the injured resource shall be determined, and the reduction in services that resulted from the discharge or release shall be estimated” (43 C.F.R. § 11.70(c)). In addition to detailing how the Trustees anticipate addressing baseline and resource recoverability, the following sub-sections outline specific approaches to quantifying ecological, groundwater, and human use service losses.

The Trustees will aim to quantify all natural resource injuries and service losses in a manner that facilitates the selection and scaling of restoration in the damage determination process (Chapter 5). This means that losses will be quantified using units useful for measuring both lost services as well as the

[8] *Per se* injuries are injuries that are objectively defined in the CERCLA NRDAR regulations, as opposed to injuries that are subjectively interpreted as a measurable adverse change in the chemical or physical quality or viability of the natural resource.

benefits provided by any restoration actions. In addition, when quantifying resource injuries and service losses, each category of loss will be evaluated to ensure losses are not being double counted.

If quantification is not possible for certain resources or services, the Trustees also may address such losses qualitatively by targeting restoration activities that compensate for those losses in a general way (again, ensuring losses are not double counted). Finally, the Trustees also reserve the right to consider different approaches for quantifying injuries and losses beyond the approaches discussed herein.

4.2.1 BASELINE

Baseline is defined as the condition(s) that would have existed if the hazardous substances had not been released in the assessment area (43 C.F.R. §11.14(e)). Therefore, baseline data should reflect expected conditions in the assessment area had the release of hazardous substances not occurred, taking into account natural processes and changes that result from human activities (e.g., structural alterations, releases of treated or untreated wastewater, and other factors unrelated to the releases of hazardous substances). Because site-specific historical data applicable to establishing baseline conditions are not readily available for the Anacostia River assessment area, the Trustees plan to use, in order of priority, data from reference/control areas (43 C.F.R. § 11.72(d)), relevant literature (43 C.F.R. § 11.72(c)(2)), and/or site-specific studies (43 C.F.R. § 11.72(c)(5)).

4.2.2 RESOURCE RECOVERABILITY

Recovery period is defined as the time required for the injured resources and their services to return to their baseline condition, as defined by the trustees (43 C.F.R. § 11.14(gg)). The rate of resource recovery will be determined based on information on the nature, scope, and severity of natural resource injuries; the nature, extent, and timing of remedial activities; the expected natural attenuation of contamination; and estimates of resource recoverability implied by trends in resource monitoring data or derived from the literature. If available, site-specific time-series data may be used to estimate trends in natural resource recovery; or for remediated areas, pre- and post-remedial monitoring data may be used. In some cases, however, the Trustees may apply assumptions related to the time frame or extent of resource recoverability.

4.2.3 ECOLOGICAL INJURY QUANTIFICATION

For purposes of ecological injury quantification, the Trustees anticipate using equivalency-based methods (see text box on Equivalency Analyses in NRDAR below), which are specifically approved valuation methodologies in the CERCLA NRDAR regulations (43 C.F.R. § 11.83(c)(2),(3)). Equivalency analyses quantify resource losses from contamination over the spatial extent and time frame of injury and quantify resource gains from restoration over the spatial extent and time frame of the restoration project(s).

For this assessment, the Trustees anticipate quantifying ecological injury in terms of lost services on a habitat basis by focusing on representative species (i.e., components of a habitat) using habitat equivalency analysis (HEA). While habitat sub-types may be quantified separately, it is likely that the habitat of focus will be aquatic habitat, broadly including in-stream as well as any hydrologically connected wetland habitat. However, the Trustees also may consider quantifying injury to specific resources (e.g., threatened or endangered species, or individual biological species found to be disproportionately harmed) using resource equivalency analysis (REA). To account for baseline, the

Trustees may adjust service losses in the HEA analyses either at the habitat component (e.g., representative species) or overall habitat level.

EQUIVALENCY ANALYSES IN NRDAR

Equivalency analyses are methods for scaling the amount of restoration needed to offset a certain amount of natural resource injury. They consider resource losses, as well as the gains, from compensatory restoration over time, employing the concept of discounting. Two common variants of these types of analyses are resource and habitat equivalency analysis (REA and HEA, respectively). A third method, habitat-based resource equivalency method (HaBREM), has also emerged in recent years.

RESOURCE EQUIVALENCY ANALYSIS (REA)

REA is commonly used to quantify lost ecosystem services when the injury is specific to a particular resource or biological species or species group, particularly when the nature of the injury lends itself to quantification in terms of units of the resource. For example, for a biological resource REA, the unit of injury may be the number of organisms lost (or their biomass) and may also potentially include their lost future somatic (i.e., physical) growth and/or reproductive potential. For a groundwater REA, the unit of injury may be unit volumes of groundwater (e.g., gallons or acre-feet). REA then applies modeling to quantify unit losses over time with discounting to put past and future changes in the selected measurement unit into a common present value. One advantage of REA is its targeted focus on a resource specifically identified as having been adversely affected by a release of a hazardous substance. Once resource losses have been quantified, resource gains provided through restoration are similarly quantified, and restoration projects are scaled to ensure the quantity of resources restored is equivalent to the quantity that was lost.

HABITAT EQUIVALENCY ANALYSIS (HEA)

HEA is most commonly undertaken when injury or service losses can more reasonably be said to accrue to a geographic area. Instead of evaluating resource losses to one specific resource, as is done in REA, resource losses are evaluated more holistically on a habitat basis. Service loss estimates across multiple species (or species groups or habitat components) are combined to generate an overall service loss estimate for a given area. Discounting is then used to scale past and future losses, which are typically measured in present value units of "area-time" (e.g., discounted service acre-years). Similar to REA, the benefits of a given restoration project(s) are also quantified, using the same units (e.g., discounted service acre-years provided by restoration), and the amount of restoration needed to compensate for losses is identified.

HABITAT-BASED RESOURCE EQUIVALENCY METHOD (HaBREM)

HaBREM is a variant of HEA that employs resource-based metrics (e.g., biological abundance, plant cover, etc.) to explicitly quantify service losses and scale resource gains within a habitat equivalency framework. It similarly uses modeling and discounting, like both methods above, but aims to scale habitat losses and gains based on specific resource-focused metrics that may be objectively quantified using standard scientific field research methods.

4.2.4 GROUNDWATER INJURY QUANTIFICATION

It is anticipated that a REA approach will be used for assessing and scaling restoration for groundwater losses. As noted above, REA methods are based on balancing the injury to natural resources that has occurred over time with an equivalent amount of restoration, taking into account the nature and duration of the injury and the nature and timing of the restoration. Thus, for a groundwater REA, it will be necessary to characterize the baseline quality of the groundwater, quantify the amount of injured groundwater, and delineate the time frame of the injury.

The quantity of injured groundwater may be quantified either as a stock volume or a flow (or flux) of groundwater passing through the aquifer over a unit of time (e.g., on an annual basis). Either approach will require information about the spatial extent of the groundwater contamination and the physical properties of the aquifer. For example, to calculate flow, the surface area and the recharge rate of the groundwater contaminant plume will be needed. Delineating the time frame of injury will include determining when it began, how it may have changed over time, and when (or if) it will end.

4.2.5 HUMAN USE LOSS QUANTIFICATION

In the context of NRDAR, the benefits that a natural resource provides to a community are referred to as "services" (43 C.F.R. §11.14(nn)). As noted in Section 3.2, "services" include the physical and biological functions performed by the resource, including the human uses of those functions. The goal of the NRDAR process is to restore natural resources to provide the full range of services that would be provided in the absence of natural resource injuries and to compensate the public for any interim losses of those services.[9] As discussed in Chapter 3, there are various services provided by natural resources within the assessment area that accrue directly to humans, which may be quantified using a variety of approaches or described qualitatively.

Despite successful past and ongoing efforts to restore the health of the Anacostia River, natural resource services provided to communities along the Anacostia River have historically been, or remain, diminished. Potentially affected human use services include recreational services such as fishing, birdwatching, boating, and swimming, as well as the opportunity to gather and socialize outdoors without concern about exposure to hazardous substances. Impairments due to hazardous substances can also, among other outcomes, lead to reductions in the contribution of the natural resources to community cohesion and well-being (Chen et al. 2019, de Bell et al. 2017, Nutsford et al. 2016, Polyakov et al. 2022, Völker and Kistemann 2013). The release of hazardous substances and the resulting natural resource injuries and service losses may contribute to environmental justice (EJ) concerns if communities of color or economically disadvantaged people are disproportionately deprived of access to healthy natural resources.[10]

---

[9] As noted in Section 1.8, compensable value for interim losses includes both past losses and losses that will occur until the injured resources and services are returned to baseline.

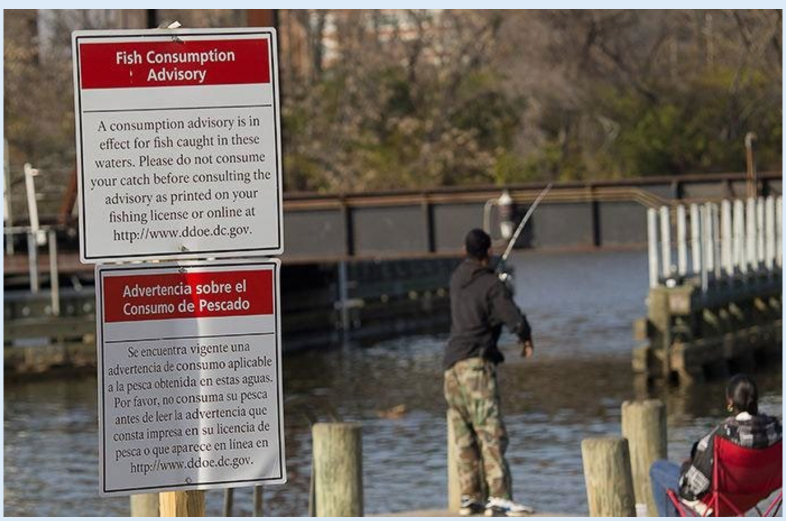
[10] As defined by the U.S. Environmental Protection Agency (EPA), EJ is "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations and policies." Fair treatment means, among other things, that "no group of people should bear a disproportionate share of the negative environmental consequences resulting from industrial, governmental and commercial operations or policies." Meaningful involvement for the purposes of NRDAR includes community participation in restoration planning and implementation. (https://www.epa.gov/environmentaljustice/learn-about-environmental-justice.)

The Trustees will aim to quantify human use service losses using units of resource use when possible (e.g., foregone recreational visits, diminished recreational experience, lost subsistence harvest opportunities). For example, to quantify fishing losses, the Trustees anticipate using a benefits transfer approach using existing data (see text box on Benefits Transfer, below). This may include an estimate of the number of fishing trips not taken to the Anacostia River due to the presence of hazardous substance releases and/or the number of fishing trips taken under degraded conditions, and the value of those trips.

BENEFITS TRANSFER

Benefits transfer involves adapting research estimating economic values under one set of circumstances to an alternate situation. For example, literature that places a social welfare value on foregone or diminished recreational trips or visits may be used to monetize quantified lost and diminished trips.

Example for Recreational Fishing: Historical and on-going fish consumption advisories issued by the District of Columbia and State of Maryland may affect anglers' choices about whether to fish in the affected waterbodies and reduce the enjoyment of those who do. Responses of anglers faced with resource contamination and associated fish consumption restrictions and advisories include reducing the total number of fishing trips, taking fewer or no trips to the affected areas, and frequenting less desirable alternative sites. They may also cause anglers to change the species of fish they eat, change their cooking/cleaning methods, convert to catch-and-release angling, or pursue a different activity altogether. A benefits transfer for fishing, for example, would thus rely on data on foregone fishing trips paired with information in the peer-reviewed literature on the value the public places on recreational fishing trips to calculate a measure of lost value. Damages may be determined in terms of lost and/or diminished trips.



Additionally, the reduction in natural resource services from the Anacostia River and associated uses may have been borne disproportionately and adversely by economically disadvantaged communities and communities of color. As such, the release of hazardous substances to the Anacostia River may have contributed to broader economic or social disadvantage. Given this broader harm, it may be appropriate for the Trustees to focus on restoration of ecological health, recreational opportunities, and other services provided by natural resources in a manner that will benefit the local communities in particular. To understand the impacts of hazardous substances in the Anacostia River on adjacent communities, the Trustees will identify and, to the extent possible, incorporate various metrics that evaluate EJ implications of these substances.

As described in Chapter 1, the Trustees will use existing data to quantify losses. To the extent existing data are limited, the Trustees may consider conducting primary data collection to support quantification of human use service losses, including effects on recreational and subsistence activities and EJ communities. For example, while fishing activity data have been collected for the assessment area, data on other recreational activities that may be conducted within the assessment area are more limited.

4.3 INFORMATION SOURCES

Contaminant concentration and toxicity data are available to the Trustees through an environmental database maintained by NOAA, the Data Integration Visualization Exploration and Reporting database (DIVER; https://www.diver.orr.noaa.gov/), which contains records from thousands of surface water, sediment, invertebrate, and fish samples collected within the Anacostia River. In addition, groundwater sampling data from PECSs are available from site-specific remedial investigation reports.[11] Finally, other relevant publicly available resources have been compiled and reviewed by the Trustees for consideration and use as part of the NRDAR process.[12] More than 800 published documents are available and include peer-reviewed literature, state and Federal government data and reports, industry data and reports, and other grey literature. The Trustees will review and utilize these information sources to complete the NRDAR. Given the great extent of available information, the Trustees anticipate being able to complete the NRDAR primarily using existing information. However, to the extent key information gaps are revealed, the Trustees reserve the right to collect additional primary data.

4.4 PLANNED OR POTENTIAL ACTIVITIES

Using the approaches detailed above, the Trustees anticipate conducting a number of specific activities as part of the injury assessment. Exhibit 4-1 lists some of the planned or potential assessment activities the Trustees anticipate conducting to enable quantification of injuries to natural resources and related service losses.

[11] See, for example, Ridolfi (2003), Geosyntec (2013), Environmental Consultants and Contractors (2004), AECOM (2016, 2019, 2020), CH2M Hill (2018), and Johnson Company (2012, 2016).

[12] See, for example, the administrative record for the Anacostia River Sediment Project: https://restoretheanacostiariver.com/library.

