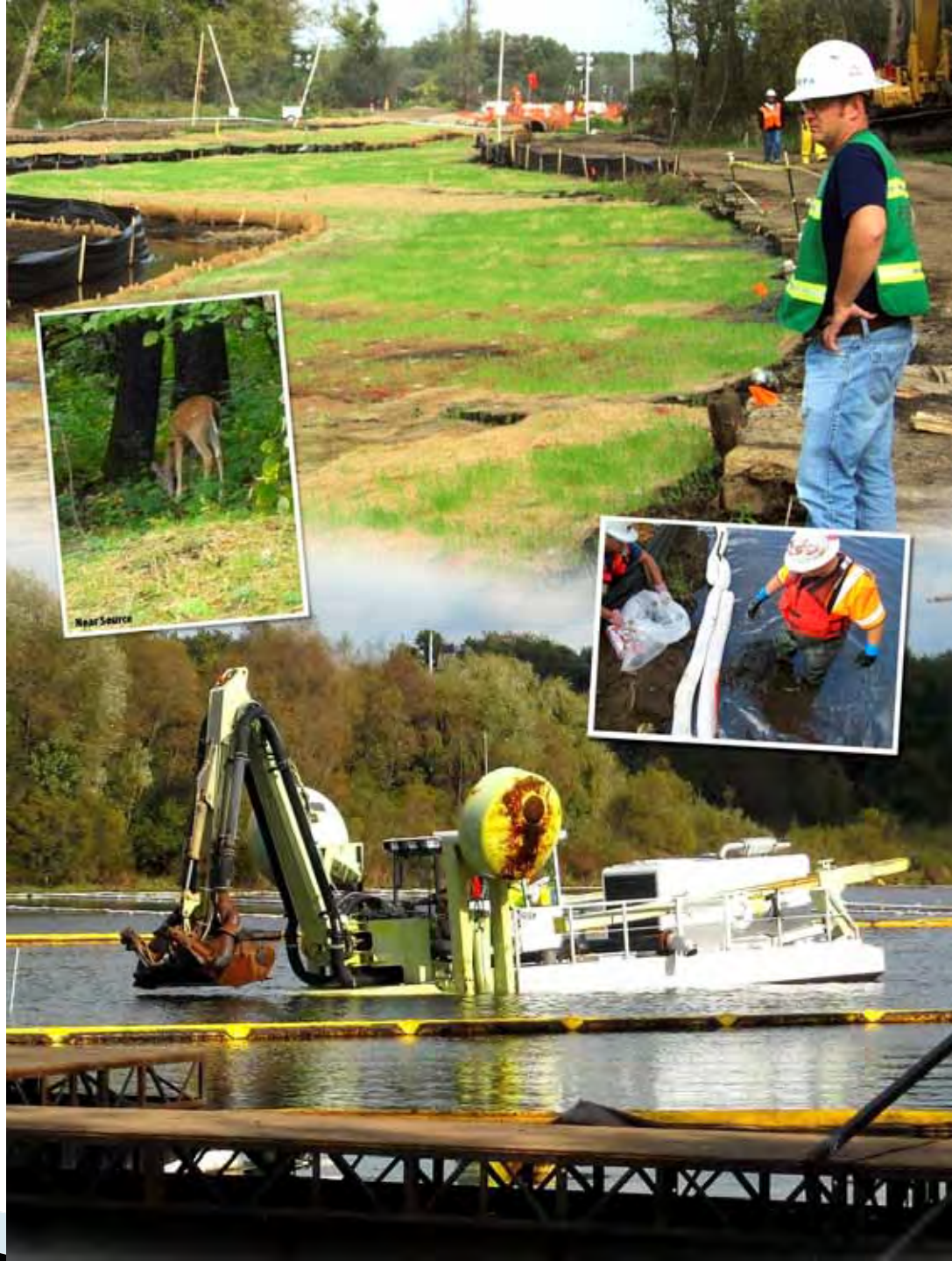
Appendix A: Photographs of the Areas Impacted by the Enbridge Line 6B Oil Discharges and of Response Actions
from U.S. EPA presentations in 2010 and 2015

Enbridge Line 6B Incident

Public Update and Availability Session

October 14, 2010
(Day 81)



Pipeline Release Site

Division A

Oil coming out of culvert on Talmadge Creek on first day of spill, July 26, 2010.

Exposed pipeline during the first week of the oil spill response.

Initial cleanup of a 5-acre contaminated zone in the pipeline break area. Photo shows a dewatering operation.

Second week of contaminated soil cleanup near the pipeline break.

After four weeks, contaminated land located by the pipeline break was backfilled with clean soil.

Restored and re-vegetated pipeline break area on Oct. 11, 2010.

Talmadge Creek

Division B

Talmadge Creek day one: creek and floodplain completely oil-covered.

Initial containment measure in the creek includes skimmers, containment booms, and siphon dams.

Surface water was reduced to heavy sheen by the end of the response's first week.

To access the creek in order to remove contaminated soil, swamp mat roads were established. Note white oil pads placed to absorb oil.

Talmadge Creek after soil scrapping was completed. Contaminated soil staging pads visible on the right side of the picture.

Talmadge Creek following restoration, which included soil backfilling, coconut matting, vegetation seeding, and silt fencing.

View of Talmadge Creek on Oct. 14, 2010.

Kalamazoo River

Division C, D, & E

Kalamazoo River on July 26, 2010, day one of the response: oil covered the river from bank to bank.

Within one week, presence of heavy oil reduced to a sheen.

In August 2010, most sheen production came from contaminated vegetation on the riverbanks and islands.

Example of sheening during week two and three of the response.

By mid-August, all contaminated islands were contained.

Some islands required soil removal.

Ceresco Dam

Division C

July 26, 2010, Ceresco Dam: note the oil flowing over the dam.

By the end of the first week, oil reduced to a heavy sheen.

Oil caught in backwater vegetation just upstream from Ceresco Dam.

Containment booming established to control vegetation sheening upstream of Ceresco Dam.

October 2010: submerged oil cleanup started upstream of Ceresco Dam.

Condition of stream bank just downstream of Ceresco Dam in late July 2010.

Same location, late September 2010.

Morrow Lake, October 11, 2010.

Sampling and Assessment

Containment

Contamination Recovery

Staging

Soil Removal

Disposal

Shoreline Cleanup

Floodplain Cleanup

Airlifting excavation equipment into an inaccessible floodplain.

Floodplain Cleanup

Excavation of floodplain contamination & staging of one-ton waste bags.

Decontamination

Decontamination of containment boom.

Decontamination

Decontamination of containment boom.

Submerged Oil

Dredging at Ceresco Dam

Ceresco Dam dredging operation and submerged oil aeration cells along the north bank.

Amphibex dredge used to remove approximately 18 inches of sediment from upstream of Ceresco Dam.

Geotube filter system used to capture contaminated sediment.

Ceresco Dam dredging progress as of Oct. 12, 2010: green indicates completed areas and blue shows areas in progress.

Submerged Oil

Aeration, Flushing, Agitation

Submerged oil recovery at “Mill Pond Area” in Battle Creek.

Example of submerged oil aeration, flushing, and recovery. Sediment is agitated to reintroduce oil to the surface so it can be collected.

Close-up shot of aeration activities.

Operation and Maintenance

Long Term Activity

Riverbank flushing activities.

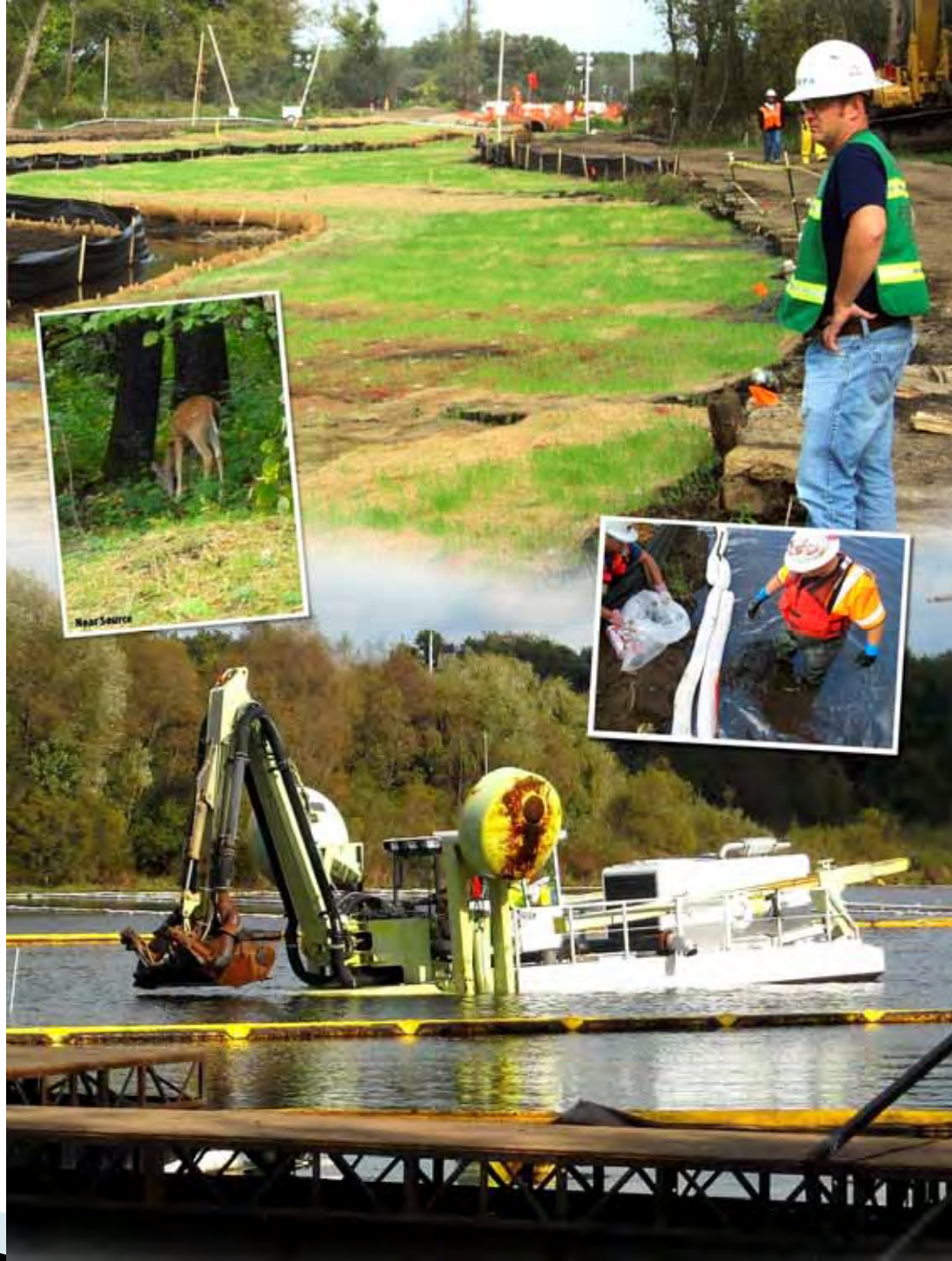
Riverbank restoration and long-term containment . Some areas on river will be monitored over time for potential contamination.

Residual contamination on islands will be monitored over time.

Stains on trees and rocks will fade over time and do not present health or environmental risks.

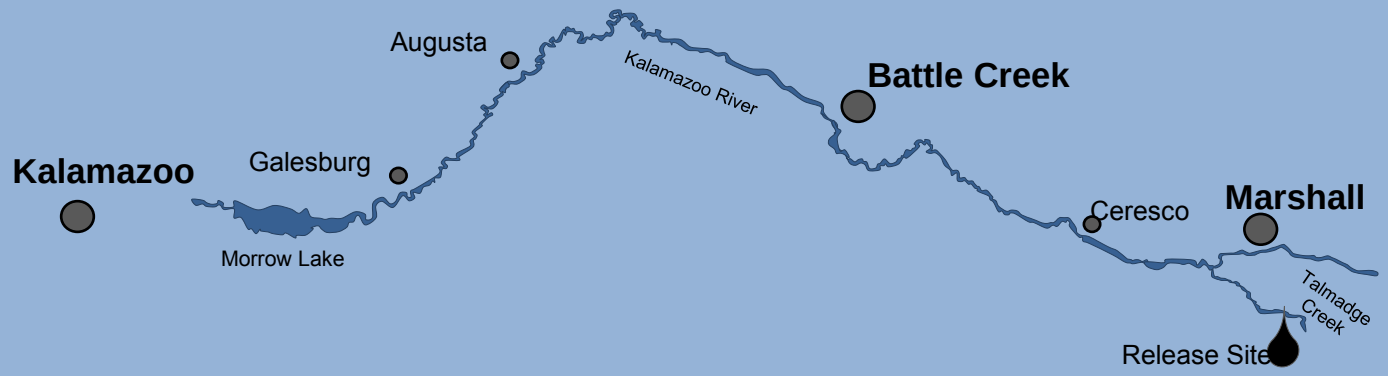
Other areas will require long-term operation and maintenance to continue to reduce contamination levels.

Thank You



U.S. EPA Presentation at No Spills Conference, January 2015

Enbridge Oil Spill



Source Area

August 4, 2010

Source Area

Battle Creek
Kalamazoo
Ceresco
Marshall
Source

2010/08/07 07:50

Source Area

August 5, 2010

Source Area

September 20, 2012

Source Area

September 17, 2014

Talmadge Creek

November 11, 2011

Talmadge Creek

September 17, 2014

Talmadge Creek and Kalamazoo River Confluence

March 5, 2012

Talmadge Creek and Kalamazoo River Confluence

September 17, 2014

Frac Tank City

September 17, 2014

Island A

September 17, 2014

MP 4.5 Overbank Excavation

September 17, 2014

Ceresco

September 17, 2014

Ceresco Dredge Pad

September 17, 2014

MP 11.25 Overbank Excavation

September 17, 2014

Mill Ponds

August 17, 2014

Mill Ponds Dredge Pad

September 17, 2014

MP 21.5 Sediment Trap

September 17, 2014

Morrow Lake Delta

July 17, 2014

E 3.5 Boat Launch and Staging Area

September 17, 2014

Morrow Lake Dredge Pad

September 17, 2014

Morrow Lake

September 17, 2014

EPA Metrics Project Total

Progress Under EPA Orders (as of 10/06/2014)

- Waste shipped off site
  - Haz Soil – 19,644 cubic yards
  - Non-haz Soil – 327,669 cubic yards
  - Non-Haz Soil and Debris – 64,815 cubic yards
  - Haz Debris – 12,075 cubic yards
  - Non-Haz Water – 11,934,503 gallons
  - Haz Water - 3,594,579 gallons
  - Oil (as recoverable crude) – 766,288 gallons
  - Calculated oil total from all sources – 1,201,098 gallons

Appendix B: Floodplain Oiling Report

STRATUS CONSULTING

Kalamazoo River Floodplain Oiling Survey Data Report

Prepared for:

Stephanie Millsap
U.S. Fish and Wildlife Service
and
Enbridge NRDA Trustee Council

Kalamazoo River
Floodplain Oiling Survey
Data Report

Prepared for:

Stephanie Millsap
U.S. Fish and Wildlife Service
and
Enbridge NRDA Trustee Council

Prepared by:

Stratus Consulting Inc.
PO Box 4059
Boulder, CO 80306-4059
303-381-8000

1920 L St. NW, Suite 420
Washington, DC 20036

Contacts:

Kaylene Ritter, PhD
Allison Ebbets

January 3, 2012

Confidential Attorney/Consultant Work Product – Privileged

SC12521

Contents

List of Figures vii
List of Tables xi
List of Acronyms and Abbreviations xiii

Executive Summary 1

Section 1 Introduction 3

1.1 Objectives and Scope 4

Section 2 Field Survey Methods 6

2.1 Protocol Development 8
2.2 Survey Approach: Floodplain Sections and Transects 8
2.2.1 Transect naming conventions 11
2.3 Field Data Collection Methods 11
2.3.1 Survey field methods 11
2.3.2 Data recording methods 20
2.3.3 Surveying of islands 20
2.3.4 Surveying areas impacted by response activities 21
2.4 Daily Data Management Methods 21

Section 3 Database Development and GIS Mapping Methods 22

3.1 Database Development 22
3.2 GIS Methods 24
3.2.1 Transects and oil delineation areas by percent oiling 24
3.2.2 Habitat types 27
3.2.3 Habitat features 27

Section 4 Results 27

4.1 Floodplain Oiling Results 27
4.2 Habitat Type Results 29
4.3 Habitat Feature Results 33

References 34

Appendices

A Floodplain Survey Work Plan
B Description of Closing Polygons

Figures

1 Overview of the study area 5
2 Example of 1–10% oiling 6
3 Heavy oiling on emergent vegetation 7
4 GIS-generated N-S transects in the Kalamazoo River floodplain 10
5 Example hard copy datasheet used in the field from August 13 to 18, 2010 13
6 Example ODA delineated in the Kalamazoo River floodplain and a photograph taken during data collection at one of the ODA waypoints 16
7 Revised data entry form for transects, implemented August 28, 2010 17
8 Revised data entry form for ODAs, implemented August 28, 2010 18
9 Overview map showing the transects and ODAs surveyed during the floodplain survey (MP 0–7.5) 35
10 Overview map showing the transects and ODAs surveyed during the floodplain survey (MP 7.25–16.5) 36
11 Overview map showing the transects and ODAs surveyed during the floodplain survey (MP 16–25) 37
12 Overview map showing the transects and ODAs surveyed during the floodplain survey (MP 22.25–32.75) 38
13 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 2.25–3.25) 39
14 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 3.25–4.25) 40
15 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 4.25–5.25) 41
16 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 5.25–6.25) 42
17 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 6.25–7.25) 43
18 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 7.5–8.5) 44
19 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 8.5–9.25) 45
20 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 9.5–10.5) 46
21 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 10.5–11.5) 47

22 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 11.25–12.5) 48
23 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 12.75–14) 49
24 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 13.5–14.75) 50
25 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 14.75–15.5) 51
26 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 18–19) 52
27 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 19–20) 53
28 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 20–21) 54
29 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 21–22.25) 55
30 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 22–24) 56
31 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 29–29.5) 57
32 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 29.75–30) 58
33 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 30.25–31) 59
34 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 31–31.75) 60
35 Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 31.75–32.25) 61
36 Map showing the habitat types identified at each waypoint during the floodplain survey (MP 0–7.5) 62
37 Map showing the habitat types identified at each waypoint during the floodplain survey (MP 7.25–16.5) 63
38 Map showing the habitat types identified at each waypoint during the floodplain survey (MP 16–25) 64
39 Map showing the habitat types identified at each waypoint during the floodplain survey (MP 22.25–32.75) 65
40 Map showing the waypoint locations where vernal pools and/or water features were identified and the degree of oiling recorded at the corresponding waypoint (MP 0–7.5) 66

41 Map showing the waypoint locations where vernal pools and/or water features were identified and the degree of oiling recorded at the corresponding waypoint (MP 7.25–16.5) 67
42 Map showing the waypoint locations where vernal pools and/or water features were identified and the degree of oiling recorded at the corresponding waypoint (MP 16–25) 68
43 Map showing the waypoint locations where vernal pools and/or water features were identified and the degree of oiling recorded at the corresponding waypoint (MP 22.25–32.75) 69

Tables

1 Inventory of floodplain protocol changes 9
2 Number of transects walked by division 28
3 Total floodplain miles walked by division 28
4 Oiling by habitat type 30
5 Summary of habitat feature results 33
6 Presence and health of skunk cabbage 34

Acronyms and Abbreviations

DBH	diameter at breast height
GIS	geographic information system
GPS	global positioning system
ID	identification
MP	mile post
NRDA	natural resource damage assessment
ODA	oil delineation area
QA	quality assurance
QC	quality control
SCAT	Shoreline Cleanup and Assessment Technique
USFWS	U.S. Fish and Wildlife Service

Executive Summary

The Enbridge Oil spill occurred on July 26, 2010, near Marshall, Michigan. Soon after the spill, the state and federal natural resource Trustees and Enbridge cooperated on a floodplain survey. The purpose of the survey was to use ground surveys to document the degree and extent of oiling in the Kalamazoo River floodplain from Talmadge Creek (where the spill originated) downstream to approximately five miles upstream of Morrow Lake and to record the types of habitat and specific habitat features within this floodplain. This report describes the objectives, approach, and methods of the floodplain oiling survey, and presents the results of the survey. The report does not present any interpretation of the results in terms of natural resource injury or restoration scaling.

The survey took place from August 13, 2010, to September 2, 2010. The survey was conducted according to detailed written protocols that were developed specifically for this survey. Multiple field teams that included both trustee and Enbridge representatives conducted the survey. The written field protocols were modified during the course of the survey to adjust to field conditions and to incorporate the transition from using hardcopy forms to computer tablets for data recording. The field-collected data were tracked and managed under chain of custody procedures to ensure the integrity of the raw data.

Floodplain on both sides of the river from Talmadge Creek to Morrow Lake, a distance of approximately 25 river miles, was surveyed by field crews. The field surveys were conducted primarily along linear transects situated either perpendicular to river flow or along N-S compass lines. Transects were approximately 50 m apart from each other. Selected areas (e.g., islands, areas of heavy oiling of at least 50 ft^2 in the floodplain) were surveyed at a more detailed level. Field crews surveyed a total of 742 transects on both sides of the river.

The raw field survey data was processed to allow for data presentation in maps and tables, which are presented in this report. Any decisions that were made during data processing were carefully recorded and are presented in this report for transparency. The intent of the data processing was to be able to present and summarize the data in figure and table format in ways that accurately reflect the original raw field data as closely as possible. We intentionally minimized as much as possible any data interpretation in the data processing step.

The results of the floodplain oiling survey are presented here in tables and maps. The highest degree of oiling occurred from mile post (MP) 2.25 to MP 17.25 (Division C). In this area, 76% of surveyed transects were 1–10% oiled. All areas with heavy oiling at least 50 ft^2 in size (called "oil delineation areas," or ODAs) identified by field crews were located between MP 2.25 and MP 17.25. Downstream of MP 17.5, few observations of oil were made along transects and no ODAs were identified. The maps and tables presented here show that the predominant habitat

type identified during the survey was forested wetland. The types of habitat features observed included water features, vernal pools, downed trees, and skunk cabbage.

1. Introduction

On July 26, 2010, a discharge of heavy crude oil (Cold Lake Blend) from the Enbridge Energy Partners, L.P. (Enbridge) line 6B, located along Talmadge Creek, was discovered near the Town of Marshall in Calhoun County, Michigan. The oil traveled down Talmadge Creek approximately 2.2 miles and into the Kalamazoo River (AECOM, 2011). The line 6B discharge point is on the outskirts of Marshall (North ½ Section 2, T3S, R6W, Latitude: 42.2395273, Longitude: -84.9662018). Upon discovery of the discharge, the pipeline was shut down and isolation valves were closed, stopping the discharge of the oil. Enbridge estimates that approximately 20,082 barrels (843,444 gallons) of heavy crude oil were discharged (AECOM, 2011).

Prior to the spill event, from July 22 through 25, 2010, heavy rains had fallen in the area of and upstream of the oil spill, increasing the volume of water in the Kalamazoo River and inundating the floodplain. During this period, the Town of Ceresco (approximately 5 miles west of the spill) received an estimated 5.70 in. of rain and the Town of Albion (approximately 10 miles east of the spill) received an estimated 5.65 in. of rain (AECOM, 2011). Based on readings at the stream gauge in Marshall (gauge 4103500), at the time of the spill event, the flood stage was estimated to be between a 10- and 25-year flood event (AECOM, 2011). When the oil was discharged, it was carried with the flooding river and distributed in the inundated floodplain. Within a few days of the spill event, the water had receded from the floodplain to the main river channel.

The Trustees have engaged in preassessment activities since the occurrence of the spill. The Trustees include the Michigan Department of Environmental Quality, the Michigan Department of Natural Resources, the Michigan Department of the Attorney General, the U.S. Department of Interior acting through the U.S. Fish and Wildlife Service (USFWS) and the Bureau of Indian Affairs, the U.S. Department of Commerce acting through the National Oceanic and Atmospheric Administration, the Nottawaseppi Huron Band of the Potawatomi, and the Match-E-Be-Nash-She-Wish Band of the Potawatomi. Many of these activities have been conducted cooperatively with Enbridge.

The Trustees and Enbridge, working together as a cooperative natural resource damage assessment (NRDA) group (the NRDA group), conducted a floodplain survey soon after the oil spill occurred. The purpose of the survey was to document the spatial extent and degree of oiled habitat within the Kalamazoo floodplain, between the confluence with Talmadge Creek [defined as mile post (MP) 2] and approximately five miles upstream of Morrow Lake (MP 32.25). This report, produced by Stratus Consulting on behalf of the Trustees, describes the methods used in the field to collect data and the data management methods and geographic information system (GIS) database development. The field survey results are also presented in tables and maps.

1.1 Objectives and Scope

Based on field reconnaissance of the floodplain by the Trustees and Enbridge representatives soon after the spill (August 9–12, 2010) and reports and observations made by response personnel, it was clear that there was oil in the floodplain as a result of the incident. The NRDA group estimated that floodplain vegetation and soils were oiled at a background level of 1–10% (as defined in Owens and Sergy, 1994), interspersed with much more heavily oiled patches of varying spatial dimensions. Response activities were focused on characterizing oil within the river and along the shoreline using the Shoreline Cleanup and Assessment Technique (SCAT), which is focused on assessing shoreline areas. Based on initial floodplain reconnaissance, the NRDA group determined that there was a need to document the amount of oil present in the floodplain and designed a floodplain survey that was implemented independently of the SCAT survey. The primary study objectives of the floodplain survey were to characterize the areal extent and degree of oiling in the Kalamazoo River floodplain that resulted from the Enbridge pipeline spill and the general floodplain habitat types that were oiled. The NRDA floodplain survey results could be evaluated in conjunction with the SCAT survey results, and later response efforts to document the extent of floodplain oiling, in order to develop a more comprehensive, overall description of shoreline and floodplain oiling.

The geographical scope of the oiled floodplain study encompassed the Kalamazoo River floodplain from the confluence of Talmadge Creek and the Kalamazoo River (MP 2.0) to just upstream of Morrow Lake (MP 32.25; Figure 1). Incident Command designated Talmadge Creek and the Kalamazoo River downstream of the pipeline break into Divisions A through E. Division A encompassed the spill area on Talmadge Creek (MP 0–0.25), Division B encompassed the area just downstream of the spill to the confluence of Talmadge Creek and the Kalamazoo River (MP 0.25–2), Division C extended from the confluence of Talmadge Creek and the Kalamazoo River downstream past Battle Creek (MP 2.25–17.25), Division D extended from MP 17.5 through 23.75, and Division E extended from MP 24 to Morrow Dam at MP 40. The Kalamazoo River floodplain between MP 2 and MP 32.25 (including Divisions B, C, D, and part of E), where the NRDA group had permission to access, was surveyed. Response actions or private property restrictions precluded access to some parts of the floodplains; consequently, these parcels could not be surveyed.

The survey work was initiated in early August and completed in early September 2010. The initial reconnaissance work was undertaken between August 9 and 12. Survey work took roughly three weeks, and was conducted from August 13 to September 2, 2010.

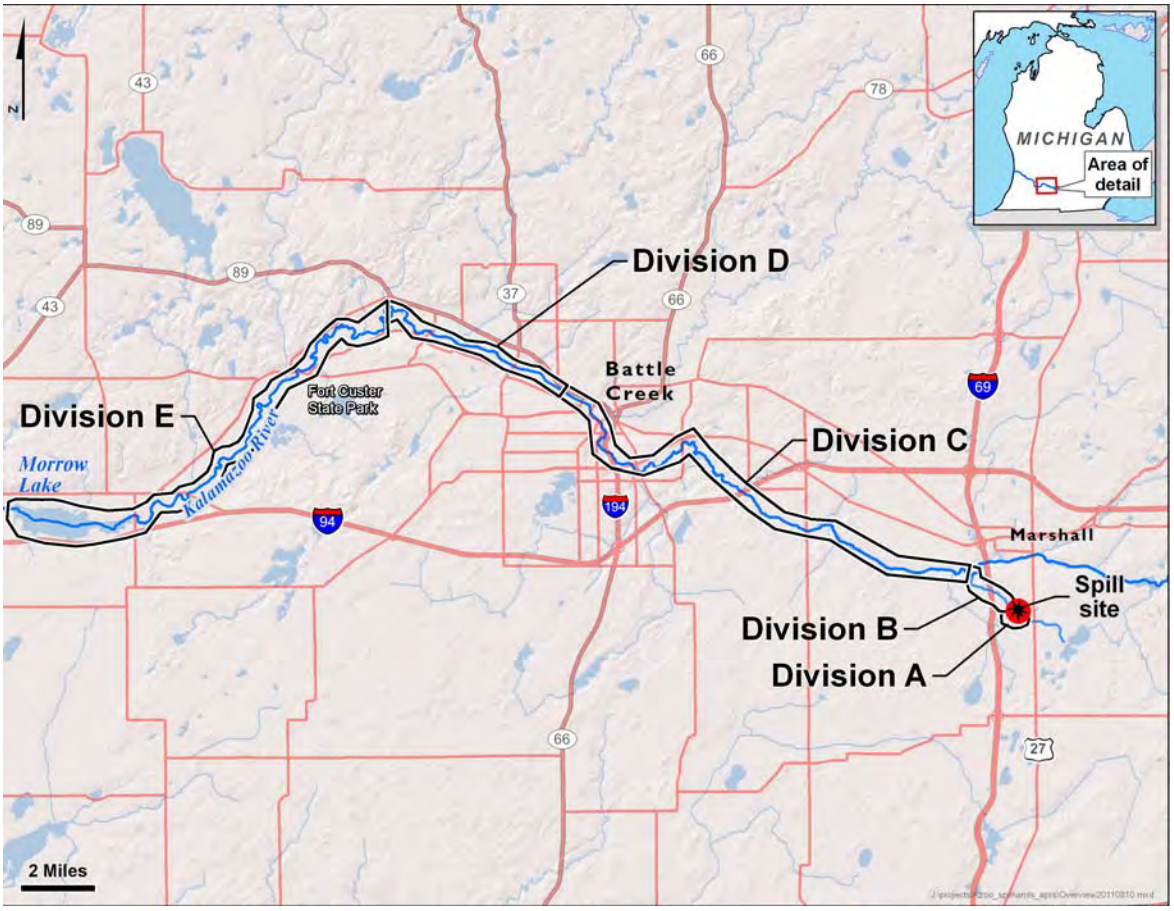


Figure 1. Overview of the study area.

The remainder of this report is organized as follows:

- Section 2 describes the field survey methods
- Section 3 describes database development and GIS mapping methods
- Section 4 presents results of the floodplain survey.

2. Field Survey Methods

Initial field reconnaissance indicated that the floodplain areas which were under water at the time of the spill were oiled at a background level of 1–10%, interspersed with much more heavily oiled patches of varying spatial dimensions. For the purposes of the floodplain survey, sporadic oiling was specifically defined as 1% (trace) to 10% oil covering floodplain surfaces including soil, vegetation, and tree trunks. Figure 2 provides an example of 1–10% oiling, and Figure 3 provides an example of heavy oiling. Additional examples are provided in the floodplain characterization protocol in Appendix A.

Figure 2. Example of 1–10% oiling.

Figure 3. Heavy oiling on emergent vegetation.

The main objectives of the survey was to characterize the areal extent and degree of oiling in the Kalamazoo River floodplain that resulted from the Enbridge pipeline spill, and to characterize the general floodplain habitat types that were oiled.

The remainder of this section is structured as follows:

- Section 2.1 describes protocol development, based on initial reconnaissance work in the field
- Section 2.2 describes the survey approach
- Section 2.3 describes field data collection methods
- Section 2.4 describes daily data management methods.

2.1 Protocol Development

Representatives of the cooperative NRDA group conducted four days (August 9–12, 2010) of reconnaissance in Division C, near MP 10 and the C3.2 boat ramp. The purpose of the reconnaissance work was to understand field conditions, including oiling and habitat, to inform the study design. The reconnaissance team found that the floodplain vegetation and soils were oiled throughout and that there were areas with heavy oiling.

After completing the initial reconnaissance investigation (August 9–12, 2010), the NRDA group developed a protocol to survey the floodplain. The protocol was tested in the field on August 13–14, 2010. The floodplain survey protocol, "Protocols for Characterizing Kalamazoo River Floodplain Oiling," is included in Appendix A, and the survey methods are summarized below.

Due to changing field conditions, observations made during the field sampling effort, and availability of data collection tools, the protocol was revised several times during the survey (the final version of the protocol is included in Appendix A). These revisions were made to improve the efficiency or methods of data collection based on field experience, address new conditions encountered in the field (e.g., areas where response occurred before the floodplain survey reached that location), and include new technology as it became available (e.g., electronic data entry tablets). Protocol modifications are described in relevant sections of this report. In addition, Table 1 summarizes all modifications made to the protocol as field work progressed.

2.2 Survey Approach: Floodplain Sections and Transects

The survey was conducted using a systematic approach in which the floodplain was split into 400-m-wide sections (sections) and each section was further divided into eight transects (transects) spaced 50 m apart. In the original protocol, the transects were oriented perpendicular to the river, with the 50-m spacing measured along the Kalamazoo River shoreline. However, that approach resulted in an uneven density of surveyed areas within sections, especially in areas where the river was more sinuous. For example, some transect lines cross and others diverge, leaving large unsurveyed areas within sections.

To address this uneven transect coverage, a revised approach was developed in which the transects were oriented parallel to each other in a N-S direction. All transect lines were generated using GIS and assigned a unique identifier. This modification became effective August 17, 2010 (Figure 4).

Table 1. Inventory of floodplain protocol changes

Section in this report	Floodplain protocol change	Protocol revision date	Reason
2.2	Orient transects N-S rather than perpendicular to the river	8/17/2010	Improve consistency, predetermine transect locations, follow general orientation of the floodplain
Implementation of use of electronic tablets			
2.3.2	Use electronic tablets to record field data	8/19/2010	Enter data directly in electronic format, integrate data in field (observations, waypoints, photographs), avoid errors related to data entry
2.3.1	Use Bluetooth global positioning system (GPS) unit to collect waypoint coordinates	8/19/2010	GPS coordinates automatically inserted into data entry form
2.3.1	Stop taking photographs of handheld GPS units	8/19/2010	GPS information integrated directly into data entry form
Implementation of revised protocol			
2.3.1	Waypoint transitions simplified to three types: start, habitat transition, end	8/28/2010	Provide increased clarity in data collection
2.3.1	For transect waypoints, do not record specific habitat features [pooled oil, water feature, vernal pool, downed tree, and skunk cabbage (*symplocarpus foetidus*)]	8/28/2010	Simplify data collection in the field, reduce the amount of information recorded at each point
2.3.1	For transect waypoints, degree of oiling is set to default of 1–10%; if oiling outside of this range is observed, record information about the percent of oiling in the notes field	8/28/2010	Simplify data collection in the field, reduce the amount of information recorded at each point
2.3.1	For oil delineation area (ODA) waypoints, identify the purpose (start, directional transition, end)	8/28/2011	Provide increased clarity ODA delineation
2.3.1	For ODAs, record specific habitat features once per ODA rather than at each ODA waypoint (pooled oil, water feature, vernal pool, downed tree, and skunk cabbage)	8/28/2010	Simplify data collection in the field, reduce the amount of information recorded at each point
2.3.1	For ODAs, record the habitat type once per ODA rather than at each ODA waypoint (forested upland, prairie, forested wetland, human managed, other)	8/28/2010	Simplify data collection in the field, reduce the amount of information recorded at each point
2.3.1	Record percent of oiling for ODA once; oiling still recorded for soil, herbs, shrubs, and trees	8/28/2010	Simplify data collection in the field, reduce the amount of information recorded at each point

Table 1. Inventory of floodplain protocol changes (cont.)

Report section	Floodplain protocol change	Date implemented	Reason
Implementation of surveys on islands and in response areas			
2.3.3	Document oil on islands	8/25/2010	Capture information about oil on islands in the Kalamazoo River
2.3.4	Document areas where cleanup actions have been completed	8/23/2010	Record areas where oil was removed from the floodplain (these areas would have been ODAs if field crews encountered them before response crews cleaned them), document areas where a substantial amount of oil had been present in the floodplain

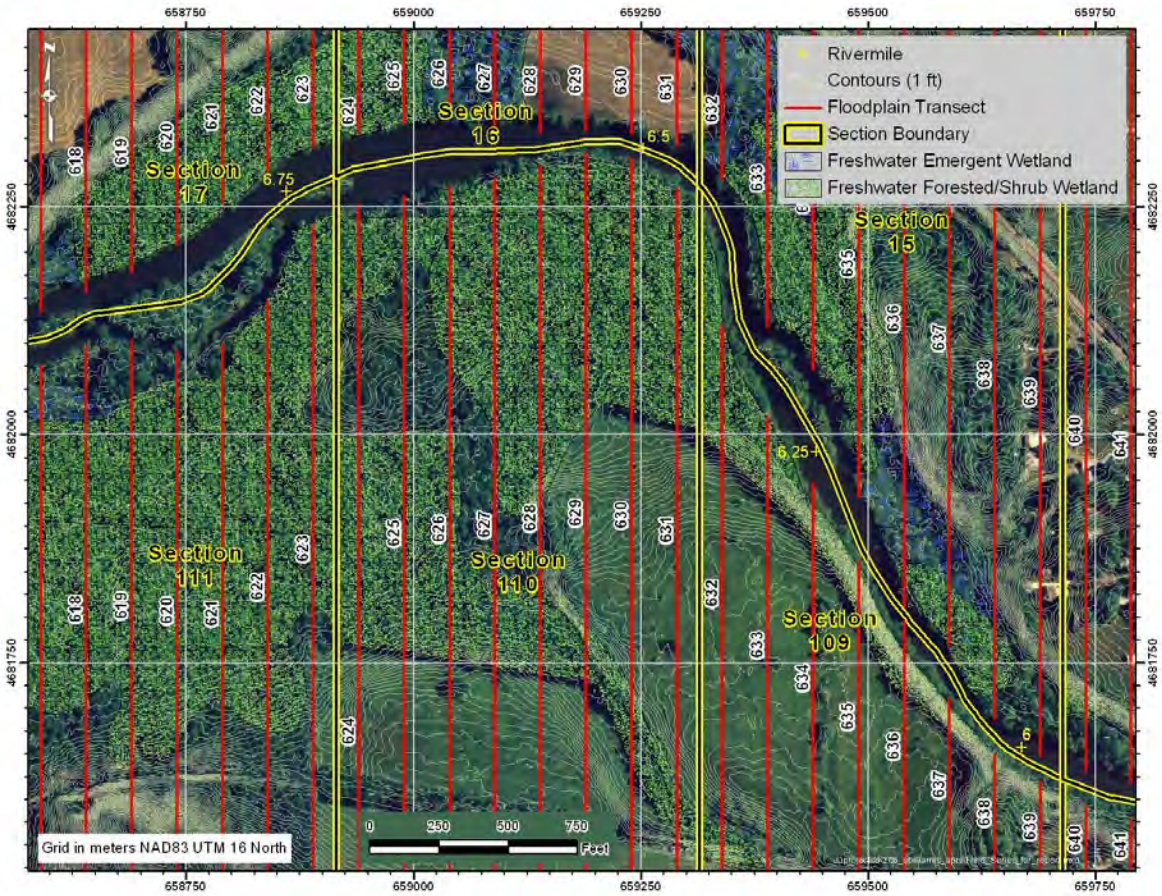


Figure 4. GIS-generated N-S transects in the Kalamazoo River floodplain.

A random sampling technique (with a random number generator) was used to select the sections to be surveyed daily. Upon implementation of the survey, it became evident that some private lands could not be accessed for surveying. Thus, accessibility dictated where work could be conducted, and sections were randomly selected within those areas where the crew had access to the floodplain. The NRDA group coordinated with Enbridge personnel daily to identify which land parcels were accessible for surveying (i.e., permission given by owners to access their land). By August 17, 2010, field work was no longer limited by access in Division C. Permission was not granted for large areas in Divisions D and E within the timeframe of the survey, but the areas where permission was granted were surveyed.

2.2.1 Transect naming conventions

When recording data, each transect was assigned a unique identification (ID). Individual floodplain transect IDs were generated using a combination of the unique transect ID and riverbank orientation when facing downriver. For example, transect number 124 located on the right riverbank was labeled 124R.

Island transects were named using a similar convention. Island transects in Division C downriver of Ceresco Dam were named sequentially, working upriver from the Mill Pond in Battle Creek (Division C and D boundaries) to Ceresco Dam starting at 900. Similarly, island transects in Division C between Ceresco Dam and the Talmadge Creek confluence were labeled sequentially from 1,000. All island transects were given a left riverbank orientation code, regardless of which side of the river they were located. For example, the fifth island located upriver from Ceresco Dam was labeled 905L.

2.3 Field Data Collection Methods

This section describes the methods used to collect data in the floodplain.

2.3.1 Survey field methods

The floodplain survey was conducted by teams of two field personnel (field crews). Each crew included one member representing the Trustees and one member representing Enbridge. On occasion, one crew consisted of two Trustee representatives or two Enbridge representatives. Most days, four crews of two field personnel each were deployed in the field.

Transects

The field crews verified the start location of each transect using a GPS unit and detailed transect maps. Once correctly positioned, the crew took three photographs marking the start of the transect: one of the GPS unit with coordinates visible, one facing north, and the other facing south. For each waypoint, the data recorder filled out the field datasheet (specific information recorded at each waypoint is described below). Field crews were instructed to note any instances where terrain or vegetation made it difficult to observe 25 m on either side of the transect. Data collection sheets included a space for recording additional relevant notes and observations (Figure 5).

Each transect was initiated with a waypoint. If there was no oil present at the first waypoint or if the habitat was physically inaccessible (e.g., a steep bank), only one waypoint was collected and the transect was ended. If the first waypoint was in an area at least sporadically oiled, and the location was physically accessible, the field crew began walking along the transect. At specific transitions, field crews marked additional waypoints and recorded data on the field datasheet. Transitions that warranted a waypoint and data collection included:

- Habitat transition
- Beginning of an ODA, defined as an area with oil coverage greater than 1–10%, covering a surface area least 50 ft^2
- End of a transect, defined as:
    - The point at which oiling is reduced to “no visible oil”
    - An area of greatly reduced habitat quality (e.g., housing development or agricultural field)
    - A point 15 ft past the edge of the floodplain (based on visual estimation).

For each transect, general information was recorded about the location of the transect, the date, field crew members, and equipment.

Floodplain Characterization Data Sheet (Version 5.0) Site _____/_____ (Sheet ___ of ___)

River Mile (tenths) ____.____ Bank Side Descending (R/L) ____ Date ___/___/2010 Data Collector/Recorder _____

GPS/Photo Operator _____ GPS Unit ID _____ GPS Photo (Y ___, #_____) GPS Start Waypoint _____ Camera ID_____

TRANSECT ID (Rivermile.transect):_____OIL DELINEATION AREA ID (A-Z): _____ Time:_____

Waypoint # (____) **Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Oiling: Soil visible? (Y___/N___) If Y % oil covered soil (____%) % oil covered herbs (____%) % oil covered shrubs (____%) % oil covered trees (____%)
Features: Pooled oil (>50ft^2)?[1] (Y__/N__) Water feature (>50ft^2)?[2] (Y__/N__) Vernal pool (>50ft^2)?[3] (Y__/N__) Downed tree (>4" DBH)?[4] (Y__/N__) **Skunk Cabbage**: Present? (Y___/N___) If present, healthy___/defoliated____/new shoots_____ (combination ok) **Photos #s** _____
Notes: _____

Waypoint # (____) **Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Oiling: Soil visible? (Y___/N___) If Y % oil covered soil (____%) % oil covered herbs (____%) % oil covered shrubs (____%) % oil covered trees (____%)
Features: Pooled oil (>50ft^2)?[1] (Y__/N__) Water feature (>50ft^2)?[2] (Y__/N__) Vernal pool (>50ft^2)?[3] (Y__/N__) Downed tree (>4" DBH)?[4] (Y__/N__) **Skunk Cabbage**: Present? (Y___/N___) If present, healthy___/defoliated____/new shoots_____ (combination ok) **Photos #s** _____
Notes: _____

Waypoint # (____) **Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Oiling: Soil visible? (Y___/N___) If Y % oil covered soil (____%) % oil covered herbs (____%) % oil covered shrubs (____%) % oil covered trees (____%)
Features: Pooled oil (>50ft^2)?[1] (Y__/N__) Water feature (>50ft^2)?[2] (Y__/N__) Vernal pool (>50ft^2)?[3] (Y__/N__) Downed tree (>4" DBH)?[4] (Y__/N__) **Skunk Cabbage**: Present? (Y___/N___) If present, healthy___/defoliated____/new shoots_____ (combination ok) **Photos #s** _____
Notes: _____

Waypoint # (____) **Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Oiling: Soil visible? (Y___/N___) If Y % oil covered soil (____%) % oil covered herbs (____%) % oil covered shrubs (____%) % oil covered trees (____%)
Features: Pooled oil (>50ft^2)?[1] (Y__/N__) Water feature (>50ft^2)?[2] (Y__/N__) Vernal pool (>50ft^2)?[3] (Y__/N__) Downed tree (>4" DBH)?[4] (Y__/N__) **Skunk Cabbage**: Present? (Y___/N___) If present, healthy___/defoliated____/new shoots_____ (combination ok) **Photos #s** _____
Notes: _____

Waypoint # (____) **Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Oiling: Soil visible? (Y___/N___) If Y % oil covered soil (____%) % oil covered herbs (____%) % oil covered shrubs (____%) % oil covered trees (____%)
Features: Pooled oil (>50ft^2)?[1] (Y__/N__) Water feature (>50ft^2)?[2] (Y__/N__) Vernal pool (>50ft^2)?[3] (Y__/N__) Downed tree (>4" DBH)?[4] (Y__/N__) **Skunk Cabbage**: Present? (Y___/N___) If present, healthy___/defoliated____/new shoots_____ (combination ok) **Photos #s** _____
Notes: _____

Figure 5. Example hard copy datasheet used in the field from August 13 to 18, 2010.

At each waypoint, the following information was recorded:

- Waypoint ID (number identifying the waypoint in the handheld GPS unit)
- Habitat type (these are broad categories intended only to provide documentation of the general habitat present):
  - Forested upland
  - Prairie
  - Forested wetland
  - Human managed (e.g., pasture, lawn)
  - Other (if other, field crews provided a description)
- Oiling – percent of oil present on soil and vegetation for the following specific habitat features:
  - Percent of oil-covered soil if soil visible
  - Percent of oil-covered herbs
  - Percent of oil-covered shrubs
  - Percent of oil-covered trees
- Habitat features (recorded as presence or absence):
  - Pooled oil (> 50 ft^2)
  - Water feature (> 50 ft^2)
  - Vernal pool (> 50 ft^2)
  - Downed tree [> 4-in. diameter at breast height (DBH)]
- Skunk cabbage:
  - Whether present
  - If present
    - Healthy
    - Defoliated
    - New shoots
- Photographs
- Notes – an area was left for field crews to record notes.

Some logistical modifications were made to the protocol when the tablets were introduced. First, waypoint coordinates were taken using a Bluetooth-linked GPS unit that was integrated into the data entry form (see Section 2.3.2 for more details) at each waypoint. Table 1 summarizes all protocol changes.

Oil delineation areas

ODAs were defined as areas with greater than sporadic oiling covering an area at least 50 ft^2 (Figure 3). Crews were instructed to leave the transect to inspect any suspected ODAs, such as side channels connected to the river, and return to the transect at the point where they left the transect. Every ODA encountered was delineated.

ODAs were delineated by taking waypoints at key points of direction change to make a polygon encompassing the ODA. Figure 6 shows a single, example ODA delineated in the field and associated photograph taken at one of the ODA waypoints. At each point defining an ODA the same information was recorded using the same methods and data entry forms described above for waypoints in a transect. ODA waypoints were recorded on a separate data entry form and labeled with the transect where the ODA was found and a unique ODA identifier. As with the transect waypoint data, this information was recorded, initially on field datasheets from August 13 to 18, 2010, and later in electronic format on the tablets from August 19 to September 2, 2010. If the team could not safely walk the perimeter of the oiled area, a waypoint was taken in the center of the area and dimensions were visually estimated.

On August 27, 2010, the data collected to date were reviewed. Based on this review and on an assessment of remaining available crew time to complete the survey, changes were made to the information recorded at transect waypoints and at ODAs. Figures 7 and 8 show the revised datasheets that were used to develop the revised tablet data entry form. Table 1 summarizes all protocol changes.

Specifically, the following modifications were made to the field data collection methods.

Transect waypoints

- Transitions that warranted a transect waypoint were simplified from the list provided in Section 2.3.1 to three types:
    - Start
    - Habitat transition
    - End

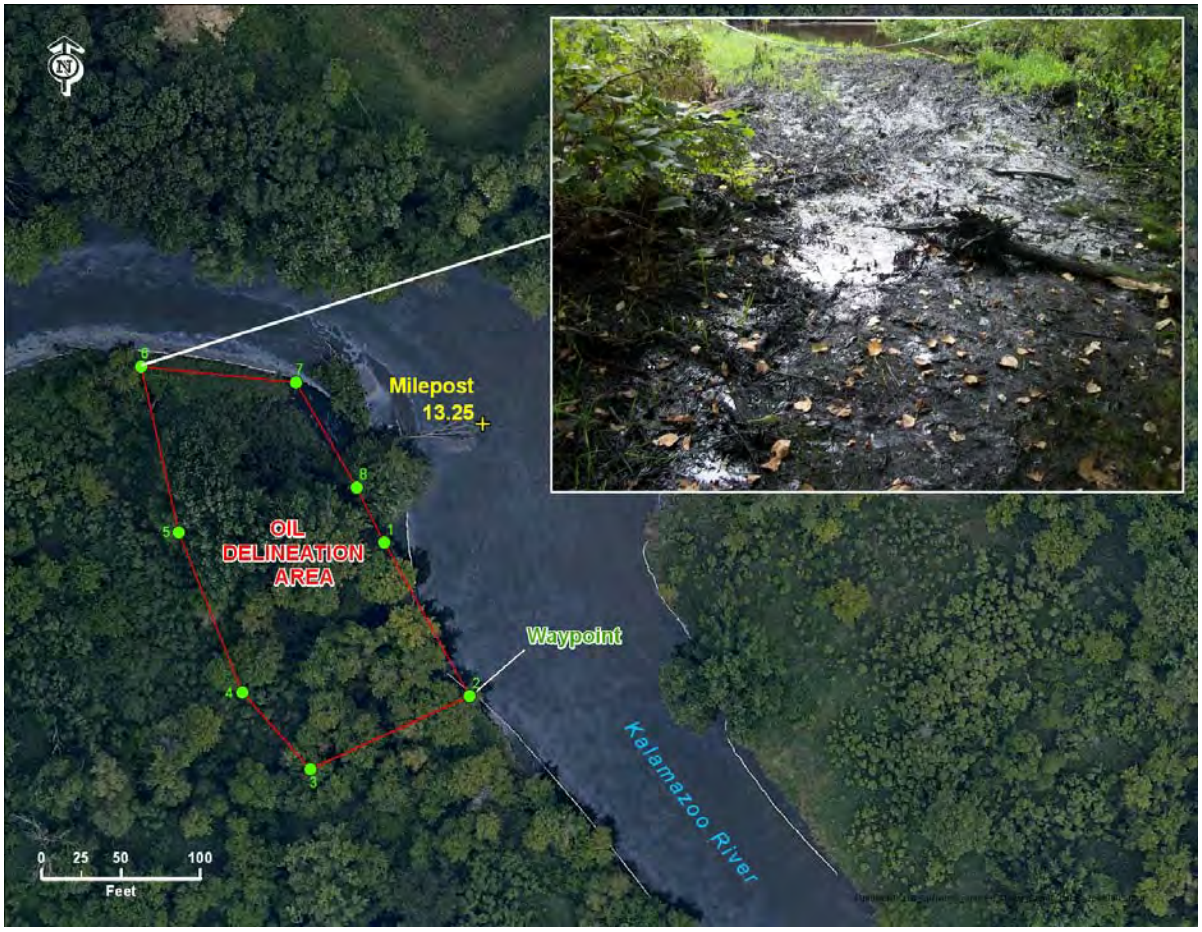


Figure 6. Example ODA delineated in the Kalamazoo River floodplain and a photograph taken during data collection at one of the ODA waypoints.

Floodplain Characterization **Transect** Data Sheet (Version 6.0) Site _____/_____ (Sheet __ of __)

River Mile _____ Bank Side Descending (R/L) ____ Date ___/___/2010 Data Collector/Recorder _____

GPS/Photo Operator _____ GPS Unit ID _____ GPS Photo (Y ___, #_____) GPS Start Waypoint _____ Camera ID_____

TRANSECT ID:_____OIL DELINEATION AREA ID (A-Z): _____ Time:_____

Waypoint # (____) Waypoint Type (S,HT,E):_____**Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Photos #s _____
Notes: _____
_____

Waypoint # (____) Waypoint Type (S,HT,E):_____**Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Photos #s _____
Notes: _____
_____

Waypoint # (____) Waypoint Type (S,HT,E):_____**Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Photos #s _____
Notes: _____
_____

Waypoint # (____) Waypoint Type (S,HT,E):_____**Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Photos #s _____
Notes: _____
_____

Waypoint # (____) Waypoint Type (S,HT,E):_____**Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Photos #s _____
Notes: _____
_____

Waypoint Type: S = Start, HT: Habitat Transition; E = End **Habitat types**: FU = forested upland, P = prairie, FW = forested wetland, M= marsh, H = human managed (e.g. pasture, lawn), O = other (if other, describe)

Figure 7. Revised data entry form for transects, implemented August 28, 2010.

Floodplain Characterization **Oil Polygon** Data Sheet (Version 6.0) Site ____/_____ (Sheet __ of __)

River Mile ____ Bank Side Descending (R/L) ___ Date ___/___/2010 Data Collector/Recorder _____

GPS/Photo Operator _____ GPS Unit ID _____ GPS Photo (Y ___ #_____) GPS Start Waypoint _____ Camera ID_____

TRANSECT ID:_____OIL DELINEATION AREA ID (A-Z): _____ Time:_____

Oil Polygon Waypoint # (___) , **Waypoint Type (S, DT, E):**_____**Photos #s** _____<take GPS coordinates>

Oil Polygon Waypoint # (___) , **Waypoint Type (S, DT, E):**_____**Photos #s** _____<take GPS coordinates>

Oil Polygon Waypoint # (___) , **Waypoint Type (S, DT, E):**_____**Photos #s** _____<take GPS coordinates>

Oil Polygon Waypoint # (___) , **Waypoint Type (S, DT, E):**_____**Photos #s** _____<take GPS coordinates>

Oil Polygon Waypoint # (___) , **Waypoint Type (S, DT, E):**_____**Photos #s** _____<take GPS coordinates>

Oil Polygon Waypoint # (___) , **Waypoint Type (S, DT, E):**_____**Photos #s** _____<take GPS coordinates>

Oil Polygon Waypoint # (___) , **Waypoint Type (S, DT, E):**_____**Photos #s** _____<take GPS coordinates>

Oil Polygon Waypoint # (___) , **Waypoint Type (S, DT, E):**_____**Photos #s** _____<take GPS coordinates>

Oil Polygon Waypoint # (___) , **Waypoint Type (S, DT, E):**_____**Photos #s** _____<take GPS coordinates>

Oil Polygon Waypoint # (___) , **Waypoint Type (S, DT, E):**_____**Photos #s** _____<take GPS coordinates>

Oil Polygon Waypoint # (___) , **Waypoint Type (S, DT, E):**_____**Photos #s** _____<take GPS coordinates>

Oil Polygon Waypoint # (___) , **Waypoint Type (S, DT, E):**_____**Photos #s** _____<take GPS coordinates>

Oil Polygon Habitat type (FU, P, FW, M, H, O): _____ If O, describe _____

Polygon Oiling: Soil visible? (Y___/N___) If Y % oil covered soil (___%) % oil covered herbs (___%) % oil covered shrubs (___%) % oil covered trees (___%)

Oil Polygon Features: Water feature (>50ft²)? (Y__/N__) Vernal pool (>50ft²)? (Y__/N__) Downed tree (>4" DBH)? (Y__/N__)
Skunk Cabbage: Present? (Y___/N___) If present, healthy___/defoliated___/new shoots____ (combination ok)
Notes:
_____
_____
_____

Waypoint Type: S = Start, DT = Directional Transition: E = End
Habitat types: FU = forested upland, P = prairie, FW = forested wetland, M= marsh, H = human managed (e.g. pasture, lawn), O = other (if other, describe)

Figure 8. Revised data entry form for ODAs, implemented August 28, 2010.

- The percent of oiling was not recorded for transect waypoints. The default value for all transect waypoints was 1–10%, and field crews were instructed to record information about the percent of oiling, if different from the 1–10% in the notes.
- Specific habitat features (i.e., pooled oil, water feature, vernal pool, downed tree, and skunk cabbage) were not recorded at transect waypoints.
- Marsh was added to the list of habitat types.

The habitat type (i.e., forested upland, prairie, forested wetland, human managed, other) continued to be recorded, and as with the previous format, a space was provided for notes.

Oil delineation areas

- At each ODA waypoint, the waypoint number was recorded and the waypoint was classified into one of three categories (simplified from the list of transitions provided in Section 2.3.1):
  - Start
  - Directional transition
  - End
- Oil polygon habitat type – the habitat type (i.e., forested upland, prairie, forested wetland, human managed, or other) present in the ODA was recorded once for each polygon, rather than for each individual waypoint.
- Polygon oiling – the degree of oiling observed in each polygon was recorded once for the entire ODA (rather than at each waypoint). Field crews were instructed to estimate the average degree of oiling over the ODA for the same features as the original form as follows:
  - Presence of visible soil
  - Percent of oil-covered visible soil
  - Percent of oil-covered herbs
  - Percent of oil-covered shrubs
  - Percent of oil-covered trees
- Oil polygon habitat features – the presence of habitat features [same as those described in Section 2.3.1, including pooled oil (> 50 ft^2), water feature (> 50 ft^2), vernal pool (> 50 ft^2), downed tree (> 4-in. DBH, and skunk cabbage) was recorded once for the entire ODA, instead of by waypoint.

2.3.2 Data recording methods

Field data were collected using hardcopy datasheets from August 13 to 18, 2010 (Figure 5, Section 2.3.1). Data were collected using electronic tablets from August 19 to September 2, 2010.[1] On a few occasions after August 18, some field crews used hardcopy datasheets due to computer problems (August 20) or rainy weather conditions that prevented computer use in the field (September 2).

When tablets became available on August 19, 2010, the field crews spent one day together testing the tablets. Data collection with the tablets began on August 20, 2010.

The tablets were IBM ThinkPad computers with a touch screen and stylus. The tablets were supplied and maintained by Burns and McDonnell, an Enbridge contractor.

The tablet capabilities included:

- Electronic data entry form
- Linked GPS for generating waypoints within the electronic data entry form
- Software to link photographs to waypoints.

Waypoint coordinates were recorded using the GPS unit integrated with the tablet, which had the ability to import the GPS information directly into the data entry form. Handheld GPS units were used to locate transects and help field crews orient themselves in the field. Data collection methods in the field were the same when using hardcopy datasheets and tablets, except when the use of technology led to changes in the logistics and mechanics of data collection methods. Photographs were manually linked to the waypoints at the end of each day using the software provided with the tablet computers. Field crews used the handheld GPS units to orient themselves along the proper transect, and waypoints were recorded using a remote GPS unit connected to the tablet and electronic data entry form using Bluetooth technology.

2.3.3 Surveying of islands

Island survey field data were collected from August 25 to August 29, 2010, using tablets. All islands in Divisions C and D were surveyed.

1. The original intent was to collect data using an electronic tool throughout the survey. However, because the electronic data collection tablets were not available when the NRDA group began collecting data, the group agreed to initiate field data collection using hardcopy field sheets (Figure 5). When the electronic tablets became available on August 19, 2010, the protocol was revised to reflect changes that occurred when the tablets were deployed in the field.

Data collection on islands followed the same protocol as for floodplain data collection, with the following exceptions. One transect was walked longitudinally along the center of each island. The islands were small enough that the field crew could see the entire island from the mid-point, and the entire island was inspected for ODAs that were delineated when appropriate. When surveying islands, teams started at the most downriver end of the island, recorded a waypoint, took one photograph facing upriver toward the island, and then took another photograph downriver facing away from the island. A waypoint was recorded and photographs were taken in a similar manner at the end of each island transect.

2.3.4 Surveying areas impacted by response activities

As response activities within the floodplain and field work progressed, floodplain field crews began encountering areas that had been cleaned and cleared of vegetation and oil as part of these activities. Field crews were instructed to treat the cleaned and cleared areas as ODAs, record waypoints and take photographs, and identify the area as being cleaned. They clearly identified these areas as having been cleaned and recorded the percent of oiling that was observed at the time of the floodplain survey.

2.4 Daily Data Management Methods

Field crews returned to the Incident Command Center at the end of each day to download collected data. Data were distributed to both Trustee and Enbridge representatives each day. Daily data management and recordkeeping activities were the responsibility of a designated member of each team. The rest of this section describes the data management methods.

From August 13 to 18, 2010, and on August 20, 2010, when data were collected using hardcopy sheets, the following daily data management protocols were followed. After completion of each day's field activities, hardcopy field datasheets were brought to the Incident Command Center. Two photocopies of each datasheet were made; the original datasheets remained with the Stratus Consulting field supervisor, one photocopy was given to a USFWS representative, and one photocopy was given to Entrix staff. Each datasheet was also scanned into a PDF document and saved to a project folder on a USB drive and a laptop hard drive. Folders were organized by date and survey name. Data were then transcribed from the hardcopy datasheets into an Excel template. All photographs, GPS coordinates, and Excel datasets were saved in the project folder according to the predetermined data date/surveyor/data type naming conventions specified in the protocol. Each day, all data were saved in folders in individual laptops and then backed up on an external hard drive dedicated to the project, to the Entrix FTP site dedicated to the project, and to jump drives.

From August 19 to September 2, 2010, when data were collected with the tablets, the following data management protocols were followed. Each day after the field work was completed, the tablet files were saved as .xml files labeled with the date and survey name information: <date>_<last name>. (On September 2, 2010, when data were collected in the field using hardcopy datasheets due to rainy weather, field crew members entered the day's data into their tablets back at the Incident Command Center and those data were then handled as if collected using the tablets.)

Floodplain assessment photographs were uploaded to the tablet hard drive at the end of each day and saved to the Floodplain_Assessment_Survey_Photos folder and named using a predetermined convention, summarized in the protocol, that included the map transect number, L/R descending side, and photograph number. Photograph file paths were inserted into respective transect-specific files on each team's tablet, linking the photographs with the waypoint at which they were taken.

At the end of each day, after saving the complete .xml file with associated photographs, the entire file was saved on an external hard drive dedicated to the project and an additional jump drive before returning the tablet to the Burns and McDonnell trailer at the Incident Command Center. Burns and McDonnell had their own daily data management protocol, which included uploading the data to their OneTouch PM site, a Google Earth-based application that was established and intended to contain all data collected as part of the response activities related to the incident.

On August 20, 2010, the thumb drive with downloaded data from that day was lost prior to uploading the data to the external hard drive. Data for that day were recovered from the Burns and McConnell OneTouch PM site.

3. Database Development and GIS Mapping Methods

Stratus Consulting incorporated the data collected as part of the floodplain sampling effort into an Access database. The data were then summarized in tables and GIS maps (the results are presented in Section 4). Section 3.1 describes the database development and Section 3.2 the GIS mapping methods used to compile the data into electronic format.

3.1 Database Development

After all field data were collected, Stratus Consulting created an Access database to compile and manage the data.

All data were preserved in their original format and structure on a write-protected hard drive before incorporation into the database. Data included all original GPS waypoint data, scanned images of hardcopy datasheets, photographs, and .xml files from the tablets. Using an Excel spreadsheet, the original data were then inventoried as follows: collection format (hard copy or tablet), date collected, field crew members, transect IDs, GPS waypoints (for waypoints collected with handheld GPS units), approximate MP and shore side (left or right), GPS unit ID (for data collected with handheld GPS units), GPX export file name and location (for handheld GPS unit data), .xml file name (for data collected using tablets), location and name of PDF scans of hardcopy field forms, location of transect and ODA data on Stratus Consulting network, and whether data were imported into the Access database.

Next, all data entered on the hardcopy datasheets (i.e., transect ID, date, field crew members, GPS unit ID, waypoint ID, camera ID, MP, habitat type, oiling, habitat features, skunk cabbage, and photograph numbers) were entered into the Access database. Although field crews entered the data into an Excel file after returning from the field each day, a quality assurance/quality control (QA/QC) comparison of the hardcopy sheets to the Excel files indicated that there were inconsistencies between the original field sheets and the data entered into the Excel templates. Additionally, the Excel files were not in a format that would allow easy incorporation into an Access database. Therefore, it was determined to be more efficient and accurate to re-enter the data into the database from the original field datasheets. Data collected using the tablets were imported into the Access database from the .xml files using an XML translator (translates files from .xml format into Access 2010 format) provided by Burns and McDonnell, the Enbridge contractor who developed and managed the tablets in the field.

Data collected on hardcopy datasheets, the original tablet form, and modified tablet entry forms were stored in separate tables within the database. Photographs were saved as separate files, electronically linked to the database, and associated with the correct waypoints.

After data were incorporated into the Access database, a 100% QA/QC was performed on data that were manually entered into the database from the hardcopy field datasheets according to the following steps:

- Stratus Consulting received the original field datasheets and scanned PDFs. The first QA/QC step was to verify that there was an electronic version of every hardcopy datasheet.

- The data were then entered into the Access database from the PDF scans of the hardcopy datasheets.

- After all the data had been entered into the Access database, a version of the database was printed. The printed Access database was compared against the original datasheets, and any errors were identified and corrected.

- The identified errors were random and consisted of:
  - Typographical errors
  - Differences in handwriting interpretation because the handwriting was sometimes difficult to read
  - Missing information.

A QA/QC of the .xml data was not required because they were not manually entered into the database. However, to ensure that the data were translated properly from .xml format to the Access database format, we performed a QA/QC by verifying that all data in the .xml files were incorporated into the Access database.

3.2 GIS Methods

The floodplain survey results are summarized in maps and tables generated in GIS. Three sets of maps were generated. The first set of maps shows the degree of oiling recorded in the floodplain during the survey and the locations of each transect, transect waypoint, and ODA. Locations encountered in the floodplain that were impacted by response actions are also shown. The second set of maps shows what habitat type (i.e., forested upland, prairie, forested wetland, human managed, or other) was recorded in the field at each waypoint. The third set of maps shows the waypoints where water features and vernal pools were observed and the degree of oiling. Data summarized in tabular format include the number of transects walked in each division and the degree of oiling, the number of miles walked and the number of waypoints recorded, the degree of oiling associated with each habitat type, observations of habitat features, and observations about skunk cabbage and skunk cabbage health.

3.2.1 Transects and oil delineation areas by percent oiling

All waypoints collected as part of the floodplain sampling effort were imported from the Access database into GIS format. Transect waypoints were then connected to form transect lines to represent the path walked by the field crews. ODA waypoints were connected to create polygons encompassing the ODA. Each ODA polygon was created in GIS by evaluating the order in which waypoints were recorded for the ODA by the field crews, and any field crew notes describing the oiled area in relation to geographic features and physical obstructions (e.g., “edge of water closes polygon”). Notes on the generation of each polygon in GIS are provided in Appendix B.

Once the transects and ODA polygons were generated in GIS, each feature (i.e., waypoint, transect, ODA) was assigned the percent of oiling from the Access database. This was done as follows:

Waypoints

In the original protocol, the percent of oiling was recorded at each waypoint for visible soil, herbs, shrubs, and trees. Waypoints were assigned as 1–10% oiling if a value between 1 and 10% was recorded at the waypoint for least one type of vegetation or soil. If all vegetation types and soil were assigned 0% oil at a waypoint, that waypoint was assigned 0% oil. If the percent of oiling for at least one type of vegetation or soil was recorded by crews as greater than 10%, the waypoint was assigned the highest percent of oiling recorded (e.g., for a waypoint with the following recorded oiling: visible soil = 0%, herbaceous vegetation = 15%, shrubs = 0%, and trees = 0%, the waypoint would be assigned an oiling of 15%). Based on visual examination of photographs, the vegetation type with the highest recorded percent of oiling at a given waypoint was often the dominant vegetation type present at that waypoint.

Transects

Transects were assigned a percent of oiling based on the oiling information recorded at the transect waypoints. The following logic was adopted for assigning the percent of oiling to transects:

- Transects between two waypoints with 0% oiling were assigned 0% oiling
- Transects between one waypoint with 0% oiling and one waypoint with 1–10% oiling (in at least one vegetation type) were assigned 1–10% oiling
- Transects between two waypoints with 1–10% oiling (in at least one vegetation type) were assigned 1–10% oiling
- Transects between two waypoints with greater than 10% oiling were assigned 1–10% oiling (it is assumed that ODAs were not delineated at these locations because the observed greater than 10% of oiling covered an area less than 50 ft^2 at the waypoints.

According to the revised protocol, a default value of 1–10% oiling was assigned to the transect waypoints, unless information in the field notes indicated a different percent of oiling. The percent of oiling was assigned to transect lines between waypoints collected using the modified protocol by following the same logic described above.

Oil delineation areas

For ODAs mapped under the original protocol, the percent of oiling for each waypoint in the ODA was recorded on soil and on vegetation layers. Review of the photographs taken at ODA waypoints indicate that the dominant vegetation layer or soil typically had the highest percent oiling at each ODA waypoint. Thus, the overall degree of oiling for ODAs was assigned by

identifying the highest degree of oiling across soil and vegetation layers at each waypoint (which for the most part was either soil or the herbaceous layer), and then taking the average of these highest oiling percentages for all of the ODA waypoints. This method of assigning oiling to ODAs was used for data collected from August 13 to August 27, 2010. For data collected using the revised protocol (August 28 to September 2, 2010) in which a percent oiling was assigned to soil and each vegetation layer for the entire ODA, the highest percent of oiling across soil and vegetation types was assigned to the polygon.

Exceptions to GIS mapping methods

Waypoints and linear features with greater than 10% oiling

In some cases, the crews recorded greater than 10% of oiling at a single waypoint along a transect, but no ODA was delineated at those points presumably because the area with greater than 10% oiling was less than 50 ft^2.

There were also some instances where field crews specified an ODA but marked it with only two waypoints but did not provide an explanation in the field notes. These are shown on the maps as linear features, and the degree of oiling is assigned according to the values recorded by the field crews.

Transects with 0% oiling

If locations with no oil observed were encountered either at the start or at some point along a transect, the protocol indicated that the field crews should take a waypoint and end the transect. At some locations, field crews specifically indicated that there was no oil (0%) present at a waypoint but then continued along the transect. In these instances, the waypoints and transects were mapped as recorded by the field crews using the logic for assigning the percent of oiling to transects described above.

ODAs with less than 10% oiling

There were two instances where the percent of oiling for an ODA was recorded as less than 10%. In one case all waypoints in the polygon were assigned 5% oiling; in the other, the average oiling was 10%. It is unclear why the field crews delineated these areas as ODAs given that the degree of oiling was not greater than 10%. These polygons are shown in Figures 17, 18, and 21 in Section 4.1.

3.2.2 Habitat types

In the original protocol (August 13–27, 2010), the type of habitat was recorded at each transect and ODA waypoint. The habitat types were forested upland, prairie, forested wetland, human managed, or other (if other, field crews were instructed to provide a description). In the revised protocol (August 28–September 2, 2010), the type of habitat was recorded at each transect waypoint and for each ODA (i.e., habitat types were recorded once for each ODA and not at each ODA waypoint). From these data we generated a series of maps that identify the habitat type assigned to each waypoint or ODA and a table summarizing the same information.

3.2.3 Habitat features

Information about specific habitat features was collected for transects and ODAs during the floodplain survey. In the original protocol (August 13–27, 2010), the habitat features were recorded at each transect and ODA waypoint. The habitat features observed included pooled oil greater than 50 ft^2, water feature greater than 50 ft^2, vernal pool greater than 50 ft^2, downed tree greater than 4 in. DBH, and the presence and relative health of skunk cabbage, if present. After the protocol was revised to streamline data collection (August 28– September 2, 2010), habitat features were no longer recorded at transect waypoints, and were recorded for the entire ODA (not by ODA waypoint). This information was summarized in a table. A series of maps were generated identifying water features and vernal pools classified according to degree of oiling. Those areas for which this information was not collected due to the protocol revision are indicated on the maps.

4. Results

Section 4.1 presents the floodplain oiling results, Section 4.2 presents the habitat types, and Section 4.3 presents the habitat features.

4.1 Floodplain Oiling Results

The floodplain sampling effort was conducted between MP 2 in Division B and the most downstream section surveyed at MP 32.25 in Division E (approximately five miles upstream of the entrance to Morrow Lake). Field crews walked 744 transects throughout the floodplain.Table 2 summarizes the number of transects walked in each Kalamazoo River division. The majority of transects (79%) walked were in Division C (MP 2.25–17.25). The total length of transects walked was 25 miles. Table 3 summarizes transect miles walked by division.

Table 2. Number of transects walked by division

Division	MP[a]	Number of transects	Number of transects with at least 1–10% oiling	Number of transects with 0% oiling
A	0–0.25	0	0	0
B	0.25–2.00	3[b]	3[b]	0
C	2.25–17.25	581[b]	439[b]	142
D	17.5–23.75	94	35	59
E	24–40	64	7	57

a. MP shown as the nearest quarter mile that falls within each division.
b. One transect crosses from Division B to Division C (a two-waypoint transect with one waypoint in each division, which we assigned to Division B).

Table 3. Total floodplain miles walked by division

Division	MP[a]	Transect miles walked	Number of individual waypoints
A	0–0.25	0	0
B	0.25–2.00	< 0.01	2
C	2.25–17.25	17.5	170
D	17.5–23.75	6	51
E	24–40	1	28

a. MP shown as the nearest quarter mile that falls within each division.

Figures 9–35 show all transects where data were recorded during the floodplain survey and the percent of oiling recorded at each waypoint, transect, and ODAs. Figures 9–12 are overview maps that show the full extent of the survey. Figures 13–35 are detailed maps that show the sections where transects were walked. All ODAs (areas with greater than 10% oiling covering at least 50 ft^2) are located in Division C. The total area delineated as ODAs throughout the floodplain was 10.2 acres. The percent of oiling observed in ODAs ranged from 11 to 100%, except for two ODAs (described above) where the percent of oiling recorded by the field crews was less than 10%. The largest number of ODAs were in the 71–90% oiling category (34% of all ODA observations, not including the two ODAs with less than 10% oiling).

Field crews were unable to survey Division A due to response actions. Only two full transects were completed in Division B (Table 2), also due to limited access as a result of response actions. Areas in Divisions D and E where field crews did have access had some areas of sporadic oiling, although the degree of oiling observed in these two divisions was less than

Division C based on the number of transects with sporadic oiling (Table 2). Of the areas sampled during the floodplain survey, Division C had the most oil present throughout the floodplain, based on the proportion of transects with at least 1–10% oiling (Table 3), and the distribution of ODAs in the floodplain. Particularly heavily oiled areas in Division C were observed at MP 10 to 12 (Figures 20–22). Most of the single waypoints with greater than 10% oiling were also observed in Division C. In particular, a high concentration of single waypoints with greater than 10% oiling was identified from MP 10 to 12. It is presumed that these areas with greater than 10% oiling that were less than 50 ft^2. The field crews observed some locations in Division C that were not oiled. These areas were located primarily near MP 3.25, 6, and 10.5.

Field crews resurveyed some of the most heavily oiled areas later in the survey process to ensure that all ODAs were characterized. For this reason, the maps in Figures 9–35 show some overlapping of the ODAs. One ODA identified in the field notes was marked with a single point; this area was observed when data were collected using the hardcopy datasheets and waypoints were marked using handheld GPS units (maps 2 and 12, Figures 10 and 24). Two ODAs were delineated by the field crews as having 1–10% oiling, and it is unclear from the field notes and photographs why these were identified as ODAs if they were sporadically oiled (see Figures 17–19).

All of the 63 islands in the study area (MP 2.25 to 32.25) were surveyed. All islands in Division C up to MP 12.5 were sporadically oiled (Figures 9–35). Only two islands, one at MP 12.5 and one between MP 14.5 and 14.75, were not oiled. The island at MP 14.5–14.75 shows an ODA where response actions had been completed.

In general, a trend of decreasing oiling can be seen in the maps, and is illustrated in Table 2. In Division C, 76% of transects walked were sporadically oiled; in Division D, 37% of transects walked were sporadically oiled; and in Division E, 12% of transects walked were sporadically oiled. In particular, downstream of MP 18, 0% oiling was recorded at most transects. One exception occurs between MP 21.25 and 22.5, where sporadic oiling was observed (Figures 9–35).

4.2 Habitat Type Results

Figures 36–39 shows what type of habitat was identified for each waypoint during the floodplain survey. The predominant habitat types identified during the floodplain survey were forested wetland and forested upland. In areas where the heaviest oiling was observed, the most commonly identified habitat was forested wetland (e.g., the areas near MP 11–12). Table 4 summarizes these data.

Table 4. Oiling by habitat type

Habitat type	Total number of waypoints	Percent oiling 0	1–10	11–30	31–50	51–70	71–90	91–100	%0	%1–10	% > 10
Forested wetland	0	0	0	0	0	0	0	0			
Forested upland	0	0	0	0	0	0	0	0	NA	NA	NA
Human managed	0	0	0	0	0	0	0	0	NA	NA	NA
Marsh	1	0	1	0	0	0	0	0	0%	100%	0%
Prairie	0	0	0	0	0	0	0	0	NA	NA	NA
Other	2	0	2	0	0	0	0	0	0%	100%	0%
Not reported	0	0	0	0	0	0	0	0	NA	NA	NA
Division C – MP 2-5.75											
Forested wetland	56	21	19	13	1	1	0	1	38%	34%	29%
Forested upland	92	37	52	0	2	1	0	0	40%	57%	3%
Human managed	13	8	5	0	0	0	0	0	62%	38%	0%
Marsh	84	27	48	2	1	4	2	0	32%	57%	11%
Prairie	30	8	17	0	0	1	4	0	27%	57%	17%
Other	4	4	0	0	0	0	0	0	100%	0%	0%
Not reported	5	0	0	0	0	0	0	5	0%	0%	100%
Division C – MP 5.75–13											
Forested wetland	566	167	158	49	44	47	88	13	30%	28%	43%
Forested upland	259	132	82	20	17	5	3	0	51%	32%	17%
Human managed	23	15	6	1	1	0	0	0	65%	26%	9%
Marsh	74	34	23	10	4	0	3	0	46%	31%	23%
prairie	42	27	8	1	5	0	1	0	64%	19%	17%
Other	19	9	3	2	5	0	0	0	47%	16%	37%
Not reported	6	3	3	0	0	0	0	0	50%	50%	0%

Table 4. Oiling by habitat type (cont.)

Habitat type	Total number of waypoints	Percent oiling									
		0	1–10	11–30	31–50	51–70	71–90	91–100	%0	%1–10	% > 10
Division C – MP 13–15.25											
Forested wetland	89	25	46	7	4	2	5	0	28%	52%	20%
Forested upland	58	19	18	12	9	0	0	0	33%	31%	36%
Human managed	1	1	0	0	0	0	0	0	100%	0%	0%
Marsh	35	17	11	1	4	0	1	1	49%	31%	20%
Prairie	8	4	3	1	0	0	0	0	50%	38%	13%
Other	20	2	7	11	0	0	0	0	10%	35%	55%
Not reported	4	0	2	2	0	0	0	0	0%	50%	50%
Division D – MP 18–19.75											
Forested wetland	5	5	0	0	0	0	0	0	100%	0%	0%
Forested upland	8	7	1	0	0	0	0	0	88%	13%	0%
Human managed	0	0	0	0	0	0	0	0	NA	NA	NA
Marsh	0	0	0	0	0	0	0	0	NA	NA	NA
Prairie	4	4	0	0	0	0	0	0	100%	0%	0%
Other	7	6	1	0	0	0	0	0	86%	14%	0%
Not reported	0	0	0	0	0	0	0	0	NA	NA	NA
Division D – MP 20.25–22.75											
Forested wetland	66	35	31	0	0	0	0	0	53%	47%	0%
Forested upland	66	54	12	0	0	0	0	0	82%	18%	0%
Human managed	2	1	1	0	0	0	0	0	50%	50%	0%
Marsh	3	3	0	0	0	0	0	0	100%	0%	0%
Prairie	0	0	0	0	0	0	0	0	NA	NA	NA
Other	0	0	0	0	0	0	0	0	NA	NA	NA
Not reported	0	0	0	0	0	0	0	0	NA	NA	NA

Table 4. Oiling by habitat type (cont.)

Habitat type	Total number of waypoints	Percent oiling									
		0	1–10	11–30	31–50	51–70	71–90	91–100	%0	%1–10	% > 10
Division E – MP 23.25–24.25											
Forested wetland	3	2	1	0	0	0	0	0	67%	33%	0%
Forested upland	6	5	1	0	0	0	0	0	83%	17%	0%
Human managed	2	2	0	0	0	0	0	0	100%	0%	0%
Marsh	0	0	0	0	0	0	0	0	NA	NA	NA
Prairie	0	0	0	0	0	0	0	0	NA	NA	NA
Other	0	0	0	0	0	0	0	0	NA	NA	NA
Not reported	0	0	0	0	0	0	0	0	NA	NA	NA
Division E – MP 28.75–32.25											
Forested wetland	56	52	4	0	0	0	0	0	93%	7%	0%
Forested upland	35	35	0	0	0	0	0	0	100%	0%	0%
Human managed	0	0	0	0	0	0	0	0	NA	NA	NA
Marsh	2	1	1	0	0	0	0	0	50%	50%	0%
Prairie	0	0	0	0	0	0	0	0	NA	NA	NA
Other	0	0	0	0	0	0	0	0	NA	NA	NA
Not reported	0	0	0	0	0	0	0	0	NA	NA	NA

4.3 Habitat Feature Results

Table 5 summarizes the results of the habitat feature data collection. Because of the change in protocols, habitat feature data collected before and on August 27, 2010 may not be comparable to data collected after August 27, 2010. Table 6 summarizes the information on observations of skunk cabbage. These data were collected because the NRDA group had anecdotal evidence at the time of the survey that this species may be sensitive to oil (Chuck Getter, Research Planning Inc., Senior Ecologist, personal communication, August 18, 2010). These data show that skunk cabbage was observed at 212 locations; defoliated plants were observed at 160 locations,and plants growing new shoots were observed in 87 locations.

Table 5. Summary of habitat feature results[a]

	Number of observations				
Division (MP)[b]	**Pooled oil > 50 ft^2**	**Water feature > 50 ft^2**	**Vernal pool > 50 ft^2**	**Downed tree > 4 in. DBH**	**Skunk cabbage**
Division C (MP 2.25–17.25)					
ODA	60	60	17	81	62
Transect	15	185	36	270	141
Division D (MP 17.5–23.75)					
ODA[c]	NA	NA	NA	NA	NA
Transect	0	4	0	9	0
Division E (MP 24–40)					
ODA[c]	NA	NA	NA	NA	NA
Transect	0	50	1	42	8

a. From August 13 to 27, 2010, habitat features were recorded for all waypoints. During this time, the floodplain survey covered most areas in Division C, island habitats, and 11 transects in Division D. From August 28 to September 2, 2010 (during which time the survey covered Division E, and parts of Division D), observations of habitat features were recorded only for ODAs as a whole, and no longer for transect waypoints or for each individual waypoint in an ODA.
b. Although 2 transects were completed in Division B, the data were collected using the modified protocol and there were no ODAs delineated. Thus, no data about habitat features were recorded in Division B.
c. No ODAs were identified in Divisions D and E.

Figures 40–43 show the waypoint locations where water features or vernal pools were identified and the degree of oiling recorded at those locations for the time period that information on these habitat features was collected. The maps show the transects where this information was and was not collected.

Figures 40–43 illustrate that the highest density of water features and vernal pools were observed from MP 7–15. This is also the area where the highest degree of oiling was observed in the field.

Table 6. Presence and health of skunk cabbage

	Skunk cabbage (number of observations)			
Division (MP)[a]	**Presence**	**Healthy**	**Defoliated**	**New shoots**
Division C (MP 2.25–17.25)				
ODA	62	4	50	40
Transect	141	37	110	46
Division D (MP 17.5–23.75)				
ODA[b]	NA	NA	NA	NA
Transect	0	0	0	0
Division E (MP 24–40)				
ODA[b]	NA	NA	NA	NA
Transect	8	2	5	1

a. Although 2 transects were completed in Division B, the data were collected using the modified protocol and there were no ODAs delineated. Thus, no data about habitat features were recorded at these two transects.
b. No ODAs were identified in Divisions D and E.

References

AECOM. 2011. Enbridge Energy, Limited Partnership Line 6B Incident, Marshall, Michigan. Conceptual Site Model. Prepared May 10, 2011, approved July 8, 2011. Available: http://www.michigan.gov/deq/0,4561,7-135-3313_56784-248127--,00.html. Accessed 8/2/2011.

Owens, E.H. and G.A. Sergy. 1994 *Field Guide to the Documentation and Description of Oiled Shorelines*. Environment Canada, Edmonton, Alberta, Canada. March. ISBN 0-662-22048-X.

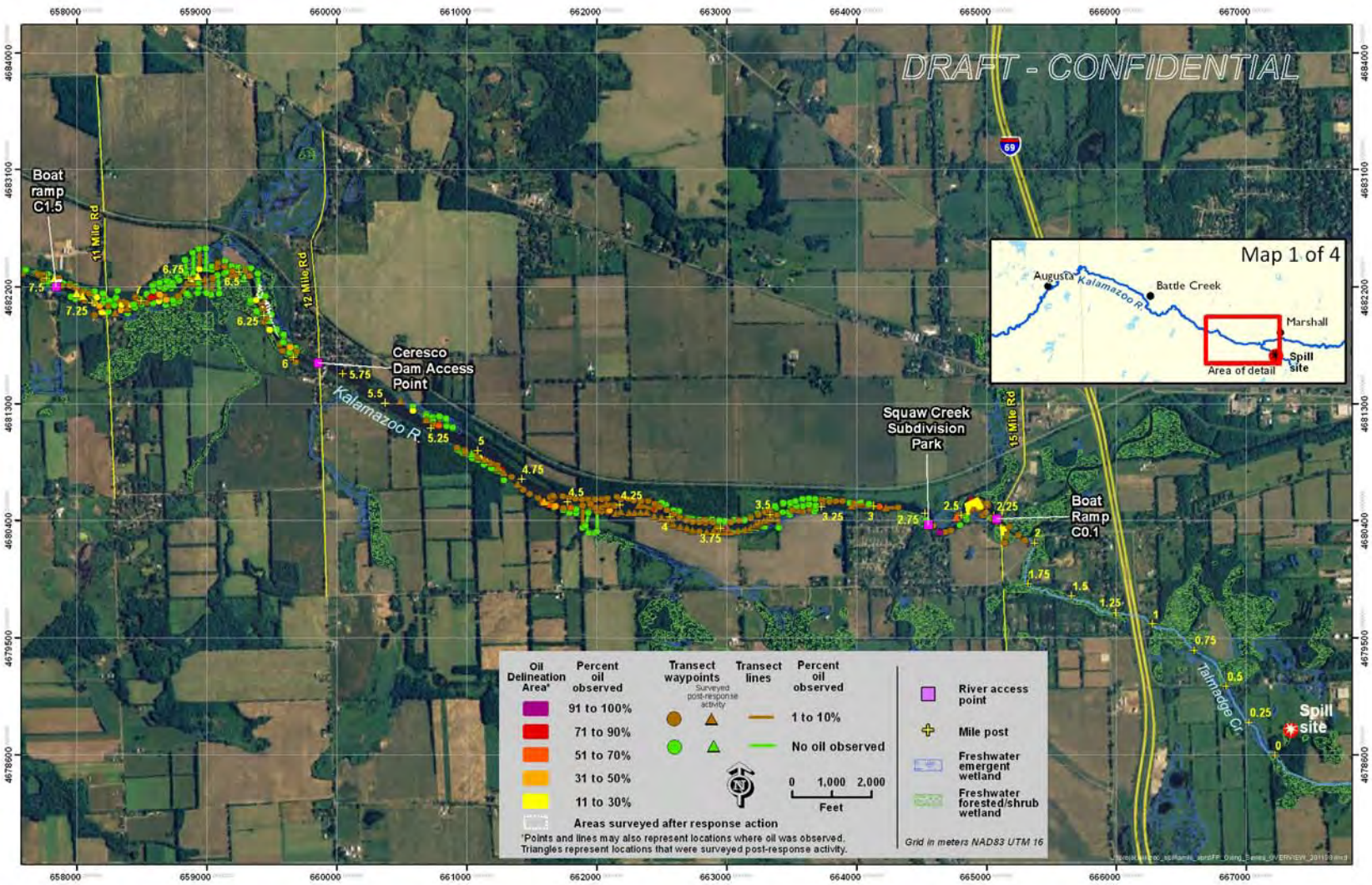


Figure 9. Overview map showing the transects and ODAs surveyed during the floodplain survey (MP 0–7.5).

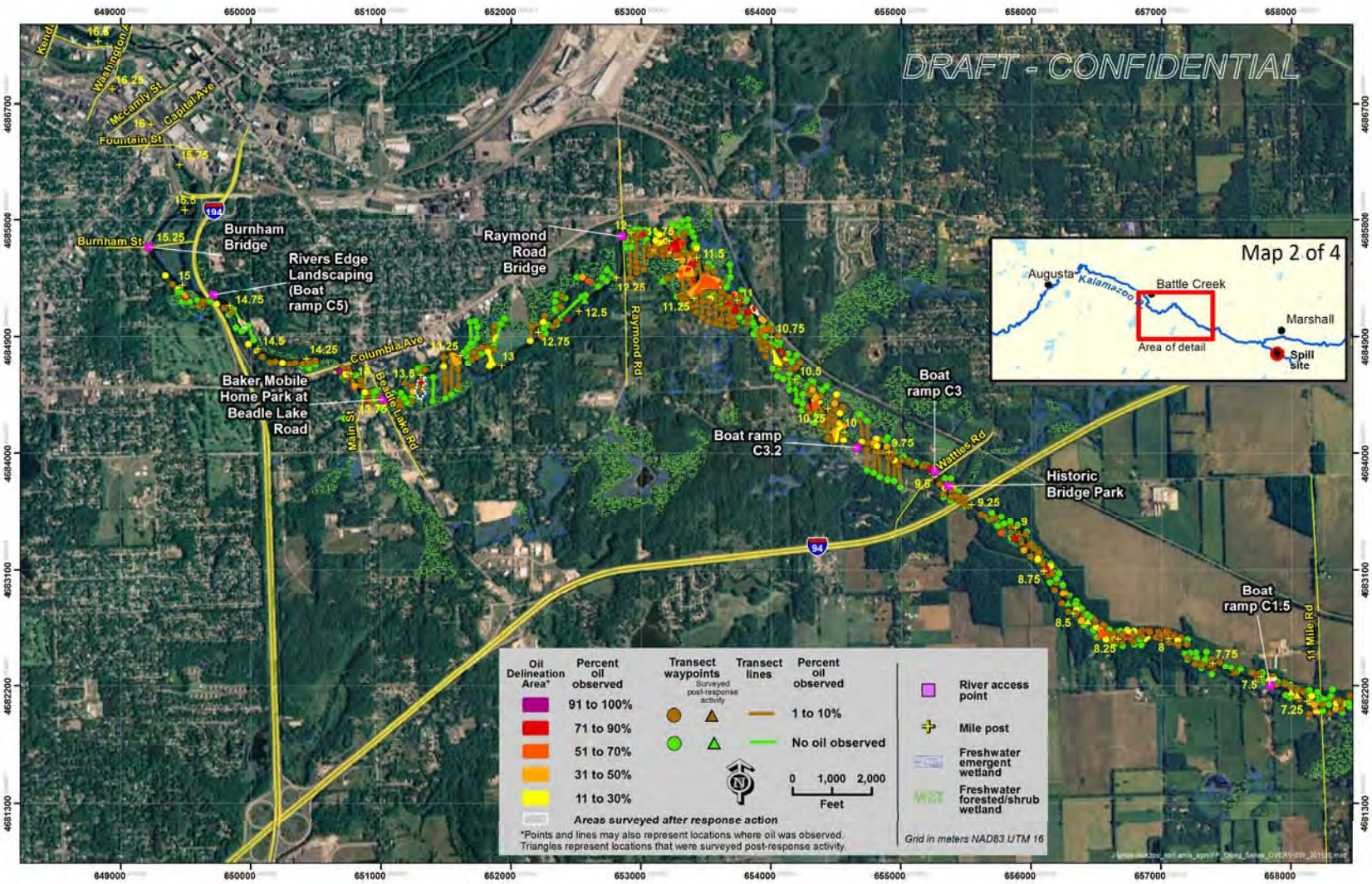


Figure 10. Overview map showing the transects and ODAs surveyed during the floodplain survey (MP 7.25–16.5).

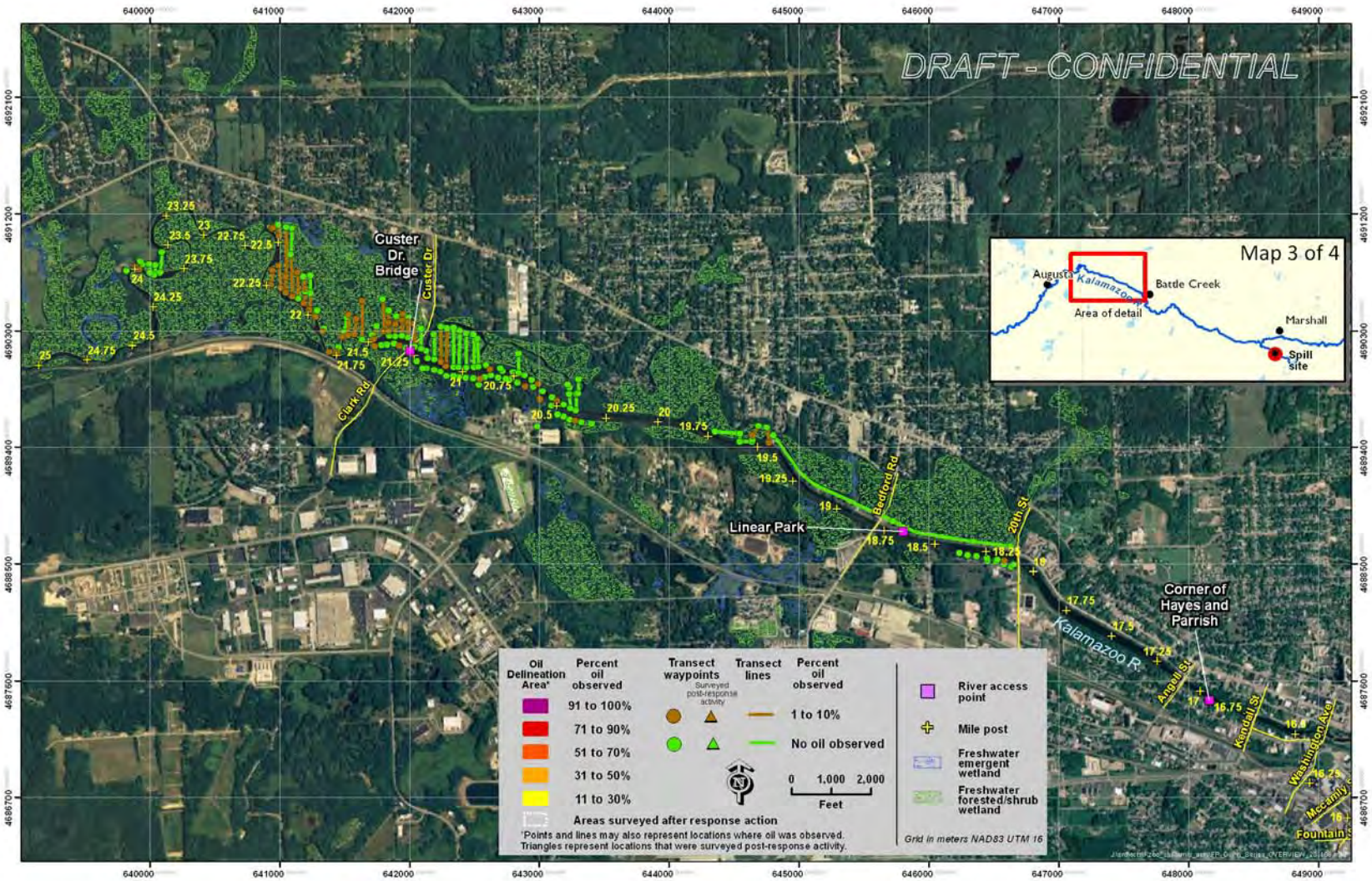


Figure 11. Overview map showing the transects and ODAs surveyed during the floodplain survey (MP 16–25).

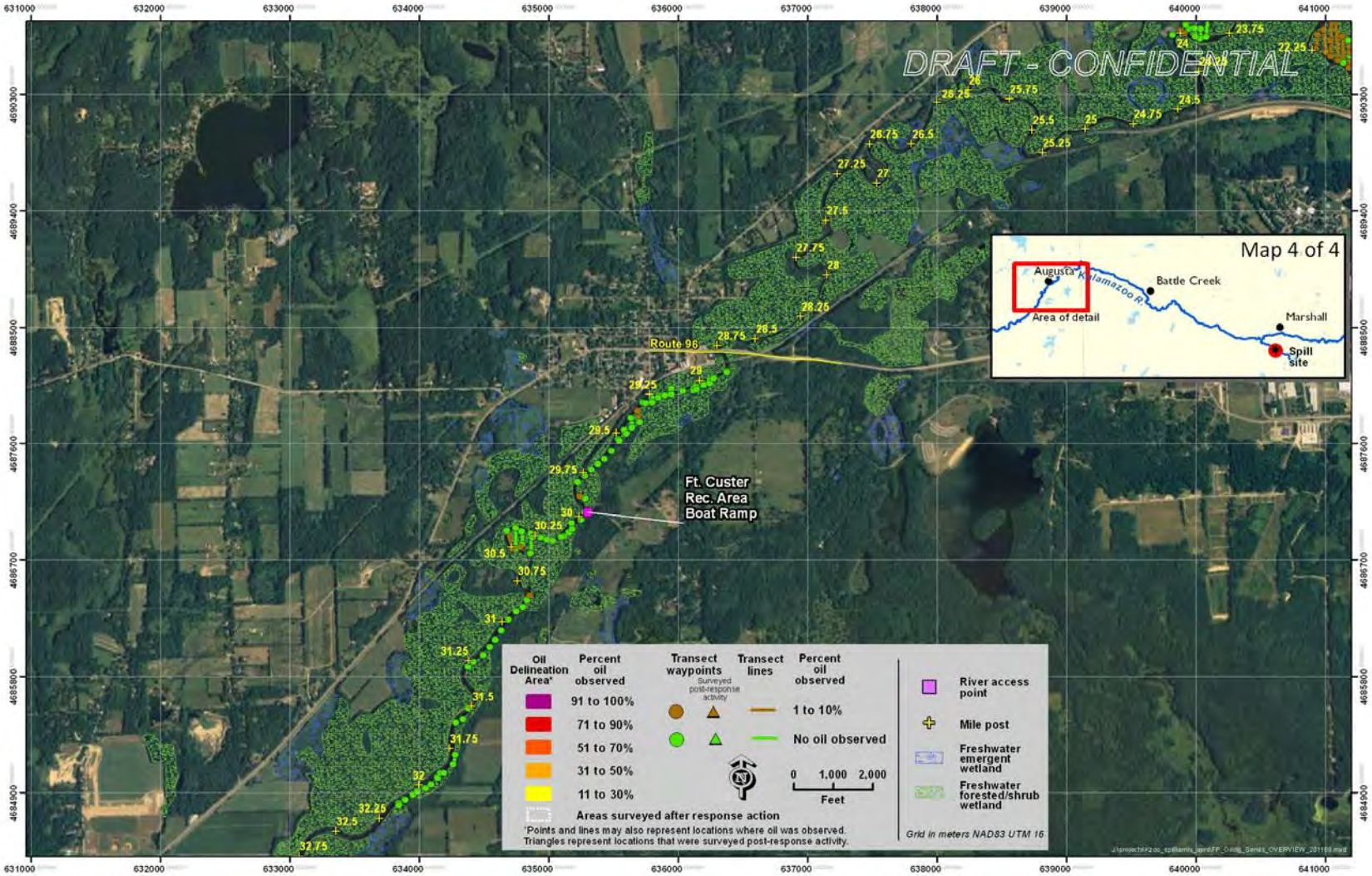


Figure 12. Overview map showing the transects and ODAs surveyed during the floodplain survey (MP 22.25–32.75).

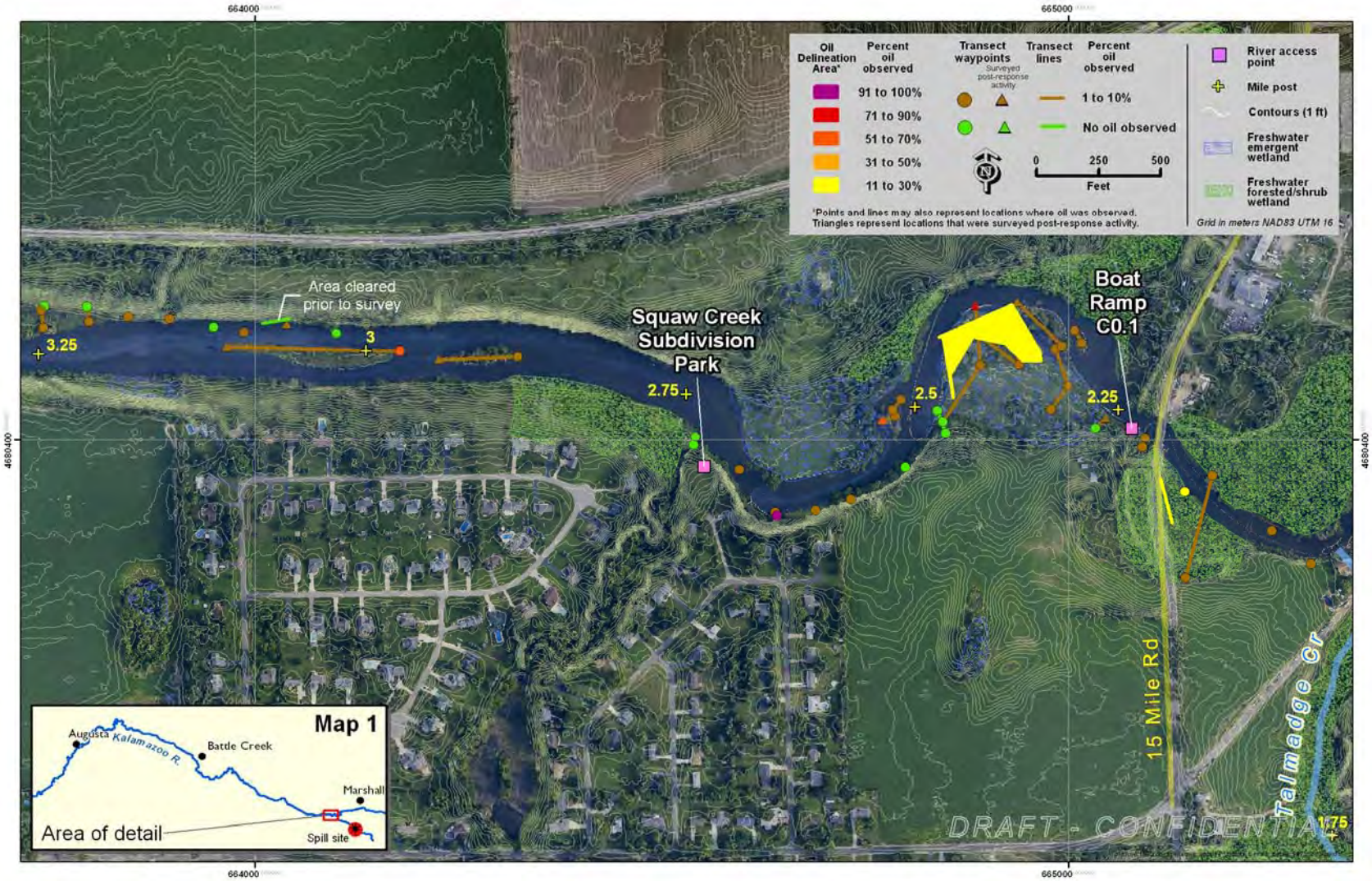


Figure 13. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 2.25–3.25).

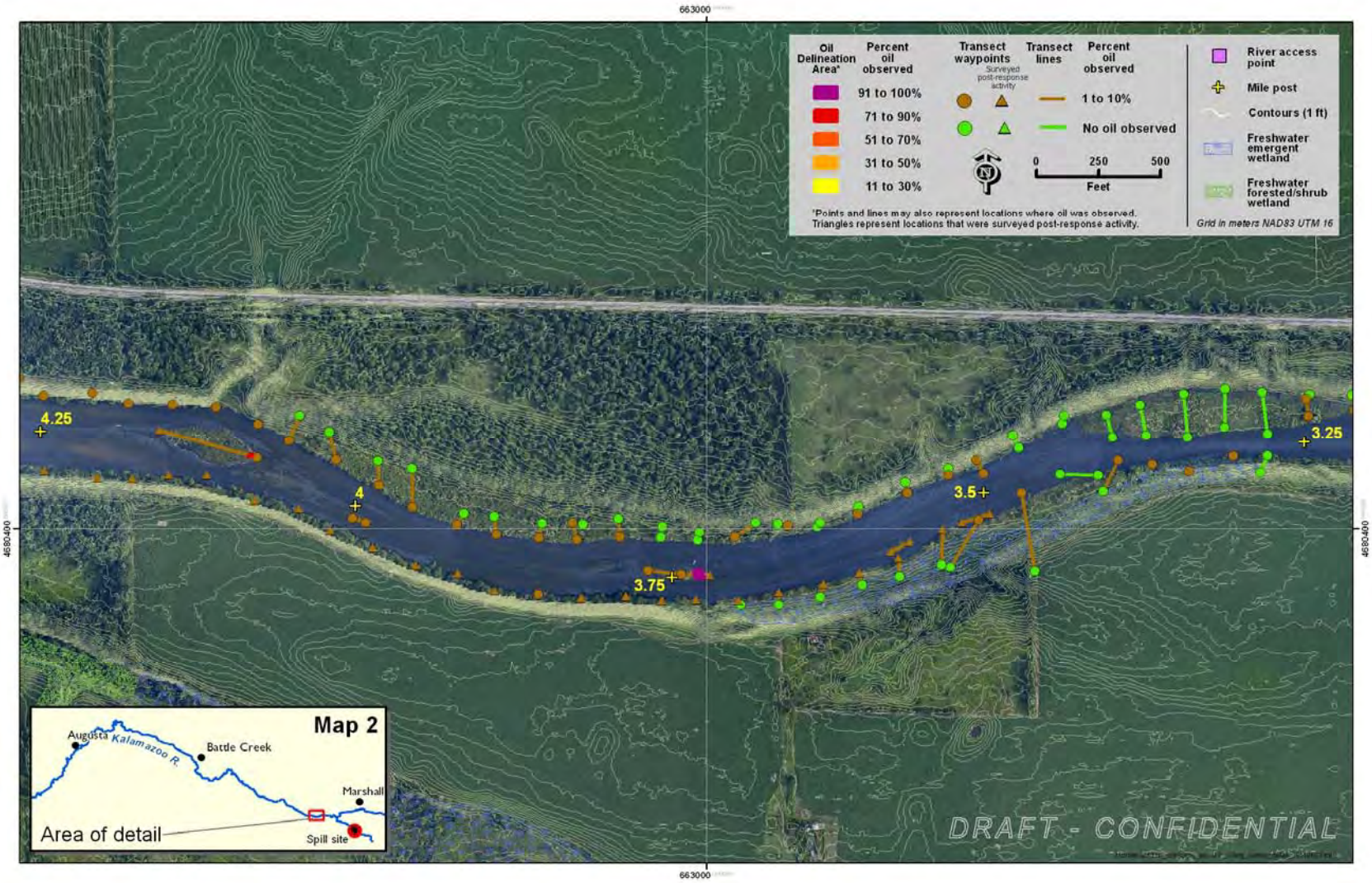


Figure 14. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 3.25–4.25).

