Appendix 1: 2002 ROUGE RIVER MYSTERY SPILL ASSESSMENT CLAIM

Attachment 1: Trustee Designation Documentation

Attachment 2: Correspondence

Attachment 3: Trustee Coordination Documentation

Note: Attachment 4, noted in the Table of Contents of Appendix 1, is in development and therefore does not appear in the draft DARP / EA.

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2002 ROUGE RIVER MYSTERY SPILL
ASSESSMENT CLAIM

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ACRONYMS

Acronym	Definition
AO	Authorized Official
ASA	Applied Science Associates
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
COTP	Commander Patrick Garrity, Captain of the Port
DRP/EA	Draft Restoration Plan/Environmental Assessment
ELFO	East Lansing Field Office
FBI	Federal Bureau of Investigation
FOSC	Federal On-Scene Coordinator
FPN	Federal Project Number
FRP/EA	Final Restoration Plan/Environmental Assessment
GIS	Geographical Information System
LAT	Lead Administrative Trustee
LC_{50}	Toxicity data (Lethal Concentration resulting in 50% mortality rate)
LEMP	Lake Erie Metropark
LTCI	Lighthouse Technical Consultants, Incorporated
MBTA	Migratory Bird Treaty Act
MDAG	Michigan Department of Attorney General
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
MSO	Marine Safety Office
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NRD	Natural Resource Damage
NRDA	Natural Resource Damage Assessment
NRDAM/GLE	NRDA Model for Great Lakes Environments
OPA	Oil Pollution Act of 1990
OSLTF	Oil Spill Liability Trust Fund
OSRO	Oil Spill Response Organization
PAH	Polycyclic Aromatic Hydrocarbons
RP	Responsible Party
SIMAP	Spill Impact Model Analysis Package
SOL	Statute of Limitations
U.S. EPA	United States Environmental Protection Agency
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service

1.0 INTRODUCTION

1.1 Assessment Claim

This document is a claim for prospective (upfront) funding of a natural resource damage assessment (NRDA) for the April 2002 Rouge River Mystery Spill (henceforth, the "Spill"). The goals of this NRDA are to:

1. Determine the nature, degree and extent (both spatial and temporal) of injuries to natural resources resulting from the April 2002 unlawful release of petroleum substances into the Rouge and Detroit Rivers (just south of Detroit, Michigan); and

2. Develop a Final Restoration Plan/Environmental Assessment (FRP/EA) that effectively restores, rehabilitates, replaces, or acquires the equivalent natural resources to compensate for injured natural resources resulting from the Spill. [The FRP/EA developed as a part of this assessment effort is intended to be the subject of a subsequent restoration claim to be submitted to National Pollution Funds Center (NPFC) in the future, assuming no responsible party (RP) is found.]

The claimants for this assessment claim include the United States Fish and Wildlife Service (USFWS), state of Michigan Department of Attorney General (MDAG), Michigan Department of Environmental Quality (MDEQ), and Michigan Department of Natural Resources (MDNR). The Claimants, as trustees of natural resources injured by the spill, are pleased to submit this assessment claim to the National Pollution Funds Center's Natural Resource Damage (NRD) Claims Division for payment by the Oil Spill Liability Trust Fund (OSLTF).

The USFWS, as Lead Administrative Trustee (LAT), looks forward to working productively with NPFC to ensure that any and all claim questions and issues are appropriately addressed in order to expedite funding of this important assessment effort.

Lighthouse Technical Consultants, Incorporated (LTCI), prepared this assessment plan/claim for the natural resource trustees under the direction of the USFWS. LTCI, and its nationally-focused consortium of experts, is a leading environmental consulting firm specializing in natural resource damage assessments, oil spill modeling, injury assessments, restoration planning, and successful natural resource damage claim development and implementation. LTCI welcomes the opportunity to assist USFWS and the state of Michigan on assessment claim implementation. For additional information regarding the preparation of this claim and LTCI's NRD claim support services, please contact:

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1.2 Assessment Claim Contents

This assessment claim addresses information requirements described in the May 7, 2002 *Natural Resource Damage Funding Guidelines* developed by the NPFC NRD Claims Division (available on the NPFC website at: http://www.uscg.mil/hq/npfc/NRD/nrd_docs.htm). Claimants have used available information to address all assessment claim information requirements found in the *Guidelines*.

To facilitate clarity and comprehensiveness within this claim, some of the information provided is not in the same order as assessment claim information requirements listed in the *Guidelines* (e.g., cost documentation has its own chapter within this claim rather than part of "Claim Information" as it appears in the *Guidelines*).

The contents of this claim are as follows:

- **Executive Summary** – Summarizes the Spill incident and major components of the assessment claim;
- **Chapter 1** – Introduces the claim and describes claim contents.
- **Chapter 2** – Provides major claim information and proposed assessment procedures.
- **Chapter 3** – Describes how the 15 CFR 990 damage assessment regulations guide the proposed NRDA.
- **Chapter 4** – Introduces and describes roles of senior federal and state personnel managing the NRDA, and contracted NRDA experts to assist in the assessments implementation.
- **Chapter 5** – Provides a schedule of proposed assessment activities.
- **Chapter 6** – Details the financial resources required to execute the proposed assessment.
- **Chapter 7** – Provides requisite certifications and signatures for the claim.
- **Chapter 8** – Provides references to literature cited in the claim document.

2.0 ASSESSMENT CLAIM OVERVIEW

2.1 Claim Information

2.1.1 Claimant Information

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Trustee designation documentation can be found in Attachment 1.0 to this claim document.

2.1.2 Incident Information

2.1.2.1 Known Incident Information

Following a heavy rain event, a mixture of (approximately 30%) diesel fuel and (approximately 70%) lube waste oil was observed the morning of April 9, 2002, in the Rouge River, south of Detroit, Michigan. The Rouge River is a tributary of the Detroit River, which flows from Lake Saint Clair southward to Lake Erie. This oil swept down the Rouge River into the Detroit River and into Lake Erie. An image of the area of impact from this incident can be found at the following Web Link: http://www.freep.com/pdf/2004/04/05/oilspill.pdf .

Since the RP was not identified (See Section 2.1.3 below.), the United States Environmental Protection Agency (U.S. EPA) and the United States Coast Guard (USCG) met and decided that USCG should be the Federal On-Scene Coordinator (FOSC) for this spill. Commander Patrick Garrity, Captain of the Port (COTP) Detroit, acted as FOSC. Initial actions in response to this spill included:

- FOSC opened a Federal Project Number (FPN) under the OSLTF (FPN: G02AAA from 4/10/2002 – 4/19/2002; after 4/19/2002 the FPN was E02503).

- Marine Pollution Control was hired by FOSC as the Oil Spill Response Organization (OSRO).

- The Unified Command was assembled, consisting of agency representatives from USFWS, U.S. EPA, National Oceanic and Atmospheric Administration (NOAA), Michigan State Police, MDEQ, and Michigan Department of Fish and Wildlife (MDFW).

- USCG personnel from the Atlantic and Gulf Strike Teams, Marine Safety Office (MSO) Toledo, MSO Cleveland, MSO Milwaukee and Ninth District Staff supplemented the crew of MSO Detroit. Coast Guard Group Detroit and USCG Air Station Detroit also provided assets and personnel to assist the FOSC.

- USCG personnel provided updates to state and local community leaders regarding spill response activities.

- In an effort to identify a RP, ships transiting the Detroit River 24 hours before the spill was observed were identified, boarded and oil samples were collected. No chemical match was found.

- Shortly after observing the spill, River Rouge was closed to all vessel traffic. River was reopened to commercial traffic on Friday, April 19, at 1200, but only between the hours of 0700-1900. River Rouge was opened to 24-hour continuous operations on May 3, 2002.

- A series of collection and containment booms were set across River Rouge mouth.

- Alerted Canada of the spill and exchanged Liaison Officers from each country to monitor spill response activities. Invoked CANUSLAK in accordance with the "Boundary Waters Treaty" and the" Great Lakes Water Quality Agreement". In accordance with the Treaty and follow-on agreements, the United States is paying for all Canadian clean-up costs since the oil emanated from the United States (Detroit/Rouge River Oil Spill Unified Command, 2002).

In the late evening of April 12, 2002, or the early morning of April 13th, another oil spill occurred after a heavy rainfall. It appeared the oil came from one of the combined sewer outfalls on the River Rouge (Baby Creek Outfall). This release was trapped in the River Rouge due to booming at the mouth, preventing further releases oil into the Detroit River. This spill was significantly greater than the first release. The following actions occurred in response to this spill:

- All free-floating oil was corralled into containment boom and then removed by vacuum truck.
- A crane removed all oiled debris from the Rouge.
- The Rouge shoreline was cleaned by high volume deluge system.
- A criminal investigation was launched by the Southeast Michigan Environmental Crimes Task Force that consists of special agents from the Federal Bureau of Investigations (FBI), USCG, U.S. EPA, MDEQ, and United States Customs Service under the direction of the Assistant United States Attorney in Detroit.

- Numerous oil samples were taken from various locations including from facilities and inside sewer lines. These samples were sent to the USCG Marine Safety Laboratory (formerly, COIL) in Groton (CT) to provide a means to match the oil in the River with the oil from one of the sample location
- Laboratory analysis confirmed the oil spilled during the first release was the same as the oil spilled during the second release.

2.1.2.2 Known Natural Resource Impacts

Oil released during the first spill impacted approximately 17 miles of shoreline in the United States and about 16 kilometers (almost 10 miles) on the Canadian side of the Detroit River. Oil dispersed from much of the impacted shoreline by the second or third day of the spill. Prompt booming of several coastal marshes (Humbug, Point Mouillee) prevented severe impacts in those locations, although approximately 1 mile of shoreline at the Lake Erie Metropark (LEMP) was badly oiled (see impact area at the following web link: http://www.freep.com/pdf/2004/04/05/oilspill.pdf). Oil persisted at LEMP and crews were dispatched on April 18, 2002, to manually cut and remove oiled marsh vegetation and remove oiled debris from shorelines at this park.

Over the course of the spill, oiled birds and reptiles were observed. USFWS retrieved 9 dead birds under the Migratory Bird Treaty Act (MBTA) and had additional reports of 2 more dead for a total of 11 dead. Three live birds protected by MBTA were rehabilitated and released. An additional 44 birds with varying degrees of oiling were observed and catalogued. USFWS strived to eliminate double counting through detailed interviews as to time and location of observations and included only the maximum observed number of any species in a specific location that were clearly described as oiled. Species of birds impacted included ruddy ducks, buffleheads, mergansers, scaup, coots, mallards, and Canada geese. The total number of birds protected by MBTA on the United States side of the spill that were either dead, rehabilitated or observed oiled was 58 (Williams 2002a).

Other wildlife directly observed to be impacted on the United States side included one dead and two rehabilitated turtles, 12 observed oiled but not captured white ducks and geese, and four rehabilitated and released white ducks and geese.

Gary McCullough (Canadian Wildlife Service) reported observations of impacted waterfowl on the Canadian side of the spill. He reported one ruddy duck that died after capture, one dead oiled Canada goose, and possibly 12 additional dead, oiled Canada geese that had been reported to him. He also reported observing live, oiled waterfowl that were not retrieved: nine Canada geese, one duck, and one mute swan. Two scaup were rehabilitated in Canada. The total number of birds from the Canadian side that would be protected by MBTA that were either dead, rehabilitated, or observed oiled was 27. Additionally, Laird Shutt (Environment Canada) reported to USFWS that he observed gulls on Fighting Island that showed a lack of motor control in wings and legs at the time when oil residue was present on vegetation along the island (Williams 2002a).

Williams (2002a) notes that the number of reportedly impacted birds and reptiles here significantly underestimate the actual number of birds and reptiles impacted. Specifically, many dead birds were likely not retrieved because of a number of factors commonly observed at other spills:

- They died and sank or were washed away prior to observation by wildlife response personnel;
- Impacted animals hid before dying;
- Wildlife response personnel were unable to search all shorelines even once;
- Wildlife response personnel did not initiate surveys until several days after the start of the spill;
- Response personnel were unable to catch all observed oiled birds (e.g., on one occasion 12 oiled ruddy ducks had come ashore and were preening, but fled to the water immediately as biologists approached, and, likely did not survive); and
- Losses due to scavenging (e.g., one of the carcasses found was partially eaten and one of the carcasses reported to wildlife response personnel disappeared before it could be retrieved, and may have been removed by a scavenger).

Accordingly, proposed injury assessment efforts for impacted animals shall employ appropriate methodologies to reconcile these underestimates in order to quantify actual losses (e.g., through use of modeling and multiplier approaches as appropriate, see Sections 2.3.1, Proposed Assessment Methods, and Section 2.3.6, Quantification of Injury, below).

In addition to bird and reptile impacts, it is likely that snakes and amphibians were impacted directly by the spill, but were not discovered by field surveys.

No fish were reported dead as a result of the oil spills. MDNR fisheries biologists state that northern pike had already spawned in shallow wetlands impacted by the spill. Accordingly, MDNR is concerned that the oil may have injured eggs or fry. Likewise, minnows and other small fish dependent on the shallow marshes that were covered with oil may have been impacted, but not readily observed. Lake sturgeon that had entered the Detroit River prior to spawning left the area immediately following the spill and later returned, but it is unknown if this movement was related to the spill or harmed their spawning.

Accordingly, additional injury assessment work is necessary to determine and quantify impacts, as appropriate, to water column organisms.

No state or federally listed threatened or endangered species are conclusively known to have been impacted by the spill at this time, but adverse effects to them may have occurred. For example, one pair of bald eagles was nesting in the area of the spill in the United States, and one large raptor was observed that may have been oiled, but visibility was poor and the bird was not conclusively determined to be either an eagle or significantly oiled. Additionally, the eastern fox snake, listed as endangered by the state of Michigan, is known to inhabit impacted marshes, but no oiled individuals were observed. The American lotus, a plant listed as threatened by the state of Michigan, is common in the area of LEMP. One of the most heavily oiled portions of the shoreline contained numerous seedpods from the previous year, which were removed as part of shoreline cleaning operations. Some reproduction by seed may have been lost, but the lotus plants themselves had not yet emerged at the time of the spill and were not oiled (Williams 2002a).

Losses to the public's use of natural resources resulting from this incident included (but is not limited to):

- Closures to the Detroit and Rouge Rivers to boating traffic following the incident;
- Reduced or lost use of LEMP;
- Reduced or lost use of Wyandote National Wildlife Refuge;
- Loss of shoreline fishing opportunity; and
- Cancellation of fishing tournament regional significance.

Injury assessment strategies are presented in Section 2.3 that addresses these potential injuries categories.

2.1.2.3 Incident Information to be Determined

Certain incident-specific information associated with the April 2002 River Rouge/Detroit River oil spill remains to be determined, specifically:

- RP for this incident;
- Volume of the petroleum products released during the spills; and
- Spill source and release conditions.

Issues related to identifying the RP for this incident are discussed in Section 2.1.3, Responsible Party Information, below. Issues related to past estimates of spill volume and spill source/release conditions are presented below in this section.

According to the NOAA Scientific Support Coordinator, LCDR Jason Maddox, following the first spill (i.e., as of April 10, 2002), an estimated 34,090.8 gallons of petroleum were released (28,409 gallons on the United States side, 5681.8 gallons on the Canadian side). Following the second release, the USCG estimated that the entire spill volume (i.e., cumulative volume from both releases) to be between 55,000 and 65,000 gallons (Williams 2002b), making the release volume for the second incident between 20,909 – 30,909 gallons. However, contractors for the U.S. EPA calculate that the cumulative spill volume for both incidents was at least 255,544 gallons (McDiarmid Jr. 2004). Given this significant range in estimated release volume (55,000 gallons – 255,544 gallons), the injury assessment for this damage assessment shall determine the "most reasonable" spill estimate volume from this incident. This is described further in Section 2.3 below.

According to U.S. EPA, the release point of this spill was a sewer pipe outfall called Baby Creek just upstream from the I-75 Bridge on the banks of the Rouge River. It is believed by U.S. EPA that heavy rainwaters washed oil from the Baby Creek Outfall into the Rouge River during both oil releases. In fact, during the spill investigation an additional 771,000 gallons of oily water – with an oil fingerprint signature close to that found in the river following the release – was found in a sewer line leading to the Baby Creek Outfall drain (McDiarmid Jr. 2004). This outfall connects to hundreds of miles of storm sewers used by hundreds of industries and can be accessed through numerous manholes. However, according to the Detroit Free Press (McDiarmid Jr. 2004), the state of Michigan does not necessarily share U.S. EPA's certitude regarding the oil release point in the Rouge River. For example, the state points to a report prepared by the Detroit Water and Sewerage Department that at least 15 oil samples collected from three different companies also matched the spilled oil and other promising leads were not followed up after the spill (McDiarmid Jr. 2004). Also, the state has not ruled out the possibility that the releases occurred from a vessel, a theory ruled out early by federal investigators.

Further, though the USCG reports that the spill occurred on April 8 or 9, 2002, MDEQ believes that the spill began earlier on April 2, 2002 (McDiarmid Jr. 2004).

Spill release location and duration will have marked impact on injury determination and quantification studies conducted as part of this proposed injury assessment. Accordingly, further research into spill incident specifics will be conducted as part of the assessment studies proposed in this claim. Additional information regarding this assessment work is found in Section 2.3 of this claim.

2.1.3 Responsible Party Information

The U.S. EPA, MDEQ, USCG, and the United States Attorney's Office investigated the April 2002 Rouge River Mystery Spill for over 2 years following the spill. Intensive investigation of all leads and possible sources for the spill did not develop sufficient evidence to charge a RP or parties, and no party has acknowledged responsibility. Having exhausted all known leads, the investigation has closed pending receipt of new information. In fact, in a July 14, 2005, email from Kris Dighe, Assistant Section Chief for the United States Department of Justice to Mark Matus, Michigan Assistant Attorney General, Kris Dighe states that "the United States Department of Justice has closed its investigation into the Rouge River Oil Spill of April 2002." A copy of this email has been included in Attachment 2.0 to this claim. According to state and federal trustees, if credible new information were received, the investigation would resume.

Because no RP has been found, trustees are submitting the present upfront assessment claim to the USCG NPFC for payment. In fact, the rationale for submitting this claim to NPFC due to its current "mystery spill" status is corroborated in a September 10, 2004, email sent by Mr. Chris Abrams, Chief of the NPFC NRD Claims Division (See Attachment 2.0.) to Dr. Lisa Williams, Contaminants Specialist at the USFWS East Lansing Field Office. According to Mr. Abrams, if the ongoing grand jury investigation does identify a RP prior to claim submission, then the claim should go first to the RP for payment. If after 90 days, the claim is not paid, then it can be submitted to NPFC for adjudication and payment, as appropriate.

2.1.4 Claim Elements and Amount of Costs and Damages Claimed

This document is a claim for upfront funding necessary to conduct a natural resource damage assessment for the April 2002 Rouge River Mystery Oil Spill incident. This claim includes the background, rationale, description and corresponding costs for proposed assessment procedures.

The total claimed cost for this upfront assessment claim is $1,089,120. A detailed breakdown of the costs claimed can be found in Section 6.0 of this claim (Cost Documentation).

It is anticipated that this proposed assessment will culminate in the development of a FRP/EA. Further, once promulgated, the FRP/EA shall serve as the basis for a subsequent restoration-based natural resource damage claim for this incident.

2.1.5 Statute of Limitations

The Statute of Limitations (SOL) under OPA for the filing of NRD claims with the NPFC is the later of the following:

1. Three (3) years from the date the injury and connection with the discharge was reasonably discoverable with due care; or

2. Three (3) years from the date of completion of the natural resource damage assessment under the damage assessment regulations published by the NOAA at 15 CFR Part 990.

In the case of the present upfront assessment claim, claimants will use the latter assessment strategy, i.e., use of the damage assessment regulations at 15 CFR Part 990. Use of these damage assessment regulations confers a less stringent time constraint with respects to completing the NRDA.

Specifically, in this claim, no NRDA has been initiated for the Rouge River Mystery Oil Spill. Accordingly, it is presumed by Claimants that the 3-year statute of limitations will not begin tolling until the proposed assessment is completed. NRDA completion is defined in this context as the date of promulgation of the FRP/EA.

2.2 Adherence to Damage Assessment Regulations

The Claimant (on behalf of self and other involved trustees) certifies that the NRDA will be conducted using the Damage Assessment Regulations at 15 CFR Part 990. Full certifications for this claim are found in Section 7.2.

2.3 Proposed Assessment Procedures

2.3.1 Proposed Assessment Methods

Given the period of time that has passed since the incident (over 2.5 years) and the fact that a number of incident specific facts regarding the Rouge River Mystery Spill remain unknown, it is not reasonable to undertake aggressive field or laboratory studies to determine the nature, degree and extent of injuries to biological resources resulting from this incident (as briefly introduced in Section 2.1.2.2). Further, since a comprehensive assessment of injuries has not been conducted, literature-based studies may only address portions of the proposed NRDA. Consequently, a comprehensive and cost-effective approach to conducting biological injury assessment studies for this incident is to use oil spill impact modeling. Due to the fact that several unknowns exist regarding this incident, upfront research is required to develop reasonable and defensible modeling inputs.

Losses to public use, described briefly in Section 2.1.2.2, shall also be determined and quantified.

Accordingly, assessment procedures proposed for the Rouge River Mystery Spill NRDA include the following:

- Research and review information on the incident;
- Develop input data for oil spill impact modeling;
- Conduct oil spill impact modeling; and
- Conduct a lost public (recreational) use assessment.

Each of these proposed assessment activities are described below.

Research and Review Incident Information: As described in Section 2.1.2.3 of this document, incident-specific information that may have a material affect on the nature, degree and spatial/temporal extent of natural resource injuries, hence requiring additional investigation. This information includes (but is not limited to) the following:

- Volume of spill;
- Chemical analysis of spilled oils;
- Release conditions, including:
  - Release location;
  - Date of first release; and
  - Duration of releases (i.e., instantaneous versus continuous).

As discussed above, incident-specific data have been the subject of considerable debate. Working with federal, state, and Dominion of Canada representatives involved with the incident, and collected spill response information, the trustees shall develop a reasonable and defensible set of release circumstances with which to base injury impact modeling studies.

The work product for this effort will be a report that provides the methods, assumption, results and discussion of Rouge River Mystery Spill incident specific information.

Develop Oil Spill Impact Modeling Input Data: In addition to the collection and derivation of defensible incident-specific data, environmental and biological data sets must be compiled for modeling spill impacts. Specifically, trustees will develop habitat data using available databases for the areas of impact within the Rouge and Detroit Rivers. River current and riverbed depth data, as well as biological assemblage databases, also will be collected for modeling input.

Work products from this task will be described and compiled in the modeling report described below.

Conduct Oil Spill Impact Modeling: Trustees propose the use of an oil spill fate and effects model to screen, determine and quantify injuries to natural resources. Specifically, trustees propose using the Spill Impact Model Analysis Package (SIMAP) model developed by Applied Science Associates (ASA), which is a revision of the Type A model (i.e., the NRDA Model for Great Lakes Environments, NRDAM/GLE) that allows the use of site-specific data and modifications. SIMAP has been successfully used to quantify invertebrate, fish, bird, reptile and mammal natural resource injuries from dozens of past oil spills, and is considered the current industry standard for modeling biological natural resource damages. For example, SIMAP was used successfully to model natural resource injuries resulting from the August 2000 Fort Lauderdale Mystery Spill. Federal and state trustees used this application of SIMAP as substantive supporting documentation for an NRD claim that was submitted to the NPFC and paid in full.

SIMAP provides detailed predictions of the three-dimensional trajectory, fate, impacts and biological effects of spilled oil. These fates and effects of the oil releases are predicted by SIMAP through the interactive use of a number of submodels, including:

- Physical fates model;
- Biological exposure and effects model;
- Stochastic model (to predict frequency and range of concentrations and probability of exceeding threshold concentrations of concern);
- Interactive Geographic Information System (GIS); and
- Environmental, oil and biological databases.

SIMAP is proposed for use in modeling Rouge River Mystery Spill fate and effects over the NRDAM/GLE for a number of reasons, including:

- The spills may have been released from a subsurface outfall. The Type A model cannot simulate a subsurface release. However, SIMAP can be readily modified to address such subsurface releases.

- SIMAP includes algorithms in its code that are needed for restoration scaling. The Type A model only outputs catch loss of fish and invertebrates. SIMAP automatically calculates:
  - The total biomass loss of all age classes of fish and invertebrates; and
  - The lost future growth of those organisms had they not been killed (i.e., production foregone).

- The toxicity data (LC_{50}) can be readily modeled in SIMAP to reflect updated information.

- The user interface tools of SIMAP are much more "user-friendly", significantly reducing modeling labor costs relative to the use of the Type A model.

Trustees shall perform modeling of the trajectory of surface oil, concentrations of toxic components (polyaromatic hydrocarbons, PAHs) in water and sediments over time, and biological injuries resulting from the spill using the SIMAP model. Specific modeling tasks include the following:

- Develop toxicity data (LC_{50}) for source oil based on PAH content;

- Incorporate site-specific wildlife data;

- Develop current data file based on on-scene observations (as available) and literature information;

- Run the oil trajectory and fates model, varying unknown parameters to evaluate sensitivity and calibrate model to observed oil locations, as available;

- Run the biological model to show best estimate and range of injuries resulting from acute toxic exposure (i.e., minimum, mean and maximum LC_{50});

- Draft and final reports will be prepared containing incident-specific, environmental, physical, biological, chemical, and toxicological data inputs, assumptions, and outputs of model runs; and

- Injuries will be quantified as numbers of biomass lost via acute toxicity and production foregone (i.e., lost future growth).

The resulting work products of these proposed modeling procedures would be a report that quantifies the nature, degree and extent of modeled injuries resulting from the Rouge River Mystery Spill.

Conduct an Assessment of Lost Public Use: Closures of waterfront recreational areas and activities, as outlined in Section 2.1.2.2 and Table 2-1, due to the spills shall be assessed through documentation review, interviews with impacted parties (e.g., harbormasters, park personnel, refuge personnel, and recreational fishing interests such as bait and tackle retailers). Lost and diminished quality of public use resulting from this lost use survey effort shall be scaled using a benefit's transfer approach.

The work product from this lost public use analysis will be a report that details the nature, degree and spatial/temporal extent of public use losses resulting from the Rouge River Mystery Spill, including a monetized valuation of these losses.

2.3.2 Use of Derived Assessment Data

The following summarizes intended uses of data collected and analyzed during Rouge River Mystery Spill injury assessment activities:

- Incident specific information collected (i.e., spill volume, chemical constituents, and release conditions) will be used as data inputs to the SIMAP oil spill impacts model;
- Environmental, physical, biological, chemical and toxicological data collected also will be used as data inputs to the SIMAP oil spill impacts model;
- SIMAP Model outputs (quantified injuries as numbers or biomass lost via acute toxicity and production foregone) shall be directly used in scaling restoration projects to compensate for biological losses resulting from the incident, likely using resource-to-resource and service-to-service scaling approaches;
- Lost public use (monetized by lost or diminished recreational activity) shall be used in scaling restoration projects identified to compensate for the nature, degree and extent of lost recreational activities, likely using a value to cost scaling approach.

2.3.3 Quality Assurance and Chain of Custody

Data generating activities shall be audited. It is anticipated that these audits shall include:

- System audits conducted to qualitatively evaluate operational details; and
- Performance audits conducted to evaluate data quality, adequacy of documentation, and technical performance characteristics.

Field-collected samples (such as petroleum samples collected during response operations) shall be checked for chain of custody. Laboratories having analyzed oil samples shall demonstrate conformance to Good Laboratory Practice Standards (GLPS), and/or other standards during period of analysis, as appropriate.

2.3.4 Nature and Scope of of Injured Resources

Based on initial surveys conducted during the response phase of the incident, a number of injuries resulting from the oil releases were observed. These injuries are briefly described in Section 2.1.2.2 (Known Natural Resource Impacts) of this document and summarized in Table 2-1 below.

Table 2-1: Potential Nature and Scope of Rouge River Mystery Spill Natural Resource Injuries

Injury Class	Nature of Injuries
Plants	Shoreline vegetation at time of spill was dormant/senescent (i.e., pre-green up vegetative state). Much of this vegetation was moderately to heavily oil-contaminated from incident. Emergent oiled cattails, a type of red winged blackbird habitat, were removed to prevent continuing oil contamination. Similarly, the American lotus (*Nelumbo lutea*), a state listed threatened plant species, was oiled. Removal of oiled lotus seedpods to prevent continuing contamination resulted in reduced seed propagation for this threatened species.
Invertebrates	Northern Riffleshell (*Epioblasma torulosa*), a member of the pearly mussel family, is a federally and state listed endangered species. This mussel species exists in the Detroit River within the area of impact. Additionally, other invertebrates that are important forage base for fish and birds – such as worms and mayflies may have been harmed and should be investigated.
Fish	Northern pike, an important regional gamefish, are believed to have spawned at the time of the incident. Further, possible spawning by a number of additional species may have been coincident with the spill and require further investigation: sturgeon (a state threatened species), walleye pike, yellow perch, etc.
Reptiles and Amphibians	Impacted coastal wetlands along the Detroit River provide habitats for rare species of reptiles including the Eastern fox snake, Eastern massasauga rattlesnake, queen snake, spotted turtle Eastern spiny soft-shell turtle, bullfrogs and chorus frogs. Post-incident response activities did confirm one dead turtle on the United States side of the Detroit River. However, due to significant vulnerabilities to petroleum exposure and injury for amphibians and reptiles, it is reasonable that additional impacts occurred over observed injuries. Given difficulties in accessing the areas impacted following the incident, it is feasible that moribund or dead reptiles and amphibians were not observed; further losses of injured species due to predation or river currents may have occurred. Accordingly, additional investigation regarding specific distribution and impacts is indicated in this assessment.

Injury Class	Nature of Injuries
Birds	USFWS retrieved 9 dead birds under the MBTA and had additional reports of 2 more dead for a total of 11 dead. Three live birds protected by MBTA were rehabilitated and released. An additional 44 birds with varying degrees of oiling were observed and catalogued. Species of birds impacted included ruddy ducks, buffleheads, mergansers, scaup, coots, mallards, and Canada geese. The total number of birds protected by MBTA on the United States side of the spill that were either dead, rehabilitated or observed oiled was 58 (Williams, 2002a).
Lost Public Use	Losses to the public's use of natural resources resulting from this incident included (but is not limited to): Closures to the Detroit and Rouge Rivers to boating traffic following the incident; Reduced or lost use of Lake Erie Metro Park (LEMP); Reduced or lost use of Wyandote National Wildlife Refuge; Loss of shoreline fishing opportunity; and Cancellation of fishing tournament regional significance.

The proposed injury assessment seeks to further investigate the nature, degree and extent of the potential injury categories in Table 2-1. Collectively, these injury categories comprise the preliminary scope of injury assessment activities for the Rouge River Mystery Spill NRDA. Additional discussion with resource experts, literature review and screening of impacts using SIMAP oil spill modeling software shall be used by trustees to finalize the scope and nature of natural resource injuries.

2.3.5 Determination of Injury

As described in Section 2.3.1 above, injuries to biological resources will be determined (i.e., linked to the spill incident) using SIMAP oil spill modeling software in combination with expert modeling data interpretation and reporting. SIMAP uses incident specific information, oil chemistry and toxicity, and local environmental and biological databases to establish a direct link between the source, pathway, (biological) receptors and manifested injurious effects (i.e., through exceeding doses of PAH that cause acute toxicity to organisms.

Additional specific information regarding SIMAP's oil spill fate and effects modeling capability can be found at the following web link: http://www.appsci.com/simap/simap.htm .

Public use injuries will be determined through documentation review and interviews to determine causation of public use losses.

2.3.6 Quantification of Injury

As described in Section 2.3.1 above, injuries to biological resources resulting from the Rouge River Mystery Spill will be quantified using SIMAP oil spill modeling software, local populations of biological assemblages of interest and expert modeling data interpretation and reporting.

Biological injury is calculated by SIMAP with the following data outputs:

- The total biomass loss of all age classes of fish and invertebrates;
- The lost future growth of those organisms had they not been killed (i.e., production foregone); and
- The total biomass of wildlife (mainly bird) injuries experienced due to the spill.

The spatial extent of injury is determined in SIMAP via the identification of discreet locations where injury occurs. This is recorded and reported using the ARCGIS function within SIMAP.

From a temporal perspective, the biological effects model computes reduction of fish and shellfish population size and catch in the present and future years using standard fisheries models. The injury includes losses due to mortality of adults, juveniles and young-of-the-year due to the spill.

Wildlife losses due to the spill are calculated using accepted algorithms that integrate population of wildlife exposed to spilled oil with risk of mortality upon exposure. Anticipated future losses due to mortalities at the time of the spill are modeled using expected biomass losses due to future growth. Alternative lines of evidence that address extent of wildlife mortalities such as using a multiplier approach (i.e., relative to collected/observed mortalities at the time of the Rouge River mystery spill) shall be considered, as appropriate.

Additional specific information regarding SIMAP's oil spill fate and effects modeling capability can be found at the following Web Link: http://www.appsci.com/simap/simap.htm .

Public use injuries will be quantified by determining the number (units) of recreational activity losses attributable to the incident and the duration of these losses.

2.3.7 Natural Recovery Estimation

Natural recovery estimation of biological resources is an important issue in this incident since it defines the temporal extent of interim lost services for which natural resource damage compensation is sought. The SIMAP model implicitly estimates the time period required for natural recovery to occur by determining the level of interim lost services. Calculation of interim lost services is described below.

Interim losses are injuries sustained in future years (pending recovery to baseline abundance) resulting from the direct kill at the time of the spill. Interim losses potentially include the following:

- Lost future uses (ecological and human services) of the killed organisms themselves;
- Lost future (somatic) growth of the killed organisms (i.e., production foregone, which provides additional services); and
- Lost future reproduction, which would otherwise recruit to the next generation.

The approach used by SIMAP is that the injury includes the direct kill and its future services, plus the lost somatic growth of the killed organisms, which would have provided additional services. Because the impact on each species, while locally significant, currently is presumed to be small compared to the scale of the total population in the area, it is assumed that density-dependent changes in survival rate are negligible, i.e., changes in natural and fishing mortality of surviving animals are assumed not to compensate for the killed animals during the natural life span of the animals killed.

The services provided by the injured organisms are measured in terms of production, i.e., biomass (kilogram [kg] wet weight) directly lost or not produced. Among other factors, services of biological systems are related to the productivity of the resources, i.e., to the amount of food produced, the usage of other resources (as food and nutrients), the production and recycling of wastes, etc. Particularly in aquatic ecosystems, the rate of turnover (production) is a better measure of ecological services than standing biomass (Odum 1971).

Thus, the sum of the standing stock killed (which resulted from production previous to the spill) plus lost future production (providing an estimation of natural resource recovery) provides a more accurate estimation of interim losses resulting from the incident, as opposed to standing stock alone (as number or kg), for measuring ecological services.

Trustees shall develop natural resource recovery estimations for lost public use through the use of literature searches, documentation review and interviews with impacted parties (e.g., harbormasters, park personnel, refuge personnel, and recreational fishing interests such as bait and tackle retailers). Public use recovery estimates shall focus on the following issues:

1. At what point following the incident did each impacted recreational activity resume (i.e., period of lost public use); and

2. Once a recreational activity resumed, was there any period of time where the public's enjoyment of the resource/activity reduced (i.e., period of diminished public use).

2.3.8 Assessment of Public Lost Use

As described in Section 2.3.1 of this document, closures of waterfront recreational areas and activities (outlined in Section 2.1.2.2) due to the spills shall be assessed through documentation review, and interviews with impacted parties (e.g., harbormasters, park personnel, refuge personnel, and recreational fishing interests such as bait and tackle retailers). Lost and diminished quality of public use resulting from this lost use survey effort shall be quantified using a benefit's transfer approach.

Specifically, the number of lost or diminished recreational activities resulting from the spill (i.e., boating trips, park visits, fishing, etc.) will be quantified. To scale the loss of public use, the unit consumer surplus value of these lost or diminished recreational activities will be developed from the recreational economics literature and transferred to the location and year of the incident (benefits transfer). Losses will be monetized through a multiplication of number of lost/diminished units of a given recreational activity by consumer surplus unit value.

The work product from this lost public use analysis will be a report that details the nature, degree and spatial/temporal extent of public use losses resulting from the Rouge River Mystery Spill, including a monetized valuation of these losses.

2.4 Avoidance or Minimization of Injuries

The trustees strived to avoid or minimize injuries to natural resources during response operations. Example injury avoidance and minimization strategies included:

- Cutting and removing oiled vegetation at LEMP to reduce continued petroleum contamination of surrounding riparian habitat; and
- Leaving sensitive riparian areas for natural oil attenuation (e.g., Detroit River islands) since active response actions could be more environmentally harmful than beneficial.

3.0 USE OF DAMAGE ASSESSMENT REGULATIONS AT 15 CFR 990 TO GUIDE CLAIMANT PROPOSED ASSESSMENT PROCESS

3.1 Jurisdiction to Pursue Oil Pollution Act of 1990 (OPA)

Trustees have jurisdiction to pursue a NRDA for the Rouge River Mystery Spill under OPA:

1. An incident has occurred, as defined in15 CFR 990, § 990.30 (i.e., discharges of oil products entered a navigable waterway (Rouge River and Detroit River) within the Exclusive Economic Zone);

2. The incident is not:

   a. Permitted under a permit issued under federal, state, or local law; or

   b. From a public vessel; or

   c. From an onshore facility subject to the Trans-Alaska Pipeline Authority Act, 43 U.S.C. 1651, *et seq*.; and

3. Natural resources under the trusteeship of the trustees may have been, or may be, injured as a result of the incident (i.e., fish and wildlife appear to have been killed/injured by this incident, and coastal habitat was contaminated by oil with vegetative communities removed during response actions).

3.2 Conditions for Collection of Preassessment Data

The present claim described in this document is for injury assessment and restoration planning activities only, not preassessment data collection actions. Therefore, this set of conditions is not applicable for this claim.

3.3 Conditions for Proceeding with Assessment

Trustees have determined that there is jurisdiction to pursue restoration under OPA, for the following reasons:

1. Injuries have resulted, or are likely to result, from the incident: known natural resource injuries resulting from the incident are summarized in Table 2-1, Nature and Scope of Injuries, in Section 2.3.4.

2. Response actions have not adequately addressed, or are not expected to address, the injuries resulting from the incident: it is concluded that response actions did not address all injuries since wildlife mortalities resulting from the incident were observed; and continued contamination of sensitive coastal habitat following response actions resulted in degradation of critical habitat.

3. Feasible primary and/or compensatory restoration actions exist to address the potential injuries: Reasonable primary and compensatory candidate restoration actions exist that could either accelerate resource recovery to baseline condition or compensate for interim ecological or public use service losses. These options include (but are not limited to) projects such as wetland restoration, improvement/expansion of park or refuge facilities, etc. (See Section 3.13 for additional discussion of candidate restoration actions.).

Accordingly, trustees determine that there is jurisdiction to pursue restoration under OPA for the Rouge River Mystery Spill.

3.4 Findings and Conditions for conducting Emergency Restoration

The present claim described in this document is for injury assessment and restoration planning activities only, not emergency restoration actions. Therefore, these findings and conditions are not applicable for this claim.

3.5 Notice of Intent to Conduct Restoration Planning

Trustees have determined that all conditions for proceeding with restoration planning have been met (per 15 CFR 990, § 990.42(a)). Accordingly, trustees shall draft and promulgate a Notice of Intent (NOI) to Conduct Restoration Planning as required under 15 CFR 990, § 990.44. The NOI likely shall include the following information:

1. The facts of the incident;
2. Trustee authority to proceed with the assessment;
3. Natural resources and services that are, or are likely to be, injured as a result of the incident;
4. Potential restoration actions relevant to the expected injuries; and
5. Where known, the potential assessment procedures to evaluate the injuries and definition of the appropriate type and scale of restoration for the injured natural resources and services.

Trustees shall make a copy of the NOI to Conduct Restoration Planning publicly available. Further, if a RP is ever identified for the Rouge River Mystery Spill, then trustees shall send a copy of the notice to the responsible parties, to the extent known, in such a way as will establish the date of receipt, and invite responsible parties' participation in the conduct of restoration planning.

3.6 Establishment of Administrative Record

Trustees shall open a publicly available administrative record to document the basis for their decisions pertaining to restoration. The administrative record shall be opened concurrently with the publication of the NOI to Conduct Restoration Planning. As appropriate, the administrative record shall include documents relied upon during the assessment, such as:

1. Any notice, draft and final restoration plans, and public comments;

2. Any relevant data, investigation reports, scientific studies, work plans, quality assurance plans, and literature; and

3. Any agreements, not otherwise privileged, among the participating trustees or with the responsible parties (if identified).

It is anticipated that the administrative record shall be maintained in a manner consistent with the Administrative Procedure Act, 5 U.S.C. 551-59, 701-06.

3.7 Designation of Lead Administrative Trustee

The incident affected state of Michigan and federal trustee jurisdictions. The USFWS is designated as the LAT for the Rouge River Mystery Spill NRDA. Lead administrative Trustee contact information can be found in Section 2.1.1 of this claim document.

3.8 Documentation of Coordination between Trustees, Public and Responsible Party

The USFWS has invited the following state and federal trustees (no tribal interests within the area of impact have been identified):

- Michigan Attorney's General (MAG);
- Michigan Department of Natural Resources (MDNR);
- Michigan Department of Environmental Quality (MDEQ); and
- National Oceanic and Atmospheric Administration (NOAA).

Invitation letters to these trustees may be found in Attachment 3.0 to this claim document. State trustees have voiced interest in participating in this NRDA with USFWS as the LAT. NOAA has stated that it does not plan to become an active trustee unless USFWS requests their participation (per Lisa Williams, USFWS discussion with Tom Brosnan, NOAA Damage Assessment Center, October 2004).

3.9 Use of Pre-Rule Assessment Procedures

Since this spill occurred after January 1996, trustees cannot elect to complete the Rouge River Mystery Spill NRDA using the pre-rule assessment approaches under either Comprehensive Environmental Response Compensation and Liability Act (CERCLA) or OPA. Thus, this consideration does not apply to the current upfront assessment claim.

3.10 Injury Determination

Trustees pursuant to 15 CFR 990, § 990.51 Injury assessment - injury determination, shall determine natural resource injuries. Specifically, trustees shall evaluate if:

1. The definition of injury has been met, as defined in 15 CFR 990, § 990.30; and
2. An injured natural resource has been exposed to the discharged oil, and a pathway can be established from the discharge to the exposed natural resource.

Table 2-1 provides a preliminary scope of natural resource injuries trustees intend to further assess. Collectively, these injury categories comprise the preliminary scope of injury assessment activities for the Rouge River Mystery Spill NRDA.

Additional discussion with resource experts, literature review and screening of impacts using SIMAP oil spill modeling software shall be used by trustees to finalize the scope and nature of natural resource injuries requiring intensive assessment and analysis.

When finalizing injury categories to assess, trustees shall consider a number of factors including:

- The natural resources and services of concern;
- The procedures available to evaluate and quantify injury and associated time and cost requirements;
- The evidence indicating exposure;
- The pathway from the incident to the natural resource and/or service of concern;
- The adverse change or impairment that constitutes injury;
- The evidence indicating injury;
- The mechanism by which injury occurred;
- The potential degree, and spatial and temporal extent of the injury;
- The potential natural recovery period; and
- The kinds of primary and/or compensatory restoration actions; that are feasible.

Methods proposed for determining biological and public use injuries from the Rouge River Mystery Spill are described further in Sections 2.3.1, 2.3.5 and 2.3.8.

3.11 Injury Quantification

Trustees shall quantify natural resource injuries shown in Table 2-1 in terms of the degree, and spatial and temporal extent of the injury to injured natural resources. To quantify spatial and temporal extent of biological injuries, SIMAP shall be used.

For public use injury quantification, documentation review and interviews with impacted parties (e.g., harbormasters, park personnel, refuge personnel, and recreational fishing interests such as bait and tackle retailers) shall be used.

Methods proposed for quantifying biological and public use injuries from the Rouge River Mystery Spill are described further in Sections 2.3.1, 2.3.6 and 2.3.8.

3.12 Natural Recovery Analysis

As part of injury quantification activities, trustees shall estimate the temporal extent of injuries, including a quantitative or qualitative estimate of the time required for natural recovery to occur without restoration, but including any response actions that occurred following the incident. SIMAP will be used to determine the period required for natural recovery of biological resources as described in Section 2.3.7.

Trustees shall develop natural resource recovery estimations for lost public use through the use of literature searches, documentation review and interviews with impacted parties (e.g., harbormasters, park personnel, refuge personnel, and recreational fishing interests such as bait and tackle retailers) as described in Section 2.3.7.

3.13 Identification of Range of Feasible Restoration Alternatives

If the results of injury determination and quantification activities justify restoration, trustees shall proceed with restoration planning. Otherwise, trustees will not take additional action on the Rouge River NRDA. However, trustees shall submit cost documentation to NPFC for all reasonable assessment costs incurred up to this point, and return unspent assessment funds to NPFC.

If injury determination and quantification justifies restoration planning, trustees shall consider a reasonable range of restoration alternatives before selecting the preferred alternative(s). Each restoration alternative shall be comprised of primary and/or compensatory restoration components that address specific injuries associated with the incident. Each alternative shall be designed so that, as a package of one or more actions, the alternative would make the environment and public whole. Only those alternatives considered technically feasible and in accordance with applicable laws, regulations, or permits shall be considered.

Natural recovery of injured resources shall also be considered.

Appropriate restoration alternatives will be identified through literature reviews and discussions with trustees, resource management units and local watershed improvement consortia, including (but not limited to):

- USFWS:
  - East Lansing Field Office;
  - Grosse Isle Office; and
  - Detroit River International Wildlife Refuge.
- MDNR;
- MDEQ;
- Michigan Natural Features Inventory;
- LEMP;
- City of Detroit;
- City of Rouge River; and
- Wayne County Department of Environment Watershed Management Division (e.g., with respect to the Rouge River National Wet Weather Demonstration Project, an EPA-sponsored demonstration of a watershed approach to pollution management).

Preliminary considerations for candidate restoration projects are described below. Identification of candidate restoration projects is subject to significant amendment as more injury assessment and candidate restoration data and information are identified through the course of the Rouge River Mystery Spill NRDA.

3.13.1 Primary Restoration

Primary restoration alternatives will be identified for further consideration from *inter alia*, the trustees and resource management entities listed above. For example, trustees may consider managing continuing inputs of petroleum contamination from Baby Creek Outfall, an ongoing source of petroleum contamination, especially following precipitation events.

3.13.2 Compensatory Restoration

Compensatory restoration alternatives will be identified for further consideration from *inter alia*, the trustees and resource management entities listed above. Preliminary compensatory restoration concepts include the following:

- *Phragmites* management at LEMP to increase bird nesting potential in pre-existing wetlands;
- Wetland restoration and/or creation (may include on- and/or off-site work, depending on project feasibility and scale);

- Shoreline softening (i.e., a method of removing hard, often impervious, manmade shoreline structure and replacing with appropriate geomorphological feature (e.g., wetlands, unconsolidated muds, etc.). Uses include improvement of shoreline and aquatic habitat and establish a biotic buffer for non-point source run-off contaminant attenuation);
- Predation control (i.e., raccoon control);
- Road crossing for wildlife (e.g., turtles);
- Spawning area development;
- Protection, easements of sensitive properties; and
- Park enhancements, fishing enhancements, interpretive signage, and resource availability outreach for lost or diminished public use.

3.14 Description of Restoration Scaling

After the types of candidate restoration actions are identified, the scale of those actions that will make the environment and public whole shall be determined. For primary restoration actions, scaling generally applies to actions involving replacement and/or acquisition of equivalent of natural resources and/or services.

For scaling determined and quantified biological injuries to restoration alternatives, trustees likely shall employ resource-to-resource and service-to-service scaling approaches using SIMAP modeling outputs (biological injuries quantified as numbers or biomass lost via acute toxicity and production foregone over time) to determine the appropriate scale of restoration projects. Specifically, trustees determine the scale of restoration actions that will provide natural resources and/or services equal in quantity, type and quality, and of comparable value as those lost as determined through SIMAP modeling studies.

For scaling lost public use restoration projects, trustees likely shall employ a valuation scaling approach. Given the anticipated magnitude of public use losses resulting from the Rouge River Mystery Spill, it is believed that a valuation scaling approach is more expeditious and cost-effective than resource-to-resource or service-to-service scaling. Though valuation of the lost services is practicable, valuation of the replacement natural resources and/or services cannot be performed within a reasonable time frame or at a reasonable cost. Accordingly, trustees propose to estimate the dollar value of the lost services and select the scale of the restoration action that has a cost equivalent to the lost value. Benefits transfer is proposed as a cost effective approach to implement this proposed value-to-cost scaling stratagem. The benefits transfer method is commonly used in oil spill natural resource damage assessments.

Where appropriate and feasible uncertainties associated with scaling restoration actions will be addressed and described.

Finally, restoration actions will be discounted to the date the restoration claim is presented to NPFC (or the RP, if one is found) for payment per 15 CFR 990, § 990.53.

3.15 Use of a Regional Restoration Plan or Other Existing Plan(s)

Trustees shall consider use of a regional restoration plan, or other appropriate existing restoration plans, for restoration planning as available. If such plans are identified for application to Rouge River restoration planning, they shall be appropriate to the particular restoration needs to adequately address determined and quantified injuries.

3.16 Restoration Evaluation and Selection of Preferred Alternative

Once a reasonable range of restoration alternatives has been developed, they shall be evaluated for selection of a preferred alternative. At minimum, selection criteria shall be based on the following:

1. The cost to carry out the alternative;
2. The extent to which each alternative is expected to meet the trustees' goals and objectives in returning the injured natural resources and services to baseline and/or compensating for interim losses;
3. The likelihood of success of each alternative;
4. The extent to which each alternative will prevent future injury as a result of the incident, and avoid collateral injury as a result of implementing the alternative;
5. The extent to which each alternative benefits more than one natural resource and/or service; and
6. The effect of each alternative on public health and safety.

Based on these evaluation factors, trustees shall select a preferred restoration alternative(s). If two or more alternatives are equally preferable based on these factors, the most cost-effective alternative shall be selected.

If additional information is needed to identify and evaluate the feasibility and likelihood of success of restoration alternatives, trustees may consider conducting restoration pilot projects. Pilot projects would only be undertaken when these projects are likely to provide the information that allows for adequate alternative evaluation, and can be conducted at a reasonable cost and in a reasonable time frame. If a pilot project were necessary, trustees would request additional funding from NPFC to address this unique requirement and provide appropriate supplementary documentation, as prescribed by NPFC, to support the claim for this additional restoration planning need.

3.17 Development of Draft and Final Restoration Plan/Environmental Assessments (DRP/EA)

OPA requires that damages be based upon a plan developed with opportunity for public review and comment. To meet this requirement, trustees propose to develop a Draft and Final

Restoration Plan/Environmental Assessment, with an opportunity for public review of and comment on the draft plan, as part of the present Rouge River Mystery Spill upfront funded assessment claim.

The DRP/EA shall include:

1. A summary of injury assessment procedures used;
2. A description of the nature, degree, and spatial and temporal extent of injuries resulting from the incident;
3. The goals and objectives of restoration;
4. The range of restoration alternatives considered, and a discussion of how such alternatives were developed and evaluated;
5. Identification of the trustees' tentative preferred alternative(s);
6. A description of past and proposed involvement of the responsible parties in the assessment; and
7. A description of monitoring for documenting restoration effectiveness, including performance criteria that will be used to determine the success of restoration or need for interim corrective action.

When developing the DRP/EA, trustees shall establish restoration objectives that are specific to the injuries. These objectives should clearly specify the desired outcome, and the performance criteria by which successful restoration will be judged. Performance criteria may include structural, functional, temporal, and/or other demonstrable factors. Trustees shall determine what criteria will:

1. Constitute success, such that responsible parties, if found, are relieved of responsibility for further restoration actions; or
2. Necessitate corrective actions in order to comply with the terms of a restoration plan or settlement agreement.

The DRP/EA shall include a monitoring component that addresses such factors as duration and frequency of monitoring needed to gauge progress and success, level of sampling needed to detect success or the need for corrective action, and whether monitoring of a reference or control site is needed to determine progress and success. Reasonable monitoring and oversight costs shall be a cost component of the subsequent restoration claim, and cover those activities necessary to gauge the progress, performance, and success of the restoration actions developed under the plan.

Public review and comment on the Draft and Final Restoration Plans will be conducted in a manner that complies with applicable federal trustee National Environmental Protection Agency

(NEPA) requirements. The specific strategies for facilitating public review and comments are to be determined, but shall address (but not be limited to) the following actions:

- Advertising availability of the draft and final restoration plans for review;
- Providing public access for review of the plans; and
- Providing venues for soliciting and collecting comments.

Pending receipt of public comments on the DRP/EA, trustees shall develop a Final Restoration Plan/Environmental Assessment (FRP/EA) that includes information required in the DRP/EA, responses to public comments, if applicable, and an indication of any changes made to the DRP.

It is presumed that the FRP/EA will serve as the basis for a subsequent restoration claim to be submitted to the NPFC, if no RP is found.

3.18 Satisfaction of Assessment Methodological Standards

Any procedures used pursuant to the damage assessment regulations at 15 CFR 990 must comply with the following standards (per § 990.27):

1. The procedure must be capable of providing assessment information of use in determining the type and scale of restoration appropriate for a particular injury;

2. The additional cost of a more complex procedure must be reasonably related to the expected increase in the quantity and/or quality of relevant information provided by the more complex procedure; and

3. The procedure must be reliable and valid for the particular incident.

Compliance of proposed assessment procedures with each of these standards is described below.

Proposed ecological assessment procedures (i.e., development of oil spill impact modeling data inputs and using these inputs to run the SIMAP model) will yield assessment information that result in a determination and quantification of the nature, degree and spatial/temporal extent of injuries. These modeling results can be directly used to scale restoration projects that compensate for discovered biological injuries. Implementation of proposed public use loss assessment procedures (i.e., literature search, document review and interviews with impacted parties) will yield data that determines and quantifies the publics lost and diminished use of restoration projects. Using a benefits transfer approach, data yielded from the public use loss injury study can be valued and, accordingly, used in public use restoration project scaling efforts.

Use of modeling for assessing biological injuries and literature search and point interviews to assess public use loss are industry-accepted cost effective approaches that heavily leverage existing information. Additional (and more costly) field and laboratory-based studies are not considered at this time to provide additional useful information and data that would substantively inform injury assessment and restoration planning efforts. Accordingly, these more costly procedures are not being proposed in the present upfront funded assessment claim.

From a reliability (i.e., consistency or repeatability) and validity (i.e., ability to approximate a "true" value) perspective, use of SIMAP to determine and quantify biological injuries uses a statistically robust stochastic approach to derive resource impacts. Such repeated simulations have been shown in past SIMAP applications to be repeatable and consistent. Further, SIMAP modeling results have been shown in many past incidents to be coincident with real world spill impact observations, demonstrating model algorithm validity. Public use impact interviews and surveys to determine quantify public use losses, and the use of benefits transfer to scale these losses, are accepted natural resource economics injury assessment procedures that have been repeatedly used for valuing public use losses in similar assessments and are well-accepted by the natural resource economics community.

3.19 Certification of Assessment Cost Reasonableness

Trustees certify that claimed assessment costs are cost reasonable. These certifications may be found in Section 7.2 of this document.

3.20 Documentation of Demand to Responsible Party for Payment

As stated in Section 2.1.3 of this document, no RP has been found for this incident. If a RP is found, then trustees will submit the Demand for assessment (and, subsequently, restoration) claim payment to the RP with documentation supporting this presentment.

However, if a RP is not found, then the Demand for assessment (and, subsequently, restoration) claim payment shall be made directly to the NRD Claims Division of the NPFC for payment from the OSLTF.

4.0 SENIOR ASSESSMENT PERSONNEL AND RESPONSIBILITIES

The following identifies agencies and senior personnel participating in the Rouge River Mystery Spill NRDA. Major roles and responsibilities for these participating interests also are included. This section outlines senior personnel only; it is anticipated that additional technical and administrative support personnel shall be required to implement the proposed NRDA in a cost-effective and timely manner.

4.1 USFWS

The USFWS shall serve as the LAT on the Rouge River Mystery Spill NRDA. As the LAT, USFWS shall execute the following actions:

- Ensure that the NRDA is implemented in a manner consistent with applicable statutes and regulations;
- Coordinate activities and interactions with NRDA participants, including:
  - Trustees;
  - Public;
  - Contractors; and
  - RP (if identified).
- Serve as primary point of contact to NPFC on NRD claim matters; and
- Cost documentation.

Senior USFWS personnel participating in the Rouge River Mystery Spill NRDA include:

- *Robyn Thorson:* Authorized Official to bring claim for NRDs (See Attachment 1.0.);
- *Lisa Williams:* Contaminant Specialist and point of contact on all technical claim matters. Lisa will supervise the NRDA;
- *Craig Czarnecki*: Field Supervisor, providing overall technical and administrative support on NRDA;
- *Niccole Wandelear:* Fisheries Biologist, providing overall technical and administrative support on NRDA;
- *Stephanie Milsap:* Contaminants Specialist, providing technical support on injury assessment and restoration alternative identification and analysis;
- *Dave Best*: Contaminants Specialist, providing technical support on injury assessment and restoration alternative identification and analysis; and

- *John Hartig:* Refuge Manager for the Detroit River International Wildlife Refuge, providing technical support on injury assessment and restoration alternative identification and analysis.

4.2 State of Michigan

The state of Michigan shall participate in the present NRDA as natural resource trustees. Designated state trustees include the following:

- MDAG;
- MDEQ; and
- MDNR.

It is anticipated that state trustees will support and participate the LAT's efforts in the following NRDA activities:

- Finalization of injured resource categories,
- Participation in planning injury assessment studies,
- Information/data sharing (e.g., incident and resource information),
- Technical and administrative review of interim reports and memoranda described in Table 5-1 (minimally, the DRP and FRP);
- Participation in identifying and analyzing restoration alternatives; and
- Support LAT in developing and implementing a robust public review process for DRP.

To date, the following state trustee agency representatives have been identified:

- Peter Manning, Assistant Attorney General, MDAG;
- William Creal, Chief, Permit Section, MDEQ; and
- Timothy Payne, Wildlife Division Supervisor, MDNR.

Contact information for these state (and federal) trustee representatives can be found in Section 2.1.1; trustee designation documentation can be found in Attachment 1.0.

4.3 Contracted Personnel

USFWS intends to use contracted expert support to assist in the implementation of the proposed Rouge River Mystery Spill NRDA. Contracted staff shall be hired by the LAT pending receipt of funding for the NRDA from NPFC. The LAT shall use contracted staff to produce interim and final NRDA-associated work products and services to inform and expedite trustee actions.

Specifically, it is envisioned that contract support would assist with the following actions:

- Development of NOI to Conduct Restoration Planning;
- Establish and maintain Administrative Record;
- Collect information and develop the Incident Information Interim Report;
- Collect data for SIMAP oil spill modeling;
- Conduct screening of candidate biological resource injuries to inform development of final biological injury categories, and produce the SIMAP Model Screening Interim Report;
- Conduct oil spill impact modeling using SIMAP and develop the SIMAP Oil Spill Impacts Interim Report;
- Conduct a study of public use losses and develop the Lost and Diminished Public Use Impacts Interim Report;
- Develop a number of interim memoranda to inform restoration planning actions, including:
  - Natural Recovery Memorandum;
  - Range of Feasible Restoration Alternatives Memorandum;
  - Restoration Scaling Memorandum;
  - Evaluation and Selection of Preferred Alternative Memorandum; and
  - Compilation of Public Comments and Responses Memorandum.
- Development of DRP/EA;
- Development of FRP/EA;
- Miscellaneous case management support (e.g., scheduling trustee meetings and recording minutes); and
- Cost documentation support.

To execute the Rouge River Mystery Spill NRDA in an efficient, cost-effective and comprehensive manner, the LAT shall seek a contracting group/consortium with expertise in the following areas:

- NPFC natural resource damage claim requirements;
- 15 CFR 990 and OPA oil spill NRDA requirements;
- Oil spill injury assessment and restoration planning procedures and processes;
- Federal and state natural resource trustees oil spill NRD claim support;
- Known (and potential) natural resource impacts from the Rouge River Mystery Spill;
- SIMAP oil spill modeling and interpretation;

- Conducting public use loss studies;
- Restoration alternative analysis and scaling;
- Developing Restoration plans;
- NRDA study quality assurance;
- Case management;
- Administrative record management; and
- Cost Documentation experience.

Ideally, to minimize administrative contracting burden, the LAT shall consider contracting with a lead contractor with expertise in successfully executing oil spill NRDA and the NPFC claims processes and procedures, and has the direct ability to subcontract with appropriate resource experts (e.g., SIMAP modelers and natural resource economists).

5.0 SCHEDULE OF ASSESSMENT ACTIONS

The schedule for major actions proposed in the Rouge River Mystery Spill assessment claim is provided in Table 5-1 below. This schedule is based on calendar months from NPFC's notification to USFWS, the LAT, that funding will be provided from the OSLTF as requested in this claim for proposed assessment activities. This schedule presumes a 30-calendar day review time of interim work products. Where memorandums and reports are referenced in Table 5-1, the schedule pertains to the final version of the report/memorandum. Draft reports and memorandums generally will be submitted two months prior to completion of the final version, hence, allowing adequate time for trustee review and incorporation of trustee comments into the finalized memorandum or report. Specific draft report and memorandum dates shall be finalized on a document-specific basis. Finally, this schedule presumes that USFWS will hire a consulting firm to support Rouge River NRDA actions.

Table 5-1: Preliminary Schedule of Rouge River NRDA Proposed Activities

Proposed NRDA Action	Calendar Months After NPFC Notification of Claim Payment
NPFC Notification to LAT of Claim Payment from OSLTF	0
LAT Procures Consulting Support for Rouge River NRDA	2
Promulgation of NOI to Conduct Restoration Planning	3
Incident Information Interim Report	5
SIMAP Model Screening Interim Report	7
SIMAP Oil Spill Impacts Interim Report	9
Lost and Diminished Public Use Impacts Interim Report	10
Natural Recovery Memorandum	11
Range of Feasible Restoration Alternatives Memorandum	12
Restoration Scaling Memorandum	14
Evaluation and Selection of Preferred Alternative Memorandum	17
Development of DRP/EA	20
30 Day DRP Public Review Coordination	21
Compilation of Public Comments and Responses Memorandum	23
Development of FRP/EA	26
Submission of Restoration Claim to NPFC*	28
Administrative Record Establishment and Maintenance	Ongoing throughout NRDA
Case Management	Ongoing throughout NRDA
Restoration Implementation	Pending Restoration Claim Funding

* Presumes no RP has been identified. If identified, claim will be submitted to RP.

6.0 COST DOCUMENTATION

6.1 Summary and Rationale of Past and Proposed Costs

Financial resources are required for both past and future costs to implement a defensible natural resource damage assessment for the Rouge River Mystery Spill that is consistent with claim requirements found in the OPA, the NRDA regulations at 15 CFR Part 990 and the interim claims regulations at 33 CFR Part 136. Costs already incurred (past costs) are summarized by agency in Table 6-1 (below) and described in further detail in Section 6.3 of this chapter. Past costs mainly address preliminary collection of response and impact data/information as well as the personnel costs associated with developing strategies for conducting the NRDA as described in chapters two and three of the present assessment claim.

Table 6-1: Summary Rouge River NRDA Assessment Costs

Agency	Past Costs	Future Costs	Total Costs
USFWS	$5,682	$978,343	$984,025
MDEQ	$1,332	$ 44,320	$45,652
MDAG	$1,170	$ 37,319	$38,489
MDNR	$0	$20,954	$20,954
Total Costs	$8,184	$1,080,936	**$1,089,120**

Future (proposed) costs required to implement the Rouge River Mystery Spill NRDA also are summarized in Table 6-1 (below) and described in further detail in Section 6.4 of this chapter. Detailed future cost data broken down by agency, year, and task may be found in Attachment 4.0 of this claim. Attachment 4.0 provides costing information for each of the four trustee agencies participating in the Rouge River Mystery Spill NRDA: USFWS, MDEQ, MDAG and MDNR. Future costs address the costs of injury assessment, restoration project identification and selection, restoration scaling, development of draft and final restoration plans and associated NRDA implementation requirements found in 15 CFR Part 990.

From Table 6-1 it can be seen that the cumulative amount of funds requested for the Rouge River Mystery Spill NRDA is $1,089,120. This amount constitutes the sum certain requested by the USFWS, the LAT, from the USCG NPFC on behalf of all participating natural resource Trustees to implement this NRDA

6.2 Inter-Trustee NRDA Memorandum or Agreement

Chapter 4 of this claim provides roles and responsibilities for state and federal natural resource trustees participating in the Rouge River NRDA, and serves as a working agreement describing each trustee's actions in the Rouge River Mystery Spill NRDA.

6.3 Costs Already Incurred

6.3.1 Past Federal Costs

Past costs incurred by the federal government associated with the Rouge River NRDA have been limited to the USFWS. Past USFWS costs included here are limited to staff time by the Technical NRDA lead, Dr. Lisa L. Williams and biologist Ms. Niccole Wandelear. Dr. Williams compiled and analyzed ephemeral data collected following the spill to determine the preliminary scope of natural resource injuries and participated in development of the assessment strategy for this NRDA. Ms. Wandelear assisted Dr. Williams in her efforts and collected response data to inform assessment strategy development. Table 6-2 below provides a summary of past USFWS costs.

Table 6-2: Past Costs for USFWS Participation in the Rouge River NRDA

Time Period	USFWS Staff	Description of Activities	Hours	Hourly Rate	Cost
May 2004 – September 2004	Williams	• Development of injury assessment strategies • Ephemeral data compilation	29.0	$46.78	$1,356.62
October 2004 – September 2005	Williams	• Continued development and refinement of injury assessment strategy • NRDA cost documentation	15.5	$49.64	$769.42
May 2004 – September 2004	Wandelear	• Collection and compilation of response information • Assisted in development of injury assessment strategies.	76.0	$33.31	$2,531.56
		Subtotal USFWS Expenses			$4,657.60
		USFWS Indirect Charge (22%)			$1,024.67
		Total Past USFWS/Federal Costs			**$5,682.27**

6.3.2 Past State of Michigan Costs

Past costs incurred by the State of Michigan associated with the Rouge River NRDA are described by agency below.

6.3.2.1 Michigan Department of Environmental Quality

MDEQ personnel (Mr. William Creal) participated in review and input on the draft natural resource damage assessment strategy. Past costs for this work are summarized in Table 6-3 below.

Table 6-3: Past Costs for MDEQ Participation in the Rouge River NRDA

Time Period	Hours (Mr. William Creal)	Description of Activities	Hourly Rate	Cost
July – September 2005	20.0	• Review and Comment on Injury Assessment Strategies proposed for Rouge River NRDA. • Participation in July 11th Trustee conference call.	$55.91	$1,118.20
		Subtotal MDEQ Expenses		$1,118.20
		MDEQ Indirect Charge (19.13%)		$213.91
		Total Past MDEQ Costs		**$1,332.11**

6.3.2.2 Michigan Department of Attorney General

MDAG personnel (Mr. Mark Matus) participated in review and input on the draft natural resource damage assessment strategy. Past costs for this work are summarized in Table 6-4 below.

Table 6-4: Past Costs for MDAG Participation in the Rouge River NRDA

Time Period	Hours (Mr. Mark Matus)	Description of Activities	Hourly Rate	Cost
July – September 2005	18.0	• Review and Comment on Injury Assessment Strategies proposed for Rouge River NRDA. • Participation in July 11th Trustee conference call.	$65.00	$1,170.00
		Total Past MDAG Costs		**$1,170.00**

6.3.2.3 Michigan Department of Natural Resources

MDNR personnel (Mr. Timothy Payne) provided limited input on the draft natural resource damage assessment strategy and cost development. Accordingly, MDNR did not incur any chargeable costs for these efforts.

6.3.3 Summary of Past Costs

Past Agency costs associated with the Rouge River Mystery Spill NRDA are summarized below in Table 6-5 below.

Table 6-5: Summary of Past Trustee Costs for the Rouge River NRDA

Agency	Past Cost
USFWS	$5,682.27
MDEQ	$1,332.11
MDAG	$1,170.00
MDNR	$0
Total Past Costs	**$8,184.38**

6.4 Future Costs

6.4.1 Work to Be Performed

Future tasks associated with the Rouge River NRDA are described in detail in the following sections of this document:

- Section 2.3 (Proposed Assessment Procedures),
- Section 3.5 (Notice of Intent to Conduct Restoration Planning),
- Section 3.6 (Establishment of Administrative Record),
- Section 3.8 (Documentation of Coordination between Trustees, Public, and Responsible Party),
- Section 3.10 (Injury Determination),
- Section 3.11 (Injury Quantification),
- Section 3.12 (Natural Recovery Analysis),
- Sections 3.13 (Identification of Range of Feasible Restoration Alternatives),
- Section 3.14 (Description of Restoration Scaling),
- Section 3.15 (Use of a Regional Restoration Plan or Other Existing Plans),
- Section 3.16 (Restoration Evaluation and Selection of Preferred Alternative),
- Section 3.17 (Development of Draft and Final Restoration Plan/Environmental Assessments),
- Section 3.18 (Satisfaction of Assessment Methodological Standards),
- Section 3.19 (Certification of Assessment Cost Reasonableness), and
- Section 3.20 (Documentation of Demand for Payment, as appropriate).

Specific roles and responsibilities of state and federal trustees and contractors to accomplish this work are described in Section 4.0 (Senior Assessment Personnel and Responsibilities).

6.4.2 Schedule of Work

The schedule for this work is provided in Section 5.0, Schedule of Assessment Actions, and is summarized in Table 5-1.

6.4.3 Estimated Level of Resources and Costs

Future costs and resources required for implementing the Rouge River NRDA are described below. These resource requirements are developed based on the cost of executing NRDA tasks as described in Chapters 2, 3, 4 and Table 5-1 of Chapter 5 of this assessment claim. A detailed breakdown of specific costs and requirements by NRDA task and trustee agency may be found in Attachment 4.0 to this claim package.

Resource requirements mainly include the cost of agency and contractor support personnel. Resource requirement estimates presume that the natural resource damage assessment will begin during the first quarter of calendar year 2006 (i.e., second quarter of federal FY 2006).

6.4.3.1 Estimated Future Federal Resource Requirements

Future federal Rouge River NRDA costs described in this claim package are limited to USFWS personnel, contract NRDA expert support and miscellaneous other direct expenses such as travel to areas of impact, restoration sites and trustee meetings, and miscellaneous expenses.

Future USFWS resource requirements associated with the NRDA are described in detail in Attachment 4.0 and summarized in Table 6-6 below.

Table 6-6: Estimated Future USFWS Resource Requirements for Rouge River NRDA

Agency	2006	2007	2008	Total
USFWS	$419,365	$431,720	$127,258	$978,343

6.4.3.2 Estimated Future State of Michigan Resource Requirements

Future resource requirements for each participating state of Michigan Trustee are based on activities described in this claim package. Detailed cost requirements may be found in Attachment 4.0.

Michigan Department of Environmental Quality

A summary of MDEQ future resource requirements for the Rouge River Mystery spill may be found in Table 6-7 below.

Table 6-7: Estimated Future MDEQ Resource Requirements for Rouge River NRDA

Agency	2006	2007	2008	Total
MDEQ	$17,028	$21,442	$5,850	$44,320

Michigan Department of Attorney General

A summary of MDAG future resource requirements for the Rouge River Mystery spill may be found in Table 6-8 below.

Table 6-8: Estimated Future MDAG Resource Requirements for Rouge River NRDA

Agency	2006	2007	2008	Total
MDAG	$12,902	$14,264	$10,153	$37,319

Michigan Department of Natural Resources

A summary of MDNR future resource requirements for the Rouge River Mystery spill may be found in Table 6-9 below.

Table 6-9: Estimated Future MDNR Resource Requirements for Rouge River NRDA

Agency	2006	2007	2008	Total
MDNR	$8,589	$9,024	$3,341	$20,954

6.4.4 Contingencies

A contingency is commonly used in the trustee community to address unforeseen future NRDA costs. For the Rouge River NRDA a 25 percent contingency is built into the USFWS and state of Michigan agencies' future labor and resource costs, including contract support to the Agencies.

There is inherent uncertainty in the amount of time and resources required for future tasks. For example, additional resources may be required for alternative assessment strategies for bird and wildlife injuries.

Moreover, all funds that remain after project completion will be returned to the NPFC for re-deposit into the OSLTF.

The proposed 25 percent contingency is commonly used to address uncertainties in future costs. For example, the state of Florida and federal (NOAA) trustees employed a 25 percent contingency to address uncertainties associated with future agency costs and selected project costs for the 2000 Fort Lauderdale Mystery Spill NRDA in their NRD claim to NPFC.

This 25 percent contingency already is built into estimated future Trustee agency resource requirements in Tables 6-6 through 6-9.

Table 6-10 (below) summarizes the overall estimated future resource requirements for each agency to implement the Rouge River Mystery Spill NRDA.

Table 6-10: Estimated Future Resource Requirements for Rouge River NRDA

Trustee Agency	Estimated Cost
USFWS	$978,343
MDEQ	$37,319
MDAG	$44,320
MDNR	$20,954
Total Future Resources Required	**$1,080,936**

6.5 Payments Received for Proposed Assessment

Claimants certify that no payments have been received regarding claimed past and future assessment costs in this claim.

6.6 Standard Forms 1080/1081

USDOI/FWS TO APPEND THIS INFORMATION TO CLAIM.

7.0 POINTS OF CONTACT AND CERTIFICATIONS

7.1 Points of Contact

The USFWS, serving as the LAT, will be the point of contact for this upfront-funded assessment claim. The official point of contact for the claim is the designated Authorized Official (AO) for the LAT, Robyn Thorson. Additionally, Dr. Lisa Williams, USFWS Contaminants Specialist at the East Lansing Field Office (ELFO), shall serve as the point of contact for claim-specific technical and financial issues. Contact information for the LAT is provided below:

Lead Administrative Trustee: USFWS

Designated Authorized Official (See Attachment 1.0)

Robyn Thorson
Regional Director
U.S. Fish and Wildlife Service
Region Three
1 Federal Drive
Ft. Snelling, MN 55111
Phone: (612) 713-5360
Fax: (612) 713-5280
email: robyn_thorson@fws.gov

Technical Contact:

Lisa L. Williams, PhD
Contaminants Specialist
U.S. Fish and Wildlife Service
East Lansing Field Office
2651 Coolidge Road, Suite 101
East Lansing, MI 48823
Telephone: (517) 351-8324
Fax: (517) 351-1443
Email: lisa_williams@fws.gov

7.2 Certifications and Signature

The following certifications and signature are required when submitting a NRD claim to the USCG NPFC:

Certifications and Signature

I, the undersigned, certify the accuracy and integrity of this claim and certify that actions taken or proposed were or will be conducted in accordance with the OPA and consistent with all applicable laws and regulations.

I, the undersigned, certify that, to the best of my knowledge and belief, no trustee(s) other than those identified in this claim has the right to present a claim for the same natural resource injuries and that payment of any subpart of this claim would not constitute double recovery for the same natural resource injuries.

I, the undersigned, agree that upon acceptance of any compensation from the Fund, I will cooperate fully with the United States in any claim or action by the United States to recover the compensation. The cooperation shall include, but is not limited to, immediately reimbursing to the Fund any compensation received from any other source for the same costs and/or damages and, providing any documentation, evidence, testimony, and other support, as may be necessary for the Fund to recover such compensation.

I, the undersigned, certify that, to the best of my knowledge and belief, the information contained in this claim represents all material facts and is true. I understand that misrepresentation of facts is subject to prosecution under Federal law (including but not limited to 18 U.S.C. 287 and 1001).

I, the undersigned, certify that the assessment was conducted in accordance with the Damage Assessment Regulations at 15 CFR 990 (promulgated by NOAA) –

No __ Yes __

______________________________________ ______________________

Claimant's Authorized Representative Date

7.3 Claim Mailing Address and Inquiries

The mailing address for the assessment claim is provided below:

National Pollution Funds Center
Natural Resource Damage Claims Division
4200 Wilson Blvd., Suite 1000
Arlington, VA 22203-1804
Phone: (202) 493-6860
Fax: (202) 493-6939

Inquiries regarding claim questions and issues for discussion with NPFC may be directed to either of the following:

Mr. Chris Abrams,
Chief, Natural Resource Damage Claims Division
Phone: (202) 493-6865
Email: CAbrams@ballston.uscg.mil

8.0 REFERENCES

Detroit/Rouge River Oil Spill Unified Command. 2002. Detroit River and River Rouge Oil Spill Synopsis. Detroit/Rouge River Oil Spill Unified Command News Release [Document 101, page 25].

Maddox, J. 2002. NOAA's SSC Report on Oil Volume Estimate of the Rouge/Detroit River Mystery Spill. IN: Garrity, P.G. Estimate of Volume of Oil Spilled on the Detroit River on April 10, 2002. Memorandum to File. United States Coast Guard. Detroit Michigan. 11 pp.

McDiarmid Jr., H. 2004. Metro Detroit's Troubled Waters: Oil Spill Standoff. Detroit Free Press. April 5, 2004. Detroit, Michigan. 2 pp.

Odum, E.P., 1971. Fundamentals of Ecology, W.B. Saunders Co., Philadelphia, 574 p.

USCG. Marine Safety Office Detroit. 2002. Vacuum Truck Photograph (Vactruckgood.jpg).

Williams, L.L. 2002a. Preliminary Summary of Impacts to Fish and Wildlife from the Rouge/Detroit Rivers Oil Spill of April 2002. Memorandum form Lisa L. Williams, USFWS East Lansing Field Office to Robert Lumadue, USFWS Law Enforcement, dated June 13, 2002. 5pp.

Williams, L.L. 2002b. Accomplishments Report: Mystery Oil Spill Impacts Wildlife in the Detroit River. Filed on May 10, 2002. USFWS, East Lansing Field Office. East Lansing, Michigan. 4 pp.

ATTACHMENTS

ATTACHMENT 1.0

TRUSTEE DESIGNATION DOCUMENTATION

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STATE OF MICHIGAN
OFFICE OF THE GOVERNOR
LANSING

JENNIFER M. GRANHOLM
GOVERNOR

JOHN D. CHERRY, JR.
LT. GOVERNOR

CA Czarnecki
Best
Brewer
Dandridge
DeCapita
Deloria
Dingledine
Eitniear
Fisher
Gourley
Hosler
Kavetsky
Kubilis
Mensing
Pastva
Tansy
Williams

September 29, 2004

Mr. Michael Leavitt
Administrator
U.S. Environmental Protection Agency
401 M Street, SW
Washington, DC 20460

Dear Mr. Leavitt:

SUBJECT: Designation of Natural Resources Trustees for the State of Michigan

Pursuant to Section 311 of the Federal Water Pollution Control Act and Section 107, of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), I am designating the Directors of the Michigan Department of Natural Resources (MDNR) and the Department of Environmental Quality (MDEQ), as co-trustees in conjunction with the Michigan Attorney General for the State of Michigan. These Trustee representatives are authorized to conduct assessments of natural resource damages that may result from the release of oil or a hazardous substance to the environment. Michigan's Attorney General, Mr. Michael Cox, will serve as co-trustee to seek recovery of damages for injury to, destruction, or loss of natural resources.

It is my intent that this designation will facilitate a coordinated and cooperative effort between the State of Michigan and the U.S. Environmental Protection Agency to ensure that all natural resource impacts resulting from environmental releases are addressed during remedial investigation, restoration, and cost recovery efforts.

We look forward to working in cooperation with Environmental Protection Agency staff of Region V, and the other natural resource Trustees working in Michigan, to protect and preserve the outstanding natural resources of our Great Lakes State. Please feel free to contact MDEQ Director, Mr. Steve Chester, and the MDNR Director, Ms. Rebecca A. Humphries, directly if you would like to discuss the respective roles of the Michigan Trustees.

Sincerely,

Jennifer M. Granholm
Governor

JMG/pd

c: ✔Mr. Craig Czarnecki, USFWS
Mr. Steven Chester, MDEQ
Ms. Rebecca A. Humphries, MDNR
Mr. Michael Cox, Attorney General

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Department of the Interior
Natural Resource Damage Assessment and Restoration Program
Authorized Official Nomination Form

Instructions: *Please answer the following questions, using one form for each "active" case, by filling in the blanks or checking the appropriate boxes. This information will be used to accomplish the "Field/Staff Level Review and Agreement" phase of the Authorized Official (AO) designation process. When complete, please return this form to the appropriate DOI/OEPC Natural Resource Damage Assessment and Restoration Regional Coordinator.*

1. Site/Incident name: Rouge/Detroit River Mystery Oil Spill
   Site/Incident name alias (if any): ____________________

2. Site/Incident location: Impacted area began near the Dix Street bridge and River Rouge intersection and continued south into the Detroit River. Three miles of the River Rouge and 16 miles of the Detroit River were impacted. The ending point for the impacted area was located in Lake Erie, near the mouth of the Detroit River.
   City: Detroit
   County/Borough/Parish: Wayne County
   Township/Range/Section and/or Latitude/Longitude (if available): N 42° 16.21' and W 83° 06.71'

3. Date of incident (if appropriate): April 9, 2002

4. Please check the appropriate box(es) identifying the priority (listed in descending order)for accomplishing this AO designation (as specified in Program Manager's 8/17/99 memo):

   - ☐ time-sensitive case (*e.g.*, settlement decisions which need to be made within the next 6 months, notices of intent to conduct assessments or restoration planning, *etc.*);
     If Checked, identify the nature of the imminent deadline and timing of that deadline:
   - ☐ case where DOI has allocated funds from the Restoration Fund for damage assessment activities;
   - ☐ case where DOI has settled its natural resource damage claims and there remains an on-going need for Departmental decision-making; or
   - ✓ case where DOI is actively involved in the assessment of damages or settlement negotiations for natural resource injuries resulting from the release of hazardous substances or the discharge of oil but funding has not been provided from the Restoration Fund.

5. Other Federal/State/Tribal trustees involved (please list):
Michigan Department of Environmental Quality (MDEQ), Michigan Attorney General, Potentially the U.S. Department of Commerce, NOAA

6. Please provide the name and title of an appropriate official in your bureau willing to serve as the AO in this case:
Robyn Thorson, Regional Director, Region 3, USFWS
or recommend another bureau to serve as the AO:
____

7. Bureau staff contact for this case:
name: Lisa L. Williams, Ph.D
mailing address: U.S. Fish & Wildlife Service, East Lansing Field Office, 2651 Coolidge Road, Suite 101, East Lansing, MI 48823
phone number: 517-351-2555
fax number: 517-351-1443
email address: lisa_williams@fws.gov

United States Department of the Interior

OFFICE OF THE SECRETARY
Washington, DC 20240

TAKE PRIDE IN AMERICA

OCT 19 2004

Memorandum

To: Robyn Thorson, Regional Director
Fish and Wildlife Service, Region 3

OCT 05 2004

From: Willie R. Taylor, Director
Office of Environmental Policy and Compliance

Subject: Rouge/Detroit River Mystery Oil Spill, Wayne County, Michigan
Natural Resource Damage Assessment and Restoration (NRDAR) Activities - Designation of Authorized Official (AO)

Under authority delegated in 207 DM 6.3.B and when designated under 521 DM 2.2.J(4), Bureau Directors act on behalf of the Secretary as the AO in conducting NRDAR activities. Pursuant to 207 DM 6.3.C such authority may be redelegated within specified limits. The Bureau Directors have delegated AO authorities and responsibilities (including authority to concur with designation of AOs) as follows: U.S. Fish and Wildlife Service to Regional Directors and the California-Nevada Operations Manager; National Park Service to the Associate Director, Natural Resources Stewardship and Science; Bureau of Land Management to State Directors; and Bureau of Indian Affairs to the Deputy Bureau Director, Trust Services or to Regional Directors as determined by the Deputy Bureau Director, Trust Services.