EXHIBIT 4-1. PLANNED OR POTENTIAL NRDAR ASSESSMENT ACTIVITIES

#[1]	TOPIC	TYPE	OBJECTIVE(S)	RATIONALE
SURFACE WATER (AND SEDIMENT) RESOURCES				
1	Sediment / Sediment-dwelling Biota Toxicity Assessment	Review/Analysis of Existing Information	• Evaluate existing toxicology literature on the effects of hazardous substances on sediment-dwelling biota. • Develop thresholds for contaminant of concern (COC) concentrations in sediment indicative of injury to sediment-dwelling biota. • Estimate COC concentrations that would be expected under baseline conditions. • Develop quantitative relationships (mathematical functions) between COC sediment concentrations and service losses.	Injury thresholds are needed to determine the locations and time frames of injuries to sediment resources. An understanding of the mathematical relationships between hazardous substance concentrations in the environment and service losses associated with adverse toxicological effects in biota, as well as an understanding of baseline contamination, is needed to develop sediment-based service losses for use in habitat equivalency analyses (see text box in Section 4.2.3), which in turn will be used to quantify resource injuries and scale restoration.
2	Evaluation of Remedial Impacts	Review/Analysis of Existing Information	• Evaluate existing information on the planned or expected remedial actions that will take place within the Anacostia River.	Actions that reduce natural resource injuries (or cause collateral injuries) must be considered during injury quantification. Data on the geographic extent and time frame of remedial activities may be incorporated into habitat equivalency analyses (see text box in Section 4.2.3).
3	Surface Water and Sediment Assessment	Desktop analysis	• Using geospatial and temporal interpolation, estimate COC concentrations throughout sediments in the aquatic habitat within the assessment area, including in areas and years in which sediment sampling has not occurred. • Estimate service losses associated with sediment contamination and remedial activities taking baseline into consideration.	Spatial and temporal analyses conducted using geographic information systems and assumptions allow for gaps in sediment COC concentrations to be filled. Estimated sediment concentrations throughout the aquatic habitat within the assessment area may then be used to estimate sediment service losses for use in the habitat equivalency analysis (see text box in Section 4.2.3). This analysis should also consider the effects of any remedial actions and baseline COC concentrations on sediment injuries (see Activity #2 above).

#[1]	TOPIC	TYPE	OBJECTIVE(S)	RATIONALE
BIOLOGICAL RESOURCES				
4	Biological Data Review	Review/Analysis of Existing Information	• Summarize existing information from studies evaluating adverse effects of hazardous substances in the assessment area on biota, including toxicological or biological survey studies. • Determine baseline condition of biological resources.	Existing studies of biological resource conditions can be used to establish service losses to biological resources stemming from hazardous substance releases. These studies need to be compiled and systematically reviewed for their potential to be used to inform injury to biota relative to baseline.
5	Fish Injury Assessment	Review/Analysis of Existing Information	• Evaluate existing toxicology literature on the effects of hazardous substances on fish. • Develop thresholds for COC concentrations in fish tissues indicative of injury. • Estimate COC concentrations in fish tissues that would be expected under baseline conditions. • Develop quantitative relationships (mathematical functions) between fish tissue COC concentrations and service losses to fish. • Estimate service losses to fish, taking into consideration baseline, based on the COC concentrations present in fish tissues. • Consider service losses from any fish-related studies evaluated in Activity #4 above.	Service losses to fish over time need to be estimated since fish occupy an important ecological niche within the habitat of the Anacostia River and also provide a variety of services to humans. Fish injury thresholds are needed to determine injuries to fish. Mathematical relationships between fish tissue residues or fish toxicity testing results and service losses, as well as an understanding of baseline fish condition, are needed to develop fish service losses to be used to quantify fish injuries and scale restoration using either resource or habitat equivalency analyses (see text box in Section 4.2.3).

#[1]	TOPIC	TYPE	OBJECTIVE(S)	RATIONALE
6	Avian Injury Assessment	Review/Analysis of Existing Information	• Evaluate existing toxicology literature on the effects of dietary hazardous substances in fish and other aquatic biota tissues to birds. • Develop thresholds for dietary COC concentrations indicative of injury to birds. • Evaluate available COC data in bird tissues, including the results of food chain modeling presented in the PAS (District of Columbia et al. 2021). • Estimate COC concentrations in bird tissues that would be expected under baseline conditions. • Develop quantitative relationships (mathematical functions) between COC concentrations in fish and other aquatic biota with bird tissue COC concentrations and the resulting service losses to birds. • Consider service losses from any bird-related studies evaluated in Activity #4 above.	Birds occupy an important ecological niche within the Anacostia River and provide a variety of services to humans. Injury thresholds are needed to determine injuries to birds. Mathematical relationships between measured or estimated avian tissue residues and service losses, as well as an understanding of baseline contamination, are needed to assess bird injuries and scale restoration using either resource or habitat equivalency analyses (see text box in Section 4.2.3).
7	Mammal Injury Assessment	Review/Analysis of Existing Information	• Evaluate existing toxicology literature on the effects of dietary hazardous substances in fish and other aquatic biota tissues to a representative mammal species. • Develop thresholds for dietary COC concentrations indicative of injury to mammals. • Evaluate available data on COC concentrations in mammal tissues, including the results of food chain modeling presented in the PAS (District of Columbia et al. 2021). • Estimate COC concentrations in mammal tissues that would be expected under baseline conditions. • Develop quantitative relationships (mathematical functions) between COC concentrations in fish and other aquatic biota with mammal tissue COC concentrations and the resulting service losses to mammals. • Consider service losses from any mammal-related studies evaluated in Activity #4 above.	Mammals occupy an important ecological niche along the Anacostia River and provide a variety of services to humans. Injury thresholds are needed to determine injuries to mammals. Mathematical relationships between measured or estimated mammal tissue residues and service losses, as well as an understanding of baseline contamination, are needed to assess injuries to mammals and scale restoration using either resource or habitat equivalency analyses (see text box in Section 4.2.3).

#[1]	TOPIC	TYPE	OBJECTIVE(S)	RATIONALE
GROUNDWATER RESOURCES				
8	Groundwater Injury Assessment	Review/Analysis of Existing Information	• Define the areal extent of injured groundwater plumes. • Define the time frame over which groundwater has and is expected to be injured. • Define the recharge rate within the vicinity of the injured groundwater.	Areal extent and time frame of injury, as well as recharge rate, are needed to quantify groundwater injury using REA for purposes of identifying the scale of restoration required (see text box in Section 4.2.3).
HUMAN USES				
9	Recreational and Subsistence Fishing Loss Assessment	Review/Analysis of Existing Information	• Using benefits transfer approaches, estimate the value of lost and/or diminished recreational and subsistence fishing activities.	Recreational and subsistence fishing has likely been adversely affected by releases of hazardous substances in the assessment area and the presence of COCs in fish tissues, as well as the issuance of fish consumption advisories. This analysis will aim to quantify the losses associated with such injuries.
10	Evaluation of Existing Non-fishing Recreational Activities	Review/Analysis of Existing Information	• Compile and evaluate existing information on additional non-fishing recreational activities within the vicinity of the Anacostia River, and the extent to which those activities have been lost or reduced due to the presence of hazardous substance releases or resource injuries.	Additional non-fishing activities (e.g., bird watching, swimming, boating) may be adversely affected by the presence of hazardous substances within the assessment area. Existing data may inform the scope and magnitude of any such losses.

#[1]	TOPIC	TYPE	OBJECTIVE(S)	RATIONALE
11	Human Use Impacts Assessment	Primary data collection	• To plan and implement a study to determine the scope and magnitude of reduction / losses to recreational and/or subsistence fishing attributable to the presence of hazardous substances in the assessment area or specific resource injuries. • To plan and implement a study to determine the scope and magnitude of reduction / losses in non-fishing recreational activity attributable to the presence of hazardous substances in the assessment area or specific resource injuries.	This activity is dependent on the outcome of the review and analysis of existing information (Activities #9 and #10). If the Trustees determine that a primary study is appropriate and likely to provide information necessary to quantify losses associated with these human use services, they may design and implement such a study under this activity.
12	Environmental Justice Assessment	Review/Analysis of Existing Information Interviews/Outreach	• Describe the role of the Anacostia River in the history of adjacent communities. • Assess and describe the mechanisms by which environmental contamination may have contributed to environmental injustice in adjacent communities. • To the extent possible, quantify adjacent communities' access to resources and whether those resources are affected by hazardous substances. • Consider restoration actions that address existing environmental injustice identified through this assessment.	Restoring and replacing injured natural resources and their services that would be provided in the absence of the release of hazardous substances may benefit from an understanding of the broader role that contamination of the Anacostia River has had on the local communities. As such, the goal of the EJ Assessment is to inform restoration project selection and scaling.

Notes:

1. Activity numbers are for clarity and do not reflect order of priority or occurrence.

CHAPTER 5 | DAMAGES DETERMINATION AND RESTORATION

The purpose of a damage determination is to "establish the amount of money to be sought in compensation for injuries to natural resources resulting from a ... release of a hazardous substance" (43 C.F.R. § 11.80(b)). This chapter addresses how damages will be determined using methods described in the CERCLA NRDAR regulations where applicable (43 C.F.R. § 11.80). As noted in Chapter 1, the Trustees will determine damages using restoration cost-based and economic valuation approaches, and the total amount of natural resource damages will include both the cost of restoration to baseline and the compensable values for interim losses (43 C.F.R. §§ 11.13(e)(3), 11.83, *et seq.*). Damages that are recovered under the CERCLA statute and the NRDAR regulations must be used for natural resource restoration (42 U.S.C. 9601, *et seq.*; 43 C.F.R. Part 11), including restoring both the injured resources as well as the services those resources provide.

5.1 ECOLOGICAL DAMAGES DETERMINATION

As indicated in Chapter 4, the Trustees anticipate using habitat- and resource-based equivalency methods to quantify ecological losses. The Trustees, therefore, also anticipate using these approaches when scaling restoration to ensure sufficient ecological benefit is provided to compensate for losses. When possible, losses and gains will be measured in the same unit (e.g., number of organisms, biomass, acres of habitat). Damages will be calculated as the cost to implement that restoration.

The Trustees will ensure that there is no “double-counting” of losses in the scaling process (43 C.F.R. § 11.84(c)). This will require evaluation of whether restoration scaled to the losses experienced by one resource will also compensate (fully or partially) for the losses associated with another injured resource. Specifically, use of equivalency-based scaling approaches will mean that the Trustees will identify and quantify the services provided by proposed restoration projects as part of the scaling process. As restoration projects are identified and evaluated, attention will need to be paid to the particular suite of services the restoration projects are anticipated to provide. Whenever possible, the Trustees will endeavor to target restoration that will restore, replace, rehabilitate, or acquire the equivalent of those resources and the services they provide that were found to be injured (i.e., in-kind replacement). In some cases, the Trustees may choose to engage in environmental restoration that is deemed worthwhile (but is not in-kind in nature) if it restores similar resources or resource services as those that were injured, or restores resources or services deemed highly important ecologically, when restoration of the same type and quality is unavailable or not possible. In these circumstances, the Trustees will evaluate the relative differences between the type and quality of the injured resources and the resources to be restored and may adjust the scope or scale of required restoration accordingly. For example, the Trustees may develop compensation ratios to account for potential differences in ecological services provided by different habitat types (e.g., wetland versus open water habitat). Such ratios may be applied to assure that any tradeoffs in the habitats, resources, or resource services targeted for restoration result in restoration projects that are sufficient to make the public whole.

5.2 GROUNDWATER DAMAGES DETERMINATION

As with the damages determination approach for ecological losses described above, the District anticipates identifying, scaling, and determining the cost (as necessary) of restoration projects required to compensate the public for groundwater injuries. There are a wide range of restoration projects that could be performed to restore lost groundwater services, such as prevention of groundwater contamination (e.g., protection of future recharge or provision of sewer in areas reliant on septic systems). Projects will be chosen based on restoration criteria, and will be scaled using REA—that is, restoration actions will be selected and scaled to replace the present value of the quantity (e.g., either as a static volume or flow) of groundwater shown to be injured in the injury quantification phase of the assessment.

5.3 HUMAN USE DAMAGES DETERMINATION APPROACH

As noted in Chapter 3, the Anacostia River supports a variety of recreational activities and uses, including kayaking, canoeing, boating, rowing, paddling, and fishing (Murray et al. 2015). Preliminarily identified injuries, such as the fish consumption advisories discussed in the beginning of Chapter 4 above, suggest that there has been, and will continue to be, associated compensable losses. As discussed in Chapter 4, recreational losses would be quantified based on the nature and extent of lost recreational services (e.g., lost and diminished recreational fishing trips; 43 C.F.R. § 11.83(c)(2)). In this manner, damages may result from reduced use of the resources or a diminished experience due to the presence of the hazardous substances.

Based on an ongoing review of available information, the Trustees anticipate that existing data on angler effort and relevant economic values may be adequate to conduct a benefit transfer-based analysis of recreational and subsistence fishing damages (43 C.F.R. § 11.83(c)(2)(vi)). Should this analysis reveal significant sources of uncertainty, or if additional information regarding the nature and extent of potential losses becomes available, the Trustees may consider designing and implementing a primary (i.e., stated, revealed, or combined stated/revealed preference) valuation study to estimate damages.[13]

Additional potential sources of recreational use losses include boating (paddling and otherwise), swimming, birding, and wildlife observation. As noted in Chapter 4, existing information suggests the likelihood of injury to these human use services. The Trustees plan to continue gathering available information on the nature, location, and levels of such activities within the assessment area, as well as the extent to which hazardous substance releases have reduced or diminished use or value. To augment existing information, the Trustees may conduct targeted qualitative research in the form of interviews or focus groups to determine whether further evaluation and potential data collection related to these other uses is warranted.

In addition to lost recreational services, the Trustees intend to consider metrics that describe the broader impact of hazardous substance injuries on communities along the Anacostia River, including economically disadvantaged neighborhoods and communities of color. The Trustees will consider both quantitative and qualitative indicators of lost and diminished services to these communities resulting from hazardous substances in the Anacostia River.

---

[13] Stated preference studies use questionnaires to ask respondents directly about their preferences, including using willingness-to-pay or willingness-to-accept scenarios to capture values respondents may hold. Revealed preference studies, by contrast, evaluate the choices that individuals make, often in related market settings, to understand the values held for a nonmarket good or service.

5.4 RESTORATION

The CERCLA NRDAR regulations emphasize that for Type B assessments, damages should be based on actions that "restore, rehabilitate, replace, or acquire the equivalent of" the injured resources and resource services (see 43 C.F.R. §§11.13(e)(3), 11.82, *et seq.*). Such actions are broadly referred to as restoration. Restoration is intended both to return injured resources to their baseline condition and to compensate for resource service losses during the period of injury.

