August 8, 2012

Mr. Ralph Dollhopf
Federal OSC and Incident Commander
U.S. EPA, Region 5
Emergency Response Branch
801 Garfield Avenue, #229
Traverse City, MI 49686

Re: Net Environmental Benefit Analysis
Enbridge Line 6B MP 608, Marshall, MI Pipeline Release

Dear Mr. Dollhopf,

Attached is my recommendation for methodologies for performing the Net Environmental Benefit Analysis (NEBA) to evaluate the potential ecological effects of further oil recovery operations during the response to the Enbridge Line 6B Oil Spill based on the individual scientific opinions that I have received. The attached documents represent response to the Federal On-Scene Coordinator's (FOSC) Charge No. 2:

> *2. a) Identify and evaluate viable procedures for assessing the toxicity of remaining submerged oil. b) Provide a recommendation for the best procedure to accomplish this goal.*

The attached documents represent my synthesis (as a Scientific Support Coordinator) of the applicable opinions and recommendations received from individuals involved with the Scientific Support Coordination Group (SSCG).

The purpose of the attached work was to evaluate the potentially detrimental effects of the remaining oil, as compared to the potentially detrimental effects from habitat disturbance associated with oil recovery operations. The attached NEBA process provides a method to rank the potential impacts from specific submerged oil recovery actions (monitored natural attenuation, enhanced deposition and recovery, agitation toolbox, dredging/vacuum truck, dewater/excavate, sweep/push, scraping, and sheen collection) on ecological resources present within distinct habitats of the Kalamazoo River.

Each individual scientist's opinion was provided to me based on his or her prior experiences in addressing issues related to oil spill recovery and potential effects of recovery. Opinions expressed by individuals from the SSCG and its subgroup are included in the attached documents, or are otherwise documented in supporting documents maintained in the response files.

I recommend adoption of this NEBA process to evaluate the potential effects of further oil recovery operations from the Kalamazoo River.

Sincerely,

/s/
Faith Fitzpatrick, Ph. D.
Scientific Support Coordinator to the FOSC for Enbridge Line 6B Oil Spill
Research Hydrologist (Fluvial Geomorphology), USGS Wisconsin Water Science Center

Net Environmental Benefit Analysis (NEBA) Relative Risk Ranking Conceptual Design

Kalamazoo River System
Enbridge Line 6B MP 608 Marshall, MI Pipeline Release
August 8, 2012

Scientific Support Coordinator: Faith Fitzpatrick (U.S. Geological Survey)

Lead Contributors: Adriana Bejarano (Research Planning, Inc.), Jacqui Michel (Research Planning, Inc.), and Lisa Williams (U.S. Fish and Wildlife Service)

Additional Science Support Coordination Group (SSCG) Contributors (alphabetical): Michael Alexander (Michigan Dept. of Environmental Quality), Dan Capone (Weston Solutions), James Chapman (U.S. Environmental Protection Agency), Mick DeGraeve (Great Lakes Environmental Center), Michelle DeLong (Michigan Dept. of Environmental Quality), and Stephen Hamilton (Michigan State University)

Background and Overview

In January 2012, the Scientific Support and Coordination Group (SSCG) met to discuss potential processes for developing recommendations and guidance to the U.S. Environmental Protection Agency's (EPA) Federal On-Scene Coordinator for Spring 2012 cleanup strategies and endpoints for the remaining submerged oil and oil-containing sediment in the Kalamazoo River associated with the July 2010 *Enbridge Line 6B* oil spill. One of the recommendations from the meeting was to develop a Net Environmental Benefit Analysis (NEBA) for the residual oil conditions in the Kalamazoo River as of spring 2012.

A NEBA is useful for weighing the environmental risks associated leaving residual submerged oil in place and allowing for natural attenuation as opposed to varying levels of physical habitat disturbance associated with recovery actions such as agitation and dredging. The NEBA approach was originally developed for remediation and restoration of petroleum-contaminated sites in marine environments (Efroymson et al., 2003). The first NEBA completed in a freshwater environment was for planning purposes related to concerns for emergency response associated with a potential oil spill from a freighter grounded or damaged near Isle Royale (Rayburn et al., 2004). The NEBA is strictly applicable for determining ecological benefits for recovery actions and identifying cleanup endpoints, after the human health and safety factors are accounted for. The NEBA does not encompass other designated uses of a water body, such as recreational or water withdrawals. The goal becaome to develop a NEBA with existing information and additional new data expected to be available within a couple of months.

Through a series of conference calls from April through June 2012, individuals of the SSCG expressed their opinions regarding a NEBA for specific recovery actions associated with the cleanup of the residual submerged oil in the Kalamazoo River using Efroymson et al. (2003) and Rayburn et al. (2004) as a guide (Figure 1). The first part of the analysis was to map channel and overbank habitat types in the Kalamazoo River and overlay them with areal delineations of moderate and heavy submerged oil simultaneously developed by the onsite operations staff using 2011 reassessment data. Cleanup history, large wood removal, and hydrodynamic model results were used to help visualize the lateral and longitudinal connections among habitat types and main channel flow and to evaluate risks. Photographs showing the physical effects from 2011 cleanup operations were examined. Data on acute sediment toxicity and chemistry from February 2012 grab ponar grab samples of the channel bottom (Appendix A) were examined by Adriana Bejarano (RPI) and Mick DeGraeve (GLEC). J. Chapman summarized available literature of ecological impacts from agitation and dredging (Appendix B). Historical and cleanup turbidity data were examined by A. Bejarano (Appendix C).

Preliminary risk rankings for each habitat type and recovery option were formulated and summarized in a matrix and reviewed by individuals in the SSCG for consistency. This document describes the (NEBA) process used to rank the potential impacts from specific submerged oil recovery actions (monitored natural attenuation, enhanced deposition, agitation toolbox, sweep/push collection, dredging/vacuum truck, dewater/excavate, scraping, and sheen collection) on ecological resources present within eight distinct habitats of the Kalamazoo River.

Habitat Selection and Description

For simplicity, and to avoid redundancy, the NEBA focuses on eight distinct habitats that are unique in character and structure and have been potentially affected by submerged oil or cleanup techniques related to submerged oil (Table 1). These eight habitat types form the basis of the risk-ranking matrix. The habitat types and associated substrates generally reflect hydrologic lateral and longitudinal connectivity, duration, and proximity to main channel flows.

Table 1. Eight major habitat types in the Kalamazoo River system's channel and floodplain environments that may be affected by residual submerged oil. Percentages are based on the total channel and floodplain area along the 40 mile reach of the Kalamazoo River affected by submerged oil from the Talmadge Creek confluence in Marshall, MI to Morrow Lake Dam in Kalamazoo, MI.

[NEBA habitat types were created from combining geomorphic features previously mapped for the channel (Tetra Tech Inc., 2011) and overbank (National Wetlands Inventory, U.S. Fish and Wildlife Service, 2012)]

Major Habitat Type	Definition and examples	Percentage of total area	Data Source
Impounded waters and associated deltas	Depositional areas of standing water or slow moving flow in the Ceresco impoundment, Kalamazoo millponds, and Morrow Lake fan and delta. May include mudflats along margins (areas of loose fine-sediment deposition but little aquatic vegetation) that become exposed during low flow. Bottom substrate generally of silt, clay, and organic matter.	6.8	Tetra Tech unpublished geomorphic mapping units
Flowing channels	Relatively fast flowing riffles, runs, glides, thalwegs, and side channels. Includes sandy depositional bars such as point bars, side channels, and multi-thread channels in deltas with current. Bottom substrate generally of sand, gravel, cobble, boulder, or bedrock.	14.2	Tetra Tech unpublished geomorphic mapping units
Depositional backwaters, pools, and side channels	Depositional areas along channel margins where widening occurs with standing or slow-moving water. Includes pools, side channels, meander cutoffs, and tributary mouths with standing or slow moving water that are connected to the main channel. May include mudflats during low flow. Bottom substrate of silt, clay, and organic matter.	2.2	Tetra Tech unpublished geomorphic mapping units
Bars	Low-lying depositional features surrounded by water with various communities of forbs, shrubs, and wetland. Above water during normal flow but lower than the floodplain or island elevations. Mainly found in Morrow Lake delta.	0.3	Tetra Tech unpublished geomorphic mapping units
Emergent wetlands	Frequently inundated fens, marshes, wet meadow near the channel margin and in the floodplain with herbaceous vegetation.	6.6	National Wetlands Inventory
Islands	Generally forested area surrounded by water and at similar elevations as the floodplain and forested scrub-shrub wetlands.	0.9	Tetra Tech unpublished geomorphic mapping units

Major Habitat Type	Definition and examples	Percentage of total area	Data Source
Oxbows, meander cutoffs, ponds	Features with standing water in overbank areas related to abandoned channels, meander cutoffs, oxbows, springfed ponds, flood chutes, and backswamps. Connected to the main channel only during floods.	0.7	National Wetlands Inventory
Forested scrub-shrub wetlands	Overbank areas with deciduous forest and scrub-shrub wetlands subject to seasonal or temporary flooding. Sometimes saturated. Includes ephemeral pools.	39.9	National Wetlands Inventory

The eight major habitat types were condensed from two main sources of data previously available in a Geographic Information System for the Marshall spill—geomorphic mapping units created by TetraTech (Tetra Tech, 2012) and the National Wetlands Inventory (U.S. Fish and Wildlife Service, 2012; http://www.fws.gov/wetlands) (Table 1). Tetra Tech's geomorphic mapping units were compiled for the riverine part of the Kalamazoo River from the Talmadge Creek confluence to the Morrow Lake dam based on interpretations from Fall 2011 core descriptions, water depth and bottom substrates recorded as part of submerged oil poling assessments, and 2011 aerial photography. The National Wetlands Inventory mapping units were limited to the floodplain of the Kalamazoo River by clipping the larger coverage of the Inventory to the 100-year flood inundation extent generated by the HEC-RAS (Hydrologic Engineering Center- River Analysis System) computer model.

Species of Concern in the Kalamazoo River System

The applicability of the NEBA is dependent on identifying the primary species of concern in each major habitat type. The primary species of concern in the Kalamazoo River system encompass a variety of biological components. Representative and example species listed in Table 2 are included because of their abundance or susceptibility to submerged oil or possible recovery techniques. The list is not exhaustive and is included primarily as an aid to visualizing potential impacts. All potential life stages were considered, although the amount of information on habitat usage is highly variable, especially for larval and juvenile stages. For a more complete description of species and biological communities see Wesley (2005).

The most sensitive species or species group in terms of expected recovery time or degree of resource impact was used to determine the NEBA risk ranking for each habitat type and proposed recovery action. For amphibians and reptiles, multiple species of turtles were usually considered the most sensitive because of their long life histories and slow reproductive rates. Their habitat requirements vary among the species (see http://www.michigan.gov/dnr/0,4570,7-153-10370_12145_12201-60656--,00.html). Turtles were especially abundant in the Kalamazoo River because of the diversity of riverine, wetland, and standing water habitats and included common map, snapping, eastern spiny softshell, painted, musk, Blanding's, eastern box, and spotted. For benthic invertebrates, freshwater mussels were usually considered the species group likely to have the longest recovery times, again because they are long-lived and have low reproductive rates. Mussel beds were very common along this section of the Kalamazoo River, with common species including mucket, spike, Wabash pigtoe, pocketbook, and white heelsplitter (Badra, 2011). No federally listed mussel species were observed in a survey conducted in the fall of 2010, but species listed by the State of Michigan were observed: one species listed as endangered (slippershell), one as threatened (eastern pondmussel), and five as species of special concern (Badra, 2011).