As the only Department of the Interior Bureau with program responsibilities affected by activities at the subject site (at this time), please sign below which will document your concurrence to serve as the AO for the subject case. Once signed, you will be the designated AO for NRDAR activities for the subject case and may immediately begin functioning as such. Responsibilities of the AO are described in 521 DM 2.2.J(3).

Once you have signed below, the original signature copy of this memorandum should be placed in the subject case's administrative record or the case file maintained by your bureau. Please also provide a copy of this memorandum with your signature to me. I will then provide copies to the NRDAR Program Work Group members and the appropriate Departmental NRDAR Regional Coordinator, thereby confirming completion of the AO designation process.

I concur with the above designation and agree to serve as the AO for the subject case.

ACTING Regional Director, Fish and Wildlife Service, Region 3 — 10/18/04 Date

cc: NRDAR Program Manager
Regional Environmental Officer, DOI, Philadelphia, PA
NRDAR Regional Coordinator, FWS, Twin Cities, MN
Field Solicitor, DOI, Pittsburg, PA (M. Lynn Taylor)

bcc: NRDAR Work Group
NRDAR RCs
file - NRDAR AO designations

ATTACHMENT 2.0

CORRESPONDENCES: JULY 14, 2005, CORRESPONDENCE FROM KRIS DIGHE, USDOJ, TO MARK MATUS, MDAG, REGARDING CLOSURE OF RESPONSIBLE PARTY INVESTIGATION; AND SEPTEMBER 10, 2004, CORRESPONDENCE FROM CHRIS ABRAMS, NPFC, TO LISA WILLIAMS, USFWS REGARDING STATUS OF UNIDENTIFIED RESPONSIBLE PARTY

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From: Kris.Dighe@usdoj.gov

Sent: Thursday, July 14, 2005 4:36 PM

To: matusm@michigan.gov

Subject: FW: 2002 ROUGE RIVER MYSTERY SPILL ASSESSMENT CLAIM

Mr. Matus

This will confirm that the U.S. Department of Justice has closed its investigation into the Rouge River Oil Spill of April 2002.

Kris Dighe

Assistant Section Chief

U.S. Department of Justice

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From: Abrams, Christopher [CAbrams@ballston.uscg.mil]
Sent: Friday, September 10, 2004 8:39 AM
To: 'Lisa_Williams@fws.gov'
Cc: 'Timothy Reilly'
Subject: Upfront Assessment Claim--Unidentified RP (Rouge River Spill)

Morning Lisa,
Tim Reilly called yesterday about potential issues surrounding your Rouge River Upfront Assessment Claim. It is the position of the NPFC-NRD that an upfront assessment claim may be submitted regardless of the current Grand Jury investigation. To date, no RP has been identified, and, as such, this spill is still classified as a "Mystery Spill". If an RP is identified previous to the submission of your claim to us, it will need to be presented to the RP. However, if no action occurs within 90 days or if payment is denied within 90 days by the RP, then the claim can be submitted to us.

In a discussion with LCDR Moon at MSO Detroit, I don't believe that an RP will be identified immediately, if at all. If we make payment on an upfront assessment claim and later a RP is identified, we will assume the responsibility for recovering our costs.

I hope this addresses your concern. Please feel free to contact me if you need any further clarification.

Look forward to working with you in the future,
Chris

Christopher W. Abrams
Claims Manager (Economist/Ecologist)
Natural Resource Damage Claims Division
National Pollution Funds Center
U.S. Coast Guard
Tel: (202)493-6865
Fax: (202)493-6939

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ATTACHMENT 3.0

TRUSTEE COORDINATION DOCUMENTATION
(LETTERS OF TRUSTEE INVITATION FROM USFWS AND RESPONSES FROM TRUSTEES)

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ATTACHMENT 3.1

NOAA INVITATION AND RESPONSE

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IN REPLY REFER TO:

United States Department of the Interior

FISH AND WILDLIFE SERVICE
East Lansing Field Office (ES)
2651 Coolidge Road, Suite 101
East Lansing, Michigan 48823-6316

October 5, 2004

Mr. David M. Kennedy, Director
Office of Response and Restoration, National Ocean Service
National Oceanic and Atmospheric Administration
SSMC4, Room 10102
1305 East-West Highway
Silver Spring, Maryland 20910-3281

Dear Mr. Kennedy:

The U.S. Fish and Wildlife Service, on behalf of the Secretary of the Interior, is developing a claim for natural resource damage assessment costs for the Rouge River and Detroit River Mystery Oil Spill of April 2002 pursuant to §102(b)(2) of the Oil Pollution Act of 1990. We are inviting you to evaluate your trusteeship and consider joining us in making a claim for assessment costs and proceeding toward restoration of natural resources injured by this spill.

We are also inviting the State of Michigan to join this effort. On September 29, 2004, Governor Granholm designated the Directors of the Michigan Department of Environmental Quality and Department of Natural Resources as co-trustees in conjunction with the Michigan Attorney General for the State of Michigan.

Federal and State investigators have not identified a responsible party for this spill, so we will be making a claim for natural resource damages to the Oil Spill Liability Trust Fund. The President, acting through the U.S. Coast Guard's National Pollution Fund Center, is authorized to use the Oil Spill Liability Trust Fund to pay the claims of natural resource trustees for uncompensated natural resource damages in accordance with §1012 of the Oil Pollution Act of 1990.

We believe that the public and their natural resources are best served by all of the natural resource trustees working together on assessment and restoration, as their respective resources allow. We look forward to hearing from you as to whether your agency will participate in this claim or not. Because we intend to submit a claim to the U.S. Coast Guard by the end of this year, your response to this matter at your earliest convenience is appreciated. If you have any questions, please feel free to contact Dr. Lisa Williams, of this office, at 517/351-8324.

Thank you in advance for your consideration and expeditious response to this matter.

Sincerely,

Michael E. DeCapita

for Craig A. Czarnecki
Field Supervisor

cc: Tom Brosnan, NOAA DAC

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From: Lisa_Williams@fws.gov [mailto:Lisa_Williams@fws.gov]
Sent: Thursday, October 28, 2004 2:11 PM
To: Timothy Reilly
Cc: Niccole_Wandelear@fws.gov
Subject: RE: Rouge NRDA Hours

I haven't heard anything from the state. Tom Brosnan called for NOAA. They do not plan to become active trustees unless we think they can be value-added through trust resource "jurisdiction" or use of their economists or other experts and we ask them to help. He said he would get a written reply to me to reflect that.

For the state, we may have to say only that we've invited them, we expect some staff involvement but no financial resources for the assessment as Michigan is under severe budget restraints.

-Lisa

Lisa L. Williams, Ph.D
U.S. Fish and Wildlife Service
2651 Coolidge Road, Suite 101
East Lansing, MI 48823

(517)351-8324 direct phone
(517)351-2555 general office phone
(517)351-1443 fax

lisa_williams@fws.gov

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ATTACHMENT 3.2

MICHIGAN DEPARTMENT OF ATTORNEY GENERAL INVITATION AND RESPONSE

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
East Lansing Field Office (ES)
2651 Coolidge Road, Suite 101
East Lansing, Michigan 48823-6316

IN REPLY REFER TO:

October 5, 2004

Mr. Michael A. Cox
Attorney General
State of Michigan
P.O. Box 30212
Lansing, Michigan 48909

Dear Mr. Cox:

The U.S. Fish and Wildlife Service, on behalf of the Secretary of the Interior, is developing a claim for natural resource damage assessment costs for the Rouge River and Detroit River Mystery Oil Spill of April 2002 pursuant to §102(b)(2) of the Oil Pollution Act of 1990. We are inviting you, as one of the State co-trustees for natural resources, to join us in making a claim for assessment costs and proceeding toward restoration of natural resources injured by this spill. Correspondingly, we also are inviting the Directors of the Michigan Department of Environmental Quality and Department of Natural Resources to participate in this assessment and restoration process.

Federal and State investigators have not identified a responsible party for this spill, so we will be making a claim for natural resource damages to the Oil Spill Liability Trust Fund. The President, acting through the U.S. Coast Guard's National Pollution Fund Center, is authorized to use the Oil Spill Liability Trust Fund to pay the claims of natural resource trustees for uncompensated natural resource damages in accordance with §1012 of the Oil Pollution Act of 1990.

We believe that the public and their natural resources are best served by all of the natural resource trustees working together on assessment and restoration. We look forward to hearing from you as to whether your agency will participate in this claim or not. Because we intend to submit a claim to the U.S. Coast Guard by the end of this year, your response to this matter at your earliest convenience is appreciated. If you have any questions, please feel free to contact Dr. Lisa Williams, of this office, at 517/351-8324.

Thank you in advance for your consideration and expeditious response to this matter.

Sincerely,

Michael E DeCapita

for Craig A. Czarnecki
Field Supervisor

cc: A. Michael Leffler

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STATE OF MICHIGAN
DEPARTMENT OF ATTORNEY GENERAL

P.O. Box 30212
LANSING, MICHIGAN 48909

MIKE COX
ATTORNEY GENERAL

November 30, 2004

✓ Czarnecki
Best
Brewer
Dandridge
DeCapita
Deloria
Dingledine
Eitniear
Fisher
Gourley
Hosler
Kavetsky
Kubilis
Mensing
Pastva
Tansy
✓ Williams

Craig A. Czarnecki
U.S. Department of Interior
2651 Cooledge Road, Suite 101
East Lansing, MI 48823-6316

Dear Mr. Czarnecki:

Re: Rouge River and Detroit River Mystery Oil Spill

Thank you for your October 5, 2004, letter inviting me, as a designated natural resources trustee for the State of Michigan, to join the Fish and Wildlife Service in developing a claim, under § 102 (b)(2) of the Oil Pollution Act of 1990, for natural resource damage assessment and restoration costs based upon the Rouge River and Detroit River Mystery Oil Spill of April 2002. I am pleased to accept your invitation.

It is my understanding that the Department of Natural Resources (DNR) and the Department of Environmental Quality (DEQ), the two other designated co-trustees for the State of Michigan, also plan to accept your invitation. We anticipate that DNR and DEQ staff will play the primary role on technical issues for the State in the damage assessment and restoration process, with Department of Attorney General staff providing consultation and support as appropriate. Please contact Mark Matus, Assistant Attorney General in Charge of our Environment, Natural Resources, and Agriculture Division, at (517) 373-7540 to coordinate our involvement in this process.

We look forward to working with you and the other trustees in this matter.

Sincerely yours,

Michael A. Cox
Attorney General

c: Rebecca Humphries, DNR
Steven Chester, DEQ
Carol Isaacs, DAG
Mark Matus, DAG

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ATTACHMENT 3.3

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY INVITATION AND RESPONSE

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
East Lansing Field Office (ES)
2651 Coolidge Road, Suite 101
East Lansing, Michigan 48823-6316

IN REPLY REFER TO:

October 5, 2004

Mr. Steven E. Chester, Director
Michigan Department of Environmental Quality
Executive Division
P.O. Box 30473
Lansing, Michigan 48909-7973

Dear Mr. Chester:

The U.S. Fish and Wildlife Service, on behalf of the Secretary of the Interior, is developing a claim for natural resource damage assessment costs for the Rouge River and Detroit River Mystery Oil Spill of April 2002 pursuant to §102(b)(2) of the Oil Pollution Act of 1990. We are inviting you, as one of the State co-trustees for natural resources to join us in making a claim for assessment costs and proceeding toward restoration of natural resources injured by this spill. Correspondingly, we also are inviting the Director of the Michigan Department of Natural Resources and the Michigan Attorney General to participate in this assessment and restoration process.

Federal and State investigators have not identified a responsible party for this spill, so we will be making a claim for natural resource damages to the Oil Spill Liability Trust Fund. The President, acting through the U.S. Coast Guard's National Pollution Fund Center, is authorized to use the Oil Spill Liability Trust Fund to pay the claims of natural resource trustees for uncompensated natural resource damages in accordance with §1012 of the Oil Pollution Act of 1990.

We believe that the public and their natural resources are best served by all of the natural resource trustees working together on assessment and restoration. We look forward to hearing from you as to whether your agency will participate in this claim or not. Because we intend to submit a claim to the U.S. Coast Guard by the end of this year, your response to this matter at your earliest convenience is appreciated. If you have any questions, please feel free to contact Dr. Lisa Williams, of this office, at 517-351-8324.

Thank you in advance for your consideration and expeditious response to this matter.

Sincerely,

Michael E. DeCapita

for Craig A. Czarnecki
Field Supervisor

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STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING

JENNIFER M. GRANHOLM
GOVERNOR

STEVEN E. CHESTER
DIRECTOR

November 19, 2004

RECEIVED
NOV 24
East Lansing Field Office (LS)
U.S. Fish & Wildlife Service

Mr. Craig A. Czarnecki
Field Supervisor
United States Department of the Interior
Fish and Wildlife Service
East Lansing Field Office
2651 Coolidge Road, Suite 101
East Lansing, Michigan 48823-6316

Dear Mr. Czarnecki:

Thank you for your letter of October 5, 2004, regarding the proposed natural resource damage claim for the Rouge River and Detroit River mystery oil spill that occurred in April 2002.

The Department of Environmental Quality (DEQ) agrees that this project would be best served by all trustees participating in the claim. Therefore, the DEQ looks forward to collaborating with you in preparing a claim for assessment costs and restoration of impaired resources. Based on preliminary discussions, we also understand that the other Michigan trustees will be participating in this claim as well.

The contact person for this claim will be Mr. William Creal, Chief, Permits Section, Water Bureau, and he can be reached at 517-335-4114.

Thank you for initiating this process. If you need further information or assistance, please contact Mr. Creal, or you may contact me.

Sincerely,

Steven E. Chester
Director
517-373-7917

cc: Mr. Stanley F. Pruss, Deputy Director, DEQ
Mr. Richard A. Powers, DEQ
Mr. James K. Cleland, DEQ
Mr. William Creal, DEQ

___ Czarnecki
___ Best
___ Brewer
___ Dandridge
___ DeCapita
___ Deloria
___ Dingledine
___ Eitniear
___ Fisher
___ Gourley
___ Hosler
___ Kavetsky
___ Kubilis
___ Mensing
___ Pastva
___ Tansy
✓ Williams

ATTACHMENT 3.4

MICHIGAN DEPARTMENT OF NATURAL RESOURCES INVITATION AND RESPONSE

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
East Lansing Field Office (ES)
2651 Coolidge Road, Suite 101
East Lansing, Michigan 48823-6316

IN REPLY REFER TO:

October 5, 2004

Ms. Rebecca A. Humphries, Director
Michigan Department of Natural Resources
Executive Division
P.O. Box 30028
Lansing, Michigan 48909

Dear Ms. Humphries:

Congratulations on your recent designation as one of the co-trustees for natural resources damage assessments and restoration for the State of Michigan!

The U.S. Fish and Wildlife Service, on behalf of the Secretary of the Interior, is developing a claim for natural resource damage assessment costs for the Rouge River and Detroit River Mystery Oil Spill of April 2002 pursuant to §102(b)(2) of the Oil Pollution Act of 1990. We are inviting you, as one of the State co-trustees for natural resources to join us in making a claim for assessment costs and proceeding toward restoration of natural resources injured by this spill. Correspondingly, we also are inviting the Director of the Michigan Department of Environmental Quality and the Michigan Attorney General to participate in this assessment and restoration process.

Federal and State investigators have not identified a responsible party for this spill, so we will be making a claim for natural resource damages to the Oil Spill Liability Trust Fund. The President, acting through the U.S. Coast Guard's National Pollution Fund Center, is authorized to use the Oil Spill Liability Trust Fund to pay the claims of natural resource trustees for uncompensated natural resource damages in accordance with §1012 of the Oil Pollution Act of 1990.

We believe that the public and their natural resources are best served by all of the natural resource trustees working together on assessment and restoration. We look forward to hearing from you as to whether your agency will participate in this claim or not. Because we intend to submit a claim to the U.S. Coast Guard by the end of this year, your response to this matter at your earliest convenience is appreciated. If you have any questions, please feel free to contact Dr. Lisa Williams, of this office, at 517-351-8324.

Thank you in advance for your consideration and expeditious response to this matter.

Sincerely,

Michael E. DeCapita

for Craig A. Czarnecki
Field Supervisor

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STATE OF MICHIGAN

JENNIFER M. GRANHOLM
GOVERNOR

DEPARTMENT OF NATURAL RESOURCES

LANSING

REBECCA A. HUMPHRIES
DIRECTOR

November 29, 2004

Mr. Craig A. Czarnecki
United States Department of the Interior
Fish and Wildlife Service
East Lansing Field Office
2651 Coolidge Road, Suite 101
East Lansing, MI 48823-6316

Dear Craig:

Thank you for your letter of October 5, 2004, regarding the natural resource damage assessment for the Rouge River and Detroit River oil spill of April 2002. We would very much appreciate the opportunity to collaborate with you on this incident. We have responded to and incurred costs investigating damage to natural resources on the Rouge and Detroit Rivers and look forward to the opportunity to conduct a more thorough investigation. We also look forward to the opportunity to provide resource restoration or restitution from this incident.

Please contact Mr. Timothy Payne, the Wildlife Division Area Supervisor for southeast Michigan in the Livonia office, at 734-953-1496 or paynet@michigan.gov. Thank you for your inclusion of the Michigan Department of Natural Resources (DNR) in this important matter.

Sincerely,

Rebecca A. Humphries
Director
517-373-2329

cc: Mr. Dennis Fedewa, Chief Deputy, DNR
Ms. Mindy Koch, Resource Management Deputy, DNR
Mr. Douglas Reeves, DNR
Mr. Timothy Payne, DNR

___ Czarnecki
___ Best
___ Brewer
___ Dandridge
___ DeCapita
___ Deloria
___ Dingledine
___ Eitniear
___ Fisher
___ Gourley
___ Hosler
___ Kavetsky
___ Kubilis
___ Mensing
___ Pastva
___ Tansy
___ Williams

Appendix 2: ROUGE RIVER 2002 MYSTERY OIL SPILL NRDA: SELECTION OF PREFERED RESTORATION ALTERNATIVES MEMORANDUM

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ROUGE RIVER 2002 MYSTERY OIL SPILL NRDA: SELECTION OF PREFERED RESTORATION ALTERNATIVES MEMORANDUM

Draft

Submitted To:
Stephanie Millsap, Contaminants Specialist
U.S. Fish and Wildlife Service
USEPA LLRS
9311 Groh Rd.
Grosse Ile, MI 48138

Submitted By:
Jonathan R. Grant and Timothy J. Reilly
Lighthouse Technical Consultants, Inc.

Pursuant to Requisition/Purchase Number: 314107015A

May 1, 2010

Selection of Restoration Alternatives for the 2002 Rouge River Mystery Oil Spill Natural Resource Damage Assessment

Introduction

On April 9, 2002 there was an oil spill on the Rouge River in Detroit Michigan. According to U.S. Environmental Protection Agency (EPA) reports, an estimated 255,544 gallons of mixed diesel and waste lubricating oil were visible on the waters of the Detroit River at or about mid-day on 10 April 2002 (Allen, 2002). The 255,544 gallons were identified as a portion of the 9 April oil spill that released oil into the Rouge River from an unknown source. Over the next few days, the spilled oil washed into the Detroit River, oiling 17 miles of the U.S. Detroit River coastline and 16 kilometers of the Canadian coastline. A second release of oil occurred from a similar release location on the night of 12 April 2002. Over the next two weeks, U.S. Coast Guard (USCG) pollution reports indicate that cleanup efforts removed 66,359 gallons of emulsion, which contained some lesser volume of oil, and much of the oiled coastal flora from the U.S. shorelines. A portion of the spill was contained within the Rouge River system with booms and most of the recovered oil was collected in this region. Oil was found in the nearby sewer system; thus, the source of the oil to the river was found to be the sewer system outfalls during and/or after a period of increased sewer flow during rain events in the area. The spill is classified as a mystery spill and a Natural Resource Damage Assessment is underway to compensate the environment and the public for natural resource losses associated with the impacts of the spilled oil.

Restoration Planning

Once injury assessment is complete or nearly complete, trustees develop a plan for restoring the injured natural resources and services. Under the Natural Resource Damage (NRD) Regulations implementing the Oil Pollution Act (OPA), 15 C.F.R. Part 990, the goal is to make the environment and public whole for injuries to natural resources and natural resource services resulting from a discharge of oil. This goal is achieved through the restoration, rehabilitation, replacement, or acquisition of equivalent natural resources and/or services. To achieve this goal, trustees must identify a reasonable range of restoration alternatives, evaluate and select the preferred alternative(s), and develop a Draft and Final Restoration Plan. Acceptable restoration actions include any of the actions authorized under OPA (restoration, rehabilitation, replacement, or acquisition of the equivalent) or some combination of those actions

Restoration actions under the OPA regulations are either primary or compensatory. Primary restoration is action taken to return injured natural resources and services to baseline, including natural recovery. Compensatory restoration is action taken to compensate for the interim losses of natural resources and/or services pending recovery. Each restoration alternative considered will contain primary and/or compensatory restoration actions that address one or more specific injuries associated with the incident. The type and scale of compensatory restoration may depend on the nature of the primary restoration action, and the level and rate of recovery of the injured natural resources and/or services given the primary restoration action. When identifying the compensatory restoration components of the restoration alternatives, trustees must first consider compensatory restoration actions that provide services of the same type and quality, and of comparable value as those lost. If compensatory actions of the same type and quality and comparable value cannot provide a reasonable range of alternatives, trustees then consider other compensatory restoration actions that will provide services of at least comparable type and quality as those lost.

As part of the restoration planning process, the Trustees identify and evaluate a wide range of projects that are capable of restoring ecological services comparable to those lost as a result of the incident. For the 2002 Rouge River Mystery Oil Spill NRDA, these include injuries to wildlife, birds, fish, and associated shoreline and riverine habitats. These identified projects are then screened to narrow the field of reasonable restoration alternatives to those projects that meet the criteria set forth in the regulations as well as additional restoration goals as determined by the Trustee Council.

This memorandum presents the reasonable restoration alternatives that are selected by the Trustees. These selected restoration alternatives will be scaled to compensate for the incident injuries and to identify the preferred restoration strategy by the Trustees. The "No Action" alternative will also be included for consideration, as required by NEPA and the OPA regulations.

Restoration Alternatives Selection Criteria: Regulation Based

The OPA regulations identify a number of criteria which the trustees should consider when evaluating restoration options. The following regulatory-based criteria were used during the selection process as the trustees selected the preferred restoration projects for the 2002 Rouge River Mystery Oil Spill NRDA.

- **Costs and Cost-Effectiveness.** Consider the relationship of expected project costs to expected resource and service benefits. Seek the least costly approach to deliver an equivalent or greater amount and type of benefits.
- **Consistency with Trustees' Restoration Goals.** Projects must meet the trustees' intent to restore, rehabilitate, replace, enhance, or acquire the equivalent of the injured resources and resource services.
- **Technical Feasibility.** The project must be technically and procedurally sound. Consider the level of risk or uncertainty and the degree of success of projects utilizing similar or identical techniques in the past.

- **Likelihood of Success.** Consider the potential for success and the level of expected return of resources and resource services. Consider also the ability to evaluate the success of the project, the ability to correct problems that arise during the course of the project, and the capability of individuals or organizations expected to implement the project.
- **Relationship to Injured Resources and/or Services (nexus).** Projects that restore rehabilitate, replace, enhance, or acquire the equivalent of the same or similar resources or services injured by the spill are preferred to projects that benefit other comparable resources or services. Consider the types of resources or services injured by the spill, the location, and the connection or nexus of project benefits to those injured resources.
- **Time to Provide Benefits.** Consider the time it takes for benefits to be provided to the target ecosystem or public to minimize interim resource loss (sooner = better).
- **Duration of Benefits.** Consider the expected duration of benefits from the project. Long-term benefits are the objective.
- **Multiple Resource and Service Benefits.** Consider the extent to which the project benefits more than one natural resource or resource service. Measure in terms of the quantity and associated quality of the types of natural resources or service benefits expected to result from the project.
- **Avoidance of Adverse Impacts.** The project should avoid or minimize adverse impacts to the environment and the associated natural resources. Adverse impacts may be caused by collateral injuries when implementing, or as a result of implementing, the project. Consider avoiding future short-term and long-term injuries as well as mitigating past injuries.
- **Compliance with Applicable Federal, State, and Local Laws and Policies.** The project must comply with applicable laws and policies.
- **Public Health and Safety.** The project must not pose a threat to public health and safety.
- **Additional Consideration.** The Consistency; Relationship; and Compliance criteria, among others listed above, all presume that the Trustees will not include projects that are already legally mandated Federal or State Agency actions.

Restoration Alternatives Selection Criteria: Resource Injury Based

The OPA regulations call for trustees to consider the relationship to the injured resources and/or services when evaluating restoration options. The trustees have completed their assessment of the nature and extent of natural resource injuries for the 2002 Rouge River Mystery Oil Spill (*Rouge River 2002 Mystery Oil Spill SIMAP Injury Report, May 15 2009* and *Rouge River 2002 Mystery Oil Spill Revised Wildlife Injury Memorandum, October 18, 2009*). These injury assessment findings were included as criteria during the selection process to identify projects that best met the types of resources or services injured by the spill, the location, and the nexus of project benefits to the quantified injuries. Based on the biological injury modeling of the incident, the trustees have identified potential impacts to the following natural resources and associated services (specific species and their relative injuries are found in the *Rouge River 2002 Mystery Oil Spill Revised Wildlife Injury Memorandum, October 18, 2009*):

For Wildlife:

- Waterfowl;
- Seabirds;
- Wading birds;
- Shorebirds;
- Scaup (listed separately due to the size of the injury to this species);
- Mammals (i.e., muskrats);
- Reptiles;
- Amphibians.

For Fish and Invertebrates:

- Small pelagic fish;
- Large pelagic fish;
- Demersal fish;
- Demersal invertebrates (i.e., worms and freshwater clams which will be put in littoral marshes, mudflats and aquatic beds).

For Shoreline (or riparian) Habitats:

- Rocky shore;
- Gravel beach;
- Sand beach;
- Mud flat;
- Marsh;
- Intertidal artificial.

Table One presents the preliminary wildlife injuries by wildlife group and Table Two presents the preliminary fish injury numbers. Tables Three and Four present the vegetation and invertebrate injuries by habitat type. The *Rouge River 2002 Mystery Oil Spill Revised Wildlife Injury Memorandum, October 18, 2009* presents the specifics of each of these wildlife groups.

Table 1. Estimated injuries (interim loss) as individual bird-years (all age classes combined) for the base case model scenario using a 1 percent slow release of the oil. ***Note that the number lost is based on a probability, and so mathematically can be < 1 animal. "-" indicates species was not present in region.***

Wildlife Group	**Individual-years Lost in Detroit River and Lake Erie**	**Individual-years Lost in Rouge River**	**Total Individual-years Lost**
Waterfowl	1,057	77.9	1,135
Seabirds	11,977	15.5	11,992
Wading birds	30.5	-	30.5
Shorebirds	351	-	351
Scaup	8,855	-	8,855
Total Bird Years			**22,365**
Total Mammal Years	398	-	**398**
Reptiles	1,238	-	1,238
Amphibians	9,448	-	9,448
Total Herptile Years			**10,690**

Table 2. Estimated injuries to fish in the Detroit River and Lake Erie using a 1 percent slow release of the oil and an LC50□ value of 44ppb for species with average sensitivity to the Rouge River diesel and lubricating oil mix.

Fishery Group	**Biomass Killed (kg)**	**Production Forgone (kg)**	**Total Injury (kg)**
Total small pelagic fish	2.2	0	2.2
Total large pelagic fish	8.4	7.2	15.6
Total demersal fish	108	102	211
Total	**119**	**110**	**228**

Table 3. Estimated areas exposed by enough oil to injure vegetation (> 1.0 mm of oil swept through either while wet or dry), by habitat type; for the base case model scenario using a 1 percent slow release of the oil.

Vegetation Injury	**Area Oiled with > 1 mm of Oil (acres)**
Fringing Marsh	11.1
Extensive Wetland	28.6

Vegetation Injury	Area Oiled with > 1 mm of Oil (acres)
Total	39.7

Table 4. Estimated areas exposed by enough oil to injure invertebrates (> 0.1 mm of oil, while dry), by habitat type; for the base case model scenario using a 1 percent slow release of the oil.

Invertebrate Injury	Area Oiled with > 0.1 mm of Oil (acres)
Gravel Beach	4.4
Sand Beach	6.3
Mud Shore	4.7
Fringing Marsh	17.5
Extensive Mudflat	6.2
Extensive Wetland	111
Total	150

Rouge River NRDA Restoration Alternatives

A number of preliminarily-identified potential restoration alternatives were identified and they are presented in Table A1, Appendix A All of the restoration alternatives in Table A1 are also presented, with greater detail, in the Preliminary Restoration Alternatives Memorandum (*Rouge River 2002 Mystery Oil Spill NRDA: Preliminary Restoration Alternatives Memorandum Draft, August 28, 2009*)

The information used in the identification of the alternatives includes documents and communications with staff from the following agencies/organizations, among others:

- United States Fish and Wildlife Service;
- Michigan Department of Natural Resources;
- Michigan Department of Environmental Quality;
    - Including Detroit River Areas of Concern;
- United States Environmental Protection Agency;
    - Including Detroit River Western Lake Erie Basin Indicator Project;
- United States Geological Survey;
- Rouge River Watershed;
- Detroit River International Wildlife Refuge;
- Pointe Mouille State Game Area;
- Lake Erie Metropark;
- Detroit River Canadian Cleanup/RAP.

Rouge River NRDA Restoration Alternative Selection

The trustees identified 56 projects as potential restoration alternatives listed in Appendix A. These 56 projects were screened by the trustee council to narrow the list of projects to those projects most capable of restoring ecological services comparable to those lost as a result of the incident. The criteria used as part of the screening process include the regulatory requirements and the injury specific assessment quantification (discussed in the Restoration Alternatives Selection Criteria Sections above) to ensure that restoration is capable of completely and fully addressing injury.

The restoration alternative screening assessment results for each of the preliminarily-identified restoration alternatives are presented in Appendix B, Table B1. The resulting streamlined list includes 14 projects that have met the initial screening requirements and that are being retained as part of the restoration scaling analysis. These 14 projects are presented in Table Five.

Table 5. List of Screened Restoration Projects Selected for Restoration Scaling Analyses.

Project	Type of Project
Brancheau Tract Invasive Species Control	Invasive species control
Eagle Island Marsh Wetland Enhancement	Wetland restoration
Gibraltar Wetlands Habitat Improvement	Invasive species control
Grassy Island Shoal Restoration	Dike reconstruction
Great Lake Marsh Restoration	Invasive species control
Humbug Marsh Habitat Improvement	Habitat improvement; invasive species control
Lady of the Lakes Wetland Enhancement	Water control
Lake Erie Marsh Preserve Wetland Restoration and Enhancement	Water control; invasive species control
Lakeplain Prairie Restoration	Invasive species control; native plant restoration/re-vegetation
Managed Coastal Wetland Restoration	Wetland restoration
Pte. Mouillee State Game Area Projects	Water control; invasive species control
Rouge River Watershed Grow Zones: Habitat Restoration and Enhancement	Native plant restoration/re-vegetation; habitat enhancement
Strong Property Shoreline Enhancements	Dike reconstruction; invasive species control
Sturgeon Bar Restoration	Shoreline stabilization; native plant re-vegetation

It should be noted that these 14 projects may not all be represented in a final Preferred Alternative as selected by the trustees; rather, some combination of a subset of these projects likely will be selected by the trustees to compensate for injured resources from a set of restoration alternatives, including a "no-action" alternative.

Rouge River NRDA Restoration Next Steps

The potential restoration alternatives identified by the trustees have been narrowed to the 14 projects most likely to address the injuries resulting from the incident. These 14 screened projects, along with the "no-action" alternative will be evaluated so that the trustees can identify a preferred restoration alternative to address the 2002 Rouge River Mystery Oil Spill injuries. To accomplish that, the projects of interest will be scaled to the injuries and then grouped them into potential restoration options, each of which address the specific injuries to the resources and compensate for the interim losses of natural resources and/or services. Each of these restoration options can then be evaluated, along with the "no action" alternative to identify the final restoration strategy that the trustees will use to develop a Draft and Final Restoration Plan.

Appendix A: Rouge River 2002 Mystery Oil Spill NRDA: Preliminary Restoration Alternatives

Table A1. Preliminary Restoration Alternatives for the 2002 Rouge River Mystery Oil Spill NRDA

Restoration Option Name	Primary Resource Benefit	Description of Project
Manhattan Marsh Preservation, Restoration and Enhancement	Birds, Wildlife	The Manhattan Marsh property lies within the City of Toledo and is perhaps the only intact moderate- to high-quality emergent marsh wetland system within City's urban center. This Category 2 marsh drains directly into Maumee Bay through Detwiler Ditch. The marsh provides important habitat for resident and migratory birds and was home to a nesting pair of bald eagles for a brief time during the 1990s. Metroparks of the Toledo Area is in the process of acquiring the marsh property through the City of Toledo. Due to previous impacts to the site, removal of debris and waste material is required around the periphery of the marsh. There is a vacant structure previously used for commercial purposes which should be removed from the site. Additionally, a water control structure should be constructed to allow regulation of water levels to control populations of the invasive narrow-leaf cattail which occurs throughout the marsh.
Managed Coastal Wetland Restoration	Birds, Wildlife	There is currently no restoration design. The Detroit River International Wildlife Refuge envisions (long-term) 20-30 acres (or some portion thereof) restored to a managed coastal wetland with the remaining being planted as native prairie
Lady of the Lakes Wetland Enhancement	Birds, Wildlife	This site is currently in the process of being surveyed for restoration design. Currently the site has no water level management and restoration design will likely have a management component.
Eagle Island Marsh Wetland Enhancement	Birds, Wildlife	Currently no restoration survey or design work has been done.
Bay Creek Hunt Club Land Acquisition	Birds, Wildlife	Owner had been in negotiation with FWS for acquisition, wasn't interested. No plans for FWS ownership or for a cooperative agreement.
Strong Property Shoreline Enhancements	Birds, Wildlife	The project would repair/reconstruct the northern dike so that area can be burned for invasive control and provide vehicle access. The property is located just south of Pte. Mouillee

Restoration Option Name	Primary Resource Benefit	Description of Project
Gibraltar Wetlands Habitat Improvement	Birds, Wildlife	This site is a recent Detroit River International Wildlife Refuge acquisition. It is a good quality wetlands but is in need of some invasive species control.
Humbug Marsh Habitat Improvement	Birds, Wildlife	This marsh needs habitat improvement and invasive species control. Invasive species control has been undertaken in the past.
Brancheau Tract Invasive Species Control	Birds, Wildlife	Invasive species control to augment restoration plan currently being implemented.
Pte. Mouillee State Game Area Zone 13	Birds, Wildlife	Construct a new 1500 foot long dike in Zone 13.
Pte. Mouillee State Game Area Sump Dike	Birds, Wildlife	Complete the sump dike and raise it 2 feet.
Pte. Mouillee State Game Area Bad Creek Unit	Birds, Wildlife	Repair the Bad Creek Unit dikes and return them to fully functioning dikes for habitat enhancement.
Pte. Mouillee State Game Area Walpatich Repair	Birds, Wildlife	Repair the east/west dikes to connect to each other for better water control within the Walpatich Unit and for habitat enhancement.
Pte. Mouillee State Game Area Water Control Structures	Birds, Wildlife	Purchase of water control structures to enhance water control and habitat enhancement'
Pte. Mouillee State Game Area Zone 13 and Lautenschlager Unit	Birds, Wildlife	Phragmites control project covering 100 acres using aerial application.
Belle Isle Fish habitat construction: Augment Existing Spawning Reef	Fish	Project would augment an already existing artificial spawning reef. Research has shown that the spawning reef is working in that area. 14 species of native fish have been shown to spawn, including lake whitefish, walleye, and yellow perch
Fighting Island (Canada) Fish habitat construction	Fish	Project would add spawning substrates on which lake sturgeon and other high-value native fish prefer to spawn - this project builds on existing Belle Isle work. Last year, in a unique U.S.-Canada partnership, a lake sturgeon spawning reef was constructed off Fighting Island in the Detroit River. It has been confirmed that sturgeon are spawning on the reef. They have also found an endangered species -- the northern madtom.
Grassy Isle Fish habitat construction	Fish	Construct fish spawning beds at NE Grassy Island and immediately south of Grassy Island on Mamajuda Island Shoal to restore historic, reputed spawning runs of lake sturgeon and lake whitefish, respectively, to the Grassy Island area

Restoration Option Name	Primary Resource Benefit	Description of Project
Belle Isle Fish habitat construction: Spawning Beds	Fish	Construct fish spawning beds of rounded rock at the head of Belle Isle to augment and increase natural reproduction of walleye and white sucker at that location
Belle Isle Fish Rearing and Stocking Facility	Fish	Build and operate a stream-side lake sturgeon egg and larvae facility on Belle Isle for the culture and subsequent release of young of the year lake sturgeon originating from Detroit River lake sturgeon adults back into the Detroit River. (This project may not have MDNR support)
Round Island acquisition	Fish	This island sits on the western perimeter of a large bay located at the southern most end of Grosse Ile, known as the Gibraltar Bay. Gibraltar Bay is considered one of the most productive and ecologically important wetland/coastal emergent shorelines in the Detroit River. Much of the undeveloped and natural shoreline of the bay is contained on the eastern side of Round Island. The bay has become a very popular year-round fishing spot, holding large numbers of seasonal perch, bass and pike. Much of this is due to the large stable aquatic macrophyte beds that remain on the bottom all year round. Once used as duck hunting camp, it is currently in jeopardy of being developed for residential use. The impacts of hardening this shoreline and the infill of the internal lowlands would be catastrophic to the functionality of the bays wetland complex. The extent of this project proposal would be the acquisition of this island from its current private owner or at a minimum, the creation of wetland setbacks and conservation easements.

Restoration Option Name	Primary Resource Benefit	Description of Project
Sugar Island acquisition	Fish	The island's maple and oak hardwoods along with its dense bush cover provides important habitat for migratory birds to stage and roost. It is also frequented on a regular basis by the local eagle population. The surrounding shoreline sandy shoal areas once saw millions of spawning smelt fill its waters. Currently several species of suckers, log perch and other fish species use the island's shallows annually. In the deeper waters that can be found off the eastern side of the island, large numbers of migrating walleye pass through the area in the spring along with the many pike that traverse its shoreline shoals. Given the current owners interest in selling the island to land developers and the lack of interest in creating any conservation easements, the best solution to protect the island and its beaches for public access is an out right purchase.
US Steel Shoal Restoration	Fish	This site in particular, with it's naturally in cut bay shoreline and preexisting shoal area, has the potential to create the largest aquatic and emergent habitat site in this section of the river. The other important feature of this site is that is already has a preexisting and partially intact rock shoal that parallels the shoreline for several 100 feet. This feature is important because of the experiences learned from other emergent shoreline projects attempted in this part of the river. Because of the tremendous current and wave surges from the heavy boat traffic, that without a protected partially emergent shoal build in front of these areas as a breakwater, any attempt to soften the shoreline with aquatic emergent vegetation will fail due to the effects of wave driven erosion. An estimated 750' of shoal reconstruction work would be needed to fully protect the shoreline habitat.
Rouge River Watershed - Rouge River National Wet Weather Demonstration Project	Fish	Design and construction of combined sewer overflow controls, sanitary sewer overflow controls, storm water management; habitat restoration; public education; support to Alliance of Rouge Communities to support Community Grants for local municipalities, with an emphasis on Grow Zones and other habitat-focused restoration. Funding sought to augment Alliance of Rouge Communities budget for mini-grants for habitat restoration within watershed.

Restoration Option Name	Primary Resource Benefit	Description of Project
Rouge Gateway Partnership: Fordson Island; Planning/Feasibility Study	Fish	Implementation of Rouge River Gateway Partnership Master Plan: various projects to promote economic development, ecosystem restoration, heritage preservation, and increased recreation along the Rouge River corridor. Several "shovel-ready" projects have been identified by Rouge communities. Specifically the Fordson Island project to dredge debris from the channel and to enhance the riverine habitat.
Rouge Gateway Partnership: Detroit, and River Rouge Fish Habitat Enhancements Segment 1	Fish	Rouge River corridor improvements (upstream of spill site: Rotunda Dr. to I-94, MI): The project will provide for environmental enhancement of the Rouge River channel by partial removal of the existing concrete lining, widening of the river channel / cross section, providing fish habitat and restoring the river banks to a more natural condition with plantings instead of concrete.
Rouge Gateway Partnership: Detroit, and River Rouge Fish Habitat Enhancements Segment 2	Fish	Rouge River corridor improvements (upstream of spill site: Michigan Ave to Rotunda Dr., MI): The project will provide for environmental enhancement of the Rouge River channel by partial removal of the existing concrete lining, widening of the river channel / cross section, providing improved fish habitat and restoring the river banks to a more natural condition with plantings instead of concrete.
Restoration of Hines Park Wetland Mitigation Bank (Wayne County)	Fish	Restoration of Wayne County Wetland Mitigation Bank: Analysis, design: restoration and construction of wetlands in Hines Park
Cook and Gladding Drain Petition Project within the Alliance of Downriver Watersheds	Fish	Drain improvement projects in various Downriver communities, to improve storm water management and eliminate E. Coli contamination from urban waterways. 2 projects ready to go: Cook and Gladding Drain Petition Project, located in Flat Rock, Huron Township, Brownstown township. It includes cleaning out of the drain, replacement of all but 2 crossings and installation of "natural stream channel" design features including deep rooted native wildflowers and grasses. Project cost = $2,800,000. Wager and Pink Intercounty Drain (extends between Wayne and Monroe County): Project includes creating a detention area, replacing culverts, removing sediment, enclosing a section of the drain and installation of "natural stream channel" design features including deep rooted native wildflowers and grasses. Project cost = $850,000.

Restoration Option Name	Primary Resource Benefit	Description of Project
Rouge River watershed, Ecorse Creek watershed, Combined Downriver watershed, Detroit River watershed, Lake St Clair watershed: Habitat Rehabilitation	Fish	Illicit discharge elimination, storm water management, public education, riverine habitat rehabilitation, support to community-based Watershed Alliances
Henry Ford Estate Dam Fish Passage; Feasibility/Planning Study	Fish	Modification of the Henry Ford Estate Dam to include a fish passage.
Wayne Road Dam Removal; Planning and Design	Fish	Modification of the Wayne Road Dam. Lowhead dam removal
Concrete Channel Modifications: For Habitats and Fish Populations	Fish	Assorted projects restoring the natural riverine habitat and flow.
Grassy Island Shoal Restoration	Fish, Birds	In the mid part of the 1900's, as part of a ship navigation system, a long dike was constructed as part of a range light system. This dike started from the shore of the north west side of the island and proceeded out from the island in an angle towards the southwest for approximately 1,500 feet. This dike created a man made bay impoundment that protected the wetland that once existed on the western side of the island. Over the past few decades high water and erosion reduced the dikes to a submerging shoal area covered by 5 to 6 feet of water. Reconstruction of this dike system would recreate the protective bay and allow the re-emergent of wetlands and the regeneration of emergent shoreline plants to this area.
N. Hennepin Marsh restoration	Fish, Birds	The first project would reduce wave action erosion through construction of a series of several long and narrow emergent shoals that would run in an arc starting from the northern end of the wetland site and curve out towards the channel, then turning south to run parallel to the Grosse Ile shoreline. The combined length of these shoal islands would total approximately 2,500 feet. The second of the two projects would include elimination and continued control of phragmites and re-vegetation of native emergent plants along the adjacent shoreline.

Restoration Option Name	Primary Resource Benefit	Description of Project
S. Hennepin Marsh Land Acquisition	Fish, Birds	Bordered by a series of three small island dikes to the east and a large portion of undeveloped vacant land along the Grosse Ile shoreline to the west, the balance of this wetland contains a very shallow macrophyte and rush bed. Much of the shoreline along Grosse Ile is part of an undeveloped parcel of property that is currently for sale. Acquisition of this property would assure no further development and potential shoreline hardening in this area.
S. Hennepin Marsh Construction	Fish, Birds	These islands are rapidly eroding. Because of the shallow nature of the waters surrounding these island dikes, much of the rebuilding materials (sand, gravel and clay) could be dredged up from the area and then rebroadcast onto the islands to rebuild then up several feet above the current elevations of the river and improve the protection they provide to themarsh behind them. Additionally, this site has a phragmites problem along its shore.
Sugar Island Restoration	Fish, Birds	The southern end of the island extends out into Lake Erie. It was once protected by large stand of cattails that helped to break the impact of the lakes waves but now is exposed to the full force of the lake as a result of years of erosion. Hundreds of feet of the island and many of the large trees have eroded off the bluff that now dominates the lower 1/3 of the island. In order to stop further erosion two possible construction solutions could be employed to correct this problem. The first would be the placement of a course of limestone rock along the length of the southern end of the island, armoring the island against the forces of the lake. The second, more beneficial method would be to create an emergent shoal that parallels the southern shoreline approximately 100' off the island, creating a dike barrier protecting the island from the lakes waves. Both projects would require about 1300' of dike work, with the second proposal requiring more material than the first

Restoration Option Name	Primary Resource Benefit	Description of Project
Celeron Island Shoal construction	Fish, Birds	The loss of the protective shoreline has led to the loss of much of the wetlands that lined the outer shoreline and the inner bay, at the center of the island. Today the island is actually two separate islands due to decades of erosion. To address this problem the construction of an off shore emergent shoal would help to break up the force of incoming waves from the lake during seasonal storms and allow for the regeneration of the islands outer shoreline emergent vegetation. Such a shoal would also create additional fish habitat, provide additional hunting opportunities and provide a protected area for migratory waterfowl and shorebirds to roost.
Detroit River International Wildlife Refuge Educational/Outreach Activities	Fish, Birds, Wildlife	Expanding Refuge educational/outreach activities, such as guided tours of Hamburg Marsh Unit and interpretive programs
Rouge River Early Warning Detection System	Fish, Birds, Wildlife	This project would install an early warning system in the several outfalls along the Rouge that seem to be sources for ongoing release episodes. Stand alone systems are available at this time and LTCI can undertake an initial review of them if the Trustees are interested.
Stony island shoal reconstructions	Fish, Birds, Wildlife	The upper bay dike adjacent to Grosse Ile had been eroded down below the current water level over a length of approximately 750 feet. The shoal that protects the wetlands of the lower bay has also disappeared under the effects of decades of erosion. The remaining submerged shoal runs perpendicular to the southwest end of the island, in the lower bay, beginning at the islands old bridge crossing and extending out off the island approximately 1250 feet to the south. Reconstruction of these shoals would provide desirable protection to Stony Island.

Restoration Option Name	Primary Resource Benefit	Description of Project
Fort Wayne Shoreline Restoration	Fish, Birds, Wildlife	Historic Fort Wayne includes 1,270 feet of river frontage that is presently comprised of large concrete riprap. The upland area includes some native trees. The U.S. Geological Survey has recommended assessment for soft shoreline engineering. Opportunities are also present for a low channel or swale in the upland area with an intermittent connection to the Detroit River. Ideally, it would be seasonally accessible to native fish species and would also benefit other wetland species including small mammals, reptiles and amphibians. Its habitat value for migratory birds would be enhanced considerably by suitable wildlife plantings including oaks, dogwoods and other fruit-bearing native shrubs, grasses and a variety of pollinator-friendly wildflowers.
Rouge Gateway Partnership: Spillway Project; Feasibility Study	Fish, Birds, Wildlife	Implementation of Rouge River Gateway Partnership Master Plan: various projects to promote economic development, ecosystem restoration, heritage preservation, and increased recreation along the Rouge River corridor. Several "shovel-ready" projects have been identified by Rouge communities. Specifically the Spillway project to incorporate swales, a wetland and access to the River at an existing spillway cut through the concrete channel.
Erie State Game Area North Maumee Bay	Fish, Birds, Wildlife	Conduct a feasibility study in North Maumee Bay to look at restoration potential.
Lake Erie Marsh Preserve Wetland Restoration and Enhancement	Wildlife	This parcel is considered by the Detroit River International Wildlife Refuge to be a significant wetland habitat within the corridor as well as a key parcel for wildlife. A restoration plan has been submitted for NOAA funding/grant. FWS supports the plan.
Detroit River (former Chrysler site) Coastal Shoreline Restoration	Wildlife	Soft shore engineering for Refuge Gateway property (the former Chrysler site, property is not FWS owned). In 2008, USFWS retained Pheasants Forever and JF New to prepare architectural and engineering drawings for wetland and shoreline restoration at the Refuge Gateway. This architecture and engineering work will be completed in 2009. It is unclear if funding is in place for project completion.
Bennett Arboretum: Habitat Preservation and Enhancement		Implementation of master plan for restoration of Bennett Arboretum, Michigan's first publicly funded arboretum and home to over 475 species of trees (many rare) . Plans include tree plantings, native wildflower and grasses, wetland overlook, welcome kiosk, interpretive trail development and interpretive signage.

Restoration Option Name	Primary Resource Benefit	Description of Project
Rouge River Watershed Grow Zones: Habitat Restoration and Enhancement		Continue implementing "Grow Zones" across Wayne County: Replace 50 acres of mowed turf with native plant grow zones and plant 1000 trees on public lands within the Wayne County watersheds to minimize storm water pollution impacts, reduce air pollution, reduce fossil fuel consumption and create a healthier more biologically diverse natural environment throughout Wayne County. Restoration work may also include prescribed burning of grow zone areas.
North Branch Ecorse Creek Drainage District: Wetland Creation and Habitat Rehabilitation		Design and construction of improvements to North Branch Ecorse Creek: Storm water detention basins; drain widening; utility relocation; bridge expansion; wetland creation within greenway and installation of "natural stream channel" design features including deep rooted native wildflowers and grasses. This project augments existing mini-grants program.

Appendix B. Restoration Alternative Screening

Table B1. Results of restoration screening analysis for preliminary restoration alternatives

Project	**Does the project have the potential to compensate for one or more of the injured resources?**	**Is there sufficient information about the project available to: (a) evaluate the project and (b) satisfy feasibility requirements?**	**Does the project meet the Trustees restoration and screening criteria for injuries experienced as a result of the 2002 Rouge River Mystery Oil Spill**	**Retained for Restoration Scaling Analysis**
Manhattan Marsh Preservation, Restoration and Enhancement	Yes	No	No	No
Lake Erie Marsh Preserve Wetland Restoration and Enhancement	Yes	Yes	Yes	Yes
Managed Coastal Wetland Restoration	Yes	Yes	Yes	Yes
Detroit River (former Chrysler site) Coastal Shoreline Restoration	Yes	No	No	No
Lady of the Lakes Wetland Enhancement	Yes	Yes	Yes	Yes
Eagle Island Marsh Wetland Enhancement	Yes	Yes	Yes	Yes
Bay Creek Hunt Club Land Acquisition:	Yes	No	No	No
Strong Property Shoreline Enhancements	Yes	Yes	Yes	Yes
Gibraltar Wetlands Habitat Improvement	Yes	Yes	Yes	Yes
Humbug Marsh Habitat Improvement	Yes	Yes	Yes	Yes
Detroit River International Wildlife Refuge Educational/Outreach Activities:	Yes	No	No	No
Brancheau Tract Invasive Species Control	Yes	Yes	Yes	Yes
Belle Isle Fish habitat construction: Augment Existing Spawning Reef	Yes	No	No	No

Project	**Does the project have the potential to compensate for one or more of the injured resources?**	**Is there sufficient information about the project available to: (a) evaluate the project and (b) satisfy feasibility requirements?**	**Does the project meet the Trustees restoration and screening criteria for injuries experienced as a result of the 2002 Rouge River Mystery Oil Spill**	**Retained for Restoration Scaling Analysis**
Fighting Island (Canada) Fish habitat construction	Yes	No	No	No
Grassy Isle Fish habitat construction	Yes	No	No	No
Belle Isle Fish habitat construction: Spawning Beds	Yes	No	No	No
Belle Isle Fish Rearing and Stocking Facility	Yes	No	No	No
Rouge River Early Warning Detection System	Yes	No	No	No
Grassy Island Shoal Restoration	Yes	Yes	Yes	Yes
N. Hennepin Marsh restoration	Yes	No	No	No
S. Hennepin Marsh Land Acquisition	Yes	No	No	No
S. Hennepin Marsh Construction	Yes	No	No	No
Stoney island shoal reconstructions	Yes	No	No	No
Round Island acquisition	Yes	No	No	No
Sugar Island acquisition	Yes	No	No	No
Sugar Island Restoration	Yes	No	No	No
Celeron Island Shoal construction	Yes	No	No	No
Fort Wayne Shoreline Restoration	Yes	Yes	No	No
US Steel Shoal Restoration	Yes	No	Yes	No
Rouge River Watershed - Rouge River National Wet Weather Demonstration Project: Augmenting Existing Alliance of Rouge Community Pass-Through Mini Grants Program	Yes	No	No	No
Rouge Gateway Partnership: Spillway Feasibility Study:	Yes	No	No	No

Project	**Does the project have the potential to compensate for one or more of the injured resources?**	**Is there sufficient information about the project available to: (a) evaluate the project and (b) satisfy feasibility requirements?**	**Does the project meet the Trustees restoration and screening criteria for injuries experienced as a result of the 2002 Rouge River Mystery Oil Spill**	**Retained for Restoration Scaling Analysis**
Rouge Gateway Partnership: Fordson Island Planning/Feasibility Study	Yes	No	No	No
Rouge Gateway Partnership: Detroit, and River Rouge Fish Habitat Enhancements Segment 1	Yes	Yes	No	No
Rouge Gateway Partnership: Detroit, and River Rouge Fish Habitat Enhancements Segment 2	Yes	Yes	No	No
Restoration of Hines Park Wetland Mitigation Bank (Wayne County)	Yes	No	No	No
Bennett Arboretum: Habitat Preservation and Enhancement	Yes	Yes	No	No
Rouge River Watershed Grow Zones: Habitat Restoration and Enhancement	Yes	Yes	Yes	Yes
North Branch Ecorse Creek Drainage District: Wetland Creation and Habitat Rehabilitation: Augmenting Existing Mini Grants Program	Yes	No	No	No
Cook and Gladding Drain Petition Project within the Alliance of Downriver Watersheds	Yes	Yes	No	No
Rouge River watershed, Ecorse Creek watershed, Combined Downriver watershed, Detroit River watershed, Lake St Clair watershed: Habitat Rehabilitation	Yes	Yes	No	No
Henry Ford Estate Dam Fish Passage Feasibility/Planning Study	Yes	No	No	No
Wayne Road Dam Removal: Planning and Design	Yes	No	No	No
Concrete Channel Modifications: For Habitats and Fish Populations	Yes	No	No	No

Project	**Does the project have the potential to compensate for one or more of the injured resources?**	**Is there sufficient information about the project available to: (a) evaluate the project and (b) satisfy feasibility requirements?**	**Does the project meet the Trustees restoration and screening criteria for injuries experienced as a result of the 2002 Rouge River Mystery Oil Spill**	**Retained for Restoration Scaling Analysis**
Pte. Mouillee State Game Area Zone 13	Yes	Yes	Yes	Yes
Pte. Mouillee State Game Area Sump Dike	Yes	Yes	Yes	Yes
Pte. Mouillee State Game Area Bad Creek Unit	Yes	Yes	Yes	Yes
Pte. Mouillee State Game Area Walpatich Repair	Yes	Yes	Yes	Yes
Pte. Mouillee State Game Area Water Control Structures	Yes	Yes	Yes	Yes
Pte. Mouillee State Game Area Zone 13 and Lautenschlager Unit: Project completed 2009	Yes	Yes	Yes	Yes
Erie State Game Area North Maumee Bay	Yes	No	Yes	No
Great Lake Marsh Restoration	Yes	Yes	Yes	Yes
Lakeplain Prairie Restoration	Yes	Yes	Yes	Yes
Sturgeon Bar Restoration	Yes	Yes	Yes	Yes
Rouge River Watershed Streambank Stabilization and In-Stream Habitat Restoration: Targeted Wood Debris BMP Implementation	Yes	No	No	No
Friends of the Rouge Frog and Toad and Volunteer Monitoring Programs	Yes	No	No	No
Rouge River Watershed Targeted Fisheries Monitoring	Yes	No	No	No

Appendix 3: ROUGE RIVER 2002 MYSTERY OIL SPILL REVISED SIMAP INJURY REPORT

Attachment A: State-of-the-Art and Research Needs for Oil Spill Impact Assessment Modeling

Attachment B: Rouge River 2002 Mystery Oil Spill SIMAP Injury Report: Sensitivity Analysis for Trajectory

Attachment C: Rouge River 2002 Mystery Oil Spill SIMAP Injury Report: Fates Model Results

Attachment D: Rouge River 2002 Mystery Oil Spill SIMAP Injury Report: Biological Data

Attachment E: Rouge River 2002 Mystery Oil Spill SIMAP Injury Report: Biological Model Results

Note: The attachments noted above are identified in the body of Appendix 3 as appendices to the report. In order to distinguish the appendices of the DARP / EA from supplementary materials to individual reports, they are referred to here as attachments. Where, in the body of this Appendix, there is a reference to an appendix (A-E), the reader should refer to the attachments (A-E) noted above.

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ROUGE RIVER 2002 MYSTERY OIL SPILL
REVISED SIMAP INJURY REPORT
Draft for Trustee Review

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EXECUTIVE SUMMARY

Oil spill modeling was performed for the 9 April 2002 oil spill into the Rouge River, MI. According to U.S. Environmental Protection Agency (EPA) reports, an estimated 255,544 gallons of mixed diesel and waste lubricating oil were visible on the waters of the Detroit River at or about mid-day on 10 April 2002 (Allen, 2002). The 255,544 gallons were identified as a portion of the 9 April oil spill that released oil into the Rouge River from an unknown source. Over the next few days, the spilled oil washed into the Detroit River, oiling 17 miles of the U.S. Detroit River coastline and 16 kilometers of the Canadian coastline. A second release of oil occurred from a similar release location on the night of 12 April 2002. Over the next two weeks, U.S. Coast Guard (USCG) pollution reports indicate that cleanup efforts removed 66,359 gallons of emulsion, which contained some lesser volume of oil, and much of the oiled coastal flora from the U.S. shorelines. A portion of the spill was contained within the Rouge River system with booms and most of the recovered oil was collected in this region. Oil was found in the nearby sewer system; thus, the source of the oil to the river was found to be the sewer system outfalls during and/or after a period of increased sewer flow during rain events in the area.

The objectives were to provide (1) an assessment of the pathways and fate of the oil; (2) an estimate exposure to the water surface, shoreline and other habitats, water column, and sediments; and (3) an estimate of injuries to wildlife, aquatic organisms, and habitats that can be used to scale compensatory restoration. Observations and data collected during and after the spill were used as much as possible as input to and to calibrate the model. Where data from the event were not available, historical information was used to make the assessment as site-specific as possible.

The analysis was performed using the model system SIMAP (Spill Impact Modeling Analysis Package). The physical fate model in SIMAP estimates the distribution of oil (as mass and concentrations) on the water surface, on shorelines, in the water column, and in the sediments. The biological exposure model in SIMAP estimates the area, volume, or portion of a stock or population affected by surface oil, concentrations of oil components in the water, and sediment contamination. Losses are estimated by species or species group for wildlife, fish and invertebrates by multiplying percent loss by species density.

The model uses incident-specific wind and current data, and transport algorithms, to calculate mass balance in various environmental compartments (water column, atmosphere, sediments, etc.) and concentrations of the oil components in water and sediments. Geographical data (habitat mapping and shoreline location) were obtained from existing Geographical Information System (GIS) databases. Depth data for the Rouge River were obtained from the National Oceanic and Atmospheric Administration (NOAA) hydrodynamic CATS model, while data for the Detroit River and Lake Erie were obtained from both the CATS model and from NOAA's National Geophysical Data Center (NGDC). Hourly wind speed and direction data during and after the spill were obtained from nearby meteorological stations. Currents were modeled with CATS using wind forcing for the time period of the spill.

Specifications for the scenario (date, timing, amount, duration of release, etc.) were based on information obtained and distributed during the response through the U.S. EPA pollution reports (EPA), U.S. Fish and Wildlife Service reports (USFWS), U.S. Coast Guard press releases and pollution reports (USCG-Press and USCG-PolReps), NOAA SCAT maps, NOAA overflight maps, and material compiled by the Detroit Free Press (DFP).

To manage (and bound) uncertainty associated with oil spill release conditions, and in order to derive a best base case scenario, several uncertain model inputs were varied as a sensitivity analysis. Some of the parameters that were varied included duration and timing of the release; width of oiling on the shore; horizontal dispersion rate (i.e., the coefficient); droplet size distribution; current flow speed, and percentage of the total oil spill volume withheld after the initial first release in order to match observations of 1,000 gal of oil remaining within the Rouge River by noon on 10 April.

Table 1 lists the total injury of wildlife, including birds, mammals, reptiles, and amphibians, for the best base case scenario for the three areas (Rouge River, Detroit River and Lake Erie) impacted by the spill. Species affected with a total injury of greater than 100 individuals per species or species group include muskrat, waterfowl, such as common merganser, greater scaup, and lesser scaup, and seabirds, such as Bonapartes gull, herring gull, and double-crested cormorant.

Table 1. Summary of estimated injuries to wildlife resulting from the release of a diesel and lubricating oil mixture into the Rouge River, Detroit River and Lake Erie.

Wildlife Group	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Waterfowl (other than scaup)	410	25	436
Scaup*	4,106		4,106
Seabirds	737	1	738
Wading birds	10	-	10
Shorebirds	58	-	58
Mammals (Muskrats)	308	0	308
Reptiles	114	0	114
Amphibians	78	0	78
Total	**5,821**	**26**	**5,848**

* Scaups are assumed to be found in Lake Erie only in waters 1-3 meters deep.

It should be noted that it is uncertain what the pre-spill densities of birds and other wildlife were before the spill. The density data used for the modeling, which was best available information, was from other locations and times (see Appendix D). However, the model results are directly proportional to the density data assumed. Therefore, if the densities assumed were a factor 2 lower, the injury results would also be a factor 2 lower. The counts of oiled animals observed oiled or dead in the field totaled 110 birds and 3 turtles. Thus, these model results suggest that one in 49 birds oiled were actually observed; whereas the rule of thumb for past spills has been about 1 in 10 might be observed. Yet, these ratios are highly uncertain, and dependant on the degree of search effort, losses to scavengers, and other factors. Estimates for the likelihood of observing oiled turtles are not available, but 1 in 100 is not unreasonable in this situation.

The injuries in fledgling or hatchling equivalents, as well as individual-years of loss, which are potential measures of injury useful in scaling restoration, are provided. Tables 2 and 3 list the equivalent losses for fledglings, hatchlings and age-one individuals, and the injury reported in equivalents losses for individual bird-, herptile- or mammal-years for the best base case scenario for the three areas (Rouge River, Detroit River and Lake Erie) impacted by the spill.

Table 2. Summary of estimated equivalent losses of bird fledglings, mammal age-zero (newly weaned) mammals, and herpetofauna hatchlings resulting from the release of a diesel and lubricating oil mixture into the Rouge River, Detroit River and Lake Erie.

	Equivalent Losses		
Wildlife Group	**Detroit River and Lake Erie**	**Rouge River**	**Total**
Waterfowl (other than scaup) fledglings	1,401	84	1,485
Scaup fledglings*	14,332	-	14,332
Seabird fledglings	2,753	4	2,757
Wading bird fledglings	34	-	34
Shorebird fledglings	200	-	200
Muskrats (newly weaned)	940	-	940
Reptile hatchlings	1,700	-	1,700
Amphibian hatchlings	143,600	-	143,600
Total	**164,960**	**88**	**165,048**

* Scaups are assumed to be found in Lake Erie only in waters 1-3 meters deep.

Table 3. Summary of estimated injuries (interim loss) as individual bird-years, mammals-years and herptile years (all age classes combined for each group) resulting from the release of a diesel and lubricating oil mixture into the Rouge River, Detroit River and Lake Erie.

	Individual-years Lost (all ages)		
Wildlife Group	**Detroit River and Lake Erie**	**Rouge River**	**Total**
Waterfowl (other than scaup)	1,057	78	1,135
Scaups*	8,855	-	8,855
Seabirds	11,977	16	11,992
Wading birds	31	-	31
Shorebirds	351	-	351
Muskrats	398	-	398
Reptiles	1,238	-	1,238
Amphibians	9,448	-	9,448
Total	**33,355**	**94**	**33,448**

* Scaups are assumed to be found in Lake Erie only in waters 1-3 meters deep.

Table 4 lists the total injury (interim loss) of fish as production forgone, i.e., the sum of the direct kill plus net growth normally to be expected of the killed organisms over the remainder of their life spans (lifetime production), for the best base case scenario using an $LC50_{\infty}$ (i.e., LC50 for infinite exposure time, which in the model is corrected for duration of exposure) value of 44ppb for species of average sensitivity to the diesel and lubricating oil mixture that was released during the spill.

Table 4. Summary of estimated injuries to fish resulting from the release of a diesel and lubricating oil mixture into the Rouge River, Detroit River and Lake Erie using a $LC50_{\infty}$ value of 44ppb for species of average sensitivity.

Fishery Species	Biomass Killed (kg)	Production Forgone (kg)	Total Injury (kg)
Total small pelagic fish	2.2	0.0	2.2
Total large pelagic fish	8.4	7.2	15.6
Total demersal fish	108	102	211
Total	**119**	**110**	**228**

1. INTRODUCTION

Oil spill modeling was performed for the 9 April 2002 oil spill into the Rouge River, MI. According to U.S. Environmental Protection Agency (EPA) reports, an estimated 255,544 gallons of mixed diesel and waste lubricating oil were visible on the waters of the Detroit River at or about mid-day on 10 April 2002 (Allen, 2002). The 255,544 gallons were identified as a portion of the 9 April oil spill that released oil into the Rouge River from an unknown source. Over the next few days, the spilled oil washed into the Detroit River, oiling 17 miles of the U.S. Detroit River coastline and 16 kilometers of the Canadian coastline. A second release of oil occurred from a similar release location on the night of 12 April 2002. Over the next two weeks, U.S. Coast Guard (USCG) pollution reports indicate that cleanup efforts removed 66,359 gallons of emulsion, which contained some lesser volume of oil, and much of the oiled coastal flora from the U.S. shorelines. A portion of the spill was contained within the Rouge River system with booms and most of the recovered oil was collected in this region. Oil was found in the nearby sewer system; thus, the source of the oil to the river was found to be the sewer system outfalls during and/or after a period of increased sewer flow during rain events in the area.

Surface oil was first observed by the Fort Street Bridge operator at 1000 (local time) on 9 April, and by the end of the day oil had been observed throughout the Rouge River and as far south as the Detroit River Light on Lake Erie. On 10 April, booms were deployed around sensitive areas throughout the Detroit River, including Elizabeth Park and Humbug Marsh, and at several locations within the Rouge River. NOAA SCAT reports indicated black oil windrows in the Detroit River south of the Rouge River; and shore oiling was observed along much of the western bank of the Detroit River (Figure 1-1). Overflights on 11 and 12 April found additional shore oiling and sheening on the banks and islands within the Detroit River (Figures 1-2 and 1-3). A second spill from a sewer outfall in the same location was reported on the morning of 13 April, involving a release of a significant amount of additional oil into the Rouge River. NOAA SCAT maps from 14 and 15 April indicated extensive staining on the western banks of the Detroit (Figures 1-4 and 1-5) and the final overflight on 16 April found sheening as far south as northwestern Lake Erie (Figure 1-6). Clean-up efforts continued for the next week and a reported 66,359 gallons of emulsion, which contains some lesser volume of oil, was removed from the Detroit and Rouge Rivers.

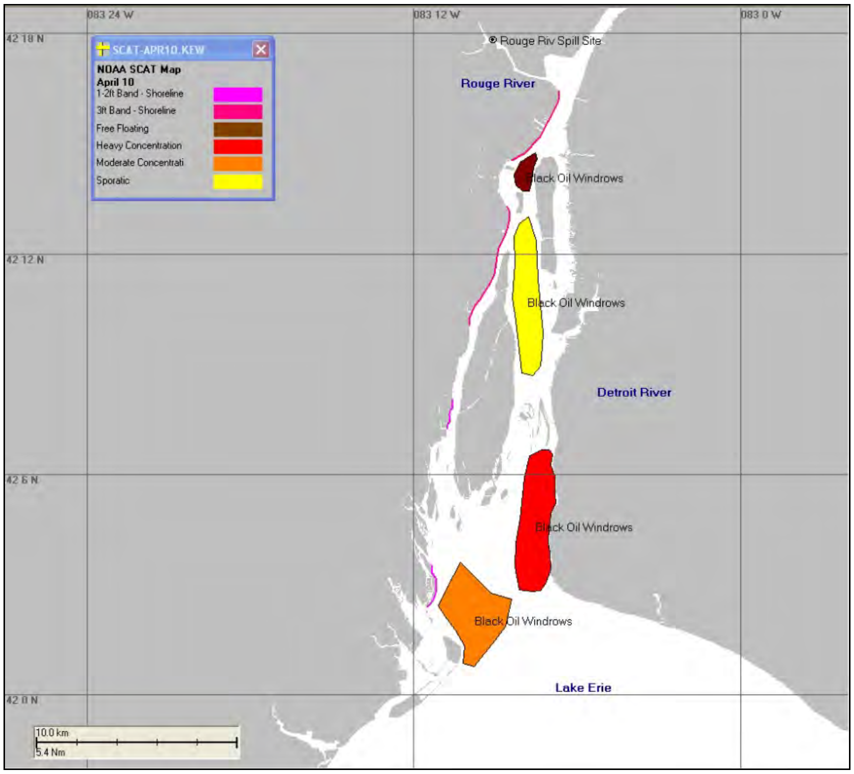

Figure 1-1. NOAA SCAT observations from 10 April 2002.

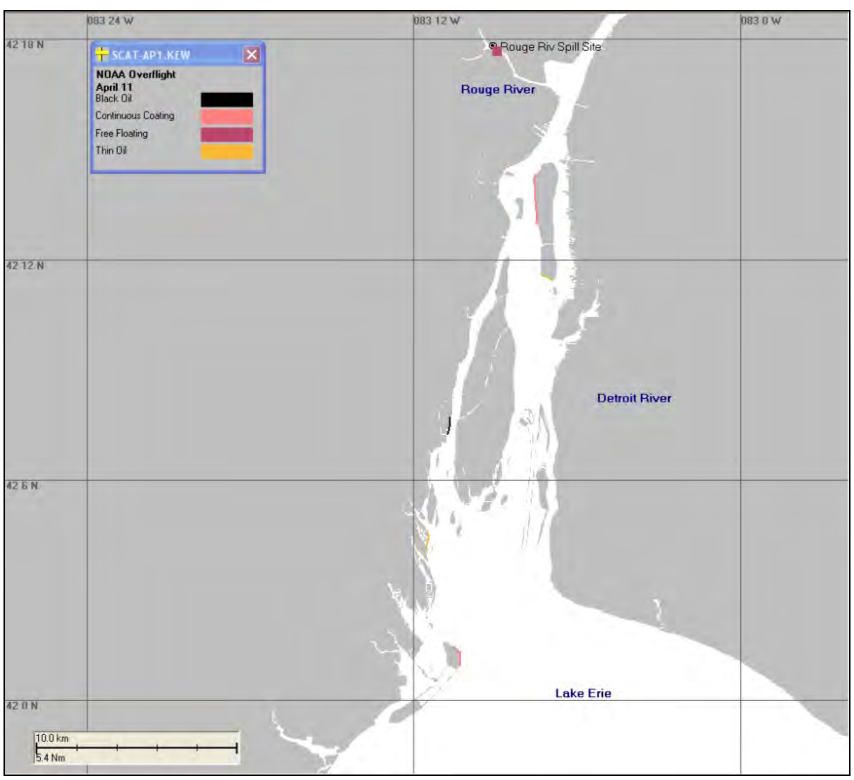

Figure 1-2. NOAA overflight observations from 11 April 2002.

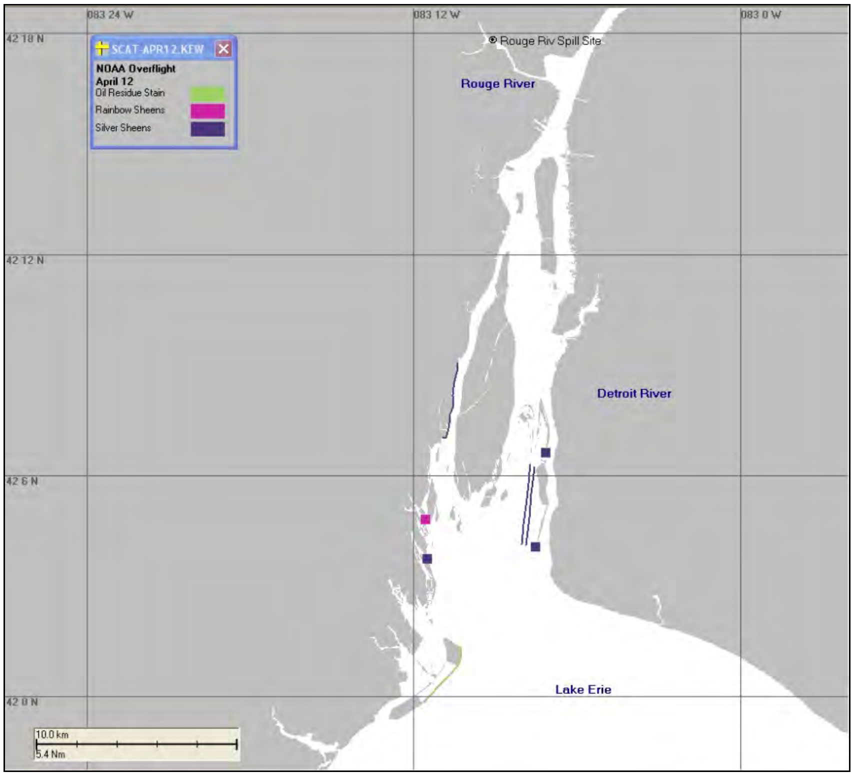

Figure 1-3. NOAA overflight observations from 12 April 2002.

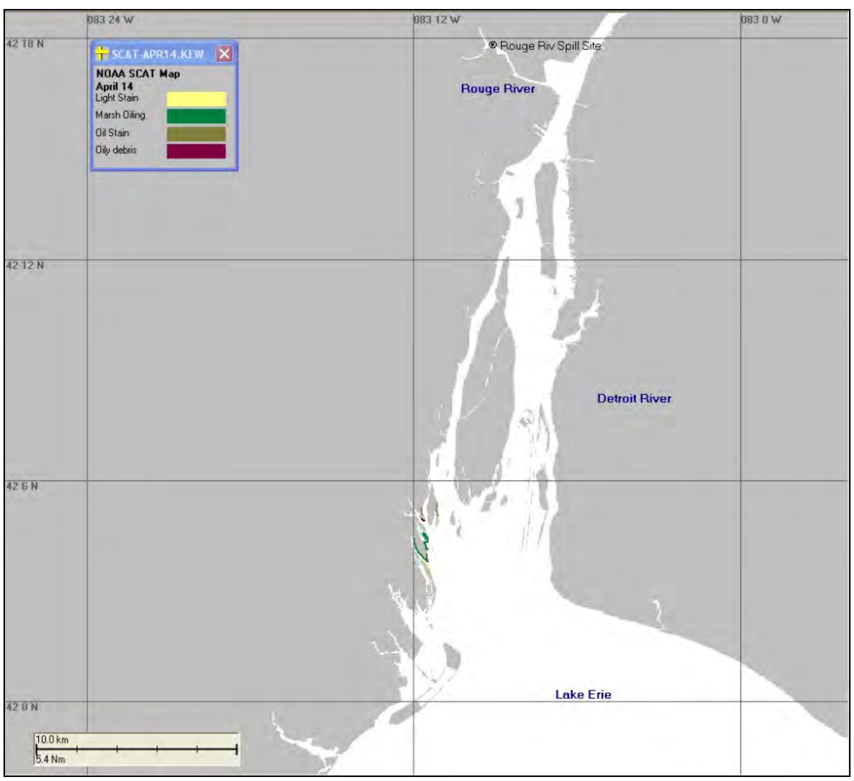

Figure 1-4. NOAA SCAT observations from 14 April 2002.

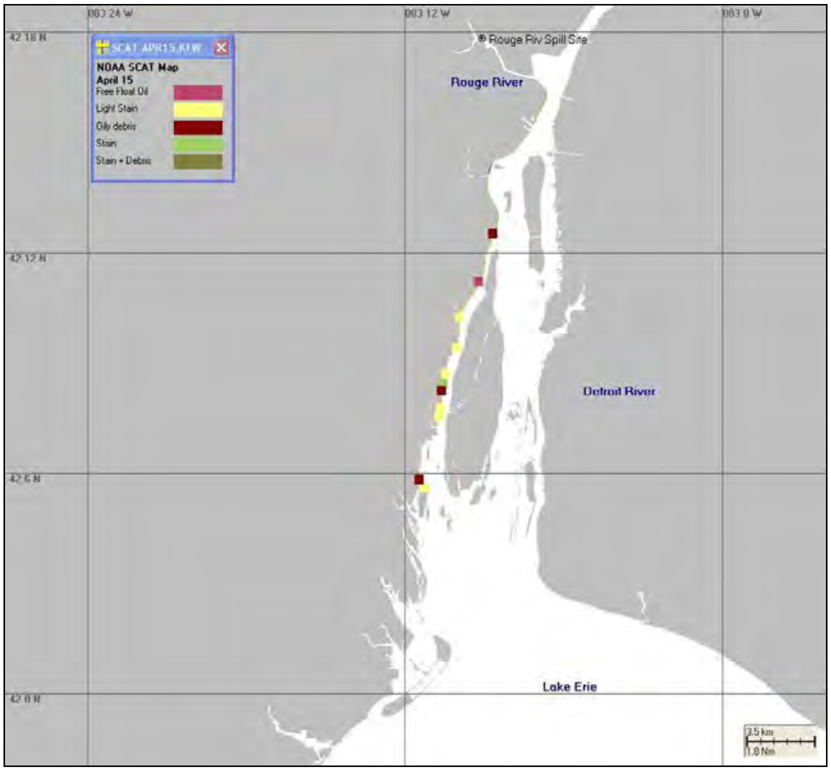

Figure 1-5. NOAA SCAT observations from 15 April 2002.

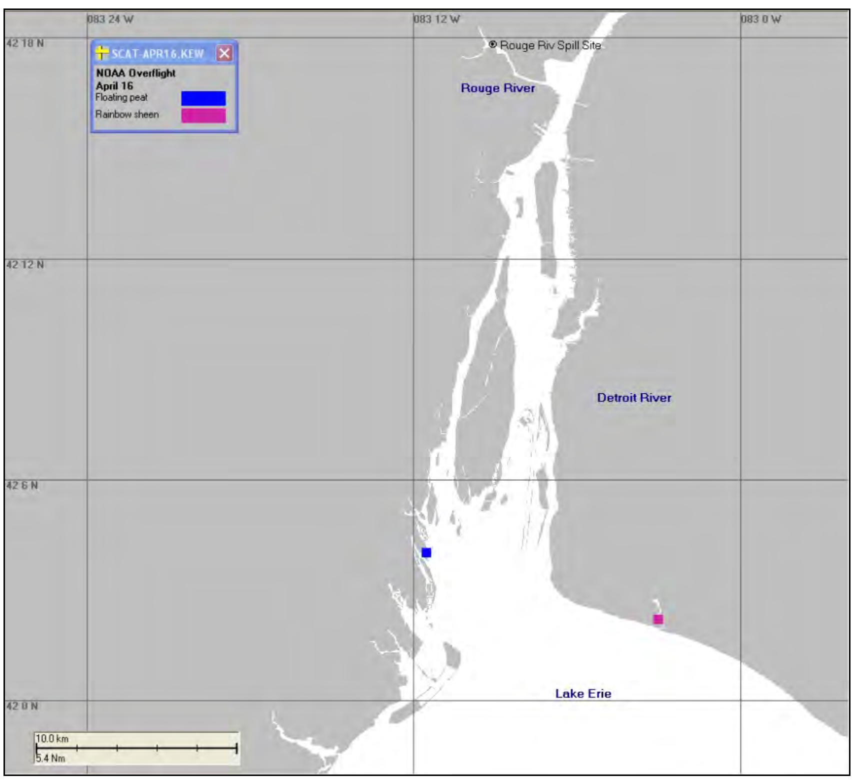

Figure 1-6. NOAA overflight observations from 16 April 2002.

The objectives were to provide (1) an assessment of the pathways and fate of the oil, and thus estimate exposure to the water surface, shoreline and other habitats, water column, and sediments; and (2) an estimate of injuries to wildlife, aquatic organisms, and habitats that can be used to scale compensatory restoration. Observations and data collected during and after the spill were used as much as possible as input to and to calibrate the model. Where data from the event were not available, historical information were used to make the assessment as site-specific as possible.

This report describes the data inputs for and results of the modeling. Inputs include habitat and depth mapping, winds, currents, other environmental conditions, oil properties, specifications of the release (amount, timing, etc.), and biological abundance.

2. MODEL DESCRIPTION

The oil spill modeling was performed using SIMAP (French McCay, 2003, 2004), which uses wind data, current data, and transport and weathering algorithms to calculate the mass of oil components in various environmental compartments (water surface, shoreline, water column, atmosphere, sediments, etc.), oil pathway over time (trajectory), surface oil distribution, and concentrations of the oil components in water and sediments. SIMAP was derived from the physical fates and biological effects submodels in the Natural Resource Damage Assessment Models for Coastal and Marine and Great Lakes Environments (NRDAM/CME and NRDAM/GLE), which were developed for the U.S. Department of the Interior (USDOI) as the basis of Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) Natural Resource Damage Assessment (NRDA) regulations for Type A assessments (French et al., 1996; Reed et al., 1996).

SIMAP contains physical fate and biological effects models, which estimate exposure and impact on each habitat and species (or species group) in the area of the spill. Environmental, geographical, physical-chemical, and biological databases supply required information to the model for computation of fates and effects. The technical documentation for the model is described in detail in Appendix A, as well as in French McCay (2003, 2004).

2.1 Physical Fates Model

The physical fate model estimates the distribution of oil (as mass and concentrations) on the water surface, on shorelines, in the water column, and in the sediments. Processes simulated include slick spreading, evaporation of volatiles from surface oil, transport on the water surface and in the water column, randomized dispersion, emulsification, entrainment of oil as droplets into the water column, resurfacing of larger droplets, dissolution of soluble components, volatilization from the water column, partitioning, sedimentation, stranding on shorelines, and degradation. Oil mass is tracked separately for lower-molecular-weight aromatics (1 to 3-ring aromatics), which are soluble and cause toxicity to aquatic organisms (French McCay, 2002), other volatiles, and non-volatiles. The lower molecular weight aromatics dissolve both from the surface oil slick and whole oil droplets in the water column, and they are partitioned in the water column and sediments according to equilibrium partitioning theory (French et al., 1996; French McCay, 2003, 2004).

"Whole" oil (containing non-volatiles and volatile components not yet volatilized or dissolved from the oil) is simulated as floating slicks, emulsions and/or tar balls, or as dispersed oil droplets of varying diameter (some of which may resurface). Sublots of the spilled oil are represented by Lagrangian elements ("spillets"), each characterized by mass of hydrocarbon components and water content, location, thickness, diameter, density, and viscosity. Spreading (gravitational and by transport processes), emulsification, weathering (volatilization and dissolution loss), entrainment, resurfacing, and transport processes determine the thickness, dimensions, and locations of floating oil over time. The output of the fate model includes the location, dimensions, and physical-chemical characteristics over time of each spillet representing the oil (French McCay, 2003, 2004).