As noted in Chapter 1, the CERCLA NRDAR regulations describe the development of an RCDP as part of the DAP (43 C.F.R. § 11.81(d)(1)). An RCDP lists a reasonable number of possible alternatives for restoration, rehabilitation, replacement, and/or acquisition of equivalent resources and their related services, selects one or more of the alternatives based on general criteria set forth in the CERCLA NRDAR regulations and site-specific criteria established by the trustees, and provides a rationale for the selected alternative(s) (43 C.F.R. § 11.81(a)). If existing data are not sufficient to develop an RCDP at the time that the DAP is released, the CERCLA NRDAR regulations allow trustees to defer development and public release of an RCDP until after completion of the injury determination or quantification phases (43 C.F.R. § 11.81(d)(1)). In this case, information needed to complete an RCDP is insufficient at this time. The Trustees may develop an RCDP later in the assessment process. To facilitate the consideration of potential restoration actions, and to solicit public review and comment on the topic of Anacostia River restoration in the context of NRDAR, the following sections identify a range of potential restoration options that have been proposed previously for consideration by a variety of stakeholders and address likely natural resource or resource service injuries.

5.4.1 RESTORATION APPROACH

The Trustees' overall approach to restoration is to target restoration actions that directly benefit natural resources and the public. Where timely restoration of injured natural resources is not feasible (e.g., removal of contaminated sediments to restore all of the services that would be provided absent the release of hazardous substances), projects that replace or off-set service losses may be undertaken. The CERCLA NRDAR regulations require that trustees undertake restoration projects to restore, enhance, replace, and/or acquire the equivalent of the injured natural resource(s) or the lost services provided by a natural resource(s). At sites with EJ implications, consideration of local impacts and the benefits of potential restoration projects to disparately affected communities can also be used to evaluate projects.

DOI, in discussing the intent of the CERCLA NRDAR regulations, noted:

> *…[t]he Department does not believe that Congress intended to allow Trustee agencies to simply restore the abstract services provided by a resource, which could conceivably be done through an artificial mechanism. For example, nothing in the language or legislative history of CERCLA suggests that replacement of a spring with a water pipeline would constitute 'restoration, rehabilitation, replacement, and/or acquisition of equivalent resources.' CERCLA requires that natural resource damages be based on the cost of restoring, rehabilitating, replacing and/or acquiring the equivalent of an actual natural resource* (Federal Register, Volume 58, Number 139, 22 July 1993).

The Trustees intend therefore to address restoration at the habitat scale by focusing on restoration projects that will compensate the public by providing ecological and human use services in or near the assessment area.

5.4.2 POTENTIAL RESTORATION OPTIONS

The overall goal of NRDAR is to restore, replace, rehabilitate, or acquire the equivalent of natural resources and their services that have been lost or diminished due to the release of hazardous substances, effectively balancing the gains provided by restoration against the past and ongoing losses.[14] The Trustees intend to focus restoration efforts on those resources and service losses determined to have been injured as part of the injury assessment. The Trustees' specific ***restoration goals*** therefore correspond to the categories of resources and services understood to have been injured (see Exhibit 4-1, above):

Surface water and sediment resources. Surface water and sediment restoration can be achieved through a variety of habitat restoration approaches, as well as specific actions targeted at reducing the loading of harmful constituents to the Anacostia River and associated tributaries and wetlands.

Biological resources. Restoration of biological resources can be achieved through activities that directly benefit certain taxa of biological species; however, the Trustees anticipate prioritizing biological resource restoration through the enhancement or creation of high-quality habitats that will support a diversity of, and a range of ecological services for, biota.

Groundwater resources. Restoration of groundwater may be achieved as a collateral benefit of certain surface water quality and habitat restoration approaches due to the connections between surface and groundwater and the natural cleansing of water that occurs as surface water infiltrates into the ground and recharges groundwater. Targeted efforts also can be undertaken to directly enhance groundwater quantity and/or quality.

Human uses of the Anacostia River. Restoration of the human uses of the Anacostia River may be achieved through various activities, which may include infrastructure improvements to enhance recreational activities. It may also include improvements in associated greenspace, especially for local communities historically and/or currently disconnected from the amenities and use opportunities that the Anacostia River could provide.

Therefore, to restore these injured resources and meet the Trustees restoration goals, the Trustees anticipate targeting the following ***restoration approaches***:

- **Improve surface water (and sediment) quality**.
- **Enhance and restore habitat**.
- **Enhance biological resources**.
- **Restore groundwater resources**.
- **Increase public access to, and enjoyment of, the Anacostia River.**

These approaches may comprise any number of specific restoration project types. Exhibit 5-1 lists these priority restoration approaches, provides restoration project type examples, and highlights how they are aligned with the resource injury categories listed above. The Trustees, however, reserve the right to

[14] In the context of EJ, the goal is to restore natural resources and services so they provide a level of benefits and use to the community that would have existed but for the release of hazardous substances. As such, EJ considerations will inform the restoration alternative selection and scaling process (i.e., the process of establishing the correct size and duration of restoration projects to off-set natural resource injuries and lost services at the site).

implement alternative or additional approaches—and specific projects—that are not specifically identified in this DAP.

Restoration of the Anacostia River has long been a priority of the District, as well as other Federal government and public stakeholders. Ongoing, but parallel efforts include the Anacostia River Sediment Project and D.C. Water's Clean Rivers Project, among others. The Trustees' restoration goals in many cases are aligned with some of the broader environmental goals that have been enumerated for the Anacostia River, including to create an Anacostia River that "supports stable fish and wildlife", "supports fish that are safe to eat", and "is publicly accessible" (DDOE 2008).

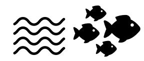
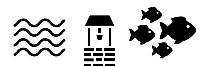
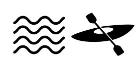
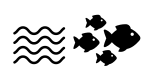
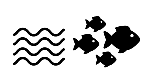
Importantly, DOEE is also in the process of developing the Anacostia River Corridor Restoration Plan (ARCRP), a two-year process to "identify and prioritize specific strategies for restoring the fish and wildlife habitat, improving water quality, adapting to climate change, and increasing equitable public access to the river corridor" (DOEE 2022a).[15] The Trustees are actively tracking and participating in the public outreach component of the development process for that Restoration Plan. The Phase 1 public survey (575 responses) and interviews of 15 community leaders, conducted in late 2022, focused on preferred activities throughout the Anacostia River corridor and how the experience could be improved though pollution reduction, better access, and addressing safety concerns (DOEE 2022b).[16] To the extent that specific restoration projects are identified in that plan that align with the restoration goals and techniques outlined above and in Exhibit 5-1, those projects could be candidates for funding through the NRDAR process.

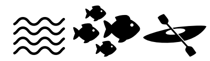
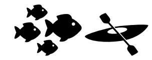
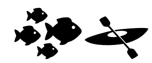
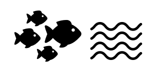
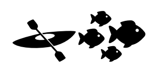
EXHIBIT 5-1. POTENTIAL RESTORATION APPROACHES AND TYPES

RESTORATION APPROACHES	RESTORATION PROJECT TYPES	DESCRIPTION AND PROJECT EXAMPLES	INJURY CATEGORIES ADDRESSED
Improve surface water (and sediment) quality	Stormwater retention	Urban runoff contains a myriad of pollutants and contributes to poor water quality. Surface water retention reduces flow velocities and allows contaminants to deposit out of the water prior to entering natural water bodies. Rain gardens, permeable pavement, rain barrels, catch basins, and green roofs are examples of water retention techniques that would improve surface water (and sediment) quality (AWTA 2002, DDOE 2012).	

[15] The Anacostia River Corridor Restoration Plan focuses on restoration within the "Anacostia River corridor", defined as the area within the 500-year floodplain.

[16] See survey results here: https://static1.squarespace.com/static/5dc46086500d3257be55730d/t/6388d2a12727f925ffef083d/1669911202478/Public+Survey+Input+Summary+PDF.pdf.

RESTORATION APPROACHES	RESTORATION PROJECT TYPES	DESCRIPTION AND PROJECT EXAMPLES	INJURY CATEGORIES ADDRESSED
	Goose management	Large populations of resident Canada geese (*Branta canadensis*) damage vegetation, displace other waterfowl, and negatively impact surface water (and sediment) quality. Managing geese populations through culling resident populations/reproductive control, habitat modification (e.g., riparian buffers, exclusion fencing), scare/harassment programs (e.g., visual deterrents and dogs), and public education (DOI 2014) would improve surface water (and sediment) quality and benefit biological resources either directly by preventing displacement or indirectly through improved habitat.	
	Contaminant reduction	Improper use and disposal of pesticides, herbicides, and fertilizers can lead to the contamination of natural resources. Public outreach, educational programs, and encouraging the use of safer alternatives can minimize contamination. Reducing combined sewer overflows and repairing sewer leaks will also reduce contamination due to sanitary discharges to waterways. Street sweeping is a cost-effective method of removing particulate debris, and associated contaminants, from streets and roadways that would otherwise enter waterways via runoff (AWTA 2002, DDOE 2012, AWRP 2010).	
Enhance and restore habitat	Wetland restoration	Creating new wetlands and/or restoring existing degraded wetlands would restore a variety of critical ecosystem and human use services (AWRP 2010). Wetland restoration techniques include backfilling ditches, constructing berms, installing water control structures, reconnecting floodplains, and removing culverts.	
	Buffer strip enhancement	Vegetated riparian buffers have been reduced through the historical development of the banks of the Anacostia River. Planting of riparian buffers along the Anacostia River, including grasses, shrubs, and trees, would protect surface water quality, provide wildlife habitat, and stabilize stream banks (AWTA 2012).	
	Enhancement of habitat in the Anacostia River	Prominent fish barriers have curtailed fish migration in the Anacostia River for decades. Removing or modifying these blockages through replacement with riffle grade control structures would make more stream habitat available for fish migration (AWRP, 2010). Natural channel design techniques such as re-establishing meanders, reconnecting the channel to the floodplain, and removing hardened structures would re-establish floodplain functions and enhance wildlife habitat as well (AWTA 2012).	

RESTORATION APPROACHES	RESTORATION PROJECT TYPES	DESCRIPTION AND PROJECT EXAMPLES	INJURY CATEGORIES ADDRESSED
	Seawall restoration	Repairing damaged portions of seawalls would address public safety, while removing certain portions of seawalls to create a "living shoreline" would provide safer access to the water for animals and people and improve the appearance and enjoyment of the Anacostia River (FEA 2021).	
Enhance biological resources	Fish stocking	Impassable barriers have adversely affected native fish species. Larval fish stocking programs would restore native fish populations in the Anacostia River (Ducnuigeen et al. 2002).	
	Bird nesting enhancement	Habitat reduction and development has reduced the number of available nesting sites for certain bird species. Installment of nest boxes in the Anacostia River area would enhance nesting habitat for local cavity nesters, such as bluebirds.[1]	
	Mussel restoration	Reintroducing common species of freshwater mussels into formerly degraded streams would improve water quality and enhance aquatic ecosystem services. Mussels filter sediments, nutrients, and bacteria from the water and provide habitat for other organisms (AWS 2023).	
Increase public access to the Anacostia River	Park enhancement	The restoration or creation of boardwalks, trails, exhibits, printed materials, and educational programs at parks would encourage park use and enhance the public experience. Removing trash directly from the tidal Anacostia River reach by boat, trash trapping devices, and volunteers would beautify public spaces and also reduce the dangers that trash pose to wildlife and aquatic plants. Purchasing land for parkland would create more opportunities for park recreation (AWTA 2012, DDOE 2012, AWRP 2010).	
	Boating/swimming access enhancement	Local programs that offer free kayaking/canoeing opportunities would make boating on the Anacostia more accessible for community members.[2] The construction of additional public boat ramps, docks, and swimming infrastructure would increase the accessibility of the Anacostia River.[3] Currently, sand bars and shallow depths can prevent boaters from safely boating on the Anacostia River. Navigational dredging of the Anacostia River would allow recreators to more safely boat by removing these barriers (DOEE 2022b).	
	Enhance fishing opportunities	Local fishing programs that promote safe fishing on the Anacostia River and proper fish preparation can enhance fishing opportunities for community members.[4] The addition of public docks and ramps along the Anacostia River would provide more spaces for anglers to fish and allow them to more easily fish by boat.	

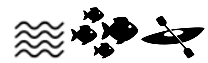
RESTORATION APPROACHES	RESTORATION PROJECT TYPES	DESCRIPTION AND PROJECT EXAMPLES	INJURY CATEGORIES ADDRESSED
Address EJ issues	Improve access and use of natural resources by local communities	Projects that create or enhance access and use of the Anacostia River and outdoor natural resources (e.g., local park improvements) by local communities and disparately affected communities in particular would address EJ concerns.	
	Enhance overall community connections to a healthy Anacostia River	Projects that engage the local community and enhance their interaction with the Anacostia River would address EJ concerns. Some examples include sponsoring events that bring disadvantaged youth from the community back to the Anacostia River, providing information on what species and quantities of fish are safe to eat, and supporting efforts to increase community involvement in restoration decisions and activities that impact the Anacostia River.	
Restore Groundwater Resources	Recharge protection, storm water management	Groundwater has been degraded throughout the Anacostia River watershed. Projects that reduce stormwater flow to the Anacostia River and enhance recharge of clean groundwater would contribute to restoring injured groundwater.	

Table Notes:
1. See, for example: https://www.hyattsvillewire.com/2022/03/08/anacostia-river-bluebirds.
2. See, for example: https://www.kingmanisland.com/green-boats.
3. See, for example: https://chesapeakebaymagazine.com/new-dock-brings-better-public-access-to-anacostia-river.
4. See, for example: https://www.chesapeakebay.net/news/blog/dishing-on-fish-consumption and https://www.anacostiariverkeeper.org/friday-night-fishing.

5.4.3 RESTORATION PROJECT EVALUATION AND SELECTION PROCESS

The Trustees will select restoration projects in accordance with the CERCLA NRDAR regulations. The CERCLA NRDAR regulations require trustees to evaluate restoration alternatives based at least on the following factors (43 C.F.R. § 11.82(d)):

- Technical feasibility.
- The relationship of the expected costs of the proposed actions to the expected benefits from the restoration, rehabilitation, replacement, and/or acquisition of equivalent resources.
- Cost-effectiveness.
- The results of any actual or planned response actions.
- Potential for additional injury resulting from the proposed restoration, including long-term and indirect impacts, to the injured resources or other resources.
- The natural recovery period.
- Ability of the resources to recover with or without the restoration.

- Potential effects of the restoration on human health and safety.
- Consistency with relevant Federal, state, and Tribal policies (as applicable).
- Compliance with applicable Federal, state, and Tribal laws (as applicable).

In addition to evaluating restoration alternatives using the listed CERCLA criteria, the Trustees will evaluate projects in context with regional plans, such as the anticipated ARCRP, ARSP and any Trustee-specific restoration planning documents.

The Trustees can also establish additional restoration criteria for purposes of screening or prioritizing specific restoration alternatives. For example, priority may be given to projects that provide additional benefits to the public that go above and beyond restoration of natural resources and resource services, which are the focus of the NRDAR process. As noted above, selected restoration alternatives will be made available to the public for review and comment. A key component of the assessment will be meaningful involvement by the local community in selecting and planning any actions to restore the Anacostia River to its baseline condition, and to replace past and ongoing service losses through restoration.