Many mammal and bird species use the riparian corridor of the Kalamazoo River system because of the diversity of riverine and wetland habitats in its extensive floodplain. The Indiana bat, a federal endangered species, is considered to be present in the Kalamazoo watershed. The Indiana bat may feed on emerging aquatic insects and thus could be indirectly impacted by reductions in populations of benthic invertebrates. At this point, direct effects on the Indiana bat are likely limited to the small potential for ingesting sheen when drinking from the water surface while in flight and the more serious concern of death, injury or displacement if any roosting trees were to be cut as part of future response actions.

Table 2. Representative and example species for major habitat types in the Kalamazoo River system's channel and floodplain environments.

Major Habitat Type	Plants	Mammals and Birds	Amphibians and Reptiles	Fish and Invertebrates
Impounded waters and associated deltas	water-lilies, arrowhead, pondweeds, wild celery, coontail, and watermilfoil	muskrat, raccoon, trumpeter swan, ducks & geese, great blue heron, spotted sandpipers, tree swallows, cedar waxwings, red-winged blackbirds, yellow warblers	snapping, eastern spiny softshell, common map turtles; northern water snakes, green frogs	smallmouth bass, bluegill, channel catfish, shiners, northern pike, some mussels, crayfish
Flowing channels	pondweeds, wild celery	muskrat, beaver, raccoon, ducks & geese, great blue heron, spotted sandpipers, belted kingfishers, tree swallows, cedar waxwings, red-winged blackbirds, yellow warblers	snapping, eastern spiny softshell, common map turtles; northern water snakes, green frogs	smallmouth and rock bass, bluegill, shiners, white sucker, golden redhorse, mussels, crayfish, mayflies, caddisflies, stoneflies
Depositional backwaters, pools, and side channels	water-lilies, pondweeds, wild celery, duckweed, filamentous algae	muskrat, beaver, raccoon, ducks & geese, great blue heron, spotted sandpipers, belted kingfishers, tree swallows, cedar waxwings, red-winged blackbirds, yellow warblers	common map, painted and Blanding's turtles; green frogs	bluegill, black crappie, largemouth bass, creek chub, spotted sucker, bowfin, amphipods, mosquitoes, beetle larvae, mayflies, crayfish

Major Habitat Type	Plants	Mammals and Birds	Amphibians and Reptiles	Fish and Invertebrates
Bars	cardinal flower, purple loosestrife, willows, cottonwood seedlings	muskrat, beaver, raccoon, ducks & geese, great blue heron, spotted sandpipers, killdeer, belted kingfishers, tree swallows, cedar waxwings, red-winged blackbirds, yellow warblers	occasional turtles (basking), green frogs	dragonflies and damselflies, butterflies and moths, beetles, spiders
Emergent wetlands	sedges, rushes, cattails, arrowhead, pickerel weed, purple loosestrife, buttercup, great blue lobelia	muskrat, raccoon, ducks & geese, great blue heron, Virginia rail, belted kingfishers, tree swallows, cedar waxwings, red-winged blackbirds, yellow warblers	painted, Blanding's and spotted turtles; green frogs, leopard frogs, western chorus frogs, spring peepers, garter snakes	juvenile sunfish & largemouth bass, johnny darters, mudminnows, white sucker along the edge, dragonflies and damselflies, butterflies and moths, leeches, mosquitoes and other dipterans, chironomids, isopods, spiders
Islands	cattails, purple loosestrife, arrowhead, willows, silver maple, cottonwood	muskrat, beaver, raccoon, ducks & geese, great blue heron, spotted sandpipers, killdeer, belted kingfishers, tree swallows, cedar waxwings, red-winged blackbirds, yellow warblers	may have turtle nests (especially in sandy soils), green frogs	dragonflies and damselflies, butterflies and moths, beetles, spiders
Oxbows, meander cutoffs, ponds	water-lilies, duckweed, filamentous algae	muskrat, beaver, raccoon, ducks & geese, great blue heron, spotted sandpipers, killdeer, belted kingfishers, tree swallows, cedar waxwings, red-winged blackbirds, yellow warblers	common map, painted and Blanding's turtles; green, leopard and wood frogs; salamanders	mudminnows, brook stickleback, bluntnose minnow, amphipods, mosquitoes, crayfish
Forested and scrub-shrub wetlands	silver maple, (dying) ash species, American elm, buttonbush, dogwood, elderberry, jewelweed, nettles, blue flag, ferns, boneset	beaver, raccoon, mice and shrews, Indiana bat, green herons, wood ducks, red-bellied woodpeckers, cedar waxwings, yellow warblers	eastern box and Blanding's turtles, spring peepers, wood frogs, gray treefrogs, salamanders	amphipods, mosquitoes and other dipterans, crayfish, spiders

Impacts of Submerged Oil Recovery Actions

Within each of these distinct habitats, resources may be impacted by eight recovery actions (Table 3) via five general pathway mechanisms (Table 4). Agitation toolbox was the primary means of liberating the oil from the sediment in 2011 cleanup operations. A large area of the Kalamazoo River was affected by agitation; some areas were agitated multiple times over the summer and fall of 2011. The sediment plumes from agitation were extensive, as shown in Figure 2.

Figure 2. Examples of agitation toolbox techniques used in the Kalamazoo River in the summer of 2011 for liberation of submerged oil from bottom sediment: A. Ceresco impoundment, B. Morrow Lake [Photos by Matthew Haak]

A. Ceresco impoundment

B. Morrow Lake

Table 3. Eight major recovery actions under consideration for 2012 cleanup activities for the Kalamazoo River system.

Recovery Action	Description
Monitored natural attenuation	Requires no active recovery but relies on natural attenuation and biodegradation. Unknown effects from oil toxicity and smothering. Unknown rates of biodegradation and weathering.
Enhanced deposition and recovery	Used in depositional areas where submerged oil is allowed to accumulate naturally or enhanced through placement of structures. Increased monitoring is done with poling assessments and sedimentation samplers. Dredging/hydrovac is likely done once after accumulation reaches desired amount. May need repeated dredging into the future, as needed; maybe about every 6 months in some places or after a flood.
Agitation toolbox	Used in depositional areas, various mechanical devices are used to agitate the surface including jets, chain drag, and rototiller. Involves removing aquatic vegetation and large wood in shallow areas before application. Typically disturbs the top 1-2 ft of material, depending on the thickness and water content of soft sediment. Involves heavy airboat traffic (noise and bank erosion) for agitation and associated sweeping. Oil/sediment plume affects turbidity and smothering to downstream areas.
Dredging/vacuum	Used in depositional areas, dredging or vacuum removal likely

Recovery Action	Description
truck	performed once or as needed. Typically removes top 0.5 to 2 ft of material. Most aquatic vegetation and roots removed.
Dewater/excavate	Used in shallow water or frequently inundated areas near channel margins, wetlands, and floodplain environments.
Sweep/push	Sweep/push by agitation toolbox of areas within the main river channel, with remobilization of oiled sediments to downstream sediment traps or impoundments. Uses hydrovac, dredging, or agitation toolbox for removal.
Scraping	Scraping is limited to the surface layer (<6 in) only during low water events (summer). Usually in mudflat areas with limited vegetation.
Sheen collection	Passive sorbents deployed by staking on bank/anchoring in water. May employ multiple types and arrangement of boom, some specific for sheen more so than oil droplets. Some done by sheen sweeping boats.

The overall risk of exposure/impact to a particular resource from each of these pathways is a function of the magnitude of impacts and the recovery of that resource to baseline/reference levels (Table 4). The magnitude of impacts may vary from low to very high (Table 5), whereas the length of recovery may vary from very short to long (Table 6). Because multiple pathways may simultaneously impact a single resource, the Relative Risk Ranking of the overall impact of specific oil recovery actions focuses on the most detrimental pathway mechanism(s). The final Relative Risk Ranking may range from low impacts with very short-term recovery (4D) to very high impacts with long recovery (1A) (Table 7).

Table 4. Potential exposure/impact pathways.

Exposure Pathway	Example	Source	Pathway Code
Aqueous Exposure	Inhalation/ingestion of whole oil droplets, dissolved components, or suspended particulates (e.g., flakes) in the water column	Globules, sheens, dissolved oil, flakes	1
Sediment Exposure	Exposure to oil globules in sediments or residual oil in sediments	Oiled sediments, macro/micro pore oil	2
Physical Trauma	Trampling, mechanical impact from equipment, impacts from removal	Mechanical stressors	3
Physical Oiling/Smothering	Direct contact with oil/oil residues	Submerged globules, surface mats and patties on sediments	4
Indirect	Food web, ingestion of contaminated food, increased water column turbidity, increased noise, impacts associated with boat traffic, sediment smothering, bank erosion,	Contaminated food, habitat disturbance	5

Exposure Pathway	Example	Source	Pathway Code
	loss/displacement of prey		
Exposure does not occur			NA

Table 5. Anticipated degree of resource impact relative to baseline/reference levels.

Categories	Estimated level of impact relative to baseline/reference (%)	Score
Low	0-10	D
Moderate	10-30	C
High	30-60	B
Very High	>60	A

Table 6. Anticipated length of recovery to baseline/reference levels.

Categories	Estimated length of recovery (years)	Score
Very short-term	< 1 year	4
Short-term	1-3	3
Intermediate-term	3-7	2
Long-term	>7; does not recover	1

Table 7. Relative Risk Ranking Matrix used for the Kalamazoo River based on Tables 5 and 6.

		Length of Recovery			
		Very short-term	**Short-term**	**Intermediate-term**	**Long-term**
Degree of resource impact	**Low**	4D	3D	2D	1D
	Moderate	4C	3C	2C	1C
	High	4B	3B	2B	1B
	Very High	4A	3A	2A	1A

Supporting Information

As part of the NEBA process, supporting data were gathered, interpreted, and synthesized for three important aspects of recovery actions related to submerged oil: (1) acute sediment toxicity tests for oiled sediment (Appendix A), (2) ecological effects from agitation (Appendix B), and (3) turbidity associated with 2011 cleanup activities (Appendix C).

Association between Aquatic Toxicity Results and Sediment Characteristics: Impacts to aquatic organisms from sediment toxicity were assessed in laboratory acute toxicity studies of seven sediment samples collected from oil-impacted backwater habitats along the Kalamazoo River in February 2012 (Appendix A). Potential adverse acute and chronic effects to benthic organisms also were evaluated using the Equilibrium Sediment Benchmark Toxic Unit Approach for coexisting PAH data from the same samples. Sediment from two heavily oiled sites and one lightly oiled site may pose acute and chronic risks to benthic fauna. However, analysis of the toxicity results in the context of several sediment characteristics (chemical and physical) showed that variables other than those related to oil residues from the *Enbridge Line 6B* oil spill may have influenced survival. Therefore, based on a relatively small sample size, it is difficult to determine with certainty if the observed biological effects were conclusively the result of the presence of residual oil from the *Enbridge Line 6B* oil spill. On the other hand, based on the weight of evidence approach and additional risk metrics, it is possible to conclude that residual oil from the *Enbridge Line 6B* oil spill, particularly in heavily oiled areas, may pose some risks to benthic receptors. Chronic effects from residual oil still remain largely unknown.