Concentrations in the water column were calculated by summing mass (in the Lagrangian particles) within each grid cell of a 50 (east-west) by 50 (north-south) by 5 vertical layer grid scaled in size each time step to just cover the dimensions of the plume. Thus, this grid expands over time. This includes all potential contamination in the water column, while maximizing the resolution of the contour map at each time step to reduce error caused by averaging mass over large cell volumes. Distribution of mass around the particle center is described as Gaussian in three dimensions, with one standard deviation equal to twice the diffusive distance ($2D_xt$ in the horizontal and $2D_zt$ in the vertical, where D_x is the horizontal and D_z is the vertical diffusion coefficient, and t is particle age). The plume grid edges are set at one standard deviation out from the outer-most particle. Concentrations of particulate (oil droplet) and dissolved aromatic concentrations are calculated in each cell and time step and saved to files for later viewing and calculations. These data are used by the biological effects model to evaluate exposure, toxicity, and effects. In addition, calculations of dissolved concentrations were made for smaller grids localized around the spill site to resolve details of potential plumes derived from fresh oil.

The SIMAP fates model quantifies, in space and over time:

- The spatial distribution of oil mass and volume on water surface over time
- Oil mass, volume and thickness on shorelines over time
- Subsurface oil droplet concentration, as total hydrocarbons, in three dimensions over time
- Dissolved aromatic concentration (which causes most aquatic toxicity) in three dimensions over time
- Total hydrocarbons and aromatics in the sediments over time

The fates model output at each time step includes:

- oil thickness (microns or g/m^2) on water surface,
- oil thickness (microns or g/m^2) on shorelines,
- subsurface oil droplet concentration (ppb), as total hydrocarbons,
- dissolved aromatic concentration in water (ppb),
- total hydrocarbon loading on sediments (g/m^2), and
- dissolved aromatics concentration in sediment pore water (ppb).

The physical fates model has been validated with more than 20 case histories, including the *Exxon Valdez* and other large spills (French McCay, 2003, 2004; French McCay and Rowe, 2004), as well as test spills designed to verify the model's transport algorithms (French et al., 1997).

2.2 Biological Effects Model – Exposure and Direct Losses of Fauna

The biological exposure model in SIMAP (Appendix A) estimates the area, volume, or portion of a stock or population affected by surface oil, concentrations of oil components in the water, and sediment contamination (French McCay, 2003, 2004). For wildlife (birds, mammals, and sea turtles), the number or fraction of a population suffering oil-induced effects is proportional to the water-surface area swept by oil of sufficient quantity to provide a lethal dose to an exposed animal. Dose is modeled as the product of concentration and exposure time (or duration). Based on calculations of the approximate area of a bird swimming through the water, an exposure index was developed for seabirds and other offshore wildlife, which is the water area swept by more than 10-μm thick (> 10 g/m^2) oil (which is sufficient to provide a lethal dose (French et al., 1996; French McCay and Rowe, 2004; Appendix A). The probability of exposure is related to behavior: i.e., the habitats used and percentage of the time spent in those habitats on the surface of the water. For shorebirds and other wildlife on or along the shore, an exposure index is length of shoreline oiled by > 10 g/m^2. Areas of exposure above these thresholds are a normal model output from SIMAP.

The biological exposure model estimates the area, volume or portion of a stock or population affected by surface oil, concentrations of oil components in the water, and sediment contamination. The biological effects model estimates losses resulting from acute exposure after a spill (i.e., losses at the time of the spill and while floating oil and acutely toxic concentrations remain in the environment) in terms of direct mortality and lost production because of direct exposure or the loss of food resources from the food web. Losses are estimated by species or species group for fish, invertebrates (i.e., shellfish and non-fished species) and wildlife (birds, mammals, sea turtles). Lost production of aquatic plants (microalgae and macrophytes) and lower trophic levels of animals are also estimated.

The area potentially affected by the spill is represented by a rectangular grid with each grid cell coded as to habitat type. The habitat grid is also used by the physical fates model to define the shoreline location and type, as well as habitat and sediment type. A habitat is an area of essentially uniform physical and biological characteristics that is occupied by a group of organisms that are distributed throughout that area. A contiguous grouping of habitat grid cells with the same habitat code represents an ecosystem in the biological model. The density of fish, invertebrates and wildlife, and rates of lower trophic level productivity, are assumed constant for the duration of the spill simulation and evenly distributed across an ecosystem. While biological distributions are known to be highly variable in time and space, data are generally not sufficient to characterize this patchiness. Oil is also patchy in distribution. The patchiness is assumed to be on the same scale so that the intersection of the oil and biota is equivalent to overlays of spatial mean distributions.

Habitats include open water, mud flat, wetland and shoreline habitats (e.g., rocky shore, gravel beach, sand beach, and artificial habitat). Habitat types are defined by depth, proximity to shoreline(s), bottom/shore type, and dominant vegetation type. With respect to proximity to shoreline(s), habitats are designated as landward or seaward (i.e., landward within the Rouge River or seaward in the Detroit River and Lake Erie, respectively). This designation allows different biological abundances to be simulated in landward and seaward zones of the same habitat type (e.g., open water with sand bottom).

In SIMAP, aquatic organisms are modeled using Lagrangian particles representing schools or groups of individuals. Pre-spill densities of fish, invertebrates, and wildlife (birds, mammals, reptiles, and amphibians) are assumed evenly distributed across each habitat type defined in the application of the model. (Habitat types may be defined to resolve areas of differing density for each species, and the impact in each habitat type is then separately computed.) Mobile fish, invertebrates, and wildlife are assumed to move at random within each habitat during the simulation period. Benthic organisms either move or remain stationary on/in the bottom. Planktonic stages, such as pelagic fish eggs, larvae, and juveniles (i.e., young-of-the-year during their pelagic stage(s)), move with the currents.

2.2.1 Wildlife

In the model, surface slicks (or other floating forms such as tar balls) of oils and petroleum products impact wildlife (birds, marine mammals, reptiles). For each of a series of surface spillets, the physical fates model calculates the location and size (radius of circular spreading spillet) as a function of time. The area swept by a surface spillet in a given time step is calculated as the quadrilateral area defined by the path swept by the spillet diameter. This area is summed over all time steps for the time period the spillet is present on the water surface and separately for each habitat type where the oil passes. Spillets sweeping the same area of water surface at the same time are superimposed. The total area swept over a threshold thickness by habitat type is multiplied by the probability that a species uses that habitat (0 or 1, depending upon its behavior) and a combined probability of oiling and mortality. This calculation is made for each surface-floating spillet and each habitat for the duration of the model simulation.

A portion of the wildlife in the area swept by the slick over a threshold thickness is assumed to die, based on probability of encounter with the slick multiplied by the probability of mortality once oiled. The probability of encounter with the slick is related to the percentage of the time an animal spends on the water or shoreline surface. The probability of mortality once oiled is nearly 100% for birds and fur-covered mammals (assuming they are not successfully treated) and much lower for other wildlife. The products of the two probabilities for various wildlife behavior groups are in Table 2-1. Estimates for the probabilities are derived from information on behavior and field observations of mortality after spills (reviewed in French et al., 1996). The threshold is 10 micron ($\sim 10 g/m^2$) thick oil, based on data and calculations in French et al. (1996). The wildlife mortality model has been validated with more than 20 case histories, including the *Exxon Valdez* and other large spills, verifying that these values are reasonable (French and Rines, 1997; French McCay 2003, 2004; French McCay and Rowe, 2004).

Area swept is calculated for the habitats occupied by each of the behavior groups of wildlife listed in Table 2-1. Species or species groups are assigned to behavior groups to evaluate their loss. Wildlife mortality is directly proportional to abundance per unit area and the percent mortalities in Table 2-1.

Table 2-1. Combined probability of encounter with the slick and mortality once oiled, if present in the area swept by a slick exceeding a threshold thickness. Area swept is calculated for the habitats occupied.

Wildlife Group	Probability	Habitats Occupied
Dabbling waterfowl	99%	Nearshore and shoreline habitats
Nearshore aerial divers	35%	Nearshore and shoreline habitats
Surface seabirds	99%	All water and shorelines
Aerial seabirds	5%	All water and shorelines
Wetland wildlife (waders and shorebirds)	35%	Wetlands, shorelines, vegetated beds
Furbearing marine mammals	75%	All water and shorelines
Surface birds in Detroit River and Lake Erie open water only	99%	All Detroit River and Lake Erie open water
Surface diving birds in Detroit River and Lake Erie open water only	35%	All Detroit River and Lake Erie open water
Aerial divers in Detroit River and Lake Erie open water only, juvenile and adult sea turtles	5%	All Detroit River and Lake Erie open water
Surface birds in Rouge River open water only	99%	All Rouge River open water
Surface diving birds in Rouge River open water only	35%	All Rouge River open water
Aerial divers in Rouge River open water only	5%	All Rouge River open water
Surface diving birds in water only	35%	All waters
Aerial divers in water only	5%	All waters

The probabilities listed in Table 2-1 are based on the literature review and analysis in French et al. (1996).

2.2.2 Fish and Invertebrates

The most toxic components of oil to water column and benthic organisms are low molecular weight compounds, which are both volatile and soluble in water, especially the aromatic compounds (Neff et al., 1976; Rice et al., 1977; Neff and Anderson, 1981; Malins and Hodgins, 1981; National Research Council, 1985, 2002; Anderson, 1985; and French McCay, 2002). This is because organisms must be exposed to hydrocarbons in order for uptake to occur and aquatic biota are exposed primarily to hydrocarbons (primarily aromatics) dissolved in water. Thus, exposure and potential effects to water column and bottom-dwelling aquatic organisms are related to concentrations of dissolved aromatics in the water. Exposure to microscopic oil droplets could also impact aquatic biota either mechanically (especially filter feeders) or as a conduit for exposure to semi-soluble aromatics (which might be taken up via the gills or digestive tract). The effects of the dissolved hydrocarbon components are additive. Other soluble compounds in oil may also add to toxic effects on biota.

Mortality is a function of duration of exposure – the longer the duration of exposure, the lower the effects concentration (see review in French McCay, 2002). At a given concentration after a certain period of time, all individuals that will die have done so. The LC50 is the lethal concentration to 50% of exposed organisms. The incipient LC50 ($LC50_\infty$) is the asymptotic LC50 reached after infinite exposure time (or long enough that that level is approached, Figure 2-1). Percent mortality is a log-normal function of concentration, with the $LC50_\infty$ or the time-corrected $LC50_t$, the center of the distribution.

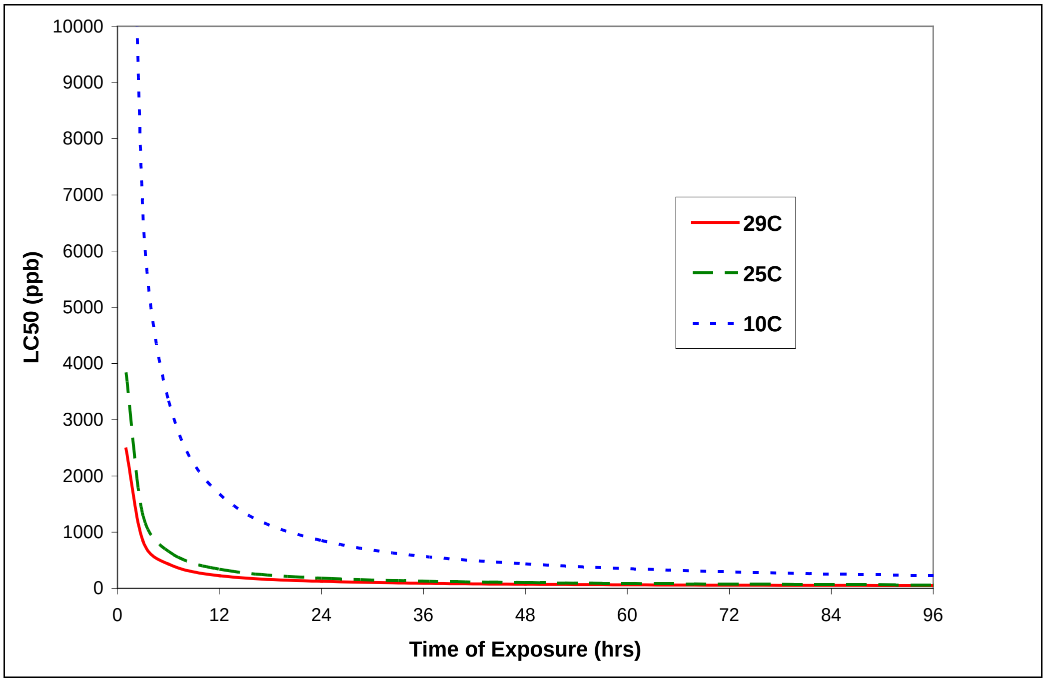

Figure 2-1. LC50 of dissolved PAH mixtures from oil, as a function of exposure duration and temperature.

The value of LC50$_\infty$ ranges from 5-400 μg/L for 95% of species exposed to dissolved PAH mixtures for over 96 hrs (French McCay, 2002; Figure 2-2). The LC50$_\infty$ for the average species is about 40-50 μg/L (ppb) of dissolved PAH (varying slightly among oils and fuels by percent composition of the PAH mixture). These LC50$_\infty$ values have been validated with oil bioassay data (French McCay, 2002), as well as in an application of SIMAP to the *North Cape* oil spill where field and model estimates of lobster impacts were within 10% of each other (French McCay, 2003). In the present spill assessment, model runs were made for the range of potential LC50$_\infty$ values based on those for species previously tested, as all species exposed have not been tested for sensitivity to oil hydrocarbons to date.

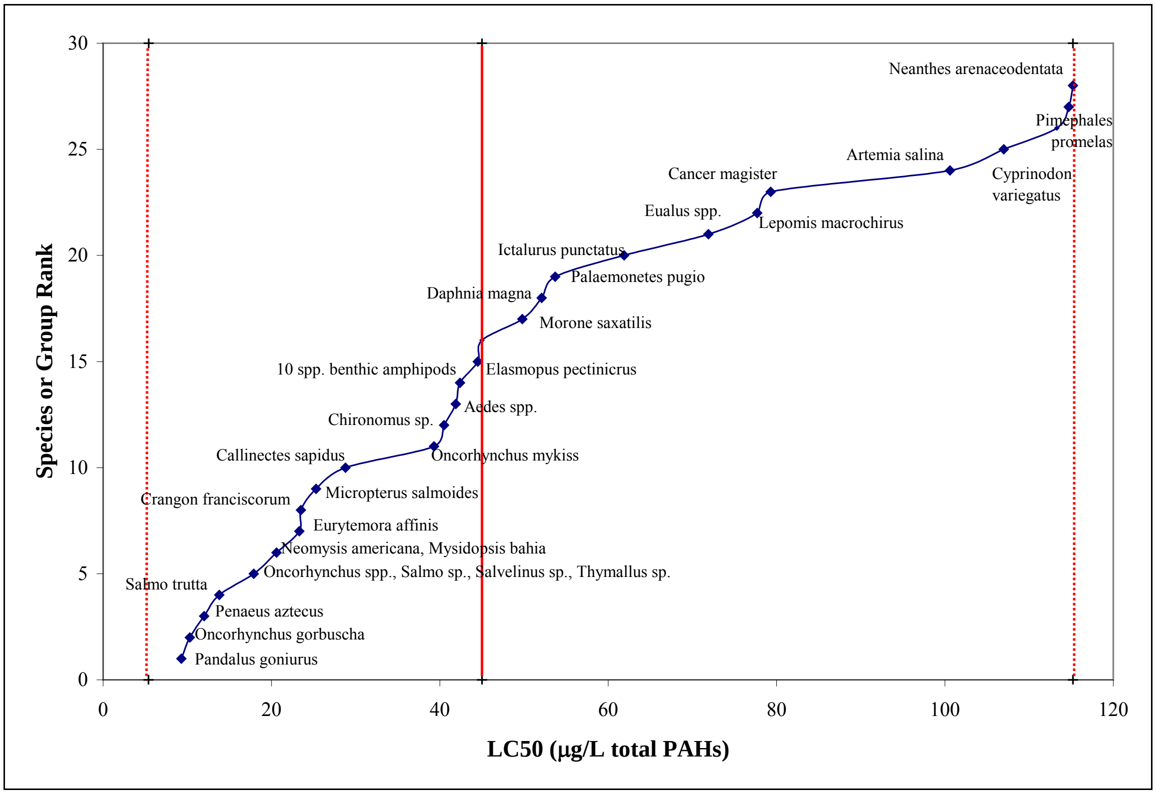

Figure 2-2. Variation in LC50$_\infty$ for dissolved PAH mixtures from a typical oil, by species in rank order of sensitivity.

Mortality of fish, invertebrates, and their eggs and larvae was computed as a function of temperature, concentration, and time of exposure. Percent mortality was estimated for each of a large number of Lagrangian particles representing organisms of a particular behavior class (i.e., planktonic, demersal, and benthic, or fish that are classed as small pelagic, large pelagic, or demersal). For each Lagrangian particle, the model evaluates exposure duration, and corrects the LC50$_\infty$ for time of exposure and temperature (Figure 2-1) to calculate mortality. (See Appendix A for details.) The percent mortalities were summed, weighed by the area represented by each Lagrangian particle to estimate a total equivalent volume for 100% mortality. In this way, mortality was estimated on a volume basis, rather than necessitating estimates of species densities to evaluate potential impacts. In addition to the mortality estimates, the volume exceeding 1 μg/L total dissolved aromatics was used as an index for exposure for fish, invertebrates, and plankton. The algorithms for these calculations and their validation are described in French McCay (2002, 2003, 2004).

2.3 Validation of the Biological Effects Exposure and Mortality Model

The biological effect model has been validated using simulations of over 20 spill events where data are available for comparison (French and Rines, 1997; French McCay, 2003, 2004; French and Rowe, 2004). In most cases (French and Rines, 1997; French McCay, 2004; French and Rowe, 2004), only the wildlife impacts could be verified because of limitations of the available observational data. However, in the *North Cape* spill simulations, both wildlife and water column impacts (lobsters) could be verified (French McCay, 2003).

2.4 Injury to Habitats

Several shoreline habitats that line the Rouge and Detroit Rivers were oiled during the spill. Wetlands are particularly vulnerable to oiling. Based on observations from spills, documented in Appendix A, Section 3.4, exposure to more than 1 mm of oil at the beginning or during the growing season adversely impacts marsh plants significantly. Thus, 1 mm is the assumed lethal threshold for wetland vegetation.

Also based on the review and analysis in Appendix A, Section 3.4, exposure to more than 0.1 mm (100 g/m^2) of oil is assumed lethal for invertebrates on all substrates. In the area of the Detroit and Rouge Rivers, significant densities of invertebrates would only occur in natural soft-sediment shorelines. Thus, injuries are quantified for wetland, sand and mud shorelines, but are assumed insignificant on man-made or rocky shorelines.

Plant and invertebrate production rates, as well as recovery rates, for each habitat type are taken into account when determining injury in these shoreline habitats. Natural recovery time for freshwater wetlands is about 5 years, based on the review of Reed et al. (1996) who cite Dunn and Best (1983) and D'Avanzo et al. (1989). The estimated time for natural recovery of estuarine intertidal invertebrates is 3-5 years (Appendix A). Recovery time estimates for freshwater shorelines are not available; however, a recovery rate at the lower end of that range, 3 years, would be expected and is assumed. The total lost production in oiled wetland and shoreline habitats was calculated from daily production rate, a sigmoid function scaled to the number of years to (99%) recovery (5 years for wetlands; 3 years for invertebrates), and annual discount rate (3%) using the equations described in Section 3.4 of Appendix A.

These injuries would typically be compensated with a wetland restoration project. If wetland injury is compensated by wetland restoration with an in-kind habitat, the scaling of that restoration requirement may be calculated with traditional Habitat Equivalency Analysis (HEA) methods (NOAA 1997, 1999). If, however, the restored habitat is not in kind, or the expected production rate of the restored habitat is expected to differ from those injured, then a modified HEA model can be used to calculate the scale of the compensatory restoration effort, where production rate of the injured and restored habitats are included in the calculations.

The required compensatory production (P_C, i.e., the injury expressed as lost production at a specific trophic level, such as primary production) is translated to area of restored habitat (H_R) by dividing by expected net gain in annual productivity per unit area in the restored habitat (P_R) times a discounting factor (D) accounting for the project life, i.e. the number of years the restored habitat will exist (λ), and the delay before realizing the benefits. Thus,

$$H_R = P_c \,/\, (P_R * D)$$

$$D = (1+d)^{\rho} \sum_{n=0}^{n=\lambda} F_n \, (1+d)^{-n}$$

where d is the annual discount rate (0.03), ρ is the number of years after the spill when the restoration project begins, and F_n is the functional value of the restored habitat n years after planting as a fraction of full function. The discount factors, $(1+d)^{\rho}$ and $(1+d)^{-n}$, decrease the value of the production by 3% for each year into the future that must pass before that production would be realized. This follows the economic model that losses or gains of restoration in the future are less valued than present production. Including identical discounting on both the injury and restoration sides of the equation allows time lags in both losses and benefits to be appropriately treated in order to measure values lost and gained fixed to a common year.

If the habitat is fully-functional from the start of the restoration project, i.e. in the case of preservation, $F_n = 1$ for all values of n, while the value of ρ is the years after the spill the habitat would be lost if it were not preserved. For an expected project life of greater than 50 years, the value of $\sum (1+d)^{-n}$ approaches 31.6. However, if new habitat is created, there will be a period of "recovery" while it develops to full function. The recovery curve is assumed sigmoid in shape and fit to a logistic equation (see Appendix A). The sigmoid curve is based on the notion that habitats would develop function slowly at first and then more rapidly, but the increase in function would level off as an asymptotic full-function level is approached.

2.5 Quantification of Wildlife Injury

Direct oiling mortalities of wildlife (birds, mammals, and reptiles) were calculated as described above in Section 2.2.1. These direct kills are a mix of adults and juveniles of varying ages. If the natural and hunting mortality rates of a species are stable in time, the population approaches an age distribution of declining numbers with age, with the total (i.e., natural plus hunting) age-specific mortality rates defining the percentage remaining alive in each subsequent age class. Restoration and restocking programs would normally be scaled to provide replacements at a particular age class. For example, a project that increases fledging rates would result in a net gain of fledglings, and the compensatory number would be equal to the fledgling-equivalents of the killed animals of mixed age classes. The fledgling-equivalents (or hatchling equivalents) to the mixed age classes of adults and juveniles killed is calculated using stage-specific and annual survival rates to construct a life table (number by age class) and then calculating a ratio of number of fledglings (or hatchlings) per animal in the population (weighed by age distribution).

In the population model, natural and hunting (harvest) mortality rates for stage (first year) and annual (>1 year old) age classes are used to estimate numbers that would remain alive by each age class. The number remaining alive at age t (years), N_t, is:

$$N_t = N_0\, e^{(-Z_a (t))}$$

$$Z_a = M_a + H_a$$

where N_0 is the number at age zero, Z_a is stage-specific or annual instantaneous total mortality, M_a is stage-specific or annual instantaneous natural mortality, and H_a is stage-specific or annual instantaneous hunting mortality, for age class a. In performing these calculations, M_a and H_a are typically higher for age class 0 to 1 than for older age classes (which are assumed to have the same annual mortality rates). Data used in these calculations are in Appendix D.

Another measure of injury is the sum of the product of number of animals killed in a given age class times the numbers of years an individual in that age class would have lived had there not been a spill (i.e., life expectancy). This injury measure is expressed as bird-years, or more generically as individual-years. The life expectancy of an age a individual is the sum of survival rate to each age, $\Sigma\, e^{(-Z_a (t-a))}$, summing t from age a to the maximum age (λ):

$$\sum_{t=a}^{\lambda} e^{(-Z_a (t-a))}$$

Discounting at 3% per year is included to translate losses in future years (interim loss) to present-day values (i.e., for the year of the spill). The discounting multiplier for translating value n years after the spill to present value (i.e., for the year of the spill) is calculated as $(1+d)^{-n} = 1/(1+d)^n$, where d=0.03. Thus, the losses in future years have a discounted value at the time of the spill. In this analysis, all discounting was calculated based on the number of years from the year of the spill. Thus, additional discounting is needed to translate all the injuries to compensatory equivalents for the year the restoration is performed. The multiplier for this calculation is $(1+d)^m$, where m is the number of years after the spill when restoration is accomplished.

2.6 Quantification of Fish and Invertebrate Injury as Lost Production

2.6.1 Approach

The injury quantification approach is provided in detail in Appendix A. The biomass (kg) of fish and invertebrates killed by the oil ("direct kill") represents biomass that had been produced before the spill. In addition to this injury, if the spill had not occurred, the killed organisms would have continued to grow and reproduce until they died naturally or were lost to fishing. This lost future (somatic) production ("production foregone") is estimated and added to the direct kill injury. The total injury is the total of the direct injury and production foregone. This total injury is expressed in "present day" (i.e., year of the spill) values using a 3% annual discount rate for future losses. Restoration should compensate for this loss. The scale of restoration needed is equivalent to production lost when both are expressed in values indexed to the same year, i.e., the injury inflated to the year restoration occurs or the restoration discounted back to the year of the spill.

Interim losses are injuries sustained in future years (pending recovery to baseline abundance) resulting from the direct kill at the time of the spill. Interim losses potentially include:

- Lost future uses (ecological and human services) of the killed organisms themselves;
- Lost future (somatic) growth of the killed organisms (i.e., production foregone, which provides additional services);
- Lost future reproduction, which would otherwise recruit to the next generation.

The approach here is that the injury includes the direct kill and its future services, plus the lost somatic growth of the killed organisms (production foregone), which would have provided additional services. Because the impact on each species, while locally significant, is relatively small compared to the scale of the total population in the area, it is assumed that density-dependent changes in survival rate are negligible, i.e., changes in natural and fishing mortality of surviving animals do not compensate for the killed animals during the natural life span of the animals killed.

It is also assumed that the injuries were not large enough to significantly affect future reproduction and recruitment in the long term. It is assumed that sufficient eggs will be produced to replace the lost animals in the next generation. The numbers of organisms affected, while potentially locally significant, are relatively small portions of the total reproductive stock. Given the reproductive strategy of the species involved to produce large numbers of eggs, of which only a few survive, it is assumed that density-dependent compensation for lost reproduction occurs naturally.

The services provided by the injured organisms are measured in terms of production, i.e., biomass (kg wet weight) directly lost or not produced. Among other factors, services of biological systems are related to the productivity of the resources, i.e., to the amount of food produced, the usage of other resources (as food and nutrients), the production and recycling of wastes, etc. Particularly in aquatic ecosystems, the rate of turnover (production) is a better measure of ecological services than standing biomass (Odum, 1971). Thus, the sum of the standing stock killed (which resulted from production previous to the spill) plus lost future production is a more appropriate metric with which to evaluate ecological services than is standing stock alone (as number or kg).

This injury estimation approach was developed and used previously in the injury quantification for the *North Cape* spill of January 1996 (French McCay et al., 2003a, French McCay and Rowe, 2003) and many other spill cases (e.g., French McCay et al., 2003b). The method makes use of the population model in SIMAP. Injuries are calculated in three steps:

1. The direct kill is quantified by life stage and age class using a standard population model used by fisheries scientists.
2. The net (somatic) growth normally to be expected of the killed organisms is computed and summed over the remainder of their life spans (termed production foregone).
3. Future interim losses are calculated in "present day" (year of the spill) values using discounting at a 3% annual rate.

The normal (natural in local waters) survival rates per year and length-weight by age relationships are used to construct a life table of numbers and kg for each annual age class. Production forgone is then estimated using the model of Jensen et al. (1988), which is commonly used in fisheries science (see below).

It should be noted that compensation is needed for lost production of each of the individual species injured, and that losses are additive. Restoration for a prey species killed will compensate for that prey killed and all the services that prey would have provided in the future to its predators and other resources. The predators that would eat that prey but were directly killed were produced before the spill from *different* prey individuals as food. Thus, the predator's production loss must be compensated in addition to the prey animals directly killed, as both losses result from the spill. This may be accomplished by providing additional prey production to compensate for the direct predator loss.

2.6.2 Equations

The production foregone population model as described by the U.S. Environmental Protection Agency in its 316(b) rule (Final Rule, Clean Water Act §316(b), National Pollutant Discharge Elimination System, Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities, USEPA, 2004) was used. This approach is recommended by fisheries scientists and the models are those typically used for entrainment and impingement fisheries impact evaluations (EPRI, 2004). The equations are based on fisheries model development described in Ricker (1975).

The production foregone population model makes use of survival rates from one stage to the next. For eggs, survival to age one (S_{e1}) is calculated as:

$$S_{e1} = 2\ S_e\ e^{-\ln(1+Se)}\ S_L\ S_j$$

where S_e, S_L, and S_j are the survival rates for each stage: egg, larvae, and juvenile. For larvae, survival to age one (S_{L1}) is calculated as:

$$S_{L1} = 2\ S_L\ e^{-\ln(1+S_L)}\ S_j$$

Natural and fishing mortality rates for annual age classes are used to estimate numbers that would remain alive by each age class. The number remaining alive at age *t* (years), N_t, is:

$$N_t = N_1\ e^{(-Z_a\,(t-1))}$$

$$Z_a = M_a + F_a$$

where N_1 is the number at age one, Z_a is annual instantaneous total mortality, M_a is annual instantaneous natural mortality, and F_a is annual instantaneous fishing mortality, for age class *a*. The annual survival rate for age *t* (S_t) is thus:

$$S_t = e^{(-Z_t)}$$

The fraction dying in a year is $1\text{-}S_t$.

Yield foregone (Y_k) (i.e., equivalent yield, or lost catch) may be calculated using the Thompson-Bell equilibrium yield model (Ricker, 1975) where the harvest at each age class is calculated from number starting the class multiplied by fishing mortality rate, $(F_a/Z_a)(1-e^{-Za})$:

$$Y_k = \sum_j \sum_a L_{jk} S_{ja}\, W_a\, (F_a/Z_a)(1-e^{-Za})$$

Y_k = foregone yield (kg) in year *k*
L_{jk} = losses of individual fish of stage *j* in the year *k*
S_{ja} = cumulative survival fraction from stage *j* to age *a*
W_a = average weight (kg) of fish at age *a*
F_a = instantaneous annual fishing mortality rate for fish of age *a*
Z_a =instantaneous annual total mortality rate for fish of age *a*

Total natural mortality (TM_k) is calculated using an analogous model:

$$TM_k = \sum_j \sum_a L_{jk} S_{ja}\, W_a\, (M_a/Z_a)(1-e^{-Za})$$

M_a = instantaneous annual natural mortality rate for fish of age *a*

For this analysis, the losses are for eggs and larvae translated to 1 year of age, i.e., one stage where j=1.

Production foregone (USEPA, 2004, Chapter A-5; based on Rago 1984 and Jensen et al., 1988) which includes yield (harvest) and the production consumed in the food web, is estimated using:

$$Y_k = \sum_j \sum_a [\, G_a L_{jk} W_a (e^{Ga-Za} - 1)\,]/[\, G_a - Z_a \,]$$

where G_a is the instantaneous growth rate for individuals of age a

Length and weight at age are estimated using the von Bertalanffy equation and a power curve of weight versus length following methods in Ricker (1975). The equations used are as follows. For length (mm) at age t (years):

$$L_t = \mathrm{L}_\infty \, [1 - e^{(-\mathrm{K}\,(t - \mathrm{t_o}))}]$$

where L_t is length (mm) at age t (years), L_∞ is the asymptotic maximum length (mm), K is the Brody growth coefficient, and $\mathrm{t_o}$ is a constant. Weight as a function of length (mm) is:

$$W_t = \alpha \, L_t^{\,\beta}$$

where W_t is wet weight (g) at age t years and α and β are constants.

Discounting at 3% per year is included to translate losses in future years (interim loss) to present-day values. The discounting multiplier for translating value n years after the spill to present value (i.e., for the year of the spill) is calculated as $(1+\mathrm{d})^{-n} = 1/(1+\mathrm{d})^n$, where d=0.03. Thus, the losses in future years have a discounted value at the time of the spill. In this analysis, all discounting will be calculated based on the number of years from the year of the spill. Thus, additional discounting is needed to translate all the injuries to compensatory equivalents for the year the restoration is performed. The multiplier for this calculation is $(1+\mathrm{d})^m$, where m is the number of years after the spill when restoration is accomplished.

3. MODEL INPUT DATA

3.1 Geographical and Model Grid

For geographical reference, SIMAP uses a rectilinear grid to designate the location of the shoreline, the water depth (bathymetry), and the shore or habitat type. The grid is generated from a digital coastline using the ESRI Arc/Info compatible Spatial Analyst program. The cells are then coded for depth and habitat type. Note that the model identifies the shoreline using this grid. Thus, in model outputs, the coastline map is only used for visual reference; it is the habitat grid that defines the actual location of the shoreline in the model.

Ecological habitat types (Table 3-1) are broadly categorized into two zones: fringing/shoreline and water. Fringing habitat types create boundaries between land and water and are typically much narrower than the size of a grid cell. Fringing habitats include river banks and various shore types. Thus, these fringing types have typical (for the region) widths associated with them in the model. In this case, "landward" is used for all habitats in the Rouge River, whereas seaward is used for Detroit River and Lake Erie.

The digital shoreline, shore type, and habitat mapping were obtained from the Environmental Sensitivity Index (ESI) Atlas database for the Lake Erie System compiled for the area by Research Planning, Inc. (RPI). These data are distributed by NOAA Hazmat (Seattle, WA). The shoreline/riparian habitats were assigned based on the shore types in the ESI Atlas. Open water areas were defaulted to sand bottom, as open water bottom type has no influence on the model results. The ESI data were compared with more recent images from Google Earth to ensure no major discrepancies in land use. Wetlands were added to the habitat grid using data from the National Wetland Inventory (http://www.fws.gov/wetlands/data/index.html). Emergent wetlands, or locations where surface water is present for extended periods especially at the beginning of the growing season, were queried from the Geospatial Wetland Digital Database and transferred into the habitat grid.

Table 3-1. Classification of habitats. Seaward (Sw) and landward (Lw) system codes are listed. (Fringing types indicated by (F) are only as wide as the shoreline habitat. Others (W = water) are a full grid cell wide and must have a fringing type on the land side.)

Habitat Code (Sw,lw)	Ecological Habitat	F or W
Water/Benthic		
11,41	Sand Bottom	W
Shoreline/Riparian		
1,31	Rocky Shore	F
2,32	Gravel Beach	F
3,33	Sand Beach	F
4,34	Fringing Mud Flat	F
5,35	Fringing Wetland	F
	Extensive Mud Flat	W
	Extensive Wetland	W

Habitat Code (Sw,lw)	Ecological Habitat	F or W
18,48	Man-made, Artificial	F

Depth data for the Rouge River were obtained from the CATS model (see Section 3.3), while data for the Detroit River and Lake Erie were obtained from both the CATS model and from National Oceanic and Atmospheric Administration, National Geophysical Data Center (NGDC). NGDC hydrographic survey data consist of large numbers of individual depth soundings and contours were generated at 1-meter intervals (Holcombe et al., 1997; Holcombe et al., 2005).

Two habitat grids were created to allow different bird densities to be applied by habitat type. In the first grid, all waters and marshes less than 1 m deep were assigned as littoral and all waters greater than 1m deep as limnetic (Figures 3-1 to 3-4). This allowed different species and densities of birds to be assigned in deeper waters than waters shallower than 1m because most waterfowl feed and rest in shallow waters (as opposed to the open deeper waters of Lake Erie and the deep channels of the rivers). The second grid was applied only to scaup, a waterfowl species that is unlikely to use the Detroit or Rouge Rivers, but has been counted in large numbers along the shores of Lake Erie in spring (Figure 3-5). Scaup commonly feed in water 1-9 meters deep, but are more commonly found in 1-3 meters of water depth (G. Souillere, USFWS, pers. comm., September 2009). In this grid (Figure 3-5), scaup were assigned to only waters between 1-3 meters deep within Lake Erie.

The gridded habitat and depth data are shown in Figures 3-1 through 3-5.

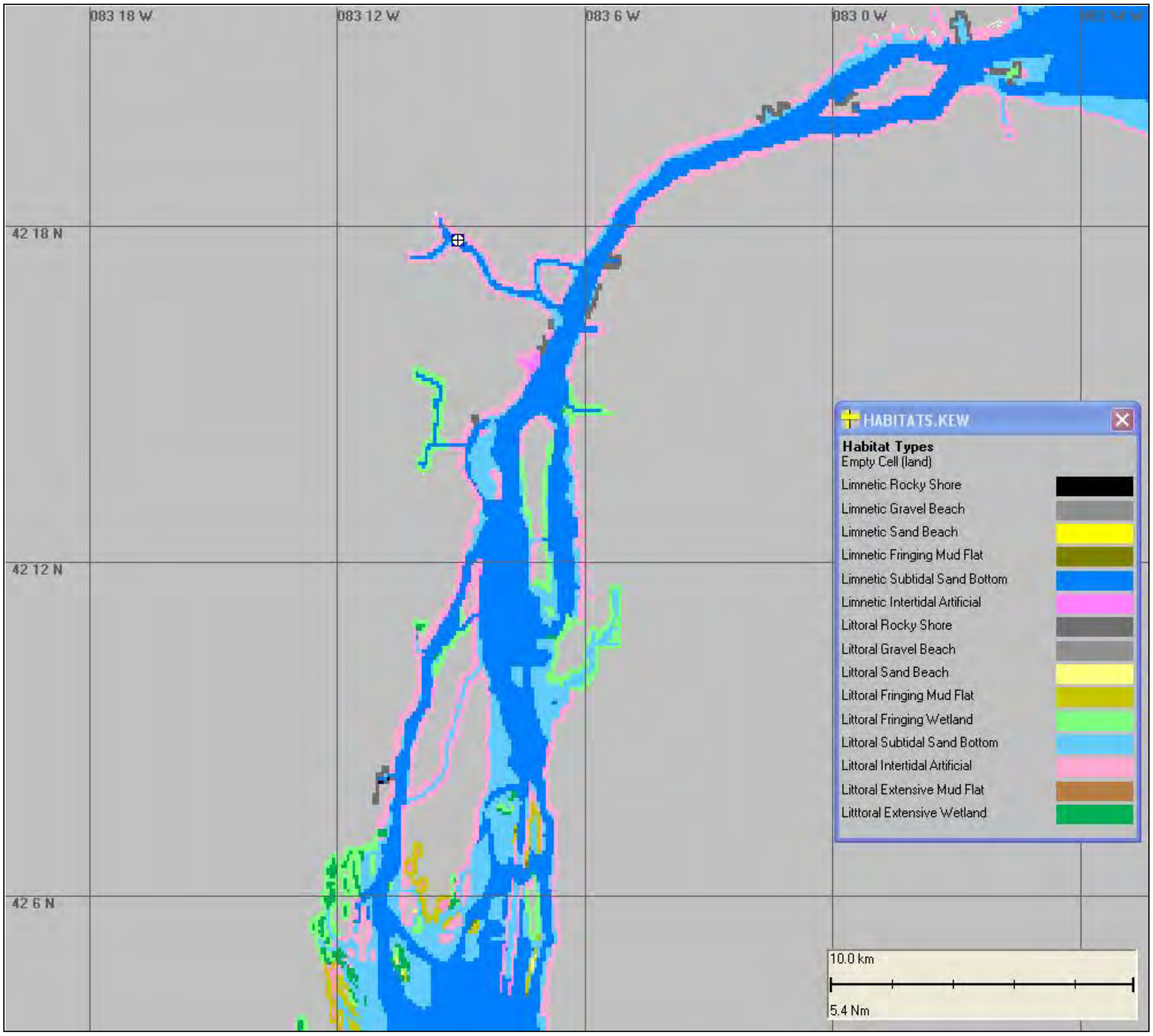

Figure 3-1. Habitat grid developed for the Rouge and Detroit Rivers. Mapped habitats based on ESI GIS data.

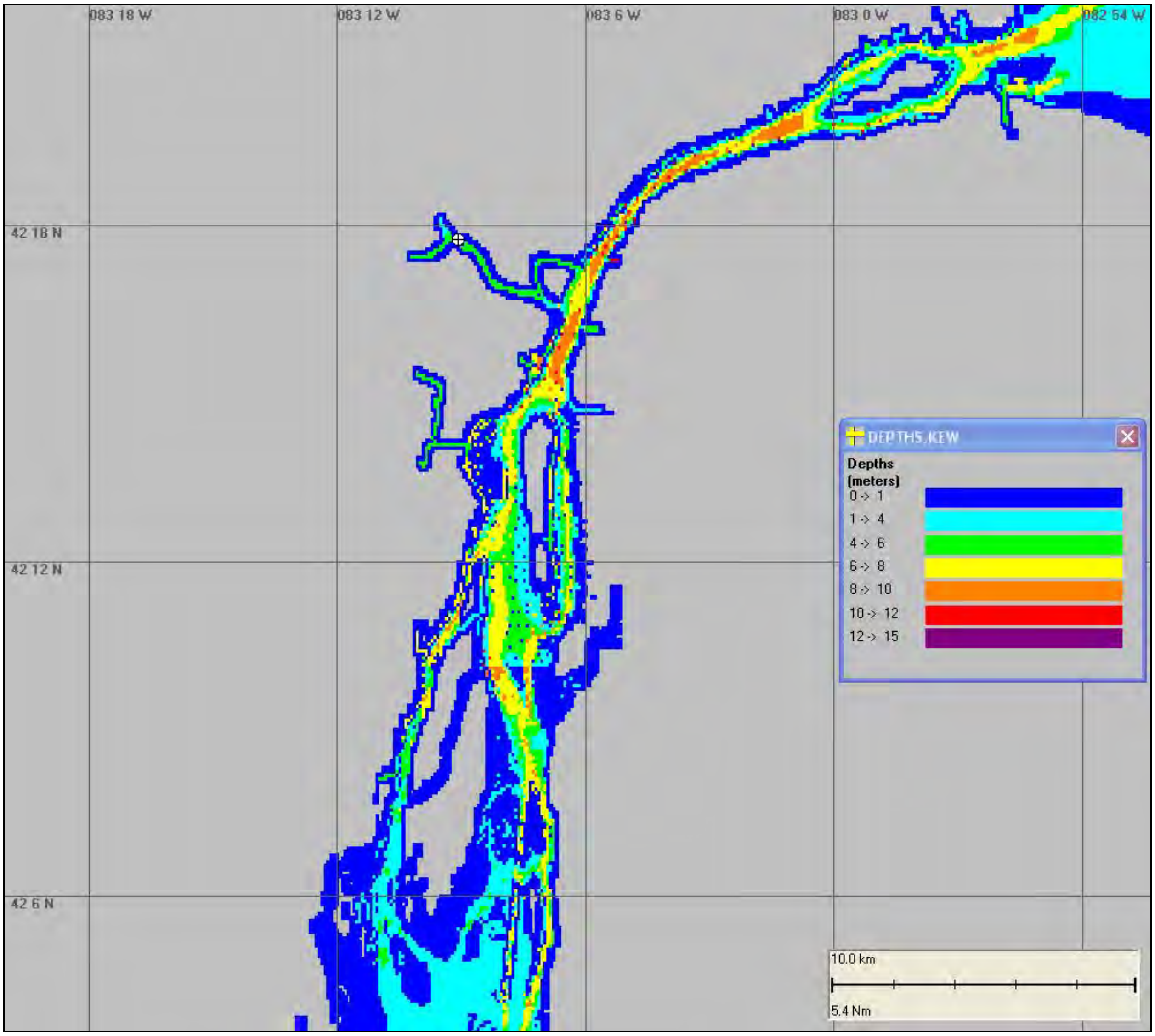

Figure 3-2. Depth grid developed for the Rouge and Detroit Rivers. Mapped depths are based on NGDC data.

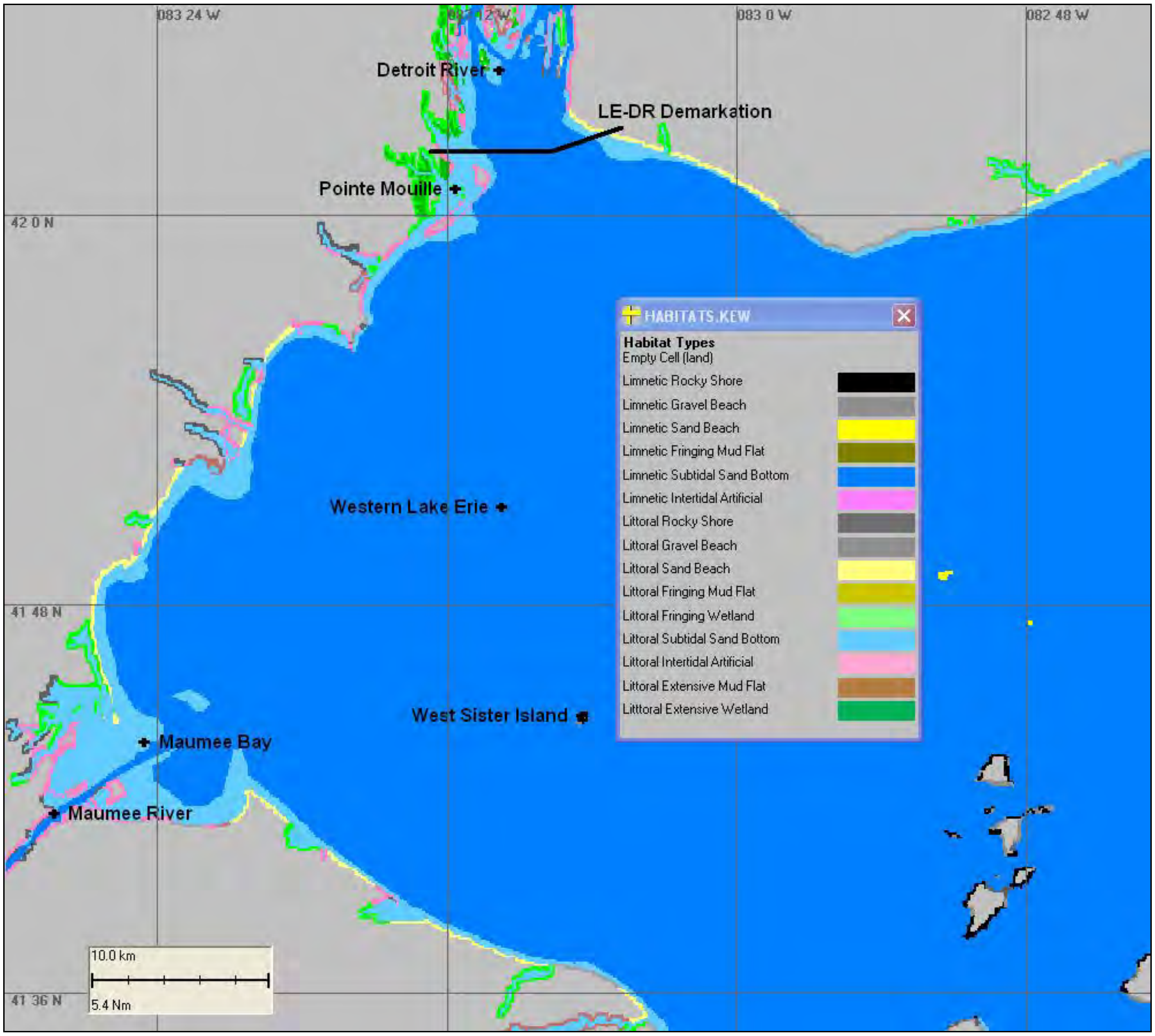

Figure 3-3. Habitat grid developed for Western Lake Erie. Mapped habitats based on ESI GIS data. The solid black line marks the delineation between the Detroit River and Lake Erie.

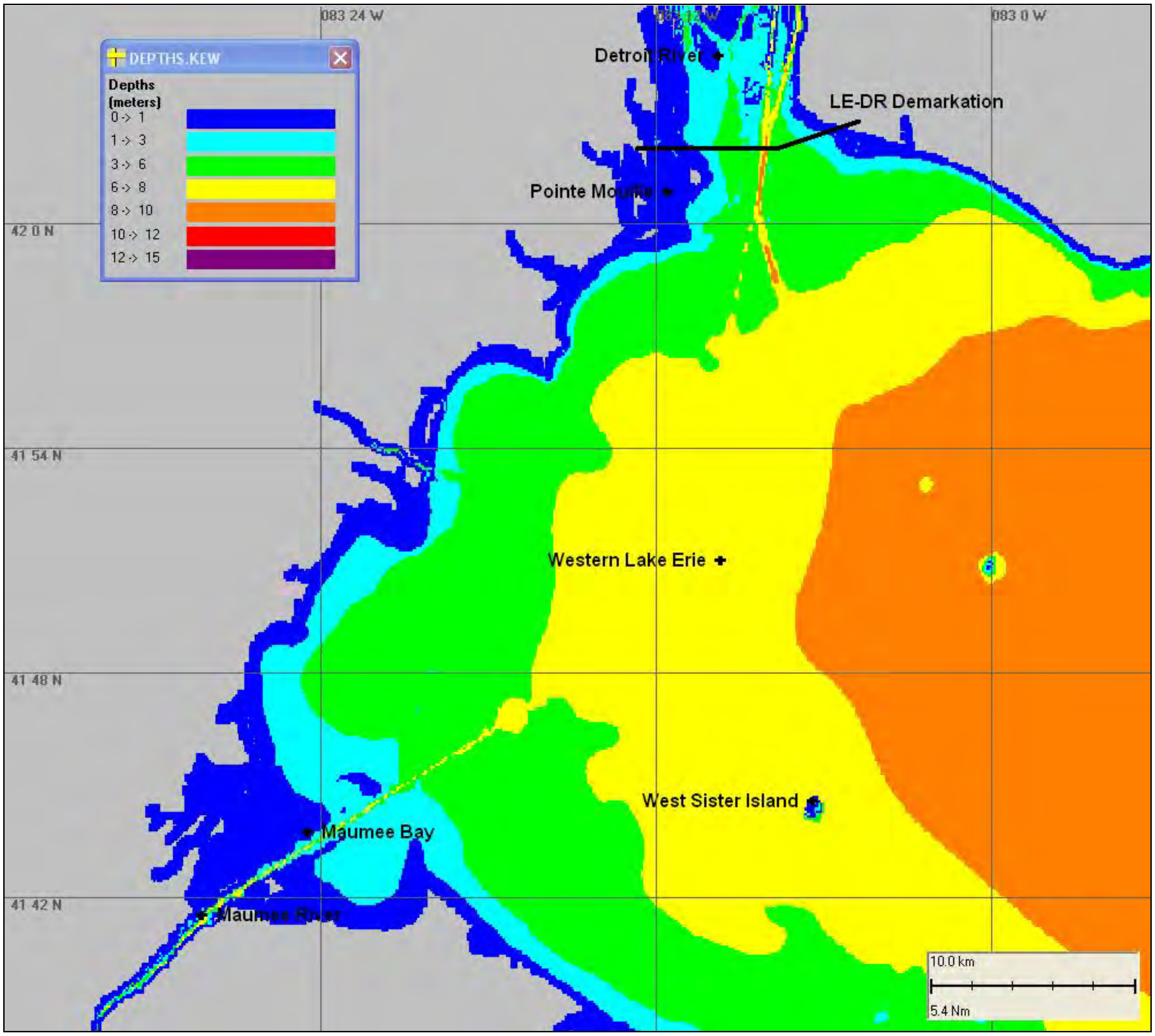

Figure 3-4. Depth grid developed for Western Lake Erie. The solid black line marks the delineation between the Detroit River and Lake Erie. Mapped depths are based on NGDC data.

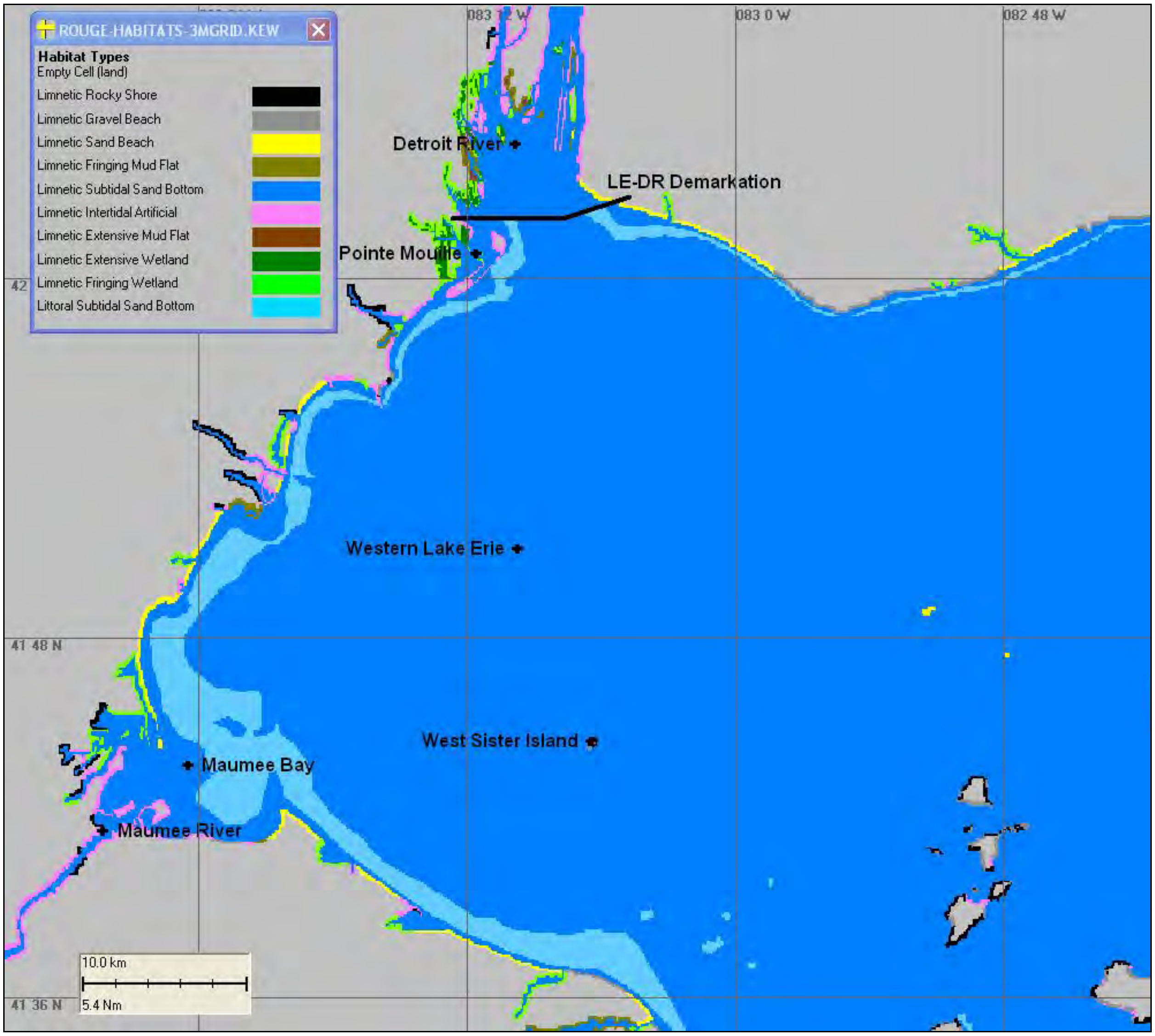

Figure 3-5. Habitat grid developed for Western Lake Erie in which scaup were applied to 1-3 meter deep water in Lake Erie. Mapped habitats based on ESI GIS data. The solid black line marks the delineation between the Detroit River and Lake Erie.

Most diving ducks feed in waters <6 meters deep (Bellrose 1980; Ewert et al. 2006). A 1-3 meter delineation for scaup habitat use (Figure 3-5) was assumed based on personal communications with Greg Souillere (USFWS). Regardless of the exact depth range in which scaups are found, it is known that they are not usually found very near shore, and that their primary diet is mollusks, particularly zebra mussels in the Great Lakes (Ewert et al. 2006). Therefore, the assumption of where scaups are found could be more based on where the zebra mussels are located in Lake Erie. In most lakes, zebra mussels are at a maximum density in waters 2-4 meters deep, and are not typically found in waters deeper than 6-8 meters (Nalepa and Schloesser 1993). Therefore, the assumption of scaups assigned to 1-3 meters within Lake Erie seems like an appropriate assumption based on their primary food source in the area. The demarcation line between the Detroit

River and Lake Erie (Figures 3-5) was made assuming scaup would not feed on either side of the main channel into the Detroit River due to ship traffic. It is possible that scaup were also not near the mouth of the Detroit River due to ship traffic, such that the line could be adjusted further out into Lake Erie (Figure 3-5). However, the mouth of the river has been noted as an important stopover point for scaups (Ewert et al. 2006), and the densities applied in the model (see below) were observed in the Pointe Mouillee area in April just after the spill, indicating the habitat delineation for scaups was appropriate.

3.2 Environmental Data

The model uses hourly wind speed and direction for the time of the spill and simulation. Wind data were acquired from the National Climatic Data center (NCDC) for the Detroit Metro Airport location (42.200001°N, 83.300003°W). Hourly mean wind speed and direction for 15 March to 30 June 2002 were compiled in the SIMAP model input file format. Figure 3-6 shows the location of the wind station used for modeling.

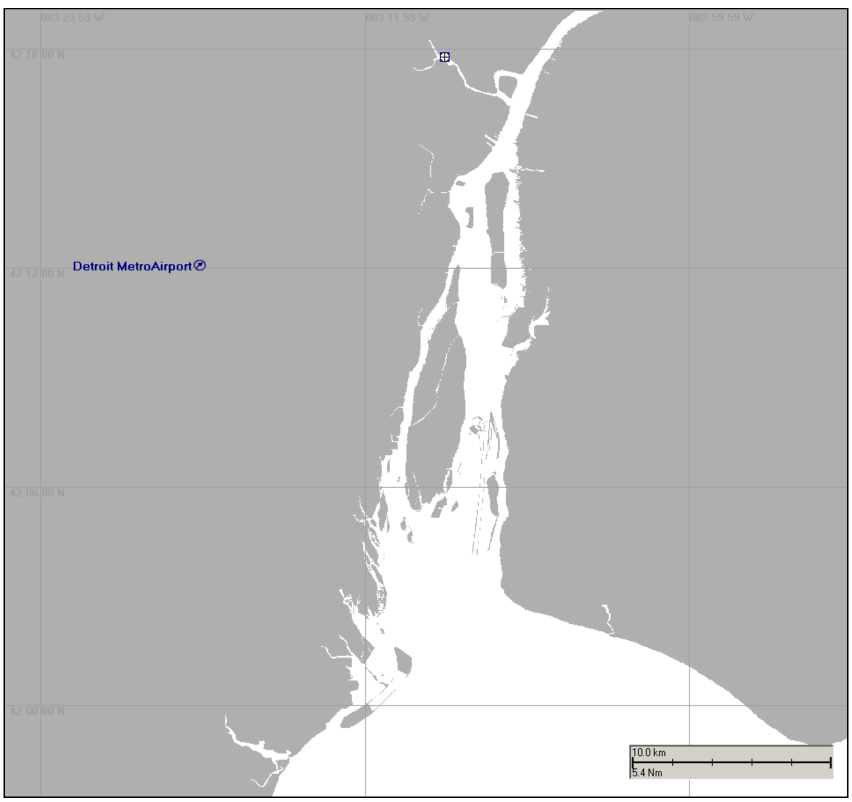

Figure 3-6. Locations of the wind station used for modeling.

Water temperature was held constant at 6°C for all model runs based on average April water temperature for West Lake Erie (41.676998°N, 82.398003°W) from NDBC. The air immediately above the water is assumed to have the same temperature as the water surface, this being the best estimate of air temperature in contact with floating oil.

The salinity was assumed to be 0 parts per thousand (French et al., 1996). The salinity value assumed in the model runs has little influence on the fate of the oil, as salinity is used to calculate water density (along with temperature), which is used to calculate buoyancy, and the oil evaluated had a density less than that of the water.

Suspended sediment was assumed to be 10 mg/l, a typical value for coastal and Great Lakes waters (Kullenberg, 1982). The sedimentation rate was set at 1 cm/day, which is the settling rate for oil-suspended sediment aggregates. Suspended sediment concentrations at this level have no significant affect on the model trajectory. Sedimentation of oil and PAHs becomes significant at concentrations greater than about 100 mg/L suspended sediment concentration. There is no indication that such high suspended sediment concentrations would occur in the areas where the spill was simulated.

The horizontal diffusion (randomized mixing) coefficient was varied for sensitivity analysis and model trajectory calibration, as described in detail in Section 4.0, below. The vertical diffusion (randomized mixing) coefficient is assumed to be 1 cm^2/sec. This is a reasonable value for nearshore and riverine waters based on empirical data (Okubo and Ozmidov, 1970; Okubo, 1971) and modeling experience.

3.3 Currents

Currents have significant influence on the trajectory and oil fate, and are critical data inputs. Wind-driven and background currents were input to the oil fates and biological effects models from a current file that was prepared for this purpose.

The Rouge River, located in southeast Michigan, is a tributary of the Detroit River that runs through the city of River Rouge and some of the most urban land in the state. The spill is located just below (downriver) the large turning basin[1]. Above the turning basin, the total river flow is well estimated by summing the flows of the lower Rouge, Middle Rouge and the Plymouth river gauges. During dry periods, the industrial inputs into the Rouge River add a significant input to the overall flow (personal communication, Ed Kluitenberg, Wayne County Rouge Program Office).

The surface oil was observed during a rainy period. Based on the river gauge data for early April, the Rouge was experiencing a relatively high flow of 70.99 m^3s^{-1} at the start of the first spill on 9 April. The second spill, observed on 13 April, occurred on another high flow day with readings of 76.17 m^3s^{-1}. Since the flow rates for both spill days were high, industrial inputs to the Rouge River are not a significant source of flow and were not considered. As mentioned above, the industrial inputs are only significant during dry periods.

The 2D circulation pattern for the Rouge and Detroit Rivers was developed using the NOAA Circulation Analysis for Trajectory Simulations (CATS) model. The Wind Analysis for Currents (WAC, Galt 1980) submodel was used, where the dynamics are dominated by shallow water wave theory, and is very applicable for river flow. River flow has faster water currents over the deeper waters depths, and shallow water wave

[1] An open area at the end of a canal that is large enough to allow vessels to turn around.

speeds are proportional to water depth. This diagnostic model has previously been used as primary tool for NOAA trajectory forecasting in this region. The model is a 2D, depth integrated model, that works well for surface currents associated with spill trajectories. CATS is a diagnostic model, which means the desired solution conditions (flow at the time of the spill) determine the flow field rather a prognostic model where the initial conditions start the model, then the model predicts the solution time period conditions. The CATS solution represents the model physics in combination with the data fields available at the time of the spill.

For scaling the CATS model, Rouge River flows from the three gauges for 9 April were used to develop an estimated total river current. Surface currents in the Detroit River were tuned to match overflight and SCAT information. The ratio of the surface currents in the Rouge River to those in the Detroit River was used to scale the CATS circulation model.[2] Once the ratio between the currents was determined, the water level boundary condition to the Rouge River was adjusted relative the water levels set at the ends of the Detroit River bathymetric domain. Figures 3-7 and 3-8 are examples of surface current vectors.

Because the SIMAP simulation utilizes a different (but overlaying) grid system for the river and western Lake Erie, the entire flow field was calibrated to match the observed transport of the oil downstream. This was a minor adjustment in the vector field, scaling the vectors up to a slightly higher rate, as explained in Appendix B on the sensitivity analysis.

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[2] Rouge River width at bathymetry grid entrance: 65.9 m; Average depth of Rouge at bathymetry grid entrance: 2 m; Flow rate for Rouge river on 9 April: 70.99034 m^3/s; (70.99034 m^3/s) / (65.9 m x 2 m) = 53.86 cm/s flow; Detroit River scaling speed at scaling point (42 deg 16.18’ N, 83 6.37’ W) = 60 cm/s.

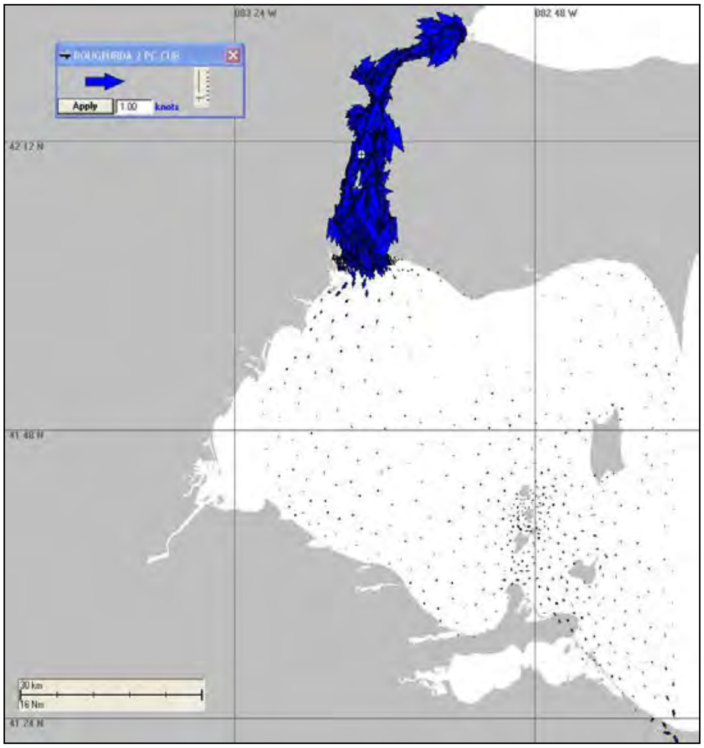

Figure 3-7. Current vector field generated by the CATS model developed for the Rouge and Detroit Rivers 9 April 2002.

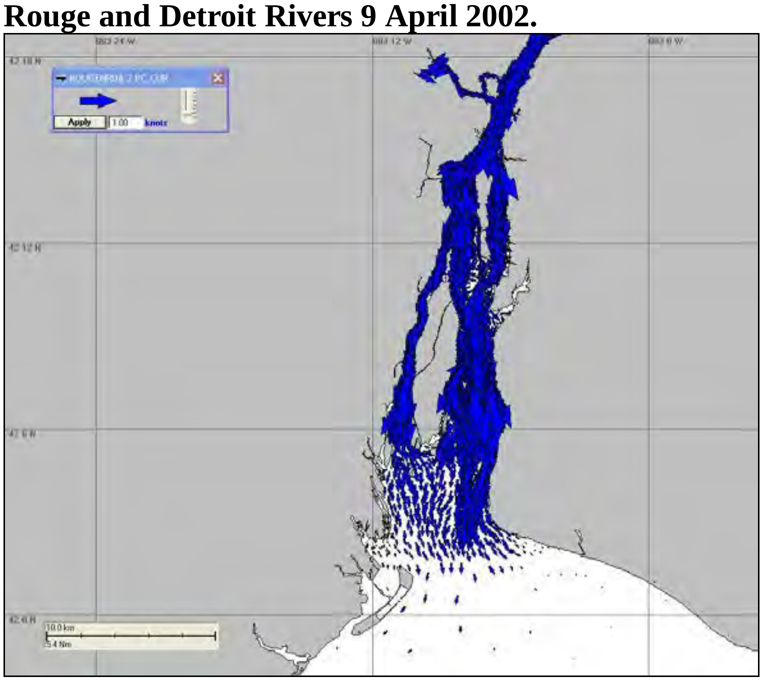

Figure 3-8. Current vector field generated by the CATS model developed for the Rouge and Detroit Rivers 9 April 2002.

3.4 Oil Properties and Toxicity

The spilled oil was a mix of diesel fuel oil and waste lubricating oil in an unknown ratio (Wang et al., 2004). Physical and chemical properties, except for BTEX and PAH concentrations, for diesel fuel oil were taken from the NRDAM/CME and NRDAM/GLE databases (French et al., 1996; Reed et al, 1996); and those for lubricating oil were taken from the Environment Canada database (Jokuty et al., 1999). Minimum oil slick thickness was assumed to be the same for both oils, 0.1mm, as they are of similar viscosity (based on McAuliffe, 1987). PAH and BTEX concentrations were taken from the oil sample measured by Wang et al. (2004) that was closest to the spill source and the least weathered (sample 44551). Weathering of oil and reduction of PAH and BTEX levels occur quickly; however, it is not technically feasible to back-calculate and estimate the initial concentrations of these compounds in the oils at the time of the spill, as the spill was for mixed waste oils of unknown initial composition. Thus, the values given for this sample, taken 24 hours after the initial report of the spill, were used in all model runs as the initial oil concentrations. For this reason, the water column contamination and resulting injuries are to some (likely small) degree underestimated.

EPA and USCG reported a total of 66,359 gallons of emulsified oil was removed from the environment. As diesel does not emulsify and assuming that lubricating oil emulsifies up to 60% in water (Jokuty et al., 1999), at least an estimated 40,000 gallons of lubricating oil was spilled. At these volumes, 12% of the 322,280 gallons spilled was lubricating oil and the remaining 88% was diesel fuel. Wang et al. (2004) examined two whole oil samples taken from the Detroit River on 10 April 2009 (9-10AM) using GC/MS analyses, finding that the oil contained <20% of weathered diesel. However, those samples were taken after the oil was in the environment for more than 24 hours, such that the diesel component might have been higher. Thus, oil properties were compiled for both oil types, and then calculated weighted mean properties for a range of assumed percentages of diesel. Because the two oils had similar properties, the mean properties were not sensitive to the relative weighing of the two oils. Thus, a 50-50 mix (equal weighing) was assumed for the model runs.

The $LC50_{mix}$ values assumed are for PAH concentrations in the water, because monoaromatics are less toxic, evaporate quickly, and contribute little to toxicity. To estimate $LC50_\infty$ values for dissolved PAHs in the water, the additive model described in French McCay (2002) was used. French McCay (2002) estimated $LC50_\infty$ at about 40-50 µg/L for typical fuels at infinite exposure time and for the average species. Ninety-five percent of species have $LC50_\infty$s between about 5 and 400 µg/L. Using the PAH data for the spilled oil, the average $LC50_\infty$ is 44 ppb, with 95% of species falling between 5 and 370 ppb. In the assessment of injuries, all species are assumed to be of average sensitivity to oil hydrocarbons, i.e., assuming $LC50_\infty = 44$ µg/L. However, the range of potential injuries for the range of $LC50_\infty$s of 5 to 370 µg/L was also be evaluated in order to bound uncertainty associated with the toxicological properties of the spilled petroleum mixture. EPA and NOAA laboratory reports from 2002 have been identified and requested. Review of data in these reports may result in revised $LC50_\infty$ estimates.

3.5 Spill Observations

On Tuesday 9 April 2002 at 1000 local time the operator of the Fort Street Bridge, in Dearborn, MI, called in an observation of oil to the USCG. The impacted areas began at the Dix Street Bridge and continued for three miles of the Rouge River, and 17 miles of the US Detroit River coastline and 16 kilometers of the Canadian coastline. A second release was reported at 0700 on 13 April 2002 in the same original area as the first release. The entire spill volume was estimated at 322,280 gallons of a mix of diesel fuel and waste lubricating oil (Allen, 2002)

Oiling observational data were compiled from U.S. EPA pollution reports (EPA), U.S. Fish and Wildlife Service Reports (USFWS), U.S. Coast Guard press releases and pollution reports (USCG-Press and USCG-PolReps), NOAA SCAT maps, NOAA overflight maps, and material compiled by the Detroit Free Press (DFP). The following is a chronological outline of observations compiled from all data sources from 9 April to 26 April 2002.

<u>April 9th</u>

- 1000 – Fort Street Bridge operator contacts USCG and reports observed oil in the Rouge River (EPA)
- 1045 – Airsta Detroit conducts overflight of Rouge River (USCG-PolRep)
- 1115 – USCG arrives on scene and observes a slug (EPA)
- 1120 – Sheening observed at Fort St. Bridge from oil slug observed at Jefferson St. Bridge (USCG-PolRep)
- 1800 – Boom in water around Rough Steel's #6 outfall (USCG-PolRep)

Observations reported scattered patches of oil on the Rouge River and the Detroit River as far south as the Detroit River Light on Lake Erie (USCG-Press) (Figures 3-9 to 3-11).

<u>April 10th</u>

- 1025 – Helicopter reports oil patches extending southward past west bank of Livingston Channel in Detroit River (USCG-PolRep)
- 1054 – Rapid shoreline assessment at Black Lagoon, patches of oil are flowing past Trenton, MI (USCG-PolRep)
- 1152 – Booming off Rouge River (USCG-PolRep)
- 1545 – Humbug Marsh has not been affected, but Humbug Marina has (USCG-PolRep)
- 1618 – Deploying boom at Elizabeth Park in Trenton, MI (USCG-PolRep)
- 1648 – Oiled bird observed at Elizabeth Park (USCG-PolRep)
- Three zones of affected areas were identified (EPA):
    - Zone 1 – Contaminated area of the Rouge River (Figure 3-8)
    - Zone 2 – From the confluence of the Rouge and Detroit Rivers to Elizabeth Park, Trenton, MI (Figure 3-9)
    - Zone 3 – Elizabeth Park into Lake Erie (Figure 3-10)

The U.S. Coast Guard closed the Rouge River to boating traffic and reported that the mouth of the Rouge River had been boomed off (USCG-Press). With evidence of oily contamination on the Rouge River shoreline downstream of the Rouge Steel outfall

(EPA), several other sections of the Rouge and Detroit rivers were also outfitted with collection booms, including Humbug Marsh and Pointe Mouille with the intention of protecting these environmentally sensitive areas (USCG-Press).

<u>April 11th</u>

The Canadian Coast Guard reported that no free floating oil remained on the Canadian side, there was only shoreline oiling (USCG-PolRep). Citizens in Trenton, MI, located 7 miles downstream of the spill origin, complained of fuel smells (EPA).

The U.S. Coast Guard estimated 1,000-5,000 gallons of oil were discharged into the water (USCG-Press). Several measures were employed to gather further information about the spill. Dye tracers were used to try and identify source of spill but results were inconclusive and samples collected from the Detroit River (near Belanger Park and Trenton Riverside Marina) were sent for analysis (EPA).

The U.S. Fish and Wildlife Service reported wildlife injuries at several area locations. At Elizabeth Park 12 Pekin ducks, 6 "wild ducks," 1 mallard, and one white goose were seen alive and oiled. On the Detroit River a fisherman reported oiled ducks to USFWS. At Lake Erie Metro Park one duck was found dead, but it was not known if the death was related to the spill. In Gibraltar three white geese were retrieved and taken to rehab. One Canada goose, alive and oiled, was spotted at the Woodmere cemetery and one at the mouth of the Rouge River. In Canada, three Canada geese and one duck were observed alive and oiled in Amherstburg.

<u>April 12th</u>

The U.S. Coast Guard received several citizen oil sighting reports from around the area. Oil was reported northwest of Lake Erie Metropark, at Dingell Park in Ecorse, MI, and at the Wyandotte Yacht Club, Wyandotte, MI. Additionally, impacted birds were observed and reported near Edmund Island (USCG-PolRep).

The U.S. Fish and Wildlife Service reported wildlife injuries at several area locations. At Lake Erie Metropark, 2 ruddy ducks and 1 mallard were found dead, and 6 "wild ducks," 4 mallards, 6 Canada geese, and 5 great egrets were observed alive and oiled. One raptor was noted as possibly oiled. At Point Mouillee CDF, 12 ruddy ducks, 1 bufflehead and 1 pied-billed grebe were reported as oiled. The ruddy ducks were observed preening on shore and the bufflehead was retrieved for rehab. In Canada, 6 oiled Canada geese were observed on Boblo Island.

April 13th

- 0700 – A second spill in the same area as the initial spill was reported (EPA)
- New slick is concentrated north of the Jefferson Street Bridge along the south bank (USCG-Press)
- 0820 – Significant amount of additional oil in Rouge River observed (USCG-PolRep)
- 0915 – Rouge River closed to all traffic (USCG-Press)
- 1235 – USCG contractor reports a flow of oil from the Baby Creek Outfall on the Rouge River (EPA)
- 1250 – free standing oil/sludge discovered in sewer access point (EPA)

The new slick was concentrated north of the Jefferson Street Bridge along the south bank (USCG-Press), and three additional access points in a line from the Dearborn Pump Station were also found contaminated (EPA). Affected Zone 3 reported only significant residual shoreline contamination remained in Humbug Marina (EPA).

The U.S. Fish and Wildlife Service reported wildlife injuries at several area locations. One oiled Canada goose was seen near the mouth of the Rouge River near Detroit Edison, and one oiled coot was seen further inland near BP Amoco.

April 14th

The U.S. Coast Guard reported and estimate of between 10,000 and 15,000 gallons of industrial oil was spilled and an estimated volume of recovered emulsified oil between 5,000 and 6,000 gallons. Additionally, the majority of Detroit River and Lake Erie had been cleaned (USCG-PolRep). A press release from the Coast Guard stated that preliminary testing indicated the oil did not contain PCBs or other hazardous chemicals (USCG-Press).

April 15th

The U.S. Fish and Wildlife Service reported wildlife injuries at several area locations. At Lake Erie Metropark, 2 mallards and 1 turtle were found oiled and dead. One ruddy duck was seen oiled. On Fort Street near the Rouge River, one Canada goose was observed oiled and head bobbing. On Jefferson Avenue, also near the Rouge River, another Canada goose was observed to be heavily oiled. In Wyandotte at the Libra Marina, one oiled turtle was retrieved for rehab.

April 16th

The U.S. Coast Guard reported an estimated total volume of recovered emulsified oil at over 16,000 gallons and the whole spill is now estimated at more than 15,000 gallons (USCG-Press).

The U.S. Fish and Wildlife Service reported wildlife injuries at several area locations. On private property in Trenton, one bird (coot or merganser) was found dead. In Gibraltar, on Bayview Street, one mallard was found dead.

April 17th

The U.S. Coast Guard reported an estimated total volume of recovered emulsified oil at over 26,000 gallons and that crews began the removal of oiled marsh flora in Lake Erie Metropark (USCG-PolRep). The Detroit Free Press also reported the oiled shoreline vegetation had been removed at Elizabeth Park (DFP).

The U.S. Fish and Wildlife Service reported wildlife injuries at several area locations. At Elizabeth Park, one coot was dead and oiled. In Lake Erie Metropark, two mallards were seen lightly oiled, preening and washing. One map turtle near the Miller Road outfall in the Rouge River, and three Canada geese near block 13000 of Powell Street in the Rouge River were observed but not oiled.

April 18th

The U.S. Coast Guard reported an estimated total volume of recovered emulsified oil at 43,120 gallons (USCG-PolRep). An estimated 2,000 gallons were recovered from the sewers in the prior 24 hours, but additional releases into the Rouge River were still a potential risk (EPA). However, the Detroit River was protected by redundant containment booms (EPA). The Detroit Free Press reported additional booms placed at the mouth of the Huron River, around Pointe Mouillee State Game Area, and north and south of Humbug Island (DFP).

The U.S. Fish and Wildlife Service reported wildlife injuries at several area locations. At the Fort Street Bridge on the Rouge River, one merganser (red-breasted or common) was found dead and oiled. In Canada, 1 mute swan and 2 scaup were seen oiled, and 1 ruddy duck and 13 Canada geese were seen dead and oiled.

Additionally, crews reported to Lake Erie Metropark to remove oiled marsh vegetation and debris from shoreline (USFWS) and the Horse Island area and Humbug Marina have also been cleaned (DFP).

April 19th

The U.S. Coast Guard reported an estimated total volume of recovered emulsified oil at 43,868 gallons (USCG-PolRep). The Detroit Free Press reported that cleanup crews had recovered around 46,000 gallons of lube oil/diesel mix since April 12th (DFP). The U.S. Fish and Wildlife Service reported one oiled mallard or black duck in Garden City.

April 20th

The U.S. Coast Guard reported an estimated total volume of recovered emulsified oil at 49,423 gallons (USCG-PolRep). The U.S. Fish and Wildlife Service reported one oiled painted turtle at the Wyandotte Yacht Club and one dead duck, oiling unknown, at the Riverview Marina.

April 22nd

The Rouge River was reopened to shipping traffic and recovery efforts on the Detroit River are nearly complete (EPA).

April 23rd

The U.S. Coast Guard reported an estimated total volume of recovered emulsified oil at 67,749 gallons and all product in the Rouge River is contained (USCG-PolRep). Additionally, the Detroit River, from mouth of Rouge to Elizabeth Park, has been cleaned (USCGPolRep).

April 24th

To date, the U.S. Coast Guard had covered approximately 70,000 gallons of emulsified oil (EPA).

April 26th

The U.S. Coast Guard reported a revised estimated total volume of recovered emulsified oil at 66,359 gallons (USCG-PolRep). The Detroit River, from mouth of Rouge to Gibraltar, has been cleaned and the source of spill remains unknown (USCG-PolRep).

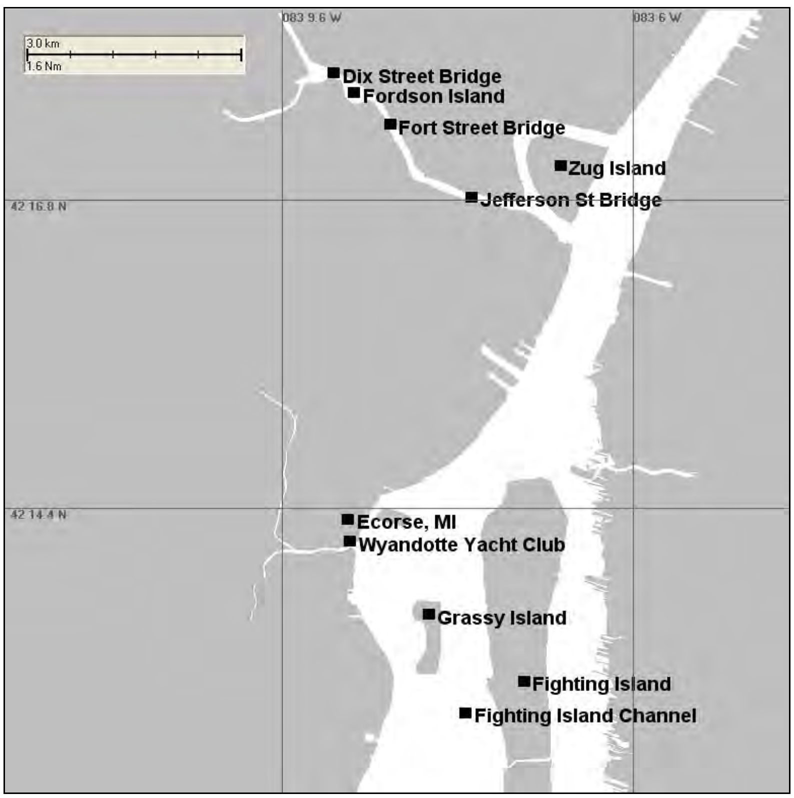

Figure 3-9. Detroit and Rouge Rivers, Assessment Zone 1.

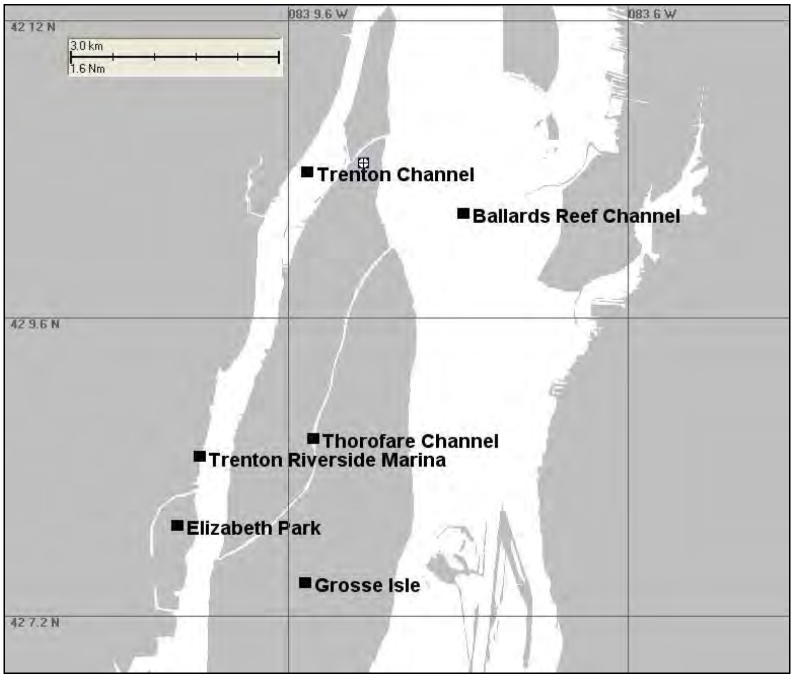

Figure 3-10. Detroit River, Assessment Zone 2.