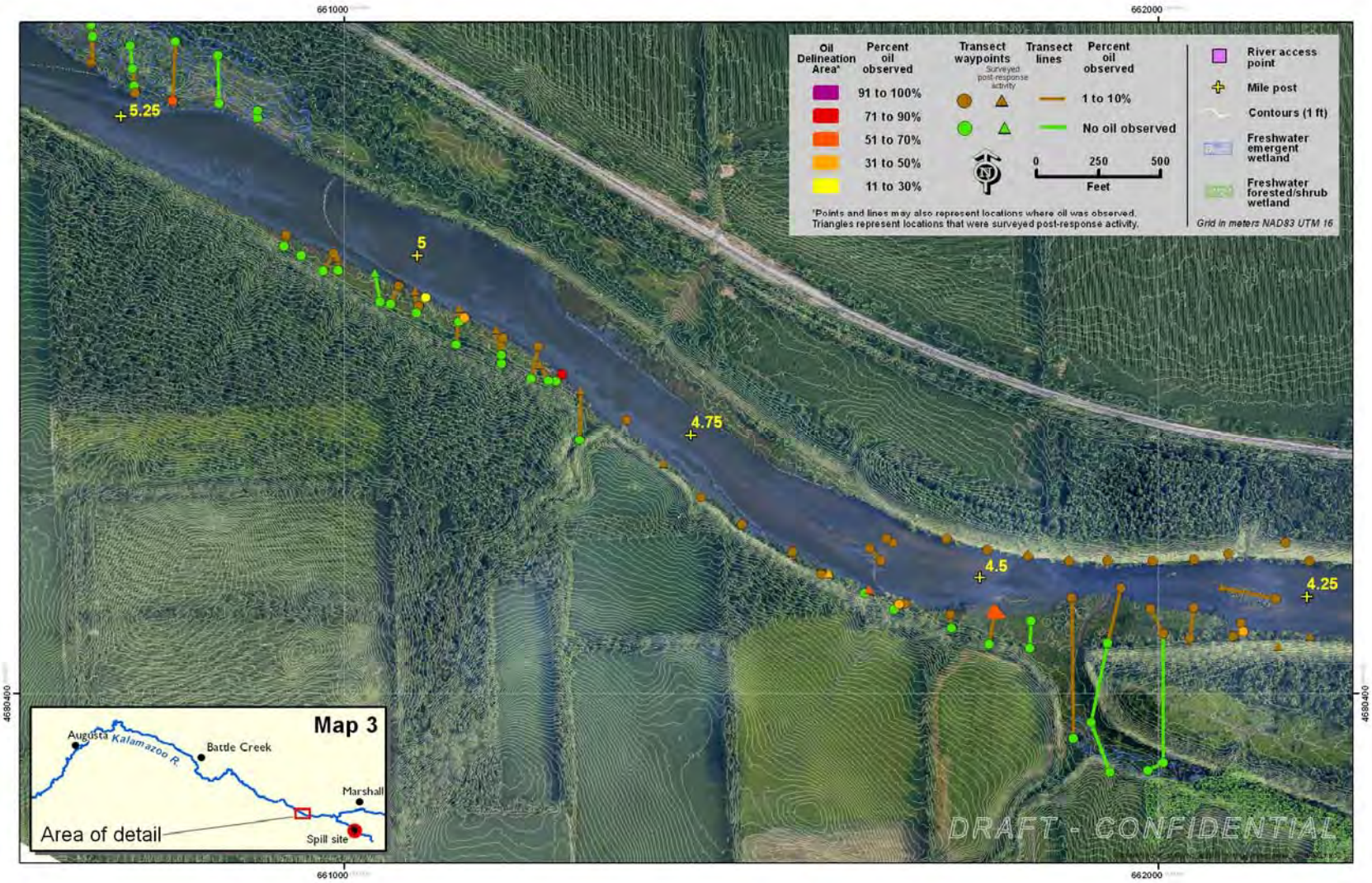


Figure 15. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 4.25–5.25).

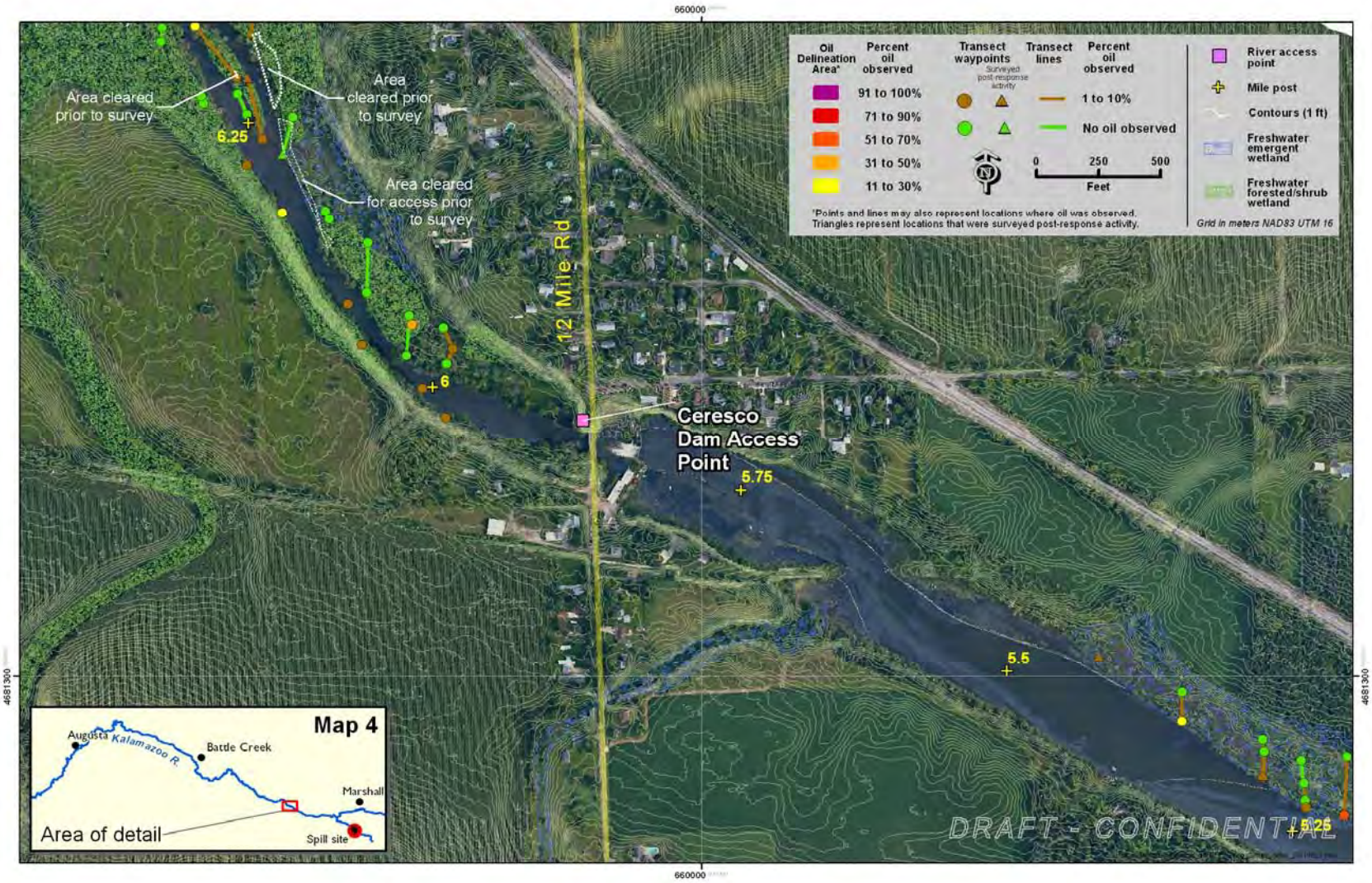


Figure 16. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 5.25–6.25).

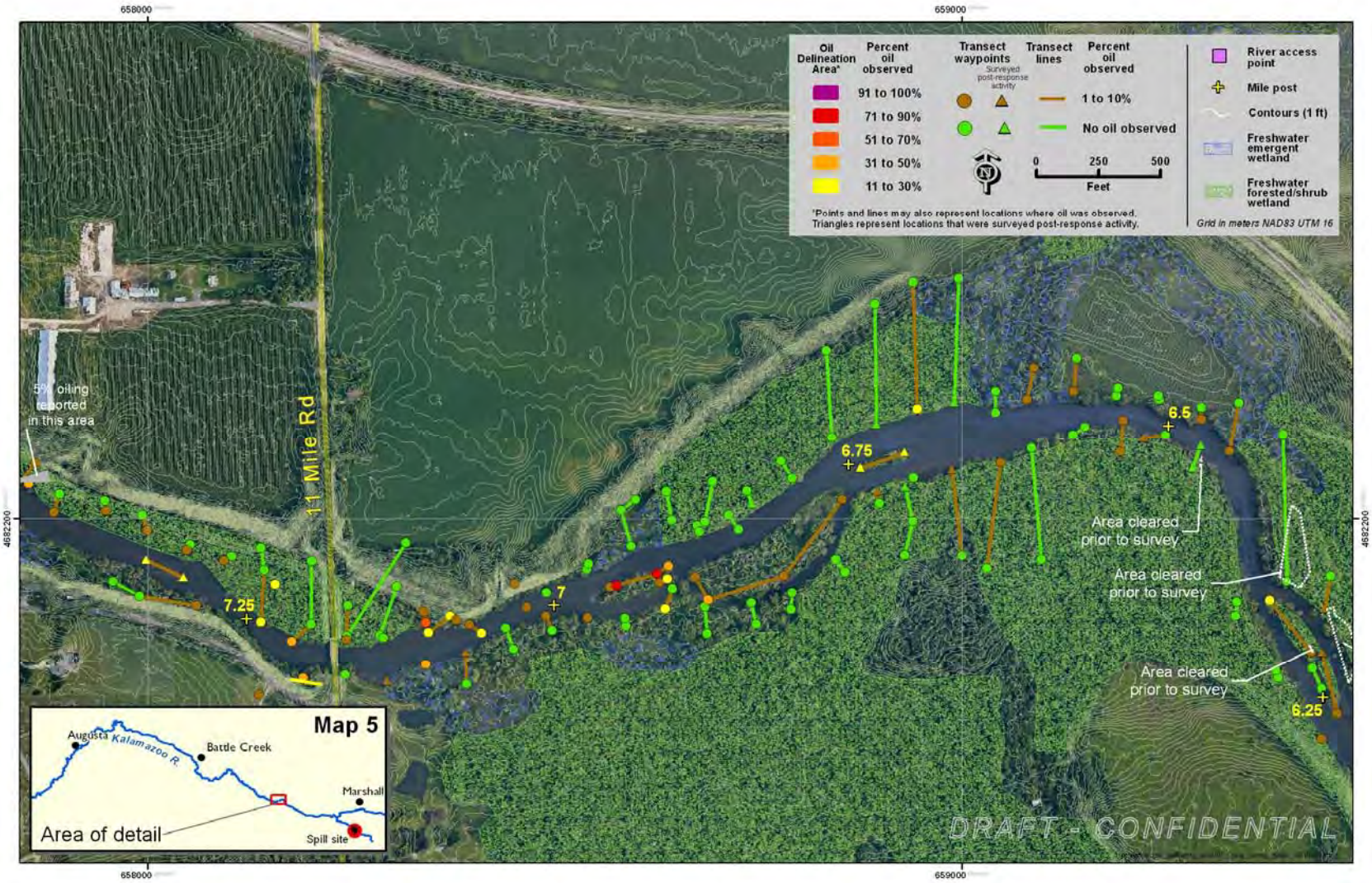


Figure 17. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 6.25–7.25).

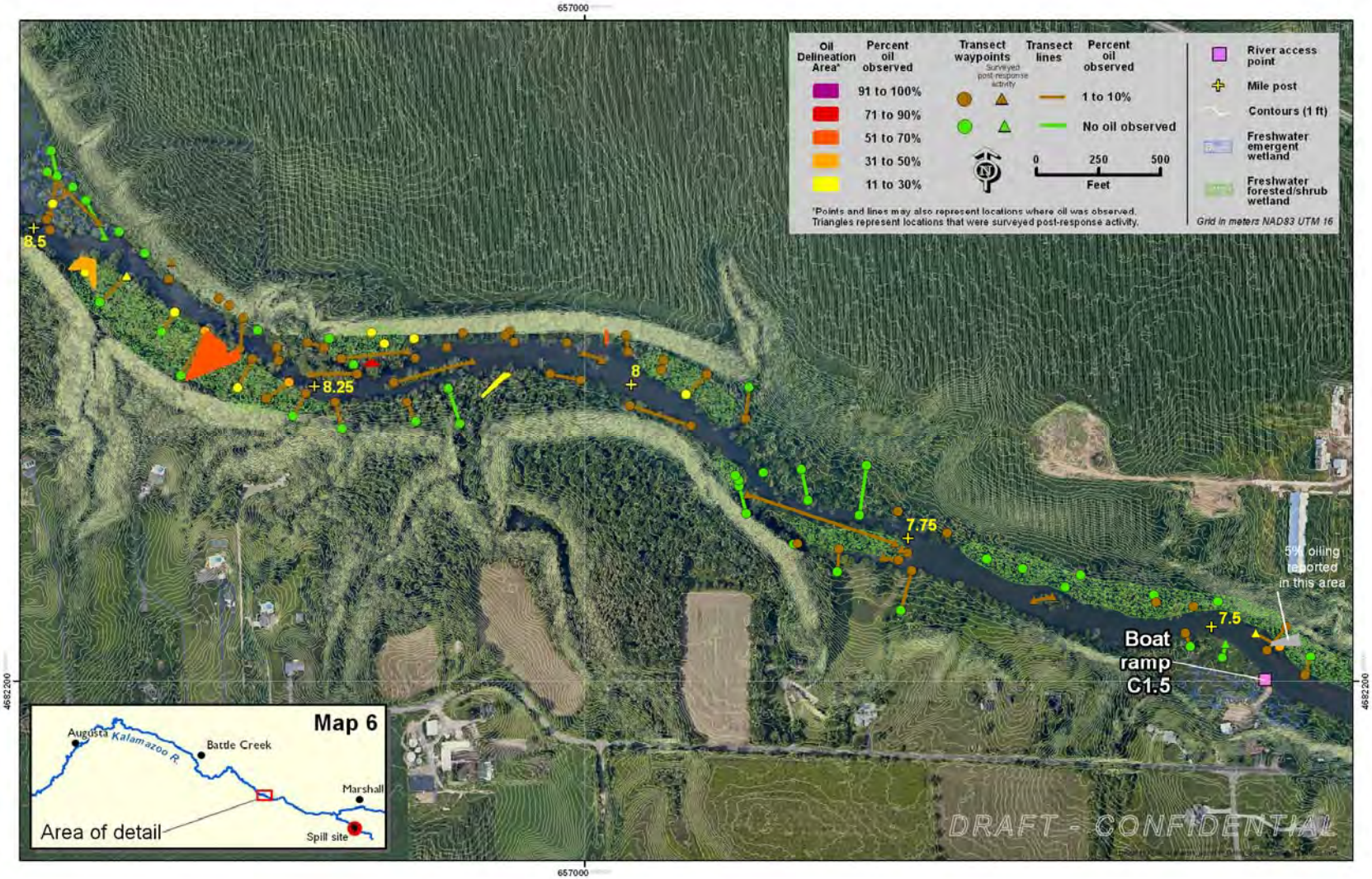


Figure 18. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 7.5–8.5).

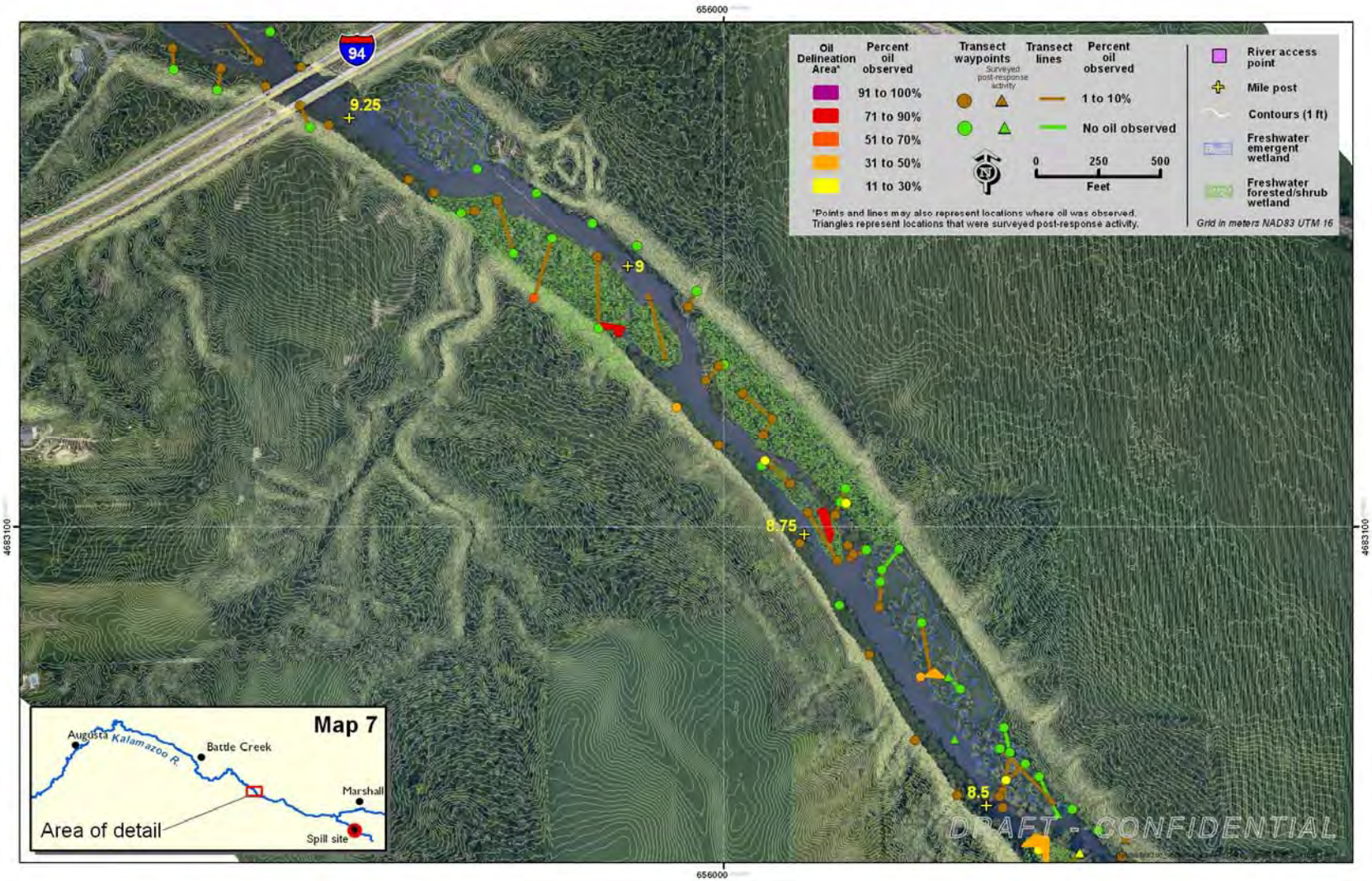


Figure 19. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 8.5–9.25).

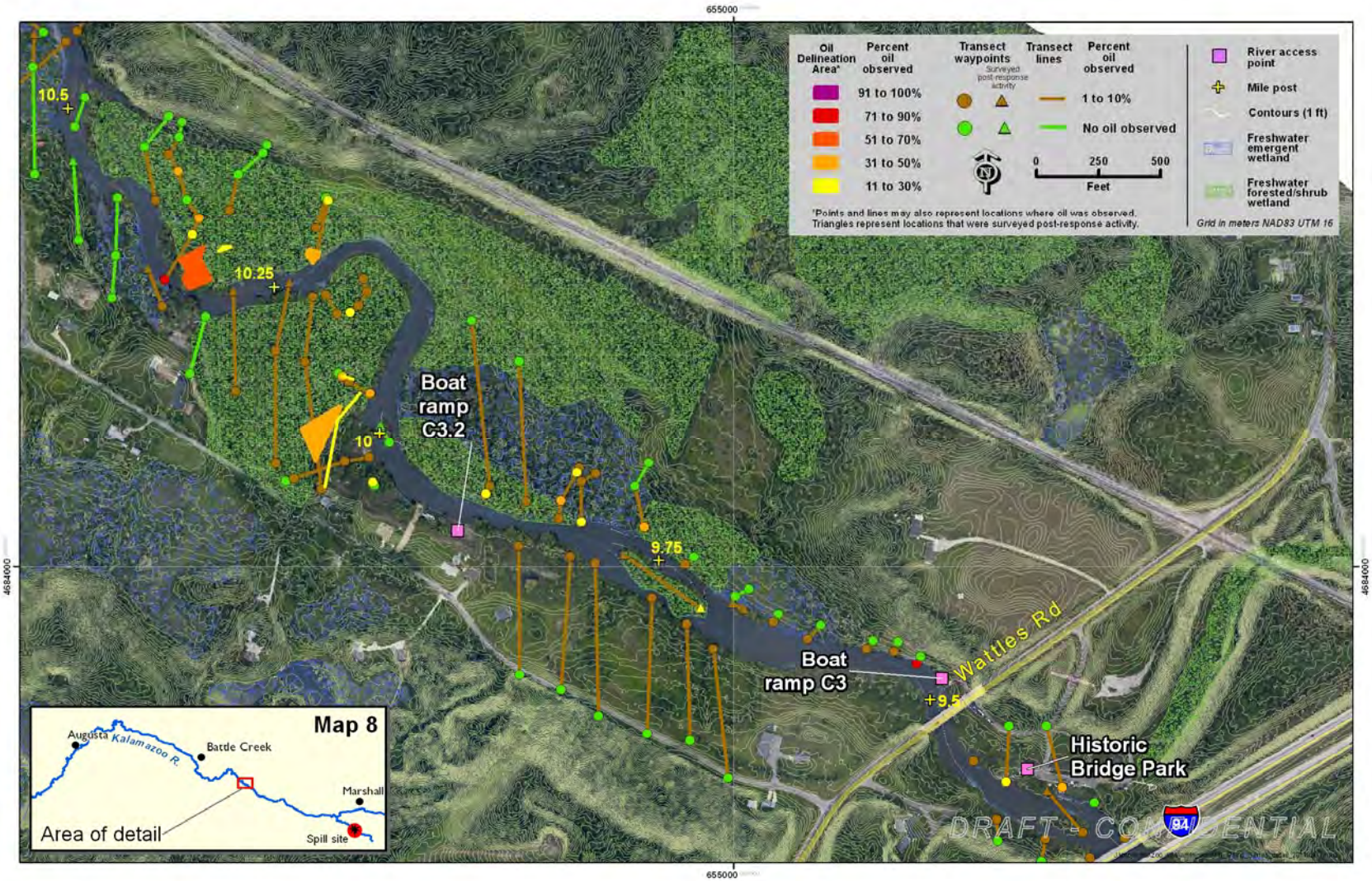


Figure 20. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 9.5–10.5).

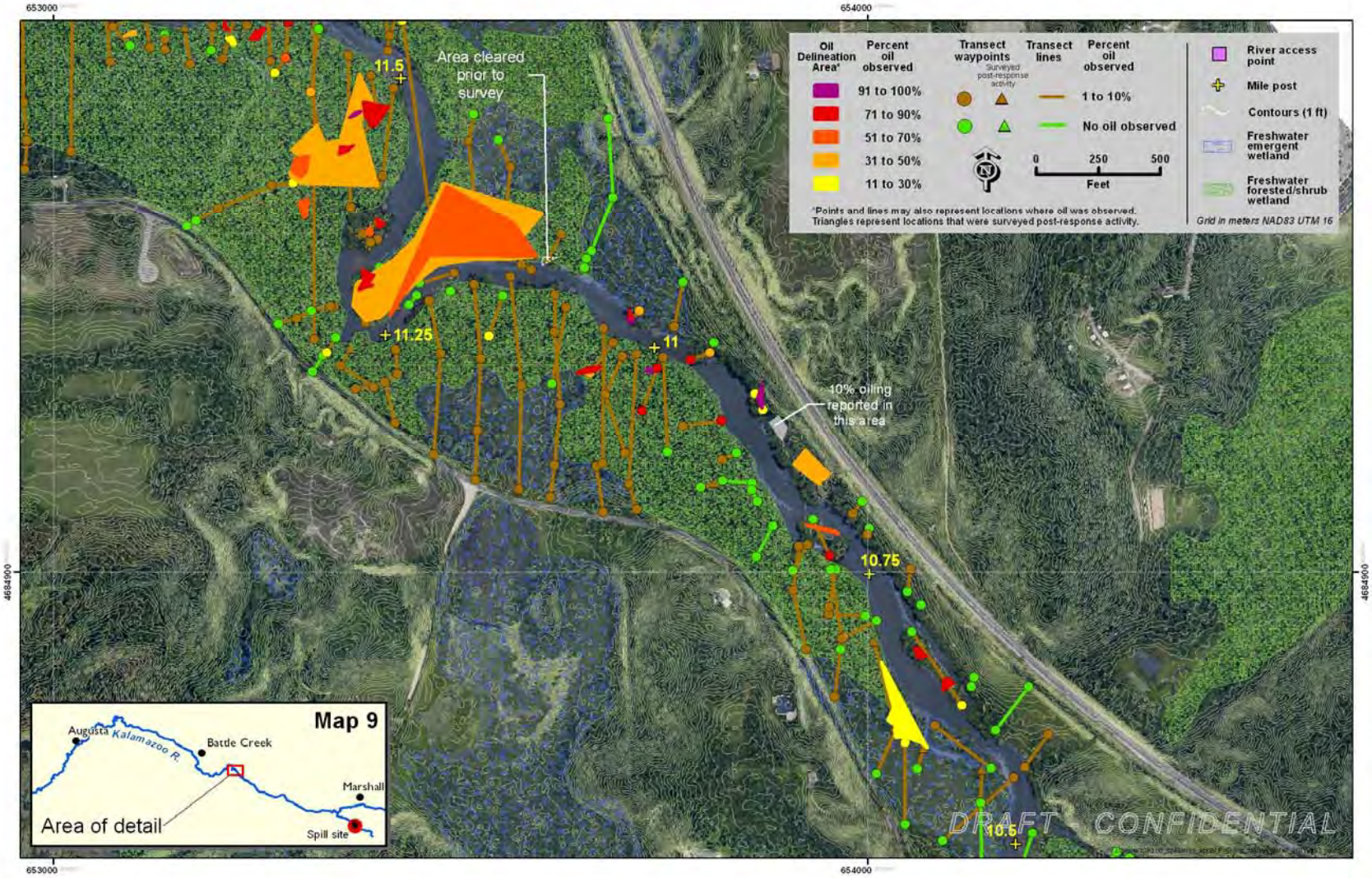


Figure 21. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 10.5–11.5).

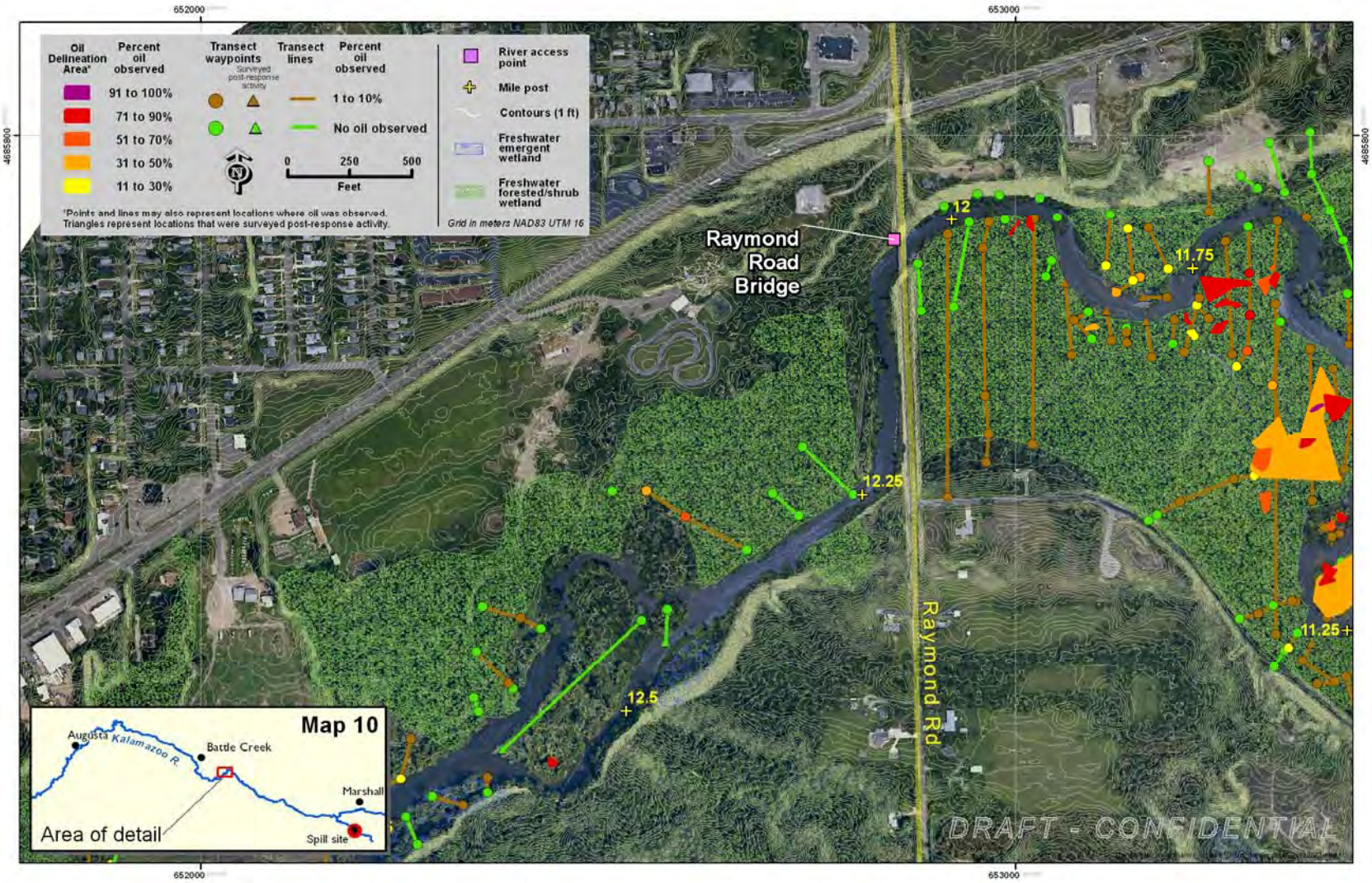


Figure 22. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 11.25–12.5).

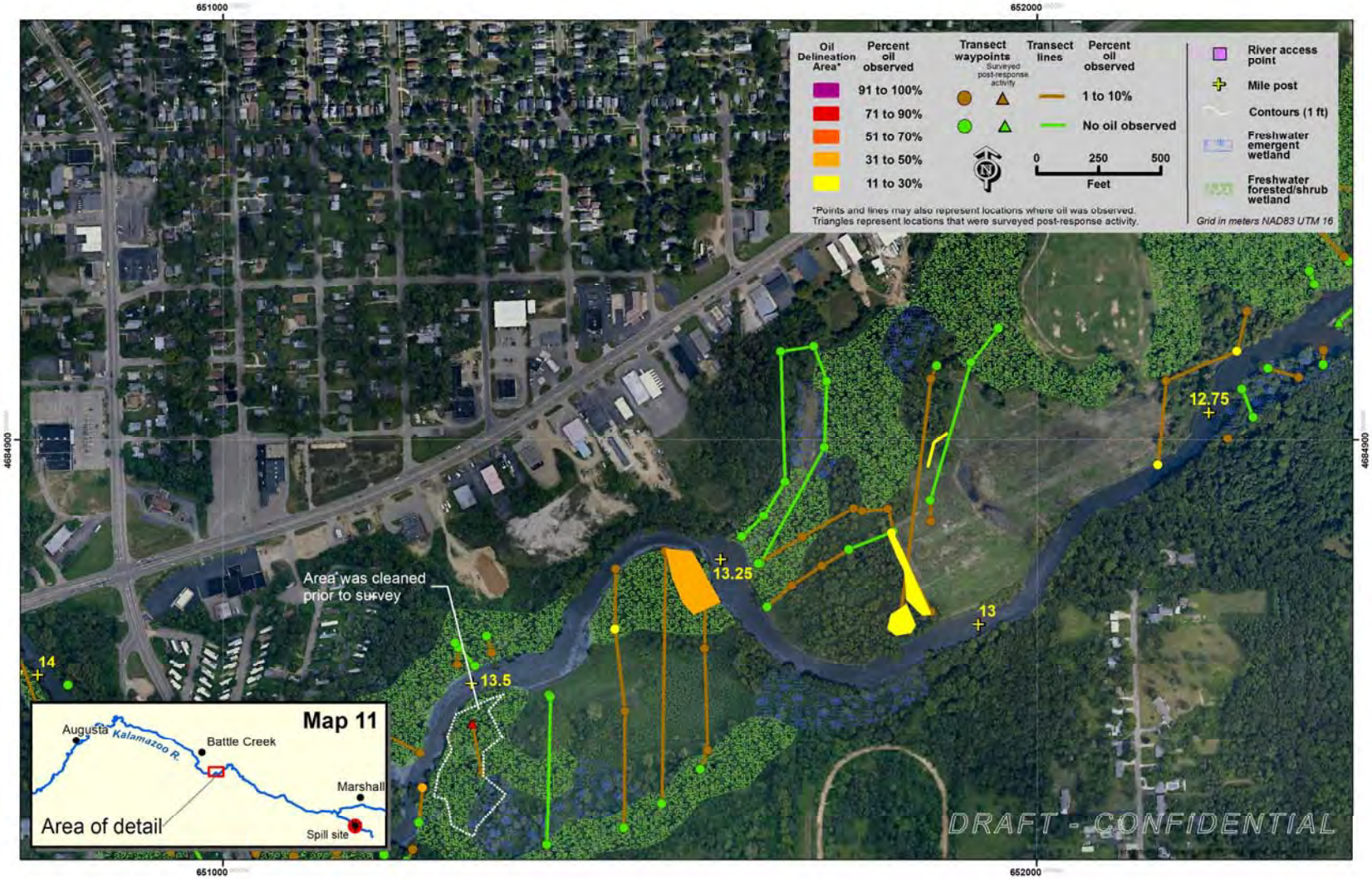


Figure 23. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 12.75–14).

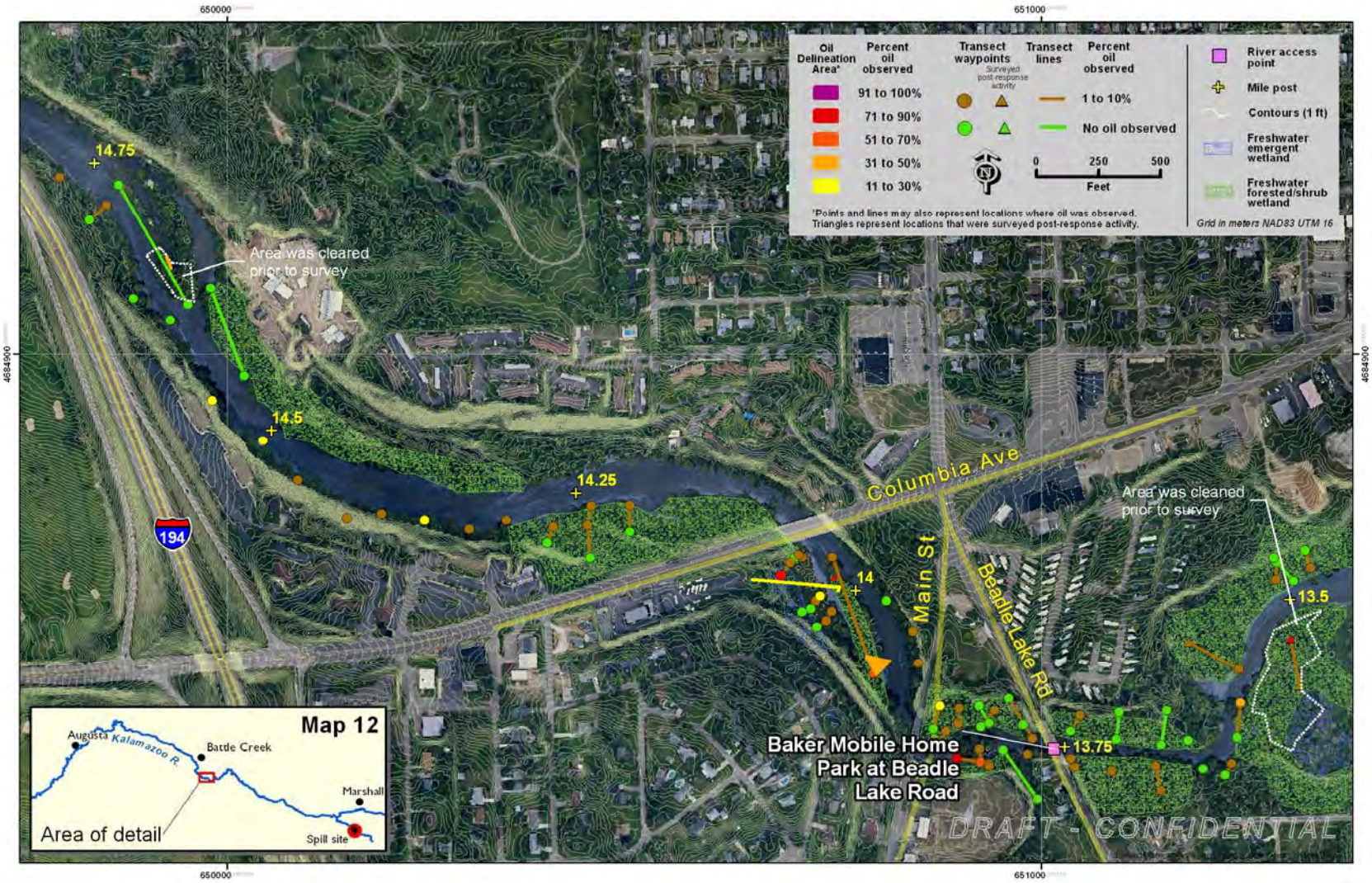


Figure 24. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 13.5–14.75).

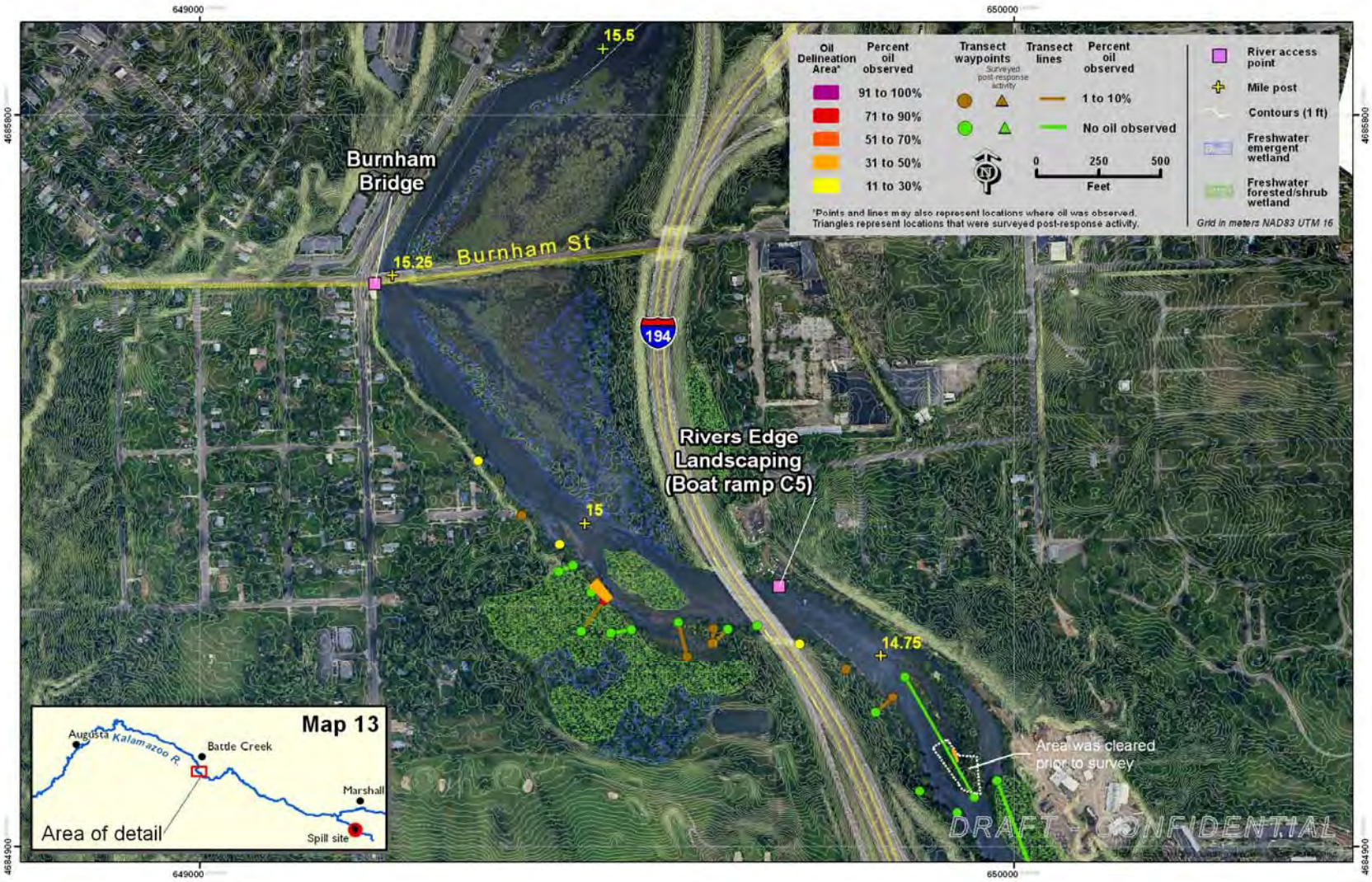


Figure 25. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 14.75–15.5).

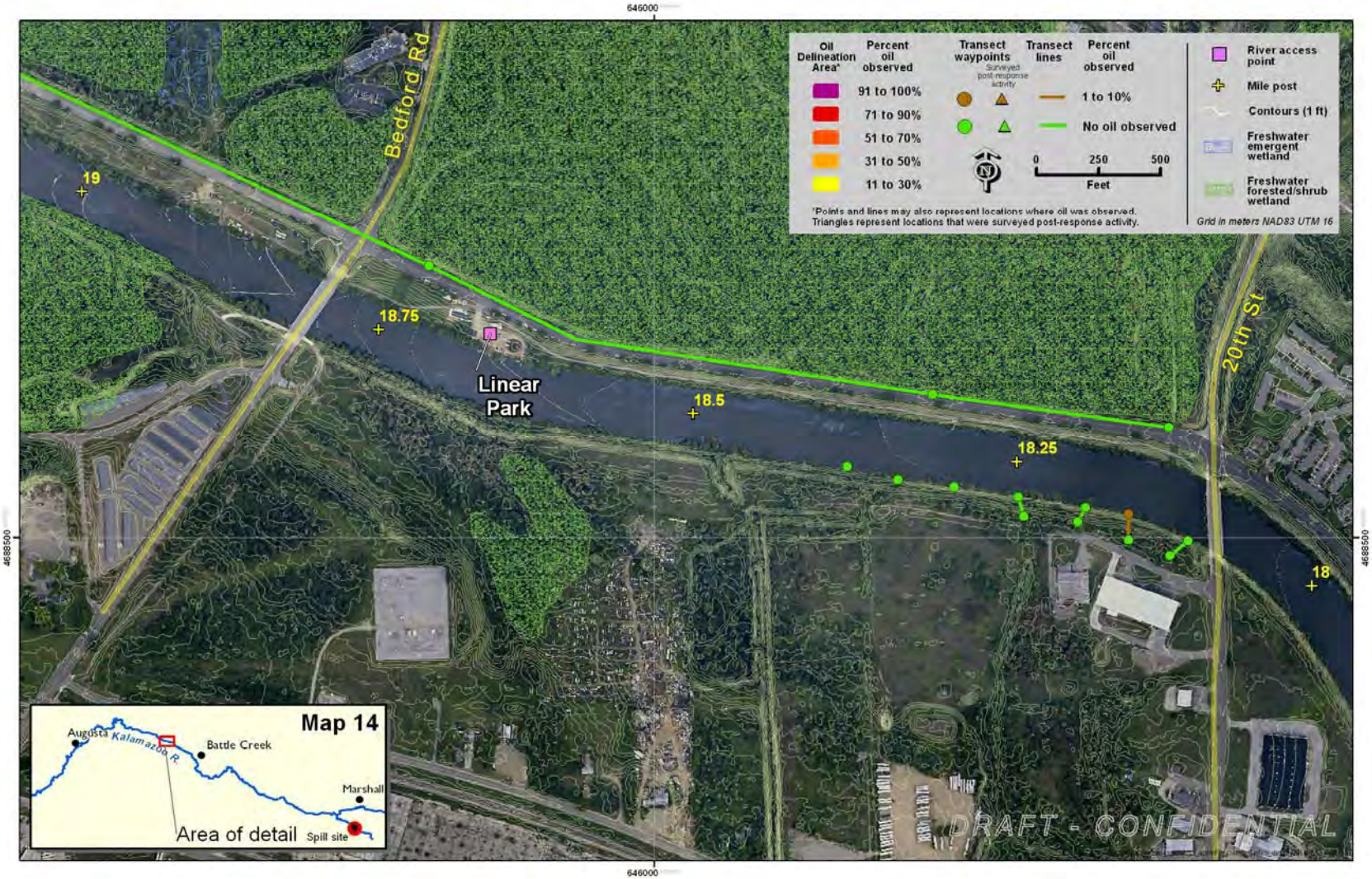


Figure 26. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 18–19).

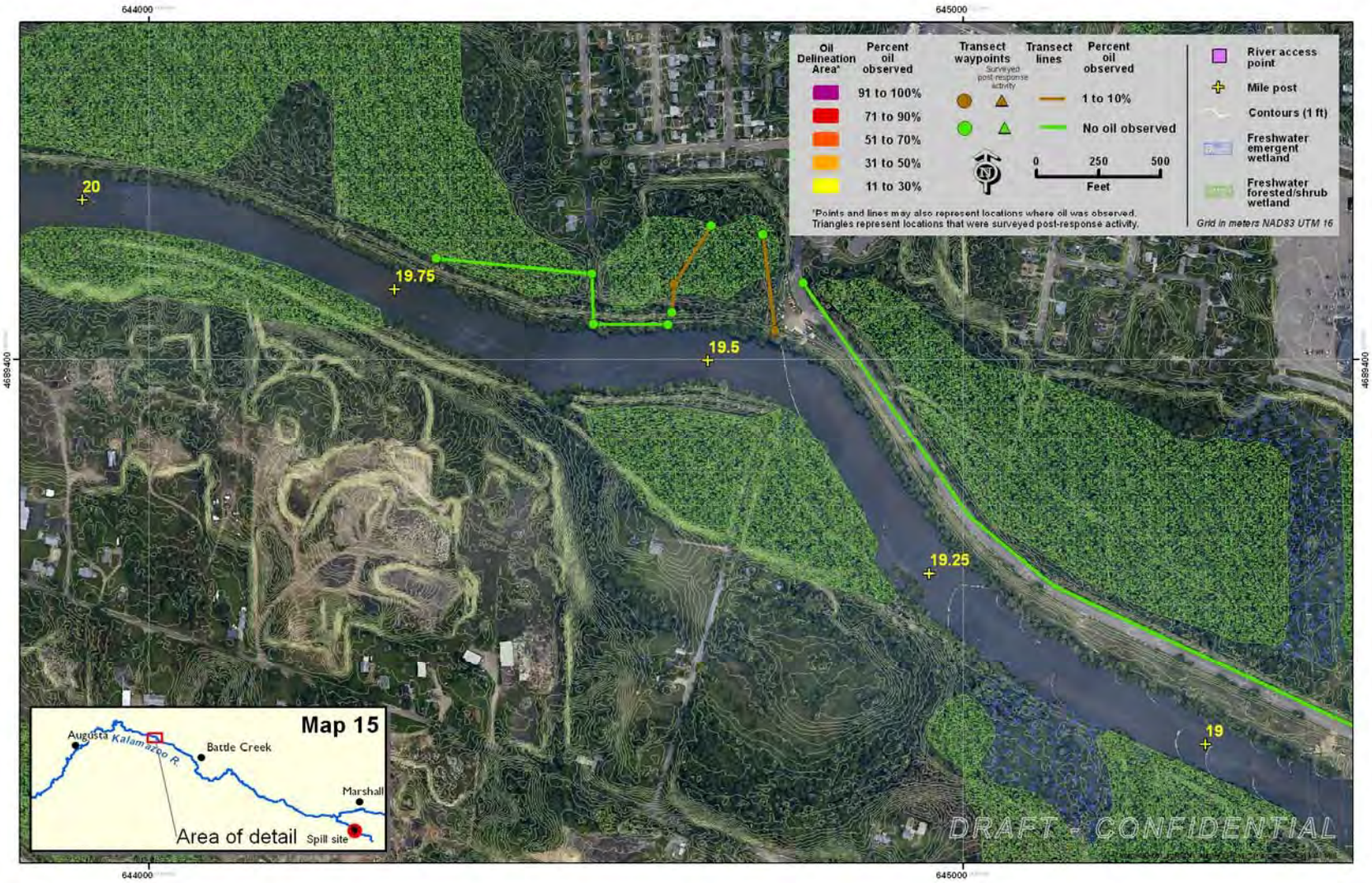


Figure 27. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 19–20).

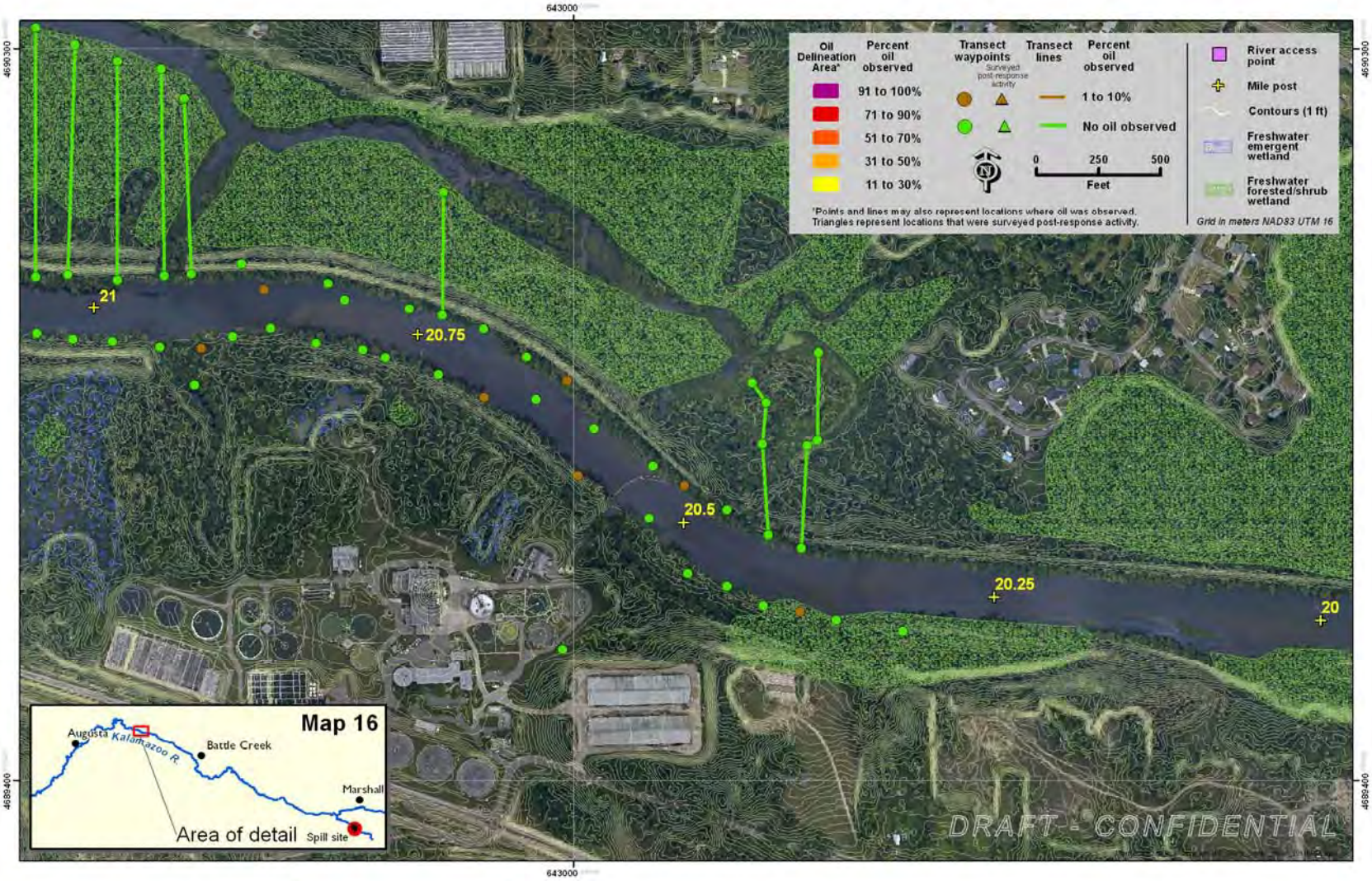


Figure 28. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 20–21).

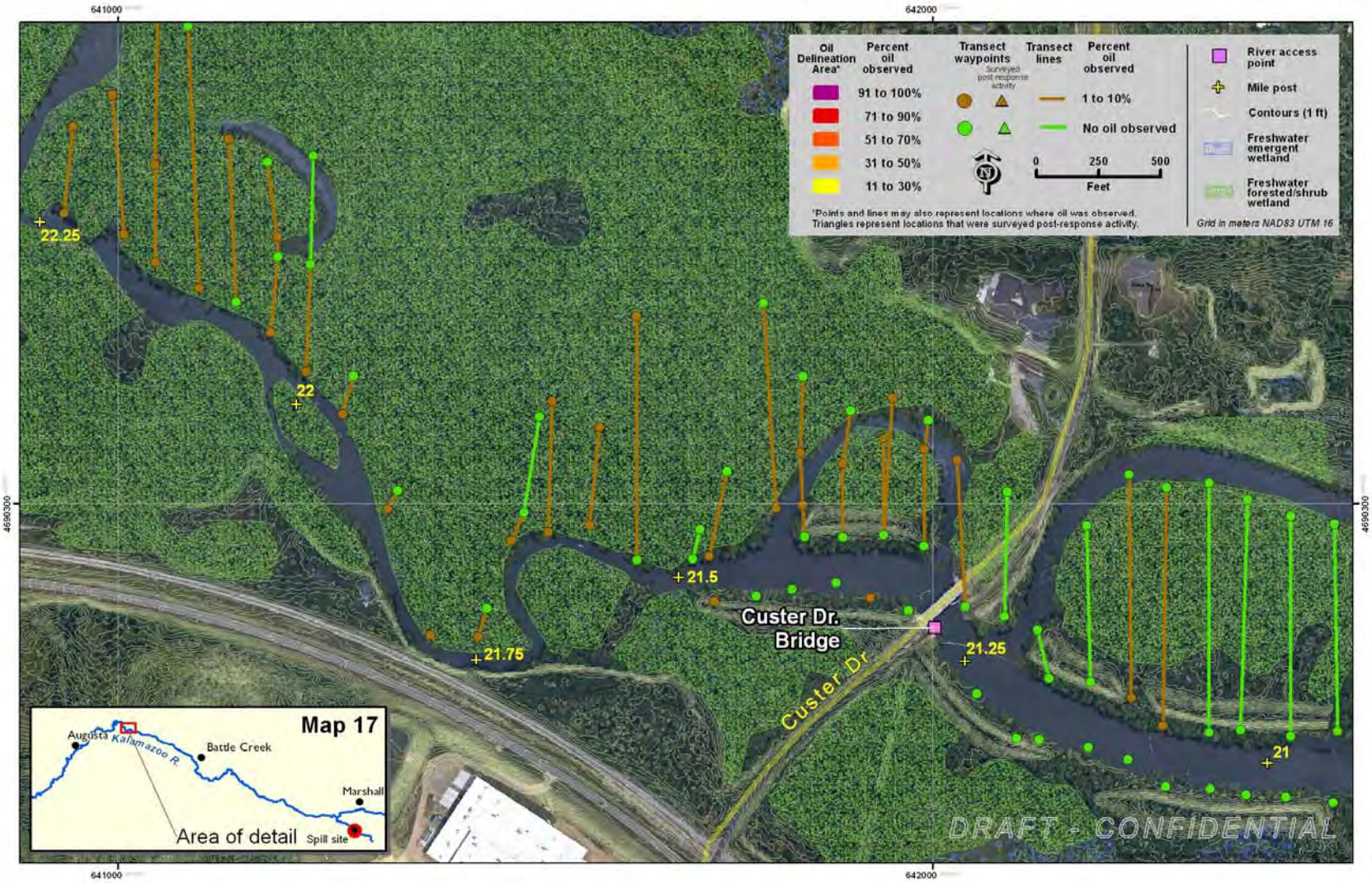


Figure 29. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 21–22.25).

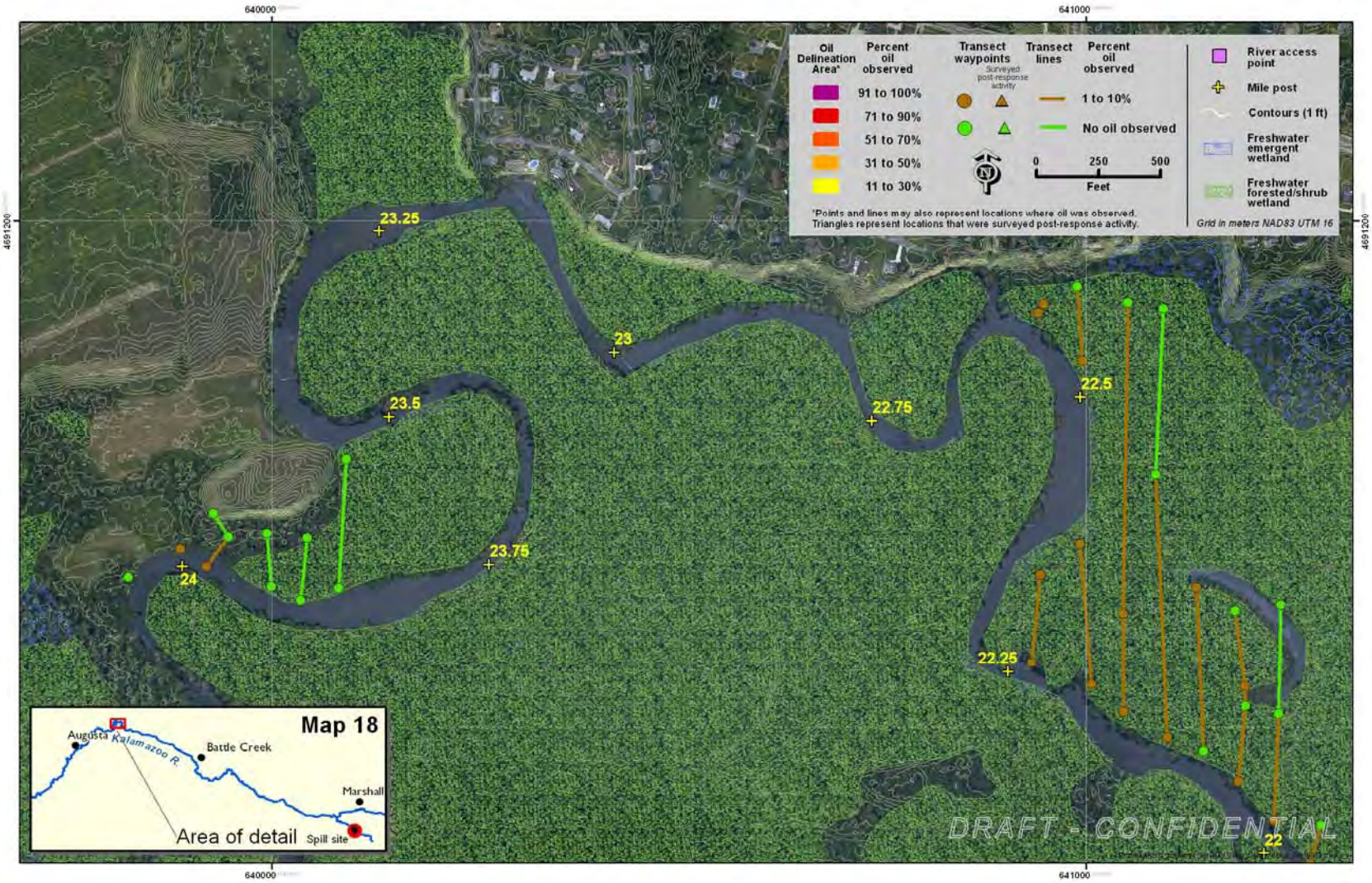


Figure 30. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 22–24).

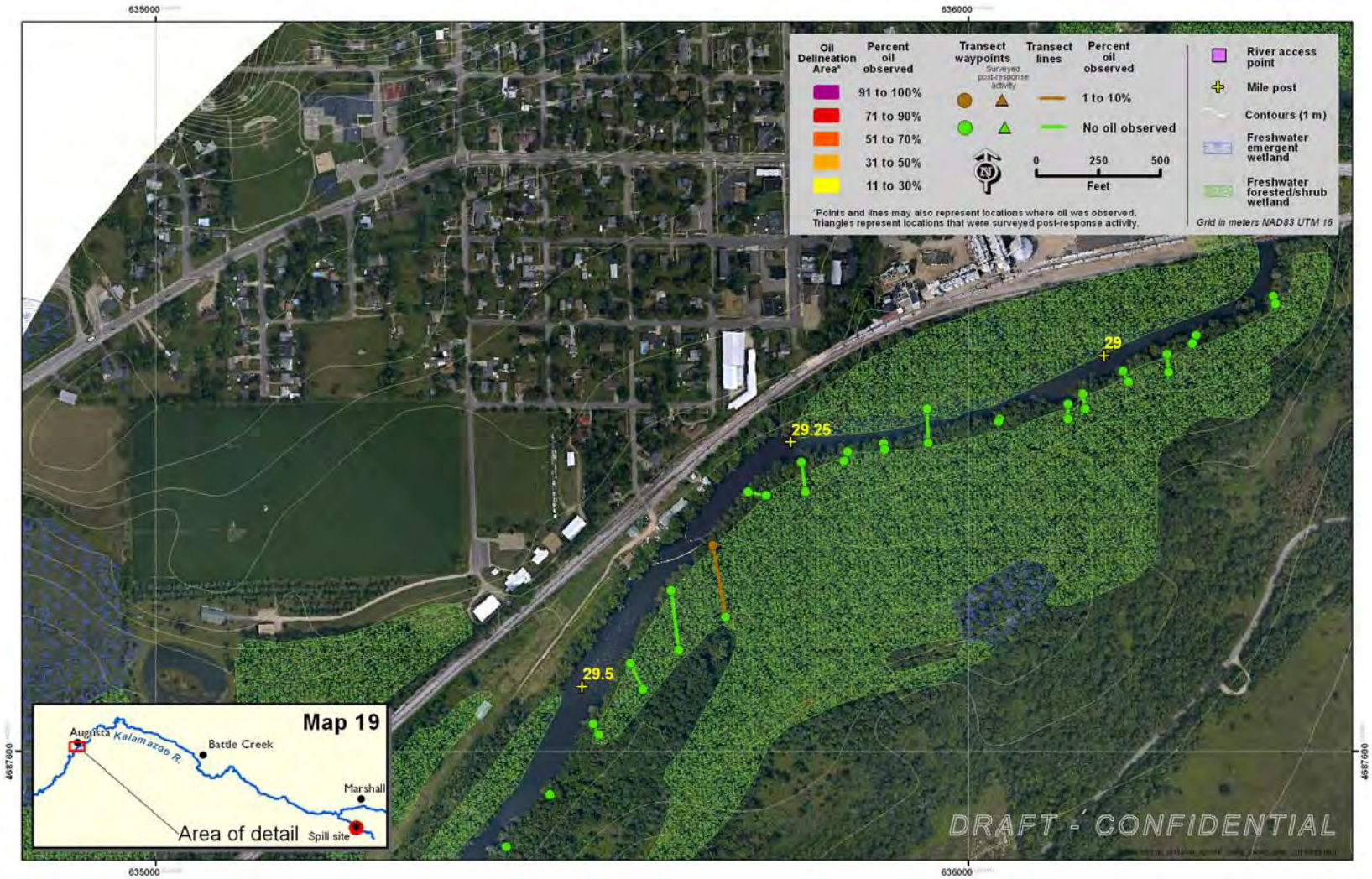


Figure 31. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 29–29.5).

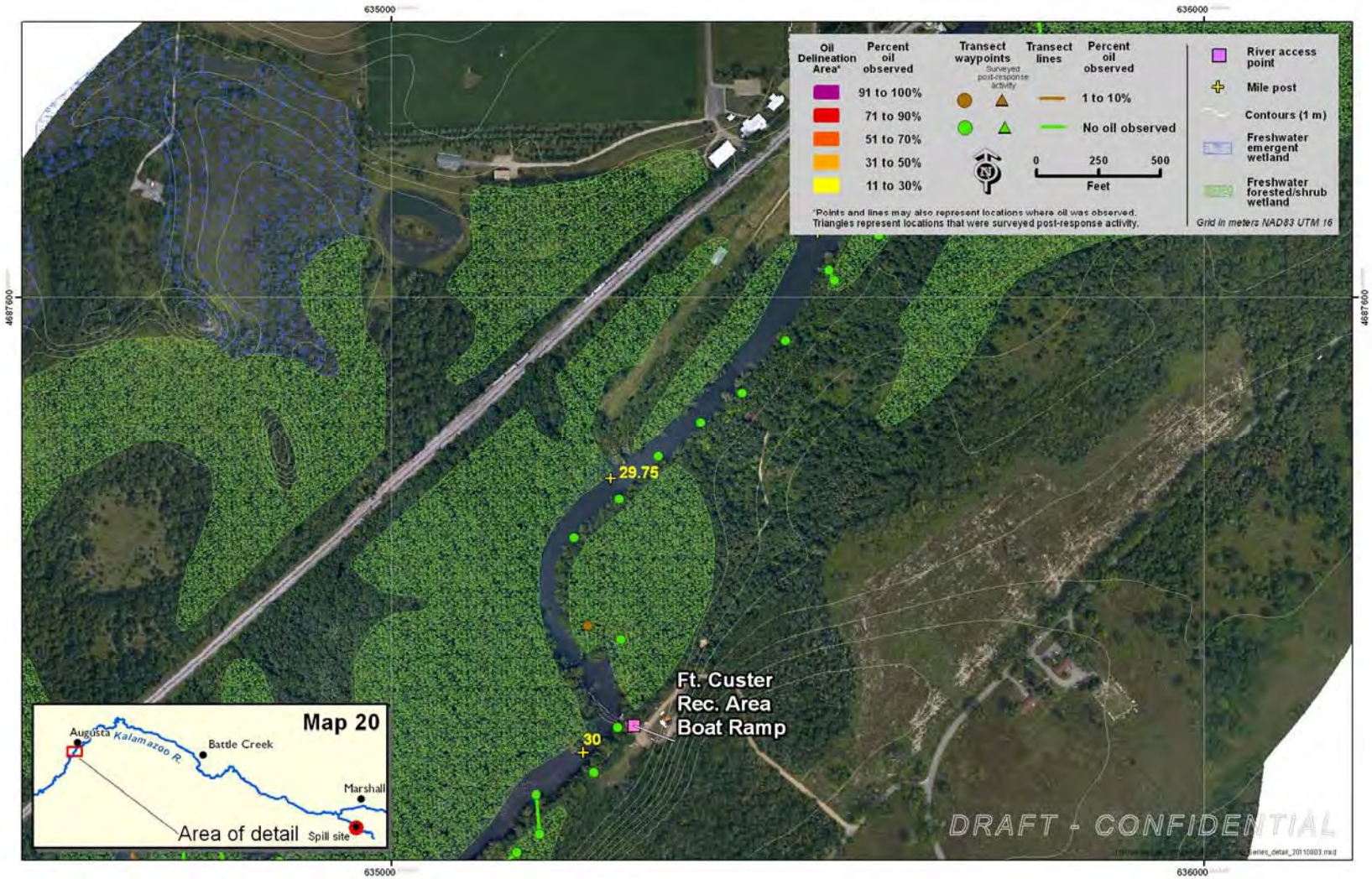


Figure 32. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 29.75–30).

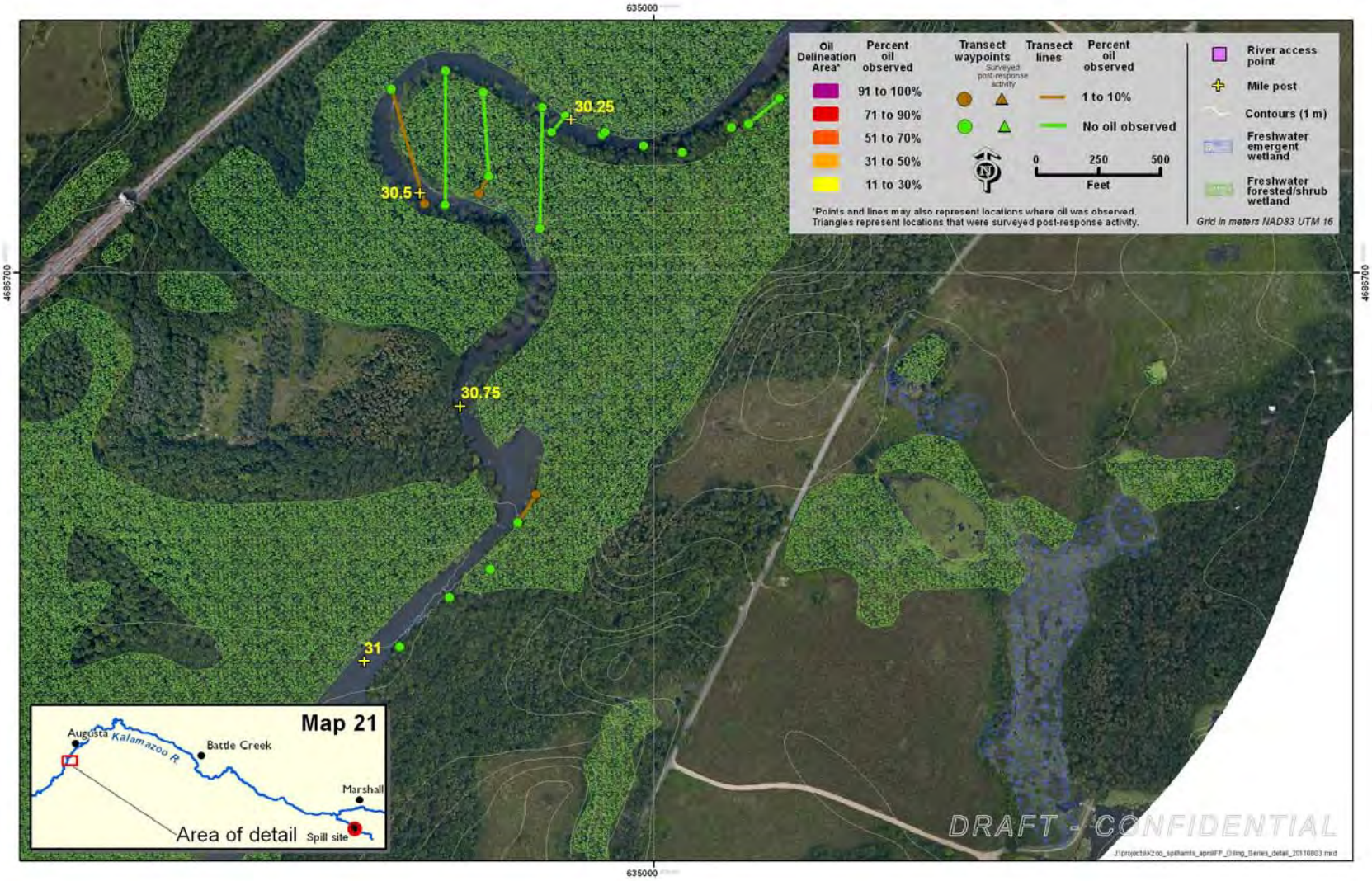


Figure 33. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 30.25–31).

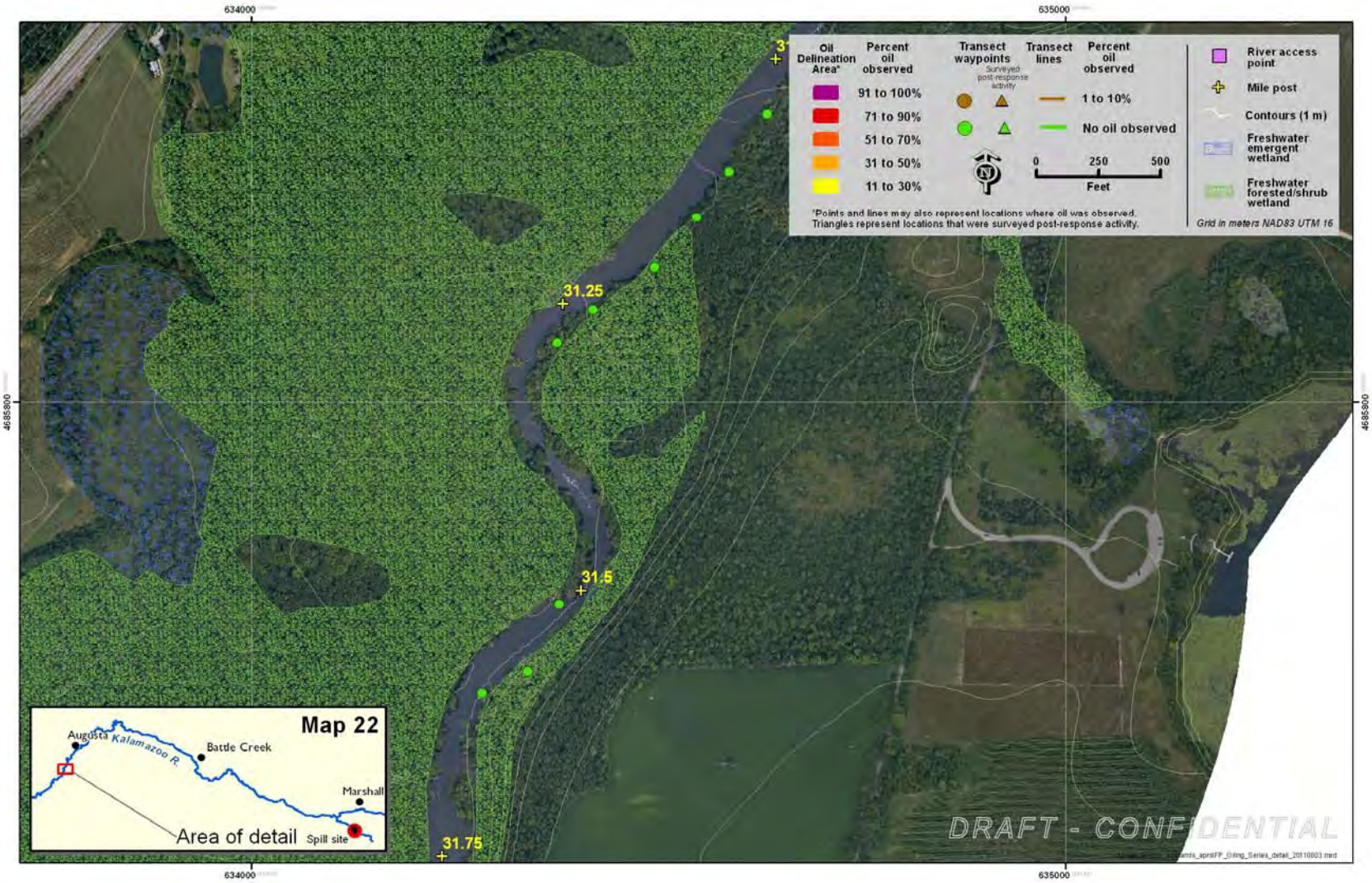


Figure 34. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 31–31.75).

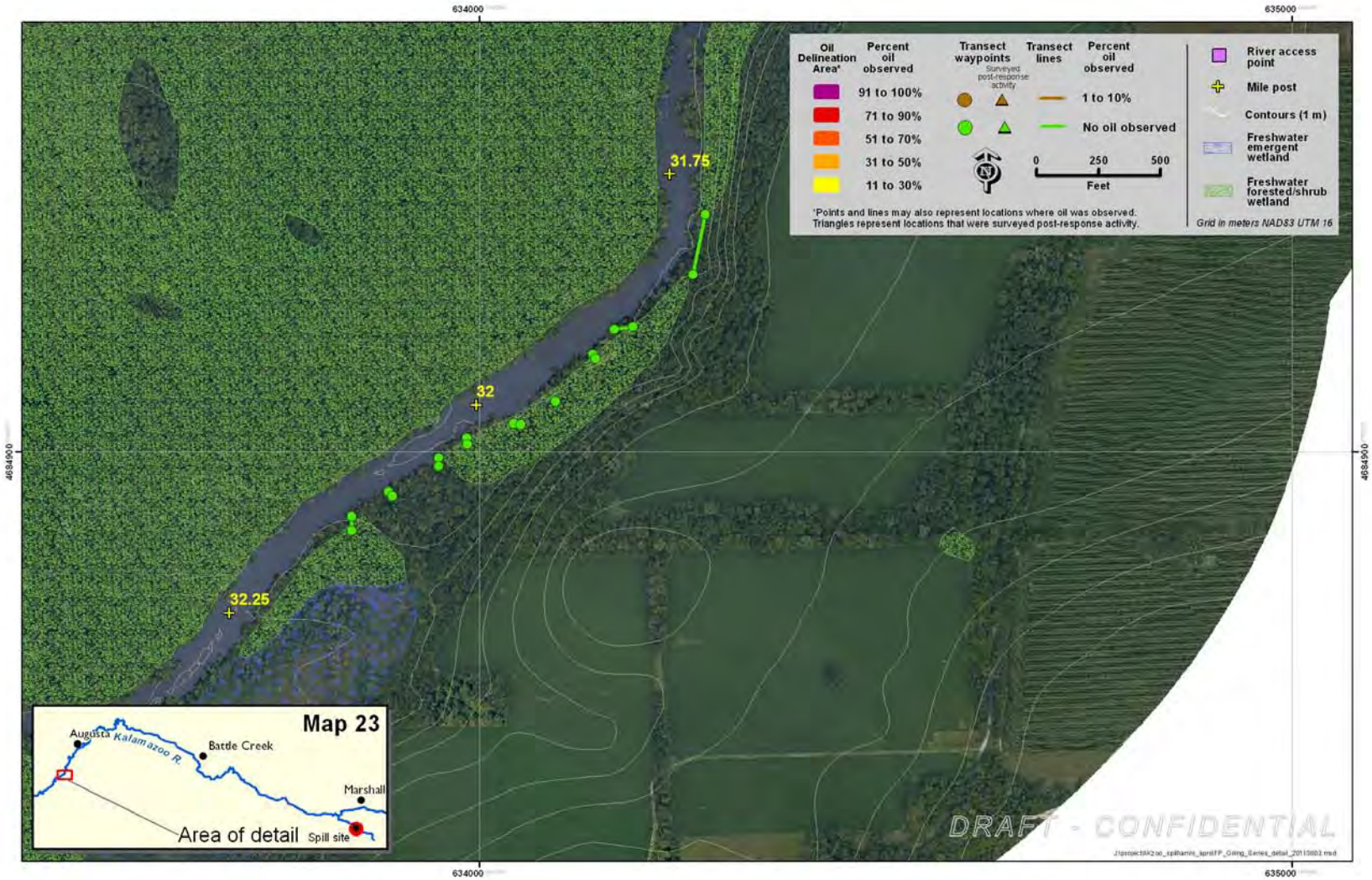


Figure 35. Detailed map showing all transects, waypoints, and ODAs surveyed during the floodplain survey (MP 31.75–32.25).

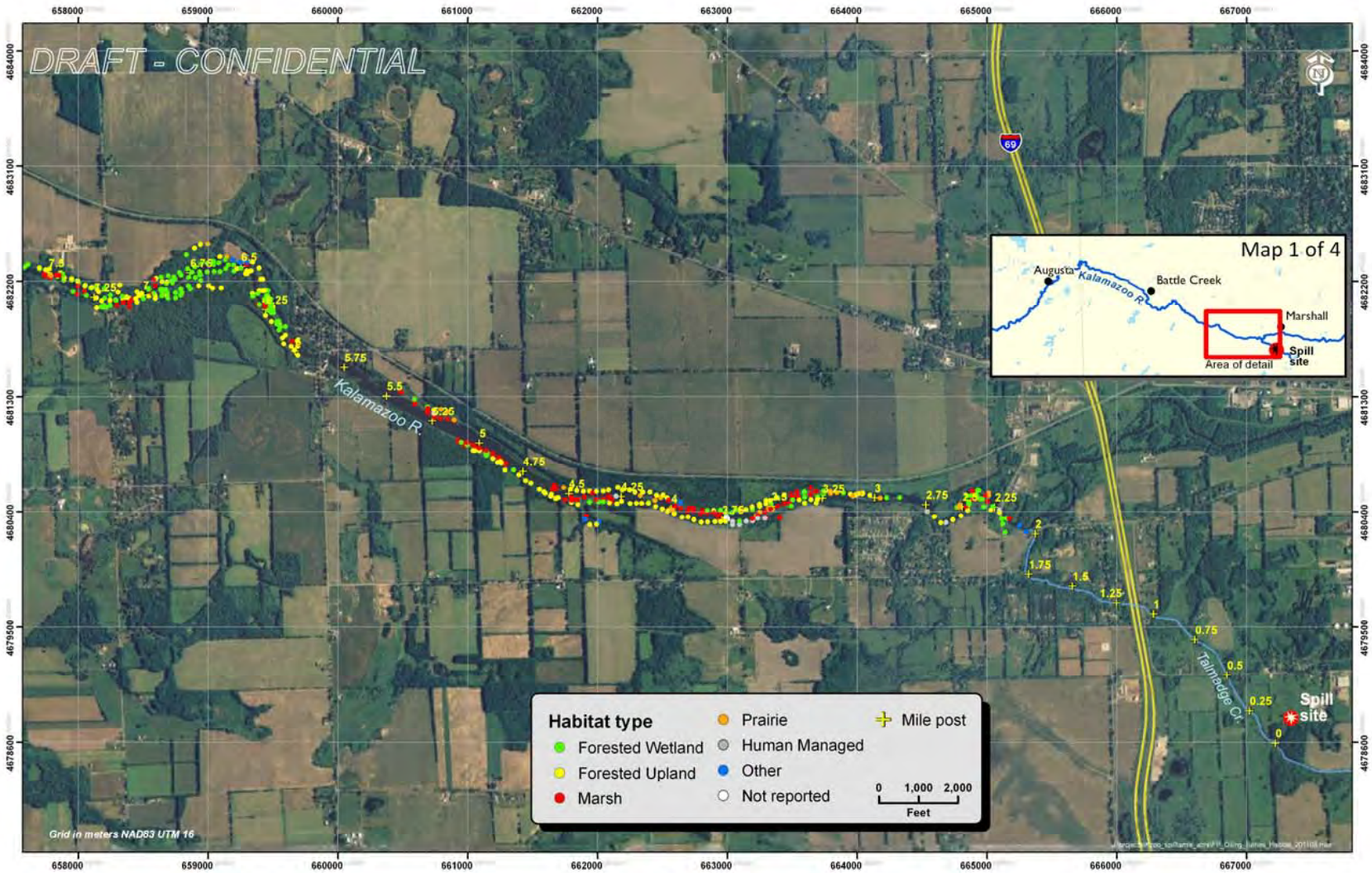


Figure 36. Map showing the habitat types identified at each waypoint during the floodplain survey (MP 0–7.5).

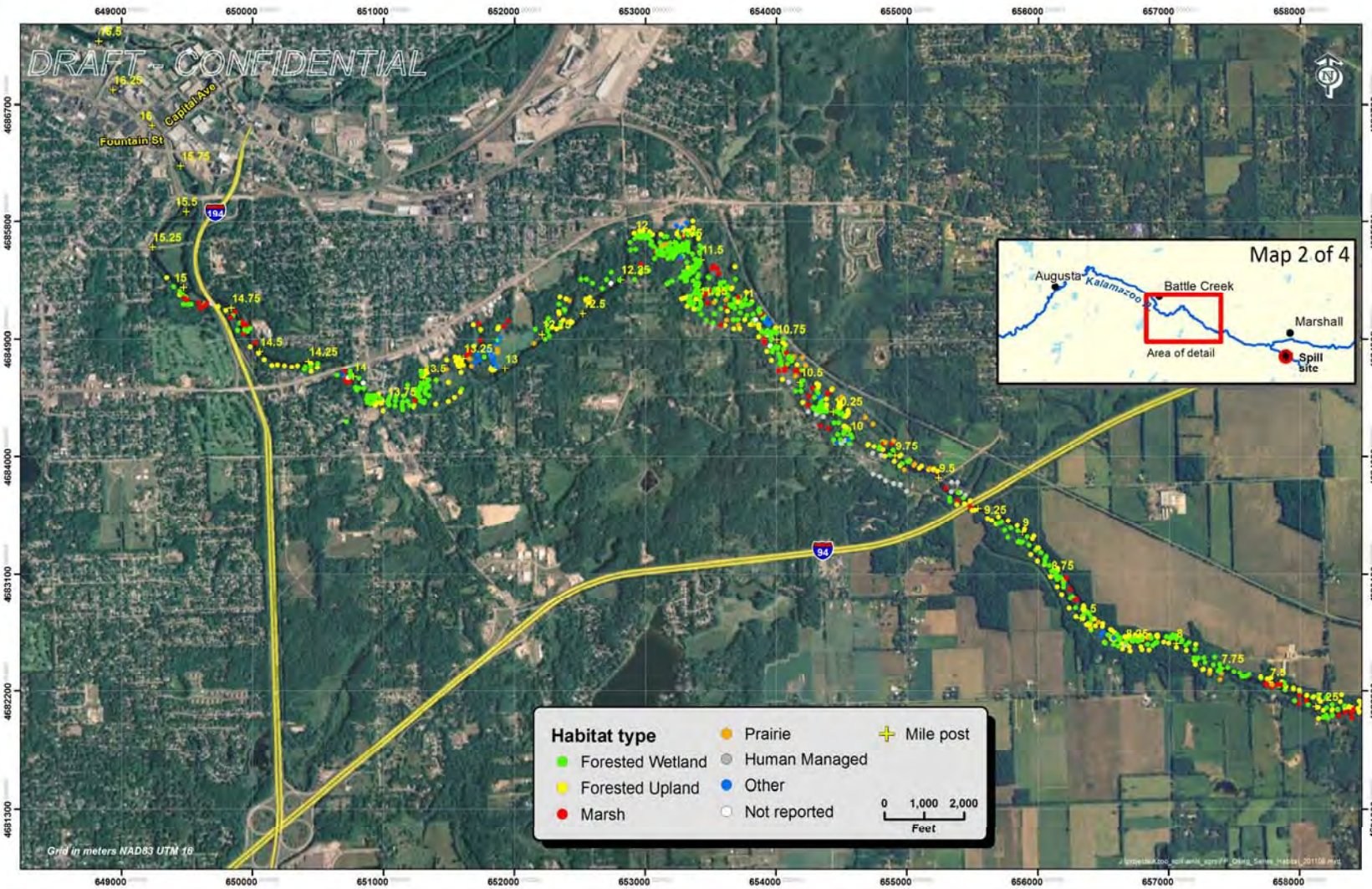


Figure 37. Map showing the habitat types identified at each waypoint during the floodplain survey (MP 7.25–16.5).

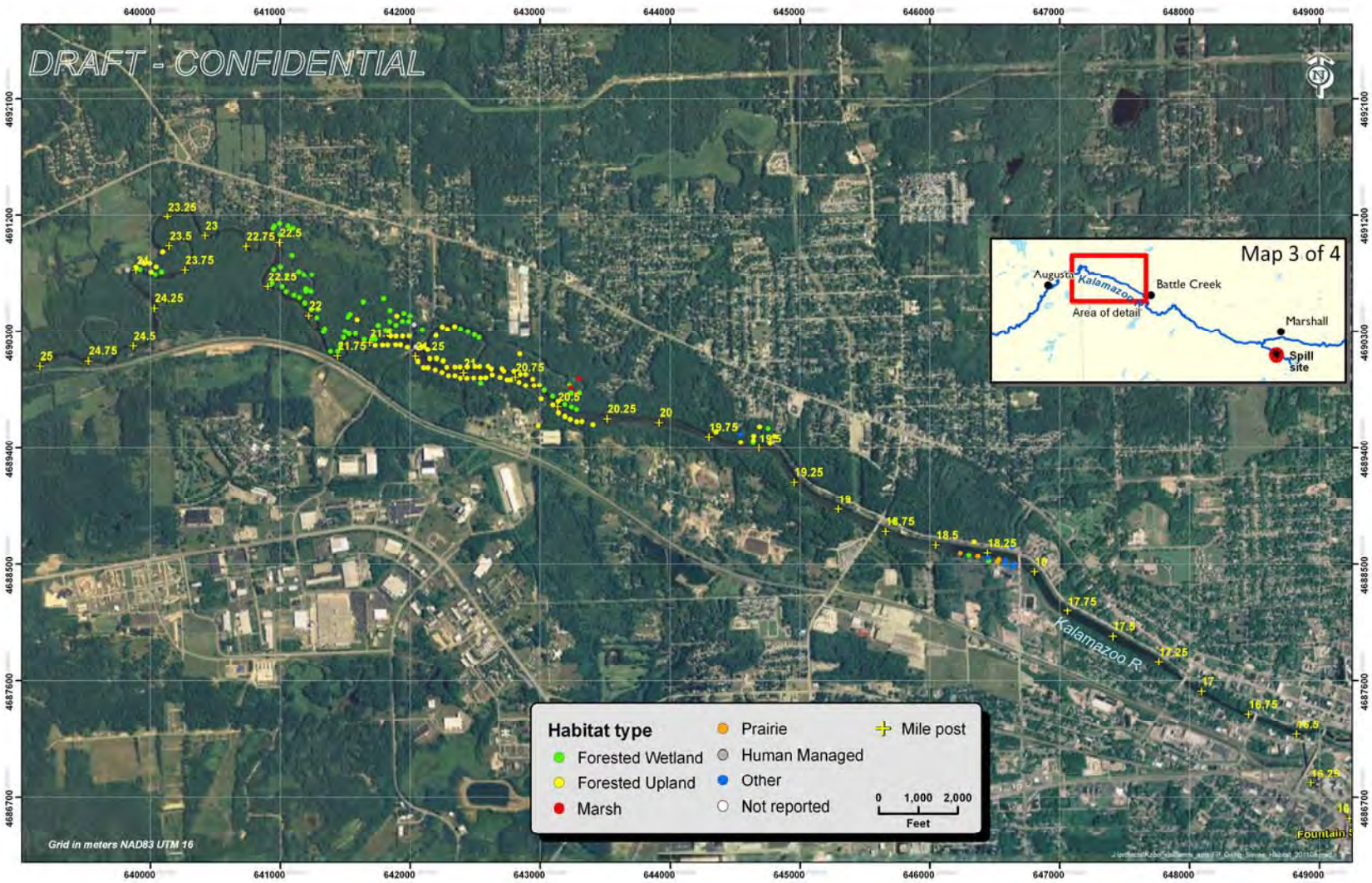


Figure 38. Map showing the habitat types identified at each waypoint during the floodplain survey (MP 16–25).

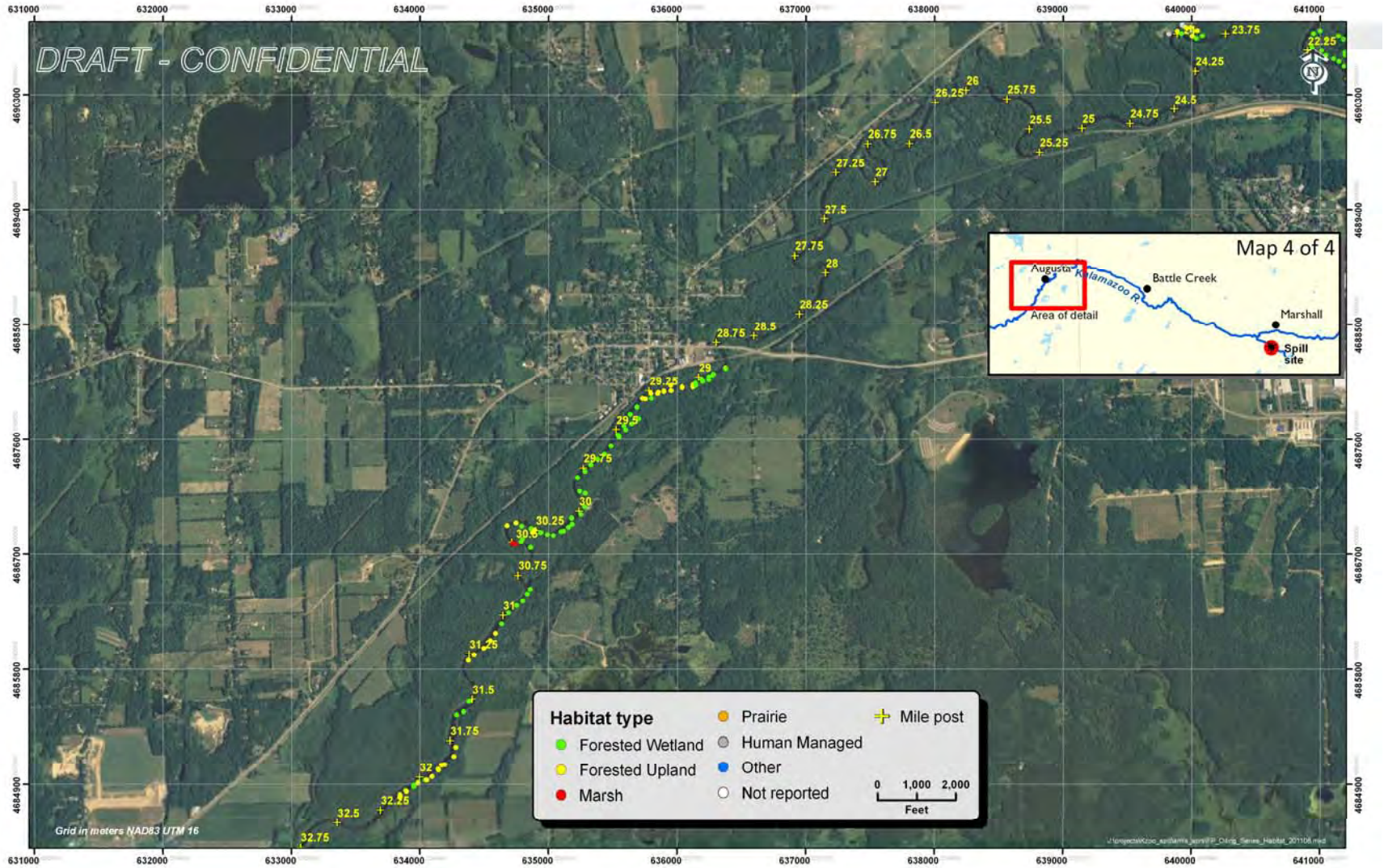


Figure 39. Map showing the habitat types identified at each waypoint during the floodplain survey (MP 22.25–32.75).

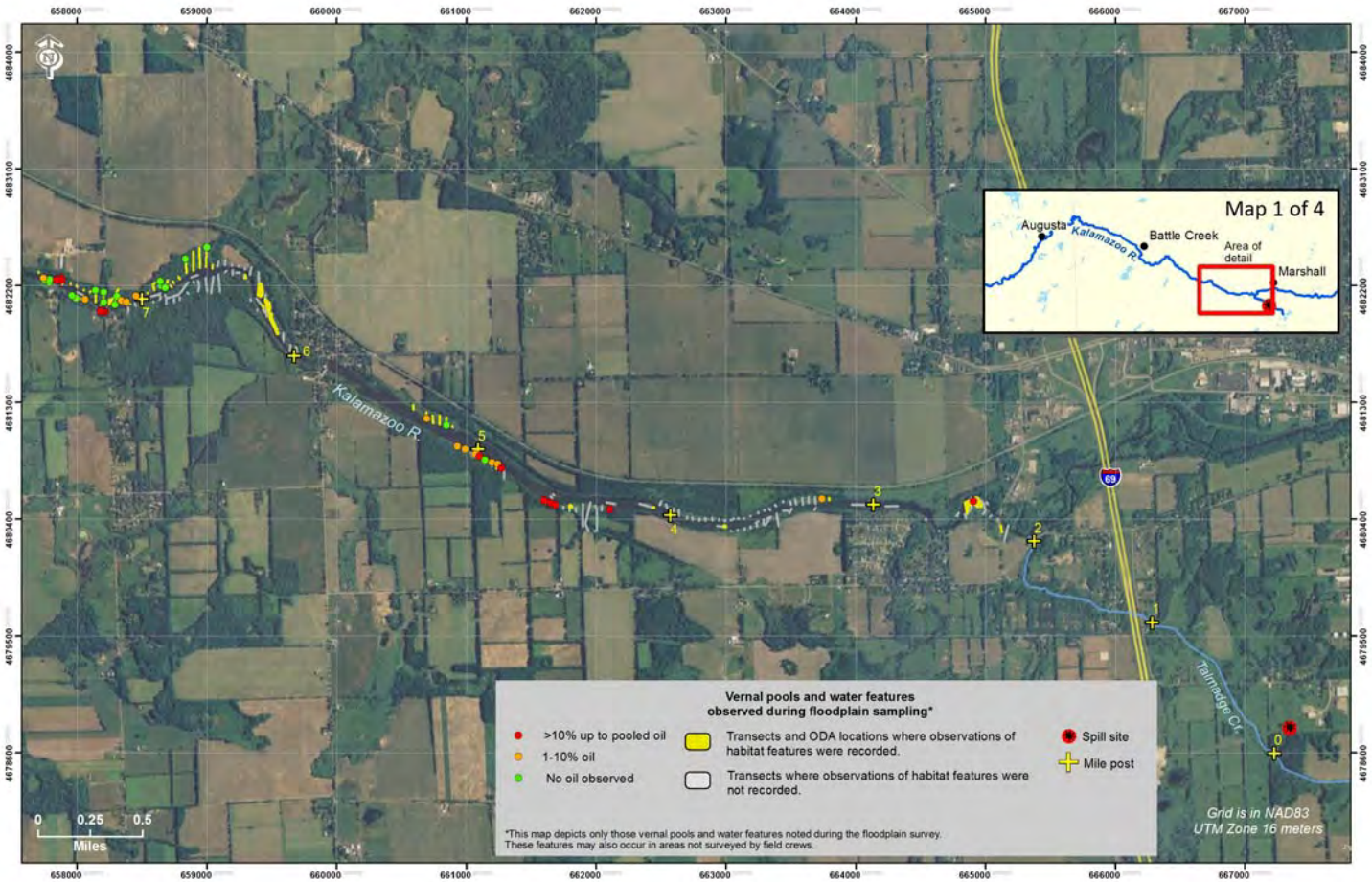


Figure 40. Map showing the waypoint locations where vernal pools and/or water features were identified and the degree of oiling recorded at the corresponding waypoint (MP 0–7.5). (Note: these data were not recorded at all waypoints during the floodplain survey and the degree of oiling was recorded for the waypoint as a whole and not the water feature or vernal pool specifically).

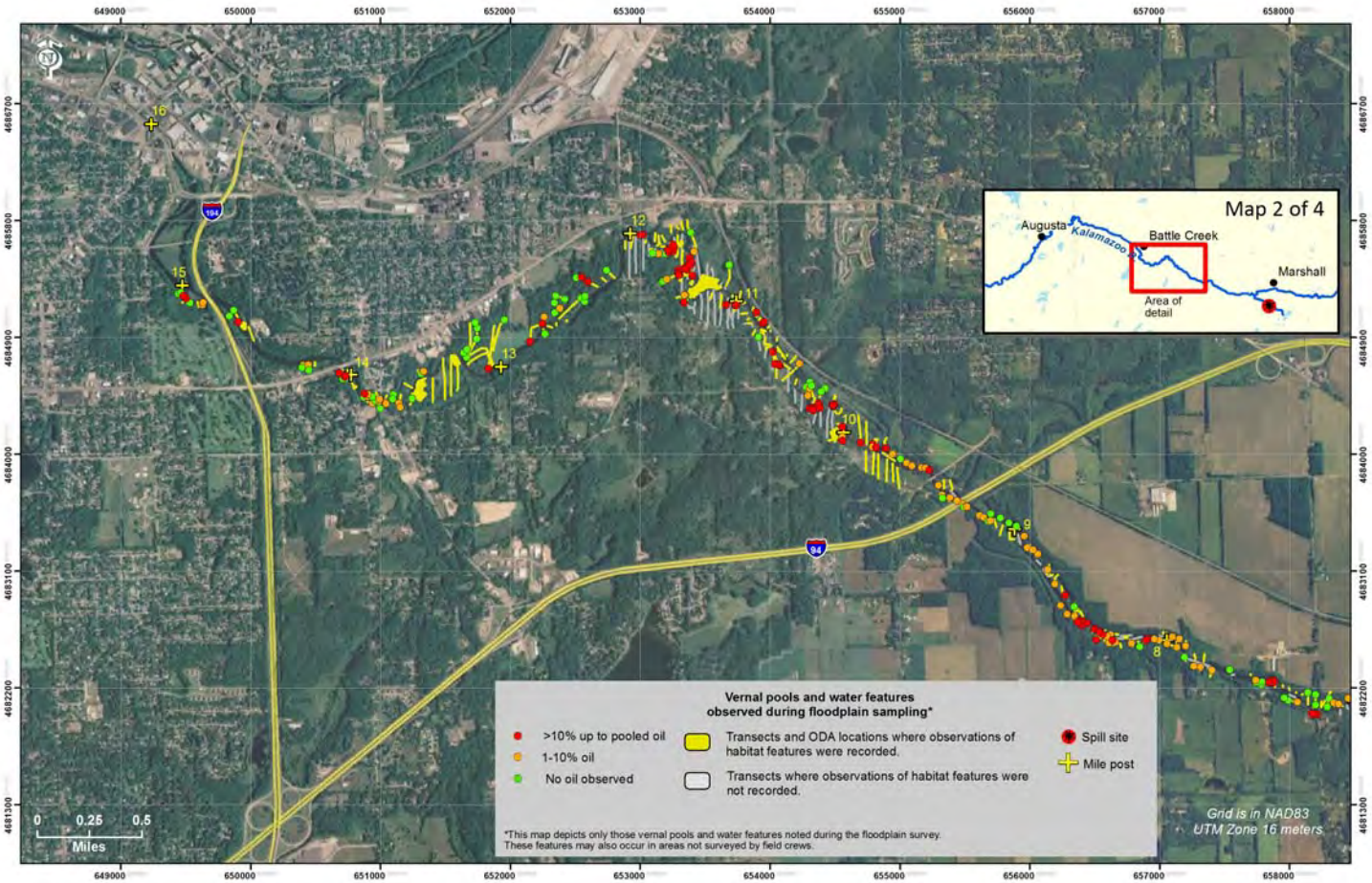


Figure 41. Map showing the waypoint locations where vernal pools and/or water features were identified and the degree of oiling recorded at the corresponding waypoint (MP 7.25–16.5). (Note: these data were not recorded at all waypoints during the floodplain survey and the degree of oiling was recorded for the waypoint as a whole and not the water feature or vernal pool specifically).