Potential Ecological Effects of Sediment Agitation: Results of a literature review (Appendix B) indicate that potential ecological effects from sediment agitation are primarily from direct mortality from physical trauma and indirect mortality from burial and turbidity, and secondarily from dissolved oxygen depletion and potential release of toxic chemicals to the water column. Based on the review, the agitation toolbox techniques used for submerged oil recovery in the Kalamazoo River potentially result in lethal impacts on benthic invertebrates, eggs, and larvae of bivalves and fish, and aquatic macrophytes. Direct adverse effects on adult fish are unlikely because of their ability to move away from oil recovery locations. The most severe damage is likely associated with direct physical trauma of the agitation itself; however, burial, smothering, and abrasion of gills or eggs by suspended sediment and turbidity-related light attenuation may also be significant depending on the spatial and temporal scale of the disturbances. Removal of large wood associated with preparing a site for agitation may also affect benthic communities. The severity of the effects and recovery time is greater for large areas with repeated agitation compared to small areas with one disturbance. The rate of recovery is also dependent on proximity of refuges for potential recolonizers and location relative to streamflow.

Potential Ecological Effects of Increased Turbidity from Sediment Agitation: Impacts to aquatic organisms from increased turbidity were assessed by comparing field turbidity measurements with values associated with biological responses (Appendix C). Review of these results showed that, under assumptions of worst- case exposure scenarios, increased turbidity from use of the agitation toolbox response methods in the Kalamazoo River may pose *moderate* (sublethal) effects to juvenile and adult fish species. *Severe* (paralethal/lethal) effects are not likely to occur during typical turbidity levels created by sediment agitation, even over extended periods of agitation (days/weeks).

Assumptions Used in Relative Risk Ranking

Several assumptions were made in determining the rankings for the impact of recovery actions on resources within a given habitat:

- Rankings are based on the current knowledge of the degree of oiling in each habitat type in the fall of 2011 and continued into spring 2012.
- In general, less physical perturbation to the environment is expected than in previous years because boat operations will be reduced and controlled more than previously and the overall intensity of cleanup activities is expected to be less.
- The magnitude of impacts of recovery actions is based on the expected footprint of the recovery action being evaluated:
    - Enhanced deposition with subsequent removal is ranked the same or similarly to dredging, even though it might affect a smaller area of the entire site if selected over dredging in a given reach.
    - The expected footprint of the recovery action was assumed to be on the order of 0.1 to 5 acres per non-contiguous application. Areas much smaller or larger than this would likely decrease or increase, respectively, the magnitude of the impact and the recovery time from it. In particular, the sweep-push recovery action would have the potential to impact large areas through agitation and turbidity plus smaller areas where periodic removal would occur.
- Within a resource group, rankings are based on aquatic organisms likely to be impacted by the greatest magnitude and length of recovery. For example, for recovery actions involving dredging, the magnitude of impacts to benthic invertebrate may be fairly uniformly severe, but aquatic insect larval communities with annual life cycles will recovery much more quickly than freshwater mussels that live for decades and may only successfully reproduce in one year out of ten. Thus, in habitats with mussels, recovery times for invertebrates are based on recovery times for this species group.
- Recovery times are based on the time from the end of the 2012 season assuming no subsequent disturbances from recovery actions, but the areas in which recovery actions (other than natural recovery) are expected to occur are assumed to have already undergone up to two years of previous recovery actions. This is important for fish, for example, because the impact of the loss of reproduction for three years in a row will have a longer and greater impact on the fish population than the loss of a single year class.
- In habitats dominated by vegetation, recovery times of resources dependent on plants for food and structure are assumed to be at least as long as for the plant community.
- Impacts to aquatic organisms from toxicity of oil constituents that might be mobilized by sediment agitation were not determined directly, as chemical concentrations were not measured in areas being actively agitated. Based on chemical concentrations measured in the water column of the Kalamazoo River generally over the course of the response, the

magnitude and spatial extent of this impact may be similar to that of the turbidity itself. Based on preliminary data on chemical characterization and biodegradation, the released oil appears to be weathering and toxicity may decrease to some extent over time.

- The NEBA is an iterative process and rankings may be updated in the future as more data are gathered from continued and ongoing assessments.

Relative Risk Matrix

The following tables provide a draft ranking of the impacts from each oil recovery actions on resources within each distinct habitat. These rankings are the result of a series in depth discussions by individuals on the SSCG on the potential effects of each of the recovery options on specific resource categories in the eight habitat types. For each resource category, risk rankings were determined based on potential damages to the most sensitive organisms that would have the longest recovery time and highest degree of resource impact (largest area of disturbance). Within each of the distinct habitats, resources may be impacted by recovery actions via eight general pathways. The exposure pathway considered to be the most detrimental is shaded and bolded within the tables. Assumptions and definitions specific to each habitat type are listed with the table for that habitat type. Supporting documentation for the tables is found in the appendices. The appendices include a preliminary analysis of existing chemistry and toxicity evaluation, a literature review on sediment effects from dredging and agitation, and a preliminary analysis of turbidity data associated with Kalamazoo River recovery operations in 2010-2011. A complete compilation of the NEBA relative risk rankings in one table is available at the end of the section.

Habitat: Impounded waters and associated deltas

General assumptions:

- Assume significant amounts of submerged oil within these habitats and thus most likely to have the most intensive oil cleanup/recovery activity
- High rates of sedimentation and potential oil burial over time, which may slow degradation of oil residues
- Influenced by oil recovery activities upstream because these habitats trap sediment moving downstream

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Recovery Action: Monitored Natural Attenuation			
Plants	1,2,**4**	4D	Plants may be coated with oil residues mobilized by natural processes.
Mammals	1,2,**4**,5	4D	Mammals (e.g., raccoons) may dig for food in oiled sediments and become directly oiled and/or facilitating the resuspension of residues into the water surface, and increasing the likelihood of oiling of fur. No obviously oiled mammals were observed in 2011, and the significantly oiled areas remaining likely comprise a small fraction of their home range; therefore, their likelihood of exposure may be relatively low.
Birds	1,2,**4**,5	4D	Birds (e.g., wood duck) may have similar exposure routes as mammals. The main exposure pathway is likely via feather coating.
Amphibians/ reptiles	1,**2**,4,5	3C	Exposure to oiled sediment is the main source of concern. This resource is relatively sensitive to oil exposure, and potential chronic/sublethal effects may occur. Based on analysis of toxicity test results and analytical chemistry, toxicity from exposure to residual oil, particularly in heavily oiled areas, cannot be conclusively ruled out (Appendix A). Turtles are of special concern in that they take a long time to reach maturity (4-20 years) and have long life spans. A significant habitat for these species, especially eastern spiny softshell turtle.
Fish	1,**2**,4,5	3C	The main resources of concern are demersal species and demersal eggs as they are directly associated with potentially oiled sediments. In the absence of submerged oil removal, impacts may result from direct contact with oil/oiled sediments. Based on analysis of toxicity test results and analytical chemistry, toxicity from exposure to residual oil, particularly in heavily oiled areas, cannot be conclusively ruled out (Appendix A).

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Invertebrates	1,**2**,4,5	3C	The main resources of concern are benthic macrofauna (e.g., amphipods) and mussels. Similar assessments as those for fish. Upstream sources of recruitment would speed recovery once sediments de-toxify. Based on analysis of toxicity test results and analytical chemistry, toxicity from exposure to residual oil, particularly in heavily oiled areas, cannot be conclusively ruled out (Appendix A).
Recovery Action: Enhanced Deposition Including Removal (e.g., dredging)			
Plants	1, 2,**3**,4,5	3B	Assumes extensive removal of plants from the habitat prior treatment. Recovery depends on the time required to fill excavation plus the time need to re-establish in the sediment bed. Footprint of follow-up enhanced deposition less than for 2011 agitation and dredging footprint.
Mammals	1,2,**4**,5	4D	Increased likelihood of exposure to residual oil in deposition areas prior to removal. Habitant disturbance and loss of habitat use will likely occur during removal, but this is expected to occur in a relatively small portion of any given home range. Need information on mammal use of this habitat, relative to the entire river/floodplain.
Birds	1,2,**4**,5	4D	Increased likelihood of exposure to residual oil in deposition areas prior to removal. Habitant disturbance and loss of habitat use will likely occur during removal, but this is expected to occur in a relatively small portion of any given home range.
Amphibians/ reptiles	1,2,**3**,4,5	2B	There is a higher degree of resource impact assuming that removal of oiled sediment incidentally removes animals. Degradation of habitat (e.g., depth, grain size) is expected. Turtle habitat impacted by removal of oiled sediments.
Fish	1,2,**3**,4,5	2B	The main resources of concern are demersal species and demersal eggs. Increased likelihood of exposure to residual oil in deposition areas prior to removal. Degradation of habitat resulting from removal of plants, which provide shelter, and removal of prey by dredging. Mobile life stages may escape injury during removal. These populations likely recover after disturbance cessation by influx of organisms from upstream sources to cleaner substrate.
Invertebrates	1,2,**3**,4,5	2B	Increased likelihood of exposure to residual oil in deposition areas prior to removal, and potential changes in sediment quality and sediment properties. Most invertebrates may not be mobile enough to escape injury

Resource Category	Pathway Code(s)	Risk Rank*	Comments
			during removal. These communities recover after disturbance cessation due to influx from upstream sources to cleaner substrate, but full recovery dependent of return of organic matter and other food items to the substrate. Mussels are the resource of concern, especially in deltas, because they will re-colonize areas slowly and only if sediment stability and appropriate flows are restored. They drive the recovery rate.
Recovery Action: Agitation Toolbox			
Plants	1,2,**3**,4	3B	Assumes extensive removal of plants from the habitat prior treatment. Localized sediment/habitat disturbance. Very high level of impacts may occur as the indirect effects of agitation likely cover areas beyond the footprint of the agitation site.
Mammals	1,2,**4**,5	4D	Coating of fur may occur as agitation facilitates the distribution of globules/sheens on the water surface and in the water column. Mammals likely avoid work areas.
Birds	1,2,**4**,5	4D	Coating of feathers may occur as agitation facilitates the distribution of globules/sheens on the water surface and in the water column. Indirect effects may occur from increased suspended solids in the water column limiting capture of prey. Birds likely avoid work areas. Birds use a variety of habitats and locations, minimizing the impacts associated with agitation.
Amphibians/ reptiles	1,2,3,4,**5**	2B	These resources likely avoid work areas, but direct impacts may occur from physical trauma. Major effects on turtle food source, hiding, and hibernation, especially eastern spiny softshell turtle, which drives the recovery rate.
Fish	**1**,2,**3**,4,**5**	2B	Eggs and less mobile fish species may be more severely impacted by physical trauma and indirect impacts (e.g., sediment smothering, turbidity; see Literature Review in Appendix B). Adults may be more impacted by exposure to oil residues mobilized into the water column by agitation. Ongoing investigations associated of agitation toolbox effects and efficacy may be used to reassess these evaluations.
Invertebrates	1,2,**3**,4,**5**	2B	The main resources of concern are benthic macrofauna, which may be more impacted by physical trauma and indirect impacts (e.g., sediment smothering). Mussels are the resource of concern, especially in deltas, because they will re-colonize areas slowly and only if sediment stability and appropriate flows are restored. They drive the recovery