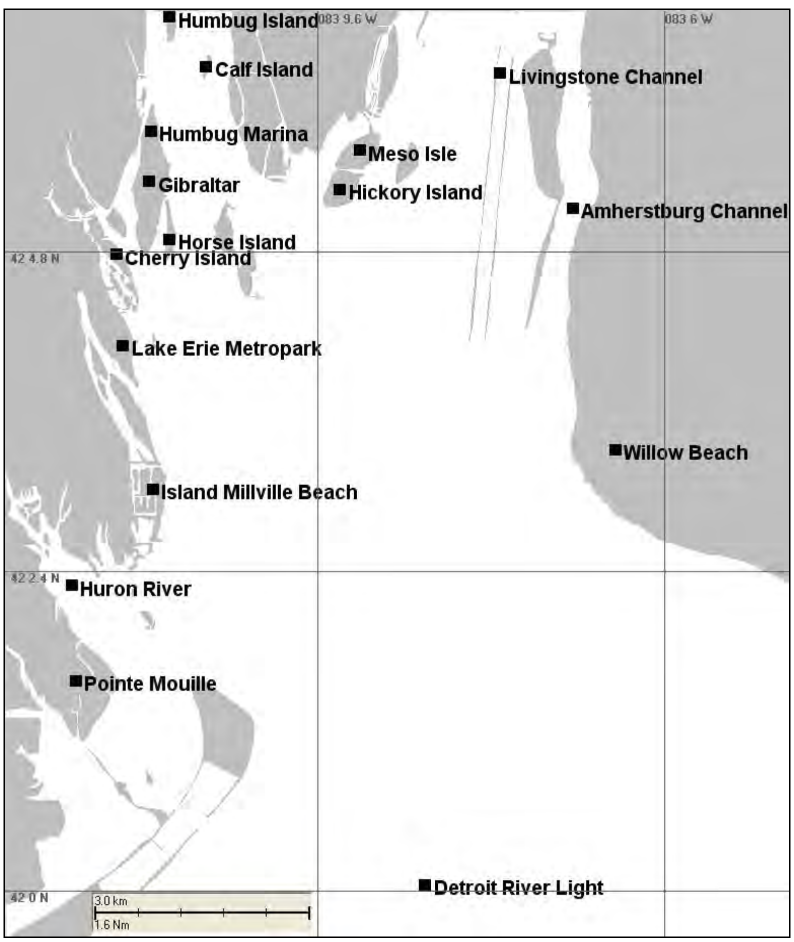

Figure 3-11. Detroit River and Northwest Lake Erie, Assessment Zone 3.

Table 3-2 provides a summary of the wildlife species that were either observed oiled, dead or alive in the vicinity of the Rouge River, Detroit River and western Lake Erie during the time of the spill, as reported above. There were a total of at least 110 birds and 3 turtles that were observed oiled or dead during the course of the oil spill.

Table 3-2. List of wildlife either observed oiled, dead or alive in the vicinity of the oil spill.

Date	Species Name	Location	Number Observed
10-April-2002	Bird, unspecified	Elizabeth Park	1
11-April-2002	Pekin duck	Elizabeth Park	12
	"Wild duck"	Elizabeth Park	6
	Mallard	Elizabeth Park	1
	White goose	Elizabeth Park	1
	Duck	Detroit River	>1
	Duck	Lake Erie Metro Park	1
	White goose	Gilbraltar	3
	Canada goose	Woodmere Cemetery	1
	Canada goose	Rouge River Mouth	1
	Canada goose	Amherstburg, Canada	3
	Duck	Amherstburg, Canada	1
12-April-2002	Bird, unspecified	Edmund Island	>1
	Ruddy duck	Lake Erie Metro Park	2
	"Wild duck"	Lake Erie Metro Park	6
	Mallard	Lake Erie Metro Park	5
	Canada goose	Lake Erie Metro Park	6
	Great egret	Lake Erie Metro Park	5
	Raptor	Lake Erie Metro Park	1
	Ruddy duck	Pt Mouillee CDF	12
	Bufflehead	Pt Mouillee CDF	1
	Pied-billed grebe	Pt Mouillee CDF	1
	Canada goose	Boblo Island, Canada	6
13-April-2002	Canada goose	Rouge River mouth near Detroit Edison	1
	Coot	Rouge River inland near BP Amoco	1
15-April-2002	Mallard	Lake Erie Metro Park	2
	Turtle	Lake Erie Metro Park	1
	Ruddy duck	Lake Erie Metro Park	1
	Canada goose	Fort St. near Rouge River	1
	Canada goose	Jefferson Ave. near Rouge River	1
	Turtle	Wyandotte at Libra Marina	1
16-April-2002	Coot or merganser	Trenton, private property	1
	Mallard	30014 Bayview St. in	1

Date	Species Name	Location	Number Observed
		Gilbraltar	
17-April-2002	Coot	Elizabeth Park	1
	Mallard	Lake Erie Metro Park	2
	Map turtle	Rouge River (Miller Rd outfall)	1 (alive, not oiled)*
	Canada goose	Rouge River (13207 Powell St)	3 (not oiled, but no longer feeding)*
18-April-2002	Merganser (red-breasted or common)	Fort St. Bridge on Rouge River	1
	Mute swan	Canada	1
	Scaup	Canada	2
	Ruddy duck	Canada	1
	Canada goose	Boblo Island, Canada	1
	Canada goose	Canada	12
19-April-2002	Mallard or black duck	Garden City	1
20-April-2002	Painted turtle	Wyandotte Yacht Club	1
	Duck	Riverview Marina	1
	Total birds observed oiled or dead		110+
	Total turtles observed oiled or dead		3

* These observations are not included in the total birds or turtles observed oiled or dead.

4. MODEL TRAJECTORY

4.1 Scenario

The model scenario involves two separate releases on 9 April and 12 April. The base scenario is a total of 339,810 gal of a mixture of diesel fuel oil and waste lubricating oil released over the course of several days from the Baby Creek Outfall (42°17'45.5" N, 83°9;4.3" W) that flows into the Rouge River.

The following assumptions were made to define the base case model scenario:

- Source of oil: 6-10 foot steel flow gate (with similar baffles upstream) that operated off hydraulic head. During the release from the outfall pipe to the Rouge River, the oil would have been mixed with water and sewage behind the gate until the pressure allowed the oil to flow and release below the gate.

- Droplet size distribution for release: assumed a droplet size distribution with a maximum of 1,000 µm diameter for base case scenario and varied between maximum of 500 µm and 5000 µm diameter for initial sensitivity analysis. These define typical droplet size distributions for releases under low ambient pressure, based on studies by Delvigne and Sweeney (1988) and Delvigne et al. (1994). The results were relatively insensitive to the range of these likely values for droplet size distribution; therefore, a range of 100-1,000 µm diameter was used.

- Volume of release: the total spill volume was set at 339,810 gallons.
  - The first component of 256,544 gal includes 255,544 gal (Allen 2002) that was observed on the waters of the Detroit River mid-day on 10 April and 1,000 gal reported cleaned from the Rouge River prior to the second release (US-PolRep).
  - The second component includes 66,276 gal, which is the volume of oil collected from the water (62,500 gal) and the banks of the Rouge River (4,776 gal) during the response (minus the 1,000 gal attributed to the first release).
  - The total spill volume of 322,820 gal based on observations was increased by 5% to account for evaporation by the time of the observation, which results in a total spill volume of 339,810 gal. This increase results in a first release on 9 April of 270,046 gal and a second release on 12 April of 69,764 gal.

- Emulsification:
  - The spill was reported as a mix of diesel and waste lubricating oils in an unknown percentage. Because samples of the oil were taken from the environment and more than 24 hours after the release, after some of the diesel had evaporated, degraded or dissolved, the original percentage of diesel is not known. When comparing the properties of diesel and

lubricating oils, the most significant difference with respect to controlling oil fate and resulting injuries is in the degree to which the oil can be emulsified into a mousse. Diesel does not emulsify and some (but not all) lubricating oils do form a mousse. From the spill observations and cleanup, it is clear that at least some of the lubricating oil emulsified to mousse containing 72% water. To simulate different ratios of diesel to lubricating oil and varying degrees of emulsification that may have occurred, the assumed maximum percent water in oil when fully emulsified as mousse was tested at three levels: 10%, 36%, and 60%. For the base case scenario, 36% maximum water content was used (50% diesel and 50% emulsifying lubrication oil), while 10% water indicates >50% diesel, an 60% water indicates >50% lubricating oil. Increasing percent water in mousse indicates a larger lubricating oil component in the spilled oil. The tests of these different percentages of water when fully emulsified in mousse provide additional sensitivity analysis of the bird injuries.

- Timing of releases:
    - Both releases to the river occurred as a result of rain runoff events when the steel flow gate overflowed.
    - Because these gates are designed to open during periods of increased outflow, the timing of the release was scaled to the timing of the precipitation. Total precipitation was added over each rain event, hourly rainfall in inches was converted to a percentage, and that percentage was used to scale the release using the two volumes mentioned above. Additionally, the timing was delayed (or lagged) for two hours to allow rain to runoff and reach the outfall (Tables 4-1 and 4-2).
    - An estimated 1,000 gal was removed from the Rouge River prior to the second spill. In order for the model to account for this, it was necessary to hold back 1% of the total spill volume and slowly release it between the end of the initial rain event and the installation of the booms at 1152 on 10 April (US-PolRep). Therefore, 100 gal were released each hour over the 27 hours between the end of the rain event and the installation of the booms. This slow release of 1% of the total spill volume simulates either oil released late or held along the shores of the Rouge River, and so not flushed out of the Rouge and into the Detroit River by 10 April.

Table 4-1. Timing of oil spill on 9 April 2002 based on hourly precipitation from Detroit Metro Airport.

Time of Day	Rain (inches)	Percent	Released Oil (gal)	Time of Release
1:00 AM	0.01	5	13,367	4:00 AM
2:00 AM	0.05	25	66,836	5:00 AM
3:00 AM	0.03	15	40,102	6:00 AM
4:00 AM	0.02	10	26,735	7:00 AM
5:00 AM	0.01	5	13,367	8:00 AM

Time of Day	Rain (inches)	Percent	Released Oil (gal)	Time of Release
6:00 AM	0.04	20	53,469	9:00 AM
7:00 AM	0.04	20	53,469	10:00 AM
8 am 4/9 – 10 am 4/10			100 gal/hr	10 am 4/9 – 12 pm 4/10
Total:	**0.2**	**100**	**270,046**	

Table 4-2. Timing of oil spill on 12-13 April 2002 based on hourly precipitation from Detroit Metro Airport.

Time of Day	Rain (inches)	Percent	Released Oil (gal)	Time of Release
5:00 PM	0.02	2	1,328	7:00 PM
6:00 PM	0.38	36	25,248	8:00 PM
7:00 PM	0.02	2	1,328	9:00 PM
8:00 PM	0	0	0	10:00 PM
9:00 PM	0	0	0	11:00 PM
10:00 PM	0	0	0	12:00 AM
11:00 PM	0	0	0	1:00 AM
12:00 AM	0	0	0	2:00 AM
1:00 AM	0	0	0	3:00 AM
2:00 AM	0	0	0	4:00 AM
3:00 AM	0.06	6	3,986	5:00 AM
4:00 AM	0.17	16	11,295	6:00 AM
5:00 AM	0.03	3	1,993	7:00 AM
6:00 AM	0	0	0	8:00 AM
7:00 AM	0.03	3	1,993	9:00 AM
8:00 AM	0.11	10	7,309	10:00 AM
9:00 AM	0.19	18	12,624	11:00 AM
10:00 AM	0.04	4	2,658	12:00 PM
Total:	**1.05**	**100**	**69,764**	

- Spill response:
  - According to Allen (2002), it is assumed that the bulk of the oil released into the Rouge River after mid-day on 10 April was contained and recovered. According to the USCG PolReps, a boom was placed across the Rouge River at 1152 on 10 April. According to NOAA overflight maps, a second boom was placed across the Rouge on 11 April, and another two booms were placed across the Rouge as of 15 April. Figure 4-1 shows the placement of all four booms. For the base case scenario, these booms were assumed to be 99% effective in stopping floating oil from entering the Detroit River.
  - Marine Pollution Control Corporation (MPC) recovered liquid oil and solid waste from Rouge and Detroit Rivers during the spill response. MPC reported 62,500 gallons of liquid product were removed in total from the surface of the Rouge River. An additional 500 gallons of liquid

product was recovered from the Detroit River (Allen 2002). A total 7,171 gallons of oil was recovered within the volume of solid waste (estimated at 5% of solid waste volume). Of this, 4,776 gallons were recovered from the banks of the Rouge and 2,395 gallons from the banks of the Detroit.

- The base case scenario only includes the removal of oil from the surface of the Rouge River between the first and second spills. The USCG PolRep mentions that MPC estimated 1,000 gal of oil had been removed from the system prior to the second spill.

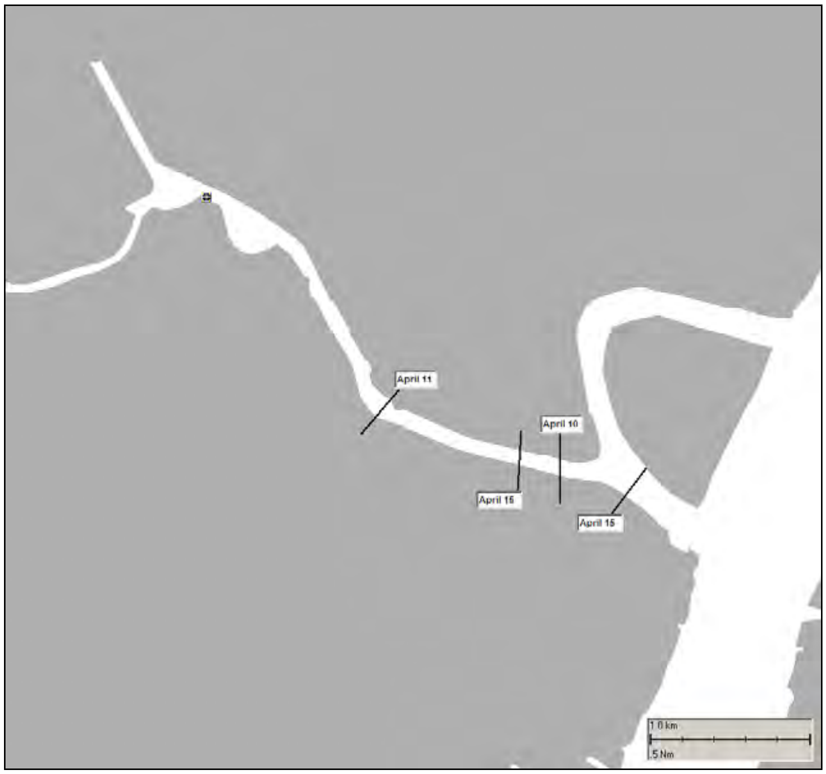

Figure 4-1. Placement of booms over the course of the two phase oil release.

4.2 Sensitivity Analysis

A sensitivity analysis was performed by varying several of the input parameters, as discussed below, and shown in Table 4-3 and Appendix B. Preliminary runs varying these parameters were used to narrow down the input assumptions that best fit the observations. Then a final set of simulations were performed for assumptions closest to best fit, to determine the best case and sensitivity to the input assumptions.

- Current flow speed was varied. A currents scaling factor affected the distribution of oil in the rivers at 12 noon on 10 April 2002 when the first overflights were recorded. For the base case scenario, a scaling factor of 1.1 was applied to the currents in order to match observations of approximately 256,000 gal of oil traveling out of the Rouge River and into the Detroit River by noon on 10 April. As a sensitivity analysis, scenarios were also run using scaling factors for current flow of 1.0 and 1.2.

- Horizontal dispersion rate (coefficient) determines the randomized dispersion of the oil and affects the degree to which the oil will flow down the river or get stuck within cells (cul-de-sacs) of the habitat grid. For the base case scenario, a horizontal dispersion coefficient of 2 m^2/sec was applied to best fit oil spill observations. As a sensitivity analysis, scenarios were also run with horizontal dispersion coefficients between 1 m^2/sec and 5 m^2/sec. Scenarios with horizontal dispersion coefficients of 1 m^2/s to 3 m^2/s were carried throughout the sensitivity analysis because scenarios with higher horizontal coefficients did not distribute the oil sufficiently in the upper part of the Detroit River.

- Initial model runs showed no oil remaining in the Rouge River. In order to match reports that 1,000 gallons were removed from the river between 10 April and 12 April (before the start of the second release) the spill release had to be modified. Trial scenarios revealed that if 1% of the total volume of the first release (255,544 gal oil on the surface of the Detroit River, Allen 2002) was withheld and evenly released until noon on 10 April, approximately 1,000 gallons of oil was found on the surface of the Rouge River on 10 April just prior to when it would have been mechanically removed. The scenarios for 0% and 3% withholding were carried through the sensitivity analysis to show the effect, if any, this factor had on the trajectory of the oil.

Table 4-3 provides the matrix of scenarios that were used for sensitivity analysis, and highlights the base case scenario that was chosen. The base case scenario involved using 1.1 for the current scaling factor, 2 m^2/sec for the horizontal dispersion coefficient, and a 1 percent slow release of oil volume until noon on 10 April to match oil observations.

Table 4-3. List of scenarios used for sensitivity analysis based on input parameters varied from base case scenario.

Scenario name	Current scaling factor	Horizontal dispersion coefficient (m^2/sec)	Percent slow release (%)
RR-2PH -FV11-2HA-1PCT	**1.1**	**2**	**1**
Test: Scaling Factor			
RR-2PH -FV10-2HA-1PCT	**1.0**	2	1
RR-2PH-FV12-2HA-1PCT	**1.2**	2	1
Test: Horizontal Coefficient			
RR-2PH -FV11-1HA-1PCT	1.1	**1**	1
RR-2PH -FV11-3HA-1PCT	1.1	**3**	1
Test: Percent Slow Release			
RR-2PH-FV11-2HA-0PCT	1.1	2	**0**
RR-2PH-FV11-2HA-3PCT	1.1	2	**3**

5. FATES MODEL RESULTS

The SIMAP model quantifies, in space and over time:

- The spatial distribution of oil mass and volume on water surface over time
- Oil mass, volume and thickness on shorelines over time
- Subsurface oil droplet concentration, as total hydrocarbons, in three dimensions over time
- Dissolved aromatic concentration (which causes most aquatic toxicity) in three dimensions over time
- Total hydrocarbons and aromatics in the sediments over time

The fates model output at each time step includes:

- oil thickness (microns or g/m^2) on water surface,
- oil thickness (microns or g/m^2) on shorelines,
- subsurface oil droplet concentration (ppb), as total hydrocarbons,
- dissolved aromatic concentration in water (ppb),
- total hydrocarbon loading on sediments (g/m^2), and
- dissolved aromatics concentration in sediment pore water (ppb).

The full model outputs of all model runs are available as *.avi files on CD and may be viewed with the Microsoft Windows Media Player or QuickTime software.

With the *.avi files, one can view the model results for all times steps of the model simulations. The maps show total hydrocarbons on and in the water, and dissolved aromatic concentrations in the water, after the spill. Concentrations in the water are calculated for a grid (50 X 50 cells horizontally, 5 layers vertically) sized to just cover the plume at the time of the output. Table 5-1 displays what movie files are available and what data is contained in the movie files.

Table 5-1. Movie files (*.AVI) description.

Files Name	Model output
Rouge_trajectory	Model trajectory indicating where there is exposure to surface oil
Rouge_THC-max	Concentrations of total hydrocarbons in the water column over time (vertical maximum at each time step)
Rouge_float-oil	Amount of surface floating oil (g/m^2) over time
Rouge_diss-arom	Concentrations (ppb) of dissolved aromatics in the water column over time (vertical maximum at each time step)

The fates model results of surface oil were visually compared to observed surface oil locations (e.g., from over-flights), scat reports, and other field data, as available. Surface oil distribution from over-flights and other observations are summarized in Section 1, above. The model conserves oil mass, estimates losses to evaporation, and so the surface oil area estimates are realistic estimates of the oil mass on the water at any given time.

Appendix C contains results for the best simulation, i.e., that simulation best agreeing with observed oil locations and shoreline oiling, and the two other simulations used for sensitivity analysis. Figure C-1 and Table C-2 shows the mass balance of oil. The graph shows, as a function of time since the release start, percent of total mass spilled on the water surface, in the water column, on shorelines, in the sediment, in the atmosphere, and degraded. Initially all of the oil is in the water column. After 7 hours, 75% of the oil is on the water surface, 12% of the oil has been entrained into the water column, 13% has evaporated, 0.1% has decayed. After 21 hours (1200 on 10 April), 72% of the oil is on the water surface, 3% of the oil has been entrained into the water column, 20% has evaporated, and 0.6% has decayed. At the end of the simulation (30 days), 12% of the oil has been entrained into the water column, 37% has evaporated, 27% is on shore, and 17% has decayed.

The "Rouge_trajectory.avi" shows the model trajectory, i.e., the path of the oil and locations where shorelines were oiled to some degree. The model replicates well the overall movement and timing of the oil, as shown in Section 1, above.

"Rouge_THC-max.avi" shows the concentrations of total hydrocarbons (oil) in the water column over time. The animated movie shows the vertical maximum concentration on any given time step.

Figure C-2 in Appendix C shows the amount of oil accumulated on shorelines for the best simulation, as mass of total hydrocarbons per unit area (averaged in each habitat grid cell). The area of shoreline that was oiled with greater than 100 g/m^2 (1mm) is estimated in the model simulation as 32,800 m^2 of total shoreline, 27,900 m^2 of which is fringing marsh. No shoreline cleanup was simulated in the model. Thus, oil simply accumulates and remains on the shore.

"Rouge_float-oil.avi" shows the surface distribution of oil. For slicks on the water surface, 1 µm is approximately equivalent to 1 g/m^2. Table 5-2 gives approximate thickness ranges for surface oil of varying appearance. Dull brown sheens are about 1 g/m^2 thick. Rainbow sheen is about 200-800 mg/m^2 and silver sheens are 50-800 mg/m^2 thick (NRC, 1985). Crude and heavy fuel oil > 1mm thick appears as black oil. Floating oil will not always have these appearances, however, as weathered oil would be in the form of scattered floating tar balls and tar mats where currents converge.

Table 5-2. Oil thickness (microns ~ g/m^2) and appearance on water (NRC, 1985).

Minimum	Maximum	Appearance
0.05	0.2	Colorless and silver sheen
0.2	0.8	Rainbow sheen
1	4	Dull brown sheen
10	100	Dark brown sheen
1000	10000	Black oil

Black oil (with thicknesses greater than 1000 g/m^2) persisted for the first 21 hours after the start of the spill. Large areas of sheen (thicknesses greater than 10 g/m2) then persisted for 12 days (2200 on 21 April).

"Rouge_diss-arom.avi" shows the maximum concentration (ppb) of dissolved aromatics passing through each model grid cell.

6. ASSESSMENT OF INJURIES

A description of the data that were used as input to the biological model for densities of wildlife and fish is provided in Appendix D. Appendix E provides a list of biological injury results for the best base case scenario and the other scenarios performed as a sensitivity analysis.

6.1 Shoreline

Table 6-1 summarizes the shoreline oiled by more than 0.1 mm (>100 g/m^2) of oil. This threshold is the minimum (dose) in the model for impact to invertebrates in the littoral areas. Mortality of the vegetation in marshes occurs above about 14 mm of oil, according to literature reviewed in French et al. (1996), but marshes are generally lost (injured) at oiling levels above 1mm (French McCay, 2009). As the affected area is non-tidal, it is assumed that the invertebrate densities in the shoreline areas oiled were negligible, except for in wetlands, and so do not include biological injuries for non-vegetated shorelines in our injury assessment and compensatory restoration scaling. Wetland injuries are assumed compensable for areas where oiling exceeded 1mm oil (Table 6-2).

Table 6-1. Shoreline oiled by >0.1 mm (>100 g/m^2) of oil, for the scenario that best fit the observations of surface oil and shoreline oiling locations, and that was used for the injury quantification.

Habitat type	Length (m)	Area (m^2)
Rocky shore	6,132	6,132
Gravel beach	8,775	8,775
Sand beach	12,476	12,476
Wetland (marsh)	40,386	40,386
Mud shore	10,150	10,150
Artificial shore	0	0
Total shoreline oiled	**67,769**	**67,769**

Table 6-2 summarizes the oil exposure of shoreline and near shore habitats for all shorelines above a range of thresholds. Note that 1g/m^2 is approximately 1 micron thick oil, and 0.1g/m^2 is the thickness of oil sheen. No shoreline cleanup was simulated in the model. Thus, in the model, oil simply accumulates and remains on the shore until it is removed by natural processes (erosion and degradation).

Table 6-2. Area of shorelines oiled (m^2) with an average thickness greater than a threshold (1mm ~ 1kg/m^2) for base case scenario.

Shore type	>1 mm	>0.1 mm	>0.01 mm	>0.001 mm	>0.0001 mm
Rocky shoreline	3,066	6,132	7,929	8,352	8,352
Gravel beach	1,692	8,775	13,955	14,695	14,801

Shore type	>1 mm	>0.1 mm	>0.01 mm	>0.001 mm	>0.0001 mm
Sand beach	3,912	12,476	15,647	17,127	17,127
Wetland (marsh)	26,959	40,386	44,192	45,672	45,672
Mud shore	5,498	10,150	12,052	12,792	12,792
Artificial shoreline	0	0	740	1,163	2,115
Total shoreline	**41,127**	**77,919**	**94,801**	**99,801**	**100,859**

6.2 Wildlife

Table 6-3 provides the estimated total injury of wildlife, including birds, mammals, reptiles, and amphibians, for the best physical fate base case scenario for the three areas (Rouge River, Detroit River and Lake Erie) impacted by the spill. Species affected with a total injury of greater than 100 individuals per species or species group include muskrat, waterfowl, such as common merganser, greater scaup, and lesser scaup, and seabirds, such as Bonapartes gull, herring gull, and doublecrested cormorant (Tables E-2 and E-3 in Appendix E).

It should be noted that it is uncertain what the pre-spill densities of birds and other wildlife were before the spill. The density data used for the modeling, which was best available information, was from other locations and times (see Appendix D). However, the model results are directly proportional to the density data assumed. Therefore, if the densities assumed were a factor 2 lower, the injury results would also be a factor 2 lower. The counts of oiled animals observed oiled or dead in the field totaled 110 birds and 3 turtles. Thus, these model results suggest that one in 49 birds oiled were actually observed; whereas the rule of thumb for past spills has been about 1 in 10 might be observed. Yet, these ratios are highly uncertain, and dependant on the degree of search effort, losses to scavengers, and other factors. Estimates for the likelihood of observing oiled turtles are not available, but 1 in 100 is not unreasonable in this situation.

Table 6-3. Summary of estimated injuries to wildlife resulting from the release of a diesel and lubricating oil mixture into the Rouge River, Detroit River and Lake Erie.

Wildlife Group	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Waterfowl (other than scaup)	410	25	436
Scaup*	4,106		4,106
Seabirds	737	1	738
Wading birds	10	-	10
Shorebirds	58	-	58
Mammals (Muskrats)	308	0	308
Reptiles	114	0	114

Wildlife Group	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Amphibians	78	0	78
Total	**5,821**	**26**	**5,848**

* Scaups are assumed to be found in Lake Erie only in waters 1-3 meters deep.

Scenarios were also run for sensitivity to emulsification of the oil, since the exact proportion of diesel to lubricating oil in the mixture is unknown. The base case scenario used 36 as the maximum percent of water when fully emulsified as mousse. The two sensitivity analysis runs that were used to test this variable, and its effect on overall bird injuries, used 10 and 60 as the maximum percent of water when fully emulsified as mousse. The 10% indicated a spill with an oil mixture that was >50% diesel and the 60% indicated a spill with an oil mixture that was >50% lubricating oil. Overall, the results in bird injuries for these cases are not much different than those for the base case. The total number of birds, not including scaup, estimated to be killed for the 10% scenario was 956 birds, and for the 60% scenario was 1,443 birds, and compared to 1,242 birds for the base case scenario (Table 6-1). This low sensitivity is because the emulsification simply affects the thickness of oil, but has little effect on the area swept by the oil.

Tables 6-4 and 6-5 lists the equivalent losses for fledglings, hatchlings and age-one individuals, and the injury reported in equivalents losses for individual bird-, herptile- or mammal-years for the best base case scenario for the three areas (Rouge River, Detroit River and Lake Erie) impacted by the spill.

Table 6-4. Summary of estimated equivalent losses of bird fledglings, mammal age-zero (newly weaned) mammals, and herpetofauna hatchlings resulting from the release of a diesel and lubricating oil mixture into the Rouge River, Detroit River and Lake Erie.

	Equivalent Losses		
Wildlife Group	Detroit River and Lake Erie	Rouge River	Total
Waterfowl (other than scaup) fledglings	1,401	84	1,485
Scaup fledglings*	14,332	-	14,332
Seabird fledglings	2,753	4	2,757
Wading bird fledglings	34	-	34
Shorebird fledglings	200	-	200
Muskrats (newly weaned)	940	-	940
Reptile hatchlings	1,700	-	1,700
Amphibian hatchlings	143,600	-	143,600
Total	**164,960**	**88**	**165,048**

* Scaups are assumed to be found in Lake Erie only in waters 1-3 meters deep.

Table 6-5. Summary of estimated injuries (interim loss) as individual bird-years, mammals-years and herptile years (all age classes combined for each group) resulting from the release of a diesel and lubricating oil mixture into the Rouge River, Detroit River and Lake Erie.

	Individual-years Lost (all ages)		
Wildlife Group	**Detroit River and Lake Erie**	**Rouge River**	**Total**
Waterfowl (other than scaup)	1,057	78	1,135
Scaups*	8,855	-	8,855
Seabirds	11,977	16	11,992
Wading birds	31	-	31
Shorebirds	351	-	351
Muskrats	398	-	398
Reptiles	1,238	-	1,238
Amphibians	9,448	-	9,448
Total	**33,355**	**94**	**33,448**

* Scaups are assumed to be found in Lake Erie only in waters 1-3 meters deep.

6.3 Fish and Invertebrates

Table 6-6 lists the total injury (interim loss) of fish as the sum of direct kill plus production forgone (i.e., the net growth normally to be expected of the killed organisms over the remainder of their life spans, lifetime production), for the best base case scenario using an $LC50_{\infty}$ value of 44ppb for species of average sensitivity to the diesel and lubricating oil mixture that was released during the spill. Species affected with a total injury of greater than 40 kg per species (or species group) using an assumed $LC50_{\infty}$ value of 44ppb for species of average sensitivity included largemouth bass and large forage fish, which includes species such as common carp and buffalos.

Table 6-6. Summary of estimated injuries to fish resulting from the release of a diesel and lubricating oil mixture into the Rouge River, Detroit River and Lake Erie using a $LC50_{\infty}$ value of 44ppb for species of average sensitivity for the base case scenario.

Fish species:	Kill (kg)	Production Forgone (kg)	Total Injury (kg)
Herrings	2.2	0.0	2.2
Marsh forage fish	0.0	0.0	0.0
Rainbow smelt	0.0	0.0	0.0
White bass	2.0	1.4	3.4
White perch	6.5	5.8	12.3
Bowfin	3.6	0.0	3.6
Bullhead catfish	1.4	1.4	2.8
Freshwater drum	1.0	1.3	2.3
Large forage fish	18.7	23.0	41.8
Largemouth bass	19.8	21.2	41.0
Longnose gar	9.1	0.0	9.1
Medium forage fish	9.8	12.7	22.5
Northern pike	0.8	0.9	1.6
Rainbow trout	0.3	0.3	0.5
Rock bass	12.2	11.3	23.4
Small forage fish	1.7	1.1	2.8
Smallmouth bass	18.6	20.1	38.7
Sunfishes	4.4	3.9	8.3
Walleye	5.2	5.4	10.5
Yellow perch	1.5	0.0	1.5
Total small pelagic fish	2.2	0.0	2.2
Total large pelagic fish	8.4	7.2	15.6
Total demersal fish	108	102	211
Total demersal invertebrates	0.0	0.0	0.0
Total mollusks	0.0	0.0	0.0
Total	**119**	**110**	**228**

Scenarios were also run for $LC50_{\infty}$ values of 5ppb (for sensitive species) and 370ppb (for insensitive species) to bound these estimates, with the total range representing 95% of sensitivities to oil hydrocarbons based on species to date. The results indicate that the fish injuries computed by the model are somewhat affected by the assumed percentage of the oil released slowly and after the majority of the first oil release had moved out of the Rouge River, which was one of the parameters varied as part of the sensitivity analysis. The total injuries to fish for the 0 percent, 1 percent and 3 percent slow release scenarios, using an $LC50_{\infty}$ value of 44ppb for species of average sensitivity, are 153 kg, 228 kg and

258 kg, respectively. The total injuries to fish for the base case (1 percent slow release) scenario with oil containing 10 percent and 60 percent water when fully emulsified in mousse, using an $LC50_{\infty}$ value of 44ppb for species of average sensitivity, are 214 kg and 155 kg, respectively. Variation in species sensitivity to oil hydrocarbons induces a factor of 20 change in injuries. Thus, the fish injuries are not very sensitive to variation in the fates model inputs assumed, but are sensitive to the toxicity parameter range tested. Note, however, that most species would be close to average in sensitivity to oil hydrocarbons. In this system, it is unlikely that any of the species present would be highly sensitive to oil hydrocarbons (PAHs), given the historical and present levels of background contamination.

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Attachment A: State-of-the-Art and Research Needs for Oil Spill Impact Assessment Modeling

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State-of-the-Art and Research Needs for Oil Spill Impact Assessment Modeling

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Abstract

Modeling can be a powerful tool for oil spill impact quantification as part of environmental risk assessments, contingency planning, and natural resource damage assessments. Historically, oil spill models have focused on trajectory and fate in aquatic environments, with impacts being assessed in most cases by evaluating the presence of biota in the area exposed to floating or shoreline oil. A few models have addressed subsurface oil concentrations to which water column biota are exposed, but most of these simply overlay fates model concentration results on maps or grids of biological distributions to assess "impact". This paper describes the state-of-the-art of biological effects modeling for the most comprehensive approach to date, a model that evaluates dose and resulting impact of oil hydrocarbons on aquatic biota including birds, mammals, reptiles, fish, invertebrates, and plants. The biological effects model is coupled to an oil trajectory and fates model that supplies required spatial and temporal quantification of oil distributions and hydrocarbon component concentrations. Model development and validation studies are reviewed, strategies for applying the model for hindcasts and risk assessments are discussed, and research and data needs are identified.

1 Introduction

There is a growing demand by both government and industry for oil spill fates and biological effects modeling to address the potential environment impacts of spills and oil-related activities. This demand is driven by government regulations, the limits of data collections from field and laboratory work, and the growing power of computers for performing data analyses and modeling calculations. Models use knowledge of physical, chemical, and biological relationships along with environmental data to simulate pollutant transport, fate and biological effects. This analysis is useful for risk assessment, contingency planning, cost-benefit analysis and natural resource damage assessment (NRDA). Modeling may be applied to investigate a single spill event, to evaluate the probable consequences of a hypothetical spill, or to determine impacts of a worst-case spill scenario. Examples of these applications include risk assessment in support of permit application, comparison of response strategies for contingency planning, and analysis of maximum liabilities for accidental spills.

A number of oil trajectory and fates models are available around the world. Several reviews of the state-of-the-art in oil spill trajectory and fate modeling have been performed over the past two decades (Huang, 1983; Spaulding, 1988; ASCE, 1996; Reed et al., 1999) to assess the state of the practice, to summarize key developments, and to project future capabilities. The reader is referred to these papers and the literature (e.g., Mackay et al., 1982; Kirstein et al., 1987; Lehr et al., 1995, 2000; Jones, 1997; Galt, 1998; Reed et al., 2000; French McCay, 2004; Boufadel et al., 2007) for descriptions of these and other oil fate models, as well as research needs.

In contrast, few model developers have carried out the analysis to quantitatively address biological impacts of oil spills in aquatic environments. In most cases, impacts are assessed by evaluating the presence or densities of biota in the areas exposed to floating or shoreline oil. In some cases, the oil fate model used for the assessment is three-dimensional, such that subsurface concentrations are considered. However, the assessment of impact is generally performed by establishing a threshold for concern and then mapping or quantifying the area "impacted". The problem with this approach is that an impact is assumed if there is an intersection of some amount of oil with biological "receptors", without consideration of dose, uptake, duration of exposure, or measurable effect.

Early modeling efforts for wildlife impact assessment relied on calculating the intersection of oil trajectories with birds or marine mammals, assuming an impact threshold (Reed et al., 1989; Jayko et al., 1990). In some cases, wildlife population and migration models were used to simulate the distribution, behavior and recovery of the affected species, in conjunction with their intersection with oil trajectories (Samuels and Lanfear, 1982; Ford, 1985, 1987, Ford et al., 1982; Brody, 1988; French and French, 1989; French et al., 1989; Seip et al., 1991). In these modeling efforts, the impact threshold for wildlife was appropriately based on a threshold oil thickness or mass for lethal or sublethal effects, although quantitative information definitively indicating what dose would be lethal was not available.

Both subsurface oil droplets and dissolved hydrocarbons must be explicitly simulated (in addition to surface floating oil and associated processes) in an oil fates model in order to be able to evaluate exposure of aquatic biota to oil hydrocarbons and biological effects. A prime case example is the *North Cape* oil spill of January 1996, which occurred during a severe winter storm where 2682 metric tons (828,000 gallons) of home heating oil (No. 2 fuel oil) spilled into the surf zone on the south coast of Rhode Island, USA. Most of the oil was entrained into the water column by heavy surf, resulting in high concentrations of dissolved components in shallow water, which took weeks to disperse, killing millions of water column and benthic organisms (French McCay, 2003). Moreover, because the many hydrocarbons in oil have varying physical-chemical properties (most significantly those related to solubility and volatility), the oil fates model must separately track chemical classes or pseudo-components of the whole oil with characteristics typical of the chemical group to simulate their separate fates (Payne et al., 1984, 1987; Kirstein et al., 1987; French et al., 1996; Jones, 1997; Reed et al., 2000; French McCay, 2004). Most oil fates models employ a Lagrangian particle approach, which enables the modeler to track physical and chemical property changes as oil weathers. This is particularly needed when oil is released over time under varying conditions. The Lagrangian methodology is also useful for biological modeling to track organisms' movements and exposure to oil (French et al., 1996; French McCay, 2003, 2004).

Potential and documented impacts of oil in aquatic environments have been reviewed by the National Research Council (NRC, 1985, 2002) as well as others (Neff et al., 1976; Neff and Anderson, 1981; Engelhardt, 1983, 1987; Teal and Howarth, 1984; Capuzzo, 1987; Geraci and St. Aubin, 1990; Rice et al., 1996; Sloan, 1999; Kingston, 2002). A biological effects model that considers all impacts of oil should include evaluation of: exposure considering movements and amounts of both oil and biota; duration of exposure and degree of accumulation in tissues; acute effects and direct impacts (lethal and sublethal) in the short-term; sublethal effects of chronic contamination; behavioral changes resulting in reduced growth, survival or reproductive success; indirect effects via reduction in food supply, habitat, or other changes in the ecosystem; impacts of spill response activities; and population level impacts caused by mortality and sublethal effects. Supporting research and information is available to quantify some but not all of these effects, as discussed below.

Herein, the state-of-the-art of biological effects modeling for use in impact and risk analyses is described, as developed by French and French (1989), French et al. (1996), and French McCay (2002, 2003, 2004), and on-going research and case analyses for NRDA and risk assessments. A biological effects model requires physical and environmental inputs including (1) wind data as time- and (optionally) spatially-varying velocities; (2) current data as time- and spatially-varying velocities; (3) environmental conditions such as temperature and salinity; and (4) physical fates model outputs that quantify spatial distributions, physical-chemical characteristics, and concentrations over time of floating oil, entrained oil droplets, dissolved hydrocarbon components, oil in sediments, and oil on shorelines. Typically, a biological effects model is coupled to an oil fates model capable of providing the needed information, such as that described by French McCay (2004). However, in the future, models could be modularized and fates models could provide standardized outputs that could be used as input to biological effects models.

This paper provides background for current research being supported by the Coastal Response Research Center at the University of New Hampshire. Previous model development, modeling approaches, available information, potential algorithms, and data needs for developing the next-generation oil spill biological effects model are being reviewed. Processes being considered in the biological effects modeling review include (1) oil hydrocarbon exposure (to floating oil, entrained droplets, dissolved hydrocarbons, oil in sediments, and oil on shoreline) for habitats, wildlife, fish and invertebrates, including consideration of behavior (i.e., normal, avoidance and attraction); (2) pathways and rates of uptake of hydrocarbons into biota; (3) lethal and sublethal effects levels for mechanical, smothering, thermal, and/or toxicological effects of (whole) oil on wildlife and aquatic biota; (4) acute and chronic toxicity of hydrocarbons on aquatic biota, including consideration of duration of exposure and long-term effects on development, growth, reproduction, etc.; (5) phototoxicity of polynuclear aromatic hydrocarbons (PAHs) on aquatic biota; and (6) population and ecosystem level effects and recovery rates. This paper focuses on model development to date: that addressing acute toxic effects resulting from short-term exposure. Long-term effects of oil hydrocarbon exposure have not been addressed in oil spill models to date, due to the complexity, site-specificity required, and paucity of quantitative information to develop such a model.

2 Coupled Physical Fates Model

The SIMAP (Spill Impact Model Application Package) physical fates model (French McCay, 2004), to which the SIMAP biological effects model is coupled

(Figure 1), is described briefly here to illustrate the needed capabilities for input to the biological effects model calculations. The SIMAP models were derived from the physical fates and biological effects submodels in the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME), which were developed for the U.S. Department of the Interior (USDOI) as the basis of Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) Natural Resource Damage Assessment (NRDA) regulations for Type A assessments (French et al., 1996). The SIMAP physical fates model is described in detail in French McCay (2004).

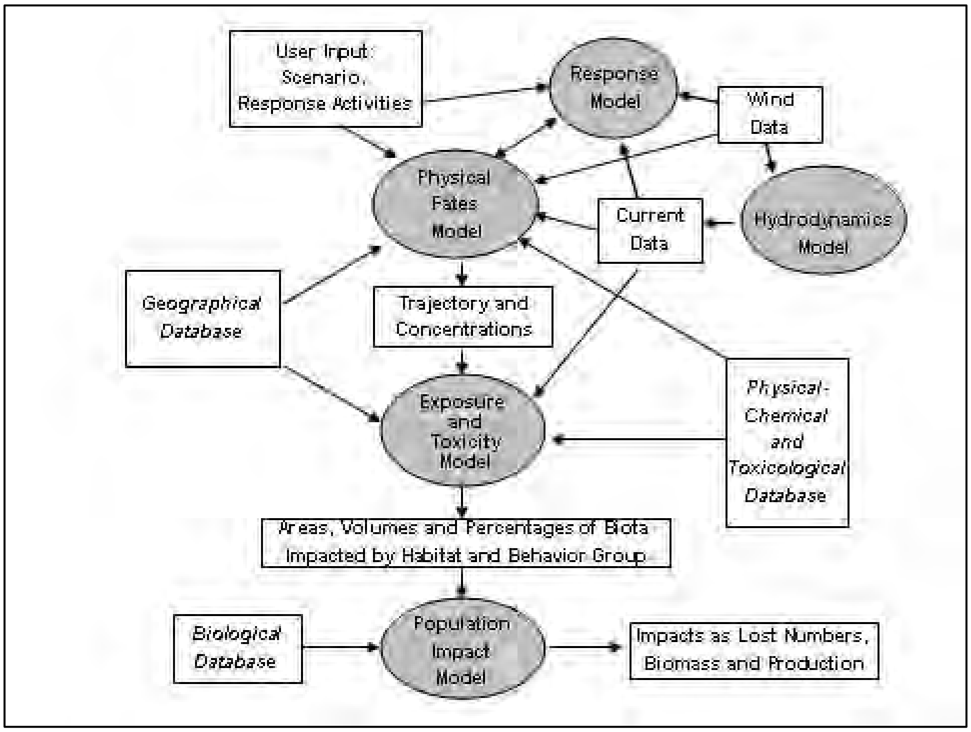

Figure 1. Diagram of the SIMAP Model System

The transport model in SIMAP (French McCay, 2003, 2004, also the earlier version in French et al., 1996) and other oil spill models (Mackay et al., 1982; Spaulding et al., 1983; Spaulding, 1988; Lehr et al., 1995, 2000; Galt, 1998; Reed et al., 1999, 2000) utilize similar algorithms for calculating advective movements and turbulent dispersion, i.e., Lagrangian elements ("LEs" or "spillets") are used to track the oil movements and weathering. The SIMAP physical fates model (French McCay, 2004) uses wind data, current data, and transport and weathering algorithms to calculate the mass of oil components in various environmental compartments (water surface, shoreline, water column, atmosphere, sediments, etc.), oil pathway over time (trajectory), surface oil distribution, and concentrations of the oil components in water and sediments over time. The distribution of oil in space and time is expressed as mass per unit area on the water surface, mass per unit area on shorelines, concentration in the water column, and mass loading per area of the sediments.

Processes simulated in the physical fates model include slick spreading, evaporation of volatiles from surface oil, transport on the water surface and in the water column, randomized dispersion, emulsification, entrainment of oil as droplets into the water column, resurfacing of larger droplets, dissolution of soluble components (i.e., lower molecular weight aromatics), volatilization from the water column, partitioning of semi-soluble components between sediments and the dissolved form, sedimentation, stranding on shorelines, and degradation. Oil mass is tracked separately for lower-molecular-weight aromatics (1 to 3-ring aromatics), which are soluble and so cause most acute toxicity to aquatic organisms (French McCay, 2002, see below), other volatiles, and non-volatiles. The lower molecular weight aromatics dissolve both from the surface oil slick and whole oil droplets in the water column, and they are partitioned in the water column and sediments according to equilibrium partitioning theory (French et al., 1996; French McCay, 2003, 2004).

"Whole" oil (containing non-volatiles and volatile components not yet volatilized or dissolved from the oil) is simulated as floating slicks, emulsions and/or tar balls, or as dispersed oil droplets of varying diameter (some of which may resurface). Sublots of the spilled oil are represented by individual spillets, each characterized by mass of hydrocarbon components and water content, location, thickness, diameter, density, and viscosity. Spreading (gravitational and by transport processes), emulsification, weathering (volatilization and dissolution loss), entrainment, resurfacing, and transport processes determine the thickness, dimensions, and locations of floating oil over time. The output of the fate model includes the location, dimensions, and physical-chemical characteristics over time of each spillet representing oil (French McCay, 2003, 2004).

Concentrations in the water column are calculated in SIMAP by summing mass (in the spillets) within each grid cell of three-dimensional grid scaled each time step to just cover the dimensions of the plume. This includes all potential contamination in the water column, while maximizing the resolution of the contour map at each time step to reduce error caused by averaging mass over large cell volumes. Distribution of mass around the particle center is described as Gaussian in three dimensions, with one standard deviation equal to twice the diffusive distance ($2D_xt$ in the horizontal and $2D_zt$ in the vertical, where D_x is the horizontal and D_z is the vertical diffusion coefficient, and t is particle age). The plume grid edges are set at one standard deviation out from the outer-most particle. Concentrations of particulate (oil droplet) and dissolved aromatic concentrations are calculated in each cell and time step and saved to files for later viewing and calculations. These data are used by the biological effects model to evaluate exposure, toxicity, and effects.

In summary, the fates model quantifies, in space and over time:

- The spatial distribution of oil mass and volume on the water surface (including flooded intertidal areas and lands) over time;
- Oil mass, volume and thickness on shorelines of varying types over time;
- Subsurface (in-water) oil droplet concentrations, as total hydrocarbons, in three spatial dimensions over time;
- Dissolved aromatic concentrations in water in three spatial dimensions over time; and
- Total hydrocarbons and aromatics in the sediments over time.

The fates model output at each time step includes:

- Oil thickness (microns or g/m^2) floating on water surfaces,
- Oil loading (g/km and g/m^2) on shorelines,

- Subsurface oil droplet concentrations in water (ppb), as total hydrocarbons,
- Dissolved aromatic concentrations in water (ppb),
- Total hydrocarbon loading on sediments (g/m^2), and
- Dissolved aromatics concentrations in sediment pore water (ppb).

The SIMAP transport model has been validated with more than 20 case histories, including the *Exxon Valdez* and other large spills (French McCay, 2003, 2004; French McCay and Rowe, 2004), as well as test spills designed to verify the model's transport algorithms (French et al., 1997; French McCay et al., 2007). It has been used in many NRDA cases in the US, as well as in ecological risk assessments for potential spills world wide.

3 Biological Effects Model

The biological exposure model estimates the area or volume where organisms are adversely affected by surface oil, concentrations of oil components in the water, and/or sediment contamination. The area or volume impacted may be multiplied by organism density to calculate an impact or evaluated as a portion of a stock or population affected. The biological effects model (Figure 2) estimates losses resulting from acute exposure after a spill (i.e., losses at the time of the spill and while floating oil and acutely toxic concentrations remain in the environment) in terms of direct mortality and lost production because of direct exposure or the loss of food resources from the food web. The model first estimates percentage losses in discrete habitat areas or volumes by behavior group (e.g., aerial seabirds in areas, pelagic fish in volumes), translating these to equivalent areas and volumes of 100% loss (i.e., by summing the percent loss times area or volume affected). These equivalent areas and volumes are then multiplied by biological density data to estimate direct losses of species or species groups of fish, invertebrates (i.e., shellfish and non-fished species) and wildlife (birds, mammals, reptiles). Lost production of aquatic plants (microalgae and macrophytes) and lower trophic levels of animals are also estimated in the direct loss model calculations. Lost production of prey species are translated to losses higher in the food web using a food web model. Future losses are calculated using a population model, accounting for lost future growth as well as natural and harvest mortalities for each life stage and annual age class.

The area potentially affected by the spill is represented by a rectangular grid with each grid cell coded as to habitat type. The same habitat grid is also used by the physical fates model to define the shoreline location and type, as well as habitat and sediment type. A habitat is an area of essentially uniform physical and biological characteristics that is occupied by a group of organisms that are distributed throughout that area. A contiguous grouping of habitat grid cells with the same habitat code represents an ecosystem in the biological model. Pre-spill densities of fish, invertebrates, and wildlife (birds, mammals, reptiles, and amphibians) are assumed evenly distributed across each habitat type defined in the application of the model. Habitat types may be defined to resolve areas of differing density for each species, and the impact in each habitat type is then separately computed. While biological distributions are known to be highly variable in time and space, data are generally not sufficient to characterize this patchiness. Oil is also patchy in distribution. The patchiness is assumed to be on the same scale so that the intersection of the oil and biota is equivalent to overlays of spatial mean distributions.

Mobile fish, invertebrates and wildlife are assumed to move at random within each ecosystem during the simulation period, a reasonable assumption for the few weeks following oil release that are modeled. Aquatic organisms are modeled using Lagrangian particles representing schools or groups of individuals. Benthic organisms remain stationary on or in the bottom. Planktonic stages, such as pelagic fish eggs and larvae are transported by the currents (input to the model).

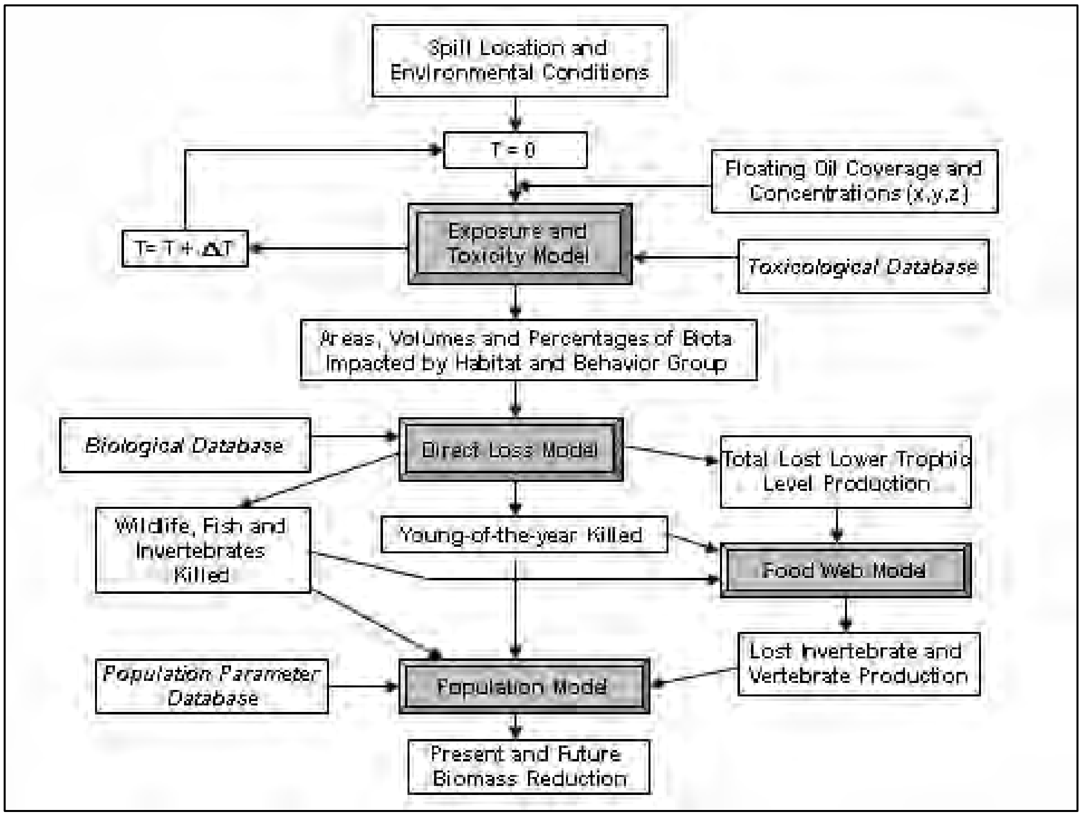

Figure 2. Diagram of the Biological Effects Model

Habitats include open water, invertebrate reef, wetland (marsh, swamp), seagrass, macroalgal bed, and shoreline environments. Habitat types are defined by depth, salinity regime, proximity to shoreline(s), bottom/shore type, dominant vegetation type, and the presence of invertebrate reefs. With respect to salinity and proximity to shoreline(s), habitats are designated as landward or seaward. This designation allows different biological abundances to be simulated in landward and seaward zones of the same habitat type (e.g., open water with sand bottom). Thus, the landward-seaward designation is operational and tailored to the needs for a particular assessment in an oil-affected area. The SIMAP model has been applied to marine, estuarine and freshwater environments, with habitats defined accordingly.

Wildlife (i.e., air-breathing vertebrates) individuals that move through the area swept by floating oil are assumed to be oiled based on probability of encounter. Those oiled above a threshold dose are then assumed to die.

Fish, shellfish, their eggs and larvae, and other plankton are affected by dissolved concentrations of hydrocarbons in the water or sediment. Mortality is calculated using laboratory acute toxicity test data (LC50, concentration lethal to 50% of test individuals) corrected for temperature and time of exposure, and assuming a log normal relationship between percent mortality and dissolved concentration. The model accounts for the uptake, accumulation and additive effects of the mixture of hydrocarbons to which the organisms are exposed. Organisms killed are integrated over space and time and by habitat type to calculate a total short term kill. This total short term kill occurs from the time of the spill until the time the contaminants are dispersed to the point where concentrations are below toxic levels.

Lower trophic level biota are generally not evaluated by species or species group, and impacts are quantified as lost production in each habitat affected. Lost primary (plant) and secondary (herbivore) production due to sublethal concentrations of dissolved hydrocarbons is estimated using the EC50, the concentration where growth rate is 50% of the clean control, correcting it for temperature and assuming a log normal relationship between percent of uninhibited growth rate and concentration. Primary and secondary production losses are integrated over space and time and by habitat to calculate the total biomass not produced during the spill. For areas affected by sublethal concentrations, the rates of production are assumed to return to normal immediately following the dispersion of the contamination to non-toxic concentrations.

For microalgae (phytoplankton and benthic microflora), concentrations which reduce production to near zero are essentially lethal. The above calculation procedure covers these losses. Reseeding of these groups into affected habitats which are no longer toxic is so rapid that recovery may be assumed immediate following dispersion of toxic concentrations. However, for macrophytes, recovery following exposure to lethal concentrations is not immediate. In habitats dominated by macrophytes (e.g., marshes, swamps, kelp beds, seagrass beds), complete mortality of plants is assumed if a lethal threshold is reached (in water concentrations or in oil coverage). Losses from the direct kill and over the period of natural recovery after the toxicity is gone are included in the tabulation for macrophytes and for animals (wildlife, fish, shellfish, eggs, larvae and benthos) dependant on the affected habitat for food or development.

Biomass which is not produced as a result of a loss of food resources is estimated using a simple food web model. The portion of the lost primary production which would have produced primary consumer (secondary producer or herbivore) biomass is estimated based on observations of ecological efficiency made on representative ecosystems. The fractions of the lost secondary production which would have been consumed by each of their predators are assumed to be proportional to the biomass of that predator relative to the sum of its competitors. The output of this part of the model is lost production of the various fish, shellfish, and wildlife species as a result of the spill. This is added to the total direct kill to yield a total loss of biomass by habitat as a short term result of the spill.

In addition to the direct kill and food web losses of eggs, larvae and juveniles, these young-of-the-year may be lost via habitat disruption. This is included in the model for macrophyte-dominated habitats affected by lethal oiling. Losses are assumed proportional to the macrophyte loss. Thus, recovery of spawning and nursery habitat in wetlands, kelp beds, and seagrass beds follows recovery of macrophyte biomass and production. Similar assumptions are made for coral reefs based on the same arguments.

Potential long term losses (losses realized after the spill has dissipated) which can result from a spill of a toxic substance include: (1) lost recruitment to a fishery of the larvae and juveniles killed at the time of the spill; (2) lost future growth of the adults killed at the time of the spill; (3) changes in food web structure and, therefore, productivity of specific trophic levels and populations; and (4) chronic effects of sublethal levels of contaminants in tissues or the environment, such as reduced growth rate or loss of reproductive potential. The first two effects are typically the most dominant following an acute event such as an oil spill. The latter two effects have not been included in any model to date, both due to the complexity of developing such models, which necessitates that they be site specific, and to the lack of quantitative information required to apply these models (e.g., see Hansen, 1984). Thus, the impacts estimated in the biological effects model are the results of acute toxicity and resulting direct effects on long term productivity and yield: lost recruitment and lost growth. As such, the model does not consider any indirect (chronic) effects or feedbacks after the spill has dissipated, such as changes in mortality due to density dependent effects, changes in food web structure and predator prey relationships, or changes in reproductive potential. The modeled spill impact extends only for the life span of the species considered, and growth and reproduction are assumed to return to normal after the effects of the spill have dissipated.

For fish and invertebrates (juveniles over the age of one year and adults of a species), it is assumed that a constant natural mortality rate (due to natural causes) applies; juveniles (over age one) and adults inhabit the same habitat at the same time; there is a constant fishing mortality rate for animals past the age of recruitment to the fishery; and that growth follows the von Bertalanffy relationship (Ricker, 1975). Using these assumptions and standard steady state fisheries models, the age structure of a population and long term losses in yield as the result of the spill may be estimated (Ricker, 1975). The direct kill, in numbers by age, is calculated from biomass killed, weight as a function of age, and natural and fishing mortality rates. For each year following the spill, the lost catch, calculated from fishing mortality, weight by age and average number alive during that year, is calculated. Thus, only those individuals which would have been caught in present and future years, and not those which would have died naturally, are included in the quantification of the future production and catch losses due to the incident.

The relatively high mortality rates of eggs and larvae are considered in the biological effects model, since a high number killed at the time of the spill would have died regardless of the spill. The young-of-the-year (eggs, larvae, and juveniles less than one year old) of each fishery species category are tracked as percents of the age one population. Young-of-the-year and older age classes are not assumed to inhabit the same environment concurrently, and their losses are calculated separately.

For waterfowl and mammals, losses to hunting are calculated assuming constant natural and hunting mortality rates over time after the spill. For all wildlife, population losses are calculated as the number not left alive in present and future years as the result of the spill, after constant natural mortality (and hunting mortality) is subtracted.

The biological effects model is designed to be generally applicable, while restricting the data and parameter requirements to information which is generally available. As part of the development of the NRDAM/CME (French et al., 1996), biological data were compiled for a series of habitat types within each of 77 regions of U.S. coastal and marine waters, as opposed to site specific information for every possible geographic location. A similar approach has been taken when applying the model to other locations outside US waters. In addition, freshwater databases have been developed for the Great lakes and other inland waters. Site- and event-specific databases have been developed for specific case investigations or risk assessments.

Required biological data for applying the model to obtain biomass and numerical losses by species are: estimates of fish and invertebrate biomass per area (kg wet weight/km^2), numbers of wildlife (birds, mammals, reptiles) per unit area (#/km^2), and rates of production for lower trophic levels (plants and invertebrates, g C m^{-2} day^{-1}). These data may be specific for the time of a spill or, if a biological database is developed, seasonal or monthly means in each habitat type.

Parameters required for the population model include estimates of natural and fishing (hunting) mortality rates, available from the fisheries and wildlife literature; age specific growth rates, available from length or weight at age catch data; and age at recruitment and life span. The spawning areas and times for fish and invertebrate species and development information for the young of all species groups are also compiled when evaluating these losses. All of these estimates are specific to habitat within each geographic region.

3.1 Wildlife: Air-Breathing Vertebrates

3.1.1 Model Algorithm

For wildlife (air-breathing vertebrates: birds, mammals, and reptiles, and adult amphibians), the number or fraction of a population suffering oil-induced effects is proportional to the water-surface area swept by oil (slicks, emulsions, or other floating forms such as tar balls) of sufficient quantity to provide a lethal dose to an exposed animal. Wildlife populations are assumed to be in equal density across each ecosystem (each grouping of like habitat grid cells) and to remix within each ecosystem each day. For each day of the simulation, those oiled above a threshold dose are assumed to die, and the remainder may be oiled in subsequent days if oil is still present on the water surface.

Wildlife individuals are assumed to move at random within the ecosystem for the period of the simulation of the spill. Studies have shown that while birds and mammals may sometimes try to avoid oil once they have experienced it, for the most part animals respond to overriding desires of obtaining food or other behaviors such that avoidance is negligible (Varoujean et al., 1983; Geraci and St. Aubin, 1988, 1990). While the majority of fulmars near an experimental spill were observed by Lorentsen and Anker-Nilssen (1993) to avoid oil, 4% entered oil sheen because they were attracted to food remains thrown overboard from the research vessel. Avoidance (or attraction) is simulated in the model by adjusting the probability of intersecting oil (see below).

For each of a series of surface spillets, the physical fates model has estimated the location and size (radius of circular spreading spillet) as a function of time. This information is input to the biological exposure model where the area swept by a surface spillet in a given time step is calculated as the quadrilateral area defined by the path swept by the spillet diameter. The areas swept by all spillets are summed over all (physical fates model) time steps in a given day, and separately for each habitat type where the oil passes. Spillets sweeping the same area of water surface at the same time are superimposed. The total area swept by oil greater than a threshold thickness in each habitat type is multiplied by the probability that a species uses that habitat (0 or 1, depending upon its behavior) and a combined probability of oiling and mortality. This calculation is made for each surface-floating spillet and each habitat for the duration of the model simulation. The calculations are summarized as follows:

$$N' = P_w \sum_{t=0}^{t=\infty} A_s \, N_t \, \Delta t \qquad (1)$$

where N' is the total number killed of a wildlife species in a given ecosystem, P_w is the probability of oiling and dying given that a surface slick is encountered for the wildlife behavior group of the species, A_s is the portion of the ecosystem area swept by oil (greater than a threshold thickness or g/m^2 such that animal would obtain a lethal dose) over the time interval Δt = 1 day, and N_t is the number remaining alive at time t (of the species and ecosystem of concern).

3.1.2 Threshold Thickness for Lethal Dose

The threshold thickness of oil that would impart a lethal dose to an intersecting wildlife individual is 10 microns (~10 g/m^2), based on the following review. See Engelhardt (1983), Clark (1984), Geraci and St. Aubin (1988), and Jenssen (1994) for reviews of the literature on oil effects on aquatic birds and marine mammals.

Varoujean et al. (1983) cite that, when confined to oil, 1 g/m^2 is 100% lethal to birds oiled by such a slick, while 0.1 g/m^2 is not enough to cause acute mortality. Peakall et al. (1985) state that blue sheen (which is < 1 μm thick, National Research Council, 1985) is not harmful to seabirds. Jenssen and Ekker (1991a,b) studied the effects of exposure of eiders to oil of varying doses. Greater than 20 ml of (crude) oil was the required dose for an effect on metabolism. However, their review of the literature revealed that an order of magnitude more oil is the required dose for significant and potentially lethal effects.

Birds incubating eggs can transfer oil to the egg from their plumage (Albers and Szaro, 1978; King and Lefever, 1979; Albers, 1980). Clutches of common eider eggs treated with 20 μl of fuel oil had significantly greater embryonic mortality than control clutches (Albers and Szaro, 1978). Hatching success was significantly reduced for mallards with plumage exposed to 100 ml/m^2 (0.1 mm) of Prudhoe Bay crude oil for 48 hours while incubating eggs (which were oiled by transfer from the adult plumage), whereas the reduction in hatching success was not significant at 5 ml/m^2 of oil exposure. However, survival rates of newly hatched ducklings and adults exposed to up to 100 ml/m^2 oil were not significantly lowered (Albers, 1980). Mortality of mallard (*Anas platyrhynchos*) eggs treated with 1 and 5 μl South Louisiana crude oil was 35% and 91%, respectively. For chicken (*Gallus gallus*) eggs, mortality was 38%, 80% and 98% with applications of 1, 5 and 10 μl of oil, respectively (Hoffman, 1978).

Wolfe and Esher (1981) exposed rice rats (*Oryzomys palustris*) to 200 ml/m^2 (~200 g/m^2) and 20 ml/m^2 (~20 g/m^2) of crude oil on the water surface in laboratory test chambers with 1 m^2 water and two islands. In both exposures, willingness to enter the water and swim was reduced, whereas survival 24 hours later was significantly lowered in the higher exposure treatment. Survival rate was not measured beyond 24 hrs after exposure. These results suggest that mortality would occur for other semi-aquatic mammals, such as muskrat (*Ondatra zibethicus*), nutria (*Myocastor coypus*), mink (*Mustela vison*), and otter (*Lutra canadensis*) that swim through oil. River otters were observed to be killed by *Exxon Valdez* oil (Spies et al., 1996).

Little research is available to quantify oil exposure effects on sea turtles. Much of what is available is synthesized by Vargo et al. (1986). In addition to direct mechanical and toxic effects, impacts include reduced hatching rates and developmental deformities (Milton et al. 2003). For turtles of all ages, ingestion of tarballs is a major issue because turtles eat anything that appears to be the same size as their preferred prey. Ingestion can result in starvation from gut blockage, decreased absorption efficiency, absorption of toxins, buoyancy problems from buildup of fermentation gasses, and other effects (Milton et al. 2003). Inhalation of vapor is of concern for turtles since when they prepare for a dive they inhale a large volume of air before submerging. They thus have prolonged exposures to any inhaled hydrocarbons. Sea turtles have not been shown to exhibit avoidance behavior when surrounded by petroleum fumes (Milton et al. 2003).

The model utilizes an estimate of the minimum (external) dose of oil that is lethal. While there is one observation of a 70 ml dose causing a significant change in metabolic rate, 200-500 ml has been observed as a lethal dose when applied to the plumage of ducks (Jenssen, 1994). In the model, 350 ml is assumed to be the lethal dose for all wildlife. Assuming swimming bird has a width of 15 cm, it would need to swim through 23 m of oil of 100 μm thickness, 230 m of oil of 10 μm thickness, or 2300 m of oil of 1 μm thickness, to obtain a dose of 350 ml. This distance spent in oil need not be in a straight line. If an animal swims 10 m/min., 23 m would be covered in about 2 minutes; 230 m in 23 min; and 2300 m in 230 min (3.8 hrs).

To determine a dose obtained by a wildlife individual swimming through oil, the area and thickness of the oil intersected need to be estimated. The SIMAP physical fates model provides an estimate of slick size (radius of a "spillet" treated as a circle) and thickness at any given time and location. If the volume of the spillet is less than 20 ml, no effects are assumed. Spillets with greater than 20 ml of oil are assumed to oil birds sufficiently to affect hatching success (if within the nesting season for the species). If the diameter of the spillet is less than 230 m, a thickness of 100 μm is assumed as a threshold thickness for oiling mortality of wildlife. If the spillet is larger than 230 m in diameter, 10 μm is assumed as a threshold thickness for oiling mortality.

3.1.3 Probability of Encounter with Oil and Mortality

The behavior of species influences the likelihood of their being oiled. Characteristics which make certain bird species more susceptible to oiling include:

spending large periods of time on the water, weak flying capability such that they dive often, having flightless feather-molting stages, diving foraging behavior, and roosting at night on water (Speich et al., 1991). Birds that roost on land (e.g., gulls, cormorants) would have a lower probability of oiling (integrated over a daily time step). Thus, the probability of encounter with the slick is related to the percentage of the time an animal spends on the water or shoreline surface, including any diel or oil avoidance behavior.

Birds, mammals, reptiles, and amphibians (wildlife) are categorized by behavior patterns, i.e.,:

- Dabbling waterfowl and surface seabirds: surface divers (ducks, geese, swans, coots, murres) spend most of their time on the surface of the water and fly from place to place only occasionally.
- Aerial nearshore divers: birds that fly over the habitat most of the day time and dive for food (e.g., gulls, terns, osprey).
- Aerial seabirds: birds that fly over the habitat most of the time and dive occasionally (e.g., albatross) or have demonstrated oil avoidance behavior (e.g., fulmar).
- Wetland wildlife: wading birds, shorebirds, muskrats, and other wildlife typical of wetlands and shallow water habitats that walk, wade or swim in shallow water, wetlands, and intertidal or shoreline habitats.
- Terrestrial wildlife: Animals which typically walk and forage in shoreline or wetland habitats, and do so only a small percentage of their time.
- Marine wildlife: Marine mammals and sea turtles swim on the surface or live under it some percentage of the time.

Once oiled, it is generally agreed that birds have a very low survival rate, even when rescue and cleaning is attempted (Bourne et al., 1967; Holmes and Cronshaw, 1977; Croxall, 1977; Ohlendorf et al., 1978; Chapman, 1981; Ford et al., 1982; Samuels and Lanfear, 1982; Varoujean et al., 1983; Ford, 1985; Evans and Nettleship, 1985; Fry, 1987; Seip et al., 1991; Anderson et al., 2000). Death may be due to loss of body heat, toxicity through the skin, and/or ingestion of toxins via grooming. Also, death may not be immediate. Samuels and Lanfear (1982) estimated that 95% of oiled seabirds die while most of the other authors cited above estimate the probability of dying near 100%. Thus, the probability of mortality once oiled is assumed 100% for birds and fur-covered mammals (assuming they are not successfully treated) and much lower for other wildlife.

The estimated products of the two probabilities for various wildlife behavior groups are in Table 1. Estimates for the probabilities are derived from information on behavior and field observations of mortality after spills. Table 2 contains generic category estimates, also calculated in the model.

Table 1. Combined probability of oil encounter and mortality once oiled assumed for species groups, if present in the area swept by oil exceeding a threshold thickness. Area swept is calculated for the habitats occupied.

Wildlife Group	Probability	Habitats Occupied
Surface divers: dabbling waterfowl	99%	Intertidal, wetland, near-shore waters, bays, lakes, ponds, rivers/streams

Wildlife Group	Probability	Habitats Occupied
Surface divers: seabirds	99%	All intertidal and waters
Nearshore aerial divers	35%	Intertidal, wetland, near-shore waters, bays, lakes, ponds, rivers/streams
Aerial seabirds	5%	All intertidal and waters
Wetland birds (waders, shorebirds)	35%	All wetlands, shorelines, seagrass beds
Terrestrial mammals in wetlands and on shorelines	0.1%	All wetlands, shorelines
Raptors (other than eagles and osprey)	0.1%	Intertidal, wetland, near-shore waters, bays, lakes, ponds, rivers/streams
Cetaceans	0.1%	All subtidal marine waters
Furbearing marine mammals	75%	All intertidal and marine waters
Furbearing aquatic mammals	75%	All shorelines and nearshore waters (freshwater and estuarine systems)
Non-fur-bearing pinnipeds, manatee	1%	All marine intertidal and waters
Sea turtles (juvenile, adult)	5%	All subtidal marine waters
Sea turtles (hatchlings)	50%	All subtidal marine waters*
Terrestrial reptiles and amphibians	75%	All shorelines and waters (typically freshwater systems)

* Oiling on nesting beaches is evaluated geographically, based on mapped information.

Table 2. Combined probability of encounter with oil and mortality once oiled for generic behavior categories, if present in the habitats listed and area swept by oil exceeding a threshold thickness.

Wildlife Group	Probability	Habitats*
Surface birds in seaward habitats only	99%	All seaward intertidal and subtidal
Surface diving birds in seaward habitats only	35%	All seaward intertidal and subtidal
Aerial divers in seaward habitats only	5%	All seaward intertidal and subtidal
Surface birds in landward habitats only	99%	All landward intertidal and waters
Surface diving birds in landward habitats only	35%	All landward intertidal and waters
Aerial divers in landward habitats only	5%	All landward intertidal and waters
Surface diving birds in water habitats only	35%	All waters
Aerial divers in water only	5%	All waters

* Intertidal includes all between-tide or terrestrial areas flooded by tides or by storm surges; seaward and landward designations are operationally defined for the area modeled, e.g., marine = seaward and estuarine = landward or estuarine = seaward and freshwater = landward.

Documentation of the probability of oiling and the mortality of wildlife which have been oiled is not readily available due to difficulties in obtaining estimates. Accurate beach counts of dead animals are not enough, since many dead individuals sink or are consumed before being washed ashore (National Research Council, 1985). In studies of the *Puerto Rican* and *Apex Houston* spills (Point Reyes Bird Observatory, 1985; Page and Carter, 1986; Page et al., 1990; Carter et al., 2003), 20 to 52 percent of oiled birds recovered from beaches were dead or died following recovery. In order to estimate the total mortality of birds attributable to each of the spills, the Point Reyes Bird Observatory scientists estimated how many birds died but were not observed. From observations of the trajectory and path width of each spill, the density of birds in the area and estimates of daily carcass deposition and survival rates for beached oiled birds, they estimated the number of birds killed by the spill for seabird species groups. The estimated mortalities averaged 90% in the *Puerto Rican* spill and 68% in the *Apex Houston* spill. These rates would be overestimates to the extent that some oiled birds survived oiling but were not observed. However, they are underestimates to the extent that oiled birds flew off to other areas before dying.

This approach (termed the Beached Bird Model, Page et al., 1990; Carter et al., 2003) of estimating total mortality from counts of oiled animals has been utilized in several large oil spill cases in the US (e.g., *Puerto Rican*, *Apex Houston, Exxon Valdez*, *Kure*, *New Carissa*, *Stuyvesant*, *Luckenback).* The calculations include corrections for losses at sea, losses on shorelines after beaching, background non-spill-related beaching rates, and observational effort and search success (Carter and Page, 1989; Ford, 1987; Ford et al., 1996). Results of these and similar detailed studies provide data for estimating probability of oiling if a bird is present in the area swept by oil.

Studies of the *Exxon Valdez* incident provide such estimates. Gundlach et al. (1991) give an estimate of 30,000 km^2 of water surface swept by oil slicks and sheen. Within this area Piatt et al. (1990) estimated that 283,000 – 370,000 seabirds were present in April 1989 when mortalities occurred. Piatt et al. (1990) estimate 100,000 – 300,000 seabirds were killed or 61% percent of those present using the midpoints. U.S.A. (1991) estimated bird kills at 260,000 – 580,000, which is 78% using the midpoints. Later reports were that about 250,000 seabirds were oiled (Spies et al., 1996; Ford et al., 1996), inferring 77% of those birds present in the area were oiled. Of these, 74% were murres.

Wilhelm et al. (2007) observed 50% of murres and 8% of dovekies on the sea surface at any given time, as opposed to flying, in the area of a crude oil spill off Newfoundland. Their mean estimate of birds oiled assumed 50% of the flying birds and all the birds on the water would intersect the oil, i.e., 75% of the murres and 54% of dovkies. However, for the flying birds Wilhelm et al. (2007) simply picked the mid-point of a range of up to 100% that would likely be oiled.

The above estimates are for seabirds of a variety of species, some of which are surface swimming and would have a high probability of contacting surface slicks (e.g., murres), while other species are aerial divers and would have a lower probability of oiling (Holmes and Cronshaw, 1977; King and Sanger, 1979; Varoujean et al., 1983; Ford et al., 1982; Samuels and Ladino, 1984; Holmes, 1984; Ford, 1985; Evans and Nettleship, 1985; Seip et al., 1991). Ford (1985) estimates the probabilities of slick encounter and subsequent mortality for several bird species. His estimates average 90% for surface swimmers and 35% for aerial divers, assuming no avoidance of slicks. These values are consistent with estimates derived from spill observations cited above. Values assumed for P_w in the present model are in Table 1. For surface swimming birds, 99% is used because the majority of evidence shows that oiled birds do not survive.

Aerial seabirds spend much of their time flying above the water surface. They are not oiled in large numbers in oil spills. A probability of 5% is reasonable (Table 1). This group would also include species known to avoid oil, such as fulmars (Lorentsen and Anker-Nilssen, 1993).

For waders and shorebirds, little information is available for estimation of probability of oiling and mortality given a slick's presence. Chapman (1981) observed shorebirds along the South Texas coast as the *Ixtoc* blowout oil came ashore there. He observed up to 10% of shorebirds present were oiled on average. At the time of maximum shoreline oiling, 40% of royal terns were observed oiled, this being the most vulnerable species. However, the oil was present as mousse and tar balls over 2 months old, in scattered patches. Chapman (1981) did observe avoidance behavior, but the availability of clean beach may have facilitated this. Thus, 10% or even 40% would be too low an estimate for probability of oiling on a beach covered with fresh oil. Since these species do contact the surface much like surface swimming birds, and oil on feet was observed by Chapman (1981) to be transferred to plumage and so be ingested, probabilities of oiling and dying are most likely near the high end of this range for waders and shorebirds. A value of 35% is assumed in the model (Table 1) and applied when oil on shorelines exceeds 100 g/m^2. At this oil thickness, a bird would need to move along a path 35 m long and 10 cm wide to obtain a lethal dose of 350 ml. Thus, the assumed threshold thickness is reasonable, as more scattered oil on a shoreline would require proportionately longer distances where birds would be in contact with oil.

For mammals, the evidence is that oiling most often causes mortality for semi-aquatic furbearers (e.g., muskrat, otter, mink, beaver) and for those marine mammals which have a fur pelage used for retaining body heat (e.g., sea otters and fur seals). This was born out in the *Exxon Valdez* incident where sea otters were the mammal species most heavily impacted (U.S.A., 1991). It was estimated that 3500 – 5500 sea otters were killed by *Exxon Valdez* oil (Spies et al., 1996). The cause of mortality for fur bearing mammals is both due to loss of body heat (exposure) and to ingestion of toxins via the frequent grooming of the pelage (Wragg, 1954; McEvan et al., 1974; Geraci and Smith, 1976; Engelhardt, 1983, 1987; Geraci and St. Aubin, 1988). It is reasonable to assume that marine and semi-aquatic furbearers will have similar sensitivity to oil (Engelhardt, 1983; and by comparison of the results of Wragg, 1954, McEvan et al., 1974, and Wolfe and Esher, 1981, for muskrats to those of the other citations above). Ford (1985) has estimated a probability of an oiling encounter plus subsequent mortality for furbearing mammals (fur seals) at 75%. This value is assumed for all swimming furbearers in the model.

It was estimated that 200 harbor seals were killed by *Exxon Valdez* oil (Spies et al., 1996). Other non-fur-bearing marine mammals could not be definitively documented as having been killed by the *Exxon Valdez* oil, although inferences from circumstantial evidence were made (Loughlin et al., 1996). Similarly, in an earlier spill in the Santa Barbara Channel, sea lions did not appear to suffer high mortality rates from oiling (Simpson and Gilmartin, 1970; Brownell and LeBoeuf, 1971; LeBoeuf, 1971). For non-furbearing pinnipeds, a low probability of oiling and mortality of 1% is assumed; while for cetaceans 0.1% is assumed (Table 1).

No estimates are available for raptors. Since bald eagles and osprey behave as aerial divers, diving for fish in the near-shore area, the estimated probability of dying of oiling is assumed to be 35%, as for other aerial diving birds. For other raptors (hawks, owls, etc.) the probability of oil mortality would be much lower because of lower encounter frequency. An estimate of 0.1% is assumed (Table 1).

Sea turtle behavior and likelihood of exposure to oil are reviewed by Vargo et al. (1986) and Shigenaka (2003, see especially Milton et al., 2003). A summary of the major spills where impacts to turtles were observed is available in Yender and Mearns (2003). Turtles do not exhibit avoidance behavior when encountering an oil slick (Milton et al. 2003). Hatchlings are the most vulnerable stage because only a small amount of oil is needed to completely coat them. Also, since smaller turtles have more limited motility, they are often caught in the same currents as oil slicks and can end up in convergence zones more frequently than juveniles or adults. Finally, hatchlings spend more time on the surface than older turtles, thus increasing the potential for contact with oil slicks (Milton et al. 2003). Once oiled, hatchlings may not be able to swim as well, thereby increasing their predation risk.

The oiling probabilities for sea turtles were derived from the following. Data from small, attached time-depth-location data logger devices, and miniature video-cameras, indicate that adult and juvenile sea turtles at sea spend only 1 to 10 % of their time at the surface, and each dive duration is generally between 30-70 minutes (Blair Witherington, Fish and Wildlife Conservation Commission, Florida Marine Research Institute, Sea Turtle Research Station, Melbourne, FL, and David Bernhart – NOAA/NMFS Southeast Region Office of Protected Resources, St. Petersburg, FL, personal communication, September 2001). Regarding the effects of oil, literature indicates a moderate to high short-term survival rate if oiling occurs (Vargo et al., 1986). There are few definitive data regarding the long term effects of oil on any reptile. The value of 5% for this combined factor is reasonable for adult and juvenile sea turtles, based on the available information.

Field observations of hatchling sea turtle behavior at sea were described by B. Witherington (pers. comm., September, 2001). Hatchlings are very buoyant and have little ability to dive (estimated maximum dive depths are 6-7 meters and less than 1 minute duration), and may dive only to avoid predation by birds. Hatchlings spend most (~99%) of their in-water time at the surface. Their size and anatomy that would make them susceptible to passing oil and potentially dying from suffocation as a result of this exposure. Hatchlings are small (41-78 mm SCL, 18-50 g, mostly less than 25 g), can only lift their head 1 or 2 cm above the surface, and have very tiny nares, about 0.5 mm diameter. The literature indicates hatchlings are injured by both fresh and weathered oil, but can survive in the short term (several weeks) after acute (2 day) exposure to weathered oil (Vargo et al., 1986). The likely range of probability for oiling and dying is 10-100%, with 50% as a best estimate.