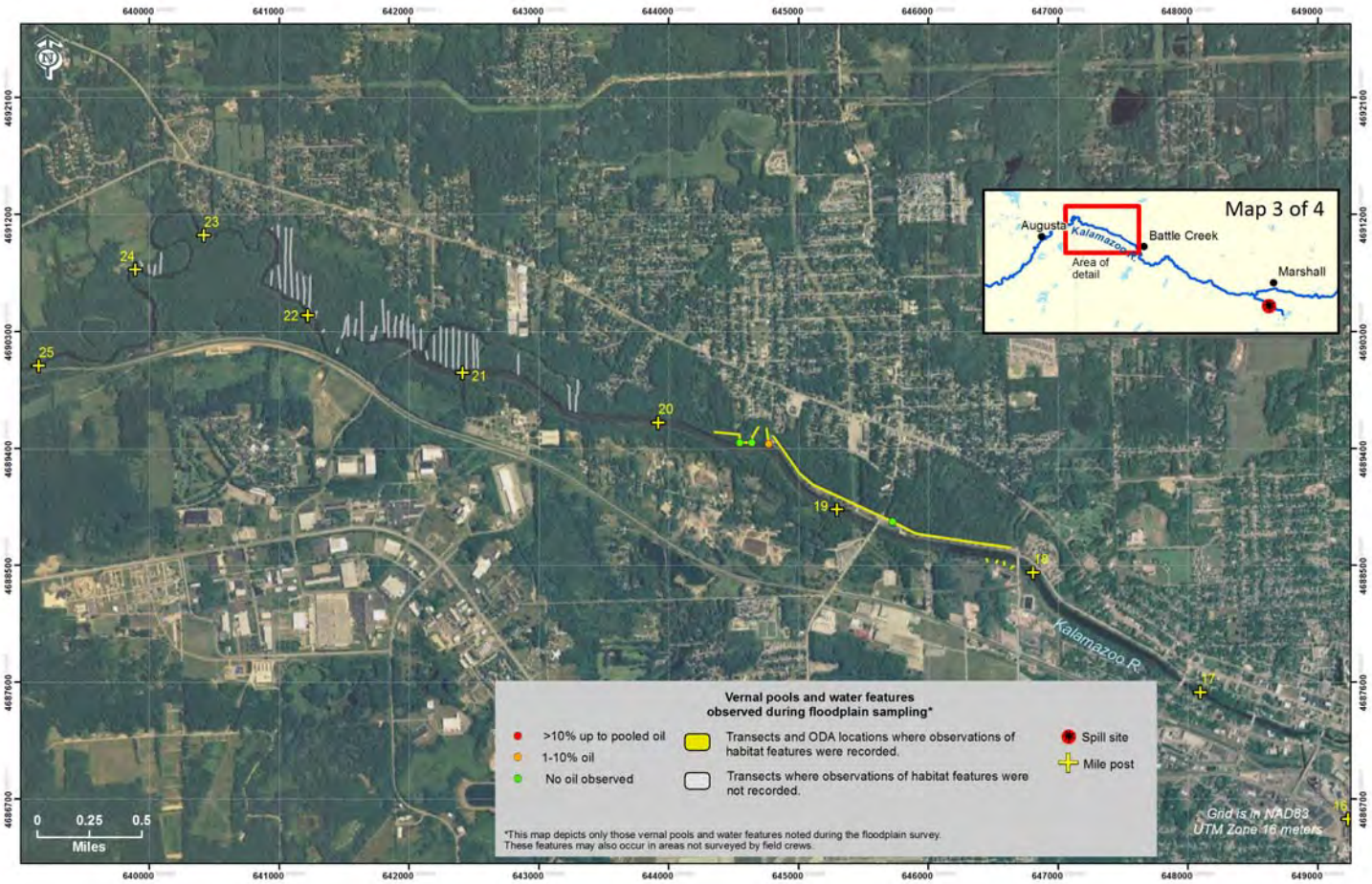


Figure 42. Map showing the waypoint locations where vernal pools and/or water features were identified and the degree of oiling recorded at the corresponding waypoint (MP 16–25). (Note: these data were not recorded at all waypoints during the floodplain survey and the degree of oiling was recorded for the waypoint as a whole and not the water feature or vernal pool specifically).

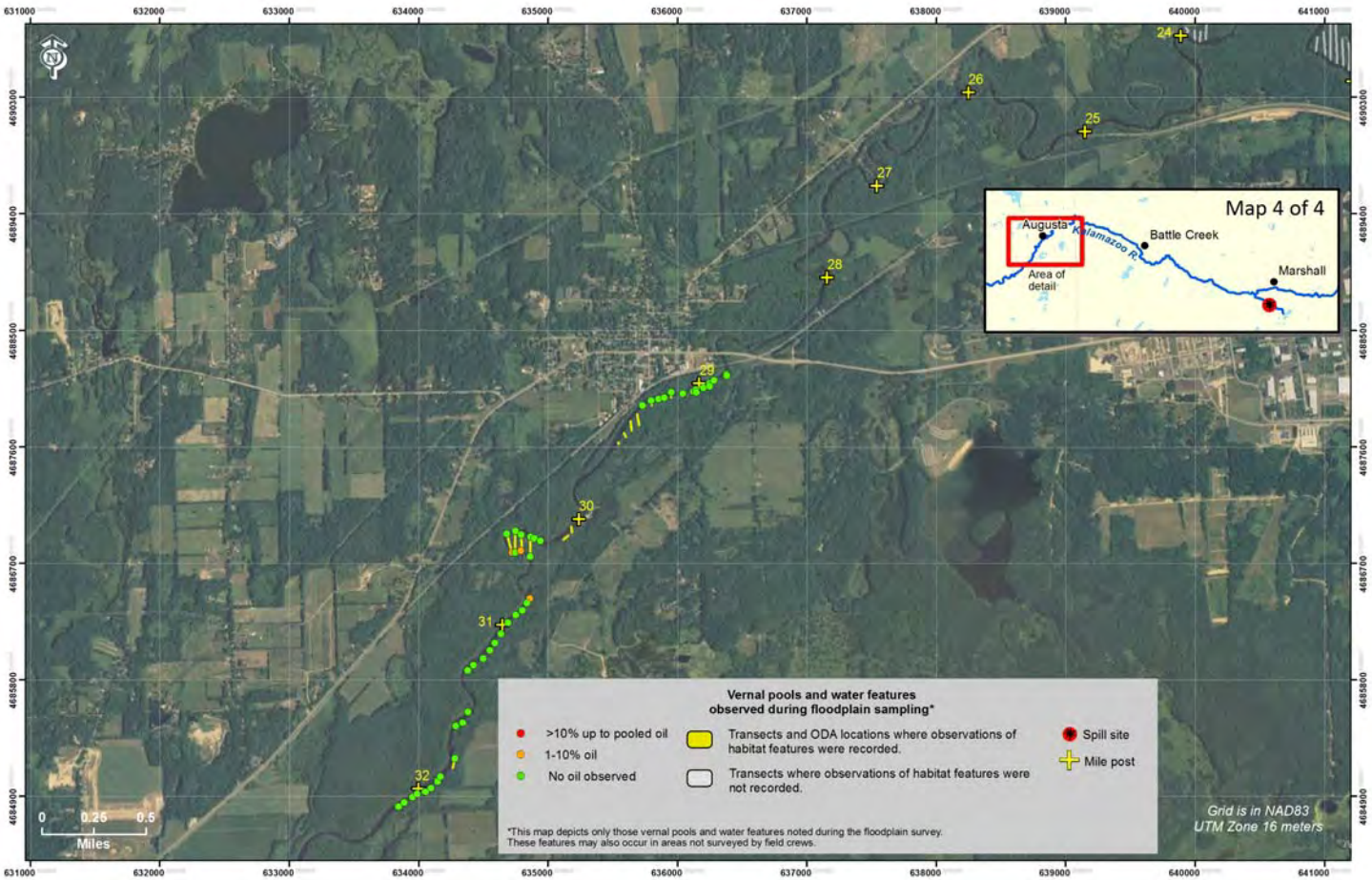


Figure 43. Map showing the waypoint locations where vernal pools and/or water features were identified and the degree of oiling recorded at the corresponding waypoint (MP 22.25–32.75). (Note: these data were not recorded at all waypoints during the floodplain survey and the degree of oiling was recorded for the waypoint as a whole and not the water feature or vernal pool specifically).

A. Floodplain Survey Work Plan

DISCUSSION DRAFT

PROTOCOLS FOR CHARACTERIZING KALAMAZOO RIVER FLOODPLAIN OILING

ENBRIDGE OIL SPILL INCIDENT

Prepared by:

Douglas Beltman
Karen Carney
Kaylene Ritter
Stratus Consulting Inc
Boulder, CO.

Chuck Getter
Industrial Economics
Cambridge, MA

August 18, 2010

Confidential – Draft

1. Introduction

On July 26, 2010, Enbridge Energy, Limited Partnership discovered a release of heavy crude oil (Cold Lake Blend) from line 6B just west of milepost 308 in the vicinity its pump station located in Marshall, Calhoun County, Michigan. Line 6B is a 30-inch, 190,000 barrels per day (bpd) line transporting light synthetics, heavy and medium crude oil from Griffith, IN, to Sarnia, Ontario. The location of the release from Line 6B is located in an undeveloped area in the outskirts of town with coordinates of approximately North ½ Section 2, T3S, R6W, Latitude: 42.2395273 Longitude: -84.9662018. Upon discovery of the release the pipeline was shut down and isolation valves closed, stopping the source of the oil; however, initial estimates are that approximately 19,500 barrels of crude oil may have been released.

The release occurred along Tallmadge Creek approximately 1.5 miles upstream of where the creek enters the Kalamazoo River. The oil flowed down Tallmadge Creek and into the Kalamazoo River. At the time of the spill, recent rains had pushed the Kalamazoo River over its banks in many areas, and as a result the spilled oil entered into the floodplains along the river. Preliminary reconnaissance has confirmed that floodplains along the river downstream of the spill contain oil, and that the oiling is heavy in some areas. Therefore, an assessment of the locations and degree of oiling in the floodplain is required. These protocols focus on a rapid assessment of the locations and degree of oiling in the floodplains and the general floodplain habitat types where the oiling occurs. Subsequent protocols and fieldwork may address more detailed characterization of the habitat in the oiled areas for natural resource damage assessment (NRDA) purposes, if necessary.

2. Objective

The objective of these protocols is to characterize the areal extent and degree of oiling in the floodplains of the Kalamazoo River that have resulted from the Enbridge Pipeline spill and to characterize the general floodplain habitat types in the areas of the spilled oil. Discussed is a procedure that would allow us to map, characterize, and delineate both the habitat types and their extent of exposure to oil.

3. Approach

The floodplain surveys will be conducted on foot by floodplain assessment teams using protocols adapted from standard Shoreline Cleanup and Assessment Technique (SCAT) protocols. Areas requiring the on-the-ground assessment will first be identified using a combination of a

previously conducted shoreline oiling survey, remote sensing data, overflight videos, GIS habitat layers, and field experience of researchers familiar with the river floodplain in this area.

4. Site Selection

The overall scope of the study is the Kalamazoo River floodplain between Talmadge Creek and Morrow Lake. Areas targeted for on-the-ground survey work will those areas that:

- Are likely to have been flooded at the time of the spill. These areas will be identified using maps, remote sensing data, the shoreline survey results, and field experience; and
- Contain at least 3 acres of floodplain habitat (based on aerial photography or GIS analysis).Smaller areas may surveyed after most large areas are surveyed.

The primary focus of the floodplain survey will be in Division C, but some surveys will be done in Division D as well. We anticipated apportioning approximately 80% of the survey level of effort (LOE) to Division C, with the balance apportioned to Division D.

Initial field reconnaissance work indicated that predicting the location and extent of oiling in the floodplain will be difficult based solely on available information (LIDAR, wetland layers from the National Wetland Inventory, shoreline oiling surveys). Initial floodplain work also indicates that surveying all floodplain within Divisions C and D may not be feasible. We are thus implementing a ‘sampling’ approach that is meant to characterize patterns of oiling across general habitat types and elevations. The ‘samples’ of river floodplain that we survey will be used to extrapolate to areas not surveyed within each of the Divisions.

Areas of river to be surveyed will be selected randomly in via GIS in Divisions C and D of the Kalamazoo River. A GIS will be used to generate randomly the areas to be sampled as follows. First, the area of interest, beginning at the confluence of Talmadge Creek and the Kalamazoo River and extending downstream to the inlet of Lake Morrow, will be divided into 400 meter wide sections that run from north to south (i.e., 400 meters across from east to west) covering the entire extent of the floodplain on both banks of the river. The 400 meter wide sections will then be identified as either right bank or left bank of the river, as delineated by the centerline of the Kalamazoo River in the National Hydrologic Database (high resolution). This will result in the entire floodplain of the Kalamazoo River in the area of interest being divided into 400 m wide (east to west) sections with borders that run straight north to south, with separate sections on the left bank and on the right bank of the river.

The left bank and right bank 400 m sections of floodplain will then be randomly assigned numbers using a random number generator. Sections for the on-the-ground survey will then be

identified based on the random number assignments, starting with number 1 and proceeding up. Separate numbering will be done for the right bank sections and for the left bank sections so that an equal number of right bank and left bank sections will be sampled.

Within each 400 m wide section identified for field surveying, eight, north–south transects 50 meters apart will then be generated. GPS coordinates of where each transect intersects the riverbank will be provided to the field team. The transects will also be identified on a map that includes land ownership parcels and whether permission has been acquired to go onto the parcels. Survey areas, or individual transects within survey areas, that fall within parcels for which teams do not have permission to enter will be not be surveyed until such permission is obtained.

Field teams are to survey along each of the eight north-south transects in a 400 m wide section until, based on their judgment, they have covered all areas along the transect that likely were under water during the time of the spill. The field teams will consult wetland maps and elevation contours in making this judgment in the field.

After one week of sampling randomly selected floodplain sections with 4 field crews, the data obtained through these surveys will be evaluated to determine the degree to which floodplain oiling is predictable based on other types of information already available for the entire floodplain area (e.g., aerial photography, LIDAR elevation data, shoreline oiling survey, river bends). The evaluation of the initial floodplain oiling data from the first week of surveying in randomly selected areas will be done cooperatively between the Trustees and Enbridge. The Trustees and Enbridge will also review progress to date and determine whether the level of effort being invested in the floodplain survey is appropriate and/or needs to be changed.

5. Characterizing Habitats and Extent of Oiling

General issues:

- Safety is the first priority with all operations during this incident. The team will follow appropriate health and safety procedures related to survey activities.
- The floodplain survey will be conducted by four teams of two members each. When practically feasible, there will be one representative from the Trustees and one from the RP on each team. Teams will access the targeted floodplain habitat areas by either airboat or car. Each team will have a designated leader, who will be responsible for managing the team activities and records.

- The teams will meet with the study coordinator in the morning prior to entering the field to review safety procedures and the protocol. A morning meeting sheet will be signed by each individual.
- Each team will contact the study coordinator around mid-day to provide a quick status report and ensure the team is safe.
- The teams will meet at the end of the day with the study coordinator to download data, review the day, make any suggestions for improving the protocol, receive transect numbers to be completed the following day.
- We plan to spend three weeks intensively surveying floodplain areas. After this initial effort, the data will be reviewed to assess whether further floodplain characterization is needed. The nature and extent of any further surveying will be done at that time.
- Landowner permission for all areas to be surveyed on foot will be obtained by Enbridge prior to the teams conducting the survey in an area.
- As noted above, the primary focus of the floodplain survey will be Division C, with approximately 20% of LOE to be used to characterize Division D.

Survey Details:

- A GIS analyst will lay out north-south transects in each 400 meter survey section, at 50 meter intervals (8 transects per survey area). Coordinates of transect endpoints will be provided to field crews prior to their surveys so that their GPS units can be used to find the start and end points of transects.
- Two approaches have been developed for identifying transects; an initial approach (which will be used until we have enough information to implement the randomized approach), and a randomized approach:
  - Until we have the information available to lay out pre-determined transects, survey teams will select their own survey areas, with each team aiming to complete 250-500 m of river each day.
    - Sites will be selected based on property access (i.e., teams will go where they can).
    - Then, within a given property, areas of particular focus will include those with floodplain habitat and low banks, determined based on LIDAR and visual inspection, that are likely to have been impacted by the spill.

- — Crews will disembark the boat, noting the relevant river mile, and take a GPS waypoint to mark the point of disembarkation, and a north and south facing photograph

- — Survey teams will then mark out four to 10 different transects (depending on what is feasible, considering the number of teams present at the site, the length of river containing floodplain habitat, the amount of area for which private land owner permission has been granted, and the difficulty of terrain) on a map, spaced approximately 50 meters apart. They will then begin to conduct surveys along the transects.

  - Once the randomized survey approach is implemented, teams will go to predetermined locations (400 m sections). Note that in the randomization scheme, if a randomly-selected section is located on private property that is still not accessible, it will be skipped. Skipped sections will be surveyed once access is obtained.

- At the beginning of each transect, a photograph of the GPS unit and a north-facing and south-facing photograph will be taken. If so equipped, the track log can also be turned on the hand-held GPS unit, according to the attached SOP (to be received from entrix). Note: We are investigating whether the tables can be adjusted for track logging.

- The survey team will then walk along the transect and observe the presence and degree of oiling in any areas within sight from the transect. Teams are specifically looking for any areas of at least 50 square feet that are more than ‘sporadically’ oiled (see photos and sheets at end of this protocol for definition). Habitat in the floodplain is assumed to be sporadically oiled unless observed to be otherwise.

- The teams should leave the transect to inspect any areas that they suspect could be oiled heavier than sporadic, such as side channels connected to the river. After inspecting these areas (and taking photographs and making appropriate records as described below if the area is more than sporadically oiled), the team will return to the transect at the point where they left it.

- The survey along the transect stops when the team reaches either:

  - the point at which oiling is reduced to ‘no visible oil’
  - an area of greatly reduced habitat quality, such as a housing development or agricultural field; or
  - a point 15’ past the upland edge of the floodplain area (based on visual estimation).

- GPS waypoints will be taken at the river edge, periodic waypoints along the transect to demarcate the transect path taken, the transect end point, and at habitat transitions. At each waypoint, two photographs will be taken, on north-facing, and one south-facing.

- If equipped with a GPS unit that allows it, GPS track logs can be collected in addition to discrete waypoints, for later coordination of photographs and spatial coordinates. Note: We are investigating if the tablets can be adjusted to provide track logs.

- If an area of at least 50 square feet with more than sporadic oiling is observed, the survey team will circumscribe the area by visually identifying and walking around the perimeter of the area, and taking GPS waypoints at key points of direction change. Note that hereafter, 'oiled zone" refers to any area more than sporadically covered in oil.

    - Prior to and after delineating the oiled zone, photos of the GPS unit will be taken.
    - If equipped with GPS units that allow for it, a GPS track log will be used to circumscribe the area.
    - To characterize each oiled zone, team members will assess the degree of oiling within the oiled zone using the standard characterization charts in Appendix A.
    - If the team cannot safely walk around the perimeter of a zone, they will take a waypoint as close to the center of the area as they can reach and estimate the dimensions of the zone area visually.
    - If using back-up hardcopy sheets, separate datasheets will be used to record information about general transect waypoints (which are meant to simply show transect trajectories and habitat changes) and distinct oiled areas.

- For areas along a transect beyond which no visible occurs, only the point on the transect at which the oiling changes from sporadic to no visible oiling will be recorded, and the transect is then complete, rather than attempting to circumscribe the area of no visible oiling.

- In addition to oiling, the following habitat information will also be recorded on datasheets by the survey teams:

    - General vegetation type (forested wetland, forested upland, marsh, prairie, human managed area, etc.)
    - GPS waypoint location and approximate size of any water features of at least approximately 50 square feet, such as vernal pools or small channels
    - Presence of downed trees (that could provide habitat cover for herpetofauna and other wildlife)

- As transects are completed, field teams will note any instances where terrain or vegetation makes it difficult to observe the 25 meters on either side of the transect.
- Field teams will also note if they were impeded from completing the transect, and why (for example, if the upland edge was too steep to climb).

6. Tablets

The following rules and conventions will be followed when entering data into the tablet electronic datasheet in the field (see data management protocol for complete data management instructions):

- Transect I.D. naming convention: <map transect number>L (for left descending side) or <map transect number>R
  - e.g., 124R
- The program does not save automatically. Therefore, hit save after taking every waypoint
- USBs will be provided to each team. Conduct a save mid-day and end-of-day:
  - File that contains survey data on the tablet: C:\users\entrix\KREOS\floodplain.xml
    - Naming convention: <date>_<last name>
    - e.g., 2010_0815_Ritter.xml

7. Equipment

Transportation needs will likely vary daily, but we estimate that three to four airboats will be needed to transport four teams of two to various points along the river. One or two boats may be appropriate on given days, and some teams may be able to drive to sites, but we assume that three boats will be needed to allow maximum team mobility.

Each team will be equipped with an IBM notebook tablet, with electronic datasheets and GPS capabilities to take way points, GPS, camera, Scat Manual, PPE (Appropriate to HASP), pens, and a waterproof field notebook. Paper datasheets will also be carried in the field, as back-up to the tablets. Extra batteries, including computer batteries will be carried.

Once electronic tablets are available, they will be used to take GPS waypoints and pictures and will contain electronic version of the datasheet. Each team will still need a GPS, camera and paper data sheets as backup.

Data management and map production

Each evening cameras, GPS units, and data sheets will be turned in for downloading, and quality control. All data (hard copies of data sheets, GPS data, photos) will be shared with RP representatives by the end of the day.

Trustee and/or RP representatives will produce GIS maps showing the extent area surveyed, and, eventually, the extent of oiling in floodplain habitat will be produced after the survey is completed.

8. Data management and map production

Each evening cameras, GPS units, and data sheets will be turned in for downloading, and quality control. All data (hard copies of data sheets, GPS data, photos) will be shared with RP representatives by the end of the day.

Trustee and/or RP representatives will produce GIS maps showing the extent area surveyed, and, eventually, the extent of oiling in floodplain habitat will be produced after the survey is completed.

Appendix A

The extent of oiling for vegetation and sediments will be used as the standard reference.

Owens, E.H. and G.A. Sergy.Field Guide to the Documentation and Description of Oiled Shorelines. Environmental Canada, March 1994.

33 PERCENT COVER ESTIMATION CHARTS

These charts are aids to help you estimate the percent oil coverage in the area you are observing. The black shading represents oil. Do not spend time trying to get a precise measure of percent cover; the four ranges listed are usually sufficient. The chart below would prove most helpful in oil band situations; the one on the following page is best for discrete oil deposits such as tarballs.

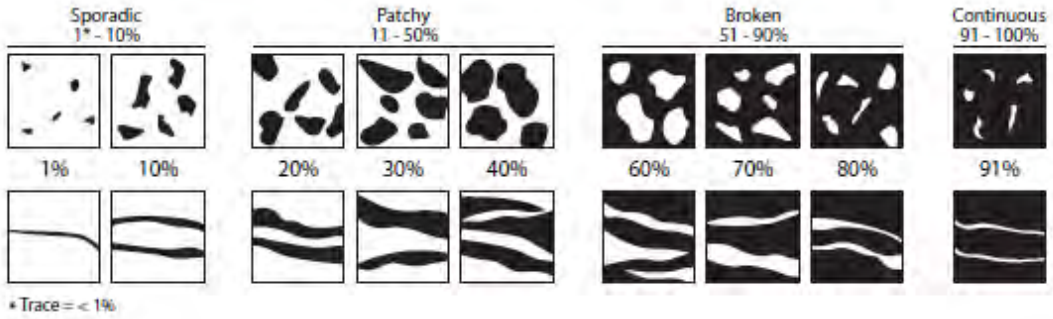
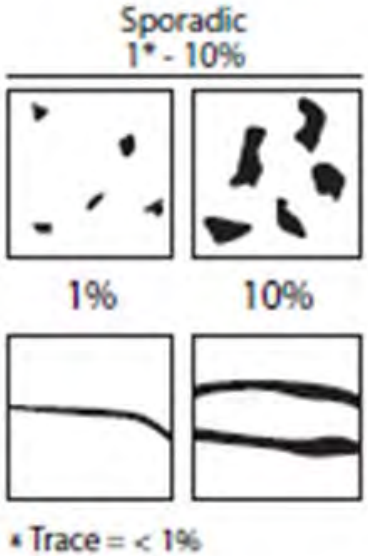


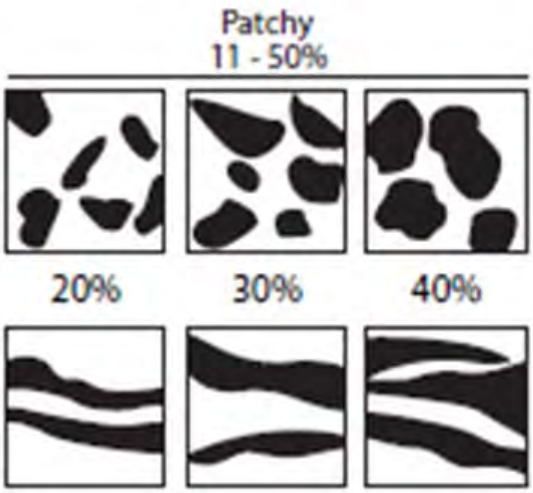
Chart source: Owens, E.H., and G.A. Sergy. Field Guide to the Documentation and Description of Oiled Shorelines. Environment Canada, Edmonton, Alberta, Canada. March 1994. ISBN 0-662-22048-X.

NO VISIBLE OIL

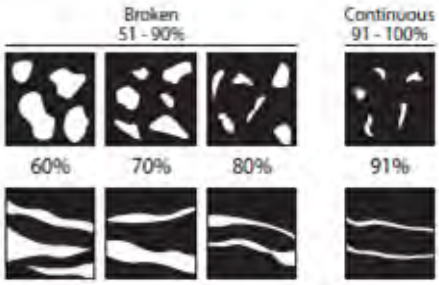
LIGHT (OR SPORADIC) OILING ON MARSH VEGETATION



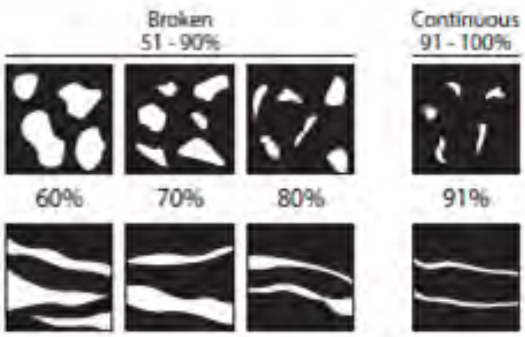
BAND OF PATCHY OIL ON EMERGANT MARSH VEGETATION



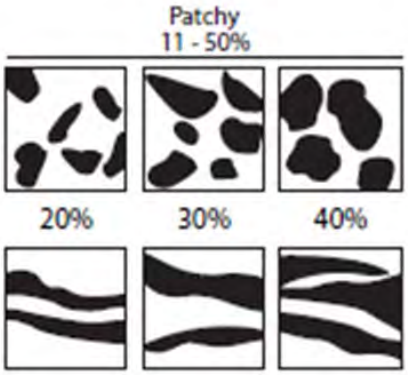
HEAVY OILING OF EMERGENT VEGETATION



HEAVY SEDIMENT OILING



MODERATE OR PATCHY OIL ON SEDIMENTS



Appendix B
Data Sheet

(In preparation)

Floodplain Characterization Data Sheet (Version 5.0) Site _____/_____ (Sheet ___ of ___)

River Mile (tenths) ____.____ Bank Side Descending (R/L) ____ Date ___/___/2010 Data Collector/Recorder _____

GPS/Photo Operator _____ GPS Unit ID _____ GPS Photo (Y ___, #_____) GPS Start Waypoint _____ Camera ID_____

TRANSECT ID (Rivermile.transect):_____OIL DELINEATION AREA ID (A-Z): _____ Time:_____

Waypoint # (____) **Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Oiling: Soil visible? (Y___/N___) If Y % oil covered soil (____%) % oil covered herbs (____%) % oil covered shrubs (____%) % oil covered trees (____%)
Features: Pooled oil (>50ft^2)?[1] (Y__/N__) Water feature (>50ft^2)?[2] (Y__/N__) Vernal pool (>50ft^2)?[3] (Y__/N__) Downed tree (>4" DBH)?[4] (Y__/N__) **Skunk Cabbage:** Present? (Y___/N___) If present, healthy___/defoliated____/new shoots_____ (combination ok) **Photos #s** _____
Notes: _____

Waypoint # (____) **Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Oiling: Soil visible? (Y___/N___) If Y % oil covered soil (____%) % oil covered herbs (____%) % oil covered shrubs (____%) % oil covered trees (____%)
Features: Pooled oil (>50ft^2)?[1] (Y__/N__) Water feature (>50ft^2)?[2] (Y__/N__) Vernal pool (>50ft^2)?[3] (Y__/N__) Downed tree (>4" DBH)?[4] (Y__/N__) **Skunk Cabbage:** Present? (Y___/N___) If present, healthy___/defoliated____/new shoots_____ (combination ok) **Photos #s** _____
Notes: _____

Waypoint # (____) **Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Oiling: Soil visible? (Y___/N___) If Y % oil covered soil (____%) % oil covered herbs (____%) % oil covered shrubs (____%) % oil covered trees (____%)
Features: Pooled oil (>50ft^2)?[1] (Y__/N__) Water feature (>50ft^2)?[2] (Y__/N__) Vernal pool (>50ft^2)?[3] (Y__/N__) Downed tree (>4" DBH)?[4] (Y__/N__) **Skunk Cabbage:** Present? (Y___/N___) If present, healthy___/defoliated____/new shoots_____ (combination ok) **Photos #s** _____
Notes: _____

Waypoint # (____) **Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Oiling: Soil visible? (Y___/N___) If Y % oil covered soil (____%) % oil covered herbs (____%) % oil covered shrubs (____%) % oil covered trees (____%)
Features: Pooled oil (>50ft^2)?[1] (Y__/N__) Water feature (>50ft^2)?[2] (Y__/N__) Vernal pool (>50ft^2)?[3] (Y__/N__) Downed tree (>4" DBH)?[4] (Y__/N__) **Skunk Cabbage:** Present? (Y___/N___) If present, healthy___/defoliated____/new shoots_____ (combination ok) **Photos #s** _____
Notes: _____

Waypoint # (____) **Habitat type (FU, P, FW, M, H, O):** _____ If O, describe _____
Oiling: Soil visible? (Y___/N___) If Y % oil covered soil (____%) % oil covered herbs (____%) % oil covered shrubs (____%) % oil covered trees (____%)
Features: Pooled oil (>50ft^2)?[1] (Y__/N__) Water feature (>50ft^2)?[2] (Y__/N__) Vernal pool (>50ft^2)?[3] (Y__/N__) Downed tree (>4" DBH)?[4] (Y__/N__) **Skunk Cabbage:** Present? (Y___/N___) If present, healthy___/defoliated____/new shoots_____ (combination ok) **Photos #s** _____
Notes: _____

B. Description of Closing Polygons

The ODAs delineated by the field crews required additional GIS processing in order to create closed polygons that could be visualized on a map. This appendix presents notes about how each ODA was drawn as a closed polygon on the map (Table B.1).

Each polygon was assigned a unique identification in the Access database. The ODAs are organized according to their unique identifier (see Unique ODA ID column in Table B.1).

For many ODAs, the waypoints were connected in order and the polygon was closed by connecting the first and last waypoints in the ODA. These are described as “close polygon.”

Some ODAs were delineated in the field in such a way that a closed polygon could not be drawn. These are described as “leave as line.” On the maps, these are represented as linear ODA features.

In some instances, connecting the waypoints in the order they were delineated in the field created irregular patterns or features with crossing lines. It is likely that this happened because of imprecision of the handheld GPS devices, which have an accuracy of approximately 3 m. For these cases, ODAs were drawn as closed polygons by connecting the waypoints to form a perimeter, even if the waypoints were not connected in order and a detailed description was provided.

Table B.1. Decisions for polygon delineations

Unique ODA ID	Decision	Additional notes
10.2L92_A	Close polygon	No additional notes.
10.2R286_A	Close polygon	No additional notes.
10.2R291_B	Close polygon	No additional notes.
10.2R301_C	Extend the polygon to the river – close polygon with a straight line rather than shape of the river because of unknown bank location	Because this was in a bend of the river, the polygon was created from the river edge to the next waypoint.
10.6L137_A	Close polygon	Used the adjacent transect line to complete the polygon.
12.5R59_A	Close polygon	The field notes say that the beginning of polygon is at waypoint 60, waypoint 59 is the start of the transect. Waypoint 59 was removed from the polygon and a new transect was created connecting waypoints 59–60.
12.5R71_B	Leave as line	No additional notes.
12.5R79_C	Close polygon	No additional notes.
13.3L93_A	Leave as line	No additional notes.
14.2L19_A	Extend the polygon to the river – close polygon with a straight line rather than shape of the river because of unknown bank location	No additional notes.
6.8L23_A	Leave as line	No additional notes.
8.5L43_A	Close polygon	No additional notes.
9.6L107_A	Leave as line	No additional notes.
9.6L114_B	Leave as line	No additional notes.
9.9L39_A	Close polygon	No additional notes.
8.5L39_B	Leave as point	No additional notes.
8.5L36_A		No additional notes.
474L_A	Close polygon	No additional notes.

Table B.1. Decisions for polygon delineations (cont.)

Unique ODA ID	Decision	Additional notes
477L_A	Close polygon	No additional notes.
533R_A	Close polygon	This polygon originally had 5 waypoints points. The first 4 make a nice polygon outline, but the 5th did not fit with the rest. In the field "Type" (type of waypoint) it said "End," while others said "Oil Polygon." The 5th point was not included as part of the polygon.
533R_B	Close polygon	No additional notes.
534R_A	Close polygon	No additional notes.
562L_A	Close polygon	No additional notes.
570R_A	Close polygon	No additional notes.
573L_A	Close polygon	No additional notes.
585R_A	Close polygon	Two of the 3 waypoints points had 0% oil recorded. However, it was noted that at this time, field crews were instructed to characterize the entire polygon with 1% oiling value, so the percent oiling was assigned to the first or last waypoint.
602R_A	Close polygon	No additional notes.
726R_A	Keep as line	Could not close the polygon.
901L_A	Close polygon	No additional notes.
901L_B	Keep as line	The field notes suggest that the pooled oil extends 15 ft north of the line; however, this is not enough information to delineate a polygon. Therefore, this ODA was left as a line.
903L_A	Close polygon	No additional notes.
903L_B	Keep as line	The field notes suggest the "Edge of water closes polygon"; however, this is not enough information to close the ODA polygon. Therefore, it was left as a line.
903L_C	Close polygon	No additional notes.
907L_A	Close polygon	The shape of this polygon was unusual; it appears that the polygon shape is irregular because of the imprecision of the GPS units. A polygon was delineated by joining the ODA waypoints in the following order: 1, 2, 4, 3, 1.

Table B.1. Decisions for polygon delineations (cont.)

Unique ODA ID	Decision	Additional notes
909L_A	Keep as line	The field notes reference a small island with oil; however, this is not enough information to create a polygon. Therefore, it was left as a line.
911L_A	Close polygon	No additional notes.
911L_B	Close polygon	The shape of this polygon was unusual; if the waypoints are connected in order, the lines form a criss-cross across a polygon. Linking waypoints 1, 2, 4, 3, 1 forms a perimeter of the points; this is how the polygon was drawn.
913L_A	Close polygon	No additional notes.
913L_B	Close polygon	This polygon overlaps with another polygon, 913L_A. These polygons were left as is.
917L_A	Close polygon	No additional notes.
919L_A	Close polygon	No additional notes.
920L_A	Close polygon	The shape of this polygon was unusual; it appears that the polygon shape is irregular because of the imprecision of the GPS units. Linking waypoints 1, 2, 4, 3, 1 forms a perimeter of the points; this is how the polygon was drawn.
921L_A	Close polygon	The shape of this polygon was unusual; linking the waypoints forms a “Z.” It appears that the field crew delineated the top of the polygon, then crossed the polygon and formed the bottom. The polygon was created by joining the waypoints that form the perimeter.
921L_B	Close polygon	No additional notes.
1003L_A	Close polygon	No additional notes.
1005L_A	Close polygon	No additional notes.
505.5L_A	Close polygon	No additional notes.
505.5L_B	Close polygon	No additional notes.
507.5 L_A	Close polygon	No additional notes.
509.5 L_A	Close polygon	No additional notes.

Table B.1. Decisions for polygon delineations (cont.)

Unique ODA ID	Decision	Additional notes
509.5 L_B	Close polygon	No additional notes.
510.5 L_A	Close polygon	Waypoints 6 and 7 cross each other. The polygon was created by connecting waypoint 5 to 6 and waypoint 6 to 8. Waypoint 7 fell within the polygon; therefore, it was not included.
510.5 L_B	Close polygon	No additional notes.
511.5L_A	Close polygon	No additional notes.
511.5L_B	Close polygon	No additional notes.
511.5L_C	Close polygon	Connecting the waypoints in order creates crossing lines; this is because of the imprecision of the GPS units. The polygon was deleted by connecting waypoints 4 and 5.
511.5L_D	Close polygon	Connecting the waypoints in order creates crossing lines between waypoints 1 and 6; this is due to the imprecision of the GPS units. The polygon was drawn by moving the lines to remove the cross.
511.5L_E	Close polygon	No additional notes.
511.5L_F	Close polygon	No additional notes.
512.5L_A	Close polygon	No additional notes.
512.5L_B	Close polygon	No additional notes.
512.5L_C	Close polygon	No additional notes.
515R_A	Close polygon	No additional notes.
518.5 L_A	Close polygon	Connecting the waypoints in order creates crossing lines. The polygon was drawn by connecting the waypoints in the following order: 2, 3, 1, 4, 5, 6.
518R_A	Close polygon	No additional notes.
535L_A	Close polygon	No additional notes.
631L_A	Close polygon	No additional notes.
633R_A	Close polygon	No additional notes.

Table B.1. Decisions for polygon delineations (cont.)

Unique ODA ID	Decision	Additional notes
634R_A	Close polygon	Connecting the waypoints in order creates crossing lines. The polygon was drawn by connecting waypoints 8 and 2; waypoint 1 falls in line between the segments.
635R_A	Close polygon	Connecting the waypoints in order creates crossing lines; this is because of the imprecision of the GPS units. The polygon was drawn by moving the vertex, which eliminated the crossing lines but kept the polygon closed.
681_A	Close polygon	No additional notes.
743L_A	Close polygon	No additional notes.
748L_A	Left as line	No additional notes.
930L_A	Close polygon	Connecting the waypoints in order creates crossing lines. The polygon was drawn by connecting the waypoints on perimeter.
934L_A	Close polygon	No additional notes.
947L_A	Close polygon	No additional notes.

STRATUS CONSULTING

1881 Ninth Street, Suite 201 Boulder, Colorado 80302 phone 303.381.8000 fax 303.381.8200 (headquarters)

1920 L Street, N.W., Suite 420 Washington, D.C. 20036 phone 202.466.3731 fax 202.466.3732

www.stratusconsulting.com

Appendix C: Wildlife Response Report

Wildlife Response Activities for the July 25-26, 2010 Enbridge Line 6B Oil Discharges near Marshall, MI

Prepared by

Scott A. Berg and Lisa L. Williams

United States Fish and Wildlife Service

East Lansing Field Office

April 7, 2015

Table of Contents

Introduction and Overview 3

Definitions 3

Incident Command System: Structure and Functions 5

Wildlife Response Activities 12

- Wildlife Deterrence 13
- Oiled Wildlife Hotline 14
- Wildlife Response Center Development 16
- Field Teams and Tactics 18
  - Use of Decoys/Bait at Cannon Net Stations (Waterfowl) 20
  - Use of Hand-Held Net Deployment Devices (Super Talon) 21
  - Use of Walk-in Traps (Waterfowl) 22
  - Use of Alpha-Chloralose on Flighted Geese 22
  - Hand-feeding Park Geese and Ducks/Hand-capture 23
  - Use of Leghold Traps (Great Blue Heron and Sandhill Crane) 23
  - Use of Live Traps (Mammals) 24
  - Turtle Trapping Techniques 24
- Volunteers and the Public 25
- Wildlife Rehabilitation 26
- Wildlife Release 30
- Training 30
- Branch Management 31

Wildlife Response Chronology 33

Introduction and Overview

On Monday, July 26, 2010, Enbridge Energy Partners (Enbridge) reported that a 30-inch pipeline had ruptured and discharged an estimated 819,000 gallons of crude oil near Marshall, Michigan. Oil discharged from Enbridge's Lakehead Line 6B on July 25-26, 2010, entered wetlands near the rupture and then flowed through Talmadge Creek to the Kalamazoo River, where it continued to flow downstream for approximately 38 miles. Aquatic and floodplain habitats were oiled as were birds, mammals, turtles and other wildlife.

Michigan Department of Natural Resources and Environment (MDNRE) and United States Fish and Wildlife Service (USFWS) mobilized on-site and received the first reports of oiled wildlife on July 26, 2010. USFWS advised Enbridge to mobilize professional rehabilitators and begin building rehabilitation facilities that evening. A wildlife hotline was established that night so that the public and responders could report sightings of oiled wildlife. Enbridge mobilized their contractor, Focus Wildlife, overnight and they then built a complete rehabilitation facility (Wildlife Response Center or WRC) over the next several days.

The USFWS developed and led the Wildlife and Environmental Assessment Branch within the Operations Section of the Incident Command System (ICS), which was used to manage the overall response to the oil discharges. This Branch provided technical assistance to U.S. Environmental Protection Agency (USEPA) on natural resource issues and field observations; led reconnaissance, capture, rehabilitation, and release of oiled animals; installed deterrence measures to try to minimize wildlife oiling and road fatalities; and provided a link between natural resource damage assessment (NRDA) field activities and the ICS management of the overall response. The USFWS, MDNRE, U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS), and contractors employed by USFWS and Enbridge performed daily reconnaissance for oiled wildlife, responded to hotline calls, and captured oiled wildlife when possible on a daily basis until mid-October of 2010 when responsibility was turned over to Enbridge and their contractors. Enbridge and Focus Wildlife led the rehabilitation functions, with Binder Park Zoo taking a major role in rehabilitation of turtles and other reptiles and amphibians. Personnel from additional zoos and volunteers also assisted in animal care and cleaning oiled wildlife. Releases of rehabilitated animals were coordinated among USFWS, MDNRE, Enbridge, and contractors.

This report describes the operations of the Wildlife and Environmental Assessment Branch from July 26, 2010 through October of 2010.

Definitions

<u>Administration/Finance</u> – a person(s) responsible for day to day financial and administrative operations during the incident.

<u>Branch Director</u> – a position within the Incident Command System that has management responsibility of the entire branch and oversees all aspects of implementation of the incident objectives in the Incident Action Plan that are assigned to the branch. The Branch Director serves

as the main contact with their respective Section Chief (e.g., Operations) and the Incident Commander or Unified Command.

Enbridge – Enbridge Energy, L.P., Enbridge Pipelines ("Lakehead") L.L.C., Enbridge Energy Partners, L.P., Enbridge Energy Management, L.L.C., Enbridge Energy Company, Inc. , Enbridge Employee Services, Inc., Enbridge Operational Services, Inc., and Enbridge Pipelines Inc.

Entrix – a private contractor hired by Enbridge to provide environmental and NRDA expertise.

Focus Wildlife – a private contractor hired by Enbridge to provide wildlife operations.

GIS Support – a person(s) assigned to provide mapping and geographical spatial data support to field operations and Incident Command.

HRM – Herpetological Resource & Management, a contractor for U.S. Fish and Wildlife Service.

IAP – Incident Action Plan, provides a concise, coherent means of capturing and communicating the overall incident priorities, objectives, and strategies in the contexts of both operational and support activities.

ICP – Incident Command Post, a centralized meeting point for Unified Command during the incident. The ICP housed representatives from each responding agency, consistent with methodology of ICS.

ICS – Incident Command System, a standardized on-scene emergency management construct specifically designed to provide an integrated organizational structure that reflects the complexity and demands of single or multiple incidents, without being hindered by jurisdictional boundaries. ICS is the combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure, designed to aid in the management of resources during incidents. It is used for all kinds of emergencies and is applicable to small as well as large and complex incidents. ICS is used by various jurisdictions and functional agencies, both public and private, to organize field-level incident management operations.

Logistics – a person(s) designated to ensure materials, services and equipment are provided for response to the incident.

MDNRE – Michigan Department of Natural Resources and Environment.

NRDA – Natural Resource Damage Assessment as described in the National Contingency Plan and either the Comprehensive Environmental Response, Compensation, and Liability Act or the Oil Pollution Act, as applicable. In this incident, NRDA teams assessed damages to natural resources and the service they provide, including collecting ephemeral data in parallel with response activities. NRDA field team conducted surveys of impacts to surface water, sediments, soil, vegetation, benthic invertebrates, fish and wildlife and coordinated these field activities through the Wildlife/Environmental Damage Assessment Branch.

Public Information Officer (PIO) – a position within the Incident Command System that manages and disseminates information related to the incident for incident personnel, the public, and media.

Safety Officer – a position within the Incident Command System, that oversees all aspects of safety and administers corrective measures in the event of a safety breach within the branch.

Stantec – a contractor hired by Enbridge to provide herpetological expertise.

Unified Command – In incidents involving multiple jurisdictions, a single jurisdiction with multi-agency involvement, or multiple jurisdictions with multi-agency involvement, Unified Command allows agencies with different legal, geographic, and functional authorities and responsibilities to work together effectively to make decisions to coordinate the response without affecting individual agency authority, responsibility, or accountability.

USDA-APHIS-WS – United States Department of Agriculture Animal and Plant Health Inspection Service – Wildlife Services

USEPA – United States Environmental Protection Agency.

USFWS – United States Fish and Wildlife Service.

Wildlife Care – specialized teams in the animal husbandry, veterinary care and rehabilitative progress of oiled wildlife. The teams consisted of veterinarians, veterinary assistants, zoologists, rehabilitators and volunteers.

Wildlife Recovery – specialized teams in locating, observing and recovering oiled wildlife for transport to the Wildlife Response Center for rehabilitation. The teams consisted of personnel from USFWS, USDA-APHIS-WS, MDNRE, Focus Wildlife, Entrix, HRM, Stantec and volunteers.

Wildlife Response Center (WRC) – a facility located in Marshall, Michigan that housed the Wildlife/Environmental Damage Assessment Branch. The facility was developed for intake, rehabilitation and conditioning of wildlife. In addition, office space was available for wildlife response agencies. This allowed for effective communications and cooperation amongst all disciplines of the branch.

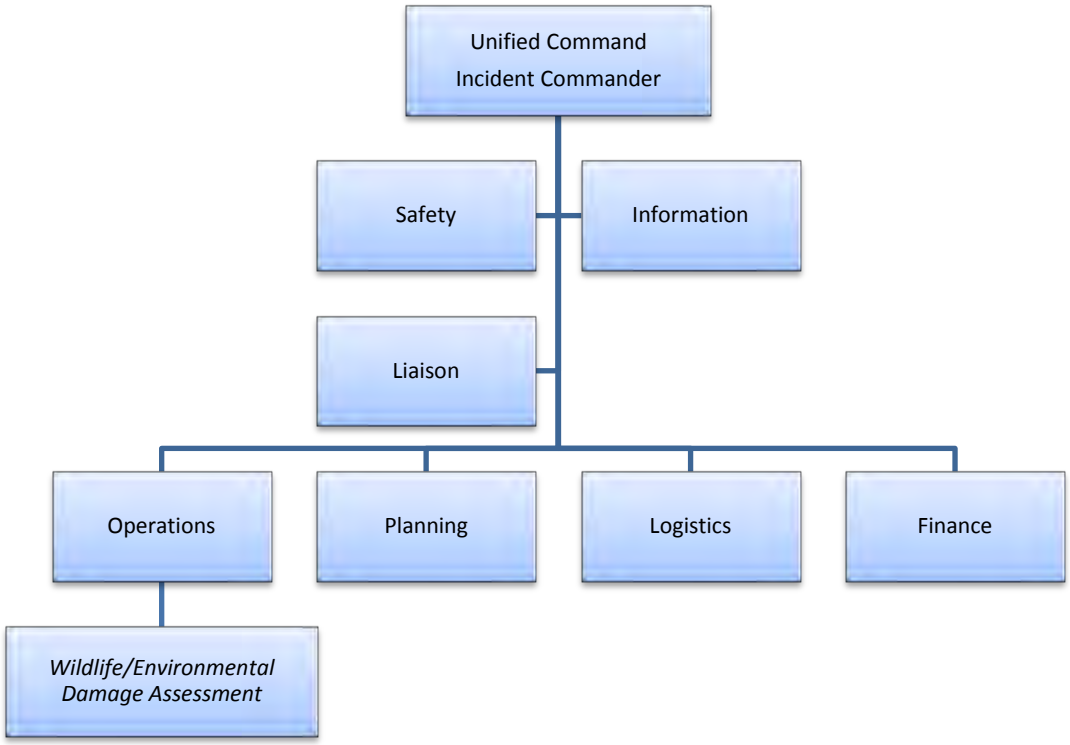
Incident Command System: Structure and Functions

ICS is a pre-determined method of response organization that clearly identifies the responsibilities, lines of communication and strategies used during any incident. ICS is designed to work across political and physical boundaries, allowing for interoperability during any emergency situation, regardless of the size.

ICS was used from the onset of the Line 6B incident, first led by Enbridge and then by a Unified Command with U.S. EPA serving as the Federal On-scene Coordinator and Incident Commander.

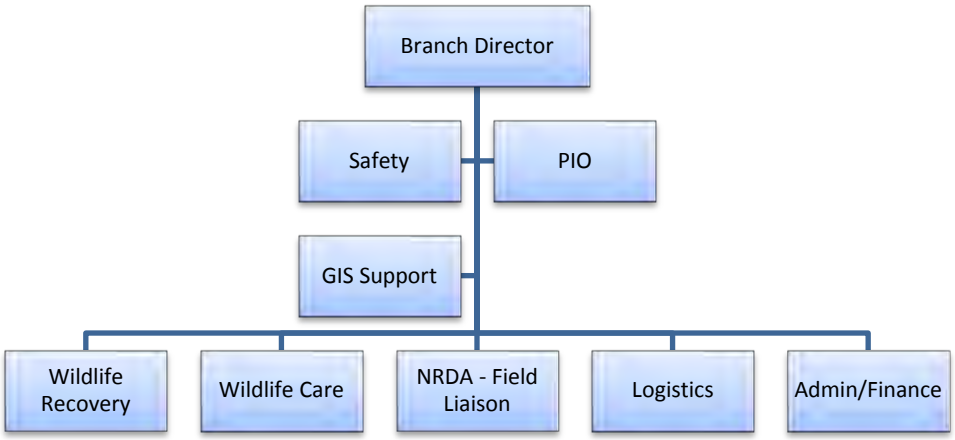
Personnel from the USFWS Fire Program assisted EPA in establishing ICS and improving its overall effectiveness, as well as being part of the leadership team for the Wildlife/Environmental Damage Assessment Branch. Within the ICS organizational structure, the Wildlife/Environmental Damage Assessment Branch was placed as one of the branches in Operations:

Incident Command



During most of the spill response, the Wildlife/Environmental Damage Assessment Branch was organized into groups and teams aligned along the following basic structure:

Wildlife/Environmental Damage Assessment Branch



The Wildlife/Environmental Damage Assessment Branch structure replicates the ICS model and is broken down into specific groups. These groups, with their descriptions, are as follows:

Branch Director

The Branch Director position was filled by USFWS personnel from the beginning of the spill through September 24, 2010, when USFWS turned over the position to Enbridge. Through most of the first three months of the response, the Branch Director was assisted by two Deputy Directors; one from USFWS and one from Enbridge. The Branch Director and Deputies were assigned oversight of all wildlife operations and reported to Unified Command through the Operations Section.

During the height of the response, the Branch Director and Deputies were assisted by Division/Group Supervisors who worked specifically with the various groups within the Branch. Division/Group Supervisors supported the groups and coordinated completion of ICS planning forms each operational period.

Safety

The Branch Safety Officer developed a Health and Safety Plan specifically for the Branch; did daily safety briefings; and, monitored working conditions, use of PPE, and waste handling for the Wildlife Response Center. Important safety concerns were exposure to oil (including volatile components like benzene), the potential for zoonotic diseases, injuries from wildlife, slip/trip/fall hazards, overheating, dehydration, and electrical hazards (especially around water in tanks, conditioning ponds, and washing areas). The Safety Officer for the Branch provided daily Safety Messages in accordance with the IAP. The Branch Safety Officer conducted continuous inspections of the WRC and took immediate corrective measures on any matters involving unsafe conditions. In addition, the Branch Safety Officer maintained a running log for all watercraft activities (float plan) and Safe Work Permits (documentation required by Enbridge). The Branch Safety Officer also helped develop and provide site-specific Hazardous Waste Operations and Emergency Response (HAZWOPER) training as needed for personnel. As the response continued, the Branch Safety Officer also wrote a Fatigue Management Plan for the Branch. No serious incidents were recorded for the Wildlife Branch.

PIO

The USFWS provided a Public Information Officer (PIO) to the Branch to address press releases and other media issues. The PIO was on-site for the first few weeks of the incident and then was located off-site for the remainder of the initial response period. The PIO also assisted with coordinating public meetings and press conferences. Originally press conferences were held daily, but then were held weekly or less often as the incident progressed.

GIS Support

MDNRE provided on-site GIS support with specialists and equipment. Mapping needs and other GIS information were channeled through this position, allowing for fast document turnaround time. GIS specialists in the WRC created maps specific to wildlife operations and managed general site maps obtained through Unified Command. GIS specialists within the branch supplied information to Unified Command on both the ongoing wildlife response and sensitive environmental areas.

Wildlife Recovery Group

Initial field teams and assignments consisted of the following teams and assignments:

- Terrestrial Teams
    - Capture/transport/survey of oiled wildlife
    - Develop alternate strategies and tactics for wildlife capture
    - Monitor/document locations/conditions where oiled birds (that could fly long distances) landed
    - Respond to Oiled Wildlife Hotline calls as needed
- Herp Teams
    - Concentrate on turtle recovery efforts
    - Coordinate with other branch/division/group operational personnel concerning turtle traps, utilizing ICS 204 (Field Assignment form) information
- Aquatic Teams
    - Survey, recover and document fish and wildlife impacted in waterways and wetland areas

As the incident progressed, additional field teams were deployed, which consisted of the following teams and assignments:

- Focus Terrestrial Team
    - Respond to Hotline calls as needed
    - Capture/transport/patrol of oiled wildlife
    - Develop alternative strategies and tactics for wildlife capture
    - Monitor/document locations/conditions where oiled birds(that could fly long distances) landed
    - Develop/provide Hazmat training as needed for necessary personnel
    - Participate in scientific support team
    - Coordinate activities using ICS 204 information
- Focus Recon Team
    - Perform reconnaissance
    - Capture/transport/patrol of oiled wildlife
    - Participate in scientific support team
    - Coordinate activities using ICS 204 information
- Beaver Trapping Team
    - Perform recon
    - Collect oiled animal locations
    - Develop/provide Hazmat training as needed for necessary personnel

    - Participate in scientific support team
    - Coordinate activities using ICS 204 information
    - Trap and recover beaver and transport back to the Wildlife Response Center
- Heron Capture Team
    - Capture/transport/patrol of oiled wildlife
    - Develop alternate strategies and tactics for heron capture
    - Respond to hotline calls as needed
    - Monitor/document locations/conditions where oiled heron land
    - Develop/provide Hazmat training as needed for necessary personnel
    - Participate in scientific support team
    - Coordinate activities using ICS 204 information
- Wildlife Data
    - Collect and process wildlife data
    - Develop/provide Hazmat training as needed for necessary personnel
    - Participate in scientific support team
    - Coordinate activities using ICS 204 information
- Stantec Herp Team Coordinator
    - Continue to concentrate on turtle recovery effort
    - Configure personnel into teams and make assignments
    - Coordinate with other branch/division/group operational personnel concerning turtle traps, utilizing ICS 204 information
    - Develop/provide Hazmat training as needed for necessary personnel
    - Participate in scientific support team
    - Coordinate activities using ICS 204 information

In addition, all teams were directed to conduct a heat stress assessment in accordance with the Health and Safety Plan for the incident. A strict work/rest schedule was enforced due to high heat and humidity levels during response. Teams also followed a lightning safety protocol for inclement weather.

Wildlife Care Group

The Wildlife Care Group operated primarily in the Wildlife Response Center (WRC), located in Marshall, Michigan. The Wildlife Care Group consisted of the following teams and assignments:

- Animal Area Intake Crew/Stabilization Area/Response Veterinarian
    - Document and photograph animal intake
    - Conduct initial examination and assessment of animals
    - Stabilize animals per Focus Wildlife policy
- Animal Care Manager/Release Coordinator
    - Document progress of treatment and rehabilitation
    - Oversee medical treatment and follow-up care for animals
    - Oversee and assist with animal release plans
- Facilities Coordinator
    - Ensure facilities are functioning appropriately for animal intake and rehabilitation
    - Develop and maintain intake, holding, cleaning and conditioning areas

- Turtle Area Crew
    - Assist veterinary staff with all aspects of turtle stabilization, feeding, rehabilitation and preparation for release
    - Develop techniques and methods for safe custody of wintering turtles
- Animal Kitchen Crew
    - Organize and maintain animal kitchen
    - Prepare and record food for varying animal species per veterinary guidelines
- Cleaning Area Crew
    - Organize and maintain cleaning area
    - Provide for safe cleaning environment for team members and animals
    - Clean oiled wildlife by using accepted practices and veterinary guidelines
    - Maintain equipment used for cleaning and ensure materials are in stock
- Conditioning Area Crew/Rehab Supervisor/Release Coordinator
    - Organize and maintain conditioning area
    - Provide for safe environment for animals to ensure reduced opportunity for escape and/or injury
    - Assist with conditioning and rehabilitation of animals using veterinary guidelines
    - Prepare animals for transport to release location
- Wildlife Deterrent Task Force
    - Develop wildlife deterrent techniques
    - Maintain deterrent devices (fencing, decoys, etc.)
    - Assist with other tasks as needed

All personnel were required to adhere to the Wildlife Response Center Safety Plan. Crew leaders also provided task-specific training to crews and volunteers.

Natural Resource Damage Assessment (NRDA) - Field Liaison

NRDA teams determined their study priorities separately from ICS, but coordinated their field activities with the rest of the response through an NRDA Field Liaison with the Wildlife/Environmental Damage Assessment Branch. The NRDA Field Liaison also ensured that all safety protocols, permit requirements, and messages from ICS reached the NRDA teams. NRDA teams conducted surveys throughout the response area to evaluate impacts to surface water, sediment, soil, vegetation, benthic invertebrates, fish and wildlife. The NRDA teams reported any of their sightings of oiled wildlife to the Branch so that dispatchers could direct wildlife response teams to the indicated locations. In addition, the Branch was able to facilitate the transfer of floodplain oiling survey information from the NRDA teams to the Planning Section.

Logistics - Wildlife Support Group

The Wildlife Support Group operated primarily in the Wildlife Response Center (WRC) and was comprised of the following:

- Dispatch/Volunteer Coordination
    - Provide radio and telephone communications with field teams
    - Relay hotline information for response
    - Maintain sign-in sheet for personnel and visitors to the WRC

    - Coordinate and assign volunteers for wildlife operations
- Equipment/Supplies Stock
    - Ensure required materials are on-hand
    - Work with local spill donation center and Logistics Section to obtain equipment and supplies
    - Develop and maintain inventory list

Administration/Finance

- Administration/Purchasing
    - Provide for support in ordering materials and equipment for wildlife response and rehabilitation
    - Work with Wildlife Support Group to ensure operational readiness of WRC
- Finance
    - Ensure financial requirements for response are met
    - Monitor daily expenditures to ensure alignment with incident funds allocation
    - Assist with payroll

Technical Assistance to the U.S. Environmental Protection Agency (EPA)

Agency personnel within the Wildlife Branch also provided technical assistance to EPA through communications with Unified Command, Operations Section, and Planning Section:

- Reviewing and commenting on Enbridge submittals
    - Operational Health and Safety Plan
    - Sampling and Analysis Plan and Quality Assurance Project Plan
    - "Remediation" plans for source area and downstream areas
    - "Restoration" plans
- Science Team/Environmental Advisory Group
    - Cleanup recommendations
    - Submerged oil
    - Seasonal outlook
- Data for removal actions and closure approvals
    - Observations of response activities and field conditions
    - Discovery and evaluation of extent of submerged oil
    - Floodplain survey data from NRDA teams
- ICS Assistance

Oiled Goose in Flight

Wildlife Response Activities

The mission of the Wildlife/Environmental Damage Assessment Branch was to:

- Provide protection of environmentally and culturally sensitive areas including wildlife and historic properties.
- Protect threatened and endangered species & continue to recover and rehabilitate injured wildlife.

From the early hours of following notification of the oil discharges into the environment, wildlife response was a high priority within the overall response.

The first USFWS biologist arrived on scene on July 26 and began developing strategies for wildlife response. Agency involvement in wildlife reconnaissance and recovery were important for the following reasons:

- Public and wildlife safety
    - Leadership, credibility and visibility
    - Local knowledge and contacts
- Validation of number and degree of oiled wildlife
- Independent observations of impacts of oil and response activities
    - Submerged oil
    - Fen
    - Other sensitive habitats
    - Worker techniques

The operation of the Branch was under USFWS leadership, but was successful because the cooperation and work contributed by many agencies, contractors, and others, including personnel from the following:

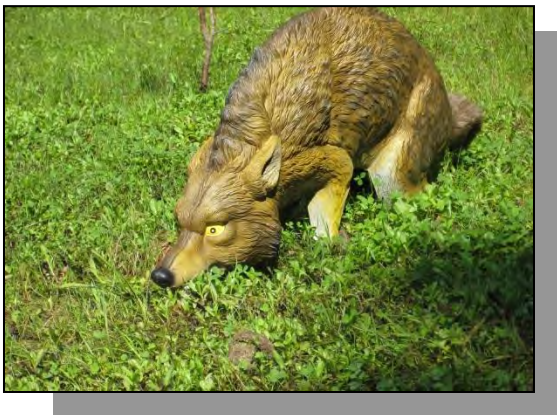
- USFWS
- MDNRE
- USDA APHIS Wildlife Services
- Michigan Department of Agriculture, Emergency Response Unit
- Stantec
- HRM
- Focus Wildlife
- Binder Park Zoo
- Manpower
- Volunteers

The following sections describe wildlife deterrence, oiled wildlife hotline, WRC development, field teams and tactics, wildlife rehabilitation, wildlife release, volunteers and the public, training, and Branch management

Wildlife Deterrence

Efforts to prevent un-oiled wildlife from becoming oiled were implemented in the early days of the spill. Deterrence crews worked on foot to construct barriers to prevent animals from entering the river. Additional deterrence strategies included:

- Silt Fencing
- Snow Fencing
- Scare Tape
- Propane Cannons
- Predator "Scarecrows"
- Response Work
    - >1,500 workers
    - Flotillas of airboats
    - Helicopters
    - Vacuum trucks



Coyote "Scarecrow" Decoy

Deterrence Fencing and Scarecrow

Deterrence fencing was also placed along a road that was being heavily used by response vehicles in order to reduce the risk to turtles after a spotted turtle was found in the area. The spotted turtle is listed by the State of Michigan as a threatened species.

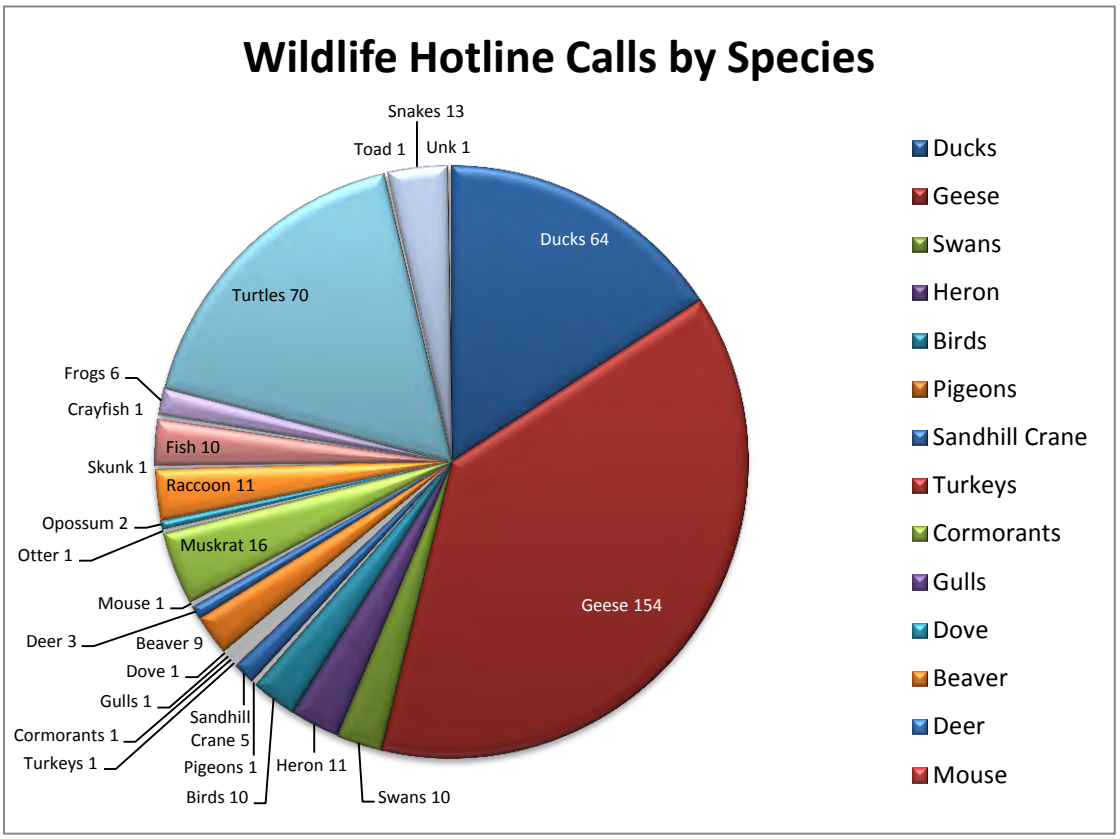
Oiled Wildlife Hotline

Enbridge developed and maintained an Oiled Wildlife Hotline that provided a single-source reporting location for members of the community and spill responders. The reports of oiled wildlife were forwarded to the Wildlife Response Center for dispatch, which allowed for timely response by wildlife field crews.

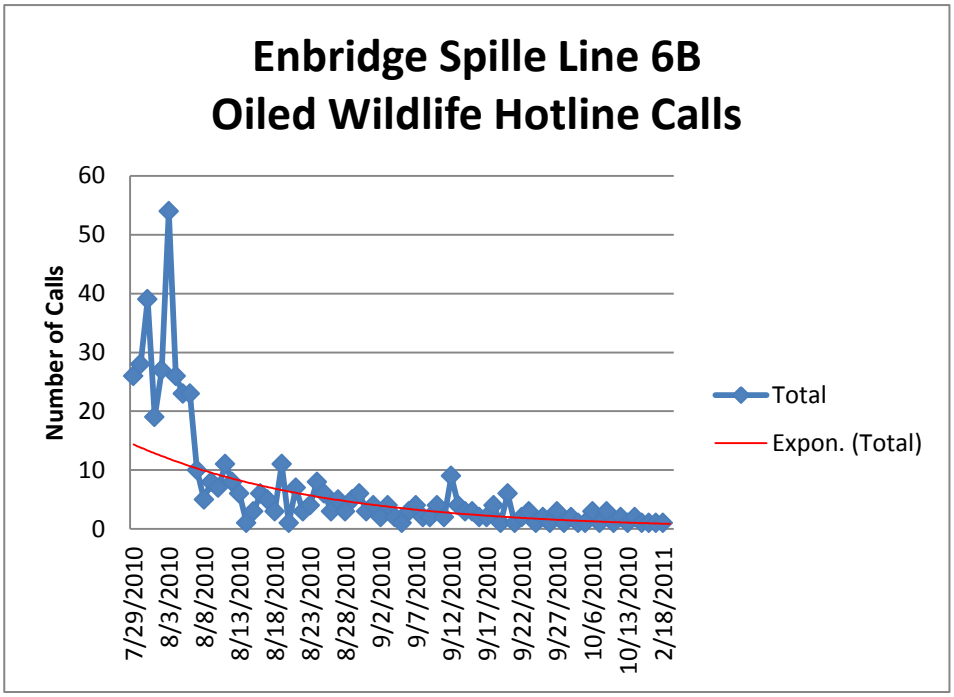
The hotline number was advertised continually, using a variety of approaches:

- Press conferences
- Press releases
- IAPs
- Flyers/Leaflets
- Business Cards
- Magnetic Door Shields
- Websites
- Wildlife Trapping Notice Signs

Heron Trapping Area



The majority of wildlife hotline calls were reports of oiled geese, turtles and ducks. Other wildlife species were also reported but with less frequency. Additionally, the hotline was used more during the first week of the spill response. Its use diminished as the incident progressed with time.



Number of Hotline Calls by Date

Waterproof business cards with the Oiled Wildlife Hotline number on its face were provided to wildlife field crews and were distributed during face to face contacts with local residents and spill responders. Several reports came in to the WRC as a result of the cards, many of which were generated by spill responders. Additionally, magnetic door shields that displayed the hotline number were provided for use on wildlife recovery vehicles. This allowed for high visibility of teams when on the road and afield and also identified responders as incident staff when stopped along roadways and near private residences.

In addition, the hotline was used for general information about the oil spill. Volunteers could use the hotline to sign up to assist at the spill. General wildlife questions could also be asked.

Wildlife Response Center Development

On Day 2 of the response, Focus Wildlife personnel arrived on-scene and began establishing the Wildlife Response Center (WRC). Enbridge and Focus Wildlife identified a facility previously used by the Firekeepers Casino in Marshall, Michigan, as having characteristics that met wildlife recovery needs. The building included office space for responding agencies and organizations and eventually was equipped with telephones and internet access. A conference room was also available and was used for daily briefings and meetings. Adequate floor space for wildlife intake, rehabilitation and conditioning allowed for flexibility in use and design. The physical structure

within the building changed frequently to address the needs of wildlife care. A large parking area on-site allowed for convenient parking of personnel and response equipment. In addition, a large conditioning facility, complete with water pools, filtration and secure housing, was established close to the main building, yet far enough from the main parking lot to minimize disturbances to recovering wildlife by vehicles and other equipment. Storage was available in two large sea containers. A large, unattached garage provided additional conditioning and storage areas.

Focus Wildlife and Enbridge built systems for water supply, handling and disposal on-site and had to make adjustments to heating, cooling, and electrical systems to provide proper climate control for recovering wildlife. To get sufficient water volume and pressure, they worked with local authorities to use nearby fire hydrants to supplement the water supply to the facility. They installed on-demand water heaters and pressure controllers to provide a reliable supply of water at the narrow range of temperature and pressure required for washing large numbers of oiled animals. They also installed several large holding tanks for waste water and arranged for vacuum trucks from the overall incident response to empty them as needed.

Wildlife Response Center

Conditioning pen area

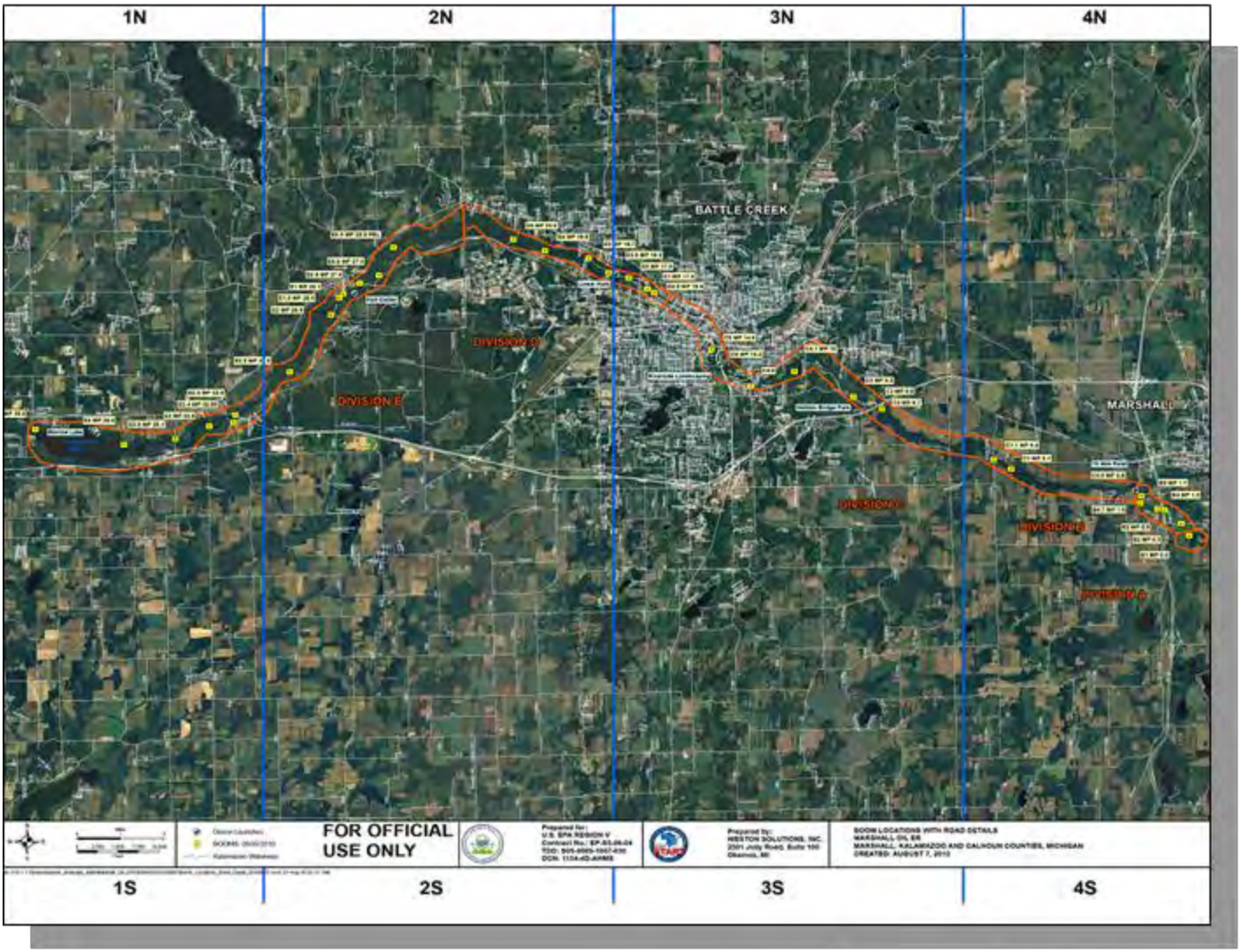
Wastewater tanks and vacuum truck

Conditioning pen

Field Teams and Tactics

Field teams were established with personnel from USFWS, USDA-APHIS-WS, MDNRE, Focus Wildlife, Stantec and a few volunteers. The teams initially located and documented oiled wildlife while the WRC was being constructed and outfitted. The teams quickly moved from observation and documentation to response and recovery once the WRC was able to accept oiled wildlife. Early in the spill, teams were accompanied by industrial hygienists to monitor concentrations of volatile compounds, particularly benzene. Later, the Branch obtained simplified meters and trained team members to use them until monitoring was no longer required by the Safety Officer.

Wildlife recovery teams used different tactics over time as the conditions changed. In the beginning of the response, the teams focused on the heavily oiled birds. Crews responded to reports from the public and response workers and were able to pick up oiled animals with hand held nets. As the most heavily oiled birds were brought in for rehabilitation, the remaining birds became wary of capture teams and crews gained more access to the river. As a result, the Branch developed geographic divisions to allow for efficient team deployment and systematic searching. In addition, specialty teams were used for targeting specific wildlife.



Geographical Response Areas

A large number of Canada Geese and other waterfowl were oiled but still able to fly. Over time, the birds appeared to learn to recognize team vehicles, to the point that certain geese would fly away upon arrival of team vehicles at potential capture sites, and to avoid certain tactics. Because of this, tactics and techniques were evaluated and new methods implemented. Original capture techniques involved teams approaching geese with large hand nets and slowly working into their locations. The teams would attempt to net the geese when they became cornered or when they would attempt to take flight. This method was ineffective for flighted birds. Tactics meetings, conducted by wildlife response personnel, identified alternative capture methods which included the following:

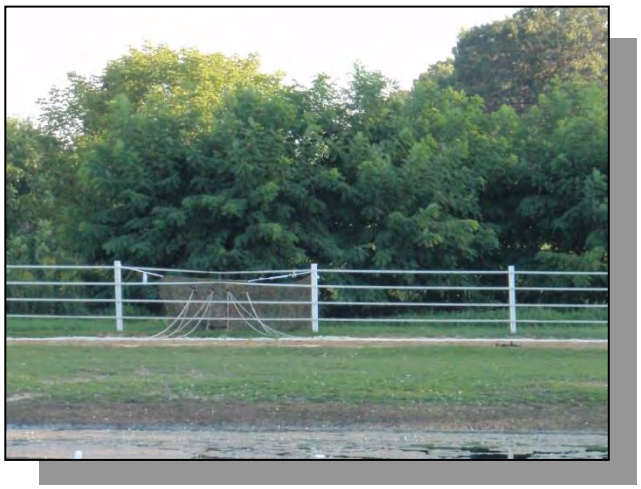
- Use of decoys and bait at cannon net stations
- Use of hand-held net deployment devices (Super Talon)
- Use of walk-in traps (waterfowl)

- Use of modified soft-catch leghold traps (Great Blue Heron and Sandhill Crane)
- Use of live traps (mammals)
- Use of box traps and commercial traps (turtles)
- Use of Alpha-chloralose on flighted geese
- Hand-feeding park geese and ducks/hand-capture

Oiled Canada Geese Watching Hand Net Operation

Use of Decoys/Bait at Cannon Net Stations (Waterfowl)

A pair of CO_2 powered cannon nets were deployed in rural areas where oiled Canada Geese repeatedly congregated. Original discussion of tactics for luring the geese into netting range included the use of goose decoys and/or bait (corn). The use of decoys was not implemented but placement of corn was used. The cannon nets were deployed successfully. Difficulty arose when trying to keep un-oiled geese from eating the bait. On several occasions the oiled geese were harassed by the un-oiled geese, causing the oiled geese to move away from the bait. During one operation at the Nottawa Painted Horse Farm trapping location, oiled geese flew into the bait before the un-oiled geese, allowing for a successful net deployment and the capture of nine birds. At the Eaton Proving Grounds trapping location, oiled geese were observed and corralled into cannon net range. Two geese were successfully captured in that attempt. Total observation and trapping effort occurred over a nine day period.

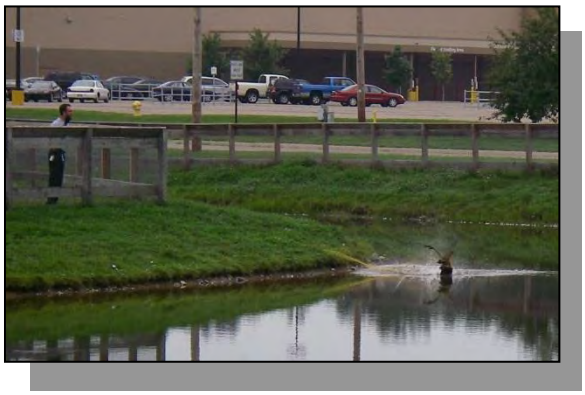


Cannon Net w/ Bait

Use of Hand-Held Net Deployment Devices (Super Talon)

Wildlife Recovery personnel made use of a hand-held net launcher called the Super Talon. The Super Talon fired a 16 foot diameter net from a hand-held launcher. Carbon dioxide (CO_2) is the propulsion source and is easily re-armed and reloaded. The net mesh comes in varying sizes, allowing for large animal or small bird capture. Additional Super Talon devices were ordered and presented to field crews. After a brief training session, the Super Talons were deployed on several capture attempts with positive results. The Super Talon's effective range varied from 5 to 10 meters.

Super Talons were fired with good overall effectiveness from stationary ground positions and from vehicles in motion. No injuries were sustained by birds captured with the devices. The devices are supplied with a relatively large mesh net that was effective for Canada geese, but mallards were able to escape. Crews experimented with a smaller net size with some success.



Super Talon Deployment

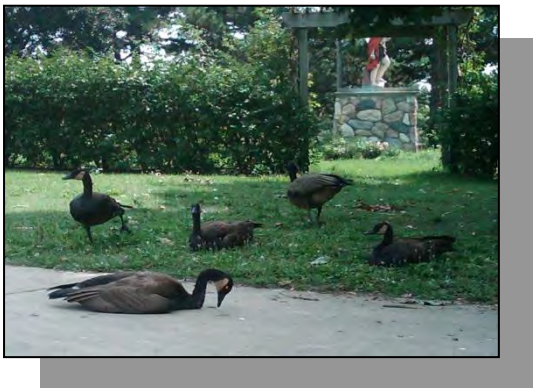
Use of Walk-in Traps (Waterfowl)

Walk-in traps were used for ducks and geese with limited success. Small walk-in traps were initially used for ducks, resulting in no captures. A large walk-in trap was constructed over time to capture Canada Geese, again with no captures. Late in the spill response, a walk-in trap was gradually constructed on a small Island that was frequented by oiled ducks on the Kalamazoo River. Bait (corn) was placed inside the trap to lure the birds inside. The trap was successfully deployed, capturing four oiled ducks. The trap's design was repeatedly modified to fit existing conditions at the trap location.

Walk-in Trap for Ducks w/ Bait

Use of Alpha-Chloralose on Flighted Geese

Alpha-chloralose, a drug that can be used to tranquilize geese, was approved for use by the MDNRE state veterinarian. APHIS personnel were able to dose individual geese by tossing treated food directly to the individual they hoped to capture. Unfortunately, geese captured this way arrived at the WRC in a stressed condition, and it was difficult to manage the timing of capture and care at intake. Working together, the agencies, Focus Wildlife, and Enbridge leaders within the Branch decided to discontinue use of alpha-chloralose for this incident.



Geese Dosed with Alpha-Chloralose

Hand-feeding Park Geese and Ducks/Hand-capture

Ducks and geese that were accustomed to hand feeding in city parks were sometimes captured by baiting them within grabbing distance. Wildlife crews would feed the birds and when close, capture the birds by hand. This method required great time in gaining confidence of the birds, but was effective in urban settings.

Use of Leghold Traps (Great Blue Heron and Sandhill Crane)

A significant number of oiled Great Blue Heron and a small number of oiled Sandhill Cranes were observed by field crews. A determination was made that a specialized team would need to be in place to capture these species of birds. Rita Seston from Entrix, a contractor for Enbridge, provided soft-catch leghold traps from her heron research with Michigan State University. She and Mike Nadeau, who had worked with her on her research, trained two USFWS personnel in proper capture and handling techniques. Mike Nadeau worked as a contractor with the USFWS personnel.

The team initially used bait fish purchased at a local bait shop to attract herons to the trap site. They discovered that bluegill were more attractive to the herons and so discontinued the use of purchased bait fish in favor of using locally caught small bluegills. The bait was placed in a partially-submerged bait box. Up to 60 leghold traps were placed around the outside of the bait box. The traps were secured to a staked main line, which would prevent the heron from flying away with the trap. To prevent injuries to herons, soft-catch traps were modified by lowering jaw tension and providing shock absorption within the tether that secured the trap to the main line.

The original clips for securing the traps were rusted and not fully functional. The clips were replaced with stainless steel decoy snaps that worked very effectively. The decoy snaps not only secured the traps to the main line but also aided in fast setup and takedown.

The strategy worked very effectively, accounting for the capture of nine Great Blue Herons. Because of the nomadic nature of Sandhill Cranes, the team was not able to effectively deploy traps to target them.

Great Blue Heron Trap Set

Use of Live Traps (Mammals)

Initial attempts to capture furbearing animals yielded mixed results. Baited live traps were deployed but resulted in the capture of primarily un-oiled raccoons. Snares were used to attempt beaver capture. One beaver received minor injuries due to the friction of the snare. Snaring was stopped and a contractor who specialized in animal control was hired. Dave Bowers of Bowers Wildlife Control utilized various live traps for capturing beaver, muskrat and other furbearing animals. The animals were handled according to protocols established by MDNRE and Focus Wildlife and no further injuries resulted from capture.

Live Trap with Raccoon

Turtle Trapping Techniques

HRM initially attempted to use basking traps to capture oiled turtles but had poor success rates. Turtles were able to escape from the initial trap design. Stantec deployed commercial turtle traps with much greater success rates. Basking and commercial traps were often times subject to disturbance because of the high volume of vessel traffic on the river, especially airboats. As the incident progressed into cooler months, two-person teams of a boat operator and wildlife technician became very effective at capturing oiled turtles with hand held nets.

Basking Trap

Commercial Turtle Trap

Volunteers and the Public

Using the hotline, press conferences, public meetings, and other outreach efforts, USFWS and MDNRE urged the public to report oiled wildlife, but not to pick up oiled wildlife themselves both for their own safety and to minimize handling stress on the wildlife. Nonetheless, some members of the public did pick up wildlife and attempt to clean them in the first few days of the spill. The Branch attempted to recover these animals for additional treatment or carcass disposal.

Thousands of people volunteered to help the animals impacted by the spill. Calhoun County provided staff to take calls from volunteers and compile data on potential volunteers. In addition to the spill information and wildlife reporting hotlines, people in the Calhoun County area were also directed to dial 211 or visit www.handsonbc.org to volunteer. The Wildlife Branch then used that information, as well as personal contacts with known individuals, to bring volunteers in for training and work. Within the Wildlife Branch, a Volunteer Manager position was established to screen, schedule, organize, and track volunteers. Enbridge staffed the Volunteer Manager position with a contractor. Overall, approximately 150 individual volunteers contributed over 7,000 hours of work.

Throughout the response, the volunteers were managed by Enbridge and their contractors. The volunteers were all adults, and were mostly women. Some volunteered as parts of groups or organizations and others were unaffiliated. A few had previous experience with oiled wildlife spill response, but most were trained on-site by Focus Wildlife. Some volunteers became contract employees. The volunteers were primarily used in supporting the rehabilitation efforts being managed by Enbridge and their contractors, and the task for which the largest number of volunteer hours was used was washing oiled turtles. A few volunteers participated in reconnaissance and capture crews for several days, but those volunteers did not return on subsequent days and this practice was discontinued.

Local wildlife rehabilitators who attempted to set up their own wildlife washing stations were encouraged by the USFWS and MDNRE to turn over any wildlife already in their care to the Wildlife Response Center and were invited to sign in and be trained as volunteers within the Wildlife Branch. This was eventually successful in providing efficient, state-of-the-art wildlife care, control of animal and waste handling and tracking, and ensuring the safety of everyone working with oiled wildlife.

In addition to volunteering, members of the public and local businesses donated generous amounts of supplies like towels, cleaning supplies, boxes and crates, bottled water, and snacks. The donations threatened to overwhelm staff and space at the Wildlife Response Center, and fortunately a local church set up a donation center near the Wildlife Response Center. The church and their volunteers set up a large tent and organized supplies. The donation center operated independently of the Incident Command structure, but the volunteers there implemented suggestions from the Wildlife Branch and made it possible for Wildlife Branch personnel to obtain donated materials very easily as needed.

Wildlife Rehabilitation

Focus Wildlife managed the day-to-day wildlife rehabilitation activities with oversight from USFWS and MDNRE. Initially they also were assisted by veterinarians and specialists with the Michigan Department of Agriculture's animal emergency response unit. Focus Wildlife brought in professionals experienced in working with oiled birds and mammals and also used local rehabilitators and volunteers with appropriate on-site training. Focus Wildlife used their established protocols that are consistent with the USFWS's manual *Best Practices for Migratory Bird Care During Oil Spill Response* (available at http://www.fws.gov/Contaminants/FWS_OSCP_05/FWSContingencyTOC.htm#D). The general steps in the rehabilitation process were as follows:

- Intake examination
- Stabilization with hydration, feeding, and medications as needed until the animal was healthy enough to undergo the intensive washing process
- Washing and rinsing
- Recovery
- Conditioning
- Veterinarian examination for fitness to release

HRM initiated turtle care at the WRC and then Dr. Chris Tabaka from Binder Park Zoo and his staff led the care, cleaning and rehabilitation of turtles. Eventually, Focus Wildlife and then Stantec led the care for turtles as well. Because the oil was often stiff and tacky on turtles, individual turtles were usually cleaned over several sessions, between which the turtles were allowed to rest and recover from being handled. Most turtles were cleaned by hand with pads, brushes, and cotton swabs; large snapping turtles were anesthetized by a veterinarian and cleaned with gentle pressure washing in wading pools.

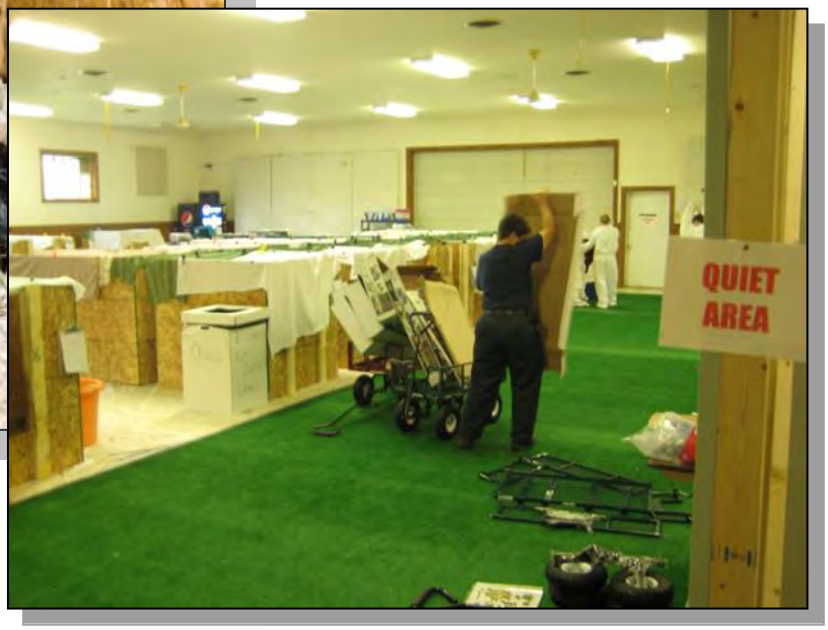
In general, care was highly successful, with survival to release rates of 84% for birds and 98% for turtles. Great Blue Heron survival was lower than for other species. Approximately half of them

developed skin lesions, lost weight, and either died or were euthanized because of their deteriorating condition, despite the best efforts of the veterinarians and animal care workers.

MDNRE and USFWS conducted or closely monitored intake documentation and received copies of all in-care records for individual animals. The agencies also supervised carcass documentation and storage, with USFWS law enforcement officers supervising the locked freezers for migratory birds.

Intake Examination of Great Blue Heron

Oiled Canada Geese



Pre-wash Stabilization Area for Birds and Mammals

Washing of Turtles (left) and Birds (right)

Mineral Oil Application to Loosen Oil on Canada Goose

Turtle Washing

Washing Snapping Turtle

Turtle Care and Recovery Area

Wildlife Release

Planning for release of rehabilitated wildlife was complicated by the often conflicting goals of releasing animals back to their capture locations as soon as they were fit and protecting them from additional oiling or disturbance. With an impacted corridor of nearly 40 miles, oil persisting in floodplains and submerged sediments, as well as ongoing response operations, made it difficult to find appropriate release sites for some species.

Birds were taken to locations away from the Kalamazoo River where they would be protected from disturbance when released. These sites included the Allegan State Game Area and the Kellogg Bird Sanctuary. Most birds were banded before release. Waterfowl received a special color band that indicated that this was an "oil spill bird" and gave a toll free number to call for more information.

Turtles were released in a variety of locations either upstream of the oiled areas, in tributaries to the Kalamazoo River, or in previously impacted areas that were thought to be free of oil. Turtles were marked with PIT tags or shell notches. Through subsequent re-capture of individual turtles, we learned that at least some turtles were returning to their capture locations (or had at least moved in that direction from their release point) and were becoming re-oiled.

Training

Training was provided for wildlife response personnel who did not have Hazardous Waste Operations and Emergency Response (HAZWOPER) 40-hour certification. Unified Command approved a four hour, site-specific, training program, entitled 4-Hour Safety Awareness Training for Oil Spill Workers, to familiarize response workers with oil spill hazards and operations. The training certification applied only to the Enbridge Line 6B incident location.

All USFWS personnel working on site had either the 24-hour or 40-hour HAZWOPER training, with some of them completing the 24-hour program just prior to deployment to the scene.

The state of Michigan utilizes a state-of-the-art 800 MHz trunked radio system. Wildlife response teams used the radios as part of the Wildlife Branch Communications Plan. Because of their complex features and unique operating environment, one of the Branch staff with extensive experience with the radios developed in-house training and provided it to Wildlife Branch personnel. This training program was then used as the training standard for all responders who carried radios.

Enbridge required all response personnel to receive specific safety training. The training was specific to Enbridge operations and safety protocols. Each responder was required to watch a 17 minute training video and pass a written examination. Upon successful completion of the training, a certification decal was awarded which had to be worn on the responder's helmet or identification card.

Off-road Utility Vehicles, or UTVs, were used extensively as the spill event progressed, so a safety training program was established. All operators of UTVs were required to complete the training and carry a UTV operator card.

Branch Management

As part of ICS, the Branch had a daily cycle of regular meetings, planning, and reporting of activities. The meetings included key personnel and were used to convey important information pertaining to the Incident Action Plan (IAP), safety and other operational issues. The meeting structures were as follows:

Morning Meeting

- Review the plan
- Safety message
- Any urgent issues for groups, needs for next day
- Break into groups
- Submit changes to Incident Action Plan (IAP) for next day

Evening Meeting

- What was planned?
- What actually happened and why?
- Plan tomorrow

Meeting times varied during the spill response to address specific needs of the Wildlife Branch. Meetings were scheduled to allow field crews the ability to maximize their work efficiency while afield.

At the conclusion of the morning Branch meetings, team leaders would assemble their respective teams and provide a tail gate meeting. The purpose of the tail gate meeting was to allow team leaders to assess the team's makeup, share vital safety information and develop team unity. Teams reviewed a prepared safety briefing, which was then signed by the team leader and all team members. This briefing sheet was carried while crews were deployed and needed to be presented to safety officers upon request. In addition, the Incident Action Plan (IAP) was also carried afield and used as a daily operations plan. Team leaders also filed a Safe Work Permit, which was required by Enbridge. If a team were to deploy on watercraft, a float plan had to be filed with the branch safety officer. The teams would then embark on their assigned tasks for the day.

Unless additional work was required, most field teams were back at the WRC for the evening meetings. Some crews worked night time operations (night ops), requiring them to re-group after the meeting and prepare for deployment. Surveillance for Canada Geese was often times performed during night ops, allowing crews to observe flight patterns, feeding habits and night roosting habits.

Night Ops Surveillance

During the course of the day, the Branch Director and staff used data and information from the Branch field teams, Operations Section, Planning Section, and Unified Command to develop and write plans for the next operational period of the response (e.g. ICS forms 204 and 215 for Assignment Lists and Operational Planning Sheet, respectively). They also wrote summaries of Branch activities for the Situation Unit in the Planning Section; updated costs and personnel numbers for the Finance Section; reviewed intake and care records; reported on the number of animals captured, in care, and released; provided technical assistance to EPA by reviewing various work plans and participating on the Science Team/Environmental Advisory Group; prepared for press conferences and public meetings; and attended meetings of the Operations Section and with Unified Command and General Staff. They also managed personnel and worked with their home and regional offices to arrange for appropriate rotations of staff over time. The Branch Director also spoke at press conferences and evening public meetings in Marshall, Battle Creek, and Kalamazoo. At the height of the Branch's activities, approximately 120 people from multiple organizations and agencies were working together to find, treat, and release oiled wildlife.

Wildlife Response Chronology

July 26, 2010, Day 1:

- U.S. Fish and Wildlife Service lead person on site
- Enbridge mobilized Focus Wildlife for wildlife care and rehabilitation
- Oiled Wildlife Hotline established and maintained by Enbridge
- Rehabilitation facility planning begins
- Additional USFWS personnel requested
- Oiled wildlife observed and recorded

July 27, 2010, Day 2:

- Incident Command System (ICS) implemented, Wildlife Branch organized with USFWS, MDNRE and Law Enforcement
- Volunteer coordination began
- Sensitive natural resources maps created and analyzed for planning
- Press conference held
- Reconnaissance of oiled fish and wildlife
- Focus Wildlife arrived on scene, Wildlife Response Center (WRC) established
- Incident Command briefings occur at 6:00 am and 6:00 pm
- Teams by Response Type:
    - Recon Teams – 1 Team

July 28, 2010 – July 31, 2010, Days 3-6

- Wildlife response underway
    - Teams primarily responded to hotline calls and locations documented on previous days
- Safety was paramount
    - Training
    - Monitoring
    - Communications Plan
- Wildlife deterrence plan implemented
- Data integrity an area of priority within the WRC
- Public outreach
    - Press
    - Rehabilitators
    - Legislators
    - Governor
- Logistical issues for WRC worked out
    - Internet access
    - Supplies allocation
    - Donations distribution and storage
    - Continued construction of intake and holding areas
- Additional USFWS personnel arrived on-scene

- Wildlife Response
- Teams by Response Type:
    - Hotline Response – 2 Teams
        - Geographic Coverage
            - Marshall
            - Roaming
    - Roaming/Transport – 1 Team
        - Geographic Coverage
            - Roaming
    - Hours of Operation: Not Known

<u>August 1, 2010 – August 2, 2010, Days 7-8:</u>

- USDA APHIS Wildlife Services specialists arrived on-scene
- Tactics meetings held, new capture techniques developed and implemented
- WRC fully functional, animal intake flowing smoothly
- Record keeping streamlined and working effectively
- Communications between wildlife response teams and WRC improved
- 4-hour HAZWOPER training provided to personnel
- Enbridge safety training provided to personnel
- Teams by Response Type:
    - Hotline Response – 3 Teams
        - Geographic Coverage
            - Ceresco/Marshall
            - Battle Creek (2 Team coverage)
    - Roaming/Transport – 1 Team
        - Geographic Coverage
            - Roaming
    - Hours of Operation: Not Known

<u>August 3, 2010 – August 4, 2010, Days 9-10:</u>

- Tactics Team developed to review and implement special capture tactics outside of hand net capture of Canada Geese
- Teams by Response Type:
    - Terrestrial Teams – 2 Teams
        - Geographic Coverage
            - Battle Creek Area
            - Marshall Area
    - Tactics Team – 1 Team
        - Tactics Deployed
            - Cannon Net
            - Super Talon Net Gun (STNG)
        - Geographic Coverage

            - Marshall Area
    - Roaming/Transport – 1 Team
        - Geographic Coverage
            - Division C
    - Hours of Operation: 0700 hrs – 1900 hrs (Tactics Team until 2200 hrs)

<u>August 5, 2010 – August 6, 2010, Days 11-12:</u>

- Teams by Response Type:
    - Terrestrial Team – 2 Teams
        - Geographic Coverage
            - Battle Creek Area
            - Marshall Area
    - Tactics Team – 1 Team
        - Tactics Deployed
            - Cannon Net
            - Super Talon Net Gun (STNG)
        - Geographic Coverage
            - Roaming
    - Scouting/Recon Team – 4 Teams
        - Geographic Coverage
            - Battle Creek Inland
            - Battle Creek Lake
            - Marshall Inland
            - Marshall Lake
    - HRM Aquatics Team – 2 Teams
        - Geographical Coverage
            - Division C Upstream from Dam
            - Turtle Trap Deployment
    - DNRE Aquatics Team – 7 Teams
        - Geographical Coverage
            - All Divisions
            - Turtle Trap Deployment
    - Hours of Operation
        - 0700 hrs – 1900 hrs

<u>August 7, 2010 – August 11, 2010, Days 13-17:</u>

- Wildlife Response Geographic Zones established 8/7/10
    - Simplified tracking of effort
    - Allowed for strategic response
    - Provided systematic geographic coverage
- Teams by Response Type:
    - Terrestrial Team – 4 Teams
        - Geographic Coverage
            - 4 South, Rocket Net/Night Ops

            - 4 North
            - 3 South
            - 1 North
    - Focus Wildlife – 1 Team
        - Geographic Coverage
            - 4 South
    - HRM Aquatics Team – 2 Teams
        - Geographical Coverage
            - Division C Upstream from Dam
    - DNRE Aquatics Team – Removed from IAP
    - Hours of Operation
        - 0700 hrs – 1800 hrs

<u>August 12, 2010 – August 15, 2010, Days 18-21:</u>

- Specialized team development expanded
- Incident Division designations utilized in addition to Geographic Zones
- Teams by Response Type:
    - Terrestrial Team – 3 Teams
        - Geographic Coverage
            - Muskrat Trapping in Div. B, C, and D
            - 3 North (2 team coverage)
    - Focus Recon Team – 1 Team
        - Geographic Coverage
            - All Divisions
    - Wildlife Hotline Response – 1 Team
        - Geographic Coverage
            - All Divisions
    - HRM Aquatics Team – 2 Teams (Demobilized on 8/13/10)
        - Geographic Coverage
            - Mill Pond (C5-C6 Upstream of Ceresco Dam)
            - Division C (Ceresco Dam and Mill Pond)
    - DNRE Aquatics Team – 4 Teams
        - Geographic Coverage
            - Division C, Electro Fishing
    - Stantec Herp Team – 3 Teams
        - Geographic Coverage
            - Divisions C & E
    - Hours of Operation
        - 0700 hrs – 1800 hrs

<u>August 16, 2010 – August 20, 2010, Days 22-26:</u>

- Heron Capture Team and Focus Terrestrial Team added to operations
- Teams by Response Type:
    - Terrestrial Team – 3 Teams

        - Geographic Coverage
            - 3 South
            - 3 North (2 teams)
    - Focus Recon Team – 1 Team
        - Geographic Coverage
            - All Divisions
    - Wildlife Hotline Response Team – 1 Team
        - Geographic Coverage
            - All Divisions
    - Heron Capture Team – 1 Team
        - Geographic Coverage
            - All Divisions
    - Stantec Herp Team – 3 Teams
        - Geographic Coverage
            - Divisions C & E
    - Stantec Herp Team Coordinator position added to IAP (8/19/10)
    - Hours of Operation
        - 0700 hrs – 1800 hrs

<u>August 21, 2010 – August 28, 2010, Days 27-34:</u>

- Trapping Team added to operations
- Evening cannon net operations added
- Teams by Response Type:
    - Terrestrial Team – 1 Team
        - Geographic Coverage
            - Division B am
            - Division E pm
            - Horse Farm Net Deployment in pm
    - Focus Terrestrial Team – 1 Team
        - Geographic Coverage
            - Arbor Inn area
    - Wildlife Hotline Response
        - Geographic Coverage
            - All Divisions
            - Recon Divisions B and C
    - Heron Capture Team – 1 Team
        - Geographic Coverage
            - All Divisions
    - Trapping Team
        - Geographic Coverage
            - All Divisions
    - Stantec Herp Team
        - Geographic Coverage
            - Divisions C & E
    - Hours of Operation

            - 0700 hrs – 1800 hrs (Except for Night Ops, until 2330 hrs and Heron Capture Team, until dark)

<u>August 29, 2010 – September 23, 2010, Days 35-60:</u>

- USDA APHIS Wildlife Services staff demobilized
- Each team's geographic coverage = all Divisions
- Teams by Response Type:
    - Focus Terrestrial Team – 1 Team
    - Focus Recon Team – 1 Team
    - Heron Capture Team – 1 Team
    - Trapping Team – 1 Team
    - Hours of Operation
        - 0715 hrs – 1730 hrs (Except for Heron Capture Team, until dark)

<u>September 25, 2010 – September 29, 2010, Days 61-66:</u>

- Additional Heron Team activated
- Each team's geographic coverage = all Divisions
- Teams by Response Type
    - Focus Terrestrial Team – 1 Team
    - Focus Recon Team – 1 Team
    - Heron Capture Team 2 Teams
    - Trapping Team – 1 Team
    - Stantec Herp Team – Team Numbers Coordinated with Focus Teams and Wildlife Care Group
    - Hours of Operation
        - 0715 hrs – 1730 hrs (Except for Heron Capture Teams, until dark)

<u>September 30, 2010 – October 15, 2010, Days 67-82:</u>

- Heron Teams and Trapping Team demobilized
- Wildlife Submerged Oil Team activated
- Teams by Response Type
    - Focus Terrestrial Team – 1 Team
        - Geographic Coverage
            - All Divisions
    - Focus Recon Team – 1 Team
        - Geographic Coverage
            - All Divisions
    - Wildlife Submerged Oil Team – 1 Team
        - Geographic Coverage

            - River System
    - Hours of Operation
        - Not Known

<u>October 16, 2010 – October 19, 2010, Days 83-86:</u>

- Focus Terrestrial Team and Focus Recon Team demobilized
- Teams by Response Type
    - Wildlife Response Team – 2 Teams
        - Geographic Coverage
            - All Divisions
    - Hours of Operation
        - Not Known

<u>October 20, 2010 – October 31, 2010, Days 87-98:</u>

- Wildlife Response Teams demobilized
- Team by Response Type
    - Hotline Response
        - Geographic Coverage
            - All Divisions
    - Stantec Coordinating Wintering of Turtles with Wildlife Care Group
    - Hours of Operation
        - Not known

Appendix D: Lake Allegan Fish Kill Investigation Report

Lake Allegan Fish Kill Investigation

Field Survey Methods

Lake Allegan is a 6-mile long reservoir with a surface area of 1,550 acres at a normal water surface elevation of 615 ft (NGVD). The shoreline length of the reservoir from Allegan Dam up to M-89 is 80,678 ft including the shoreline length of two small islands in the center of the reservoir. Sampling methods for investigating the fish kill followed procedures in Southwick and Loftus (2003) and the MDNR fish kill investigations guidebook (2003). DNR- Fisheries Division staff was divided into five crews consisting of two people per crew. Lake Allegan was separated into two strata, shoreline and open water counts, for enumerating dead fish. Shoreline counts were conducted along five segments that were 2,850 ft long (Figure 1). The total number of dead fish were first estimated within each stratum and then summed together for the total estimate. The total number of dead fish within the shoreline segments was estimated by the average number of dead fish per segment multiplied by the total number of segments in the kill area. The total number of dead fish in the open water zone was estimated by area sampling. Lake Allegan was separated into five transects. Crews were instructed to sample each transect by boat following parallel transects approximately 750 ft apart that were oriented from the north shore to the south shore of the lake. Each open water zone transect began at the end of the outer edge of the shoreline segment. The total number of dead fish in the open water zone was estimated by using an expansion factor. Expansion factor = T/(W*N); whereby T is the length of Lake Allegan, W is the transect width, and N is the number of sample transects.

Results of Investigation

A total of 27 dead fish were collected on August 5, 2010 by DNR staff along the shoreline segments (Table 1). No fish were collected from the sampled open water zones. An additional 12 northern pike, 3 spotfin shiners, and three largemouth bass were observed on August 4, 2010. The total estimated number of dead fish was 168 individuals. Fish losses were relatively minor as a result of the drawdown of Lake Allegan. The species observed were consistent with the composition of fish in Lake Allegan (DNR Fish Collection System Records).

Literature Cited

Michigan Department of Natural Resources. 2003. Fisheries Division fish kill investigation guide book. Lansing, Michigan.

Southwick, R. I., and A. J. Loftus, editors. 2003. Investigation and monetary values of fish and freshwater mussel kills. American Fisheries Society, Special Publication 30. Bethesda, Maryland.