Resource Category	Pathway Code(s)	Risk Rank*	Comments
			rate. This assumption is supported by the information provided in Appendix B. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Recovery Action: Dredging/Vacuum Truck[1]			
Plants	**3**,5	3B	Similar to Enhanced Deposition, then removal. Assumes extensive removal of plants from the habitat prior treatment. Recovery depends on the time required to fill excavation plus the time need to re-establish in the sediment bed. Need information on the scale of enhanced deposition (i.e., fraction of habitat affected.
Mammals	**5**	4D	The main impacts on mammals likely result from loss/displacement of food resources. Animals may partially compensate from resources in other areas.
Birds	**5**	4D	The main impacts on birds likely result from loss/displacement of food resources. Animals may partially compensate from resources in other areas.
Amphibians/ reptiles	3,**5**	2B	Direct impacts may occur from physical trauma/removal. Benthic food web resources may also be impacted, requiring longer recovery. Effects on turtle food source, hiding, and hibernation, especially spiny softshell turtle.
Fish	**3**,**5**	2B	Eggs and less mobile fish species may be more severely impacted by physical trauma. Adults may be more severely impacted by loss/displacement of food resources. This assumption is supported by the information provided in Appendix B. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Invertebrates	**3**,**5**	2B	Similar to Enhanced Deposition, then removal. This community may be more impacted by physical trauma/ removal and various indirect effects. These communities recover after disturbance cessation due to influx from upstream sources to cleaner substrate, but full recovery dependent of return of organic matter and other food items to the substrate. Mussels are the resource of concern, especially in deltas, because they will re-colonize areas slowly and only if sediment stability and appropriate flows are restored. They drive the recovery rate. This assumption is supported by the information provided in Appendix B. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Recovery Action: Dewater/ Excavate[2]			
Plants	NA	NA	
Mammals	NA	NA	

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Sweep/push with agitation to sediment traps followed by recovery			
Plants	2,**4**,5	3B	SAV may be affected by high turbidity and smothered with resuspended material. No effort made to control turbidity during the push phase of treatment. Similar to Agitation Toolbox effects.
Mammals	1,4,**5**	4D	Increased likelihood of exposure to residual oil in deposition areas. Temporary habitant disturbance and loss of habitat use. Similar to Agitation Toolbox effects.
Birds	1,4,**5**	4D	Increased likelihood of exposure to residual oil in deposition areas. Temporary habitant disturbance and loss of habitat use. Similar to Agitation Toolbox effects.
Amphibians/ reptiles	1,2,4,**5**	2B	Increased likelihood of exposure to residual oil in deposition areas. Temporary habitant disturbance and loss of habitat use. Similar to Agitation Toolbox effects, but there may be additional short-term impacts due to turbidity during the push phase of treatment.
Fish	1,2,4,**5**	2B	The main resources of concern are demersal species and demersal eggs. Increased likelihood of exposure to residual oil in deposition areas and increased bioavailability of oil in the water column. Mobile life stages may escape increased risk of exposure. These populations likely recover after disturbance cessation by influx of organisms from upstream sources. Similar to Agitation Toolbox effects, but there may be additional short-term impacts due to turbidity during the push phase of treatment.
Invertebrates	1,2,**4**,5	2B	Increased likelihood of exposure to residual oil in deposition areas and increased bioavailability of oil in the water column. Mobile life stages may escape increased risk of exposure. These populations likely recover after disturbance cessation by influx of organisms from upstream sources. Similar to Agitation Toolbox effects, but there may be additional short-term impacts due to turbidity during the push phase of treatment. Mussels are the resource of concern, especially in deltas, because they will re-colonize areas slowly and only if sediment stability and appropriate flows are restored. They drive the recovery rate.

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Recovery Action: Scraping			
Plants	**3**,5	4C	Mudflats in this habitat may have limited vegetation. Surface scraping may not remove deep roots or remove all vegetation; therefore, recovery will take place within a year.
Mammals	**5**	4D	Temporary habitant disturbance and loss of habitat use. Mammals will likely avoid the area during operations.
Birds	**5**	4D	Temporary habitant disturbance and loss of habitat use. Birds may be impacted by removal of food (invertebrates) and will likely avoid the area during operations.
Amphibians/ reptiles	**3**,5	4C	Physical removal of less mobile species. Rapid recovery from upstream sources.
Fish	**5**	4D	Rapid recovery of any prey removed during scraping from upstream sources.
Invertebrates	**3**,5	4C	Physical removal of surface invertebrates. Rapid recovery of any prey removed during scraping from upstream sources.
Recovery Action: Sheen collection			
Plants	**5**	4D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance.
Mammals	**5**	4D	Physical disturbance of habitat use in work areas. Mammals will likely avoid the area during operations.
Birds	**5**	4D	Physical disturbance of habitat use in work areas. Birds will likely avoid the area during operations.
Amphibians/ reptiles	**5**	4D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance.
Fish	**5**	4D	Physical disturbance of habitat use in work areas. Fish will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.
Invertebrates	**5**	4D	Physical disturbance of habitat use in work areas. Fish will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.

* Based on the most detrimental pathway mechanism (in bold/shaded).

[1] Assuming dredging of contaminated sediments in lakes. Assumed to be large scale, and assumed good control of contaminated sediment and water. Vacuum truck is unlikely to be used in this scenario.

[2] Action unlikely to take place in these habitats.

Habitat: Flowing channels (e.g., Riffles, runs, glides, thalwegs)

General assumptions:

- Assume little to no significant amounts of submerged oil within these habitats
- Influenced by oil recovery activities upstream
- Less physical damage than previous years because more controlled boat ops in the river and less cleanup activities overall

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Recovery Action: : Monitored Natural Attenuation [1]			
Plants	**4**	4D	Plants may be coated with oil residues mobilized by natural processes.
Mammals	1,**4**	4D	Oil passes through, coating fur. Likely a very short exposure given the nature of the habitat (e.g., fast moving waters).
Birds	1,**4**	4D	Oil passes through, coating feathers. Likely a very short exposure given the nature of the habitat (e.g., fast moving waters).
Amphibians/ reptiles	1,**2**,4	4D	This resource is more likely impacted from exposure to oiled sediments mobilized from upstream sources.
Fish	1,**2**,4	4D	Eggs deposited on riffles may be affected by oiled sediments mobilized from upstream sources.
Invertebrates	**1**,2,4	4D	Invertebrates may be exposed to oil residues in the water column/oiled sediments mobilized from upstream sources.
Recovery Action: Enhanced Deposition Including Removal (e.g., dredging) [2]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Agitation Toolbox [3]			
Plants	4, **5**	4D	Aquatic plants in thalwegs and riffles affected by erosion from airboat wakes and bottom scraping. May be affected by turbidity.
Mammals	1,**4**	4D	Oil remobilized into the water column passes through coating fur. Likely a very short exposure given the nature of the habitat (e.g., fast moving waters).
Birds	1,**4**,5	4D	Oil remobilized into the water column passes through coating feathers. Indirect effects may occur from increased suspended solids in the water column limiting capture of prey, or from impacts on mussel beds. Likely a short exposure given the dynamic nature of this habitat.

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Amphibians/ reptiles	1,**2**,4,5	4D	Suspended solids/oil from upstream recovery activities may have temporary effects.
Fish	1,2,4,**5**	3D	Suspended solids/oil from upstream recovery activities may affect demersal eggs. Potential indirect effects may be caused by increased boat traffic. Some of these assumptions are supported by the information provided in Appendix B. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Invertebrates	1,2,4,**5**	3D	Suspended solids/oil mobilized from upstream recovery activities may affect benthic invertebrates. Potential indirect effects may be caused by increased boat traffic. Some of these assumptions are supported by the information provided in Appendix B. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Recovery Action: Dredging/ Vacuum Truck[2]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Dewater/ Excavate[2]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Sweep/push with agitation to sediment traps followed by recovery [3]			
Plants	4, **5**	4D	Aquatic plants affected by erosion from airboat wakes and bottom scraping from increased boat activity. May be affected by increased turbidity because there will be no attempts to contain suspended sediments.
Mammals	1, **4**	4D	Oil remobilized into the water column passes through, coating fur. Likely a short exposure given the dynamic nature of the habitat (e.g., fast moving waters). Disturbance from increased boat activity.
Birds	1,**4**,5	4D	Oil remobilized into the water column passes through, coating feathers. Indirect effects may occur from increased suspended solids in the water column limiting capture of prey, or from impacts on mussel beds. Likely a short

Resource Category	Pathway Code(s)	Risk Rank*	Comments
			exposure given the dynamic nature of the habitat (e.g., fast moving waters). Disturbance from increased boat activity.
Amphibians/ reptiles	1,**2**,4,5	3D	Suspended solids/oil from upstream recovery activities may have temporary effects. Potential effects on turtle feeding. Disturbance from increased boat activity.
Fish	1,2,4,**5**	3D	Suspended solids/oil from upstream recovery activities may affect demersal eggs. Potential indirect effects may be caused by increased boat traffic. Some of these assumptions are supported by the information provided in Appendix B. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Invertebrates	1,2,4,**5**	2C	Suspended solids/oil mobilized from upstream recovery activities may affect benthic invertebrates. Potential indirect effects may be caused by increased boat traffic. Some of these assumptions are supported by the information provided in Appendix B. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Recovery Action: Scraping[2]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Sheen collection			
Plants	**5**	4D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance.
Mammals	**5**	4D	Physical disturbance of habitat use in work areas. Mammals will likely avoid the area during operations.
Birds	**5**	4D	Physical disturbance of habitat use in work areas. Birds will likely avoid the area during operations.
Amphibians/ reptiles	**5**	4D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance.
Fish	**5**	4D	Physical disturbance of habitat use in work areas. Fish will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.
Invertebrates	**5**	4D	Physical disturbance of habitat use in work areas. Mobile invertebrates will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.

* Based on the most detrimental pathway mechanism (in bold).

[1] From natural recovery (weathering and biodegradation) in places where submerged oil is not recovered upstream.

[2] Action unlikely to take place in these habitats.

[3] Agitation occurs relatively far upstream where most of the sedimentation occurs near the source, and residues in the water column are diluted as the water moves downstream.

Habitat: Depositional backwaters, pools, and side channels

General assumptions:

- Only receive substantial riverine through-flow during high-water events so natural re-colonization rates may be slower
- Vary in their local water inputs (particularly groundwater), sediment types, and degrees of connection to the river so microbial degradation potential and natural removal processes vary
- Assume recovery action will take place over most of the habitat

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Recovery Action: Monitored Natural Attenuation			
Plants	1,2,**4**	4D	The primary resource of concern is likely floating and emergent aquatic vegetation along the banks and mudflats. The most likely exposure pathway is likely via coating of remobilized oil residues.
Mammals	1,2,**4**,5	4D	Mammals may dig for food in oiled sediments resulting in direct oiling and facilitating the resuspension of residues into the water surface, and increasing the likelihood of oiling of fur. If this habitat comprises a small fraction of their home range, their likelihood of exposure may be relatively low.
Birds	1,2,**4**,5	4D	Birds may search for food within oiled sediments resulting in direct oiling and facilitating the resuspension of residues into the water surface, and increasing the likelihood of feather coating. If this habitat comprises a small fraction of their habitat, their likelihood of exposure may be relatively low.
Amphibians/ reptiles	1,**2**,4,5	3C	This habitat may be important for amphibians and reptiles. Oil may accumulate in these areas posing chronic risks to these resources. Slower oil weathering in low oxygen environments also increases risk of exposure. Based on analysis of toxicity test results and analytical chemistry, toxicity from exposure to residual oil, particularly in heavily oiled areas, cannot be conclusively ruled out (Appendix A).
Fish	**1**,**2**,4,5	3C	These habitats may not be suitable for fish eggs (?), but may be important habitats for juvenile rearing where exposure can occur via mobilization of oil residues in water and sediments. Slower oil weathering in low oxygen environments also increases risk of exposure. Based on analysis of toxicity test results and analytical chemistry, toxicity from exposure to residual oil, particularly in heavily oiled areas, cannot be conclusively ruled out (Appendix A).