Other aquatic reptiles are modeled using information for sea turtles, as these are the only reptiles where such information related to behavior and vulnerability to oil is available. Impacts to terrestrially-based turtles and snakes present in oiled habitats would likely occur at oil doses similar to those for sea turtles. However, probability of oiling of these animals (when oil is present in the habitat occupied) is likely higher than for sea turtles that spend much of their time underwater. Thus, the probability of oiling for terrestrially-based reptiles present in oiled habitats is assumed 75%, similar to fur-bearing mammals. The probability of oiling for terrestrial stages of amphibians (e.g., frogs, toads) present in oiled habitats is also assumed 75%.

In addition, any reptile eggs laid in an oiled habitat would likely be lost, as evidence shows that sea turtle eggs are killed by small doses of oil (Vargo et al., 1986). The evidence from studies on bird eggs (reviewed above) are supportive that reptile eggs should be vulnerable at low oil doses as well.

In the model, area swept is calculated for the habitats occupied by each of the behavior groups of wildlife listed in Table 1. A species or species group is assigned to a behavior group to evaluate its loss, which is calculated as the area swept multiplied by the combined probability (Table 1) and the density at the time of the spill.

The wildlife mortality model applied to birds and sea otters was evaluated with more than 20 case histories, including the *Exxon Valdez* and other large spills, verifying that these values are reasonable (French and Rines, 1997; French McCay 2003, 2004; French McCay and Rowe, 2004). Insufficient data are available to evaluate the model algorithms for other wildlife groups.

Wildlife mortality is directly proportional to abundance per unit area and the percent mortalities in Table 1. Note that the abundance of a species should be specific to the affected area at the time of the spill. For example, in the case of severe storm events such as the hurricanes, bird abundance may be lower than normal due to avoidance of the storm. Thus, the density data used for impact estimations should reflect this behavior if it is known or assumed to occur. Model uncertainty is decreased when field data are used to estimate bird density and to calibrate the probability of an at-risk bird becoming oiled.

If densities are unknown, area affected by sufficient oil to cause a lethal dose can be used as an index of potential for impacts to any wildlife present in the areas oiled. The exposure index we have used for seabirds and other offshore wildlife is the water area swept by more than 10-μm thick (> 10 g/m^2) oil, which is sufficient to provide a lethal dose, as discussed above. The probability of exposure is related to behavior: i.e., the habitats used and percentage of the time spent in those habitats on the surface of the water. For shorebirds and other wildlife on or along the shore, an exposure index is length of shoreline oiled by > 100 g/m^2. Areas of exposure above these thresholds have been used in environmental risk assessment studies (French McCay et al., 2003a, 2004, 2005a,b,c).

3.2 Aquatic Biota: Fish, Invertebrates, and In-Water Stages of Amphibians

The most acutely toxic components of oil to water column and benthic organisms are low molecular weight compounds, which are both volatile and soluble in water, especially the aromatic compounds (Neff et al., 1976; Rice et al., 1977; Neff and Anderson, 1981; Malins and Hodgins, 1981; National Research Council, 1985, 2002; Anderson, 1985; McAuliffe, 1987; and French McCay, 2002). This is because organisms must be exposed to hydrocarbons in order for uptake to occur and aquatic biota are exposed primarily to hydrocarbons (primarily aromatics) dissolved in water. Thus, exposure and potential effects to water column and bottom-dwelling aquatic organisms are related to concentrations of dissolved aromatics in the water. Exposure to microscopic oil droplets may also impact aquatic biota either mechanically (especially filter feeders) or as a conduit for exposure to semi-soluble hydrocarbons (which might be taken up via the gills or digestive tract).

The effects of the uptake and accumulation of the dissolved hydrocarbon components in tissues are additive. Thus, an additive acute toxicity model and available LC50 data for individual compounds (under known temperature and duration of exposure conditions) may be used to estimate the LC50 (lethal concentration to 50% of exposed organisms) of the mixture of monoaromatic hydrocarbons (MAHs) and PAHs in oil to which aquatic organisms are exposed. Note that the LC50 is a proxy measurement for the concentration that leads to sufficient uptake into tissues for lethal effects to occur for 50% of individuals exposed. (See French McCay (2002) for a detailed explanation of the derivation of the LC50-based model commonly used in aquatic toxicology, which is briefly summarized below). Oil toxicity is a function of MAH and PAH content and composition in the oil. The toxicity of oils and refined products has been estimated and verified with available bioassay data. The verified oil toxicity model may be used to estimate toxicity of untested oils under varying environmental conditions (French-McCay, 2002).

Hydrocarbons accumulate in lipids (such as in the cell membranes) and disrupt cellular and tissue function. The more hydrophobic is the compound, the more accumulation in the tissues and the more severe the impact. However, the more hydrophobic the compound, the less soluble it is in water, and so the less available it is to aquatic organisms. Thus, impact is the result of a balance between bioavailability (dissolved-component exposure) and toxicity once exposed (see review in DiToro et al., 2000).

PAHs are more hydrophobic than MAHs, and so are more toxic. There is a continuum from the most soluble and least toxic benzene (simplest MAH) through the naphthalenes (2-ring PAHs) to the 3- and 4-ring PAHs. The more complex 4-ring PAHs are so insoluble that they are not dissolved or (acutely) bioavailable to a significant extent. This functional relationship can be described by a regression model using available data on a variety of compounds and species (French-McCay, 2002). A similar approach has been used to develop US Environmental Protection Agency (USEPA) water and sediment quality criteria for PAHs (DiToro et al., 2000; DiToro and McGrath, 2000).

Because of the relative solubility and volatility of various MAHs and PAHs, and the relative concentrations of the various compounds in oil, most of the acute toxicity is caused by the PAHs, and specifically the substituted naphthalenes (C2- and C3-naphthalenes). However, all the compounds in the mixture contribute to toxicity (French-McCay, 2002).

Mortality is a function of duration of exposure – the longer the duration of exposure, the lower the effects concentration (see review in French McCay, 2002). This is due to the accumulation of toxicant over time up to a critical tissue concentration that causes mortality. The accumulation is slower for more hydrophobic compounds. The accumulation is also slower at colder temperature. Thus, for brief exposures at low temperature, toxic effects require a higher concentration than would be necessary at higher temperature or for instances where exposure times are longer (see Figure 3). At a given concentration after a certain period of time, all individuals that will die have done so. The incipient LC50 ($LC50_\infty$) is the asymptotic LC50 reached after infinite exposure time (or long enough that the asymptotic level is approached, Figure 3). At a given exposure duration, percent mortality is a log-normal function of concentration, with the LC50 the center of the distribution.

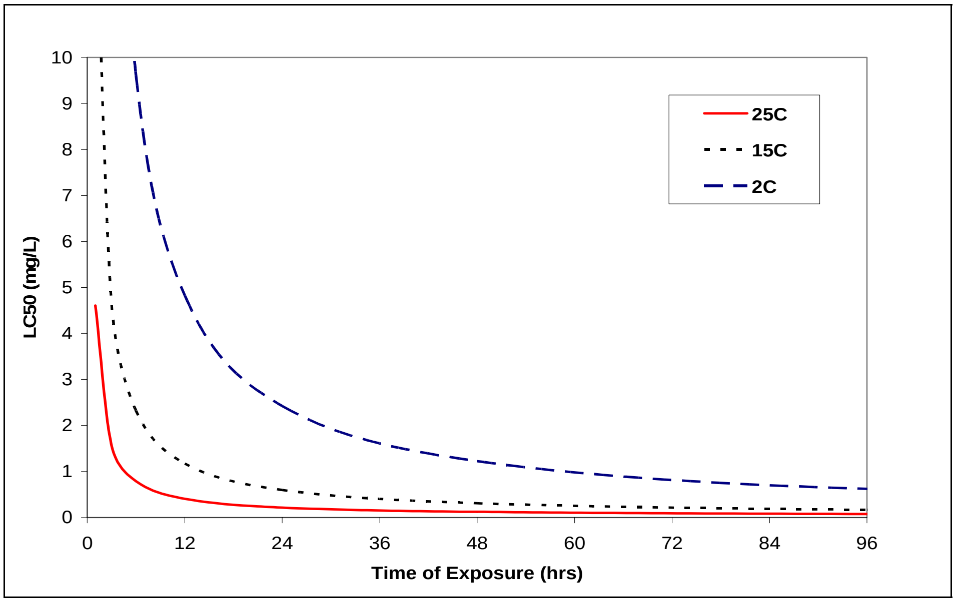

Figure 3. LC50 of dissolved PAH mixtures from oil, as a function of exposure duration and temperature (French McCay, 2002).

For most fuel and crude oils (where PAHs cause most of the toxicity), the value of $LC50_\infty$ ranges from 5-400 μg/L for 95% of species (Figure 4) exposed to dissolved PAH mixtures for over 96 hrs (which is sufficient time to approach the asymptote, as seen in Figure 3; French McCay, 2002). The $LC50_\infty$ for the average species is about 40-50 μg/L (ppb) of dissolved PAH (varying slightly among oils and fuels by percent composition of the PAH mixture). These $LC50_\infty$ values have been validated with oil bioassay data (French McCay, 2002), as well as in an application of SIMAP to the *North Cape* oil spill where field and model estimates of lobster impacts were within 10% of each other (French McCay, 2003).

Mortality of fish, invertebrates, and their eggs and larvae is computed as a function of temperature, concentration, and time of exposure. Percent mortality is estimated for each of a large number of Lagrangian particles representing organisms of a particular behavior class, i.e., planktonic, demersal (on the bottom), and benthic (in bottom sediments), or fish (or invertebrate nekton) that are classed as small pelagic (slower swimming), large pelagic (faster swimming), or demersal (near bottom) and occupying specific habitats (open water, wetland or reef; varying by seaward and landward habitats, as defined above). For each Lagrangian particle, the model evaluates exposure duration to dissolved hydrocarbons, and corrects the $LC50_\infty$ for time of exposure and temperature (Figure 3; see French McCay (2002) for equations). Percent mortality is then calculated from the mean exposure concentration, C, and the corrected $LC50_t$ using a log-normal function (with 50%

mortality at C = LC50$_t$, 1% mortality at C = LC50/100, and 99% mortality at C = 100 x LC50$_t$). The percent mortalities are summed, weighed by the area represented by each Lagrangian particle to estimate a total equivalent volume for 100% mortality. In this way, mortality is estimated on a volume basis, rather than necessitating estimates of species densities to evaluate potential impacts. In addition to the mortality estimates, the volume exceeding 1 µg/L total dissolved aromatics may be used as an index for exposure for fish, invertebrates, and plankton. The algorithms for these calculations are described in French McCay (2002, 2003, 2004).

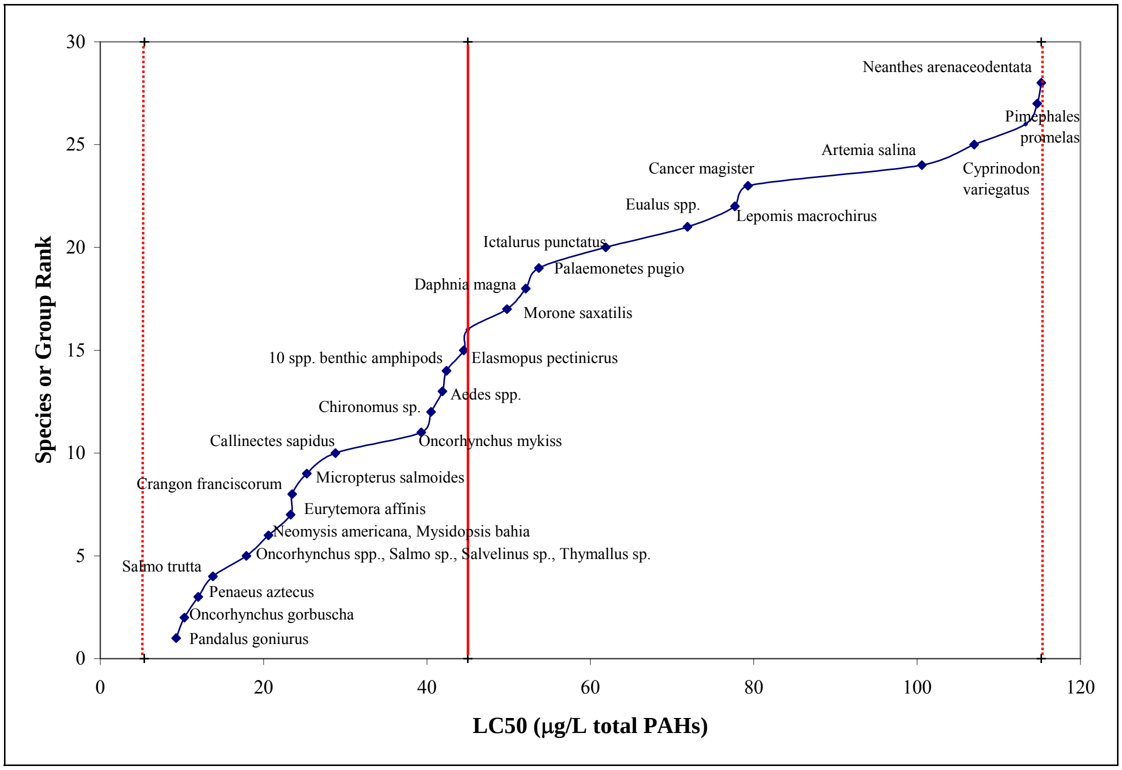

Figure 4. Variation in LC50$_\infty$ for dissolved PAH mixtures from a typical oil, by species in rank order of sensitivity (French McCay, 2002).

3.3 Sublethal Effects on Primary and Secondary Producers

Three primary producer categories are designated in the model: phytoplankton, benthic microalgae and macrophytes (macroalgae and/or angiosperms). Secondary and tertiary producers (primary and secondary consumers) which are not evaluated except through the food chain are divided into eight trophic categories: zooplankton, benthos, the air-breathing stages of insects, planktivorous forage fish, herbivorous forage fish, benthic forage fish, insectivores (e.g., moles, shrews) and small herbivorous mammals (e.g., rodents). Early life stages of insects which are aquatic are considered part of the benthos or zooplankton.

Estimates of primary production and secondary production are included in the biological database input to the model for each habitat type. Since organic carbon accumulation in sediments is less than 10% of supply in most environments, all primary production by phytoplankton and benthic microalgae is assumed to be consumed by the water column organisms and benthos (Hargrave, 1973).

Phytoplankton are assumed to inhabit the upper water column (or entire water column in shallow water or if it is mixed to the bottom) and to be uniformly distributed with depth. Thus, their exposure is to the concentration field in the surface water layer. Zooplankton are assumed to be distributed throughout the water column and are exposed to contaminant concentrations at all depths. Macrophytes, present only in shallow-water habitats, are assumed to be exposed to the average concentration over the entire water column. Benthic microalgae and the benthos are assumed to be exposed to sediment pore water concentrations.

For each time step and for each of the concentration grid cells output by the physical fates model, lost primary, zooplankton and benthic production (P_L) is calculated as follows:

$$P_L = (1 - F_k)\, P_i\, V\, \Delta t \qquad (2)$$

where F_k is the fraction of the uninhibited rate of production which is realized at the contaminant concentration, P_i is the rate of production (g dry weight m^{-3}/day^{-1}), V is volume contaminated (m^3), and Δt is the number of days contaminated. [Appropriate conversion factors for biomass and production are 12.5 from g C to g wet weight, and 40-45% of dry weight is carbon (Odum, 1971).] This calculation is performed for each habitat grid cell and vertical section of the water column affected by toxic concentrations, at each time step (Δt). Total production loss is summed over time and space.

The value of F_k is calculated from the EC50 for growth, corrected for temperature, using the log-normal toxicity model (Section 3.2) relating cumulative response (in this case, percent growth rate, F_k) to concentration. However, unlike for $LC50_\infty$'s, the EC50 is not corrected for exposure time, i.e., reduction in growth rate is assumed to be uniform over time. Since P_i is a rate per time, multiplication by Δt accounts for exposure time.

Concentrations from the spill are assumed to either be toxic (if the concentrations are high enough) or to have no effect on productivity. Although stimulation of phytoplankton primary production has been noted in a few studies, in the vast majority of studies, negative effects have been observed (National Research Council, 1985).

Biomass of upper trophic level biota which is not produced as a result of a loss of food resources from affected lower trophic levels (i.e., P_L) is estimated using a simple food web model. The portion of the lost primary production which would have produced primary consumer (secondary producer or herbivore) biomass is estimated based on observations of ecological efficiency made on representative ecosystems. Angiosperm biomass passes up the food web primarily via detritivores consuming the plant material and (more importantly) the attached microbial communities (Teal, 1962; Odum and de la Cruz, 1967; Thayer et al., 1984; Howes et al., 1985; Newell and Porter, 2000). The detritivores are then prey for larger animals (e.g. in marshes: decapods, such as grass shrimp, *Palaemonetes pugio*, and small fish, such as the mummichog, *Fundulus heteroclitus*, and other killifishes) and ultimately support production of recreationally and commercially important finfish, shellfish, waterfowl and wading birds (Teal, 1962). The ecological efficiency of detritivore production per unit primary producer production is low because a high percentage of biomass produced by the plant is broken down by microorganisms (primarily fungi at a transfer efficiency of 55%: Newell and Porter, 2000) before it can be assimilated by detritivores. Benthic meiofauna and macrofauna also directly consume benthic and epiphytic microalgae directly. French McCay and Rowe (2003) estimated the transfer efficiencies from plants to detritivores as 3.4% in (*Spartina*-dominated) saltmarsh and 7.2% in seagrass beds. Transfer efficiencies for woody vegetation would be lower than these values. As a general value, 4% is assumed in the model.

Values for production of predator per unit production of prey (i.e. ecological efficiency) for invertebrate and fish consumers of animal prey have been estimated to be 10-30% in both freshwater and marine environments by a number of authors (e.g. Slobodkin, 1960; Odum, 1971; Steele, 1974; Cohen et al., 1982; Pimm, 1982; Pauly and Christensen, 1995; Jennings et al., 2002). In the model, the transfer efficiency of fish and invertebrates consuming animal prey is assumed 20%.

For birds and mammals (which as homeotherms are less efficient), ecological efficiency is much lower, with estimates ranging from 1-5% (McNeill and Lawton, 1970; Steele, 1974; Whittaker, 1975; Grodzinski and Wunder, 1975; Pimm, 1982). In the model, the ecological efficiency of birds and mammals feeding on fish or invertebrate prey is assumed to be 2%.

Figure 5 shows the food web compartments used in the model. The fractions of the lost secondary production which would have been consumed by each of their predators are assumed to be proportional to the biomass of that predator relative to the sum of its competitors. The fraction of prey compartment *j*'s production which is consumed by predator *i*, a_{ij} is:

$$a_{ij} = \left(\rho_i \, B_i^{3/4} \right) / \sum_k \left(\rho_k \, B_k^{3/4} \right) \tag{3}$$

where B_i is biomass per unit area of predator *i*, B_k is the biomass per unit area of predator *k* which preys on *j*, where *k* represents all predators of prey *j* (including *i*), and ρ_i or ρ_k represents the ratio of consumption to biomass of the predator (*i* or *k*) relative to consumption to biomass of fish.

The correction factor ρ is based on the fact that homeotherms (birds and mammals) have higher metabolic rates at a given body size than poikilotherms (fish and invertebrates) and so have a higher consumption to biomass ratio (Zeuthen, 1953; Hemmingsen, 1960; Fenchel, 1974). Respiration rate has been shown to be proportional to body weight (W) to the 3/4 power (Kleiber, 1947; Zeuthen, 1953; Hemmingsen, 1960; Fenchel, 1974). Fenchel (1974) showed that the ratio of respiration rate to $W^{3/4}$ (where W = body weight) between homeotherms and poikilotherms is 28 (on average). Assuming food consumption is proportional to respiration rate, wildlife consumption per $W^{3/4}$ is 28 times fish consumption per $W^{3/4}$. In the biological submodel, all fish and invertebrates are assumed to have the same consumption to biomass ratio. Birds and mammals each are assumed to have 28 times higher consumption to biomass ratios at a given body size.

The total production of compartment *i* (P_i) is then equal to the sum of its consumption of prey production times the ecological efficiency, ε_i for the predator *i*.

$$P_i^{pred} = \varepsilon_i \sum_j a_{ij} \, P_j^{prey} \qquad (4)$$

where P_j is the production for prey compartment j. If the predator has no competitors, it consumes 100% of that prey's production.

Production rate estimates of primary producers (angiosperms and algae) and benthos are input to the model. Production rates of zooplankton, forage fishes, insects and secondary consumers not evaluated by individual species are calculated from their prey production rates and the trophic transfer efficiencies described above. For upper trophic level fish, invertebrate and wildlife species, biomass estimates are input to the model. Thus, in order to estimate production loss via a prey compartment where only biomass is known, i.e., for all upper trophic level losses resulting from lost primary and secondary production, the ratio of annual production to biomass (P/B) is assumed to be as derived by Banse and Mosher (1980), as follows: P/B = 0.65 $M_k^{0.37}$ for invertebrates, P/B = 2.75 $M_k^{0.26}$ for fish; and P/B = 12.88 $M_k^{0.33}$ for birds and mammals; where M_k is body mass in kcal (1 kcal/g wet weight for invertebrates, 1.3 kcal/g wet weight for fish, and 1.5 kcal/g wet weight for birds and mammals).

In calculating lost production of consumers in the food web, a proportionate loss of lower trophic level production is translated to a proportionate loss higher in the food web. For example, a 30% loss in phytoplankton is translated to a 30% loss in all of the upper trophic level production rates which are dependent ultimately on phytoplankton production. However, in the case where toxicity has reduced zooplankton, benthic or forage fish production to a greater degree than the reduction of primary production, consumers of zooplankton and benthos and forage fish are assumed to suffer proportionate losses to the losses for these food resources. Thus, zooplankton, benthos and forage fish are assumed either food limited or toxicant limited, whichever is greater.

Larvae of fish and invertebrates are assumed to feed entirely on zooplankton and to be food-limited. Feeding studies on fish larvae have shown that survival of larvae is dependent on finding high enough densities of food (Munk and Kiorboe, 1985). Thus, in the model it is assumed that reduced zooplankton production causes a proportionate reduction in larval (young-of-the-year) numbers. This is termed "indirect kill," as opposed to the direct kill via toxicity to larvae.

The output of this part of the model is lost production at lower trophic levels translated into losses of upper trophic level species (fish, invertebrates, and wildlife) as a result of the spill. This is added to the total direct kill to yield a total loss of biomass by habitat as a short term result of the spill.

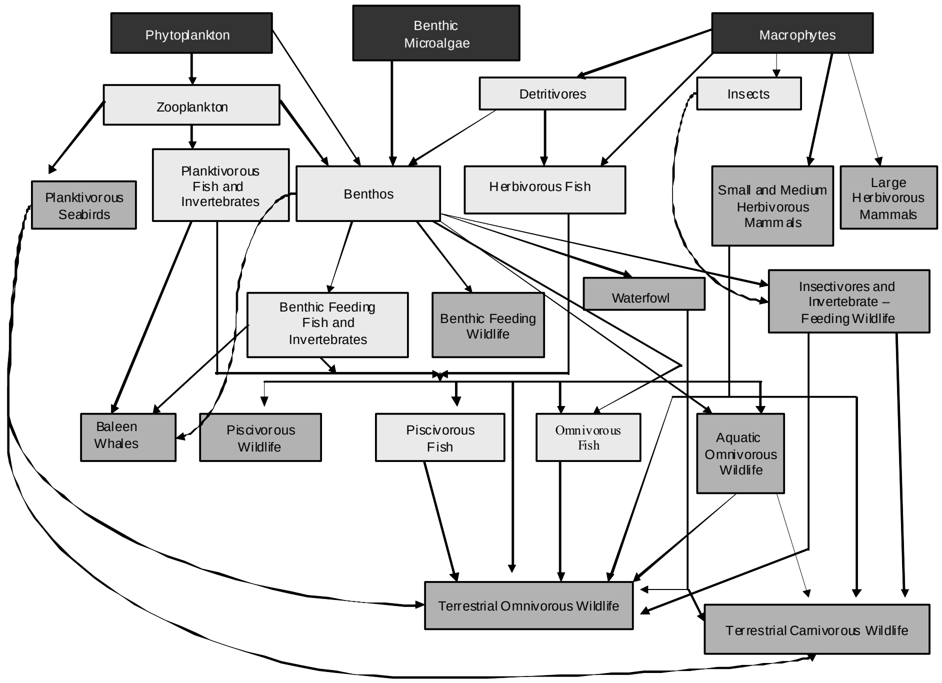

Figure 5. Food web compartments used in the model.

3.4 Intertidal, Wetland, and Terrestrial Plants and Invertebrates

In addition to the quantifying impacts in water habitats, the oiling of intertidal (wetland, rocky shore, gravel and sand beach, and mudflat) and temporarily flooded habitats with enough oil to impact plants and invertebrates may be evaluated. This is calculated as the area oiled above threshold(s) for injury times the habitat- and species-specific density or production rate of biota in that habitat and area.

Alexander and Webb (1985, 1987), Cubit et al. (1987) and Moody (1990) document mortality or other impacts on wetland vegetation by oiling in significant quantities. For submerged macrophyte and seagrass beds, dissolved concentrations of oil hydrocarbons are assumed to affect production, not surface floating oil. Exposure to floating oil is assumed lethal at the thresholds established below if the habitat area is not flooded with water at the time of exposure. No data are available to quantify effects thresholds for sunken oil on macrophytes.

Based on review of the literature performed in the late 1980s, French et al. (1996) assumed a threshold of 14 mm as lethal to wetland vegetation in the Type A model (NRDAM/CME). Alexander and Webb (1985) reported that 0.35 gal./ft^2 had a detrimental effect on Texas saltmarsh plants (*Spartina* spp), which is equivalent to about 14 mm-thick oil. The review by Moody (1990) supported the 14 mm threshold level. The Ile Grande marsh oiled by 50-200 mm of crude oil after the *Amoco Cadiz* spill was completely killed (Johnson and Pastorok, 1985). However, other data suggests the threshold for effects is lower than 14 mm. Baker (1971) reported that 0.5 mm of fresh Kuwait crude (a light oil) spread over saltmarsh vegetation was lethal when applied during the growing season (May or August), but if applied in November, growth in the following season was not affected. Baca et al. (1987) measured oil thickness in marshes where vegetation was killed by a heavy fuel spill in the Cape Fear River (NC) in 1982, finding 0.25-0.5 mm of heavy fuel oil coat on leaves of *Spartina* saltmarsh plants to be lethal and that the surface area of the affected marsh was covered with about 10 mm of oil. The reviews by Johnson and Pastorok (1985) and Shigenaka (2002) summarize other literature and case histories, and indicates that coating of the leaves is necessary for plant mortality.

Lin and Mendelssohn (1996) applied south Louisiana crude oil to natural marsh sods at rates of 0, 4, 8, 16 and 24 L/m^2 (1 L/m^2 is approximately 1 mm of oil), observing reduction in plant biomass above 4 L/m^2. The year following oil application, no regrowth of *Spartina patens* and *S. alterniflora* occurred at oil levels above 8 L/m^2. Lin et al. (2002) performed additional experiments with No. 2 fuel oil (diesel) applied to *S. alterniflora,* finding a significant decrease in total (above- plus below-ground) plant biomass at concentrations above 57 mg/g dry soil (= 2.5 L/m^2 = 2.5 mm) of oil. A significant decrease in below-ground biomass compared to the control was identified at a dosage as low as 29 mg/g dry soil (= 1.2 L/m^2 soil = 1.2 mm), but not at 14 mg/g (= 0.6 L/m^2 soil = 0.6 mm).

Based on these observations, it appears that more than 1 mm of oil during the growing season would be required to impact marsh or mangrove plants significantly. Thus, 1 mm is the assumed lethal threshold for wetland vegetation.

Numerous reports document suppression of intertidal invertebrate densities on visibly oiled shorelines and that invertebrates are more sensitive to oiling than intertidal macrophytes (e.g., Stirling, 1977; Boucher, 1980, 1985; Gilfillan et al., 1981; Cubit et al., 1987; Jackson et al., 1989; McGuinness1990; Garrity and Levings, 1993; Burns et al., 1993; Clarke and Ward, 1994; Ansari and Ingole, 2002; Yamamoto et al., 2003; Teruhisa et al., 2003; Anderson et al., 2008). However, specific measurements of the amount of oil required to lethally impact invertebrates are lacking. Owens and Sergy (1994) define oil "stain/film" as <0.1mm, oil "coat" as 0.1-1mm, and oil "cover" is 1-10mm. For benthic epifaunal invertebrates living in intertidal habitats on hard substrates, a threshold of 0.1 mm oil thickness would be enough to coat the animal and likely impact its survival and reproductive capacity, while stain (<0.1 mm) would be less likely to have an effect. Thus, 0.1 mm (100 g/m^2) of oil is assumed as the lethal threshold for invertebrates on hard substrates (rocky, artificial/man-made, rip-rap, etc.) and sediments (mud, silt, sand, or gravel) in intertidal habitats.

The impact thresholds are 1 kg/m^2 (1 mm) for vegetation and 100 g/m^2 (0.1 mm) for invertebrates. Injuries to wetland and intertidal biota oiled at these levels or higher are calculated as the product of the normal production rate (g dry weight m^{-2} day^{-1}) and the m^2-days of loss realized over a recovery period where production hyperbolically increased back to the pre-spill level over a specified number of years (based on literature documenting such recovery rates). Discounting at 3% per year is included to translate losses in future years (interim loss) to present-day values. The discounting multiplier for translating value *n* years after the spill to present value (i.e., for the year of the spill) is calculated as $(1+d)^{-n} = 1/(1+d)^n$, where d=0.03.

The recovery of plant or invertebrate production in an oiled habitat is assumed to follow a sigmoid function described by:

$$\frac{dP_R}{dt} = a_r P_R (1 - P_r) \quad (5)$$

where P_R is portion recovered, t is time, and a_r is a constant. The sigmoid function was chosen since, at first, recovery is slow while seeding/settlement and early succession takes place. Later recovery speeds up as filled-in vegetation and new settlers grow rapidly, but the final establishment of the mature habitat proceeds at a slower rate. The value of the constant a_r is derived from solution of the equation assuming P_R at $t = 0$ is 0.01 and P_R at $t = t_{rec}$ is 0.99, where upon the above equation may be solved using

$$P_R = 1/(1 + 99\, exp(-a_r t)) \tag{6}$$

What is needed is one data point of P_R at some time t. At $t = t_{rec}$, $a_r = 9.19/t_{rec}$.

In the model, losses are integrated over time using this recovery curve equation. The loss in the time interval t to $t+\Delta t$ (P_L) is calculated as follows:

$$P_L = (1-P_R)\, P_i\, A\, \Delta t \tag{7}$$

where P_i is the normal (pre-spill) production rate in the habitat, A is the area affected, and Δt is the time step.

Literature regarding the recovery rate of vegetation or other habitat structure after the structural organisms are killed or severely damaged is reviewed below and summarized in Table 3. Assumed values of t_{rec}, the time to 99% recovery, are specific to habitat type and are based on experiences from observations of natural recovery following disturbance (including spills) and from habitat creation projects. Much of the wetlands creation and restoration literature emphasizes that correct hydrology be established on the site before planting, that soils are fertile, and that the site must be properly maintained and monitored (Mancini, 1989). If these conditions are met, recovery of structure and function is much more rapid and successful. As the recovery in the model is for areas which are naturally those habitats, it is assumed that the hydrology and soils remain, and that recovery is as rapid as could be expected.

Time for recovery (to 99% function) for intertidal invertebrates (based on a natural recovery curve) is estimated as 3-5 years (French et al., 1996; Table 3; also see review below). It is assumed that the affected areas are not cleaned in a manner that would slow recovery.

Table 3. Recovery rates for vegetation or other structural organisms in habitats, and for benthic invertebrates where habitat structure is not impacted (based on review below).

Habitat	Description	Vegetation or Structure: Years to 99% Recovery	Benthic Invertebrates: Years to 99% Recovery
Rocky Shore	Rocky shore (including rock seawalls) without significant seaweed cover	-	3
Artificial Shore	Vertical piers, seawalls made of artificial, man-made materials	-	3
Gravel Beach	Gravel or cobble beach without significant seaweed cover	-	3
Sand Beach	Coarse- or fine-grained sand beach	-	3
Mud Flat	Silty-mud intertidal flats	-	3
Submerged Aquatic Bed	Seagrass or other submerged angiosperm-dominated habitats	10	3
Wetland: Emergent Marsh	Saltmarsh dominated by *Spartina* spp.; brackish marsh; intermediate marsh	15	5
Wetland: Swamp	Forested wetlands; shrub-scrub wetlands	20	5
Macroalgal Bed	Kelp or other seaweed	15	5
Coral Reef	Reefs dominated by coral	30	30
Mollusk Reef	Oyster or mussel reef	3	2

Rocky, Man-made and Artificial Shores

The *Esso Bernicia* spill in 1978 oiled rocky shorelines of the Shetland Islands and recovery was monitored for nine years. Shores which were left untreated had nearly recovered by one year later, whereas those shores which were cleaned and where the biota were obliterated had not recovered after nine years (Rolan and Gallagher, 1991). Houghton et al. (1991) observed that Prince William Sound rocky shores which were cleaned after the *Exxon Valdez* spill would take many years to recover. Broman et al. (1983) also observed that hot water cleaning after an oil spill in the Baltic Sea did more harm than good and slowed recovery dramatically. From Southward and Southward (1978), recolonization and recovery of rocky shores in Cornwall, England after the *Torrey Canyon* spill took 5-8 years if the shores were lightly oiled and received light dispersant treatment. Recovery took 9-10 years or more if the shore received repeated dispersant treatment. No sites were observed (or available) that were left untreated.

Baker et al. (1990) reported that rocky shores in the Baltic Sea had nearly recovered by one year after the *Tsesis* spill of 1977. As cited by Ganning et al. (1984) cleaning slows recovery: recovery from a medium fuel oil spill followed by mechanical cleaning in the Baltic Sea took four years, recovery from a Bunker C spill in Nova Scotia took greater than six years, and recovery from a No. 2 fuel oil spill in Baja California took over ten years. In contrast, Keller and Jackson (1991) summarize recovery of intertidal rock reefs in Panama following a medium crude oil spill as complete by one year. Yamamoto et al. (2003) and Teruhisa et al. (2003) documented decreased densities of invertebrates and vegetation in areas heavily oiled by the *Nakhodka* spill in Japan (but not cleaned). The flora and fauna recovered in 3 years. Jones et al. (1998), based on their own observations and data in Sell et al. (1995), estimate 2-5 years for recovery of rocky intertidal communities.

In the model, three years is assumed for 99% recovery (Table 2-2). Artificial shores, and rock and gravel beaches are assumed to have the same recovery rates.

Sand Beaches and Mud Flats

Keller and Jackson (1991) summarized recovery of sand beaches in Panama following oiling as being complete by 1 year, except for certain species. Bodin (1988) observed recovery of three sand beaches in Brittany, France after the *Amoco Cadiz* oil spill over the years 1978 to 1984, stating recovery of the meiofauna was complete by 1983 (5 years). Thomas (1978) observed recovery of invertebrates after 3 years on beaches oiled by the 1970 *Arrow* spill of Bunker C oil. Baker et al. (1990) cite evidence from the Baltic Sea after a 1970 spill of medium and heavy fuel oil with mechanical cleanup where recovery took four years. Judd et al. (1991) observed that Texas dune vegetation took 2-3 years to recover from removal experiments.

Thus, recovery rate is variable, depending on conditions and initial disturbance during the spill response. A median value of three years is assumed in the model (Table 3). Mud flats are assumed to recover at the same rates as sandy beaches.

Seagrass and Submerged Aquatic Beds

If seagrasses are not killed, and only leaves are injured, recovery can be rapid. Jacobs (1980) observed that eelgrass oiled by the *Amoco Cadiz* oil spill had blackened leaves and returned to normal productivity almost immediately. However, there were massive kills of invertebrates. The invertebrate community had mostly recovered by 2 years. In Panama, oil did not induce a total kill of seagrass beds, and they had recovered by 7 months after the spill (Keller and Jackson, 1991). Zieman and Zieman (1989) reviewed recovery rates for Florida seagrass beds. Their estimates are 6 months to 1 year for leaf damage, and 5 years to decades if rhizome damage is severe and no replanting is performed. They estimate it takes 2-5 years for invertebrates to recolonize a *Thalassia* bed.

In the model, if the vegetation is lost, it is assumed that replanting is performed, eliminating the recolonization lag. Recovery of the seagrass bed is assumed to take 10 years. Recovery of freshwater wetlands dominated by grasses or submerged angiosperms is assumed to take 10 years as well. If seagrass or other vegetation is not lost, invertebrates are assumed to recover in 3 years. Three years is assumed to be the recovery time for benthos in other benthic habitats.

Saltmarsh and Other Emergent Wetlands

Getter et al. (1984) state that recovery of saltmarshes after oiling takes 5-20 years, assuming no cleanup or restoration actions are performed. With cleanup and restoration (replanting), they estimate three years to vegetative cover. Baca et al. (1987) observed that marshes oiled by the *Amoco Cadiz* spill, but not cleaned or treated, had mostly recovered by 8 years.

Joy Zedler and colleagues (Pacific Estuarine Research Laboratory, PERL) followed recovery of experimentally created saltmarsh in Southern California for 7 years. In PERL (1990), they reported 60% recovery by 5 years. Two years later, recovery has not progressed significantly further (Joy Zedler, personal communication). Using the recovery model above, t_{rec} = 13 years if 60% recovery is in 5 years and t_{rec} = 18 years if 60% recovery is in 7 years.

The 130 acre Muzzi marsh in San Francisco Bay was observed for 10 years of natural recolonization. *Spartina* was dense in the channels by 5 years. In the marsh plain, it was still developing after 10 years. Species composition changed over time (Faber, 1991).

Blair (1991) reported that a saltmarsh created in Chesapeake Bay in 1984 was successful. He stated that it was nearly 100% recovered by 7 years to "almost" like a natural marsh.

Broome et al. (1986) reported on a created marsh along an eroding shoreline in North Carolina. *Spartina alterniflora* was transplanted and monitored for 10 years. The vegetation was equal to a natural marsh by 4 years. Other saltmarsh biota were not monitored.

Dunn and Best (1983) reported natural reestablishment of emergent freshwater marshes in Florida in 4-5 years. D'Avanzo et al. (1989) reports variable rates for freshwater marshes with recovery taking 2-5 years in some cases, but 15-30 years in others where soils used had no initial organic matter content.

Given the variability of recovery rates and of criteria used to estimate them, the literature does not provide a consensus of recovery time estimates. Where saltmarsh structure is lost, 15 years is assumed required for full recovery of all parts of the ecosystem (not just the vegetation). If the vegetation is not lost, 5 years is assumed for recovery of other functions, including invertebrate populations.

Forested and Shrub Wetlands (Swamps)

In examining a 6 ha mangrove forest killed after a JP-5 jet fuel spill, recovery was estimated as requiring 10 years after replanting (Ballou and Lewis, 1989). Lewis (1983) reviewed case histories of oil spills in mangroves. For one example, after a crude oil spill on St. Croix, U.S. Virgin Islands, there was no recolonization after 7 years. Recovery was estimated to require 10-50 years. Getter et al. (1984) estimated recovery after oil spill at 25-30 years if restoration were performed. Research Planning, Inc. (RPI, 1987) estimated 20 years for recovery of an oiled mangrove forest. Keller and Jackson (1991) speculated that for mangroves oiled and killed in Panama "full recovery may require many decades". Mature trees are 50-70 years old. Cubit et al. (1987) summarizes mangrove mortality and the more severe mortality of associated animals in these Panama habitats. Recovery was not complete after 5 years of monitoring. Additional review of literature on recovery of mangroves after oil spills is available in Hoff (2002).

In the model, it is assumed that replanting is performed (Section 5), eliminating the recolonization lag. Recovery of the mangrove swamp is assumed to take 20 years.

Macroalgal Beds

The most important macroalgal bed habitat is the kelp bed of the Pacific coast (*Macrocystis* spp.). Moody (1990) estimated that oiled kelp beds had 90% recovered in 3-4 years. However, after 14 years they had not fully recovered to pre-spill diversity. Foster and Schiel (1985) reviewed a 1957 oil spill in Baja California. There was massive mortality of invertebrates, but vegetation damage was less obvious. Vegetation increased rapidly (due to reduce grazing) by one year later. By four years later, most animal populations had recovered, but a few had not by six years. In the model, recovery time for the vegetation is assumed 15 years and for invertebrates where vegetation is unaffected, 5 years.

Coral Reefs

It is generally agreed that recovery of coral reefs after total destruction of the reef is very slow, but small scale impacts may take much less time for recovery. Brock et al. (1979) performed defaunation experiments on patch reefs in Hawaii. With all (and only) fish removed from small reefs, recovery took one to two years. Fucik et al. (1984) estimates that recovery after small scale localized destruction requires less than ten years. After heavy destruction, recovery takes 10-20 years. Severe impacts require several decades for recovery.

Keller and Jackson (1991) summarized observations on oiled coral reefs in Panama. At 0.5-3.0 m depth, 76% of coral was killed. At 3-6 m depth, 56% of coral was killed. Recovery was speculated to require more than a decade. There was no recovery after two years of observations. Additional review of literature regarding impacts and recovery of coral reefs after oil spills is available in Shigenaka (2001).

In the model, it is assumed that recovery following mortality of a reef requires 30 years (to 99% recovery).

Oyster Reef

Lenihan et al. (2001) found that the fish community compositions and species abundances on oyster reefs restored 6 years before sampling were largely indistinguishable from those on natural oyster reefs. Peterson et al. (2003) evaluated changes in abundance of fish and large mobile crustaceans on oyster reefs over time, finding that for reefs constructed in summer, development of fish and mobile crustacean abundance is virtually complete by the next spring-summer season. Densities do not increase in successive years (Grabowski, 2002). Thus, recovery of reef invertebrates, given structure already present, requires 1-2 years, depending on the timing of the spill impacts. Two years is assumed in the model.

However, if the reef structure is destroyed (e.g, during storms, Livingston et al., 1999), recovery of oyster reefs would take more time. Three years is assumed in the model.

3.5 Quantification of Fish and Invertebrate Impact as Lost Production

3.5.1 Approach

The biomass (kg) of fish and invertebrates killed represents biomass produced before the spill. In addition to this impact, if the spill had not occurred, the killed organisms would have continued to grow until they died naturally or to fishing. This lost future (somatic) production is estimated and added to the direct kill to calculate the total production foregone. The loss is expressed in "present day" (i.e., year of the spill) values using a 3% annual discount rate for future losses.

In a natural resource damage assessment (NRDA, based on US regulations and practice), restoration should compensate for this loss. The scale of restoration needed is equivalent to production lost when both are expressed in values indexed to the same year, i.e., the injury (impact) inflated to the year restoration occurs or the restoration discounted back to the year of the spill.

Interim losses are sustained in future years (pending recovery to baseline abundance) resulting from the direct kill at the time of the spill. Interim losses potentially include:

- Lost future uses (ecological and human services) of the killed organisms themselves;
- Lost future (somatic) growth of the killed organisms (i.e., production foregone, which provides additional services);
- Lost future reproduction, which would otherwise recruit to the next generation.

The approach used here is that the total loss includes the direct kill and its future services, plus the lost somatic growth of the killed organisms, which would have provided additional services. Because the impact on each species, while locally significant, is relatively small compared to the scale of the total population in the area, it is assumed that density-dependent changes in survival rate are negligible, i.e., changes in natural and fishing mortality of surviving animals do not compensate for the killed animals during the natural life span of the animals killed.

It is also assumed that the impacts were not large enough to significantly affect future reproduction and recruitment in the long term. It is assumed that sufficient eggs will be produced to replace the lost animals in the next generation. The numbers of organisms affected, while potentially locally significant, are relatively small portions of the total reproductive stock. Given the reproductive strategy of the species involved to produce large numbers of eggs, of which only a few survive, it is assumed that density-dependent compensation for lost reproduction occurs naturally.

The services provided by the injured organisms are measured in terms of production, i.e., biomass (kg wet weight) directly lost or not produced. Among other factors, services of biological systems are related to the productivity of the resources, i.e., to the amount of food produced, the usage of other resources (as food and nutrients), the production and recycling of wastes, etc. Particularly in aquatic ecosystems, the rate of turnover (production) is a better measure of ecological services than standing biomass (Odum, 1971). Thus, the sum of the standing stock killed (which resulted from production previous to the spill) plus lost future production is a more appropriate scaler, as opposed to standing stock alone (as number or kg), for measuring lost ecological services.

This injury estimation approach was developed and used previously in the injury quantification for the *North Cape* spill of January 1996 (French McCay et al., 2003b, French McCay and Rowe, 2003) and many other spill cases (e.g., French McCay et al., 2003c). The method makes use of the population model in SIMAP. Injuries are calculated in three steps:

1. The direct kill is quantified by age class using a standard population model used by fisheries scientists.
2. The net (somatic) growth normally to be expected of the killed organisms is computed and summed over the remainder of their life spans (termed production foregone).
3. Future interim losses are calculated in "present day" (year of the spill) values using discounting at a 3% annual rate.

The normal (natural in local waters) survival rates per year and length-weight by age relationships are used to construct a life table of numbers and kg for each annual age class. Production forgone is then estimated using the model of Jensen et al. (1988), which is commonly used in fisheries science (see below).

It should be noted that compensation would be needed for lost production of each of the individual species injured, and that losses are additive. Restoration for a prey species killed will compensate for that prey killed and all the services that prey would have provided in the future to its predators and other resources. The predators that would eat that prey but were directly killed were produced before the spill from *different* prey individuals as food. Thus, the predator's production loss must be compensated in addition to the prey animals directly killed. This may be accomplished by providing additional prey production to compensate for the direct predator loss.

3.5.2 Equations

The production foregone population model as described by the U.S. Environmental Protection Agency in its 316(b) rule (USEPA, 2004) is used. This approach is recommended by fisheries scientists and the models are those typically used for entrainment and impingement fisheries impact evaluations (EPRI, 2004). The equations are based on fisheries model development described in Ricker (1975).

The production foregone population model makes use of survival rates from one stage to the next. For eggs, survival to age one (S_{e1}) is calculated as:

$$S_{e1} = 2\ S_e\ e^{-\ln(1+Se)}\ S_L\ S_j \qquad (8)$$

where S_e, S_L, and S_j are the survival rates for each stage: egg, larvae, and juvenile. For larvae, survival to age one (S_{L1}) is calculated as:

$$S_{L1} = 2\ S_L\ e^{-\ln(1+S_L)}\ S_j \qquad (9)$$

Natural and fishing mortality rates for annual age classes are used to estimate numbers that would remain alive by each age class. The number remaining alive at age *t* (years), N_t, is:

$$N_t = N_1\ e^{(-Z_a\,(t-1))} \qquad (10)$$

$$Z_a = M_a + F_a \qquad (11)$$

where N_1 is the number at age one, Z_a is annual instantaneous total mortality, M_a is annual instantaneous natural mortality, and F_a is annual instantaneous fishing mortality, for age class *a*. The annual survival rate for age *t* (S_t) is thus:

$$S_t = e^{(-Z_t)} \quad (12)$$

The fraction dying in a year is $1\text{-}S_t$.

Yield foregone (Y_k) (i.e., equivalent yield, or lost catch) may be calculated using the Thompson-Bell equilibrium yield model (Ricker, 1975) where the harvest at each age class is calculated from number starting the class multiplied by fishing mortality rate, $(F_a/Z_a)(1\text{-}e^{-Za})$:

$$Y_k = \sum_j \sum_a L_{jk} S_{ja} W_a (F_a/Z_a)(1\text{-}e^{-Za}) \quad (13)$$

where:

Y_k = foregone yield (kg) in year k
L_{jk} = losses of individual fish of stage j in the year k
S_{ja} = cumulative survival fraction from stage j to age a
W_a = average weight (kg) of fish at age a
F_a = instantaneous annual fishing mortality rate for fish of age a
Z_a =instantaneous annual total mortality rate for fish of age a

Total natural mortality (TM_k) is calculated using an analogous model:

$$TM_k = \sum_j \sum_a L_{jk} S_{ja} W_a (M_a/Z_a)(1\text{-}e^{-Za}) \quad (14)$$

where M_a is the instantaneous annual natural mortality rate for fish of age a.

For this analysis, the losses are for eggs and larvae translated to 1 year of age, i.e., one stage where j=1.

Production foregone (USEPA, 2004, Chapter A-5; based on Rago, 1984 and Jensen et al., 1988) which includes yield (harvest) and the production consumed in the food web, is estimated using:

$$Y_k = \sum_j \sum_a [\, G_a L_{jk} W_a (e^{Ga\text{-}Za} - 1) \,]/[\, G_a - Z_a \,] \quad (15)$$

where G_a is the instantaneous growth rate for individuals of age a.

Length and weight at age are estimated using the von Bertalanffy equation and a power curve of weight versus length following methods in Ricker (1975). The equations used are as follows. For length (mm) at age t (years):

$$L_t = L_\infty \,[1 - e^{(-K\,(t - t_o))}] \quad (16)$$

where L_t is length (mm) at age t (years), L_∞ is the asymptotic maximum length (mm), K is the Brody growth coefficient, and t_o is a constant. Weight as a function of length (mm) is:

$$W_t = \alpha\, L_t^{\ \beta} \quad (17)$$

where W_t is wet weight (g) at age t years and α and β are constants.

Discounting at 3% per year (NOAA, 1997) is included to translate losses in future years (interim loss) to present-day values. The discounting multiplier for translating value *n* years after the spill to present value (i.e., for the year of the spill) is calculated as $(1+d)^{-n} = 1/(1+d)^n$, where d=0.03. Thus, the losses in future years have a discounted value at the time of the spill. In this analysis, all discounting will be calculated based on the number of years from the year of the spill. Thus, additional discounting is needed to translate all the injuries to compensatory equivalents for the year the restoration is performed. The multiplier for this calculation is $(1+d)^m$, where *m* is the number of years after the spill when restoration is accomplished.

4 Discussion

Validation

The model has been validated using simulations of over 20 spill events where data are available for comparison (French and Rines, 1997; French McCay, 2003, 2004; French and Rowe, 2004). In most cases (French and Rines, 1997; French McCay, 2004; French and Rowe, 2004), only the wildlife impacts could be verified because of limitations of the available observational data. However, in the *North Cape* spill simulations, both wildlife and water column impacts (lobsters) could be verified. Field and model estimates of lobster impacts were within 10% of each other (French McCay, 2003).

Hindcasts and NRDA

The model has proved useful in numerous hindcast studies as part of NRDAs. The most accurate approach for using a model in an NRDA is to obtain sufficient field data to provide input to the model and calibrate the results.

In the event of an oil spill, in order to fully characterize the impact by field sampling, water and sediment samples would be needed at frequent time intervals over the first few weeks after the release (and especially in the first 24-48 hours), and with enough spatial coverage to characterize the extent of contamination. In addition, comprehensive sampling of each of the species affected is needed in the exposed and unaffected areas. Because marine organisms are so patchy in their distribution, large numbers of stations and samples within stations are needed to accurately map abundance. Such extensive sampling of all (or even selected) species affected is often not feasible, given the rapidity at which the evidence disappears (by scavenging of killed organisms and by migration of animals into the impacted area). Thus, in practice, the needed sampling would require a considerable effort, which is usually both infeasible and too costly to be justifiable by the expected impact of the spill. In spite of these obstacles, historically, attempts at quantification have primarily been made by collecting field data. A more practical and realistic approach is to combine field sampling with modeling.

Biological sampling should be designed to establish pre-spill baseline (by number and weight for each species and life stage and by size classes, as appropriate) and what types of organisms were exposed. Biological effects modeling may then be used to quantify impacts. If it is feasible, field data collections could be focused on exposed species of particular concern, such that enough data might be collected to indicate and possibly quantify the impacts. If this is possible, such data may be used to verify the modeling results.

Modeling may be used to estimate the range of potential injuries, given the range in species sensitivity and acute toxicity values that have been observed in laboratory-based bioassays performed and reported previously (French McCay, 2002). Given the large variation in sensitivity of various species and life stages (Figure 4), and that many important species have not been tested, acute toxicity bioassays should be performed on exposed organisms of concern to provide more accurate estimates of impact. To simplify this and avoid artifacts of whole-oil bioassays, the toxicity tests can be performed for single hydrocarbon exposures and the toxicity of the dissolved hydrocarbon mixture resulting from oil exposure can be calculated from the bioassay results using the modeling approach described in French McCay (2002).

Risk Assessment Consequence Analyses

In environmental risk assessment studies (e.g., French McCay et al., 2003a, 2004, 2005a,b,c) the objective is to assess potential consequences if a spill were to occur. Hence, multiple model runs and conditions need to be evaluated to develop an expectation of risk of oil impacting each resource of concern. To evaluate the distribution of potential impacts resulting from variation in environmental conditions, the model is run many times, randomizing the start date and time. In addition or alternatively, various other model inputs may be varied within specified ranges or according to probability distributions, such as the spill volume, location, release depth, release duration, density of biota of concern, toxicity values, and assumed parameters for model algorithms. The multiple model runs provide a frequency distribution of model results, for which statistics (e.g., mean, standard deviation, maximum) are calculated and plotted, such as for probabilities of exceeding effects endpoints, areas impacted above these thresholds, or numbers of animals killed. Response strategies (i.e., removal from clean up, booming) may be incorporated into the model and considered in the assessment.

The potential spill conditions causing the median or the worst-case impacts to specific resources may be identified using the probabilistic model results. For example, a worst case for sensitive resources along the coast may be those wind and current conditions which would maximize exposure to those resources. The individual worst case scenario may then be examined in more detail, forecasting it using the 3-dimensional fates and biological effects models, quantifying the worst possible exposure for that resource of concern. Sensitivity analysis provides measures of uncertainty for these predictions. Other worst case scenarios may be identified for additional resources of concern, such as seabirds, marine mammal, sea turtles, fish, etc; and examined in detail with fates and biological effects model analyses. Alternatively, the range of potential impacts may be identified.

Research Needs

The above-described model represents the state-of-the-art for oil spill biological effects modeling. Research needs for informing model parameterization and developing new algorithms are outlined below.

- **Wildlife oiling probabilities**: For wildlife the probabilities of exposure to oil, given presence in the area swept by oil, would be less uncertain with additional quantitative observational data from spills. For example, counts by species in an area oiled could be followed up by counts of oiled birds recovered (with necessary corrections for losses and search effort).

- **Avoidance or attraction behavior**: Wildlife may avoid oil or learn to avoid oil. Alternatively, wildlife may be attracted to biota impacted by oil and become oiled. While many anecdotal observations have been reported, quantitative information to include such behavior in a model is lacking. Alternatively, the issue can be addressed by altering densities of animals exposed.
- **Fish and invertebrate behavior**: Behavioral detail for fish and invertebrates, both in general and in the presence of oil (e.g., avoidance, attraction), could potentially improve accuracy of the modeled movements. Data needed are the details of vertical distribution on a diel basis and overall migration speed of these organisms (as opposed to localized or temporary swimming speed).
- **Effects of suspended oil droplets**: To date, modeling has only quantified acute effects of dissolved hydrocarbon components. While anecdotal information exists to indicate that suspended oil droplets impact aquatic biota, data quantifying the dose-response relationship are lacking. In SIMAP, the fates and concentrations of suspended oil droplets are simulated, such that concentration estimates are available for such evaluations.
- **Impacts on neuston**: The sea surface environment provides an important habitat for many organisms commonly referred to as neuston. Fish eggs, fish larvae and crustacean larvae, including several commercially important species, have been found to encompass significant portions of neustonic communities (Grant, 1986). Besides the permanent invertebrate inhabitants of the surface layer, commonly referred to as euneuston, the larvae of several macroinvertebrates including various families of corals, crabs and spiny lobster have been observed to be concentrated in the surface layer. Larval fish of some species appear to actively seek the surface layer by adjusting their swim bladder to become buoyant (e.g., sardines, Santos et al., 2006). Certain species of fish are noted as having larval stages which are completely neustonic or surface dwelling (i.e. gurnards, (Dactylopteridae)) (Cowen, 2002). Floating fish eggs are particularly vulnerable to the impacts of oil (Longwell, 1977; Longwell and Hughes, 1980). These neustonic assemblages are subject to surface contamination, such as floating oil and oil entrained by breaking waves in the surface wave-mixed layer. Ignoring the presence of neuston has lead to underestimation of oil spill impacts in the past (Grant, 1986). Observational and experimental information is needed to support model algorithm development and parameterization.
- **Impacts on surfacing fish**: In addition to larvae and zooplankton, there are several species of adult fish which utilize the sea surface habitat, e.g., flying fish, halfbeaks and needlefish spend a significant amount of time swimming and breaking the sea surface. Many fish species come to the surface to fill their swim bladders. Oil spills which sweep pelagic areas where these and other surface-dwelling species are found likely impact these species. Injury due to physical interaction between adult fish at the sea surface and floating oil/tar has not been assessed to date for lack of information with which to address the issue.

- **Acute toxicity for short-term (several hour) exposures**: Research and the literature have well-documented that the uptake of semi-soluble organics such as hydrocarbons in oil continues for days to weeks until the tissue concentrations reach effects levels (see reviews in DiToro et al., 200; French McCay, 2002). Indeed, standard acute toxicity tests are performed for 96 hours or longer on this basis (Sprague, 1969; Swartz et al., 1995). The relationship of effects level (LC50) versus duration of exposure is based on uptake modeling and what data is available for short-duration (i.e., hours) exposures. Additional bioassay data for exposures of a few hours are needed to calibrate and verify these relationships.
- **Phototoxicity**: It is well understood that UV light induces phototoxic effects for some PAHs in oil (Barron et. al., 2003, 2004; Lee, 2003; Kirby et al., 2007). UV light intensity decreases with increasing latitude and depth into the water column. However, organisms in shallow water and in the neuston could be significantly affected by phototoxicity of PAHs accumulated in their tissues if they lack pigmentation for protection from these effects (Lee, 2003; Barron et al., 2005). The magnitude of this effect should be evaluated and phototoxicity included in modeling assessments if significant.
- **Chronic effects of oil**: Long-term effects of PAHs from oil are well documented in the literature. Such effects have not been formally included in biological effects models to date. However, the physical fates modeling to support such inclusion would need to be very comprehensive and accurate for such inclusion to be reasonably accurate. Alternatively, and more accurately, long-term biological effects modeling could be driven by observational data of sediment and shoreline concentrations of PAHs. This latter approach is recommended, given the duration of exposure and feasibility of sampling sediments. Concentrations in the water column are of short duration and, thus, do not result in chronic exposures in that habitat.
- **Population and ecosystem level impacts** result from acute and chronic effects on individuals. Modeling of such effects can rely on the extensive literature related to effects of disturbance and recovery. Such modeling has not been attempted for impacts of oil spills to date, due to the magnitude of the task and uncertainties involved.

Finally, it should be noted that the level of detail required in a model varies by the circumstances and needs of the assessment. For example, if water column contamination from a spill results in minimal or negligible toxicity, the accuracies of input density data, algorithms governing water column organism behavior, and population level modeling for fish and invertebrates are inconsequential to results. Also, if an ecological risk assessment is being performed, such that the analysis involves comparisons among alternatives, use of organism density data may not be required; rather comparisons of areas or water volumes impacted can be used. Sensitivity analysis, varying inputs within the range of uncertainty, is used to quantify and convey the uncertainties of model results. This elucidates important assumptions and data inputs for a particular application of the model. Calibration may be used to improve accuracy for specific hindcasts.

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Attachment B: Rouge River 2002 Mystery Oil Spill SIMAP Injury Report: Sensitivity Analysis for Trajectory

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ROUGE RIVER 2002 MYSTERY OIL SPILL
SIMAP INJURY REPORT
Appendix B: Sensitivity Analysis for Trajectory
Draft for Trustee Review

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May 9, 2011

Several variables were assessed to determine which set provided the best trajectory to match the observations of the Rouge River mystery spill. This sensitivity analysis tested the speed of the currents, the advective horizontal dispersion coefficient, and a slow release of a percentage of the total spill (Table B-1). Preliminary runs varying these parameters were used to narrow down to the input assumptions that best fit the observations. Then a final set of simulations were performed for assumptions closest to best fit, to determine the best case and sensitivity to the input assumptions. The currents scaling factor affected the distribution of oil in the rivers at 12 noon on 10 April 2002 when the first overflights were recorded. This component was varied between 1.0 and 1.2. The horizontal dispersion coefficient controls the random horizontal component of the oil's movement and was varied between 1 and 5 m^2/s. Results from runs with horizontal dispersion coefficients of 1 m^2/s to 3 m^2/s are shown below. Runs with higher horizontal coefficients did not distribute the oil sufficiently in the upper part of the Detroit River. The slow release was added to model oil that remained in the Rouge River on 10 April to match observations. For this variable, percentages of 0, 1, and 3 were tested.

From these runs, a base case was chosen that best matched the overflight observations. This required that the run show surface oil throughout the Detroit River with large patched between the top of Grosse Isle and Fighting Island, around the Livingstone Channel and just north of Point Mouille at the mouth of the Detroit River. Additionally, shore oil needed to impact much of the western bank of the Detroit, around Grassy Island as well as much of the Canadian shoreline. This appendix contains the mass balance of oil in the system at 12 noon on 10 April 2002 (Table B-2) and figures of the maximum amount of surface oil (g/m^2) passing through each model grid cell also at 12 noon on 10 April 2002 (Figures B-1 – B-5).

Table B-1. List of scenarios used for sensitivity analysis.

Scenario name	Current scaling factor	Horizontal dispersion coefficient (m^2/sec)	Percent slow release (%)
RR-2PH-FV11-2HA-1PCT	**1.1**	**2**	**1**
Test: Scaling Factor			
RR-2PH-FV10-2HA-1PCT	**1.0**	2	1
RR-2PH-FV12-2HA-1PCT	**1.2**	2	1
Test: Horizontal Coefficient			
RR-2PH-FV11-1HA-1PCT	1.1	**1**	1
RR-2PH-FV11-3HA-1PCT	1.1	**3**	1
Test: Percent Slow Release			
RR-2PH-FV11-2HA-0PCT	1.1	2	**0**
RR-2PH-FV11-2HA-3PCT	1.1	2	**3**

Table B-2. Mass of oil (metric tonnes) on the surface, in the water column, on shore, evaporated, decayed, in the sediment and cleaned (removed) from the system at noon on 10 April 2002.

Scenario	Surface	Water Column	Ashore	Evaporated	Decayed	Sediment
RR-2PH-FV11-2HA-1PCT	**65.91**	**2.57**	**10.95**	**19.42**	**1.00**	**0.14**
Test: Scaling Factor						
RR-2PH-FV10-2HA-1PCT	64.97	2.52	12.13	19.25	1.00	0.12
RR-2PH-FV12-2HA-1PCT	66.76	3.95	9.43	18.70	1.01	0.15
Test: Horizontal Coefficient						
RR-2PH-FV11-1HA-1PCT	67.15	5.16	3.71	22.92	0.96	0.09
RR-2PH-FV11-3HA-1PCT	57.18	0.62	15.39	25.69	0.94	0.18
Test: Percent Slow Release						
RR-2PH-FV11-2HA-0PCT	63.96	2.70	11.37	20.83	0.99	0.15
RR-2PH-FV11-2HA-3PCT	64.41	2.85	11.83	19.76	0.99	0.15

Base Case:

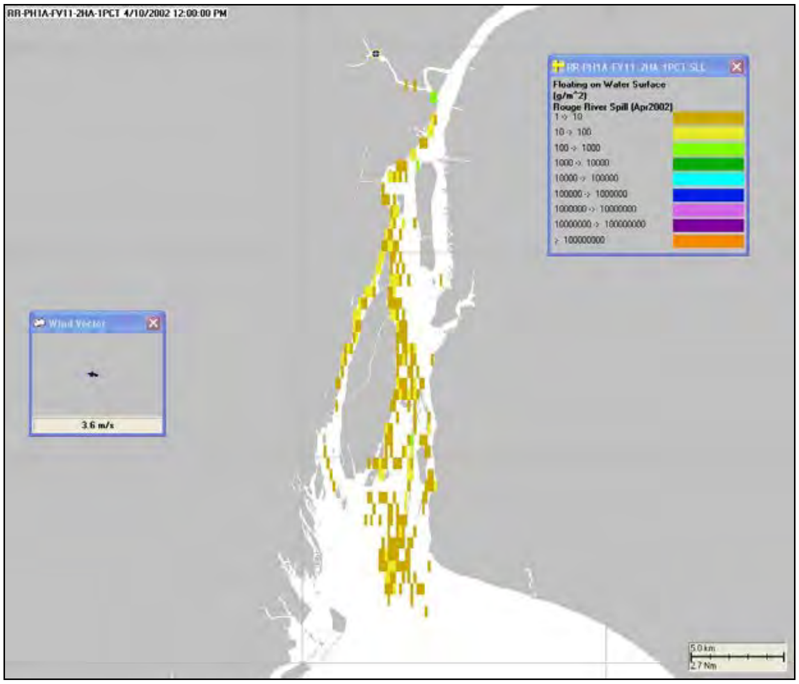

Figure B-1. RR-2PH-FV11-2HA-1PCT: the maximum amount of surface oil (g/m^2) passing through each model grid cell also at noon on 10 April 2002.

Testing the Current Scaling Factor:

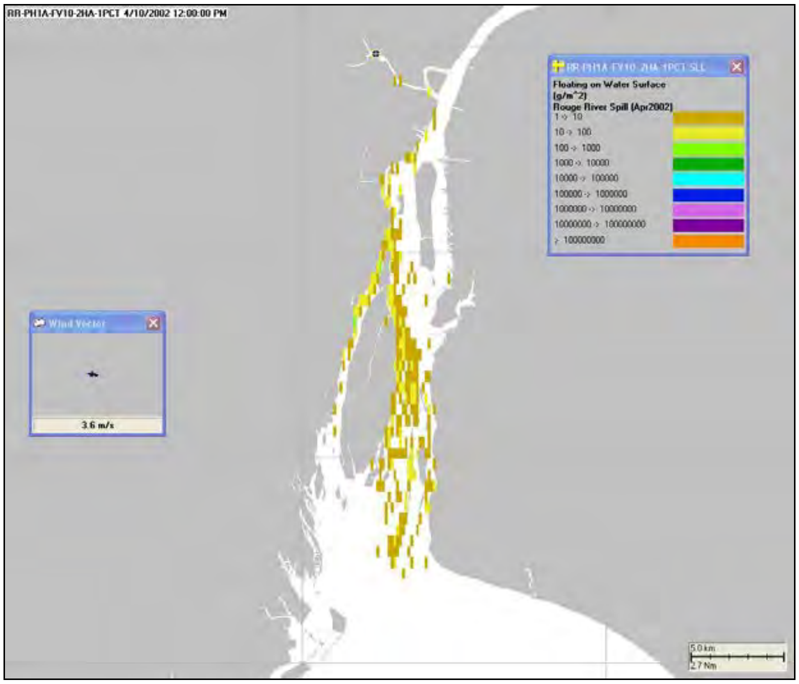

Figure B-2. RR-2PH-FV10-2HA-1PCT: the maximum amount of surface oil (g/m^2) passing through each model grid cell also at noon on 10 April 2002.

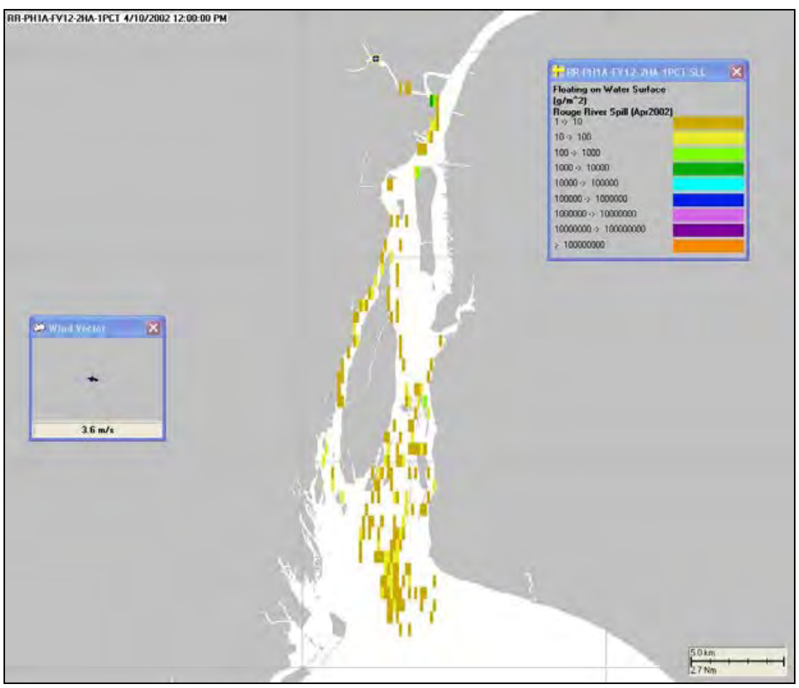

Figure B-3. RR-2PH-FV12-2HA-1PCT: the maximum amount of surface oil (g/m^2) passing through each model grid cell also at noon on 10 April 2002.

Testing the Advective Horizontal Dispersion Coefficient:

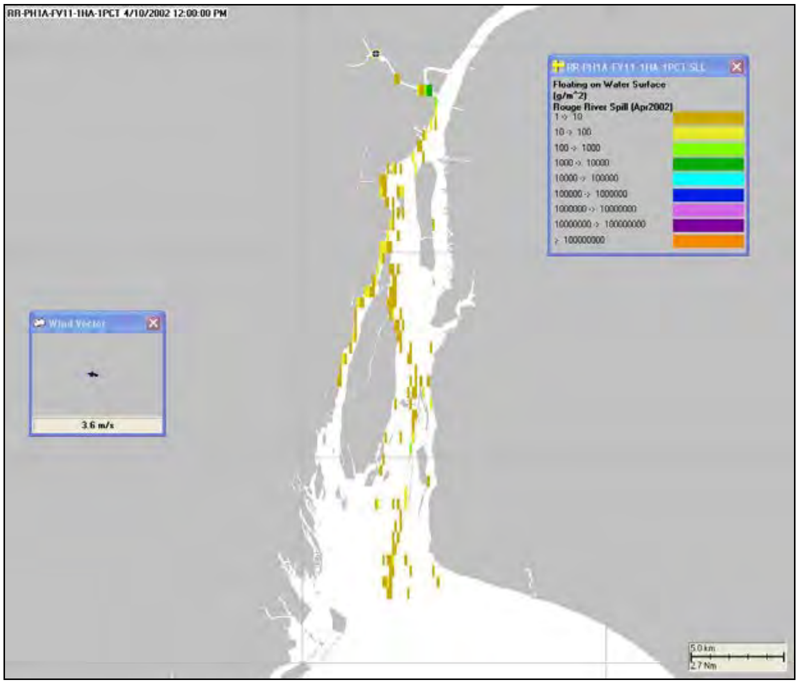

Figure B-4. RR-2PH-FV11-1HA-1PCT: the maximum amount of surface oil (g/m^2) passing through each model grid cell also at noon on 10 April 2002.

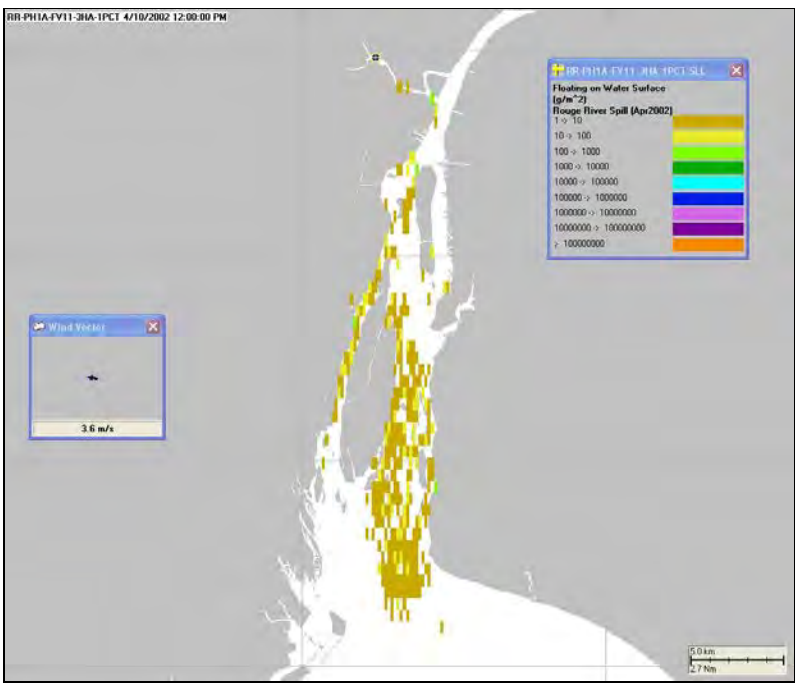

Figure B-5. RR-2PH-FV11-3HA-1PCT: the maximum amount of surface oil (g/m^2) passing through each model grid cell also at noon on 10 April 2002.

Testing the Percent Slow Release:

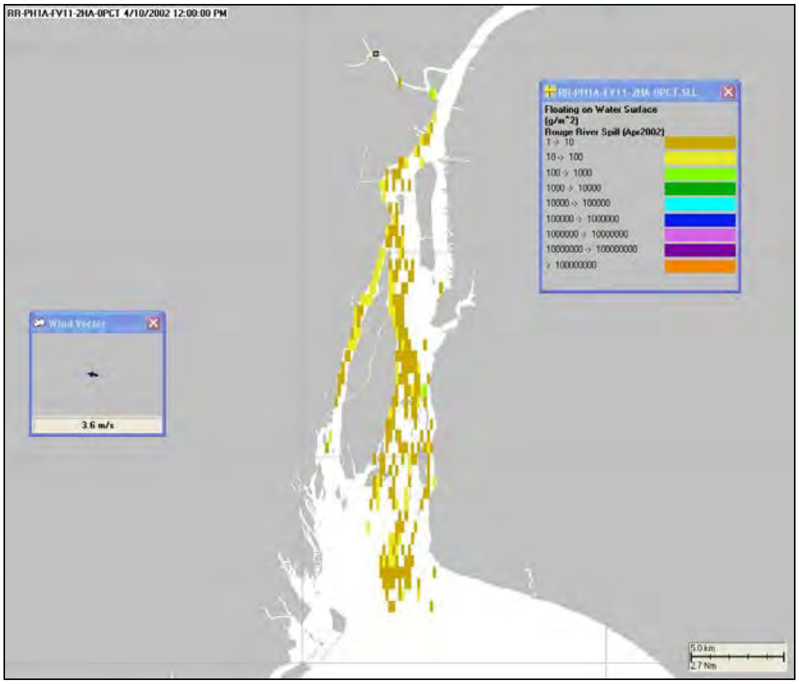

Figure B-6. RR-2PH-FV11-2HA-0PCT: the maximum amount of surface oil (g/m^2) passing through each model grid cell also at noon on 10 April 2002.

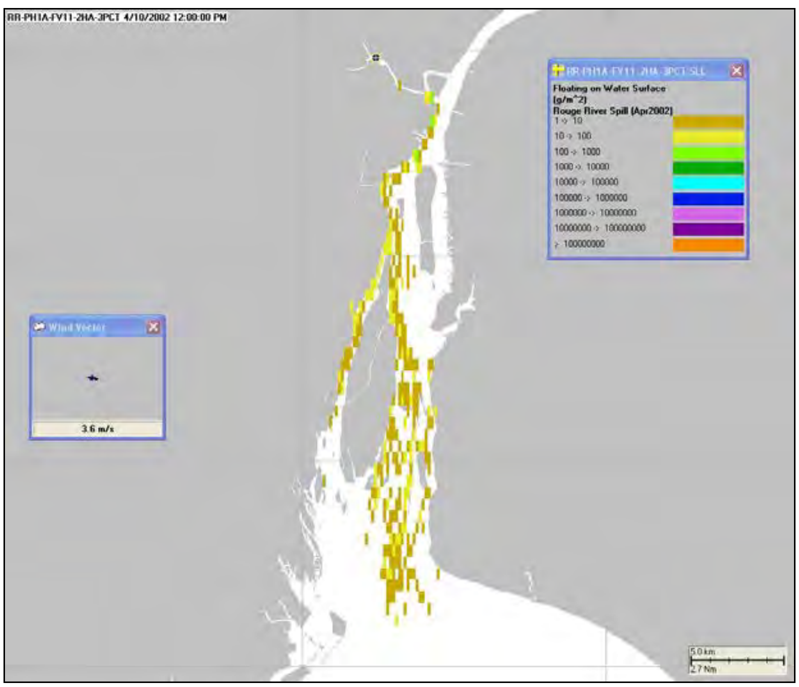

Figure B-7. RR-2PH-FV11-2HA-3PCT: the maximum amount of surface oil (g/m^2) passing through each model grid cell also at noon on 10 April 2002.

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Attachment C: Rouge River 2002 Mystery Oil Spill SIMAP Injury Report: Fates Model Results

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ROUGE RIVER 2002 MYSTERY OIL SPILL
SIMAP INJURY REPORT
Appendix C: Fates Model Results
Draft for Trustee Review

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Pursuant to Requisition/Purchase Number: 314107015A

December 20, 2013

C.1 Description of Fate and Mass Balance

This section of Appendix C provides the fates model results for the best simulation of the spill, scenario name "RR-2PH-FV11-2HA-1PCT-1MGrid".

The over-all mass balance of oil hydrocarbons as a function of time is in Figure C-1.

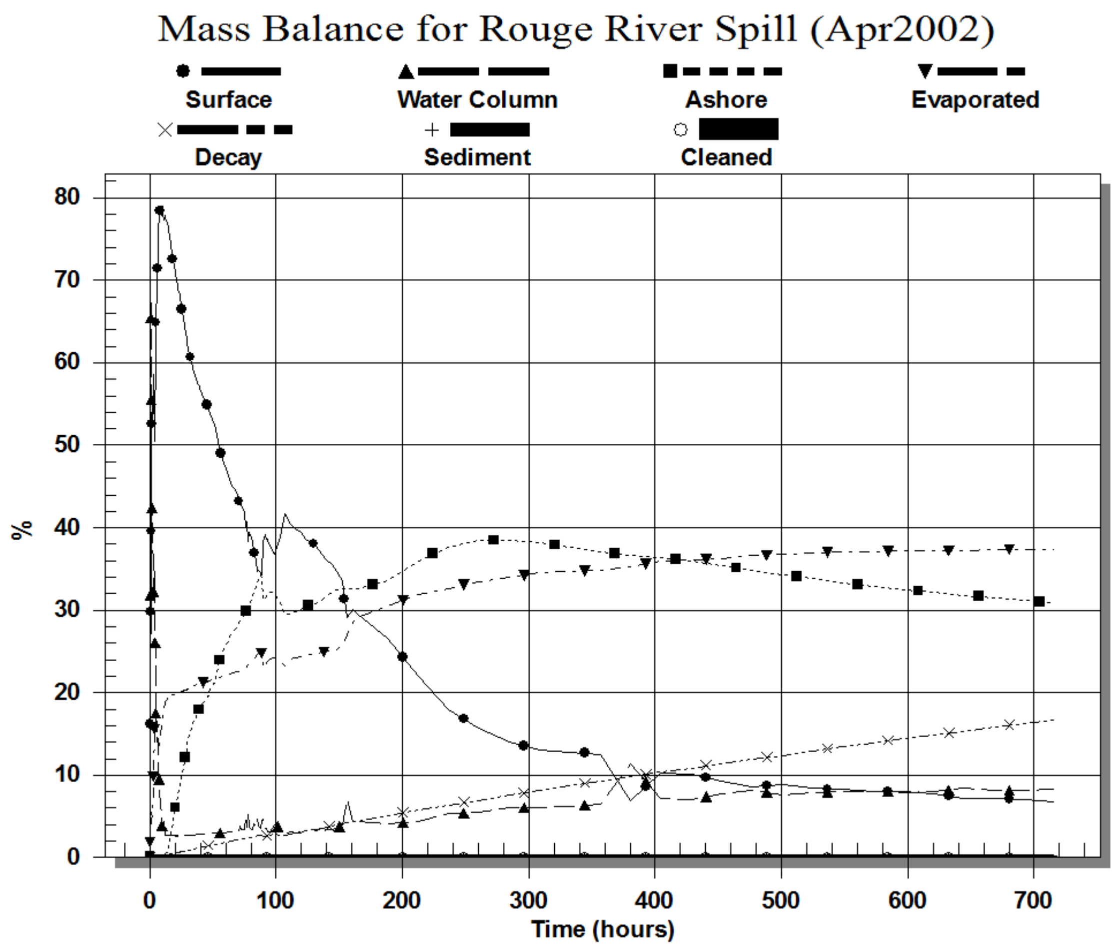

Figure C-1. Over all mass balance of oil versus time after the spill for the base case simulation (RR-2PH-FV11-2HA-1PCT-1MGrid).

Table C-1 Mass balance of oil over time (hours since the spill started) in the best simulation.