Table 1. Dead fish recovered from survey segments in the shoreline segments of Lake Allegan on August 05, 2010.

species	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
Common carp		2		1	1
Black crappie	1				
Bluegill		1			
Bluntnose minnow	3	1			
Largemouth bass		1			
Yellow bullhead				2	14

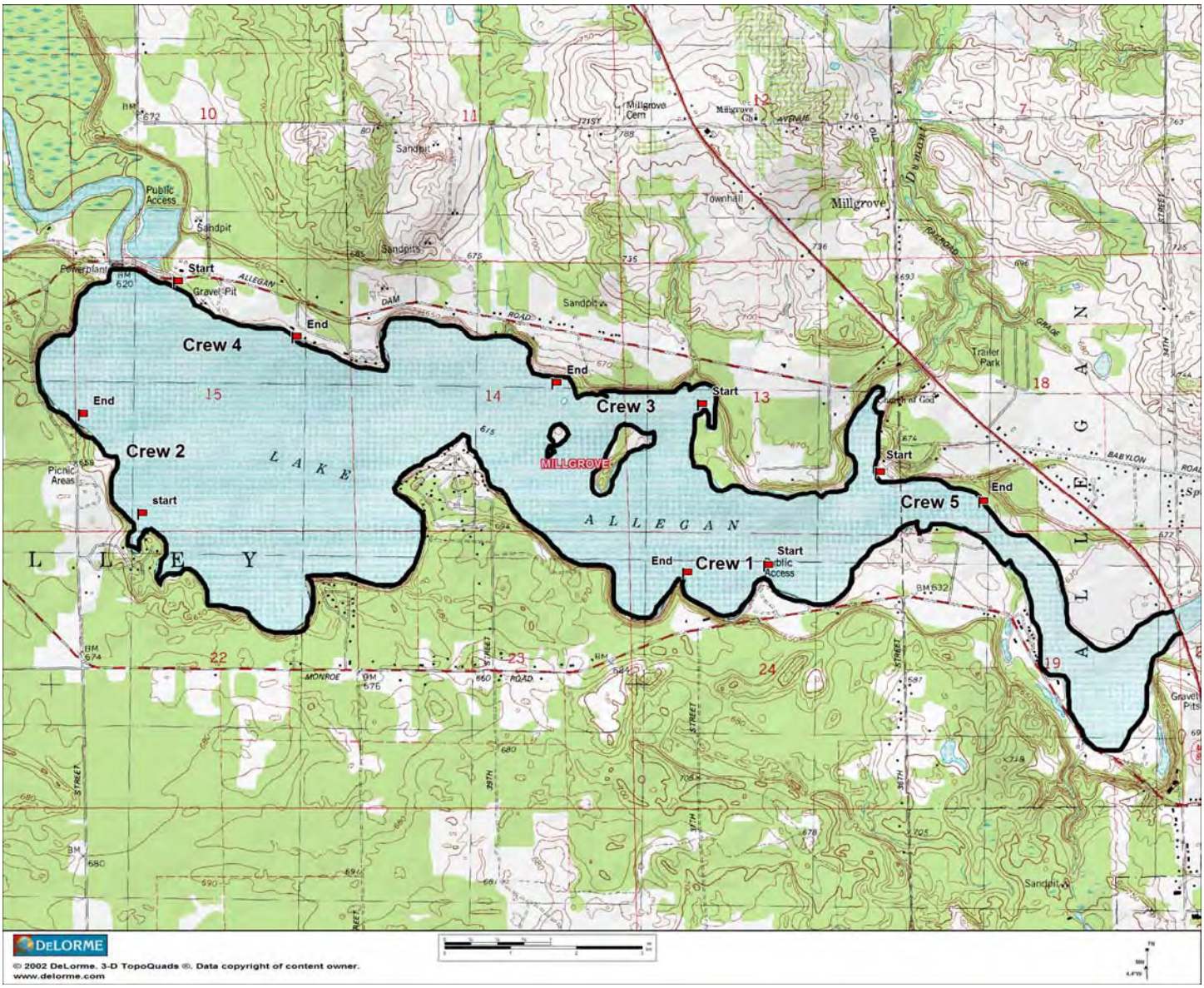


Figure 1. Lake Allegan Reservoir illustrating surveyed shoreline segments.

Lake Allegan Fish Kill Investigation
Enbridge Line 6b Incident

Submitted by:
Kregg Smith
Fisheries Biologist
Southern Lake Michigan Management Unit
MDNR Plainwell

August 9, 2010

Appendix E: Fish Health Assessment Report

Michigan Department of
Natural Resources

Fisheries Division

Fish Health Laboratory
Laboratory Report

To: Martha Wolgamood
Wolf Lake State Fish Hatchery

Report date: 1/17/10

Necropsy date: 8/3/10, 8/12/10, 8/19/10

MSU-AAHL No.: 100802-(1-3)-D-SLM
100812-(1-3)-D-SLM
100819-(2-4)-D-SLM

Host: 44 common white sucker, *Catostomus commersonii*
60 common shiner, *Luxilus cornutus*
60 golden redhorse sucker, *Moxostoma erythrurum*
60 golden redhorse sucker, *Moxostoma erythrurum*
60 spotfin shiner, *Notropis spilopterus*
60 sand shiner, *Notropis stramineus*
60 golden redhorse sucker, *Moxostoma erythrurum*
60 common shiner, *Luxilus cornutus*
60 rock bass, *Ambloplites rupestris*

Locality: Kalamazoo River

Collector: MDNRE

Date collected: 8/2/10, 8/11/10, 8/18/10

Purpose of examination: for baseline health assessment of fish following recent oil spill

Condition of fish submitted: Three species of fish were collected from three different sampling locations, totaling nine case submissions. 1) From the Marshal Impoundment in Calhoun County, upstream of the Marshall Dam, 44 common white sucker, 60 common shiner, and 60 golden redhorse sucker were collected on 8/2/10. 2) From Shady Ben Campground in Kalamazoo County, 60 golden redhorse sucker, 60 spotfin sucker, and 60 sand shiner were collected on 8/11/10. 3) From Wattles Rd. Bridge, downstream of Historic Bridge Park in Calhoun County, 60 golden redhorse sucker, 60 common shiner, and 60 rock bass were collected on 8/18/10. All fish were live at the time of collection and submitted to the laboratory dead on ice.

Testing results/Diagnosis:

- Fish generally appeared to be in good health.
- External gross examination of the dead fish revealed multifocal dermal lesions and generalized erythema on the common white sucker collected 8/2/10. Fin and ventral hemorrhages were prevalent on golden redhorse sucker and sand shiners submitted on 8/11/10. Ocular hemorrhages were observed on the majority of spotfin shiners.
- Internal examination revealed mild to moderate congestion in few livers and kidneys of common white sucker and common shiner collected 8/2/10. No other signs of disease were noted in dead fish.
- Samples of the kidney, spleen, and heart were submitted for virologic testing on epithelioma papulosum cyprini (EPC) and fathead minnow (FHM) cell lines. Inoculated cell lines were incubated at 15° and 25° C in accordance with the guidelines of the American Fisheries Society Fish Health Section Bluebook (2010). After two passages on all cell lines for a total of 28 days, there was no cytopathic effect noted and therefore declared negative for viruses detectable by the aforementioned cell lines.
- Fish were submitted dead, and therefore bacterial cultures were not taken.
- Gills were mildly autolyzed in the submitted fish. Gill and skin scrapings from the freshly dead fish collected on 8/2/10 revealed mild to moderate amounts of *Trichodina* sp., monogeneans, and larval

trematodes. No other parasites were noted. Skin and gill scrapings were not performed on dead fish from other collection dates.

Recommendations:

- No overt signs of disease were noted in all fish that were submitted.
- Repeated sampling may provide an opportunity to evaluate the long term effects of the oil spill on the health of these populations of fish.

Prepared by: Mohamed Faisal, D.V.M., Ph.D

cc: Gary Whelan

Appendix F: Health Assessment and Histopathologic Analyses of Fish Collected from the Kalamazoo River, Michigan, Following Discharges of Diluted Bitumen Crude Oil from the Enbridge Line 6B

Health Assessment and Histopathologic Analyses of Fish Collected from the Kalamazoo River, Michigan, Following Discharges of Diluted Bituman Crude Oil from the Enbridge Line 6B

By Diana M. Papoulias, Vanessa Veléz, Diane K. Nicks, and Donald E. Tillitt

Administrative Report 2014

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2014

For product and ordering information:
World Wide Web: http://www.usgs.gov/pubprod
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment:
World Wide Web: http://www.usgs.gov
Telephone: 1-888-ASK-USGS

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Although this report is in the public domain, permission must be secured from the individual copyright owners to reproduce any copyrighted material contained within this report.

Acknowledgments

Funding for this study was provided by the US Fish and Wildlife Service (FWS), East Lansing Field Office, East Lansing, Michigan. We were assisted in the field and with logistics by personnel from the FWS (Edward Karecki and Stephanie Millsap), Michigan Department of Natural Resources (Olen Gannon, Matt Smith, Mike Wilson, Ed Pearce, Scott Hanshue, Jay Wesley, and Kregg Smith), and Enbridge contractor (John Hess). Lisa Williams (FWS) and Jessica Winters (National Oceanic and Atmospheric Administration) provided valuable comments on an early draft.

We were assisted in the laboratory by personnel from the Columbia Environmental Research Center (CERC), Biochemistry and Physiology Branch (Mandy Annis, Rachel Claunch, Claire McMenamy, and Ashley White). Fish biologists (CERC) Christopher Schmitt and Aida Farag provided valuable comments on an early draft.

Table of Contents

Acknowledgments 3

Figures 6

Tables 7

Conversion Factors 8

Abbreviations 9

Abstract 11

Introduction 13

Methods 15

- Necropsy 16
- Condition Factor and Hepatosomatic Index 17
- Health Assessment Index 17
- Hematology 17
- Histopathology 18
- Additional Samples 20
- Statistics 20

Results 21

- Condition Factor 21
- Hepatosomatic Index 22
- Health Assessment Index 22
- Hematology 22
  - Hemoglobin 22
- Leukocytes and thrombocytes 23
- Head Kidney 23

Spleen....23

Gill....25

Discussion....26

References Cited....33

Appendix 1. Field datasheets....67

Appendix 2. Chain-of-custody forms....68

Figures

Figure 1. Approximate location of sample sites along the Kalamazoo River in Michigan. 38

Figure 2. Percent of smallmouth bass (SMB) and golden redhorse (GRH) with splenic parasites 39

Figure 3. Example of parasites found in histological sections 40

Figure 4. Mean score indicating the prevalence of splenic lymphoid tissue 41

Figure 5. Histological sections of golden redhorse sucker spleen spleens 42

Figure 6. Percent of fish with fibrosis, lipid deposits, or necrosis in spleens 43

Figure 7. Example of fibrosis 44

Figure 8. Example of necrosis 45

Figure 9. Example of lipid 46

Figure 10. Mucus cell counts in gill 47

Figure 11. Example of mucus cells 48

Figure 12. Example of macrophage aggregates in smallmouth bass 57

Figure 13. Example of macrophage aggregates in golden redhorse sucker 58

Figure 14. Example of histological section of normal gill 60

Figure 15. Example of aneurism and blood congestion 61

Figure 16. Example of histological section of gill showing curling and degenerated lamellae 62

Figure 17. Example of epithelium on secondary lamelleae lifting away from gill and fusion 63

Figure 18. Example of epithelial hyperplasia 64

Tables

Table 1. Mean size of smallmouth bass (SMB) and golden redhorse (GRH) 49

Table 2. Mean condition factor (CF) of smallmouth bass (SMB) and golden redhorse (GRH) 50

Table 3. Mean hepatosomatic index (HSI) for smallmouth bass (SMB) 51

Table 4. Mean scores for the Health Assessment Index (HAI) 52

Table 5. Mean hemoglobin (Hb) for smallmouth bass (SMB) and golden redhorse (GRH) 53

Table 6. Thrombocytes, leukocytes, and the ratio of granulocytes (G) to lymphocytes (L) in blood smears..... 54

Table 7. Macrophage aggregates in spleens of smallmouth bass 56

Table 8. Macrophage aggregates in spleens of golden redhourse 55

Table 9. Gill lesions in fish from Marshall Impoundment 59

Table 10. Immunohistochemical staining for CYP1A..... 65

Table 11. Estimated age (years) of smallmouth bass from 4 sites on the Kalamazoo River. 66

Conversion Factors

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
inch (in.)	25.4	millimeter (mm)
mile (mi)	1.609	kilometer (km)
	Volume	
cubic millimeter (mm^3)	3.3814×10^{-5}	ounce
deciiliter (dL)	0.02642	gallon (gal)
	Mass	
gram (gr)	0.03527	ounce, avoirdupois (oz)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
$°F=(1.8\times°C)+32$

Abbreviations

AFS American Fisheries Society (AIFRB)

AIFRB American Institute of Fishery Research Biologists

ANOVA analysis of variance

ASIH American Society of Ichthyologist and Herpetologists

BEST Biomonitoring of Environmental Status and Trends

CERC Columbia Environmental Research Center

CF condition factor

CYP1A cytochrome P450 1A

EROD ethoxyresorufin-O-deethylase

FWS U.S. Fish and Wildlife Service

g gravitational

G:L ratio granulocytes to lymphocytes

GRH golden redhorse sucker

H&E hematoxylin and eosin

HAI health assessment index

Hb hemoglobin

HB Historic Bridge

HSI hepatosomatic index

LR Legacy Ranch

MA macrophage aggregates

MI Marshall Impoundment

NBF neutral buffered formalin

NOAA National Oceanic and Atmospheric Administration

p probability

PAH polyaromatic hydrocarbon

PHAH planar halogenated aromatic hydrocarbons

PROC GLM general linear model procedure

SB Shady Bend

SMB smallmouth bass

USGS U.S. Geological Survey

Health Assessment and Histopathologic Analyses of Fish Collected from the Kalamazoo River, Michigan, Following Discharges of Diluted Bituman Crude Oil from the Enbridge Line 6B

By Diana M. Papoulias, Vanessa Veléz, Diane K. Nicks, and Donald E. Tillitt

Abstract

On July 25, 2010, a 30-inch diameter pipeline ruptured near Marshall, Michigan, and began discharging diluted bituman crude oil that flowed for approximately 38 miles down the Kalamazoo River. The U.S. Fish and Wildlife Service requested assistance from the U.S. Geological Survey Columbia Environmental Research Center in assessing the adverse health effects of this accident on fish at various locations in the Kalamazoo River downstream from the oil discharge. The objective was to compare fish collected from three oiled sites against fish collected from a reference site for a suite of biological indicators (bioindicators). The bioindicators of adverse health effects were selected to target multiple levels of biological organization and included an evaluation of condition, tissue histopathology, immunotoxicity, induction of CYP1A, and a necropsy-based assessment of health. The results for these bioindicators were overall similar for both species and among the three oiled sites. Most of the bioindicator results for fish from the oiled sites contrasted with and were different from the bioindicator results obtained for fish collected from a reference site above and unaffected by the oil discharge. Moreover, results from this evaluation are consistent with both laboratory studies of polyaromatic

hydrocarbon (PAH) toxicity to fish and field assessments of catastrophic oil spills or chronic PAH contamination from multiple anthropogenic sources.

Introduction

On July 25, 2010, at Enbridge Line 6B, a 30-inch diameter pipeline owned by Enbridge Energy ruptured near Marshall, Michigan, and began discharging diluted bitumen crude oil into a wetland adjacent to Talmadge Creek. The oil flowed through Talmadge Creek into the Kalamazoo River, a Lake Michigan tributary. The Kalamazoo River was in flood stage at the time of the discharge and the oil flowed into its flood plain and down the river for approximately 38 miles to Morrow Lake. The U.S. Fish and Wildlife Service (FWS) requested that the U.S. Geological Survey (USGS) Columbia Environmental Research Center (CERC) conduct a necropsy-based evaluation to aid their assessment of the adverse health effects on fish at various locations in the Kalamazoo River downstream from the oil discharge site.

The objective of this evaluation was to compare fish from these oiled sites against fish from a site that was not oiled for a suite of biological indicators (bioindicators). There is wide acceptance for the use of bioindicators to evaluate biological harm to aquatic organisms resulting from catastrophic oil spills (Martinez-Gomez and others, 2010; Law and others, 2011). The sublethal indicators of adverse effects on fish were selected based on their known association with degraded environments or polycyclic aromatic hydrocarbon (PAH) exposure. Golden redhorse (*Moxostoma erythrurum*), a benthic feeder, and smallmouth bass (*Micropterus dolomieu*), a piscivore, were the fish species chosen for collection. These fish species were collected because they represent different trophic levels and are commonly found in the affected areas of the Kalamazoo River as well as upstream and downstream from the affected area. Additionally, sucker and bass species have been commonly studied at sites used for biological monitoring, including PAH-impacted sites (Schmitt and others, 1993).

The bioindicators selected for this assessment target multiple levels of biological organization: the individual, tissue, cell, and biochemical levels. Bioindicators at the level of the individual fish included in this assessment are the biomarkers: condition, the relation of the liver weight to the body weight (hepatosomatic index [HSI]), and the calculation of a fish health index. Fish condition is commonly

assessed using weight and length measurements (Blackwell and others, 2000). Variation from an expected weight for a given length may be due to nutrition, environmental quality, or stage of reproductive maturity. Abnormally small HSI values may reflect depleted energy reserves and may indicate poor fish health. Abnormally large HSI values may be associated with increased production of xenobiotic metabolizing enzymes, an increased parasite load, or other pathological changes (Schmitt and others, 1999). Health indices integrate observations of gross abnormalities during the necropsy into a single numerical value that can be scaled and used to assess general fish health (Schmitt and others, 1999).

Polycyclic aromatic hydrocarbons have been reported to suppress the immune system and therefore spleen, head kidney, and blood were examined (Hart and others, 1998; Reynaud and Deschaux, 2006; Reynaud and others, 2008; Uribe and others, 2011). In addition to spleen and head kidney histopathology, macrophage aggregates were quantified. Macrophage aggregates are collections of phagocytic macrophages containing cellular debris collected in the body and are found in fish spleen and head kidney (Fournie and others, 2001). Macrophage aggregates typically contain pigments such as hemosiderin, lipofuscin, ceroid, and melanin according to the type of degraded material engulfed. Macrophage number and size are used as biomarkers because these measurements have been determined to be associated with a number of environmental stressors including exposure to polycyclic aromatic hydrocarbons (Wolke, 1992; Agius and Roberts, 2003). Hematological biomarkers diagnostic of immune system dysfunction included leukocyte counts. Leukocyte profiles provide a prognostic evaluation of the level of stress an organism is experiencing (Davis and others, 2008). Hemoglobin was also measured; low hemoglobin is an indicator of anemia and has been associated with exposure to PAHs (Martinez and others, 2008).

Gills serve important respiratory and excretory functions that require a highly vascular and large surface area. The gill tissues are in direct contact with the surrounding water and therefore a primary site of contaminant contact and uptake. Mucus cells on gill lamellae proliferate when stimulated by irritants

and a number of gill histopathologies are induced by exposure to polycyclic aromatic hydrocarbons (Martinez and others, 2008). Production of cytochrome P450 1A (CYP1A) is a well-known response to exposure to PAHs and has been determined to be produced in gills of PAH-exposed fish (Stegeman and Lech, 1991; Moore and others, 2003). In gills, the CYP1A biomarker can be detected with immunohistochemistry.

This report details the results of work by the CERC for the following:

- collection and preservation of gill, spleen, head kidney, liver, bile, and plasma from 110 fish;
- preparation of whole blood smears and conduct of differential analysis of leukocytes;
- calculation of a health assessment index;
- identification of histopathologic lesions in gill, spleen, and head kidney; and
- preservation and storage of samples for possible future analysis.

Methods

A biologist from the CERC Biochemistry and Physiology Branch was onsite August 19 and 20, 2010, to conduct necropsies and collect tissues. Michigan Department of National Resources, FWS, and Enbridge personnel collected fish using boat electrofishing, and used net pens to hold the captured fish in the river until necropsy.

Ten to 15 individuals of two fish species, a mid-water piscivore species, smallmouth bass (SMB), and a benthic sucker species, golden redhorse (GRH), were targeted for collection at four sites on the Kalamazoo River. The size of GRH targeted were 10 inches (in.) to 15 in. and the size of SMB targeted were greater than or equal to 14 in. Sites were selected to ensure a fish collection from each of the three different river divisions as segmented by Incident Command, which roughly corresponded to the degree of observed river oiling. An upstream reference fish collection was also selected. The Historic Bridge (Division C), Legacy Ranch (Division D), and Shady Bend (Division E) sites were downstream (9 miles,

22 miles, and 27 miles, respectively) from the oil discharge. The Marshall Impoundment location was upstream of the oil discharge location and served as a reference site (fig. 1).

Necropsy

Field necropsy procedures generally followed those used by USGS in the Biomonitoring of Environmental Status and Trends (BEST) program (Schmitt and others, 1999). A blood sample was obtained from the posterior caudal vein using a previously prepared heparinized needle (20 gauge) and syringe kept cold on wet ice. A part of the collected whole blood was used for blood smear slides and hemoglobin measurements. An additional part of the whole blood used for hormone and protein analyses was decanted from the syringe barrel into a heparinized vacutainer and held on wet ice. After blood collection, the fish was euthanized with a sharp blow to the head, weighed (grams [gr]), and the total length was measured (in millimeters [mm]). Visual observations were made of external features and grossly visible tissue anomalies were recorded; some abnormal tissues were dissected and preserved in 10-percent neutral buffered formalin (NBF) for histopathologic analysis. A gill arch, generally the second arch of the left gill, of each fish was removed, placed in a histo-cassette, and preserved in 10-percent NBF. The liver of each SMB was carefully removed with the gall bladder intact. The gall bladder was dissected from the liver, bile collected in a clean cryovial, and the entire liver was weighed. The gall bladders of GRH were dissected directly and bile collected. Because GRH have a diffuse liver that is difficult to accurately weigh, liver weight could not be obtained. Duplicate subsamples of the liver tissue from each fish were collected and flash frozen in a dry ice/ethanol slurry for ethoxyresorufin-O-deethylase (EROD) analysis. Liver, spleen, gonad, head kidney, and hind kidney were examined for abnormalities. A single piece of the spleen and head kidney were removed, placed in separate histo-cassettes and preserved in 10-percent neutral buffered formalin. Upon completion of the internal examination, the fish carcass and pieces of organs were wrapped in aluminum foil for proper and secure disposal. Work surfaces and instruments were cleaned with 70-percent ethanol followed with an acetone rinsing. Chilled blood

samples were centrifuged at 3,000 g (gravitational force) for 15 minutes and plasma was aspirated into duplicate cryovials and flash frozen in a dry ice/ethanol slurry. Samples were stored in a secured location under appropriate preservation conditions until shipment. All samples were shipped to CERC at the end of the field sampling period and stored in a secure location under appropriate preservation conditions until analysis.

All field data were recorded on datasheets. Originals were digitally scanned at CERC, copies were sent to FWS East Lansing Field Office, and originals were archived at CERC (appendix 1). Samples collected in the field were transferred to CERC with chain-of-custody documentation (appendix 2).

Condition Factor and Hepatosomatic Index

Fulton's condition factor was calculated as the body weight (grams) x 10^5 ÷ (body length (mm))^3 (Thompson (1917). Hepatosomatic Index (HSI) was calculated as the liver weight (grams) ÷ body weight (grams) x 100. Hepatosomatic Index was calculated only for SMB.

Health Assessment Index

Numerical values were assigned to internal and external observations of lesions recorded in the field, and a necropsy-based fish health assessment index (HAI) score was calculated for each fish by summing the values for all organs (Schmitt and others, 1999). The HAI score ranges from 1 (healthy) to 220 (unhealthy). The suite of gross abnormalities selected for this assessment was chosen to be consistent with abnormalities commonly assessed in fish health monitoring programs (Fournie and others, 1996). Examples of abnormalities assessed included grossly visible disorders of the eye (exophthalmia, hemorrhage, opacity, emboli, missing), opercles (shortening, deformities, parasites), body and fin surfaces (ulcers, parasites, discolored areas or raised growths), and disorders of the gills and skeleton.

Hematology

Triplicate drops of whole blood were used to make three fresh-preparation blood smear slides. Slides were air-dried then immersed in 100-percent methanol for 10 minutes for preservation. One blood

smear slide was stained and viewed for each fish to evaluate the leukocyte (white blood cell) population. Cells were stained using the three-step Quick-Dip 3 differential stain (Mercedes Medical, Sarasota, Florida). Leukocytes (lymphocytes, monocytes, and granulocytes) and thrombocytes were counted using a Nikon 90i® and NIS-Elements® digital imaging software (v 4.10; Nikon Instruments Inc., Melville, New York) at 600x or 1,000x magnification. Cell counting continued until an approximate total of 200 leukocyte and thrombocyte cells had been counted and categorized.

Hemoglobin measurements were made following manufacturer's instructions by placing a droplet of blood onto a HemoCue® cassette and inserting the cassette into a HemoCue 201+ analyzer (Brea, California).

Histopathology

Gill, spleen, and head kidney were preserved in 10-percent neutral buffered formalin. Before tissue processing, tissues were rinsed twice in HEPES (4-(2-hydroxyethyl)-1-piperazineethanesulfonic acid) buffer, once in 50-percent ethanol, and then transferred to 70-percent ethanol. Gills were decalcified with Cal-Ex II™ (Thermo Fisher Scientific, Waltham, Massachusetts) for 45 minutes. Tissues were processed and infiltrated with paraffin using a Shandon Excelsior® Tissue Processor through a typical xylene and ethanol series (Thermo Fisher Scientific). Infiltrated tissues were embedded in paraffin using a Microm® EC350-2 (Thermo Fisher Scientific) embedding center. Sections were cut at 7 microns on a Leica RM 2235 microtome (Leica Microsystems, Wetzlar, Germany). All microscopy was accomplished using a Nikon 90i with digital imaging capability. NIS Elements software was used to process and analyze digital images. The examiner made evaluations and counts without knowing from which site the fish were collected, except for the viewing of organs of a few individuals of each species from the reference site, which were used to orient and educate the examiner unfamiliar with the histomorphology of these species.

Two slides were made of each spleen of each fish. One slide was stained with hematoxylin and eosin (H&E), a general nuclear stain, and the other slide was stained with Pearl's stain (Luna, 1968) for macrophage aggregates. Macrophage aggregates for each fish were quantified by area and number in five fields of view at 20x and reported as a fraction of the total area of tissue viewed and as the average area of an individual macrophage aggregate (MA). Pigments associated with MAs and whether MAs were loose or clustered into centers were noted. Spleens were evaluated for presence or absence of lipid deposits, necrosis, fibrosis, and parasites; identification of parasites was not attempted. The prominence of lymphoid tissue was scored from 1 to 3 with 1 being low, 2 being moderate, and 3 being high prevalence; scores of individual fish were averaged to obtain a site score for each species.

Head kidney tissue sections were stained with H&E (Luna, 1968). Head kidney was evaluated for (1) presence or absence of parasites; (2) MAs; (3) enlarged blood vessels; (4) increased leukocytes; (5) interrenal cell hyperplasia, pyknosis, and vacuolation; and (6) chromaffin cell proliferation and vacuolation. Five individuals of each species from each site were evaluated.

Gills were evaluated for lesions, mucus cells, and for immunohistochemical staining of cytochrome P450 1A. Sections for evaluation of lesions were stained with H&E (Luna, 1968). Lesions were scored for occurrence and severity as follows: 0 equals none, 1 equals low, 2 equals moderate, 3 equals high. Scores were summed for each fish species and lesion type and percent of fish with a lesion was reported. Mucus cells were specifically stained with periodic acid Schiff and alcian blue (pH 2.5) and counted on five secondary lamellae (Alvarado and others, 2006). Numbers of mucocytes were normalized to total length along lamellae on which cells were counted. Gill sections were semiquantified for CYP1A staining. Paraffin sections of gill tissue for CYP1A were deparaffinized and rehydrated before heat-induced antigen epitope retrieval following the citrate buffer method (http://www.ihcworld.com/_protocols/epitope_retrieval/citrate_buffer.htm). A mouse anti-cod CYP1A antibody (Biosense Laboratories, Bergen, Norway), previously demonstrated to be broadly cross-reactive

among fish species, was applied following the vendor's suggestions for use in immunohistochemistry (Ueng and others, 1992). Gill showing positive CYP1A staining was semiquantified by counting the areas of positive staining on five primary lamellae for five fish from each species from each site. In cases where more than five lamellae were attached to the gill arch and present on the slide, all were counted and a correction factor applied.

Additional Samples

Additional samples, collected but not analyzed, are being stored at CERC. Liver samples collected for EROD, blood samples collected for hormone or protein analysis, and bile samples for biomarkers of PAH exposure were stored at -80 degrees Celsius (°C) at CERC. An additional 19 bile samples collected by FWS were included for storage with the samples CERC collected.

Statistics

All measurements were tested for significant differences among sites by one-way (site as fixed effect) Analysis-of-Variance (ANOVA) using a general linear model procedure (PROC GLM) in SAS v.9.3 (SAS Institute, Inc., Cary, North Carolina). Significance level used to judge statistical significance was p=0.05. When no sex-related differences (Student's t-test) were detected for a measurement, data from both sexes were combined. Percent thrombocytes and leukocytes were log-transformed for statistical analyses. Condition factor, HSI, and ratio of leukocytes were arcsine transformed. If measurements did not meet assumptions of normality and homogeneity of variance after transformation, a Kruskal-Wallis rank test was used. The percentages of fish with spleen parasites or with a specific splenic or gill lesion were analyzed for differences between the reference site and the sites downstream from the oil discharge by computing an odds ratio with a chi-square statistic. No statistics were provided on gill scores. Significance level used to judge statistical significance was p=0.05. Only summary descriptive statistics are provided for CYP1A immunohistochemistry in gill tissue because staining conditions were not optimal. This endpoint was added late in the study and after tissues had been field-collected. For

optimal staining, preservation of gills should have followed a different procedure than was followed in this study. Results indicate presence or absence of CYP1A induction and relative intensity among sites.

All research was conducted in accordance with the procedures described by the American Society of Ichthyologist and Herpetologists (ASIH), American Fisheries Society (AFS), and American Institute of Fishery Research Biologists (AIFRB), "Guidelines for Use of Fishes in Field Research" (American Fisheries Society and others, 2004); and with all CERC guidelines for the humane treatment of test organisms during culture and experimentation.

Results

A total of 110 fish were collected for necropsy: 64 adult females, 45 adult males, and one juvenile. The targeted number of fish for each species (15) was collected at every site except Shady Bend where only 10 fish of each species were collected because of field sampling time constraints (table 1). Greater numbers of females than males of both species were collected at all sites except Legacy Ranch, although ratios of males to females were close to one except at Marshall Impoundment for both species and at Shady Bend for golden redhorse (table 1). No site-specific significant differences were observed in lengths of males and of females of both species or weights of smallmouth bass (table 1); however, site-specific differences in weights of GRH females were observed. Female GRH were heaviest at Historic Bridge and Marshall Impoundment and weighed the least at Shady Bend (table 1).

Condition Factor

Condition factors (CF) did not differ between the sexes in either species at any site. Overall, fish from the oiled sites, Legacy Ranch and Shady Bend, had significantly smaller CFs than those from the reference site, Marshall Impoundment (table 2). Condition factors for SMB, but not GRH, from Historic Bridge were also less than at Marshall Impoundment (table 2).

Hepatosomatic Index

There were no significant differences in HSI between male and female SMB; therefore, the data were combined. Hepatosomatic index was greatest for SMB from Historic Bridge and least for those at Marshall Impoundment the reference site (table 3).

Health Assessment Index

Fish from the oiled sites generally had more anomalies and lesions, and thus greater HAI scores, than those from the reference area. Marshall Impoundment was the only site at which there were significant sex-related differences, in both species, of the health assessment index (table 4). This statistical difference between the sexes may be because fewer males than females, of each species, were captured and available for evaluation at Marshall Impoundment in contrast to the other sites (except GRH at Shady Bend) which had equal numbers of males and females. To be consistent among sites, HAI scores were calculated for each site and species with the sexes combined. Marshall Impoundment fish had the lowest HAI scores compared to the other sites (table 4). Scores tended to be numerically higher in GRH than smallmouth bass. The few anomalies observed on fish from Marshall Impoundment included those associated with the eyes, body surface, and fins. During visual assessment, the fish from sites downstream from the oil discharge had relatively more lesions on these same areas of the body and, in addition, had lesions on their gills.

Hematology

Hemoglobin

Mean hemoglobin values ranged from 2.7 to 6.2 gr/dL (grams/deciliter) in both species and sexes, collectively. Golden redhorse from Historic Bridge had the smallest hemoglobin values. Hemoglobin values for SMB did not differ significantly among sites. Hemoglobin concentrations in male and female GRH from Historic Bridge were lower than at other sites; however, a statistically significant difference was found only with females from Marshall Impoundment and with females from Legacy Ranch (table 5).

Leukocytes and thrombocytes

Significant differences in leukocytes, but not thrombocytes, were found between the fish collected at sites below the oil discharge and those collected from the reference site. Percent lymphocytes of GRH from Historic Bridge and Legacy Ranch, the two sites closest to the oil discharge, were statistically, but likely not biologically, smaller than for fish from Marshall Impoundment, whereas lymphocytes of GRH from Shady Bend were greater (table 6). Granulocytes and monocytes of GRH were not significantly different between Marshall Impoundment and the affected sites (table 6). In contrast to GRH, more lymphocytes and fewer granulocytes were counted in blood of SMB from Historic Bridge and Legacy Ranch compared to SMB from Marshall Impoundment (table 6). Monocytes were slightly and significantly elevated in SMB from Shady Bend relative to those from Marshall Impoundment (table 6). The ratio of granulocytes to lymphocytes was different between the two species but similar between the sexes within a species at most sites (table 6). Ratios for GRH were significantly larger at Legacy Ranch and smaller at Shady Bend compared to Marshall Impoundment (table 6). Ratios for SMB were significantly smaller at all sites for both sexes except for females at Shady Bend.

Head Kidney

Lesions in head kidney were minor and not remarkable across species and sites. Histopathology of head kidneys of fish from the reference site was similar to that observed in head kidneys of fish from the oiled sites.

Spleen

Numbers or sizes of MAs in spleen tissue of fish from sites downstream from the discharged oil were larger than those for MAs of fish from the reference site, Marshall Impoundment. Macrophage aggregates in spleen tissues of SMB were significantly larger in size in fish from Historic Bridge and Shady Bend than those fish from Marshall Impoundment and Legacy Ranch (table 7); however, average

MA size in spleen tissues did not differ significantly among sites for GRH (table 8). Total MA area as a fraction of the area of spleen examined was greater in GRH, but not SMB, from Historic Bridge compared to fish from Marshall Impoundment (tables 7 and 8). Additionally, both species from Shady Bend had a greater total MA area than those from Marshall Impoundment (tables 7 and 8). Numerically, fish from oiled sites had more MAs than did fish from the Marshall Impoundment unaffected by the oil discharge; however, this relation was only significant for GRH with Historic Bridge and Legacy Ranch sites (tables 7 and 8).

Macrophage aggregates in all fish contained varying amounts (not quantified) of hemosiderin and lipofuscin/ceroid pigments. The most commonly observed pigment was hemosiderin. Macrophage aggregates from Historic Bridge fish contained melanin, but melanin was not observed in fish from any other site. Qualitatively, the density of pigments in MAs for both species followed a high to low pattern as follows: Historic Bridge > (greater than) Legacy Ranch > Shady Bend >Marshall Impoundment. Most of the MAs in all fish were present as encapsulated centers, although greater than 30 percent of GRH from Historic Bridge and Legacy Ranch also had many loose macrophage aggregates. Loose MAs are more typical of the type of MA found in soft-rayed fishes (that is, GRH) than in spiny-rayed fish (that is, SMB). Loose MAs may also indicate a more recent appearance of an MA before formation of an encapsulated center.

Splenic parasite numbers were variable between species and among sites downstream from the oil discharge relative to the reference site. Parasites were commonly found in SMB spleens but were uncommon in golden redhorse. Smallmouth bass from Shady Bend had more parasites than bass from Marshall Impoundment but fewer parasites were found in SMB from Historic Bridge compared to Marshall Impoundment (figs. 2 and 3). No parasites were observed in GRH from Marshall Impoundment and occurred in 10 percent or less of GRH from the other sites (fig. 2).

Scores for prominence of lymphoid tissue were lower for fish from oiled sites compared to those from Marshall Impoundment for both species but significantly different only for the golden redhorse (figs. 4 and 5).

Splenic lesions were more numerous in fish from sites downstream from the oil discharge than in fish from the reference site. No fibrosis or necrosis and a low incidence of lipid deposits were observed in Marshall Impoundment fish in contrast to fish from oiled sites. Lipid deposits were not observed in GRH from Marshall Impoundment but this splenic lesion was observed in a few SMB at this site. The incidence of lipid deposits, necrosis, and fibrosis varied between fish species from oiled sites and among oiled sites but overall were significantly greater in both species at all oiled sites relative to the reference site. Relative to other lesions, lipid deposits in SMB and fibrosis in GRH were the more prominent lesions (figs. 6, 7, 8, 9).

Gill

Sites downstream from where oil was discharged had more fish with gill lesions than did the reference site where fish were not exposed to oil. Overall, seven types of gill lesions were observed: aneurisms, blood congestion, epithelial cell hyperplasia, epithelial lifting, curling of secondary lamellae, fusion of secondary lamellae, and parasites. At no site were all fish completely lesion-free, and one or more fish of each species at a site was observed to have at least one of these lesions (table 9). No gill lesions were found in 7 of 30 fish from Marshall Impoundment, 1 of 30 fish from Historic Bridge, and 4 of 30 fish from Legacy Ranch. Only 1 of the 20 fish from Shady Bend had no gill lesions (table 9). Epithelial lifting and hyperplasia, aneurisms, congestion, and parasites were significantly more prevalent in gills of GRH from the oiled sites than in those from the reference site, and these effects were more severe in fish from the oiled sites than for fish from the reference site (table 9). Gill aneurisms, blood congestion, curling, and fusion were significantly more prevalent in SMB, at some but not all oiled sites, than those at the reference site (table 9).

Mucous producing cells and cells producing the CYP1A protein were more numerous on gills of fish at the sites downstream from the oil discharge than at the reference site. Significantly fewer mucocytes were measured at the reference site, Marshall Impoundment, than at the three oiled sites for both species (figs. 10 and 11). CYP1A produced by gill cells, as detected by immunohistochemistry staining, was observed in fewer GRH individuals, fewer cells were stained in fish of both species, and staining was overall much lighter in fish from Marshall Impoundment as compared to fish from the oiled sites (table 10). Two individuals of each species from Historic Bridge had extensive areas of CYP1A-positive staining that was unlike any other fish examined.

Discussion

Three weeks after the Enbridge Line 6B discharged oil into Talmadge Creek and the Kalamazoo River, two species of fish were collected from three locations downstream from the spill and from an upstream reference site. The objective of these collections was to compare fish from oiled sites to fish from a site that was not oiled for a suite of bioindicators. These indicators of adverse effects on fish were selected based on their known association with degraded environments or reported association with PAH exposure.

Interpretation of some bioindicators (for example, condition) can be affected by large differences in size, maturity, and age. There were no species-specific length differences among sites although GRH females from Legacy Ranch and Shady Bend tended to weigh less than GRH from Historic Bridge or Marshall Impoundment. Fish were collected after the reproductive season, and as a result during field necropsy, gonads of all individual fish were determined to be at an intermediate stage between ripe and spent. Age was not determined for these fish, but an estimate of age of SMB based on local data of the relation between length and age was made (Jay Wesley, Michigan Department of Natural Resources, oral commun., December 2012). Estimated age of SMB was variable at all sites, but on average females were

younger (3–5 years old) than males (5–6 years old) (table 11). No age-length data were available to make a comparable estimate of age for golden redhorse. The HAI scores from Marshall Impoundment indicate that the reference site provided sufficiently healthy fish and therefore bioindicator results at this site could be reliably used as benchmarks of normal when evaluating results from sites downstream from the oil discharge.

Timing and location of fish collections in relation to when and where the oil was discharged may have affected the severity of the bioindicator response. Polycyclic aromatic hydrocarbons are also common in aquatic environments found near human activity. Therefore, a background level of response is to be expected. Fish for this health assessment were collected 3 weeks after the pipeline break and between 9 and 27 miles below the point of oil discharge. Total extractable hydrocarbon (TEH) concentrations measured in Kalamazoo River surface water were elevated downstream from the oil discharge point relative to concentrations upstream from the discharge (Stephanie Millsap, US Fish and Wildlife Service, oral commun., December 2012). Concentrations of TEH in surface water decreased during the 3 weeks before fish collections but remained elevated compared to upstream concentrations at the time of fish collections. Consistently, surface water at Historic Bridge, 9 miles below the discharge, contained slightly greater concentrations of TEHs than Legacy Ranch and Shady Bend, which were another 13–18 miles downstream (Stephanie Millsap, FWS, oral commun., December, 2012). Heavier fractions of the diluted bitumen from this spill sank to the bottom of the river and became associated with sediments. At the time that the fish were collected, the submerged oil was likely acting as a source of polycyclic aromatic hydrocarbons (PAHs) to benthic invertebrates, the overlying water, and aquatic organisms in this stretch of river. Because of the discharge of oil, the Kalamazoo River was closed to the public, but the oil spill response resulted in heavy boat traffic from john boats with small outboard motors and from airboats, every day until well after fish were sampled for this study.

General health metrics (CF, HSI, HAI score) consistently indicated poorer health of fish from sites downstream from the oil discharge relative to fish from the reference site. Moreover, these results were comparable to other studies that used these same biomarkers to assess fish health after exposure to PAHs. Lower condition factors were reported for flatfishes from a location near an oil refinery terminal and for sea bass exposed in the laboratory to crude oil (Kahn, 2003; Kerambrun and others, 2012). The flatfish in Kahn's (2003) evaluation also had heavier livers and therefore increased HSI values and an increased incidence of epidermal lesions especially on skin, gills, and fins compared to flatfish from a reference site. Increased numbers of fish with fin and gill lesions and the severity of those lesions were the variables that most strongly affected the high HAI scores in Kalamazoo River fish downstream from the oil discharge site. Nevertheless, the degree to which habitat differences between the impoundment, where the reference fish were collected, and the more freely flowing river reaches where the oiled fish were collected cannot be evaluated solely from the data obtained in this study. Condition, weight, and length data from SMB and GRH fish surveys on the Kalamazoo River before the Enbridge oil discharge incident may provide useful comparative information for example.

Organ-related differences were similar across species and across sites, and are consistent with literature reports of PAH effects. Macrophage aggregates were either larger or more numerous in fish from oiled sites than fish from the reference site. This same response of MAs has been reported for fish collected from chronically oiled locations (Haensly and others, 1982; Marty and others, 1999; Kahn, 2003). Macrophage aggregates are a good indicator of the general stress of a fish, which may or may not be due to contaminant exposure. In this study, the fish were exposed to contaminants and may also have been experiencing stress from the disturbance of the response activities. Marty and others (1999) attributed increased MAs to the old age of Pacific herring (*Clupea pallasii*) caught in the vicinity of the Exxon Valdez oil spill. Throughout the life of a fish, MAs collect and isolate debris that cannot be metabolized and eliminated; therefore, older fish would tend to accumulate higher concentrations of debris

and MAs (Fournie and others, 2001). In the present assessment, age estimated from length (only for SMB) was similar across sites and linear regression analyses did not support a relation between MAs and age (data not shown).

Spleen lesions, gill lesions, and mucocytes on gill lamellae were all more prevalent in fish from sites downstream from the oil discharge compared to reference fish. Gill lesions, aneurisms, and blood congestion were consistently elevated in fish from sites downstream from the oil discharge and these same types of lesions were observed in fish exposed to water-soluble diesel oil (Simonato and others, 2008). Kahn (2003) found flatfishes from marine areas contaminated with oil had severe gill epithelial cell hypertrophy and fusion, lesions which were observed infrequently or less severely in Kalamazoo River fish perhaps because of the shorter period of exposure. In contrast, gill mucocytes were elevated in both the present study and Kahn (2003) and also Haensly and others (1982) perhaps because these cells are a first line of defense against irritants.

The biomarker CYP1A was clearly identified in gills of both species of fish from all Kalamazoo River sites; however, the response was strongest at sites downstream from the oil discharge site. Cytochrome P450 1A expression is the classic biomarker for chemicals that work through the aryl hydrocarbon receptor biochemical pathway (Whyte and others, 2000). These chemicals include PAHs as well as planar halogenated aromatic hydrocarbons (PHAH). The CYP1A protein is produced primarily in fish hepatocytes and to a lesser extent in kidney and gill (Tuvikene, 1995). Immunohistochemistry of fish gills using antibodies to CYP1A has been successfully used to identify field exposure of fishes to polycyclic aromatic hydrocarbons (Moore and others, 2003). Most recently, it was used to demonstrate a graded exposure response over time to oil spilled during the Deepwater Horizon accident (Dubansky and others, 2013). The low intensity of CYP1A expression at the reference site is not unexpected because of the prevalence and stochastic widespread distribution of PAHs in aquatic habitats.

The blood diagnostic indicators in the present assessment were somewhat inconsistent between species and among sites. This is perhaps explained by taxonomic differences in fish physiology and species-specific habitat and trophic characteristics. Hemoglobin concentrations within normal ranges are diagnostic of general health and the values measured in this study are consistent with values reported in the literature for seemingly healthy fish (Powers and others, 1939; Schmitt and others, 1993). Anemia is indicated by abnormally low hemoglobin concentrations but the etiology of this condition varies (Heath, 1995). A few reports associate lowered hemoglobin concentrations in fish with exposure to crude oil or water-soluble diesel oil (Alkindi and others, 1996; Kahn, 2003; Simonato and others, 2008; Hedayati and Jahanbakhshi, 2012). In contrast, fish collected in a petroleum-contaminated area by Kahn (1998) did not have lowered hemoglobin concentrations, but did have increased levels of hemosiderin compared to reference fish. Exposure of fish to oil is postulated to cause lysis of blood cells and thus the release of hemosiderin, a pigment commonly found in macrophage aggregates (Alkindi and others, 1996). The qualitative MA pigment observations in the present study are consistent with this effect. Although hemoglobin concentrations from the site closest to the oil discharge were statistically less than those from the reference site only for GRH females, together the hemoglobin concentrations and hemosiderin biomarkers support an exposure to oil in the present evaluation.

Parasite infestation was also somewhat inconsistent among species and sites. The effect of environmental stressors on parasitism in fish can be variable and complex in part because the stressor may increase the fishes' vulnerability to parasitic infection and have adverse effects directly on the parasite at some stage in its lifecycle. Moreover, ectoparasites are thought to increase and endoparasites to decrease in fish exposed to chemical contaminants (Kahn, 2003 and references therein). In the present fish health evaluation, macroscopically visible ectoparasites were infrequent on both species; however, fin erosion, which was frequently noted in fish from sites downstream from the oil discharge, may have been due to microscopic ectoparasites that would not have been seen during necropsy. Also, gill parasites were not

noted during necropsy but were observed during histopathology evaluations and were increased in GRH at Historic Bridge, the site closest to the oil discharge. Compared to fish from the reference site, splenic endoparasites in SMB were lowest at the two sites closest to the oil discharge and greatest at the site farthest from the oil whereas, in GRH, splenic parasites were sparse in fish from oiled sites and absent in reference fish. These results can be interpreted as a general response to stress given the limited macroscopic evaluation of parasite infestation of the collected fish from the Kalamazoo River, the relatively brief time the fish would have been exposed to the discharged oil, and potential habitat differences between the free-flowing stretch of the river and the impounded reservoir where the reference fish were caught. Another factor to be considered is that the presence of significant boat traffic as part of the oil spill response may have also stressed fish in the areas downstream from the discharge.

Polycyclic aromatic hydrocarbons are generally expected to suppress the fish immune system. The characteristic leukocyte profile reported for fish exposed to PAHs includes a decrease in lymphocytes (Kahn, 2003; Hedayati and Jahanbakhshi, 2012; McNeil and others, 2012); however, there is an incomplete understanding of the mechanisms of immunotoxicity and species-specific effects (Reynaud and Deschaux, 2006). Immunosuppression can hinder fish from fighting bacterial and viral infections, and this can lead to lesions on the external surfaces such as the frayed fins and gill hyperplasia observed in fish from some of the Kalamazoo River oiled sites (McNeil and others, 2012). The spleen is a primary immune system organ in fish and the location of lymphocyte production. On average, spleen lymphoid tissue appeared reduced in fish from Kalamazoo River sites downstream from the oil discharge. A similar observation was made for anterior kidney of fish exposed to select PAH compounds (Hart and others, 1998; Holladay and others, 1998); however, Reynaud and Deschaux (2006) presented contradictory results wherein PAHs stimulated and suppressed lymphocyte proliferation depending on chemical, dose, and species. Counts and ratios of circulating leukocytes in the blood are also common measurements for assessing general environmental stress effects on fish (Davis and others, 2008). A popular diagnostic of

general stress is the ratio of circulating granulocytes to lymphocytes wherein granulocytes increase and lymphocytes decrease. In contrast to PAH-induced immunosuppression, general stress-related lymphopenia is usually accompanied by an increase in granulocytes (Davis and others, 2008). The immune system response patterns observed in fish from the Kalamazoo River study are mixed. Circulating lymphocytes were only slightly depressed in GRH at the Historic Bridge site and granulocytes and the granulocyte-to-lymphocyte (G:L) ratio were not different when compared to GRH from the reference site. Golden redhorse from Legacy Ranch did show the general stress pattern in G:L ratio relative to GRH from Marshall Impoundment. In comparison to the reference site, Shady Bend (the site farthest from the discharge; fig. 1) GRH had a slight increase in lymphocytes, no difference in granulocytes, and a resulting decrease in the G:L ratio. Golden redhorse monocytes were few and not significantly different among sites, suggesting that the fish were not likely diseased. In contrast to the blood results, splenic lymphoid tissue was significantly reduced in all GRH from Kalamazoo River oiled sites. Together, GRH immune system suppression attributed to PAH exposure is suggested by the qualitatively observed lower lymphocyte production in the spleen but at the time of sampling was not reflected by the distribution of leukocyte types in the blood.

Results for SMB are even more difficult to interpret. In contrast to GRH, circulating lymphocytes in SMB from the two sites closest to the oil discharge tended to be greater compared to lymphocyte levels in SMB from the reference site. Granulocytes were fewer in SMB at the two sites closest to the discharge and G:L ratios less, excepting that for the female from Shady Bend, compared to the SMB from the reference site. Monocytes, which phagocytize foreign particles, were elevated only in SMB at Shady Bend and this is consistent with the elevated splenic parasites observed for SMB at this site. Assuming the leukocyte profile in fish from Marshall Impoundment is representative of normal, it seems that PAH effects an increase in SMB lymphocytes. The fact that splenic lymphoid tissue was not statistically reduced in SMB at oiled sites as it was for GRH may be related to these leukocyte results. Although

differences in blood leukocyte patterns exist between the oiled fish and the reference fish, a lack of information on the normal and stressed profiles in SMB and GRH hinders a clear interpretation of these immunological endpoints.

A number of health parameters, from the biochemical level to the individual fish level were evaluated in fish collected in the Kalamazoo River downstream from the Enbridge Line 6B discharge point. The results for these bioindicators were overall similar for both species and among the three oiled sites. Most of the bioindicator results for fish from the oiled sites contrasted with and were significantly different from the bioindicator results obtained for fish collected from a reference site above and unaffected by the oil discharge. Moreover, results from this evaluation are consistent with both laboratory studies of PAH toxicity to fish and field assessments of catastrophic oil spills or chronic PAH contamination from multiple anthropogenic sources. The present fish health evaluation has demonstrated that fish at sites as far as 27 miles downstream from the Enbridge Line 6B pipeline discharge point were less healthy than fish from above the discharge point, showed signs of generalized stress, and showed effects in specific endpoints that were consistent with the adverse effects expected from exposure to crude oil.

References Cited

American Fisheries Society, American Institute of Fishery Research Biologists, and American Society of Ichthyologist and Herpetologists, 2004, Guidelines for the Use of Fishes in Research: American Fisheries Society, Bethesda, Maryland, 57 p.

Agius, C., and Roberts, R.J., 2003, Review melano-macrophage centres and their role in fish pathology: Journal of Fish Diseases, v. 26, p. 499–509.

Alkinidi, A.Y.A., Brown, J.A., Waring, C.P., and Collins, J.E., 1996, Endocrine, osmoregulatory, respiratory and haematological parameters in flounder exposed to the water soluble fraction: Journal of Fish Biology, v. 49, p. 1,291–1,305.

Alvarado, N.E., Quesada, I., Hylland, K., Marigómez, I., and Soto, M., 2006, Quantitative changes in metallothionein expression in target cell-types in the gills of turbot (*Scophthalmus maximus*) exposed to Cd, Cu, Zn and after a depuration treatment: Aquatic toxicology, v. 77, no. 1, p. 64–77.

Blackwell, B.G., Brown, M.L., and Willis, D.W., 2000, Relative weight (Wr) status and current use in fisheries assessment and management: Reviews in Fisheries Science, v. 8, no. 1, p. 1–44.

Clark, T.D., Eliason, E.J., Sandblom, E., Hinch, S.G., and Farrell, A.P., 2008, Calibration of a hand-held haemoglobin analyser for use on fish blood: Journal of Fish Biology, v. 73, no. 10, p. 2,587–2,595.

Davis, A.K., Maney, D.L., and Maerz, J.C., 2008, The use of leukocyte profiles to measure stress in vertebrates—A review for ecologists: Functional Ecology, v. 22, no. 5, p. 760–772.

Dubansky, B., Whitehead, A., Miller, T., Rice, C.D., Galvez, F., and Miller, J.T., 2013, Multitissue molecular, genomic, and developmental effects of the Deepwater Horizon oil spill on resident Gulf killifish (*Fundulus grandis*): Environmental Science & Technology, v. 47, no. 10, p. 5,074–5,082.

Fournie, J.W., Summers, J.K., Courtney, L.A., Engle, V.D., and Blazer, V.S., 2001, Utility of splenic macrophage aggregates as an indicator of fish exposure to degraded environments: Journal of Aquatic Animal Health, v. 13, no. 2, p. 105.

Fournie, J.W., Summers, J.K., and Weisberg, S.B., 1996, Prevalence of gross pathological abnormalities in estuarine fishes: Transactions of the American Fisheries Society, v. 125, no. 4, p. 581–590.

Hart, L., Smith, S.A., Smith, J.B., Robertson, J., Besteman, E.G., and Holladay, S.D., 1998, Subacute immunotoxic effects of the polycyclic aromatic hydrocarbon 7,12-dimethylbenzanthracene (DMBA) on spleen and pronephros leukocytic cell counts and phagocytic cell activity in tilapia (*Oreochromis niloticus*): Aquatic Toxicology, v. 41, no. 1–2, p. 17–29.

Haensly, W.E., Neff, J.M., Sharp, J.R., Morris, A.C., Bedgood, M.F., and Boem, P.D., 1982, Histopathology of *Pleuronectes platessa* L. from Aber Wrac'h and Aber Benoit, Brittany, France—Long-term effects of the Amoco Cadiz crude oil spill: Journal of Fish Diseases, v. 5, no. 5, p. 365–391.

Heath, A.G., 1995. Water Pollution and Fish Physiology, 2nd ed. CRC Press, Boca Raton, 359 p.

Hedayati, A., and Jahanbakhshi, A., 2012, The effect of water-soluble fraction of diesel oil on some hematological indices in the great sturgeon *Huso huso*: Fish physiology and Biochemistry, v. 38, no. 6, p. 1,753–1,758.

Holladay, S.D., Smith, S.A., Besteman, E.G., Deyab, A.S., Gogal, R.M., Hrubec, T., Robertson, J.L., and Ahmed, S.A., 1998, Benzo[a]pyrene-induced hypocellularity of the pronephros in tilapia (*Oreochromis niloticus*) is accompanied by alterations in stromal and parenchymal cells and by enhanced immune cell apoptosis: Veterinary Immunology and Immunopathology, v. 64, no. 1, p. 69–82.

Khan, R., 1998, Influence of petroleum at a refinery terminal on feral winter flounder, *Pleuronectes americanus*: Bulletin of Environmental Contamination and Toxicology, v. 61, no. 6, p. 770–777.

Khan, R.A., 2003, Health of flatfish from localities in Placentia Bay, Newfoundland, contaminated with petroleum and PCBs: Archives of Environmental Contamination and Toxicology, v. 44, no. 4, p. 485–492.

Kerambrun, E., Le Floch, S., Sanchez, W., Thomas Guyon, H., Meziane, T., Henry, F., and Amara, R., 2012, Responses of juvenile sea bass, *Dicentrarchus labrax*, exposed to acute concentrations of crude oil, as assessed by molecular and physiological biomarkers: Chemosphere, v. 87, no. 7, p. 692–702.

Law, R.J., Kirby, M.F., Moore, J., Barry, J., Sapp, M., and Balaam, J., 2011, PREMIAM—Pollution Response in Emergencies Marine Impact Assessment and Monitoring, Post-incident monitoring guidelines: Cefas, Lowestoft, Science Series Technical Report, v. 146, 164 p.

Luna, L.G., ed., 1968, Manual of histological staining methods of the Armed Forces Institute of Pathology (3d ed.): New York, McGraw-Hill Book Co., p. 212.

Martinez, B.R., Delatim, J., and Guedes, C.L.B., 2008, Biochemical , physiological , and histological changes in the neotropical fish *Prochilodus lineatus* exposed to diesel oil: v. 69, p. 112–120.m,

Martinez-Gómez, C., Vethaak, A.D., Hylland, K., Burgeot, T., Köhler, A., Lyons, B.P., Thain, J., Gubbins, M.J., and Davies, I.M., 2010, A guide to toxicity assessment and monitoring effects at lower levels of biological organization following marine oil spills in European waters—ICES: Journal of Marine Science, v. 67, p. 1,105–1,118.

Marty, G.D., Okihiro, M.S., Brown, E.D., Hanes, D., and Hinton, D.E., 1999, Histopathology of adult Pacific herring in Prince William Sound, Alaska, after the Exxon Valdez oil spill: Canadian Journal of Fisheries and Aquatic Sciences, v. 56, no. 3, p. 419–426.

McNeill, S.A., Arens, C.J., Hogan, N.S., Köllner, B., and van den Heuvel, M.R., 2012, Immunological impacts of oil sands-affected waters on rainbow trout evaluated using an in situ exposure: Ecotoxicology and Environmental Safety, v. 84, p. 254–261.

Moore, M.J., Mitrofanov, I.V, Valentini, S.S., Volkov, V.V, Kurbskiy, A.V, Zhimbey, E.N., Eglinton, L.B., and Stegeman, J.J., 2003, Cytochrome P4501A expression, chemical contaminants and histopathology in roach, goby and sturgeon and chemical contaminants in sediments from the Caspian Sea, Lake Balkhash and the Ily River Delta, Kazakhstan: Marine Pollution Bulletin, v. 46, no. 1, p. 107–119.

Powers and others 1939

Reynaud, S., and Deschaux, P., 2006, The effects of polycyclic aromatic hydrocarbons on the immune system of fish—A review: Aquatic Toxicology, v. 77, no. 2, p. 229–238.

Reynaud, S., Raveton, M., and Ravanel, P., 2008, Interactions between immune and biotransformation systems in fish—A review: Aquatic Toxicology, v. 87, no. 3, p. 139–45.

Schmitt, C.J., Blazer, V.S., Dethloff, G.M., Tillitt, D.E., Gross, T.S., DeWeese, L.R., Smith, S.B., Goede, R.W., Bartish, T.A., and Kubiak, T.J., 1999, Biomonitoring of Environmental Status and Trends

(BEST) Program—Field procedures for assessing the exposure of fish to environmental contaminants: Columbia, Missouri, Geological Survey Information and Technology Report USGS/BRD-1999-007, 35 p. plus appendixes.

Schmitt and others 1993

Simonato, J.D., Guedes, C.L.B., and Martinez, C.B.R., 2008, Biochemical, physiological, and histological changes in the neotropical fish *Prochilodus lineatus* exposed to diesel oil: Ecotoxicology and Environmental Safety, v. 69, p. 112–120.

Stegeman, J.J., and Lech, J.J., 1991, Cytochrome P-450 monooxygenase systems in aquatic species—Carcinogen metabolism and biomarkers for carcinogen and pollutant exposure: Environmental Health Perspectives, v. 90, p. 101–109.

Thompson, D'A. W., 1942. On Growth and Form. Cambridge University Press, Cambridge.

Tuvikene, A., 1995, Responses of fish to polycyclic aromatic hydrocarbons (PAHs): Annales Zoologici Fennici, v. 32, p. 295–309.

Ueng, T-H., Ueng, Y-F., and Park, S.S., 1992, Comparative induction of cytochrome P450 dependent monooxygenase in the livers and gills of tilapia and carp: Aquatic Toxicology, v. 23, p. 49–64.

Uribe, C., Folch, H., Enriquez, R., and Moran, G., 2011, Innate and adaptive immunity in teleost fish—A review: Veterinarni Medicina, v. 56, no. 10, p. 486–503.

Whyte, J.J., Jung, R.E., Schmitt, C.J., and Tillitt, D.E., 2000, Ethoxyresorufin-o-deethyalse (EROD) activity in fish as a biomarker of chemical exposure: Critical Reviews in Toxicology, v. 30, no. 4, p. 347-350.

Wolke, R. E., 1992, Piscine macrophage aggregates—A review: Annual Review of Fish Diseases, v. 2, p. 91–108.

Figure 1. Approximate location of sample sites along the Kalamazoo River in Michigan. The Enbridge Line 6B pipeline break occurred near Talmadge Creek, which enters the Kalamazoo River downstream from Marshall, Michigan. The upstream reference area is in the Marshall Impoundment (MI), and the sampling sites within the Kalamazoo River downstream from the oil discharges are Historic Bridge (HB) Legacy Ranch (LR), and Shady Bend (SB).

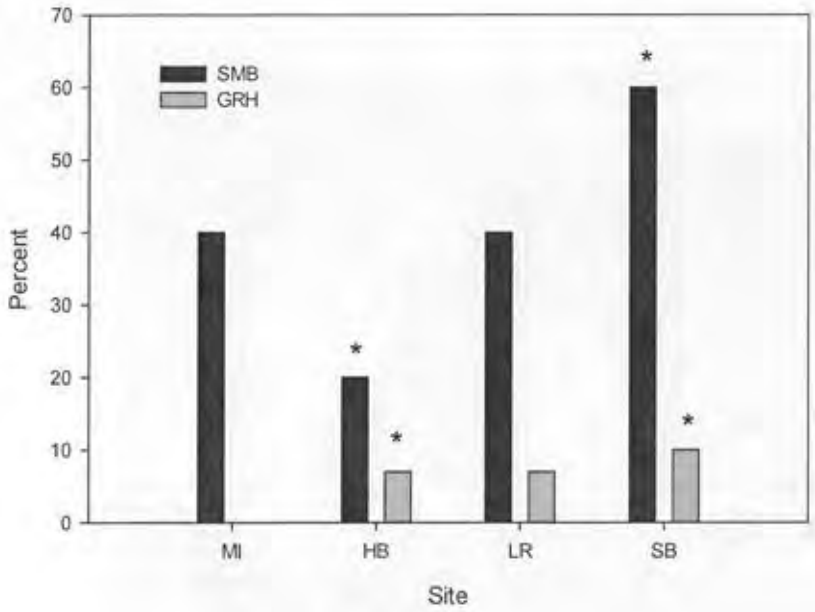


Figure 2. Percent of smallmouth bass (SMB) and golden redhorse (GRH) with splenic parasites from Historic Bridge (HB), Legacy Ranch (LR), Shady Bend (SB) and a reference site, Marshall Impoundment (MI). An asterisk above a bar indicates a significant difference ($p \leq 0.05$) between fish of a given species at the oiled site and at the reference site. [$\leq$ is less than or equal to]

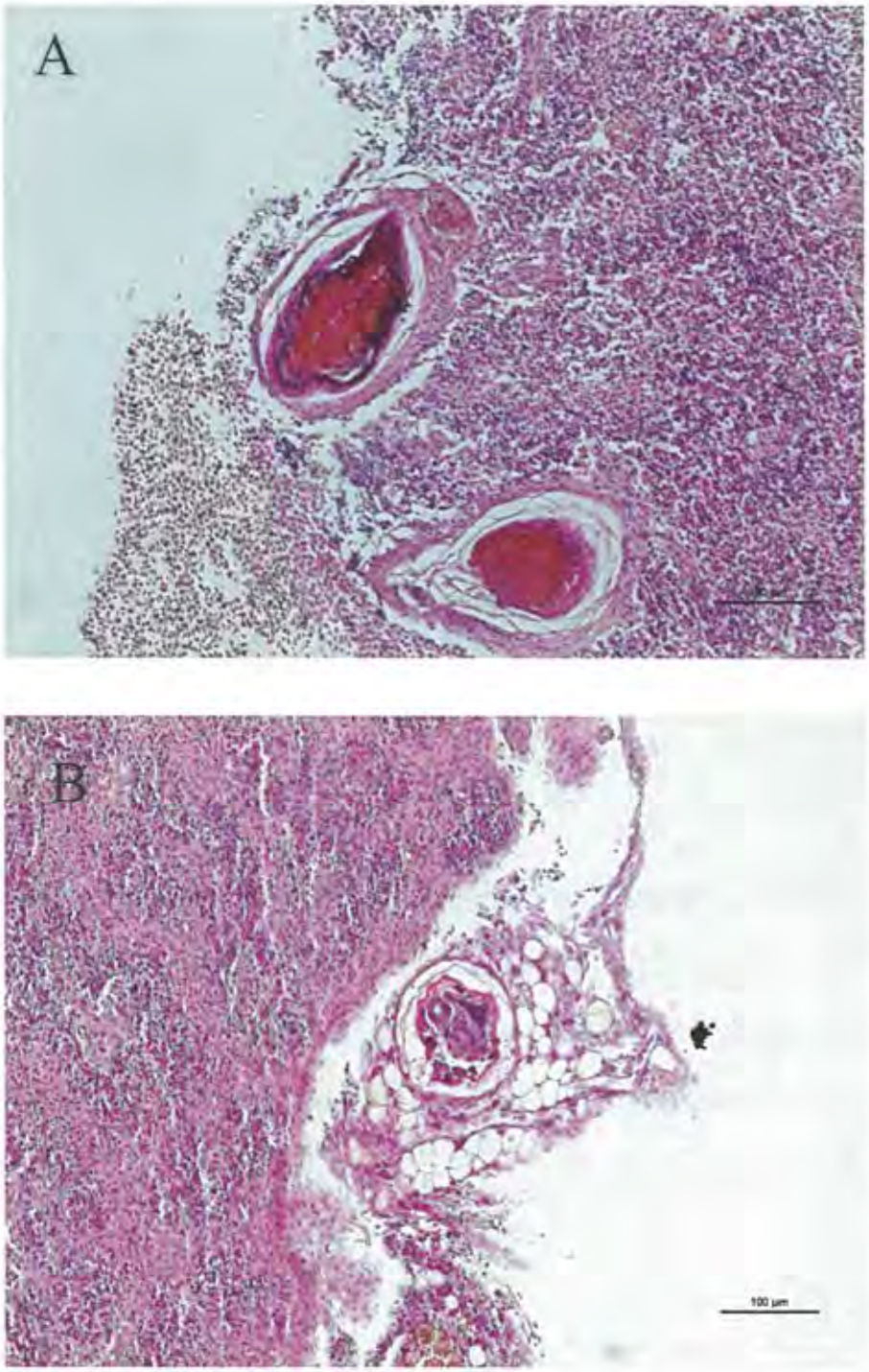


Figure 3. Example of parasites found in histological sections of smallmouth bass spleen from *A*, Marshall Impoundment and *B*, Shady Bend. Scale bar represents 100 microns.

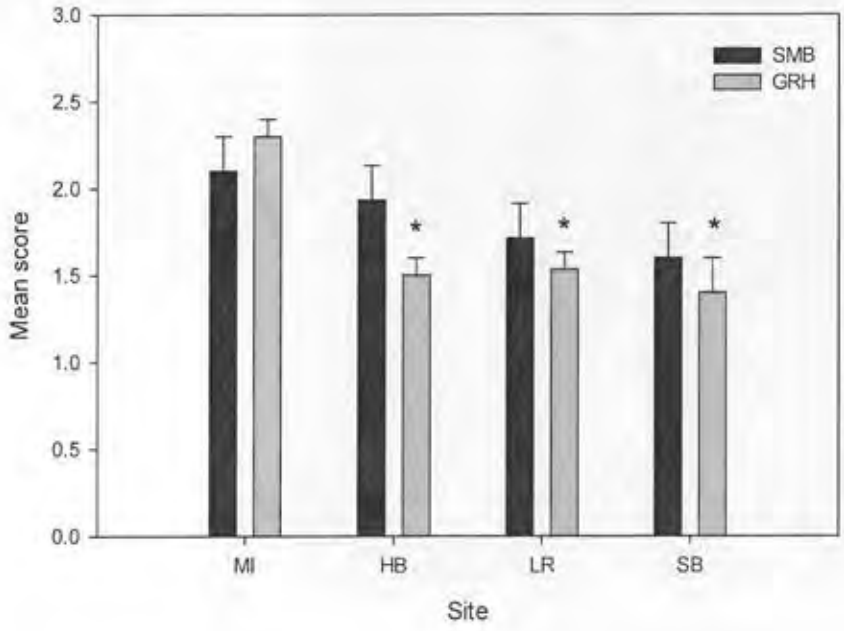


Figure 4. Mean score indicating the prevalence of splenic lymphoid tissue for smallmouth bass (SMB) and golden redhorse (GRH) from Historic Bridge (HB), Legacy Ranch (LR), Shady Bend (SB), and a reference site, Marshall Impoundment (MI). Error bar represents one standard error (SE) of the mean. An asterisk above a bar indicates a significant difference ($p \leq 0.05$) between the respective species and the reference site.[$\leq$ is less than or equal to]

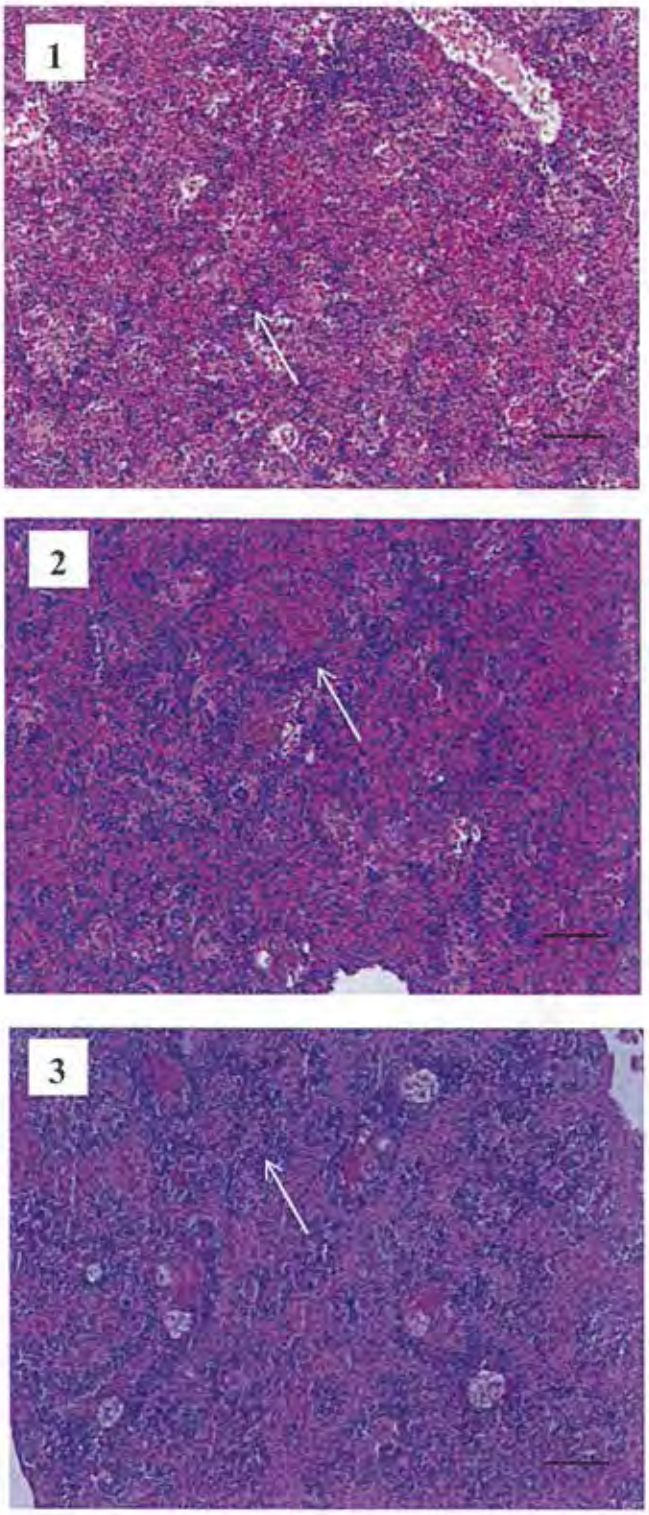


Figure 5. Histological sections of golden redhorse sucker spleen. Spleens were classified 1–3 according to the amount of lymphoid tissue (arrows) present. Scale bar represents 100 microns.

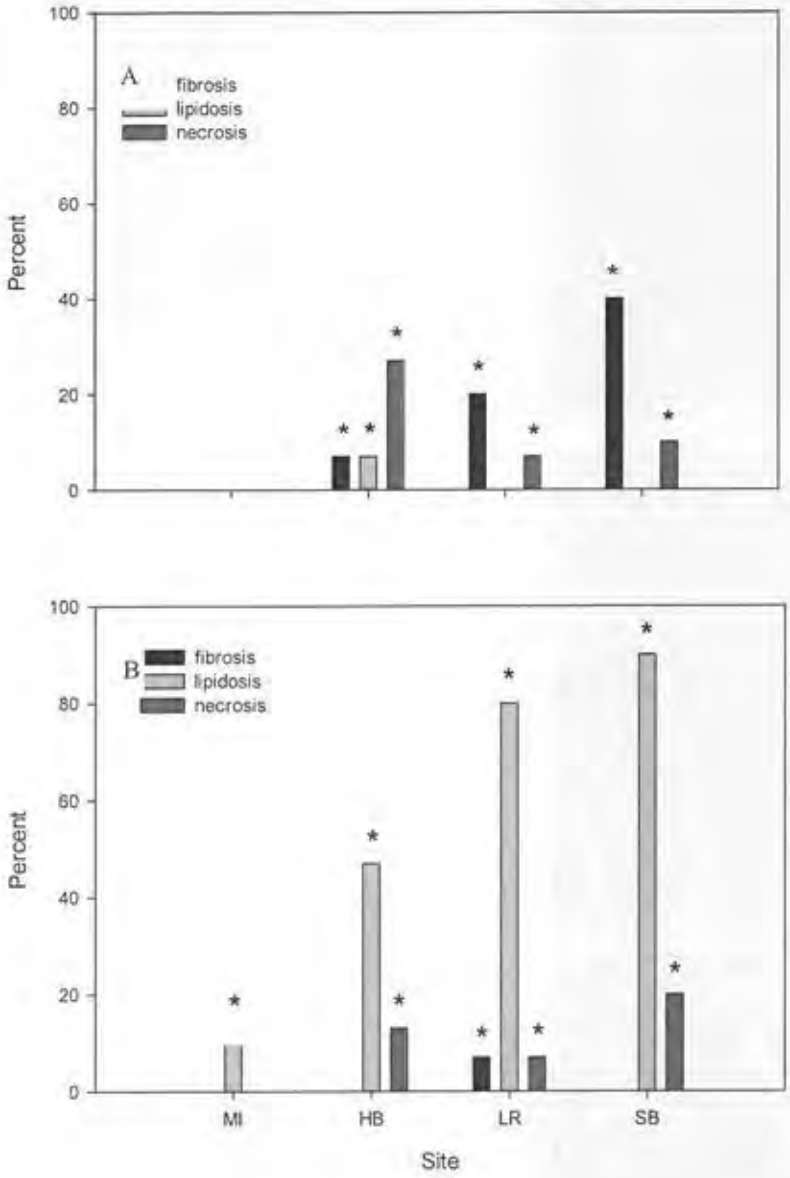


Figure 6. Percent of *A*, golden redhorse sucker and *B*, smallmouth bass with fibrosis, lipid deposits, or necrosis in spleens from three sites Historic Bridge (HB), Legacy Ranch (LR), and Shady Bend (SB) affected by the Enbridge Line 6B oil discharge and a reference site, Marshall Impoundment (MI). An asterisk above a bar indicates a significant difference ($p \leq 0.05$) between the oiled site and the reference site. [$\leq$ is less than or equal to]

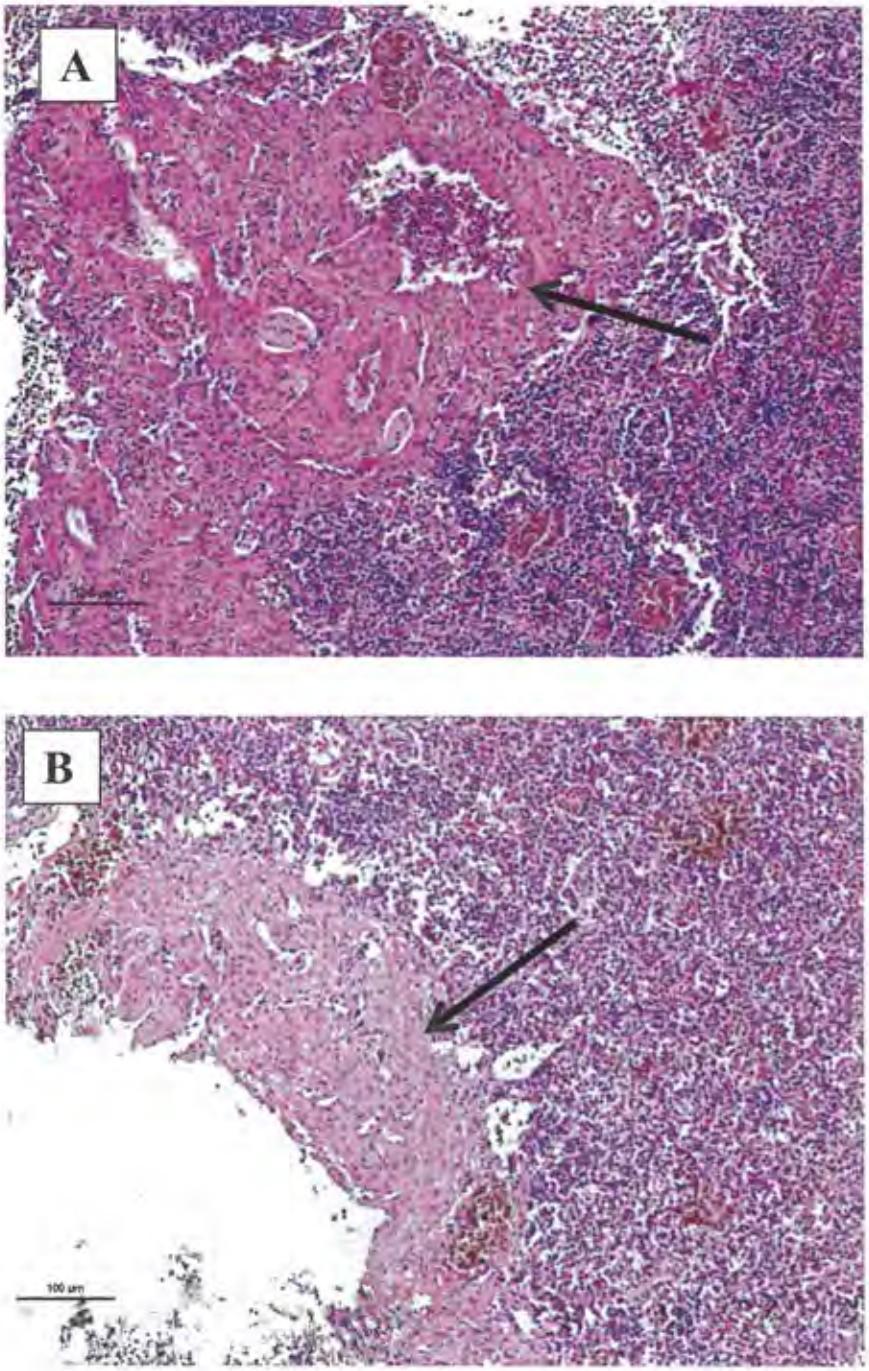


Figure 7. Example of fibrosis (arrow) in histological section of spleen of golden redhorse sucker from *A*, Shady Bend, and *B*, Historic Bridge. Scale bar represents 100 microns.

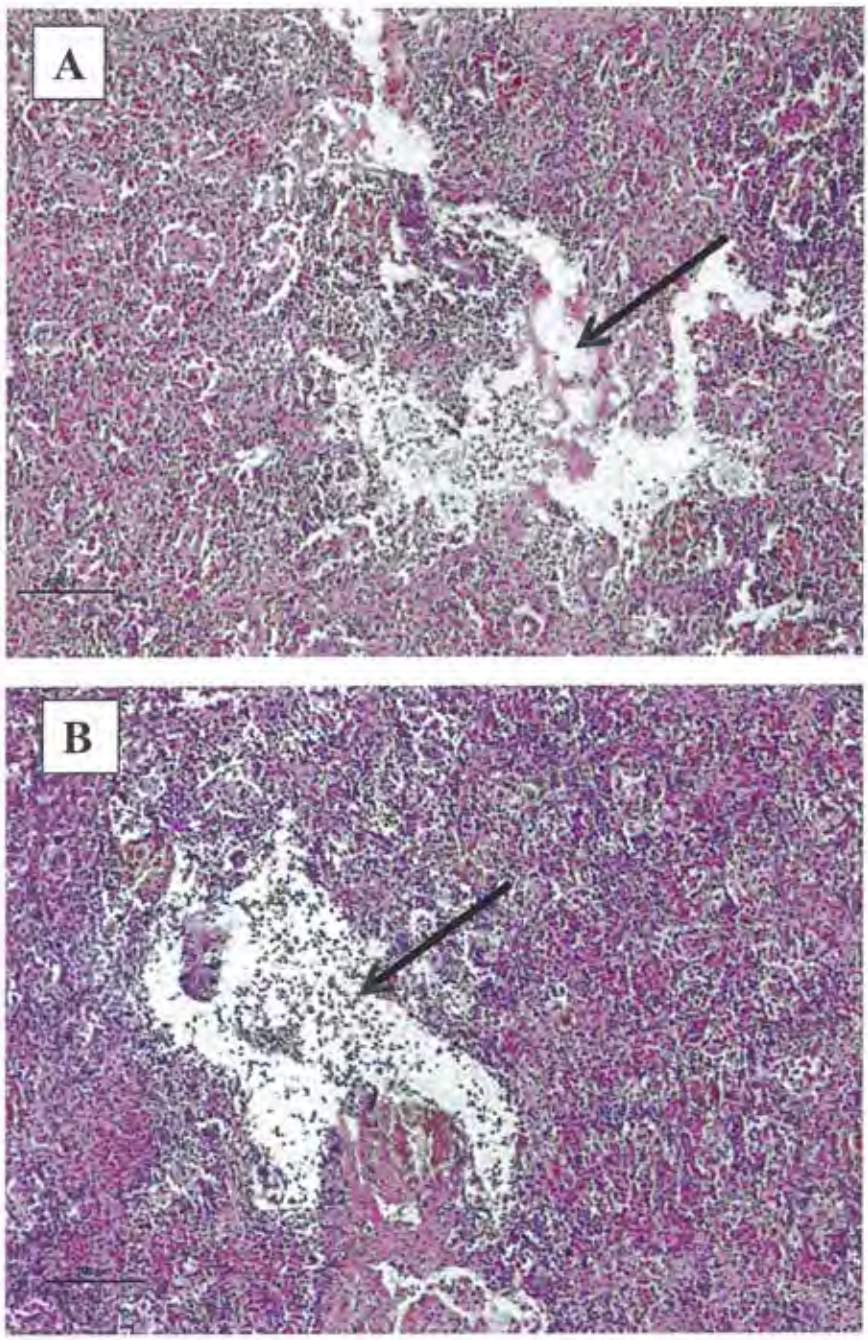


Figure 8. Example of necrosis (arrow) in histological section of spleen of golden redhorse sucker from *A*, Legacy Ranch and *B*, Historic Bridge. Scale bar represents 100 microns.

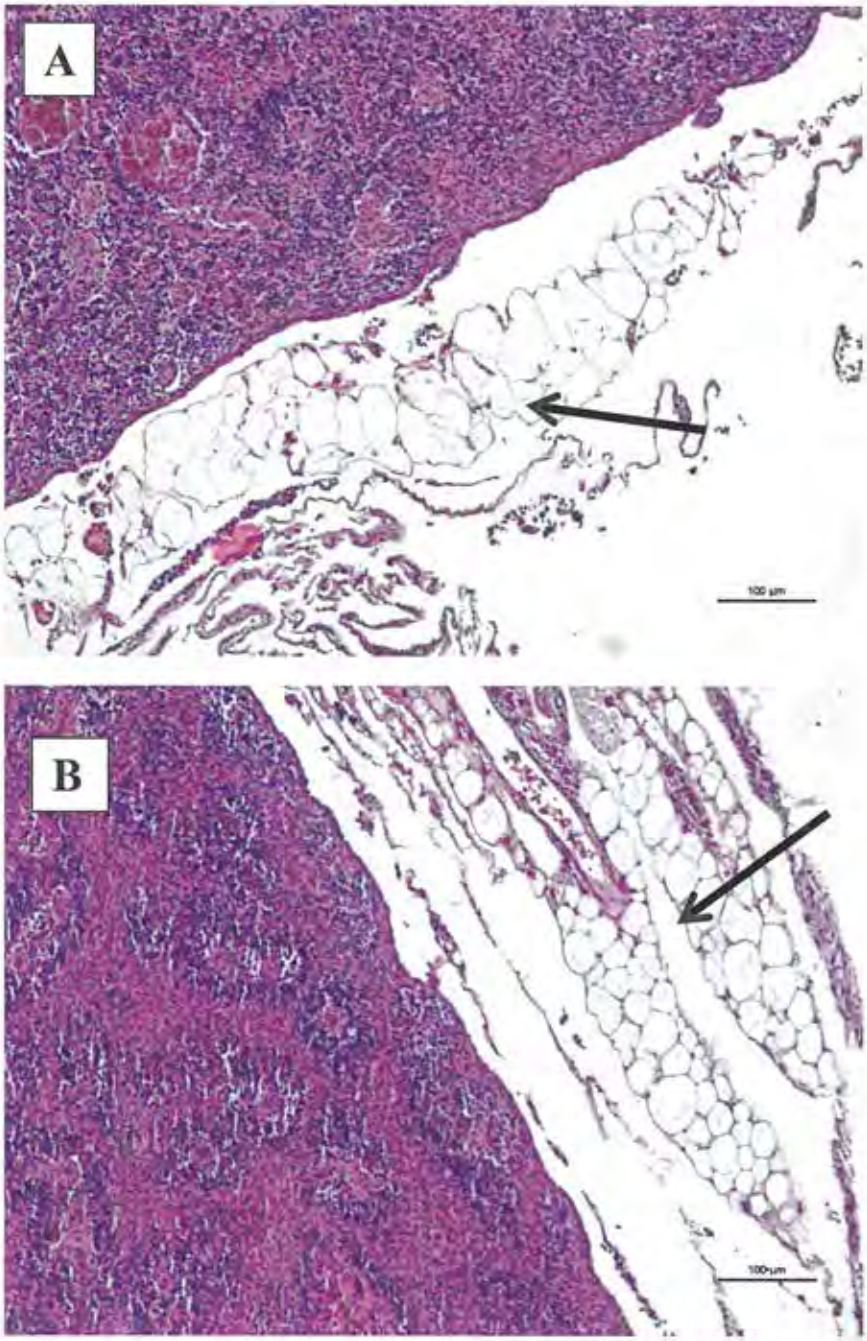


Figure 9. Example of lipid (arrow) encapsulating spleen in histological section from golden redhorse sucker from *A*, Marshall Impoundment and *B*, Shady Bend. Scale bar represents 100 microns.

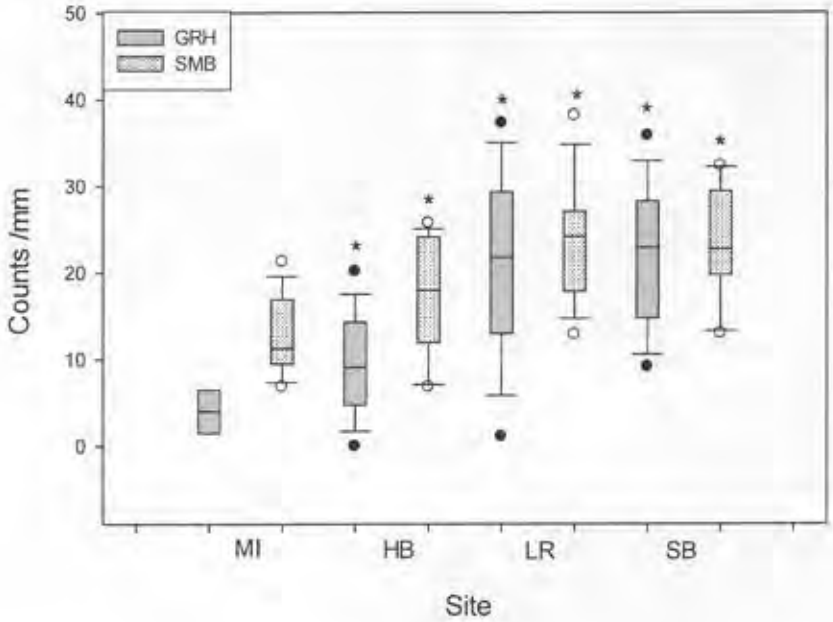


Figure 10. Mucus cell counts per millimeter gill filament in golden redhorse sucker (GRH) and smallmouth bass (SMB) from Historic Bridge (HB), Legacy Ranch (LR), Shady Bend (SB), and a reference site, Marshall Impoundment (MI). The boundary of the box closest to zero indicates the 25th percentile, a line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers (error bars) above and below the box indicate the 90th and 10th percentiles, and symbols outside the box indicate outlying points. An asterisk above a bar indicates a significant difference ($p \leq 0.05$) between the respective species and the reference site. [$\leq$ is less than or equal to]

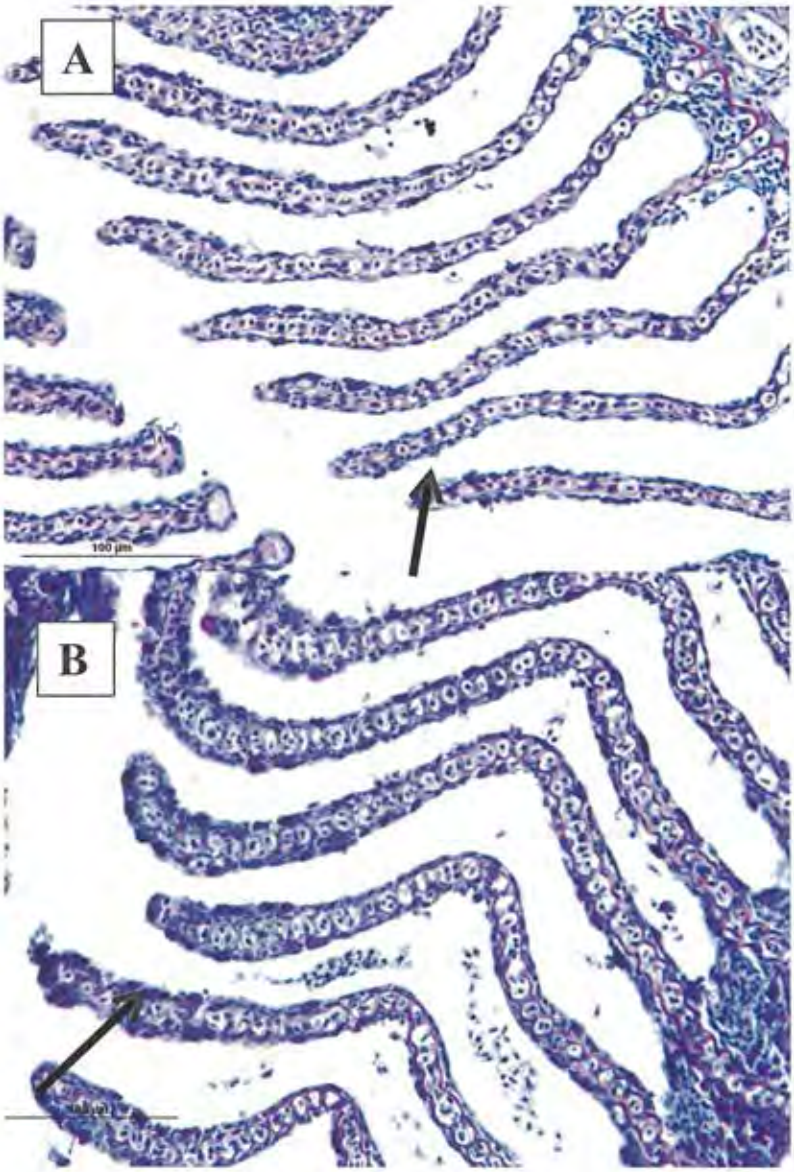


Figure 11. Example of mucus cells (arrows) on secondary lamellae in histological sections of gills from golden redhorse sucker collected from *A*, Marshall Impoundment and *B*, Historic Bridge. Scale bar represents 100 microns.

Table 1. Mean size of smallmouth bass (SMB) and golden redhorse sucker (GRH) from Marshall Impoundment (reference site) and three sites affected by the Enbridge Line 6B oil discharge. [millimeter = mm; number = N; grams = gr; standard deviation = SD]

Site	Species	Sex	N	Length (mm) mean (SD)	Weight (gr) mean (SD)	Significant differences[1]
Marshall Impoundment	SMB	M	5	339 (50)	602 (264)	
	SMB	F	10	315 (62)	475 (260)	
	GRH	M	3	391 (28)	634 (102)	
	GRH	F	12	427 (23)	827 (177)	AC
Historic Bridge	SMB	M	7	364 (71)	706 (364)	
	SMB	F[2]	7	283 (53)	261 (122)	
	GRH	M	7	371 (67)	570 (263)	
	GRH	F	8	440 (50)	933 (262)	A
Legacy Ranch	SMB	M	8	318 (63)	401 (185)	
	SMB	F	7	267 (43)	263 (118)	
	GRH	M	8	370 (26)	486 (94)	
	GRH	F	7	412 (27)	686 (166)	BC
Shady Bend	SMB	M	5	345 (61)	690 (297)	
	SMB	F	5	398 (78)	514 (398)	
	GRH	M	2	377 (28)	410 (85)	
	GRH	F	8	324 (29)	635 (134)	B

[1] Males and females were significantly different ($p \leq 0.05$) in length and weight and were therefore analyzed separately. The only site-related effects were for weight of GRH females. The same letter indicates no significant site differences ($p > 0.05$) among weights of GRH females.
[2] An eighth female was captured but not included because it was juvenile.

Table 2. Mean condition factor (CF) of smallmouth bass (SMB) and golden redhorse sucker (GRH) from Marshall Impoundment (reference site) and three sites affected by the Enbridge Line 6B oil discharge. [number = N; standard deviation = SD]

Site	Species	Sex	N	CF mean (SD)	Significant differences[1]
Marshall Impoundment	SMB	M	5	1.46 (0.17)	A
	SMB	F	10	1.40 (0.07)	
	GRH	M	3	1.06 (0.06)	A
	GRH	F	12	1.05 (0.07)	
Historic Bridge	SMB	M	7	1.36 (0.09)	B
	SMB	F	7	1.15 (0.33)	
	GRH	M	7	1.05 (0.04)	A
	GRH	F	8	1.06 (0.07)	
Legacy Ranch	SMB	M	8	1.22 (0.25)	B
	SMB	F	7	1.32 (0.12)	
	GRH	M	8	0.95 (0.05)	B
	GRH	F	7	0.97 (0.12)	
Shady Bend	SMB	M	5	1.21 (0.09)	B
	SMB	F	5	1.27 (0.12)	
	GRH	M	2	0.99	B
	GRH	F	8	0.99 (0.03)	

[1] Sexes were not significantly different ($p>0.05$) and were combined within a species for significance testing among sites. The same letter within a species indicates no significant differences ($p>0.05$).

Table 3. Mean hepatosomatic index (HSI) for smallmouth bass (SMB) from Marshall Impoundment (reference site) and three sites affected by the Enbridge Line 6B oil discharge. [number = N; standard deviation = SD]

Site	Species	Sex	N	HSI mean (SD)	Significant differences[1]
Marshall Impoundment	SMB	M	5	0.54 (0.06)	A
	SMB	F	10	0.53 (0.09)	
Historic Bridge	SMB	M	7	0.75 (0.09)	B
	SMB	F	7	1.19 (1.02)	
Legacy Ranch	SMB	M	8	0.75 (0.54)	AC
	SMB	F	7	0.57 (0.07)	
Shady Bend	SMB	M	5	0.63 (0.07)	C
	SMB	F	5	0.57 (0.11)	

[1] Sexes were not significantly different and were combined for significance testing among sites.
The same letter indicates no significant difference ($p>0.05$).

Table 4. Mean scores for the Health Assessment Index (HAI) for smallmouth bass (SMB) and golden redhorse sucker (GRH) from Marshall Impoundment (reference site) and three sites affected by the Enbridge Line 6B oil discharge. [(number = N; standard deviation = SD].

Site	Species	Sex	N	HAI mean (SD)	Significant differences[1]
Marshall Impoundment	SMB	M	5	0 (0)	A
	SMB	F	10	1 (3)	
	GRH	M	3	23 (23)	A
	GRH	F	12	6 (9)	
Historic Bridge	SMB	M	7	26 (11)	B
	SMB	F	7	30 (0)	
	GRH	M	7	59 (17)	B
	GRH	F	8	60 (11)	
Legacy Ranch	SMB	M	8	36 (11)	C
	SMB	F	7	33 (5)	
	GRH	M	8	43 (10)	C
	GRH	F	7	44 (21)	
Shady Bend	SMB	M	5	48 (22)	C
	SMB	F	5	36 (5)	
	GRH	M	2	25 (7)	C
	GRH	F	8	45 (18)	

[1]Sexes (except fish from Marshall Impoundment) were not significantly different ($p>0.05$) and were combined within a species for significance testing among sites. The same letter within a species indicates no significant difference ($p>0.05$).

Table 5. Mean hemoglobin (Hb) for smallmouth bass (SMB) and golden redhorse sucker (GRH) from Marshall Impoundment (reference site) and three sites affected by the Enbridge Line 6B oil discharge. [grams/deciliter = gr/dL; number = N; standard deviation = SD]

Site	Species	Sex	N	Hb[1] (gr/dL) mean (SD)	Significant differences[2]
Marshall Impoundment	SMB	M	5	5.8 (0.5)	
	SMB	F	10	5.4 (0.8)	
	GRH	M	3	3.7 (0.8)	
	GRH	F	11	5.0 (0.6)	A
Historic Bridge	SMB	M	7	6.2 (1.4)	
	SMB	F	7	5.6 (1.4)	
	GRH	M	6	2.7 (0.9)	
	GRH	F	8	3.0 (1.7)	B
Legacy Ranch	SMB	M	8	6.0 (1.3)	
	SMB	F	7	4.7 (1.8)	
	GRH	M	7	4.4 (1.3)	
	GRH	F	7	5.2 (1.1)	A
Shady Bend	SMB	M	5	6.2 (1.2)	
	SMB	F	4	5.2 (0.8)	
	GRH	M	2	4.4	
	GRH	F	7	4.3 (0.9)	AB

[1]Hemoglobin values were corrected following Clark and others (2008).
[2]Sexes were not significantly different ($p>0.05$) for both species and all stations except GRH from Marshall Impoundment and SMB from Legacy Ranch. Sexes were analyzed separately within a species for significance testing among sites. Significant differences ($p\leq0.05$), found only among GRH females, are indicated by different letters.

Table 6. Thrombocytes, leukocytes, and the ratio of granulocytes (G) to lymphocytes (L) in blood smears of smallmouth bass (SMB) and golden redhorse sucker (GRH) from a Marshall Impoundment (reference site) and three sites associated with the Enbridge Line 6B oil discharge. Monocytes, granulocytes, and lymphocytes are reported as a percent of total leukocytes. Thrombocytes are reported as a percent of total thrombocytes plus leukocytes. [number = N; stand deviation = SD].

				Leukocytes[1]			
Site	Species Sex	N	Thrombocytes[1] mean (SD)	Monocytes mean (SD)	Lymphocytes mean (SD)	Granulocytes mean (SD)	G:L Ratio[2]
Marshall Impoundment	SMB F	10	3 (4)	3 (4)	72 (12)	26 (11)	0.32
	SMB M	5					0.53
	GRH F	12	15 (8)	1 (1)	93 (8)	6 (7)	0.07
	GRH M	3					
Historic Bridge	SMB F	7	2 (2)	1 (1)	94 (4)*	4 (4)*	0.05 *
	SMB M	7					0.05 *
	GRH F	8	16 (13)	1 (1)	91 (5)*	7 (5)	0.08
	GRH M	7					
Legacy Ranch	SMB F	7	1 (2)	1 (1)	96 (3)*	3 (3)*	0.03 *
	SMB M	8					0.04 *
	GRH F	7	24 (16)	1 (1)	86 (10)*	13 (9)	0.16 *
	GRH M	8					
Shady Bend	SMB F	5	3 (2)	5 (7)*	81 (17)	14 (12)	0.36
	SMB M	5					0.07 *
	GRH F	8	17 (11)	2 (2)	97 (3)*	2 (2)	0.02 *
	GRH M	2					

[1]Sexes were not significantly different ($p>0.05$) and were combined within a species for significance testing among sites. Within a column, means with an asterisk are significantly different ($p<0.05$) from respective species from Marshall Impoundment.

[2]Sexes were only significantly different ($p\leq0.05$) for SMB. Smallmouth bass sexes were analyzed separately for significance testing among sites whereas, GRH were combined for the analysis. Means with an asterisk are significantly different ($p<0.05$) from respective species and sex from Marshall Impoundment.

Table 7. Macrophage aggregates (MA) in spleens of smallmouth bass from a reference site (Marshall Impoundment) and three sites affected by the Enbridge Line 6B oil discharge. Within a column, means with the same letter are not significantly different (p>0.05). [square microns = µm2; number = N; standard deviation = SD, > is greater than]

Site	N	Total MA Area / μm^2 mean ± SD (range)	Size of MA (μm^2) mean ± SD (range)	Number MAs / μm^2 mean ± SD (range)
Marshall Impoundment	15	0.008±0.008 A (0–0.03)	1106±895 A (0–3044)	$4.9x10^{-6}$±$4.5x10^{-6}$ A ($0–1.3x10^{-5}$)
Historic Bridge	14	0.02±0.01 AB (0–0.05)	2523±1529 B (834–6695)	$5.6x10^{-6}$±$2.5x10^{-6}$ A ($1.90x10^{-6}–1.0x10^{-5}$)
Legacy Ranch	15	0.01±0.008 AB (0–0.02)	1505±845 A (0–3946)	$7.2x10^{-6}$±$5.3x10^{-6}$ A ($0–2.3x10^{-5}$)
Shady Bend	10	0.02±0.01 B (0.01–0.05)	3190±1484 B (1222–6059)	$7.7x10^{-6}$±$2.6x10^{-6}$ A ($3.3x10^{-6}–1.1x10^{-5}$)

Table 8. Macrophage aggregates (MA) in spleens of golden redhorse sucker from a reference site (Marshall Impoundment) and three sites affected by the Enbridge Line 6B oil discharge. Within a column, means with the same letter are not significantly different ($p>0.05$). [square microns = μm2; number = N; standard deviation = SD, > is greater than]

Site	N	Total MA Area / μm^2 mean ± SD (range)	Size of MA (μm^2) mean ± SD (range)	Number MAs / μm^2 mean ± SD (range)
Marshall Impoundment	15	0.02±0.01 A (0–0.04)	1232±567 A (0–2202)	$1.1x10^{-5}$±$6.9x10^{-6}$ B ($0–2.5x10^{-5}$)
Historic Bridge	15	0.05±0.06 BC (0–0.28)	2788±3674 A (365–16120)	$1.7x10^{-5}$±$6.2x10^{-6}$ A ($4.0x10^{-6}–2.5x10^{-5}$)
Legacy Ranch	15	0.02±0.01 AC (0.01–0.06)	1330±379 A (764–2127)	$1.9x10^{-5}$±$1.0x10^{-5}$ A ($8.8x10^{-6}–4.2x10^{-5}$)
Shady Bend	10	0.03±0.02 BC (0–0.07)	1714±1197 A (0–4809)	$1.7x10^{-5}$ $8.9x10^{-6}$ AB ($0–3.6x10^{-5}$)

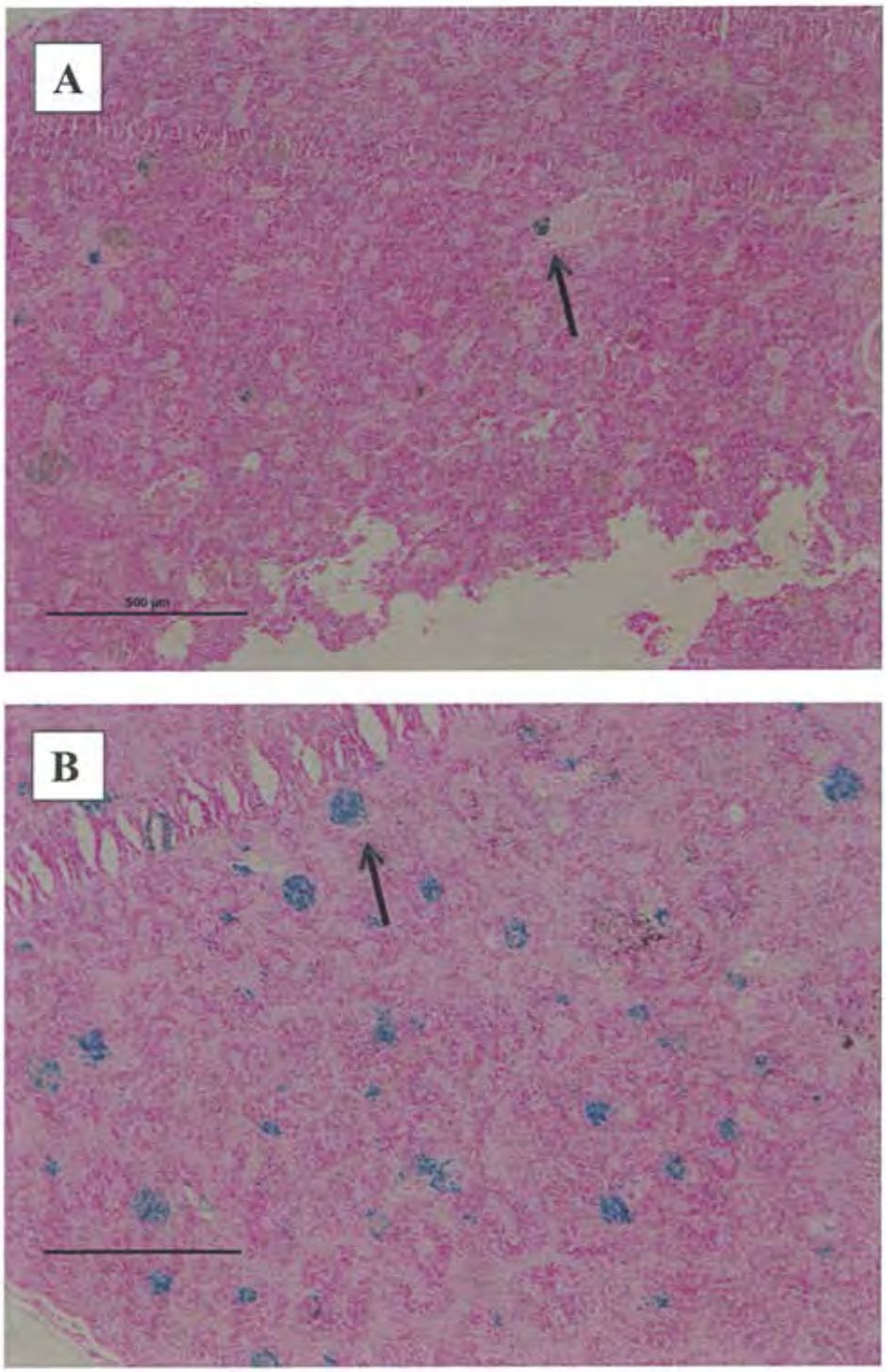


Figure 12. Example of macrophage aggregates (arrow) in histological section of spleen from smallmouth bass from *A*, Marshall Impoundment and *B*, Shady Bend. Scale bar represents 500 microns.