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Invertebrates	**1**,**2**,4,5	3C	Benthic macroinvertebrates are likely exposed via mobilization of oil residues in water and sediments. Natural deposition of oil in combination with slow biodegradation may increase risk of exposure and cause chronic effects. Based on analysis of toxicity test results and analytical chemistry, toxicity from exposure to residual oil, particularly in heavily oiled areas, cannot be conclusively ruled out (Appendix A).
Recovery Action: Enhanced Deposition Including Removal (e.g., dredging)			
Plants	1,2, **3**,4	3A	Assumes extensive removal of plants from the habitat prior treatment. Recovery depends on the time required to fill excavation plus the time need to reestablish in the sediment bed. Need to determine if plant species are different from those in Morrow Lake delta.
Mammals	1,2,4,**5**	3D	Increased likelihood of exposure in deposition areas prior to removal. Habitant disturbance and loss of habitat use will likely occur during removal. Muskrats are herbivore mammal and could be affected by vegetation removal/loss.
Birds	1,2,4,5	4D	Increased likelihood of exposure in deposition areas prior to removal. Habitant disturbance and loss of habitat use will likely occur during removal.
Amphibians/ reptiles	1,2,3,4,**5**	2B	This habitat may be important for amphibians and reptiles. There is a high degree of resource impact from oil deposition and subsequent loss of habitat (e.g., depth, grain size) during removal. Main effects on turtles, but not as much of area affected as delta/impoundment.
Fish	1,2,4,**5**	3B	These habitats may not be suitable for fish eggs (?), but may be important habitats for juvenile rearing. Increased likelihood of exposure in deposition areas prior to removal. Habitat degradation results from removal of plants, which provide shelter, and removal of prey by dredging/vacuum. Their mobility may allow them to escape direct injury. Plants provide important habitat so recovery is linked to plant recovery. Some of these assumptions are supported by the information provided in Appendix B. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Invertebrates	1,2, **3**,4,5	3A	Most macroinvertebrates may not be mobile enough to escape injury during removal. Increased likelihood of exposure in deposition areas prior to removal, and potential changes in sediment quality and sediment properties. Influx of organisms from adjacent waters is expected to drive recovery. Plants provide important habitat, thus, invertebrate recovery is linked to plant recovery. Mussels

Resource Category	Pathway Code(s)	Risk Rank*	Comments
			are uncommon in these environments. Other macroinvertebrates have relatively short life histories. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Recovery Action: Agitation Toolbox			
Plants	1,2,**3**,4	3A	Loss of plants from physical removal prior to agitation. Also sedimentation outside the footprint. Very high level of impacts may occur as the indirect effects of agitation likely cover areas beyond the footprint of the agitation site.
Mammals	1,2,4,**5**	3D	Coating of fur may occur as agitation facilitates the distribution of sheens/globules on the water surface and in the water column. The most likely impacts are associated with disruption of food supply and habitat, with recoveries likely associated with recovery of prey and vegetation. The impacted habitat likely comprises a small fraction of their home range; therefore, mammals can compensate for changes in food supply by foraging in less impacted/unimpacted habitats, if available within home range. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Birds	1,2,4,**5**	4D	Coating of feathers may occur as agitation facilitates the distribution of sheens/globules on the water surface and in the water column. Most likely impacts are associated with disruption of food supply, with recoveries likely associated with recovery of prey. The impacted habitat likely comprises a small fraction of their home range; therefore, birds can compensate for changes in food supply by foraging in less impacted/unimpacted habitats. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Amphibians/ reptiles	1,2,3,4,**5**	2B	These resources may be impacted as agitation facilitates the distribution of sheens/globules on the water surface and in the water column. The most likely impacts are associated with disruption of food supply, with recoveries likely associated with recovery of prey. Turtles are long-lived. Some of these assumptions are supported by the information provided in Appendix B. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Fish	1,2,4,**5**	3B	The main resources of concern are juvenile fish and small fish species. Fish may be impacted as agitation facilitates the distribution of sheens/globules on the water surface and in the water column. The most likely impacts are associated with degradation their habitat (e.g., removal of

Resource Category	Pathway Code(s)	Risk Rank*	Comments
			plants) and alterations of food supply. Mobile life stages are likely to avoid physical injury. Some of these assumptions are supported by the information provided in Appendix B. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Invertebrates	1,2, **3**,4,5	3A	The main resources of concern are benthic species associated with the substrate. Invertebrates are likely to be physically impacted by agitation. Influx of organisms from adjacent waters is expected. Plants provide important habitat so recovery is linked to plant recovery. Some of these assumptions are supported by the information provided in Appendix B. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Recovery Action: Dredging/ Vacuum Truck[1]			
Plants	**3**,5	3A	Loss of plants from physical removal during treatment, which could affect entire treatment area.
Mammals	**5**	3D	The most likely impacts are associated with disruption of habitat use and food supply. Recoveries are likely associated with habitat recovery. The impacted habitat likely comprises a small fraction of their home range; therefore, mammals can compensate for changes in food supply by foraging in less impacted/unimpacted habitats, if available within home range.
Birds	**5**	4D	The most likely impacts are associated with disruption of habitat use and food supply. Recoveries are likely associated with habitat recovery. The impacted habitat likely comprises a small fraction of their home range; birds can compensate for limited habitat degradation by using similar habitats, if available within home range.
Amphibians/ reptiles	3,**5**	2B	The most likely impacts are associated with disruption of habitat use and food supply, though there could be mortality by physical removal or damage during treatment. Recoveries are likely associated with habitat recovery.
Fish	3,**5**	3B	The main resources of concern are juvenile fish and small fish species. Fish unable to escape prior to excavation may be physically impacted, but the most likely impacts are associated with habitat loss.
Invertebrates	**3**,5	3A	The main resources of concern are benthic species associated with substrates that are likely physically impacted by dredging, which could affect entire treatment area.
Recovery Action: Dewater/ Excavate			
Plants	**3**,5	3A	Impacts may be associated with access corridors and work areas, as well as with physical removal of plants in the

Resource Category	Pathway Code(s)	Risk Rank*	Comments
			entire treatment area.
Mammals	**5**	3D	The most likely impacts are associated with disruption of habitat use and food supply. Recoveries are likely associated with habitat recovery. The impacted habitat likely comprises a small fraction of their home range; therefore, mammals can compensate for changes in food supply by foraging in less impacted/unimpacted habitats, if available within home range.
Birds	**5**	4D	The most likely impacts are associated with disruption of habitat use and food supply. Recoveries are likely associated with the recovery of the habitat. The impacted habitat likely comprises a small fraction of their home range; therefore, birds can compensate for limited habitat degradation by using similar habitats, if available within home range.
Amphibians/ reptiles	3,**5**	2B	The most likely impacts are associated with disruption of habitat use and food supply. Recoveries are likely associated with habitat recovery.
Fish	3,**5**	3B	The main resources of concern are juvenile fish and small fish species. Fish unable to escape prior to dewater/excavate are likely physically impacted, but the most likely impacts are associated with habitat loss.
Invertebrates	**3**,5	3A	The main resources of concern are benthic species associated with the substrate, which are likely physically impacted by these activities, which could affect entire treatment area. Influx of organisms from adjacent waters is expected to facilitate recovery.
Recovery Action: Sweep/push with agitation to sediment traps followed by recovery [2]			
Plants	**3**	3A	Loss of plants from physical removal during treatment, which could affect entire treatment area. These are likely transient impacts, and not repetitive treatment (1 time treatment); therefore, recovery is expected to be fast.
Mammals	1,4,**5**	3D	The most likely impacts are associated with disruption of habitat use and food supply. These are likely transient impacts, and not repetitive treatment (1 time treatment); therefore, recovery is expected to be fast. Mammals can compensate for limited habitat degradation by using similar habitats, if available within home range.
Birds	1,4,**5**	4D	The most likely impacts are associated with disruption of habitat use and food supply. These are likely transient impacts, and not repetitive treatment (1 time treatment); therefore, recovery is expected to be fast. Birds can compensate for limited habitat degradation by using similar habitats, if available within home range.

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Amphibians/ reptiles	4,**5**	2B	Increased likelihood of exposure to residual oil in deposition areas. Temporary habitant disturbance and loss of habitat use. Similar to agitation toolbox effects, but there may be additional short-term impacts due to sediment/oil accumulation prior to treatment.
Fish	1,2,4,**5**	3B	The main resources of concern are juvenile fish and small fish species. Agitation without turbidity control of the entire feature will result in the disruption of habitat use and food supply.
Invertebrates	1,2,**4**,5	3A	The main resources of concern are benthic species associated with the substrate. Invertebrates are likely to be physically impacted by the agitation of the entire feature without turbidity control. Influx of organisms from adjacent waters is expected.
Recovery Action: Scraping			
Plants	**3**,5	3C	Mudflats in this habitat may have some vegetation. Surface scraping may not remove deep roots or remove all vegetation. Thus, recovery will take place within a year.
Mammals	**5**	4D	Temporary habitant disturbance and loss of habitat use. Mammals will likely avoid the area during operations.
Birds	**5**	4D	Temporary habitant disturbance and loss of habitat use. Birds may be impacted by removal of food (invertebrates) and will likely avoid the area during operations.
Amphibians/ reptiles	**3**,5	3C	Physical removal of less mobile species. Rapid recovery from upstream sources.
Fish	**5**	4C	Rapid recovery of any prey removed during scraping from upstream sources.
Invertebrates	**3**,5	3C	Physical removal of surface invertebrates. Rapid recovery of any prey removed during scraping from upstream sources.
Recovery Action: Sheen collection			
Plants	**5**	4D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance.
Mammals	**5**	4D	Physical disturbance of habitat use in work areas. Mammals will likely avoid the area during operations.
Birds	**5**	4D	Physical disturbance of habitat use in work areas. Birds will likely avoid the area during operations.
Amphibians/ reptiles	**5**	3D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance. Increased boat activity.
Fish	**5**	4D	Physical disturbance of habitat use in work areas. Fish will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.
Invertebrates	**5**	4D	Physical disturbance of habitat use in work areas. Mobile

Resource Category	Pathway Code(s)	Risk Rank*	Comments
			invertebrates will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.

* Based on the most detrimental pathway mechanism (in bold).

[1] Assumed good control of contaminated sediment and water.

[2] Only instream agitation without recovery, with treatment impacting the entire footprint.

Habitat: Bars

General assumptions:

- Oil potentially located under the sediment surface from penetration through macropores or coarse sediment (i.e. sand)
- Might be sources of sheening banks
- Habitat above water at normal river flow, and frequently inundated during higher water
- Mainly in Morrow Lake delta and vegetated with forbs and shrubs.