REFERENCES

AECOM. (2016). Operable Unit 2 – Remedial Investigation and Feasibility Study, Washington Gas Light East Station Site. Draft Mobilization 2 Technical Memorandum. Prepared for Washington Gas Light. September.

AECOM. (2019). Operable Unit 2 – Remedial Investigation and Feasibility Study, Washington Gas Light East Station Site. Technical Memorandum 5. Hydrogeologic Data and Mass Flux/Mass Discharge Results. Prepared for Washington Gas. August.

AECOM. (2020). Remedial Investigation Report. Final. Benning Road Facility, 3400 Benning Road, N.E., Washington, DC 20019. Prepared for Pepco and Pepco Energy Services. February. Available online at: https://www.benningservicecenter.com/library/documents/RemedialInvestigationReport(Final)/RemedialInvestigationReport(Final)_February2020.pdf.

Anacostia Watershed Restoration Partnership (AWRP). (2010). Anacostia River watershed restoration plan and report. Final draft. February. Available online at: https://www.anacostia.net/archive/download/arp/Anacostia-Report-Web-Quality.pdf.

Anacostia Watershed Society (AWS). (2023). Mussel restoration. Available online at: https://www.anacostiaws.org/what-we-do/river-restoration-projects/habitat-restoration/mussel-restoration.html.

Anacostia Watershed Toxics Alliance (AWTA). (2002). Charting a course toward restoration: a contaminated sediment management plan. Available online from the ARSP administrative record at: https://www.dropbox.com/sh/moh193z9qk7038c/AAD_ZrohaH-NANeh7lnzOO5Za?dl=0&preview=Charting+A+Course+Towards+Restoration_+A+Toxic+Chemical+Management+Strategy+for+the+Anacostia+River.pdf.

Bergstrom, J.C., Boyle, K.J., Job, C.A., and Kealy, M.J. (1996). Assessing the economic benefits of ground water for environmental policy decisions. *JAWRA Journal of the American Water Resources Association,* 32(2), 279-291.

Bergstrom, J.C., Boyle, K.J., and Poe, G.L. (2001). The economic value of water quality. *Faculty and Staff Monograph Publications*, 159. Available online at: https://digitalcommons.library.umaine.edu/fac_monographs/159.

CH2M Hill. (2018). Operable Unit 1 Groundwater Focused Remedial Investigation Report Facility-Wide Remedial Investigation Report. Washington Navy Yard Washington, DC. Prepared for the Department of the Navy Naval Facilities Engineering Command Washington.

Chen, W.Y., Li, X., and Hua, J. (2019). Environmental amenities of urban rivers and residential property values: a global meta-analysis. *Science of the Total Environment*, 693, 133628-133628. doi: 10.1016/j.scitotenv.2019.133628.

de Bell, S., Graham, H., Jarvis, S., and White, P. (2017). The importance of nature in mediating social and psychological benefits associated with visits to freshwater blue space. *Landscape and Urban Planning*, 167, 118-127. https://doi.org/10.1016/j.landurbplan.2017.06.003.

Department of Energy and Environment (DOEE). (2018). Anacostia River Sediment Project (ASRP) Anacostia River Use Survey/ASRP Updates. March 8.

Department of Energy and Environment (DOEE). (2020). Interim Record of Decision (ROD). Early action areas in the main stem, Kingman Lake, and Washington Channel. Anacostia River sediment project, Department of Energy and Environment, Government of the District of Columbia. Available online at: https://www.dropbox.com/s/iunneje3g7a8l8n/Anacostia%20River%20Sediment%20Project_Interim%20Record%20of%20Decision_2020Sept30.pdf?dl=0.

Department of Energy and Environment (DOEE). (2022a). Restoring the Anacostia River. Available online at: www.restoretheanacostiariver.com.

Department of Energy and Environment (DOEE). (2022b). Anacostia River corridor restoration plan public survey #1 consolidated summary of responses. Washington, DC. October. Available online at: https://static1.squarespace.com/static/5dc46086500d3257be55730d/t/6388d2a12727f925ffef083d/1669911202478/Public+Survey+Input+Summary+PDF.pdf.

District Department of the Environment (DDOE). (2008). Anacostia 2032: plan for a fishable and swimmable Anacostia River. May. Available online at: http://ddotfiles.com/awi/documents/Anacostia2032.pdf.

District Department of the Environment (DDOE). (2012). Anacostia River Watershed Implementation Plan (WIP). January. Available online at: https://doee.dc.gov/sites/default/files/dc/sites/ddoe/publication/attachments/Anacostia_WIP_2012_Final.pdf.

U.S. Department of the Interior (DOI). (2014). Anacostia Park Wetlands and Resident Canada Goose Management Plan/Environmental Impact Statement. National Park Service. October. Available online at: https://parkplanning.nps.gov/document.cfm?parkID=425&projectID=18040&documentID=51012.

U.S. Department of the Interior (DOI). (2017). Anacostia Park Management Plan Environmental Assessment. National Park Service. National Capital Parks – East. Washington, DC. February. Available online at: https://parkplanning.nps.gov/document.cfm?documentID=77221.

U.S. Department of the Interior (DOI). (Undated). Foundation Document Overview Anacostia Park and Kenilworth Park and Aquatic Gardens. National Park Service. District of Columbia. Available online at: http://npshistory.com/publications/foundation-documents/anac-keaq-fd-overview.pdf.

District of Columbia, United States Department of the Interior, and National Oceanic and Atmospheric Administration. (2021). Pre-assessment screen determination for Anacostia River. Washington, DC. Available online at: https://www.dropbox.com/s/6ucs84rt6y76uex/20210728_FINAL_PAS_signed%2020211001.pdf?dl=0.

Ducnuigeen, J., Cummins, J., Trieu, P., and Galli, J. (2002). Spring 2002 Anacostia tributary system river herring monitoring/reconnaissance and larval stocking project. Prepared for Potomac Crossing Consultants. Interstate Commission on the Potomac River Basin and Metropolitan Washington Council of Governments. Available online at: https://www.potomacriver.org/publications/spring-2002-anacostia-tributary-system-river-herring-monitoringreconnaissance-and-larval-stocking-project/.

Environmental Consultants and Contractors, Inc. (2004). Tri-annual groundwater monitoring report, sampling date: August 2, 2004, Steuart Investment Company Site, 1721 South Capitol Street, S.W., Washington, D.C., 20003, D.C. LUST Case No. 87-012. November.

U.S. Environmental Protection Agency (EPA). (1993). Interim report on data and methods for assessment of 2,3,7,8-tetrachlorodibenzo-p-doxin risks to aquatic life and associated wildlife. Office of Research and Development. Washington, DC. EPA/600/R-93/055. March.

U.S. Environmental Protection Agency (EPA). (1995). A framework for measuring the economic benefits of groundwater. October. Available online at: https://www.epa.gov/environmental-economics/framework-measuring-economic-benefits-ground-water-1995.

Facility Engineering Associates, P.C. (FEA). (2021). Final report for project scoping assessment, rehabilitate Anacostia River Seawalls National Capital Parks – East (NACE), NPS Order No. 140P2019F0280, FEA Project No. R05.2015.000986.009.

Fiske, S.J., and Callaway, D. (2019). Subsistence fishing on the Potomac and Anacostia Rivers: an ethnographic resource study. University of Maryland. National Park Service, National Capital Region. Chesapeake Watershed Cooperative Ecosystem Studies Unit. #P11AC30805. September. Available online at: http://npshistory.com/publications/nace/subsistence-fishing.pdf.

Freeman, A.M. (2003). The measurement of environmental and resource values, theory and methods. Resources for the Future, Washington, D.C.

Geosyntec Consultants. (2013). Final yard office site assessment report and corrective action plan, Benning Yard, District of Columbia. April.

Gibson, J.C. and McClafferty, J.A. (2005). Chesapeake Bay angler interviews: identifying populations at risk for consuming contaminated fish in three regions of concern. CMI-HDD-05-01. Conservational Management Institute. Chesapeake Bay Program. March 29.

The Johnson Company, Inc. (JCO). (2012). Feasibility study report: Kenilworth Park Landfill. Northeast, Washington, D.C. Prepared for the National Park Service, April. Available online at: https://parkplanning.nps.gov/document.cfm?parkID=498&projectID=42556&documentID=47544.

The Johnson Company, Inc. (JCO). (2016). Supplemental groundwater study report, Kenilworth Park Landfill. Prepared for the National Park Service. November 18.

MacDonald, D.D., Ingersoll, C.G., and Berger, T.A. (2000). Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. *Archives of Environmental Contamination and Toxicology*, 39, 20-31. Available online at: https://doi.org/10.1007/s002440010075.

Maryland Department of the Environment (MDE). (2023). Maryland fish consumption advisories. Accessed March 23, 2023: https://mde.maryland.gov/programs/Marylander/fishandshellfish/Documents/Maryland_Fish_Advisories.pdf.

McGee, B.L., Pinkney, A.E., Velinsky, D.J., Ashley, J.T., Fisher, D.J., Ferrington, L.C., and Norberg-King, T.J. (2009). Using the sediment quality triad to characterize baseline conditions in the Anacostia River, Washington, DC, USA. *Environmental Monitoring and Assessment*, 156, 51-67. Available online at: https://doi.org/10.1007/s10661-008-0462-8.

Murray, R., Wilson, S., Dalemarre, L., Chanse, V., Phoenix, J., and Baranoff, L. (2020). Should we put our feet in the water? Use of a survey to assess recreational exposures to contaminants in the Anacostia River. *Environmental Health Insights*, 9(s2), 19-27. Available online at: https://journals.sagepub.com/doi/full/10.4137/EHI.S19594.

National Oceanic and Atmospheric Administration (NOAA). (2007). Anacostia River watershed database and mapping project. Natural Resources. Available online at: http://mapping2.orr.noaa.gov/website/portal/AnacostiaRiver/natresources_fish.html.

National Research Council. (1997). Valuing ground water: economic concepts and approaches. Washington, DC: The National Academies Press. Available online at: https://doi.org/10.17226/5498.

Nutsford, D., Pearson, A.L., Kingham, S., and Reitsma, F. (2016). Residential exposure to visible blue space (but not green space) associated with lower psychological distress in a capital city. *Health and Place*, 39, 70-78.

OpinionWorks. (2012). Addressing the risk: understanding and changing anglers' attitudes about the dangers of consuming Anacostia fish. October. Available online at: https://drive.google.com/file/d/1QO4yi1nr2n5_cdCPu6y5o-9LrGNEbzti/view.

Polyakov, M., Iftekhar, M.S., Fogarty, J., and Buurman, J. (2022). Renewal of waterways in a dense city creates value for residents. *Ecological Economics*, 199. Available online at: https://www.sciencedirect.com/science/article/abs/pii/S0921800922001306.

QuanTech. (2020). Anacostia River creel angler survey. Summary report for AECOM environment. February.

Raffensperger, J.P., Voronin, L.M., and Dieter, C.A. (2021). Simulation of groundwater flow in the aquifer system of the Anacostia River and surrounding watersheds, Washington, DC, Maryland, and Virginia (No. 2013-5225). U.S. Geological Survey. Available online at: https://pubs.er.usgs.gov/publication/sir20135225.

Ridolfi Engineers, Inc. (2003). Phase 1 Environment Site Assessment, Poplar Point Site (section one), Washington, D.C. Prepared for the District of Columbia and the National Oceanic and Atmospheric Administration.

Robinson, M. (2022). Federal/DC Local Agency Joint Meeting #1: Background on the DC Anacostia River Corridor Restoration Plan. Partnering & Environmental Conservation Branch. Watershed Protection Division. Department of Energy and Environment. May 24.

Schlekat, C.E., McGee, B.L., Boward, D.M., Reinharz, E., Velinsky, D.J., and Wade, T.L. (1994). Tidal River Sediments in the Washington, DC area. III. Biological effects associated with sediment contamination. *Estuaries*, 17(2), 334-344.

SmithGroup. (2019). Anacostia River Pool Study: A feasibility study for a swimming facility in the Anacostia River, Washington, DC. Available online at: https://www.anacostiariverpool.com/study.

Sun, H., Bergstrom, J.C., and Dorfman, J.H. (1992). Estimating the benefits of groundwater contamination control. *Journal of Agricultural and Applied Economics*, 24(2), 63-71.

Tetra Tech. (2019a). Appendix I Baseline Ecological Risk Assessment. Anacostia River Sediment Project, Washington, D.C. Prepared for Department of Energy and Environment. October.

Tetra Tech. (2019b). Remedial Investigation Report. Anacostia River Sediment Project, Washington DC. Prepared for Department of Energy and Environment. December.

Tetra Tech. (2019c). Surface Water Model Report Anacostia River Sediment Project Hydrodynamic and Fate and Transport Modeling. Prepared for Department of Energy and Environment. December.

Van den Berg, M., Birnbaum, L., Bosveld, A.T., Brunström, B., Cook, P., Feeley, M., Giesy, J.P., Hanberg, A., Hasegawa, R., Kennedy, S.W., and Kubiak, T. (1998). Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. *Environmental Health Perspectives*, 106(12), 775-792. Available online at: https://ehp.niehs.nih.gov/doi/10.1289/ehp.98106775.

Völker, S., and Kistemann, T. (2013). "I'm always entirely happy when I'm here!" Urban blue enhancing Human Health and Well-Being in Cologne and Düsseldorf, Germany. *Social Science and Medicine*, 78, 113-124. Available online at: https://www.sciencedirect.com/science/article/abs/pii/S0277953612008039.

Walsh, B.M., Campbell, J.P., Costanzo, S.D., Dennison, W.C., Lehman, M., Milton, M. Nortrup, M., and Syphax, S. (2016). National Capital Parks – East Natural Resource Condition Assessment: National Capital Region. Natural Resource Report NPS/NACE/NRR--2016/1197. National Park Service. Fort Collins, Colorado. Available online at: https://irma.nps.gov/DataStore/Reference/Profile/2229145.

APPENDIX A | QUALITY ASSURANCE PLAN

The Trustees recognize the importance of data quality in the context of the collection, compilation, evaluation, and reporting of environmental data necessary to perform the assessment. This Appendix serves as the Quality Assurance Plan (QAP) for the NRDAR. It has been developed to ensure that all environmental data and related information relied upon in the NRDAR are scientifically valid for their intended use.

Although the DAP emphasizes the use of existing information, it is possible that the Trustees may collect some primary data as part of the NRDAR. Therefore, the guidance detailed below focuses primarily on quality assurance (QA)/quality control (QC) elements to consider in the context of project planning for specific primary data collection efforts.