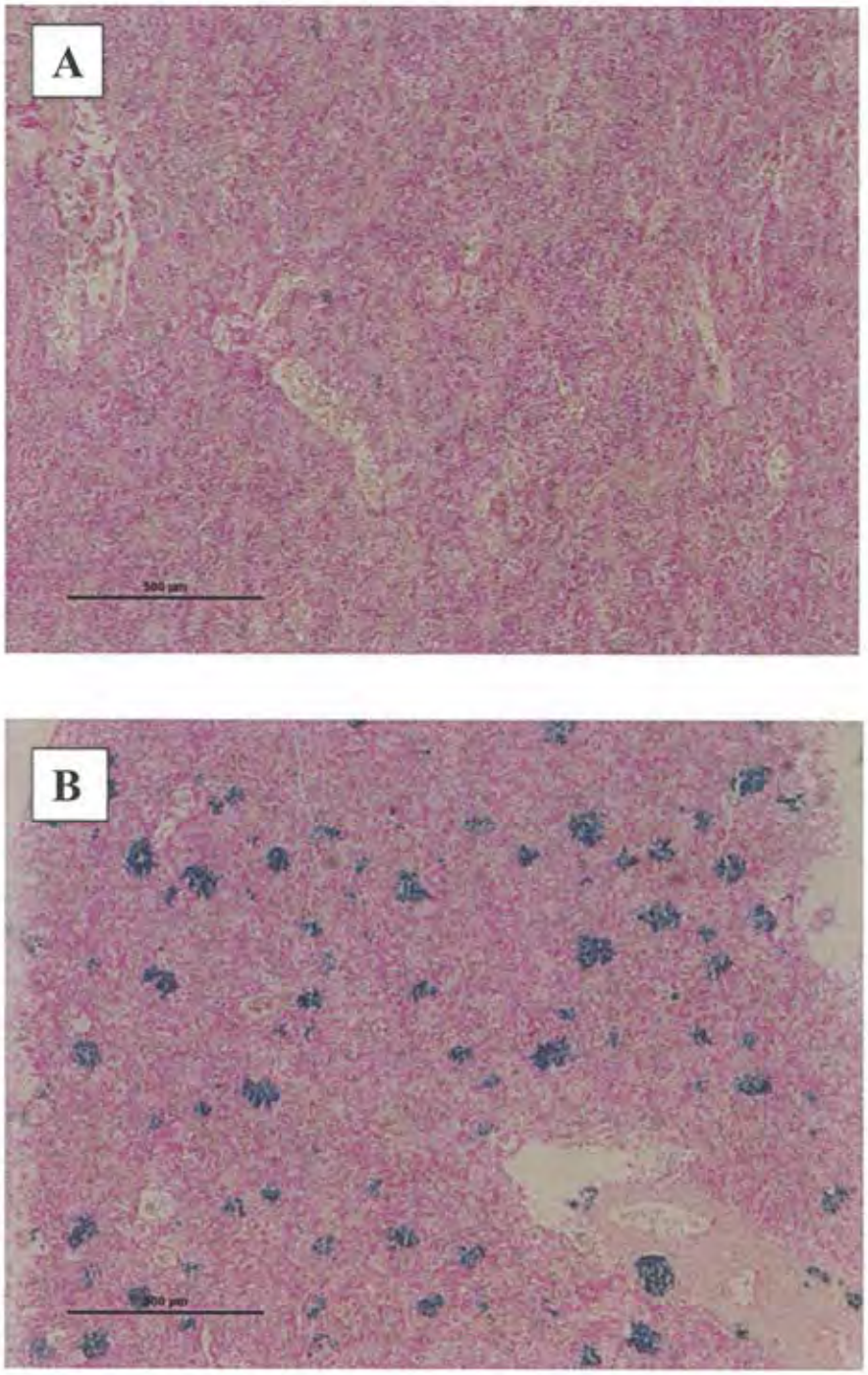


Figure 13. Example of macrophage aggregates (arrow) in histological section of spleen from golden redhorse from *A*, Marshall Impoundment and *B*, Historic Bridge. Scale bar represents 500 microns.

Table 9. Gill lesions in fish from Marshall Impoundment (**MI**), Historic Bridge (HB), Legacy Ranch (LR), and Shady Bend (SB) as percent of fish with a lesion (Percent) and severity score (Score; see text for explanation; maximum score is 45 and a higher number indicates lesion is more severe). Percent fish from oiled sites within brackets [ ] are significantly different ($p \leq 0.05$) from the reference site, Marshall Impoundment. [≤ is less than or equal to]

	Golden redhorse sucker		Smallmouth bass	
	Percent	Score	Percent	Score
Lesion	(**MI**-HB-LR-SB)	(**MI**-HB-LR-SB)	(**MI**-HB-LR-SB)	(**MI**-HB-LR-SB)
Epithelial Lifting	**13**-[27-47-50]	**2**-11-12-12	**20**-20-[33]-10	**3**-3-5-2
Epithelial hyperplasia	**47**-[67]-53-0	**8**-19-12-0	**60**-53-60-40	**11**-11-12-9
Aneurism	**33**-[60-60-70]	**10**-19-16-17	**27**-[60]-27-20	**6**-19-4-5
Curling	**40**-33-40-40	**9**-5-7-8	**7**-13-0-[20]	**1**-2-0-1
Congestion	**33**-40-[53-50]	**6**-12-12-11	**13**-[27-27-50]	**3**-5-4-9
Parasites	**7**-[20-0-0]	**1**-4-0-0	**0**-0-0-0	**0**-0-0-0
Fusion secondary lamellae	**13**-7-7-[0]	**2**-1-2-0	**7**-[20]-7-[0]	**1**-4-1-0

Figure 14. Example of histological section of *A*, normal gill secondary lamellae and a section *B*, showing many primary lamellae one of which is shortened. Scale bar in top panel represents 100 microns and scale bar in bottom panel represents 500 microns.

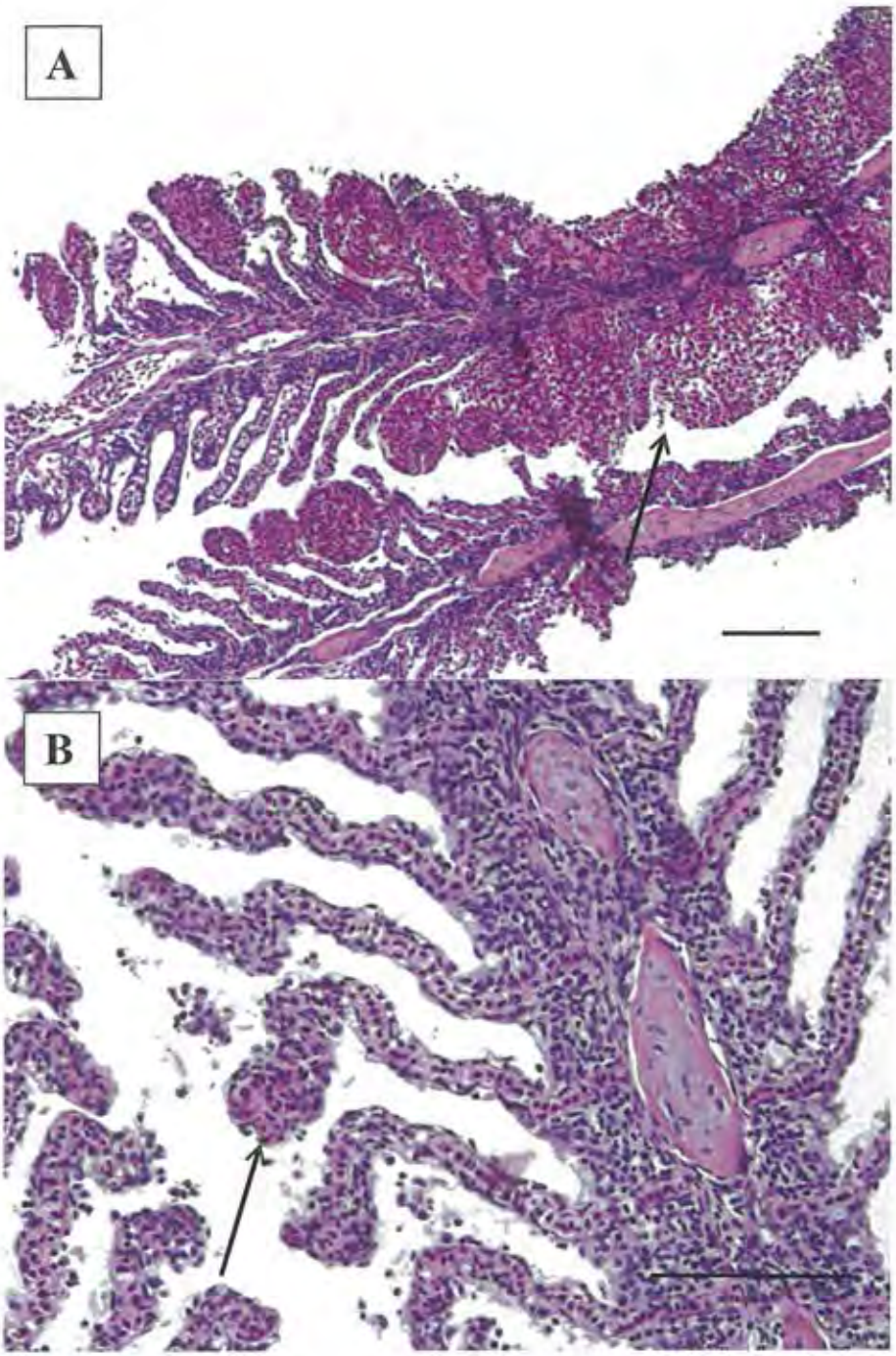


Figure 15. Example of aneurism (arrow) in secondary lamellae of an *A*, histological gill section and *B*, blood congestion (arrow) in secondary lamellae. Scale bars represent 100 microns.

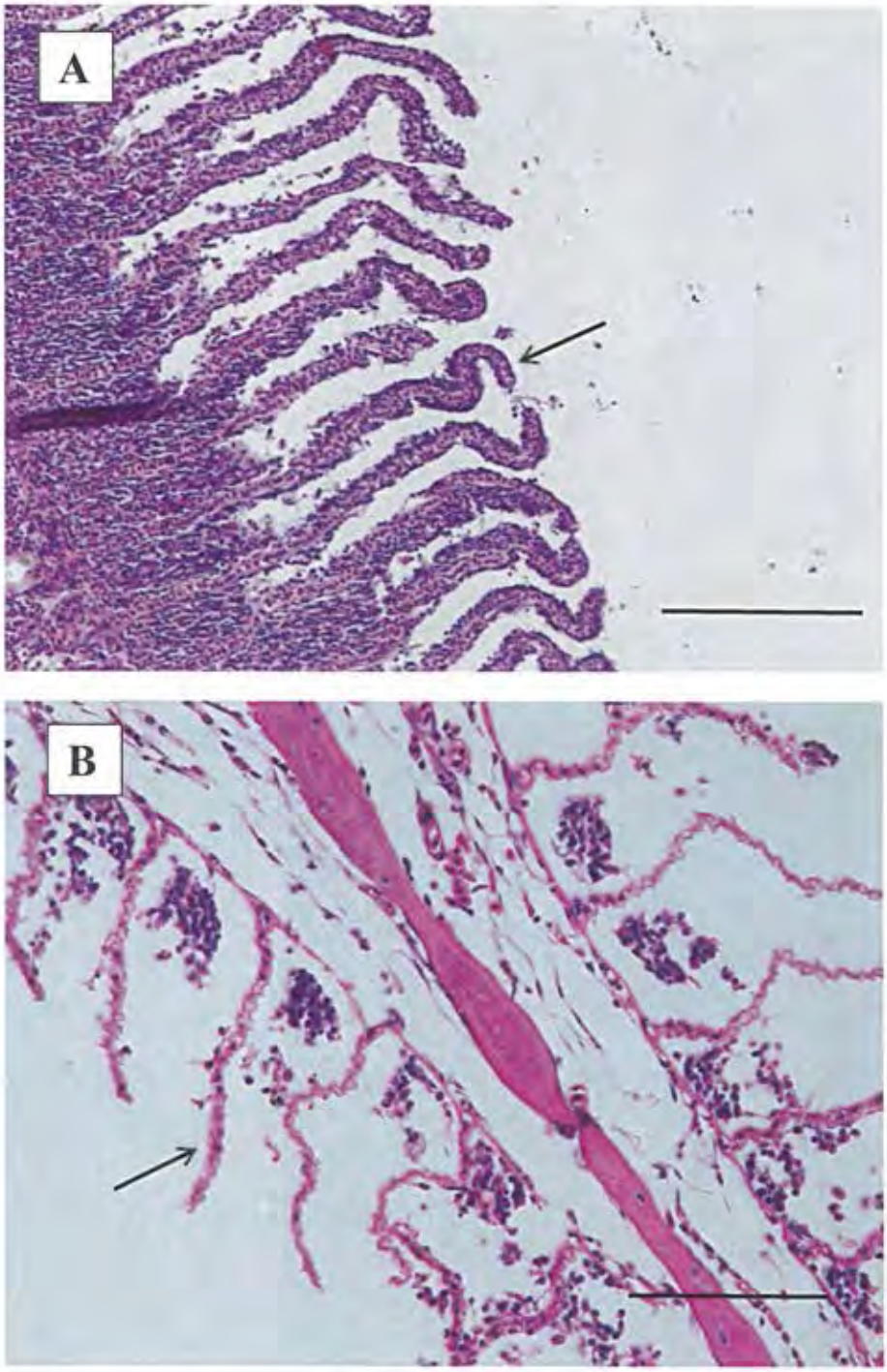


Figure 16. Example of histological section of gill showing *A*, curling at ends of secondary lamellae (arrow) and *B*, degenerated secondary lamellae stripped of epithelial cells (arrow). Scale bar represents 100 microns.

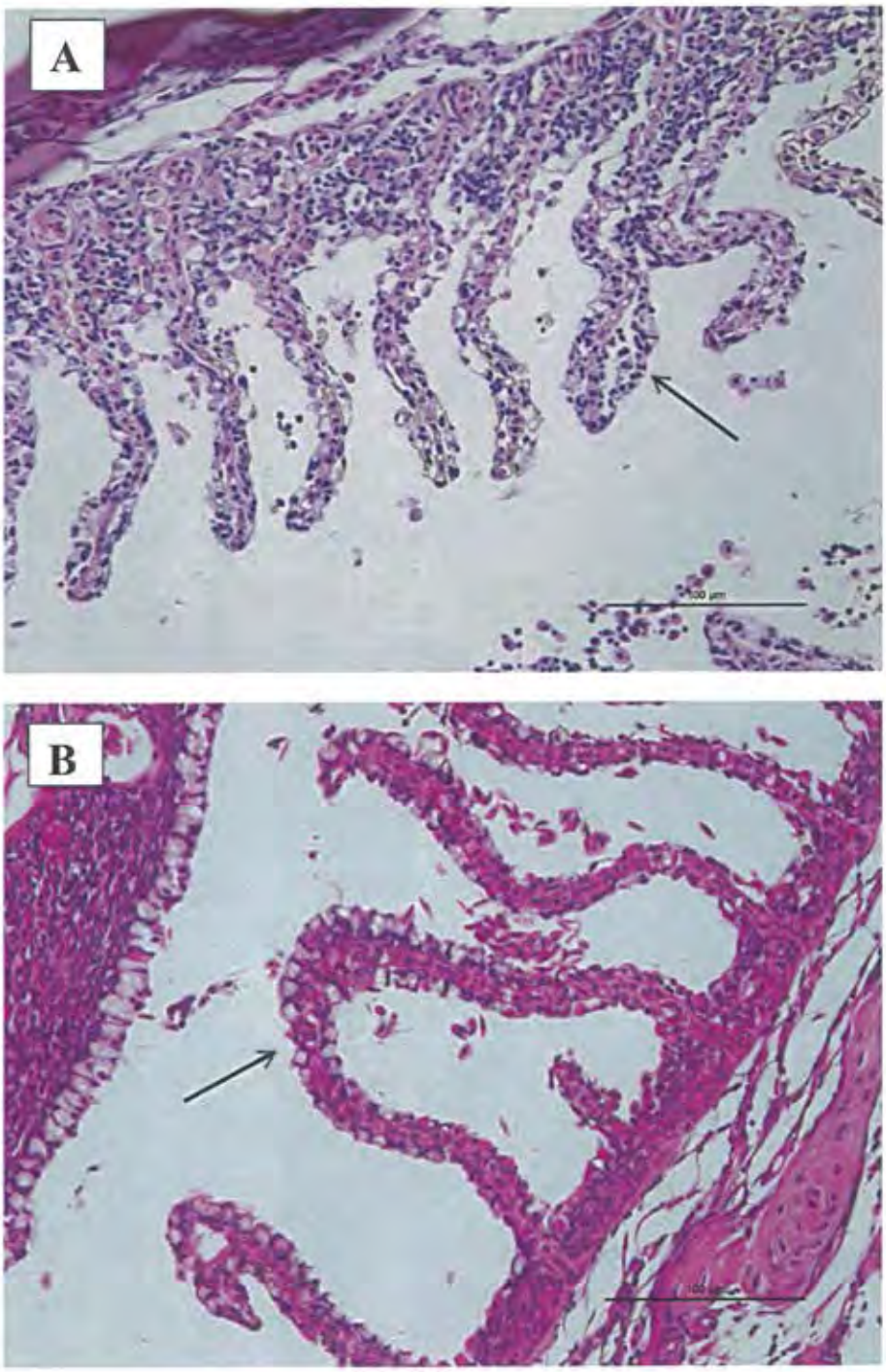


Figure 17. Example of epithelium on *A*, secondary lamellae lifting away from gill (arrow) and *B*, secondary lamellae fusing together (arrow). Scale bar represents 100 microns.

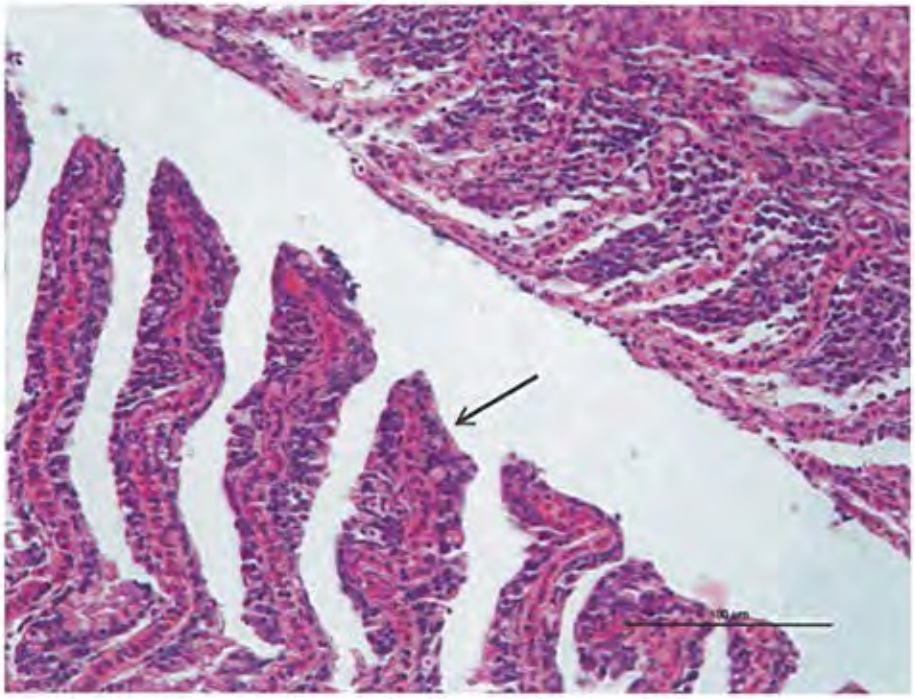


Figure 18. Example of epithelial hyperplasia in secondary lamellae (arrow). Scale bar represents 100 microns.

Table 10. Immunohistochemical staining for CYP1A in gills of smallmouth bass (SMB) and golden redhorse sucker (GRH) from Marshall Impoundment (MI; reference site), Historic Bridge (HB), Legacy Ranch (LR), and Shady Bend (SB). Areas of positive staining were counted on approximately five primary lamellae of five fish[1] for each species and site. Results are reported as mean number of stained areas (Mean), number of fish that did not show any staining (No stain), and the minimum and maximum (Range) of stained cells observed in the sample of fish from a given site.

	Species						
	SMB			GRH			
Site	Mean	No stain	Range	Mean	No stain	Range	Comment
MI	3	1	2–6	2	4	3–6	Stain light
HB	5	0	2–9	5	1	1–23	Large areas stained
LR	5	1	6–8	11	0	2–16	
SB	5	0	2–8	5	0	3–15	

[1]Seven GRH were evaluated for site MI.

Table 11. Estimated age (years) of smallmouth bass from four sites on the Kalamazoo River. (number = N; coefficient of variation = CV).

Site	Sex	N	Mean	Range	CV
Marshall Impoundment	F	10	4	3–7	3
	M	5	5	4–7	4
Historic Bridge	F	7	4	3–7	3
	M	7	6	4–9	3
Legacy Ranch	F	7	3	2–4	6
	M	8	5	3–7	3
Shady Bend	F	5	5	3–10	2
	M	5	6	48	4

Appendix 1. Field datasheets

See attached electronic files or CD

Appendix 2. Chain-of-custody forms

USGS
science for a changing world

U.S.Department of the Interior
U.S.GEOLOGICAL SURVEY
Columbia Environmental Research Center
4200 New Haven Road
Columbia, Missouri 65201

Chain-of-Custody Record **Attachment 1**

Study No:

Study Name: Enbridge Oil Spill near Marshall, MI Fish Health Assessment

Control No:

Samplers (Signature): Diane K. Nicks, John Hess & Employees of MI DNRE

page 1 of 3

Sample Identification	Date	Time	Type *	Remarks and Observations
1-30 tissues	8-19-10		F	Marshall Impoundment Samples, See inventory Attached.
31-60 tissues	8-19-10 8-20-10		F	Historic Bridge Park samples, see inventory Attached.
61-90 tissues	8-19-10 8-20-10		F	Legacy Ranch Samples, see inventory attached.
91-110 tissues	8-20-10		F	Shady Bend Samples, see inventory attached.

Relinquished by (Signature)	Date/Time	Received by (Signature)	Relinquished by (Signature)	Date/Time	Received by (Signature)
Diane K. Nicks	8-20-10 9:30 pm	8-24-10 9:30 AM Diane K. Nicks			
Relinquished by (Signature)	Date/Time	Received by (Signature)	Relinquished by (Signature)	Date/Time	Received by (Signature)
Relinquished by (Signature)	Date/Time	Received for Laboratory by (Signature)	Date/Time	Remarks	

* W=water, S=sediment, P=plant, F=fish, B=benthos, O=other, define in remarks

Page 2-of 3

Enbridge Oil Spill near Marshall, MI Fish Health Assessment Sample Inventory (x indicates sample present)

			Histological Samples (10% NBF)			Frozen (-80°C)					blood smear slides			
Site	Fish #	Species	gill (left)	spleen	head kidney	liver A	liver B	bile	plasma A	plasma B	A	B	C	Comments
Marshall Impoundment	1	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Marshall Impoundment	2	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	3	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	4	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	5	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	6	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	7	golden redhorse sucker	x	x	x	x	x	x	x		x	x	x	
Marshall Impoundment	8	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	9	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	10	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	11	golden redhorse sucker	x	x	x	x	x		x	x	x	x	x	
Marshall Impoundment	12	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	13	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	Liver A in Bile A vial & Bile in Liver A vial
Marshall Impoundment	14	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	15	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	16	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	17	smallmouth bass	x	x	x	x	x	x	x		x	x	x	
Marshall Impoundment	18	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	19	smallmouth bass	x	x	x	x	x	x	x		x	x	x	
Marshall Impoundment	20	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	21	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	22	smallmouth bass	x	x	x	x	x	x			x	x	x	sample may be labeled as head kidney
Marshall Impoundment	23	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	24	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	25	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	26	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	27	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	28	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Marshall Impoundment	29	smallmouth bass	x	x	x	x	x	x	x		x	x	x	small sample
Marshall Impoundment	30	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Historic Bridge Park	31	smallmouth bass	x	x	x	x	x	x	x		x	x	x	
Historic Bridge Park	32	smallmouth bass	x	x	x	x	x	x	x		x	x	x	small sample, Liver A in Bile A vial & Bile in Liver A vial
Historic Bridge Park	33	smallmouth bass	x	x	x	x	x	x	x		x	x	x	small sample
Historic Bridge Park	34	smallmouth bass	x	x	x	x	x		x		x	x	x	small sample w/ RBC's ?; Liver A in Bile vial
Historic Bridge Park	35	smallmouth bass	x	x	x	x	x	x	x		x	x	x	small sample w/ RBC's ?
Historic Bridge Park	36	smallmouth bass	x	x	x	x	x				x	x	x	
Historic Bridge Park	37	smallmouth bass	x	x	x	x	x	x	x		x	x	x	
Historic Bridge Park	38	smallmouth bass	x	x	x	x	x	x	x		x	x	x	
Historic Bridge Park	39	smallmouth bass	x	x	x	x	x	x			x	x	x	
Historic Bridge Park	40	smallmouth bass	x	x	x	x	x	x	x		x	x	x	small sample
Historic Bridge Park	41	smallmouth bass	x	x	x	x	x	x	x		x	x	x	small sample w/ RBC's ?
Historic Bridge Park	42	smallmouth bass	x	x	x	x	x	x	x		x	x	x	small sample
Historic Bridge Park	43	smallmouth bass	x	x	x	x	x	x	x		x	x	x	Liver A in Bile A vial & Bile in Liver A vial
Historic Bridge Park	44	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Historic Bridge Park	45	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Historic Bridge Park	46	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Historic Bridge Park	47	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Historic Bridge Park	48	golden redhorse sucker	x	x	x	x	x		x		x	x	x	
Historic Bridge Park	49	golden redhorse sucker	x	x	x	x	x	x	x		x	x	x	
Historic Bridge Park	50	golden redhorse sucker	x	x	x	x	x	x			x	x	x	Not noted on data sheet
Historic Bridge Park	51	golden redhorse sucker	x	x	x	x	x	x	x		x	x	x	not good sample?
Historic Bridge Park	52	golden redhorse sucker	x	x	x	x	x	x	x		x	x	x	Not noted on data sheet
Historic Bridge Park	53	golden redhorse sucker	x	x	x	x	x		x		x	x	x	
Historic Bridge Park	54	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Historic Bridge Park	55	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Historic Bridge Park	56	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Historic Bridge Park	57	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Historic Bridge Park	58	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Historic Bridge Park	59	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Historic Bridge Park	60	golden redhorse sucker	x	x	x	x	x		x	x	x	x	x	

Appendix 2. (continued)

page 3 of 3

Enbridge Oil Spill near Marshall, MI Fish Health Assessment Sample Inventory (x indicates sample present)

			Histological Samples (10% NBF)			Frozen (-80°C)					Blood smear slides			
Site	Fish #	Species	gill (left)	spleen	head kidney	liver A	liver B	bile	plasma A	plasma B	A	B	C	Comments
Legacy Ranch	61	smallmouth bass	x	x	x	x	x	x	x		x	x	x	
Legacy Ranch	62	smallmouth bass	x	x	x	x	x	x	x		x	x	x	
Legacy Ranch	63	smallmouth bass	x	x	x	x	x	x	x		x	x	x	small sample
Legacy Ranch	64	smallmouth bass	x	x	x	x	x	x	x		x	x	x	
Legacy Ranch	65	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Legacy Ranch	66	smallmouth bass	x	x	x	x	x	x	x		x	x	x	jelled
Legacy Ranch	67	smallmouth bass	x	x	x	x	x	x	x		x	x	x	sample had very little plasma all RBC's ?
Legacy Ranch	68	smallmouth bass	x	x	x	x	x	x	x		x	x	x	sample had very little plasma all RBC's ?
Legacy Ranch	69	smallmouth bass	x	x	x	x	x	x	x		x	x	x	sample had very little plasma all RBC's ? Bile sample collected from work surface
Legacy Ranch	70	smallmouth bass	x	x	x	x	x	x	x		x	x	x	small sample
Legacy Ranch	71	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	72	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	73	smallmouth bass	x	x	x	x	x	x	x		x	x	x	
Legacy Ranch	74	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	75	smallmouth bass	x	x	x	x	x	x	x		x	x	x	
Legacy Ranch	76	golden redhorse sucker	x	x	x	x	x	x	x		x	x	x	
Legacy Ranch	77	golden redhorse sucker	x	x	x	x	x		x	x	x	x	x	
Legacy Ranch	78	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	79	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	there is an extra #79 plasma vial??
Legacy Ranch	80	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	81	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	82	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	83	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	84	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	85	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	86	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	87	golden redhorse sucker	x	x	x	x	x		x	x	x	x	x	
Legacy Ranch	88	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	89	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Legacy Ranch	90	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	
Shady Bend	91	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	
Shady Bend	92	smallmouth bass	x	x	x	x	x	x	x		x	x	x	
Shady Bend	93	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	94	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	95	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	96	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	97	smallmouth bass	x	x	x	x	x	x	x		x	x	x	Not noted on data sheet
Shady Bend	98	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	99	smallmouth bass	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	100	smallmouth bass	x	x	x	x	x	x	x		x	x	x	Not noted on data sheet
Shady Bend	101	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	102	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	103	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	104	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	105	golden redhorse sucker	x	x	x	x	x	x	x		x	x	x	Not noted on data sheet
Shady Bend	106	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	107	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	108	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	109	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet
Shady Bend	110	golden redhorse sucker	x	x	x	x	x	x	x	x	x	x	x	Not noted on data sheet

Appendix G: Fish Status and Trends Report 2010

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION
APRIL 2011

SUMMARY REPORT

A FISH SURVEY OF SITES ON THE KALAMAZOO RIVER AND TALMADGE CREEK NEAR THE ENBRIDGE OIL SPILL IN MARSHALL CALHOUN AND KALAMAZOO COUNTIES, MICHIGAN SEPTEMBER 2010

DRAFT

INTRODUCTION

On July 26, 2010, a 30-inch diameter pipeline ruptured discharging heavy crude oil into a wetland and then into Talmadge Creek, a tributary to the Kalamazoo River. The amount of oil discharged is estimated at 819,000 to 1,000,000 gallons. The oil flowed down 2.2 miles of Talmadge Creek, a small coolwater stream, before entering the Kalamazoo River. The oil migrated approximately 35 miles downstream to Morrow Pond. The Kalamazoo River drains approximately 2,020 square miles of southwest Michigan and has a length of 175 miles from it headwaters to Lake Michigan. It is a medium to large sized warmwater river with a sporadically confined channel as it meanders between moraine and man-made features from Marshall to Battle Creek and meanders freely in broad valleys from Battle Creek to Morrow Pond (Wesley 2005).

During September 2010, staff of the Michigan Department of Natural Resources, Fisheries Division with assistance from Entrix, Inc. (a consultant of Enbridge) and Michigan Department of Environmental Quality, Water Resources Division conducted fish community and habitat surveys on the Kalamazoo River and Talmadge Creek. The objective of these surveys was to access the effects of the oil spill and associated cleanup activities on fish communities and habitat. Surface Water Assessment Section, Water Resources Division, Department of Environmental Quality also collected macroinvertebrate and aquatic habitat data using their Procedure 51 protocol (MDEQ 2011). A study plan has been developed and additional surveys will be conducted in the future to monitor the long-term effects of the oil spill and associated cleanup activities on the fish and macroinvertebrate communities and aquatic habitat (Wesley and Walterhouse 2010). Refer to Appendix 1 for more detailed site and catch data.

METHODS

Selected sites (Figure 1) were chosen with emphasis on sites with historic (i.e. baseline) survey data that were collected prior to the oil spill (Wesley and Walterhouse 2010). Fisheries Division has a long-term Status and Trends Site at 11 Mile Road on the Kalamazoo River. Surveys at this site follow standardized sampling procedures that allow for temporal comparisons as well as comparisons to similar streams across the region and

state (Wills et al. 2008). This Status and Trends protocol, described in Wills et al. 2008, was used at the other sites for consistency. Wadeable shocking equipment and methods were used on Talmadge Creek at the 17 Mile Road (reference) and 15½ Mile Road sites, and on the Kalamazoo River at the 17 Mile (reference), 15 Mile, and 11 Mile sites. Boomshocking (boat) equipment and methods were used at the Custer Road site on the Kalamazoo River. Historic surveys at these sites used similar shocking equipment except the 15 Mile Road and Custer Road sites were conducted using a fish toxicant known as rotenone (Towns 1984).

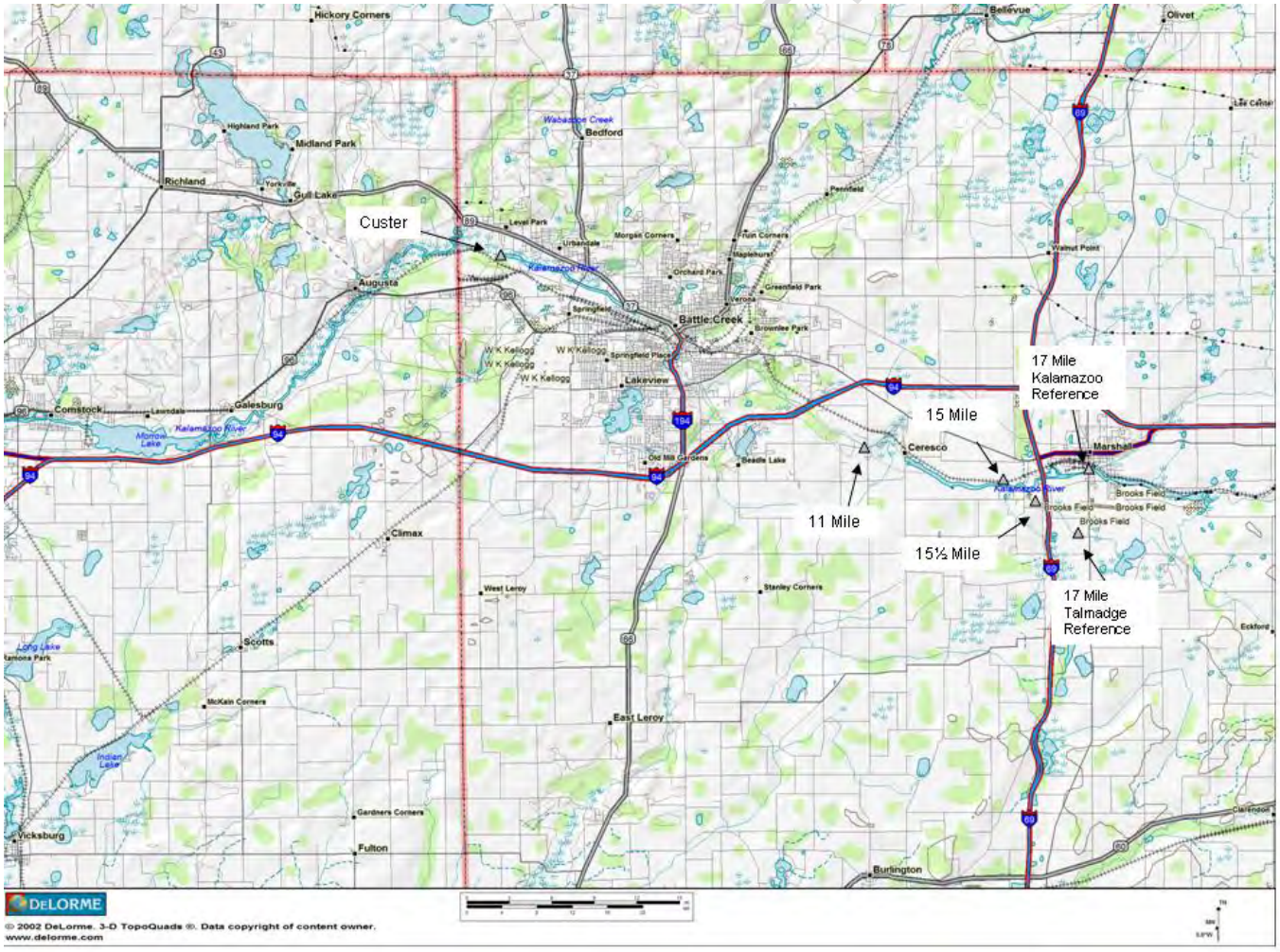


Figure 1. Fish sampling locations on the Kalamazoo River and Talmadge Creek, September 2010.

SUMMARY and OBSERVATIONS

The fish abundance and diversity in Talmadge Creek were significantly lower downstream of the oil spill compared to the reference site and the 2002 survey. Habitat conditions also changed with a wider and shallow stream with low abundance of cover at the downstream location, which was a result of clean up activities.

Fish diversity and catch at the 15 Mile site on the Kalamazoo River was consistent with the reference site at 17 Mile Road. Diversity and catch declined at the 11 Mile Road and Custer Road sites. Smallmouth bass catch was much lower at the 11 Mile Road site compared to 2008 and 2009. There also appeared to be a decline in the number of age 0 smallmouth bass at the 15 and 11 Mile Road sites.

Although the focus of this summary was not on habitat, there was a reduction in woody structure and over-hanging brush at the 15 and 11 Mile Road sites. Bank erosion was observed around the island at 11 Mile Road.

SAMPLING RESULTS

Talmadge Creek

Two surveys were conducted on Talmadge Creek on September 16th, 2010. The reference site was between the spill site and 17 Mile Road. The habitat at 17 Mile Road had more wetland than stream characteristics, so the crew continued downstream until a stream channel was more evident. There was no historic fisheries data for comparison at this reference site. Talmadge Creek was also sampled in the oil impacted reach at 15½ Mile Road (MP 1.25), which was historically surveyed on July 12th, 2000.

Talmadge Creek – 17 Mile Road (Reference)

The 17 Mile Road site had an average stream width of 9.2 ft with an average depth of 4.3 inches. The water clarity was slightly turbid, and it appeared to be at an average flow based on visual observations. The substrate was mostly sand (82%), silt (8%), gravel (5%), large cobble (3%), and small cobble (2%). The stream was characterized as all run habitat. Undercut banks, overhanging vegetation, aquatic vegetation, and woody structure were observed in moderate abundance. The measured stream discharge was 1.04 cfs.

A backpack shocker was used to sample 500 ft of stream. A total of 633 fish were surveyed representing six species. Most of the catch was made up of central mudminnow and mottled sculpin. These species of fish are typically associated with headwater and coolwater streams. For standardization purposes, the catch per effort (number of fish per acre of area surveyed) was calculated to assist with comparison among sites and sample years (Figures 2 and 3).

DRAFT

Talmadge Creek - 15½ Mile Road

The 15½ Mile Road site was located downstream of the road to avoid response activities and for easier access (a wood matt road ran down the floodplain). The stream had an average width of 14.9 ft with an average depth of 3.5 inches. Talmadge Creek gains groundwater between this section and 17 mile Road as the discharge increased to 2.4 cfs. The water clarity was turbid and flowing at an average level based on visual observations. The substrate consisted of gravel (63%), sand (20%), silt (7%), boulders (7%), large cobble (1.5%), and small cobble (1.5%). The stream was characterized as 54% run and 46% riffle habitat. The few boulders and logs were the only cover habitat available. The July 2000 survey was conducted upstream of 15½ Mile Road. This section of stream was narrower (5.5 ft), deeper (1.1 ft), and had more habitat in the form of overhanging brush, wild celery, and watercress. This section was adjacent to a mowed yard.

A backpack shocker was used to sample 500 ft of stream in both the 2000 and 2010 surveys. Only three species of fish were collected in 2010. The central mudminnow was most numerous with 53 fish collected followed by brook stickleback (6) and grass pickerel (1). These species are typically associated with small streams and wetlands. The survey in 2000 collected 11 species of fish with a total of 192 fish collected. The catch per effort was also higher in 2000 compared to 2010 for all species except brook stickleback, which were not observed in 2000 (Figure 3).

DRAFT

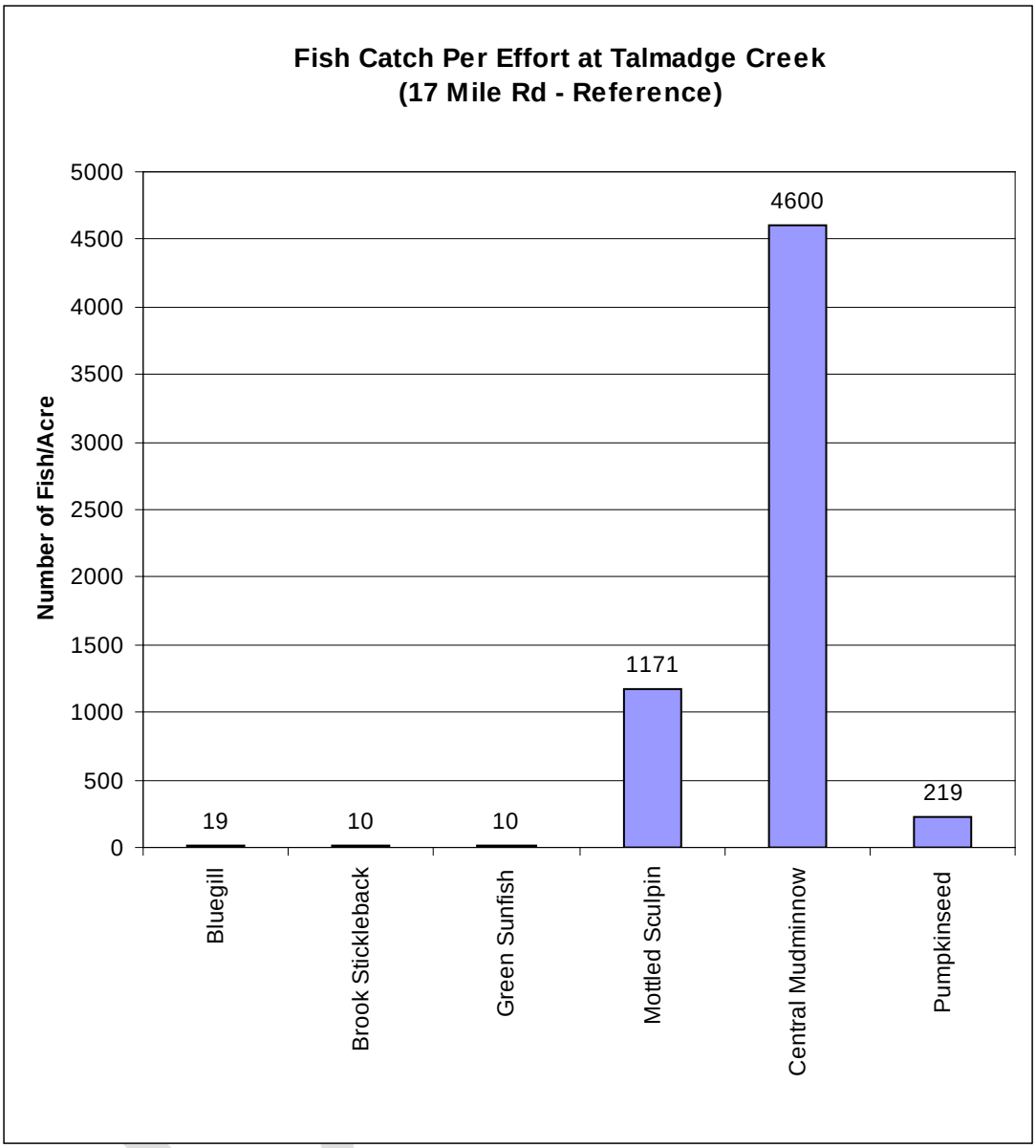


Figure 2. Fish catch per effort (number per Acre) in September 2010 for Talmadge Creek at 17 Mile Road (reference site).

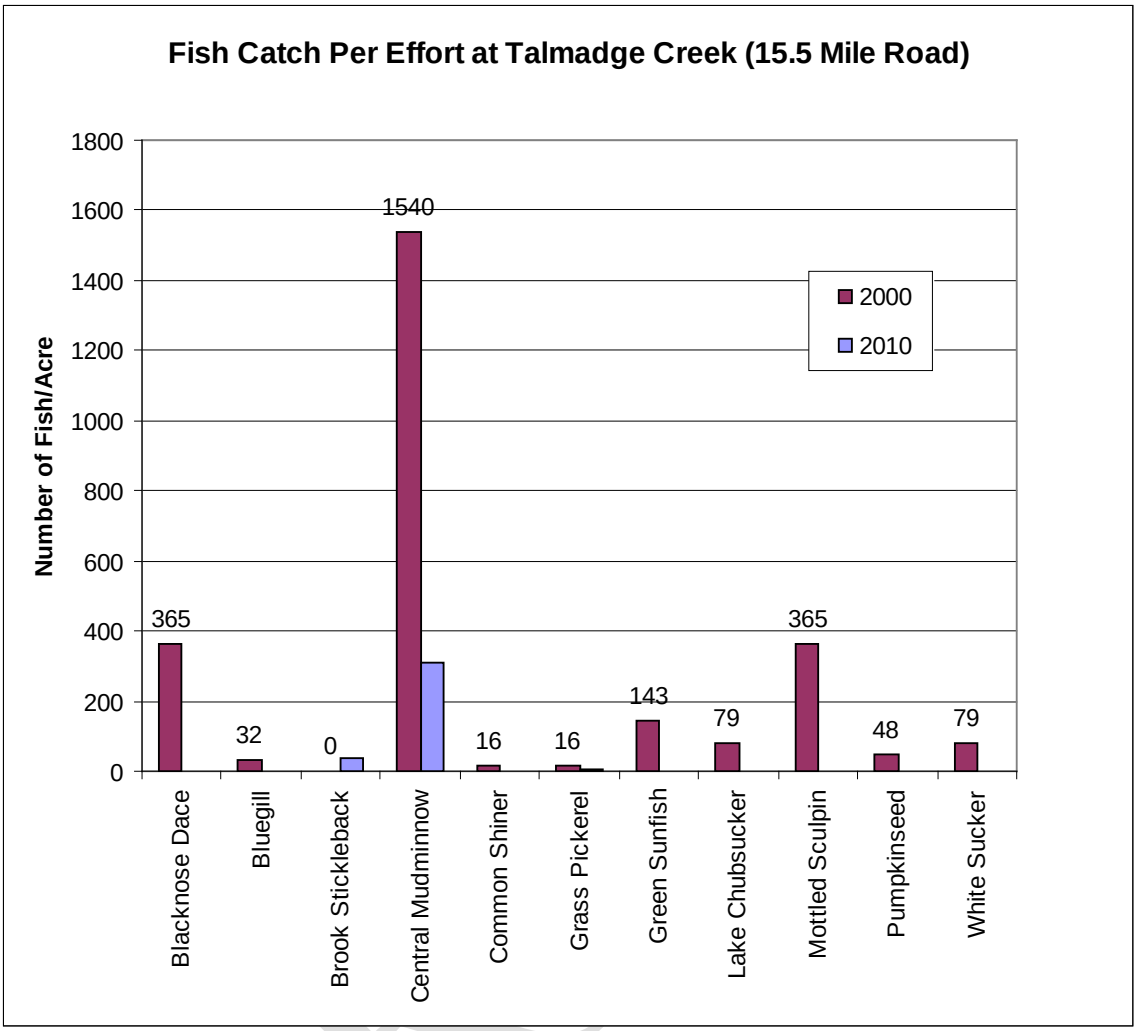


Figure 3. Fish catch per effort (number per Acre) in July 2000 and September 2010 for Talmadge Creek at 15½ Mile Road.

Kalamazoo River – 17 Mile Road (Reference)

The 17 Mile Road location was upstream of the oil spill and had historical fish data from 2002 making it a good reference site for the Kalamazoo River. This site was relatively deep making some areas difficult to wade and shock. As a result, the section length was reduced from 1,000 ft to 800 ft during the survey conducted on September 8, 2010.

The average width was 100 ft with an average depth of 21.6 inches. The water clarity was slightly turbid. Cover consisted of a moderate abundance of undercut banks, aquatic plants, and woody structure with limited deep pools, boulders, and overhanging vegetation. Habitat conditions appeared similar to 2002.

A stream shocker was used to sample the left and right banks. The catch was combined from both banks giving a total catch of 403 fish representing 25 species. Based on catch per effort, northern hog sucker, rock bass, and smallmouth bass were the most abundant species (Figure 4). The catch per effort and species composition were similar between 2010 and 2002 except pumpkinseed sunfish and common white sucker made up more of the catch in 2002. Smallmouth bass from age 0 to age 10 were collected with most (87%) of the catch being age 0. The average length of the smallmouth bass was 4.5 inches.

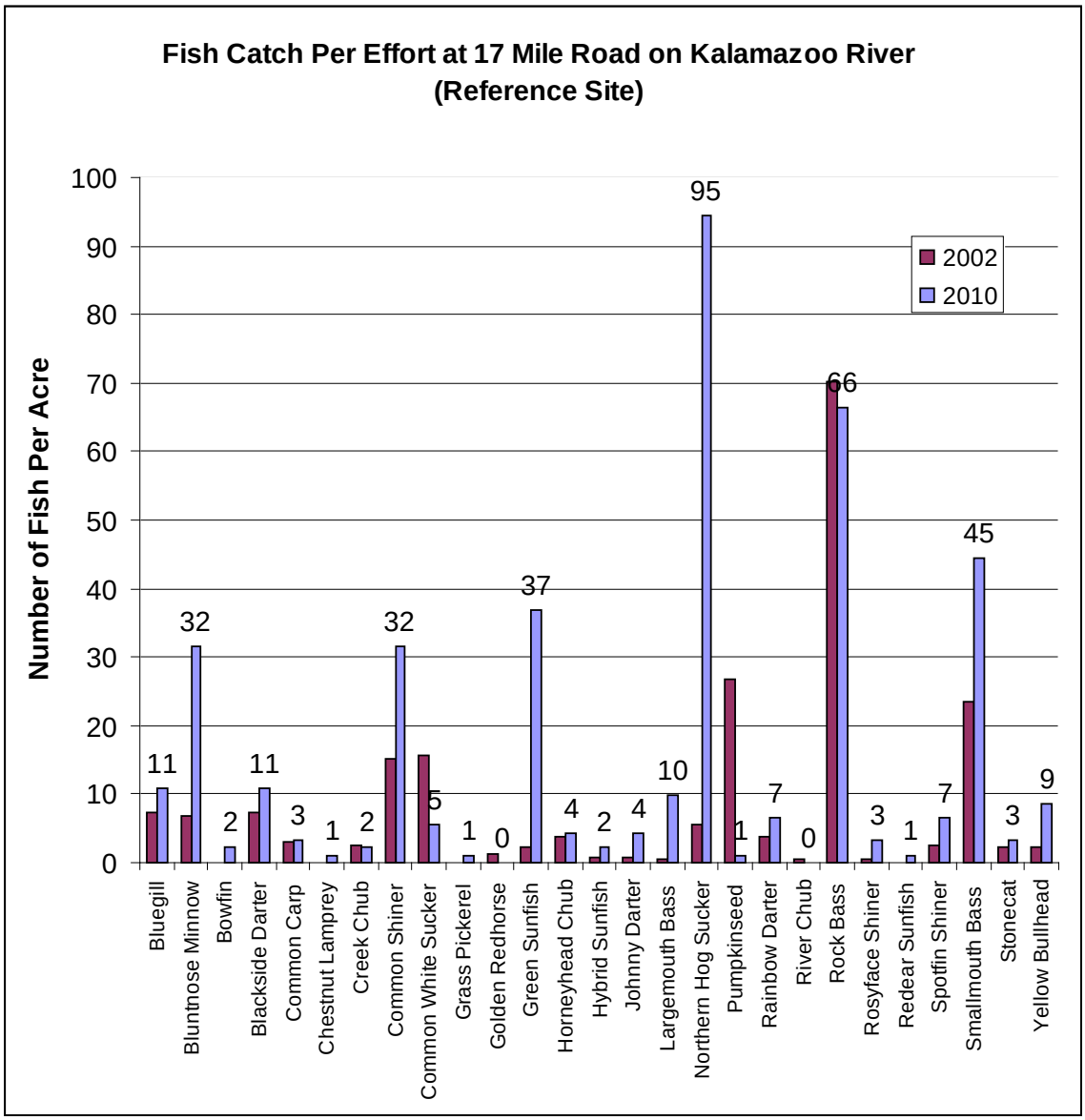


Figure 4. Fish catch per effort (number per Acre) in August 2002 and September 2010 for the Kalamazoo River at 17 Mile Road (reference site).

Kalamazoo River – 15 Mile Road

The 15 Mile Road site started 500 ft below the Squaw Creek mouth and ended 500 ft upstream for a total of 1,000 ft. This section is downstream from the 1982 rotenone survey (Towns 1984), which was conducted right at the 15 Miles Road bridge. The site was moved for a more wadeable section and to move away from a busy response access site.

The average width was 153 ft with an average depth of 18.2 inches. The water clarity was slightly turbid. The channel was characterized as 54% run and 46% riffle habitat. Cover consisted of a moderate abundance of boulders and aquatic plants with limited deep pools, overhanging vegetation, undercut banks, woody structure. The bottom substrate consisted of gravel (45%), small cobble (28%), sand (14%), large cobble (6%), silt (5%), and boulder (2%). Water levels appeared slightly above normal with an estimated discharge of 304 cfs. The section of river surveyed in 1982 was deeper and narrower than this section.

A stream shocker was used to sample the left and right banks. The combined total catch was 871 fish with 27 different species. Rainbow darter, green sunfish, rock bass, and creek chub were the most abundant (Figure 5). The presence and number of darters is a good indication of more riffle habitat compared to the deeper water surveyed upstream in 1982. The relatively high species diversity is an indication of transitional habitat as the Kalamazoo River enters the Ceresco Impoundment. Catch per effort comparisons are shown in Figure 5; however, different methods were used between 1982 (rotenone) and 2010 (stream shocking). Rotenone is a fish toxicant that samples the entire river section; whereas, the stream shocking effort only sampled the left and right banks. Smallmouth bass from age 0 to age 10 were collected with most (63%) of the catch being age 0. The average length of the smallmouth bass was 7.8 inches. The species diversity and catch were similar to the 17 Mile Road reference section, although there appeared to be more and younger smallmouth bass at the reference site compared to this section (based on age data in Appendix 1).

DRAFT

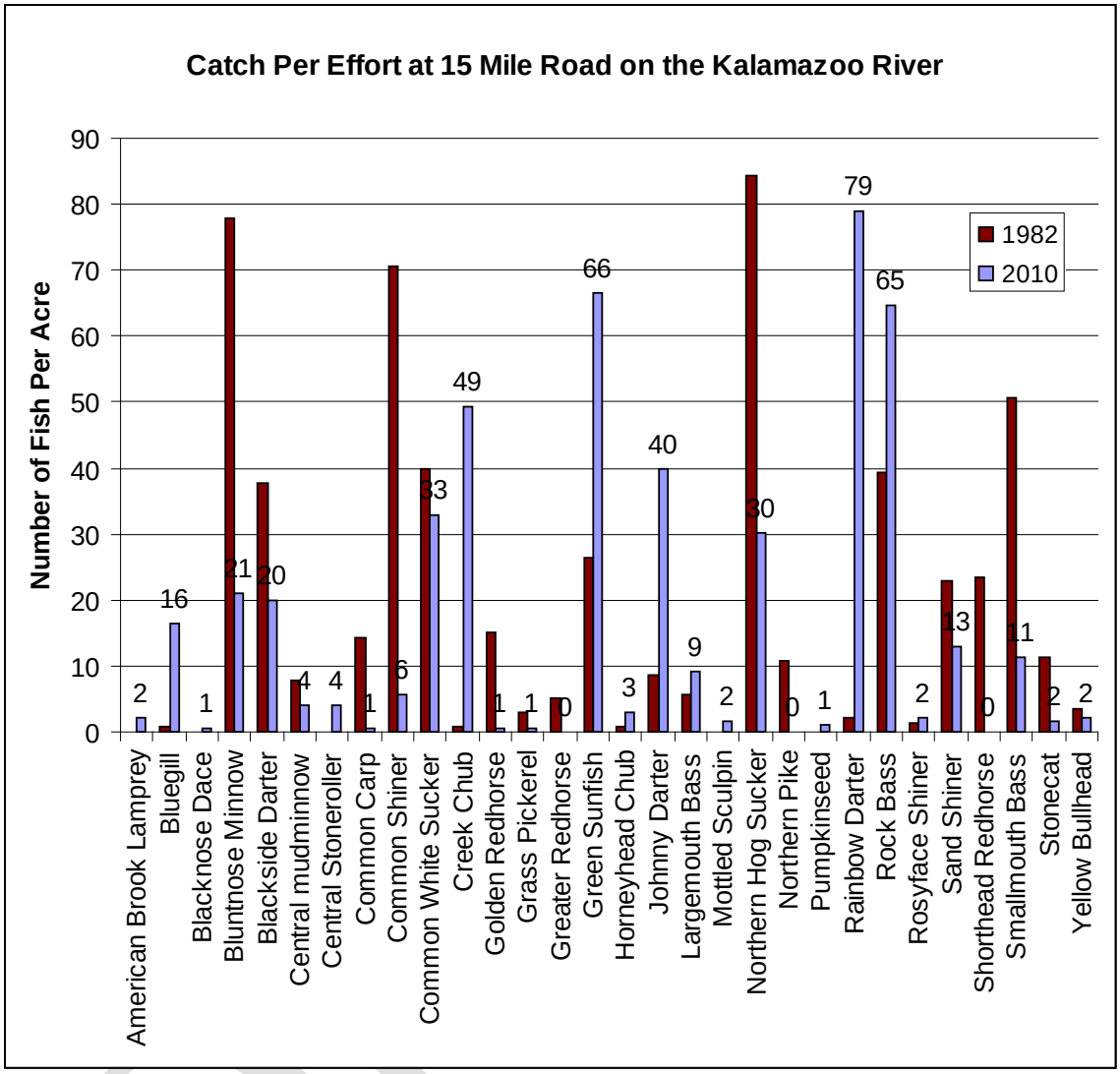


Figure 5. Fish catch per effort (number per Acre) in July 1982 and September 2010 for the Kalamazoo River at 15 Mile Road.

Kalamazoo River – 11 Mile Road

The 11 Mile Road site was a Status and Trends fixed site for smallmouth bass that has been surveyed annually since 2008. Only smallmouth bass were collected in 2008 while all species of fish were collected in 2009 and 2010. The site extends 1,000 ft downstream of 11 Mile Road and is permanently marked to ensure the same effort from year to year. The entire site was wadeable.

The water clarity was slightly turbid. The average width was 142 ft with an average depth of 15.8 inches, which has been consistent for the past three years. The channel habitat was primarily riffle (85%) and run (15%). The bottom type consisted of gravel (33%), small cobble (26%), large cobble (15%), boulder (12%), sand (7%), silt (3%), and island (2%). This is similar to past surveys with a small reduction in the size of the island. The

vegetation on the island had been removed, and there was evidence of bank erosion. Cover consisted of a moderate abundance of boulders and aquatic plants with limited deep pools, overhanging vegetation, undercut banks, and woody structure. Water levels appeared above normal with an estimated discharge of 321 cfs.

The combined total catch of the left and right bank streamshocker efforts was 327 fish representing 20 species. These results were lower than the 2009 survey that collected 594 fish representing 24 species. Rock bass dominated the catch (Figure 6). Compared to 2009 the catch of each species was down except for rock bass and green sunfish. The smallmouth bass catch per effort was 56% and 43% lower than 2008 and 2009, respectively. There appeared to be a lack of small sized bass from the 2009 and 2010 year classes. Smallmouth bass ages ranged from 0 to 8 with most (34%) of the catch at age 3. The average length of the smallmouth bass was 10.0 inches.

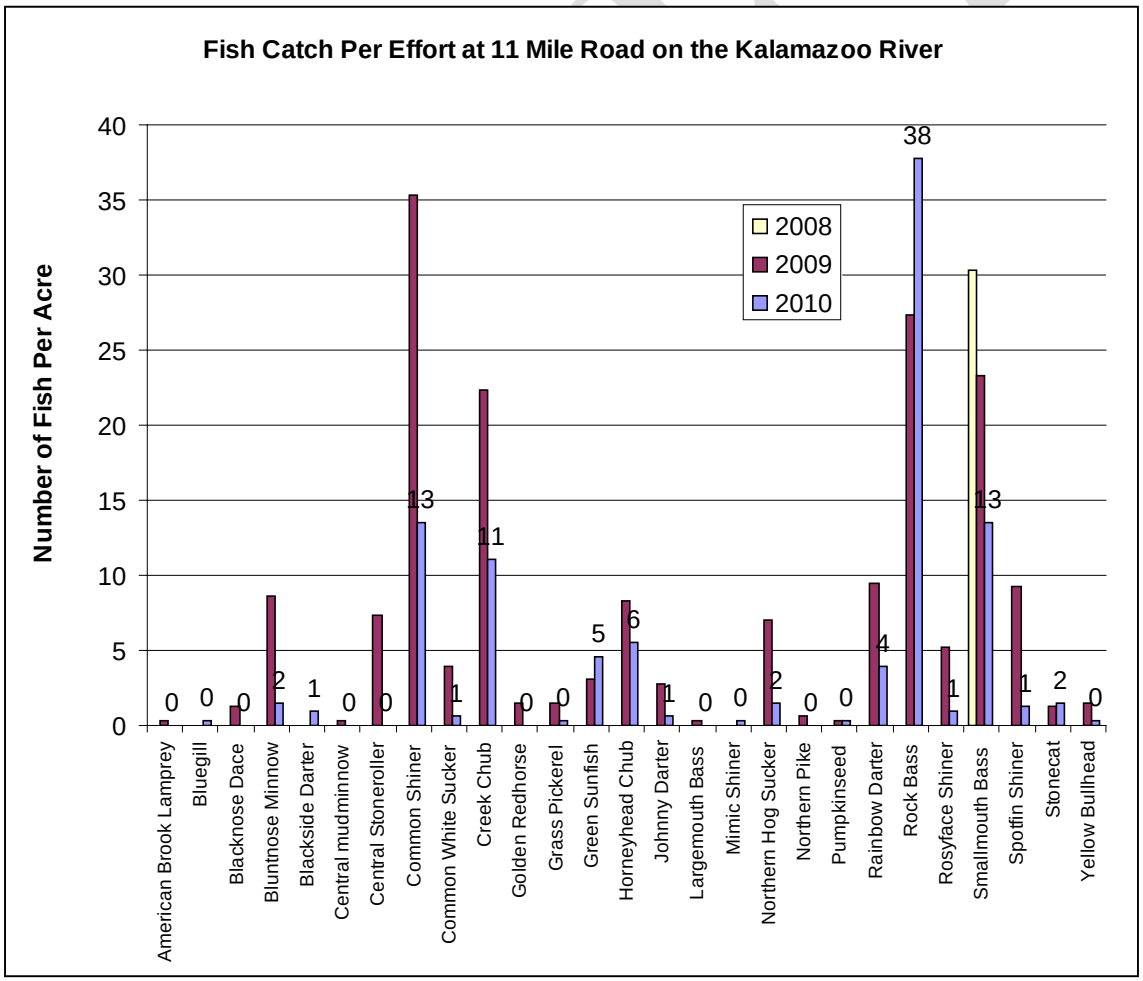


Figure 6. Fish catch per effort (number per Acre) in August 2008, September 2009, and September 2010 for the Kalamazoo River at 11 Mile Road.

Kalamazoo River – Custer Road

This site began approximately 1,320 ft downstream of Custer Road and continued downstream 4,224 ft (approximately MP 21.5 to 22.5). The 1982 rotenone survey sampled 540 ft of stream starting 2,640 ft downstream of Custer Road (Towns 1984). This section of river was not wadeable and required all sampling to be conducted from a boat.

The average width was 71 ft with an average depth of 36 inches. The water clarity was clear. Woody structure and undercut banks were common with limited overhanging vegetation and aquatic vegetation for cover habitat. Due to the depth of the site, other habitat parameters were not measured. Refer to MDEQ (2011) for more habitat details.

A boomshocker (boat) was used to sample the left descending bank in a downstream direction as part of a non-wadeable protocol (Wills et al. 2008). The total catch was 223 fish with 17 different species represented. Golden redhorse, northern hog sucker, rock bass, and smallmouth bass were most abundant (Figure 7). The presence of golden redhorse, walleye, and channel catfish indicate deeper river habitat characteristics. The 1982 survey collected 28 species. The lower species diversity in the 2010 survey was probably due to the difference in sampling procedures. Boomshocking gear sampled the top three to five feet of water, making it difficult to collect smaller species such as darters and minnows that inhabit gravel areas on the bottom of the river. Direct catch per effort comparisons should not be made between 1982 and 2010, since rotenone was used in 1982. Rotenone was much more efficient at sampling all water depths compared to the boomshocking gear. Better comparisons can be made with future boomshocking data at this site. Smallmouth bass from age 1 to age 10 were collected with most (33%) of the catch being age 1. No young of year smallmouth bass were collected. The average length of the smallmouth bass was 11.0 inches.

DRAFT

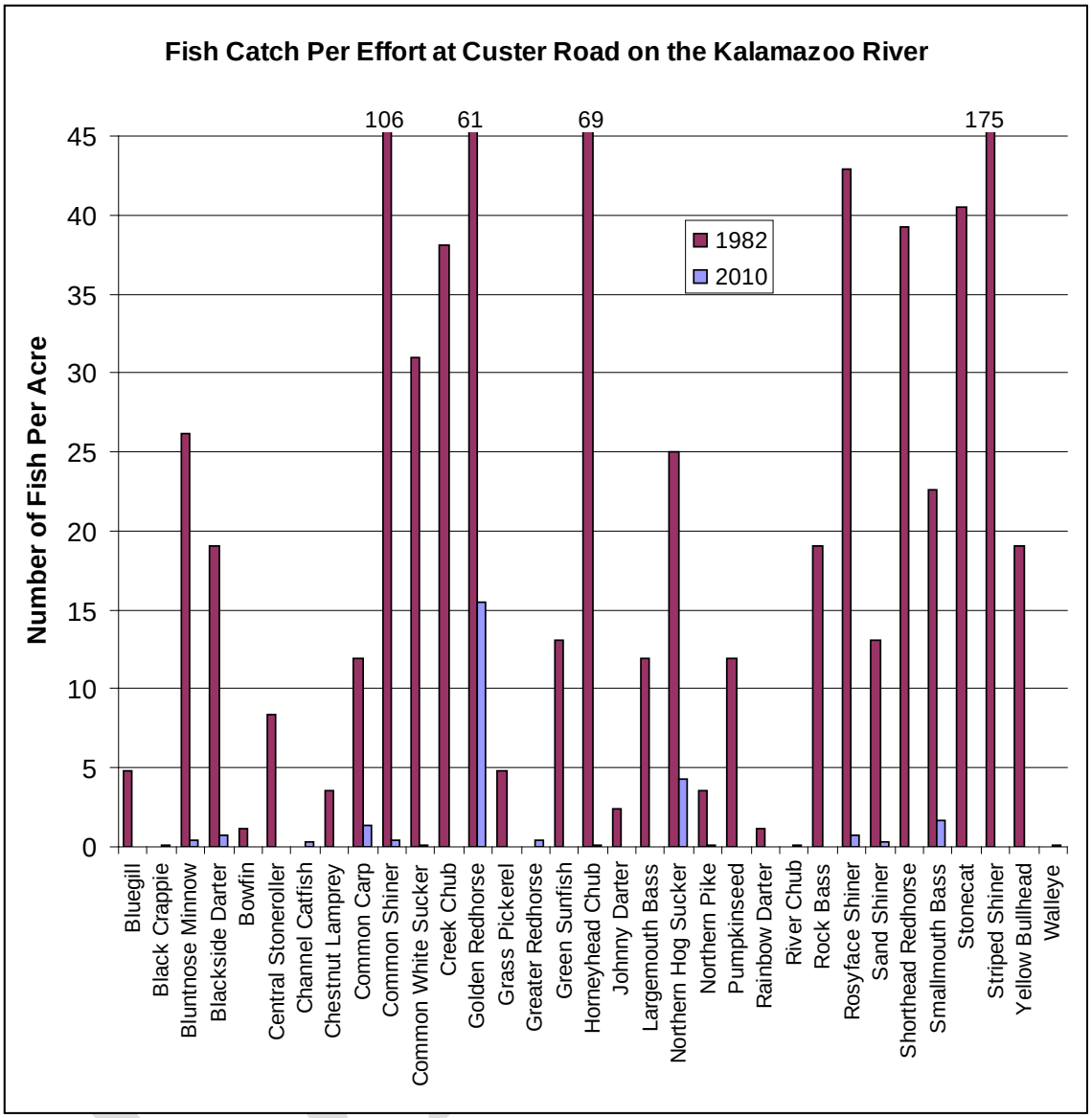


Figure 7. Fish catch per effort (number per Acre) in August 1982 and September 2010 for the Kalamazoo River at downstream of Custer Road.

Report by: Jay Wesley, SLMMU Manager
Fisheries Division
Department of Natural Resources

Fieldwork by: Matt Smith, Fisheries Technician
Olen Gannon, Fisheries Technician
Mike Wilson, Fisheries Technician
Ed Pearce, Fisheries Technician Supervisor
Brian Gunderman, Fisheries Biologist
Jay Wesley, SLMMU Manager
Fisheries Division
Department of Natural Resources

Fieldwork Assistance by:
Dusty Tazelaar, Entrix
Mike Nadeau, Entrix
John Matousek, Entrix
Mike Walterhouse, Water Resources Division, MDEQ
Bill Taft, Water Resources Division, MDEQ
Mike Alexander, Water Resources Division, MDEQ
David Rook, Fisheries Volunteer

REFERENCES

MDEQ. 2011. A biological survey of sites on the Kalamazoo River and Talmadge Creek near the Enbridge oil spill in Marshall, Calhoun County, Michigan, September 2010. Michigan Department of Environmental Quality, Water Resources Division, MI/DEQ/WRD-11/010.

Towns. G.L. 1984. A fisheries survey of the Kalamazoo River, July and August 1982. Michigan Department of Natural Resources, Fisheries Division, Technical Report 84-7.

Wesley, J.K. 2005. Kalamazoo River assessment. Michigan Department of Natural Resources, Fisheries Division, Special Report 35, Ann Arbor.

Wesley, J.K., and M. Walterhouse. 2010. Workplan for macroinvertebrate, fish, and habitat sampling on the Kalamazoo River and Talmadge Creek to evaluate aquatic ecosystem effects of oil exposure and cleanup procedures. Michigan Department of Natural Resources and Environment, Fisheries Division and Water Resources Division, September 2, 2010.

Wills, T.C., T.G. Zorn, A.J. Nuhfer, and D.M. Infante. 2008 Draft. Stream status and trends program sampling protocols. Chapter 26 *in* Manual of Fisheries Survey Methods. Michigan Department of Natural Resources, Fisheries Internal Document, Ann Arbor.

DRAFT

DRAFT

Appendix H1: Macroinvertebrate Report 2010

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER RESOURCES DIVISION
FEBRUARY 2011

STAFF REPORT

A BIOLOGICAL SURVEY OF SITES ON THE KALAMAZOO RIVER AND TALMADGE CREEK NEAR THE ENBRIDGE OIL SPILL IN MARSHALL CALHOUN COUNTY, MICHIGAN SEPTEMBER 2010

INTRODUCTION

On July 26, 2010, a 30-inch diameter pipeline ruptured discharging heavy crude oil into a culvert that leads to Talmadge Creek, a tributary to the Kalamazoo River, which drains into Lake Michigan. The amount of oil discharged is estimated at 819,000 to 1,000,000 gallons. The Kalamazoo River is bordered by wetland, forest, residential properties, farmland, and commercial properties for the approximate 35-mile stretch of impacted river in Calhoun County between Marshall and Morrow Lake.

During September 2010, staff of the Surface Water Assessment Section (SWAS), Water Resources Division, conducted qualitative macroinvertebrate community and stream habitat surveys on the Kalamazoo River and Talmadge Creek. The objective of these surveys was to monitor the short-term effects of the oil spill and associated cleanup activities on macroinvertebrate communities and aquatic habitat. SWAS staff also assisted Fisheries Division staff with fish collection efforts and quantitative stream habitat assessments. The Fisheries Division is preparing a separate report, which details the fish and quantitative stream habitat sampling efforts. Additional surveys will be conducted in the future to monitor the short- and long-term effects of the oil spill and associated cleanup activities on the fish and macroinvertebrate communities and aquatic habitat (Wesley and Walterhouse, 2010).

METHODS

Most of the sites that were selected for this survey were specifically chosen because of historic (i.e., baseline) surveys that were conducted prior to the oil spill. An additional site on Talmadge Creek was added just upstream of the oil spill because stream flow at the historic control site further upstream at 17 Mile Road was minimal and the stream habitat had characteristics more typical of a wetland. A survey was also conducted at a site on the Kalamazoo River downstream of Talmadge Creek, where historical survey data was lacking, but the upstream proximity of Talmadge Creek warranted the addition of the site to determine impacts.

The surveys described in this report were conducted according to the guidelines of the SWAS Procedure 51 (MDEQ, 1990). Procedure 51 surveys conducted prior to 2008 and those conducted in 2010 were performed with nearly the same methodology except the macroinvertebrate sample size was increased from 100 to 300 with the 2008 revision to Procedure 51. The macroinvertebrate communities were scored with metrics that rate water bodies from excellent (+5 to +9) to poor (-5 to -9). Macroinvertebrate ratings from +4 to -4 are considered acceptable. Negative ratings that are acceptable are indicative of water bodies that are strongly tending toward poor, while positive ratings that are acceptable indicate slight impairment (Creal et al., 1996). Stream habitat was qualitatively evaluated at each station using a scoring system, which ranged in value from 0 (poor) to 200 (excellent).

Sampling locations are shown in Figure 1.

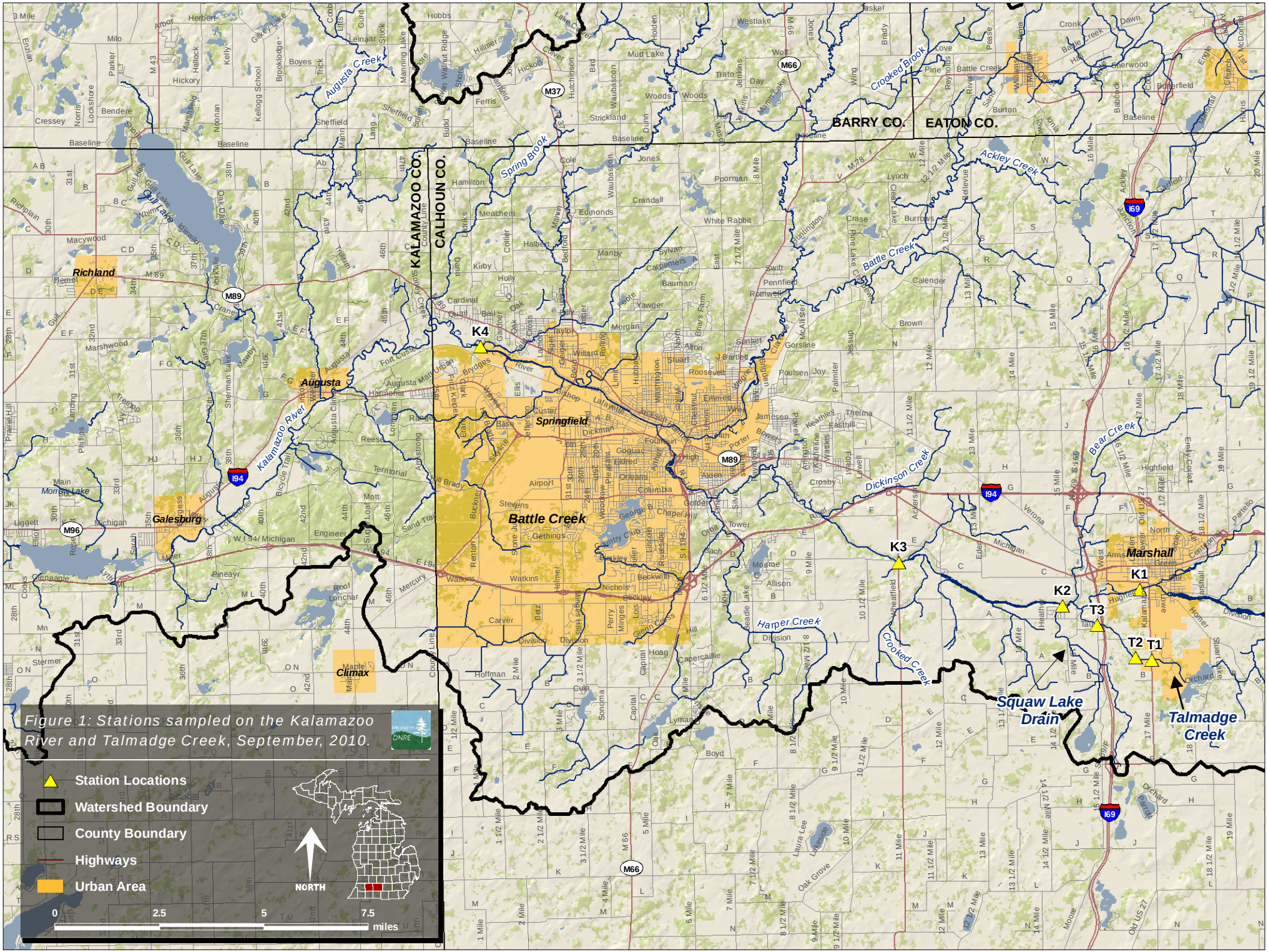


Figure 1: Stations sampled on the Kalamazoo River and Talmadge Creek, September, 2010.

Station Locations
Watershed Boundary
County Boundary
Highways
Urban Area

SUMMARY and OBSERVATIONS

Macroinvertebrate abundance and diversity were drastically reduced in Talmadge Creek and the Kalamazoo River downstream of the oil spill. Procedure 51 qualitative macroinvertebrate scores and ratings alone do not adequately measure the impact of the oil spill and associated cleanup activities.

Sampling efforts in depositional zones at all of the impacted sites on Talmadge Creek and the Kalamazoo River caused a disturbance that produced a surface oil sheen. The water and sediment at all of the impacted sites also had a notable petroleum odor.

The shallow riffle habitat at the impacted Kalamazoo River sites (stations K2 and K3) had obviously been heavily disturbed by the boat traffic associated with the cleanup operations. The cobble habitat in the riffles was abnormally clean and free of periphyton, loose (not embedded at all), and many of the boulders and cobbles were marked with material from boat hulls and propellers.

The waves associated with the abnormal boat traffic were creating turbidity and causing bank erosion. The wave action was also likely dislodging macroinvertebrates, especially in shallow habitats.

SAMPLING RESULTS

Talmadge Creek - Macroinvertebrates

The macroinvertebrate community sampling results for stations on Talmadge Creek are presented in Table 1a and the macroinvertebrate community metrics, scores, and ratings are presented in Table 1b. The stations are arranged in an upstream to downstream sequence. Two stations were surveyed as controls upstream of the oil spill. The control station at 17 Mile Road (station T1) was surveyed in 1999 allowing for comparisons with the current survey (Cooper, 2000). The control station downstream of 17 Mile Road (station T2) had never been surveyed but the stream habitat and greater flow volume were more similar to conditions downstream on the oil impacted segment of Talmadge Creek. Talmadge Creek was sampled in the oil impacted reach at 15½ Mile Road (station T3) where a survey was also conducted in 1999 (Cooper, 2000). Station T3 is one mile downstream (Mile Post 1.0) of where oil from the pipeline failure entered Talmadge Creek.

The macroinvertebrate community sampling results documented that of the 3 sites surveyed on Talmadge Creek, station T3 received the lowest score, supported the fewest taxa, and was dominated by Chironomidae (midge) larvae. The upstream site (station T2) that was comparable in terms of stream habitat and flow received an overall score of +1 compared to the score of -4 at station T3. The number of taxa decreased from 27 at station T2 to only 7 at station T3. Specific taxa that were present at both stations T1 and T2 that were absent at station T3 included Hirudinea, Amphipoda, Hydracarina, Caenidae, Limnephilidae, Physidae, Planorbidae, and Sphaeriidae.

The results of the current macroinvertebrate survey are presented along with the historic survey results from 1999 (Cooper, 2000) at stations T1 and T3 in Tables 2a and 2b. The upstream control site at station T1 consisted of taxa predominately associated with wetland habitat during both surveys. Some of the differences in macroinvertebrate community overall scores, number of taxa, and specific community attributes can likely be attributed to seasonal changes in abundance. The 1999 survey was conducted in July while the 2010 survey was conducted in September. At station T3 the overall macroinvertebrate score did not change significantly from 1999 to 2010; however, the overall macroinvertebrate community changed from a rather

balanced community where 19 total taxa were identified, to a community dominated by one taxa with only 7 total taxa present.

Kalamazoo River - Macroinvertebrates

The macroinvertebrate community sampling results for stations on the Kalamazoo River are presented in Table 3a and the macroinvertebrate community metrics, scores, and ratings are presented in Table 3b. The stations are arranged in an upstream to downstream sequence. The control station on the Kalamazoo River was upstream of the oil spill in Marshall at Kalamazoo Street (station K1). Three sites on the Kalamazoo River were surveyed in the reach that was impacted by the oil spill and the associated cleanup activities. Station K2 was located on the Kalamazoo River in the vicinity of the Squaw Lake Drain confluence at about Mile Post 2.75. Station K3 was downstream of the Ceresco Dam at 11 Mile Road approximately at Mile Post 7.25. Station K4 on the Kalamazoo River was located downstream of the city of Battle Creek at Custer Drive at about Mile Post 21.25.

The upstream control site on the Kalamazoo River (station K1) had an overall macroinvertebrate community score of +5 and a rating of excellent. The abundance of Simuliidae (black fly) larvae at the site impacted several metrics and lowered the overall score. The macroinvertebrate community at station K2 scored +6 and was rated as excellent. The site still harbored a diversity of taxa, many of which are considered intolerant of pollution. Downstream at station K3, the macroinvertebrate community scored +3 and was rated as acceptable. The site still supported a diversity of taxa, many of which are intolerant of pollution. The macroinvertebrate community further downstream at station K4 scored +2 and was also rated as acceptable. The 20 taxa collected at the site were reduced compared to the upstream sites where greater than 30 taxa were collected. The greater taxa diversity upstream at stations K1, K2, and K3, compared to downstream at station K4, is likely related to the greater diversity of in-stream substrates and cover at the upstream sites.

The results of the 2010 macroinvertebrate survey on the Kalamazoo River at Kalamazoo Street (station K1) are presented along with historic survey results from 1999 (Cooper, 2000) and 2004 (Walterhouse, 2005) in Tables 4a and 4 b. The macroinvertebrate community at K1 scored +4 to +6 during the current and previous sampling events and was rated as acceptable or excellent. The 34 taxa collected in September 2010 compares fairly well with 40 taxa collected in August 2004 and the 20 taxa collected in September 1999.

The results of the macroinvertebrate survey on the Kalamazoo River at 11 Mile Road (station K3) are presented along with historic sampling results from 2004 (Walterhouse, 2005) and 2008 (LeSage, 2009) in Tables 5a and 5b. In August 2004, 44 taxa were collected at the site and the macroinvertebrate community scored +6 and was rated as excellent. In late August 2008, the site was surveyed as part of a quality assurance evaluation of Procedure 51 (method and crew variance) by 2 crews who each sampled the site twice on one day (Lesage, 2009). The number of taxa collected during the four sampling efforts ranged from 44 to 56 and the macroinvertebrate community scores ranged from +2 to +4 with ratings of acceptable. The sampling effort in September 2010 produced only 31 taxa, but still resulted in a macroinvertebrate community score of + 3 and an acceptable rating. Many of the taxa, particularly filter feeding organisms, which were present in 2004 and 2008, were not collected in 2010.

The results of the macroinvertebrate survey on the Kalamazoo River at Custer Drive (station K4) are presented along with historic sampling results from 1994 (Kosek, 1994), 2004 (Walterhouse, 2005) and 2009 (Walterhouse, 2011) in Tables 6a and 6b. Ironically, this site was surveyed on September 15, 2009, and again exactly one year later. In 2009, 33 taxa were collected and the macroinvertebrate community scored +6 and was rated as excellent. In 2010,

20 taxa were collected and the macroinvertebrate community scored +2 and was rated as acceptable. Previous surveys in 1994 and 2004 were conducted in part because of the upstream proximity to the Battle Creek Wastewater Treatment Plant (NPDES #MI0022276) discharge. The previous surveys documented macroinvertebrate scores of +4 and +2 with acceptable ratings in 1994 and 2004, respectively.

Talmadge Creek – Stream Habitat

Qualitative stream habitat assessment results for sites on Talmadge Creek are presented in Table 7. The habitat at station T1 was rated as good primarily because of the wide natural wetland riparian corridor adjacent to the stream channel. The substrate was soft muck and flow was limited creating habitat that would be better classified as wetland habitat. Downstream at station T2 stream habitat was rated as excellent. Flow was slightly greater than at station T1. Riffle habitat was lacking and sand was the predominant substrate but some gravel and cobble were present along with an abundance of in-stream cover. The riparian corridor was a wide undisturbed scrub/shrub wetland.

The in-stream habitat, stream banks, and adjacent riparian corridor at station T3 were highly disturbed due to the cleanup activities and were rated as marginal. Riffle habitat was present but in-stream cover was extremely limited. The substrate was primarily sand with lesser amounts of gravel and limited cobble. A different habitat assessment technique was used in 1999; however, the average stream width was 18 feet this year compared to the width of 6 feet that was documented during the survey in 1999 (Cooper, 2000).

Kalamazoo River – Stream Habitat

The qualitative stream habitat evaluations for sites on the Kalamazoo River are presented in Table 8. Riffle habitat was lacking at the upstream control site (station K1) and glide/pool metrics were used to produce an overall stream habitat rating of good. In-stream habitat was abundant and included moderate amounts of large woody debris, aquatic vegetation, and root wads. The stream substrate was diverse with a nearly equal mixture of cobble, gravel, sand, and silt along with scattered boulders. The only significant detraction from the overall habitat score was the limited width of the riparian zone.

The riffle/run habitat on the Kalamazoo River at station K2 was rated as excellent. The dominant substrate was cobble with lesser amounts of gravel, sand, silt, and boulders. Additional forms of in-stream habitat such as undercut banks, large woody debris, aquatic vegetation, overhanging vegetation, and root wads had been reduced by activities associated with the cleanup activities.

The overall stream habitat at station K3 on the Kalamazoo River was rated as excellent using riffle/run metrics. Cobble and gravel were the dominant substrates along with scattered boulders and lesser amounts of sand and silt along the stream margins. Others forms of in-stream cover that were still moderately abundant included large woody debris, aquatic vegetation, and root wads. Cleanup operations had nearly eliminated all overhanging vegetation.

The Kalamazoo River at station K4 is much larger with an average width estimated at 360 feet and an estimated average depth of 2.5 feet. The overall stream habitat was rated as good using glide/pool metrics. The wide wooded floodplain at this site inflates the overall stream habitat score. In-stream habitat that is suitable for macroinvertebrate colonization was limited. Sand was the predominant form of substrate with scattered patches of gravel and occasional cobbles and boulders. Silt was the second most common form of substrate, but it was primarily

limited to the stream margins. Other in-stream cover present in sparse quantities were aquatic vegetation, large woody debris, root wads, and undercut banks.

Macroinvertebrate Abundance

Procedure 51 is a qualitative collection method that involves sampling all available in-stream habitats to produce a composite macroinvertebrate sample that is typically subsampled until 300 organisms have been identified and counted. After 300 organisms have been counted, the remainder of the composite sample is examined for large and/or rare organisms that were not identified in the initial subsamples. These organisms are added as one individual to the total taxa list. Typically, only a small volume of the composite sample is needed to yield the 300 organisms required by Procedure 51. This is especially true in streams such as the Kalamazoo River that have a diversity of in-stream habitat types, especially in riffle habitats that were present at stations K2 and K3. The majority of the sample is typically examined for large and/or rare taxa. Counting the entire composite sample is seldom necessary, except in streams that are either habitat-limited or have serious violations of Michigan's Water Quality Standards. Macroinvertebrate abundance in the composite samples at the upstream control sites on Talmadge Creek (stations T1 and T2) and the Kalamazoo River (station K1) was normal. The abundance of macroinvertebrates in the composite samples collected at all of the impacted sites on Talmadge Creek (station T3) and Kalamazoo River (stations K2, K3, and K4) was so low that the entire composite sample was counted at all of the sites and the goal of enumerating 300 organisms was not achieved at the site on Talmadge Creek and station K4 on the Kalamazoo River.

The sampling effort at the impacted sites on Talmadge Creek and the Kalamazoo River was more intensive than normal. Each macroinvertebrate sample from the different habitat types was inspected before it was added to the composite sample in an effort to identify habitat that was not impacted. It was apparent during the sampling effort that the abundance of macroinvertebrates associated with all of the different habitat types was extremely low and extra effort was expended sampling all forms of habitat at all depths and flow velocities in order to obtain a sample of 300 organisms.

Report by: Mike Walterhouse, Aquatic Biologist
Surface Water Assessment Section
Water Resources Division

Fieldwork by: Mike Alexander, Aquatic Biologist
Bill Taft, Aquatic Biologist
Mike Walterhouse, Aquatic Biologist
Surface Water Assessment Section
Water Resources Division

Fieldwork Assistance by:
John Matousek, Entrix
Mike Nadeau, Entrix
Dusty Tazelaar, Entrix

REFERENCES

Creal, W., S. Hanshue, S. Kosek, M. Oemke, and M. Walterhouse. 1996. Update of GLEAS Procedure 51 Metric Scoring and Interpretation. MDEQ Staff Report #MI/DEQ/SWQ-96/068 (revised 5/98).

Cooper, J. 2000. A Biological Survey of the Kalamazoo River and Selected Tributaries, June-September, 1999. MDEQ Staff Report #MI/DEQ/SWQ-00/090.

Kosek, S. 1994. A Biological Survey of the Kalamazoo River Upper Watershed, Hillsdale, Jackson, and Calhoun Counties, July-September 1994. MDEQ Staff Report #MI/DNR/SWQ-94/077.

Lesage, S. 2009. A Quality Assurance Evaluation of Qualitative Biological and Habitat Survey Protocols for Wadeable Streams and Rivers 2008. MDEQ Staff Report #MI/DEQ/WB-09/029.

MDEQ. 1990. SWAS Procedure 51 - Qualitative Biological and Habitat Survey Protocols for Wadeable Streams and Rivers, April 24, 1990. Revised June 1991, August 1996, January 1997, May 2002, and December 2008.

Walterhouse, M. 2005. A Biological Survey of Sites in the Upper Kalamazoo River Watershed Calhoun and Jackson Counties, Michigan, August 2004. MDEQ Staff Report #MI/DEQ/WB-05/066.

Walterhouse, M. 2011. A Biological Survey of Sites in the Kalamazoo River Watershed, Allegan, Barry, Calhoun, Eaton, Hillsdale, Jackson, Kalamazoo, and Van Buren Counties, Michigan. August and September 2009. MDEQ Staff Report #MI/DEQ/WRD-11/004.

Wesley, J.K. and M. Walterhouse, 2010. Workplan For Macroinvertebrate, Fish, And Habitat Sampling On The Kalamazoo River And Talmadge Creek To Evaluate Aquatic Ecosystem Effects Of Oil Exposure And Cleanup Procedures. Michigan Department of Natural Resources, Fisheries Division and Water Resources Division, September 2, 2010.

Table 1A. Qualitative macroinvertebrate sampling results for sites on Talmadge Creek in the vicinity of the Enbridge oil spill, Calhoun County, September, 2010

TAXA	Talmadge Creek 17 Mile Road 9/16/2010 STATION T1	Talmadge Creek downstream 17 Mile Road 9/16/2010 STATION T2	Talmadge Creek 15 1/2 Mile Road 9/16/2010 STATION T3
ANNELIDA (segmented worms)			
Hirudinea (leeches)	31	3	
Oligochaeta (worms)	8		8
ARTHROPODA			
Crustacea			
Amphipoda (scuds)	34	107	
Decapoda (crayfish)		2	
Arachnoidea			
Hydracarina	1	1	
Insecta			
Ephemeroptera (mayflies)			
Baetidae		12	21
Caenidae	37	14	
Odonata			
Anisoptera (dragonflies)			
Libellulidae	7		
Zygoptera (damselflies)			
Calopterygidae	1	27	1
Coenagrionidae		1	
Hemiptera (true bugs)			
Belostomatidae	1	1	1
Corixidae		1	
Gerridae		1	
Notonectidae		1	
Megaloptera			
Sialidae (alder flies)		3	
Trichoptera (caddisflies)			
Hydropsychidae		6	
Leptoceridae		1	
Limnephilidae	1	1	
Uenoidae		1	
Coleoptera (beetles)			
Dytiscidae (total)		1	
Haliplidae (adults)		8	
Hydrophilidae (total)		1	
Diptera (flies)			
Chironomidae	79	38	150
Culicidae		1	
Simuliidae		60	15
MOLLUSCA			
Gastropoda (snails)			
Ancylidae (limpets)	1	28	1
Physidae	4	1	
Planorbidae	5	6	
Pelecypoda (bivalves)			
Sphaeriidae (clams)	81	22	
TOTAL INDIVIDUALS	291	349	197

Table 1B. Macroinvertebrate metric evaluation of sites on Talmadge Creek in the vicinity of the Enbridge oil spill, Calhoun County, September, 2010.

METRIC	Talmadge Creek 17 Mile Road 9/16/2010 STATION T1 Value	Score	Talmadge Creek downstream 17 Mile Road 9/16/2010 STATION T2 Value	Score	Talmadge Creek 15 1/2 Mile Road 9/16/2010 STATION T3 Value	Score
TOTAL NUMBER OF TAXA	14	1	27	1	7	-1
NUMBER OF MAYFLY TAXA	1	0	2	1	1	-1
NUMBER OF CADDISFLY TAXA	1	0	4	1	0	-1
NUMBER OF STONEFLY TAXA	0	-1	0	-1	0	-1
PERCENT MAYFLY COMP.	12.71	0	7.45	0	10.66	0
PERCENT CADDISFLY COMP.	0.34	-1	2.58	-1	0.00	-1
PERCENT DOMINANT TAXON	27.84	0	30.66	0	76.14	-1
PERCENT ISOPOD, SNAIL, LEECH	14.09	-1	10.89	-1	0.51	1
PERCENT SURF. AIR BREATHERS	0.34	1	4.30	1	0.51	1
TOTAL SCORE	-1		1		-4	
MACROINV. COMMUNITY RATING	ACCEPT.		ACCEPT.		ACCEPT.	

Table 2a. Qualitative macroinvertebrate sampling results at sites on Talmadge Creek, Calhoun County, 1999 and 2010.

TAXA	Talmadge Creek 17 Mile Road 7/12/1999 STATION T1	Talmadge Creek 17 Mile Road 9/16/2010 STATION T1	Talmadge Creek 15 1/2 Mile Road 7/12/1999 STATION T3	Talmadge Creek 15 1/2 Mile Road 9/16/2010 STATION T3
ANNELIDA (segmented worms)				
Hirudinea (leeches)		31		
Oligochaeta (worms)		8	1	8
ARTHROPODA				
Crustacea				
Amphipoda (scuds)	30	34	10	
Decapoda (crayfish)	2		3	
Arachnoidea				
Hydracarina	3	1	15	
Insecta				
Ephemeroptera (mayflies)				
Baetidae	2		7	21
Caenidae	6	37		
Odonata				
Anisoptera (dragonflies)				
Aeshnidae	4		1	
Gomphidae	1			
Libellulidae		7		
Zygoptera (damselflies)				
Calopterygidae	10	1	3	1
Coenagrionidae	10			
Hemiptera (true bugs)				
Belostomatidae		1		1
Corixidae	1		5	
Gerridae	1		1	
Veliidae			1	
Megaloptera				
Sialidae (alder flies)			1	
Trichoptera (caddisflies)				
Hydropsychidae			1	
Limnephilidae	1	1		
Coleoptera (beetles)				
Elmidae			2	
Diptera (flies)				
Ceratopogonidae	1			
Chironomidae	25	79	30	150
Simuliidae			6	15
Tabanidae			1	
MOLLUSCA				
Gastropoda (snails)				
Ancylidae (limpets)		1	1	1
Physidae	1	4	2	
Planorbidae	3	5	1	
Pelecypoda (bivalves)				
Sphaeriidae (clams)	5	81		
TOTAL INDIVIDUALS	106	291	92	197

Table 2b. Macroinvertebrate metric evaluation at sites on Talmadge Creek, Calhoun County, 1999 and 2010.

	Talmadge Creek 17 Mile Road 7/12/1999 STATION T1		Talmadge Creek 17 Mile Road 9/16/2010 STATION T1		Talmadge Creek 15 1/2 Mile Road 7/12/1999 STATION T3		Talmadge Creek 15 1/2 Mile Road 9/16/2010 STATION T3	
METRIC	Value	Score	Value	Score	Value	Score	Value	Score
TOTAL NUMBER OF TAXA	17	1	14	1	19	0	7	-1
NUMBER OF MAYFLY TAXA	2	1	1	0	1	0	1	-1
NUMBER OF CADDISFLY TAXA	1	0	1	0	1	-1	0	-1
NUMBER OF STONEFLY TAXA	0	-1	0	-1	0	-1	0	-1
PERCENT MAYFLY COMP.	7.55	0	12.71	0	7.61	0	10.66	0
PERCENT CADDISFLY COMP.	0.94	-1	0.34	-1	1.09	-1	0.00	-1
PERCENT DOMINANT TAXON	28.30	0	27.84	0	32.61	0	76.14	-1
PERCENT ISOPOD, SNAIL, LEECH	3.77	1	14.09	-1	4.35	0	0.51	1
PERCENT SURF. AIR BREATHERS	1.89	1	0.34	1	7.61	0	0.51	1
TOTAL SCORE	2		-1		-3		-4	
MACROINV. COMMUNITY RATING	ACCEPT.		ACCEPT.		ACCEPT.		ACCEPT.	

Table 3A. Qualitative macroinvertebrate sampling results for sites on the Kalamazoo River in the vicinity of the Enbridge oil spill, Calhoun County, September 2010.

TAXA	Kalamazoo River Kalamazoo St. 9/9/2010 STATION K1	Kalamazoo River Squaw Lk Drain confluence 9/15/2010 STATION K2	Kalamazoo River 11-Mile Rd 9/9/2010 STATION K3	Kalamazoo River Custer Drive 9/15/2010 STATION K4
PORIFERA (sponges)	1	1		1
ANNELIDA (segmented worms)				
Hirudinea (leeches)	1		3	
Oligochaeta (worms)	1	2	4	1
ARTHROPODA				
Crustacea				
Amphipoda (scuds)	8	43		13
Decapoda (crayfish)	1	2	1	
Isopoda (sowbugs)	1	2		3
Arachnoidea				
Hydracarina	1		2	
Insecta				
Ephemeroptera (mayflies)				
Baetidae	26	67	54	12
Caenidae	1			1
Ephemerellidae		1		
Heptageniidae	22	22	17	4
Isonychiidae	3	11	3	
Tricorythidae	3	10	3	2
Odonata				
Anisoptera (dragonflies)				
Aeshnidae		2	1	1
Gomphidae		1	2	7
Zygoptera (damselflies)				
Calopterygidae	1	13	3	2
Coenagrionidae	1	2	7	34
Plecoptera (stoneflies)				
Perlidae		1		
Pteronarcyidae	2	1	1	
Hemiptera (true bugs)				
Belostomatidae		4		
Corixidae	1	3		
Gerridae	1			1
Nepidae		1		
Pleidae	1			
Megaloptera				
Corydalidae (dobson flies)			2	
Sialidae (alder flies)		2		
Trichoptera (caddisflies)				
Brachycentridae	5			6
Helicopsychidae		5		
Hydropsychidae	18	10		54
Hydroptilidae		1	1	
Leptoceridae	6	1	2	
Limnephilidae		2		
Philopotamidae	2			
Polycentropodidae	1			
Uenoidae		6	3	
Coleoptera (beetles)				
Dytiscidae (total)			1	
Gyrinidae (adults)	1		1	
Haliplidae (adults)			15	
Elmidae	2	5	7	
Psephenidae (larvae)	1		1	
Diptera (flies)				
Ceratopogonidae		1		
Chironomidae	6	20	18	21
Simuliidae	196	27		
Tabanidae	1	1		
Tipulidae		3		
MOLLUSCA				
Gastropoda (snails)				
Ancylidae (limpets)	1	1	1	12
Hydrobiidae		6	3	
Lymnaeidae		17	5	
Physidae	1			2
Planorbidae			1	1
Pleuroceridae	2	1	86	
Pelecypoda (bivalves)				
Corbiculidae	1	9	2	7
Sphaeriidae (clams)	1		49	
Unionidae (mussels)		1	1	
TOTAL INDIVIDUALS	321	308	300	185

Table 3B. Macroinvertebrate metric evaluation of sites on the Kalamazoo River in the vicinity of the Enbridge oil spill, Calhoun County, September 2010.

	Kalamazoo River Kalamazoo St. 9/9/2010 STATION K1		Kalamazoo River Squaw Lk Drain confluence 9/15/2010 STATION K2		Kalamazoo River 11-Mile Rd 9/9/2010 STATION K3		Kalamazoo River Custer Drive 9/15/2010 STATION K4	
METRIC	Value	Score	Value	Score	Value	Score	Value	Score
TOTAL NUMBER OF TAXA	34	1	38	1	31	1	20	0
NUMBER OF MAYFLY TAXA	5	1	5	1	4	1	4	1
NUMBER OF CADDISFLY TAXA	5	1	6	1	3	0	2	0
NUMBER OF STONEFLY TAXA	1	1	2	1	1	1	0	-1
PERCENT MAYFLY COMP.	17.13	0	36.04	1	25.67	1	10.27	0
PERCENT CADDISFLY COMP.	9.97	0	8.12	0	2.00	-1	32.43	1
PERCENT DOMINANT TAXON	61.06	-1	21.75	0	28.67	0	29.19	0
PERCENT ISOPOD, SNAIL, LEECH	1.87	1	8.77	0	33.00	-1	9.73	0
PERCENT SURF. AIR BREATHERS	1.25	1	2.60	1	5.67	1	0.54	1
TOTAL SCORE	5		6		3		2	
MACROINV. COMMUNITY RATING	EXCELLENT		EXCELLENT		ACCEPT.		ACCEPT.	

Table 4A. Qualitative macroinvertebrate sampling results at Kalamazoo Street (17 Mile Rd), Kalamazoo River, Calhoun County, 1999, 2004 and 2010.

TAXA	Kalamazoo River Kalamazoo St. 9/18/1999 STATION K1	Kalamazoo River Kalamazoo St. 8/16/2004 STATION K1	Kalamazoo River Kalamazoo St. 9/9/2010 STATION K1
PORIFERA (sponges)		1	1
ANNELIDA (segmented worms)			
Hirudinea (leeches)			1
Oligochaeta (worms)		1	1
ARTHROPODA			
Crustacea			
Amphipoda (scuds)	30	5	8
Decapoda (crayfish)		1	1
Isopoda (sowbugs)		2	1
Arachnoidea			
Hydracarina	2	1	1
Insecta			
Ephemeroptera (mayflies)			
Baetidae	15	5	26
Caenidae		2	1
Ephemerellidae		2	
Heptageniidae	4	5	22
Isonychiidae		1	3
Tricorythidae			3
Odonata			
Anisoptera (dragonflies)			
Aeshnidae	2	1	
Gomphidae		1	
Zygoptera (damselflies)			
Calopterygidae		1	1
Coenagrionidae	2	3	1
Plecoptera (stoneflies)			
Perlidae	6		
Pteronarcyidae		1	2
Hemiptera (true bugs)			
Corixidae		5	1
Gerridae	2	1	1
Mesoveliidae		1	
Nepidae		1	
Pleidae			1
Megaloptera			
Sialidae (alder flies)		1	
Trichoptera (caddisflies)			
Brachycentridae	2	5	5
Glossosomatidae	2		
Helicopsychidae	4		
Hydropsychidae	8	15	18
Lepidostomatidae		1	
Leptoceridae		2	6
Limnephilidae	10	3	
Philopotamidae	4	1	2
Phryganeidae		1	
Polycentropodidae		2	1
Uenoidae		1	
Coleoptera (beetles)			
Gyrinidae (adults)		1	1
Elmidae	3	3	2
Gyrinidae (larvae)		1	
Psephenidae (larvae)			1
Diptera (flies)			
Chironomidae	4	15	6
Simuliidae		5	196
Tabanidae		1	1
MOLLUSCA			
Gastropoda (snails)			
Ancylidae (limpets)	1	1	1
Physidae	2		1
Planorbidae		1	
Pleuroceridae			2
Viviparidae		1	
Pelecypoda (bivalves)			
Corbiculidae		1	1
Pisidiidae	2		
Sphaeriidae (clams)	2	1	1
TOTAL INDIVIDUALS	107	104	321

Table 4B. Macroinvertebrate metric evaluation at Kalamazoo Street (17 Mile Rd), Kalamazoo River, Calhoun County, 1999, 2004 and 2010.