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Recovery Action: Monitored Natural Attenuation			
Plants	**4**	4D	Possible coating of vegetation at the water line from oil mobilized during spring/other floods.
Mammals	2,**4,** 5	4D	Mammals may dig for food in oiled sediments resulting in direct oiling and facilitating the resuspension of residues onto the sediment surface, and increasing the likelihood of oiling of fur.
Birds	**4,** 5	4D	Contact with exposed oil may cause coating of feathers.
Amphibians/ reptiles	**2**,4	4D	Turtle eggs may be found in this habitat and can be in direct contact with oiled substrate. The patchy nature of the oil may imply low likelihood of egg exposure. Amphibians and other reptiles use these habitats as well.
Fish	NA	4D	Fish are not likely impacted by subsurface oil in these habitats. They could be affected by oiled sediments mobilized from treatment of upstream bars.
Invertebrates	**2**,4	4D	Invertebrates may be adversely impacted from direct contact with exposed oil.
Recovery Action: Enhanced Deposition Including Removal (e.g., dredging)[1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Agitation Toolbox			
Plants	**3**	4D	Potential physical damage at the water-bar edge
Mammals	**3**	4D	Potential physical damage at the water-bar edge
Birds	**3**	4D	Potential physical damage at the water-bar edge
Amphibians/ reptiles	**3**	4D	Potential physical damage at the water- bar edge
Fish	**3**	4D	Potential physical damage at the water-bar edge
Invertebrates	**3**	4D	Potential physical damage at the water-bar edge
Recovery Action: Dredging/ Vacuum Truck[1]			

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Dewater/ Excavate			
Plants	**3**	3B	The most likely source of impacts is due to access corridors and work areas that may indirectly damage vegetation. High potential for damage from trampling.
Mammals	3,**5**	3D	This is likely an important river access habitat for mammals. Localized habitat disturbance is the most likely impact, though similar undisturbed habitats may be available.
Birds	**5**	3D	Localized habitat disturbance is the most likely impact, though similar undisturbed habitats may be available.
Amphibians/ reptiles	3,**5**	3B	This is likely an important habitat for amphibians and reptiles. Localized habitat disturbance is the most likely impact, though similar undisturbed habitats may be available.
Fish	**5**	4D	Juvenile fish may use the edges of this habitat for shelter.
Invertebrates	3,**5**	3B	Benthic invertebrates may be potentially impacted by from habitat disturbance. Dependence on plants unknown.
Recovery Action: Sweep/push with agitation to sediment traps followed by recovery [1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Scraping[1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Sheen collection			

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Plants	**5**	4D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance.
Mammals	**5**	4D	Physical disturbance of habitat use in work areas. Mammals will likely avoid the area during operations.
Birds	**5**	4D	Physical disturbance of habitat use in work areas. Birds will likely avoid the area during operations.
Amphibians/ reptiles	**5**	3D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance. Increased boat activity.
Fish	**5**	4D	Physical disturbance of habitat use in work areas. Fish will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.
Invertebrates	**5**	4D	Physical disturbance of habitat use in work areas. Mobile invertebrates will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.

* Based on the most detrimental pathway mechanism (in bold).

[1] Action unlikely to take place in these habitats.

Habitat: Emergent wetlands (e.g., marshes, wet meadow)

General assumptions:

- Oil potentially located under the sediment surface or in plant tussocks from penetration through macropores
- Oil potentially located under the sediment surface near water table from penetration through macropores or coarse sediment (i.e. sand)
- Might be sources of sheening banks
- Low biodegradation rates due to low oxygen in saturated sediment
- Large range of habitat size and potential disturbance area, assume that in most cases the entire wetland will not be affected

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Recovery Action: : Monitored Natural Attenuation			
Plants	**2**,4	4D	Plants may be impacted by direct contact with the oiled substrate. Need information on the scale of oiled sediments (i.e., hot spots or large areas).
Mammals	2,**4**,5	4D	Mammals may dig for food in oiled sediments resulting in direct oiling and facilitating the resuspension of residues into the sediment surface, and increasing the likelihood of coating of fur.
Birds	**2**,4,5	4D	Passerines and other birds may poke around the sediments in search for food increasing their likelihood of ingestion of oiled sediments, and coating of feathers.
Amphibians/ reptiles	1,**2**,4,5	2D	Exposure to oiled sediments is the most likely pathway mechanism. The magnitude of effects depends on the size of the impacted area (assumed a small/patchy area). Given slow oil weathering rates in these habitats chronic exposures are likely. Recovery will likely be long because of slow accumulation of litter and deposition of sufficient sediments creating a clean surface layer. Need information on the scale of oiled sediments (i.e., hot spots or large areas).
Fish	1,**2**,4,5	2D	The greater impacts may occur on small fish and juveniles with small home ranges. Given slow oil weathering rates in these habitats, chronic exposures are likely. Recovery will likely be long because of slow accumulation of litter and deposition of sufficient sediments creating a clean surface layer. Need information on the scale of submerged oil (i.e., hot spots or large areas).
Invertebrates	1,**2**,4,5	2D	Invertebrates in direct contact could be acutely and chronically impacted by submerged oil. Recovery will likely be long because of slow accumulation of litter and deposition of sufficient sediments creating a clean surface layer. Need information on the scale of submerged oil (i.e.,

Resource Category	Pathway Code(s)	Risk Rank*	Comments
			hot spots or large areas).
Recovery Action: Enhanced Deposition Including Removal (e.g., dredging)[1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Agitation Toolbox[1]			
Plants	**3**	4D	Potential physical damage at the water-bar edge
Mammals	**3**	4D	Potential physical damage at the water-bar edge
Birds	**3**	4D	Potential physical damage at the water-bar edge
Amphibians/ reptiles	**3**	4D	Potential physical damage at the water- bar edge
Fish	**3**	4D	Potential physical damage at the water-bar edge
Invertebrates	**3**	4D	Potential physical damage at the water-bar edge
Recovery Action: Dredging/ Vacuum Truck[1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Dewater/ Excavate			
Plants	**3**	2B	The most likely source of impacts is due to access corridors and work areas that may indirectly damage vegetation. If the habitat is not backfilled, recovery of the plant community is likely to be slow. High potential for damage from trampling.
Mammals	**5**	2D	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Mammals are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats.
Birds	**5**	2C	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Birds are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats but nests may be disturbed.
Amphibians/ reptiles	3,**5**	2B	Less mobile species will be likely more severely impacted by habitat degradation. Indirect impacts will likely persist until the habitat recovers from physical impacts.

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Fish	3,**5**	2C	Less mobile species will be likely more severely impacted by habitat degradation. Indirect impacts will likely persist until the habitat recovers from physical impacts.
Invertebrates	3,**5**	2B	Less mobile species will be likely more severely impacted by habitat degradation. Indirect impacts will likely persist until the habitat recovers from physical impacts.
Recovery Action: Sweep/push with agitation to sediment traps followed by recovery [1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Scraping[2]			
Plants	3,**5**	3B	Surface scraping may not remove deep roots or remove all vegetation, especially in dense vegetation areas. Thus, recovery will take place within a year.
Mammals	**5**	3D	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Mammals are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats.
Birds	**5**	3D	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Birds are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats. May affect ground nesters.
Amphibians/ reptiles	**3**,5	3C	The magnitude of effects depends on the size of the impacted area (assumed a small/patchy area) and season. Indirect impacts will likely persist until the habitat recovers from physical impacts.
Fish	**5**	3C	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Fish are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats.
Invertebrates	3,**5**	3B	Physical removal of surface invertebrates. Recovery will depend on the recovery of plants and influx of invertebrates from upstream sources. Trauma and habitat loss to burrowing crayfish.
Recovery Action: Sheen collection			
Plants	**5**	4D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance. Increased boat traffic and wakes cause bank erosion.

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Mammals	**5**	4D	Physical disturbance of habitat use in work areas. Mammals will likely avoid the area during operations.
Birds	**5**	4D	Physical disturbance of habitat use in work areas. Birds will likely avoid the area during operations.
Amphibians/ reptiles	**5**	4D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance.
Fish	**5**	4D	Physical disturbance of habitat use in work areas. Fish will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.
Invertebrates	**5**	4D	Physical disturbance of habitat use in work areas. Mobile invertebrates will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.

* Based on the most detrimental pathway mechanism (in bold).
[1] Action unlikely to take place in these habitats.
[2] Some vegetation would be removed in scraping, but not as deep or extensive as excavation.

Habitat: Islands (e.g., forested islands)

General assumptions:

- Above water except during high flood events
- Excavation of oil and oily debris located under the sediment surface and buried from penetration through macropores
- May have sheening banks.
- Likely that majority of island is affected by oil
- Range of area of disturbance from recovery, from complete to partial excavation.

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Recovery Action: : Monitored Natural Attenuation			
Plants	2,**4**	4D	Possible coating of vegetation at the water line from oil mobilized during spring/other floods.
Mammals	2,**4**	4D	Digging behavior may increase likelihood of exposure and oil smothering
Birds	**4**	4D	Contact with exposed oil may cause coating of feathers
Amphibians/ reptiles	**2**,4	4D	Turtle eggs may be found in this habitat and can be in direct contact with oiled substrate. The patchy nature of the oil may imply low likelihood of egg exposure.
Fish	NA	NA	
Invertebrates	**2**,4	4D	Invertebrates may be adversely impacted from direct contact with oiled sediments, including burrowing crayfish.
Recovery Action: Enhanced Deposition including removal (e.g., dredging)[1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Agitation Toolbox[1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Dredging/ Vacuum Truck[1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/	NA	NA	

Resource Category	Pathway Code(s)	Risk Rank*	Comments
reptiles			
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Dewater/ Excavate			
Plants	**3**	1B	The most likely source of impacts is due to access corridors and work areas that may indirectly damage vegetation. If the habitat is not backfilled, recovery of the plant community is likely to be slow. Woody vegetation would take a long time to recover but only part of the plant community.
Mammals	**5**	1A	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Mammals are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats. Indiana bat habitat totally affected by loss of mature and dying trees.
Birds	**5**	2B	Assuming that these islands are not key nesting areas. Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Birds are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats
Amphibians/ reptiles	3,**5**	2B	Habitat degradation is the most likely impacting mechanism. Indirect impacts will likely persist until the habitat recovers from physical disturbance and vegetation removal. The impacted area is likely a small proportion of the available habitat.
Fish	NA	NA	
Invertebrates	3, **5**	3B	Loss of habitat is likely the most likely impacting mechanism for terrestrial insects. The impacted area is likely a small proportion of the available habitat.
Recovery Action: Sweep/push with agitation to sediment traps followed by recovery [1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Scraping[1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/	NA	NA	

Resource Category	Pathway Code(s)	Risk Rank*	Comments
reptiles			
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Sheen collection			
Plants	**5**	4D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance.
Mammals	**5**	4D	Physical disturbance of habitat use in work areas. Mammals will likely avoid the area during operations.
Birds	**5**	4D	Physical disturbance of habitat use in work areas. Birds will likely avoid the area during operations.
Amphibians/ reptiles	**5**	3D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance. Increased boat activity
Fish	**5**	4D	Physical disturbance of habitat use in work areas. Fish will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.
Invertebrates	**5**	4D	Physical disturbance of habitat use in work areas. Mobile invertebrates will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.

* Based on the most detrimental pathway mechanism (in bold).

[1] Action unlikely to take place in these habitats.