When only existing information or data are used, the Trustees (or any consultants or Principal Investigators (PIs) working on their behalf) shall make every effort to document the quality of the underlying data and take into consideration the intended use and objective(s) of the previously generated data when deciding on its applicability to the NRDAR. However, not all standard quality system components are necessarily applicable to the use of existing data. That is, quality system components shall be consistent with, and supportive of, project objectives (i.e., will have a graded approach, as described in EPA 2001). In other words, the level of application of quality system controls to an environmental data program can vary according to the intended use of the results and the degree of confidence needed in the quality of the results. Given the unique need in the NRDAR to understand historical resource conditions, the Trustees will make every effort to use existing data, keeping in mind and appropriately documenting its underlying quality. The Trustees shall also reserve the right to implement additional, more stringent quality management systems (or standards), depending on the intended use of the existing data.

For any new studies (i.e., primary data collection) that are specifically undertaken to support the NRDAR process, appropriate study-specific quality assurance project plans (QAPPs) will be developed according to the general principles described below. As noted by EPA (2001), QAPPs will "vary according to the nature of the work being performed and the intended use of the data" and as such, need to be tailored to match the specific data-gathering needs of a particular project (40 C.F.R. § 300.5). Primary data collection under the NRDAR effort may entail different data-gathering efforts. This could include efforts as diverse as collection of environmental samples or solicitation of information through surveys of the public. Therefore, the Trustees will ensure that individual study plans that include appropriate QAPP components are developed in circumstances where primary data collection will take place. In developing such plans, the Trustees may consult EPA's Guidance for Quality Assurance Project Plans (EPA 2002a).

In general, a project-specific QAPP must provide sufficient detail to demonstrate that:

- The project's technical and quality objectives are identified and agreed upon;
- The intended measurements, data generation, or data acquisition methods are appropriate for achieving project objectives;
- Assessment procedures are sufficient for confirming that data of the type and quality needed and expected are obtained; and
- Any limitations on the use of the data can be identified and documented (EPA 2001).

Accordingly, project-specific QAPPs developed for this assessment will include the four elements called for by EPA:

- **Project Management** – documents that the project has a defined goal(s), that the participants understand the goal(s) and the approach to be used, and that the planning outputs have been documented;
- **Data Generation and Acquisition** – ensures that all aspects of project design and implementation including methods for sampling, measurement and analysis, data collection or generation, data compiling/handling, and QC activities are documented and employed;
- **Assessment and Oversight** – assesses the effectiveness of the implementation of the project and associated QA and QC activities; and,
- **Data Validation and Usability** – addresses the QA activities that occur after the data collection or generation phase of the project is completed.

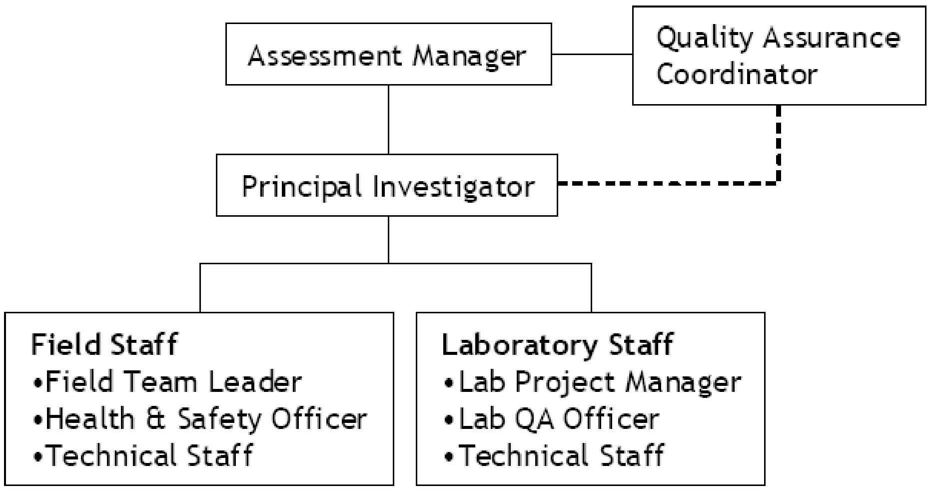
Each of these elements, as well as some additional quality system components, are addressed in greater detail in the sections below.

A.1 PROJECT MANAGEMENT

Effective implementation of project objectives requires clear project organization, which includes carefully defining the roles and responsibilities of each project participant. Unambiguous personnel structures help ensure that each individual is aware of his or her specific areas of responsibility, as well as clarifying internal lines of communication and authority, which is important for decision-making purposes as projects progress. Individuals' and organizations' roles and responsibilities may vary by study or task, but each person's role and responsibility should be clearly described in the project's study plan. Exhibit A-1 below presents a generic personnel plan for a NRDAR project. The actual personnel plan may be tailored to the needs of the specific task, based on scope, the specific goals of the task, staffing, or other factors.

The Assessment Manager is the designated Trustee representative with responsibility for the review and acceptance of the project-specific study plan. This individual is also responsible for ensuring that the project's goals and design will meet the broader requirements of the NRDAR. The Assessment Manager coordinates efforts with the Quality Assurance Coordinator and oversees the PI for the study. Note that in some cases, the Principal Investigator may be the same person as the Assessment Manager.

The QA Coordinator oversees the overall conduct of the quality system. Appointed by the Trustees, this individual's responsibilities include, but are not limited to: reviewing/assisting the PI with the development of project-specific study plans; conducting audits and ensuring implementation of both project-specific and overall plans; archiving samples, data, and all documentation supporting the data in a secure and accessible form; and reporting to the Trustees. To ensure independence, the person serving as QA Coordinator will not serve as either the Assessment Manager or as a PI for any NRDAR study.



Study-specific PIs oversee the design and implementation of particular NRDAR studies. Each PI has the responsibility to ensure that all health, safety, and relevant QA requirements are met. If deviations from the QAPP occur, the PI (or his/her designee) will document these deviations and report them to the Assessment Manager and the QA Coordinator.

The Field Team Leader supervises day-to-day field investigations, including sample collection, field observations, and field measurements. The Field Team Leader generally is responsible for ensuring compliance with all field quality assurance procedures defined in the study-specific QAPP. Similarly, the Laboratory Project Manager is responsible for monitoring and documenting the quality of laboratory work. The Health & Safety Officer (who may also be the Field Team Leader) is responsible for ensuring adherence to specified safety protocols in the field.

A.2 SHARING DATA, SPLIT SAMPLES, AND ANALYTICAL RESULTS

Section 11.31(a)(4) of the CERCLA NRDAR regulations states that, “The Assessment Plan shall contain procedures and schedules for sharing data, split samples, and results of analyses, when requested, with any identified potentially responsible parties and other natural resource trustees.”

If the Trustees determine that a study should be implemented, a study plan with appropriate QAPP components will be developed in collaboration with a PI. These QAPPs will include study objectives, approaches for sharing and publishing data and analytical results with relevant parties, and conditions and procedures for sharing split samples with PRPs.

A.3 DATA GENERATION AND ACQUISITION

All studies under the direction of the Trustees that are specifically undertaken to generate primary data in support of the NRDAR will have a prepared QAPP that will be completed prior to the initiation of any work. These QAPPs will be submitted to, and approved by, the QA Coordinator or designee and generally include:

- Rationale for generating or acquiring the data;
- Proposed method(s) for generating or acquiring the data, including descriptions of (or references to) standard operating procedures for all sampling or data-generating methods and analytical methods;
- Types and numbers of samples required;
- Analyses to be performed;
- Sampling locations and frequencies;
- Sample handling and storage procedures;
- Chain-of-custody procedures;
- Data quality requirements (for instance, with respect to precision, accuracy, completeness, representativeness, comparability, and sensitivity);
- Description of the procedures to be used in determining if the data meet these requirements;
- Description of the interpretation techniques to be used, including statistical analyses; and
- Split sample protocols and procedures for archiving samples and management of residuals.

In addition, to the extent practicable, laboratories are required to comply with Good Laboratory Practices (21 C.F.R. Part 58). This includes descriptions and documentation of maintenance, inspections of instruments, and acceptance testing of instruments, equipment, and their components, as well as the calibration of such equipment and the maintenance of all records relating to these exercises. Documentation to be included with the final report(s) from each study will include field logs for the collection or generation of the samples, chain of custody records, and other QA/QC documentation as applicable.

A.4 ASSESSMENT AND OVERSIGHT

To ensure that the study plan for each project is implemented effectively, the QA Coordinator will review QAPPs for all Trustee studies that generate data. The QA Coordinator or designee will also audit all such studies. Audits will include technical system audits (e.g., evaluations of operations) as well as scrutinizing data and reports (e.g., evaluations of data quality and adequacy of documentation).

If, in the professional opinion of the QA Coordinator, the results of an audit indicate a compromise in the quality of the collection, generation, analysis, or interpretation of the data, the QA Coordinator has the authority to stop work by oral direction. Within a pre-agreed upon time frame of this direction, the QA Coordinator should submit to the Trustee Council a written report describing the necessity for this direction. The Assessment Manager should also consult with the Trustees regarding measures to be taken in response to the QA Coordinator’s report.

A.5 DATA VALIDATION AND USABILITY

In addition to the assessment and oversight activities described previously, analytical data may need to be considered for validation by an independent third party. Prompt validation of analytical data can assist the analyst or analytical facility in developing data that meet the requirements for precision and accuracy. If undertaken, it is expected that data validation should use the study-specific study plans and EPA Guidance on Environmental Verification and Validation (EPA 2002b).

REFERENCES

U.S. Environmental Protection Agency (EPA). (2001). EPA requirements for quality assurance project plans. EPA QA/R-5. March. Reissued May 2006.

U.S. Environmental Protection Agency (EPA). (2002a). Guidance for quality assurance project plans. EPA QA/G-5. Office of Environmental Information. EPA/240/R-02/009. Washington, DC. December. Available online at: http://www.epa.gov/quality/qs-docs/g5-final.pdf.

U.S. Environmental Protection Agency (EPA). (2002b). Guidance on environmental data verification and data validation. EPA QA/G-8. Office of Environmental Information. EPA/240/R-02/004. Washington, DC. November. Available online at: http://www.epa.gov/quality/qs-docs/g8-final.pdf.

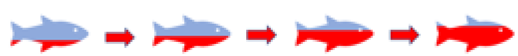
APPENDIX B | INFORMATION ON THE CONTAMINANTS OF CONCERN OF INITIAL FOCUS FOR THE ECOLOGICAL INJURY ASSESSMENT

POLYCYCLIC AROMATIC HYDROCARBONS (PAHS)

PAHs are a class of organic compounds comprising more than 100 different individual chemicals composed of two or more fused benzene rings. PAHs are present in petroleum and petroleum products, but also arise from the incomplete combustion of organic matter, such as coal, oil, wood, or garbage. Exhaust from automobiles and trucks is often a major source of PAHs in urban environments. PAHs may exist as vapors or attach to particles and, thus, are typically associated with soil or sediment, though small fractions of these chemicals can re-volatilize into the air or dissolve into surface or groundwater. PAHs have high resistance to biodegradation and can persist in the environment for long periods of time. When humans are exposed to PAHs, the compounds can accumulate in the kidneys, liver, and fatty tissue. The International Agency for Research on Cancer (IARC) and the U.S. Environmental Protection Agency (EPA) have classified eight PAHs as probably or possibly carcinogenic (ASTDR 1995).[17]

BIOACCUMULATION VS BIOMAGNIFICATION

Bioaccumulation: contaminants accumulate in organisms over time through respiration, consumption of contaminated food, and dermal absorption.



Biomagnification: contaminants accumulate up the food chain.

Source: Alexander (1999).

In ambient water, PAHs preferentially adsorb to particulate organic matter and can accumulate in bottom sediments due to their low solubility and hydrophobicity (McGrath et al. 2019, Nikolaou et al. 2009). In sediment, PAHs have been shown to be toxic to sediment-dwelling biological organisms, and sediment quality guidelines have been developed for their protection (Jesus et al. 2022, McGrath et al. 2019). In marine sediments, studies have demonstrated PAH toxicity to algae and mussels through alteration of growth and protein functions, respectively (Nikolaou et al. 2009, Tolun et al. 2001, Maria et al. 2013). In freshwater sediments, a review of PAH toxicity to benthic fauna by Jesus et al. (2022) showed that toxic outcomes include adverse effects on growth, reproduction, and survival of benthic organisms, but vary depending on the hydrophobicity of the individual PAH compound and

[17] The IARC lists benz[a]anthracene and benzo[a]pyrene as probably carcinogenic to humans and benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, and indeno[1,2,3-c,d]pyrene as possibly carcinogenic to humans (ASTDR 1995). The EPA lists benz[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene as probably carcinogenic to humans (ASTDR 1995).

porewater concentration (Jesus et al, 2022). PAHs, especially the higher molecular weight compounds, do not tend to biomagnify up the food chain because higher trophic level organisms can metabolize and excrete PAHs (Malcom and Shore 2003, Poston 2001, Honda and Suzuki 2020).

Fish may be exposed to PAHs in sediments and water via respiration, ingestion, and absorption; though toxicity varies by species (Logan 2007). Toxicological effects reported in fish include narcosis, growth inhibition, cardiac dysfunction, and liver tumors and lesions (Barron et al. 2000, Incardona et al. 2004, Logan 2007). In fact, liver tumors in brown bullhead (*Ameiurus nebulosus*) have been associated with PAHs and other contaminants in the Anacostia River (Pinkney et al. 2019). Like fish, birds may be exposed to PAHs in sediments due to consumption of contaminated invertebrate prey (King et al. 2020). However, birds rapidly metabolize PAHs, so PAHs are rarely detectable in avian tissues (Malcom and Shore 2003). Nevertheless, PAHs in egg-laying females and eggs have been shown to impair avian reproduction, though sensitivity to PAHs is species-dependent (Malcom and Shore 2003). Cardiovascular and neurological effects in birds have also been associated with PAH exposure via spilled oil, which may include other toxic chemical constituents (Takeshita et al. 2021). PAHs have been reported as carcinogenic (ATSDR 1995) and may adversely affect immune function and alter bone metabolism in mammals (Honda and Suzuki 2020, Malcom and Shore 2003). Finally, in the context of oil spills, respiratory, reproduction, endocrine, immune, and metabolism problems in mammals have been partially attributed to PAHs (Takeshita et al. 2021).