METRIC	Kalamazoo River Kalamazoo St. 9/18/1999 STATION K1 Value	Score	Kalamazoo River Kalamazoo St. 8/16/2004 STATION K1 Value	Score	Kalamazoo River Kalamazoo St. 9/9/2010 STATION K1 Value	Score
TOTAL NUMBER OF TAXA	20	0	40	1	34	1
NUMBER OF MAYFLY TAXA	2	0	5	1	5	1
NUMBER OF CADDISFLY TAXA	6	1	9	1	5	1
NUMBER OF STONEFLY TAXA	1	1	1	1	1	1
PERCENT MAYFLY COMP.	17.76	0	14.42	0	17.13	0
PERCENT CADDISFLY COMP.	28.04	0	29.81	1	9.97	0
PERCENT DOMINANT TAXON	28.04	0	14.42	1	61.06	-1
PERCENT ISOPOD, SNAIL, LEECH	2.80	1	4.81	0	1.87	1
PERCENT SURF. AIR BREATHERS	1.87	1	8.65	0	1.25	1
TOTAL SCORE	4		6		5	
MACROINV. COMMUNITY RATING	ACCEPT.		EXCELLENT		EXCELLENT	

Table 5a. Qualitative macroinvertebrate sampling results at 11 Mile Road, Calhoun County, 2004, 2008 and 2010.

TAXA	Kalamazoo River 11-Mile Rd 8/16/2004 STATION K3	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3	Kalamazoo River 11-Mile Rd 9/9/2010 STATION K3
PORIFERA (sponges)	1					
PLATYHELMINTHES (flatworms)						
Turbellaria		4				
BRYOZOA (moss animals)	1					
ANNELIDA (segmented worms)						
Hirudinea (leeches)		1	1	1	3	3
Oligochaeta (worms)	1	13	18	20	19	4
ARTHROPODA						
Crustacea						
Amphipoda (scuds)	5	3	8	54	12	
Decapoda (crayfish)	1	1	1	1	1	1
Isopoda (sowbugs)			2	1	2	
Arachnoidea						
Hydracarina	1	4	2			2
Insecta						
Ephemeroptera (mayflies)						
Baetidae	5	42	46	26	48	54
Caenidae	2	2	1	2	5	
Ephemerellidae		1	1			
Ephemeridae				1		
Heptageniidae	5	6	4	3	2	17
Isonychiidae	3	1	1	4	1	3
Tricorythidae	2	8	8	5	4	3
Odonata						
Anisoptera (dragonflies)						
Aeshnidae	1	1	1	1		1
Gomphidae	1	1	1	1	1	2
Libellulidae	1		1			
Macromiidae			1			
Zygoptera (damselflies)						
Calopterygidae	2	2	13	1	11	3
Coenagrionidae	2	4	3	16	2	7
Plecoptera (stoneflies)						
Perlidae	2					
Pteronarcyidae			1			1
Hemiptera (true bugs)						
Belostomatidae		1		1		
Corixidae	5	3	15	8	7	
Gerridae	1	1	1	2	2	
Mesoveliidae	1	1	2	5	1	
Naucoridae				1		
Notonectidae			1			
Pleidae	1		1	2	1	
Megaloptera						
Corydalidae (dobson flies)	1		1		1	2
Sialidae (alder flies)	1	1	1	3		
Neuroptera (spongilla flies)						
Sisyridae	1					
Trichoptera (caddisflies)						
Brachycentridae		2	3	10	1	
Glossosomatidae			1			
Helicopsychidae	1	8	9	8	4	
Hydropsychidae	12	45	48	19	29	
Hydroptilidae		4	17	6	8	1
Lepidostomatidae			1			
Leptoceridae	1	1	3	1	1	2
Limnephilidae	3	1	1			
Philopotamidae	1	1				
Phryganeidae	1					
Polycentropodidae	2	2	1	1	1	
Uenoidae	2	2	1	1	1	3
Lepidoptera (moths)						
Pyralidae			1	1	1	
Coleoptera (beetles)						
Gyrinidae (adults)	1	1	1			1
Haliplidae (adults)		1	1	4	1	15
Hydrophilidae (total)	1	1	1			
Elmidae	2	9	6	6	5	7
Gyrinidae (larvae)				1	1	
Psephenidae (larvae)			1	1		1
Scirtidae (larvae)		1				
Diptera (flies)						
Ceratopogonidae	1			2	1	
Chironomidae	12	21	20	51	23	18
Culicidae				4		
Ptychopteridae			1			
Simuliidae	5	22	21	2	9	
Tabanidae		3	1	1	2	
Tipulidae		1	1	1		
MOLLUSCA						
Gastropoda (snails)						
Ancylidae (limpets)	1	1	1		2	1
Hydrobiidae		29	10	73	87	3
Physidae		3	1	4	3	
Planorbidae	1	4	6	7	11	1
Pleuroceridae		100	90	21	17	86
Valvatidae	1					
Viviparidae		1	2	1	2	
Pelecypoda (bivalves)						
Corbiculidae	1	1	1	1	1	2
Sphaeriidae (clams)	1	22	10	20	9	49
Unionidae (mussels)	1	1	1	1	1	1
TOTAL INDIVIDUALS	98	389	398	407	346	300

Table 5b. Macroinvertebrate metric evaluation at 11 Mile Road, Calhoun County, 2004, 2008 and 2010.

METRIC	Kalamazoo River 11-Mile Rd 8/16/2004 STATION K3 Value	Score	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3 Value	Score	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3 Value	Score	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3 Value	Score	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3 Value	Score	Kalamazoo River 11-Mile Rd 9/9/2010 STATION K3 Value	Score
TOTAL NUMBER OF TAXA	44	1	48	1	56	1	48	1	43	1	30	1
NUMBER OF MAYFLY TAXA	5	1	6	1	6	1	6	1	5	1	4	1
NUMBER OF CADDISFLY TAXA	8	1	9	1	10	1	7	1	7	1	3	0
NUMBER OF STONEFLY TAXA	1	1	0	-1	1	1	0	-1	0	-1	1	1
PERCENT MAYFLY COMP.	17.35	0	15.42	0	15.33	0	10.07	0	17.34	0	25.67	1
PERCENT CADDISFLY COMP.	23.47	0	16.97	0	21.36	0	11.30	0	13.01	0	2.00	-1
PERCENT DOMINANT TAXON	12.24	1	25.71	0	22.61	0	17.94	1	25.14	0	28.67	0
PERCENT ISOPOD, SNAIL, LEECH	3.06	1	35.73	-1	28.39	-1	26.54	-1	36.71	-1	33.00	-1
PERCENT SURF. AIR BREATHERS	10.20	0	2.31	1	6.03	1	6.63	1	4.05	1	5.67	1
TOTAL SCORE	6		2		4		3		2		3	
MACROINV. COMMUNITY RATING	EXCELLENT		ACCEPT.		ACCEPT.		ACCEPT.		ACCEPT.		ACCEPT.	

Table 6a. Qualitative macroinvertebrate sampling results at Custer Drive, Calhoun County, 1994, 2004, 2009 and 2010.

TAXA	Kalamazoo River Custer Drive 9/9/1994 STATION K4	Kalamazoo River Custer Drive 8/17/2004 STATION K4	Kalamazoo River Custer Drive 9/15/2009 STATION K4	Kalamazoo River Custer Drive 9/15/2010 STATION K4
PORIFERA (sponges)				1
PLATYHELMINTHES (flatworms)				
Turbellaria	2			
BRYOZOA (moss animals)		1		
ANNELIDA (segmented worms)				
Oligochaeta (worms)				1
ARTHROPODA				
Crustacea				
Amphipoda (scuds)	20	20	56	13
Decapoda (crayfish)		1	1	
Isopoda (sowbugs)	1	1	2	3
Insecta				
Ephemeroptera (mayflies)				
Baetiscidae			1	
Baetidae		5	16	12
Caenidae	2			1
Ephemerellidae	25	1		
Heptageniidae	2	5	1	4
Tricorythidae		5	3	2
Odonata				
Anisoptera (dragonflies)				
Aeshnidae	2	1	1	1
Gomphidae			2	7
Libellulidae			3	
Zygoptera (damselflies)				
Calopterygidae	2	2		2
Coenagrionidae	8	1	12	34
Plecoptera (stoneflies)				
Perlidae			1	
Perlodidae	1			
Pteronarcyidae			1	
Hemiptera (true bugs)				
Belostomatidae	2		1	
Corixidae		3		
Gerridae		1	2	1
Mesoveliidae	3	1		
Naucoridae	1			
Pleidae	1	1	1	
Veliidae			2	
Megaloptera				
Corydalidae (dobson flies)			1	
Sialidae (alder flies)	1			
Trichoptera (caddisflies)				
Brachycentridae		5	5	6
Hydropsychidae	4	5	103	54
Leptoceridae			3	
Limnephilidae		2		
Molannidae			2	
Philopotamidae	1		2	
Phryganeidae			1	
Polycentropodidae		1		
Coleoptera (beetles)				
Dytiscidae (total)			1	
Gyrinidae (adults)		1	1	
Elmidae	2	2	16	
Diptera (flies)				
Chironomidae	16	35	54	21
Culicidae		1		
Simuliidae	4	3	2	
MOLLUSCA				
Gastropoda (snails)				
Ancylidae (limpets)	1		6	12
Physidae		1	4	2
Planorbidae				1
Pleuroceridae			1	
Viviparidae		1		
Pelecypoda (bivalves)				
Corbiculidae		1		7
Sphaeriidae (clams)	1	1		
Unionidae (mussels)		1	1	
TOTAL INDIVIDUALS	102	109	309	185

Table 6b. Macroinvertebrate metric evaluation at Custer Drive, Calhoun County, 1994, 2004, 2009 and 2010.

METRIC	Kalamazoo River Custer Drive 9/9/1994 STATION K4 Value	Score	Kalamazoo River Custer Drive 8/17/2004 STATION K4 Value	Score	Kalamazoo River Custer Drive 9/15/2009 STATION K4 Value	Score	Kalamazoo River Custer Drive 9/15/2010 STATION K4 Value	Score
TOTAL NUMBER OF TAXA	22	0	29	1	33	1	20	0
NUMBER OF MAYFLY TAXA	3	0	4	1	4	1	4	1
NUMBER OF CADDISFLY TAXA	2	0	4	0	6	1	2	0
NUMBER OF STONEFLY TAXA	1	1	0	-1	2	1	0	-1
PERCENT MAYFLY COMP.	28.43	1	14.68	0	6.80	0	10.27	0
PERCENT CADDISFLY COMP.	4.90	0	11.93	0	37.54	1	32.43	1
PERCENT DOMINANT TAXON	24.51	0	32.11	0	33.33	0	29.19	0
PERCENT ISOPOD, SNAIL, LEECH	1.96	1	2.75	1	4.21	0	9.73	0
PERCENT SURF. AIR BREATHERS	6.86	1	7.34	0	2.59	1	0.54	1
TOTAL SCORE	4		2		6		2	
MACROINV. COMMUNITY RATING	ACCEPT.		ACCEPT.		EXCELLENT		ACCEPT.	

Table 7. Habitat evaluation for sites on Talmadge Creek in the vicinity of the Enbridge oil spill, Calhoun County, September 2010.

HABITAT METRIC	Station T1 Talmadge Creek 17 Mile Road GLIDE/POOL	Station T2 Talmadge Creek downstream 17 Mile Road GLIDE/POOL	Station T3 Talmadge Creek 15 1/2 Mile Road RIFFLE/RUN
Substrate and Instream Cover			
Epifaunal Substrate/ Avail Cover (20)	10	13	6
Embeddedness (20)*			13
Velocity/Depth Regime (20)*			8
Pool Substrate Characterization (20)**	11	13	
Pool Variability (20)**	10	10	
Channel Morphology			
Sediment Deposition (20)	8	10	13
Flow Status - Maint. Flow Volume (10)	9	9	3
Flow Status - Flashiness (10)	9	10	0
Channel Alteration (20)	13	16	1
Frequency of Riffles/Bends (20)*			18
Channel Sinuosity (20)**	10	15	
Riparian and Bank Structure			
Bank Stability (L) (10)	9	10	0
Bank Stability (R) (10)	9	10	0
Vegetative Protection (L) (10)	10	10	0
Vegetative Protection (R) (10)	10	10	0
Riparian Veg. Zone Width (L) (10)	10	10	5
Riparian Veg. Zone Width (R) (10)	10	10	1
TOTAL SCORE (200):	138	156	68
HABITAT RATING:	GOOD (SLIGHTLY IMPAIRED)	EXCELLENT (NON- IMPAIRED)	MARGINAL (MODERATELY IMPAIRED)

Note: Individual metrics may better describe conditions directly affecting the biological community while the Habitat Rating describes the general riverine environment at the site(s).

Date:	9/16/2010		9/16/2010		9/16/2010	
Weather:	Cloudy		Rainy		Cloudy	
Air Temperature:	70	Deg. F.	70	Deg. F.	70	Deg. F.
Water Temperature:	62	Deg. F.	62	Deg. F.	58	Deg. F.
Ave. Stream Width:	4	Feet	5	Feet	18	Feet
Ave. Stream Depth:	0.4	Feet	0.3	Feet	0.3	Feet
Surface Velocity:	0.5	Ft./Sec.	0.75	Ft./Sec.	1	Ft./Sec.
Estimated Flow:	0.8	CFS	1.125	CFS	5.4	CFS
Stream Modifications:	Dredged		None		Dredged	
Nuisance Plants (Y/N):	N		N		N	
STORET No.:	130336		130405		130335	
Stream Name:	Talmadge Creek		Talmadge Creek		Talmadge Creek	
Road Crossing/Location:	17 Mile Road		downstream 17 Mile Road		15 1/2 Mile Road	
County Code:	13		13		13	
TRS:	03S06W01		03S06W02		02S06W34	
Latitude (dd):	42.2394598		42.2402		42.251717	
Longitude (dd):	-84.9632235		-84.97066		-84.9885712	
Ecoregion:	SMNITP		SMNITP		SMNITP	
Stream Type:	Warmwater		Warmwater		Warmwater	
USGS Basin Code:	4050003		4050003		4050003	

* Applies only to Riffle/Run stream Surveys
** Applies only to Glide/Pool stream Surveys

COMMENTS:

Table 8. Habitat evaluation for sites on the Kalamazoo River in the vicinity of the the Enbridge oi spill, Calhoun County, September 2010.

HABITAT METRIC	Station K1 Kalamazoo River Kalamazoo St. GLIDE/POOL	Station K2 Kalamazoo River Squaw Lk Drain confluence RIFFLE/RUN	Station K3 Kalamazoo River 11-Mile Rd RIFFLE/RUN	Station K4 Kalamazoo River Custer Drive GLIDE/POOL
Substrate and Instream Cover				
Epifaunal Substrate/ Avail Cover (20)	18	16	15	10
Embeddedness (20)*		18	18	
Velocity/Depth Regime (20)*		18	15	
Pool Substrate Characterization (20)**	18			11
Pool Variability (20)**	16			8
Channel Morphology				
Sediment Deposition (20)	13	16	15	6
Flow Status - Maint. Flow Volume (10)	9	9	9	9
Flow Status - Flashiness (10)	7	7	8	8
Channel Alteration (20)	18	18	18	16
Frequency of Riffles/Bends (20)*		15	15	
Channel Sinuosity (20)**	15			13
Riparian and Bank Structure				
Bank Stability (L) (10)	9	7	9	8
Bank Stability (R) (10)	9	9	9	8
Vegetative Protection (L) (10)	4	6	8	9
Vegetative Protection (R) (10)	8	9	10	9
Riparian Veg. Zone Width (L) (10)	3	6	7	9
Riparian Veg. Zone Width (R) (10)	4	9	10	9
TOTAL SCORE (200):	151	163	166	133
HABITAT RATING:	GOOD (SLIGHTLY IMPAIRED)	EXCELLENT (NON-IMPAIRED)	EXCELLENT (NON-IMPAIRED)	GOOD (SLIGHTLY IMPAIRED)

Note: Individual metrics may better describe conditions directly affecting the biological community while the Habitat Rating describes the general riverine environment at the site(s).

Date:	9/9/2010	9/15/2010	9/9/2010	9/15/2010
Weather:	Sunny	Sunny	Sunny	Sunny
Air Temperature:	71 Deg. F.	55 Deg. F.	72 Deg. F.	64 Deg. F.
Water Temperature:	70 Deg. F.	64 Deg. F.	58 Deg. F.	65 Deg. F.
Ave. Stream Width:	120 Feet	200 Feet	150 Feet	360 Feet
Ave. Stream Depth:	3 Feet	1.5 Feet	1.5 Feet	2.5 Feet
Surface Velocity:	1 Ft./Sec.	1.25 Ft./Sec.	1.25 Ft./Sec.	0.6 Ft./Sec.
Estimated Flow:	360 CFS	375 CFS	281.25 CFS	540 CFS
Stream Modifications:	None	None	None	None
Nuisance Plants (Y/N):	N	N	N	N
STORET No.:	130211	130406	130048	130052
Stream Name:	Kalamazoo River	Kalamazoo River	Kalamazoo River	Kalamazoo River
Road Crossing/Location:	Kalamazoo St.	Squaw Lake Drain confluence	11-Mile Rd	Custer Drive
County Code:	13	13	13	13
TRS:	02S06W26	02S06W33	02S07W25	01S08W29
Latitude (dd):	42.26391	42.25852	42.27429	42.35074
Longitude (dd):	-84.96836	-85.00469	-85.08097	-85.27561
Ecoregion:	SMNITP	SMNITP	SMNITP	SMNITP
Stream Type:	Warmwater	Warmwater	Warmwater	Warmwater
USGS Basin Code:	4050003	4050003	4050003	4050003

* Applies only to Riffle/Run stream Surveys
** Applies only to Glide/Pool stream Surveys

COMMENTS:

Appendix H2: Macroinvertebrate Report 2011

MI/DEQ/WRD-12/012

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER RESOURCES DIVISION
FEBRUARY 2012

STAFF REPORT

A BIOLOGICAL SURVEY OF SITES ON THE KALAMAZOO RIVER AND TALMADGE CREEK NEAR THE ENBRIDGE OIL SPILL IN MARSHALL CALHOUN COUNTY, MICHIGAN AUGUST 2011

INTRODUCTION

On July 26, 2010, a 30-inch diameter pipeline ruptured and discharged heavy crude oil into Talmadge Creek, a tributary to the Kalamazoo River, which drains into Lake Michigan. The amount of oil discharged is estimated at 819,000 to 1,000,000 gallons. The oil flowed down 2.2 miles of Talmadge Creek, a small designated warmwater stream, before entering the Kalamazoo River downstream of Marshall, Michigan. The Kalamazoo River is also a designated warmwater stream that is bordered by wetland, forest, residential properties, farm land, and commercial properties for the approximate 35-mile stretch of impacted river in Calhoun and Kalamazoo Counties between Marshall and Morrow Lake.

During September 2010, staff of the Surface Water Assessment Section (SWAS), Water Resources Division, Michigan Department of Environmental Quality (MDEQ), with assistance from Entrix, conducted qualitative macroinvertebrate community and stream habitat surveys on the Kalamazoo River and Talmadge Creek. The survey documented that macroinvertebrate abundance and diversity were drastically reduced in both water bodies because of the oil spill and associated cleanup activities (Walterhouse, 2011b). SWAS and Entrix staff also assisted staff of the Michigan Department of Natural Resources (MDNR), Fisheries Division, with fish collection efforts and quantitative stream habitat assessments. The MDNR, Fisheries Division, reported reduced fish abundance and diversity along with impacts to stream habitat in Talmadge Creek (Wesley, 2011 [draft]). Fish community diversity and catch also declined at two of the three sites on the Kalamazoo River, which were impacted by the oil spill and cleanup activities.

During August 2011, SWAS staff reconducted qualitative macroinvertebrate community and stream habitat surveys on the Kalamazoo River and Talmadge Creek. The objective of these surveys was to monitor the short- and long-term effects of the oil spill and associated cleanup activities on macroinvertebrate communities and aquatic habitat. SWAS staff also assisted the MDNR, Fisheries Division, staff with fish collection efforts and quantitative stream habitat assessments. The MDNR, Fisheries Division, is preparing a separate report, which details the fish and quantitative stream habitat sampling efforts. Additional surveys will be conducted in the future to monitor the long-term effects of the oil spill and associated cleanup activities on the fish and macroinvertebrate communities and aquatic habitat (Wesley and Walterhouse, 2010).

METHODS

Most of the sites that were selected for this survey were specifically chosen because of historic (i.e., baseline) surveys that were conducted prior to the oil spill (Wesley and Walterhouse, 2010). An additional site on Talmadge Creek was added just upstream of the oil spill because stream flow at the historic control site further upstream at 17 Mile Road was minimal and the habitat had more wetland than stream characteristics. A survey was also conducted at a site on the Kalamazoo River downstream of Talmadge Creek and 15 Mile Road, where historical

survey data were lacking, but the proximity of Talmadge Creek upstream warranted the addition of the site to determine impacts.

The surveys described in this report were conducted according to the SWAS Procedure 51 (MDEQ, 1990). Procedure 51 surveys conducted prior to 2008 and those conducted in 2011 were performed with nearly the same methodology except the macroinvertebrate sample size was increased from 100 to 300 with the 2008 revision to Procedure 51. The macroinvertebrate communities were scored with metrics that rate water bodies from excellent (+5 to +9) to poor (-5 to -9). Macroinvertebrate ratings from +4 to -4 are considered acceptable. Negative ratings that are acceptable are indicative of water bodies that are strongly tending toward poor, while positive ratings that are acceptable indicate slight impairment (Creal et al., 1996). Stream habitat was qualitatively evaluated at each station using a scoring system that ranged in value from 0 (poor) to 200 (excellent).

Sampling locations are shown in Figure 1.

SUMMARY AND OBSERVATIONS

Qualitative macroinvertebrate scores and ratings alone do not adequately measure the impact of the oil spill and associated cleanup activities.

In summary, macroinvertebrate abundance and diversity improved in Talmadge Creek, compared to 2010, downstream of the oil spill where cleanup operations have altered the instream and riparian habitat. The stream channel is now completely exposed to sunlight, which appears to have increased productivity at least in terms of taxa diversity. However, overall macroinvertebrate abundance in Talmadge Creek was still impacted compared to the sites upstream of the oil spill.

The abundance and diversity of macroinvertebrates at sites impacted by the oil spill on the Kalamazoo River were also improved compared to 2010, but abundance was still impacted compared to historic sampling efforts prior to the oil spill.

Oil sheen and odors were not noted on the segment of Talmadge Creek where sampling was conducted.

Sampling efforts in depositional zones at all of the impacted sites on the Kalamazoo River caused a disturbance that produced surface oil sheen. The sediments at the impacted sites on the Kalamazoo River also had a notable petroleum odor. Petroleum odors were detected in the water only at the site downstream of Battle Creek (station K4).

The shallow riffle habitat at the impacted Kalamazoo River sites (stations K2 and K3), which were obviously disturbed in 2010 by the abnormally heavy boat traffic associated with the cleanup operations, appeared to be recovering. The cobble habitat was beginning to be colonized by periphyton and macroinvertebrates in the riffles.

Limited observations of areas of Talmadge Creek and the Kalamazoo River where stream bank erosion problems developed during cleanup operations appeared to be stabilized with various stream bank stabilization techniques.

The amount of sediment in the depositional areas of the Kalamazoo River, particularly downstream of Battle Creek, appears to have increased in terms of both depth and aerial coverage.

SAMPLING RESULTS

Talmadge Creek - Macroinvertebrates

The macroinvertebrate community sampling results for stations on Talmadge Creek are presented in Table 1a and the macroinvertebrate community metrics, scores, and ratings are presented in Table 1b. The stations are arranged in an upstream to downstream sequence. Two stations were surveyed as controls upstream of the oil spill. The control station at 17 Mile Road (station T1) was surveyed in 1999 allowing for comparisons with the 2010 and 2011 surveys (Cooper, 2000). The control station downstream of 17 Mile Road (station T2) had never been surveyed but the stream habitat and greater flow volume were more similar to conditions downstream on the oil impacted segment of Talmadge Creek. Talmadge Creek was sampled in the oil impacted reach at 15 ½ Mile Road (station T3) where a survey was also conducted in 1999 (Cooper, 2000). Station T3 is one mile downstream (Mile Post 1.0) of where oil from the pipeline failure entered Talmadge Creek.

The 2011 macroinvertebrate community sampling results documented that of the three sites surveyed on Talmadge Creek, station T3 received the highest score and supported a similar number taxa as the upstream control site (station T2). The upstream site (station T2) that was comparable in terms of stream flow received an overall score of +1 compared to the score of +4 at station T3. The number of taxa decreased slightly from 26 at station T2 to 24 at station T3. The higher macroinvertebrate community score at station T3 was a product of more mayflies and caddisflies in terms of both taxa and overall relative abundance. Specific taxa that were present at both stations T1 and T2 that were absent at station T3 included Hirudinea, Amphipoda, Caenidae, Coenagrionidae, and Sphaeriidae.

The results of the 2010 and 2011 macroinvertebrate surveys are presented along with the historic survey results from 1999 (Cooper, 2000) at station T1 in Tables 2a and 2b. The upstream control site at station T1 consisted of taxa predominately associated with wetland habitat during all of the surveys. The diversity and composition of taxa along with the overall scores at this wetland site has remained fairly constant.

The macroinvertebrate community sampling results from 2010 and 2011 at station T2 are presented in Tables 3a and 3b. The overall macroinvertebrate community score was +1 both years. The number of taxa identified was similar both years with the only major differences from 2010 to 2011 being a decline in the abundance of Simuliidae and mayflies, and an increase in the abundance of Amphipoda.

The results of the 1999 (Cooper, 2000), 2010, and 2011 macroinvertebrate surveys are presented in Tables 4a and 4b. At station T3 the overall macroinvertebrate score did not change significantly from 1999 (-3) to 2010 (-4); however, the overall macroinvertebrate community changed from a rather balanced community where 19 total taxa were identified, to a community dominated by one taxa with only 7 total taxa present. The sampling in 2011 produced 24 taxa and a macroinvertebrate community score of +4. This is a dramatic change from both the 1999 and 2010 survey results and is likely a recovery phase response to cleanup and restoration efforts on Talmadge Creek. The removal of trees, shrubs, herbaceous plants, and grasses during the response phase of the oil cleanup has allowed more direct sunlight and an associated proliferation of filamentous algal growth on the stream substrate. This station showed large numerical increases in filter feeders (Hydropsychidae and Simulidae), collector gatherers (Baetidae), and filamentous algae piercers (Hydroptilidae). These four families accounted for 80 percent of the total macroinvertebrate assemblage, which is not uncommon in disturbed systems during early succession. Mackay (1992) reports, “In many instances, denuded channel areas are recolonized by successions of different invertebrate assemblages. First to appear are blackflies, chironomids, and baetid mayflies, which often reach high densities

early in the recolonization." This appears to be what has occurred at this site. Additional years of assessment will be needed to fully document short- and long-term impacts associated with the oil spill aftermath. Note that the stream banks and substrate of Talmadge Creek were disturbed once again after the 2011 survey by additional cleanup operations, so this recovery may be set back once again.

Kalamazoo River - Macroinvertebrates

The macroinvertebrate community sampling results for stations on the Kalamazoo River are presented in Table 5a and the macroinvertebrate community metrics, scores, and ratings are presented in Table 5b. The stations are arranged in an upstream to downstream sequence. The control station on the Kalamazoo River was upstream of the oil spill in Marshall at Kalamazoo Street (station K1). Three sites on the Kalamazoo River were surveyed in the reach that was impacted by the oil spill and the associated cleanup activities. Station K2 was located on the Kalamazoo River in the vicinity of the Squaw Lake Drain confluence at about Mile Post 2.75. Station K3 was downstream of the Ceresco Dam at 11 Mile Road approximately at Mile Post 7.25. Station K4 on the Kalamazoo River was located downstream of the city of Battle Creek at Custer Drive at about Mile Post 21.25.

The upstream control site on the Kalamazoo River (station K1) had an overall macroinvertebrate community score of +6 and a rating of excellent. The macroinvertebrate community at station K2 scored +6 and was rated as excellent. The site harbored the most taxa of any of the stations surveyed on the Kalamazoo River in 2011. Downstream at station K3, the macroinvertebrate community scored +5 and was rated as excellent. The site supported a diversity of taxa, many of which are considered intolerant of pollution. The macroinvertebrate community further downstream at station K4 scored +1 and was rated as acceptable. The 27 taxa collected at the site were reduced compared to the upstream sites where greater than 35 taxa were collected. The greater taxa diversity upstream at stations K1, K2, and K3, compared to downstream at station K4, is likely related to the greater diversity of in-stream substrates and cover at the upstream sites.

The results of the 2011 macroinvertebrate survey on the Kalamazoo River at Kalamazoo Street (station K1) are presented along with historic survey results from 1999 (Cooper, 2000), 2004 (Walterhouse, 2005), and 2010 (Walterhouse, 2011b) in Tables 6a and 6b. The macroinvertebrate community at K1 has scored +4 to +6 during the current and previous sampling events and has rated acceptable or excellent. The 35 taxa collected in August 2011 compares well with the 34 taxa collected in 2010 and the 40 taxa collected in 2004.

The results of the 2010 (Walterhouse, 2011b) and 2011 macroinvertebrate surveys on the Kalamazoo River downstream of 15 Mile Road at the Squaw Lake Drain confluence (station K2) are presented in Tables 7a and 7b. The macroinvertebrate community scored +6 and was rated as excellent during both investigations. The taxa that were present along with the overall composition of the community were fairly consistent between years.

Macroinvertebrate survey results from 2011 on the Kalamazoo River at 11 Mile Road (station K3) are presented along with historic sampling results from 2004 (Walterhouse, 2005), 2008 (LeSage, 2009), and 2010 (Walterhouse, 2011b) in Tables 8a and 8b. In August 2004, 44 taxa were collected at the site and the macroinvertebrate community scored +6 and was rated as excellent. In late August 2008, the site was surveyed as part of a quality assurance evaluation of Procedure 51 (method and crew variance) by two crews who each sampled the site twice on one day (Lesage, 2009). The number of taxa collected during the four sampling efforts ranged from 44 to 56 and the macroinvertebrate community scores ranged from +2 to +4 with ratings of acceptable. The sampling effort in September 2010 produced only 31 taxa, but still resulted in a macroinvertebrate community score of +3 and an acceptable rating. In 2011,

the number of macroinvertebrate taxa collected increased to 36 and the community scored +5 and was rated excellent. Several taxa of filter feeding macroinvertebrates that were absent in 2010 were collected once again in 2011.

The results of the macroinvertebrate survey in 2011 on the Kalamazoo River at Custer Drive (station K4) are presented along with historic sampling results from 1994 (Kosek, 1994), 2004 (Walterhouse, 2005), 2009 (Walterhouse, 2011a) and 2010 (Walterhouse, 2011b) in Tables 9a and 9b. Previous surveys in 1994 and 2004 were conducted in part because of the upstream proximity to the Battle Creek Wastewater Treatment Plant (National Pollutant Discharge Elimination System Permit #MI0022276) discharge. The previous surveys documented macroinvertebrate scores of +4 and +2 with acceptable ratings in 1994 and 2004, respectively. In 2009, 33 taxa were collected and the macroinvertebrate community scored +6 and was rated as excellent. In 2010, 20 taxa were collected and the macroinvertebrate community scored +2 and was rated as acceptable. The sampling effort in 2011 produced 27 taxa that resulted in a score of +1 and an acceptable rating. The percentage of surface air breathers relative to the overall macroinvertebrate community in 2011 was abnormally high.

Talmadge Creek – Stream Habitat

Qualitative stream habitat assessment results for sites on Talmadge Creek are presented in Table 10. The habitat at station T1 was rated as good primarily because of the wide, natural wetland riparian corridor adjacent to stream channel. The substrate was soft muck and flow was limited creating habitat that would be better classified as wetland habitat. Downstream at station T2 stream habitat was rated as good. Flow was slightly greater than at station T1. Riffle habitat was lacking and sand was the predominant substrate but some gravel and cobble were present along with an abundance of in-stream cover. The riparian corridor was a wide, undisturbed scrub/shrub wetland.

In 2010, the in-stream habitat, stream banks, and adjacent riparian corridor at station T3 were highly disturbed due to the cleanup activities and were rated as marginal. In 2011, the overall stream habitat was rated at the lower range of good. The stream banks and riparian zone were stabilized with vegetative cover and various structures. The stream channel was narrower than in 2010 and riffle habitat was present, but in-stream cover was still extremely limited. The substrate was primarily sand and gravel with a limited amount of cobble still present. The disturbance from cleanup activities has effectively created a clean channel that is silt free.

It is important to note that after the August 2011 survey, additional cleanup operations were conducted on Talmadge Creek that involved dredging the stream banks and channel. Restoration activities are expected to be completed prior to sampling again in 2012.

Kalamazoo River – Stream Habitat

The qualitative stream habitat evaluations for sites on the Kalamazoo River are presented in Table 11. Riffle habitat was lacking at the upstream control site (station K1) and glide/pool metrics were used to produce an overall stream habitat rating of good. In-stream habitat was abundant and included moderate amounts of large woody debris, aquatic vegetation, and root wads. The stream substrate was diverse with a nearly equal mixture of cobble, gravel, sand, and silt along with scattered boulders. The only significant detraction from the overall habitat score was the limited width of the riparian zone.

The riffle/run habitat on the Kalamazoo River at station K2 was rated at the upper end of good. The dominant substrates were cobble and gravel with lesser amounts of sand, silt, and boulders. Additional forms of in-stream habitat such as undercut banks, large woody debris, aquatic vegetation, overhanging vegetation, and root wads had been reduced by activities

associated with the cleanup operations. Submergent aquatic vegetation is beginning to become established once again and was present in about 15 percent of the reach.

The overall stream habitat at station K3 on the Kalamazoo River was rated as good using riffle/run metrics. Cobble and gravel were the dominant substrates along with scattered boulders and lesser amounts of sand and silt along the stream margins. Others forms of in-stream cover that were still moderately abundant included large woody debris, aquatic vegetation, and root wads. Cleanup operations have nearly eliminated all overhanging vegetation. It was observed that the size of the depositional areas had increased, compared to 2010, and the depth of the soft sediments in these areas was also much greater.

The Kalamazoo River at station K4 is much larger with an average width estimated at 360 feet and an estimated average depth of 2.9 feet. The overall stream habitat was rated as good using glide/pool metrics. The wide, wooded floodplain at this site inflates the overall stream habitat score. In-stream habitat that is suitable for macroinvertebrate colonization was limited. Sand was the predominant form of substrate at this site in 2010. Sampling in 2011 found that the predominant form of substrate in this wide, deep segment of the Kalamazoo River is now silt with sand being the second most common form of substrate. Only scattered patches of gravel are present and cobbles and boulders are rare. The amount of large woody debris along the margins of the stream channel has increased due to the severe wind storms, which impacted the Battle Creek area in the spring of 2011. Other in-stream cover present in sparse quantities were aquatic vegetation, root wads, and undercut banks.

Macroinvertebrate Abundance

Procedure 51 is a qualitative collection method that involves sampling all available in-stream habitats to produce a composite macroinvertebrate sample that is typically sub-sampled until 300 organisms have been identified and counted. After 300 organisms have been counted, the remainder of the composite sample is examined for large and/or rare organisms that were not identified in the initial sub-samples. These organisms are added as one individual to the total taxa list. Typically, only a small volume of the composite sample is needed to yield the 300 organisms required by Procedure 51. This is especially true in streams such as the Kalamazoo River that have a diversity of in-stream habitat types, especially in riffle habitats like those present at stations K2 and K3. The majority of the sample is typically examined for large and/or rare taxa. Counting the entire composite sample is seldom necessary, except in streams that are either habitat-limited or have serious violations of Michigan's Water Quality Standards.

Macroinvertebrate abundance in the composite samples at the upstream control sites on Talmadge Creek (stations T1 and T2) and the Kalamazoo River (station K1) was normal in 2010 and 2011. The abundance of macroinvertebrates in the composite samples collected at all of the impacted sites on Talmadge Creek (station T3) and Kalamazoo River (stations K2, K3, and K4) in 2010 was so low that the entire composite sample was counted at all of the sites and the goal of enumerating 300 organisms was not achieved at the site on Talmadge Creek and station K4 on the Kalamazoo River. In 2011, the abundance of macroinvertebrates was greater than in 2010 at all of the impacted sites on Talmadge Creek and the Kalamazoo River. It was still necessary to count the entire macroinvertebrate composite sample at the impacted site (station T3) on Talmadge Creek and two (stations K2 and K4) of the three impacted sites on the Kalamazoo River. The abundance of macroinvertebrates at station K4 is still extremely limited.

Report by: Mike Walterhouse, Aquatic Biologist
Surface Water Assessment Section
Water Resources Division

Fieldwork by: Bill Taft, Aquatic Biologist
Mike Walterhouse, Aquatic Biologist
Surface Water Assessment Section
Water Resources Division
Michigan Department of Environmental Quality

Fieldwork by: John Matousek, Entrix

REFERENCES

Creal, W., S. Hanshue, S. Kosek, M. Oemke, and M. Walterhouse. 1996. Update of GLEAS Procedure 51 Metric Scoring and Interpretation. MDEQ Staff Report #MI/DEQ/SWQ-96/068 (revised 5/98).

Cooper, J. 2000. A Biological Survey of the Kalamazoo River and Selected Tributaries, June-September 1999. MDEQ, SWQD, Report #MI/DEQ/SWQ-00/090.

Kosek, S. 1994. A Biological Survey of the Kalamazoo River Upper Watershed, Hillsdale, Jackson, and Calhoun Counties, July-September 1994. MDNR, SWQD, Report #MI/DNR/SWQ-94/077.

Lesage, S. 2009. A Quality Assurance Evaluation of Qualitative Biological and Habitat Survey Protocols for Wadeable Streams and Rivers, 2008. MDEQ, SWAS, Report #MI/DEQ/WB-09/029.

Mackay, R.J. 1992. Colonization by Lotic Macroinvertebrates: A Review of Processes and Patterns. Canadian Journal of Fisheries and Aquatic Sciences 49: 617-628.

MDEQ. 1990. SWAS Procedure 51 - Qualitative Biological and Habitat Survey Protocols for Wadeable Streams and Rivers, April 24, 1990. Revised June 1991, August 1996, January 1997, May 2002, and December 2008.

Walterhouse, M. 2005. A Biological Survey of Sites in the Upper Kalamazoo River Watershed Calhoun and Jackson Counties, Michigan, August 2004. MDEQ, SWAS, Report #MI/DEQ/WB-05/066.

Walterhouse, M. 2011a. A Biological Survey of Sites in the Kalamazoo River Watershed, Allegan, Barry, Calhoun, Eaton, Hillsdale, Jackson, Kalamazoo, and Van Buren Counties, Michigan. August and September 2009. MDEQ, SWAS, Report #MI/DEQ/WRD-11/004.

Walterhouse, M. 2011b. A Biological Survey of Sites on the Kalamazoo River and Talmadge Creek Near the Enbridge Oil Spill in Marshall, Calhoun County, Michigan. September 2010. MDEQ, SWAS, Report #MI/DEQ/WRD-11/010.

Wesley, J.K. 2011 Draft. A Fish Survey of Sites on the Kalamazoo River and Talmadge Creek Near the Enbridge Oil Spill in Marshall, Calhoun and Kalamazoo Counties, Michigan, September 2010. Michigan Department of Natural Resources, Fisheries Division.

Wesley, J.K. and M. Walterhouse. 2010. Workplan for Macroinvertebrate, Fish, and Habitat Sampling on the Kalamazoo River and Talmadge Creek to Evaluate Aquatic Ecosystem Effects of Oil Exposure and Cleanup Procedures. MDNR, Fisheries Division, and MDEQ, Water Resources Division, September 2, 2010.

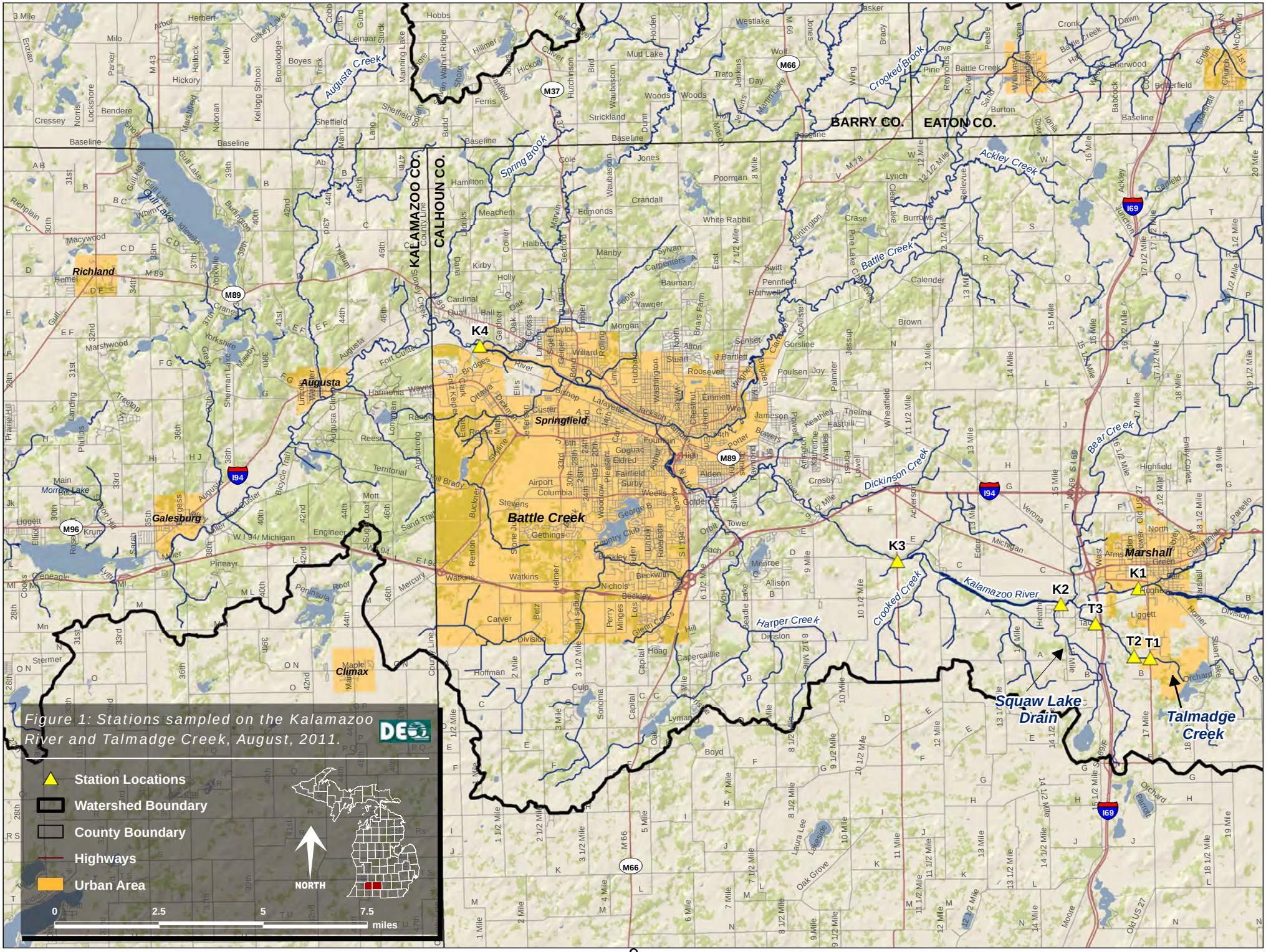


Figure 1: Stations sampled on the Kalamazoo River and Talmadge Creek, August, 2011.

Station Locations
Watershed Boundary
County Boundary
Highways
Urban Area

Table 1A. Qualitative macroinvertebrate sampling results for sites on Talmadge Creek in the vicinity of the Enbridge oil spill, Calhoun County, August 2011.

TAXA	Talmadge Creek 17 Mile Road 8/29/2011 STATION T1	Talmadge Creek downstream 17 Mile Road 8/29/2011 STATION T2	Talmadge Creek 15 1/2 Mile Road 8/29/2011 STATION T3
ANNELIDA (segmented worms)			
Hirudinea (leeches)	18	5	
Oligochaeta (worms)	11	1	1
ARTHROPODA			
Crustacea			
Amphipoda (scuds)	3	184	1
Decapoda (crayfish)		2	
Isopoda (sowbugs)	5		
Arachnoidea			
Hydracarina			5
Insecta			
Ephemeroptera (mayflies)			
Baetidae		1	105
Caenidae	65	2	
Heptageniidae			1
Isonychiidae			2
Tricorythidae			8
Odonata			
Anisoptera (dragonflies)			
Aeshnidae		3	1
Libellulidae	2		
Zygoptera (damselflies)			
Calopterygidae		37	15
Coenagrionidae	2	2	
Hemiptera (true bugs)			
Belostomatidae		1	
Gerridae	1	1	1
Notonectidae		5	
Pleidae			1
Veliidae		1	
Megaloptera			
Sialidae (alder flies)		5	
Trichoptera (caddisflies)			
Hydropsychidae		14	48
Hydroptilidae		8	55
Leptoceridae		3	1
Uenoidae			1
Coleoptera (beetles)			
Dytiscidae (total)		1	1
Haliplidae (adults)		2	
Hydrophilidae (total)	1		1
Elmidae		3	
Diptera (flies)			
Chironomidae	7	14	21
Ephydridae			1
Ptychopteridae	1		
Simuliidae		2	57
Tabanidae			1
Tipulidae			1
MOLLUSCA			
Gastropoda (snails)			
Ancylidae (limpets)		1	
Physidae	2	2	1
Planorbidae	1	1	1
Pelecypoda (bivalves)			
Sphaeriidae (clams)	171	4	
TOTAL INDIVIDUALS	290	305	331

Table 1B. Macroinvertebrate metric evaluation of sites on Talmadge Creek in the vicinity of the Enbridge oil spill, Calhoun County, August, 2011.

METRIC	Talmadge Creek 17 Mile Road 8/29/2011 STATION T1 Value	Score	Talmadge Creek downstream 17 Mile Road 8/29/2011 STATION T2 Value	Score	Talmadge Creek 15 1/2 Mile Road 8/29/2011 STATION T3 Value	Score
TOTAL NUMBER OF TAXA	14	1	26	1	24	0
NUMBER OF MAYFLY TAXA	1	1	2	1	4	1
NUMBER OF CADDISFLY TAXA	0	-1	3	0	4	0
NUMBER OF STONEFLY TAXA	0	-1	0	-1	0	-1
PERCENT MAYFLY COMP.	22.41	1	0.98	-1	35.05	1
PERCENT CADDISFLY COMP.	0.00	-1	8.20	0	31.72	1
PERCENT DOMINANT TAXON	58.97	-1	60.33	-1	31.72	0
PERCENT ISOPOD, SNAIL, LEECH	8.97	0	2.95	1	0.60	1
PERCENT SURF. AIR BREATHERS	1.03	1	3.61	1	1.21	1
TOTAL SCORE	0		1		4	
MACROINV. COMMUNITY RATING	ACCEPT.		ACCEPT.		ACCEPT.	

Table 2A. Qualitative macroinvertebrate sampling results at 17 Mile Road, Talmadge Creek, Calhoun County.

TAXA	Talmadge Creek 17 Mile Road 7/12/1999 STATION T1	Talmadge Creek 17 Mile Road 9/16/2010 STATION T1	Talmadge Creek 17 Mile Road 8/29/2011 STATION T1
ANNELIDA (segmented worms)			
Hirudinea (leeches)		31	18
Oligochaeta (worms)		8	11
ARTHROPODA			
Crustacea			
Amphipoda (scuds)	30	34	3
Decapoda (crayfish)	2		
Isopoda (sowbugs)			5
Arachnoidea			
Hydracarina	3	1	
Insecta			
Ephemeroptera (mayflies)			
Baetidae	2		
Caenidae	6	37	65
Odonata			
Anisoptera (dragonflies)			
Aeshnidae	4		
Gomphidae	1		
Libellulidae		7	2
Zygoptera (damselflies)			
Calopterygidae	10	1	
Coenagrionidae	10		2
Hemiptera (true bugs)			
Belostomatidae		1	
Corixidae	1		
Gerridae	1		1
Trichoptera (caddisflies)			
Limnephilidae	1	1	
Coleoptera (beetles)			
Hydrophilidae (total)			1
Diptera (flies)			
Ceratopogonidae	1		
Chironomidae	25	79	7
Ptychopteridae			1
MOLLUSCA			
Gastropoda (snails)			
Ancylidae (limpets)		1	
Physidae	1	4	2
Planorbidae	3	5	1
Pelecypoda (bivalves)			
Sphaeriidae (clams)	5	81	171
TOTAL INDIVIDUALS	106	291	290

Table 2B. Macroinvertebrate metric evaluation at 17 Mile Road, Talmadge Creek, Calhoun County

METRIC	Talmadge Creek 17 Mile Road 7/12/1999 STATION T1 Value	Score	Talmadge Creek 17 Mile Road 9/16/2010 STATION T1 Value	Score	Talmadge Creek 17 Mile Road 8/29/2011 STATION T1 Value	Score
TOTAL NUMBER OF TAXA	17	1	14	1	14	1
NUMBER OF MAYFLY TAXA	2	1	1	0	1	1
NUMBER OF CADDISFLY TAXA	1	0	1	0	0	-1
NUMBER OF STONEFLY TAXA	0	-1	0	-1	0	-1
PERCENT MAYFLY COMP.	7.55	0	12.71	0	22.41	1
PERCENT CADDISFLY COMP.	0.94	-1	0.34	-1	0.00	-1
PERCENT DOMINANT TAXON	28.30	0	27.84	0	58.97	-1
PERCENT ISOPOD, SNAIL, LEECH	3.77	1	14.09	-1	8.97	0
PERCENT SURF. AIR BREATHERS	1.89	1	0.34	1	1.03	1
TOTAL SCORE	2		-1		0	
MACROINV. COMMUNITY RATING	ACCEPT.		ACCEPT.		ACCEPT.	

Table 3A. Qualitative macroinvertebrate sampling results downstream of 17 Mile Road, Talmadge Creek, Calhoun County.

TAXA	Talmadge Creek downstream 17 Mile Road 9/16/2010 STATION T2	Talmadge Creek downstream 17 Mile Road 8/29/2011 STATION T2
ANNELIDA (segmented worms)		
Hirudinea (leeches)	3	5
Oligochaeta (worms)		1
ARTHROPODA		
Crustacea		
Amphipoda (scuds)	107	184
Decapoda (crayfish)	2	2
Arachnoidea		
Hydracarina	1	
Insecta		
Ephemeroptera (mayflies)		
Baetidae	12	1
Caenidae	14	2
Odonata		
Anisoptera (dragonflies)		
Aeshnidae		3
Zygoptera (damselflies)		
Calopterygidae	27	37
Coenagrionidae	1	2
Hemiptera (true bugs)		
Belostomatidae	1	1
Corixidae	1	
Gerridae	1	1
Notonectidae	1	5
Veliidae		1
Megaloptera		
Sialidae (alder flies)	3	5
Trichoptera (caddisflies)		
Hydropsychidae	6	14
Hydroptilidae		8
Leptoceridae	1	3
Limnephilidae	1	
Uenoidae	1	
Coleoptera (beetles)		
Dytiscidae (total)	1	1
Haliplidae (adults)	8	2
Hydrophilidae (total)	1	
Elmidae		3
Diptera (flies)		
Chironomidae	38	14
Culicidae	1	
Simuliidae	60	2
MOLLUSCA		
Gastropoda (snails)		
Ancylidae (limpets)	28	1
Physidae	1	2
Planorbidae	6	1
Pelecypoda (bivalves)		
Sphaeriidae (clams)	22	4
TOTAL INDIVIDUALS	349	305

Table 3B. Macroinvertebrate metric evaluation downstream of 17 Mile Road, Talmadge Creek, Calhoun County.

METRIC	Talmadge Creek downstream 17 Mile Road 9/16/2010 STATION T2 Value	Score	Talmadge Creek downstream 17 Mile Road 8/29/2011 STATION T2 Value	Score
TOTAL NUMBER OF TAXA	27	1	26	1
NUMBER OF MAYFLY TAXA	2	1	2	1
NUMBER OF CADDISFLY TAXA	4	1	3	0
NUMBER OF STONEFLY TAXA	0	-1	0	-1
PERCENT MAYFLY COMP.	7.45	0	0.98	-1
PERCENT CADDISFLY COMP.	2.58	-1	8.20	0
PERCENT DOMINANT TAXON	30.66	0	60.33	-1
PERCENT ISOPOD, SNAIL, LEECH	10.89	-1	2.95	1
PERCENT SURF. AIR BREATHERS	4.30	1	3.61	1
TOTAL SCORE	1		1	
MACROINV. COMMUNITY RATING	ACCEPT.		ACCEPT.	

Table 4A. Qualitative macroinvertebrate sampling results at 15 1/2 Mile Road, Talmadge Creek, Calhoun County.

TAXA	Talmadge Creek 15 1/2 Mile Road 7/12/1999 STATION T3	Talmadge Creek 15 1/2 Mile Road 9/16/2010 STATION T3	Talmadge Creek 15 1/2 Mile Road 8/29/2011 STATION T3
ANNELIDA (segmented worms)			
Oligochaeta (worms)	1	8	1
ARTHROPODA			
Crustacea			
Amphipoda (scuds)	10		1
Decapoda (crayfish)	3		
Arachnoidea			
Hydracarina	15		5
Insecta			
Ephemeroptera (mayflies)			
Baetidae	7	21	105
Heptageniidae			1
Isonychiidae			2
Tricorythidae			8
Odonata			
Anisoptera (dragonflies)			
Aeshnidae	1		1
Zygoptera (damselflies)			
Calopterygidae	3	1	15
Hemiptera (true bugs)			
Belostomatidae		1	
Corixidae	5		
Gerridae	1		1
Pleidae			1
Veliidae	1		
Megaloptera			
Sialidae (alder flies)	1		
Trichoptera (caddisflies)			
Hydropsychidae	1		48
Hydroptilidae			55
Leptoceridae			1
Uenoidae			1
Coleoptera (beetles)			
Dytiscidae (total)			1
Hydrophilidae (total)			1
Elmidae	2		
Diptera (flies)			
Chironomidae	30	150	21
Ephydridae			1
Simuliidae	6	15	57
Tabanidae	1		1
Tipulidae			1
MOLLUSCA			
Gastropoda (snails)			
Ancylidae (limpets)	1	1	
Physidae	2		1
Planorbidae	1		1
TOTAL INDIVIDUALS	92	197	331

Table 4B. Macroinvertebrate metric evaluation at 15 1/2 Mile Road, Talmadge Creek, Calhoun County.

METRIC	Talmadge Creek 15 1/2 Mile Road 7/12/1999 STATION T3 Value	Score	Talmadge Creek 15 1/2 Mile Road 9/16/2010 STATION T3 Value	Score	Talmadge Creek 15 1/2 Mile Road 8/29/2011 STATION T3 Value	Score
TOTAL NUMBER OF TAXA	19	0	7	-1	24	0
NUMBER OF MAYFLY TAXA	1	0	1	-1	4	1
NUMBER OF CADDISFLY TAXA	1	-1	0	-1	4	0
NUMBER OF STONEFLY TAXA	0	-1	0	-1	0	-1
PERCENT MAYFLY COMP.	7.61	0	10.66	0	35.05	1
PERCENT CADDISFLY COMP.	1.09	-1	0.00	-1	31.72	1
PERCENT DOMINANT TAXON	32.61	0	76.14	-1	31.72	0
PERCENT ISOPOD, SNAIL, LEECH	4.35	0	0.51	1	0.60	1
PERCENT SURF. AIR BREATHERS	7.61	0	0.51	1	1.21	1
TOTAL SCORE	-3		-4		4	
MACROINV. COMMUNITY RATING	ACCEPT.		ACCEPT.		ACCEPT.	

Table 5A. Qualitative macroinvertebrate sampling results for sites on the Kalamazoo River in the vicinity of the Enbridge oil spill, Calhoun County, August 2011.

TAXA	Kalamazoo River Kalamazoo St. 8/31/2011 STATION K1	Kalamazoo River Squaw Lake Drain confluence 8/31/2011 STATION K2	Kalamazoo River 11-Mile Road 8/31/2011 STATION K3	Kalamazoo River Custer Drive 8/29/2011 STATION K4
PLATYHELMINTHES (flatworms)				
Turbellaria			2	
ANNELIDA (segmented worms)				
Hirudinea (leeches)			1	
Oligochaeta (worms)	1	1	19	2
ARTHROPODA				
Crustacea				
Amphipoda (scuds)	27	11	15	29
Decapoda (crayfish)		1	1	
Isopoda (sowbugs)	3	1		1
Arachnoidea				
Hydracarina	1	5		1
Insecta				
Ephemeroptera (mayflies)				
Baetidae	35	69	71	13
Caenidae		2		1
Ephemerellidae		3	1	
Heptageniidae	21	23	7	5
Isonychiidae	10	21	1	
Potamanthidae				2
Tricorythidae	10	18	9	8
Odonata				
Anisoptera (dragonflies)				
Aeshnidae	1		1	
Gomphidae	3		2	3
Zygoptera (damselflies)				
Calopterygidae	2	5	1	
Coenagrionidae	24	1	11	24
Plecoptera (stoneflies)				
Perlidae	1	2	1	
Pteronarcyidae	1		1	
Hemiptera (true bugs)				
Corixidae	2			
Gerridae	7	8	1	14
Pleidae	1	2		1
Veliidae		1		
Megaloptera				
Corydalidae (dobson flies)			1	
Trichoptera (caddisflies)				
Brachycentridae	20	5	2	1
Helicopsychidae	1	5		
Hydropsychidae	56	22	35	11
Hydroptilidae	1	3	1	5
Leptoceridae	5	9	5	1
Limnephilidae			1	
Philopotamidae	5	5		
Polycentropodidae	1	1	1	
Uenoidae		2	4	
Coleoptera (beetles)				
Dytiscidae (total)		1		
Gyrinidae (adults)	38			63
Haliplidae (adults)		1		
Hydrophilidae (total)		1		1
Elmidae	8	11	32	72
Psephenidae (larvae)		2		
Diptera (flies)				
Athericidae		1		
Chironomidae	9	19	9	4
Culicidae		1		
Simuliidae	30	30	3	1
Tabanidae	2	1	1	
Tipulidae		1		1
MOLLUSCA				
Gastropoda (snails)				
Ancylidae (limpets)	1			1
Hydrobiidae			6	
Physidae	1	4	4	1
Planorbidae	2	2	5	
Pleuroceridae	7	9	27	
Pelecypoda (bivalves)				
Corbiculidae	1	2	1	
Pisidiidae				1
Sphaeriidae (clams)	4	1	54	1
Unionidae (mussels)		1	1	
TOTAL INDIVIDUALS	342	314	338	268

Table 5B. Macroinvertebrate metric evaluation of sites on the Kalamazoo River in the vicinity of the Enbridge oil spill, Calhoun County, August, 2011.

METRIC	Kalamazoo River Kalamazoo St. 8/31/2011 STATION K1 Value	Score	Kalamazoo River Squaw Lake Drain confluence 8/31/2011 STATION K2 Value	Score	Kalamazoo River 11-Mile Road 8/31/2011 STATION K3 Value	Score	Kalamazoo River Custer Drive 8/29/2011 STATION K4 Value	Score
TOTAL NUMBER OF TAXA	35	1	42	1	36	1	27	1
NUMBER OF MAYFLY TAXA	4	1	6	1	5	1	5	1
NUMBER OF CADDISFLY TAXA	7	1	8	1	7	1	4	0
NUMBER OF STONEFLY TAXA	2	1	1	1	2	1	0	-1
PERCENT MAYFLY COMP.	22.22	1	43.31	1	26.33	1	10.82	0
PERCENT CADDISFLY COMP.	26.02	0	16.56	0	14.50	0	6.72	0
PERCENT DOMINANT TAXON	16.37	1	21.97	0	21.01	0	26.87	0
PERCENT ISOPOD, SNAIL, LEECH	4.09	0	5.10	0	12.72	-1	1.12	1
PERCENT SURF. AIR BREATHERS	14.04	0	4.78	1	0.30	1	29.48	-1
TOTAL SCORE	6		6		5		1	
MACROINV. COMMUNITY RATING	EXCELLENT		EXCELLENT		EXCELLENT		ACCEPT.	

Table 6A. Qualitative macroinvertebrate sampling results at Kalamazoo Street, Kalamazoo River, Calhoun County.

TAXA	Kalamazoo River Kalamazoo St. 9/18/1999 STATION K1	Kalamazoo River Kalamazoo St. 8/16/2004 STATION K1	Kalamazoo River Kalamazoo St. 9/9/2010 STATION K1	Kalamazoo River Kalamazoo St. 8/31/2011 STATION K1
PORIFERA (sponges)		1	1	
ANNELIDA (segmented worms)				
Hirudinea (leeches)			1	
Oligochaeta (worms)		1	1	1
ARTHROPODA				
Crustacea				
Amphipoda (scuds)	30	5	8	27
Decapoda (crayfish)		1	1	
Isopoda (sowbugs)		2	1	3
Arachnoidea				
Hydracarina	2	1	1	1
Insecta				
Ephemeroptera (mayflies)				
Baetidae	15	5	26	35
Caenidae		2	1	
Ephemerellidae		2		
Heptageniidae	4	5	22	21
Isonychiidae		1	3	10
Tricorythidae			3	10
Odonata				
Anisoptera (dragonflies)				
Aeshnidae	2	1		1
Gomphidae		1		3
Zygoptera (damselflies)				
Calopterygidae		1	1	2
Coenagrionidae	2	3	1	24
Plecoptera (stoneflies)				
Perlidae	6			1
Pteronarcyidae		1	2	1
Hemiptera (true bugs)				
Corixidae		5	1	2
Gerridae	2	1	1	7
Mesoveliidae		1		
Nepidae		1		
Pleidae			1	1
Megaloptera				
Sialidae (alder flies)		1		
Trichoptera (caddisflies)				
Brachycentridae	2	5	5	20
Glossosomatidae	2			
Helicopsychidae	4			1
Hydropsychidae	8	15	18	56
Hydroptilidae				1
Lepidostomatidae		1		
Leptoceridae		2	6	5
Limnephilidae	10	3		
Philopotamidae	4	1	2	5
Phryganeidae		1		
Polycentropodidae		2	1	1
Uenoidae		1		
Coleoptera (beetles)				
Gyrinidae (adults)		1	1	38
Elmidae	3	3	2	8
Gyrinidae (larvae)		1		
Psephenidae (larvae)			1	
Diptera (flies)				
Chironomidae	4	15	6	9
Simuliidae		5	196	30
Tabanidae		1	1	2
MOLLUSCA				
Gastropoda (snails)				
Ancylidae (limpets)	1	1	1	1
Physidae	2		1	1
Planorbidae		1		2
Pleuroceridae			2	7
Viviparidae		1		
Pelecypoda (bivalves)				
Corbiculidae		1	1	1
Pisidiidae	2			
Sphaeriidae (clams)	2	1	1	4
TOTAL INDIVIDUALS	107	104	321	342

Table 6B. Macroinvertebrate metric evaluation at Kalamazoo Street, Kalamazoo River, Calhoun County.

METRIC	Kalamazoo River Kalamazoo St. 9/18/1999 STATION K1 Value	Score	Kalamazoo River Kalamazoo St. 8/16/2004 STATION K1 Value	Score	Kalamazoo River Kalamazoo St. 9/9/2010 STATION K1 Value	Score	Kalamazoo River Kalamazoo St. 8/31/2011 STATION K1 Value	Score
TOTAL NUMBER OF TAXA	20	0	40	1	34	1	35	1
NUMBER OF MAYFLY TAXA	2	0	5	1	5	1	4	1
NUMBER OF CADDISFLY TAXA	6	1	9	1	5	1	7	1
NUMBER OF STONEFLY TAXA	1	1	1	1	1	1	2	1
PERCENT MAYFLY COMP.	17.76	0	14.42	0	17.13	0	22.22	1
PERCENT CADDISFLY COMP.	28.04	0	29.81	1	9.97	0	26.02	0
PERCENT DOMINANT TAXON	28.04	0	14.42	1	61.06	-1	16.37	1
PERCENT ISOPOD, SNAIL, LEECH	2.80	1	4.81	0	1.87	1	4.09	0
PERCENT SURF. AIR BREATHERS	1.87	1	8.65	0	1.25	1	14.04	0
TOTAL SCORE	4		6		5		6	
MACROINV. COMMUNITY RATING	ACCEPT.		EXCELLENT		EXCELLENT		EXCELLENT	

Table 7A. Qualitative macroinvertebrate sampling results downstream of 15 Mile Raod, Kalamazoo River, Calhoun County.

TAXA	Kalamazoo River Squaw Lake Drain confluence 9/15/2010 STATION K2	Kalamazoo River Squaw Lake Drain confluence 8/31/2011 STATION K2
PORIFERA (sponges)	1	
ANNELIDA (segmented worms)		
Oligochaeta (worms)	2	1
ARTHROPODA		
Crustacea		
Amphipoda (scuds)	43	11
Decapoda (crayfish)	2	1
Isopoda (sowbugs)	2	1
Arachnoidea		
Hydracarina		5
Insecta		
Ephemeroptera (mayflies)		
Baetidae	67	69
Caenidae		2
Ephemerellidae	1	3
Heptageniidae	22	23
Isonychiidae	11	21
Tricorythidae	10	18
Odonata		
Anisoptera (dragonflies)		
Aeshnidae	2	
Gomphidae	1	
Zygoptera (damselflies)		
Calopterygidae	13	5
Coenagrionidae	2	1
Plecoptera (stoneflies)		
Perlidae	1	2
Pteronarcyidae	1	
Hemiptera (true bugs)		
Belostomatidae	4	
Corixidae	3	
Gerridae		8
Nepidae	1	
Pleidae		2
Veliidae		1
Megaloptera		
Sialidae (alder flies)	2	
Trichoptera (caddisflies)		
Brachycentridae		5
Helicopsychidae	5	5
Hydropsychidae	10	22
Hydroptilidae	1	3
Leptoceridae	1	9
Limnephilidae	2	
Philopotamidae		5
Polycentropodidae		1
Uenoidae	6	2
Coleoptera (beetles)		
Dytiscidae (total)		1
Haliplidae (adults)		1
Hydrophilidae (total)		1
Elmidae	5	11
Psephenidae (larvae)		2
Diptera (flies)		
Athericidae		1
Ceratopogonidae	1	
Chironomidae	20	19
Culicidae		1
Simuliidae	27	30
Tabanidae	1	1
Tipulidae	3	1
MOLLUSCA		
Gastropoda (snails)		
Ancylidae (limpets)	1	
Hydrobiidae	6	
Lymnaeidae	17	
Physidae		4
Planorbidae		2
Pleuroceridae	1	9
Pelecypoda (bivalves)		
Corbiculidae	9	2
Sphaeriidae (clams)		1
Unionidae (mussels)	1	1
TOTAL INDIVIDUALS	308	314

Table 7B. Macroinvertebrate metric evaluation downstream of 15 Mile Road, Kalamazoo River, Calhoun County.

METRIC	Kalamazoo River Squaw Lake Drain confluence 9/15/2010 STATION K2 Value	Score	Kalamazoo River Squaw Lake Drain confluence 8/31/2011 STATION K2 Value	Score
TOTAL NUMBER OF TAXA	38	1	42	1
NUMBER OF MAYFLY TAXA	5	1	6	1
NUMBER OF CADDISFLY TAXA	6	1	8	1
NUMBER OF STONEFLY TAXA	2	1	1	1
PERCENT MAYFLY COMP.	36.04	1	43.31	1
PERCENT CADDISFLY COMP.	8.12	0	16.56	0
PERCENT DOMINANT TAXON	21.75	0	21.97	0
PERCENT ISOPOD, SNAIL, LEECH	8.77	0	5.10	0
PERCENT SURF. AIR BREATHERS	2.60	1	4.78	1
TOTAL SCORE	6		6	
MACROINV. COMMUNITY RATING	EXCELLENT		EXCELLENT	

Table 8a. Qualitative macroinvertebrate sampling results at 11 Mile Road, Kalamazoo River, Calhoun County.

TAXA	Kalamazoo River 11-Mile Rd 8/16/2004 STATION K3	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3	Kalamazoo River 11-Mile Rd 9/9/2010 STATION K3	Kalamazoo River 11-Mile Road 8/31/2011 STATION K3
PORIFERA (sponges)	1						
PLATYHELMINTHES (flatworms)							
Turbellaria		4					2
BRYOZOA (moss animals)	1						
ANNELIDA (segmented worms)							
Hirudinea (leeches)		1	1	1	3	3	1
Oligochaeta (worms)	1	13	18	20	19	4	19
ARTHROPODA							
Crustacea							
Amphipoda (scuds)	5	3	8	54	12		15
Decapoda (crayfish)	1	1	1	1	1	1	1
Isopoda (sowbugs)			2	1	2		
Arachnoidea							
Hydracarina	1	4	2			2	
Insecta							
Ephemeroptera (mayflies)							
Baetidae	5	42	46	26	48	54	71
Caenidae	2	2	1	2	5		
Ephemerellidae		1	1				1
Ephemeridae				1			
Heptageniidae	5	6	4	3	2	17	7
Isonychiidae	3	1	1	4	1	3	1
Tricorythidae	2	8	8	5	4	3	9
Odonata							
Anisoptera (dragonflies)							
Aeshnidae	1	1	1	1		1	1
Gomphidae	1	1	1	1	1	2	2
Libellulidae	1		1				
Macromiidae			1				
Zygoptera (damselflies)							
Calopterygidae	2	2	13	1	11	3	1
Coenagrionidae	2	4	3	16	2	7	11
Plecoptera (stoneflies)							
Perlidae	2						1
Pteronarcyidae			1			1	1
Hemiptera (true bugs)							
Belostomatidae		1		1			
Corixidae	5	3	15	8	7		
Gerridae	1	1	1	2	2		1
Mesoveliidae	1	1	2	5	1		
Naucoridae				1			
Notonectidae			1				
Pleidae	1		1	2	1		
Saldidae					1		
Veliidae					1		
Megaloptera							
Corydalidae (dobson flies)	1		1		1	2	1
Sialidae (alder flies)	1	1	1	3			
Neuroptera (spongilla flies)							
Sisyridae	1						
Trichoptera (caddisflies)							
Brachycentridae		2	3	10	1		2
Glossosomatidae			1				
Helicopsychidae	1	8	9	8	4		
Hydropsychidae	12	45	48	19	29		35
Hydroptilidae		4	17	6	8	1	1
Lepidostomatidae			1				
Leptoceridae	1	1	3	1	1	2	5
Limnephilidae	3	1	1				1
Philopotamidae	1	1					
Phryganeidae	1						

Table 8a. Qualitative macroinvertebrate sampling results at 11 Mile Road, Kalamazoo River, Calhoun County.

TAXA	Kalamazoo River 11-Mile Rd 8/16/2004 STATION K3	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3	Kalamazoo River 11-Mile Rd 9/9/2010 STATION K3	Kalamazoo River 11-Mile Road 8/31/2011 STATION K3
Polycentropodidae	2	2	1	1	1		1
Uenoidae	2	2	1	1	1	3	4
Lepidoptera (moths)							
Pyralidae			1	1	1		
Coleoptera (beetles)							
Dytiscidae						1	
Gyrinidae (adults)	1	1	1			1	
Haliplidae (adults)		1	1	4	1	15	
Hydrophilidae (total)	1	1	1				
Elmidae	2	9	6	6	5	7	32
Gyrinidae (larvae)				1	1		
Psephenidae (larvae)			1	1		1	
Scirtidae (larvae)		1					
Diptera (flies)							
Ceratopogonidae	1			2	1		
Chironomidae	12	21	20	51	23	18	9
Culicidae				4			
Ptychopteridae			1				
Simuliidae	5	22	21	2	9		3
Tabanidae		3	1	1	2		1
Tipulidae		1	1	1			
MOLLUSCA							
Gastropoda (snails)							
Ancylidae (limpets)	1	1	1		2	1	
Hydrobiidae		29	10	73	87	3	6
Lymnaeidae						5	
Physidae		3	1	4	3		4
Planorbidae	1	4	6	7	11	1	5
Pleuroceridae		100	90	21	17	86	27
Valvatidae	1						
Viviparidae		1	2	1	2		
Pelecypoda (bivalves)							
Corbiculidae	1	1	1	1	1	2	1
Sphaeriidae (clams)	1	22	10	20	9	49	54
Unionidae (mussels)	1	1	1	1	1	1	1
TOTAL INDIVIDUALS	98	389	398	407	346	300	338

Table 8b. Macroinvertebrate metric evaluation at 11 Mile Road, Kalamazoo River, Calhoun County.

METRIC	Kalamazoo River 11-Mile Rd 8/16/2004 STATION K3 Value	Score	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3 Value	Score	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3 Value	Score	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3 Value	Score	Kalamazoo River 11-Mile Rd 8/27/2008 STATION K3 Value	Score	Kalamazoo River 11-Mile Rd 9/9/2010 STATION K3 Value	Score	Kalamazoo River 11-Mile Road 8/31/2011 STATION K3 Value	Score
TOTAL NUMBER OF TAXA	44	1	48	1	56	1	48	1	44	1	31	1	36	1
NUMBER OF MAYFLY TAXA	5	1	6	1	6	1	6	1	5	1	4	1	5	1
NUMBER OF CADDISFLY TAXA	8	1	9	1	10	1	7	1	7	1	3	0	7	1
NUMBER OF STONEFLY TAXA	1	1	0	-1	1	1	0	-1	0	-1	1	1	2	1
PERCENT MAYFLY COMP.	17.35	0	15.42	0	15.33	0	10.07	0	17.34	0	25.67	1	26.33	1
PERCENT CADDISFLY COMP.	23.47	0	16.97	0	21.36	0	11.30	0	13.01	0	2.00	-1	14.50	0
PERCENT DOMINANT TAXON	12.24	1	25.71	0	22.61	0	17.94	1	25.14	0	28.67	0	21.01	0
PERCENT ISOPOD, SNAIL, LEECH	3.06	1	35.73	-1	28.39	-1	26.54	-1	36.71	-1	33.00	-1	12.72	-1
PERCENT SURF. AIR BREATHERS	10.20	0	2.31	1	6.03	1	6.63	1	4.05	1	5.67	1	0.30	1
TOTAL SCORE	6		2		4		3		2		3		5	
MACROINV. COMMUNITY RATING	EXCELLENT		ACCEPT.		ACCEPT.		ACCEPT.		ACCEPT.		ACCEPT.		EXCELLENT	

Table 9a. Qualitative macroinvertebrate sampling results at Custer Drive, Kalamazoo River, Calhoun County.

TAXA	Kalamazoo River Custer Drive 9/9/1994 STATION K4	Kalamazoo River Custer Drive 8/17/2004 STATION K4	Kalamazoo River Custer Drive 9/15/2009 STATION K4	Kalamazoo River Custer Drive 9/15/2010 STATION K4	Kalamazoo River Custer Drive 8/29/2011 STATION K4
PORIFERA (sponges)				1	
PLATYHELMINTHES (flatworms)					
Turbellaria	2				
BRYOZOA (moss animals)		1			
ANNELIDA (segmented worms)					
Oligochaeta (worms)				1	2
ARTHROPODA					
Crustacea					
Amphipoda (scuds)	20	20	56	13	29
Decapoda (crayfish)		1	1		
Isopoda (sowbugs)	1	1	2	3	1
Arachnoidea					
Hydracarina					1
Insecta					
Ephemeroptera (mayflies)					
Baetiscidae			1		
Baetidae		5	16	12	13
Caenidae	2			1	1
Ephemerellidae	25	1			
Heptageniidae	2	5	1	4	5
Potamanthidae					2
Tricorythidae		5	3	2	8
Odonata					
Anisoptera (dragonflies)					
Aeshnidae	2	1	1	1	
Gomphidae			2	7	3
Libellulidae			3		
Zygoptera (damselflies)					
Calopterygidae	2	2		2	
Coenagrionidae	8	1	12	34	24
Plecoptera (stoneflies)					
Perlidae			1		
Perlodidae	1				
Pteronarcyidae			1		
Hemiptera (true bugs)					
Belostomatidae	2		1		
Corixidae		3			
Gerridae		1	2	1	14
Mesoveliidae	3	1			
Naucoridae	1				
Pleidae	1	1	1		1
Veliidae			2		
Megaloptera					
Corydalidae (dobson flies)			1		
Sialidae (alder flies)	1				
Trichoptera (caddisflies)					
Brachycentridae		5	5	6	1
Hydropsychidae	4	5	103	54	11
Hydroptilidae					5
Leptoceridae			3		1
Limnephilidae		2			
Molannidae			2		
Philopotamidae	1		2		
Phryganeidae			1		
Polycentropodidae		1			
Coleoptera (beetles)					
Dytiscidae (total)			1		
Gyrinidae (adults)		1	1		63
Hydrophilidae (total)					1
Elmidae	2	2	16		72
Diptera (flies)					
Chironomidae	16	35	54	21	4
Culicidae		1			
Simuliidae	4	3	2		1
Tipulidae					1
MOLLUSCA					
Gastropoda (snails)					
Ancylidae (limpets)	1		6	12	1
Physidae		1	4	2	1
Planorbidae				1	
Pleuroceridae			1		
Viviparidae		1			
Pelecypoda (bivalves)					
Corbiculidae		1		7	
Pisidiidae					1
Sphaeriidae (clams)	1	1			1
Unionidae (mussels)		1	1		
TOTAL INDIVIDUALS	102	109	309	185	268

Table 9b. Macroinvertebrate metric evaluation at Custer Drive, Kalamazoo River, Calhoun County.

METRIC	Kalamazoo River Custer Drive 9/9/1994 STATION K4 Value	Score	Kalamazoo River Custer Drive 8/17/2004 STATION K4 Value	Score	Kalamazoo River Custer Drive 9/15/2009 STATION K4 Value	Score	Kalamazoo River Custer Drive 9/15/2010 STATION K4 Value	Score	Kalamazoo River Custer Drive 8/29/2011 STATION K4 Value	Score
TOTAL NUMBER OF TAXA	22	0	29	1	33	1	20	0	27	1
NUMBER OF MAYFLY TAXA	3	0	4	1	4	1	4	1	5	1
NUMBER OF CADDISFLY TAXA	2	0	4	0	6	1	2	0	4	0
NUMBER OF STONEFLY TAXA	1	1	0	-1	2	1	0	-1	0	-1
PERCENT MAYFLY COMP.	28.43	1	14.68	0	6.80	0	10.27	0	10.82	0
PERCENT CADDISFLY COMP.	4.90	0	11.93	0	37.54	1	32.43	1	6.72	0
PERCENT DOMINANT TAXON	24.51	0	32.11	0	33.33	0	29.19	0	26.87	0
PERCENT ISOPOD, SNAIL, LEECH	1.96	1	2.75	1	4.21	0	9.73	0	1.12	1
PERCENT SURF. AIR BREATHERS	6.86	1	7.34	0	2.59	1	0.54	1	29.48	-1
TOTAL SCORE	4		2		6		2		1	
MACROINV. COMMUNITY RATING	ACCEPT.		ACCEPT.		EXCELLENT		ACCEPT.		ACCEPT.	

Table 10. Habitat evaluation for sites in the vicinity of the Enbridge oil spill, Talmadge Creek, Calhoun County, August 2011.

HABITAT METRIC	Station T1 Talmadge Creek 17 Mile Road GLIDE/POOL	Station T2 Talmadge Creek downstream 17 Mile Road GLIDE/POOL	Station T3 Talmadge Creek 15 1/2 Mile Road RIFFLE/RUN
Substrate and Instream Cover			
Epifaunal Substrate/ Avail Cover (20)	3	11	8
Embeddedness (20)*			8
Velocity/Depth Regime (20)*			10
Pool Substrate Characterization (20)**	6	13	
Pool Variability (20)**	6	8	
Channel Morphology			
Sediment Deposition (20)	6	8	15
Flow Status - Maint. Flow Volume (10)	9	9	9
Flow Status - Flashiness (10)	9	9	8
Channel Alteration (20)	11	15	10
Frequency of Riffles/Bends (20)*			13
Channel Sinuosity (20)**	6	11	
Riparian and Bank Structure			
Bank Stability (L) (10)	9	9	9
Bank Stability (R) (10)	9	9	9
Vegetative Protection (L) (10)	9	10	3
Vegetative Protection (R) (10)	9	10	3
Riparian Veg. Zone Width (L) (10)	9	10	7
Riparian Veg. Zone Width (R) (10)	9	10	7
TOTAL SCORE (200):	110	142	119
HABITAT RATING:	GOOD (SLIGHTLY IMPAIRED)	GOOD (SLIGHTLY IMPAIRED)	GOOD (SLIGHTLY IMPAIRED)

Note: Individual metrics may better describe conditions directly affecting the biological community while the Habitat Ratin
describes the general riverine environment at the site(s).
* Applies only to Riffle/Run stream Surveys
** Applies only to Glide/Pool stream Surveys

Date:	8/29/2011		8/29/2011		8/29/2011	
Weather:	Sunny		Sunny		Partly Cloudy	
Air Temperature:	60	Deg. F.	72	Deg. F.	80	Deg. F.
Water Temperature:	60	Deg. F.	68	Deg. F.	75	Deg. F.
Ave. Stream Width:	3	Feet	6	Feet	12	Feet
Ave. Stream Depth:	0.3	Feet	0.3	Feet	0.2	Feet
Surface Velocity:	0.5	Ft./Sec.	0.5	Ft./Sec.	0.9	Ft./Sec.
Estimated Flow:	0.45	CFS	0.9	CFS	2.16	CFS
Stream Modifications:	Dredged		None		Bank Stabilization	
Nuisance Plants (Y/N):	N		N		N	
STORET No.:	130336		130405		130335	
Stream Name:	Talmadge Creek		Talmadge Creek		Talmadge Creek	
Road Crossing/Location:	17 Mile Road		downstream 17 Mile Road		15 1/2 Mile Road	
County Code:	13		13		13	
TRS:	03S06W01		03S06W02		02S06W34	
Latitude (dd):	42.2394598		42.2402		42.251717	
Longitude (dd):	-84.9632235		-84.97066		-84.9885712	
Ecoregion:	SMNITP		SMNITP		SMNITP	
Stream Type:	Warmwater		Warmwater		Warmwater	
USGS Basin Code:	4050003		4050003		4050003	
COMMENTS:	Wetland habitat				The riparian zone and the stream channel have been subjected to major alterations during clean up operations	

Table 11. Habitat evaluation for sites in the vicinity of the Enbridge oil spill, Kalamazoo River, Calhoun County, August 2011.

HABITAT METRIC	Station K1 Kalamazoo River Kalamazoo St. GLIDE/POOL	Station K2 Kalamazoo River Squaw Lake Drain confluence GLIDE/POOL	Station K3 Kalamazoo River 11-Mile Road RIFFLE/RUN	Station K4 Kalamazoo River Custer Drive GLIDE/POOL
Substrate and Instream Cover				
Epifaunal Substrate/ Avail Cover (20)	16	13	13	6
Embeddedness (20)*			16	
Velocity/Depth Regime (20)*			16	
Pool Substrate Characterization (20)**	16	16		10
Pool Variability (20)**	16	11		8
Channel Morphology				
Sediment Deposition (20)	14	16	10	11
Flow Status - Maint. Flow Volume (10)	9	9	9	8
Flow Status - Flashiness (10)	7	8	6	4
Channel Alteration (20)	16	18	18	13
Frequency of Riffles/Bends (20)*			11	
Channel Sinuosity (20)**	15	11		6
Riparian and Bank Structure				
Bank Stability (L) (10)	8	9	8	7
Bank Stability (R) (10)	8	9	8	7
Vegetative Protection (L) (10)	7	9	5	9
Vegetative Protection (R) (10)	7	6	9	9
Riparian Veg. Zone Width (L) (10)	3	10	5	9
Riparian Veg. Zone Width (R) (10)	4	3	9	9
TOTAL SCORE (200):	146	148	143	116
HABITAT RATING:	GOOD (SLIGHTLY IMPAIRED)	GOOD (SLIGHTLY IMPAIRED)	GOOD (SLIGHTLY IMPAIRED)	GOOD (SLIGHTLY IMPAIRED)

Note: Individual metrics may better describe conditions directly affecting the biological community while the Habitat Rating describes the general riverine environment at the site(s).
* Applies only to Riffle/Run stream Surveys
** Applies only to Glide/Pool stream Surveys

Date:	8/31/2011	8/31/2011	8/31/2011	8/29/2011
Weather:	Cloudy	Partly Cloudy	Partly Cloudy	Sunny
Air Temperature:	72 Deg. F.	76 Deg. F.	83 Deg. F.	82 Deg. F.
Water Temperature:	70 Deg. F.	69 Deg. F.	72 Deg. F.	72 Deg. F.
Ave. Stream Width:	120 Feet	200 Feet	150 Feet	360 Feet
Ave. Stream Depth:	3 Feet	1.5 Feet	1.5 Feet	2.9 Feet
Surface Velocity:	1 Ft./Sec.	1.25 Ft./Sec.	1.25 Ft./Sec.	0.6 Ft./Sec.
Estimated Flow:	360 CFS	375 CFS	281.25 CFS	626.4 CFS
Stream Modifications:	None	None	None	Dredged
Nuisance Plants (Y/N):	N	N	N	N
STORET No.:	130211	130406	130048	130052
Stream Name:	Kalamazoo River	Kalamazoo River	Kalamazoo River	Kalamazoo River
Road Crossing/Location:	Kalamazoo St.	Squaw Lake Drain confluence	11-Mile Road	Custer Drive
County Code:	13	13	13	13
TRS:	02S06W26	02S06W33	02S07W25	01S08W29
Latitude (dd):	42.26391	42.25852	42.27429	42.35074
Longitude (dd):	-84.96836	-85.00469	-85.08097	-85.27561
Ecoregion:	SMNITP	SMNITP	SMNITP	SMNITP
Stream Type:	Warmwater	Warmwater	Warmwater	Warmwater
USGS Basin Code:	4050003	4050003	4050003	4050003
COMMENTS:		Impacted by oil spill clean up operations	Impacted by oil spill clean up operations	Impacted by oil spill clean up operations

Appendix H3: Macroinvertebrate Report 2012

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER RESOURCES DIVISION
APRIL 2013

STAFF REPORT

A BIOLOGICAL SURVEY OF SITES ON THE KALAMAZOO RIVER AND TALMADGE CREEK NEAR THE ENBRIDGE OIL SPILL IN MARSHALL CALHOUN COUNTY, MICHIGAN SEPTEMBER 2012

INTRODUCTION

On July 26, 2010, a 30-inch diameter pipeline ruptured and discharged heavy crude oil into Talmadge Creek, a tributary to the Kalamazoo River, which drains into Lake Michigan. The amount of oil discharged is estimated at 819,000 to 1,000,000 gallons. The oil flowed down 2.2 miles of Talmadge Creek, a small designated warmwater stream, before entering the Kalamazoo River downstream of Marshall, Michigan. The Kalamazoo River is also a designated warmwater stream that is bordered by wetland, forest, residential properties, farm land, and commercial properties for the approximate 35-mile stretch of impacted river in Calhoun and Kalamazoo Counties between Marshall and Morrow Lake.

In September 2010, staff of the Surface Water Assessment Section (SWAS), Water Resources Division (WRD), Michigan Department of Environmental Quality (MDEQ), with assistance from Entrix (currently Cardno ENTRIX), conducted qualitative macroinvertebrate community and stream habitat surveys on the Kalamazoo River and Talmadge Creek. The survey documented that macroinvertebrate abundance and diversity were drastically reduced in both water bodies because of the oil spill and associated cleanup activities (Walterhouse, 2011). SWAS and Entrix staff also assisted staff of the Michigan Department of Natural Resources (MDNR), Fisheries Division, with fish collection efforts and quantitative stream habitat assessments. The MDNR, Fisheries Division, reported reduced fish abundance and diversity along with impacts to stream habitat in Talmadge Creek (Wesley and Walterhouse, 2010a). Fish community diversity and catch also declined at two of the three sites on the Kalamazoo River, which were impacted by the oil spill and cleanup activities.

In August 2011, SWAS staff again conducted qualitative macroinvertebrate community and stream habitat surveys on the Kalamazoo River and Talmadge Creek. The objective of these surveys was to monitor the short- and long-term effects of the oil spill and associated cleanup activities on macroinvertebrate communities and aquatic habitat. Macroinvertebrate abundance and diversity reported in 2011 (Walterhouse, 2012) in Talmadge Creek were found to have improved from results collected in 2010 (Walterhouse, 2011) in the sections of stream where cleanup activities were conducted, but were still found to be impacted when compared to upstream sites. No oil sheen or odor was noted during the 2011 surveys in Talmadge Creek as both odor and sheen had been observed in 2010. Kalamazoo macroinvertebrate abundance and diversity also improved when compared to 2010 data, but abundance was still impacted when compared to historic data. Oil sheen along with petroleum odor was noted at some Kalamazoo River site locations when sampling near depositional areas. Shallow riffle habitat at Stations K2 and K3 (Figure 1), which were described as having been severely disturbed by cleanup activities during the 2010 survey, were noted in 2011 as recovering with noticeable new colonization of periphyton and macroinvertebrates. Sediment deposition, particularly downstream of Battle Creek, was noted as appearing to have increased by both depth and

aerial coverage during the 2011 surveys. Complete results are available in the 2011 MDEQ report (Walterhouse, 2011).

In September 2012, SWAS staff conducted additional qualitative macroinvertebrate community and stream habitat surveys on the Kalamazoo River and Talmadge Creek. The objective of these surveys was to continue to monitor the short- and long-term effects of the oil spill and associated cleanup activities on macroinvertebrate communities and aquatic habitat. Future surveys will be conducted to monitor the long-term effects of the oil spill and associated cleanup activities on the fish and macroinvertebrate communities and aquatic habitat (Wesley and Walterhouse, 2010b).

SWAS staff also assisted the MDNR, Fisheries Division, with fish collection and quantitative stream habitat assessments. The MDNR, Fisheries Division, is preparing a separate report which details the fish and quantitative stream habitat sampling efforts.

METHODS

The sites selected for this survey were specifically chosen because of historic (i.e., baseline) surveys that were conducted prior to the oil spill (Wesley and Walterhouse, 2010a) and the fact that they were used in previous years for monitoring the long-term effects of the oil spill and associated cleanup activities. An additional site (Station T2, Figure 1) on Talmadge Creek was added in 2011 just upstream of the oil spill because stream flow at the historic control site further upstream (Station T1, Figure 2) at 17 Mile Road was minimal. Station T1 could not be sampled due to low water in 2012. Station T2 (Figure 4) is similar in width and flow to the impacted reach at Station T3. The surveys described in this report were conducted according to the SWAS Procedure 51 (MDEQ, 1990; Creal et al., 1996). The macroinvertebrate communities were scored with metrics that rate water bodies from excellent (+5 to +9) to poor (-5 to -9). Macroinvertebrate ratings from +4 to -4 are considered acceptable. Negative ratings that are acceptable indicate water bodies that are tending toward poor, while positive ratings that are acceptable indicate slight impairment (Creal et al., 1996). Stream habitat was qualitatively evaluated at each station using a scoring system that ranged from 0 (poor) to 200 (excellent).

Sampling locations are shown in Figure 1.

SUMMARY AND OBSERVATIONS

Qualitative macroinvertebrate scores and ratings alone do not adequately measure the impact of the oil spill and associated cleanup activities.

Cleanup and channel restoration activities in Talmage Creek continued after the August 2011 survey was completed due to discoveries of undetected oil spill deposits, which required removal. Macroinvertebrate abundance and diversity in Talmadge Creek, downstream of the oil spill where cleanup operations have altered the in-stream and riparian habitat (Station T3, Figure **1**), are much improved in 2012 compared to 2010 data and are similar to 2011 data (Table 1 and 2). The stream channel has been nearly entirely exposed to sunlight for the past two years (Figure 4), which appears to have increased productivity at least in terms of taxa diversity (Table 2 and 4). Station T3 appears to still show signs of impact from the oil spill, consistent with 2011 sampling results, in that the macroinvertebrate species composition at Station T3 is much different from Station T2 (upstream of the oil spill and cleanup activities, Figure 4) and is dominated by species known to reach high densities during the early stages of recolonization (Mackay, 1992). The total number of taxa (Table 2) was slightly higher at

Station T3 and the overall macroinvertebrate Procedure 51 scores at Stations T2 and T3 were both in the “acceptable” category (Table 1).

Kalamazoo River sites reported scores similar to 2011 results (Table 1) with Sites K2, K3, and K4 all showing slight increases in overall scores. The score at Site K1 decreased from +6 in 2011 to +3 in 2012. This decrease can mainly be attributed to the fact that no stoneflies were collected in 2012 during the survey.

Oil sheen or odor was not noted during sampling at any of the Talmadge Creek or Kalamazoo River sites in 2012, but a slight oil sheen was noted in the sampling bucket while processing at the most downstream site (K4). Limited observations of areas of Talmadge Creek and the Kalamazoo River where stream bank erosion issues developed during response and cleanup activities appeared to continue to be stabilized with various stream bank stabilization techniques.

Table 1. Qualitative Macroinvertebrate scores from Procedure 51 surveys conducted over multiple years at Kalamazoo River (K) and Talmadge Creek (T) sites (Figure 1).

	Years							
Station	**1994**	**1999**	**2004**	**2008**	**2009**	**2010**	**2011**	**2012**
T1	--	2	--	--	--	-1	0	--[2]
T2	--	--	--	--	--	1	1	0
T3	--	-3	--	--	--	-4	4	3
K1	--	4	6	--	--	5	6	3
K2	--	--	--	--	--	6	6	8
K3	--	--	6	2,4,3,2[1]	--	3	5	6
K4	4	--	2	--	6	2	1	4

(+5 to +9) Excellent (+4 to -4) Acceptable (-5 to -9) Poor
Surveys conducted prior to 2008 used a Procedure 51 protocol, which only required a macroinvertebrate sample size of 100 compared to the requirement of 300 after the revision.
[1] Location was scored multiple times in 2008 as part of a quality assurance/quality control (QA/QC) process.
[2]Location was not sampled due to low water levels.

Table 2. Total number of taxa recorded from Procedure 51 surveys conducted over multiple years at Kalamazoo River and Talmadge Creek sites (Figure 1).

	Years							
Station	**1994**	**1999**	**2004**	**2008**	**2009**	**2010**	**2011**	**2012**
T1	--	17	--	--	--	14	14	--[2]
T2	--	--	--	--	--	27	26	28
T3	--	19	--	--	--	7	24	30
K1	--	20	40	--	--	34	35	40
K2	--	--	--	--	--	38	42	38
K3	--	--	44	48,56,48,44[1]	--	31	36	42
K4	22	--	29	--	33	20	27	28

[1] Location was scored multiple times in 2008 as part of a QA/QC process.
[2]Location was not sampled due to low water levels.
Surveys conducted prior to 2008 used a Procedure 51 protocol, which only required a macroinvertebrate sample size of 100 compared to the requirement of 300 after the revision.

SAMPLING RESULTS

Talmadge Creek - Macroinvertebrates

The 2012 macroinvertebrate community sampling results for stations (T2, T3, Figure 1) on Talmadge Creek are presented in Table 3. Macroinvertebrate metrics, scores, and ratings for these sites are located in Table 4. Station T1, which had been sampled in past years, was not sampled in 2012 due to lack of flow and low water levels (Figure 2). Station T2 (Figure 4) was sampled to serve as a control station for comparison to Station T3, which is in the impacted portion of Talmadge Creek. The results from these two stations in 2012 are very similar to documented results from 2011 (Walterhouse, 2012). Station T3 received a higher score (3) than the control site (0) and had a slightly greater diversity of invertebrates. Station T3 was highly disturbed by cleanup activities since 2010 and is in a continuing state of recovery. The macroinvertebrate community present at Station T3 is different in species composition when compared to the upstream control at Station T2 and is dominated by species commonly associated with areas that have been disturbed and in the early stages of recolonization (Mackay, 1992). The removal of trees, shrubs, herbaceous plants, and grasses during the response activity has allowed for direct sunlight to reach the stream by opening the vegetated canopy (Figure 3). This increase in direct sunlight has allowed for the proliferation of filamentous algal growth on the stream substrate, which is not present in such quantity at the upstream control station (T2). Blackflies (Simulidae), midges (Chironomidae), and mayflies (Baetidae), which are some of the first species to appear in highly disturbed areas (Mackay, 1992), were prevalent at Station T3 while being absent or at much lesser concentrations at Station T2.

The comparable results from 2011 and 2012 are not unexpected as the stream channel was once again disturbed by additional cleanup activities after the 2011 surveys took place, which likely set back recovery. Additional years of assessment will be needed to fully document short- and long-term impacts associated with the oil spill and response activities.

Kalamazoo River - Macroinvertebrates

The 2012 macroinvertebrate results for the Kalamazoo River sites (K1, K2, K3, and K4) are presented in Table 5. Macroinvertebrate metrics, scores, and ratings are presented in Table 6. The stations are situated in an upstream to downstream sequence as depicted in Figure 1. The control station on the Kalamazoo River was upstream of the oil spill in Marshall at Kalamazoo Street (Station K1). Three sites on the Kalamazoo River were surveyed in the reach impacted by the oil spill and the associated cleanup activities. Station K2 was located on the Kalamazoo River in the vicinity of the Squaw Lake Drain confluence at about Mile Post 2.75. Station K3 was downstream of the Ceresco Dam at 11 Mile Road approximately at Mile Post 7.25. Station K4 on the Kalamazoo River was located downstream of the city of Battle Creek at Custer Drive at about Mile Post 21.25.

The upstream control site (K1) had an overall macroinvertebrate score of +3 and rating of acceptable. This score is down from the 2011 survey results of (+6/excellent). The reduction in score between the 2011 and 2012 (Table 1) results is largely attributed to the fact that no stoneflies (Plecoptera) were noted in 2012 at this location where two individuals were recorded in 2011. Besides the absence of stoneflies, the overall species composition at Station K1 in 2012 was very similar to 2011 results, with more taxa actually being recorded in 2012 (Table 2).

Station K2 received a score of +8 and a rating of “excellent,” which is a slight increase from the 2010 and 2011 rating of excellent (+6). Species composition and diversity was similar to 2011

with 42 taxa recorded in 2011 and 38 identified in 2012. The increase in score can be attributed to a slight decrease in percent dominant taxa and slight increase in percent caddisfly composition.

Downstream at Station K3, the score was +6 with a rating of "excellent." This station harbored the most diversity of the 2012 Kalamazoo River locations with 42 taxa recorded. The score is a slight increase from +5 in 2011 (Table 1).

Station K4, the most downstream location, produced a score of +4 and a rating of acceptable. As it did in 2010 and 2011, this site produced the least diversity with 28 species documented. This reduction in number of taxa can likely be attributed to the lack of diversity of in-stream substrates, which were abundant at upstream locations. This score is an increase from the score of +1 recorded in 2011. The species composition was similar to that recorded in 2011 (Table 1); a slight change in the percentage composition of some species was the cause of this increase in score.

Macroinvertebrate Abundance

Procedure 51 is a qualitative collection method that involves sampling all available in-stream habitats to produce a composite macroinvertebrate sample that is typically sub-sampled until 300 organisms have been identified and counted. After 300 organisms have been counted, the remainder of the composite sample is examined for large and/or rare organisms that were not identified in the initial sub-samples. These organisms are added as one individual to the total taxa list. Typically, only a small volume of the composite sample is needed to yield the 300 organisms required by Procedure 51. This is especially true in streams such as the Kalamazoo River that have a diversity of in-stream habitat types, especially in riffle habitats like those present at Stations K2 and K3. The majority of the sample is typically examined for large and/or rare taxa. Counting the entire composite sample is seldom necessary, except in streams that are either habitat-limited or have serious violations of Michigan's Water Quality Standards. Macroinvertebrate abundance in the composite samples at the upstream control sites on Talmadge Creek (Stations T1 and T2) and the Kalamazoo River (Station K1) was normal in 2010 and 2011. The abundance of macroinvertebrates in the composite samples collected at all of the impacted sites on Talmadge Creek (Station T3) and Kalamazoo River (Stations K2, K3, and K4) in 2010 was so low that the entire composite sample was counted at all of the sites and the goal of enumerating 300 organisms was not achieved at Station T3 on Talmadge Creek and Station K4 on the Kalamazoo River.

In 2011, the abundance of macroinvertebrates was greater than in 2010 at all of the impacted sites on Talmadge Creek and the Kalamazoo River. It was still necessary to count the entire macroinvertebrate composite sample at the impacted site (Station T3) on Talmadge Creek and two stations (K2 and K4) of the three impacted sites on the Kalamazoo River. The abundance of macroinvertebrates at Station K4 was extremely limited.

In 2012, the abundance of macroinvertebrates was improved relative to results found in 2011 at the impacted sites on Talmadge Creek and the Kalamazoo River in that none of the sites required the complete enumeration of the entire contents of the composite sample. Abundance at Station K4 was still limited in comparison to the upstream sites.

Talmage Creek - Stream Habitat

Qualitative stream habitat assessment results for 2012 in Talmadge Creek are presented in

Table 7. Stations T2 and T3 both were rated “good,” with Station T2 scoring 138 and Station T3 scoring 125 out of a possible 200. These scores are nearly identical to 2010 results, as little has changed. Again, because of lack of flow and minimal water, Station T1 was not evaluated as it had been in past years.

Riffle habitat at Station T2 was lacking and sand was the predominant substrate, but some gravel and cobble were present along with an abundance of in-stream cover. The riparian corridor was a wide, undisturbed scrub/shrub wetland.

In 2010, the in-stream habitat, stream banks, and adjacent riparian corridor at Station T3 were highly disturbed due to the cleanup activities and were rated as marginal. In 2011, after the August 2011 survey, additional cleanup operations were conducted on Talmadge Creek that involved dredging the stream banks and channel. The overall 2012 habitat score was slightly higher than in 2011, but still on the lower end of “good.” The stream banks and riparian zone were stabilized with vegetative cover and various structures. The stream channel remains narrower than in 2010. Riffle habitat was present, but in-stream cover was still extremely limited. The substrate was primarily sand and small gravel with a limited amount of cobble still present. The disturbance from cleanup activities has effectively created a clean channel that is silt free.

Kalamazoo River - Stream Habitat

The qualitative stream habitat scores for 2012 are presented in Table 8. Results are very similar to the 2011 evaluation. All sites were scored as glide/pool habitat except for Station K3, which had significant riffle/run habitat and was scored as such.

At the upstream control site, Station K1 (17 Mile Road) in-stream habitat was abundant and included moderate amounts of large woody debris, aquatic vegetation, and root wads. The stream substrate was diverse with a nearly equal mixture of cobble, gravel, sand, and silt along with scattered boulders. The only significant detraction from the overall habitat score was the limited width of the riparian zone. This site scored “good” as it did in 2011.

Station K2 (Squaw Lake Drain Confluence) scored on the lower end of “excellent” in comparison to its upper end of “good” rating in 2011. The total score at Station K2 only differed by 7 points with the site receiving 148 in 2011, and 155 in 2012, out of a total of 200 points. In-stream cover was slightly higher and sediment deposition was rated as slightly lower in 2012. The dominant substrates were cobble and gravel with lesser amounts of sand, silt, and boulders. Submergent aquatic vegetation is still only beginning to become established and was present in about 15 percent of the reach.

Station K3 (11 Mile Road) received the exact same score as in 2011, and was rated on the upper end of “good.” Cobble and gravel were the dominant substrates along with scattered boulders and lesser amounts of sand and silt along the stream margins. Others forms of in-stream cover that were still moderately abundant included large woody debris, aquatic vegetation, and root wads. Cleanup operations had nearly eliminated all overhanging vegetation, but regrowth along the river edge is evident. Substantial depositional areas are still observed at this site.

Station K4 (Upstream of Custer Road), is substantially larger in average width and depth than the other sites surveyed (Figure 5). This station was rated “good;” the same as in 2011. The in-stream habitat suitable for colonization is limited at this site, but the wide, forested floodplain helps to increase its habitat score. Sand and silt make up approximately 85 percent of the

substrate at this site, with only small, scattered patches of gravel present. Large woody debris resulting from dead trees and wind storms make up the majority of in-stream habitat. Aquatic vegetation, overhanging vegetation, and undercut banks are also present in limited quantities at this location.

Report by: John Matousek, Aquatic Biologist
Surface Water Assessment Section
Water Resources Division
Michigan Department of Environmental Quality

Field Work by: Mike Walterhouse, Aquatic Biologist
John Matousek, Aquatic Biologist
Surface Water Assessment Section
Water Resources Division
Michigan Department of Environmental Quality

Literature Cited

Creal, W., S. Hanshue, S. Kosek, M. Oemke, and M. Walterhouse. 1996. Update of GLEAS Procedure 51 Metric Scoring and Interpretation. MDEQ Staff Report #MI/DEQ/SWQ-96/068. Revised May 1998.

Mackay, R. J. 1992. Colonization by Lotic Macroinvertebrates: A Review of Processes and Patterns. Canadian Journal of Fisheries and Aquatic Sciences, 49: 617-628.

MDEQ. 1990. SWAS Procedure 51 - Qualitative Biological and Habitat Survey Protocols for Wadable Streams and Rivers, April 24, 1990. Revised June 1991, August 1996, January 1997, May 2002, and December 2008.

Walterhouse, M. 2011. A Biological Survey of Sites on the Kalamazoo River and Talmadge Creek Near the Enbridge Oil Spill in Marshall, Calhoun County, Michigan. MDEQ Staff Report #MI/DEQ/WRD-11/010.

Walterhouse, M. 2012. A Biological Survey of Sites on the Kalamazoo River and Talmadge Creek Near the Enbridge Oil Spill in Marshall, Calhoun County, Michigan. August 2011. MDEQ Staff Report #MI/DEQ/WRD-12/012.

Wesley, J. K., and Walterhouse, M. 2010a. A Fish Survey of Sites on the Kalamazoo River and Talmadge Creek Near the Enbridge Oil Spill in Marshall, Calhoun and Kalamazoo Counties, Michigan. Lansing: MDNR, Fisheries Division.