Habitat: Oxbows/meander cutoffs, ponds (e.g., springfed ponds, dugout ponds)

General assumptions:

- Potential hot-spots of oiled sediments
- Fine-grained, high organic-rich sediments where microbial degradation rates and natural removal process are slow due to low oxygen
- Recovery activity likely affects entire feature

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Recovery Action: Monitored Natural Attenuation			
Plants	1,2,**4**	4D	Floating and emergent aquatic vegetation is the primary resource of concern. Most impacts would likely be the result of coating from mobilization of submerged oil in sediments.
Mammals	1,2,**4**,5	4D	The primary pathway of exposure is likely oil coating of the fur. This habitat likely comprises a small fraction of their home range (?); therefore, their likelihood of exposure may be relatively low.
Birds	1,2,**4**,5	4D	The primary pathway of exposure is likely oil coating of the feathers. This habitat likely comprises a small fraction of their home range (?); therefore, their likelihood of exposure may be relatively low.
Amphibians/ reptiles	1,**2**,4,5	4D	Turtles are the primary resource of concern. The primary pathway of exposure is direct contact with oiled sediments.
Fish	**1**,2,4,5	4D	This habitat is not likely an important spawning habitat. The primary pathway of exposure is direct contact with oil residues resuspended in the water column.
Invertebrates	1,**2**,4,5	2C	The primary pathway of exposure is direct contact with oil residues in the sediments. The slow biodegradation of oil in these habitats may increase risk of exposure and cause chronic effects. Recovery of this community is likely a function of the recovery of the sediment bed by accumulation of clean sediment. Based on analysis of toxicity test results and analytical chemistry, toxicity from exposure to residual oil, particularly in heavily oiled areas, cannot be conclusively ruled out (Appendix A).
Recovery Action: Enhanced Deposition including removal (e.g., dredging)			
Plants	1,2,**3**,4	2A	Plants physically removed from deposition areas where oil accumulated may take longer to recover as their recovery depends on the time required to fill excavation, plus the time need to reestablish in the sediment bed. Activities are likely to cover entire oxbow and recovery times are longer because of isolation.
Mammals	1,2,4,**5**	3D	Increased likelihood of exposure in deposition areas prior to removal. Habitant disturbance and loss of habitat use

Resource Category	Pathway Code(s)	Risk Rank*	Comments
			will likely occur during removal. The most likely impacts are associated with disruption of food supply, with recoveries likely associated with the recovery of the prey.
Birds	1,2,4,**5**	3D	Increased likelihood of exposure in deposition areas prior to removal. Habitant disturbance and loss of habitat use will likely occur during removal. The most likely impacts are associated with disruption of food supply, with recoveries likely associated with the recovery of the prey.
Amphibians/ reptiles	1,2,3,4,**5**	2B	There is a moderate degree of resource impact from oil deposition and subsequent loss of habitat (e.g., depth, grain size) during removal.
Fish	1,2,4,**5**	3B	Increased likelihood of exposure in deposition areas prior to removal, though these areas likely represent a small fraction of their habitat. Their mobility may allow them to escape injury during removal. Some of these assumptions are supported by the information provided in Appendix B.
Invertebrates	1,2,3,4,**5**	2A	Most invertebrate may not be mobile enough to escape injury during removal. Increased likelihood of exposure in deposition areas prior to removal, and potential changes in sediment quality and sediment properties. These communities likely recover within a few years after disturbance cessation. Influx of organisms from adjacent habitats is expected. Some of these assumptions are supported by the information provided in Appendix B.
Recovery Action: Agitation Toolbox			
Plants	1,2,**3**,4	2A	Loss of plants from physical removal prior to agitation. Given the nature of this habitat, high impacts are expected. The recovery of the plant community likely depends on the recovery of the substrate.
Mammals	1,2,4,**5**	3D	This habitat may be an important habitat for mammals. The most likely impacts are associated with disruption of food supply, with recoveries likely associated with the recovery of the prey. However, mammals can compensate for changes in food supply by foraging in less impacted/unimpacted habitats. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Birds	1,2,4,**5**	3D	This habitat may be an important habitat for birds. The most likely impacts are associated with disruption of food supply, with recoveries likely associated with the recovery of the prey. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Amphibians/ reptiles	1,2,3,4,**5**	2B	These resources may be impacted as agitation facilitates the distribution of sheens/globules on the water surface and

Resource Category	Pathway Code(s)	Risk Rank*	Comments
			in the water column. The most likely impacts are associated with disruption of food supply, with recoveries likely associated with the recovery of the prey. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Fish	1,2,3,4,**5**	3B	The main resources of concern are juvenile fish and small fish species. Fish may be impacted as agitation facilitates the distribution of sheens on the water surface and oil globules in the water column. The most likely impacts are associated with habitat degradation and alterations of food supply. Fish are stressed by turbidity and low dissolved oxygen. Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Invertebrates	1,2,**3**,4,5	2A	The main resources of concern are benthic species associated with the substrate. Invertebrates are likely to be physically impacted by agitation. High impacts may occur, with recovery depending on the recovery of the substrate. Influx of organisms from adjacent waters may be limited by habitat connectivity Ongoing investigations associated with Charge 4 may be used to reassess these evaluations.
Recovery Action: Dredging/ Vacuum Truck[1]			
Plants	**3**,5	2A	A significant fraction of the plant community may be likely physically impacted during dredging operations.
Mammals	**5**	3D	This habitat may be an important habitat for mammals. The most likely impacts are associated with disruption of food supply and loss of habitat use. However, mammals can compensate for changes in food supply by foraging in less impacted/unimpacted habitats.
Birds	**5**	3D	This habitat may be an important habitat for birds. The most likely impacts are associated with disruption of food supply and loss of habitat use.
Amphibians/ reptiles	**3**,5	2B	These resources may be physically impacted, and because of their long life spans, recovery may be slow.
Fish	3,**5**	3B	The primary resource of concern is small fish with limited home ranges. Fish may be impacted through loss of habitat use and alteration of their food supply. Effects may be compounded by the limited/transient habitat connectivity.
Invertebrates	**3**,5	2A	The main resources of concern are benthic species associated with the substrate. Invertebrates are likely to be physically impacted by dredging. Moderate impacts may occur, with recovery depending on the recovery of the substrate. Influx of organisms from adjacent waters may be restricted by the limited/transient habitat connectivity.
Recovery Action: Dewater/ Excavate			

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Plants	**3**,5	2A	The most likely source of impacts is due to access corridors and work areas that may indirectly damage vegetation. If the habitat is not backfilled recovery of the plant community is likely to be slow
Mammals	**5**	3D	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Mammals are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats
Birds	**5**	3D	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Birds are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats
Amphibians/ reptiles	**3**,5	2B	Less mobile species will be likely more severely impacted by physical trauma and habitat degradation.
Fish	3,**5**	2A	Less mobile species will likely be more severely impacted by habitat degradation. Indirect impacts will likely persist until the habitat recovers from physical impacts.
Invertebrates	**3**,5	2A	Less mobile species will be likely more severely impacted by habitat degradation, though the main source of impacts is likely through physical trauma. Indirect impacts will likely persist until the habitat becomes suitable to support invertebrates, and until it recovers from physical impacts. Influx of organisms from adjacent waters may be restricted by limited/transient habitat connectivity.
Recovery Action: Sweep/push with agitation to sediment traps followed by recovery [2]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Scraping			
Plants	**3**,5	4C	Surface scraping may not remove deep roots or remove all vegetation, especially in dense vegetation areas. Thus, recovery will take place within a year.
Mammals	**5**	4D	Temporary habitant disturbance and loss of habitat use. Mammals will likely avoid the area during operations.
Birds	**5**	4D	Temporary habitant disturbance and loss of habitat use. Birds may be impacted by removal of food (invertebrates) and will likely avoid the area during operations.
Amphibians/ reptiles	**3**,5	4C	Physical removal of less mobile species. Rapid recovery from adjacent areas.

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Fish	**5**	4D	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts.
Invertebrates	**3**,5	3C	Physical removal of surface invertebrates. Slow recovery, which will depend on influx from adjacent sources.
Recovery Action: Sheen collection			
Plants	**5**	4C	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance.
Mammals	**5**	4D	Physical disturbance of habitat use in work areas. Mammals will likely avoid the area during operations.
Birds	**5**	4D	Physical disturbance of habitat use in work areas. Birds will likely avoid the area during operations.
Amphibians/ reptiles	**5**	4C	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance.
Fish	**5**	4D	Physical disturbance of habitat use in work areas. Fish will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.
Invertebrates	**5**	4C	Physical disturbance of habitat use in work areas. Mobile invertebrates will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.

* Based on the most detrimental pathway mechanism (in bold).

[1] Assumed good control of contaminated sediment and water.

[2] Action unlikely to take place in these habitats.

Habitat: Forested/scrub-shrub wetlands

- Vegetation is dominated by woody species, including shrub carr, which have slow growth rates
- Sedimentation rates are slow
- Oil potentially located under the sediment surface from penetration through macropores
- Vernal pools most sensitive habitat

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Recovery Action: : Monitored Natural Attenuation			
Plants	2,**4**	4D	Possible coating of vegetation at the water line from oil mobilized during spring/other floods.
Mammals	2,**4**,5	4D	Mammals may dig for food in oiled sediments resulting in direct oiling and facilitating the resuspension of residues into the sediment surface, and increasing the likelihood of oiling of fur.
Birds	2,**4**,5	4D	Contact with remobilized oil may cause oiling of feathers.
Amphibians/ reptiles	**2**,4	3D	Amphibians/reptiles in direct contact with oiled substrate may be physically coated or have increased uptake through the skin. Uncertainty for exposure effects for reproduction of amphibians in vernal pools.
Fish	NA	NA	
Invertebrates	**2**,4	3D	Invertebrates may be adversely impacted from direct contact with oiled sediments, including borrowing crayfish. Uncertainty for exposure effects for reproduction of invertebrates in vernal pools.
Recovery Action: Enhanced Deposition including removal (e.g., dredging)[1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Agitation Toolbox[1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Dredging/ Vacuum Truck[1]			
Plants	NA	NA	

Resource Category	Pathway Code(s)	Risk Rank*	Comments
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Dewater/ Excavate			
Plants	**3**	1D	The most likely source of impacts is due to access corridors and work areas that may indirectly damage vegetation. Recovery is based on removal of mature trees.
Mammals	**5**	1D	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Mammals are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats. Indiana bats use of mature trees or snags; therefore, this species would be directly affected.
Birds	**5**	3D	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Birds are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats.
Amphibians/ reptiles	3,**5**	2B	The impacted area is likely a small proportion of the available habitat. Salamander and frog populations dependent on vernal pools. Vernal pools compose a small footprint of overall forested wetland but are critical for amphibian reproduction. Potential loss of large wood on banks for turtle basking.
Fish	NA	NA	
Invertebrates	3,**5**	3D	Less mobile species will be likely more severely impacted by habitat degradation, though the main source of impacts is likely through physical trauma. The impacted area is likely a small proportion of the available habitat.
Recovery Action: Sweep/push with agitation to sediment traps followed by recovery [1]			
Plants	NA	NA	
Mammals	NA	NA	
Birds	NA	NA	
Amphibians/ reptiles	NA	NA	
Fish	NA	NA	
Invertebrates	NA	NA	
Recovery Action: Scraping[2]			
Plants	NA	3C	Surface scraping may not remove deep roots or remove all vegetation, especially in dense vegetation areas. Scraping would generally not require removing trees. Therefore, the

Resource Category	Pathway Code(s)	Risk Rank*	Comments
			recovery will take place within several years.
Mammals	NA	4D	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Mammals are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats.
Birds	NA	3D	Indirect impacts (e.g., loss of habitat, loss/displacement of prey) will likely persist until the habitat recovers from physical impacts. Birds are likely to compensate from impacts by foraging in undisturbed/less disturbed habitats. Maybe some disturbance for shrub/ground nesters.
Amphibians/ reptiles	NA	3B	The magnitude of effects depends on the size of the impacted area (assumed small/patchy). Indirect impacts will likely persist until the habitat recovers from physical disturbance. Vernal pools compose a small footprint of overall forested wetland but are critical for amphibian reproduction. Need to account for antecedent conditions and season of oil recovery (hibernation, breeding, juvenile rearing, feeding).
Fish	NA	NA	
Invertebrates	NA	3D	Physical removal of surface invertebrates. Recovery will depend on the recovery of plants and influx of invertebrates from adjacent sources.
Recovery Action: Sheen collection[3]			
Plants	**5**	4D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance.
Mammals	**5**	4D	Physical disturbance of habitat use in work areas. Mammals will likely avoid the area during operations. Increased boat activity.
Birds	**5**	4D	Physical disturbance of habitat use in work areas. Birds will likely avoid the area during operations.
Amphibians/ reptiles	**5**	3D	Physical damage from repeated anchoring and staking of sorbents and sorbent maintenance. Increased boat activity.
Fish	**5**	NA	
Invertebrates	**5**	4D	Physical disturbance of habitat use in work areas. Mobile invertebrates will likely avoid the area during operations. Bottom disturbance by boat traffic in shallow water.

* Based on the most detrimental pathway mechanism (in bold)

[1] Action unlikely to take place in these habitats.