Time (hr)	% on Water Surface	% in Atmos-phere	% in Water Column	% in Sediment	% Ashore	% Decayed	% Spilled
0.08	0	0	99.9965	0	0	0.0035	1
0.17	74.9914	0.0001	25.0015	0	0	0.0069	1
0.25	34.8367	1.2828	63.6185	0	0.2551	0.0069	1
0.33	48.3782	1.894	49.4837	0	0.2353	0.0089	2
0.42	57.3504	3.4967	38.8896	0	0.251	0.0123	2
0.5	32.3182	3.813	63.6308	0	0.2258	0.0121	2
0.58	37.713	4.2664	57.794	0	0.2126	0.0139	3
0.67	40.6108	5.5733	53.5636	0	0.235	0.0172	3
0.75	38.5554	5.4995	55.7342	0	0.1939	0.017	3
0.83	40.4881	5.9894	53.3205	0	0.1832	0.0188	4
0.92	41.5119	7.1729	51.0921	0	0.2012	0.022	4
1	27.2089	5.4408	67.1889	0	0.1438	0.0175	6
2	53.3292	5.608	40.9617	0	0.072	0.0292	25
3	56.9489	11.3314	31.5783	0	0.0885	0.0531	35
4	50.4675	16.6195	32.7375	0	0.0994	0.0762	43
5	66.7106	17.4371	15.6336	0	0.1186	0.1003	49
6	71.0043	14.4893	14.2943	0	0.1056	0.1066	64
7	75.2067	12.9292	11.6427	0	0.1014	0.1201	79
8	78.1482	14.3683	7.1728	0	0.155	0.1559	79
9	77.8909	15.8123	5.7966	0	0.3093	0.1911	79
10	78.9407	16.9144	3.5883	0	0.331	0.2258	79
11	77.2563	17.7907	4.3443	0	0.3487	0.2601	79
12	77.8099	18.6152	2.8485	0	0.4326	0.2939	79
13	77.2969	19.0394	2.7369	0	0.5994	0.3275	79
14	76.84	19.286	2.715	0	0.7981	0.3609	79
15	76.0725	19.4584	2.7271	0	1.3478	0.3942	79
16	75.2207	19.6026	2.7164	0	2.0329	0.4274	79
17	74.1573	19.705	2.6934	0	2.9838	0.4606	79
18	72.8206	19.7576	2.6726	0	4.2556	0.4936	79
19	71.8944	19.8092	2.6558	0	5.1139	0.5267	79
20	71.0138	19.8518	2.6783	0	5.8967	0.5594	79
21	70.2537	19.8993	2.6673	0	6.5873	0.5924	79
22	69.2831	19.9812	2.6613	0	7.4492	0.6252	79
23	68.5937	20.029	2.6557	0	8.0636	0.658	79
24	67.698	20.0834	2.65	0	8.8778	0.6908	79
25	66.6687	20.1262	2.7198	0	9.7618	0.7235	79
26	65.9983	20.191	2.7149	0	10.3397	0.7562	79
27	65.1573	20.2573	2.7115	0	11.0852	0.7888	79
28	64.3609	20.3312	2.7088	0	11.7775	0.8215	79
29	62.9319	20.3719	2.7019	0	13.1402	0.854	79
30	61.8164	20.408	2.6957	0	14.1934	0.8865	79

Time (hr)	% on Water Surface	% in Atmos-phere	% in Water Column	% in Sediment	% Ashore	% Decayed	% Spilled
31	61.2108	20.4849	2.6874	0	14.698	0.9189	79
32	60.8134	20.556	2.6849	0.0001	14.994	0.9516	79
33	60.0493	20.6402	2.6866	0	15.6398	0.984	79
34	59.2695	20.7261	2.6493	0	16.3385	1.0167	79
35	58.7471	20.8142	2.6508	0	16.7387	1.0493	79
36	58.4127	20.8932	2.6474	0	16.965	1.0818	79
37	57.9879	20.9825	2.8293	0	17.086	1.1143	79
38	57.493	21.0583	2.8225	0	17.4795	1.1468	79
39	57.1234	21.1089	2.8168	0	17.7715	1.1794	79
40	56.5744	21.1472	2.8095	0.0001	18.2565	1.2122	79
41	56.3157	21.1835	2.8049	0	18.451	1.2449	79
42	56.0017	21.2191	2.8021	0.0003	18.6991	1.2776	79
43	55.7012	21.2541	2.7997	0	18.9346	1.3103	79
44	55.3452	21.2891	2.7976	0	19.2254	1.3426	79
45	55.1176	21.3308	2.7956	0	19.3812	1.3749	79
46	54.8054	21.3858	2.7934	0	19.6079	1.4076	79
47	54.3179	21.4362	2.7914	0	20.0147	1.4398	79
48	53.8621	21.4905	2.7898	0	20.3857	1.4719	79
49	53.2231	21.5395	2.9812	0	20.7522	1.5041	79
50	52.799	21.5866	2.9794	0	21.0987	1.5362	79
51	52.6184	21.633	2.9777	0	21.2026	1.5683	79
52	51.9337	21.6845	2.976	0	21.8055	1.6003	79
53	51.1816	21.7362	2.9742	0	22.4756	1.6325	79
54	50.5078	21.7867	2.9727	0	23.0685	1.6644	79
55	49.7687	21.8364	2.9709	0	23.7277	1.6963	79
56	49.2079	21.8849	2.9693	0	24.2096	1.7282	79
57	48.8086	21.947	2.9677	0	24.5166	1.7601	79
58	48.4014	22.0104	2.9656	0	24.8306	1.792	79
59	47.7421	22.0723	2.9544	0	25.4074	1.8238	79
60	47.2305	22.1377	2.9528	0	25.8233	1.8556	79
61	46.7778	22.1981	3.1566	0	25.9802	1.8873	79
62	46.4117	22.2563	3.155	0	26.258	1.919	79
63	45.9205	22.3006	3.1533	0	26.6749	1.9506	79
64	45.4052	22.3328	3.1516	0	27.1281	1.9822	79
65	45.1469	22.3675	3.1499	0	27.3218	2.0139	79
66	44.9761	22.407	3.1479	0	27.4235	2.0455	79
67	44.7803	22.4426	3.1463	0	27.5538	2.077	79
68	44.6021	22.4812	3.1447	0	27.6635	2.1085	79
69	44.3581	22.5244	3.1432	0	27.8344	2.1399	79
70	43.7343	22.5677	3.1415	0	28.3852	2.1713	79
71	42.7274	22.6291	3.7999	0	28.6406	2.203	79
72	42.8395	22.7027	3.3393	0.0084	28.8749	2.2351	79
73	42.5183	22.7732	3.4714	0.0072	28.9623	2.2676	79
74	42.1856	22.817	3.4588	0.006	29.2325	2.3001	79

Time (hr)	% on Water Surface	% in Atmos-phere	% in Water Column	% in Sediment	% Ashore	% Decayed	% Spilled
75	41.9761	22.8602	3.4486	0.0055	29.3771	2.3325	79
76	40.022	22.9725	4.8983	0.0061	29.7361	2.365	79
77	40.6645	23.1815	3.6823	0.0146	30.0598	2.3973	79
78	38.2944	23.42	5.5581	0.0133	30.2846	2.4296	79
79	39.4965	23.6841	3.6688	0.0201	30.668	2.4617	79
80	38.878	23.8147	3.4744	0.0187	31.3195	2.4938	79
81	38.3592	23.9191	3.4331	0.0173	31.7445	2.5258	79
82	37.1018	24.0286	4.1081	0.0159	32.1868	2.5578	79
83	36.7354	24.2254	4.0238	0.0145	32.4102	2.5898	79
84	35.9166	24.4271	4.1728	0.0131	32.8478	2.6216	79
85	34.6726	24.6141	4.741	0.0116	33.3064	2.6534	79
86	34.8173	24.7622	3.9724	0.0101	33.7521	2.6852	79
87	34.6702	24.8509	3.641	0.0086	34.1116	2.7168	79
88	34.5128	24.8983	3.6113	0.0071	34.2223	2.7474	80
89	34.298	24.6798	4.3539	0.0055	33.9165	2.7454	80
90	38.3891	22.9839	4.6678	0.0037	31.3934	2.5613	87
91	39.1093	23.2983	3.585	0.0023	31.4214	2.5831	88
92	38.5675	23.5324	3.5399	0.0009	31.7432	2.6153	88
93	38.557	23.7381	3.1763	0	31.8809	2.6469	88
94	38.112	23.9153	3.164	0	32.1303	2.6775	88
95	37.8546	24.0836	3.1557	0	32.1964	2.7089	88
96	37.4905	24.2611	3.2004	0	32.3078	2.7394	88
97	36.9647	24.4262	3.5913	0	32.2472	2.7698	88
98	36.6448	24.5221	3.544	0	32.4914	2.7969	88
99	36.826	24.343	3.8572	0	32.1884	2.7846	89
100	38.4044	23.8025	3.8742	0	31.197	2.7212	92
101	38.9979	23.9006	3.2921	0	31.0727	2.7359	93
102	38.7141	24.0347	3.2832	0	31.2022	2.765	93
103	38.8167	23.9353	3.3976	0	31.0754	2.7742	94
104	39.6879	23.5103	3.5942	0	30.4683	2.7385	96
105	41.3863	22.9335	3.5187	0	29.4876	2.6732	99
106	41.7701	23.034	3.0896	0	29.4204	2.6853	100
107	41.6787	23.2499	2.8798	0	29.4748	2.7162	100
108	41.3903	23.504	2.8618	0	29.4962	2.747	100
109	41.0347	23.6938	3.0477	0	29.4456	2.7777	100
110	40.7911	23.8303	3.0456	0	29.524	2.8082	100
111	40.5393	23.9952	3.0592	0	29.5668	2.8388	100
112	40.3577	24.0844	3.0485	0	29.6396	2.8692	100
113	40.2347	24.15	3.0437	0	29.6701	2.9007	100
114	40.095	24.2055	3.0409	0	29.7268	2.9311	100
115	39.923	24.2577	3.0395	0	29.8178	2.9614	100
116	39.7876	24.3062	3.0378	0	29.8759	2.9917	100
117	39.6802	24.336	3.033	0	29.9281	3.022	100
118	39.589	24.3708	3.0315	0	29.9558	3.0522	100

Time (hr)	% on Water Surface	% in Atmos-phere	% in Water Column	% in Sediment	% Ashore	% Decayed	% Spilled
119	39.4655	24.3964	3.0278	0	30.0271	3.0824	100
120	39.3859	24.4194	3.0249	0	30.0564	3.1126	100
121	39.2363	24.4431	3.2073	0	29.9698	3.1428	100
122	38.9663	24.4686	3.2049	0	30.1866	3.173	100
123	38.7126	24.4858	3.2023	0	30.3955	3.2031	100
124	38.6148	24.5057	3.2	0	30.4456	3.2332	100
125	38.4963	24.5299	3.1987	0	30.5111	3.2633	100
126	38.3433	24.5516	3.1964	0	30.6146	3.2933	100
127	38.2465	24.5732	3.1945	0	30.6618	3.3234	100
128	38.1921	24.5884	3.191	0.0006	30.673	3.3543	100
129	38.1424	24.6025	3.1886	0	30.6809	3.385	100
130	38.0803	24.6167	3.1862	0	30.7012	3.4149	100
131	37.9123	24.6512	3.19	0	30.8009	3.4449	100
132	37.8135	24.6867	3.1909	0	30.8332	3.4749	100
133	37.5569	24.7312	3.4632	0	30.7432	3.5048	100
134	37.4743	24.7768	3.4032	0	30.8104	3.5347	100
135	37.0914	24.8241	3.4943	0	31.025	3.5645	100
136	36.7863	24.8701	3.544	0	31.2045	3.5943	100
137	36.5474	24.9158	3.5843	0	31.3276	3.6241	100
138	36.5114	24.9518	3.4612	0	31.4211	3.6539	100
139	36.2831	24.9852	3.4289	0	31.6186	3.6836	100
140	36.0895	25.0173	3.4099	0.0028	31.7661	3.7138	100
141	35.9139	25.0445	3.4027	0.0014	31.8919	3.7449	100
142	35.7924	25.07	3.3973	0	31.9635	3.776	100
143	35.6649	25.101	3.3989	0	32.0289	3.8056	100
144	35.4847	25.1296	3.3945	0	32.1553	3.8352	100
145	35.2076	25.157	3.5583	0	32.2115	3.8649	100
146	35.0374	25.1844	3.5556	0	32.3272	3.8946	100
147	34.8638	25.2184	3.5652	0	32.4278	3.9242	100
148	34.7121	25.2548	3.5714	0	32.5074	3.9537	100
149	32.977	25.3085	5.1318	0	32.5989	3.9831	100
150	33.3165	25.412	4.6467	0	32.6116	4.0126	100
151	33.12	25.5579	4.6428	0	32.6366	4.042	100
152	33.5219	25.7118	4.0486	0	32.6457	4.0713	100
153	32.1983	25.8998	5.1238	0	32.6768	4.1005	100
154	31.6209	26.2087	5.358	0	32.6819	4.1298	100
155	32.2894	26.5316	4.3416	0	32.6776	4.159	100
156	29.3829	26.8646	6.8938	0	32.6703	4.1878	100
157	27.8687	27.3311	7.8899	0	32.6933	4.2164	100
158	27.543	27.7674	7.8865	0	32.5576	4.2448	100
159	29.192	28.1663	5.7781	0	32.59	4.273	100
160	30.2406	28.4397	4.4149	0.0024	32.5995	4.3021	100
161	29.8698	28.6348	4.5491	0.0009	32.6132	4.3316	100
162	29.6688	28.8101	4.5465	0	32.6135	4.3604	100

Time (hr)	% on Water Surface	% in Atmos-phere	% in Water Column	% in Sediment	% Ashore	% Decayed	% Spilled
163	29.8231	28.9445	4.2092	0	32.6344	4.3882	100
164	29.3814	29.054	4.4972	0	32.6509	4.4159	100
165	29.5496	29.1544	4.1772	0.0004	32.6727	4.445	100
166	29.5178	29.2202	4.0905	0	32.6977	4.473	100
167	29.4915	29.2627	4.02	0	32.7245	4.5007	100
168	29.445	29.2915	3.977	0	32.7575	4.5282	100
174	27.5661	29.5278	5.3824	0	32.8273	4.6957	100
180	27.4794	30.3234	4.069	0	33.2683	4.8593	100
186	26.8676	30.5063	4.1169	0	33.4855	5.023	100
192	25.4197	30.6642	4.8248	0	33.901	5.1896	100
198	22.7883	31.1716	6.3951	0	34.2921	5.3523	100
204	22.0235	31.6676	5.6944	0	35.0982	5.5155	100
210	22.0376	31.8929	4.5	0	35.8972	5.6716	100
216	21.6272	31.9354	4.3622	0	36.2443	5.8302	100
222	21.1482	31.9889	4.5319	0	36.3454	5.9849	100
228	17.3639	32.2935	7.1585	0	37.0448	6.1386	100
234	18.1924	32.6225	5.3852	0	37.5083	6.2909	100
240	15.7144	32.9021	7.0788	0	37.8617	6.4422	100
246	16.3555	33.1124	6.0848	0	37.854	6.5927	100
252	16.7954	33.3118	5.0557	0	38.0945	6.7419	100
258	15.8218	33.4394	5.5544	0	38.2932	6.8906	100
264	13.7025	33.5502	7.0766	0	38.6305	7.0395	100
270	14.9833	33.6618	5.6359	0	38.5316	7.1866	100
276	14.4242	33.7869	5.8064	0	38.6487	7.3331	100
282	12.6884	33.9313	7.4192	0	38.4815	7.4789	100
288	12.8869	34.0534	7.0007	0	38.4342	7.6242	100
294	13.2562	34.1436	6.6292	0	38.2018	7.7686	100
300	13.2139	34.2983	6.3293	0	38.2474	7.9104	100
306	12.3503	34.4515	6.9779	0	38.1661	8.0535	100
312	13.2439	34.5225	5.8709	0	38.1661	8.1958	100
318	13.1226	34.5637	5.989	0	37.9846	8.3394	100
324	12.6844	34.6133	6.287	0	37.9337	8.4808	100
330	12.7948	34.6619	6.2261	0	37.694	8.6225	100
336	12.8011	34.686	6.1437	0	37.6054	8.7631	100
360	12.4679	34.8101	6.4267	0	36.973	9.3216	100
384	10.1517	35.341	7.8721	0	36.7628	9.8717	100
408	10.2872	35.9765	6.9584	0	36.3652	10.412	100
432	10.0477	36.0878	7.0669	0	35.8565	10.9404	100
456	9.6032	36.3071	7.3337	0	35.2932	11.462	100
480	8.903	36.638	7.7165	0	34.7662	11.9757	100
504	8.8439	36.7574	7.6669	0	34.2491	12.4819	100
528	8.5353	36.9393	7.7558	0	33.7875	12.9815	100
552	8.2857	37.0214	7.9308	0	33.2865	13.4749	100
576	7.7017	37.1336	8.3363	0	32.8652	13.9624	100
600	7.9703	37.1757	7.934	0	32.475	14.4443	100

Time (hr)	% on Water Surface	% in Atmos-phere	% in Water Column	% in Sediment	% Ashore	% Decayed	% Spilled
624	7.7572	37.2192	7.9966	0	32.1038	14.9226	100
648	7.3735	37.2812	8.1296	0	31.8212	15.3938	100
672	7.1648	37.3213	8.1225	0	31.531	15.8597	100
696	6.8708	37.3634	8.3148	0	31.1298	16.3206	100
720	6.7813	37.4051	8.207	0	30.8295	16.7764	100

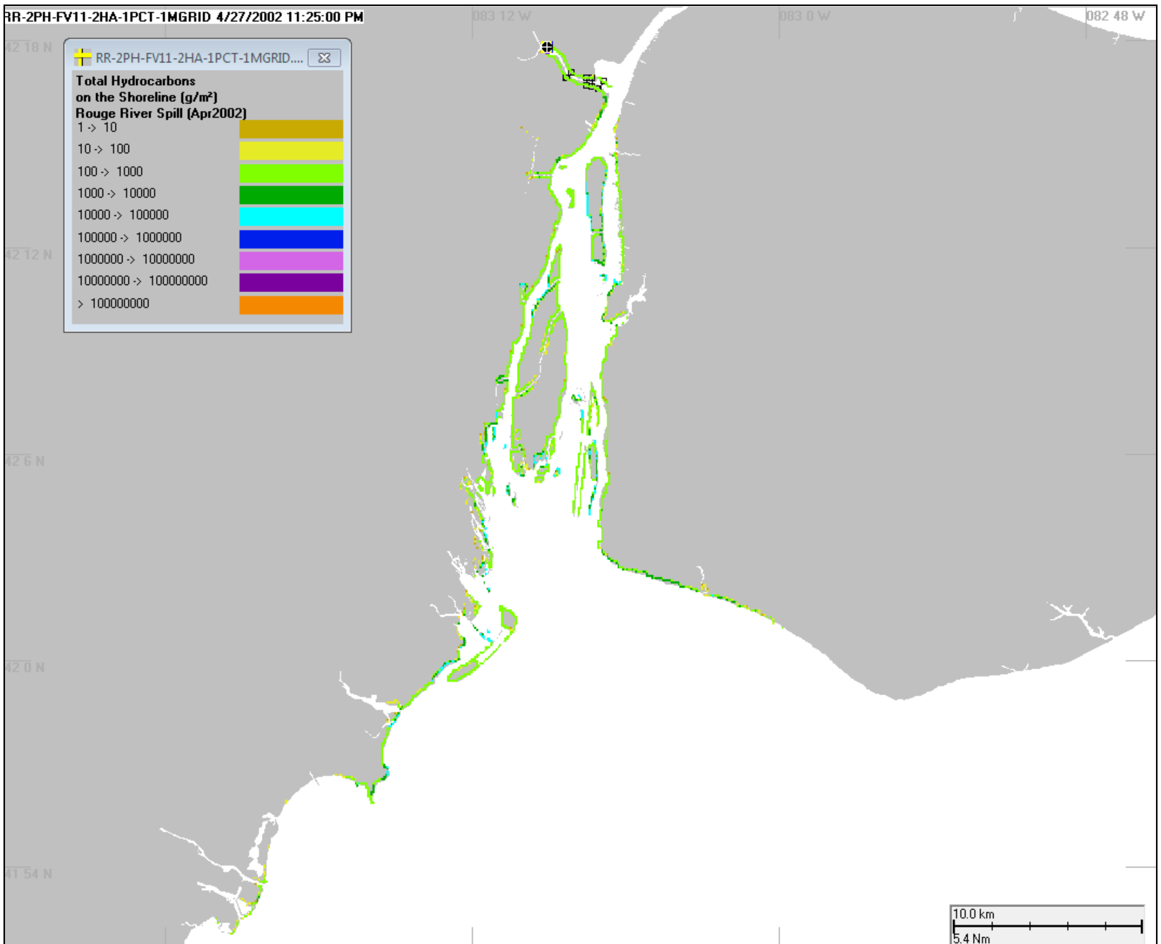

Figure C-2. Amount (g/m^2) of oil accumulated on shorelines at the end of the base case simulation (RR-2PH-FV11-2HA-1PCT-1MGrid), as mass of total hydrocarbons per unit area (averaged in each habitat grid cell).

C.2 Shoreline Oiling

Tables C-3 to C-8 provide the shoreline oiling results for the base case (RR-2PH-FV11-2HA-1PCT) and the other scenarios run as a sensitivity analysis (Table C-2). The width of oiling all of the shore types is assumed to be 1 meter; therefore, in each of these cases, the length (m) of shore oiled is equal to the area (m^2) of shore oiled.

Table C-2. List of scenarios used for sensitivity analysis of shoreline oiling.

Scenario name	Description
RR-2PH-FV11-2HA-1PCT-1MGrid	**Base case**
RR-2PH-FV11-2HA-0PCT-1MGrid	Base case with 0% slow release
RR-2PH-FV11-2HA-3PCT-1MGrid	Base case with 3% slow release
RR-2PH-FV11-2HA-1PCT-10MO-1MGrid	Base case with 10% water in oil when fully emulsified as mousse
RR-2PH-FV11-2HA-1PCT-60MO-1MGrid	Base case with 60% water in oil when fully emulsified as mousse

Table C-3. Base scenario : RR-2PH-FV11-2HA-1PCT-1MGrid - Area (m^2) of shoreline oiled by shore type with average thickness of oil greater than thresholds specific to impacts on animals (0.1 mm) and vegetation (1mm).

Shore Type	Area (m^2) > threshold for animals (0.1 mm)	Area (m^2) > threshold for vegetation (1 mm)
Rocky shoreline	6,132	3,066
Gravel beach	8,775	1,692
Sand beach	12,476	3,912
Mud shore	40,386	26,959
Fringing marsh	10,150	5,498
Artificial shoreline	0	0
Total shoreline	**77,919**	**41,127**

Table C-3. Base scenario : RR-2PH-FV11-2HA-1PCT-1MGrid - Total area (m^2) oiled at any time using a thickness threshold greater than 0.01 mm.

Shore Type	Area (m^2) > threshold of 0.01 mm
Marsh/wetland	2,276,577
Mud flats	134,171
Total	**2,410,748**

Table C-4. Scenario : RR-2PH-FV11-2HA-0PCT-1MGrid - Area (m^2) of shoreline oiled by shore type with average thickness of oil greater than thresholds specific to impacts on animals (0.1 mm) and vegetation (1mm).

Shore Type	Area (m^2) > threshold for animals (0.1 mm)	Area (m^2) > threshold for vegetation (1 mm)
Rocky shoreline	6,026	3,383
Gravel beach	9,727	2,220
Sand beach	11,207	4,335
Mud shore	9,198	5,075
Fringing marsh	40,915	28,757
Artificial shoreline	-	-
Total shoreline	**77,073**	**43,770**

Table C-5. Scenario : RR-2PH-FV11-2HA-0PCT-1MGrid - Total area (m^2) oiled at any time using a thickness threshold greater than 0.01 mm.

Shore Type	Area (m^2) > threshold of 0.01 mm
Marsh/wetland	2,247,025
Mud flats	153,597
Total	**2,400,622**

Table C-6. Scenario : RR-2PH-FV11-2HA-3PCT-1MGrid - Area (m^2) of shoreline oiled by shore type with average thickness of oil greater than thresholds specific to impacts on animals (0.1 mm) and vegetation (1mm).

Shore Type	Area (m^2) > threshold for animals (0.1 mm)	Area (m^2) > threshold for vegetation (1 mm)
Rocky shoreline	5,921	3,172
Gravel beach	10,784	2,115
Sand beach	12,687	3,912
Mud shore	9,410	4,969
Fringing marsh	41,338	28,228
Artificial shoreline	-	-
Total shoreline	**80,140**	**42,396**

Table C-7. Scenario : RR-2PH-FV11-2HA-3PCT-1MGrid - Total area (m^2) oiled at any time using a thickness threshold greater than 0.01 mm.

Shore Type	Area (m^2) > threshold of 0.01 mm
Marsh/wetland	2,296,514
Mud flats	148,581
Total	**2,445,095**

Table C-8. Scenario : RR-2PH-FV11-2HA-1PCT-10MO-1MGrid - Area (m^2) of shoreline oiled by shore type with average thickness of oil greater than thresholds specific to impacts on animals (0.1 mm) and vegetation (1mm).

Shore Type	Area (m^2) > threshold for animals (0.1 mm)	Area (m^2) > threshold for vegetation (1 mm)
Rocky shoreline	5,180	2,960
Gravel beach	5,392	1,692
Sand beach	9,304	2,643
Mud shore	8,987	5,075
Fringing marsh	37,214	25,902
Artificial shoreline	-	-
Total shoreline	**66,077**	**38,272**

Table C-9. Scenario : RR-2PH-FV11-2HA-1PCT-10MO-1MGrid - Total area (m^2) oiled at any time using a thickness threshold of greater than 0.01 mm.

Shore Type	Area (m^2) > threshold of 0.01 mm
Marsh/wetland	2,031,155
Mud flats	101,255
Total	**2,132,410**

Table C-10. Scenario : RR-2PH-FV11-2HA-1PCT-60MO -1MGrid - Area (m^2) of shoreline oiled by shore type with average thickness of oil greater than thresholds specific to impacts on animals (0.1 mm) and vegetation (1mm).

Shore Type	Area (m^2) > threshold for animals (0.1 mm)	Area (m^2) > threshold for vegetation (1 mm)
Rocky shoreline	7,506	2,855
Gravel beach	11,841	1,798
Sand beach	14,484	2,960
Mud shore	13,110	6,026
Fringing marsh	48,633	29,814
Artificial shoreline	-	-
Total shoreline	**95,574**	**43,453**

Table C-11. Scenario : RR-2PH-FV11-2HA-1PCT-60MO-1MGrid - Total area (m^2) oiled at any time using a thickness threshold of greater than 0.01 mm.

Shore Type	Area (m^2) > threshold of 0.01 mm
Marsh/wetland	2,545,406
Mud flats	300,596
Total	**2,846,002**

C.3 Model Output Description

The following text describes the model output that can be viewed in the *.avi files provided on CD.

The “Rouge_trajectory.avi” file shows the model trajectory for the best simulation of the spill indicating where there is exposure to surface oil. The points in the trajectory plots below represent the center of mass for “spillets” used to simulate the spill. The map locations are cumulative, the previous oil locations are displayed along with the present ones at the time of the snapshot. Each spillet is a sublot of the total mass spilled. The spillet is transported by currents and surface wind drift. The mass distribution around the spillet center spreads (for surface slicks) and disperses over time according to the horizontal dispersion coefficient. Note that the shoreline shown in these model outputs are for visual reference only, whereas the habitat (and corresponding depth) grid (Section 3.1 of main report) defines the actual shoreline to the model

The “Rouge_THC-max.avi” shows the concentrations of total hydrocarbons (oil) in the water column over time. The animated movie shows the vertical maximum concentration on any given time step.

The “Rouge_float-oil.avi” file shows the maximum amount of surface oil (g/m^2) passing through each model grid cell.

The “Rouge_diss-arom.avi” file shows the maximum concentration (ppb) of dissolved aromatics passing through each model grid cell.

Attachment D: Rouge River 2002 Mystery Oil Spill SIMAP Injury Report: Biological Data

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ROUGE RIVER 2002 MYSTERY OIL SPILL
SIMAP INJURY REPORT
Appendix D: Biological Data
Draft for Trustee Review

Submitted To:
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Pursuant to Requisition/Purchase Number: 314107015A

May 9, 2011

D.1 Wildlife Abundance

Spring bird densities were based on Pointe Mouillee spring shorebird survey data. This survey counts all birds found within the Pointe Mouillee Wildlife Refuge and State Game Area on at least a bimonthly schedule (Robison, 2009). Additional bird density data from the Ohio Division of Wildlife (ODW) Aerial Waterfowl Survey provided a means to estimate the ratio of bird densities in open waters, as opposed to the protected waters of Pointe Mouillee (Figure D-1). For the ODW survey, one transect was in western Lake Erie, from the mouth of the Maumee River to West Sister Island. This survey, which is only conducted through March, counts all birds observed over approximately 8.7 square miles (22.5 km^2) of open water (Witt, 2009). March open water abundances were averaged over years 2000-2006. The Pointe Mouillee Shorebird Survey data were used in the modeling for waterfowl and grebes; however, the data were corrected using the ratio of Pointe Mouillee Survey data averaged for the month of April from 2002-2008 to the March data of the ODW Aerial Waterfowl Survey. Three species were found in both datasets and had the following ratios: American black duck = 15.17, canvasback = 100.91 and mallard = 327.04. The average ratio derived from these species was 148, and the Pointe Mouillee density estimates were divided by 148 and applied to all waters < 1m deep in the model grid (i.e., covering the Rouge River, Detroit River and Lake Erie).

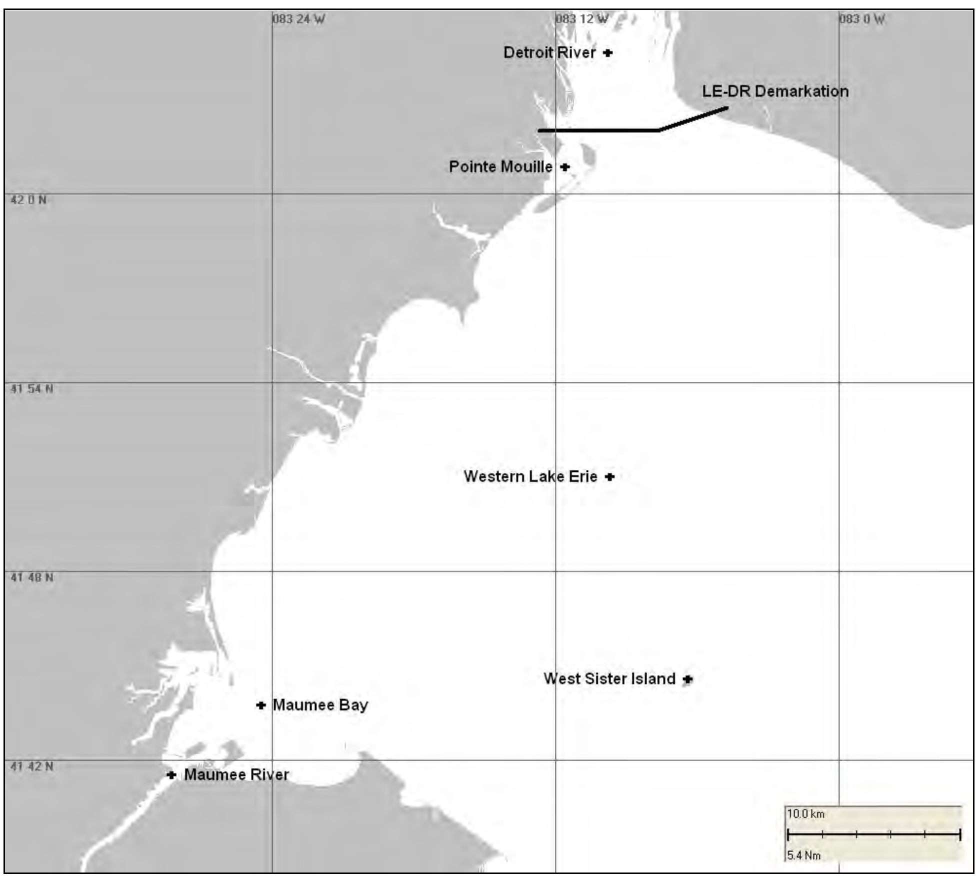

Figure D-1. Bird survey locations in Western Lake Erie. The solid black line marks the delineation between the Detroit River and Lake Erie.

When comparing the Pt. Mouillee Shorebird Survey to the open water western Lake Erie survey, mergansers and scaups were found in approximately equal densities in both open water near shore and marshes. Therefore, the observed densities from the Pt. Mouillee Survey were used, uncorrected, for mergansers in <1m deep waters of Detroit River and Lake Erie and for scaups in 1-3 deep waters of Lake Erie.

Abundance data from Stapanian and Waite (2003) were used for cormorants, Bonaparte's gulls, herring gulls and ring-billed gulls. This survey counted birds along 31 established transects in four habitats in western Lake Erie, including offshore of waterbird refuges, offshore of beaches with human development, on reefs and shoals, and in open water. Mean abundances for the open water and developed shorelines were used for these species in the modeling. For terns and the other gull species not included in Stapanian and Waite (2003), the Pointe Mouillee Shorebird Survey data were used and corrected using a ratio of counted gull and cormorant species based on the Pointe Mouillee Shorebird Survey to the Stapanian and Waite (2003) survey for open water and developed shorelines. The four species found in both data sets that were used to create the ratio for gulls and cormorants were Bonaparte's gull, herring gull, ring-billed gull, and double-crested cormorant. The ratio derived from the data for these species was 29.

The Pointe Mouillee Shorebird Survey data were used for wading birds and shorebirds, which use wetlands and shorelines only. No correction factor was used on the data for these species.

Herpetological data was contracted from the Detroit River Herpetological Survey (Mifsud, pers. comm.). These data had previously been summarized in a report to the U.S. Fish and Wildlife Service (Mifsud, 2006). Data from the 15 sites surveyed south of the Rouge River were averaged and input for spring months. These data are only an estimate as surveys were performed throughout the spring and summer months, these species are notoriously shy, and their activity, and thus ability to be detected, is greatly affected by the weather conditions (Mifsud, 2009). These data were applied to the wetlands portions of the habitat grid.

Muskrat densities included in the model were from the NRDAM/GLE and input for spring months (Tori, 1989). These data was applied to the wetlands portions of the habitat grid.

Table D-1 provides the wildlife density data that were used in the model, based on the assumptions outlined above.

Table D-1. Wildlife density data (#/km^2) used in the model for the Rouge River, Detroit River and Lake Erie using an average of 2002-2008 April data from the Pointe Mouillee Survey.

Species Name:	Abundances (#/km^2) in Detroit River and Lake Erie	Abundances (#/km^2) in Rouge River
American black duck	0.01	0
American coot	1.11	1.11
American widgeon	0.08	0.08
Blue-winged teal	0.04	0.04
Bufflehead	0.04	0.04

Species Name:	Abundances (#/km^2) in Detroit River and Lake Erie	Abundances (#/km^2) in Rouge River
Canada goose	0.12	0.12
Canvasback	0.05	0.05
Common goldeneye	0.002	0.002
Common loon	0.001	0
Eurasian Wigeon	0.0004	0.0004
Gadwall	0.33	0.33
Green-winged teal	0.42	0.42
Horned grebe	0.002	0.002
Long-tailed duck	0.0001	0
Mallard	0.06	0.06
Red-breasted merganser	1.41	0
Common merganser	1.74	0
Hooded merganser	0.28	0
Northern pintail	0.10	0.10
Northern shoveler	0.07	0.07
Pied-billed grebe	0.02	0.02
Redhead	0.13	0.13
Ring-necked duck	0.06	0.06
Ruddy duck	0.17	0.17
Surf scoter	0.0001	0
Scaup, greater*	45.4	0
Scaup, lesser*	55.6	0
Scaup spp. (unidentified)*	3.16	0
Mute swan	0.07	0.07
Tundra swan	0.0002	0.0002
Wood duck	0.0002	0
Bonapartes gull	0.43	0.43
Caspian tern	0.06	0.06
Doublecrested cormorant	0.60	0.60
Forsters tern	0.05	0.05
Glaucous gull	0.001	0.001
Great black-back gull	0.004	0.004
Herring gull	0.47	0.47
Lesser black-back gull	0.001	0.001
Ring-billed gull	0.21	0.21
American bittern	0.01	0
Black-crowned heron	0.29	0
Common moorhen	0.09	0
Great blue heron	1.73	0
Great egret	1.19	0
Green heron	0.01	0
Sandhill crane	0.03	0
Sora	0.19	0
Virginia rail	0.05	0
American avocet	0.21	0
Black-necked stilt	0.01	0

Species Name:	Abundances (#/km^2) in Detroit River and Lake Erie	Abundances (#/km^2) in Rouge River
Common snipe	1.32	0
Dunlin	10.6	0
Greater yellowlegs	1.21	0
Killdeer	1.25	0
Least sandpiper	0.03	0
Lesser yellowlegs	2.28	0
Long-bill dowitcher	0.05	0
Pectoral sandpiper	3.00	0
Semipalmated plover	0.01	0
Short-bill dowitcher	0.02	0
Solitary sandpiper	0.01	0
Spotted sandpiper	0.07	0
Willet	0.23	0
Wilsons snipe	0.21	0
Muskrat	108.00	0
Black rat snake	0.03	0
Blandings turtle	0.54	0
Butlers garter snake	1.88	0
Eastern fox snake	1.48	0
Eastern garter snake	4.56	0
Eastern spiny softshell	0.40	0
Map turtle	18.15	0
Midland paint turtle	15.50	0
Northern brown snake	0.84	0
Northern water snake	1.74	0
Red-ear slider turtle	0.40	0
Snapping turtle	3.09	0
American toad	4.73	0
Bullfrog	4.33	0
Gray tree frog	0.10	0
Green frog	2.82	0
Leopard frog	14.96	0
Western chorus frog	0.13	0
Wood frog	0.07	0
Total scaups	104.2	0
Total waterfowl (other than scaups)	6.3	2.9
Total seabirds	1.8	1.8
Total waders and shorebirds	20.5	0
Total mammals	108.0	0
Total reptiles	48.61	0
Total amphibians	27.14	0

D.2 Wildlife Behaviors

The various wildlife behavior groups were applied to specific sections of the littoral/limnetic habitat grid, as shown in Figure 3-1 of the main SIMAP Injury report. All waterfowl (dabblers, coots, diving ducks, and grebes) were applied to littoral waters and structured/wetland habitats. Aerial seabirds, such as cormorants, gulls and terns, were applied to all waters. Waders (herons, etc.), shorebirds (yellowlegs, sandpipers, etc.), reptiles and amphibians, were applied to all structured/wetland habitats. The lack of structured/wetland habitats in the Rouge River due to grid resolution precluded waders, shorebirds, reptiles and amphibians from injury within this region. The probabilities of oiling were based on analyses built into the SIMAP model, as described in the SIMAP Injury report and French McCay (2009).

After applying species based on behavior group, further assumptions were made taking shoreline development into account. A correction was made for species that were assumed to not occur within the Rouge River due to its heavily developed shoreline. Species removed from the Rouge River, and therefore applied to only appropriate habitat types in the Detroit River and Lake Erie, were the American black duck, mergansers, scoters, loons, long-tailed duck and wood duck. Another correction was made for two species of scaup, which were assumed to only be found within Lake Erie and not in either the Rouge or Detroit Rivers.

D.3 Wildlife Life History

Table D-2 provides the wildlife life history data that were used in the model. Data for bird species and muskrat are from the NRDAM/GLE database. Frog and toad data are based on life history values for the American bullfrog and Northern leopard frog (Hine et al. 1981; Duellman and Trueb, 1994; Smith and Keinath 2007; Myers et al. 2008). Turtle life history is based on the Common map turtle and the Painted turtle in Michigan (Ernst et al., 1994). Snake life history is based on Eastern garter snake and Northern water snake life histories (Harding, 1997; Brown and Weatherhead 1999; Myers et al. 2008)

Table D-2. Wildlife life history parameters used in the model.
(M = natural mortality, H = hunting mortality, YrRepr = age of reproduction, Life = max.age (yrs), MoHat = mo. hatched, MoFlg = age (mo.) fledged, F-Hat = #hatched/adult, F-Flg = #fledged/adult, AveKg = ave. wt in kg)

Species Name	M-1yr	M>1yr	H-1yr	H>1yr	YrRepr	Life	MoHat	MoFlg	F-Hat	F-Flg	AveKg
American black duck	0.65	0.4	0.33	0.2	1	10	6	2	2.1	1.2	0.8
American coot	0.65	0.4	0.33	0.2	1	10	6	2	2.1	1.2	0.8
American widgeon	0.65	0.4	0.33	0.2	1	10	6	2	2.1	1.2	0.8
Blue-winged teal	0.65	0.4	0.33	0.2	1	10	6	2	2.1	1.2	0.8
Bufflehead	0.73	0.62	0.36	0.22	2	15	6	2	1.5	1.3	1.1
Canada goose	0.55	0.35	0.47	0.16	3	20	6	2	1.7	1.4	5
Canvasback	0.73	0.62	0.36	0.22	2	15	6	2	1.5	1.3	1.1
Common goldeneye	0.73	0.42	0.36	0.22	2	15	6	2	1.5	1.3	1.1

Species Name	M-1yr	M>1yr	H-1yr	H>1yr	YrRepr	Life	MoHat	MoFlg	F-Hat	F-Flg	AveKg
Common merganser	0.73	0.42	0.36	0.22	2	15	6	2	1.5	1.3	1.1
Dabblers	0	0	0	0	1	1	5	5	0	0	0
Diving ducks	0	0	0	0	1	1	5	5	0	0	0
Gadwall	0.65	0.4	0.33	0.2	1	10	6	2	2.1	1.2	0.8
Greater scaup	0.73	0.42	0.36	0.22	2	15	6	2	1.5	1.3	1.1
Green-winged teal	0.65	0.4	0.33	0.2	1	10	6	2	2.1	1.2	0.8
Hooded merganser	0.73	0.42	0.36	0.22	2	15	6	2	1.5	1.3	1.1
Horned grebe	0.24	0.11	0	0	2	24	6	2	1.3	1	0.4
Lesser scaup	0.73	0.42	0.36	0.22	2	15	6	2	1.5	1.3	1.1
Mallard	0.65	0.4	0.33	0.2	1	10	6	2	2.1	1.2	0.8
Mute swan	0.15	0.15	0	0	3	25	6	2	0.6	0.5	6.7
Northern pintail	0.65	0.4	0.33	0.2	1	10	6	2	2.1	1.2	0.8
Northern shoveler	0.65	0.4	0.33	0.2	1	10	6	2	2.1	1.2	0.8
Pied-billed grebe	0.24	0.11	0	0	2	24	6	2	1.3	1	0.4
Red-breast merganser	0.73	0.42	0.36	0.22	2	15	6	2	1.5	1.3	1.1
Redhead	0.73	0.42	0.36	0.22	2	15	6	2	1.5	1.3	1.1
Ring-necked duck	0.73	0.62	0.36	0.22	2	15	6	2	1.5	1.3	1.1
Ruddy duck	0.65	0.4	0.33	0.2	1	10	6	2	2.1	1.2	0.8
Scaup	0.73	0.42	0.36	0.22	2	15	6	2	1.5	1.3	1.1
Wood duck	0.65	0.4	0.33	0.2	1	10	6	2	2.1	1.2	0.8
Bonapartes gull	0.33	0.1	0	0	4	15	6	1	1.17	0.75	1.1
Caspian tern	0.52	0.14	0	0	3	25	6	1	0.89	0.37	0.16
Doublecrested cormorant	0.24	0.16	0	0	3	23	6	2	1.37	0.79	2
Forsters tern	0.52	0.14	0	0	3	25	6	1	0.89	0.37	0.16
Great black-back gull	0.33	0.1	0	0	4	15	6	1	1.17	0.75	1.1
Herring gull	0.33	0.1	0	0	4	15	6	1	1.17	0.75	1.1
Ring-billed gull	0.33	0.1	0	0	4	15	6	1	1.17	0.75	1.1
Black-crowned heron	0.68	0.34	0	0	2	17	5	2	1.59	0.84	1.3
Great blue heron	0.68	0.34	0	0	2	17	5	2	1.59	0.84	1.3
Great egret	0.68	0.34	0	0	2	17	5	2	1.59	0.84	1.3
Sora	0.68	0.34	0	0	2	17	5	2	4.5	2.3	1.3
American avocet	0.38	0.09	0	0	3	15	5	1	1.75	0.9	0.1
Common snipe	0.53	0.2	0	0	1	8	5	1	1.8	0.87	0.03
Dunlin	0.53	0.2	0	0	1	8	5	1	1.8	0.87	0.03
Greater yellowlegs	0.53	0.2	0	0	1	8	5	1	1.8	0.87	0.03
Killdeer	0.53	0.2	0	0	1	8	5	1	1.8	0.87	0.03
Lesser yellowlegs	0.53	0.2	0	0	1	8	5	1	1.8	0.87	0.03

Species Name	M-1yr	M>1yr	H-1yr	H>1yr	YrRepr	Life	MoHat	MoFlg	F-Hat	F-Flg	AveKg
Pectoral sandpiper	0.53	0.2	0	0	1	8	5	1	1.8	0.87	0.03
Willet	0.53	0.2	0	0	1	8	5	1	1.8	0.87	0.03
Wilsons snipe	0.53	0.2	0	0	1	8	5	1	1.8	0.87	0.03
Muskrat	0.71	0.75	0.63	0.48	1	10	6	1	7.5	4.9	1.2
Black rat snake	0.6	0.5	0	0	2	8	8	0	20	0	0.15
Blandings turtle	0.81	0.24	0	0	8	20	8	0	20	0	0.35
Butlers garter snake	0.6	0.5	0	0	2	8	8	0	20	0	0.15
Eastern fox snake	0.6	0.5	0	0	2	8	8	0	20	0	0.15
Eastern garter snake	0.6	0.5	0	0	2	8	8	0	20	0	0.15
Eastern spiny softshell	0.81	0.24	0	0	8	20	8	0	20	0	0.35
Map turtle	0.81	0.24	0	0	14	20	8	0	24	0	0.35
Midland paint turtle	0.81	0.24	0	0	8	20	8	0	20	0	0.35
N brown snake	0.6	0.5	0	0	2	8	8	0	20	0	0.15
N water snake	0.6	0.5	0	0	2	8	8	0	20	0	0.15
Red-ear slider turtle	0.81	0.24	0	0	8	20	8	0	20	0	0.35
Snapping turtle	0.81	0.24	0	0	8	20	8	0	20	0	0.35
American toad	0.95	0.75	0	0	1	4	5	0	3,000	0	0.023
Bullfrog	0.95	0.75	0	0	1	4	5	0	20,000	0	0.15
Gray tree frog	0.95	0.75	0	0	1	4	5	0	3,000	0	0.023
Green frog	0.95	0.75	0	0	1	4	5	0	3,000	0	0.023
Leopard frog	0.95	0.75	0	0	1	4	5	0	3,000	0	0.023
W chorus frog	0.95	0.75	0	0	1	4	5	0	3,000	0	0.023
Wood frog	0.95	0.75	0	0	1	4	5	0	3,000	0	0.023

D.4 Fish Biomass

Three sources were used to generate the fish database to evaluate impacts from the Rouge River spill. In 2006, the USGS and the Lake Erie Biological Station (LEBS) conducted a survey for forage fish in the western basin of Lake Erie (Kocovsky et al., 2007). The sampling stations were located between Point Pelee and the western edge of the lake in Ontario and Michigan waters. Samples were collected in June and contained individuals of all size classes. The second study was also conducted in 2006 by Michigan Department of Natural Resources (MIDNR). This survey sampled nearshore fish populations of the Detroit River in July. Electrofishing was used to sample all class ranges (Francis, 2009b). The third source was an estimate of the walleye population travelling through the Detroit River. MIDNR estimated 1.7 million age 2 and older walleye were in the Detroit River between March and May 2002 (Francis, 2009a). Walleye densities were calculated by estimating the area of the Detroit River and scaling for higher migration rates in April using catch-per-unit-effort data from a MIDNR creel survey (Francis, 2005).

To use the data collected, densities (#/area) had to be converted to biomass (kg/area). In order to do this, life history on all species was collected. Biomass (kg/km^2) for each species was estimated by calculating the weight of fish in the population by age class using the number sampled per unit area from the abundance data as a basis and assuming a stable age distribution defined by annual mortality rates (see French McCay, 2009). Individual weight by age class was derived from the von Bertalanffy length at age, and the standard weight verses length, relationships (Ricker, 1975). Life history parameters including L_∞, K, alpha(a) and beta(b) were used to derive these relationships (see Table D-4 for values used). The population was modeled over time using the standard exponential growth equation:

$$N(t) = N_o e^{-zt}$$

Where N(t) represents the population at a given time t, N_o represents the population at time 0, z represents total mortality or the intrinsic rate of natural decrease, and t is time. The mortality rates (natural (M) and fishing (F)) and age recruited to fishery used for each species are listed in Table D-4.

Due to availability of life history information, species were grouped into larger categories and characteristics of a representative species life history were used for the conversions. Species listed individually were bowfins, longnose gar, northern pike, rainbow trout, silversides, rock bass, largemouth bass, smallmouth bass, yellow perch, walleye, white perch, and freshwater drum. The following species groups were comprised of the individual species listed:

- Herrings: combined alewife and gizzard shad
- Bullhead catfishes (brown, black, yellow)
- Sunfishes: sunfish (orangespotted, green, longear), bluegill, pumpkinseed
- Large forage fish: common carp and buffalos (bigmouth and black)
- Medium forage fish: quillback, redhorses (golden, silver, shorthead), suckers (spotted, white, northern hog), and goldfish
- Small forage fish: shiners (spotfin, spottail, emerald, mimic, sand, common, striped, golden), bluntnose minnows, chubs (hornyhead, river), brook silversides, banded killifish

If a species was only found in the Lake Erie study, the density number given in the report was used. If a species was found in both the Lake Erie and Detroit River surveys, the densities were averaged. Numerical densities were then converted using compiled life history information and the model described above. All species except rainbow trout were applied to all habitats. Rainbow trout, because they were only found in the western basin of Lake Erie, were only applied to open water habitat of the Detroit River and Lake Erie.

Table D-3 provides the fish biomass data that were used in the model, based on the assumptions outlined above.

Table D-3. Fish biomass data (kg/km^2) used in the model for the Rouge River, Detroit River and Lake Erie.

Species Name	Biomass (kg/km^2) in Detroit River and Lake Erie	Biomass (kg/km^2) in Rouge River
Herrings	233	233
Sunfishes	233	233
Rainbow smelt	2.6	0
Freshwater drum	54	54
White perch	219	219
Bowfin	202	202
Bullhead catfish	77	77
Marsh forage fish	3,400	3,400
Large forage fish	1,027	1,027
Medium forage fish	639	639
Small forage fish	79	79
Rainbow trout	16	16
Northern pike	49	49
White bass	64	64
Rock bass	411	411
Smallmouth bass	504	504
Largemouth bass	1,050	1,050
Longnose gar	514	514
Walleye	188	188
Yellow perch	86	86

D.5 Fish Life History

Table D-4 provides the fish life history data that were used in the model. All data were compiled from the FishBase database, unless otherwise noted. Parameters collected from FishBase were from the data source in closest proximity or similar habitat to the Detroit River and Lake Erie system.

Mortality data were collected from a variety of sources for each species, generally from primary literature. Bowfin (*Amia calva*) and rainbow trout (*Oncorhynchus mykiss*) were compiled from FishBase, the remaining data were collected from the following sources:

- Freshwater drum (*Aplodinotus grunniens*) was based on Bur (1984) for Lake Erie
- Yellow perch (*Perca flavescens*) was based on Henderson and Nepszy (1990) for Lake Erie and Lake St. Clair and GLFC (1987; 1988, Lake Erie).
- Bullheads and catfish were based on values for the channel catfish (*Ictalurus punctatus*) from Haak (1987) for Michigan.
- Herrings were based on values for the gizzard shad (*Dorosoma cepedianum*) from Michaletz (1998) for several Missouri lakes and reservoirs.
- Northern pike (*Esox lucius*) was based on LeCren (1987) from Canada.

- Large forage fish were based on values for the common carp (*Cyprinus carpio*); fishing mortality was based on McLenmore et al. (1991) Kentucky and natural mortality was based on Reed et al. (1992) and references therein.
- Sunfishes were based on values for the bluegill (*Lepomis macrochirus*); fishing mortality was based on McLenmore et al (1991) for Kentucky water bodies and natural mortality was based on Goedde and Coble (1981) from Wisconsin.
- Rock bass (*Ambloplites rupestris*) was collected from Covington et al. (1983) for Missouri streams.
- White perch (*Morone americana*) was based on Great Lakes Fishery Commission (GLFC) (1987; 1988).
- White bass (*Morone chrysops*) was based on Colvin (2002) from Missouri water bodies.
- Longnose gar (*Lepisosteus osseus*) was based on Hoffmeister et al. (2007) from Indiana.
- Medium forage fish were based on values for the white sucker (*Catostomus commersoni*) from Wakefield and Beckman (2005) for a Missouri lake and tributaries; fishing mortality was assumed to be zero.
- Largemouth bass (*Micropterus salmoides*) was based on Allen et al. (2008), and references therein, from Iowa.
- Walleye (*Sander vitreus*) was based on the GLFC Lake Erie Coordinated Percid Management Study (2004).
- Smallmouth bass (*Micropterus dolomieu*) was from Calhoun (1966).

Table D-4. Fish life history parameters used in the model.
(M = natural mortality, F = fishing mortality, YrRecr = age of recruitment, Life = max.age (yrs) Lmax, K, to = vonBertalanffy parameters, a,b = wt(g)-L(cm) parameters, Kg-max = max wt in kg)

Species group	Age	M	F	Yr Recr	Life	Lmax (cm)	K	to	a	b	kg-max
Herrings	7	1.11	0	2	7	43.7	0.480	0	1	3.071	109.1
Marsh forage fish	All	0.20	0	1	11	9.0	0.580	-0.4	0.011	3	0.01
Rainbow smelt	All	1.10	1	2	6	22.5	0.723	0	0.005	3.034	0.1
White bass	All	0.40	0.94	2	9	35.7	0.454	0	0.016	3.132	1.2
White perch	All	0.40	0.2	2	6	52.0	0.073	-1.52	0.012	3.02	1.8
Bowfin	19	0.37	0	1	19	73.5	0.328	0	0.009	3	3.6
Bullhead catfish	All	0.19	0.26	2	10	38.8	0.229	-0.13	1	2.924	44.1
Freshwater drum	All	0.30	0.36	2	16	128.9	0.063	-0.707	0.005	3	10.7
Large forage fish	All	0.50	0.06	2	12	74.8	0.157	0	1	3.025	466.2
Largemouth bass	All	0.43	0.39	2	13	55.4	0.200	0	0.024	2.993	4.0
Longnose gar	8	0.30	0.65	2	8	140.0	0.080	-5.8	1	3.12	4,965
Medium forage fish	All	0.55	0	2	12	55.6	0.150	0.08	1	3.04	201.8
Northern pike	All	0.30	0.65	2	24	142.0	0.140	0	1	2.779	957.7
Rainbow trout	All	1.40	0	2	8	74.4	0.383	0.62	0.014	2.911	3.9
Rock bass	All	0.17	0.78	4	9	19.2	0.340	0	0.047	2.969	0.3
Small forage fish	All	0.86	0	2	12	12.0	0.530	0	0.001	3.2	0.003
Smallmouth bass	All	0.45	0.25	5	14	49.3	0.230	0	0.018	3.052	2.6
Sunfishes	All	0.36	0.36	2	12	19.2	0.340	0	0.022	3.11	0.2
Walleye	All	0.32	0.15	5	20	54.4	0.237	0	0.008	3.097	1.9
Yellow perch	5	0.35	1.04	3	5	49.3	0.165	0	0.017	3.015	2.2

D.6 Primary and Invertebrate Production

A phytoplankton production value of 0.061 g C/m^2/d for the Detroit River was used for the spring months (NRDAM/GLE: Edwards et al., 1987; Edsall et al., 1988). This number was applied to all open water.

A zooplankton production value of 0.0093 g C/m^2/d and macrozoobenthos biomass value of 0.0060 g C/m^2/d was used for the Detroit River during the spring months (NRDAM/GLE: Edwards et al., 1987; Edsall et al., 1988). These numbers were applied to all open water.

The macrophyte production for the Detroit River was converted from a yearly value into a daily value (NRDAM/GLE: Edwards et al., 1987; Edsall et al., 1988). Daily values were then multiplied by two because growth is limited in autumn and winter seasons. Submerged macrophyte production of 0.3836 g C/m^2/d was used for spring months in aquatic bed habitats. An emergent macrophyte production rate of 1.0247 g C/m^2/d was used for spring months in emergent wetland habitats. Benthic microflora production for the Detroit River was also multiplied by two to account for little growth during the cold seasons, and a production rate of 0.086 g C/m^2/d was used for spring months in all nearshore and wetland habitats.

Table D-5 provides the primary and secondary productivity rates by habitat type within the Detroit River area for the spring months. The primary productivity rates indicate the production of phytoplankton, macrophytes and benthic microflora in the area, while the secondary productivity rates represents the production of zooplankton and benthic invertebrates.

Table D-5. Primary and secondary productivity rates during the spring in the area of the Detroit River.

	Primary Productivity Rates (g C/m^2/d)			Secondary Productivity Rates (g C/m^2/d)		
Habitat Type	**Phytoplankton**	**Macrophytes**	**Benthic Microflora**	**Zooplankton**	**Macro-zoobenthos**	**Benthic Invertebrates**
Rocky shoreline	0.72					
Gravel beach	0.72					
Sand beach	2.0					
Marsh/wetland	2.0	0.19	0.043	0.0093	0.006	0.025
Mud flats	2.0					

D.7 References

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Attachment E: Rouge River 2002 Mystery Oil Spill SIMAP Injury Report: Biological Model Results

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ROUGE RIVER 2002 MYSTERY OIL SPILL
SIMAP INJURY REPORT
Appendix E: Biological Model Results
Draft for Trustee Review

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Pursuant to Requisition/Purchase Number: 314107015A

May 9, 2011

E.1 Biological Model Results

The biological model was run on the base case (RR-2PH-FV11-2HA-1PCT, as described in Appendix B, Sensitivity Analysis), the two sensitivity cases for the percent slow release (0% and 3% slow release; Table E-1) as these inputs were the most uncertain ones for the fates model, and two sensitivity cases varying the oil property of percent water when fully emulsified as mousse (10% and 60%: Table E-1). For the fish and invertebrate injury, each of the three scenarios were then modeled using three $LC50_{\infty}$ values to estimate injuries for sensitive, average and insensitive species. Table E-1 provides the matrix of biological scenarios modeled.

Table E-1. List of scenarios used for sensitivity analysis for biological modeling.

Scenario name	$LC50_{\infty}$ for sensitive species	$LC50_{\infty}$ for average species	$LC50_{\infty}$ for insensitive species
RR-2PH-FV11-2HA-1PCT (base case)	**5**	**44**	**370**
RR-2PH-FV11-2HA-0PCT	5	44	370
RR-2PH-FV11-2HA-3PCT	5	44	370
RR-2PH-FV11-2HA-1PCT-10MO	5	44	370
RR-2PH-FV11-2HA-1PCT-60MO	5	44	370

For the wildlife injury estimates, the results were divided into those for the Rouge River only, and those for the Detroit River and Lake Erie, combined, because of different assumed densities of animals in each area. Tables E-2 to E-25 provide the wildlife injury results for the five fates scenarios modeled. The results indicate that the wildlife injuries computed by the model are insensitive to the assumed percentage of the oil released slowly and after the majority of the first oil release had moved out of the Rouge River.

It should be noted that it is uncertain what the pre-spill densities of birds and other wildlife were before the spill. The density data used for the modeling, which was best available information, was from other locations and times (see Appendix D.1). However, the model results are directly proportional to the density data assumed. Therefore, if the densities assumed were a factor 2 lower, the injury results would also be a factor 2 lower. The counts of animals observed oiled or dead in the field totaled 110 birds and 3 turtles. Thus, these model results suggest that one in 49 birds oiled were actually observed; whereas the rule of thumb for past spills has been about 1 in 10 might be observed. Yet, these ratios are highly uncertain, and dependant on the degree of search effort, losses to scavengers, and other factors. Estimates for the likelihood of observing oiled turtles are not available, but 1 in 100 is not unreasonable in this situation.

Due to the fact that the scaup injury accounted for the majority of the wildlife injury, those injuries are presented in separate tables. These injuries are high due to the assumed pre-spill density of 104 individuals/km^2 in Lake Erie waters from 1-3 meters in depth (Figure 3-5 of main SIMAP Injury Report). While this abundance seems high, these numbers (the mean observed in Pointe Mouillee area in April 2002-2008) were corroborated by two species counts: one from close to shore in the Pointe Mouillee marsh area (on 13 April 2002, 109 individuals/km2 were counted there) and the other from an open water survey between Maumee Bay and West Sister Island (101 individuals/km^2, sampling location shown in Figure D-1). Additionally, the model estimate of the area oiled for waters between 1 and 3 meters deep in Lake Erie was 39.4 km^2, a reasonable estimate; and scaup are known to spend most of their time on the water surface (and so are very vulnerable to oiling). Therefore, the calculations indicating that there should be close to 5,000 scaups oiled is realistic.

The area of habitat between 1 and 3 meters deep in western Lake Erie was 212 km^2; therefore, applying an average abundance of 104 scaup/km^2 results in a total population estimate of approximately 22,000 scaup in Western Lake Erie in April. For the entire Upper Mississippi River and Great Lakes Joint Venture Region, the spring migration estimate for scaup is approximately 1.5 million birds, and the winter population is approximately 200,000 birds (Souillere et al. 2007). The model simulation killed 18.6% of the population, or 4,106 individuals. Even though these numbers seem large based on reported observations after the spill, there are several reasons this should be a reliable injury estimate. First, scaup are not often found close to shore; therefore, they are unlikely to take refuge in the areas that were easily surveyed after the spill. Secondly, scaup are dark in color (brown, non-breeding plumage being prevalent in April for both species), which would make identifying an oiled bird from shore nearly impossible. Third, the scale of impact is due to the fact that much of the oil impacted the area surrounding Pointe Mouillee, where high abundances of scaup have been documented in April, and that nearly 40 km^2 of habitat 1-3 meters in depth (Figures E-1 and E-2) were estimated as oiled 11 April through 14 April 2002.

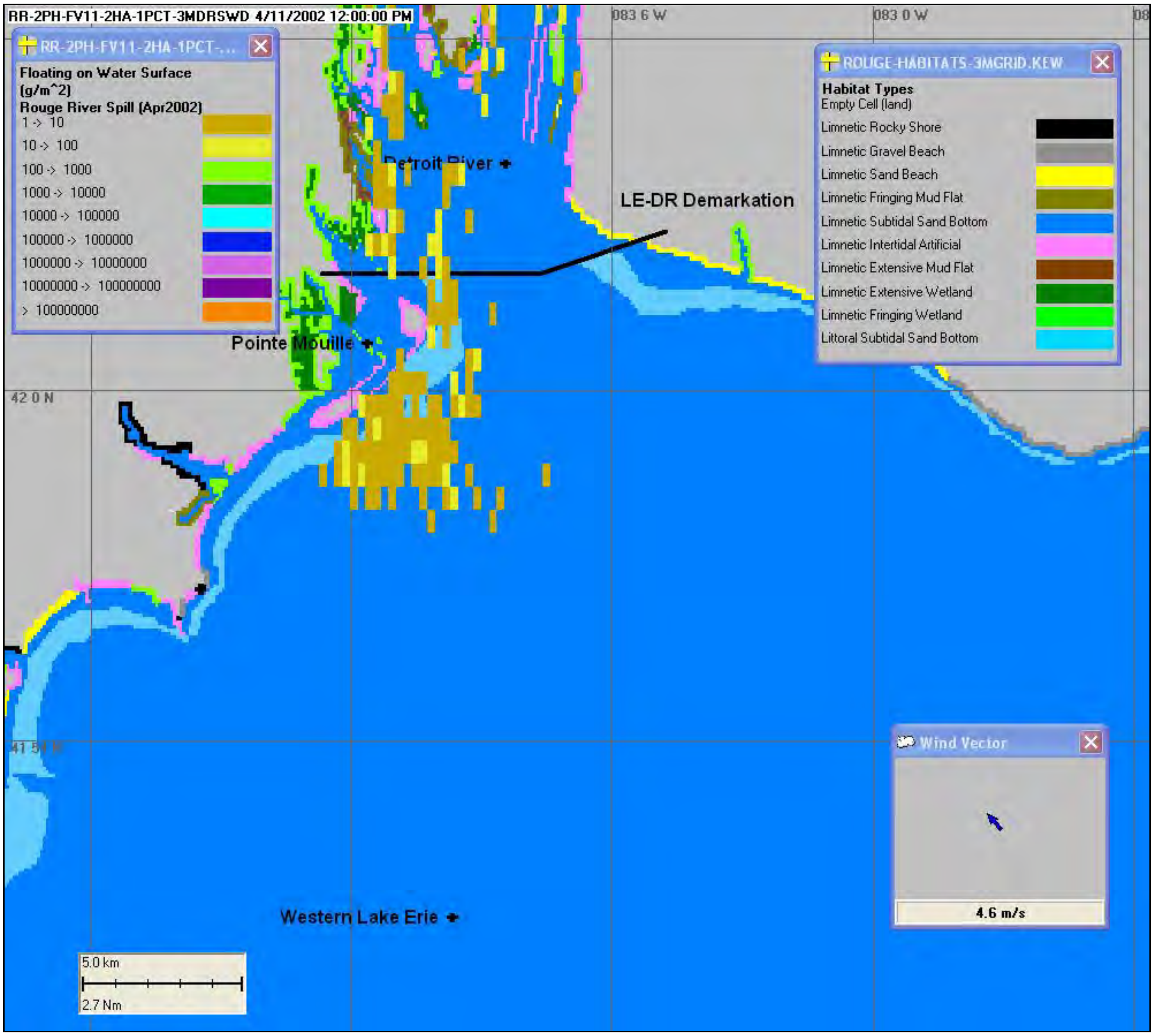

Figure E-1. Concentration of oil on the surface of the water at noon on 11 April 2002 over the habitat grid developed for scaup, which were applied to 1-3 meter deep water in Lake Erie. The solid black line marks the delineation between the Detroit River and Lake Erie.

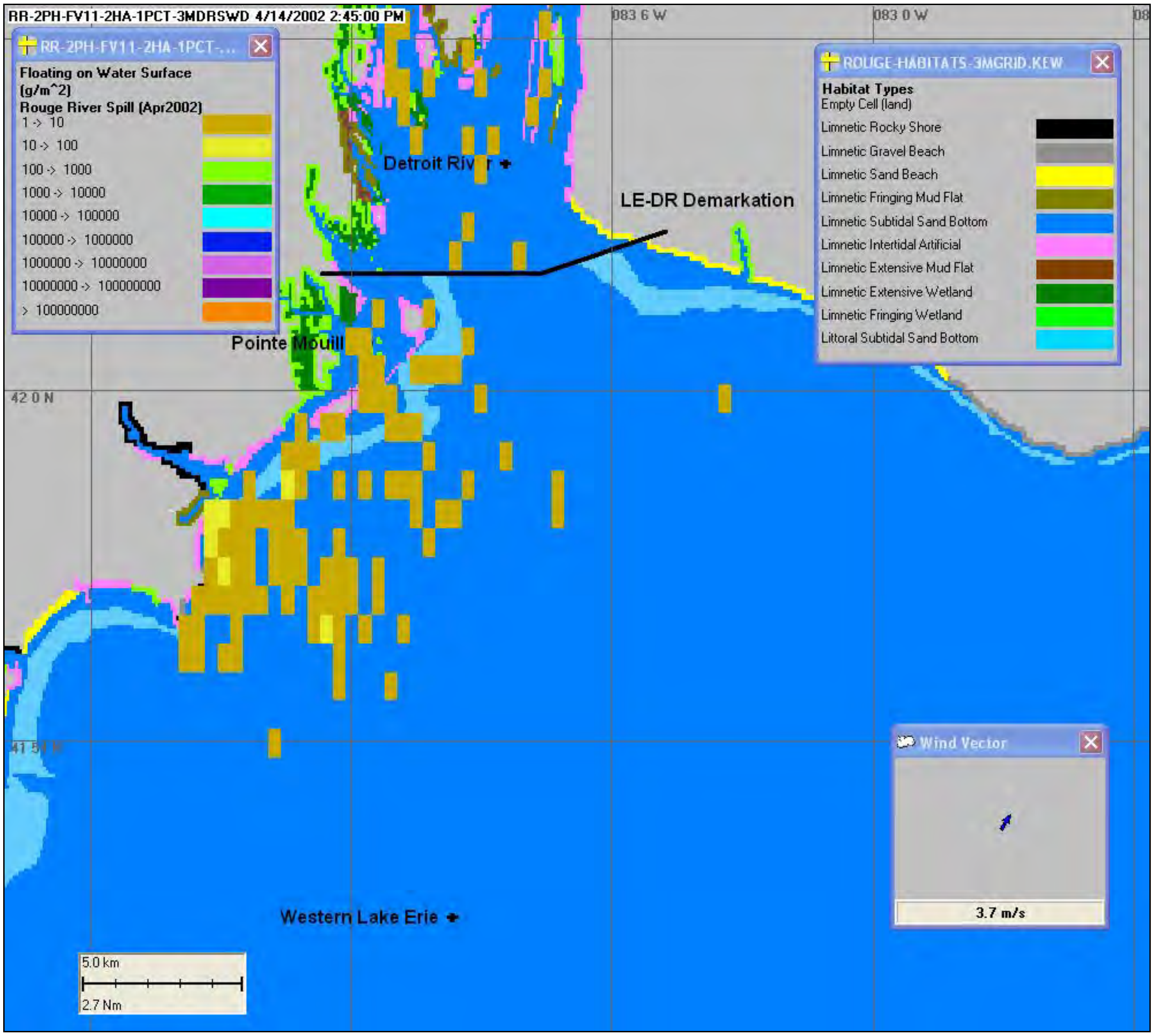

Figure E-2. Concentration of oil on the surface of the water at 2:45 pm on 14 April 2002 over the habitat grid developed for scaup which were applied to 1-3 meter deep water in Lake Erie. The solid black line marks the delineation between the Detroit River and Lake Erie.

Table E-2. RR-2PH-FV11-2HA-1PCT: Estimated injuries to avifauna (other than scaups) for the Detroit River, Lake Erie and Rouge River using a 1 percent slow release of the oil. Note that the number oiled is based on a probability, and so mathematically can be < 1 animal. "-" indicates species was not present in region, whereas zeros indicate the injury estimate is less than 0.1 individual.

Avian Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
American black duck	0.5	-	0.5
American coot	72.5	9.9	82.4
American widgeon	4.9	0.7	5.6
Blue-winged teal	2.6	0.4	2.9
Bufflehead	2.4	0.3	2.7
Canada goose	8.0	1.1	9.0
Canvasback	3.1	0.4	3.5
Common goldeneye	0.1	0.0	0.1
Common loon	0.0	-	0.0
Eurasian Wigeon	0.0	0.0	0.0
Gadwall	21.5	2.9	24.4
Green-winged teal	27.4	3.7	31.1
Horned grebe	0.1	0.0	0.2
Long-tailed duck	0.0	-	0.0
Mallard	4.0	0.5	4.6
Red-breasted merganser	91.7	-	91.7
Common merganser	114	-	114
Hooded merganser	18.1	-	18.1
Northern pintail	6.3	0.9	7.2
Northern shoveler	4.4	0.6	5.0
Pied-billed grebe	1.0	0.1	1.2
Redhead	8.7	1.2	9.8
Ring-necked duck	3.8	0.5	4.3
Ruddy duck	10.8	1.5	12.2
Surf scoter	0.0	-	0.0
Mute swan	4.8	0.7	5.4
Tundra swan	0.0	0.0	0.0
Wood duck	0.1	-	0.1
Bonapartes gull	173	0.2	173
Caspian tern	23.5	0.0	23.6
Doublecrested cormorant	242	0.3	242
Forsters tern	22.1	0.0	22.1
Glaucous gull	0.2	0.0	0.2

Avian Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Great black-back gull	1.7	0.0	1.7
Herring gull	191	0.3	191
Lesser black-back gull	0.2	0.0	0.2
Ring-billed gull	83.4	0.1	83.5
American bittern	0.0	-	0.0
Black-crowned heron	0.8	-	0.8
Common moorhen	0.3	-	0.3
Great blue heron	4.9	-	4.9
Great egret	3.4	-	3.4
Green heron	0.0	-	0.0
Sandhill crane	0.1	-	0.1
Sora	0.5	-	0.5
Virginia rail	0.2	-	0.2
American avocet	0.6	-	0.6
Black-necked stilt	0.0	-	0.0
Common snipe	3.8	-	3.8
Dunlin	30.1	-	30.1
Greater yellowlegs	3.4	-	3.4
Killdeer	3.6	-	3.6
Least sandpiper	0.1	-	0.1
Lesser yellowlegs	6.5	-	6.5
Long-bill dowitcher	0.1	-	0.1
Pectoral sandpiper	8.6	-	8.6
Semipalmated plover	0.0	-	0.0
Short-bill dowitcher	0.1	-	0.1
Solitary sandpiper	0.0	-	0.0
Spotted sandpiper	0.2	-	0.2
Willet	0.7	-	0.7
Wilsons snipe	0.6	-	0.6
Total Waterfowl	410	25	436
Total Seabirds	737	1	738
Total Wading birds	10	-	10
Total Shorebirds	58	-	58
Total All Avian Species	1,215	26	1,241

Table E-3. RR-2PH-FV11-2HA-1PCT: Estimated injuries to scaups for the base case model scenario using a 1 percent slow release of the oil. "-" indicates species was not present in region.

Scaup Species	Number Killed in Lake Erie	Number Killed in Rouge and Detroit River*	Total Number Killed
Scaup spp.	125	-	125
Greater scaup	1,789	-	1,789
Lesser scaup	2,192	-	2,192
Total All Scaup Species			4,106

***Scaup species assumed to only occur in Lake Erie waters from 1-3m deep.**

Table E-4. RR-2PH-FV11-2HA-1PCT: Estimated injuries to mammals for the base case model scenario using a 1 percent slow release of the oil. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

Mammal Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Muskrat	308	-	308
Total All Mammal Species			308

Table E-5. RR-2PH-FV11-2HA-1PCT: Estimated injuries to herpetofauna for the base case model scenario using a 1 percent slow release of the oil. Note that the number oiled is based on a probability, and so mathematically can be < 1 animal. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

Herptile Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Black rat snake	0.0	-	0.0
Blandings turtle	1.5	-	1.5
Butlers garter snake	0.0	-	0.0
Eastern fox snake	0.0	-	0.0
Eastern garter snake	0.1	-	0.1
Eastern spiny softshell	1.2	-	1.2
Map turtle	51.8	-	51.8
Midland painted turtle	44.2	-	44.2
Northern brown snake	0.0	-	0.0
Northern water snake	5.0	-	5.0
Red-ear slider turtle	1.2	-	1.2
Snapping turtle	8.8	-	8.8
American toad	13.5	-	13.5
Bullfrog	12.4	-	12.4
Gray tree frog	0.3	-	0.3

Herptile Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Green frog	8.0	-	8.0
Leopard frog	42.7	-	42.7
Western chorus frog	0.4	-	0.4
Wood frog	0.2	-	0.2
Total Reptiles			114
Total Amphibians			77.5
Total All Herptile Species			191.3

Table E-6. RR-2PH-FV11-2HA-1PCT: Estimated equivalent losses of bird fledglings (other than scaups) for the base case model scenario using a 1 percent slow release of the oil. Note that the number lost is based on a probability, and so mathematically can be < 1 animal. "-" indicates species was not present in region.

	Equivalent Fledgling Losses		
Avian Species	**Detroit River and Lake Erie**	**Rouge River**	**Total**
American black duck	1.5	-	1.5
American coot	240	32.7	273
American widgeon	16.3	2.2	18.5
Blue-winged teal	8.5	1.2	9.7
Bufflehead	8.4	1.1	9.5
Canada goose	24.4	3.3	27.7
Canvasback	10.8	1.5	12.3
Common goldeneye	0.4	0.1	0.5
Common loon	0.3	-	0.3
Eurasian Wigeon	0.1	0.0	0.1
Gadwall	71.2	9.7	80.9
Green-winged teal	90.8	12.3	103
Horned grebe	0.5	0.1	0.6
Long-tailed duck	0.0	-	0.0
Mallard	13.3	1.8	15.1
Red-breasted merganser	320	-	320
Common merganser	396	-	396
Hooded merganser	63.0	-	63.0
Northern pintail	20.9	2.8	23.8
Northern shoveler	14.6	2.0	16.6
Pied-billed grebe	4.0	0.6	4.6
Redhead	30.2	4.1	34.3
Ring-necked duck	13.2	1.8	15.0
Ruddy duck	37.5	5.1	42.6

	Equivalent Fledgling Losses		
Avian Species	**Detroit River and Lake Erie**	**Rouge River**	**Total**
Surf scoter	0.0	-	0.0
Mute swan	13.6	1.8	15.4
Tundra swan	0.0	0.0	0.0
Wood duck	0.5	-	0.5
Bonapartes gull	635	0.8	636
Caspian tern	83.7	0.1	83.8
Doublecrested cormorant	940	1.2	941
Forsters tern	78.5	0.1	78.6
Glaucous gull	0.8	0.0	0.8
Great black-back gull	6.3	0.0	6.3
Herring gull	702	0.9	703
Lesser black-back gull	0.8	0.0	0.8
Ring-billed gull	306	0.4	307
American bittern	0.1	-	0.1
Black-crowned heron	2.8	-	2.8
Common moorhen	0.9	-	0.9
Great blue heron	16.4	-	16.4
Great egret	11.3	-	11.3
Green heron	0.1	-	0.1
Sandhill crane	0.3	-	0.3
Sora	1.8	-	1.8
Virginia rail	0.5	-	0.5
American avocet	2.1	-	2.1
Black-necked stilt	0.1	-	0.1
Common snipe	13.3	-	13.3
Dunlin	106	-	106
Greater yellowlegs	12.2	-	12.2
Killdeer	12.6	-	12.6
Least sandpiper	0.3	-	0.3
Lesser yellowlegs	17.2	-	17.2
Long-bill dowitcher	0.5	-	0.5
Pectoral sandpiper	30.2	-	30.2
Semipalmated plover	0.1	-	0.1
Short-bill dowitcher	0.2	-	0.2
Solitary sandpiper	0.1	-	0.1
Spotted sandpiper	0.7	-	0.7
Willet	2.3	-	2.3
Wilsons snipe	2.2	-	2.2
Total Waterfowl			1,485

Avian Species	Equivalent Fledgling Losses		
	Detroit River and Lake Erie	Rouge River	Total
Total Seabirds			2,757
Total Wading birds			34.2
Total Shorebirds			200
Total All Avian Species			4,476

Table E-7. RR-2PH-FV11-2HA-1PCT: Estimated equivalent losses of scaup fledglings for the base case model scenario using a 1 percent slow release of the oil. "-" indicates species was not present in region.

Scaup Species	Fledglings Lost		
	Lake Erie	Rouge and Detroit River	Total
Scaup spp.	435	-	435
Greater scaup	6,245	-	6,245
Lesser scaup	7,652	-	7,652
Total All Scaup Species			14,332

Table E-8. RR-2PH-FV11-2HA-1PCT: Estimated equivalent losses of age-zero (newly-weaned) mammals for the base case model scenario using a 1 percent slow release of the oil. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

Mammal Species	Equivalent Newly-Weaned Individuals Lost		
	Detroit River and Lake Erie	Rouge River	Total
Muskrat	940	-	940
Total All Mammal Species			940

Table E-9. RR-2PH-FV11-2HA-1PCT: Estimated equivalent losses of herpetofauna hatchlings for the base case model scenario using a 1 percent slow release of the oil. Note that the number lost is based on a probability, and so mathematically can be < 1 animal. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

Herptile Species	Equivalent Hatchling Losses			
	Number Hatched per Adult	Detroit River and Lake Erie	Rouge River	Total
Black rat snake	20	0.0	-	0.0
Blandings turtle	20	33.0	-	33.0
Butlers garter snake	20	0.3	-	0.3

Herptile Species	Equivalent Hatchling Losses			
	Number Hatched per Adult	**Detroit River and Lake Erie**	**Rouge River**	**Total**
Eastern fox snake	20	0.2	-	0.2
Eastern garter snake	20	0.7	-	0.7
Eastern spiny softshell	20	24.7	-	24.7
Map turtle	24	4067	-	407
Midland painted turtle	20	952	-	952
Northern brown snake	20	0.1	-	0.1
Northern water snake	20	74.2	-	74.2
Red-ear slider turtle	20	24.7	-	24.7
Snapping turtle	20	190	-	190
American toad	3,000	13,180	-	13,180
Bullfrog	20,000	80,030	-	80,030
Gray tree frog	3,000	280	-	280
Green frog	3,000	7,850	-	7,850
Leopard frog	3,000	41,690	-	41,690
Western chorus frog	3,000	374	-	374
Wood frog	3,000	187.0	-	187.0
Total Reptiles				1,700
Total Amphibians				143,600
Total All Herptile Species				145,300

Table E-10. RR-2PH-FV11-2HA-1PCT: Estimated injuries (interim loss) for avian species (excluding scaups) as individual bird-years (all age classes combined) for the base case model scenario using a 1 percent slow release of the oil. Note that the number lost is based on a probability, and so mathematically can be < 1 animal. "-" indicates species was not present in region.

	Individual-years Lost (all ages)		
Avian Species	**Detroit River and Lake Erie**	**Rouge River**	**Total**
American black duck	1.3	-	1.3
American coot	201	27.3	228
American widgeon	13.6	1.84	15.4
Blue-winged teal	7.1	0.97	8.1
Bufflehead	5.2	0.7	5.9
Canada goose	29.8	4.05	33.8
Canvasback	6.7	0.91	7.6

	Individual-years Lost (all ages)		
Avian Species	**Detroit River and Lake Erie**	**Rouge River**	**Total**
Common goldeneye	0.3	0.03	0.3
Common loon	0.6	-	0.6
Eurasian Wigeon	0.1	0.01	0.1
Gadwall	59.4	8.08	67.5
Green-winged teal	75.8	10.3	86.1
Horned grebe	2.2	0.29	2.5
Long-tailed duck	0.0	-	0.0
Mallard	11.1	1.51	12.6
Red-breasted merganser	198	-	198
Common merganser	245	-	245
Hooded merganser	38.9	-	38.9
Northern pintail	17.5	2.37	19.8
Northern shoveler	12.2	1.65	13.8
Pied-billed grebe	16.4	2.23	18.7
Redhead	18.6	2.53	21.2
Ring-necked duck	8.1	1.11	9.3
Ruddy duck	23.2	3.15	26.4
Surf scoter	0.0	-	0.0
Mute swan	65.5	8.9	74.4
Tundra swan	0.2	0.02	0.2
Wood duck	0.3	-	0.3
Bonapartes gull	2,990	3.86	2,994
Caspian tern	188	0.24	188
Doublecrested cormorant	3,836	4.95	3,840
Forsters tern	176	0.23	176
Glaucous gull	3.5	0	3.5
Great black-back gull	29.6	0.04	29.6
Herring gull	3,307	4.27	3,311
Lesser black-back gull	3.5	0	3.5
Ring-billed gull	1,443	1.86	1,444
American bittern	0.1	-	0.1
Black-crowned heron	2.5	-	2.5
Common moorhen	0.8	-	0.8
Great blue heron	14.6	-	14.6
Great egret	10.1	-	10.1
Green heron	0.1	-	0.1
Sandhill crane	0.2	-	0.2
Sora	1.6	-	1.6
Virginia rail	0.4	-	0.4

	Individual-years Lost (all ages)		
Avian Species	**Detroit River and Lake Erie**	**Rouge River**	**Total**
American avocet	3.9	-	3.9
Black-necked stilt	0.3	-	0.3
Common snipe	24.3	-	24.3
Dunlin	194	-	194
Greater yellowlegs	22.2	-	22.2
Killdeer	23.0	-	23.0
Least sandpiper	0.5	-	0.5
Lesser yellowlegs	16.3	-	16.3
Long-bill dowitcher	0.8	-	0.8
Pectoral sandpiper	55.2	-	55.2
Semipalmated plover	0.2	-	0.2
Short-bill dowitcher	0.3	-	0.3
Solitary sandpiper	0.2	-	0.2
Spotted sandpiper	1.2	-	1.2
Willet	4.3	-	4.3
Wilsons snipe	3.9	-	3.9
Total Waterfowl			1,135
Total Seabirds			11,992
Total Wading birds			30.5
Total Shorebirds			351
Total All Avian Species			13,510

Table E-11. RR-2PH-FV11-2HA-1PCT: Estimated injuries (interim loss) as individual scaup-years for the base case model scenario using a 1 percent slow release of the oil. "-" indicates species was not present in region.

	Individual-years Lost		
Scaup Species	**Lake Erie**	**Rouge and Detroit River**	**Total**
Scaup spp.	269	-	269
Greater scaup	3,859	-	3,859
Lesser scaup	4,728	-	4,728
Total All Scaup Species			8,855

Table E-12. RR-2PH-FV11-2HA-1PCT: Estimated injuries (interim loss) as individual mammal-years (all age classes combined) for the base case model scenario using a 1 percent slow release of the oil. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

	Individual-years Lost (all ages)		
Mammal Species	**Detroit River and Lake Erie**	**Rouge River**	**Total**
Muskrat	398	-	398
Total All Mammal Species			398

Table E-13. RR-2PH-FV11-2HA-1PCT: Estimated injuries (interim loss) as individual herptile-years (all age classes combined) for the base case model scenario using a 1 percent slow release of the oil. Note that the number lost is based on a probability, and so mathematically can be < 1 animal. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

	Individual-years Lost (all ages)		
Herptile Species	**Detroit River and Lake Erie**	**Rouge River**	**Total**
Black rat snake	0.0	-	0.0
Blandings turtle	23.9	-	23.9
Butlers garter snake	0.2	-	0.2
Eastern fox snake	0.2	-	0.2
Eastern garter snake	0.6	-	0.6
Eastern spiny softshell	17.9	-	17.9
Map turtle	294	-	294
Midland painted turtle	689	-	689
Northern brown snake	0.1	-	0.1
Northern water snake	57.5	-	57.5
Red-ear slider turtle	17.9	-	17.9
Snapping turtle	137	-	137
American toad	867	-	867
Bullfrog	5,270	-	5,270
Gray tree frog	18.4	-	18.4
Green frog	517	-	517
Leopard frog	2,743	-	2,743
Western chorus frog	24.6	-	24.6
Wood frog	12.3	-	12.3
Total Reptiles			1,238
Total Amphibians			9,448
Total All Herptile Species			10,690

Table E-14. RR-2PH-FV11-2HA-0PCT: Estimated injuries to avifauna (other than scaups) for the Detroit River, Lake Erie, and Rouge River using a 0 percent slow release of the oil.