Wesley, J. K., and Walterhouse, M. 2010b. Workplan for Macroinvertebrate, Fish, and Habitat Sampling on the Kalamazoo River and Talmadge Creek to Evaluate Aquatic Ecosystem Effects of Oil Exposure and Cleanup Procedures. Lansing: MNDR, Fisheries Division and MDEQ, Water Resources Division.

List of Tables

Table 1. Qualitative Macroinvertebrate scores from Procedure 51 surveys conducted over multiple years at Kalamazoo River (K) and Talmadge Creek (T) sites (Figure 1). 3
Table 2. Total number of taxa recorded from Procedure 51 surveys conducted over multiple years at Kalamazoo River and Talmadge Creek sites (Figure 1). 3
Table 3. Qualitative macroinvertebrate sampling results for Talmadge Creek sites, September 2012 10
Table 4. Macroinvertebrate metric evaluation at Talmadge Creek sites, September 2012 11
Table 5. Qualitative macroinvertebrate sampling results for Kalamazoo River sites, September 2012 12
Table 6. Macroinvertebrate metric evaluation at Kalamazoo River sites, September 2012 14
Table 7. Habitat evaluation for Talmadge Creek sites, September 2012 14
Table 8. Habitat evaluation for Kalamazoo River sites, September 2012 15

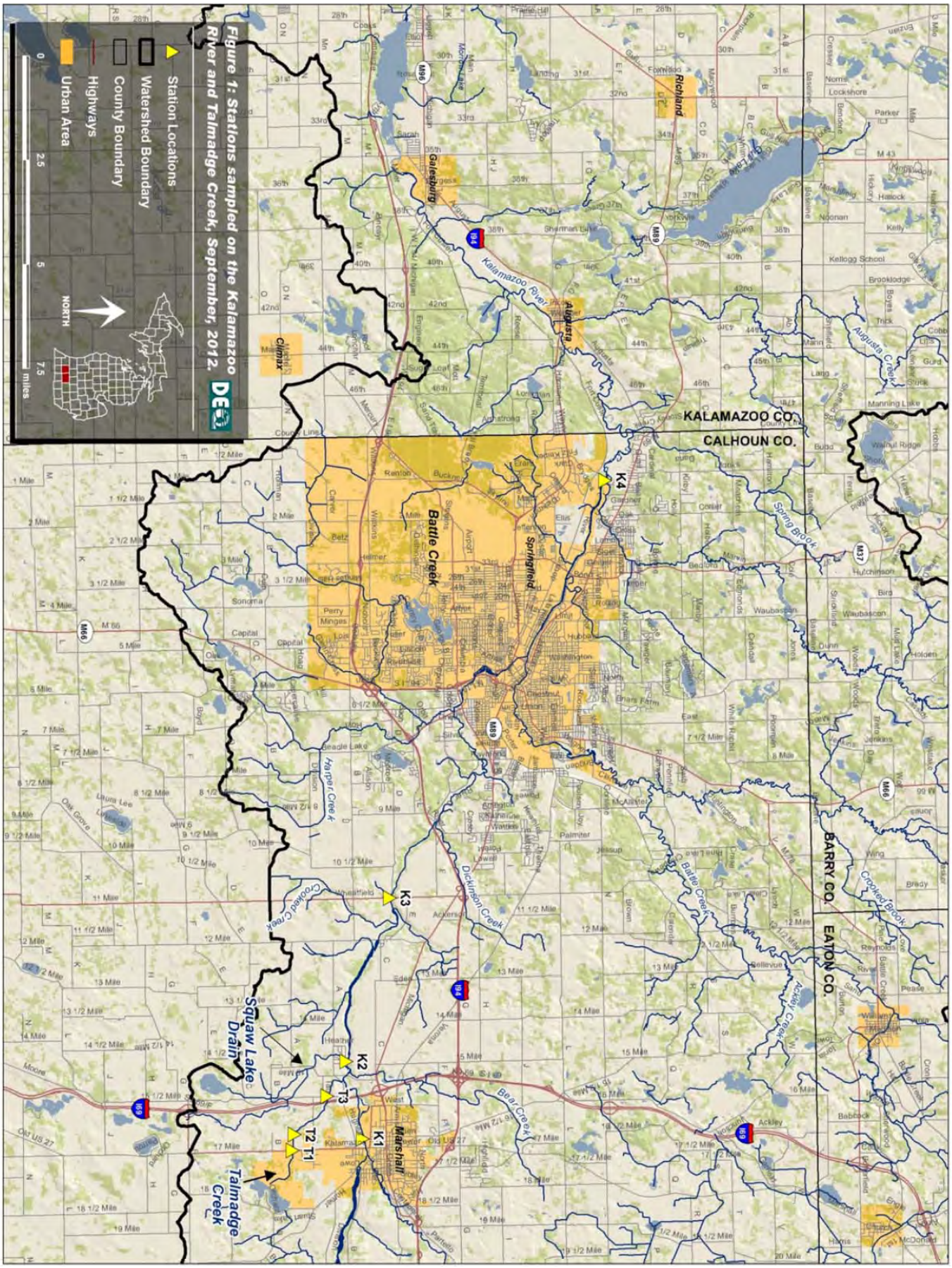


Figure 1. Stations sampled on the Kalamazoo River and Talmadge Creek, September 2012.

Table 3. Qualitative macroinvertebrate sampling results for Talmadge Creek sites, September 2012.

	Talmadge Creek Downstream of 17 Mile Rd. Station T2 9/11/2012	**Talmadge Creek 15 ½ Mile Rd. Station T3** 9/11/2012
TAXA		
ANNELIDA (segmented worms)		
Hirudinea (leeches)	1	
Oligochaeta (worms)	1	4
ARTHROPODA		
Crustacea		
Amphipoda (scuds)	203	18
Arachnoidea		
Hydracarina	5	2
Insecta		
Ephemeroptera (mayflies)		
Baetidae	1	13
Caenidae		3
Ephemerellidae		2
Heptageniidae		15
Isonychiidae		20
Odonata		
Anisoptera (dragonflies)		
Aeshnidae	1	
Gomphidae	1	1
Libellulidae	1	
Zygoptera (damselflies)		
Calopterygidae	17	1
Coenagrionidae	1	1
Hemiptera (true bugs)		
Belostomatidae		1
Corixidae	3	3
Gerridae	1	
Mesoveliidae		1
Nepidae		1
Saldidae	5	
Trichoptera (caddisflies)		
Hydropsychidae	2	76
Hydroptilidae		1
Leptoceridae	1	10
Limnephilidae	1	2
Molannidae	1	1
Coleoptera (beetles)		
Dytiscidae (total)	1	
Haliplidae (adults)	1	1
Elmidae	1	
Gyrinidae (larvae)		1
Haliplidae (larvae)		1
Diptera (flies)		
Ceratopogonidae	1	1
Chironomidae	42	149
Culicidae		2

Table 3. Qualitative macroinvertebrate sampling results for Talmadge Creek sites, September 2012.

	Talmadge Creek Downstream of 17 Mile Rd. Station T2 9/11/2012	**Talmadge Creek 15 ½ Mile Rd. Station T3** 9/11/2012
Simuliidae		13
Tabanidae	1	
Tipulidae	3	
MOLLUSCA		
Gastropoda (snails)		
Ancylidae (limpets)	2	1
Hydrobiidae		1
Physidae	1	6
Planorbidae	4	2
Pelecypoda (bivalves)		
Sphaeriidae (clams)	18	
TOTAL INDIVIDUALS	321	354

Table 4. Macroinvertebrate metric evaluation at Talmadge Creek sites, September 2012.

	Talmadge Creek Downstream of 17 Mile Rd. Station T2 9/11/2012		**Talmadge Creek 15 ½ Mile Rd. Station T3** 9/11/2012	
METRIC	Value	Score	Value	Score
TOTAL NUMBER OF TAXA	28	1	30	1
NUMBER OF MAYFLY TAXA	1	0	5	1
NUMBER OF CADDISFLY TAXA	4	1	5	1
NUMBER OF STONEFLY TAXA	0	-1	0	-1
% MAYFLY COMP.	0.31	-1	14.97	0
% CADDISFLY COMP.	1.56	-1	25.42	0
% DOMINANT TAXON	63.24	-1	42.09	-1
% ISOPOD, SNAIL, LEECH	2.49	1	2.82	1
% SURFACE AIR BREATHERS	3.43	1	2.54	1
TOTAL SCORE	**0**		**3**	
Community Rating	Acceptable		Acceptable	

Table 5. Qualitative macroinvertebrate sampling results for Kalamazoo River sites, September 2012.

TAXA	Kalamazoo River at Kalamazoo St. (17 Mile Rd.) Station K1 9/11/2012	Kalamazoo River Squaw Lake Drain Confluence Station K2 9/12/2012	Kalamazoo River 11-Mile Rd. Station K3 9/12/2012	Kalamazoo River Custer Drive Station K4 9/12/2012
PLATYHELMINTHES (flatworms)				
Turbellaria	2		1	
ANNELIDA (segmented worms)				
Hirudinea (leeches)	1		1	
Oligochaeta (worms)	1	9	5	
ARTHROPODA				
Crustacea				
Amphipoda (scuds)	109	22	6	5
Decapoda (crayfish)	1	1	1	1
Isopoda (sowbugs)	5		1	3
Arachnoidea				
Hydracarina		1		2
Insecta				
Ephemeroptera (mayflies)				
Baetidae	24	23	63	37
Caenidae	1	4		4
Ephemerellidae	13	5	11	
Heptageniidae	11	8	3	2
Isonychiidae		3	7	
Leptophlebiidae				1
Tricorythidae	3	19	3	8
Odonata				
Anisoptera (dragonflies)				
Aeshnidae		1	1	1
Gomphidae	1			1
Zygoptera (damselflies)				
Calopterygidae	6	3	3	
Coenagrionidae	18	3	1	32
Plecoptera (stoneflies)				
Pteronarcyidae		2	1	
Hemiptera (true bugs)				
Corixidae	4			1
Gerridae	1		1	6
Mesoveliidae		1		1
Nepidae	1			
Pleidae	1			7
Megaloptera				
Corydalidae (dobson flies)		1		
Sialidae (alder flies)	1		1	
Trichoptera (caddisflies)				
Brachycentridae	40	3	1	1
Glossosomatidae			1	
Helicopsychidae	3	26	2	
Hydropsychidae	34	54	80	85
Hydroptilidae	3	1	2	6

Table 5. Qualitative macroinvertebrate sampling results for Kalamazoo River sites, September 2012.

	Kalamazoo River at Kalamazoo St. (17 Mile Rd.) Station K1 9/11/2012	**Kalamazoo River Squaw Lake Drain Confluence Station K2** 9/12/2012	**Kalamazoo River 11-Mile Rd. Station K3** 9/12/2012	**Kalamazoo River Custer Drive Station K4** 9/12/2012
Leptoceridae	7	8	1	1
Limnephilidae	4		1	
Philopotamidae	3	1		
Polycentropodidae	1			2
Uenoidae		2	27	2
Lepidoptera (moths)				
Pyralidae		1	1	1
Coleoptera (beetles)				
Gyrinidae (adults)	1			
Elmidae	8	3	6	19
Haliplidae (larvae)	1			
Psephenidae (larvae)		3		
Diptera (flies)				
Ceratopogonidae			1	
Chironomidae	15	44	34	77
Culicidae		1	2	
Simuliidae	16	12	19	4
Tabanidae	1		1	
Tipulidae		1		
MOLLUSCA				
Gastropoda (snails)				
Ancylidae (limpets)	8	1	1	8
Hydrobiidae		4	4	
Lymnaeidae	3	10	36	
Physidae	4	2	5	
Planorbidae	1	1	3	4
Pleuroceridae	1	7	13	
Viviparidae			1	
Pelecypoda (bivalves)				
Corbiculidae	1	13	3	
Sphaeriidae (clams)	6	8	8	
Unionidae (mussels)			1	
TOTAL INDIVIDUALS	365	312	364	322

Table 6. Macroinvertebrate metric evaluation at Kalamazoo River sites, September 2012.

	Kalamazoo River at Kalamazoo St. (17 Mile Rd.) Station K1 9/11/2012		**Kalamazoo River Squaw Lake Drain Confluence Station K2** 9/12/2012		**Kalamazoo River 11-Mile Rd. Station K3** 9/12/2012		**Kalamazoo River Custer Drive Station K4** 9/12/2012	
METRIC	Value	Score	Value	Score	Value	Score	Value	Score
TOTAL NUMBER OF TAXA	40	1	38	1	42	1	28	1
NUMBER OF MAYFLY TAXA	5	1	6	1	5	1	5	1
NUMBER OF CADDISFLY TAXA	8	1	7	1	8	1	6	1
NUMBER OF STONEFLY TAXA	0	-1	1	1	1	1	0	-1
% MAYFLY COMP.	14.25	0	19.87	1	23.90	1	16.15	0
% CADDISFLY COMP.	26.03	0	30.45	1	31.59	1	30.12	1
% DOMINANT TAXON	29.86	0	17.31	1	21.98	0	26.40	0
% ISOPOD, SNAIL, LEECH	6.30	0	8.01	0	17.86	-1	4.66	0
% SURFACE AIR BREATHERS	2.19	1	0.64	1	0.82	1	4.66	1
TOTAL SCORE	**3**		**8**		**6**		**4**	
Community Rating	Acceptable		Excellent		Excellent		Acceptable	

Table 7. Habitat evaluation for Talmadge Creek sites, September 2012.

HABITAT METRIC	**Talmadge Creek Downstream of 17 Mile Rd. Station T2** 9/11/2012 RIFFLE/RUN	**Talmadge Creek 15 ½ Mile Rd. Station T3** 9/11/2012 RIFFLE/RUN
Substrate and Instream Cover		
Epifaunal Substrate/ Available Cover (20)	11	8
Embeddedness (20)*	11	14
Velocity/Depth Regime (20)*	11	11
Pool Substrate Characterization (20)**		
Pool Variability (20)**		
Channel Morphology		
Sediment Deposition (20)	11	13
Flow Status - Maintained Flow Volume (10)	8	8
Flow Status - Flashiness (10)	9	8
Channel Alteration (20)	13	5
Frequency of Riffles/Bends (20)*	8	16
Channel Sinuosity (20)**		
Riparian and Bank Structure		
Bank Stability (L) (10)	9	8
Bank Stability (R) (10)	9	8
Vegetative Protection (L) (10)	9	6
Vegetative Protection (R) (10)	9	6
Riparian Veg. Zone Width (L) (10)	10	7
Riparian Veg. Zone Width (R) (10)	10	7
TOTAL SCORE (200):	138	125
HABITAT RATING:	GOOD	GOOD
	(SLIGHTLY IMPAIRED)	(SLIGHTLY IMPAIRED)
Date:	9/11/2012	9/11/2012
Weather:	Sunny	Sunny
Air Temperature:	65 °F	70 °F
Water Temperature:	58°F	65°F

Table 7. Habitat evaluation for Talmadge Creek sites, September 2012.

	Talmadge Creek Downstream of 17 Mile Rd. Station T2 9/11/2012	**Talmadge Creek 15 ½ Mile Rd. Station T3** 9/11/2012
Average Stream Width:	5 ft.	8 ft.
Average Stream Depth:	0.2 ft.	0.25 ft.
Surface Velocity:	0.2 ft./sec	0.5 ft./sec
Estimated Flow:	0.2 cfs	1 cfs
Stream Modifications:	None	Dredged
Nuisance Plants (Y/N):	N	N
Report Number:	MI/DEQ/WRD-13/011	MI/DEQ/WRD-13/011
STORET No.:	130405	130335
Stream Name:	Talmadge Creek	Talmadge Creek
Road Crossing/Location:	D/S of 17 Mile Road	15 1/2 Mile Road
County Code:	13	13
TRS:	03S06W02	02S06W34
Latitude (dd):	42.2402	42.251717
Longitude (dd):	-84.97066	-84.9885712
Ecoregion:	SMNITP	SMNITP
Stream Type:	Warmwater	Warmwater
USGS Basin Code:	4050003	4050003

* Applies only to Riffle/Run stream Surveys

** Applies only to Glide/Pool stream Surveys

Note: Individual metrics may better describe conditions directly affecting the biological community while the Habitat Rating describes the general riverine environment at the site(s).

Table 8. Habitat evaluation for Kalamazoo River sites, September 2012.

HABITAT METRIC	**Kalamazoo River at Kalamazoo St. (17 Mile Rd.) Station K1** GLIDE/POOL	**Kalamazoo River Squaw Lake Drain Confluence Station K2** GLIDE/POOL	**Kalamazoo River 11-Mile Rd. Station K3** RIFFLE/RUN	**Kalamazoo River Custer Drive Station K4** GLIDE/POOL
Substrate and Instream Cover				
Epifaunal Substrate/ Available Cover (20)	18	15	15	10
Embeddedness (20)*			16	
Velocity/Depth Regime (20)*			13	
Pool Substrate Characterization (20)**	18	16		13
Pool Variability (20)**	16	15		8
Channel Morphology				
Sediment Deposition (20)	16	18	13	11
Flow Status - Maintained Flow Volume (10)	9	8	8	7
Flow Status - Flashiness (10)	7	7	8	4
Channel Alteration (20)	18	18	16	15
Frequency of Riffles/Bends (20)*			11	
Channel Sinuosity (20)**	13	13		8
Riparian and Bank Structure				
Bank Stability (L) (10)	9	8	8	9
Bank Stability (R) (10)	9	8	8	9
Vegetative Protection (L) (10)	1	9	4	9
Vegetative Protection (R) (10)	8	6	9	9
Riparian Veg. Zone Width (L) (10)	1	10	4	10
Riparian Veg. Zone Width (R) (10)	5	4	10	10

Table 8. Habitat evaluation for Kalamazoo River sites, September 2012.

	Kalamazoo River at Kalamazoo St. (17 Mile Rd.) Station K1	**Kalamazoo River Squaw Lake Drain Confluence Station K2**	**Kalamazoo River 11-Mile Rd. Station K3**	**Kalamazoo River Custer Drive Station K4**
TOTAL SCORE (200):	148	155	143	132
HABITAT RATING:	GOOD	EXCELLENT	GOOD	GOOD
	(SLIGHTLY IMPAIRED)	(NON-IMPAIRED)	(SLIGHTLY IMPAIRED)	(SLIGHTLY IMPAIRED)
Date:	9/11/2012	9/12/2012	9/12/2012	9/12/2012
Weather:	Sunny	Sunny	Sunny	Sunny
Air Temperature:	75°F	70°F	75°F	79°F
Water Temperature:	68°F	65°F	68°F	74°F
Average Stream Width:	120 ft.	210 ft.	160 ft.	360 ft.
Average Stream Depth:	2.5 ft.	1.3 ft.	1.2 ft.	1.5 ft.
Surface Velocity:	0.6 ft./sec	1 ft./sec	1.1 ft./sec	0.7 ft./sec
Estimated Flow:	180 cfs	273 cfs	211.2 cfs	378 cfs
Stream Modifications:	None	None	None	None
Nuisance Plants (Y/N):	N	N	N	N
Report Number:	MI/DEQ/WRD-13/011	MI/DEQ/WRD-13/011	MI/DEQ/WRD-13/011	MI/DEQ/WRD-13/011
STORET No.:	130211	130406	130048	130052
Stream Name:	Kalamazoo River	Kalamazoo River	Kalamazoo River	Kalamazoo River
Road Crossing/Location:	u/s Marshall WWTP - d/s Kalamazoo St.	Squaw Lake Drain confluence	11-Mile Road	Custer Drive
County Code:	13	13	13	13
TRS:	02S06W26	02S06W33	02S07W25	01S08W29
Latitude (dd):	42.26391	42.25852	42.27429	42.35074
Longitude (dd):	-84.96836	-85.00469	-85.08097	-85.27561
Ecoregion:	SMNITP	SMNITP	SMNITP	SMNITP
Stream Type:	Warmwater	Warmwater	Warmwater	Warmwater
USGS Basin Code:	4050003	4050003	4050003	4050003

* Applies only to Riffle/Run stream Surveys

** Applies only to Glide/Pool stream Surveys

Note: Individual metrics may better describe conditions directly affecting the biological community while the Habitat Rating describes the general riverine environment at the site(s).

Figure 2. Site T1 upstream reference site. This site is more of a wetland site than the more downstream locations (T2 and T3). T1 was unable to be sampled in 2012 due to low water levels. Photo taken by William Taft, 2011.

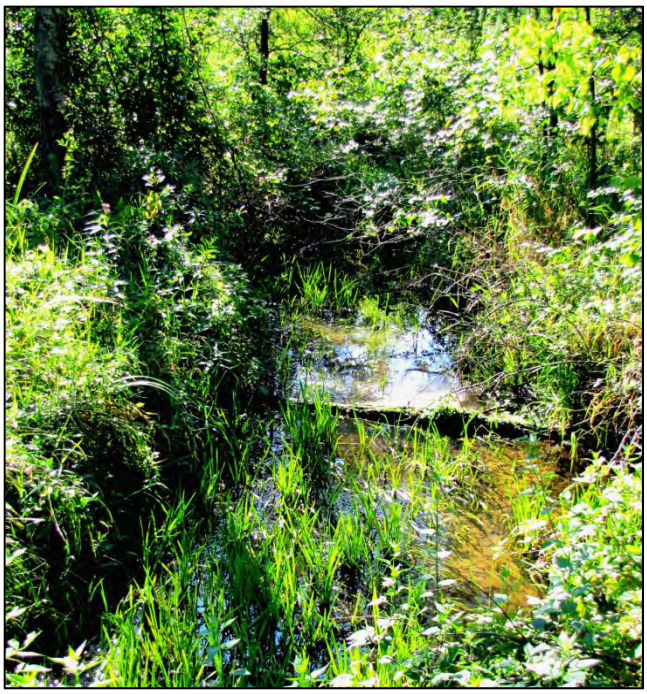


Figure 4. Site T2 upstream reference location. This site was sampled as a reference location in 2010, 2011, and 2012. T2 is heavily vegetated and comparable in flow to T3 (impacted site). Photo by William Taft, 2011.

Figure 3. Site T3 on Talmadge Creek. Image shows open canopy and artificial structure along stream bank. Photo by William Taft, 2011.

Figure 5. Site K4, Upstream of Custer Drive on the Kalamazoo River. This site is much wider and slower than any of the upstream Kalamazoo River or Talmadge Creek Sites. Photo by William Taft, 2011.

Appendix I: Mussel Shell Survey Report

Mussel Shell Survey Report: Kalamazoo River Unionid Mussel Shell Survey in the Marshall and Battle Creek Area October 2010

Prepared for:

Stephanie Millsap, U.S. Fish & Wildlife Service
and
Kalamazoo River Enbridge Line 6B Oil Spill Trustee Council

Prepared by:

Pete Badra, Michigan Natural Features Inventory
with assistance from
Stratus Consulting Inc.

July 20, 2011

1. Introduction

On July 26, 2010, an oil release from Enbridge Energy Partners, L.P. (Enbridge) line 6B was discovered. The line, located in Marshall, Calhoun County, Michigan, is a 30-inch, 283,000-barrels per day line that transports light synthetics and heavy and medium crude oil. The release occurred in an undeveloped area on the outskirts of town with coordinates of approximately North ½ Section 2, T3S, R6W, Latitude: 42.2395273, Longitude: -84.9662018. Upon discovery of the release, the pipeline was shut down and isolation valves closed, stopping the flow of the oil. The exact amount of oil released prior to the shutdown is unknown. However, it is estimated that at least 1 million gallons of crude oil was released to nearby Talmadge Creek and to the Kalamazoo River (U.S. EPA, 2010; Enbridge Energy, 2011).

Soon after the spill, the Trustees for the Natural Resource Damage Assessment (NRDA), in coordination with Enbridge, began to collect ephemeral data on potentially injured natural resources in Talmadge Creek and the Kalamazoo River and their watersheds. The Trustees include the U.S. Department of the Interior, represented by the U.S. Fish and Wildlife Service and the Bureau of Indian Affairs; the State of Michigan, represented by the Michigan Department of Natural Resources (MDNR), the Michigan Department of Environmental Quality (MDEQ), and the Michigan Attorney General; the U.S. Department of Commerce, represented by the National Oceanic and Atmospheric Administration; the Nottawaseppi Huron Band of the Potawatomi; and the Match-E-Be-Nash-She-Wish Band of Potawatomi. As a part of the ephemeral data collection, a mussel shell survey was conducted in October 2010. The survey was conducted to document post-mortem mussel shells that, depending on their relative condition, may be indicative of injury to mussels as a result of exposure to contaminants released during the spill; physical injuries to mussels as a result of response activities, such as crushing by boat traffic, habitat alterations, and sedimentation; or factors unrelated to the incident.

This report describes the mussel shell survey, which was conducted in October 2010 on the Kalamazoo River from the Marshall Impoundment to the Town of Battle Creek, Michigan, and summarizes the survey findings. The Trustees and Enbridge collaboratively developed the study work plan and conducted the survey field work.

Survey results may be used in combination with other information to help identify and characterize potential injuries to mussel communities resulting from potential exposure to oil or from physical injury (i.e., damaged or crushed shells) caused by oil spill response activities, as well as to distinguish spill-related effects from mortality likely to be unrelated to this incident. Results may also be used to evaluate the need for additional studies to quantify impacts to mussels as a result of the spill and to aid in the development of such studies.

1.1 Background on Unionid Mussels

Freshwater unionid mussels belong to one of four bivalve families that live along the bottoms of creeks, rivers, and lakes in Michigan. Nationwide, unionid mussels are among the most endangered groups of animals. A 1993 review of the status of unionid species by the American Fisheries Society found that 97 of 292 species that occur in the United States are considered endangered (Williams et al., 1993). Mussel population declines have been attributed to habitat degradation from pollution, physical alterations such as dams, and pressure from exotic species [e.g., zebra mussels (*Dreissena polymporpha)*].

Michigan's rivers and streams support significant populations of mussels, including federal- and state-listed endangered species. There are 46 unionid mussel species that occur in Michigan, 19 of which are state-listed as threatened or endangered. A total of 28 unionid mussel species have been observed in the Kalamazoo River Watershed. These include three state endangered species, three state threatened species, and six species of special concern[1] (Badra, 2010). There are no known federally listed mussel species present in the watershed. Between Marshall and Battle Creek, the stretch of the river where this study took place, 13 unionid mussel species have been observed since 1929 (Table 1).

Unionid mussels are an important component of Michigan's natural history and play important ecological roles in stream ecosystems. Unionids can be important to stream foodwebs, often comprising the highest percentage of biomass relative to other benthic stream organisms (Strayer et al., 1994). They are a key component in the food chain, linking aquatic microorganisms to muskrats, crayfish, birds, and other predators. Unionids are also intricately linked to fish communities because they depend on fish to act as hosts in the completion of their life cycle and provide a mechanism for dispersal and gene flow (Kat, 1984; Watters, 1992, 1995). They can also play a role in water quality, as the action of their filter feeding can change the particulate content of river water (Pusch et al., 2001).

Mussels are also important because they can act as ecosystem and water quality indicators. Many unionid mussel species are long-lived, some with life spans of 50 years or more. Mature mussels are generally sessile, spending most of their lives within a particular location in a stream. Furthermore, unionids are sensitive to many contaminants and, because they are filter feeders, can bioaccumulate contaminants. Given these characteristics, mussels can provide long-term information about ecosystem health and can be valuable indicators of water quality and biological integrity (Strayer, 1999; Grabarkiewicz and Davis, 2008).

1. Unlike state-listed threatened or endangered mussel species, species of special concern are not protected by Part 365 of PA 451, 1994 Michigan Natural Resources and Environmental Protection Act, but have been identified by the state to be of concern because of declining populations (MNFI, 2010).

Table 1. Unionid mussel species observed in past surveys of the Kalamazoo River between Marshall, Michigan, and Battle Creek, Michigan. These data may include both shells and live individuals. Historical records were obtained from five separate locations surveyed in 1929 and 1934. In 2000, one location in Wattles Park, Emmett Township, Michigan, near Historic Bridge Park was surveyed.

Common name	Species	State status	Historical records (1929; 1934)	Wattle's Park area (2000)
Mucket	*Actinonaias ligamentina*			X
Elktoe	*Alasmidonta marginata*	Special concern	X	X
Spike	*Elliptio dilatata*		X	
Wabash pigtoe	*Fusconaia flava*		X	X
Plain pocketbook	*Lampsilis cardium*		X	
Fatmucket	*Lampsilis siliquoidea*		X	
White heelsplitter	*Lasmigona complanata*			X
Creek heelsplitter	*Lasmigona compressa*		X	X
Fluted-shell	*Lasmigona costata*		X	X
Round pigtoe	*Pleurobema sintoxia*	Special concern	X	
Strange floater	*Strophitus undulates*		X	X
Ellipse	*Venustaconcha ellipsiformis*	Special concern	X	
Rainbow	*Villosa iris*	Special concern	X	

Sources: University of Michigan Museum of Zoology's Mollusk Collection records; Mulcrone and Mehne (2001).

1.2 Characterization of Mussel Shells Post-Mortem

The degree of mussel shell weathering, location of shells within a river system, and physical condition of shells can provide qualitative estimates of when, where, and how mussel death may have occurred. Rough estimates of time post-mortem can be made by evaluating and scoring the physical weathering of shells. Table 2 describes post-mortem shell age categories and their associated physical characteristics; this scale was developed by the Michigan Natural Features Inventory (MNFI) and adapted for use in this study. This terminology is commonly used to describe the condition of shells (see e.g., Badra 2009, Myers-Kinzie et al 2001, and Hoke 2005), but the physical definitions and estimates of time post-mortem provided in Table 2 were developed specifically for this study based on professional judgment. Shell decay rates are governed by streamflow rates and water chemistry, as described in Strayer and Malcom 2007.

Table 2. Mussel shell weathering scale developed by MNFI

Scale	Category	Physical shell characteristics	Approximate time post-mortem
1	Fresh dead	Soft tissue intact	Less than several days
2	Recent dead	No soft tissue, aside from hinge ligament	Several days to a few (2–3) weeks
3	Moderately worn 1	Hinge intact, marl not covering lower portion, light algae on inside of shell	A few (2–3) weeks to a few (2–3) months
4	Moderately worn 2	Hinge intact or not intact, marl can be covering entire shell, heavy algae and/or marl on inside of shell, most of periostracum intact, shell has most of its original strength	Greater than 2–3 months
5	Heavily worn	Periostracum worn and peeling, shell at least somewhat chalky and fragile	Greater than 3 months

The presence of intact soft tissue and hinge ligament allows for a relatively narrow post-mortem dating of a shell, since tissue and ligament degrade relatively quickly post-mortem. However, beyond this point, it is only possible to match shell wear categories to relatively broad timescales. With increased time post-mortem, microhabitat factors play a larger role in determining the amount of shell wear. For example, a shell that is buried in soft sediments will wear more slowly than a shell that is exposed to stream current on the surface of a rocky substrate. The difference in shell wear between the two would be relatively small over a shorter time period (e.g., one month post-mortem) and relatively large over a longer time period (e.g., five months post-mortem). The approximate time post-mortem given in Table 2 reflects this increased variation in the rate of shell wear as time post-mortem increases.

In addition to the degree of weathering, observations of physical damage to shells (e.g., broken, chipped, or crushed shells) can provide information on impacts to mussels. Shells can be damaged as a result of numerous processes in a river system. The three most relevant processes to this study include physical wearing and breaking of shells as a result of normal (non-spill related) in-stream processes, chipping as a result of animal predation, and crushing as a result of anthropogenic activities. The nature of the damage to the shells resulting from these three processes is quite distinct, and it is often possible to ascertain how shells were damaged by examining the characteristics of the damage.

Shells that have been worn over a relatively long period of time through normal in-stream processes become fragile and are often found with pieces broken off. These shells can be distinguished by the general wearing characteristics and nature of the breakage. For example, these shells typically fall into the “heavily worn” category described in Table 2, as shells having worn and peeling periostraca that are chalky and fragile. Breakage typically initiates around the

edges where the shell is thinnest. For the purposes of this study, these shells are referred to as being “broken.”

Shells that have been damaged as a result of foraging by aquatic mammals also have many distinguishing features. Piles of foraged mussel shells, or middens, are often found along the banks of rivers that support freshwater mussels and mammals, such as the Kalamazoo River. Middens are easily identified in the field due to the large number of single shells in one area and unique markings on the shells. The shells are typically chipped along the thin edges (where the predator has worked to open the shell) and often have scratches or bite marks. Middens are also identifiable by their physical location. For example, they are typically found in areas with abundant cover and easy access to shallow water, such as logjams.

Shells may also be damaged as a result of being physically crushed when a mussel is still alive or still has most of its original strength (i.e., up to two to three months post-mortem). This type of damage is distinct in that the shells are split with a clean, sharp edge, often through the thickest part of the shell. The crushing of mussel shells requires a relatively heavy impact or force that is not reflective of normal in-stream weathering processes or predation. Following the oil spill prior to this study, anecdotal observations in the Kalamazoo River suggested that mussels were crushed during response activities, including by boats passing over shallow sections of the river where mussels were exposed and by response crews wading in the river and stepping on mussels. Based on previous experience conducting mussel surveys across the state, observations of crushed mussel shells are very unusual. For the purpose of this report, shells exhibiting the characteristics of physical crushing described above are referred to as being “crushed.”

This study classified damaged shells into the three categories described above: broken, chipped, or crushed, in order to characterize the type of damage occurring at sampling locations. Table 3 summarizes the definitions of these three categories.

Table 3. Mussel shell damage categories identified for this study by MNFI

Category	Physical characteristics of shell
Broken	Shell is worn and thin, with breakage due to natural river processes in thinnest parts of the shell
Chipped	Shell has scratches and bite marks near the thin edges caused by predation
Crushed	Shell still has most of its original strength, with a sharp-edged break through the thick part of the shell due to non-natural heavy impact

Figures 1 and 2 illustrate the difference between the two types of damage most relevant to this study: broken shells and crushed shells.

Figure 1. Photographs of shells that have been gradually worn to a fragile state over time to a point where they are easily broken, where broken is defined as damage caused by normal in-stream processes. Top: moderately worn 2 strange floater; bottom: heavily worn elktoe.

Photograph taken by J. Matousek on October 18, 2010, in segment MS-1.

Figure 2. Photographs of crushed shells, where crushed is defined as damage caused by a heavy impact. Top: recent spike; bottom: moderately worn 1 pocketbook.

Photograph taken by J. Matousek on October 19, 2010, in segment MS-2.

1.3 Objectives and Scope

Given the ecological importance of mussels and field observations of crushed mussel shells in the Kalamazoo River, the Trustees, in cooperation with Enbridge, designed and initiated this mussel shell survey to document the extent of recent dead mussels at the site that may be attributed to the oil spill and subsequent response actions.

Specifically, the objectives of this study were to:

- Within survey sites, document the proportion of mussel shells observed at each stage of weathering and by species
- Survey selected segments of the Kalamazoo River from the Marshall Impoundment to the Town of Battle Creek for mussel shells that were less than approximately three months post-mortem (i.e., the post-mortem age that could reflect mussel death associated with the spill; the survey was conducted in late October 2010, and the spill occurred three months earlier in late July 2010)
- Document species occurrences in sampling segments using observations of both live mussels and mussel shells
- Delineate the spatial extent of mussel shells that were less than approximately three months post-mortem within the selected river segments.

Information on the degree of weathering of mussel shells and the location of dead mussels is ephemeral and will largely be lost over time as shells deteriorate and are displaced. Thus, this survey was conducted in October 2010 to capture ephemeral, time-sensitive data on the occurrence and location of post-mortem mussel shells. Though the purpose of the study was to survey post-mortem mussel shells, observations of live mussels were also recorded when encountered in the field. In the fall, live mussels begin to burrow deeper into the sediment, where they spend winter months. Thus, observations of live mussels recorded during this survey are likely not representative of live mussel abundance and should not be interpreted as a live mussel population survey. However, information from the mussel shell survey may be used to design a more intensive and quantitative mussel community survey (i.e., a live mussel survey), if deemed necessary, for the late spring or summer.

2. Methods

The mussel shell survey was performed on October 18–21 and October 25, 2010, pursuant to the field work plan (Appendix A). The study was performed by MNFI, with assistance from Stratus

Consulting on behalf of the Trustees, in cooperation with Enbridge and their contractor (Cardno ENTRIX). Survey field work was completed on a daily basis by either six or seven staff (depending upon individual availability), representing MDEQ, MDNR, Stratus Consulting, Cardno ENTRIX, and MNFI. Staff included Pete Badra (MNFI), Michael Carney (Stratus Consulting), Ryan Grafton (Cardno ENTRIX), John Matousek (Cardno ENTRIX), Mike Wilson (MDNR), Matt Wesener (MDEQ), Bill Taft (MDEQ), and Mike Walterhouse (MDEQ). All decisions regarding fieldwork were made by consensus of the field team.

This section describes locations and survey field methods. Modifications from the field work plan, made based on conditions encountered in the field, are also described.

2.1 Segment Locations

Five sampling segments were identified on the Kalamazoo River between the Marshall Impoundment and the Mill Pond in the Town of Battle Creek [Mile Post (MP) 15.5] in the mussel shell survey work plan (see Appendix A). Note that river miles are reported in MPs, the reference system established by Enbridge. The MPs begin at the spill site on Talmadge Creek (MP 0.0), the confluence of Talmadge Creek with the Kalamazoo River is marked as MP 2.2, and MPs extend downriver on the Kalamazoo River to Morrow Lake (MP 37.75).

Prior to sampling each segment, segment start locations were finalized in the field, based on the location of access points and the conditions encountered in the river. As indicated in the work plan, shell surveys were conducted in an upriver direction from the segment start location to the end of the proposed segment or as far upriver as could be covered in a single field day. Table 4 describes each sampling segment. A map of segment locations is provided in Figure 3.

Most sampling segments were accessed on foot. A boat was used at segment MS-5 to transport the survey crew over stretches of habitat that were too deep to wade.

Sampling segment locations were selected according to proximity to the spill site, areas of known response activities, locations of boat launches (and hence elevated boat activity), un-impacted areas upstream of the spill site (e.g., reference locations), and based on locations where mussel shells had been observed during prior NRDA fieldwork.

The following sections of the report describe the methods that were used when conducting the mussel shell survey, specifically, how survey sites within a sampling segment were delineated (Section 2.2) and characterized (Section 2.3). Additional collected information is described in Section 2.4, and documentation procedures are described in Section 2.5. Finally, modifications to the original work plan (Appendix A) that were made during the survey as a result of conditions met in the field are provided (Section 2.6).

Table 4. Summary of segment locations and date sampled. River miles are in MPs downriver from the pipeline release, as reported by Enbridge (with the confluence of Talmadge Creek and the Kalamazoo River at MP 2.2). Segment start and end coordinates were taken at the middle of the down- and upriver extremities, respectively, of each sampling segment.

Segment ID	Segment description and access notes	Nearest MP		Latitude	Longitude	Survey date
MS-1	Reference area downriver of the Marshall Impoundment along River Walk Park to 17 Mile Road Bridge. Segment was accessed from the boardwalk that runs along the north bank of the river.	Start:	[a]	42.26480	-84.96385	10/18/2010
		End:	[a]	42.26211	-84.95550	
MS-2	Talmadge Creek confluence area; segment located just downriver from 15 Mile Road Bridge, boat ramp C0.1. Segment was accessed from community park off of Squaw Creek Road.	Start:	3.0	42.25925	-85.01009	10/19/2010
		End:	2.25	42.25864	-84.99898	
MS-3	11 Mile Road Bridge/C1.5 boat ramp area. Segment was accessed from 11 Mile Road Bridge by walking downriver from the bridge along a trail on left bank to start location.	Start:	7.75	42.27732	-85.09117	10/20/2010
		End:	7.25	42.27443	-85.08154	
MS-4	C3.2 boat ramp area near Historic Bridge Park. Segment was accessed from boat ramp parking lot by walking downriver from the parking lot along a trail on right bank to start location.	Start:	10.25	42.29591	-85.12777	10/21/2010
		End:	9.25	42.29373	-85.12421	
MS-5	C5 boat ramp area near Rivers Edge Landscaping and Mill Pond. Segment was accessed from C5 boat ramp by traveling downriver by boat to start location.	Start:	15.5	42.30768	-85.18924	10/25/2010
		End:	14.5	42.30119	-85.18023	

a. River mile MP not available because sampling segment is upriver of the pipeline release. MS-1 was located approximately 2.5 miles upriver from the spill site.

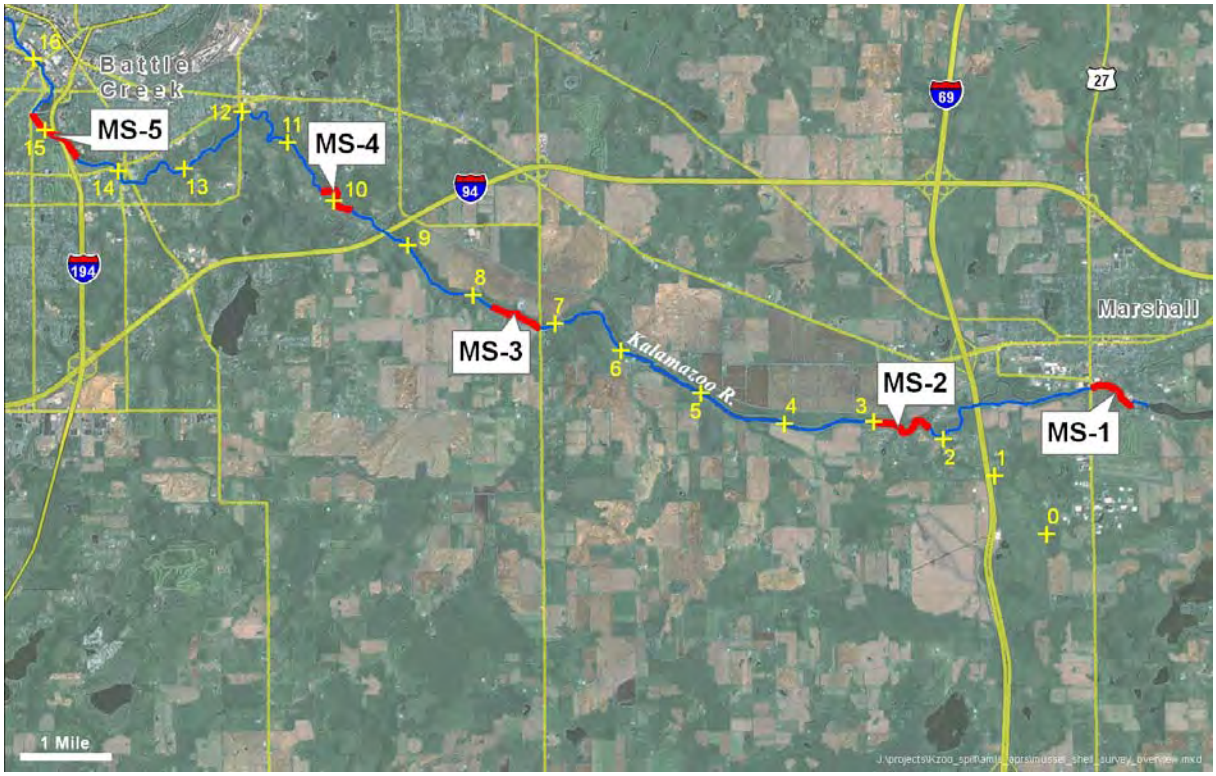


Figure 3. Overview of fall 2010 sampling locations on the Kalamazoo River between Marshall Impoundment and Battle Creek, Michigan.

2.2 Delineation of Survey Sites

Once the sampling segment start location was identified and coordinates recorded, surveyors slowly waded in an upriver direction and inspected the substrate for mussel shells. The field crew used glass-bottom buckets and/or polarized eyeglasses to view the river bottom. Observations of live mussels and mussel shells were recorded in field notebooks. The physical condition of mussel shells was screened according to the shell weathering scale described in Table 2. When a fresh dead or recent dead shell was found (see Table 2), surveyors thoroughly inspected the immediate area for additional fresh dead or recent dead shells. If no additional shells were observed in close proximity [~3 meters (m)], the species, weathering category, and location were recorded in field notebooks, and the survey crew continued upriver in the segment. If more than one fresh dead or recent dead shell was observed, the approximate area in which the fresh dead or recent dead shells were observed was delineated into a survey site. The boundaries of the

delineated site encompassed the area in which fresh dead or recent dead shells were found and extended upriver and extended across the river width until shells were no longer observed, with one exception. Survey site 2010.10.21-4-2 was located within a very large area of crushed shells that was too large to fully characterize in one day. Thus, at this site, the crew delineated a smaller area within the large area of crushed shells. Survey site boundary designation rationale for each survey site is provided in the results section (Section 3). The dimensions, river orientation, and boundary coordinates of the survey site were recorded on dedicated field datasheets and are also provided in the results section.

2.3 Survey Site Characterization

All shells and live mussels within a delineated survey site were collected in buckets and mesh bags and brought ashore for examination and enumeration. Each live mussel and shell was identified to species, and the physical condition was scored according to the shell weathering scale (Table 2). Single half shells and connected hinged shells were counted as a single observation. After all mussels and shells from a delineated site were enumerated and scored, shells and live mussels were returned to the river. Habitat information, such as substrate classification and water depth, was also recorded for each survey site.

2.4 Additional Collected Information

In addition to the fresh dead and recent dead mussel shell survey methods described above, additional mussel community information was collected for each sampling segment. This included noting presence of live mussels, non-native dreissenid mussels (*Dreissena polymorpha* and *D. bugensis*), and Asian clams (*Corbicula fluminea*) at each site. Sampling segment-specific species lists were made using observations of shells or live mussels.

2.5 Documentation

Survey information was recorded onto dedicated datasheets and in field notebooks (see Appendices B and C, respectively). Additional information such as field personnel, start and stop times, coordinates, and photograph information was recorded on sampling segment datasheets or in field notebooks.

Each day, field datasheets were scanned to an electronic Portable Document Format (PDF) file and saved on a computer hard drive. Original hardcopy datasheets were retained by MNFI. Photographs were taken with a single camera and backed up to a hard drive at the end of each survey day. Geographic positioning system (GPS) waypoints and track log files were also saved to a hard drive.

2.6 Work Plan Modifications

Table 5 summarizes modifications from the survey work plan.

Table 5. Modifications from the survey work plan

Work plan section	Proposed method	Field modifications
Table 1	Mussel shell weathering scale categories included fresh dead, recent dead, moderately worn, and heavily worn	An additional category of shell weathering was created to better capture the wide range of moderately worn shell characteristics encountered in the field. Specifically, moderately worn was split into two categories, and descriptions for each category were developed (see Table 1 in work plan). All segment characterizations incorporated this change, and include “moderately worn 1” and “moderately worn 2” categories, with the exception of MS-2. Field datasheets were changed to include the additional shell weathering category.
Mussel shell survey protocol	The survey site is delineated and surveyed simultaneously in an upriver direction until fresh dead or recent dead shells are no longer encountered, at which point the site boundary is defined	Survey sites were delineated and then surveyed. Note that single fresh dead/recent dead shell observations were still recorded.
Table 1	Reference sampling segment numbered MS-5 and RM not identified	Location selected for reference survey segment and renumbered MS-1.
None	None	The reference segment was walked, but no survey site was initially delineated, because no fresh dead or recent dead shells were encountered (observation of fresh/recent dead is the trigger for delineation of a survey site within a segment). However, the crew decided to return to the reference segment and delineate a survey site so that there would be a survey site within the reference segment for comparative purposes.

3. Results

This section presents mussel shell survey results. Results are presented for the five survey segments, MS-1 through MS-5. General observations are provided for each segment, and data collected at delineated survey sites within segments are also summarized.

Six survey sites within the five segments were delineated during the survey. This included one survey site in the reference sampling segment (MS-1) and one site in segment MS-2. Two survey sites were delineated in segment MS-3, and two were delineated in MS-4. No sites were delineated in segment MS-5. The location of each survey site is given in Table 6. Completed field datasheets and field notebooks are provided in Appendices B and C, respectively. Photographs taken during the survey are available upon request or can be accessed via the ENTRIX hosted File Transfer Protocol (FTP) site.

Table 6. Mussel shell survey sites that were delineated within sampling segments

Survey site		Latitude (N)	Longitude (W)	Survey date	Segment	Survey site surface area (m^2)
2010.10.21-1-1	Start:	42.26305	-84.95710	10/21/2010	MS-1	133
	End:	42.26284	-84.95668			
2010.10.19-2-1	Start:	42.25979	-85.01019	10/19/2010	MS-2	288
	End:	42.25983	-85.00980			
2010.10.20-3-1	Start:	42.27737	-85.09080	10/20/2010	MS-3	113
	End:	42.27736	-85.09071			
2010.10.20-3-2	Start:	42.27657	-85.08723	10/20/2010	MS-3	248
	End:	42.27661	-85.08678			
2010.10.21-4-1	Start:	42.29591	-85.12740	10/21/2010	MS-4	190
	End:	42.29600	-85.12704			
2010.10.21-4-2	Start:	42.29390	-85.12488	10/21/2010	MS-4	216
	End:	42.29370	-85.12486			

3.1 Segment MS-1

Segment MS-1, a reference area upstream of the pipeline release, was located on the Kalamazoo River 2.5 miles upriver from the Talmadge Creek confluence. Approximately 0.6 miles of the 1-mile segment was surveyed, from the Kalamazoo Avenue Bridge to just downriver of the Marshall Impoundment (Figure 4). Rice Creek enters the Kalamazoo River at the approximate midpoint of this sampling segment. The August 2010 mussel tissue and sediment sampling site (SE-2) was also located in this segment. One survey site was delineated in this segment.

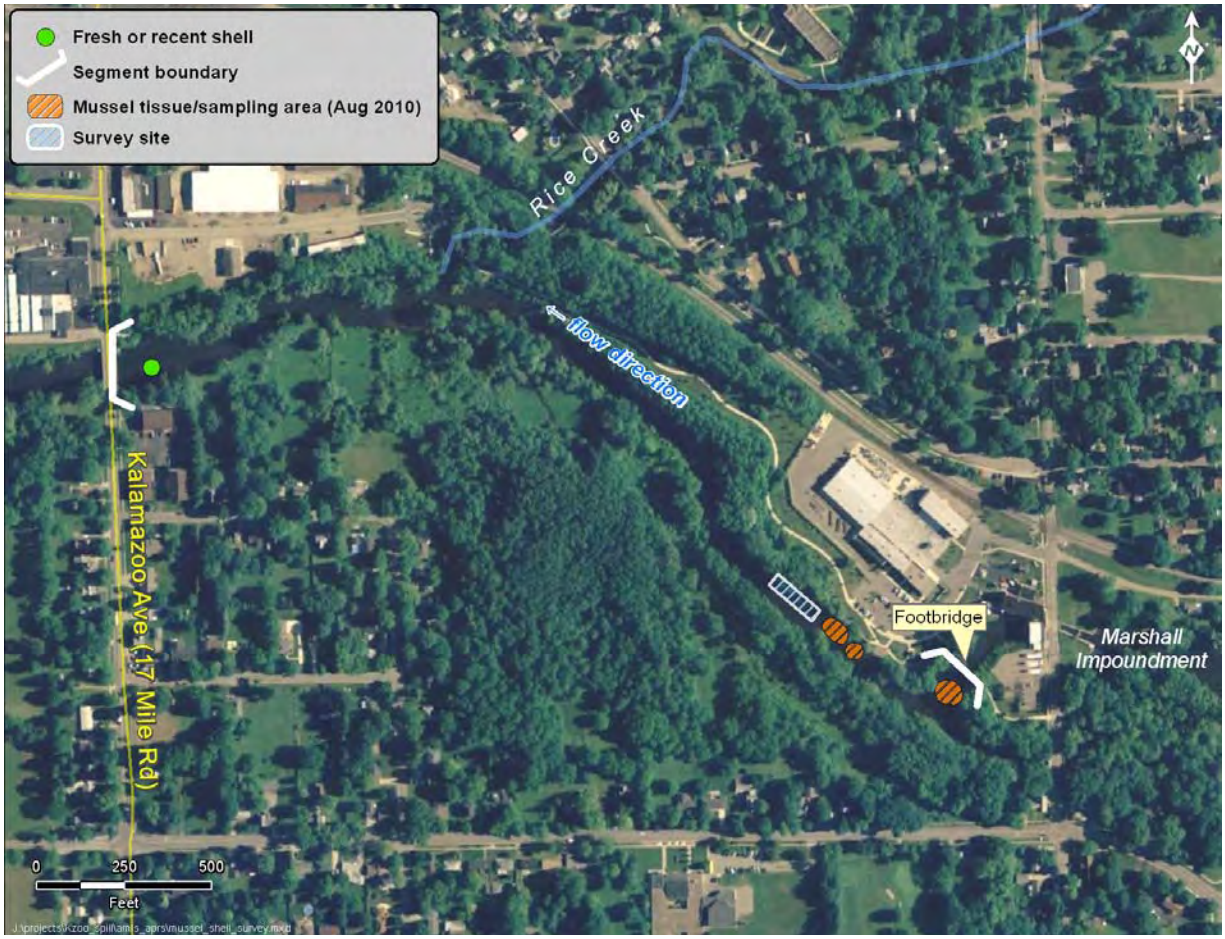


Figure 4. Sampling segment MS-1.

3.1.1 General conditions

During the survey, the weather was seasonably warm (~ 55°F) and cloudy. Turbidity was very low, and the river bottom was visible in all wadeable areas. Approximately 80% of this sampling segment was shallow enough to wade. Most of the area directly downriver of the Rice Creek confluence was too deep to wade. In the area downriver of the Rice Creek confluence, only the substrate in shallower water along the shoreline was surveyed.

The substrate was variable and ranged from sand in depositional areas to coarse gravel and cobble in swift-flowing areas. Encrusting and filamentous algae covered gravel and cobbles. No visible submerged oil or oil sheening was observed during the survey. Glass bottles, pieces of metal, and general refuse were observed throughout the site.

3.1.2 Segment MS-1 shell observations

Shells of 16 unionid mussel species were observed in segment MS-1 (Table 7). This included the state threatened slippershell (*Alasmidonta viridis*) and state endangered eastern pondmussel (*Ligumia nasuta*), which was represented by a single shell observation. As noted in Table 7, four species of special concern were also found in this sampling segment. In addition to finding shells, five species of live mussels were also observed. These included spike, pocketbook, creek heelsplitter, fluted-shell, and ellipse (a species of special concern). Non-native Asian clam shells and live individuals were also observed in this segment.

Table 7. Unionid mussel species[a] observed in sampling segment MS-1. Includes both living and shell observations made throughout the waded 0.6 miles of the segment, including observations in the survey site (2010.10.21-1-1).

			Species observed	
Common name	**Species**	**State status**	**Shell**	**Live**
Mucket	*Actinonaias ligamentina*		X	
Elktoe	*Alasmidonta marginata*	Special concern	X	
Slippershell	*Alasmidonta viridis*	Threatened	X	
Cylindrical papershell	*Anodontoides ferussacianus*		X	
Spike	*Elliptio dilatata*		X	X
Wabash pigtoe	*Fusconaia flava*		X	
Fatmucket	*Lampsilis siliquoidea*		X	
Pocketbook	*Lampsilis cardium*		X	X
White heelsplitter	*Lasmigona complanata*			
Creek heelsplitter	*Lasmigona compressa*		X	X
Fluted-shell	*Lasmigona costata*		X	X
Eastern pondmussel	*Ligumia nasuta*	Endangered	X	
Round pigtoe	*Pleurobema sintoxia*	Special concern	X	
Giant floater	*Pyganodon grandis*		X	
Strange floater	*Strophitus undulates*		X	
Paper pondshell	*Utterbackia imbecillis*	Special concern		
Ellipse	*Venustaconcha ellipsiformis*	Special concern	X	X
Rainbow	*Villosa iris*	Special concern	X	
Total number of unionid species			16	5

a. In addition to unionid mussels, live non-native Asian clam and shells were observed in the segment.

State status sources: MDNRE, 2010; MNFI, 2010.

Observed shells in segment MS-1 were mostly moderately to heavily worn shells. These shells were coated with a layer of encrusting marl and algae to an extent that they often had to be cleaned off with a knife to identify. One recent dead pocketbook mussel shell was observed in the 0.6-mile survey segment (Figure 4). This observation was made near the downriver boundary of the segment. A survey site was not delineated at the location of this shell, because only a single recent dead shell was found.

Damaged shells that were worn and broken were observed in MS-1. These shells all had heavily advanced weathering (i.e., fell within moderately worn 2 and heavily worn categories) indicating the breakage likely occurred as a result of natural in-stream weathering processes. No crushed shells were observed, nor were any middens or chipped shells.

3.1.3 MS-1 survey site 2010.10.21-1-1

One survey site was delineated in segment MS-1 (survey site 2010.10.21-1-1). Only one recent dead shell was observed within segment MS-1, and no fresh dead shells were found. Therefore, a survey site was not delineated during the initial visit to the segment on October 18, 2010. On October 21, 2010, the survey crew decided to return to segment MS-1 and delineate a reference survey site to enable comparison of a reference with downstream survey sites. The survey crew agreed upon an area with a relatively high number of shells at the head of a shallow riffle within the sampling segment to designate as a survey site. This location was chosen because it had a high number of shells and was representative of the general habitat within the segment.

The survey site consisted of a shallow, 0.3- to 0.7-m-deep area that was 19-m-long and 7-m-wide, with a total surface area of 133 square meters (m^2). The survey site boundary delineation was not based on occurrence of fresh dead or recent dead shells. The boundaries were arbitrarily delineated to generate a survey site surface area similar to previously delineated survey sites in other sampling segments. The substrate within the site was a mix of pebble [64–16 millimeters (mm) diameter], gravel (16–2 mm), and sand (2–0.0625 mm).

Table 8 summarizes the mussel species observations and shell weathering characterization results for the MS-1 survey site. Shells from nine species were observed in the survey site. Pocketbook shells were most dominant, comprising 27% of all shells found, followed by fluted-shell (23%). Fatmucket and rainbow shells were least common, contributing less than 1% of the total number of shells observed. One live pocketbook mussel was observed in the survey site.

A total of 213 shells were found in the survey site, representing a density of 1.6 shells/m^2. No fresh dead, recent dead, or moderately worn 1 shells were observed in survey site 2010.10.21-1-1 (Table 8). All of the shells in this site were covered with heavy marl and encrusting algae (Figure 5).

Table 8. Segment MS-1 survey site 2010.10.21-1-1 shell weathering characterization results

Species	Fresh dead	Recent dead	Moderately worn 1	Moderately worn 2	Heavily worn
Mucket	–	–	–	–	–
Elktoe	–	–	–	5	2
Slippershell	–	–	–	–	–
Cylindrical papershell	–	–	–	–	–
Spike	–	–	–	28	8
Wabash pigtoe	–	–	–	25	16
Fatmucket	–	–	–	3	–
Pocketbook	–	–	–	46	11
White heelsplitter	–	–	–	–	–
Creek heelsplitter	–	–	–	–	–
Fluted-shell	–	–	–	30	19
Eastern pondmussel	–	–	–	–	–
Round pigtoe	–	–	–	–	–
Giant floater	–	–	–	–	–
Strange floater	–	–	–	7	4
Paper pondshell	–	–	–	–	–
Ellipse	–	–	–	6	–
Rainbow	–	–	–	2	1
Total number of shells	0	0	0	152	61
Percentage	0.0%	0.0%	0.0%	71%	29%

A total of 14 broken shells were observed within the survey site, mostly Wabash pigtoe. These shells were observed to be broken, rather than crushed.

3.2 Segment MS-2

Sampling segment MS-2 was located on the Kalamazoo River just downriver from the Talmadge Creek confluence. Approximately 0.8 miles of the 1-mile segment was surveyed, from MP 3.0 to 15 Mile Road Bridge (Figure 6). Squaw Creek enters the Kalamazoo River at the approximate midpoint of this sampling segment, and Bear Creek enters the river near the upriver boundary. Boat ramp C0.1 was located in this segment, which was closed at the time of the survey. One survey site was delineated in this segment.

(a)

(b)

Figure 5. Photographs of (a) an MS-1 shell with heavy marl and encrusting algae and (b) shells collected from survey site 2010.10.21-1-1.

Photograph taken by J. Matousek on (a) October 18, 2010, and (b) October 21, 2010.

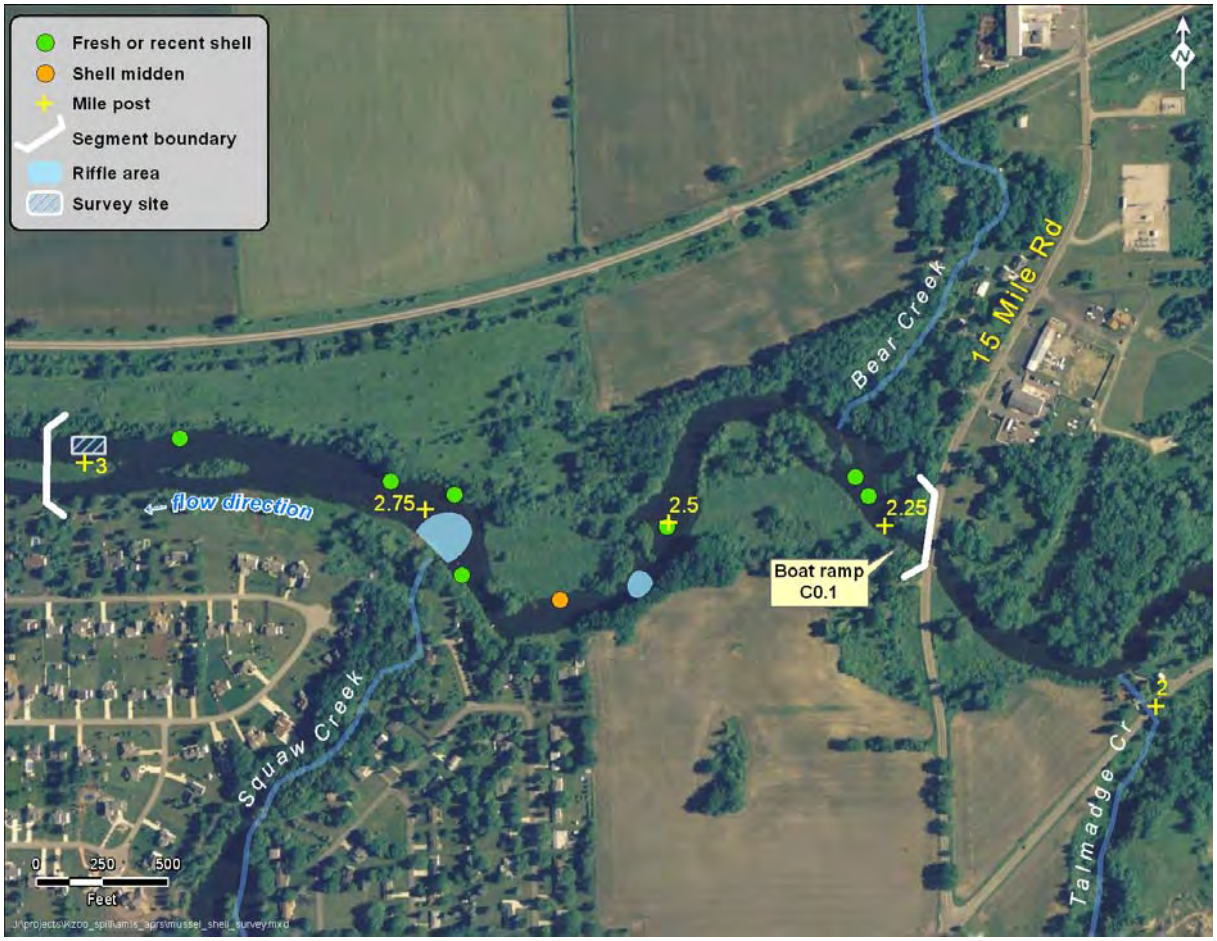


Figure 6. Sampling segment MS-2.

3.2.1 General conditions

During the survey, the weather was seasonably warm (~ 50°F) and cloudy. Turbidity was low, and the river bottom substrate was visible in all wadeable areas. The entire sampling segment was shallow enough to wade. Response/cleanup activities were occurring within this segment at the time of the survey. These activities were centered around islands where cleanup crews were replacing absorbent oil booms. A few air- and propeller-driven boats were also observed throughout the segment, but they did not noticeably affect turbidity.

Most of the river bottom within the segment consisted of shallow runs and riffles with relatively swift water. Coarse gravel and cobble were the dominant substrate types for most of the segment. Fine silty sediment was common in depositional areas, especially around the islands between booms and the shore. A large silt deposit was observed downriver of boat ramp C0.1, located on the right river bank, near 15 Mile Road Bridge (Figure 6). Oil sheens were observed on the water surface after wading through this silt deposit.

3.2.2 Segment MS-2 shell observations

Shells of 15 unionid mussel species were observed in segment MS-2 (Table 9). One state threatened species (slippershell) and four species of special concern were observed. Most live mussels were observed in a deep run just upriver of the Squaw Creek confluence and included spike, Wabash pigtoe, fatmucket, pocketbook, white heelsplitter, and creek heelsplitter species. Non-native Asian clams were also found in this segment.

In addition to the delineated site described below in Section 3.2.3, there were eight observations of fresh dead and recent dead shells made in this segment in areas that were not delineated (Table 10). These shells were recorded, but the observations did not initiate delineation of survey sites, as they were isolated shell occurrences. A single fresh dead pocketbook was found near the Squaw Creek confluence with soft tissue still intact (Figure 7).

Damaged shells were observed throughout this segment and included shells thought to be broken by natural in-stream weathering processes and predator activity and shells thought to be crushed as a result of anthropogenic activity. Heavily weathered and broken shells were observed in the segment. These shells were similar to broken shells observed in the MS-1 reference segment. A shell midden was observed near a shallow riffle, immediately upriver of the Squaw Creek confluence. A resident adjacent to this midden spoke to the survey crew and indicated that they had recently seen a mink near the shell deposit. Crushed shells were also observed, especially in a large shallow riffle just downriver of the Squaw Creek confluence. This riffle seemed to be an area that naturally accumulates mussel shells; most of these shells appeared to be mostly moderately to heavily weathered. Many of the accumulated shells were observed to have been crushed. Since shells were thought to be damaged post-mortem, a survey site was not delineated. This decision was supported by the fact that the same riffle was surveyed for live mussels during the August 2010 mussel tissue and sediment sampling event, at which time no live mussels were observed.

Table 9. Unionid mussel species[a] observed in sampling segment MS-2. Includes both living and shell observations made throughout the waded 0.8 miles of the segment, including observations in the survey site (2010.10.19-2-1).

			Species observed	
Common name	**Species**	**State status**	**Shells**	**Live**
Mucket	*Actinonaias ligamentina*		X	
Elktoe	*Alasmidonta marginata*	Special concern	X	
Slippershell	*Alasmidonta viridis*	Threatened	X	
Cylindrical papershell	*Anodontoides ferussacianus*		X	
Spike	*Elliptio dilatata*		X	X
Wabash pigtoe	*Fusconaia flava*		X	X
Fatmucket	*Lampsilis siliquoidea*		X	X
Pocketbook	*Lampsilis cardium*		X	X
White heelsplitter	*Lasmigona complanata*		X	X
Creek heelsplitter	*Lasmigona compressa*		X	X
Fluted-shell	*Lasmigona costata*		X	
Eastern pondmussel	*Ligumia nasuta*	Endangered		
Round pigtoe	*Pleurobema sintoxia*	Special concern	X	
Giant floater	*Pyganodon grandis*			
Strange floater	*Strophitus undulates*		X	
Paper pondshell	*Utterbackia imbecillis*	Special concern		
Ellipse	*Venustaconcha ellipsiformis*	Special concern	X	
Rainbow	*Villosa iris*	Special concern	X	
Total number of unionid species			15	6

a. In addition to unionid mussels, live non-native Asian clam and shells were observed in the segment.

State status sources: MDNRE, 2010; MNFI, 2010.

Table 10. Isolated observations of fresh dead, recent dead, and crushed shells made within sampling segment MS-2

Observation	Latitude	Longitude	Comments/details
Single recent dead rainbow shell	42.25968	-85.00858	Single shell occurrence
Single recent dead pocketbook shell	42.25954	-85.00601	Single shell occurrence
Two recent dead spike shells found together and two crushed pocketbook shells found	42.25940	-85.00508	Two shells observed in the same location were treated as a single shell occurrence
Single recent dead pocketbook shell	42.25848	-85.00513	Single shell occurrence
Single fresh dead pocketbook shell	42.25790	-85.00304	Single shell occurrence, with soft tissue intact
Single recent dead spike shell	42.25895	-84.99899	Single shell occurrence
Single recent dead pocketbook shell	42.25866	-84.99890	Single shell occurrence
Location of a few recent dead shells	42.25867	-85.00183	Site not delineated due to only finding a few shells, species not identified
Shell midden	42.25800	-85.00352	Pile of chipped shells
Area of crushed shells	42.25889	-85.00510	Mussels were likely not killed by being crushed, but shells crushed post-mortem
Area of crushed shells	42.25820	-85.00215	Mussels were likely not killed by being crushed, but shells crushed post-mortem
Crushed fluted shell, spike, and rainbow found; several live pocketbooks found	42.25825	-85.00249	Crushed shells occurred in shallow riffle areas
A few recent dead and crushed shells found	42.22579	-85.00167	

Figure 7. Photographs of a fresh dead pocketbook with soft tissue intact found in segment MS-2 just upriver from Squaw Creek confluence.

Photograph taken by J. Matousek on October 19, 2010.

3.2.3 MS-2 survey site 2010.10.19-2-1

The survey site delineated in segment MS-2, survey site 2010.10.19-2-1, was located near MP 3.0 at the downriver boundary of the sampling segment. The survey site consisted of a shallow, 0.4-m-deep area that was 32-m-long and 9-m-wide, with a total surface area of 288 m^2. The survey site was delineated after finding a scattered deposit of recent dead shells. The site upriver and river-width boundaries were extended until no further recent shell observations were made. Substrate within the site was a mix of pebble (64–16 mm diameter), gravel (16–2 mm), and sand (2–0.0625 mm).

The observed shells within the site represented 11 species (Table 11). Spike shells were most dominant, comprising 31% of all shells found. Wabash pigtoe shells were also common (19%). Shells of mucket and the threatened slippershell were least common, contributing to less than 1% of the total number of shells observed. Four species of special concern, elktoe, round pigtoe, ellipse, and rainbow, were relatively common in the survey site. No live mussels were observed within the survey site.

Table 11 summarizes the mussel species observed and shell weathering characterization results for the MS-2 survey site. A total of 264 shells were collected (0.9 shells/m^2), which included 6 recent dead shells. Damaged shells were observed within the survey site. These shells appeared to be older shells in which mortality would have occurred prior to the spill. No middens or recent dead/fresh dead crushed shells were observed in this sampling site.

3.3 Segment MS-3

Sampling segment MS-3 was located on the Kalamazoo River between Ceresco and Historic Bridge Park, just downriver from 11 Mile Road Bridge. Approximately 0.6 miles of the 1-mile segment was surveyed, from MP 7.75 to immediately downriver of the 11 Mile Road Bridge (Figure 8). Boat ramp C1.5 was located in this segment, which was closed at the time of the survey. A mussel tissue sample collection site from the mussel tissue and sediment sampling field work that was completed in late August 2010 was also located in this segment. Two survey sites were delineated in this segment.

3.3.1 General conditions

During the survey, the weather was sunny and windy, with an air temperature of ~ 50°F. Turbidity was moderate and gradually increased throughout the day. This limited the crew's ability to survey the full 1-mile segment. High turbidity may have been associated with dredging in the Ceresco Impoundment, which was occurring upgradient at the same time that this segment was being surveyed.

Table 11. Segment MS-2 survey site 2010.10.19-2-1 shell weathering characterization results

Species	Fresh dead	Recent dead	Moderately worn 1 and 2[a]	Heavily worn
Mucket	–	–	1	–
Elktoe	–	–	4	7
Slippershell	–	–	2	1
Cylindrical papershell	–	–	–	–
Spike	–	2	63	17
Wabash pigtoe	–	1	44	6
Fatmucket	–	–	–	–
Pocketbook	–	1	25	10
White heelsplitter	–	–	–	–
Creek heelsplitter	–	–	–	–
Fluted-shell	–	1	6	5
Eastern pondmussel	–	–	–	–
Round pigtoe	–	–	7	2
Giant floater	–	–	–	–
Strange floater	–	1	18	13
Paper pondshell	–	–	–	–
Ellipse	–	–	14	1
Rainbow	–	–	10	2
Total number of shells	0	6	194	64
Percentage	0.0%	2.3%	74%	24%

a. MS-2 was surveyed prior to the development of “moderately worn 1” and “moderately worn 2” weathering categories. These two subcategories are included in all other segments.

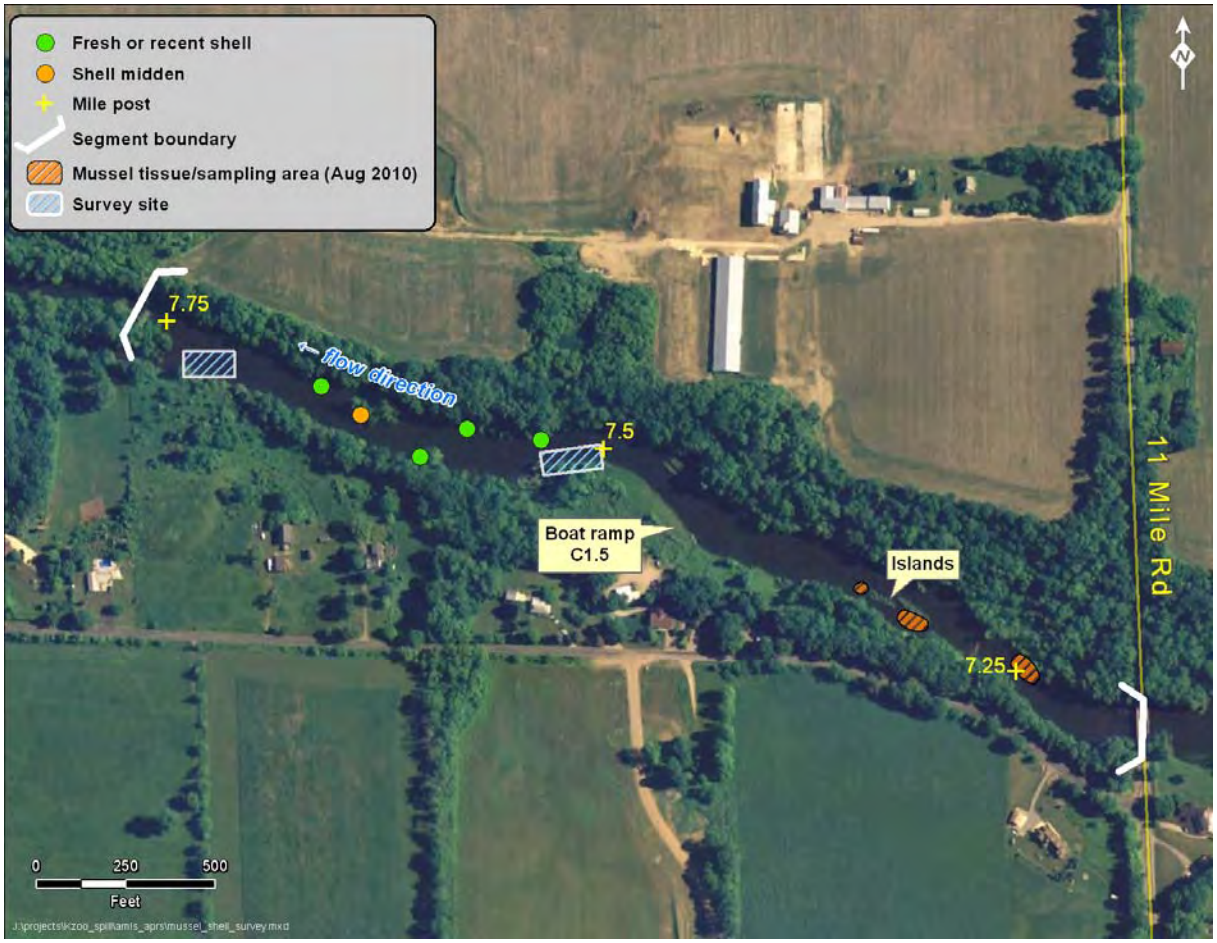


Figure 8. Sampling segment MS-3.

The substrate in segment MS-3 was highly variable. Shallow areas such as riffles with moderate flow were dominated by coarse sand and gravel. Substrates in slower, slightly deeper water and shallow areas near the river bank were covered with a surficial layer of fine silt. In these areas, mussel shells were blanketed with silt. Shell inspections often required picking these shells from the river bottom and washing off accumulated silt. Siltation was notably heavy at the downriver boundary of the segment, near boat ramp C1.5, and around two islands located approximately 0.1 mile downriver from 11 Mile Road Bridge. Larger cobble and bedrock were common between these two islands and 11 Mile Road Bridge. Oil sheening was observed near the two islands and near the boat ramp after wading through the soft, silty sediments. One dead frog was observed, and some oil was noted on the vegetation of one of the islands.

3.3.2 Segment MS-3 shell observations

Shells of 12 unionid mussel species were observed in segment MS-3 (Table 12). This included the state threatened slippershell and two species of special concern. Live mucket were common near the downriver segment boundary and in sediments between bedrock outcrops at the upriver segment boundary. Live spike, Wabash pigtoe, pocketbook, and white heelsplitter species were also observed. Non-native Asian clams were also found in this segment.

Table 12. Unionid mussel species[a] observed in sampling segment MS-3. Includes both living and shell observations made throughout the waded 0.6 miles of the segment, including observations in the survey sites (2010.10.20-3-1; 2010.10.20-3-2).

			Species observed	
Common name	**Species**	**State status**	**Shell**	**Live**
Mucket	*Actinonaias ligamentina*		X	X
Elktoe	*Alasmidonta marginata*	Special concern	X	
Slippershell	*Alasmidonta viridis*	Threatened	X	
Cylindrical papershell	*Anodontoides ferussacianus*		X	
Spike	*Elliptio dilatata*		X	X
Wabash pigtoe	*Fusconaia flava*		X	X
Fatmucket	*Lampsilis siliquoidea*			
Pocketbook	*Lampsilis cardium*		X	X
White heelsplitter	*Lasmigona complanata*		X	X
Creek heelsplitter	*Lasmigona compressa*		X	
Fluted-shell	*Lasmigona costata*		X	
Eastern pondmussel	*Ligumia nasuta*	Endangered		
Round pigtoe	*Pleurobema sintoxia*	Special concern		
Giant floater	*Pyganodon grandis*			
Strange floater	*Strophitus undulates*		X	
Paper pondshell	*Utterbackia imbecillis*	Special concern		
Ellipse	*Venustaconcha ellipsiformis*	Special concern		
Rainbow	*Villosa iris*	Special concern	X	
Total number of unionid species			12	5

a. In addition to unionid mussels, live non-native Asian clam and shells were observed in the segment.

State status sources: MDNRE, 2010; MNFI, 2010.

This was the first segment in which shells were categorized into moderately worn 1 and 2 categories (see Section 2.6). Many moderately worn 1 shells were observed in this segment. Most of these shells were covered by a layer of silt that made classifying between recent and moderately worn 1 weathering categories difficult. For example, silt staining on the inside of a recent shell may have caused it to appear moderately worn. Conversely, silt may have covered a moderately worn 1 shell so that algae did not grow inside of the shell, creating an appearance more consistent with a recent dead shell.

There were multiple isolated observations of recent shells in this segment that were recorded but did not warrant survey site delineation. These observations occurred within four general areas located in the downriver portion of the segment, ending immediately downriver of boat ramp C1.5 (Table 13; Figure 8). The number of shells or species in these four areas was not recorded due to time constraints. However, a survey site was delineated at the upriver end of this area, where moderately worn 1 shell observations became more concentrated (site 2010.10.20-3-2; see Section 3.3.4).

Table 13. Isolated observations of recent dead and crushed shells made within sampling segment MS-3

Observation	Latitude	Longitude	Comments/details
A relatively large concentration of live mussels found along with crushed shells and a few recent dead shells.	42.27723	-85.08967	Species not identified; shells likely crushed post-mortem
A few recent dead shells found with crushed shells	42.27673	-85.08885	Species not identified; shells likely crushed by boats in this shallow area
A few recent dead shells found	42.27683	-85.08839	Species not identified
A few recent dead shells found with crushed shells	42.27670	-85.08770	Species not identified; shells likely crushed by boats in this shallow area
Large deposit of moderately weathered shells	42.27545	-85.08370	Found around the islands near upriver segment boundary; mostly moderately worn 2 but included some moderately worn 1 shells with ligaments attached
Shell midden	42.27710	-85.08945	Pile of chipped shells
Pile of recent dead shells, possible shell midden	42.27599	-85.08549	Uncertain if deposit was a midden or a pile made by someone gathering shells
A concentration of live muckets found	42.27443	-85.08154	

A large deposit of moderately worn shells was observed around the islands immediately downriver of 11 Mile Road Bridge (Table 13; Figure 8). This area was not delineated into a survey site because most of the shells were moderately worn 2. In addition, it was nearing the end of the day and turbidity was increasing, which interfered with the crew's ability to scan the river bottom for shells. Another deposit of recent shells was discovered just upriver and next to boat ramp C1.5. These shells, which were buried in soft silt along the river bank, might have been associated with a midden that was covered with silt but did not show signs of chipping or scratch marks consistent with mussel predation damage. These shells could have been disposed of by someone gathering shells in the area. Although the origin of this shell deposit was not confirmed, it was concluded in the field that it was likely not associated with oil or response activities, thus a survey site was not delineated at this location.

Damaged shells were observed throughout this segment. Similar to segments MS-1 and MS-2, broken, fragile, and worn shells were observed. Chipped shells were also found. These observations were associated with a shell midden. Additionally, a large pile of chipped shells was observed at the tail end of an island downriver from boat ramp C1.5. Observations of crushed shells that were recent dead and moderately worn were made downriver of the boat ramp in shallow riffle areas (Table 13; Figures 8 and 9). Survey site 2010.10.20-3-2 was delineated at the upriver end of this area (see Section 3.3.4).

3.3.3 MS-3 survey site 2010.10.20-3-1

Survey site 2010.10.20-3-1 was located near MP 7.75 at the downriver boundary of the sampling segment. The survey site consisted of a shallow, 0.4-m-deep area that was 15-m-long and 7.5-m-wide, with a total surface area of 113 m^2. The survey site boundary delineation was based on finding a scattered deposit of shells that were characterized as recent/moderately worn 1. Boundaries were extended to the point at which recent dead shells were no longer observed. The substrate within this site was a mix of pebble (64–16 mm diameter), gravel (16–2 mm), and sand (2–0.0625 mm).

Shells from eight species of mussels were found in the delineated site (Table 14), approximately 60% of which were mucket. Wabash pigtoe were also common, comprising 16% of the total number of shells. Elktoe (a species of special concern) and spike shells were least common. No state threatened or endangered species were observed in this site. A total of 14 live mussels were also observed, most of which were mucket.

Figure 9. Photographs of crushed shells found downriver of boat ramp C1.5.

Photograph taken by J. Matousek on October 20, 2010.

Table 14. Segment MS-3 survey site 2010.10.20-3-1 shell weathering characterization results

Species	Fresh dead	Recent dead	Moderately worn 1	Moderately worn 2	Heavily worn
Mucket	–	–	3	88	1
Elktoe	–	–	–	1	–
Slippershell	–	–	–	–	–
Cylindrical papershell	–	–	–	–	–
Spike	–	–	–	1	–
Wabash pigtoe	–	–	–	24	1
Fatmucket	–	–	–	–	–
Pocketbook	–	–	–	7	2
White heelsplitter	–	–	–	2	–
Creek heelsplitter	–	–	–	–	–
Fluted-shell	–	–	3	16	1
Eastern pondmussel	–	–	–	–	–
Round pigtoe	–	–	–	–	–
Giant floater	–	–	–	–	–
Strange floater	–	–	–	3	2
Paper pondshell	–	–	–	–	–
Ellipse	–	–	–	–	–
Rainbow	–	–	–	–	–
Total number of shells	0	0	6	142	7
Percentage	0.0%	0.0%	3.9%	92%	4.5%

A total of 155 shells were collected from survey site 2010.10.20-3-1, which equates to 1.4 shells/m^2. Although no fresh dead or recent dead shells were found, six moderately worn 1 shells (3.9% of all shells collected) were observed. As mentioned above, distinguishing between recent and moderately worn 1 weathering of shells was difficult due to heavy siltation in this segment and survey site. Only one damaged shell, a mucket, was identified in this survey site. The low occurrence of damaged shells at this site might be associated with its location in the river. This site was located in slow-moving water near the right river bank (Figure 8) in an area that may not have been impacted by boat or foot traffic.

3.3.4 MS-3 survey site 2010.10.20-3-2

Survey site 2010.10.20-3-2 was a river bar located near MP 7.5, downriver of boat ramp C1.5. The depth of this site was variable (0.3–0.7 m). Site dimensions were 31-m-long and 8-m-wide, with a total surface area of 248 m^2. The survey site boundary delineation was based on finding a scattered deposit of recent dead shells; boundaries were extended to the point at which recent shells were no longer found. The substrate was a mix of pebble (64–16 mm diameter), gravel (16–2 mm), and sand (2–0.0625 mm).

Shells from 10 species were observed in this survey site (Table 15). Strange floater shells were most common (26% of all shells) followed by spike, elktoe, and mucket; all shells were found in similar proportions. Cylindrical papershell and creek heelsplitter shells were least common, represented by only one shell observation each. Five slippershell shells (state threatened) also were observed. Eight live mucket were found in this site.

Table 15. Segment MS-3 survey site 2010.10.20-3-2 shell weathering characterization results

Species	Fresh dead	Recent dead	Moderately worn 1	Moderately worn 2	Heavily worn
Mucket	–	–	2	17	1
Elktoe	–	–	–	11	10
Slippershell	–	–	–	–	5
Cylindrical papershell	–	–	–	1	–
Spike	–	4	4	12	2
Wabash pigtoe	–	–	2	7	1
Fatmucket	–	–	–	–	–
Pocketbook	–	–	–	–	–
White heelsplitter	–	–	–	–	–
Creek heelsplitter	–	–	–	1	–
Fluted-shell	–	–	–	5	2
Eastern pondmussel	–	–	–	–	–
Round pigtoe	–	–	–	–	–
Giant floater	–	–	–	–	–
Strange floater	–	2	1	23	8
Paper pondshell	–	–	–	–	–
Ellipse	–	–	–	–	–
Rainbow	–	–	–	3	5
Total number of shells	0	6	9	80	34
Percentage	0.0%	4.7%	7.0%	62%	26%

A total of 129 shells were collected from this survey site (0.5 shells/m^2). Approximately 12% of the shells collected at this site were either recent dead (4.7%) or moderately worn 1 (7.0%), indicative of being less than three months post-mortem. Crushed elktoe, strange floater, and spike were also observed within this survey site. The total number of crushed shells was not recorded.

3.4 Segment MS-4

Sampling segment MS-4 was located on the Kalamazoo River just downriver from Historic Bridge Park. Approximately 0.5 miles of the 1-mile segment was surveyed, from MP 10.25 to MP 9.25 (Figure 10). Boat ramp C3.2 was located in this segment, which was in use at the time of the survey. The upriver boundary of the segment was approximately 1/5 of a mile downriver of where the August 2010 mussel tissue and sediment sampling occurred near boat ramp C3.2 at Historic Bridge Park. Two survey sites were delineated in this segment.

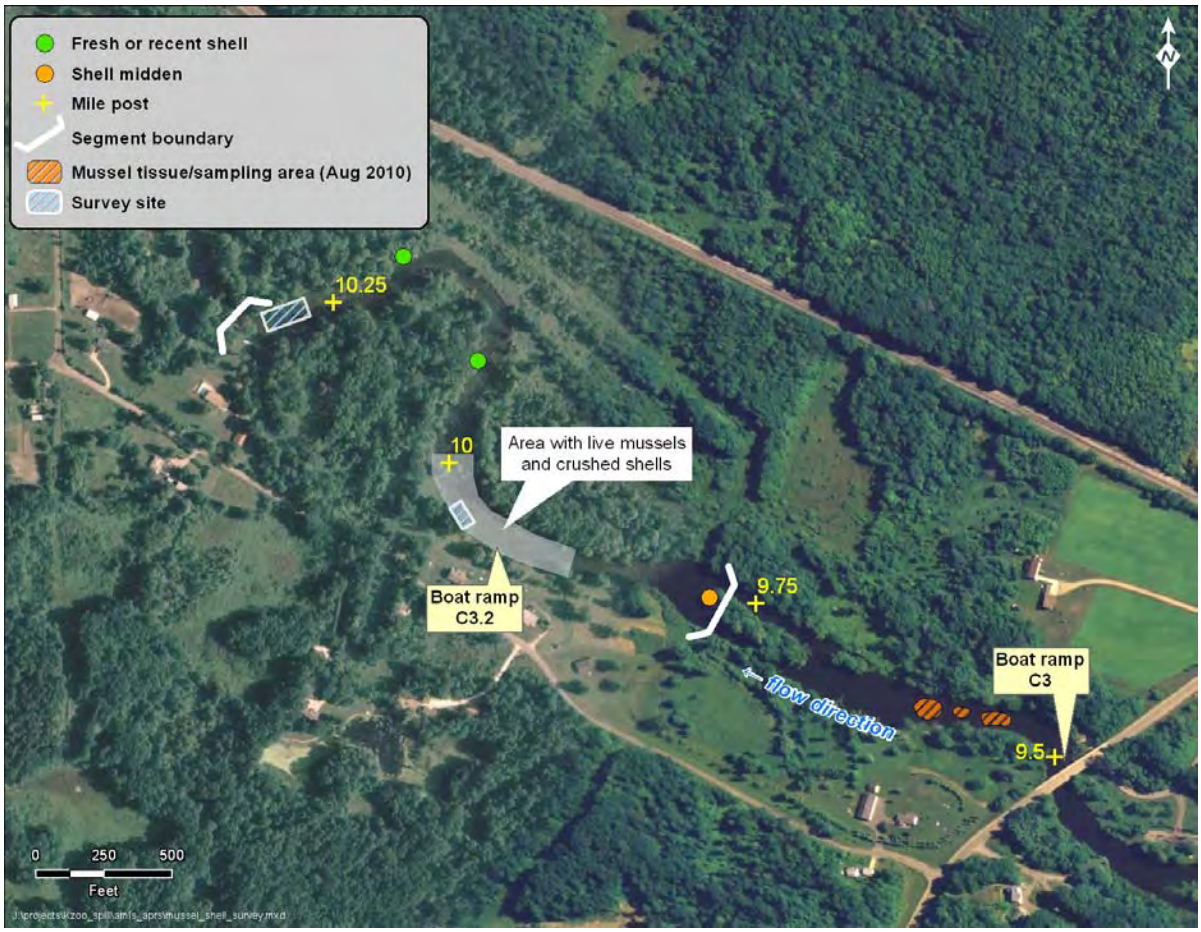


Figure 10. Sampling segment MS-4.

3.4.1 General conditions

At the start of the survey, the weather was sunny and cool (~ 45°F) but deteriorated to windy and cold with rain soon thereafter. Moderate turbidity was noted throughout the survey area, with periods of high turbidity when airboats ran through the segment. The survey was interrupted a number of times due to airboat passage. Interruptions generally lasted a few minutes in order to allow water to clear and enable viewing of the substrate. At times airboat traffic was so heavy that the survey crew exited the river due to safety concerns. Airboats were also observed hitting the bottom of the river when they powered up to get over shallow riffle areas.

Substrate was dominated by gravel and cobble, with areas of coarse sand and silt. Silt was common near boat ramp C3.2 and along the river banks. Most of the segment consisted of runs and riffles with shallow swift-flowing water. Shallow areas showed signs of being scoured by airboats and included lighter-colored sediments where the river bottom was disturbed. Oil sheening was observed near the toe of an island at the upriver boundary of this segment.

3.4.2 Segment MS-4 shell observations

Shells of 12 unionid mussel species were observed in segment MS-4 (Table 16). This included the state threatened slippershell and two species of special concern. Live mucket were common and live spike and Wabash pigtoe were also observed. A notable number of live mucket were observed downriver and in deeper water in undisturbed sediments directly across from boat ramp C3.2. Non-native Asian clams were found in this segment.

Shells representative of all weathering states were observed in segment MS-4. Two accumulations of recent shells were observed in the segment that were not delineated as survey sites in order to allow more time to survey the rest of the segment (Table 17). These accumulations included three recent mucket and two recent Wabash pigtoe mussel shells.

Damaged shells were observed throughout this segment. Similar to all other segments, fragile and worn shells were observed. Chipped shells were also found. These observations were associated with a shell midden observed at the tail end of an island located at the upriver segment boundary (Table 17). Crushed shells were observed in three shallow areas within this segment. The first was a shallow riffle at the downriver segment boundary. This area was delineated into survey site 2010.10.21-4-1. A second smaller area of crushed shells was noted just upriver from this site (Table 17). This second area was not delineated as a survey site because it was smaller and time did not allow further sampling. The third area of crushed mussels was located downriver of boat ramp C3.2. A survey site was delineated in this area (site 2010.10.21-4-2). However, due to the large extent of crushed mussels in this area and time constraints, the survey site represented only a small proportion of the total area of crushed shells. The approximate boundaries of this large area of crushed shells and survey site 2010.10.21-4-2 are shown in Figure 10.

Table 16. Total unionid mussel species[a] observed in sampling segment MS-4. Includes shell observations made throughout the waded 0.5 miles of the segment, including observations in the survey sites (2010.10.21-4-1; 2010.10.21-4-2).

			Species observed	
Common name	**Species**	**State status**	**Shell**	**Live**
Mucket	*Actinonaias ligamentina*		X	X
Elktoe	*Alasmidonta marginata*	Special concern	X	
Slippershell	*Alasmidonta viridis*	Threatened	X	
Cylindrical papershell	*Anodontoides ferussacianus*		X	
Spike	*Elliptio dilatata*		X	X
Wabash pigtoe	*Fusconaia flava*		X	X
Fatmucket	*Lampsilis siliquoidea*			
Pocketbook	*Lampsilis cardium*		X	
White heelsplitter	*Lasmigona complanata*		X	
Creek heelsplitter	*Lasmigona compressa*		X	
Fluted-shell	*Lasmigona costata*		X	
Eastern pondmussel	*Ligumia nasuta*	Endangered		
Round pigtoe	*Pleurobema sintoxia*	Special concern		
Giant floater	*Pyganodon grandis*			
Strange floater	*Strophitus undulates*		X	
Paper pondshell	*Utterbackia imbecillis*	Special concern		
Ellipse	*Venustaconcha ellipsiformis*	Special concern		
Rainbow	*Villosa iris*	Special concern	X	
Total number of unionid species			12	3

a. In addition to unionid mussels, live non-native Asian clam and shells were observed in the segment.

State status sources: MDNRE, 2010; MNFI, 2010.

Table 17. Isolated observations of recent dead and crushed shells made within sampling segment MS-4

Observation	Latitude	Longitude	Comments/details
A few crushed recent dead shells found	42.29617	-85.12585	Shells found in a 2–3 m^2 area; included mucket and Wabash pigtoe shells
A few crushed moderately worn 1 and recent dead shells found	42.29573	-85.12447	Observed species included mucket and Wabash pigtoe
Notable number of live mussels, recent dead shells, and crushed shells observed	42.29464	-85.12506	Coordinates indicate the start point of observations; Figure 10 shows the full extent of the area A survey site was delineated within this area
Area with crushed shells	42.29608	-85.12664	Species not identified; shells likely crushed by boats in this shallow area
Midden	42.29300	-85.12127	Pile of chipped shells located at upriver segment boundary
A few crushed recent dead shells found in riffle	42.29581	-85.12732	
One heavily worn slippershell found	42.29624	-85.12480	Shell was encased in marl

Live mussels in this segment and in survey sites were observed lying on their sides in shallow water. This was not observed in any other segments and could have been caused by boats scraping along the river bottom. Some of these displaced mussels had deep scratches on their shells but were not cracked. Observations of crushed shells were also made in this area (Figure 11). This was particularly evident in the area where survey site 2010.10.21-4-2 was delineated.

3.4.3 MS-4 survey site 2010.10.21-4-1

Sampling site 2010.10.21-4-1 was located near MP 10.25 at the downriver boundary of the sampling segment. The survey site consisted of a shallow riffle, 0.4-m-deep area that was 19-m-long and 10-m-wide, with a total surface area of 190 m^2. This survey site boundary delineation was based on finding a deposit of recent shells; boundaries were extended to the extent of recent shell observations. The substrate was a mix of pebble (64–16 mm diameter), gravel (16–2 mm), and sand (2–0.0625 mm).

Figure 11. Photograph of a crushed live mucket. This mussel was found approximately 10 m downriver from boat ramp C3.2.

Photograph taken by J. Matousek on October 21, 2010.

Shells from eight mussel species were found in this survey site (Table 18). Mucket shells were dominant, representing 72% of all shells that were found. Wabash pigtoe, the second most common species, only represented 11% of all shells. Slippershell (state threatened), creek heelsplitter, and strange floater shells were least common, with only a single shell found for each species. Shells from one species of special concern, elktoe, were also observed in low numbers. Three live mucket were also observed in this site.

A total of 74 shells were collected from this survey site (0.4 shells/m^2). Nine recent dead shells (12% of all shells collected) and eight moderately worn 1 shells (11%) were also observed. Some of these recent dead shells were categorized as crushed. The survey crew observed an airboat scraping against the river bottom while surveys were underway in the delineated site. The crew walked over the riffle where the airboat had passed and observed crushed recent dead shells in this area.

Table 18. Segment MS-4 survey site 2010.10.21-4-1 shell weathering characterization results

Species	Fresh dead	Recent dead	Moderately worn 1	Moderately worn 2	Heavily worn
Mucket	–	7	4	41	1
Elktoe	–	–	–	1	1
Slippershell	–	–	–	1	–
Cylindrical papershell	–	–	–	–	–
Spike	–	–	–	3	1
Wabash pigtoe	–	1	3	4	–
Fatmucket	–	–	–	–	–
Pocketbook	–	–	–	–	–
White heelsplitter	–	–	–	–	–
Creek heelsplitter	–	–	1	–	–
Fluted-shell	–	–	–	4	–
Eastern pondmussel	–	–	–	–	–
Round pigtoe	–	–	–	–	–
Giant floater	–	–	–	–	–
Strange floater	–	1	–	–	–
Paper pondshell	–	–	–	–	–
Ellipse	–	–	–	–	–
Rainbow	–	–	–	–	–
Total number of shells	0	9	8	54	3
Percentage	0.0%	12%	11%	73%	4.1%

3.4.4 MS-4 survey site 2010.10.21-4-2

Site 2010.10.21-4-2 was located just downriver of boat ramp C3.2. Depth was 0.4 m and the dimensions were 18-m-long and 12-m-wide, with a surface area of 216 m^2. This survey site boundary delineation was based on finding a scattered deposit of recent dead shells, many of which were crushed. The extent of the recent dead shells was larger than the site boundaries (Figure 10), but the entire area was not included due to time constraints. Therefore, this survey site is only a subsample of the total area of recent dead and crushed shells. The substrate was a mix of pebble (64–16 mm diameter), gravel (16–2 mm), and sand (2–0.0625 mm).

Shells from eight species were observed in this site. Similar to the other MS-4 survey site (2010.10.21-4-1), mucket were the dominant species observed, comprising 85% of all shells. Elktoe (species of special concern) and Wabash pigtoe shells were also common (both 5% of the total shells). Cylindrical papershell, pocketbook, and rainbow (a species of special concern) shells were least common, comprising less than 1% of all shells observed at the site. No state threatened or endangered species shells were observed in this site. A total of 12 live mucket and two Wabash pigtoe shells were also observed in this site.

A total of 155 shells were collected from the survey site (0.7 shells/m^2). Approximately 7% of the shells collected at this site were either recent dead (3.9%) or moderately worn 1 (3.2%). Twenty-one damaged shells were observed in this site. Nineteen of these shells were considered to be crushed (all mucket). One crushed live mucket and one Wabash pigtoe shell were also observed (Table 19).

Table 19. Segment MS-4 survey site 2010.10.21-4-2 shell weathering characterization results

Species	Fresh dead	Recent dead	Moderately worn 1	Moderately worn 2	Heavily worn
Mucket	–	3	4	124	–
Elktoe	–	–	1	4	3
Slippershell	–	–	–	–	–
Cylindrical papershell	–	–	–	1	–
Spike	–	–	–	1	2
Wabash pigtoe	–	3	–	5	
Fatmucket	–	–	–	–	–
Pocketbook	–	–	–	1	–
White heelsplitter	–	–	–	–	–
Creek heelsplitter	–	–	–	–	–
Fluted-shell	–	–	–	2	–
Eastern pondmussel	–	–	–	–	–
Round pigtoe	–	–	–	–	–
Giant floater	–	–	–	–	–
Strange floater	–	–	–	–	–
Paper pondshell	–	–	–	–	–
Ellipse	–	–	–	–	–
Rainbow	–	–	–	–	1
Total number of shells	0	6	5	138	6
Percentage	0.0%	3.9%	3.2%	89%	3.9%

3.5 Segment MS-5

Sampling segment MS-5 was located just upriver from the Mill Pond in Battle Creek. This was the most downriver segment that was surveyed. Approximately 0.7 miles of the 1-mile segment was surveyed, from MP 15.25 to MP 14.5 (Figure 12). Boat ramp C5 was located in this segment, which was in use at the time of the survey. No survey sites were delineated in this segment.

Figure 12. Sampling segment MS-5.

3.5.1 General conditions

During the survey, the weather was partly cloudy and seasonably warm (~ 60°F). A boat was used to access this segment because the water was too deep to safely wade through. Approximately one-third of MS-5 was too deep to survey (> 1 m). In addition, this segment was partially impounded by the Mill Pond Dam, and slow current speed caused fine particles to settle out of the water column and cover the bottom. This heavy sedimentation also limited the amount of habitat that could be thoroughly surveyed and made inspecting the river bottom in some areas difficult. A sudden and noticeable increase in turbidity occurred just as the surveyors reached the upstream end of the sampling segment, which effectively ended survey activities.

3.5.2 Segment MS-5 shell observations

Despite high turbidity and sedimentation, 12 mussel species were observed in this segment (Table 20). This was the only segment that did not contain cylindrical papershell and creek heelsplitter and the only site in which paper pondshell, a species of special concern, was observed (Figure 13). Only two species, spike and Wabash pigtoe, were observed live. Asian clams were also observed in this segment.

Shells in this segment were mostly moderately worn 2. No fresh dead or recent dead shells were observed. Moderately worn 1 shells were observed, but a survey site was not delineated because these shells were associated with a shell midden. Two crushed mucket shells were observed, one near boat ramp C5 and one near MP 14.75 in shallow water. Heavy sedimentation of fine particles and turbidity obscured the view of shells on the bottom and may have reduced the surveyors' ability to find fresh dead or recent dead shells within this segment.

4. Summary

4.1 Species Observed

Shells from 18 unionid species were observed in the Kalamazoo River during this survey. This included one state endangered species, one state threatened species, and five species of special concern (Table 21). When compared to University of Michigan Museum of Zoology's Mollusk Collection records and Wattles Park (Historic Bridge Park) survey results reported by Mulcrone and Mehne (2001), five new mussel species were observed during this survey, including the state endangered eastern pondmussel and threatened slippershell. In addition, non-native Asian clam (*Corbicula fluminea*) were found in all of the sampling segments.

Table 20. Total unionid mussel species[a] observed in sampling segment MS-5

Common name	Species	State status	Species observed
Mucket	*Actinonaias ligamentina*		X
Elktoe	*Alasmidonta marginata*	Special concern	X
Slippershell	*Alasmidonta viridis*	Threatened	X
Cylindrical papershell	*Anodontoides ferussacianus*		
Spike	*Elliptio dilatata*		X[b]
Wabash pigtoe	*Fusconaia flava*		X[b]
Fatmucket	*Lampsilis siliquoidea*		
Pocketbook	*Lampsilis cardium*		X
White heelsplitter	*Lasmigona complanata*		X
Creek heelsplitter	*Lasmigona compressa*		
Fluted-shell	*Lasmigona costata*		X
Eastern pondmussel	*Ligumia nasuta*	Endangered	
Round pigtoe	*Pleurobema sintoxia*	Special concern	X
Giant floater	*Pyganodon grandis*		
Strange floater	*Strophitus undulates*		X
Paper pondshell	*Utterbackia imbecillis*	Special concern	X
Ellipse	*Venustaconcha ellipsiformis*	Special concern	
Rainbow	*Villosa iris*	Special concern	X
Total number of unionid species			12

a. In addition to unionid mussels, live non-native Asian clam and shells were observed in the segment.
b. In addition to observing shells of this species, live individuals were also observed in the segment.

State status sources: MDNRE, 2010; MNFI, 2010.

The number of species and dominant species observed varied across segments (Table 22). The reference segment (MS-1) had the highest number of mussel species (16). Pocketbook shells were dominant in this segment, and shells of other species such as fluted-shell were also common. At MS-2, shells of 15 mussel species were observed. Spike shells were dominant in the MS-2 survey site, followed by Wabash pigtoe. In both the MS-3 and MS-4 segments, shells representative of 12 mussel species were identified, and mucket shells were dominant at all surveyed sites in these two segments. At MS-5, 12 species were observed. MS-5 was the only segment in which paper pondshell shells (species of special concern) were observed and cylindrical papershell and creek heelsplitter shells were not observed.

Figure 13. Photograph of a moderately worn 2 paper pondshell observed in segment MS-5.

Photograph taken by J. Matousek on October 25, 2010.

Table 21. Occurrences of state listed and special concern mussel species for each sampling segment

Species	State status	MS-1	MS-2	MS-3	MS-4	MS-5
Elktoe	Species of special concern	X	X	X	X	X
Slippershell	Threatened species	X	X	X	X	X
Eastern pondmussel	Endangered species	X				
Round pigtoe	Species of special concern	X	X			X
Paper pondshell	Species of special concern					X
Ellipse	Species of special concern	X	X			
Rainbow	Species of special concern	X	X	X	X	X

Sources: MDNRE, 2010; MNFI, 2010.