POLYCHLORINATED BIPHENOLS (PCBS)

PCBs are synthetically made, chlorine-containing compounds that were produced, and typically exist in the environment, as mixtures of individual congeners. Each congener consists of two joined benzene (phenyl) rings on which one or more chlorines have been substituted for the hydrogen atoms; thus, different congeners have different numbers and placements of chlorine atoms around the benzene rings. Certain PCBs have chlorine atoms positioned in locations that gives them a coplanar form, which is similar to the molecular structure of dioxin compounds (another kind of highly toxic, persistent organic pollutant). The structural similarity of dioxins and dioxin-like coplanar PCBs means they have a similar mode of toxicity. Because of this, scientists developed a “toxic equivalency” framework through which the total toxic effects of this group of compounds can be estimated (see text box on Dioxin-like Toxic Equivalency, below). PCBs were utilized widely in electrical equipment until 1977 when their manufacture was banned due to their persistence in the environment and toxicity. Despite stopping the use of PCBs decades ago, these compounds remain in the environment due to their high resistance to environmental degradation. PCBs’ fate in the environment is influenced by molecular weight, with heavier compounds being less water-soluble and more strongly adsorbing to sediment. Humans are commonly exposed to PCBs through ingestion of PCB-contaminated food sources such as meat or fish. After entering the body, PCBs have the capacity to remain stored in the fat and liver for years. The IARC and EPA have classified PCBs as probable carcinogens (ASTDR 2000).

In the environment, PCBs tend to adhere to soil or sediment particles since their chemical structure makes them hydrophobic. However, in aquatic environments, sediment-associated PCBs can cause adverse chemical and biological effects on aquatic organisms. Aqueous and sediment toxicity tests conducted on estuarine invertebrates have shown PCBs affect survival of benthic amphipods and shrimp (Finkelstein et al. 2020). However, PCBs can also bioaccumulate in aquatic animals as well as biomagnify through food chains, leading to greater PCB exposures to higher trophic level organisms, with exposure modulated by food chain position and lipid content (Ngoubeyou et al. 2022). Given the biomagnification potential of PCBs, human exposure through the consumption of contaminated food, especially fish, is considered a public health concern.

DIOXIN-LIKE TOXIC EQUIVALENCY

Dioxins are a class of chlorinated organic compounds that are similar in chemical structure and toxicity to coplanar PCBs and other chemicals called furans. Given these chemical similarities, scientists developed a framework to consider the aggregate toxicity of mixtures of these contaminants. In this framework, the potency of an individual PCB congener is estimated by multiplying the tissue concentration of the congener in question by a toxic equivalency factor (TEF) for that congener to yield the toxic equivalent (TEQ) of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Toxicity is normalized in this way to TCDD because it is considered to be the most toxic individual dioxin compound (ASTDR 1998). As a result, the TEF for TCDD has a value of 1 and the TEFs for all of the other, less potent congeners have a value equal to or less than 1.

The toxic potency for the whole mixture of PCBs, dioxins, and furans thus can be determined from the sum of the calculated TEQs (ΣTEQs) for each congener. In the environment, the congener composition of PCB mixtures can vary widely, and as a result, so too can the dioxin-like toxic potential of these mixtures. Further, since biological organisms can exhibit different toxicity to dioxin-like compounds, the TEQ calculations are organism-specific. This led to the establishment of mammalian, fish, and avian TEFs (Van den Berg et al. 1998).

The TEQ approach is recognized by the World Health Organization (WHO), the United States Environmental Protection Agency (U.S. EPA) and by many other jurisdictions as a valid approach for assessing toxicity of PCB mixtures (Van den Berg et al. 2006).

Fish may be exposed to PCBs through respiration via gills and ingestion of PCB-contaminated food and sediment (Ngoubeyou et al. 2022). PCB concentrations tend to be higher in predatory fish due to biomagnification. In a study in Green Bay, Wisconsin, elevated PCBs were associated with increased incidences of lesions and liver tumors in walleye (*Stizostedium vitreum vitreum*) (Barron et al. 2000). A literature review by Berninger and Tillitt (2019) established a protective lower limit of 0.1 ug/g of PCBs in fish tissue, below which adverse toxicological effects to fish should not occur (Berninger and Tillit 2019). Birds are typically exposed to PCBs via consumption of PCB-contaminated prey, so exposure varies by species, dietary patterns, and metabolic rates. For example, in birds near the PCB-contaminated Hudson River, eggs of piscivorous and omnivorous birds had greater concentrations than insectivorous bird eggs, though concentrations of specific PCB congeners varied, reflecting differences in the birds' diets (Custer et al. 2010). PCB contamination in eggs can cause reproductive failure; for example, reductions in osprey (*Pandion haliaetus*) hatching success have been attributed to PCB exposure (Toschik et al. 2005). In addition, PCBs also can cause detrimental effects in birds including endocrine disruption, immunotoxicity, and teratogenesis (Barron et al. 1995). Mammals are also primarily exposed to PCBs by consuming PCB-contaminated prey, frequently fish (Ngoubeyou et al. 2022). In mammals, ingesting PCBs has been shown to cause neurotoxic effects by damaging neurotransmitter pathways (Mariussen and Fonnum 2001). PCBs can also cause harm after birth, as PCBs can be maternally transferred to offspring (Ngoubeyou et al. 2022).

DICHLORODIPHENYLTRICHLOROETHANE (DDT)

Dichlorodiphenyltrichloroethane (DDT), and its breakdown products, dichlorodipheyldichoroethylene (DDE) and dichlorodiphenyldichloroethane (DDD), are persistent organochlorine pesticides. DDT was used extensively for agricultural and non-agricultural purposes until 1979 when the United States and other countries banned its use due to concerns about impacts to non-target receptors. Some DDT use continues globally but it is regulated by the Stockholm Convention, which restricts usage to control diseases like malaria and leishmaniasis. DDT exists in different isomeric forms and breakdown products in the environment; hence, DDT and related compounds (DDE and DDD) are often measured as total or sum DDT. DDT is highly mobile in the environment and is resistant to degradation. Biological organisms are most frequently exposed to DDT via consumption of DDT-contaminated food. This is the main pathway for human exposure as well, with an increased likelihood of exposure in places where DDT is still used today. Exposure to DDT can result in liver toxicity, as well as developmental and reproductive effects. In addition, the EPA and IARC have categorized DDT as a probable carcinogen, with cancers of the liver and lungs a particular concern (ATSDR 2022a).

DDT is ubiquitous in aquatic habitat sediments due to its low water solubility and resistance to environmental degradation (Ma et al. 2019). In such habitats, DDT-contaminated sediments pose a threat to sediment-dwelling biota (Hellou et al. 2013, Ma et al. 2019). Benthic organisms are primarily exposed to DDT through uptake from feeding due to DDT's propensity to bind to particulate matter (Hellou et al. 2013). Midges (*Chironomus dilutus*), a freshwater benthic invertebrate, experienced mortality when exposed to sediment spiked with DDT, and reduced growth, impaired emergence, and fecundity in chronic toxicity tests using field-collected DDT-contaminated sediment (Ma et al. 2019). In addition to causing toxicity to benthic organisms, DDT biomagnifies through the food web and poses greater concern for predators like birds and mammals (Hellou et al. 2013). Even when lower trophic level organisms have low tissue residues of DDT, the contamination can still pose a threat to predators due to bioaccumulation and biomagnification (Beckvar et al. 2005, Hellou et al. 2013).

DDT has been shown to adversely affect survival, growth, reproductive, and behavioral endpoints in fish, though a protective whole body DDT threshold of 0.6 mg/kg wet weight in adult fish tissue has been established based on studies of lethal endpoints in salmonids and other fish (Beckvar et al. 2005). In contrast, DDT toxicological studies for birds have typically investigated reproductive impairments. The first discovered toxic effect of DDT was bird eggshell thinning in the 1940s. This led to many DDT studies testing bird reproductive failure and led to the association of population declines of predator bird species with DDT use; ultimately, DDT in eggs was proven to cause eggshell thinning. Studies also revealed that birds exposed to DDT experienced endocrine, immune, and nervous system impairments, impacting behaviors like migration, aggression, and attentiveness. Beyond birds, reproductive impairment has also been observed in sea lions with elevated DDT exposures, and DDT has been hypothesized to cause premature delivery and stillbirth in mammals. Whales exposed to high DDT concentrations were found to exhibit reproductive impairment in addition to immunosuppression and lesions (Hellou et al. 2013). Such findings are supported by toxicological studies on rats that have revealed DDT can cause neurotoxicity, oxidative stress, and hepatic tumors (Harada et al. 2016).

CHLORDANE

Chlordane is a persistent organochlorine pesticide like DDT and was used beginning in 1948 through the 1980s as a pesticide on agricultural crops, lawns, gardens, and homes. Technical chlordane, in its application as a pesticide, is a complex mixture of chlordane isomers and other organochlorine chemicals. The majority (60-85%) is cis- and trans-chlordane. Other key constituents frequently measured in the environment are cis- and trans-nonachlor, which are two additional isomers of chlordane, and heptachlor epoxide and oxychlordane, two metabolites. EPA initially banned all uses of chlordane except for the control of termites in 1983. Then, EPA banned all uses in 1988, citing concerns for human health, environmental persistence, and wildlife risks. Chlordane tends to bind strongly to soil and sediment and does not break down easily in air. Since it tends to persist in the environment it can be expected to accumulate in sediment and enter the food chain long after application has ceased. IARC has classified chlordane as a possible human carcinogen while the EPA has classified it as a probable carcinogen (ATSDR 2018).

In water, chlordane tends to bind to sediment or particulate matter in the water column. Acute toxicity tests of chlordane on the water flea (*Daphnia magna*) have shown immobilization, reproductive, and growth effects (Manar et al. 2009). Significant effects on survival were also found in chronic toxicity tests at high exposure levels (Manar et al. 2009). Chlordane can also accumulate in aquatic fish, birds, and mammals particularly in fatty tissues (Azim et al. 2011). Accumulation varies based on species-level factors such as metabolism and diet (Borgå et al. 2007). A study of seabirds showed that little auk (*Alle alle*) poorly metabolized and showed greater accumulation of chlordane compared to other birds (Borgå et al. 2007). The persistent and bioaccumulative nature of chlordane has led to the FDA restricting the levels of chlordane allowable in animal fat ingested by humans (USFDA 2000).

Despite no current use, fish continue to be exposed to residual chlordane in the environment through diet, respiration, and dermal contact, though consumption of chlordane-contaminated benthic invertebrates is the primary exposure route for fish (Azim et al. 2011). Toxic effects of chlordane exposure in fish include hyperexcitability, increased respiration rate, erratic swimming, loss of equilibrium, and convulsions (Azim et al. 2011, NRCC 1974). Birds are sensitive to chlordane as well and exhibit sluggishness, reduced food intake, and weight loss upon chlordane poisoning (Stickel et al. 1983). Chlordane exposure has also been shown to impair reproduction in domesticated ducks and other waterfowl (Stickel et al. 1983). Most knowledge regarding mammalian toxicity of chlordane is from studies on laboratory animals. Mammals tend to accumulate chlordane in the liver and kidney. Although mammals can eliminate chlordane via feces, elevated exposures can result in adverse effects on growth and reproduction (Nomeir and Hajjar 1987).

LEAD

Lead is a metal used in many consumer, industrial, agricultural, and medicinal applications. It does not degrade but instead exists in various chemical forms distributed throughout the environment. Lead tends to adsorb strongly to organic matter present in sediment and soil. Adsorption limits the rate of leaching into water, but water chemistry (e.g., low pH, low dissolved organic carbon) can make lead more prone to dissolution. Humans may be exposed to lead in ambient air, food, drinking water, soil, dust, and consumer products. Lead is quickly eliminated from blood (i.e., on a time frame of months) but can remain in bones for longer periods of time. Exposure to lead has been shown to impair organ systems and both the EPA and IARC have classified lead as probably carcinogenic to humans (ATSDR 2020).

Sediments are a common environmental repository for lead in aquatic environments (Rubio-Franchini and Rico-Martínez 2011). At known lead release sites (e.g., downstream of mining), aquatic plants, algae, and aquatic invertebrates have been shown to contain elevated concentrations of lead (Besser et al. 2009, Rubio-Franchini and Rico-Martínez 2011). Chronic sediment toxicity tests have shown that amphipods including *Hyalella azteca* experience reduced survival in sediments with elevated metal contamination including lead (Besser et al. 2009). There is no evidence that biomagnification of lead occurs in aquatic organisms in marine or freshwater environments. However, lower trophic level organisms contain greater lead concentrations than higher trophic level organisms, likely because the majority of lead uptake comes from exposure to lead contaminated sediment and water (Suedel et al. 1994).

Fish are primarily exposed to lead through the gills (i.e., via respiration), as dietary and dermal exposure routes are less important; however, fish can eliminate lead (Rubio-Franchini and Rico-Martínez 2011). The toxic effects of lead to fish include oxidative stress, immune system responses, and neurotoxicity (Ishaque et al. 2020). Like fish, birds may be exposed to lead through inhalation and diet. In birds, lead inhibits the activity of key blood proteins and causes immunosuppression. Other avian toxicological effects due to lead exposure include anorexia, lethargy, convulsions, and leg paralysis (Franson and Pain 2011). In mammals, lead tends to accumulate in the kidney, but can also accumulate in other organs. The primary toxicological mechanism is oxidative stress as the metal reduces proteins and forms reactive oxygen species, which can affect organs throughout the body (Pal et al. 2015).

MERCURY

Mercury is a toxic metal that exists in the environment due to natural sources like wildfires but can also be mobilized from anthropogenic sources like fossil fuel burning. Global bio-geochemical cycling of mercury involves transitions between the atmosphere, surface water, and land (sediment and soil). When present in aquatic habitats, mercury may be converted to methyl mercury, a particularly toxic form of mercury for humans and fish and wildlife species. Humans are primarily exposed to elemental mercury through inhalation, the use of mercury in dental fillings, and diet (ATSDR 2022b). Fish are a significant source of mercury exposure for humans, and the EPA regularly advises children and pregnant women to limit consumption of certain fish species due to elevated mercury levels (EPA 2023). In the body, mercury binds to enzymes and other proteins which creates the potential for a variety of toxicological effects. The IARC and EPA do not classify elemental mercury as carcinogenic but classify methylmercury as possibly carcinogenic (ATSDR 2022b).

In aquatic ecosystems, mercury is toxic to benthic invertebrates, including amphipods, midges, and mayflies. Toxic effects include reduced survival, growth, and development (Conder et al. 2015). When mercury enters the food chain, biomagnification occurs and can result in mercury concentrations in higher trophic level organisms that are millions of times greater than surface water concentrations (Lavoie et al. 2013). Biomagnification of mercury is consistently observed in both freshwater and marine environments and is a major concern for fish and fish-eating wildlife. Sources of mercury uptake in fish include consumption of mercury-contaminated prey and sediment plus respiration through the gills. Mercury primarily targets the central nervous system and kidney, causing appetite loss, brain lesions, and behavioral changes that alter growth, reproduction, and development. Various fish species, including snakehead (*Channa punctatus)* and goldfish (*Carassius auratus*), demonstrated immunotoxicological effects (Morcillo et al. 2017). Similar to fish, birds are primarily exposed to mercury through their diet, which varies by species (Carravieri 2022, Robinson et al. 2012). Birds are at a high risk of mercury toxicity due to its ability to biomagnify through food chains, but birds can excrete mercury via feces, feathers, and egg-laying (Robinson et al. 2012). Mercury is also known to impact birds by altering food foraging abilities, metabolic rates, and stress responses (Carravieri 2022). Other toxicological effects include reproductive impairments like decreased egg hatchability, decreased offspring and likeliness to breed, and altered hormones (Ackerman et al. 2016, Evers et al. 2008). In mammals, mercury adversely affects protein production and function, causes neurotoxic effects due to the impairment of neural stem cells and neuron production that impact the central nervous system, and causes oxidative stress (Abbott and Nigussie 2021).