Avian Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
American black duck	0.5	0.0	0.5
American coot	71.2	9.6	80.9
American widgeon	4.8	0.7	5.5
Blue-winged teal	2.5	0.3	2.9
Bufflehead	2.4	0.3	2.7
Canada goose	7.8	1.1	8.9
Canvasback	3.0	0.4	3.4
Common goldeneye	0.1	0.0	0.1
Common loon	0.0	0.0	0.0
Eurasian Wigeon	0.0	0.0	0.0
Gadwall	21.1	2.9	24.0
Green-winged teal	26.9	3.6	30.6
Horned grebe	0.1	0.0	0.2
Long-tailed duck	0.0	0.0	0.0
Mallard	3.9	0.5	4.5
Merganser red-breast	90.0	0.0	90.0
Merganser, common	111.5	0.0	111.5
Merganser, hooded	17.7	0.0	17.7
Northern pintail	6.2	0.8	7.0
Northern shoveler	4.3	0.6	4.9
Pied-billed grebe	1.0	0.1	1.2
Redhead	8.5	1.2	9.6
Ring-necked duck	3.7	0.5	4.2
Ruddy duck	10.6	1.4	12.0
Scoter, surf	0.0	0.0	0.0
Swan, mute	4.7	0.6	5.3
Swan, tundra	0.0	0.0	0.0
Wood duck	0.1	0.0	0.1
Bonapartes gull	170.0	0.2	170.2
Caspian tern	23.2	0.0	23.2
Doublecrested cormorant	237.9	0.3	238.2
Forsters tern	21.7	0.0	21.7
Glaucous gull	0.2	0.0	0.2
Great black-backed gull	1.7	0.0	1.7
Herring gull	187.9	0.2	188.2
Lesser black-backed gull	0.2	0.0	0.2
Ring-billed gull	82.0	0.1	82.1
American bittern	0.1	-	0.1
Black-crowned heron	1.0	-	1.0
Common moorhen	0.3	-	0.3
Great blue heron	5.6	-	5.6
Great egret	3.8	-	3.8
Green heron	0.1	-	0.1

Avian Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Sandhill crane	0.1	-	0.1
Sora	0.6	-	0.6
Virginia rail	0.2	-	0.2
American avocet	0.7	-	0.7
Black-necked stilt	0.1	-	0.1
Common snipe	4.3	-	4.3
Dunlin	34.1	-	34.1
Greater yellowlegs	3.9	-	3.9
Killdeer	4.0	-	4.0
Least sandpiper	0.1	-	0.1
Lesser yellowlegs	7.4	-	7.4
Long-bill dowitcher	0.2	-	0.2
Pectoral sandpiper	9.7	-	9.7
Semipalmated plover	0.0	-	0.0
Short-bill dowitcher	0.1	-	0.1
Solitary sandpiper	0.0	-	0.0
Spotted sandpiper	0.2	-	0.2
Willet	0.8	-	0.8
Wilsons snipe	0.7	-	0.7
Total Waterfowl			427.7
Total Seabirds			725.7
Total Wading birds			11.8
Total Shorebirds			66.3
Total All Avian Species			1,231.5

Table E-15. RR-2PH-FV11-2HA-0PCT: Estimated injuries to mammals for the Detroit River, Lake Erie, and Rouge River using a 0 percent slow release of the oil. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

Mammal Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Muskrat	348.7	-	348.7
Total All Mammal Species			348.7

Table E-16. RR-2PH-FV11-2HA-0PCT: Estimated injuries to herpetofauna for the Detroit River, Lake Erie, and Rouge River using a 0 percent slow release of the oil. Note that the number oiled is based on a probability, and so mathematically can be < 1 animal. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

Herptile Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Black rat snake	0.0	-	0.0
Blandings turtle	1.7	-	1.7
Butlers garter snake	0.0	-	0.0
Eastern fox snake	0.0	-	0.0
Eastern garter snake	0.1	-	0.1
Eastern spiny softshell	1.3	-	1.3
Map turtle	58.6	-	58.6
Midland painted turtle	50.0	-	50.0
Northern brown snake	0.0	-	0.0
Northern water snake	5.6	-	5.6
Red-ear slider turtle	1.3	-	1.3
Snapping turtle	10.0	-	10.0
American toad	15.3	-	15.3
Bullfrog	14.0	-	14.0
Gray tree frog	0.3	-	0.3
Green frog	9.1	-	9.1
Leopard frog	48.3	-	48.3
Western chorus frog	0.4	-	0.4
Wood frog	0.2	-	0.2
Total Reptiles			128.7
Total Amphibians			87.6
Total All Herptile Species			216.3

Table E-17. RR-2PH-FV11-2HA-3PCT: Estimated injuries to avifauna (other than scaups) for the Detroit River, Lake Erie and Rouge River using a 3 percent slow release of the oil.

Avian Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
American black duck	0.5	0.0	0.5
American coot	71.8	9.7	81.5
American widgeon	4.9	0.7	5.5
Blue-winged teal	2.6	0.3	2.9
Bufflehead	2.4	0.3	2.7
Canada goose	7.9	1.1	8.9
Canvasback	3.1	0.4	3.5
Common goldeneye	0.1	0.0	0.1
Common loon	0.0	0.0	0.0
Eurasian Wigeon	0.0	0.0	0.0
Gadwall	21.3	2.9	24.1
Green-winged teal	27.1	3.7	30.8
Horned grebe	0.1	0.0	0.2
Long-tailed duck	0.0	0.0	0.0
Mallard	4.0	0.5	4.5
Merganser red-breast	90.7	0.0	90.7
Merganser, common	112.3	0.0	112.3
Merganser, hooded	17.9	0.0	17.9
Northern pintail	6.2	0.9	7.1
Northern shoveler	4.4	0.6	4.9
Pied-billed grebe	1.0	0.1	1.2
Redhead	8.6	1.2	9.7
Ring-necked duck	3.7	0.5	4.2
Ruddy duck	10.6	1.4	12.1
Scoter, surf	0.0	0.0	0.0
Swan, mute	4.7	0.6	5.3
Swan, tundra	0.0	0.0	0.0
Wood duck	0.1	0.0	0.1
Bonapartes gull	158.7	0.2	158.9
Caspian tern	21.6	0.0	21.7
Doublecrested cormorant	222.1	0.3	222.4
Forsters tern	20.3	0.0	20.3
Glaucous gull	0.2	0.0	0.2
Great black-backed gull	1.6	0.0	1.6
Herring gull	175.5	0.2	175.7
Lesser black-backed gull	0.2	0.0	0.2
Ring-billed gull	76.5	0.1	76.6
American bittern	0.0	-	0.0
Black-crowned heron	0.9	-	0.9
Common moorhen	0.3	-	0.3
Great blue heron	5.2	-	5.2
Great egret	3.6	-	3.6
Green heron	0.0	-	0.0

Avian Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Sandhill crane	0.1	-	0.1
Sora	0.6	-	0.6
Virginia rail	0.2	-	0.2
American avocet	0.6	-	0.6
Black-necked stilt	0.0	-	0.0
Common snipe	4.0	-	4.0
Dunlin	31.6	-	31.6
Greater yellowlegs	3.6	-	3.6
Killdeer	3.7	-	3.7
Least sandpiper	0.1	-	0.1
Lesser yellowlegs	6.8	-	6.8
Long-bill dowitcher	0.1	-	0.1
Pectoral sandpiper	9.0	-	9.0
Semipalmated plover	0.0	-	0.0
Short-bill dowitcher	0.1	-	0.1
Solitary sandpiper	0.0	-	0.0
Spotted sandpiper	0.2	-	0.2
Willet	0.7	-	0.7
Wilsons snipe	0.6	-	0.6
Total Waterfowl			431
Total Seabirds			678
Total Wading birds			11
Total Shorebirds			61
Total All Avian Species			1,180

Table E-18. RR-2PH-FV11-2HA-3PCT: Estimated injuries to mammals for the Detroit River, Lake Erie, and Rouge River using a 3 percent slow release of the oil. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

Mammal Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Muskrat	323.3	-	323.3
Total All Mammal Species			323

Table E-19. RR-2PH-FV11-2HA-3PCT: Estimated injuries to herpetofauna for the Detroit River, Lake Erie, and Rouge River using a 3 percent slow release of the oil. Note that the number oiled is based on a probability, and so mathematically can be < 1 animal. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

Herptile Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Black rat snake	0.0	-	0.0
Blandings turtle	1.6	-	1.6
Butlers garter snake	0.0	-	0.0
Eastern fox snake	0.0	-	0.0
Eastern garter snake	0.1	-	0.1
Eastern spiny softshell	1.2	-	1.2
Map turtle	54.3	-	54.3
Midland painted turtle	46.4	-	46.4
Northern brown snake	0.0	-	0.0
Northern water snake	5.2	-	5.2
Red-ear slider turtle	1.2	-	1.2
Snapping turtle	9.2	-	9.2
American toad	14.2	-	14.2
Bullfrog	13.0	-	13.0
Gray tree frog	0.3	-	0.3
Green frog	8.4	-	8.4
Leopard frog	44.8	-	44.8
Western chorus frog	0.4	-	0.4
Wood frog	0.2	-	0.2
Total Reptiles			119
Total Amphibians			81
Total All Herptile Species			200

Table E-20. RR-2PH-FV11-2HA-1PCT-10MO: Estimated injuries to avifauna (other than scaups) for the Detroit River, Lake Erie and Rouge River using a 1 percent slow release of the oil and an oil mixture with 10 percent water when fully emulsified as mousse.

Avian Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
American black duck	0.4	0.0	0.4
American coot	64.4	9.1	73.4
American widgeon	4.4	0.6	5.0
Blue-winged teal	2.3	0.3	2.6
Bufflehead	2.1	0.3	2.4
Canada goose	7.1	1.0	8.1
Canvasback	2.7	0.4	3.1
Common goldeneye	0.1	0.0	0.1
Common loon	0.0	0.0	0.0
Eurasian Wigeon	0.0	0.0	0.0
Gadwall	19.1	2.7	21.8
Green-winged teal	24.3	3.4	27.7
Horned grebe	0.1	0.0	0.1
Long-tailed duck	0.0	0.0	0.0
Mallard	3.6	0.5	4.1
Merganser red-breast	81.3	0.0	81.3
Merganser, common	100.7	0.0	100.7
Merganser, hooded	16.0	0.0	16.0
Northern pintail	5.6	0.8	6.4
Northern shoveler	3.9	0.6	4.5
Pied-billed grebe	0.9	0.1	1.1
Redhead	7.7	1.1	8.8
Ring-necked duck	3.4	0.5	3.8
Ruddy duck	9.5	1.4	10.9
Scoter, surf	0.0	0.0	0.0
Swan, mute	4.2	0.6	4.8
Swan, tundra	0.0	0.0	0.0
Wood duck	0.1	0.0	0.1
Bonapartes gull	120.8	0.2	121.0
Caspian tern	16.5	0.0	16.5
Doublecrested cormorant	169.2	0.3	169.5
Forsters tern	15.4	0.0	15.5
Glaucous gull	0.1	0.0	0.1
Great black-backed gull	1.2	0.0	1.2
Herring gull	133.6	0.2	133.9
Lesser black-backed gull	0.1	0.0	0.1
Ring-billed gull	58.3	0.1	58.4
American bittern	0.0	-	0.0
Black-crowned heron	0.6	-	0.6
Common moorhen	0.2	-	0.2
Great blue heron	3.8	-	3.8
Great egret	2.6	-	2.6

Avian Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Green heron	0.0	-	0.0
Sandhill crane	0.1	-	0.1
Sora	0.4	-	0.4
Virginia rail	0.1	-	0.1
American avocet	0.5	-	0.5
Black-necked stilt	0.0	-	0.0
Common snipe	2.9	-	2.9
Dunlin	23.0	-	23.0
Greater yellowlegs	2.6	-	2.6
Killdeer	2.7	-	2.7
Least sandpiper	0.1	-	0.1
Lesser yellowlegs	5.0	-	5.0
Long-bill dowitcher	0.1	-	0.1
Pectoral sandpiper	6.5	-	6.5
Semipalmated plover	0.0	-	0.0
Short-bill dowitcher	0.0	-	0.0
Solitary sandpiper	0.0	-	0.0
Spotted sandpiper	0.1	-	0.1
Willet	0.5	-	0.5
Wilsons snipe	0.5	-	0.5
Total Waterfowl			387
Total Seabirds			516
Total Wading birds			8
Total Shorebirds			44
Total All Avian Species			956

Table E-21. RR-2PH-FV11-2HA-1PCT-10MO: Estimated injuries to mammals for the base case model scenario using a 1 percent slow release of the oil and an oil mixture with 10 percent water when fully emulsified as mousse. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

Mammal Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Muskrat	235.5	-	235.5
Total All Mammal Species			235.5

Table E-22. RR-2PH-FV11-2HA-1PCT-10MO: Estimated injuries to herpetofauna for the base case model scenario using a 1 percent slow release of the oil and an oil mixture with 10 percent water when fully emulsified as mousse. Note that the number oiled is based on a probability, and so mathematically can be < 1 animal. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

Herptile Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Black rat snake	0.0	-	0.0
Blandings turtle	1.2	-	1.2
Butlers garter snake	0.0	-	0.0
Eastern fox snake	0.0	-	0.0
Eastern garter snake	0.0	-	0.0
Eastern spiny softshell	0.9	-	0.9
Map turtle	39.6	-	39.6
Midland painted turtle	33.8	-	33.8
Northern brown snake	0.0	-	0.0
Northern water snake	3.8	-	3.8
Red-ear slider turtle	0.9	-	0.9
Snapping turtle	6.7	-	6.7
American toad	10.3	-	10.3
Bullfrog	9.4	-	9.4
Gray tree frog	0.2	-	0.2
Green frog	6.1	-	6.1
Leopard frog	32.6	-	32.6
Western chorus frog	0.3	-	0.3
Wood frog	0.2	-	0.2
Total Reptiles			87
Total Amphibians			59
Total All Herptile Species			146

Table E-23. RR-2PH-FV11-2HA-1PCT-60MO: Estimated injuries to avifauna (other than scaups) for the Detroit River, Lake Erie and Rouge River using a 1 percent slow release of the oil and an oil mixture with 60 percent water when fully emulsified as mousse.

Avian Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
American black duck	0.6	0.0	0.6
American coot	85.6	10.2	95.7
American widgeon	5.8	0.7	6.5
Blue-winged teal	3.0	0.4	3.4
Bufflehead	2.8	0.3	3.2
Canada goose	9.4	1.1	10.5
Canvasback	3.7	0.4	4.1
Common goldeneye	0.1	0.0	0.2
Common loon	0.0	0.0	0.0
Eurasian Wigeon	0.0	0.0	0.0
Gadwall	25.4	3.0	28.4
Green-winged teal	32.3	3.8	36.2
Horned grebe	0.2	0.0	0.2
Long-tailed duck	0.0	0.0	0.0
Mallard	4.7	0.6	5.3
Merganser red-breast	108.1	0.0	108.1
Merganser, common	134.0	0.0	134.0
Merganser, hooded	21.3	0.0	21.3
Northern pintail	7.5	0.9	8.3
Northern shoveler	5.2	0.6	5.8
Pied-billed grebe	1.2	0.2	1.4
Redhead	10.2	1.2	11.4
Ring-necked duck	4.5	0.5	5.0
Ruddy duck	12.7	1.5	14.2
Scoter, surf	0.0	0.0	0.0
Swan, mute	5.6	0.7	6.3
Swan, tundra	0.0	0.0	0.0
Wood duck	0.2	0.0	0.2
Bonapartes gull	199.8	0.3	200.1
Caspian tern	27.2	0.0	27.3
Doublecrested cormorant	279.7	0.4	280.1
Forsters tern	25.5	0.0	25.6
Glaucous gull	0.2	0.0	0.2
Great black-backed gull	2.0	0.0	2.0
Herring gull	221.0	0.3	221.3
Lesser black-backed gull	0.2	0.0	0.2
Ring-billed gull	96.4	0.1	96.5
American bittern	0.1	-	0.1
Black-crowned heron	1.0	-	1.0
Common moorhen	0.3	-	0.3
Great blue heron	5.7	-	5.7
Great egret	3.9	-	3.9

Avian Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Green heron	0.1	-	0.1
Sandhill crane	0.1	-	0.1
Sora	0.6	-	0.6
Virginia rail	0.2	-	0.2
American avocet	0.7	-	0.7
Black-necked stilt	0.1	-	0.1
Common snipe	4.4	-	4.4
Dunlin	34.9	-	34.9
Greater yellowlegs	4.0	-	4.0
Killdeer	4.1	-	4.1
Least sandpiper	0.1	-	0.1
Lesser yellowlegs	7.5	-	7.5
Long-bill dowitcher	0.2	-	0.2
Pectoral sandpiper	9.9	-	9.9
Semipalmated plover	0.0	-	0.0
Short-bill dowitcher	0.1	-	0.1
Solitary sandpiper	0.0	-	0.0
Spotted sandpiper	0.2	-	0.2
Willet	0.8	-	0.8
Wilsons snipe	0.7	-	0.7
Total Waterfowl			510
Total Seabirds			853
Total Wading birds			12
Total Shorebirds			68
Total All Avian Species			1,443

Table E-24. RR-2PH-FV11-2HA-1PCT-60MO: Estimated injuries to mammals for the base case model scenario using a 1 percent slow release of the oil and an oil mixture with 60 percent water when fully emulsified as mousse. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

Mammal Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Muskrat	356.8	-	356.8
Total All Mammal Species			356.8

Table E-25. RR-2PH-FV11-2HA-1PCT-60MO: Estimated injuries to herpetofauna for the base case model scenario using a 1 percent slow release of the oil and an oil mixture with 60 percent water when fully emulsified as mousse. Note that the number oiled is based on a probability, and so mathematically can be < 1 animal. "-" indicates species was not present in region (due to lack of sufficient habitat to be resolved in the model grid).

Herptile Species	Number Killed in Detroit River and Lake Erie	Number Killed in Rouge River	Total Number Killed
Black rat snake	0.0	-	0.0
Blandings turtle	1.8	-	1.8
Butlers garter snake	0.0	-	0.0
Eastern fox snake	0.0	-	0.0
Eastern garter snake	0.1	-	0.1
Eastern spiny softshell	1.3	-	1.3
Map turtle	60.0	-	60.0
Midland painted turtle	51.2	-	51.2
Northern brown snake	0.0	-	0.0
Northern water snake	5.8	-	5.8
Red-ear slider turtle	1.3	-	1.3
Snapping turtle	10.2	-	10.2
American toad	15.6	-	15.6
Bullfrog	14.3	-	14.3
Gray tree frog	0.3	-	0.3
Green frog	9.3	-	9.3
Leopard frog	49.4	-	49.4
Western chorus frog	0.4	-	0.4
Wood frog	0.2	-	0.2
Total Reptiles			132
Total Amphibians			90
Total All Herptile Species			221

Tables E-26 to E-30 provide the estimated injuries to fish from the oil spill based on a $LC50_{\infty}$ value of 44ppb for species with average sensitivity to the Rouge River diesel and lubricating oil mixture. Scenarios were also run for $LC50_{\infty}$ values of 5ppb (for sensitive species) and 370ppb (for insensitive species) to bound these estimates, with the total range representing 95% of sensitivities to oil hydrocarbons based on species to date. The results indicate that the fish injuries computed by the model vary somewhat depending on the assumed percentage of the oil released slowly and after the majority of the first oil release had moved out of the Rouge River. The total injuries to fish for the 0 percent, 1 percent and 3 percent slow release scenarios, using an $LC50_{\infty}$ value of 44ppb for species of average sensitivity, are 153 kg, 228 kg and 258 kg, respectively. The total injuries to fish for the base case (1 percent slow release) scenario with oil containing 10 percent and 60 percent water when fully emulsified in mousse, using an $LC50_{\infty}$ value of 44ppb for species of average sensitivity, are 214 kg and 155 kg, respectively. Variation in species sensitivity to oil hydrocarbons induces a factor of 20 change in injuries. Thus, the fish injuries are not very sensitive to variation in the fates model inputs assumed, but are sensitive to the toxicity parameter range tested. Note, however, that most species would be close to average in sensitivity to oil hydrocarbons. In this system, it is unlikely that any of the species present would be highly sensitive to oil hydrocarbons (PAHs), given the historical and present levels of background contamination.

Table E-26. RR-2PH-FV11-2HA-1PCT: Estimated injuries to fish in the Rouge River, Detroit River, and Lake Erie using a 1 percent slow release of the oil and an LC50□value of 44ppb for species with average sensitivity to the Rouge River diesel and lubricating oil mix.

Fish species:	Kill (#)	Kill (kg)	Production Forgone (kg)	Total Injury (kg)
Herrings	1.5	2.2	0.0	2.2
Marsh forage fish	0.0	0.0	0.0	0.0
Rainbow smelt	0.0	0.0	0.0	0.0
White bass	11.3	2.0	1.4	3.4
White perch	227	6.5	5.8	12.3
Bowfin	0.9	3.6	0.0	3.6
Bullhead catfish	24.4	1.4	1.4	2.8
Freshwater drum	8.5	1.0	1.3	2.3
Large forage fish	70.2	18.7	23.0	41.8
Largemouth bass	98.8	19.8	21.2	41.0
Longnose gar	6.5	9.1	0.0	9.1
Medium forage fish	131	9.8	12.7	22.5
Northern pike	1.2	0.8	0.9	1.6
Rainbow trout	2.0	0.3	0.3	0.5
Rock bass	174	12.2	11.3	23.4
Small forage fish	2,940	1.7	1.1	2.8
Smallmouth bass	64.0	18.6	20.1	38.7

Fish species:	Kill (#)	Kill (kg)	Production Forgone (kg)	Total Injury (kg)
Sunfishes	139	4.4	3.9	8.3
Walleye	17.2	5.2	5.4	10.5
Yellow perch	3.8	1.5	0.0	1.5
Total small pelagic fish	1.5	2.2	0.0	2.2
Total large pelagic fish	238.0	8.4	7.2	15.6
Total demersal fish	3,680	108	102	211
Total demersal invertebrates	0.0	0.0	0.0	0.0
Total mollusks	0.0	0.0	0.0	0.0
Total	3,920	119	110	228

Table E-27. RR-2PH-FV11-2HA-0PCT: Summary of estimated injuries to fish in the Rouge River, Detroit River, and Lake Erie using a 0 percent slow release of the oil and an LC50∞ value of 44ppb for species with average sensitivity to the Rouge River diesel and lubricating oil mix.

Fish species:	Kill (#)	Kill (kg)	Production Forgone (kg)	Total Injury (kg)
Herrings	1.0	1.4	0.0	1.4
Marsh forage fish	0.0	0.0	0.0	0.0
Rainbow smelt	0.0	0.0	0.0	0.0
White bass	12.3	2.1	1.5	3.7
White perch	246.9	7.1	6.3	13.4
Bowfin	0.6	2.3	0.0	2.3
Bullhead catfish	15.5	0.9	0.9	1.8
Freshwater drum	5.4	0.6	0.8	1.4
Large forage fish	44.5	11.9	14.6	26.5
Largemouth bass	62.7	12.5	13.5	26.0
Longnose gar	4.1	5.8	0.0	5.8
Medium forage fish	90.9	6.8	8.8	15.6
Northern pike	0.9	0.6	0.6	1.1
Rainbow trout	1.4	0.2	0.2	0.4
Rock bass	110.6	7.7	7.1	14.9
Small forage fish	1,863.6	1.1	0.7	1.8
Smallmouth bass	40.6	11.8	12.8	24.6
Sunfishes	88.4	2.8	2.5	5.3
Walleye	10.9	3.3	3.4	6.7
Yellow perch	2.4	1.0	0.0	1.0
Total small pelagic fish	1.0	1.4	0.0	1.4
Total large pelagic fish	259	9.2	7.8	17.0
Total demersal fish	2,342.4	69.2	65.8	135.0

Fish species:	Kill (#)	Kill (kg)	Production Forgone (kg)	Total Injury (kg)
Total demersal invertebrates	0.0	0.0	0.0	0.0
Total mollusks	0.0	0.0	0.0	0.0
Total	2,602.5	79.8	73.6	153.4

Table E-28. RR-2PH-FV11-2HA-3PCT: Estimated injuries to fish in the Rouge River, Detroit River, and Lake Erie using a 3 percent slow release of the oil and an $LC50_{\infty}$ value of 44ppb for species with average sensitivity to the Rouge River diesel and lubricating oil mix.

Fish species:	Kill (#)	Kill (kg)	Production Forgone (kg)	Total Injury (kg)
Herrings	1.4	2.0	0.0	2.0
Marsh forage fish	0.0	0.0	0.0	0.0
Rainbow smelt	0.0	0.0	0.0	0.0
White bass	15.1	2.6	1.9	4.5
White perch	304.1	8.7	7.8	16.5
Bowfin	1.0	4.0	0.0	4.0
Bullhead catfish	27.3	1.6	1.6	3.1
Freshwater drum	9.5	1.1	1.4	2.5
Large forage fish	78.6	21.0	25.8	46.7
Largemouth bass	110.6	22.1	23.8	45.9
Longnose gar	7.2	10.2	0.0	10.2
Medium forage fish	141.7	10.6	13.7	24.4
Northern pike	1.3	0.9	0.9	1.8
Rainbow trout	2.2	0.3	0.3	0.6
Rock bass	195.0	13.6	12.6	26.2
Small forage fish	3,287.9	1.9	1.2	3.1
Smallmouth bass	71.6	20.8	22.5	43.3
Sunfishes	156.0	4.9	4.4	9.3
Walleye	19.2	5.8	6.0	11.8
Yellow perch	4.3	1.7	0.0	1.7
Total small pelagic fish	1.4	2.0	0.0	2.0
Total large pelagic fish	319.2	11.3	9.7	21.0
Total demersal fish	4,113.4	120.5	114.1	234.6
Total demersal invertebrates	0.0	0.0	0.0	0.0
Total mollusks	0.0	0.0	0.0	0.0
Total	4,434.0	133.9	123.8	257.6

Table E-29. RR-2PH-FV11-2HA-1PCT-10MO: Estimated injuries to fish in the Rouge River, Detroit River, and Lake Erie using a 1 percent slow release of the oil and an LC50$_{\infty}$ value of 44ppb for species with average sensitivity to the Rouge River diesel and lubricating oil mix with oil containing 10 percent water when fully emulsified as mousse (i.e., assuming a low percentage of lubricating oil in the oil mixture).

Fish species:	Kill (#)	Kill (kg)	Production Forgone (kg)	Total Injury (kg)
Herrings	1.0	1.5	0.0	1.5
Marsh forage fish	0.0	0.0	0.0	0.0
Rainbow smelt	0.0	0.0	0.0	0.0
White bass	13.3	2.3	1.7	4.0
White perch	267.0	7.6	6.8	14.4
Bowfin	0.8	3.3	0.0	3.3
Bullhead catfish	22.5	1.3	1.3	2.6
Freshwater drum	7.8	0.9	1.2	2.1
Large forage fish	64.7	17.3	21.2	38.5
Largemouth bass	91.1	18.2	19.6	37.8
Longnose gar	6.0	8.4	0.0	8.4
Medium forage fish	119.3	9.0	11.5	20.5
Northern pike	1.1	0.7	0.8	1.5
Rainbow trout	1.8	0.2	0.3	0.5
Rock bass	160.6	11.2	10.4	21.6
Small forage fish	2,707.9	1.6	1.0	2.6
Smallmouth bass	58.9	17.1	18.6	35.7
Sunfishes	128.5	4.1	3.6	7.7
Walleye	15.8	4.8	4.9	9.7
Yellow perch	3.5	1.4	0.0	1.4
Total small pelagic fish	1.0	1.5	0.0	1.5
Total large pelagic fish	280.3	9.9	8.5	18.4
Total demersal fish	3,390.4	99.5	94.3	193.7
Total demersal invertebrates	0.0	0.0	0.0	0.0
Total mollusks	0.0	0.0	0.0	0.0
Total	3,671.7	110.9	102.7	213.6

Table E-30. RR-2PH-FV11-2HA-1PCT-60MO: Estimated injuries to fish in the Rouge River, Detroit River, and Lake Erie using a 1 percent slow release of the oil and an $LC50_{\infty}$ value of 44ppb for species with average sensitivity to the Rouge River diesel and lubricating oil mix with oil containing 60 percent water when fully emulsified as mousse (i.e., assuming a high percentage of lubricating oil in the oil mixture).

Fish species:	**Kill (#)**	**Kill (kg)**	**Production Forgone (kg)**	**Total Injury (kg)**
Herrings	1.4	2.1	0.0	2.1
Marsh forage fish	0.0	0.0	0.0	0.0
Rainbow smelt	0.0	0.0	0.0	0.0
White bass	12.0	2.1	1.5	3.6
White perch	240.8	6.9	6.1	13.0
Bowfin	0.6	2.3	0.0	2.3
Bullhead catfish	15.7	0.9	0.9	1.8
Freshwater drum	5.5	0.7	0.8	1.5
Large forage fish	45.3	12.1	14.9	27.0
Largemouth bass	63.8	12.8	13.7	26.5
Longnose gar	4.2	5.9	0.0	5.9
Medium forage fish	88.7	6.7	8.6	15.2
Northern pike	0.8	0.5	0.6	1.1
Rainbow trout	1.4	0.2	0.2	0.4
Rock bass	112.5	7.9	7.3	15.1
Small forage fish	1,896.8	1.1	0.7	1.8
Smallmouth bass	41.3	12.0	13.0	25.0
Sunfishes	90.0	2.9	2.5	5.4
Walleye	11.1	3.4	3.5	6.8
Yellow perch	2.5	1.0	0.0	1.0
Total small pelagic fish	1.4	2.1	0.0	2.1
Total large pelagic fish	252.8	9.0	7.6	16.6
Total demersal fish	2,380.2	70.1	66.6	136.7
Total demersal invertebrates	0.0	0.0	0.0	0.0
Total mollusks	0.0	0.0	0.0	0.0
Total	2,634.3	81.1	74.2	155.3

E.2 Biological Model Results - Spatial

Figures E-3 to E-5 show the percent losses (the direct kill due to exposure to dissolved aromatics) for three behavior classes of fish: demersal, small pelagic and large pelagic. The injury represents a small percentage of the fish present in the Rouge River. Concentrations were diluted sufficiently by the time they reached the Detroit River such that the injury was not significant there. The fish were assumed in the model to remain within the Rouge River for the duration of the spill simulation, and so were exposed long enough for an injury to result.

Pelagic young-of-year represent planktonic stages of fish. The plankton are transported out of the Rouge River with the currents, and so their exposure was likely brief and did not cause much injury. Figure E-6 shows the ultimate locations of injured individuals at the end of the simulation.

Figure E-3 Percent loss of demersal fish and invertebrates at the end of the base case simulation.

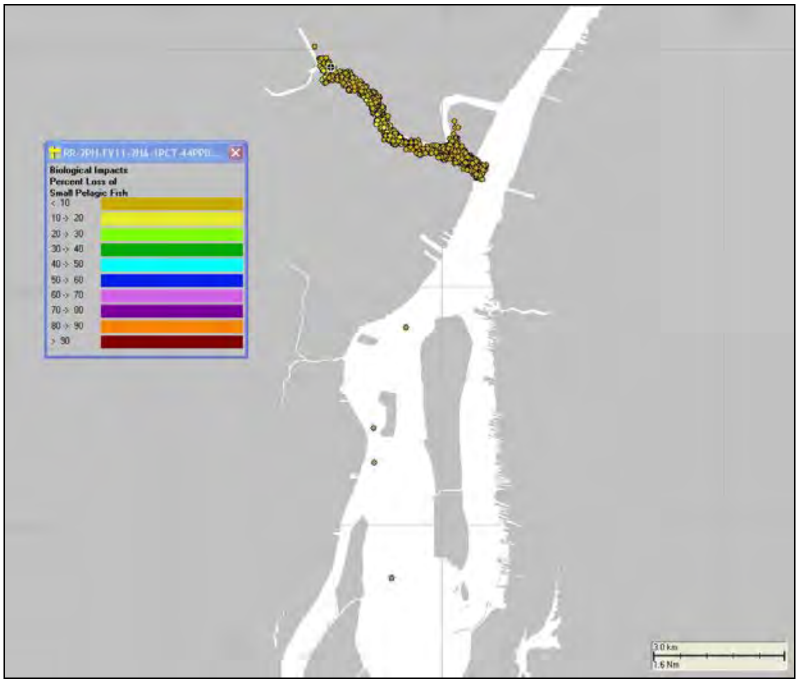

Figure E-4 Percent loss of small pelagic fish at the end of the base case simulation.

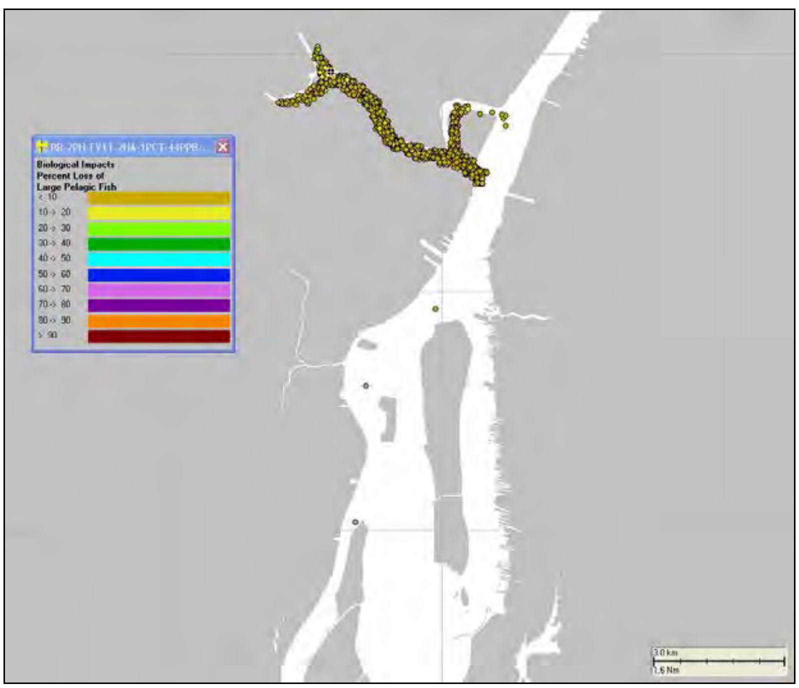

Figure E-5 Percent loss of large pelagic fish at the end of the base case simulation.

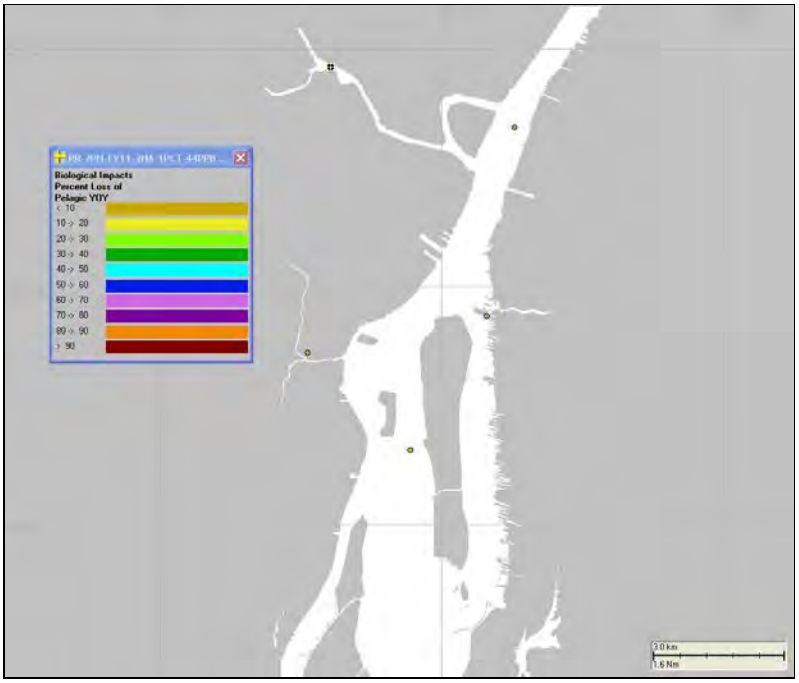

Figure E-6 Percent loss of pelagic young-of-year at the end of the base case simulation.

E.3 References

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Appendix 4: ROUGE RIVER 2002 MYSTERY OIL SPILL SIMAP INJURY REPORT: Restoration Scaling Model and Results

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ROUGE RIVER 2002 MYSTERY OIL SPILL
SIMAP INJURY REPORT
Restoration Scaling Model and Results
Draft for Trustee Review

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Bioenergetics Modeling to Rear Fledglings

Habitat Equivalency Analysis (HEA) has been used by state and federal trustees to estimate the restored habitat required to compensate for habitat injured, taking into account the time before the project is begun (lag time after the spill and injuries occur), the time for development of the restored habitat, the ultimate productivity of services in the new habitat as compared to that injured, the duration of the restoration project life, and discounting of future habitat services at 3% per year). The approach and equations are described in NOAA (1997, 1999), LA DEQ et al. (2003), and French-McCay and Rowe (2003).

In a HEA trophic transfer model, a trophic transfer model is used to calculate wildlife production as a function of production of food resources by a restored habitat. This is the simplest approach for scaling restoration, which is typically used for small spills. It follows the same approach as for fish and invertebrates, except it replaces the biomass of the wildlife directly killed with wildlife biomass at an equivalent trophic level. This approach does not address the species one-to-one or the age structure of the animals lost, and so the varying relative value of different age classes of animals lost (i.e., that older animals "cost" more to replace in terms of food and improved survivorship).

An alternative approach (as was used for the EverReach spill) is to calculate a habitat scale requirement based on energetic costs of rearing fledglings. A bioenergetic model was used to calculate food requirements (by parent and chick) to grow a chick to fledging, including a percentage loss due to mortality. Then, the scale of wetland required in compensation was that which would produce the required amount of food (e.g., fish). A similar approach could be used for mammal losses based on equivalents of reared or weaned individuals to the killed animals. However, a species-specific bioenergetic model would require elaborate spreadsheet calculations, and was not feasible within the scope of this project based on data availability.

Instead of developing an incident specific bioenergetic model, a literature search was conducted on bioenergetic models of species typical of those in the area of the spill, and the data provided from those studies on food requirements to rear a fledgling was used as inputs into a trophic HEA model. The needed data include the amount of food required per chick until fledging plus the amount of additional food required by a parent bird over-and-above that required by a non-breeding bird per chick reared. Then, the kilograms of food needed per fledgling was multiplied by fledgling-equivalents killed to get the biomass (kilograms) of food (fish or invertebrate) that need to be restored. The biomass of food to restore (assuming piscivores consume small pelagic fish and invertebrate consumers consume benthic invertebrates) was then input into a trophic HEA model to calculate the area of wetland required to produce the food for the fledgling, with appropriate discounting. The below outlines the calculations, using fish as an example food (i.e., for piscivorous birds):

kg fish needed/fledgling * fledgling-equivalents killed = fish to restore

fish to restore → trophic HEA → marsh needs

The bird species injured include the following groups, categorized by taxonomic groupings and primary food. Bioenergetics data needs for rearing a chick to fledging were developed for at least one representative of each group:

- Dabbling ducks (consume invertebrates)
- Geese (consume invertebrates, vegetation)
- Swans (consume invertebrates, vegetation)
- Diving ducks (consume invertebrates)
- Diving ducks and grebes (consume fish)
- Cormorants (consume fish)
- Gulls (consume fish)
- Terns (consume fish)
- Waders (consume fish)
- Shorebirds (consume invertebrates)

The bioenergetics data developed for each group are summarized in Table 1 below. The total weight of food required per fledging was developed from literature sources using the group representative listed in the table. The food requirements are summed over the development period from hatching to fledging, accounting for higher food requirements of larger chicks. To calculate the food requirements of non-breeding adults, the following equations (from Nagy, 1987) describing food ingestion (FI) rates in grams of dry matter/day as a function of body weight in grams (M) were used:

$$\text{For seabirds: } FI = 0.495M^{0.704}$$
$$\text{For all other birds: } FI = 0.648M^{0.651}$$

To determine the food requirements of breeding adults, a ratio of 2.9 was applied to the food ingestion rates calculated for non-breeders. This ratio is based on data for great blue heron from Bennett et al. (1993), who state that the above provisioning levels (assuming both parents contribute equally to feeding the chicks) represent a 2.6- and 3.2-fold increase in the amount of maintenance energy that the parents must obtain in order to meet the energy needs of themselves and their chicks during the time of peak energy consumption of the chicks. The food ingestion rates for breeding adults were then multiplied by the length of the fledgling period to determine the total amount of extra food required for breeding adults.

The injured mammals include only muskrat. Given that this species is a vegetarian, and is not a species of concern, the simple trophic HEA modeling approach was used. The directly oiled biomass (number times average weight per animal) of muskrat was used for the scaling calculations.

The injured reptiles and amphibians are not species that would provide care to their young. The injury has been calculated three ways: as a direct loss of biomass, hatchling-equivalents lost, and number-years of loss. However, the simple trophic HEA modeling approach, using the directly oiled biomass (number times average weight per animal), was used, as these groups are function in the trophic web most similar to fish. Their metabolic rates and food needs are also most like fish, as they are all poikilotherms (cold-blooded animals).

Table 1. Summary of bioenergetics data developed for bird groups.

Group	Group Representative	Fledgling Losses (Total for Group)[1]	Total Food Required per Fledging (g)[14]	Total Extra Food Required for Breeding Adults (g)[2]	Total Food Required for Replacing Fledgling-Equivalents Lost (kg)[3]
Piscivorous birds					
Waders	Great blue heron	342	23,720[5]	41,704	2,238
Diving ducks and grebes	Great-crested grebe	7,523.8	8,120[6]	20,745	217,173
Cormorants	Double-crested cormorant	941.0	15,188[7]	45,064	56,697
Gulls	Herring gull	1,653.9	7,008[8]	26,625	55,626
Terns	Common tern	162.4	600[9]	3,807	716
Birds feeding on invertebrates/ vegetation[4]					
Shorebirds	Black-tailed godwit	200.1	2,675[10]	0	535
Geese and swans	Greater snow goose	43.1	1,841[11]	0	79
Dabbling ducks	American black duck	585.3	2,793[12]	0	1,635
Diving ducks	Canvasback	7,664.3	7,514[13]	0	57,593

[1] From biological model results.

[2] To calculate the food requirements of non-breeding adults, the following equations (from Nagy, 1987) describing food ingestion (FI) rates in grams of dry matter/day as a function of body weight in grams (M) were used. For seabirds: $FI = 0.495M^{0.704}$. For all other birds: $FI = 0.648M^{0.651}$. To determine the food requirements of breeding adults, a ratio of 2.9 was applied to the food ingestion rates calculated for non-breeders.

[3] Number of fledglings-equivalents lost * (food required per fledgling + extra food required for breeding adults).

[4] It is assumed that for these groups, parents don't expend significantly more energy raising chicks.

[5] Source: Bennet et al. (1995). Estimate was obtained by integrating the energy budgets of male and female hand-reared chicks over all age intervals and then averaged males and females together.

[6] Source: Ulenaers and van Vessem (1994). Estimate was obtained by integrating intake per day over a period of 10 weeks.

[7] Source: Dunn (1975). Estimate was obtained by integrating food intake over 5-day age intervals. The values used for integration were estimated from a graph (provided in the reference) of total food intake per bird per day versus days of age.

[8] Source: Dunn (1980). Estimate was obtained by integrating food intake over 5-day age intervals. The values used for integration were estimated from a graph (provided in the reference) of total food intake per bird per day versus days of age.

[9] Source: Langham (1972) and Pearson (1964). Estimate was obtained using weight at age data from Langham (1972) and Pearson's (1964) equation for seabird food requirements (described in Langham, 1972) to estimate food requirements per day. This was integrated over the entire chick period, assuming the chick period is 25 days.

[10] Source: Schekkerman and Visser (2001). Estimate was obtained by estimating daily metabolized energy at 5-day age intervals from a graph of metabolized energy versus age. Metabolized energy was divided by a digestive efficiency of 69.9% (from Schekkerman and Visser, 2001) to estimate gross energy consumed per day, and integrated across the entire chick period.

[11] Source: Manseau and Gauthier (1993). Manseau and Gauthier (1993) provided data for the percent time spent feeding and food intake per hour for grass and sedge meadows. To determine the number of hours spent feeding per day, it was assumed that available feeding time was 12 hrs/day and multiplied by the percent time spent feeding. The estimate of number of hours spent feeding per day was multiplied by food intake per hour (average of grass and sedge), and integrated across entire chick period.

[12] Source: Penney and Bailey (1970). Estimate was obtained by averaging the mean total food consumed per bird in 8 weeks for both experimental groups.

[13] Source: Perry et al. (1986). Estimate was obtained by averaging daily feed intake values from both experimental time periods and all pens for Diet 2 (which was an invertebrate diet). The daily average was multiplied by the number of days from hatch to fledge (i.e., 62 days) to get total consumed.

[14] For data sources where intake was provided as kJ/day, it was necessary to convert to g/day. For piscivores, an average of 5 kJ/g was used (Cherel and Ridoux, 1992; Perez 1994). For invertebrate consumers, an average of energy to weight ratio data was used from benthic invertebrate data provided in Mendonca et al. (2007), and converted to wet weight using 0.22 g dry weight/g wet weight (from Nixon and Ovaitt, 1973) to obtain a final estimate of 5.08 kJ/g.

HEA with Trophic Web Model

This model for scaling required compensatory restoration and uses HEA with a trophic web model to calculate the required area of restored habitat to produce the same biomass as lost due to a spill. Scaling methods used here were initially developed for use in the *North Cape* case, as described in French et al. (2001), French McCay and Rowe (2003) and French McCay et al. (2003a). These methods have also been used in several other cases, as well as in successful claims for 23 cases submitted by the Florida Department of Environmental Protection to the U.S. Coast Guard, National Pollution Fund Center (French McCay et al., 2003b).

The habitat restoration model is based on food chain transfers, such that equivalent production at the same trophic level as the losses is produced by the restoration project. The approach uses energetic efficiencies to scale across trophic levels. Benefits of habitat to each trophic level are estimated by assuming that the production of consumers is proportional to prey production gained by the restoration of habitat. The habitat restoration model balances the production foregone losses with trophically equivalent production, discounting future gains in compensatory production relative to present losses such that interest is paid, analogous to economic discounting (French McCay and Rowe, 2003).

The basis for using this model is that restoration should provide equivalent quality fish and invertebrate biomass to compensate for the lost fish and invertebrate production. Likewise for wildlife, restoration should also replace the wildlife biomass that was lost. Equivalent quality implies same or similar species with equivalent ecological role and value for human uses. The equivalent production or replacement should be discounted to present-day values to account for the interim loss between the time of the injury and the time when restoration provides equivalent ecological and human services.

Habitat creation or preservation projects have been used to compensate for injuries of wildlife, fish and invertebrates. The concept is that the restored habitat leads to a net gain in wildlife, fish and invertebrate production over and above that produced by the location before the restoration. The size of the habitat (acreage) is scaled to just compensate for the injury (interim loss).

In the model developed by French McCay and Rowe (2003), the habitat may be seagrass bed, saltmarsh, oyster reef, freshwater or brackish wetland, or other structural habitats that provide such ecological services as food, shelter, and nursery habitat and are more productive than open bottom habitats. The injuries are scaled to the new primary (plant) or secondary (e.g., benthic) production produced by the created habitat, as the entire food web benefits from this production. A preservation project that would avoid the loss of habitat could also be scaled to the production preserved. The latter method would only be of net gain if the habitat is otherwise destined to be destroyed. In this analysis, it is assumed that only habitat creation projects would be undertaken.

The approach used here for scaling the size of the needed project is to use primary production to measure the benefits of the restoration. The total injuries in kg are translated into equivalent plant (angiosperm) production as follows. Plant biomass passes primarily through the detrital food web via detritivores consuming the plant material and attached microbial communities. When macrophytes are consumed by detritivores, the ecological efficiency is low because of the high percentage of structural material produced by the plant, which must be broken down by microorganisms before it can be used by the detritivore. Each species group is assigned a trophic level relative to that of the detritivores. If the species group is at the same trophic level as detritivores, it is assumed 100% equivalent, as the resource injured would presumably have the same ecological value in the food web as the detritivores. If the injured resource preys on detritivores or that trophic level occupied by the detritivores, the ecological efficiency is that for trophic transfer from the prey to the predator. Values for production of predator per unit production of prey (i.e., ecological efficiency) are taken from the ecological literature, as reviewed by French McCay and Rowe (2003). The ecological efficiencies assumed are in Table 2.

Table 2. Assumed ecological efficiencies for one trophic step (French McCay and Rowe, 2003).

Consumer	Prey/food	% Efficiency
Invertebrate or finfish	Macrophyte	0.023
Invertebrate or finfish	Microalgae	10
Invertebrate	Microorganisms	20
Invertebrate or finfish	Detritivores	10
Invertebrate or fish	Invertebrate	20
Invertebrate or fish filter feeder	Plankton	20
Medium (200-1000g) fish piscivore	Finfish	10
Large (>1kg) fish piscivore	Finfish	4
Reptiles, amphibians	Invertebrates	20
Reptiles (piscivore/predator)	Finfish/Invertebrates	20
Birds, mammals (herbivores)	Macrophyte	0.03
Birds, mammals	Invertebrate	2
Birds, mammals (piscivores)	Finfish	2

The equivalent compensatory amount of angiosperm (plant) biomass of the restored resource is calculated as kilograms of injury divided by ecological efficiency. The ecological efficiency is the product of the efficiency of transfer from angiosperm to invertebrate detritivore and efficiency from detritivore to the injured resource, accounting for each step up the food chain from detritivore to the trophic level of concern. Table 3 lists the composite ecological efficiency relative to benthic invertebrate production for each trophic group evaluated in the modeling.

Table 3. Composite ecological efficiency relative to benthic invertebrate production by trophic group.

Species Category	Trophic Level	Ecological Efficiency Relative to Benthic Detritivores (%)
Fish and Invertebrates:		
Small pelagic fish	planktivorous	20
Large pelagic fish	piscivores/predators	0.8
Demersal fish	bottom feeders	10
Crustaceans	bottom feeders	20
Benthic invertebrates	filter/bottom feeder	100
Birds:		
Waterfowl	bottom feeders	2
Seabirds	piscivores	0.4
Waders	piscivores	0.4
Shorebirds	bottom feeders	2
Raptors	piscivores	0.4
Kingfishers	piscivores	0.4

Species Category	Trophic Level	Ecological Efficiency Relative to Benthic Detritivores (%)
Other wildlife:		
Herbivorous mammals	herbivores	0.03
Reptiles, amphibians	invertebrate feeders	20
Reptiles	piscivores	4

The productivity gained by the created habitat is corrected for less than full functionality during recovery using a sigmoid recovery curve. Discounting at 3% per year is included for delays in production because of development of the habitat, and delays between the time of the injury and when the production is realized in the restored habitat. The equations and assumptions may be found in French McCay and Rowe (2003).

The needed data for the scaling calculations are:

- number of years for development of full function in a restored habitat;
- annual primary production rate per unit area (P) of restored habitat at full function (which may be less than that of natural habitats);
- delay before restoration project begins; and
- project lifetime (years the restored habitat will provide services).

The calculations below are based on emergent marsh wetland restoration, as this habitat is most frequently used for compensation; thus, it is used for estimating the potential restoration needs and Natural Resource Damage Assessment (NRDA) costs.

<u>Wetland Restoration</u>

Restoration scaling calculations for wetland were performed following the methods in French McCay and Rowe (2003). It is assumed that the emergent marsh requires 15 years to reach full function (based on LA DEQ et al., 2003), ultimately reaching 100% of natural habitat productivity, the restoration begins in 2014 (12 years after the spill), and the project lifetime is 20 years (LA DEQ et al., 2003).

Klopatek and Stevens (1978) evaluated primary production of various emergent macrophytes in a southeastern Wisconsin freshwater marsh ecosystem. The marsh area evaluated was approximately 2,025 ha, including a 600-ha shallow water impoundment. The marsh vegetation included lowland forest, shrub carr and submergent aquatics, with predominately edge meadow and emergent aquatic communities. With estimates for litter loss and belowground production, annual net primary production ranged from 1,181 g/m^2/year for *Carex lacustris* to nearly 3200 g/m^2/year for *Typha latifolia*. They also noted that if the emergent, submergent, free-floating macrophytes are included (plus possible algae production), the net annual primary production for the marsh system probably lies between 2,800 and 3,800 g/m^2/year. Table 4 provides a summary of the net annual primary production (g/m^2/year) from Klopatek and Stevens (1978) that was used for this (202 Rouge River NRDA) restoration scaling.

Table 4. Summary of net annual primary production rates used for wetland restoration scaling (Source: Klopatek and Stevens 1978).

Macrophyte Species	Net annual primary production ($g/m^2/yr$)	Notes
Typha latifolia	3200	Includes above and below ground
Scirpus fluviatilis	1533	Includes above and below ground
Carex lacustris	1181	Includes above and below ground
Phalaris arundinacea	2028	Aboveground only
Salix interior	1902	Includes above and below ground; Annual net production is likely underestimated because it was based on a single sample taken in September.

For the injured resources, all weights are as wet weight and dry weight is assumed 22% of wet weight (Nixon and Oviatt, 1973). The ratio of carbon to dry weight is assumed 0.45 (French et al., 1996). For the wildlife, the body mass per animal (from French et al. [1996] or from Sibley [2003]) is used to estimate injury in kg (multiplying by number killed and summing each species category).

F.3 Restoration Scaling Results

The injury totals compensated are listed in Tables 5 and 6, along with restoration areas by species group. Compensation for marsh injuries (to the entire habitat) are developed in Table 7.

Table 5. Scale of restoration (acres) for compensation of injuries to wildlife, fish and invertebrates, assuming fully restored habitat produces 2,800 g dry weight/m^2 annually as natural habitat dominated by *Carex lacustris* plus mixed species (see text).

Species Category	Total Injury (kg, wet weight)	Trophic Level	Production Yield (%)	Compensatory Production (kg, dry weight)	Habitat Area (m2)	Habitat Area (acres)
Small pelagic fish	2.2	planktivorous	20	103	6	0.001
Large pelagic fish	15.6	piscivores/ predators	0.8	18,274	1027	0.254
Demersal fish	211	bottom feeders	10	19,774	1112	0.275
Small fish for birds	332,449	bottom feeders	20	15,577,788	875641	216.4
Invertebrates for birds	59,842	filter/bottom feeder	100	560,808	31524	7.789
Amphibians	3.35	bottom feeders	20	157	9	0.002
Reptiles	18.53	bottom feeders	20	868	49	0.012
Reptiles	20.26	piscivores/ predators	4	4,747	267	0.066
Muskrats	369.9	herbivores	0.03	11,555,104	649523	160.5
Totals:						
Subtotal fish and invertebrates	392,409			16,176,748	909,309	224.69
Subtotal herps, mammals	412			11,560,876	649,847	160.57
Total all species	392,821			27,737,624	1,559,156	385.3

Table 6. Scale of restoration (acres) for compensation of injuries to wildlife, fish and invertebrates, assuming fully restored habitat produces 3,800 g dry weight/m^2 annually as natural habitat dominated by *Typha latifolia*.

Species Category	Total Injury (kg, wet weight)	Trophic Level	Production Yield (%)	Compensatory Production (kg, dry weight)	Habitat Area (m2)	Habitat Area (acres)
Small pelagic fish	2.2	planktivorous	20	106	4	0.001
Large pelagic fish	15.6	piscivores/ predators	0.8	18,868	789	0.195
Demersal fish	211	bottom feeders	10	20,416	854	0.211
Small fish for birds	332,449	bottom feeders	20	16,083,602	672,586	166.2
Invertebrates for birds	59,842	filter/bottom feeder	100	579,018	24,213	5.983
Amphibians	3.35	bottom feeders	20	162	7	0.002
Reptiles	18.53	bottom feeders	20	896	37	0.009
Reptiles	20.26	piscivores/ predators	4	4,901	205	0.051
Muskrats	369.9	herbivores	0.03	11,930,301	498,903	123.3
Totals:						
Subtotal fish and invertebrates	392,409			16,702,010	697,477	172.6
Subtotal herps, mammals	412			11,936,260	499,152	123.3
Total all species	392,821			28,638,270	1,197,599	295.9

Restoration for Complete Loss of Habitat

If the entire habitat is killed, such as by lethal oiling of vegetation, and that same habitat is replanted, a simple HEA calculation (NOAA, 1997) can be performed such that the amount of habitat required is calculated accounting for the recovery of the functionality of the habitat. The equivalent area should be discounted to present-day values (i.e., at 3% per year of delay) to account for the interim loss between the time of the injury and the time when restoration provides equivalent ecological services. The approach and equations are described in NOAA (1997, 1999).

Results – Restoration Requirements for Habitat Injuries

The areas of habitat oiled with more than 1mm of oil, which has been shown to be lethal to wetlands (French McCay, 2009), are listed in Table 8. Areas of habitat restoration which would compensate for these losses (using a 20-year project life beginning 12 years after the spill, and assuming 15 years for recovery) are also listed in Table 8. Note that these restorations requirements would be in addition to those listed in the previous section.

Table 7. Total shoreline (wetland) area oiled by >1mm (>1kg/m^2) of oil, which would be lethal to vegetation and all associated biota; and scale of in-kind wetland restoration using the standard HEA model (assumes the same wetland type is fully restored as was injured).

Habitat Type	Area Oiled (m^2)	Area of Compensatory Restoration (m^2)	Area of Compensatory Restoration (acres)
Wetland	26,959	916.62	0.226

The amounts of wetland required in compensation for the quantified wildlife, fish and invertebrate injuries are summarized in Table 8.

Table 8. Scale of restoration (acres) for compensation of injuries to wildlife, fish and invertebrates.

Dominant Plant	Fish	Birds	Herps	Mammals	Marsh	Total
Typha latifolia	0.407	172	0.062	123	0.226	296
Carex lacustris plus mixed spp.	0.530	224	0.080	161	0.226	385

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APPENDIX 5: 2002 ROUGE RIVER MYSTERY OIL SPILL - Restoration scaling, calculation of Discounted Service Acre Years (DSAYs) assuming a 30 year project life cycle, including both implementation and maintenance.

Rouge River Compensatory Wetland Restoration Requirements Calculations - FINAL

May 2015 - M. Annis

Assumes: 1) spill occurs in 2002; 2) Restoration begins in 2016 (14 years after spill); 3) Emergent marsh requires 15 years to reach full function (based on LA DEQ et al., 2003), ultimately reaching 100% of natural habitat productivity; 4) Project lifetime is 30 years (LA DEQ et al., 2003); 5) Wetlands are dominated by *Carex lacustris* and *Typha latifolia*; and 6) habitat/resource recovery function is linear based on Penn and Tomasi (2002).

Conversion factor for change in project initation date as per Tim's email 4/11/14:

1.03exp (2016-2014)=1.03 exp (2)=1.0609

Discounted Service Acre-Years restored per Acre of Sedge Wetland Restored as per scaling dec 2012

16.3

Discounted Service Acre-Years restored per Acre of Cattail Wetland Restored as per scaling dec 2012

16.3

	Compensatory Lake Sedge Marsh (Acres) if beginning 2014	Lake Sedge Acres 2016	Sedge DSAY 2016	Compensatory Common Cattail Marsh (Acres) 2014	C. Cattail Acres 2016	Cattail DSAY 2016
All Birds	224	237.64	3873.56	172	182.47	2974.34
Muskrats	161	170.80	2784.12	123	130.49	2127.00
Reptiles and Amphibians	0.08	0.08	1.38	0.062	0.07	1.07
Fish	0.53	0.56	9.17	0.407	0.43	7.04
Marsh Habitat	0.226	0.240	3.908	0.226	0.24	3.91
Totals	385	409.33	6672.13	296	313.70	5113.36

DSAYs Expected from Proposed Projects*	30 yrs project life
Project	DSAYs produced
Humbug & Monguagon	912.65
Gibraltar-70acres	620.61
Great Lakes Marsh	671.40
Pt. Mouillee Pump-Lautenschalger Unit	470.92
Pt. Mouillee Pump-Vermet Unit	1177.30
Pt. Mouillee Pump-Humphries Unit	1246.89
Pt. Mouillee substitute Bad Creek (30acres)	334.93
Total	5434.70
Proposed supplemental LEMP Projects:	
Marsh Edge	147.17
Shoreline	47.47
LakePlain	255.61
Subtotal Supplemental LEMP	450.24
Total with extra LEMP acres	5884.95

50%:50% Mix of Cattail and Sedge DSAY required if project begins 2016 = 5892.75

DSAYs achieved - Preferred Restoration Alternative = 5884.95

DSAYs Required / DSAYs Achieved (%) = 99.90%

Rouge River Compensatory Wetland Restoration Requirements Calculations - FINAL

April 25, 2014 - M. Annis

Assumes: 1) spill occurs in 2002; 2) Wetland Restoration occurrs in 2016 (14 years after spill); 3) Emergent marsh requires 15 years to reach full function (based on LA DEQ et al., 2003), ultimately reaching 100% of natural habitat productivity; 4) Project lifetime is 20 years once wetland matures, achieving 100% function (LA DEQ et al., 2003); 5) Wetland is dominated by *Carex Lacustris* ; and 6) habitat/resource recovery function is linear based on Penn and Tomasi (2002).

Model Carex Wetland

Year Restoration Initiated	Restoration Year	*Carex lacustris* restoration required (acres) (Grant et al. 2011)	Percent Service Gain	Adjusted Service Gains (Acres)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Discounted Service Acre Years (DSAYs) gained
2016	2016	409.23	6.67	27.30	1.03	0	1.0000	27.30
2016	2017	409.23	13.34	54.59	1.03	-1	0.9709	53.00
2016	2018	409.23	20.01	81.89	1.03	-2	0.9426	77.19
2016	2019	409.23	26.68	109.18	1.03	-3	0.9151	99.92
2016	2020	409.23	33.35	136.48	1.03	-4	0.8885	121.26
2016	2021	409.23	40.02	163.77	1.03	-5	0.8626	141.27
2016	2022	409.23	46.69	191.07	1.03	-6	0.8375	160.02
2016	2023	409.23	53.36	218.37	1.03	-7	0.8131	177.55
2016	2024	409.23	60.03	245.66	1.03	-8	0.7894	193.93
2016	2025	409.23	66.70	272.96	1.03	-9	0.7664	209.20
2016	2026	409.23	73.37	300.25	1.03	-10	0.7441	223.42
2016	2027	409.23	80.04	327.55	1.03	-11	0.7224	236.63
2016	2028	409.23	86.71	354.84	1.03	-12	0.7014	248.88
2016	2029	409.23	93.38	382.14	1.03	-13	0.6810	260.22
2016	2030	409.23	100.00	409.23	1.03	-14	0.6611	270.55
2016	2031	409.23	100.00	409.23	1.03	-15	0.6419	262.67
2016	2032	409.23	100.00	409.23	1.03	-16	0.6232	255.02
2016	2033	409.23	100.00	409.23	1.03	-17	0.6050	247.59
2016	2034	409.23	100.00	409.23	1.03	-18	0.5874	240.38
2016	2035	409.23	100.00	409.23	1.03	-19	0.5703	233.38
2016	2036	409.23	100.00	409.23	1.03	-20	0.5537	226.58
2016	2037	409.23	100.00	409.23	1.03	-21	0.5375	219.98
2016	2038	409.23	100.00	409.23	1.03	-22	0.5219	213.57
2016	2039	409.23	100.00	409.23	1.03	-23	0.5067	207.35
2016	2040	409.23	100.00	409.23	1.03	-24	0.4919	201.31
2016	2041	409.23	100.00	409.23	1.03	-25	0.4776	195.45
2016	2042	409.23	100.00	409.23	1.03	-26	0.4637	189.76
2016	2043	409.23	100.00	409.23	1.03	-27	0.4502	184.23
2016	2044	409.23	100.00	409.23	1.03	-28	0.4371	178.86
2016	2045	409.23	100.00	409.23	1.03	-29	0.4243	173.66
2016	2046	409.23	100.00	409.23	1.03	-30	0.4120	168.60
2016	2047	409.23	100.00	409.23	1.03	-31	0.4000	163.69
2016	2048	409.23	100.00	409.23	1.03	-32	0.3883	158.92
2016	2049	409.23	100.00	409.23	1.03	-33	0.3770	154.29
2016	2050	409.23	100.00	409.23	1.03	-34	0.3660	149.80
2016	2051	409.23	100.00	409.23	1.03	-35	0.3554	145.43

Discounted Service Acre Years (DSAY) of wetland habitat, invertebrates and wildlife gained from *Carex* restoration: 6670.84

Magnitude of *Carex lacustris* wetland restoration required for Rouge River Compensatory Restoration (acres): 409

Discounted Service Acre-Years restored per Acre of *Carex* Wetland Restored: 16.30

Rouge River Compensatory Wetland Restoration Requirements Calculations - FINAL

April 25, 2014 - M. Annis

Assumes: 1) spill occurrs in 2002; 2) Wetland Restoration occurrs in 2016(14 years after spill); 3) Emergent marsh requires 15 years to reach full function (based on LA DEQ et al., 2003), ultimately reaching 100% of natural habitat productivity; 4) Project lifetime is 20 years once wetland matures (LA DEQ et al., 2003); 5) Wetland is dominated by *Typha latifolia*; and 6) habitat/resource recovery function is linear based on Penn and Tomasi (2002).

Model Typha Wetland

Year Restoration Initiated	Restoration Year	*Typha latifolia* restoration required (acres) (Grant et al. 2011)	Percent Service Gain	Adjusted Service Gains (Acres)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Discounted Service Acre Years (DSAYs) gained
2016	2016	313.70	6.67	20.92	1.03	0	1.0000	20.92
2016	2017	313.70	13.34	41.85	1.03	-1	0.9709	40.63
2016	2018	313.70	20.01	62.77	1.03	-2	0.9426	59.17
2016	2019	313.70	26.68	83.70	1.03	-3	0.9151	76.59
2016	2020	313.70	33.35	104.62	1.03	-4	0.8885	92.95
2016	2021	313.70	40.02	125.54	1.03	-5	0.8626	108.29
2016	2022	313.70	46.69	146.47	1.03	-6	0.8375	122.66
2016	2023	313.70	53.36	167.39	1.03	-7	0.8131	136.10
2016	2024	313.70	60.03	188.31	1.03	-8	0.7894	148.66
2016	2025	313.70	66.70	209.24	1.03	-9	0.7664	160.36
2016	2026	313.70	73.37	230.16	1.03	-10	0.7441	171.26
2016	2027	313.70	80.04	251.09	1.03	-11	0.7224	181.39
2016	2028	313.70	86.71	272.01	1.03	-12	0.7014	190.78
2016	2029	313.70	93.38	292.93	1.03	-13	0.6810	199.47
2016	2030	313.70	100.00	313.70	1.03	-14	0.6611	207.39
2016	2031	313.70	100.00	313.70	1.03	-15	0.6419	201.35
2016	2032	313.70	100.00	313.70	1.03	-16	0.6232	195.49
2016	2033	313.70	100.00	313.70	1.03	-17	0.6050	189.79
2016	2034	313.70	100.00	313.70	1.03	-18	0.5874	184.27
2016	2035	313.70	100.00	313.70	1.03	-19	0.5703	178.90
2016	2036	313.70	100.00	313.70	1.03	-20	0.5537	173.69
2016	2037	313.70	100.00	313.70	1.03	-21	0.5375	168.63
2016	2038	313.70	100.00	313.70	1.03	-22	0.5219	163.72
2016	2039	313.70	100.00	313.70	1.03	-23	0.5067	158.95
2016	2040	313.70	100.00	313.70	1.03	-24	0.4919	154.32
2016	2041	313.70	100.00	313.70	1.03	-25	0.4776	149.82
2016	2042	313.70	100.00	313.70	1.03	-26	0.4637	145.46
2016	2043	313.70	100.00	313.70	1.03	-27	0.4502	141.22
2016	2044	313.70	100.00	313.70	1.03	-28	0.4371	137.11
2016	2045	313.70	100.00	313.70	1.03	-29	0.4243	133.12
2016	2046	313.70	100.00	313.70	1.03	-30	0.4120	129.24
2016	2047	313.70	100.00	313.70	1.03	-31	0.4000	125.48
2016	2048	313.70	100.00	313.70	1.03	-32	0.3883	121.82
2016	2049	313.70	100.00	313.70	1.03	-33	0.3770	118.27
2016	2050	313.70	100.00	313.70	1.03	-34	0.3660	114.83
2016	2051	313.70	100.00	313.70	1.03	-35	0.3554	111.48

Discounted Service Acre Years (DSAYs) of Wetland habitat, invertebrates and wildlife gained from *Typha* wetland restoration **5113.61**

Magnitude of *Typha latifolia* wetland restoration required for Rouge River Compensatory Restoration (acres) = **314**

Discounted Service Acre Years restored per acre of *Typha* wetland restored = **16.30**

Rouge River Compensatory Wetland Restoration Service Gains: Humbug Marsh/Monguagon Creek Bank Habitat Improvements

Compensatory Restoration Project Scaling Assumptions: 1) This project involves both invasives control in Humbug Marsh (i.e., *Phragmites* removal on 25% of 410 acres = 102.5 acres) and stabilization of the Monguagon Creek riparian zone - 0.44 acres - by vegetation planting and by other means; 2) wetland/riparian bank restoration occurs in 2016; 3) Emergent marsh requires 10 years to reach full function since habitat is already partially functional (based on LA DEQ et al., 2003); 4) habitats ultimately reach 90% of natural habitat service functionality (fully developed habitat services reduced in productivity due to required continued invasives management such as *Phragmites* control); 5) Project lifetime is 30 years inclusive of maturation period.; 6) restored wetland is dominated by an assumed mix of *Carex lacustris* and *Typha latifolia*; and 7) habitat/resource recovery function is linear based on Penn and Tomasi (2002).

January 22, 2015 Meeting: Acres and Functionality per agreement with Greg Norwood. Full functionality reached after 10 yrs, initial functionality estimated as 33%.

Year Restoration Initiated	Restoration Year	Restoration Acreage	Percent Services Provided	Precent Baseline Services	Percent Net Services Gained	Adjusted Service Gains (Acres)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Discounted Service Acre Years (DSAYs) Gained
2016	2016	102.94	33.00	33.00	0.00	0.00	1.03	0	1.0000	0.00
2016	2017	102.94	38.70	33.00	5.70	5.87	1.03	-1	0.9709	5.70
2016	2018	102.94	44.40	33.00	11.40	11.74	1.03	-2	0.9426	11.06
2016	2019	102.94	50.10	33.00	17.10	17.60	1.03	-3	0.9151	16.11
2016	2020	102.94	55.80	33.00	22.80	23.47	1.03	-4	0.8885	20.85
2016	2021	102.94	61.50	33.00	28.50	29.34	1.03	-5	0.8626	25.31
2016	2022	102.94	67.20	33.00	34.20	35.21	1.03	-6	0.8375	29.48
2016	2023	102.94	72.90	33.00	39.90	41.07	1.03	-7	0.8131	33.40
2016	2024	102.94	78.60	33.00	45.60	46.94	1.03	-8	0.7894	37.06
2016	2025	102.94	84.30	33.00	51.30	52.81	1.03	-9	0.7664	40.47
2016	2026	102.94	90.00	33.00	57.00	58.68	1.03	-10	0.7441	43.66
2016	2027	102.94	90.00	33.00	57.00	58.68	1.03	-11	0.7224	42.39
2016	2028	102.94	90.00	33.00	57.00	58.68	1.03	-12	0.7014	41.15
2016	2029	102.94	90.00	33.00	57.00	58.68	1.03	-13	0.6810	39.96
2016	2030	102.94	90.00	33.00	57.00	58.68	1.03	-14	0.6611	38.79
2016	2031	102.94	90.00	33.00	57.00	58.68	1.03	-15	0.6419	37.66
2016	2032	102.94	90.00	33.00	57.00	58.68	1.03	-16	0.6232	36.56
2016	2033	102.94	90.00	33.00	57.00	58.68	1.03	-17	0.6050	35.50
2016	2034	102.94	90.00	33.00	57.00	58.68	1.03	-18	0.5874	34.47
2016	2035	102.94	90.00	33.00	57.00	58.68	1.03	-19	0.5703	33.46
2016	2036	102.94	90.00	33.00	57.00	58.68	1.03	-20	0.5537	32.49
2016	2037	102.94	90.00	33.00	57.00	58.68	1.03	-21	0.5375	31.54
2016	2038	102.94	90.00	33.00	57.00	58.68	1.03	-22	0.5219	30.62
2016	2039	102.94	90.00	33.00	57.00	58.68	1.03	-23	0.5067	29.73
2016	2040	102.94	90.00	33.00	57.00	58.68	1.03	-24	0.4919	28.86
2016	2041	102.94	90.00	33.00	57.00	58.68	1.03	-25	0.4776	28.02
2016	2042	102.94	90.00	33.00	57.00	58.68	1.03	-26	0.4637	27.21
2016	2043	102.94	90.00	33.00	57.00	58.68	1.03	-27	0.4502	26.42
2016	2044	102.94	90.00	33.00	57.00	58.68	1.03	-28	0.4371	25.65
2016	2045	102.94	90.00	33.00	57.00	58.68	1.03	-29	0.4243	24.90
2016	2046	102.94	90.00	33.00	57.00	58.68	1.03	-30	0.4120	24.17

Discounted Service Acre Years (DSAYs) of wetland habitat, invertebrates and wildlife gained from Humbug Marsh/ Monguagon Creek restoration: **912.65**

Rouge River Compensatory Wetland Restoration Service Gains: Gibraltar Wetland Restoration

Compensatory Restoration Project Scaling Assumptions: 1) This project involves redesign of Gibraltar wetland (i.e., to enhance hydrology of 70 acre wetland parcel); 2) wetland restoration occurs in 2016; 3) Emergent marsh requires 10 years to reach full function since habitat is already partially functional (based on LA DEQ et al., 2003); 4) habitats ultimately reach 90% of natural habitat service functionality (fully developed habitat services reduced in productivity due to required continued invasives management such as *Phragmites* control); 5) Project lifetime is 30 years inclusive of the maturation period; 6) restored wetland is dominated by an assumed mix of *Carex lacustris* and *Typha latifolia*; and, 7) habitat/resource recovery function is linear based on Penn and Tomasi (2002).

January 22, 2015 Meeting: Adjusted by Greg Norwood to reflect only emergent marsh which would be impacted by management due to hydro survey with 70 acres at 33% functionality, full maturity reached after 10yrs.

Year Restoration Initiated	Restoration Year	Restoration Acreage	Percent Services Provided	Precent Baseline Services	Percent Net Services Gained	Adjusted Service Gains (Acres)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Discounted Service Acre Years (DSAYs) Gained
2016	2016	70.00	33.00	33.00	0.00	0.00	1.03	0	1.0000	0.00
2016	2017	70.00	38.70	33.00	5.70	3.99	1.03	-1	0.9709	3.87
2016	2018	70.00	44.40	33.00	11.40	7.98	1.03	-2	0.9426	7.52
2016	2019	70.00	50.10	33.00	17.10	11.97	1.03	-3	0.9151	10.95
2016	2020	70.00	55.80	33.00	22.80	15.96	1.03	-4	0.8885	14.18
2016	2021	70.00	61.50	33.00	28.50	19.95	1.03	-5	0.8626	17.21
2016	2022	70.00	67.20	33.00	34.20	23.94	1.03	-6	0.8375	20.05
2016	2023	70.00	72.90	33.00	39.90	27.93	1.03	-7	0.8131	22.71
2016	2024	70.00	78.60	33.00	45.60	31.92	1.03	-8	0.7894	25.20
2016	2025	70.00	84.30	33.00	51.30	35.91	1.03	-9	0.7664	27.52
2016	2026	70.00	90.00	33.00	57.00	39.90	1.03	-10	0.7441	29.69
2016	2027	70.00	90.00	33.00	57.00	39.90	1.03	-11	0.7224	28.82
2016	2028	70.00	90.00	33.00	57.00	39.90	1.03	-12	0.7014	27.99
2016	2029	70.00	90.00	33.00	57.00	39.90	1.03	-13	0.6810	27.17
2016	2030	70.00	90.00	33.00	57.00	39.90	1.03	-14	0.6611	26.38
2016	2031	70.00	90.00	33.00	57.00	39.90	1.03	-15	0.6419	25.61
2016	2032	70.00	90.00	33.00	57.00	39.90	1.03	-16	0.6232	24.86
2016	2033	70.00	90.00	33.00	57.00	39.90	1.03	-17	0.6050	24.14
2016	2034	70.00	90.00	33.00	57.00	39.90	1.03	-18	0.5874	23.44
2016	2035	70.00	90.00	33.00	57.00	39.90	1.03	-19	0.5703	22.75
2016	2036	70.00	90.00	33.00	57.00	39.90	1.03	-20	0.5537	22.09
2016	2037	70.00	90.00	33.00	57.00	39.90	1.03	-21	0.5375	21.45
2016	2038	70.00	90.00	33.00	57.00	39.90	1.03	-22	0.5219	20.82
2016	2039	70.00	90.00	33.00	57.00	39.90	1.03	-23	0.5067	20.22
2016	2040	70.00	90.00	33.00	57.00	39.90	1.03	-24	0.4919	19.63
2016	2041	70.00	90.00	33.00	57.00	39.90	1.03	-25	0.4776	19.06
2016	2042	70.00	90.00	33.00	57.00	39.90	1.03	-26	0.4637	18.50
2016	2043	70.00	90.00	33.00	57.00	39.90	1.03	-27	0.4502	17.96
2016	2044	70.00	90.00	33.00	57.00	39.90	1.03	-28	0.4371	17.44
2016	2045	70.00	90.00	33.00	57.00	39.90	1.03	-29	0.4243	16.93
2016	2046	70.00	90.00	33.00	57.00	39.90	1.03	-30	0.4120	16.44

Discounted Service Acre Years (DSAYs) of wetland habitat, invertebrates and wildlife gained from Gibraltar Wetland restoration **620.61**

Rouge River Compensatory Wetland Restoration Service Gains: LEMP Coastal Marsh Edge Restoration

Compensatory Restoration Project Scaling Assumptions: 1) This project involves treatment of non-native invasive species on 16 acres of coastal marsh edge; 2) restoration occurs in 2016; 3) Emergent marsh requires 11 years to reach full function since habitat is already partially functional (based on LA DEQ et al., 2003); 4) habitats ultimately reach 90% of natural habitat service functionality (fully developed habitat services reduced in productivity due to required continued invasives management such as *Phragmites* control); 5) Project lifetime is 30 years inclusive of maturation period; 6) restored wetland is dominated by an assumed mix of *Carex lacustris* and *Typha latifolia*; and 7) habitat/resource recovery function is linear based on Penn and Tomasi (2002).

Possible addition to restoration to meet DSAY needs of injuried resources: 16 acres of edge marsh. Assuming functionality is 30% and with maturity reached after 11yrs.

Year Restoration Initiated	Restoration Year	Restoration Acreage	Percent Services Provided	Precent Baseline Services	Percent Net Services Gained	Adjusted Service Gains (Acres)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Discounted Service Acre Years (DSAYs) Gained
2016	2016	16.00	30.00	30.00	0.00	0.00	1.03	0	1.0000	0.00
2016	2017	16.00	35.70	30.00	5.70	0.91	1.03	-1	0.9709	0.89
2016	2018	16.00	41.40	30.00	11.40	1.82	1.03	-2	0.9426	1.72
2016	2019	16.00	47.10	30.00	17.10	2.74	1.03	-3	0.9151	2.50
2016	2020	16.00	52.80	30.00	22.80	3.65	1.03	-4	0.8885	3.24
2016	2021	16.00	58.50	30.00	28.50	4.56	1.03	-5	0.8626	3.93
2016	2022	16.00	64.20	30.00	34.20	5.47	1.03	-6	0.8375	4.58
2016	2023	16.00	69.90	30.00	39.90	6.38	1.03	-7	0.8131	5.19
2016	2024	16.00	75.60	30.00	45.60	7.30	1.03	-8	0.7894	5.76
2016	2025	16.00	81.30	30.00	51.30	8.21	1.03	-9	0.7664	6.29
2016	2026	16.00	87.00	30.00	57.00	9.12	1.03	-10	0.7441	6.79
2016	2027	16.00	90.00	30.00	60.00	9.60	1.03	-11	0.7224	6.94
2016	2028	16.00	90.00	30.00	60.00	9.60	1.03	-12	0.7014	6.73
2016	2029	16.00	90.00	30.00	60.00	9.60	1.03	-13	0.6810	6.54
2016	2030	16.00	90.00	30.00	60.00	9.60	1.03	-14	0.6611	6.35
2016	2031	16.00	90.00	30.00	60.00	9.60	1.03	-15	0.6419	6.16
2016	2032	16.00	90.00	30.00	60.00	9.60	1.03	-16	0.6232	5.98
2016	2033	16.00	90.00	30.00	60.00	9.60	1.03	-17	0.6050	5.81
2016	2034	16.00	90.00	30.00	60.00	9.60	1.03	-18	0.5874	5.64
2016	2035	16.00	90.00	30.00	60.00	9.60	1.03	-19	0.5703	5.47
2016	2036	16.00	90.00	30.00	60.00	9.60	1.03	-20	0.5537	5.32
2016	2037	16.00	90.00	30.00	60.00	9.60	1.03	-21	0.5375	5.16
2016	2038	16.00	90.00	30.00	60.00	9.60	1.03	-22	0.5219	5.01
2016	2039	16.00	90.00	30.00	60.00	9.60	1.03	-23	0.5067	4.86
2016	2040	16.00	90.00	30.00	60.00	9.60	1.03	-24	0.4919	4.72
2016	2041	16.00	90.00	30.00	60.00	9.60	1.03	-25	0.4776	4.59
2016	2042	16.00	90.00	30.00	60.00	9.60	1.03	-26	0.4637	4.45
2016	2043	16.00	90.00	30.00	60.00	9.60	1.03	-27	0.4502	4.32
2016	2044	16.00	90.00	30.00	60.00	9.60	1.03	-28	0.4371	4.20
2016	2045	16.00	90.00	30.00	60.00	9.60	1.03	-29	0.4243	4.07
2016	2046	16.00	90.00	30.00	60.00	9.60	1.03	-30	0.4120	3.96

Discounted Service Acre Years (DSAYs) of wetland habitat, invertebrates and wildlife gained: 147.17

Rouge River Compensatory Wetland Restoration Service Gains: LEMP Lake Erie Shoreline Restoration

Compensatory Restoration Project Scaling Assumptions: 1) This project involves treatment of non-native and invasive species on 9 acres along the Lake Erie shoreline within the Lake Erie Metro Park; 2) Wetland restoration occurs in 2016; 3) Emergent marsh requires 6 years to reach full function since habitat is already partially functional (based on LA DEQ et al., 2003); 4) Habitats ultimately reach 90% of natural habitat service functionality (fully developed habitat services reduced in productivity due to required continued invasives management such as *Phragmites* control); 5) Project lifetime is 30 years inclusive of maturation period; 6) Restored wetland habitat is dominated by an assumed mix of *Carex lacustris* and *Typha latifolia*; and, 7) Habitat/resource recovery function is linear based on Penn and Tomasi (2002).