Table 22. Mussel shell species observed in each sampling segment

Species	MS-1	MS-2	MS-3	MS-4	MS-5
Mucket	X	X	X	X	X
Elktoe	X	X	X	X	X
Slippershell	X	X	X	X	X
Cylindrical papershell	X	X	X	X	
Spike	X	X	X	X	X
Wabash pigtoe	X	X	X	X	X
Fatmucket	X	X			
Pocketbook	X	X	X	X	X
White heelsplitter		X	X	X	X
Creek heelsplitter	X	X	X	X	
Fluted-shell	X	X	X	X	X
Eastern pondmussel	X				
Round pigtoe	X	X			X
Giant floater	X				
Strange floater	X	X	X	X	X
Paper pondshell					X
Ellipse	X	X			
Rainbow	X	X	X	X	X
Total number of unionid species	16	15	12	12	12

4.2 Shell Weathering

Table 23 provides shell weathering characterization results for the six survey sites. Fresh dead, recent dead, and moderately worn 1 shells were estimated to be less than three months post-mortem, as described in the agreed-upon work plan (Attachment A and Table 2 of this document), and these categories were combined in Table 23 for analysis purposes. The proportion of these shells within survey sites increases downriver from the spill, with the greatest percentage observed in segment MS-4 at site 2010.10.21-4-1 (23%). No fresh dead, recent dead, or moderately worn 1 shells were observed in the upstream reference segment, despite having the greatest density of shells. In summary, fresh dead, recent dead, and moderately worn 1 shells were more common in segments and survey sites downriver of the spill site compared to the reference site.

Table 23. Summary of delineated survey site shell weathering results. Percentage of shells < 3 months post-mortem was derived by dividing the total number of fresh dead, recent dead, and moderately worn 1 shells by the total number of shells observed in the site.

Segment/survey site	Shell density (shells/m^2)	Total number of shells	Number of fresh and recent dead shells	Number of moderately worn 1 shells	Shells < 3 months post-mortem (%)
MS-1					
2010.10.21-1-1	1.6	213	0	0	0%
MS-2					
2010.10.19-2-1	0.9	264	6	N/A	2.3%
MS-3					
2010.10.20-3-1	1.4	155	0	6	3.9%
2010.10.20-3-2	0.5	129	6	9	12%
MS-4					
2010.10.21-4-1	0.4	74	9	8	23%
2010.10.21-4-2	0.7	155	6	5	7.1%
MS-5 – no survey sites delineated within this segment					
N/A = MS-2 was surveyed prior to the development of "moderately worn 1" and "moderately worn 2" weathering categories; therefore, the number of moderately worn 1 shells is not available.					

4.3 Shell Damage

Damaged shells were observed in all five segments, but crushed shells were only found in the segments downriver of the spill site (Table 24). Broken shells that were in advanced stages of weathering were common in all segments, as would be expected as a result of natural in-stream weathering processes. Piles of chipped mussel shells were also common. These observations were associated with shell middens, which were observed in all but one of the segments. Crushed shells were observed in segments downriver of the spill site. No crushed shells were observed in the reference segment. The crushed shells included recent and moderately worn 1 shells, and crushed live mussels were also observed. Crushed shells were most often found in shallow water habitats downriver from boat ramps and in areas of high boat traffic. The largest area of crushed shells was found just downriver from boat ramp C3.2 in segment MS-4. The substrate in this area was discolored where boats had scraped along the river bottom. This area also contained a notable number of live mussels, some of which were lying exposed on their sides, with scratches on their shells. Others were crushed, including one individual that was still alive.

Table 24. Summary of damaged shells observed in each sampling segment. As categorized by the field team for the purposes of this study, broken shells are considered shells damaged due to advanced weathering, chipped shells are associated with predation, and crushed shells are defined as shells damaged by heavy impact (e.g., boat or foot traffic).

	Broken shells	Chipped shells	Crushed shells
MS-1	X		
MS-2	X	X	X
MS-3	X	X	X
MS-4	X	X	X
MS-5	X	X	X

4.4 Additional Observations

Additional observations of potential oil-spill-related impacts to mussel habitat were noted in sampling segments downriver from the spill site. Observations included oil sheens, elevated turbidity, and sedimentation/siltation:

- In segment MS-2, near boat ramp C1.5, oil sheens were observed in a heavily silted area near the location of two recent dead mussel shells. Moderate to high turbidity and siltation were observed in segments downriver from the spill site.
- Heavy siltation of river substrate and mussel shells were observed in segment MS-3. Fine silt covered the river substrate and mussel shells in areas with slow-moving water, and recent dead shells were often observed in these areas. Siltation may be the result of high turbidity from upriver dredging, eroding banks (observed near boat ramp C1.5), and/or boat traffic.
- Turbidity increased in segment MS-4, especially when boats passed through the survey site.
- Turbidity was greatest at the most downriver segment (MS-5), where it adversely affected the ability to conduct the survey. Despite conducting the survey of segment MS-5 under conditions of high turbidity and heavy sedimentation, crushed mussel shells were observed in this segment. This included two crushed mucket shells, one near boat ramp C5 and one near MP 14.75 in shallow water.
- A relatively large number of young live spike and mucket shells was found at MS-5. Based on a count of visible annular rings, these individuals were as young as three years old. This is notable because unionid mussels this young are not often observed during surveys, indicating that successful reproduction has occurred for these species in the recent past.

References

Badra, P. J. 2009. Status of Native Freshwater Mussels, Including the Northern Riffleshell (*Epioblasma torulosa rangiana*) and Rayed Bean (*Villosa fabalis*), in Detroit River, Michigan. Report number MNFI 2009-5. Report to U.S. Fish and Wildlife Service, Ft. Snelling, MN. 15pp.

Badra, P.J. 2010. Assessment of the Status and Distribution of Native Mussels (Unionidae) in Michigan, and Results of Unionid Surveys in the Eastern Upper Peninsula and Huron-Clinton Metroparks. Report number MNFI 2010-11. Report to Michigan Department of Natural Resources and Environment, Water Bureau, Lansing.

Enbridge Energy. 2011. Enbridge Energy, Limited Partnership. Line 6B Response Website: About Lakehead. Available: http://response.enbridgeus.com/response/main.aspx?id = 12780.

Grabarkiewicz, J. and W. Davis. 2008. *An Introduction to Freshwater Mussels as Biological Indicators*. EPA-260-R-08-015. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC.

Hoke, E. 2005. The unionid mussels of the Big Blue River Basin of northeastern Kansas and southeastern Nebraska. *Transactions of the Nebraska Academy of Sciences* 30:33–58.

Kat, P.W. 1984. Parasitism and the Unionacea (Bivalvia). *Biological Review* 59:189–207.

MDNRE. 2010. Michigan Administrative Code R299.1021. Endangered and Threatened Species. Available: http://www.state.mi.us/orr/emi/admincode.asp?AdminCode = Number&Admin_Num = 29900061&RngHigh = 29999999.

MNFI. 2010. Michigan's Special Animals. Endangered, Threatened, Special Concern, and Probably Extirpated. Michigan Natural Features Inventory. Available: http://web4.msue.msu.edu/mnfi/data/special_animals_list.pdf.

Mulcrone, R.S. and C. Mehne. 2001. Freshwater Mussels of the Kalamazoo River, Michigan, from Battle Creek to Saugatuck. Prepared for Lisa L. Williams U. S. Fish and Wildlife Service. October 1.

Myers-Kinzie, M.L., S.P. Wente, and A. Spacie. 2001. Occurrence and Distribution of Freshwater Mussels in Small Streams of Tippecanoe County, Indiana. *Proceedings of the Indiana Academy of Science* 110:141–150.

Pusch, M., J. Siefert, and N. Walz. 2001. Filtration and respiration rates of two Unionid species and their impact on the water quality of a lowland river. In *Ecology and Evolution of the Freshwater Mussels Unionoida*, G. Bauer and K. Wachtler (eds.). Springer, Berlin, pp. 317–325.

Strayer, D.L. 1999. Freshwater mollusks and water quality. *Journal of the North American Benthological Society* 18:1.

Strayer, D.L., D.C. Hunter, L.C. Smith, and C.K. Borg. 1994. Distribution abundance, and roles of freshwater clams (Bivalvia, Unionidae) in the freshwater tidal Hudson River. *Freshwater Biology* 31(2):239–248.

Strayer, D.L. and H.M. Malcom. 2007. Shell decay rates of native and alien freshwater bivalves and implications for habitat engineering. *Freshwater Biology* 52:1611–1617.

U.S. EPA. 2010. Removal Administrative Order in the Matter of Enbridge Energy Partners, L.P. Docket Number CWA 1321-5-10-001. July, 27. Available: http://www.epa.gov/enbridgespill/pdfs/enbridge_removal_order_20100727.pdf.

Watters, G.T. 1992. Unionids, fishes, and the species-area curve. *Journal of Biogeography* 19:481–490.

Watters, G.T. 1995. Small dams as barriers to freshwater mussels (Bivalvia, Unionoida) and their hosts. *Biological Conservation* 75:79–85.

Williams, J.D., M.L. Warren, Jr., K.S. Cummings, J.L. Harris, and R.L. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. *Fisheries* 18:6–22.

A. Mussel Shell Survey Work Plan

October 16, 2010

Unionid mussel shell survey in the Kalamazoo River watershed, in the Marshall and Battle Creek, MI area

Introduction

On July 26, 2010, Enbridge Energy, Limited Partnership discovered a release of heavy crude oil (Cold Lake Blend) from line 6B just west of milepost 608 in the vicinity of its pump station located in Marshall, Calhoun County, Michigan. Line 6B is a 30-inch, 190,000 barrels per day (bpd) line transporting light synthetics, heavy and medium crude oil from Griffith, IN, to Sarnia, Ontario. The location of the release from Line 6B is located in an undeveloped area in the outskirts of town with coordinates of approximately North ½ Section 2, T3S, R6W, Latitude: 42.2395273 Longitude: -84.9662018. Upon discovery of the release the pipeline was shut down and isolation valves closed, stopping the source of the oil; however, initial estimates are that approximately 1 million gallons of crude oil may have been released to Talmadge Creek (approximately 1.5 miles) and to the Kalamazoo River.

Unionid mussels are an important biological resource in the state of Michigan and component of the state's natural heritage. Of the 46 unionid species that occur in Michigan, 19 are threatened or endangered in the state. One state endangered, three state threatened, and six special concern species have been documented in the Kalamazoo River since 1989 (Peter Badra, MNFI, personal communication, 2010). Anecdotal observations of dead mussels, and "fresh" and recent dead mussel shells (see below for definition of "fresh" and "recent") in areas of response activities in the river are suggestive of mussel injuries, including physical injuries caused by the breaking of shells by boat and other transportation on the river, as well as potentially injuries due to exposure to released contaminants.

Scope

This work plan describes freshwater bivalve (mussel) shell survey activities on the Kalamazoo River from Marshall impoundment to the town of Battle Creek, MI. The proposed survey will be conducted by the Michigan Natural Features Inventory (MNFI) and Stratus Consulting on behalf of the natural resource trustees (Trustees) in cooperation with Enbridge. Results may be used to identify and characterize potential injury to mussel communities resulting from toxicity due to exposure to hazardous substances, and physical injury (e.g., crushed shells) as a result of response activities, associated with the release of oil into Talmadge Creek and Kalamazoo River. Some of these data are ephemeral. Information on the location of dead mussels and the "freshness" of mussel shells will largely be lost over time and during spring high water events, if

not observed and recorded this fall. Additionally, survey information can be used to design a more intensive mussel community survey to be conducted next year.

The survey will focus on locating "fresh" or "recent" dead mussel shells. Interpretation of the age of mussel shells post-mortem can be made based on the condition of the shells according to the scale and physical characteristics described in Table 1. Classification of the age of shells post-mortem using this scale is qualitative and somewhat approximate. However, the scale is sufficiently precise for the purposes of this survey, which is to identify shells of dead mussels associated with the spill event and response activities. In other words, shells that fall into the first two categories in Table 1.

Table 1. Mussel shell scale

Scale	Category	Physical characteristics	Approximate post-mortem shell age
1	Fresh dead	Soft tissue intact	Several days
2	Recent dead	No soft tissue, aside from hinge ligament	Couple of weeks up to ~3 months
3	Moderately worn	Most of periostracum intact, shell has most of its original strength	3 months to one year
4	Heavily worn	periostracum worn and peeling, shell at least somewhat chalky and fragile	Greater than one year

Note that this survey is focused on mussel shells, and it is not intended as a mussel population survey. Occurrence and abundance of live mussels will be documented, if they are encountered during the shell survey. However, the survey is being conducted in the fall, the time of year when live mussels burrow into the sediment, where they spend winter months. Therefore, estimates on live mussel abundance made during this survey may not reflect the actual of live mussel abundance at surveyed sites.

The survey will be conducted in October 2010. It is anticipated that the survey will take approximately five days in the field, with five crew members, and may require a boat and supplies, to be arranged by MNFI.

Objectives

The objectives of this study are as follows:

- Survey selected segments of the Kalamazoo River from Marshall impoundment to the town of Battle Creek for fresh and recent dead mussel shells.

- Delineate the spatial extent of fresh and recent dead mussel shells within the selected segments. Delineated spatial areas of fresh and recent dead mussel shells will define survey sites.
- Within survey sites, document mussel shells observed, including species and condition (state of shell weathering; 1 through 4). Observed live mussels will also be recorded.

Preliminary Sampling Locations

Five discrete sampling segments have been identified on the Kalamazoo River between Marshall Impoundment and the Mill Pond at the Town of Battle Creek (approximate river mile 15.5). Sampling segments have been selected according to proximity to the spill site, areas of known response activities, locations of boat launches (and hence elevated boat activity), and prior mussel tissue and sediment sampling locations. The mussel shell survey protocol will be conducted at each of the sampling segment as time permits. Note that the locations may be subject to change, depending upon conditions encountered when in the field. The segments consist of one reference and four locations downstream of the release. An additional reference segment may be added, based on need, as judged by the crew while in the field.

Each sampling segment represents approximately one mile of river. One sampling segment will be sampled each day as described in Table 2. The crew will cover as much of the mile identified at each site as they can in one day, and then progress to the next site the following day. Though the crew may be successful at covering the full mile at each site, this is somewhat uncertain, and will depend upon field conditions encountered. The crews will move to a new segment each day even if the previous segment was not fully surveyed to ensure adequate coverage of the impacted length of the river. The segments will only be surveyed in habitat that is practically accessible. (i.e., not too deep or swift to wade, or contain complex habitat that limits observation of the river bottom).

Table 2. Mussel shell survey sampling segments and schedule. River miles area as reported by Enbridge.

Sampling day	Sampling segment (river miles; RM)	Attributes	Map figure number
1	MS-1: Down river of Marshall Impoundment (RM not available)	Reference area, contains a past survey location	Figure 1
2	MS-2: Talmadge Creek confluence area (RM 2.25 to 3.25)	Exposure area, contains a boat ramp and near a past survey location	Figure 2
3	MS-3: Boat ramp near 11 Mile Road Bridge (RM 7.00 to 8.00)	Exposure area, contains a boat ramp and past survey location	Figure 3
4	MS-4: Boat ramp near Historic Bridge Park (RM 9.25 to 10.25)	Exposure area, contains two boat ramps and past survey location	Figure 4
5	MS-5: Boat ramp at Rivers Edge Landscaping (RM 14.5 to 15.5)	Exposure area, contains a boat ramp and near sediment sparging/removal locations	Figure 5

Figure 1. Sampling segment downriver of Marshall Impoundment (MS-1).

Figure 2. Talmadge Creek confluence area sampling segment (MS-2).

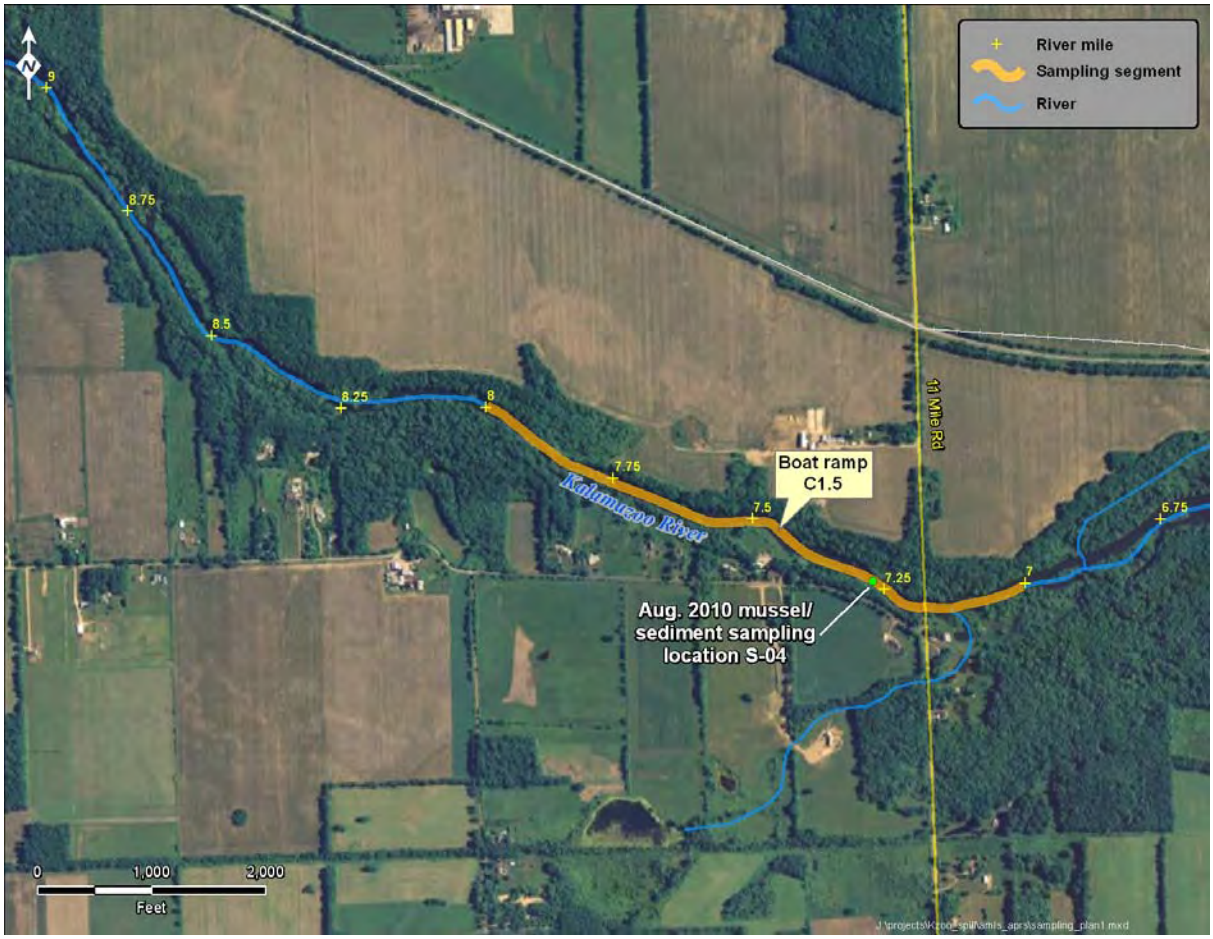


Figure 3. Sampling segment near 11 Mile Road bridge (MS-3).

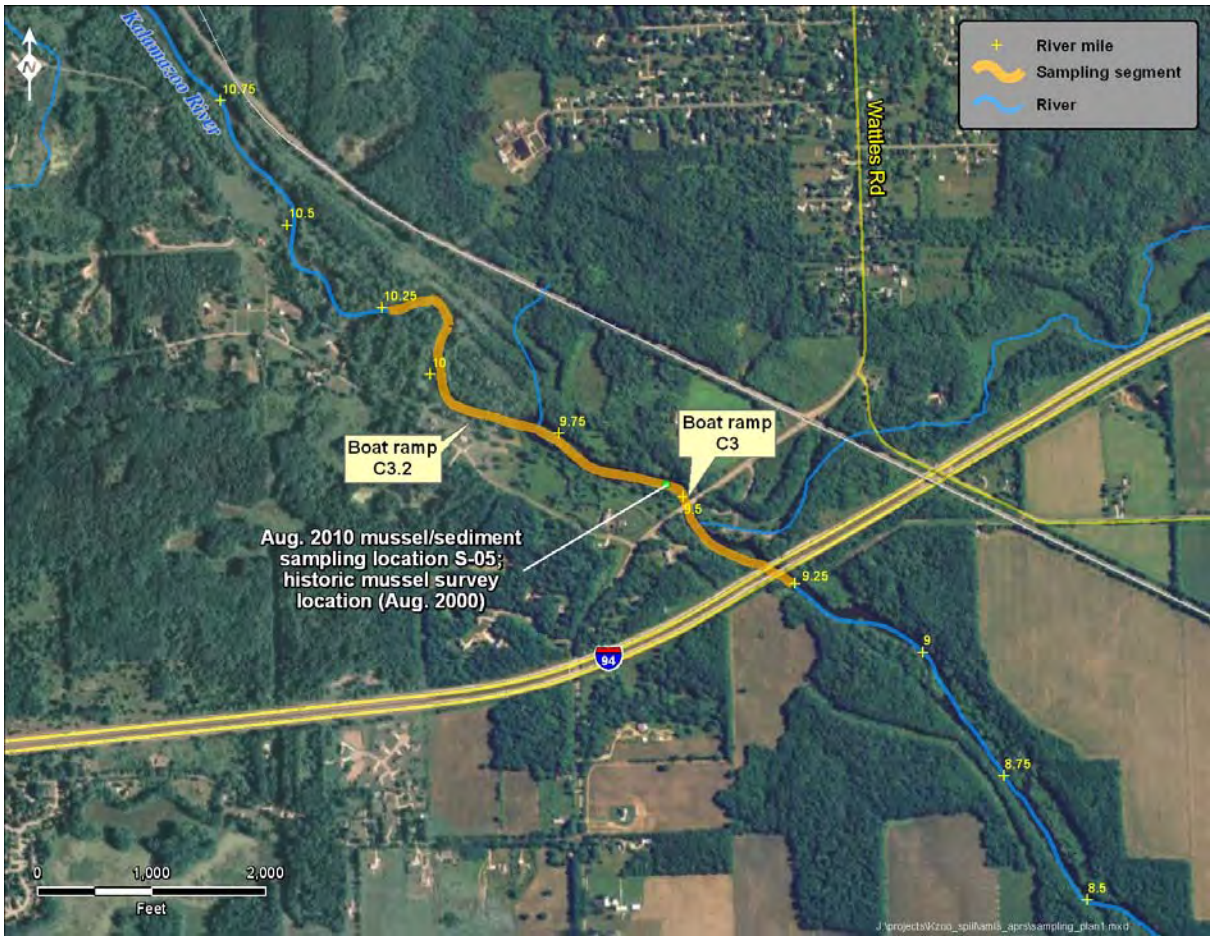


Figure 4. Sampling segment near Historic Bridge Park (MS-4). Historic mussel survey conducted by (Mulcrone and Mehne, 2001) in the summer of 2000.

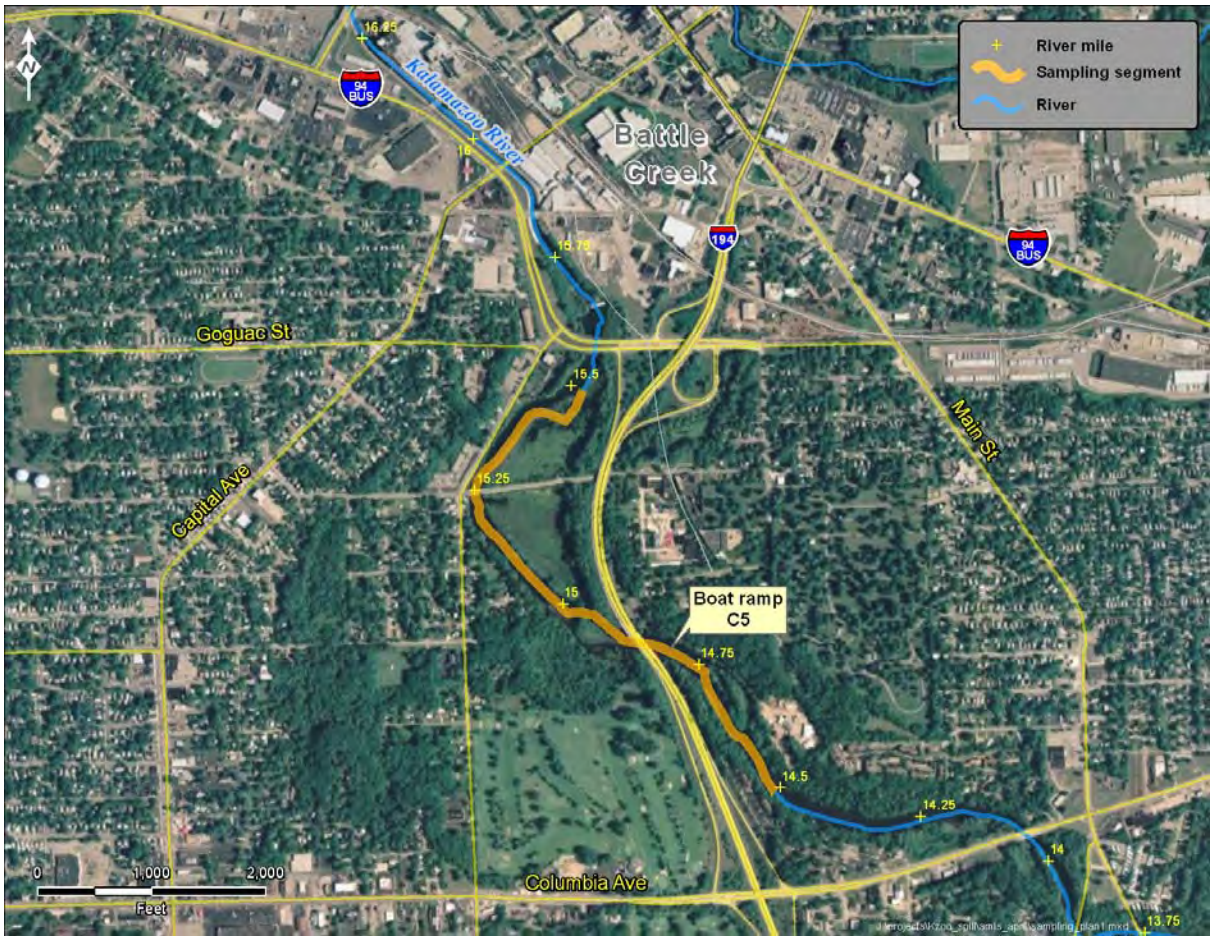


Figure 5. Sampling segment near Rivers Edge Landscaping in Battle Creek, MI (MS-5).

Survey Methods

The mussel shell survey will led by MNFI and Stratus Consulting on behalf of the Trustees, in cooperation with Enbridge representatives. There will be a total of four to five crew members. Surveys will follow the mussel shell survey protocol (provided below). These methods may be modified to suit conditions encountered in the field as necessary. Any changes to the method made in the field will be recorded and shared with all parties involved. This survey will focus on identifying fresh and recent dead native mussel species shells. However, presence of older shells (category 3 and 4), and live mussels and non-native dreissenid mussels (*Dreissena polymorpha* and *Dreissena bugensis*) and Asian clams (*Corbicula fluminea*) will be noted in survey sites.

Survey information will be recorded onto a survey site-dedicated datasheet (Attachment 1). One datasheet will be used for each survey site. Additional information such as field personnel, start and stop times and coordinates, and photograph information will be recoded on a sampling segment datasheet. Only one sampling segment datasheet will be completed each day.

Note, that the survey will not be possible if river conditions, such as high flow and turbidity, limit observation of mussel shells. If it is determined that the substrate and mussel shells observations can not be made in wadable river reaches (depths ~1 meter) the survey will not be conducted until conditions improve.

Mussel Shell Survey Protocol

- Travel upriver through the sampling segment by wading.
- The crew will wade the river in a parallel line, inspecting the substrate with a stream bottom viewer and/or polarized glasses. Encountered objects may need to be picked up to enable identification of shells, and their categorization according to the shell scale (see Table 1).
- When fresh dead or recent dead mussel shells are encountered, this defines the downriver boundary of a survey site:
    - The survey site boundary GPS coordinates are taken and recorded in the datasheet (Attachment 1)
    - Survey sites will be named according to a predetermined naming convention:
        - Survey date (Year.Month.Day) – sampling segment ID – consecutive survey number conducted in the sampling segment
        - Example: 2010.10.26–2–004

- The survey site is delineated and surveyed simultaneously:
  - The crew continues to advance upriver (and across the wadable river-width), and all shells encountered are picked up and examined to identify the species and condition of the shell according to the shell scale (see Table 1 for shell scale).
  - Each observed shell, its species, and condition (1-4) are recorded in the field datasheet (Attachment 1).
  - Each observed live mussel is also identified and recorded in the datasheet.
  - Once crew members reach a point (upriver and across the wadable river width) where fresh/recent dead shells are no longer encountered, this defines a boundary of the survey site. At this boundary, the crew stops recording shell and live mussel observations.
  - Once the boundaries of the survey site have been identified, the dimensions of the survey site are then recorded in the datasheet, including survey site boundary lengths, a sketch of the survey site is drawn, and average water depth is recorded.
- An estimated proportion of substrate surface area covered with fresh/recent dead shells in the entire survey site (see datasheet for percentage categories) is then recorded on the datasheet.
  - Proportion estimates will be performed by at a minimum two crew members (and preferably with all crew members), and the agreed upon values will be recorded on one datasheet
- Notes regarding occurrence of shell piles, or other pertinent survey related information on the field datasheet in the spaces provided.
- Representative shell samples may be collected; samples will be place inside a labeled paper bag; shells will be stored at MNFI.
  - Sample labels will include the following information:
    - Collection date, time, and GPS coordinates (decimal degrees to five decimal places)
    - Name, affiliation, and phone number of collector
    - Species and condition represented by the sampled shell
- Pictures should be taken so that each species and shell condition is documented for the survey site. Pictures should also be taken of any other pertinent subjects while conducting the survey. The crew will work with a GPS unit and keep a tracklog running.
  - A common GPS unit and camera will be used and supplied by Entrix
  - The GPS unit will be reset, once, at the beginning of the survey

- Once a day, a picture of the GPS screen will be taken (the easiest way is to take it from a distance and do not zoom in) that shows the time on the GPS screen to the nearest second (see Attachment 2 for GPS tracklog and photo management protocol).

- Continue traveling upriver inspecting substrate, until fresh/recent dead shells are observed again. This defines the downriver boundary of the next survey site. Continue defining survey sites, and conducting surveys until the entire sampling segment has been inspected.
  - If the mile long sampling segment cannot be surveyed in the scheduled field day (Table 2), then estimated proportion of the sampling segment that had been sampled will be documented on the field datasheet

- At the end of each day field datasheets will be scanned into a pdf file. Scanned datasheets, pictures, and GPS tracklogs will be saved onto a backup device, such as a USB port or external drive. These data will then be uploaded to the Entrix and trustee's ftp sites. Trustees will retain the original datasheets and will provide copies to Entrix/Enbridge as requested.
  - Pdf datasheets and pictures files will be named according to a predetermined naming convention:
    - YearMonth.Day.Shell.Datasheet.sequential.series (example: 2010.Oct.25.Shell.Datasheet.015)
    - YearMonth.Day.Shell.Tracklog (example: 2010.Oct.25.Shell.Tracklog)
    - YearMonth.Day.Shell.Picture.sequential.series (example: 2010.Oct.25.Shell.Picture.005).

Reporting

The survey will be summarized in report format. The report will include a summary of survey methods and results. The report will include a map showing surveyed locations and brief description of relevant conditions at each location. For each survey site location, the report will include a description of the weathering condition of dead shells in the entire survey location for each native mussel species. Locations of live mussels and occurrence of non-native mussels will also be reported.

Reference

Mulcrone, R.S. and C. Mehne. 2001. Freshwater Mussels of the Kalamazoo River, Michigan, from Battle Creek to Saugatuck. Prepared for Lisa L. Williams U. S. Fish and Wildlife Service. October 1.

Attachment 1. Field Datasheets

Field Recorder:	Page ___/___
Enbridge Oil Spill Mussel Shell Survey Field Datasheet	
Location Information	
Sampling Segment:	
Site Description/Landmarks/Access/Other Notes:	
GPS Coordinates (decimal degrees to 5 decimal places)	
Start location	End location
Latitude:	Latitude:
Longitude:	Longitude:
Start Time:	End Time:
Weather Conditions:	
Air Temperature:	
Personnel Present	
Name - Affiliation	Name - Affiliation

Photograph Documentation			
Camera id/owner:		GPS unit id/owner:	
Photo #	Time	Photographer/Camera	Subject

Survey Site	(in consecutive order)	Page ___/___
Surveyor(s):		Date:

Enbridge Oil Spill Mussel Shell Survey – Mussel Survey Data

Habitat Information

Coordinates at downriver boundary:

Survey Site Area Measurements

Dimensions	Est. length (m)	Draw shape (label sides and flow direction)
Side 1		
Side 2		
Side 3		
Side 4 (opt)		
Depth (1/10 meter)		

Proportion of substrate covered by shells

Coverage (check one)

>1%	1 to 5%	6 to 25%	26 to 50 %	51 – 75%	>75%

Shell piles: y/n

Notes:

Non-native species present (Y/N):

Sampling Segment:							Page ___/___
Field Recorder:							Date:
Shell and Mussel Observations							
		Shell Condition (check one)					
Species (G. species)	Live Mussel (check)	Fresh	Recent dead	Mod. worn	Heavily worn	Crushed shells (Y/N)	Notes/observations

Sampling Segment:							Page ___/___
Field Recorder:							Date:
Shell and Mussel Observations (cont'd)							
		Shell Condition (check one)					
Species (G. species)	Live Mussel (check)	Fresh	Recent dead	Mod. worn	Heavily worn	Crushed shells (Y/N)	Notes/observations

Sampling Segment:			Page ___/___
Field Recorder:			Date:
Photograph Documentation (cont)			
Photo #	Time	Photographer/Camera	Subject

Attachment 2. Entrix Protocol for Using a Digital Camera, GPS, and the Photolink Software

- GPS (these directions typically apply to Garmin handheld units)
  - Set GPS units to decimal degrees
    - Main menu/setup/units/hddd.ddddd
  - Set GPS track mode to on
    - Main Menu/tracks
    - It is best if the track log is cleared before you start
    - Intervals should be adjusted based on mode of transportation (i.e., increase interval if walking, decrease interval if boating)
  - Setup GPS track mode
    - Main menu/tracks/options/setup track log
  - Select local time for time display
    - Main menu/setup/time
  - Check to make sure that the GPS is "ready to navigate" when you are taking pictures
  - To save a waypoint
    - Main menu/mark/ok – saves the waypoint using the number in the flag as the ID number. The number automatically increases with each waypoint you save. You can rename the waypoint by editing the label in the flag.
  - To navigate to a waypoint
    - Main menu/find/waypoints
- Camera
  - Set camera time to GPS date and time to the nearest second.
  - After changing camera batteries, check to make sure time has not reset to some default.
  - Take a picture of the GPS screen (the easiest way is to take it from a distance and do not zoom in) that shows the time on the GPS screen to the nearest second. **This only needs to be done once per day.**
- Photolink
  - You must have the GPS with you and have the track-logs on in order to georeference your pictures.
  - The GPS photolink program automatically downloads your track log when you process your photos. Be aware that you can not use a track log saved on the GPS in photolink.

- You can save track logs to your computer using the Garmin Mapsource software if you do not have the photolink software. This is the only program I've found that saves the tracklog in a format that can be used by photolink. It comes with most Garmin map packages and is available as a stand alone program.

B. Field Datasheets

15mile +

Field Recorder: J. Matowich	Date: 10/18/10	Page 1/1

Enbridge Oil Spill Mussel Shell Survey Field Datasheet

Location Information

Sampling Segment: Reference Location

Site Description/Landmarks/Access/Other Notes:

Start @ 17 mile Rd Bridge

GPS Coordinates (decimal degrees to 5 decimal places)

Start location 17mile strt	End location 17mile end
Latitude: N 42.26480	Latitude: N 42.26211
Longitude: W084.96385	Longitude: W084.95558
Start Time: 10:20 am	End Time: 15:33

Weather Conditions: Cloudy, 55°F

Air Temperature: 55°F

Personnel Present

Name - Affiliation	Name - Affiliation
John Matowich / ENTRIX	
Matt Wesener / DNRE	
Bill Taft / DNRE	
Mike Wilson / DNRE	
Pete Badra / MNFI	
Mike Kearney / Stratus	

Photograph Documentation

Camera id/owner: GPS unit id/owner:

Photo #	Time	Photographer/Camera	Subject
1			Spike, Recent dead
2			Eastern pond mussel, mod worn
3			Rainbow, mod. worn
4			Spike, Live
5			Pocketbook, Live
6			Pocketbook, mod worn
7			Rainbow, mod. worn
8			Elk toe, heavily worn
9			Cylindrical papershell, heavily worn
10			Ligner shell, mod worn
11			Elliptio, Live
12			Giant floater, mod. worn
13			Strange floater, mod worn
14			Creek Heelsplitter, Heavily worn
15, 16, 17			Crew photo
18, 19			Mucket, Mod. worn
20, 21			Round pigtoe, Mod worn

Field Recorder: J. Matousek Date: 19 Oct 2010 Page 1/3

Enbridge Oil Spill Mussel Shell Survey Field Datasheet

Location Information ~~MS-2M~~ North MS-02

Sampling Segment:

Site Description/Landmarks/Access/Other Notes:

Start at River mile 3.0

GPS Coordinates (decimal degrees to 5 decimal places)

MS02 STRT Start location	Boat launch End location MS02END
Latitude: N 42.25925	Latitude: N 42.25864
Longitude: W085.01009	Longitude: W084.99898
Start Time: 09:30	End Time: 16:44

Weather Conditions: Cloudy

Air Temperature: ~50°F

Personnel Present

Name - Affiliation	Name - Affiliation
John Matousek - ENTRIX	
Mike Wilson - DNRE	
Matt Lederer - DNRE	
Bill Taft - DNRE	
Pete Badra - MNFI	
Mike Carney - Stratus	

Photograph Documentation

Camera id/owner: GPS unit id/owner:

Photo #	Time	Photographer/Camera	Subject
1,2		GPS time	GPS, time
3,4			Wabash pigtoe - mod worn
5			Strange - floater - mod worn
6			Rainbow - mod. worn
7			Asian clam - mod worn
8			Spike - Recent dead
9			Pocketbook - Live
10			Elktoe - mod. worn
11			Creek heelsplitter, mod worn
12,13			fluted shell, mod. worn
14			Wabash pigtoe, mod. worn
15			Elipse, mod worn
16			White heelsplitter, Live
17			Mucket mod. shell
18			fluted shell, stain inside
19			Elktoe, cracked top
20			Slipper shell
21,22,23			Crow photos
24			Pocketbook, cracked, Recent dead

25 - Recent spike

26 - Mod. worn broken shell pocket book

Survey Site (in consecutive order) Page 21 4

MS-02 Transect 1

Surveyor(s): Matousek, Taft, Bodra, Weaver, Carney, Wilson Date: 19 Oct 10

Enbridge Oil Spill Mussel Shell Survey – Mussel Survey Data

Habitat Information

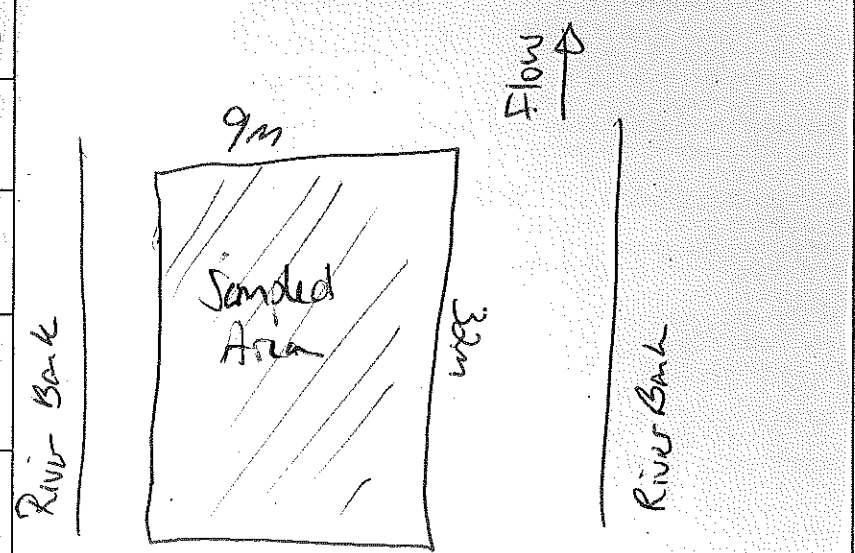
Coordinates at downriver boundary:

N 42.25979 W 085.01019 to N 42.25983 W 085.01996

Survey Site Area Measurements

Dimensions	Est. length (m)
Side 1	9m
Side 2	32m
Side 3	9m
Side 4 (opt)	32m
Depth (1/10 meter)	4/10 m

Draw shape (label sides and flow direction)



Proportion of substrate covered by shells

Coverage (check one)

<1%	1 to 5%	6 to 25%	26 to 50 %	51 – 75%	>75%
Less than 1%					

Shell piles: y/n

Notes:

Asian Clams observed

Non-native species present (Y/N):

Start ~5m from (L) bank, cover ~~approx 10m~~ 9m of stream channel wide and 32m long

Sampling Segment: MS-02 transect 1 (at Mile 3.0 sign) Page 3 of 3

Field Recorder: J. Matousek Date: 19 Oct 10

Shell and Mussel Observations (cont'd) way pt MS02 TRAN1 START N42.25979 W085.01019

Species (G. species)	Live Mussel (check)	Shell Condition (check one): Fresh	Recent dead	Mod. worn	Heavily worn	Crushed shells (Y/N)	Notes/observations
Habersnipgtoe ~~Spike~~			/	卌 卌	卌 /		moderate 卌 卌 ////
				卌 卌			
				卌 卌			
Spike			//	卌 卌	卌 卌		moderate 卌 卌 ///
Spike				卌 卌	卌 //		
				卌 卌			
				卌 卌			
				卌 卌			
Pocket beach			/	卌 卌	卌 卌		
				卌 卌			
				卌			
Rainbow				卌 卌	//		
Fluted shell			/	卌 /	卌		
Mucket				/			
Elliptoe				////	卌 //		
Elipse				卌 卌	/		
				////			
Strange floater			/	卌 卌	卌 卌		
				卌 ///	///		
Round pigtoe				卌 //	//		
Sugar-shell				//	/		

Asian Clams also observed

End point MS02 TRAN END (12:15)

N42.25983 W085.00980

Sampling Segment: MS-02 Page 8/14

Field Recorder: Matrunk Date: 19 Oct 10

Photograph Documentation (cont)

Photo #	Time	Photographer/Camera	Subject
27			Pocketbook, mud worm, broken shell
28			Spike, recent dead, broken shell
29			Pocketbook, recent, broken shell
30			shell deposit (animal related)
31			fat mucket Live
32, 33, 34			fresh dead pocketbook
35			broken shells
36			broken spike shells, + pocketbook
37			Cylindrical papershell

Field Recorder: J. Matousek Date: 20 oct 2010 Page 1/4

Enbridge Oil Spill Mussel Shell Survey Field Datasheet

Location Information

Sampling Segment: MS-03

Site Description/Landmarks/Access/Other Notes:

Put in at the 11 mile road bridge crossing
walked down to mile marker 7.75

GPS Coordinates (decimal degrees to 5 decimal places)

time 10:13 Start location mile marker 7.75	End location
Latitude: N 42.27732	Latitude: N 42.27443 W 085.08154
Longitude: W 085.09117	Longitude: W 085.08154
Start Time: 10:13	End Time: 16:30

Weather Conditions: Sunny

Air Temperature: <50°F

Personnel Present

Name - Affiliation	Name - Affiliation
Ryan Grafton Cardno Entrix	
John Matousek Cardno Entrix	
Pete Badra - MNFI	
Matt Wagner - DNRE	
Mike Wilson DNRE	
Mike Carney - Stratus	

Photograph Documentation

Camera id/owner: GPS unit id/owner:

Photo #	Time	Photographer/Camera	Subject
1,2		Matousek / #1	GPS time/date
3			Mucket / moderate 2
4			Elk toe / moderate 2
5			Spike / moderate 1
6			Ludwig heelsplitter / Live
7			Black pigtoe / moderate 2
8			fluted shell / moderate 2
9			Strange floater / moderate 2
10			Pocketbook / moderate 2
11,12,13			Crawdaddies
14,15			Moderate / example Mucket
16			Rainbow Moderate 2
17			Mucket with hole/damage
18			Slipper - heavy worn
19			Cylindrical papershell mod 2
20			Recent looking shells

Survey Site (in consecutive order) Page 2/4

MS-3 Transect 1

Surveyor(s): Matousek, Barden, Carey, Grafton, Wilson, Wagner Date: 20 oct 2010

Enbridge Oil Spill Mussel Shell Survey – Mussel Survey Data

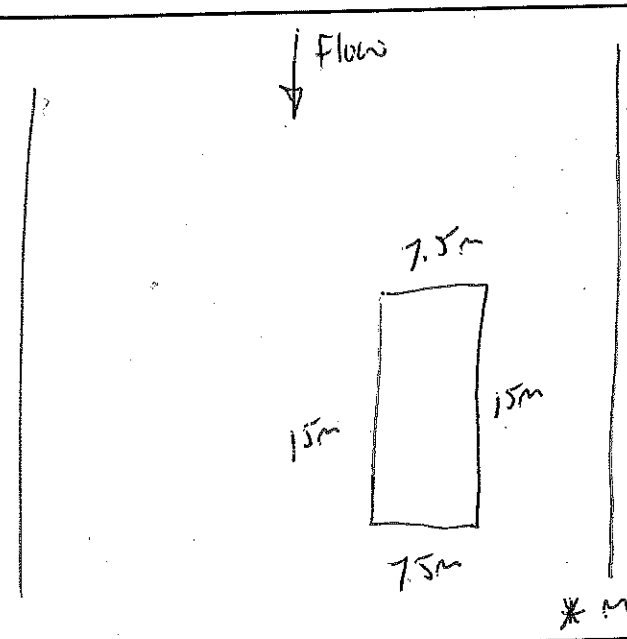
Habitat Information

Coordinates at downriver boundary: N42.27737 W085.09080 Upstream boundary N42.27736 W085.09071

Survey Site Area Measurements

Dimensions	Est. length (m)
Side 1	7.5m
Side 2	15m
Side 3	7.5m
Side 4 (opt)	15m
Depth (1/10 meter)	4/10 m

Draw shape (label sides and flow direction)



* mile marker 7.75

Proportion of substrate covered by shells

Coverage (check one)

>1%	1 to 5%	6 to 25%	26 to 50 %	51 – 75%	>75%
	✓				

Shell piles: y/n

Notes: Very encrusted shells. All/most shell with significant marl coating

Non-native species present (Y/N):

Asian Clams

7.5m x 15m Rectangular Section

Sampling Segment: MS-3 Transect 1 Page 3/4

Field Recorder: J. Matousek Date: 20 Oct 2010

Shell and Mussel Observations (cont'd)

		Shell Condition (check one)					
Species (G. species)	Live Mussel (check)	Fresh	Recent dead	Mod. worn (1)	~~Heavily worn~~ mod. (2)	~~Crushed shells (CND)~~ Heavily worn	Notes/observations
Pocketbook					卌 //	//	
Mucket	卌 卌			///	卌 卌	/	broken shells /
	/				卌 卌		additional mod (2)
					卌 卌		卌 卌 卌 卌 卌
					卌 卌		///
					卌 卌		
					卌 卌		
Fluted shell				///	卌 卌	/	
					卌 /		
Wabash pigtoe	//				卌 卌	/	
					卌 卌		
					////		
Elk toe					/		
White heelsplitter					//		
Strange floater					///	//	
Spike	/				/		

8m x 31m

Sampling Segment: MS-3 Transect 2 Page 4/4

Field Recorder: Matousek Date: 20 Oct 2010

Shell and Mussel Observations (cont'd)

Species (G. species)	Live Mussel (check)	Shell Condition (check one) Fresh	Recent dead	Mod. worn (1)	~~Heavily worn~~ Mod (2)	~~Crushed shells (Y/N)~~ Heavily worn	Notes/observations
Mucket	5 3			2	5 5 2	1	
Slipper shell						5	
Elktoe					5 5 5 1	5 5 3	broken shell on some
Strange floater			2	1	5 5 5 5 3 1	5 5 3	broken shells on some
Spike			4	4	5 5 2	2	broken shell on some
Wabash pigtoe				2	5 3 2	1	
Rainbow					3	5	
fluted shell					3	2	
Cylindrical papershell					1		
Creek heelsplitter					1		

Asian Clam

Survey Site MS-3 Transect 2 (in consecutive order)	Page ___/___
Surveyor(s): Matousek, Bodna, Heuer, Wilson, Conley, Grafton	Date: 20 oct 2010

Enbridge Oil Spill Mussel Shell Survey – Mussel Survey Data

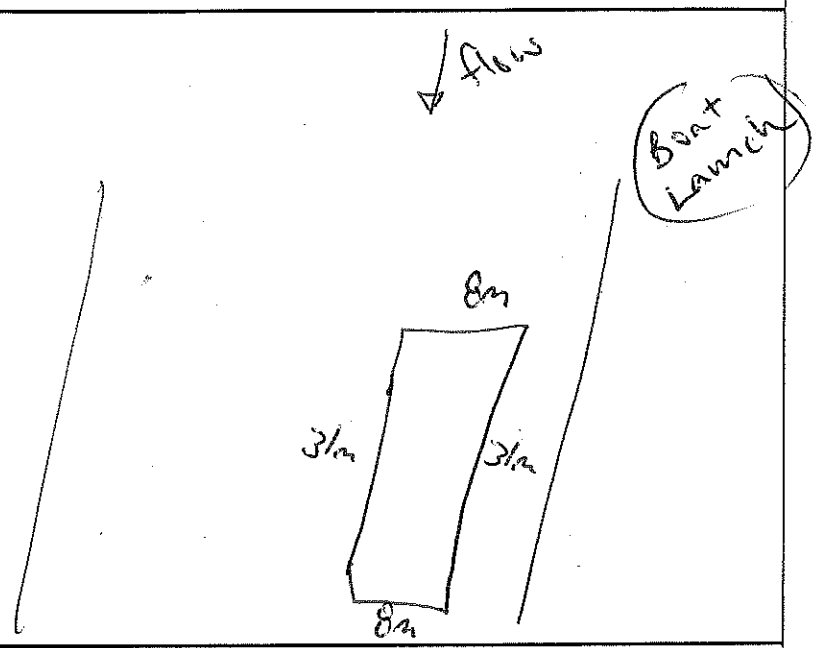
Habitat Information

Coordinates at downriver boundary:

Start N42.27657 W085.08723 end (upriver boundary) N42.27661 W085.08678

Survey Site Area Measurements

Dimensions	Est. length (m)	Draw shape (label sides and flow direction)
Side 1	8m	
Side 2	3/m	
Side 3	8m	
Side 4 (opt)	3/m	
Depth (1/10 meter)		



Proportion of substrate covered by shells

Coverage (check one)

<1%	1 to 5%	6 to 25%	26 to 50 %	51 – 75%	>75%
✓					

Shell piles: y/n

Notes:

Non-native species present (Y/N):

Asian Clams

Field Recorder: J. Matousek Date: 21 Oct 2010 Page 1/8

Enbridge Oil Spill Mussel Shell Survey Field Datasheet

Location Information

Sampling Segment: MS-4

Site Description/Landmarks/Access/Other Notes:

Started below mile marker 10.25 below boat launch @ 3.2

GPS Coordinates (decimal degrees to 5 decimal places)

Start location	End location
Latitude: N42.29591	Latitude: N42 29373
Longitude: W085.12777	Longitude: W 085.12421
Start Time: 09:30	End Time: 13:13

Weather Conditions: Sunny

Air Temperature: ~45-55°F

Personnel Present

Name - Affiliation	Name - Affiliation
John Matousek / Cardno Entrix	
Ryan Crafton / Cardno Entrix	
Bill Taft / DNRE	
Matt Wisnet / DNRE	
Mike Wilson / DNRE	
Mike Carney / Stratus	

Photograph Documentation

Camera id/owner: GPS unit id/owner:

Photo #	Time	Photographer/Camera	Subject
1,2		Matousek / #1	GPS data/time
3,4			Boat Launch
5			Strong flutter, Moderate 2
6			Mucket, Moderate 2
7			Elk toe, Heavy worn
8			Wabash pigtoe, Moderate 2
9			Pocket book, Heavy worn
10			Sheepshell, cracked
11			Spike, moderate 1
12			White heelsplitter, Recent
13			fluted shell, moderate 2
14			Creek heelsplitter, broken
15,16,17			Crew photos
18,19			Mucket, worn shell
20			Hybrid pearlshell
21,22			Mucket, cracked shell - Live

wide
19m X 10m

Survey Site	(in consecutive order)	Page 2/8
MS-4	Transect 1	

Surveyor(s):	Date:
Matousek, Wisemer, Tuft, Carney, Sadler, Wilson, Grathen	21 oct 2010

Enbridge Oil Spill Mussel Shell Survey – Mussel Survey Data

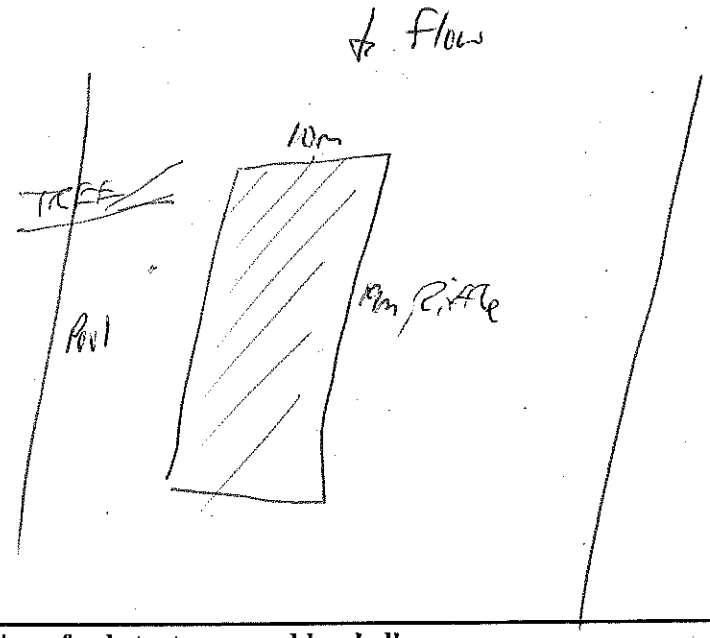
Habitat Information

Coordinates at downriver boundary: MS4 TRNSTRT upstream boundary
N42.29591 W085.12740 N42.29600 W085.12704

Survey Site Area Measurements

Dimensions	Est. length (m)
Side 1	10m
Side 2	19m
Side 3	10m
Side 4 (opt)	19m
Depth (1/10 meter)	

Draw shape (label sides and flow direction)



Proportion of substrate covered by shells

Coverage (check one)

<1%	1 to 5%	6 to 25%	26 to 50 %	51 – 75%	>75%
✓					

Shell piles: y/n

Notes:
Some cracked and Recent dead found in this area

Non-native species present (Y/N):
Asian Clams

Sampling Segment: MS-4 Transect 1 Page 3 of 8

Field Recorder: Matousch Date: 21 Oct 2010

Shell and Mussel Observations (cont'd)

		Shell Condition (check one)					
Species (G. species)	Live Mussel (check)	Fresh	Recent dead	Mod. worn (1)	~~Heavily worn~~ Mod (2)	~~Crushed shells (Y/N)~~ Heavy	Notes/observations
Mucket	/		卌 //	////	卌 卌	/	some crushed/broken shells
					卌 卌		additional mod (2)
					卌 卌		/
					卌 卌		
Wabash pigtoe	/		/	///	////		
Fluted shell					////		
Elk toe					/	/	
Spike	/				///	/	
Creek heelsplitter				/			
Slipper shell					/		
Strange floater			/				

Survey Site (in consecutive order) Page 4/8

MS-4 Transect 2

Surveyor(s): Matousek, Wiseman, Taft, Grafton, Carey, Wilson, Badra Date: 21-Oct-2010

Enbridge Oil Spill Mussel Shell Survey – Mussel Survey Data

Habitat Information

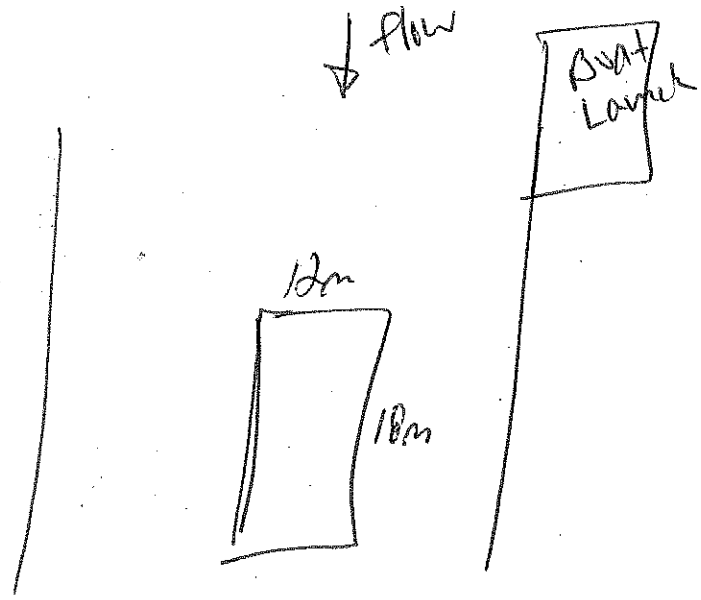
Coordinates at downriver boundary: N42.29390 W085.12488

upstream sounding N 42.29370 W085.12486

Survey Site Area Measurements

Dimensions	Est. length (m)
Side 1	12m
Side 2	18m
Side 3	12m
Side 4 (opt)	18m
Depth (1/10 meter)	

Draw shape (label sides and flow direction)



Proportion of substrate covered by shells

Coverage (check one)

>1%	1 to 5%	6 to 25%	26 to 50 %	51 – 75%	>75%
	n/%				

Shell piles: y/n

Notes:
Many shell pieces, fresh dead, and shell fragments - Heavy Boat traffic through this area

Non-native species present (Y/N):
Asian Clams

Sampling Segment: MS-4 Transect 2 Page 5 of 8

Field Recorder: Date: 2 Oct 2010

Shell and Mussel Observations (cont'd)

Species (G. species)	Live Mussel (check)	Shell Condition (check one): Fresh	Recent dead	Mod. worn (1)	~~Heavily worn~~ Mod (2)	~~Crushed shells (Y/N)~~ Heavily	Notes/observations
Muckrat	卌 卌		𝍸	𝍸	卌 卌		broken shells/cracked 卌 卌 卌 𝍸
	𝍸				卌 卌		
					卌 卌		Cracked-Live 1 (photo taken)
					卌 卌		
					卌 卌		additional mod(2)
					卌 卌		卌 卌 卌 卌 卌 卌 卌 卌 卌 卌
					卌 卌		𝍸
fluted					𝍸		
Wabash pigtoe	𝍸		𝍸		卌		broken shells/cracked 1
Spike					1	𝍸	
Cylindrical papershell					1		
Pocketbook					1		
Elktoe				1	𝍸	𝍸	
Kanitbow						1	

Asian Clam

Field Recorder: J. Matousek Date: 21 oct 2010 Page 6 of 8

Enbridge Oil Spill Mussel Shell Survey Field Datasheet

Location Information

Sampling Segment: MS-1

Site Description/Landmarks/Access/Other Notes:

Reference location just downstream of Marshall impoundment
Set up a transect for alternate spill area transects

MS1 TRN1 STRT wpt.

GPS Coordinates (decimal degrees to 5 decimal places)

Start location	End location
Latitude: N42 26305	Latitude: N42 26284
Longitude: W084 95710	Longitude: W084.95668
Start Time: 15:53	End Time: 17:00

Weather Conditions: Partly cloudy

Air Temperature: 50°F

Personnel Present

Name - Affiliation	Name - Affiliation
Jim Matousek - Cardno Entrix	
Mike Corey - Stratus	
Matt Weaver - DNRE	
Bill Taft - DNRE	
Mike Wilson - DNRE	
Pete Badra - MNFF	
Ryan Grafton - Cardno Entrix	

Photograph Documentation

Camera id/owner: GPS unit id/owner:

Photo #	Time	Photographer/Camera	Subject
1			Reference area Transect 1

Survey Site (in consecutive order) Page 7/8

MS1 Transect 1

Surveyor(s): Toft, Wesner, Matonsek, Crosby, Grafton, Bodin, Wilson

Date: 21 Oct 2010

Enbridge Oil Spill Mussel Shell Survey – Mussel Survey Data

Habitat Information

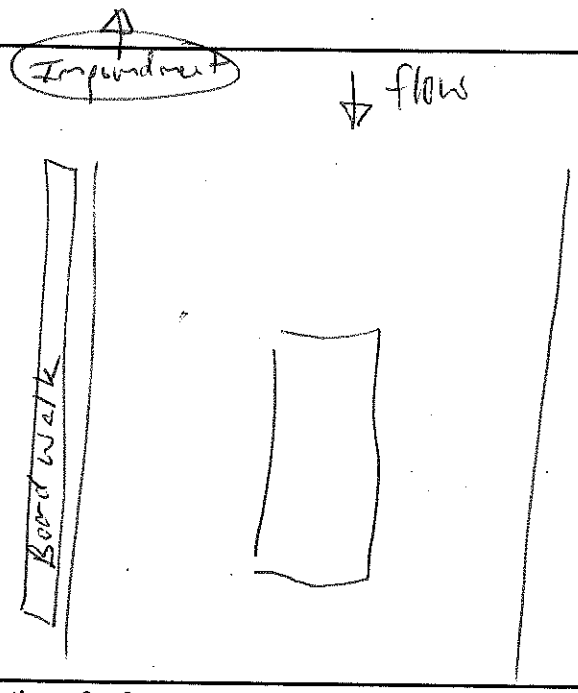
Coordinates at downriver boundary: N 42 26 305 W084.957 1/8

upstream boundary N 42.26 284 W084.95668

Survey Site Area Measurements

Dimensions	Est. length (m)
Side 1	7m
Side 2	19m
Side 3	7m
Side 4 (opt)	19m
Depth (1/10 meter)	

Draw shape (label sides and flow direction)



Proportion of substrate covered by shells

Coverage (check one)

>1%	1 to 5%	6 to 25%	26 to 50 %	51 – 75%	>75%

Shell piles: y/n

Notes:
Reference Area

Non-native species present (Y/N):
Asian Clams

19m x 7m

Sampling Segment: MS-1 Transect 1 Page 8/8

Field Recorder: Matowash Date: 21 Oct 2010

Shell and Mussel Observations (cont'd)

Species (G. species)	Live Mussel (check)	Shell Condition (check one) Fresh	Recent dead	Mod. worn (1)	~~Heavily worn~~ Mod (2)	~~Crushed shells (Y/N)~~ Mod (3)	Notes/observations
Fluted shell					5 5 5 5 5 5 5 5 5	5 5 5 5 5 5 5 5 4	
Pocketbook	1				5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	5 5 5 5 5 5 5 5 5 1	crushed shell 4
Spike					5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	5 5 5 5 5 5 5 5 5	crushed shell 3
Wabash pigtoe					5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	5 5 5 5 5 5 5 5 5 1	crushed shell 5 5 5 1
Strange floater					5 5 5 5 5 2	4 4 4 4	
Rainbow					2	1	
Elktoe					5 5 5 5	2	crushed shell 1
Fat Mucket					4 4 4		
Elipse					5 5 5 5 1		

Heavy Mud and algae on all shells found

10/25/10 JM

Field Recorder: Matousek Date: ~~10/26/10~~ 10/25/10 Page 1/1

Enbridge Oil Spill Mussel Shell Survey Field Datasheet

Location Information

Sampling Segment: MS-5

Site Description/Landmarks/Access/Other Notes:

Kalamazoo + Fonda intersection Boat launch at ~~Riverside~~ Riverside.

GPS Coordinates (decimal degrees to 5 decimal places)

Start location	End location
Latitude: N42.30768	Latitude: N42.30119
Longitude: W085.18924	Longitude: W085.18023
Start Time: 10:00	End Time: 12:30

Weather Conditions: ~60° Partly Cloudy

Air Temperature: ~60°

Personnel Present

Name - Affiliation	Name - Affiliation
Matt Wagner DNRE	
Mike Walterhouse DNRE	
Bill Taft DNRE	
Mike Wilson - DNRE	
John Matousek - ENTRIX	
Pete Badra - MNFI	

Photograph Documentation

Camera id/owner: GPS unit id/owner:

Photo #	Time	Photographer/Camera	Subject
~~1~~ 2			GPS time data
4			Paper pondshell mud 2
5			White heelsplitter mud 2
6			Slipper shell mud 2
7			Wabash pigtoe mud 2
8			Mucket - mud 2
9			Fluted shell - mud 2
10			Pocketbook - mud 2
11			Spike - mud 2
12			Elktoe - mud 2
13			Rainbow - mud 2
14			Strange floater - mud 2
15			Round pigtoe

No transect conducted at MS-5 due to lack of recent Dead shells, High siltation, and water depth

C. Field Notebooks

MC / Oct. 18 2010 / Marshall Imp. River front park

- Arrived @ site around 9:00 am for the group safety meeting and go over the plan
- Started @ bridge approx 1/4 of a mile from the proposed downstream end of the sampling segment (water below bridge was FAST and deep) - Also developed potential private property issues if we would have had to portage
- Access run for the apartment parking lot and worked upriver
- finished with site around 3:30 @ the park
- saw less live mussels than when conducting the mussel assess survey

MC / Oct 8 2010 / Marshall, MI

- Site MS-2 Recon
- ~~Boat~~ ramp and decon areas are closed and posted as such
- no way to launch or least there might be land to park there as well
- Directions to community park
- 1/5 mile Rd (R) on A Drive North
(R) on River Park Drive
(L) on Squaw Creek Rd
immediate (R) onto gravel Rd. @ Light / Pump pole

MC / Oct 19, 2010 / Marshall MI

- mussel survey site MS-02
  Down River of 15 Mile Rd Bridge
- good visibility / low turbidity
- some response / clean up work occurring around islands, replacing ~~about~~ boom
- little ~~boat~~ traffic
- conducted survey for most of sampling segment
- ended @ C-1 boat ramp
- seemed like there was a lot of siltation around boat ramp
- oil sheen obs. when walking through sediments around boat ramp
- live mussels observed in deeper runs in middle of sampling segment

MC / Oct 20, 2010 / Marshall MI

- mussel survey site - MS-03
- walked along trail downriver to start of sampling segment
- noticed that there were a lot of mussel shells in the stream condition between ~~fresh~~ recent and moderate at start of segment
  lots of live mussels also obs. at start of survey segment
- turbidity was high throughout most of the day but could still see the bottom for most of the segment.
- obs. shell piles near areas with live mussels, obviously fm an animal, bite marks on edge of shells

MC / Oct 21 2010 / Wattles Park MI

- Boat ramp C3 2, sampling site MS-04
- walked downriver to start of sampling segment and decided to extend site downriver another ~100 meters to include a shallow riffle
- cracked shells obs. in and around shallow riffle in areas w/ lighter substrate, lighter substrate looked like it was an artifact of boats bottoming out, actually saw a boat bottom out and power through the riffle
- live mussels obs. on top of substrate in boat scraped substrate, some live mussels had scratched shells

MC / Oct 21 2010 / Site MS-04

- lots of boat traffic - almost to the point where it was unsafe to be in river, had to move out of the channel when we heard them coming.
- ~~note~~ high turbidity throughout the day especially when the boats sped by
- large shallow area just downriver of boat ramp had alot of crushed mussel shells, scratched live mussels and displaced live mussels
- upriver of boat ramp there was lots of silt on substrate, ended survey just upriver of boat ramp

10/18/10

Mussel shell survey @ Riverfront park
MNFI, ENTRIX, Stratus, DNRE
participating in survey @ 9:30 start time
Safety paperwork completed for
ENTRIX and Enbridge
Walked downstream to put in @
17 mile bridge to walk upstream
to begin survey.
Asian Clams seen
Little mussel list between (17 mile start)

~~Pocket Book~~		Shell	Live
Pocketbook	~~IIII~~	✓	1 ✓
Wabashpigtoe	III	✓	
Eastern pond mussel	1	✓	
fluted shell			1 ✓
Spike		✓	✓
Rainbow		✓	
Elktoe		✓	
Cylindrical papershell		✓	
Slipper shell		✓	
Elipse			✓
Giant floater		✓	
Strange floater		✓	
Creek heel splitter		✓	✓

"Rite in the Rain"

Stop for lunch 12:40
Return to River @ 13:40 pm
Some crew from morning, put back into River at same spot as took out. 5 people using wetsuits or clear bottom buckets. J. Matousek taking notes and photos. A few deeper spots avoided due to depth of water.
No more than 20 m of complete River avoided
Left or Right bank necessary to avoid due to water depth throughout entire reach.

	Live	Shell
Mucket		✓
Roundpigtoe		✓

Pocketbook observed displaying luce
Gills with larvae.
Crew worked up to small island just downstream of impoundment
End time 15:33

JCB

19 oct 2010

Mussel shell survey
Location MS
ENTREX, DNRE, MNFI, status
participating in survey
MS-02 start
N 42 25925 W 085.01009

Species List

	Live	Shell
Strange floater		✓
Rainbow		✓
Asian Clam		✓
Spike	✓	✓
Pocketbook	✓	✓
Creek heelsplitter	✓	✓
Elktoe		✓
fluted shell		✓
Wabash pigtoe	✓	✓
Round pigtoe (?)		✓
Elliptic		✓
White heelsplitter	✓	
Mucket		✓
Slipper shell		✓
fat Mucket	✓	
Cylindrical papershell		✓

"Rite in the Rain"

Some recent dead found near 3 mi marker. Some crushed shell as well but difficult to determine how old crushed top shells are. Looks like old shell that maybe got stepped on by cleaning crew - may have broken due to older condition of shell.

A single recent dead rainbow found at waypt. Recent rainbow
N 42.25968 W 085.00858

A single recent dead pocketbook found at waypt. Recent pocket
N 42° 25954 W 085.00601
- photo taken

A single spike found at waypt. Recent spike
N 42.25940 W085.00508 (Mile post 2.75)
- photo taken
- at same point, broken shell pocketbook found - photo taken
- another pocketbook w/ broken shell collected here - photo taken
- another recent dead spike here photo taken

A recent dead pocketbook w/ broken shell found at waypt. Recent pocbook
N 42.°25848 W 085.00513
- photo taken

Stopped for lunch break @ 13:40
Returned to River @ 14:40
Crew worked upstream from park searching for recent/fresh dead shells
upstream travel fairly quick, scanning for shells
Deposit of recent dead shells found
Decision made that likely due to animal feeding and deposit of shells
photo taken next to log that shells are near. Confirmed sighting of a mink by landowner - next to the shell deposit area.

Fresh dead pocketbook found at waypt. FRESH POCKET
N 42.25790 W 085.00304
no damage evident to shell
flesh contained in shell pic taken

"Rite in the Rain"

Avis R
No Sh
Rental
If you h
Where
Gas Se

Some broken shells found at
Broken shells (waypt.)
N 42.25825 W 085.00249
fluted shell, spike, + Rainbow
pic. taken
Several live pocketbooks found
in this area
Scattered broken shells in this
area likely due to high foot/boat
traffic in this area. Concentrated
to shallow riffle areas
Live mussel seen near bank
waypt "Brokespikes"
N 42.22579 W 085.00167
pic taken just downstream of
mile marker 2.5
A few recent dead shells and cracked
shells found along side, but agreed
that many fewer than expected
were seen
Stopped survey @ boat launch at
15 mile Road crossing
N 42.25864 W 084.99898
Recent dead pocketbook found at wypt.
"Recentpock" N 42.25866 W 084.99890
Recent dead spike found at wypt "Recspike"
N 42.25895 W 084.99899

20 Oct 2010

MS-3
DNRE, Status) MNFI, ENTRIX on
crew. Parked at 1/mile road bridge
traveled downstream to begin survey
Decided to add category to the
moderately worn designation

moderate 1	moderate 2
• hinge intact	• hinge intact or not intact
• marl not covering lower portion	• marl can be covering entire shell
• light algae ~~on~~ on inside of shell	• heavy algae or sedimentation on inside

Will be noted during a delineated
section survey and on photos

Species List	Live	Shell
Mucket	✓	✓
Elliptoe		✓
Spike		✓
White heelsplitter	✓	✓
Wabash pigtoe	✓	✓
fluted shell		✓
Strange floater		✓

"Rite in the Rain"

https://www.avis.com/car-rental/reservation/print-res-confirmation.ac
10/21/2010

No Show
Rental Op
If you have
Where2 G
Gas Service

Cont. Species List	Live	Shell
Asian Clams		✓
Pocketbook	✓	✓
Rainbow		✓
Creek heelsplitter		✓
Slipper shell		✓
Cylindrical papershell		✓

Large quantity of Mucket shell and fluted shells in this area along with Live muckets.
Site delineated for survey just upstream of mile marker 7.75
Start point waypt. (MS3 TRAN1STRT)
N 42.27737 W 085.09080
Large Concentration of Live mussels upstream of transect 1 at point
N 42.27723 W 085.08967
also shell fragments in area and recent dead
A few recent dead and cached shells at
N 42.27673 W 085.08885

More recent shells found at
N 42.27683 W 085.08839
this is the area below the main boat launch at
Reduced number of recent dead and broken shells noted at
N 42.27670 W 085.08770
Stopped for lunch @ 12:45
Returned to river at 13:45
Decision made to do another transect just downstream of the boat launch near mile marker 7.5
labeled as MS-3 transect 2
Start (downstream)
N 42.27657 W 085.08723
End (upstream)
N 42.27661 W 085.08678
Periodic turbidity noticed during survey, perhaps due to upstream dredging or boat traffic
Deposit of Recent to Moderate shells found at N 42.27599 W 085.08549
probable animal deposit and then covered in sediment. Shells appear to be recent but this likely due to the Rite in the Rain

No Show

Rental Opt

If you have

Where2 GP

Gas Service

09:30 21 oct 2010

Start Point at boat launch at 3-2 @ N42 29296 W085.12425 Walked downstream to area below mile marker 10.25 to riffle observed to have shell available. Start point of survey @ "M54 STRT" N 42.29591 W 085.12777

Species List	Live	Shell
Muchett	✓	✓
Strange floater		✓
~~Muchet~~ Elktoe		✓
Slipper shell		✓
Asian Clam		✓
Spike	✓	✓
Wabash pigtoe	✓	✓
Pocketbook		✓
White heelsplitter		✓
fluted shell		✓
Cylindrical papershell		✓

sediment they were tagged in. These shells were likely uncovered by boat traffic and wave action. Photo taken. No damage to shells evident, Look to be in good condition but were buried in sediment. River visibility much less than earlier mainly due to turbidity increase.

Significant amount of live mucketts noted below bridge @ 11 mile crossing @ N42.27443 W085.08154

Oil sheen noticed when walking through soft sediment. Completed Survey @ 11 mile bridge 16:30

JLB
JJH 21 oct 2010

Avis Re
No Sho
Rental C
If you ha
Where2
Gas Serv

Some Recent and broken shells
in riffle at N42.29581 W085.12732
Started transect 1 @ "MS4TRNSTRT"
N 42.29.591 W 085.12740 (bottom)
Area chosen due to observation of
recent dead shells and cracked shells at
riffle location.
MS4 TRNEND N42.29600 W085.12704
19m x 10m transect
Some broken shells @ N42.29608 W085.12664

Recent dead found @ N42.29617 W085.12585
Mucket, wabash pigtoe, found in a
Limited area ~ 2-3m²
Slipper shell heavily worn @
N 42.29.24 W085.1248
Some moderate (1) / Recent dead
found at
N42.29573 W085.12447
Mucket (2), wabash pigtoe
Also some broken shells observed
Significant amount of Live shells
at N42.29464 W085.12494
from this pt. to the boat launch
several Recent dead, cracked, broken
shell & pieces observed, more than through
the rest of the reach

MS-4 transect 2 started just
downstream of boat launch @ mile
marker 10.0
Stop for lunch @ 12:30 Returned
to River @ 1:50
Completed count of Transect 2
mussels collected.
Good population of Live mussels
observed directly across from boat
launch @ N42.29373 W085.12421
Some animal shell deposits observed
upstream of boat launch
Significant amount of turbidity due to
boat traffic.
Decision made to survey up to mile
marker 9.75 and terminate survey
due to turbidity & reduced visibility
Also high boat traffic a safety concern
Left MS-4 @ 15:15 to travel
to reference area to complete a
transect there
MS-1 Transect 1 completed @
N42.26305 W084.95710 (start)
N42.26284 W084.95668 (end)
end time ~17:00

"Rite in the Rain"

10/25/10 Site MS-5
intersection of Kenosha & Fox
Boat launch at area We will
be using the MNFI Boat at this
location. ENTRIX, MNFI DNRE
present for this location. Status
unable to attend.
Launched boat @ 09:30. Traveled
downstream to begin survey just downstream
of Mile marker 15.25. Water too
deep to wade, looked from boat while
traveling upstream. Booms blocking
downstream travel past mile 15.25
Exited boat @ "MS-5 STRT"
N42.30768 W085.18924
Water temp 56°F

Species	Live	Shell
Paper pondshell		✓
White Heelsplitter		✓
Slipperyshell		✓
Mucket		✓
Spike	✓	✓
Washboard	✓	✓
Fluted shell		✓
Pocketbook		✓

Heavy fresh siltation. Difficult to
see shells, likely buried in slower areas
Animal midden found at
N42.30683 W085.18854

Continued

Species	Live	Shell
Elktoe		✓
Rainbow		✓
Orange floater		✓
Asian Clam		✓
Roundlipped		✓

Traveled by boat and walking through
lower ½ of Reach. Several deep
areas that had to be avoided due
to water depth and limited visibility
Some air boat traffic causing some
turbidity issues
Large Animal deposit found all
around area N42.30383 W085.18172
Almost all Mucket with a few
Elktoe and Spike. Most are
Moderately worn (2) with an occasional
Mod. (1)

End of transect is at mile marker 14.05 @ N42.30119 W085.18023
Water became very turbid at 12:00 visibility very poor.
No Recent dead shells found to trigger conducting a transect. Also deep water and siltation a factor limiting success of a survey.
End time 12:30

"Rite in the Rain"

Appendix J: Summary of Public Comments and Trustee Responses

Appendix J: Summary of Public Comments and Trustee Responses

This appendix summarizes the written and verbal public comments by topic and provides the response of the Trustees to each issue. A copy of the written public comments is provided in Appendix K.

Support for Proposed Projects

One commenter noted that the recommended project ideas are all worthy projects that will ultimately improve the Kalamazoo River and its surrounding communities. None of the commenters expressed any concerns with the proposed preferred projects.

> *Trustee Response:*
> The Trustees appreciate the positive comment and have selected all of the proposed preferred projects that were described in the Draft DARP/EA.

Battle Creek Concrete Channel Restoration

One commenter urged the Trustees to include the removal of the channelized portion of the Kalamazoo River within the City of Battle Creek in this NRDA process as well as for an NRDA that is currently being conducted for the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site that is downstream of the portion of the Kalamazoo River that was impacted by the discharges of oil from the Enbridge Line 6B. This latter NRDA is referred to as the PCB NRDA in the comment. The commenter suggested that funding from the Enbridge NRDA settlement be used to fund a full hydrology study of the system and that the PCB NRDA could be used toward removal of the concrete channel. This commenter described the project in some detail in an attachment to her comment. An additional 33 commenters expressed support for this comment.

> *Trustee Response:*
> The Trustees have carefully reviewed this proposed project and have expanded their description of this project in the Final DARP/EA (Section 4.9.1). The Trustees agree that this project could provide significant benefits to natural resources in-stream and along a restored riparian corridor, if feasible, and have shared this suggestion and the information provided with the Trustees for the PCB NRDA. Because the Trustees can provide benefits to natural resources to compensate for the losses through the other proposed preferred projects at a lower cost, the Trustees did not select the Battle Creek concrete channel restoration project at this time.

Additional Restoration Suggestions

In addition to supporting the Battle Creek concrete channel restoration, one commenter suggested additional ideas for locations where land could be purchased to expand or create riparian parks and where paddling park features could be added in the Battle Creek area, including removing a low head dam at the Washington Ave Bridge and replacing it with a white water paddling feature.

> *Trustee Response:*

By accepting as restoration the creation and expansion of riparian parks that Enbridge has already completed, the Trustees believe that the public has been fully compensated for interim recreational lost use of natural resources.

Proposed Penalties

One commenter stated that the proposed penalties for Enbridge were "grossly insufficient".

Trustee Response:

NRDA is a compensatory process, not punitive. Penalties for Enbridge are being addressed under different authorities.

Appendix K: Compilation of Public Comments Received on Draft Damage Assessment and Restoration Plan / Environmental Assessment

Enbridge NRDA: Public Comments on Draft DARP/EA

Compiled by Lisa L. Williams, USFWS
July 28, 2015

Comment #1
From: Daniel Burton <dtburton15@gmail.com>
Date: Wed, Jun 17, 2015 at 8:50 PM
Subject: Enbridge NRDA Comment
To: kzoorivernrda@fws.gov

I would like to provide a few comments with regard to the Enbridge NRDA. I think the list of recommended improvement project ideas are all worthy projects and will ultimately improve the Kalamazoo River and its surrounding communities. I also agree for the most part with the assessment for improvements of the concrete channel in Battle Creek. This nearly mile long channel significantly impacts the rivers aesthetic quality, its recreational value as well as its overall health.Removal is not a likely option due to flooding concerns, yet I would like to suggest a study to route the river to the east side of the city moving the confluence with the Battle Creek River just above the downtown area. The design of the new river should allow for the river to be diverted into the current concrete channel during high flow events to avoid flooding, yet allow the river to flow more naturally during normal flows. The ecological and aesthetic value to the new river flow are obvious, and I believe there would also be economical value by combining the Kalamazoo and Battle Creek Rivers before the downtown area. The combined flows could allow the downtown area of the Battle Creek River to be developed into a paddlers park. I am not proposing a whitewater park, but instead a beginner to intermediate place to learn the basics of paddling in moving water (eddies, ferries, turning, stopping, etc). Where a family could take the kids to develop safe paddling skills before heading off into more remote and unknown rivers where accidents can be more dangerous. A place where paddlers new to the sport or coaches looking for a venue to teach beginners to paddle could go to improve their skills. Downtown Battle Creek could benefit economically from such development.

In addition to that larger idea, I would like to toss out a couple more:
- purchase the forested property next to Paddlers Grove to expand this park while protecting more undeveloped riparian
- purchase the riparian land on the south side of the Battle Creek River between Washington Ave and the Kalamazoo River confluence. Remove the empty buildings and convert into Confluence Park. Remove the current unsafe low head dam at the Washington Ave Bridge and replace with a white water feature with access using the confluence park. In addition, add a few whitewater features on the last 100 feet of the concrete channel on the Kalamazoo River at the confluence to again provide whitewater paddling to the area. These improvements will add economical and recreational value to the river.

Thanks for your efforts to improve the Kalamazoo River and its watershed.

Dan Burton

Comment #2
From: Christine Kosmowski <ckosmowski@calhouncountymi.gov>
Date: Wed, Jul 22, 2015 at 4:50 PM

Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>
Cc: "John Macfarlane (jmacfarlane@mumfordlaw.com)" <jmacfarlane@mumfordlaw.com>

Hello, Lisa:

I am writing to urge the inclusion of the removal of the channelized portion of the Kalamazoo River within the City of Battle Creek for the Enbridge NRDA and the PCB NRDA. I suggest that monies from the Enbridge NRDA be used to fund a full hydrology study of the system and that PCB NRDA monies be applied towards the removal of the concrete. The reasons for the suggestion are outlined in the attached document. In general, however, the removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource after having been disconnected from it for over 50 years.

Thank you for your consideration.

Sincerely,
Christine Kosmowski
Water Resources Commissioner
Calhoun County
315 W. Green Street
Marshall, MI 49068
T: 269-781-0790
C: 269-317-4000
E: ckosmowski@calhouncountymi.gov

Attachment – NRDA_Concrete_Channel.pdf

Restoration of the Channelized Portion of the Kalamazoo River in Battle Creek, Michigan

Project Description

The Kalamazoo River in downtown Battle Creek, Michigan was channelized with concrete by the United States Army Corp of Engineers (USACE) approximately fifty years ago for flood control. The channelization eliminates the potential for spawning, resting and feeding areas for a broad variety of fish, amphibians, plant life and other terrestrial organisms and thus acts as a deterrent to the establishment wildlife. In addition, the riparian buffer has been removed which has caused the water temperature to increase above the tolerance of some fish species. This segment of the Kalamazoo River is also inaccessible to the public for recreational purposes, affords poor water quality and has a very poor aesthetic character.

Restoration Objectives

This project is intended to provide compensatory restoration for the in-stream habitats and aquatic natural resources (like mussels and fish) that were injured as a result of the Enbridge Line 6B oil discharges by increasing the aquatic functions and values directly in the Kalamazoo River.

The proposed project is the modification of approximately 4,000 linear feet of concrete channel and the restoration of the channel to a natural setting by adding pools and riffles, a riparian buffer, and a fish passage at the dam upstream of the channel.

The proposed project includes creation of naturally landscaped park space along the river banks, together with a non-motorized pathway, in order to allow for access to and recreational use of the river.

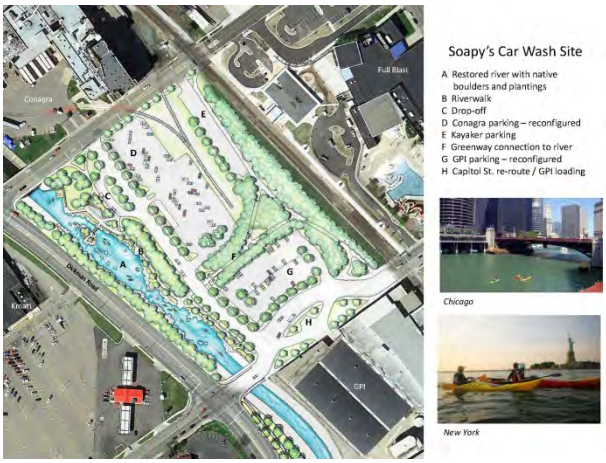
Probability of Success and Monitoring

Removing the concrete armor along the stretch of the Kalamazoo River within the city limits of Battle Creek, Michigan, will be highly successful in restoring aquatic habitat, native riparian plant communities, fish migration and spawning areas. It will also improve water quality. The biggest barriers to the success of the project are the cost to remove the concrete, property acquisition, and the removal of contaminated sediment from a brownfield site adjacent to the river. A full hydrology study is also needed to adequately determine the engineering design.

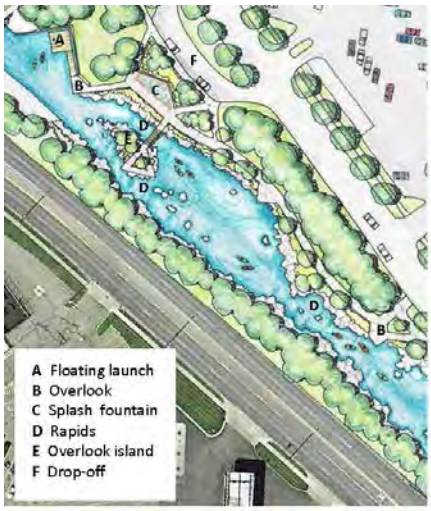
The United States Army Corps of Engineers (USACE) developed a pre-feasibility model and rejected the removal of the channel. However, the model was based on limited data. Per the USACE report, "the accuracy and precision of the hydraulic model is uncertain and the output is only an approximation at best." Therefore, a complete hydraulic model should be funded to be able to fully determine the feasibility of removing the channel. The Kalamazoo River Watershed Council supports the funding of such a study.

Environmental and Socio-Economic Impacts

No long-term adverse environmental or socio-economic impacts are expected from this project. In fact, positive benefits are expected. The project will have the added bonus of reconnecting the community to this water source that has been inaccessible for the past 50 years. The project ties in nicely with two recent statewide initiatives: *Michigan Blue Economy* and *Sustaining Michigan's Water Heritage* (Water Strategy). Both emphasize the importance of water and Placemaking for communities. The Water Strategy, for example, stresses the importance of protecting and restoring aquatic ecosystems and creating vibrant waterfronts and areas for water-based recreation.



Mill Pond Site



Cherry Creek, Denver

LA River, Los Angeles

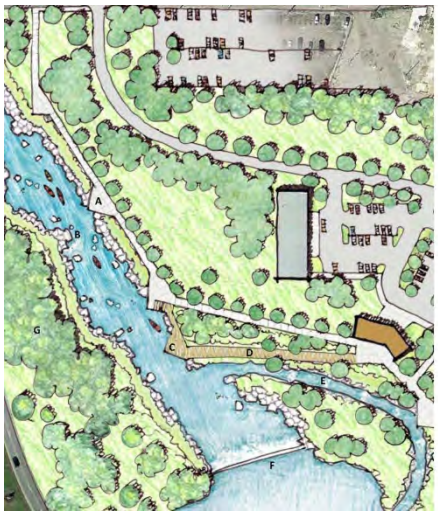
Adaptive Kayak Launch

Newly constructed launch on the Detroit River at Bishop Park in Wyandotte

Floating platform with hinged approach will be required due to fluctuating river elevation.

Platform is equipped with electronic lift powered by solar voltaic cells.

Confluence Park, where Cherry Creek meets the South Platte River, Denver



A Riverwalk / overlook perches
B Native boulders and bank plantings
C Floating launch pad
D Boardwalk to launch area
E Fish ladder
F Existing dam
G Woodland planting/habitat

Natural fish by-pass, Williamston, MI

Rouge River, Detroit

Cost
$30 to $50M for the full restoration. $100K to $300K is anticipated for a full hydrology study of the system. This project is expected to be a partnership among the City of Battle Creek, Battle Creek Whitewater, Inc., the Battle Creek Community Foundation, the Calhoun County Water Resources Commissioner, and other community organizations.

Evaluation
The stretch of the channelized section of the Kalamazoo River was directly impacted by the Enbridge Line 6B Oil Discharges from July 2010. The oil from the discharge flowed completely through this community of 53,000. One of the larger areas of submerged oil that resulted from the event is just upstream of the channel in the area known as the Mill Ponds. Submerged oil remains there and will need to be monitored for many years to come.

This project will have negative short-term impacts to natural resources, but will have overall long-term positive environmental impacts by restoring aquatic habitat, native riparian plant communities, fish migration and spawning areas, and improving water quality

Comment #3
From: John Macfarlane <jmacfarlane@mumfordlaw.com>
Date: Fri, Jul 24, 2015 at 11:59 AM
Subject: Enbridge NRDA comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>
Cc: "Christine Kosmowski (ckosmowski@calhouncountymi.gov)" <ckosmowski@calhouncountymi.gov>, "Larry Rizor (architects.inc@prodigy.net)" <architects.inc@prodigy.net>

Dear Dr. Williams, I am writing on behalf of Battle Creek Whitewater, Inc. in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek. Battle Creek Whitewater, Inc. is a nonprofit foundation established for the purpose of promoting the restoration of the Kalamazoo River within the City of Battle Creek to a more natural waterway, as well as to promote the creation and operation of a public park along and within the Kalamazoo River. The portion of the Kalamazoo River that is encased in a concrete channel as it flows through the City of Battle Creek is a blight on the landscape and a deterrent to any type of recreational use of the river. The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource. Please consider funding a hydrology study to evaluate the feasibility of removing of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

John H. Macfarlane
On behalf of Battle Creek Whitewater, Inc.
68 E. Michigan Ave.
Battle Creek, MI 49017
ph. 269-968-6146
fax 269-968-1147
jmacfarlane@mumfordlaw.com
www.westmichiganlawyers.com

Comment #4
From: Conor Macfarlane <csm@3eyetech.com>
Date: Fri, Jul 24, 2015 at 3:48 PM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

Dear Dr. Williams,

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek. The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

As a local business owner, I am particularly interested in relocating my growing company headquarters to downtown Battle Creek along a renovated and more aesthetically pleasing river.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process.

Thank you.

Conor Macfarlane
President & CEO
3Eye Technologies
csm@3eyetech.com
O 269.841.5064
C 773.301.5537

Comment #5
From: Brian Turk <bturk@3eyetech.com>
Date: Fri, Jul 24, 2015 at 4:01 PM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Comment #6
From: Mandi Weiss <mandi@3eyetech.com>
Date: Fri, Jul 24, 2015 at 4:02 PM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

Dr. Williams-

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.
The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.
Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process.

Thank you.

Mandi Weiss
3Eye Technologies
Corporate Account Manager
312-241-1482 (office)
269-753-2995 (cell)

Comment #7
From: Patrick McClure <patrick@3eyetech.com>
Date: Fri, Jul 24, 2015 at 4:05 PM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

Dr. Williams,

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Thanks,

Patrick McClure
3Eye Technologies
Operations Coordinator
269-841-5298 (office)
269-377-3250 (cell)
patrick@3eyetech.com

Comment #8
From: Dominick Reed <dreed@3eyetech.com>
Date: Fri, Jul 24, 2015 at 4:06 PM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.
The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.
Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process.

Thank you.

Dominick Reed
3Eye Technologies
Marketing Coordinator
312-241-1480 (office)
269-589-9542 (cell)
dreed@3eyetech.com
Connect with 3Eye on LinkedIn

Comment #9
From: TJ Hagist <tjhagist@3eyetech.com>
Date: Fri, Jul 24, 2015 at 4:09 PM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>
Hello,

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.
The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.
Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

TJ Hagist
3Eye Technologies
Warehouse Manager
tjhagist@3eyetech.com
O: 269-841-5584

Comment #10
From: Nancy Macfarlane <nancy.macfarlane54@gmail.com>
Date: Sat, Jul 25, 2015 at 1:36 PM
Subject: Enbridge NRDA Comment
To: kzoorivernrda@fws.gov

As a former Battle Creek city commissioner and over 30 year resident of Battle Creek, I am in support of the removal of the concrete channel within the Kalamazoo River in Battle Creek.

Restoring the river will enhance economic development, improve water quality, and be much more aesthetically appealing.

The channelled portion of the river is located in one of the main gateways into downtown Battle Creek. Besides the cement, the "river" channel is surrounded on both sides by tall chain link fence, making a visually unappealing entry into the city, and prohibiting community members from using the river. Restoring the river could remedy this situation.

Please remove the channel under the DARP or NRDA PCB process.

Sincerely,

Nancy Macfarlane
104 Lakewood Dr.
Battle Creek, MI 49015

Comment #11

From: Brian Engelhardt <brian.james.engelhardt@gmail.com>
Date: Sat, Jul 25, 2015 at 2:01 PM
Subject: Enbridge NRDA Comment
To: kzoorivernrda@fws.gov

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.
The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.
Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Comment #12
From: <nelsonx5@comcast.net>
Date: Sat, Jul 25, 2015 at 3:05 PM
Subject: Enbridge NRDA Comment
To: kzoorivernrda@fws.gov

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process.

Thank you.

Laura Nelson
Kalamazoo, MI

Comment #13
From: R.Adams <hob641@gmail.com>
Date: Sat, Jul 25, 2015 at 3:55 PM
Subject: Enbridge NRDA Comment
To: kzoorivernrda@fws.gov

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource. Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process.

Thank you,

Ron Adams
IT Software, Staffing, Consultancy
734-355-6166

Comment #14
From: Karen Parker <kwparker1099@gmail.com>
Date: Sun, Jul 26, 2015 at 7:26 AM
Subject: Enbridge NRDA Comment
To: kzoorivernrda@fws.gov

Dear Dr. Lisa Williams -
I am writing in fervent support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process.

Your thoughtful consideration - and funding approval - is greatly appreciated!

Karen W. Parker
922A Capital Avenue SW
Battle Creek, MI 49015
269-967-5069

Comment #15

From: Jackie DeHaan <jdh49017@gmail.com>
Date: Sun, Jul 26, 2015 at 4:16 PM
Subject: Enbridge NRDA Comment
To: kzoorivernrda@fws.gov

Dr. Williams -
I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.
The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.
This project is very important to Battle Creek, as well as its neighbors.
Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.
Jackie DeHaan

_____
Jackie DeHaan
Nonprofit Consultant
jdh49017@gmail.com
269-966-9030
www.jackiedehaan.com

Comment #16

From: <kathleenbess@comcast.net>
Date: Sun, Jul 26, 2015 at 4:55 PM
Subject: Enbridge NRDA Comment
To: kzoorivernrda@fws.gov

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.
The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.
Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Kathleen L. Bess
Battle Creek, Michigan

Comment #17

From: alcoa1961 <alcoa1961@tx.rr.com>
Date: Sun, Jul 26, 2015 at 8:43 PM
Subject: "Enbridge NRDA Comment"
To: EastLansing@fws.gov, kzoorivernrda@fws.gov, Annette_Trowbridge@fws.gov

The proposed penalties for Enbridge after their heinous Kalamazoo pipeline spill in 2010 are grossly insufficient.

Unless you enact much more expensive penalties, Enbridge and other pipeline companies will laugh themselves to death in their private board rooms, while screaming bloody murder in public.

Please increase those penalties by at least a factor of five. Use the extra money to hire more pipeline inspectors so that pipeline companies can't continue to build risky pipelines and operate them unsafely.

Thank you,
[unsigned in original e-mail]

Comment #18
From: Macfarlane, Teresa <Teresa.Macfarlane@kellogg.com>
Date: Mon, Jul 27, 2015 at 8:58 AM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.
The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.
Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Teresa Macfarlane
Kellogg Company
Director, Customer Operations
269-961-3796 (office)
773-410-8423 (cell)

Comment #19
From: Adams Hagist, Megan <Megan.Adamshagist@kellogg.com>
Date: Mon, Jul 27, 2015 at 9:04 AM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

Good morning –

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Megan Adams Hagist
IT Business Analyst – OCM | Workplace Solutions | Kellogg Company
O: 269-282-7054
megan.adamshagist@kellogg.com

Comment #20
From: Sosville, Wendy <Wendy.Sosville@kellogg.com>
Date: Mon, Jul 27, 2015 at 9:07 AM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Wendy Sosville
KNA PMO
(O) 269/961-2742
(M) 269/209-8583

Comment #21
From: Cascioli, Debra <Debra.Cascioli@kellogg.com>
Date: Mon, Jul 27, 2015 at 9:08 AM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.
The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.
Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process.

Thank you!

Debra Cascioli
Kellogg Company
Customer Logistics Services
269-961-2643 (office)

Comment #22

From: Nelson Karre <NKarre@vcflaw.com>
Date: Mon, Jul 27, 2015 at 9:16 AM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>
Cc: Nelson Karre <NKarre@vcflaw.com>

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.
I share with Ms. Kosmowski the view that the removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource. This will help bring more healthy activity to Battle Creek's downtown.
Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Nelson Karre
70 West Michigan Ave., Suite 450
Battle Creek, MI 49017
269.965.7000
269.965.0646 facsimile

Comment #23
From: Beuchler, Tyra <Tyra.Beuchler@kellogg.com>
Date: Mon, Jul 27, 2015 at 9:24 AM
Subject: Enbridge NRDA Comments
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Tyra Beuchler
Global IT Commercial Business Solutions
Process & Engagement Team
Office: 269.961.3877|Mobile: 269.924.6255

Comment #24
From: Mike Segal <segal_mike@hotmail.com>
Date: Mon, Jul 27, 2015 at 10:00 AM
Subject: Enbridge NRDA Comment
To: kzoorivernrda@fws.gov

Dr. Lisa L. Williams,

I am writing in support of Calhoun County Water Resources Commissioner Christine Kosmowski's comments regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

I fully support the improved water quality and better habitat that the removal of the concrete channel will help foster.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process.

Thank you,

Mike Segal

Comment #25
From: Rebecca L. Fleury <RLFleury@battlecreekmi.gov>
Date: Mon, Jul 27, 2015 at 10:35 AM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

To Whom it May Concern:
I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the hydrology study and exploration of removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.
The hydrology study is important to determine whether or not the concreate channel can be removed to help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.
Please consider funding the study and exploration of the removal of the concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.
Sincerely,
Rebecca L. Fleury
City Manager
City of Battle Creek
10 North Division Street Rm 206
Ph – 269-966-3378
Ex – 1201
rlfleury@battlecreekmi.gov

Mission for Battle Creek City Government
To ensure a safe, prosperous and culturally enriched community.

Vision for Battle Creek City Government
We envision Battle Creek as an extraordinary community where
people choose to live, work and play.

Comment #26
From: Mark Schauer <mark.schauer@comcast.net>
Date: Mon, Jul 27, 2015 at 11:42 AM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

Dear Dr. Williams:

I'm writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process.

Thank you,

Mark Schauer
1795 Hamilton Road
Battle Creek, MI 49017
269.209.3940

Comment #27
From: Kate <katesegal@hotmail.com>
Date: Mon, Jul 27, 2015 at 11:50 AM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

I am writing in strong support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource. Currently, the concrete channel prevents the community from taking full advantage of this water resource and creates a blight throughout our downtown.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process.

Thank you,
Kate Segal
108 Pinehurst Lane
Battle Creek, MI 49015

Comment #28
From: Stuart Family <snmstuart@hotmail.com>
Date: Mon, Jul 27, 2015 at 1:05 PM
Subject:

To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Mark F Stuart 2624 Ramblin Dr. Battle Creek, Mi 49014

Comment #29
From: Andy Helmboldt <helmboldt4bc@gmail.com>
Date: Mon, Jul 27, 2015 at 1:40 PM
Subject: Enbridge NRDA Comment
To: kzoorivernrda@fws.gov

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Andy Helmboldt
Battle Creek City Commissioner, At-Large
269-660-9659

Comment #30
From: Turk, Stephanie <Stephanie.Turk@kellogg.com>
Date: Mon, Jul 27, 2015 at 3:15 PM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.
The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.
Stephanie Turk
Stephanie Turk | Sr.Manager| Kellogg Customer Operations |O: 269-961-3021 C: 269-420-1724

Comment #31
From: Annette Chapman <Annette@bccfoundation.org>
Date: Mon, Jul 27, 2015 at 3:20 PM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>
Cc: Brenda Hunt <Brenda@bccfoundation.org>

Dr. Lisa L. Williams, Chair NRDA Trustees:

On behalf of the Battle Creek Community Foundation, it is my pleasure to provide this email of support for funding consideration under the DARP or the NRDA PCB process, specifically for the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek, submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner.

We are supportive of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek. The removal of the concrete channel will assist in creating better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

The mission of the Battle Creek Community Foundation is to assist people and organizations in investing in our community and its residents to make a positive difference, therefore creating a vibrant, healthy and viable community. We feel that supporting the goal of restoring the shores of the Kalamazoo River in its confines of the existing channel or in part, is an important investment to effectively facilitate positive community change.

We have been working with the City of Battle Creek and the Calhoun County Water Resource Commissioner as a partner, in supporting environmental stewardship efforts in our community, as well as other projects that contribute directly to our community's health, welfare and quality of life.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Brenda L. Hunt
President & CEO
Battle Creek Community Foundation
32 West Michigan Avenue
Battle Creek, MI 49017
Phone: (269) 962-2181
Fax: (269) 962-2182
www.bccfoundation.org

Comment #32
From: Hagist, Jack <Jack.Hagist@kellogg.com>
Date: Mon, Jul 27, 2015 at 3:45 PM
Subject: Enbridge NRDA Comment
To: "kzoorivernrda@fws.gov" <kzoorivernrda@fws.gov>

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding
the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource. It will also go a
Long way to improve the look and feel of downtown Battle Creek.
Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Jack Hagist
Office: 269-961-2499
Cell: 269-274-3022
Kellogg's Global Business Services

Comment #33
From: Kathryn Sellers <ksellers131@gmail.com>
Date: Mon, Jul 27, 2015 at 3:59 PM
Subject: "Enbridge NRDA Comment
To: kzoorivernrda@fws.gov

I am writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

The removal of the concrete channel will help create better aquatic habitat, improve water quality, and will help reconnect the community to this valuable water resource.

Please consider funding the removal of this unsightly concrete channel, or at least a portion of the channel, under the DARP or the NRDA PCB process. Thank you.

Comment #34
From: Architects Incorporated <architects.inc@prodigy.net>
Date: Mon, Jul 27, 2015 at 5:04 PM
Subject: " Enbridge NRDA Comment"
To: "Dr. Lisa L. Williams" <kzoorivernrda@fws.gov>
Cc: JMacfarlane@mumfordlaw.com

Dr. Williams,
I'm writing in support of the comments made by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the City of Battle Creek, Michigan.
The removal of the concrete channel will help create better water aquatic habitat,improve water quality, and will help reconnect the community to this valuable resource.
Please consider funding the removal of this unsightly concrete channel, or removal of portions of channel where oppurtunity for river enhancement and development are possible under the DARP or NERDA PCB process.
My company renovated a historic barn at the confluence of the Battle Creek and Kalamazoo rivers and have investigated other historic properties along the concrete channel. At this pivotal time a number of vacant industrial zoned properties exist and are available for acquisition which would allow river widening along the channel between street bridges crossing the channel. Such improvements could provide more and safer access to the river for recreational and development purposes as well as wetland creation and possibly increasing flood capacity.
The flood control project has worked in the past but now is a barrier to community revitalization and treats the river like a waste product. It is time that the channel be removed so the river can again re-energize the community's development as it has done so many times in the past.
Larry Rizor,Historic Barn LLC

Architects Incorporated, P.C.
49 South Cass Street, Suite 3B
Battle Creek, Michigan 49017
Phone: (269) 968-4300, Fax: (269) 968-7120
e-mail: architects.inc@prodigy.net www.archinc.biz

Comment #35
From: Larry Anderson <larryanderson077@gmail.com>
Date: Tue, Jul 28, 2015 at 12:05 AM
Subject: "Enbridge NRDA Comment"
To: kzoorivernrda@fws.gov
Cc: Chris Kosmowski <ckosmowski@calhouncountymi.gov>

We are writing in support of the comments submitted by Christine Kosmowski, Calhoun County Water Resources Commissioner, regarding the removal of the concrete channel within the Kalamazoo River in the City of Battle Creek.

Our Kalamazoo River is not only a beautiful but wonderful resource for Battle Creek and Calhoun County. This river essentially comes to a screeching halt as far as canoers and kayakers are concerned when it reaches downtown Battle Creek due to the concrete channel. There certainly newer concepts for replacing the flood channel that will not only protect property from flood damage, but open this stretch to enhance the west entrances to downtown Battle Creek, provide a continuation of the "navigable" river for canoes and kayaks and perhaps even rafters. Restoring this section will also improve fishing, habitat for water birds, and beneficial aquatic plants.

Under the DARP or the NRDA PCB process, we are hopeful that a project or projects would help restore the concrete channel to a more natural state.

Thanks you for considering our comments.

Sincerely,

Larry and Susan Anderson
12 Lakeside Drive
Battle Creek, MI 49015
269-964-4752