REFERENCES

Abbott, L. C., and Nigussie, F. (2021). Mercury toxicity and neurogenesis in the mammalian brain. *International Journal of Molecular Sciences*, 22(14), 7520. Available online at: https://doi.org/10.3390/ijms22147520.

Ackerman, J.T., Eagles-Smith, C.A., Herzog, M.P., Hartman, C.A., Peterson, S.H., Evers, D.C., Jackson A.K., Elliott J.E., Vander Pol, S.S., and Bryan, C.E. (2016). Avian mercury exposure and toxicological risk across western North America: A synthesis. *Science of the Total Environment*, 568, 749-769. Available online at: https://doi.org/10.1016/j.scitotenv.2016.03.071.

Agency for Toxic Substances and Disease Registry (ATSDR). (1995). Toxicological profile for polycyclic aromatic hydrocarbons. U.S. Department of Health and Human Services. Public Health Service. August. Available online at: https://www.atsdr.cdc.gov/ToxProfiles/tp69.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR). (1998). Toxicological Profile for chlorinated dibenzo-*p*-dioxins. U.S. Department of Health and Human Services. Public Health Service. December. Available online at: https://www.atsdr.cdc.gov/ToxProfiles/tp104.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR). (2000). Toxicological profile for polychlorinated biphenyls (PCBs). U.S. Department of Health and Human Services, Public Health Service. November. Available online at: https://www.atsdr.cdc.gov/ToxProfiles/tp17.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR). (2018). Toxicological profile for chlordane. U.S. Department of Health and Human Services. Public Health Service. February. Available online at: https://www.atsdr.cdc.gov/ToxProfiles/tp31.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR). (2020). Toxicological profile for lead. U.S. Department of Health and Human Services. Public Health Service. August. Available online at: https://www.atsdr.cdc.gov/ToxProfiles/tp13.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR). (2022a). Toxicological profile for DDT, DDE, and DDD. U.S. Department of Health and Human Services. Public Health Service. April. Available online at: https://www.atsdr.cdc.gov/toxprofiles/tp35.pdf.

Agency for Toxic Substances and Disease Registry (ATSDR). (2022b). Toxicological profile for mercury (Draft for public comment). U.S. Department of Health and Human Services. Public Health Service. April. Available online at: https://www.atsdr.cdc.gov/ToxProfiles/tp46.pdf.

Alexander, D.E. (1999). Bioaccumulation, bioconcentration, biomagnification. In: Environmental Geology. Encyclopedia of Earth Science. Springer, Dordrecht, 43-44. Available online at: https://doi.org/10.1007/1-4020-4494-1_31.

Azim, M.E., Letchumanan, M., Rayash, A.A., Shimoda, Y., Bhavsar, S.P., and Arhonditsis, G.B. (2011). Detection of temporal trends of α-and γ-chlordane in Lake Erie fish communities using dynamic linear modeling. *Ecotoxicology and Environmental Safety*, 74(5), 1107-1121. Available online at: https://doi.org/10.1016/j.ecoenv.2011.04.019.

Barron, M.G., Anderson, M.J., Cacela, D., Lipton, J., Teh, S.J., Hinton, D.E., Zelikoff, J.T., Dikkeboom, A.L., Tillitt, D.E., Holey, M., and Denslow, N. (2000). PCBs, liver lesions, and biomarker responses in adult walleye (*Stizostedium vitreum vitreum*) collected from Green Bay, Wisconsin. *Journal of Great Lakes Research*, 26(3), 250-271. Available online at: https://doi.org/10.1016/S0380-1330(00)70691-5.

Barron, M.G., Galbraith, H., and Beltman, D. (1995). Comparative reproductive and developmental toxicology of PCBs in Birds. *Comparative Biochemistry and Physiology Part C: Pharmacology, Toxicology and Endocrinology*, 112(1), 1-14. Available online at: https://doi.org/10.1016/0742-8413(95)00074-7.

Beckvar, N., Dillon, T.M., and Read, L.B. (2005). Approaches for linking whole-body fish tissue residues of mercury or DDT to biological effects thresholds. *Environmental Toxicology and Chemistry*, 24(8), 2094-2105. Available online at: https://doi.org/10.1897/04-284R.1.

Berninger, J.P., and Tillitt, D.E. (2019). Polychlorinated biphenyl tissue-concentration thresholds for survival, growth, and reproduction in fish. *Environmental Toxicology and Chemistry*, 38(4), 712-736. Available online at: https://doi.org/10.1002/etc.4335.

Besser, J.M., Brumbaugh, W.G., Allert, A.L., Poulton, B.C., Schmitt, C.J., and Ingersoll, C.G. (2009). Ecological impacts of lead mining on Ozark streams: toxicity of sediment and pore water. *Ecotoxicology and Environmental Safety*, 72(2), 516-526. Available online at: https://doi.org/10.1016/j.ecoenv.2008.05.013.

Borgå, K., Hop, H., Skaare, J.U., Wolkers, H., and Gabrielsen, G.W. (2007). Selective bioaccumulation of chlorinated pesticides and metabolites in arctic seabirds. *Environmental Pollution*, 145(2), 545-553. Available online at: https://doi.org/10.1016/j.envpol.2006.04.021.

Carravieri, A., Vincze, O., Bustamante, P., Ackerman, J.T., Adams, E.M., Angelier, F., Chastel, O., Cherel, Y., Gilg, O., Golubova, E., and Kitaysky, A. (2022). Quantitative meta-analysis reveals no association between mercury contamination and body condition in birds. *Biological Reviews*, 97(4), 1253-1271. Available online at: https://doi.org/10.1111/brv.12840.

Conder, J.M., Fuchsman, P.C., Grover, M.M., Magar, V.S., and Henning, M.H. (2015). Critical review of mercury sediment quality values for the protection of benthic invertebrates. *Environmental Toxicology and Chemistry*, 34(1), 6-21. Available online at: https://doi.org/10.1002/etc.2769.

Custer, C.M., Custer, T.W., and Dummer, P.M. (2010). Patterns of organic contaminants in eggs of an insectivorous, an omnivorous, and a piscivorous bird nesting on the Hudson River, New York, USA. *Environmental Toxicology and Chemistry*, 29(10), 2286-2296. Available online at: https://doi.org/10.1002/etc.276.

U.S. Environmental Protection Agency (EPA). Basic information about mercury. Accessed April 10, 2023: https://www.epa.gov/mercury/basic-information-about-mercury.

Franson, J.C., and D.J. Pain. (2011). Lead in birds. In: W.N. Beyer and J.P. Meador (Eds.), *Environmental Contaminants in Biota: Interpreting Tissue Concentrations* (pp. 563–593). Taylor and Francis Group.

Harada, T., Takeda, M., Kojima, S., and Tomiyama, N. (2016). Toxicity and carcinogenicity of dichlorodiphenyltrichloroethane (DDT). *Toxicological Research*, 32(1), 21-33. Available online at: https://doi.org/10.5487/TR.2016.32.1.021.

Hellou, J., Lebeuf, M., and Rudi, M. (2013). Review on DDT and metabolites in birds and mammals of aquatic ecosystems. *Environmental Reviews*, 21(1), 53-69. Available online at: https://doi.org/10.1139/er-2012-0054.

Honda, M., and Suzuki, N. (2020). Toxicities of polycyclic aromatic hydrocarbons for aquatic animals. *International Journal of Environmental Research and Public Health*, 17(4), 1363. Available online at: https://doi.org/10.3390/ijerph17041363.

Incardona, J.P., Collier, T.K., and Scholz, N.L. (2004). Defects in cardiac function precede morphological abnormalities in fish embryos exposed to polycyclic aromatic hydrocarbons. *Toxicology and Applied Pharmacology*, 196(2), 191-205. Available online at: https://doi.org/10.1016/j.taap.2003.11.026.

Ishaque, A., Ishaque, S., Arif, A., and Abbas, H.G. (2020). Toxic effects of lead on fish and human. *Biological and Clinical Sciences Research Journal*, 2020(1). Available online at: https://doi.org/10.54112/bcsrj.v2020i1.47.

Jesus, F., Pereira, J.L., Campos, I., Santos, M., Ré, A., Keizer, J., Nogueira, A., Gonçalves, F.J., Abrantes, N., and Serpa, D. (2022). A review on polycyclic aromatic hydrocarbons distribution in freshwater ecosystems and their toxicity to benthic fauna. *Science of the Total Environment*, 153282. Available online at: https://doi.org/10.1016/j.scitotenv.2022.153282.

Lavoie, R.A., Jardine, T.D., Chumchal, M.M., Kidd, K.A., and Campbell, L.M. (2013). Biomagnification of mercury in aquatic food webs: a worldwide meta-analysis. *Environmental Science and Technology*, 47(23), 13385-13394. Available online at: https://doi.org/10.1021/es403103t.

Logan, D.T. (2007). Perspective on ecotoxicology of PAHs to fish. *Human and Ecological Risk Assessment*, 13(2), 302-316. Available online at: https://doi.org/10.1080/10807030701226749.

Ma, P., Li, H., and You, J. (2019). Full–life cycle toxicity assessment of sediment-bound DDT and its degradation products on *Chironomus dilutus*. *Environmental Toxicology and Chemistry*, 38(12), 2698-2707. Available online at: https://doi.org/10.1002/etc.4593.

Malcolm, H.M., and Shore, R.F. (2003). Effects of PAHs on terrestrial and freshwater birds, mammals and amphibians. In: P.E.T. Douben (Ed.), *PAHs: an ecotoxicological perspective* (pp. 225-241).

John Wiley and Sons. Available online at: https://onlinelibrary.wiley.com/doi/book/10.1002/0470867132.

Manar, R., Bessi, H., and Vasseur, P. (2009). Reproductive effects and bioaccumulation of chlordane in *Daphnia magna*. *Environmental Toxicology and Chemistry: An International Journal*, 28(10), 2150-2159. Available online at: https://doi.org/10.1897/08-564.1.

Maria, V.L., Gomes, T., Barreira, L., and Bebianno, M.J. (2013). Impact of benzo(a)pyrene, Cu and their mixture on the proteomic response of *Mytilus galloprovincialis*. *Aquatic Toxicology*, 144, 284-295. Available online at: https://doi.org/10.1016/j.aquatox.2013.10.009.

Mariussen, E., and Fonnum, F. (2001). The effect of polychlorinated biphenyls on the high affinity uptake of the neurotransmitters, dopamine, serotonin, glutamate and GABA, into rat brain synaptosomes. *Toxicology*, 159(1-2), 11-21. Available online at: https://doi.org/10.1016/S0300-483X(00)00374-7.

McGrath, J.A., Joshua, N., Bess, A.S., and Parkerton, T.F. (2019). Review of polycyclic aromatic hydrocarbons (PAHs) sediment quality guidelines for the protection of benthic life. *Integrated Environmental Assessment and Management*, 15(4), 505-518. Available online at: https://doi.org/10.1002/ieam.4142.

Morcillo, P., Esteban, M.A., and Cuesta, A. (2017). Mercury and its toxic effects on fish. *AIMS Environmental Science*, 4(3), 386-402. Available online at: https://www.aimspress.com/article/10.3934/environsci.2017.3.386.

National Research Council of Canada (NRCC). (1974). Chlordane: Its effects on Canadian ecosystems and its chemistry. Associate Committee on Scientific Criteria for Environmental Quality. Subcommittee on Pesticides and Related Compounds. Natural Research Council of Canada Publishing. NRCC No. 14094. Ottawa, Ontario, Canada. 189 pp.

Ngoubeyou, P.S.K., Wolkersdorfer, C., Ndibewu, P.P., and Augustyn, W. (2022). Toxicity of polychlorinated biphenyls in aquatic environments–A review. *Aquatic Toxicology*, 106284. Available online at: https://doi.org/10.1016/j.aquatox.2022.106284.

Nikolaou, A., Kostopoulou, M., Petsas, A., Vagi, M., Lofrano, G., and Meric, S. (2009). Levels and toxicity of polycyclic aromatic hydrocarbons in marine sediments. *TrAC Trends in Analytical Chemistry*, 28(6), 653-664. Available online at: https://doi.org/10.1016/j.trac.2009.04.004.

Nomeir, A.A., and Hajjar, N.P. (1987). Metabolism of chlordane in mammals. In: Ware, G.W. (Eds.), *Reviews of Environmental Contamination and Toxicology*, vol 100. Springer, New York, NY. Available online at: https://doi.org/10.1007/978-1-4612-4804-0_1.

Pal, M., Sachdeva, M., Gupta, N., Mishra, P., Yadav, M., and Tiwari, A. (2015). Lead exposure in different organs of mammals and prevention by curcumin–nanocurcumin: a review. *Biological Trace Element Research*, 168, 380-391. Available online at: https://doi.org/10.1007/s12011-015-0366-8.

Pinkney, A.E., Harshbarger, J.C., Rutter, M.A., and Sakaris, P.C. (2019). Trends in liver and skin tumor prevalence in brown bullhead (*Ameiurus nebulosus*) from the Anacostia River, Washington, DC, and nearby waters. *Toxicologic Pathology*, 47(2), 174-189. Available online at: https://pubmed.ncbi.nlm.nih.gov/30798780/.

Poston, T. (2001). Treated wood issues associated with overwater structures in marine and freshwater environments [White Paper]. Washington Department of Fish and Wildlife, Washington Department of Ecology, and Washington Department of Transportation. Available online at: https://wdfw.wa.gov/sites/default/files/publications/00053/wdfw00053.pdf.

Robinson, S.A., Lajeunesse, M.J., and Forbes, M.R. (2012). Sex differences in mercury contamination of birds: testing multiple hypotheses with meta-analysis. *Environmental Science and Technology*, 46(13), 7094-7101. Available online at: https://doi.org/10.1021/es204032m.

Rubio-Franchini, I., and Rico-Martínez, R. (2011). Evidence of lead biomagnification in invertebrate predators from laboratory and field experiments. *Environmental Pollution*, 159(7), 1831-1835. Available online at: https://doi.org/10.1016/j.envpol.2011.03.021.