Possible addition to restoration to meet DSAY needs of injuried resources: 9 acres of shoreline marsh. Assuming functionality is 60% and with maturity reached after 6 yrs.

Year Restoration Initiated	Restoration Year	Restoration Acreage	Percent Services Provided	Precent Baseline Services	Percent Net Services Gained	Adjusted Service Gains (Acres)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Discounted Service Acre Years (DSAYs) Gained
2016	2016	9.00	60.00	60.00	0.00	0.00	1.03	0	1.0000	0.00
2016	2017	9.00	65.70	60.00	5.70	0.51	1.03	-1	0.9709	0.50
2016	2018	9.00	71.40	60.00	11.40	1.03	1.03	-2	0.9426	0.97
2016	2019	9.00	77.10	60.00	17.10	1.54	1.03	-3	0.9151	1.41
2016	2020	9.00	82.80	60.00	22.80	2.05	1.03	-4	0.8885	1.82
2016	2021	9.00	88.50	60.00	28.50	2.57	1.03	-5	0.8626	2.21
2016	2022	9.00	90.00	60.00	30.00	2.70	1.03	-6	0.8375	2.26
2016	2023	9.00	90.00	60.00	30.00	2.70	1.03	-7	0.8131	2.20
2016	2024	9.00	90.00	60.00	30.00	2.70	1.03	-8	0.7894	2.13
2016	2025	9.00	90.00	60.00	30.00	2.70	1.03	-9	0.7664	2.07
2016	2026	9.00	90.00	60.00	30.00	2.70	1.03	-10	0.7441	2.01
2016	2027	9.00	90.00	60.00	30.00	2.70	1.03	-11	0.7224	1.95
2016	2028	9.00	90.00	60.00	30.00	2.70	1.03	-12	0.7014	1.89
2016	2029	9.00	90.00	60.00	30.00	2.70	1.03	-13	0.6810	1.84
2016	2030	9.00	90.00	60.00	30.00	2.70	1.03	-14	0.6611	1.79
2016	2031	9.00	90.00	60.00	30.00	2.70	1.03	-15	0.6419	1.73
2016	2032	9.00	90.00	60.00	30.00	2.70	1.03	-16	0.6232	1.68
2016	2033	9.00	90.00	60.00	30.00	2.70	1.03	-17	0.6050	1.63
2016	2034	9.00	90.00	60.00	30.00	2.70	1.03	-18	0.5874	1.59
2016	2035	9.00	90.00	60.00	30.00	2.70	1.03	-19	0.5703	1.54
2016	2036	9.00	90.00	60.00	30.00	2.70	1.03	-20	0.5537	1.49
2016	2037	9.00	90.00	60.00	30.00	2.70	1.03	-21	0.5375	1.45
2016	2038	9.00	90.00	60.00	30.00	2.70	1.03	-22	0.5219	1.41
2016	2039	9.00	90.00	60.00	30.00	2.70	1.03	-23	0.5067	1.37
2016	2040	9.00	90.00	60.00	30.00	2.70	1.03	-24	0.4919	1.33
2016	2041	9.00	90.00	60.00	30.00	2.70	1.03	-25	0.4776	1.29
2016	2042	9.00	90.00	60.00	30.00	2.70	1.03	-26	0.4637	1.25
2016	2043	9.00	90.00	60.00	30.00	2.70	1.03	-27	0.4502	1.22
2016	2044	9.00	90.00	60.00	30.00	2.70	1.03	-28	0.4371	1.18
2016	2045	9.00	90.00	60.00	30.00	2.70	1.03	-29	0.4243	1.15
2016	2046	9.00	90.00	60.00	30.00	2.70	1.03	-30	0.4120	1.11

Discounted Service Acre Years (DSAYs) of wetland habitat, invertebrates and wildlife gained: 47.47

Rouge River Compensatory Wetland Restoration Service Gains: LEMP Lakeplain Prairie Restoration

Compensatory Restoration Project Scaling Assumptions: 1) This project involves treatment of non-native and invasive species in lakeplain prairie habitat within the Lake Erie MetroPark; 2) wetland restoration occurs in 2016; 3) Habitat requires 8 years to reach full function since habitat is already partially functional (based on LA DEQ et al., 2003); 4) habitats ultimately reach 90% of natural habitat service functionality (fully developed habitat services reduced in productivity due to required continued invasives management such as *Phragmites* control); 5) Project lifetime is 30 years inclusive of maturation period; 6) restored prairie is dominated by native species; and, 7) habitat/resource recovery function is linear based on Penn and Tomasi (2002).

Possible addition to restoration to meet DSAY needs of injuried resources: 38 acres of lake plain marsh. Assuming functionality is 50% and with maturity reached after 8 yrs.

Year Restoration Initiated	Restoration Year	Restoration Acreage	Percent Services Provided	Precent Baseline Services	Percent Net Services Gained	Adjusted Service Gains (Acres)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Discounted Service Acre Years (DSAYs) Gained
2016	2016	38.00	50.00	50.00	0.00	0.00	1.03	0	1.0000	0.00
2016	2017	38.00	55.70	50.00	5.70	2.17	1.03	-1	0.9709	2.10
2016	2018	38.00	61.40	50.00	11.40	4.33	1.03	-2	0.9426	4.08
2016	2019	38.00	67.10	50.00	17.10	6.50	1.03	-3	0.9151	5.95
2016	2020	38.00	72.80	50.00	22.80	8.66	1.03	-4	0.8885	7.70
2016	2021	38.00	78.50	50.00	28.50	10.83	1.03	-5	0.8626	9.34
2016	2022	38.00	84.20	50.00	34.20	13.00	1.03	-6	0.8375	10.88
2016	2023	38.00	89.90	50.00	39.90	15.16	1.03	-7	0.8131	12.33
2016	2024	38.00	90.00	50.00	40.00	15.20	1.03	-8	0.7894	12.00
2016	2025	38.00	90.00	50.00	40.00	15.20	1.03	-9	0.7664	11.65
2016	2026	38.00	90.00	50.00	40.00	15.20	1.03	-10	0.7441	11.31
2016	2027	38.00	90.00	50.00	40.00	15.20	1.03	-11	0.7224	10.98
2016	2028	38.00	90.00	50.00	40.00	15.20	1.03	-12	0.7014	10.66
2016	2029	38.00	90.00	50.00	40.00	15.20	1.03	-13	0.6810	10.35
2016	2030	38.00	90.00	50.00	40.00	15.20	1.03	-14	0.6611	10.05
2016	2031	38.00	90.00	50.00	40.00	15.20	1.03	-15	0.6419	9.76
2016	2032	38.00	90.00	50.00	40.00	15.20	1.03	-16	0.6232	9.47
2016	2033	38.00	90.00	50.00	40.00	15.20	1.03	-17	0.6050	9.20
2016	2034	38.00	90.00	50.00	40.00	15.20	1.03	-18	0.5874	8.93
2016	2035	38.00	90.00	50.00	40.00	15.20	1.03	-19	0.5703	8.67
2016	2036	38.00	90.00	50.00	40.00	15.20	1.03	-20	0.5537	8.42
2016	2037	38.00	90.00	50.00	40.00	15.20	1.03	-21	0.5375	8.17
2016	2038	38.00	90.00	50.00	40.00	15.20	1.03	-22	0.5219	7.93
2016	2039	38.00	90.00	50.00	40.00	15.20	1.03	-23	0.5067	7.70
2016	2040	38.00	90.00	50.00	40.00	15.20	1.03	-24	0.4919	7.48
2016	2041	38.00	90.00	50.00	40.00	15.20	1.03	-25	0.4776	7.26
2016	2042	38.00	90.00	50.00	40.00	15.20	1.03	-26	0.4637	7.05
2016	2043	38.00	90.00	50.00	40.00	15.20	1.03	-27	0.4502	6.84
2016	2044	38.00	90.00	50.00	40.00	15.20	1.03	-28	0.4371	6.64
2016	2045	38.00	90.00	50.00	40.00	15.20	1.03	-29	0.4243	6.45
2016	2046	38.00	90.00	50.00	40.00	15.20	1.03	-30	0.4120	6.26

Discounted Service Acre Years (DSAYs) of wetland habitat, invertebrates and wildlife gained: 255.61

Rouge River Compensatory Wetland Restoration Service Gains: Great Lakes Marsh Restoration

Compensatory Restoration Project Scaling Assumptions: 1) This project involves management of invasives in Great Lakes Marsh (esp. *Phragmites*, and, possibly, flowering rush and European frogbit) 350 acre marsh parcel; 2) wetland restoration occurs in 2016; 3) Emergent marsh requires 10 years to reach full function since habitat is already partially functional (based on LA DEQ et al., 2003); 4) habitats ultimately reach 90% of natural habitat service functionality (fully developed habitat services reduced in productivity due to required continued invasives management such as Phragmites control); 5) Project lifetime is 30 years inclusive of the maturation period; 6) restored wetland is dominated by an assumed mix of *Carex lacustris* and *Typha latifolia*; and, 7) habitat/resource recovery function is linear based on Penn and Tomasi (2002).

February 23, 2015 Phone Meeting : Paul Muelle requested maintenance for 350 acres of marsh which had completed initial phrag control measures through a GLRI grant in Spring 2015. After initial treatment the 350 acre marsh is estimated to be 80% functional with 3 yrs to reach functionality.

Year Restoration Initiated	Restoration Year	Restoration Acreage	Percent Services Provided	Precent Baseline Services	Percent Net Services Gained	Adjusted Service Gains (Acres)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Discounted Service Acre Years (DSAYs) Gained
2016	2016	350.00	80.00	80.00	0.00	0.00	1.03	0	1.0000	0.00
2016	2017	350.00	85.70	80.00	5.70	19.95	1.03	-1	0.9709	19.37
2016	2018	350.00	90.00	80.00	10.00	35.00	1.03	-2	0.9426	32.99
2016	2019	350.00	90.00	80.00	10.00	35.00	1.03	-3	0.9151	32.03
2016	2020	350.00	90.00	80.00	10.00	35.00	1.03	-4	0.8885	31.10
2016	2021	350.00	90.00	80.00	10.00	35.00	1.03	-5	0.8626	30.19
2016	2022	350.00	90.00	80.00	10.00	35.00	1.03	-6	0.8375	29.31
2016	2023	350.00	90.00	80.00	10.00	35.00	1.03	-7	0.8131	28.46
2016	2024	350.00	90.00	80.00	10.00	35.00	1.03	-8	0.7894	27.63
2016	2025	350.00	90.00	80.00	10.00	35.00	1.03	-9	0.7664	26.82
2016	2026	350.00	90.00	80.00	10.00	35.00	1.03	-10	0.7441	26.04
2016	2027	350.00	90.00	80.00	10.00	35.00	1.03	-11	0.7224	25.28
2016	2028	350.00	90.00	80.00	10.00	35.00	1.03	-12	0.7014	24.55
2016	2029	350.00	90.00	80.00	10.00	35.00	1.03	-13	0.6810	23.83
2016	2030	350.00	90.00	80.00	10.00	35.00	1.03	-14	0.6611	23.14
2016	2031	350.00	90.00	80.00	10.00	35.00	1.03	-15	0.6419	22.47
2016	2032	350.00	90.00	80.00	10.00	35.00	1.03	-16	0.6232	21.81
2016	2033	350.00	90.00	80.00	10.00	35.00	1.03	-17	0.6050	21.18
2016	2034	350.00	90.00	80.00	10.00	35.00	1.03	-18	0.5874	20.56
2016	2035	350.00	90.00	80.00	10.00	35.00	1.03	-19	0.5703	19.96
2016	2036	350.00	90.00	80.00	10.00	35.00	1.03	-20	0.5537	19.38
2016	2037	350.00	90.00	80.00	10.00	35.00	1.03	-21	0.5375	18.81
2016	2038	350.00	90.00	80.00	10.00	35.00	1.03	-22	0.5219	18.27
2016	2039	350.00	90.00	80.00	10.00	35.00	1.03	-23	0.5067	17.73
2016	2040	350.00	90.00	80.00	10.00	35.00	1.03	-24	0.4919	17.22
2016	2041	350.00	90.00	80.00	10.00	35.00	1.03	-25	0.4776	16.72
2016	2042	350.00	90.00	80.00	10.00	35.00	1.03	-26	0.4637	16.23
2016	2043	350.00	90.00	80.00	10.00	35.00	1.03	-27	0.4502	15.76
2016	2044	350.00	90.00	80.00	10.00	35.00	1.03	-28	0.4371	15.30
2016	2045	350.00	90.00	80.00	10.00	35.00	1.03	-29	0.4243	14.85
2016	2046	350.00	90.00	80.00	10.00	35.00	1.03	-30	0.4120	14.42

Discounted Service Acre Years (DSAYs) of wetland habitat, invertebrates and wildlife gained from Great Lakes Marsh restoration: 671.40

Rouge River Compensatory Wetland Restoration Service Gains: Pointe Mouillee Wetland Restoration - Lautenschlager Unit

Compensatory Restoration Project Scaling Assumptions: 1) This project involves replacing a main pump station at the Pointe Mouillee State Game Area, improving water level control in the wetlands os several units including this Lautenschalger Unit of 70 marsh acres. Improving the State's ability to control water levels at the State Game Area facilitates wetland management and invasives control, thereby directly improving wetland function, services and quality; 2) wetland restoration occurs in 2016; 3) Emergent marsh requires 7 years to reach full function since habitat is already partially functional (based on LA DEQ et al., 2003); 4) habitats ultimately reach 90% of natural habitat service functionality (fully developed habitat services reduced in productivity due to required continued invasives management such as Phragmites control); 5) Project lifetime is 30 years inclusive of maturation period; 6) restored wetland is dominated by an assumed mix of *Carex lacustris* and *Typha latifoli* a; and, 7) habitat/resource recovery function is linear based on Penn and Tomasi (2002).

January 22, 2015 Meeting: Zach Cooley provided Lautenschalger Unit as an emergent marsh which would be affected by proposed electric pump station. Emergent Marsh on the unit is 70 acres at 50% current functionality, needing 40% increase in functionality to reach 90%. Zach estimates a pump life of 30-50 yrs with regular maintenance. Full functionality reached after 7yrs.

Year Restoration Initiated	Restoration Year	Restoration Acreage	Percent Services Provided	Precent Baseline Services	Percent Net Services Gained	Adjusted Service Gains (Acres)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Discounted Service Acre Years (DSAYs) Gained
2016	2016	70	50.00	50.00	0.00	0.00	1.03	0	1.0000	0.00
2016	2017	70	55.70	50.00	5.70	3.99	1.03	-1	0.9709	3.87
2016	2018	70	67.10	50.00	11.40	7.98	1.03	-2	0.9426	7.52
2016	2019	70	72.80	50.00	17.10	11.97	1.03	-3	0.9151	10.95
2016	2020	70	78.50	50.00	22.80	15.96	1.03	-4	0.8885	14.18
2016	2021	70	84.20	50.00	28.50	19.95	1.03	-5	0.8626	17.21
2016	2022	70	89.90	50.00	34.20	23.94	1.03	-6	0.8375	20.05
2016	2023	70	90.00	50.00	40.00	28.00	1.03	-7	0.8131	22.77
2016	2024	70	90.00	50.00	40.00	28.00	1.03	-8	0.7894	22.10
2016	2025	70	90.00	50.00	40.00	28.00	1.03	-9	0.7664	21.46
2016	2026	70	90.00	50.00	40.00	28.00	1.03	-10	0.7441	20.83
2016	2027	70	90.00	50.00	40.00	28.00	1.03	-11	0.7224	20.23
2016	2028	70	90.00	50.00	40.00	28.00	1.03	-12	0.7014	19.64
2016	2029	70	90.00	50.00	40.00	28.00	1.03	-13	0.6810	19.07
2016	2030	70	90.00	50.00	40.00	28.00	1.03	-14	0.6611	18.51
2016	2031	70	90.00	50.00	40.00	28.00	1.03	-15	0.6419	17.97
2016	2032	70	90.00	50.00	40.00	28.00	1.03	-16	0.6232	17.45
2016	2033	70	90.00	50.00	40.00	28.00	1.03	-17	0.6050	16.94
2016	2034	70	90.00	50.00	40.00	28.00	1.03	-18	0.5874	16.45
2016	2035	70	90.00	50.00	40.00	28.00	1.03	-19	0.5703	15.97
2016	2036	70	90.00	50.00	40.00	28.00	1.03	-20	0.5537	15.50
2016	2037	70	90.00	50.00	40.00	28.00	1.03	-21	0.5375	15.05
2016	2038	70	90.00	50.00	40.00	28.00	1.03	-22	0.5219	14.61
2016	2039	70	90.00	50.00	40.00	28.00	1.03	-23	0.5067	14.19
2016	2040	70	90.00	50.00	40.00	28.00	1.03	-24	0.4919	13.77
2016	2041	70	90.00	50.00	40.00	28.00	1.03	-25	0.4776	13.37
2016	2042	70	90.00	50.00	40.00	28.00	1.03	-26	0.4637	12.98
2016	2043	70	90.00	50.00	40.00	28.00	1.03	-27	0.4502	12.61
2016	2044	70	90.00	50.00	40.00	28.00	1.03	-28	0.4371	12.24
2016	2045	70	90.00	50.00	40.00	28.00	1.03	-29	0.4243	11.88
2016	2046	70	90.00	50.00	40.00	28.00	1.03	-30	0.4120	11.54

Discounted Service Acre Years (DSAYs) gained: 470.92

Rouge River Compensatory Wetland Restoration Service Gains: Pointe Mouillee Wetland Restoration - Vermet Unit

Compensatory Restoration Project Scaling Assumptions: 1) This project involves replacing a main pump station at the Pointe Mouillee State Game Area, improving water level control in the wetlands of several units including this Vermet Unit of 175 marsh acres. Improving the State's ability to control water levels at the State Game Area facilitates wetland management and invasives control, thereby directly improving wetland function, services and quality; 2) wetland restoration occurs in 2016; 3) Emergent marsh requires 7 years to reach full function since habitat is already partially functional (based on LA DEQ et al., 2003); 4) habitats ultimately reach 90% of natural habitat service functionality (fully developed habitat services reduced in productivity due to required continued invasives management such as Phragmites control); 5) Project lifetime is 30 years inclusive of maturation period; 6) restored wetland is dominated by an assumed mix of *Carex lacustris* and *Typha latifolia*; and 7) habitat/resource recovery function is linear based on Penn and Tomasi (2002).

January 22, 2015 Meeting: Zach Cooley provided Vermet Unit as an emergent marsh which would be affected by proposed electric pump station. Emergent Marsh on the unit is 175 acres at 50% current functionality, needing 40% increase in functionality to reach 90%. Zach estimates a pump life of 30-50 yrs with regular maintenance. Full maturity reached after 7 yrs

Year Restoration Initiated	Restoration Year	Restoration Acreage	Percent Services Provided	Precent Baseline Services	Percent Net Services Gained	Adjusted Service Gains (Acres)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Discounted Service Acre Years (DSAYs) Gained
2016	2016	175	50.00	50.00	0.00	0.00	1.03	0	1.0000	0.00
2016	2017	175	55.70	50.00	5.70	9.98	1.03	-1	0.9709	9.68
2016	2018	175	67.10	50.00	11.40	19.95	1.03	-2	0.9426	18.80
2016	2019	175	72.80	50.00	17.10	29.93	1.03	-3	0.9151	27.39
2016	2020	175	78.50	50.00	22.80	39.90	1.03	-4	0.8885	35.45
2016	2021	175	84.20	50.00	28.50	49.88	1.03	-5	0.8626	43.02
2016	2022	175	90.00	50.00	34.20	59.85	1.03	-6	0.8375	50.12
2016	2023	175	90.00	50.00	40.00	70.00	1.03	-7	0.8131	56.92
2016	2024	175	90.00	50.00	40.00	70.00	1.03	-8	0.7894	55.26
2016	2025	175	90.00	50.00	40.00	70.00	1.03	-9	0.7664	53.65
2016	2026	175	90.00	50.00	40.00	70.00	1.03	-10	0.7441	52.09
2016	2027	175	90.00	50.00	40.00	70.00	1.03	-11	0.7224	50.57
2016	2028	175	90.00	50.00	40.00	70.00	1.03	-12	0.7014	49.10
2016	2029	175	90.00	50.00	40.00	70.00	1.03	-13	0.6810	47.67
2016	2030	175	90.00	50.00	40.00	70.00	1.03	-14	0.6611	46.28
2016	2031	175	90.00	50.00	40.00	70.00	1.03	-15	0.6419	44.93
2016	2032	175	90.00	50.00	40.00	70.00	1.03	-16	0.6232	43.62
2016	2033	175	90.00	50.00	40.00	70.00	1.03	-17	0.6050	42.35
2016	2034	175	90.00	50.00	40.00	70.00	1.03	-18	0.5874	41.12
2016	2035	175	90.00	50.00	40.00	70.00	1.03	-19	0.5703	39.92
2016	2036	175	90.00	50.00	40.00	70.00	1.03	-20	0.5537	38.76
2016	2037	175	90.00	50.00	40.00	70.00	1.03	-21	0.5375	37.63
2016	2038	175	90.00	50.00	40.00	70.00	1.03	-22	0.5219	36.53
2016	2039	175	90.00	50.00	40.00	70.00	1.03	-23	0.5067	35.47
2016	2040	175	90.00	50.00	40.00	70.00	1.03	-24	0.4919	34.44
2016	2041	175	90.00	50.00	40.00	70.00	1.03	-25	0.4776	33.43
2016	2042	175	90.00	50.00	40.00	70.00	1.03	-26	0.4637	32.46
2016	2043	175	90.00	50.00	40.00	70.00	1.03	-27	0.4502	31.51
2016	2044	175	90.00	50.00	40.00	70.00	1.03	-28	0.4371	30.60
2016	2045	175	90.00	50.00	40.00	70.00	1.03	-29	0.4243	29.70
2016	2046	175	90.00	50.00	40.00	70.00	1.03	-30	0.4120	28.84

Discounted Service Acre Years (DSAYs) gained: 1177.30

Rouge River Compensatory Wetland Restoration Service Gains: Pointe Mouillee Wetland Restoration - Humphries Unit

Compensatory Restoration Project Scaling Assumptions: 1) This project involves replacing a main pump station at the Pointe Mouillee State Game Area, improving water level control in the wetlands of several units including this Humphries Unit of 650 marsh acres. Improving the State's ability to control water levels at the State Game Area facilitates wetland management and invasives control, thereby directly improving wetland function, services and quality; 2) wetland restoration occurs in 2016; 3) Emergent marsh requires 3 years to reach full function since habitat is already partially functional (based on LA DEQ et al., 2003); 4) habitats ultimately reach 90% of natural habitat service functionality (fully developed habitat services reduced in productivity due to required continued invasives management such as *Phragmites* control); 5) Project lifetime is 30 years inclusive of maturation period; 6) restored wetland is dominated by an assumed mix of *Carex lacustris* and *Typha latifolia* ; and 7) habitat/resource recovery function is linear based on Penn and Tomasi (2002).

January 22, 2015 Meeting: Zach Cooley provided Humphries Unit as an emergent marsh which would be affected by proposed electric pump station. Emergent Marsh on the unit is 175 acres at 80% current functionality, needing 10% increase in functionality to reach 90%. Zach estimates a pump life of 30-50yrs with regular maintenance. Based on LA DEQ et al 2003, requires 3 yrs to reach full function given current functionality.

Year Restoration Initiated	Restoration Year	Restoration Acreage	Percent Services Provided	Precent Baseline Services	Percent Net Services Gained	Adjusted Service Gains (Acres)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Discounted Service Acre Years (DSAYs) Gained
2016	2016	650	80.00	80.00	0.00	0.00	1.03	0	1.0000	0.00
2016	2017	650	85.70	80.00	5.70	37.05	1.03	-1	0.9709	35.97
2016	2018	650	90.00	80.00	10.00	65.00	1.03	-2	0.9426	61.27
2016	2019	650	90.00	80.00	10.00	65.00	1.03	-3	0.9151	59.48
2016	2020	650	90.00	80.00	10.00	65.00	1.03	-4	0.8885	57.75
2016	2021	650	90.00	80.00	10.00	65.00	1.03	-5	0.8626	56.07
2016	2022	650	90.00	80.00	10.00	65.00	1.03	-6	0.8375	54.44
2016	2023	650	90.00	80.00	10.00	65.00	1.03	-7	0.8131	52.85
2016	2024	650	90.00	80.00	10.00	65.00	1.03	-8	0.7894	51.31
2016	2025	650	90.00	80.00	10.00	65.00	1.03	-9	0.7664	49.82
2016	2026	650	90.00	80.00	10.00	65.00	1.03	-10	0.7441	48.37
2016	2027	650	90.00	80.00	10.00	65.00	1.03	-11	0.7224	46.96
2016	2028	650	90.00	80.00	10.00	65.00	1.03	-12	0.7014	45.59
2016	2029	650	90.00	80.00	10.00	65.00	1.03	-13	0.6810	44.26
2016	2030	650	90.00	80.00	10.00	65.00	1.03	-14	0.6611	42.97
2016	2031	650	90.00	80.00	10.00	65.00	1.03	-15	0.6419	41.72
2016	2032	650	90.00	80.00	10.00	65.00	1.03	-16	0.6232	40.51
2016	2033	650	90.00	80.00	10.00	65.00	1.03	-17	0.6050	39.33
2016	2034	650	90.00	80.00	10.00	65.00	1.03	-18	0.5874	38.18
2016	2035	650	90.00	80.00	10.00	65.00	1.03	-19	0.5703	37.07
2016	2036	650	90.00	80.00	10.00	65.00	1.03	-20	0.5537	35.99
2016	2037	650	90.00	80.00	10.00	65.00	1.03	-21	0.5375	34.94
2016	2038	650	90.00	80.00	10.00	65.00	1.03	-22	0.5219	33.92
2016	2039	650	90.00	80.00	10.00	65.00	1.03	-23	0.5067	32.93
2016	2040	650	90.00	80.00	10.00	65.00	1.03	-24	0.4919	31.98
2016	2041	650	90.00	80.00	10.00	65.00	1.03	-25	0.4776	31.04
2016	2042	650	90.00	80.00	10.00	65.00	1.03	-26	0.4637	30.14
2016	2043	650	90.00	80.00	10.00	65.00	1.03	-27	0.4502	29.26
2016	2044	650	90.00	80.00	10.00	65.00	1.03	-28	0.4371	28.41
2016	2045	650	90.00	80.00	10.00	65.00	1.03	-29	0.4243	27.58
2016	2046	650	90.00	80.00	10.00	65.00	1.03	-30	0.4120	26.78
									Discounted Service Acre Years (DSAYs) gained:	**1246.89**

Rouge River Compensatory Wetland Restoration Service Gains: Pointe Mouillee Wetland Restoration - Bad Creek Unit

Compensatory Restoration Project Scaling Assumptions: 1) This project involves infrastructure replacement for moist soil management of the Bad Creek Unit (30acres). Improving the State's ability to control water levels at the State Game Area facilitates wetland management and invasives control, thereby directly improving wetland function, services and quality; 2) wetland restoration occurs in 2016; 3) Emergent marsh requires 14 years to reach full function since habitat is already partially functional (based on LA DEQ et al., 2003); 4) habitats ultimately reach 90% of natural habitat service functionality (fully developed habitat services reduced in productivity due to required continued invasives management such as *Phragmites* control); 5) Project lifetime is 30 years inclusive of maturation period; 6) restored wetland is dominated by an assumed mix of *Carex lacustris* and *Typha latifolia*; and, 7) habitat/resource recovery function is linear based on Penn and Tomasi (2002).

January 22, 2015 Meeting: Zach Cooley provided Bad Creek Unit as a substitute for the original Cripple Creek Unit. Moist Soil management will occur on 30 acres at 10% current functionality, needing 80% increase in functionality to reach 90%. Based on LA DEQ et al 2003, requires 14 yrs to reach full function given current functionality.

Year Restoration Initiated	Restoration Year	Restoration Acreage	Percent Services Provided	Precent Baseline Services	Percent Net Services Gained	Adjusted Service Gains (Acres)	Discount Rate (1+r)	Span of Years (Years)	Discount Factor	Discounted Service Acre Years (DSAYs) Gained
2016	2016	30	10.00	10.00	0.00	0.00	1.03	0	1.0000	0.00
2016	2017	30	15.70	10.00	5.70	1.71	1.03	-1	0.9709	1.66
2016	2018	30	21.40	10.00	11.40	3.42	1.03	-2	0.9426	3.22
2016	2019	30	27.10	10.00	17.10	5.13	1.03	-3	0.9151	4.69
2016	2020	30	32.80	10.00	22.80	6.84	1.03	-4	0.8885	6.08
2016	2021	30	38.50	10.00	28.50	8.55	1.03	-5	0.8626	7.38
2016	2022	30	44.20	10.00	34.20	10.26	1.03	-6	0.8375	8.59
2016	2023	30	49.90	10.00	39.90	11.97	1.03	-7	0.8131	9.73
2016	2024	30	55.60	10.00	45.60	13.68	1.03	-8	0.7894	10.80
2016	2025	30	61.30	10.00	51.30	15.39	1.03	-9	0.7664	11.80
2016	2026	30	67.00	10.00	57.00	17.10	1.03	-10	0.7441	12.72
2016	2027	30	72.70	10.00	62.70	18.81	1.03	-11	0.7224	13.59
2016	2028	30	78.40	10.00	68.40	20.52	1.03	-12	0.7014	14.39
2016	2029	30	84.10	10.00	74.10	22.23	1.03	-13	0.6810	15.14
2016	2030	30	89.80	10.00	79.80	23.94	1.03	-14	0.6611	15.83
2016	2031	30	90.00	10.00	80.00	24.00	1.03	-15	0.6419	15.40
2016	2032	30	90.00	10.00	80.00	24.00	1.03	-16	0.6232	14.96
2016	2033	30	90.00	10.00	80.00	24.00	1.03	-17	0.6050	14.52
2016	2034	30	90.00	10.00	80.00	24.00	1.03	-18	0.5874	14.10
2016	2035	30	90.00	10.00	80.00	24.00	1.03	-19	0.5703	13.69
2016	2036	30	90.00	10.00	80.00	24.00	1.03	-20	0.5537	13.29
2016	2037	30	90.00	10.00	80.00	24.00	1.03	-21	0.5375	12.90
2016	2038	30	90.00	10.00	80.00	24.00	1.03	-22	0.5219	12.53
2016	2039	30	90.00	10.00	80.00	24.00	1.03	-23	0.5067	12.16
2016	2040	30	90.00	10.00	80.00	24.00	1.03	-24	0.4919	11.81
2016	2041	30	90.00	10.00	80.00	24.00	1.03	-25	0.4776	11.46
2016	2042	30	90.00	10.00	80.00	24.00	1.03	-26	0.4637	11.13
2016	2043	30	90.00	10.00	80.00	24.00	1.03	-27	0.4502	10.80
2016	2044	30	90.00	10.00	80.00	24.00	1.03	-28	0.4371	10.49
2016	2045	30	90.00	10.00	80.00	24.00	1.03	-29	0.4243	10.18
2016	2046	30	90.00	10.00	80.00	24.00	1.03	-30	0.4120	9.89

Discounted Service Acre Years (DSAYs) of wetland habitat, invertebrates and wildlife gained from Pointe Mouillee wetland restoration: 334.93

References for Rouge River Mystery Spill Scaling

Grant, J.R., Reilly, T.J., French-McCay, D., Rowe, J., and E. Graham. 2011. Rouge River 2002 Mystery Oil Spill SIMAP Injury Report: Review). LTCI, Rockport, MA; and ASA, Narragansett, RI. 15 pp.

LA DEQ et al. 2003. The Louisiana Regional Restoration Planning Program, Draft Regional Restoration Plan, Region 2. Louisiana Dep Natural Resources, Louisiana Department of Wildlife and Fisheries, Louisiana Oil Spill Coordinator's Office, National Oceanic and Atmo September 2003.

Penn, T. and T. Tomasi. 2002. Environmental Assessment: Calculating Resource Restoration for an Oil Discharge in Lake Barre, LA, Verlag. pp. 691–702.

Appendix 6: NEPA Categorical Exclusions - U.S. Department of the Interior Departmental Manual 6, Section 516, Chapter 8.5 (516 DM 8.5)

Attachment A: Department of Interior NEPA Categorical Exclusions

Attachment B: NEPA Compliance Checklist

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NEPA COMPLIANCE CHECKLIST

State: Michigan **Federal Financial Assistance Grant/Agreement/Amendment Number:** SEE ATTACHED

Grant/Project Name: Rouge River Mystery Oil Spill - Damage Assessment and Restoration Plan

This proposal ☑ **is**; ☐ **is not completely covered by categorical exclusion ____ in 516 DM 2, Appendix ____; and/or 516 DM 6, Appendix** 1.

(check (✓) one) (Review proposed activities. An appropriate categorical exclusion must be identified before completing the remainder of the Checklist. If a categorical exclusion cannot be identified, or the proposal cannot meet the qualifying criteria in the categorical exclusion, or an extraordinary circumstance applies (see below), an EA must be prepared.)

Extraordinary Circumstances:

Will This Proposal *(check (✓) yes or no for each item below)*:

Yes	No		
☐	✓	1.	Have significant adverse effects on public health or safety.
☐	✓	2.	Have significant adverse effects on such natural resources and unique geographic characteristics as historic or cultural resources; park, recreation or refuge lands; wilderness areas; wild or scenic rivers; national natural landmarks; sole or principal drinking water aquifers; prime farmlands; wetlands (Executive Order 11990); floodplains (Executive Order 11988); national monuments; migratory birds (Executive Order 13186); and other ecologically significant or critical areas under Federal ownership or jurisdiction.
☐	✓	3.	Have highly controversial environmental effects or involve unresolved conflicts concerning alternative uses of available resources [NEPA Section 102(2)(E)].
☐	✓	4.	Have highly uncertain and potentially significant environmental effects or involve unique or unknown environmental risks.
☐	✓	5.	Have a precedent for future action or represent a decision in principle about future actions with potentially significant environmental effects.
☐	✓	6.	Have a direct relationship to other actions with individually insignificant but cumulatively significant environmental effects.
☐	✓	7.	Have significant adverse effects on properties listed or eligible for listing on the National Register of Historic Places as determined by either the bureau or office, the State Historic Preservation Officer, the Tribal Historic Preservation Officer, the Advisory Council on Historic Preservation, or a consulting party under 36 CFR 800.
☐	✓	8.	Have significant adverse effects on species listed, or proposed to be listed, on the List of Endangered or Threatened Species, or have significant adverse effects on designated Critical Habitat for these species.
☐	✓	9.	Have the possibility of violating a Federal law, or a State, local, or tribal law or requirement imposed for the protection of the environment.
☐	✓	10.	Have the possibility for a disproportionately high and adverse effect on low income or minority populations (Executive Order 12898).
☐	✓	11.	Have the possibility to limit access to and ceremonial use of Indian sacred sites on Federal lands by Indian religious practitioners or significantly adversely affect the physical integrity of such sacred sites (Executive Order 13007).
☐	✓	12.	Have the possibility to significantly contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area or actions that may promote the introduction, growth, or expansion of the range of such species (Federal Noxious Weed Control Act and Executive Order 13112).

(If any of the above extraordinary circumstances receive a "Yes" check (✓), an EA must be prepared.)

☐ Yes ☑ No This grant/project includes additional information supporting the Checklist.

Concurrences/Approvals:

Project Leader: [signature] Date: 9/11/15

State Authority Concurrence: ________________ Date: __________

(with financial assistance signature authority, if applicable)

Within the spirit and intent of the Council of Environmental Quality's regulations for implementing the National Environmental Policy Act (NEPA) and other statutes, orders, and policies that protect fish and wildlife resources, I have established the following administrative record and have determined that the grant/agreement/amendment:

☑ **is a categorical exclusion as provided by 516 DM 6, Appendix 1 and/or 516 DM 2, Appendix 1. No further NEPA documentation will therefore be made.**

☐ **is not completely covered by the categorical exclusion as provided by 516 DM 6, Appendix 1 and/or 516 DM 2, Appendix 1. An EA must be prepared.**

Service signature approval:

RO or WO Environmental Coordinator: ________________ Date: __________

Staff Specialist, Division of Federal Assistance: ________________ Date: __________

(or authorized Service representative with financial assistance signature authority)

FWS Form 3-2185
Revised 02/2004

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NEPA Categorical Exclusions

U.S. Department of the Interior Departmental Manual 6,
Section 516, Chapter 8.5 (516 DM 8.5)

The text presented below is from the above-cited section of the Department of Interior Departmental manual. This section is referred to in FWS Form 3-2185 (attached) as 516 DM 6 Appendix. The Trustees for the 2002 Rouge River Mystery Oil Spill have proposed to implement four projects to compensate for resource injuries associated with the Spill:

- **Humbug Marsh/Monguagon Creek Bank Habitat Improvements**
- **Gibraltar Wetland Restoration**
- **Great Lakes Marsh Restoration**
- **Pointe Mouillee Wetland Restoration**

These projects were evaluated for their compliance with departmental direction regarding the use of Categorical Exclusions under the National Environmental Policy Act of 1969 (NEPA; 40 CFR 1508). Relevant text is indicated by the use of **underlined, bold text;** notes and comments documenting the rationale used for the selection of a particular categorical exclusion is indicated by the use of ***bold italic text***.

516 DM 8.5

8.5 **Categorical Exclusions**. Categorical exclusions are classes of actions which do not individually or cumulatively have a significant effect on the human environment. Categorical exclusions are not the equivalent of statutory exemptions. If exceptions to categorical exclusions apply, under 516 DM 2, Appendix 2 of the Departmental Manual, the Departmental categorical exclusions cannot be used. In addition to the actions listed in the Departmental categorical exclusions outlined in Appendix 1 of 516 DM 2, the following Service actions are designated categorical exclusions unless the action is an exception to the categorical exclusion.

A. General.

(1) Changes or amendments to an approved action when such changes have no or minor potential environmental impact.

(2) Personnel training, environmental interpretation, public safety efforts, and other educational activities, which do not involve new construction or major additions to existing facilities.

(3) The issuance and modification of procedures, including manuals, orders, guidelines, and field instructions, when the impacts are limited to administrative effects.

(4) The acquisition of real property obtained either through discretionary acts or when acquired by law, whether by way of condemnation, donation, escheat, right-of-entry, escrow, exchange, lapses, purchase, or transfer and that will be under the jurisdiction or control of the United States. Such acquisition of real property shall be in accordance with 602 DM 2 and the Service's procedures, when the acquisition is from a willing seller, continuance of or minor modification to the existing land use is planned, and the acquisition planning process has been performed in coordination with the affected public.

B. Resource Management. Prior to carrying out these actions, the Service should coordinate with affected Federal agencies and State, tribal, and local governments.

(1) Research, inventory, and information collection activities directly related to the conservation of fish and wildlife resources which involve negligible animal mortality or habitat destruction, no introduction of contaminants, or no introduction of organisms not indigenous to the affected ecosystem.

(2) The operation, maintenance, and management of existing facilities and routine recurring management activities and improvements, including renovations and replacements which result in no or only minor changes in the use, and have no or negligible environmental effects on-site or in the vicinity of the site.

PROJECTS:

Gibraltar Wetland Restoration
Pointe Mouillee Wetland Restoration

The Gibraltar Wetland Restoration and Point Mouillee Wetland Restoration projects would include the replacement and improvement of various existing water control infrastructures including replacing pumps, gates, and dikes for better hydrology management of the wetlands. These actions are thought to have minimal disruptions to the human and natural environment.

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(3) The construction of new, or the addition of, small structures or improvements, including structures and improvements for the restoration of wetland, riparian, instream, or native habitats, which result in no or only minor changes in the use of the affected local area. The following are examples of activities that may be included.

(a)The installation of fences.
(b)The construction of small water control structure
(c)The planting of seeds or seedlings and other minor revegetation actions.
(d)The construction of small berms or dikes.
(e)The development of limited access for routine maintenance and management purposes.

PROJECTS:

Humbug Marsh/Monguagon Creek Bank Habitat Improvements
Gibraltar Wetland Restoration
Pointe Mouillee Wetland Restoration

The Humbug Marsh/Monguagon Creek Bank Habitat Improvements project would include soft substrate stabilization techniques, and replanting riparian and wetland vegetation. The Gibraltar and Pointe Mouillee Wetland Restoration projects would involve the construction of small water control structures, and dikes. These projects are anticipated to have limited environmental or human impact.

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(4) The use of prescribed burning for habitat improvement purposes, when conducted in accordance with local and State ordinances and laws.

(5) Fire management activities, including prevention and restoration measures, when conducted in accordance with Departmental and Service procedures.

(6) The reintroduction or supplementation (e.g., stocking) of native, formerly native, or established species into suitable habitat within their historic or established range, where no or negligible environmental disturbances are anticipated.

PROJECTS :

Humbug Marsh/Monguagon Creek Bank Habitat Improvements
Gibraltar Wetland Restoration
Great Lakes Marsh Restoration
Pointe Mouillee Wetland Restoration

The Humbug Marsh/Monguagon Creek Bank Habitat Improvement project would reintroduce native riparian and wetland plant species to increase diversity and bank stabilization. Gibraltar Wetland Restoration, Great Lakes Marsh Restoration, and Pointe Mouillee Wetland Restoration projects would increase habitat quality and diversity through the reintroduction of native wetland plants. These projects are anticipated to have limited impact to the natural or human environment.

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(7) Minor changes in the amounts or types of public use on Service or State-managed lands, in accordance with existing regulations, management plans, and procedures.

(8) Consultation and technical assistance activities directly related to the conservation of fish and wildlife resources.

(9) Minor changes in existing master plans, comprehensive conservation plans, or operations, when no or minor effects are anticipated. Examples could include minor changes in the type and location of compatible public use activities and land management practices.

(10) The issuance of new or revised site, unit, or activity-specific management plans for public use, land use, or other management activities when only minor changes are planned. Examples could include an amended public use plan or fire management plan.

(11) Natural resource damage assessment restoration plans, prepared under sections 107, 111, and 122(j) of the Comprehensive Environmental Response Compensation and Liability Act (CERCLA); section 311(f)(4) of the Clean Water Act; and the Oil Pollution Act; when only minor or negligible change in the use of the affected areas is planned.

PROJECTS :

Humbug Marsh/Monguagon Creek Bank Habitat Improvements
Gibraltar Wetland Restoration
Great Lakes Marsh Restoration
Pointe Mouillee Wetland Restoration

The Humbug Marsh/Monguagon Creek Bank Habitat Improvements, Gibraltar Wetland Restoration, Great Lakes Marsh Restoration, and Pointe Mouillee Wetland Restoration project s are proposed restoration projects developed by the Trustees of the Rouge River Mystery Oil Spill as part of the natural resource damage assessment restoration plan (DARP) and as such has undergone extensive assessment to limit their impact on both the natural and human environment.

C. Permit and Regulatory Functions.

(1) The issuance, denial, suspension, and revocation of permits for activities involving fish, wildlife, or plants regulated under 50 CFR Chapter 1, Subsection B, when such permits cause no or negligible environmental disturbance. These permits involve endangered and threatened species, species listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), marine animals, exotic birds, migratory birds, eagles, and injurious wildlife.

(2) The issuance of ESA section 10(a)(1)(B) "low-effect" incidental take permits that, individually or cumulatively, have a minor or negligible effect on the species covered in the habitat conservation plan.

(3) The issuance of special regulations for public use of Service-managed land, which maintain essentially the permitted level of use and do not continue a level of use that has resulted in adverse environmental effects.

(4) The issuance or reissuance of permits for limited additional use of an existing right-of-way for underground or above ground power, telephone, or pipelines, where no new structures (i.e., facilities) or major improvement to those facilities are required; and for permitting a new right-of-way, where no or negligible environmental disturbances are anticipated.

(5) The issuance or reissuance of special use permits for the administration of specialized uses, including agricultural uses, or other economic uses for management purposes, when such uses are compatible, contribute to the purposes of the refuge system unit, and result in no or negligible environmental effects.

(6 The denial of special use permit applications, either initially or when permits are reviewed for renewal, when the proposed action is determined not compatible with the purposes of the refuge system unit.

(7) Activities directly related to the enforcement of fish and wildlife laws, not included in 516 DM 2, Appendix 1.4. These activities include:
(a) Assessment of civil penalties.
(b) Forfeiture of property seized or subject to forfeiture.
(c) The issuance or reissuance of rules, procedures, standards, and permits for the designation of ports, inspection, clearance, marking, and license requirements

pertaining to wildlife and wildlife products, and for the humane and healthful transportation of wildlife.

(8) Actions where the Service has concurrence or coapproval with another agency and the action is a categorical exclusion for that agency. This would normally involve one Federal action or connected actions where the Service is a cooperating agency.

D. Recovery Plans. Issuance of recovery plans under section 4(f) of the ESA.

E. Financial Assistance.

(1) State, local, or private financial assistance (grants and/or cooperative agreements), including State planning grants and private land restorations, where the environmental effects are minor or negligible.

(2) Grants for categorically excluded actions in paragraphs A, B, and C, above; and categorically excluded actions in Appendix 1 of 516 DM 2.

Humbug Marsh - Monguagon Creek Bank Restoration - Projected Costs

Materials			Acres / Year	Cost / Year	Years	Extended Cost
Herbicides:			60	$1,300	30	$39,000
Expendable Equipment / Supplies				$750	30	$22,500
Subtotal Materials						$61,500
Labor	**Hours / Year**	**Cost / Hour**		**Cost / Year**	**Years**	**Extended Cost**
Staff Biologist	100	$24.00		$2,400	30	$72,000
Admin Staff Support	20	$24.00		$480	30	$14,400
Contractor - Herbicides				$2,000	30	$60,000
Contract Technicians				$7,500	30	$225,000
Staff Technicians				$3,840	30	$115,200
Training				$1,000	30	$30,000
Subtotal Labor						$516,600
Maintenance				**Cost / Year**		
Equipment Maintenance				$1,500	30	$45,000
Levee / Access Maintenance				$2,500	30	$75,000
Subtotal Maintenance						$120,000
Implementation Monitoring				**Cost / Year**		
Staff Biologist	24	$24.00		$576	30	$17,280
Project Leader	16	$48.00		$768	30	$23,040
Subtotal Implementation Monitoring						$40,320
Subtotal						**$738,420**
Subtotal - Adjusted for Inflation / Investment						**$661,663**
Contingency (15%)						**$99,249**
Total Restoration Costs						**$760,912**

Humbug Marsh - Monguagon Creek Bank Restoration - Projected Costs

Year	Labor Cost / Year	Non-labor Cost / Year	Contracts Cost / Year	Indirects Cost / Year	Sum Cost / Year	Calculation Present Value	Real Rate of Return	Rate of Return	Rate Inflation
2016	$9,064	$6,050	$9,500		$24,614	$24,614	-0.60	1.70	2.30
2017	$9,064	$6,050	$9,500		$24,614	$24,763	-0.60	1.70	2.30
2018	$9,064	$6,050	$9,500		$24,614	$24,912	-0.60	1.70	2.30
2019	$9,064	$6,050	$9,500		$24,614	$24,874	-0.35	1.95	2.30
2020	$9,064	$6,050	$9,500		$24,614	$24,713	-0.10	2.20	2.30
2021	$9,064	$6,050	$9,500		$24,614	$24,553	0.05	2.35	2.30
2022	$9,064	$6,050	$9,500		$24,614	$24,321	0.20	2.50	2.30
2023	$9,064	$6,050	$9,500		$24,614	$24,103	0.30	2.60	2.30
2024	$9,064	$6,050	$9,500		$24,614	$23,840	0.40	2.70	2.30
2025	$9,064	$6,050	$9,500		$24,614	$23,534	0.50	2.80	2.30
2026	$9,064	$6,050	$9,500		$24,614	$23,347	0.53	2.83	2.30
2027	$9,064	$6,050	$9,500		$24,614	$23,148	0.56	2.86	2.30
2028	$9,064	$6,050	$9,500		$24,614	$22,936	0.59	2.89	2.30
2029	$9,064	$6,050	$9,500		$24,614	$22,714	0.62	2.92	2.30
2030	$9,064	$6,050	$9,500		$24,614	$22,480	0.65	2.95	2.30
2031	$9,064	$6,050	$9,500		$24,614	$22,235	0.68	2.98	2.30
2032	$9,064	$6,050	$9,500		$24,614	$21,980	0.71	3.01	2.30
2033	$9,064	$6,050	$9,500		$24,614	$21,714	0.74	3.04	2.30
2034	$9,064	$6,050	$9,500		$24,614	$21,440	0.77	3.07	2.30
2035	$9,064	$6,050	$9,500		$24,614	$21,156	0.80	3.10	2.30
2036	$9,064	$6,050	$9,500		$24,614	$20,863	0.83	3.13	2.30
2037	$9,064	$6,050	$9,500		$24,614	$20,563	0.86	3.16	2.30
2038	$9,064	$6,050	$9,500		$24,614	$20,255	0.89	3.19	2.30
2039	$9,064	$6,050	$9,500		$24,614	$19,939	0.92	3.22	2.30
2040	$9,064	$6,050	$9,500		$24,614	$19,617	0.95	3.25	2.30
2041	$9,064	$6,050	$9,500		$24,614	$19,288	0.98	3.28	2.30
2042	$9,064	$6,050	$9,500		$24,614	$18,954	1.01	3.31	2.30
2043	$9,064	$6,050	$9,500		$24,614	$18,615	1.04	3.34	2.30
2044	$9,064	$6,050	$9,500		$24,614	$18,271	1.07	3.37	2.30
2045	$9,064	$6,050	$9,500		$24,614	$17,923	1.10	**3.40**	2.30
Subtotals:	**$271,920**	**$181,500**	**$285,000**	**$0**	**$738,420**	**$661,663**			
Total - Present Value:	**$661,663**								
Contingency (15%):	**$99,249**								
Total Restoration:	**$760,912**								

Rate of Inflation	CBO Projection's of Demographic, Economic, and Other Trends. Appendix A. June 2015. The 2015 long-term budget outlook. Growth of the Consumer Price Index.
Rate of Return	OMB Circular No. A-94, Appendix C. December 2014. 30 year rate of return
Rate of Return	OMB Circular No. A-94, Variable rate of return - linear interpolation, Years 1-3 constant rate of return.

Gibraltar Marsh Restoration - Projected Costs

Materials

	Pints / Acre	Cost / pint	Acres / Year	Cost / Year	Years	Extended Cost
Herbicides:			70	$1,500	30	$45,000
Expendable Equipment / Supplies				$750	30	$22,500
Subtotal Materials						$67,500

Labor

	Hours / Year	Cost / Hour		Cost / Year	Years	Extended Cost
Implementation						
Contract Hydrology						$40,000
Staff Biologist	100	$24.00		$2,400	30	$72,000
Admin Staff Support	20	$24.00		$480	30	$14,400
Contractor - Herbicides	10	$200.00		$2,000	30	$60,000
Contract Technicians				$7,500	30	$225,000
Staff Technicians	240	$16.00		$3,840	30	$115,200
Training				$1,000	30	$30,000
Subtotal Labor						$556,600

Maintenance

Equipment maintenance			$1,500		30	$45,000
Levee / Access Maintenance			$2,500		30	$75,000
Subtotal Maintenance						$120,000

Implementation Monitoring

Staff Biologist	24	$24.00		$576	30	$17,280
Project Leader	16	$48.00		$768	30	$23,040
Subtotal Implementation Monitoring						$40,320

Subtotal	**$784,420**
Subtotal - Present Value - Adjusted for Inflation / Investment	**$707,039**
Contingency (15%)	**$106,056**
Total Restoration Costs	**$813,095**

Gibraltar Marsh Restoration - Projected Costs

Year	Labor Cost / Year	Non-labor Cost / Year	Contracts Cost / Year	Indirects Cost / Year	Sum Cost / Year	Calculation Present Value	Real Rate of Return	Rate of Return	Rate Inflation
2016	9064	6250	49500		64814	64814	-0.60	1.70	2.30
2017	9064	6250	9500		24814	24964	-0.60	1.70	2.30
2018	9064	6250	9500		24814	25114	-0.60	1.70	2.30
2019	9064	6250	9500		24814	25076	-0.35	1.95	2.30
2020	9064	6250	9500		24814	24914	-0.10	2.20	2.30
2021	9064	6250	9500		24814	24752	0.05	2.35	2.30
2022	9064	6250	9500		24814	24518	0.20	2.50	2.30
2023	9064	6250	9500		24814	24299	0.30	2.60	2.30
2024	9064	6250	9500		24814	24034	0.40	2.70	2.30
2025	9064	6250	9500		24814	23725	0.50	2.80	2.30
2026	9064	6250	9500		24814	23536	0.53	2.83	2.30
2027	9064	6250	9500		24814	23336	0.56	2.86	2.30
2028	9064	6250	9500		24814	23123	0.59	2.89	2.30
2029	9064	6250	9500		24814	22898	0.62	2.92	2.30
2030	9064	6250	9500		24814	22662	0.65	2.95	2.30
2031	9064	6250	9500		24814	22416	0.68	2.98	2.30
2032	9064	6250	9500		24814	22158	0.71	3.01	2.30
2033	9064	6250	9500		24814	21891	0.74	3.04	2.30
2034	9064	6250	9500		24814	21614	0.77	3.07	2.30
2035	9064	6250	9500		24814	21328	0.80	3.10	2.30
2036	9064	6250	9500		24814	21033	0.83	3.13	2.30
2037	9064	6250	9500		24814	20730	0.86	3.16	2.30
2038	9064	6250	9500		24814	20419	0.89	3.19	2.30
2039	9064	6250	9500		24814	20101	0.92	3.22	2.30
2040	9064	6250	9500		24814	19776	0.95	3.25	2.30
2041	9064	6250	9500		24814	19445	0.98	3.28	2.30
2042	9064	6250	9500		24814	19108	1.01	3.31	2.30
2043	9064	6250	9500		24814	18766	1.04	3.34	2.30
2044	9064	6250	9500		24814	18419	1.07	3.37	2.30
2045	9064	6250	9500		24814	18068	1.10	**3.40**	2.30
Subtotals:	**$271,920**	**$187,500**	**$325,000**		**$784,420**	**$707,039**			

Total - Present Value:	**$707,039**
Contingency (15%):	**$106,056**
Total Restoration Costs:	**$813,095**

Rate of Inflation	CBO Projection's of Demographic, Economic, and Other Trends. Appendix A. June 2015. The 2015 long-term budget outlook. Growth of the Consumer Price Index.
Rate of Return	OMB Circular No. A-94, Appendix C. December 2014. 30 year rate of return
Rate of Return	OMB Circular No. A-94, Variable rate of return - linear interpolation, Years 1-3 constant rate of return.

Great Lakes Marsh- Lake Erie MetroPark - Projected Costs

Materials				Cost / Year	Years	Extended Cost
Herbicides				$1,000	30	$30,000
Expendable Equipment / Supplies				$750	30	$22,500
Subtotal Materials						**$52,500**

Labor	Hours / Year	Cost / Hour	Benefits Cost/Hr (Indirect costs)	Cost / Year	Years	Extended Cost
Staff Supervision - Invasive Control	40	$25.73	$20.70	$1,857.20	30	$55,716
Admin Staff Support	20	$24.00	$20.70	$894.00	30	$26,820
Marsh Edge - NNIS Control; Supervisor	24	$25.73	$20.70	$1,114.32	30	$33,430
HCMA NRD Technician	16	$14.50	$1.30	$252.80	30	$7,584
Lake Erie Shore - NNIS Control; Supervisor	16	$25.73	$20.70	$742.88	30	$22,286
Lakeplain Prairie - NNIS Control: Supervisor	16	$25.73	$20.70	$742.88	30	$22,286
HCMA NRD Technician	8	$14.50	$1.30	$126.40	30	$3,792
LEMP Technician	40	$14.50	$1.30	$632.00	30	$18,960
Staff - GIS - Project Planning	16	$25.73	$20.70	$742.88	30	$22,286
Subtotal Labor						**$213,161**

Maintenance						
Equipment maintenance				$1,500	30	$45,000
Levee / Access Maintenance				$2,000	30	$60,000
Subtotal Maintenance						**$105,000**

Implementation Monitoring						
Staff Biologist	40	$25.73	$20.70	$1,857	30	$55,716
Subtotal Implementation Monitoring						**$55,716**

Subtotal	**$426,377**
Subtotal Adjusted for Inflation / Investment	**$382,056**
Contingency (15%)	**$57,308**
Total Restoration Costs	**$439,364**

Great Lakes Marsh- Lake Erie MetroPark - Projected Costs

Year	Labor Cost / Year	Non-labor Cost / Year	Contracts Cost / Year	Indirects Cost / Year	Sum Cost / Year	Calculation Present Value	Real Rate of Return	Rate of Return	Rate Inflation
2016	$8,963	$5,250			$14,213	$14,213	-0.60	1.70	2.3
2017	$8,963	$5,250	none	incorporated	$14,213	$14,298	-0.60	1.70	2.3
2018	$8,963	$5,250		in labor costs	$14,213	$14,385	-0.60	1.70	2.3
2019	$8,963	$5,250			$14,213	$14,363	-0.35	1.95	2.3
2020	$8,963	$5,250			$14,213	$14,270	-0.10	2.20	2.3
2021	$8,963	$5,250			$14,213	$14,177	0.05	2.35	2.3
2022	$8,963	$5,250			$14,213	$14,043	0.20	2.50	2.3
2023	$8,963	$5,250			$14,213	$13,918	0.30	2.60	2.3
2024	$8,963	$5,250			$14,213	$13,766	0.40	2.70	2.3
2025	$8,963	$5,250			$14,213	$13,589	0.50	2.80	2.3
2026	$8,963	$5,250			$14,213	$13,481	0.53	2.83	2.3
2027	$8,963	$5,250			$14,213	$13,366	0.56	2.86	2.3
2028	$8,963	$5,250			$14,213	$13,244	0.59	2.89	2.3
2029	$8,963	$5,250			$14,213	$13,115	0.62	2.92	2.3
2030	$8,963	$5,250			$14,213	$12,980	0.65	2.95	2.3
2031	$8,963	$5,250			$14,213	$12,839	0.68	2.98	2.3
2032	$8,963	$5,250			$14,213	$12,691	0.71	3.01	2.3
2033	$8,963	$5,250			$14,213	$12,538	0.74	3.04	2.3
2034	$8,963	$5,250			$14,213	$12,380	0.77	3.07	2.3
2035	$8,963	$5,250			$14,213	$12,216	0.80	3.10	2.3
2036	$8,963	$5,250			$14,213	$12,047	0.83	3.13	2.3
2037	$8,963	$5,250			$14,213	$11,873	0.86	3.16	2.3
2038	$8,963	$5,250			$14,213	$11,695	0.89	3.19	2.3
2039	$8,963	$5,250			$14,213	$11,513	0.92	3.22	2.3
2040	$8,963	$5,250			$14,213	$11,327	0.95	3.25	2.3
2041	$8,963	$5,250			$14,213	$11,138	0.98	3.28	2.3
2042	$8,963	$5,250			$14,213	$10,945	1.01	3.31	2.3
2043	$8,963	$5,250			$14,213	$10,749	1.04	3.34	2.3
2044	$8,963	$5,250			$14,213	$10,550	1.07	3.37	2.3
2045	$8,963	$5,250			$14,213	$10,349	1.10	3.40	2.3
Subtotals:	**$268,877**	**$157,500**	**$0**	**$0**	**$426,377**	**$382,056**			

Total - Present Value: **$382,056**

Contingency (15%): **$57,308**

Total Restoration Costs: **$439,364**

Rate of Inflation CBO Projection's of Demographic, Economic, and Other Trends. Appendix A. June 2015. The 2015 long-term budget outlook. Consumer Price Index

Rate of Return OMB Circular No. A-94, Appendix C. December 2014. 30 year rate of return

Rate of Return OMB Circular No. A-94, Variable rate of return - linear interpolation, Years 1-3 constant rate of return.

Pointe Mouillee Restoration - Projected Costs

	Hours / Year	Cost / Hour	Cost / Year	Years	Extended Cost	
Materials			Cost / Year	Years	Extended Cost	
Equipment:						
Vertical Electric Pumps					$400,000	First Year
Gravel - Portable Pump Pad					$2,000	Implementation
Expendable Equipment / Supplies			$1,000.00	30	$30,000	
Herbicides			$2,000.00	30	$60,000	
Subtotal Materials					**$492,000**	
Labor	Hours / Year	Cost / Hour	Cost / Year	Years	Extended Cost	
Admin Staff Support	40	$24.00	$960.00	30	$28,800	
Contract - Dike Reconstruction					$130,000	Implementation
Contract - Electrical - Pumps					$80,000	Over
Contract - Concrete - Pumps					$75,000	Years
Contract - Helicopter (herbicides)					$50,000	two to
Installation Agri-drain / Culverts					$4,000	four
Subtotal Labor					**$367,800**	
Maintenance						
ASV Mulcher - rental			$3,000	30	$90,000.00	
Equipment maintenance			$1,500	30	$45,000	
Levee / Access Maintenance			$3,000	30	$90,000	
Maintenance staff	40	$30.00	$1,200	30	$36,000	
Subtotal Maintenance					**$261,000**	
Implementation Monitoring						
Staff Biologist	40	$30.00	$1,200	30	$36,000	
Subtotal Implementation Monitoring					**$36,000**	
Subtotal					**$1,156,800**	
Subtotal Adjusted for Inflation / investment					**$1,116,824**	
Contingency (15%)					**$167,524**	
Total Restoration Costs					**$1,284,347**	

Pointe Mouillee Restoration - Projected Costs

Year	Labor Cost / Year	Non-labor Cost / Year	Pumps Cost / Year	Contracts Cost / Year	Indirects Cost / Year	Sum Cost / Year	Calculation Present Value	Real Rate of Return	Rate of Return	Rate Inflation
2016	$2,160	$11,700	$402,000			$415,860	$415,860	-0.60	1.70	2.30
2017	$2,160	$11,700		$113,000		$126,860	$127,626	-0.60	1.70	2.30
2018	$2,160	$11,700		$113,000		$126,860	$128,396	-0.60	1.70	2.30
2019	$2,160	$11,700		$113,000		$126,860	$128,201	-0.35	1.95	2.30
2020	$2,160	$11,700				$13,860	$13,916	-0.10	2.20	2.30
2021	$2,160	$11,700				$13,860	$13,825	0.05	2.35	2.30
2022	$2,160	$11,700				$13,860	$13,695	0.20	2.50	2.30
2023	$2,160	$11,700				$13,860	$13,572	0.30	2.60	2.30
2024	$2,160	$11,700				$13,860	$13,424	0.40	2.70	2.30
2025	$2,160	$11,700				$13,860	$13,252	0.50	2.80	2.30
2026	$2,160	$11,700				$13,860	$13,146	0.53	2.83	2.30
2027	$2,160	$11,700				$13,860	$13,034	0.56	2.86	2.30
2028	$2,160	$11,700				$13,860	$12,915	0.59	2.89	2.30
2029	$2,160	$11,700				$13,860	$12,790	0.62	2.92	2.30
2030	$2,160	$11,700				$13,860	$12,658	0.65	2.95	2.30
2031	$2,160	$11,700				$13,860	$12,520	0.68	2.98	2.30
2032	$2,160	$11,700				$13,860	$12,377	0.71	3.01	2.30
2033	$2,160	$11,700				$13,860	$12,227	0.74	3.04	2.30
2034	$2,160	$11,700				$13,860	$12,073	0.77	3.07	2.30
2035	$2,160	$11,700				$13,860	$11,913	0.80	3.10	2.30
2036	$2,160	$11,700				$13,860	$11,748	0.83	3.13	2.30
2037	$2,160	$11,700				$13,860	$11,579	0.86	3.16	2.30
2038	$2,160	$11,700				$13,860	$11,405	0.89	3.19	2.30
2039	$2,160	$11,700				$13,860	$11,228	0.92	3.22	2.30
2040	$2,160	$11,700				$13,860	$11,046	0.95	3.25	2.30
2041	$2,160	$11,700				$13,860	$10,861	0.98	3.28	2.30
2042	$2,160	$11,700				$13,860	$10,673	1.01	3.31	2.30
2043	$2,160	$11,700				$13,860	$10,482	1.04	3.34	2.30
2044	$2,160	$11,700				$13,860	$10,288	1.07	3.37	2.30
2045	$2,160	$11,700				$13,860	$10,092	1.10	**3.40**	2.30
Subtotals:	**$64,800**	**$351,000**	**$402,000**	**$339,000**	**$0**	**$1,156,800**	**$1,116,824**			
Total - Present Value:	**$1,116,824**									
Contingency (15%):	**$167,524**									
Total Restoration Costs:	**$1,284,347**									

Rate of Inflation CBO Projection's of Demographic, Economic, and Other Trends. Appendix A. June 2015. The 2015 long-term budget outlook. Growth of CPI.

Rate of Return OMB Circular No. A-94, Appendix C. December 2014. 30 year rate of return

Rate of Return OMB Circular No. A-94, Variable rate of return - linear interpolation, Years 1-3 constant rate of return

Fish and Wildlife Service - Outcome Based Monitoring

Year	Labor Cost / Year	Travel Cost / Year	Indirect Costs 55%	Sum Cost / Year	Calculation Present Value	Real Rate of Return	Rate of Return	Rate Inflation
2016	$25,000	$3,000	$15,400	$43,400	$43,400	-0.60	1.70	2.30
2017	$25,000	$3,000	$15,400	$43,400	$43,662	-0.60	1.70	2.30
2018	$25,000	$3,000	$15,400	$43,400	$43,926	-0.60	1.70	2.30
2019						-0.35	1.95	2.30
2020						-0.10	2.20	2.30
2021						0.05	2.35	2.30
2022	$25,000	$3,000	$15,400	$43,400	$42,883	0.20	2.50	2.30
2023	$25,000	$3,000	$15,400	$43,400	$42,499	0.30	2.60	2.30
2024	$25,000	$3,000	$15,400	$43,400	$42,036	0.40	2.70	2.30
2025						0.50	2.80	2.30
2026						0.53	2.83	2.30
2027						0.56	2.86	2.30
2028	$25,000	$3,000	$15,400	$43,400	$40,442	0.59	2.89	2.30
2029	$25,000	$3,000	$15,400	$43,400	$40,049	0.62	2.92	2.30
2030	$25,000	$3,000	$15,400	$43,400	$39,637	0.65	2.95	2.30
2031						0.68	2.98	2.30
2032						0.71	3.01	2.30
2033						0.74	3.04	2.30
2034	$25,000	$3,000	$15,400	$43,400	$37,803	0.77	3.07	2.30
2035	$25,000	$3,000	$15,400	$43,400	$37,303	0.80	3.10	2.30
2036	$25,000	$3,000	$15,400	$43,400	$36,787	0.83	3.13	2.30
Totals	**$225,000**	**$27,000**	**$184,800**	**$520,800**	**$490,426**			

Costs - Present Value:	**$490,426**
Contingency (15%)	**$73,564**
Grand Total:	**$563,990**

Monitoring intended to coincide with academic Master's program - three year degree cycle, monitoring every other three years. First three years reference sites, baseline, development of indices, implementation of treatments. Monitoring of multiple trophic levels consistent with resources injured: vegetation, benthic macroinvertebrates, birds.

Fish and Wildlife Service - Future Trustee Costs

Notes: FWS Trustee Future costs directly from the FWS NRDA - Cost Estimation Tool.

Cost Category	Amount
Labor and Benefits	**$316,354**
Travel	$7,570
Contracts	**$0**
Supplies and Equipment	**$0.00**
Land and Structures	**$0.00**
Vehicles	**$4,891.00**
FWS Indirect Support	**$275,228.00**
DOI Indirect Support	**$53,274.00**
Total Adjusted for Inflation	**$657,317.00**
Present Value	**$440,773.00**
Contingency	**$66,116.00**
Total Projected Cost	**$506,888.00**

Parameters:

Contingency: 15%

FWS Indirects: 87%

Benefit Rate: 25%

DOI Indirect: 16.84%

Rate of inflation and return identical to those used for projects

Fish and Wildlife Service - Future Trustee Costs

	Annual Cost =	$21,910.56	$657,316.81 / 30

Year	Annual Cost - w/ inflation	Present Value	Rate of Return
2016	$21,911	$21,911	1.70
2017	$21,911	$21,544	1.70
2018	$21,911	$21,184	1.70
2019	$21,911	$20,677	1.95
2020	$21,911	$20,084	2.20
2021	$21,911	$19,508	2.35
2022	$21,911	$18,893	2.50
2023	$21,911	$18,307	2.60
2024	$21,911	$17,705	2.70
2025	$21,911	$17,089	2.80
2026	$21,911	$16,575	2.83
2027	$21,911	$16,067	2.86
2028	$21,911	$15,566	2.89
2029	$21,911	$15,071	2.92
2030	$21,911	$14,584	2.95
2031	$21,911	$14,105	2.98
2032	$21,911	$13,633	3.01
2033	$21,911	$13,169	3.04
2034	$21,911	$12,714	3.07
2035	$21,911	$12,267	3.10
2036	$21,911	$11,829	3.13
2037	$21,911	$11,400	3.16
2038	$21,911	$10,981	3.19
2039	$21,911	$10,570	3.22
2040	$21,911	$10,169	3.25
2041	$21,911	$9,778	3.28
2042	$21,911	$9,396	3.31
2043	$21,911	$9,024	3.34
2044	$21,911	$8,662	3.37
2045	$21,911	$8,309	**3.40**
Totals	**$657,317**	**$440,773**	
Present Value	**$440,773**		
Contingency (15%)	**$66,116**		
Estimated Cost	**$506,888**		

FWS CET calculates PV incorporating contingency costs over 30 years - In the case of NPFC funding - contingency funds are not held in trust by the Service and only available over the first six years of project implementation. Contingency added after calculation of present value as simple percentage.

MDEQ - Future Trustee Costs

Expense	Cost / Hour	Hours / Month	Extended Cost - 360 Months
Labor			
Senior Staff	50.16	4.00	$72,230
Admin staff support	23.78	4.00	$34,243
Subtotal Labor			$106,474
Travel (per year)	Mileage rate	Miles / Year	Extended Costs
Travel within Michigan	0.230	250	$1,725
TOTAL ESTIMATED EXPENSES			**$108,199**
Subtotal Adjusted for Inflation / investment			**$96,952**
Contingency			**$0**
Total Restoration Costs			**$96,952**

Senior staff hourly rate with benefits, approximately equivalent to CONUS GS-13/1; 25% benefits

One trustee meeting per year; one site visit per restoration project per year. Estimated 250 miles per year.

MDEQ - Future Trustee Costs

Cost per year adjusted for investment / inflation:

Year of Implementation	Labor Staff Time	Travel In-State	Indirect Costs	Sum Costs per Year	Calculation Present Value	Real Rate of Return	Rate of Return	Rate Inflation
2016	$3,549.12	$57.50		$3,606.62	$3,606.62	-0.60	1.70	2.30
2017	$3,549.12	$57.50		$3,606.62	$3,628.39	-0.60	1.70	2.30
2018	$3,549.12	$57.50		$3,606.62	$3,650.29	-0.60	1.70	2.30
2019	$3,549.12	$57.50		$3,606.62	$3,644.76	-0.35	1.95	2.30
2020	$3,549.12	$57.50		$3,606.62	$3,621.08	-0.10	2.20	2.30
2021	$3,549.12	$57.50		$3,606.62	$3,597.62	0.05	2.35	2.30
2022	$3,549.12	$57.50		$3,606.62	$3,563.64	0.20	2.50	2.30
2023	$3,549.12	$57.50		$3,606.62	$3,531.78	0.30	2.60	2.30
2024	$3,549.12	$57.50		$3,606.62	$3,493.26	0.40	2.70	2.30
2025	$3,549.12	$57.50		$3,606.62	$3,448.31	0.50	2.80	2.30
2026	$3,549.12	$57.50		$3,606.62	$3,420.93	0.53	2.83	2.30
2027	$3,549.12	$57.50		$3,606.62	$3,391.74	0.56	2.86	2.30
2028	$3,549.12	$57.50		$3,606.62	$3,360.80	0.59	2.89	2.30
2029	$3,549.12	$57.50		$3,606.62	$3,328.16	0.62	2.92	2.30
2030	$3,549.12	$57.50		$3,606.62	$3,293.88	0.65	2.95	2.30
2031	$3,549.12	$57.50		$3,606.62	$3,258.01	0.68	2.98	2.30
2032	$3,549.12	$57.50		$3,606.62	$3,220.62	0.71	3.01	2.30
2033	$3,549.12	$57.50		$3,606.62	$3,181.76	0.74	3.04	2.30
2034	$3,549.12	$57.50		$3,606.62	$3,141.50	0.77	3.07	2.30
2035	$3,549.12	$57.50		$3,606.62	$3,099.92	0.80	3.10	2.30
2036	$3,549.12	$57.50		$3,606.62	$3,057.07	0.83	3.13	2.30
2037	$3,549.12	$57.50		$3,606.62	$3,013.02	0.86	3.16	2.30
2038	$3,549.12	$57.50		$3,606.62	$2,967.85	0.89	3.19	2.30
2039	$3,549.12	$57.50		$3,606.62	$2,921.62	0.92	3.22	2.30
2040	$3,549.12	$57.50		$3,606.62	$2,874.41	0.95	3.25	2.30
2041	$3,549.12	$57.50		$3,606.62	$2,826.29	0.98	3.28	2.30
2042	$3,549.12	$57.50		$3,606.62	$2,777.33	1.01	3.31	2.30
2043	$3,549.12	$57.50		$3,606.62	$2,727.60	1.04	3.34	2.30
2044	$3,549.12	$57.50		$3,606.62	$2,677.18	1.07	3.37	2.30
2045	$3,549.12	$57.50		$3,606.62	$2,626.13	1.10	3.40	2.30
Total:	**$106,474**	**$1,725**		**$104,592**	**$96,952**			

al Present Value: **$96,952**

Contingency: **$0**

Total Cost: **$96,952**

Rate of Inflation CBO Projection's of Demographic, Economic, and Other Trends. Appendix A. June 2015. The 2015 long-term budget outlook. Consumer Price Index

Rate of Return OMB Circular No. A-94, Appendix C. December 2014. 30 year rate of return

Rate of Return OMB Circular No. A-94, Variable rate of return - linear interpolation, years 1-3 constant rate of return.

MDNR - Future Trustee Costs

Expense	Cost / Hour	Hours / Month	Extended Cost - 360 Months
Labor			
Senior Staff	50.16	4.00	$72,230
Admin staff support	23.78	4.00	$34,243
Subtotal Labor			$106,474
Travel (per year)	**Mileage rate**	**Miles / Year**	**Extended Costs**
Travel within Michigan	0.230	250	$1,725
TOTAL ESTIMATED EXPENSES			$108,199
Subtotal Adjusted for Inflation / investment			$96,952
Contingency			$0
Total Restoration Costs			$96,952

Senior staff hourly rate with benefits, approximately equivalent to CONUS GS-13/1; 25% benefits

One trustee meeting per year; one site visit per restoration project per year. Estimated 250 miles per year.

MDNR - Future Trustee Costs

Cost per year adjusted for investment / inflation:

Year of Implementation	Labor Staff Time	Travel In-State	Indirect Costs	Sum Costs per Year	Calculation Present Value	Real Rate of Return	Rate of Return	Rate Inflation
2016	$3,549.12	$57.50		$3,606.62	$3,606.62	-0.60	1.70	2.30
2017	$3,549.12	$57.50		$3,606.62	$3,628.39	-0.60	1.70	2.30
2018	$3,549.12	$57.50		$3,606.62	$3,650.29	-0.60	1.70	2.30
2019	$3,549.12	$57.50		$3,606.62	$3,644.76	-0.35	1.95	2.30
2020	$3,549.12	$57.50		$3,606.62	$3,621.08	-0.10	2.20	2.30
2021	$3,549.12	$57.50		$3,606.62	$3,597.62	0.05	2.35	2.30
2022	$3,549.12	$57.50		$3,606.62	$3,563.64	0.20	2.50	2.30
2023	$3,549.12	$57.50		$3,606.62	$3,531.78	0.30	2.60	2.30
2024	$3,549.12	$57.50		$3,606.62	$3,493.26	0.40	2.70	2.30
2025	$3,549.12	$57.50		$3,606.62	$3,448.31	0.50	2.80	2.30
2026	$3,549.12	$57.50		$3,606.62	$3,420.93	0.53	2.83	2.30
2027	$3,549.12	$57.50		$3,606.62	$3,391.74	0.56	2.86	2.30
2028	$3,549.12	$57.50		$3,606.62	$3,360.80	0.59	2.89	2.30
2029	$3,549.12	$57.50		$3,606.62	$3,328.16	0.62	2.92	2.30
2030	$3,549.12	$57.50		$3,606.62	$3,293.88	0.65	2.95	2.30
2031	$3,549.12	$57.50		$3,606.62	$3,258.01	0.68	2.98	2.30
2032	$3,549.12	$57.50		$3,606.62	$3,220.62	0.71	3.01	2.30
2033	$3,549.12	$57.50		$3,606.62	$3,181.76	0.74	3.04	2.30
2034	$3,549.12	$57.50		$3,606.62	$3,141.50	0.77	3.07	2.30
2035	$3,549.12	$57.50		$3,606.62	$3,099.92	0.80	3.10	2.30
2036	$3,549.12	$57.50		$3,606.62	$3,057.07	0.83	3.13	2.30
2037	$3,549.12	$57.50		$3,606.62	$3,013.02	0.86	3.16	2.30
2038	$3,549.12	$57.50		$3,606.62	$2,967.85	0.89	3.19	2.30
2039	$3,549.12	$57.50		$3,606.62	$2,921.62	0.92	3.22	2.30
2040	$3,549.12	$57.50		$3,606.62	$2,874.41	0.95	3.25	2.30
2041	$3,549.12	$57.50		$3,606.62	$2,826.29	0.98	3.28	2.30
2042	$3,549.12	$57.50		$3,606.62	$2,777.33	1.01	3.31	2.30
2043	$3,549.12	$57.50		$3,606.62	$2,727.60	1.04	3.34	2.30
2044	$3,549.12	$57.50		$3,606.62	$2,677.18	1.07	3.37	2.30
2045	$3,549.12	$57.50		$3,606.62	$2,626.13	1.10	**3.40**	2.30
Total:	**$106,474**	**$1,725**		**$104,592**	**$96,952**			

Total Present Value: **$96,952**

Contingency: **$0**

Total Cost: **$96,952**

Rate of Inflation CBO Projection's of Demographic, Economic, and Other Trends. Appendix A. June 2015. The 2015 long-term budget outlook. Consumer Price Index

Rate of Return OMB Circular No. A-94, Appendix C. December 2014. 30 year rate of return

Rate of Return OMB Circular No. A-94, Variable rate of return - linear interpolation, years 1-3 constant rate of return.

MDAG Trustee Future Costs

Labor / Expense	Cost / Hour	Hours / Month	Extended Cost - 360 Months
Senior Staff	50.16	4.00	$72,230
Admin staff support	23.78	4.00	$34,243
Subtotal Labor			$106,474
Travel (per year)	Mileage rate	Miles / Year	Extended Costs
Travel within Michigan	0.230	250	$1,725
TOTAL ESTIMATED EXPENSES			**$108,199**
Subtotal Adjusted for Inflation / investment			**$96,952**
Contingency			**$0**
Total Restoration Costs			**$96,952**

Senior staff hourly rate with benefits, approximately equivalent to CONUS GS-13/1; 25% benefits

One trustee meeting per year; one site visit per restoration project per year. Estimated 250 miles per year.

MDAG - Future Trustee Costs

Cost per year adjusted for investment / inflation:

Year of Implementation	Labor Staff Time	Travel In-State	Indirect Costs	Sum Costs per Year	Calculation Present Value	Real Rate of Return	Rate of Return	Rate Inflation
2016	$3,549.12	$57.50		$3,606.62	$3,606.62	-0.60	1.70	2.30
2017	$3,549.12	$57.50		$3,606.62	$3,628.39	-0.60	1.70	2.30
2018	$3,549.12	$57.50		$3,606.62	$3,650.29	-0.60	1.70	2.30
2019	$3,549.12	$57.50		$3,606.62	$3,644.76	-0.35	1.95	2.30
2020	$3,549.12	$57.50		$3,606.62	$3,621.08	-0.10	2.20	2.30
2021	$3,549.12	$57.50		$3,606.62	$3,597.62	0.05	2.35	2.30
2022	$3,549.12	$57.50		$3,606.62	$3,563.64	0.20	2.50	2.30
2023	$3,549.12	$57.50		$3,606.62	$3,531.78	0.30	2.60	2.30
2024	$3,549.12	$57.50		$3,606.62	$3,493.26	0.40	2.70	2.30
2025	$3,549.12	$57.50		$3,606.62	$3,448.31	0.50	2.80	2.30
2026	$3,549.12	$57.50		$3,606.62	$3,420.93	0.53	2.83	2.30
2027	$3,549.12	$57.50		$3,606.62	$3,391.74	0.56	2.86	2.30
2028	$3,549.12	$57.50		$3,606.62	$3,360.80	0.59	2.89	2.30
2029	$3,549.12	$57.50		$3,606.62	$3,328.16	0.62	2.92	2.30
2030	$3,549.12	$57.50		$3,606.62	$3,293.88	0.65	2.95	2.30
2031	$3,549.12	$57.50		$3,606.62	$3,258.01	0.68	2.98	2.30
2032	$3,549.12	$57.50		$3,606.62	$3,220.62	0.71	3.01	2.30
2033	$3,549.12	$57.50		$3,606.62	$3,181.76	0.74	3.04	2.30
2034	$3,549.12	$57.50		$3,606.62	$3,141.50	0.77	3.07	2.30
2035	$3,549.12	$57.50		$3,606.62	$3,099.92	0.80	3.10	2.30
2036	$3,549.12	$57.50		$3,606.62	$3,057.07	0.83	3.13	2.30
2037	$3,549.12	$57.50		$3,606.62	$3,013.02	0.86	3.16	2.30
2038	$3,549.12	$57.50		$3,606.62	$2,967.85	0.89	3.19	2.30
2039	$3,549.12	$57.50		$3,606.62	$2,921.62	0.92	3.22	2.30
2040	$3,549.12	$57.50		$3,606.62	$2,874.41	0.95	3.25	2.30
2041	$3,549.12	$57.50		$3,606.62	$2,826.29	0.98	3.28	2.30
2042	$3,549.12	$57.50		$3,606.62	$2,777.33	1.01	3.31	2.30
2043	$3,549.12	$57.50		$3,606.62	$2,727.60	1.04	3.34	2.30
2044	$3,549.12	$57.50		$3,606.62	$2,677.18	1.07	3.37	2.30
2045	$3,549.12	$57.50		$3,606.62	$2,626.13	1.10	**3.40**	2.30
Total:	**$106,474**	**$1,725**		**$104,592**	**$96,952**			

Rate of Inflation CBO Projection's of Demographic, Economic, and Other Trends. Appendix A. June 2015. The 2015 long-term budget outlook. Consumer Price Index

Rate of Return OMB Circular No. A-94, Appendix C. December 2014. 30 year rate of return

Rate of Return OMB Circular No. A-94, Variable rate of return - linear interpolation, years 1-3 constant rate of return.

Cost Summary - Rouge River Restoration

Project	Cost - 30 years Adjusted for Investment and Inflation
Humbug - Monguagon	$760,912
Gibraltar	$813,095
Great Lakes Marsh	$439,364
Pointe Mouille	$1,284,347
Total:	**$3,297,718**

Average Cost per DSAY: **$560.30**

Trustee Future Costs	Cost - 30 years Adjusted for Investment and Inflation
FWS	$471,174
FWS Monitoring	$563,990
MDEQ	$96,952
MDNR	$96,952
MDAG	$96,952
Total Future Trustee Costs	**$1,229,068**
Grand Total:	**$4,526,785**

Outcome-based monitoring relative to implementation: **17.10%**

Average Cost per DSAY - Inclusive of monitoring and Trustee costs: **$769.12**