Stickel, L.F., Stickel, W.H., Dyrland, R.A., and Hughes, D.L. (1983). Oxychlordane, HCS-3260, and nonachlor in birds: Lethal residues and loss rates. *Journal of Toxicology and Environmental Health, Part A Current Issues*, 12(4-6), 611-622. Available online at: https://doi.org/10.1080/15287398309530453.

Suedel, B.C., Boraczek, J.A., Peddicord, R.K., Clifford, P.A., and Dillon, T.M. (1994). Trophic transfer and biomagnification potential of contaminants in aquatic ecosystems. *Reviews of Environmental Contamination and Toxicology*, 21-89. Available online at: https://doi.org/10.1007/978-1-4612-2656-7_2.

Tolun, L.G., Okay, O.S., Gaines, A.F., Tolay, M., Tüfekçi, H., and Kıratlı, N. (2001). The pollution status and the toxicity of surface sediments in Izmit Bay (Marmara Sea), Turkey. *Environment International*, 26(3), 163-168. Available online at: https://doi.org/10.1016/S0160-4120(00)00096-9.

Toschik, P.C., Rattner, B.A., McGowan, P.C., Christman, M.C., Carter, D.B., Hale, R.C., Matson, C.W., and Ottinger, M.A. (2005). Effects of contaminant exposure on reproductive success of ospreys (*Pandion haliaetus*) nesting in Delaware River and Bay, USA. *Environmental Toxicology and Chemistry*, 24(3), 617-628. Available online at: https://doi.org/10.1897/04-141R.1.

U.S. Food and Drug Administration (FDA). (2000). Guidance for industry: action levels for poisonous or deleterious substances in human food and animal feed: chlordane. August. Available online at: https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-industry-action-levels-poisonous-or-deleterious-substances-human-food-and-animal-feed#chlodane.

APPENDIX C | DISTRICT OF COLUMBIA SPECIES OF GREATEST CONSERVATION NEED

Names are reported as presented in the 2015 District of Columbia Wildlife Action Plan, available at https://www1.usgs.gov/csas/swap/state_list.html#state=District%20of%20Columbia (accessed June 2023).

Scientific Name	Common Name	Taxonomic Group
Ambystoma maculatum	Spotted Salamander	Amphibians
Ambystoma opacum	Marbled Salamander	Amphibians
Anaxyrus americanus	American Toad	Amphibians
Anaxyrus fowleri	Fowler's Toad	Amphibians
Desomognathus fuscus	Northern Dusky Salamander	Amphibians
Eurycea bislineata	Northern Two-lined Salamander	Amphibians
Hyla chrysoscelis	Cope's Gray Treefrog	Amphibians
Hyla cinerea	Green Treefrog	Amphibians
Hyla versicolor	Gray Treefrog	Amphibians
Lithobates clamitans	Green Frog	Amphibians
Lithobates palustris	Pickerel Frog	Amphibians
Lithobates sphenocephalus	Southern Leopard Frog	Amphibians
Lithobates sylvatica	Wood Frog	Amphibians
Notopthalmus viridescens	Eastern Newt	Amphibians
Plethodon cinereus	Redback Salamander	Amphibians
Pseudacris crucifer	Northern Spring Peeper	Amphibians
Pseudacris feriarum	Upland Chorus Frog	Amphibians
Pseudotriton ruber	Northern Red Salamander	Amphibians
Aix sponsa	Wood Duck	Birds
Ammodramus savannarum	Grasshopper Sparrow	Birds
Anas rubripes	American Black Duck	Birds
Antrostomus vociferus	Eastern Whip-poor-will	Birds
Botaurus lentiginosus	American Bittern	Birds
Cardellina canadensis	Canada Warbler	Birds
Catharus fuscescens	Veery	Birds
Certhia americana	Brown Creeper*	Birds
Chaetura pelagica	Chimney Swift	Birds
Chordeiles minor	Common Nighthawk	Birds
Cistothorus palustris	Marsh Wren	Birds

Coccyzus americanus	Yellow-billed cuckoo	Birds
Colinus virginianus	Northern Bobwhite	Birds
Dolichonyx oryzivorus	Bobolink	Birds
Egretta caerulea	Little Blue Heron	Birds
Empidonax traillii	Willow Flycatcher	Birds
Euphagus carolinus	Rusty Blackbird	Birds
Falco peregrinus	Peregrine Falcon	Birds
Falco sparverius	American Kestrel	Birds
Gallinago delicata	Wilson's Snipe	Birds
Geothlypis formosa	Kentucky Warbler	Birds
Haliaeetus leucocephalus	Bald Eagle	Birds
Helmitheros vermivorum	Worm-eating Warbler	Birds
Hylocichla mustelina	Wood Thrush	Birds
Icteria virens	Yellow-breasted Chat	Birds
Icterus galbula	Baltimore Oriole	Birds
Ixobrychus exilis	Least Bittern	Birds
Megascops asio	Eastern Screech-Owl	Birds
Melanerpes erythrocephalus	Red-headed Woodpecker	Birds
Mniotita varia	Black-and-white Warbler	Birds
Nyctanassa violacea	Yellow-crowned Night Heron	Birds
Nycticorax nycticorax	Black-crowned Night Heron	Birds
Parkesia motacilla	Louisiana Waterthrush	Birds
Pipilo erythrophthalmus	Eastern Towhee	Birds
Piranga olivacea	Scarlet Tanager	Birds
Porzana carolina	Sora	Birds
Progne subis	Purple Martin	Birds
Protonotaria citrea	Prothonotary Warbler	Birds
Rallus limicola	Virginia Rail	Birds
Scolopax minor	American Woodcock	Birds
Seiurus aurocapilla	Ovenbird	Birds
Setophaga caerulescens	Black-throated Blue Warbler	Birds
Setophaga castanea	Bay-breasted Warbler	Birds
Setophaga cerulea	Cerulean Warbler	Birds
Setophaga citrina	Hooded Warbler	Birds
Setophaga discolor	Prairie Warbler	Birds
Setophaga fusca	Blackburnian Warbler	Birds
Setophaga pensylvanica	Chestnut-sided Warbler	Birds
Setophaga virens	Black-throated Green Warbler	Birds
Spizella pusilla	Field Sparrow	Birds
Sterna forsteri	Forster's Tern	Birds
Sturnella magna	Eastern Meadowlark	Birds

Toxostoma rufum	Brown Thrasher	Birds
Tringa flavipes	Lesser Yellowlegs	Birds
Vermivora chrysoptera	Golden-winged Warbler	Birds
Vermivora cyanoptera	Blue-winged Warbler	Birds
Vireo flavifrons	Yellow-throated Vireo	Birds
Vireo griseus	White-eyed Vireo	Birds
Acanthocyclops columbiensis	Copepod sp.	Crustaceans
Attheyella (Mrazekiella) carolinensis	Copepod sp.	Crustaceans
Attheyella (Mrazekiella) obatogamensis	Copepod sp.	Crustaceans
Attheyella (Mrazekiella) spinipses	A harpacticoid copepod	Crustaceans
Bryocamptus (B.) zschokkei alleganiensis	Copepod sp.	Crustaceans
Bryocamptus (Bryocamptus) hutchinsoni	Copepod sp.	Crustaceans
Bryocamptus (Bryocamptus) minutus	Copepod sp.	Crustaceans
Bryocamptus (Limocamptus) nivalis	Copepod sp.	Crustaceans
Cambarus acuminatus	Acuminate crayfish	Crustaceans
Cambarus diogenes	Devil Crawfish	Crustaceans
Cambarus dubius	Upland Burrowing Crayfish	Crustaceans
Diacyclops harryi	Copepod sp.	Crustaceans
Diacyclops navus	Copepod sp.	Crustaceans
Eucyclops elegans	Copepod sp.	Crustaceans
Macrocyclops albidus	Copepod sp.	Crustaceans
Paracyclops poppei	Copepod sp.	Crustaceans
Skistodiaptomus pallidus	A calanoid copepod	Crustaceans
Stygobromus hayi	Hay's Spring Amphipod	Crustaceans
Stygobromus kenki	Kenk's Amphipod	Crustaceans
Stygobromus pizzinii	Pizzini's Cave Amphipod	Crustaceans
Stygobromus sextarius	Capital Area groundwater amphipod	Crustaceans
Stygobromus tenuis potomacus	Potomac Groundwater Amphipod	Crustaceans
Acipenser brevirostrum	Shortnose Sturgeon	Fish
Acipenser oxyrinchus	Atlantic Sturgeon	Fish
Alos mediocris	Hickory Shad	Fish
Alosa aestivalis	Blueback Herring	Fish
Alosa pseudoharengus	Alewife	Fish
Alosa sapidissima	American Shad	Fish
Ameriurus nebulosus	Brown Bullhead	Fish
Amia calva	Bowfin	Fish
Anguilla rostrata	American Eel	Fish

Margariscus margarita	Pearl Dace	Fish
Morone saxatilis	Striped Bass	Fish
Notropis bifrenatus	Bridle Shiner	Fish
Anax longipes	Comet Darner	Insects
Archilestes grandis	Great Spreadwing	Insects
Argia sedula	Blue-ringed Dancer	Insects
Arigomphus villosipes	Unicorn Clubtail	Insects
Bombus affinis	Rusty-patched Bumble Bee	Insects
Callophrys/Incisalia irus	Frosted Elfin	Insects
Cordulegaster erronea	Tiger Spiketail	Insects
Danaus plexippus	Monarch	Insects
Enallagma aspersum	Azure Bluet	Insects
Enallagma basidens	Double-striped Bluet	Insects
Enallagma divagans	Turquoise Bluet	Insects
Enallagma traviatum	Slender Bluet	Insects
Erpetogomphus designatus	Eastern Ringtail	Insects
Euphydryas phaeton	Baltimore Checkerspot	Insects
Euphyes dion	Dion Skipper	Insects
Gomphus exilis	Lancet Clubtail	Insects
Gomphus vastus	Cobra Clubtail	Insects
Hagenius brevistylus	Dragonhunter	Insects
Hesperia leonardus	Leonard's Skipper	Insects
Ischnura kellicotti	Lilypad Forktail	Insects
Ischnura ramburii	Rambur's Forktail	Insects
Lasioglossum michiganense	A Sweat Bee	Insects
Lestes forcipatus	Sweetflag Spreadwing	Insects
Lestes inaequalis	Elegant Spreadwing	Insects
Lycaena hyllus	Bronze Copper	Insects
Nasiaeschna pentacantha	Cyrano Darner	Insects
Nehalennia gracilis	Sphagnum Sprite	Insects
Nehalennia irene	Sedge Sprite	Insects
Neurocordulia obsoleta	Umber Shadowdragon	Insects
Oodes americanus	A Ground Beetle	Insects
Polites origenes	Crossline Skipper	Insects
Pompeius verna	Little Glassywing	Insects
Protandrena abdominalis	A Mining Bee	Insects
Pseudopanurgus virginicus	A Slender Tri-color Mining Bee	Insects
Satyrium edwardsii	Edwards' Hairstreak	Insects
Somatochlora filosa	Fine-lined Emerald	Insects
Somatochlora linearis	Mocha Emerald	Insects
Somatochlora tenebrosa	Clamp-tipped Emerald	Insects

Speyeria cybele cybele	Great Spangled Frittilary	Insects
Stylogomphus albistylus	Eastern Least Clubtail	Insects
Stylurus plagiatus	Russet-tipped Clubtail	Insects
Tachopteryx thoreyi	Grey Petaltail	Insects
Blarnia brevicauda	Short-tailed Shrew	Mammals
Castor canadensis	American Beaver	Mammals
Didelphis virginiana	Virginia Opossum	Mammals
Eptesicus fuscus	Big Brown Bat	Mammals
Glaucomys volans	Southern Flying Squirrel	Mammals
Lasionycteris noctivagans	Silver Haired Bat	Mammals
Lasiurus borealis	Eastern Red Bat	Mammals
Lasiurus cinereus	Hoary Bat	Mammals
Lontra canadensis	Northern American River Otter	Mammals
Mephitis mephitis	Striped Skunk	Mammals
Microtus pennsylvanicus	Meadow Vole	Mammals
Myotis leibii	Eastern-Small Footed Bat	Mammals
Myotis lucifugus	Little Brown Bat	Mammals
Myotis septentrionalis	Northern Long-eared Bat	Mammals
Neovison vison	American Mink	Mammals
Nycticeius humeralis	Evening Bat	Mammals
Ondrata zibethicus	Muskrat	Mammals
Perimyotis subflavus	Tri-colored Bat	Mammals
Sylvilagus floridanus	Eastern Cottontail	Mammals
Tamias striatus	Eastern Chipmunk	Mammals
Urocyon cinereoargentus	Gray Fox	Mammals
Alasmidonta heterodon	Dwarf Wedgemussel	Mollusks
Alasmidonta undulata	Triangle Floater	Mollusks
Alasmidonta varicosa	Brook Floater	Mollusks
Anguispira fergusoni	Coastal-plain Tigersnail	Mollusks
Anodonta implicata	Alewife Floater	Mollusks
Fontigens bottimeri	Appalachian Springsnail	Mollusks
Lampsilis cariosa	Yellow Lampmussel	Mollusks
Lasmigona subviridis	Green Floater	Mollusks
Leptodea ochracea	Tidewater Mucket	Mollusks
Ligumia nasuta	Eastern Pondmussel	Mollusks
Stenotrema barbatum	Bristled Slitmouth	Mollusks
Ephydatia sp.	A Freshwater Sponge	Other Invertebrates
Spongilla sp.	A Freshwater Sponge	Other Invertebrates
Agkistrodon contortrix	Northern Copperhead	Reptiles
Carphophis amoneous	Eastern Worm Snake	Reptiles
Chrysemys picta picta	Eastern Painted Turtle	Reptiles

Clemmys guttata	Spotted Turtle	Reptiles
Crotalus horridus	Timber Rattlesnake	Reptiles
Diadophis punctatus	Northern Ringneck Snake	Reptiles
Glyptemys insculpta	Wood Turtle	Reptiles
Glyptemys muhlenbergii	Bog Turtle	Reptiles
Kinosternon subrubrum	Eastern Mud Turtle	Reptiles
Opheodrys aestivus	Rough Green Snake	Reptiles
Plestidon faciatus	Five-lined Skink	Reptiles
Pseudemys rubriventris	Eastern Redbelly Turtle	Reptiles
Regina septemvittata	Queen Snake	Reptiles
Sternotherus odoratus	Common Musk Turtle	Reptiles
Storeria dekayi dekayi	Northern Brown Snake	Reptiles
Terrepene carolina carolina	Eastern Box Turtle	Reptiles
Thamnophis sirtalus	Eastern Garter Snake	Reptiles

APPENDIX D | COMMENTS RECEIVED ON THE DRAFT ANACOSTIA RIVER DAMAGE ASSESSMENT PLAN

RESERVED