[2] If trees are removed for scraping than dewater/excavate rankings would apply.

[3] Assumes no sheen collection in this habitat itself.

Summary NEBA Relative Risk Matrix

Habitats	Resource Category	Recovery Actions: Monitored Natural Attenuation	Enhanced Deposition	Agitation Toolbox	Dredging/ Vacuum Truck	Dewater/ Excavate	Sweep/Push	Scraping	Sheen Collection
Impounded waters and associated deltas	Plants	4D	3B	3B	3B	NA	3B	4C	4D
	Mammals	4D	4D	4D	4D	NA	4D	4D	4D
	Birds	4D	4D	4D	4D	NA	4D	4D	4D
	Amphibians/reptiles	3C	2B	2B	2B	NA	2B	4C	4D
	Fish	3C	2B	2B	2B	NA	2B	4D	4D
	Invertebrates	3C	2B	2B	2B	NA	2B	4C	4D
Flowing channels	Plants	4D	NA	4D	NA	NA	4D	NA	4D
	Mammals	4D	NA	4D	NA	NA	4D	NA	4D
	Birds	4D	NA	4D	NA	NA	4D	NA	4D
	Amphibians/reptiles	4D	NA	4D	NA	NA	3D	NA	4D
	Fish	4D	NA	3D	NA	NA	3D	NA	4D
	Invertebrates	4D	NA	3D	NA	NA	2C	NA	4D
Depositional backwaters, pools, and side channels	Plants	4D	3A	3A	3A	3A	3A	3C	4D
	Mammals	4D	3D	3D	3D	3D	3D	4D	4D
	Birds	4D	4D	4D	4D	4D	4D	4D	4D
	Amphibians/reptiles	3C	2B	2B	2B	2B	2B	3C	3D
	Fish	3C	3B	3B	3B	3B	3B	4C	4D
	Invertebrates	3C	3A	3A	3A	3A	3A	3C	4D
Bars	Plants	4D	NA	4D	NA	3B	NA	NA	4D
	Mammals	4D	NA	4D	NA	3D	NA	NA	4D
	Birds	4D	NA	4D	NA	3D	NA	NA	4D
	Amphibians/reptiles	4D	NA	4D	NA	3B	NA	NA	3D
	Fish	4D	NA	4D	NA	4D	NA	NA	4D
	Invertebrates	4D	NA	4D	NA	3B	NA	NA	4D
Emergent wetlands	Plants	4D	NA	4D	NA	2B	NA	3B	4D
	Mammals	4D	NA	4D	NA	2D	NA	3D	4D
	Birds	4D	NA	4D	NA	2C	NA	3D	4D
	Amphibians/reptiles	2D	NA	4D	NA	2B	NA	3C	4D
	Fish	2D	NA	4D	NA	2C	NA	3C	4D
	Invertebrates	2D	NA	4D	NA	2B	NA	3B	4D
s l a n d	Plants	4D	NA	NA	NA	1B	NA	NA	4D

Habitats	Resource Category	Recovery Actions							
		Monitored Natural Attenuation	Enhanced Deposition	Agitation Toolbox	Dredging/ Vacuum Truck	Dewater/ Excavate	Sweep/Push	Scraping	Sheen Collection
	Mammals	4D	NA	NA	NA	1A	NA	NA	4D
	Birds	4D	NA	NA	NA	2B	NA	NA	4D
	Amphibians/reptiles	4D	NA	NA	NA	2B	NA	NA	3D
	Fish	NA	NA	NA	NA	NA	NA	NA	4D
	Invertebrates	4D	NA	NA	NA	3B	NA	NA	4D
Oxbows, meander cutoffs, ponds	Plants	4D	2A	2A	2A	2A	NA	4C	4C
	Mammals	4D	3D	3D	3D	3D	NA	4D	4D
	Birds	4D	3D	3D	3D	3D	NA	4D	4D
	Amphibians/reptiles	4D	2B	2B	2B	2B	NA	4C	4C
	Fish	4D	3B	3B	3B	2A	NA	4D	4D
	Invertebrates	2C	2A	2A	2A	2A	NA	3C	4C
Forested/ scrub-shrub wetlands	Plants	4D	NA	NA	NA	1D	NA	3C	4D
	Mammals	4D	NA	NA	NA	1D	NA	4D	4D
	Birds	4D	NA	NA	NA	3D	NA	3D	4D
	Amphibians/reptiles	3D	NA	NA	NA	2B	NA	3B	3D
	Fish	NA	NA	NA	NA	NA	NA	NA	NA
	Invertebrates	3D	NA	NA	NA	3D	NA	3D	4D

Preliminary Findings (June 2012)

The Kalamazoo River NEBA is an iterative and adaptive process, and it was developed with the best expert judgment of individuals on the SSCG. Based on available data for toxicity and chemistry, the fall 2011 distribution of residual submerged oil, and known sediment disturbance and turbidity associated with agitation and dredging, organisms are generally thought to have shorter recovery times and less degree of impact for natural attenuation and sheen collection than for agitation toolbox, dredging, dewater/excavate, and sweep and push techniques. Some risk of toxicity to benthic receptors is possible in heavily oiled areas, and biodegradation rates in different habitats are unknown. Rankings for scraping were mostly in between the more disruptive techniques and natural attenuation and sheen collection. Even with natural attenuation, monitoring is necessary to determine the degree of oiling and weathering over time, which may impact the rankings.

The Kalamazoo River system has thick beds of native aquatic and emergent vegetation in a variety of relatively slow and fast water habitats. Most of the physical removal techniques result in removal or disturbance of the vegetation. The recovery time and degree of resource impacts for amphibians/reptiles, fish, and invertebrates in many habitats are the same or worse than for aquatic vegetation since the plants provide food and shelter for many species.

Next Steps

Four main information gaps were identified during the NEBA development including: (1) additional acute and chronic sediment toxicity data, (2) toxicity and physical smothering associated with agitation toolbox techniques, (3) oil biodegradation rates, and (4) quantification of volume of remaining oil. The relative risk rankings should be reviewed and updated if necessary as more data are generated. The proposed agitation experiment as part of the FOSC's Charge 4 may help distinguish differences in relative risk rankings for agitation toolbox compared to dredging/hydrovac methods. However, large changes associated with the NEBA relative risk rankings are not expected.

The NEBA relative risk rankings for each recovery action and habitat will be integrated into site-specific recovery recommendations for each of the 2012 tactical areas. An additional NEBA for planning emergency response to heavy oil spills in riverine systems may be developed. The NEBA rankings are for the use of the FOSC, MI DEQ and onsite operations for consideration in tactical approaches for residual submerged oil removal and for assisting the FOSC and DEQ in determining cleanup endpoints.

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Appendixes

A. Analysis on the Association between Aquatic Toxicity Results and Sediment Characteristics (A. Bejarano)
B. Review of Potential Ecological Effects of Sediment Agitation (J. Chapman)
C. Analysis of Potential Ecological Effects of Increased Turbidity from Sediment Agitation (A. Bejarano)

Appendix A

Analysis on the Association between Aquatic Toxicity Results and Sediment Characteristics from Samples Collected within the Kalamazoo River Enbridge Line 6B MP 608 Marshall, MI Pipeline Release

In support of the SSCG's Net Environmental Benefit Analysis Subgroup
Prepared by Adriana C. Bejarano, Research Planning, Inc.
June 27, 2012

Background

Sediment samples were collected for toxicity testing and chemical characterization following SSCG recommendations. Ten-day whole sediment toxicity tests using *Chironomus dilutus* and *Hyalella azteca* were performed by the Great Lakes Environmental Center, Inc. (GLEC), and included survival, growth and biomass as the toxicity endpoints (GLEC, 2012). Analytical chemistry (PAHs, TEHs) and sediment characterization (TOC and sediment composition) were also performed (ALPHA, 2012) in a subset of samples collected and used for the toxicity tests (Appendix A1).

Objectives

The main objective of this analysis is to provide an overview on the strength of association between the toxicity results provided by GLEC and the analytical metrics associated with these samples. Note that for the purposes of this analysis, the sediment sample collected from Talmadge Creek upstream of the pipeline release (SETC0000C210) was used as the field reference. The rational for the selection of this site is provided in detail in Appendix A2. This assumption is conservative and biased towards over-prediction of effects (risks).

This analysis focuses on:

- Determining if sediments collected along the Kalamazoo River and influenced by the *Enbridge Line 6B* oil spill pose adverse risks to benthic biota;
- Determining if the observed adverse effects in the two test species are associated with the residual oil from the *Enbridge Line 6B* oil spill;
- Determining if confounding factors may have contributed to the observed adverse effects in the two test species.

The results from these analyses may inform the Net Environmental Benefit Analysis (NEBA) currently under development by the SSCG, and may provide a better understanding of the need for future toxicity testing. Note that most of the samples collected for toxicity testing and analytical chemistry within the impacted area of the Kalamazoo River, were collected from backwater habitats (15 of 20 samples), and therefore the analysis presented here may represent a worst-case scenario (assuming slower oil degradation rates in this habitat).

Assessment of the Potential Adverse Risks to Aquatic Biota

Two metrics were used to screen samples with the greatest potential for toxicity to benthic resources. Potential risk of adverse effects from PAHs and metals were assessed in samples collected within the impacted area, and included only samples with Fall 2011 poling classification information (None N, Light L, Moderate M, Heavy H). Sample sizes by oiling categories were as follows: N=3, L=4, M=6, H=7. Potential adverse effects to benthos from 64 coexisting PAHs were evaluated using the Equilibrium Sediment Benchmark Toxic Unit approach (USEPA, 2003), while potential adverse effects from metals were evaluated using the Simultaneously Extracted Metals/Acid Volatile Sulfide ratio (SEM/AVS)[1]. In both cases, there may be adverse effects to benthic fauna if the metric exceeds unity (i.e., PAH TU acute and/or chronic >1, SEM/AVS>1). Note that for the purposes of this analysis, the sediment sample collected from Talmadge Creek upstream of the oil spill (SETC0000C210) was used as the field reference (Appendix A2). This assumption is conservative and biased towards over-prediction of effects (risks).

Only one sample (SEKR0335R001), collected from a lightly oiled site, exceeded acute PAH benchmarks, while the same sample and another sample collected from a lightly oiled area (SEKR2816R016), plus two samples from heavy oiled areas (SEKR0510C001 and SEKR2131R014) exceeded chronic PAH benchmarks (Figure 1; Appendix A). Metal benchmarks were exceeded in one sample collected from a non-oiled site (SEKR3510R018) and in one sample from a heavy oiled area (SEKR3771C029). Of the six samples where benchmarks were exceeded, only one sample (SEKR0335R001) was found to have a significant reduction in *Chironomus* survival (comparisons made vs. the Talmadge Creek sample, SETC0000C210; GLEC 2012).

Based on the information presented above using equilibrium partitioning theory, PAHs and metals in these sediments are minimally or not at all bioavailable to the benthic biota in even in the most impacted sediments, and therefore, potential adverse effects are not expected. However, the above analysis does suggest that there may be chronic effects (based on equilibrium partitioning theory, and not on toxicity tests) from exposure to PAHs, particularly in areas categorized as heavily oiled. It is important to note that this assessment is based on a relatively small number of samples that were simultaneously used in *acute* toxicity tests with *Chironomus* and *Hyalella* (as opposed to longer-duration chronic toxicity tests). Therefore, additional information may be needed to validate the initial conclusions from this assessment.

[1] In equi-molar concentrations for divalent metals that form insoluble metal sulphides (cadmium, copper, lead, nickel, zinc). Other metal related metrics (excess SEM= SEM-AVS (µmol/g), and Organic Carbon Normalized Excess SEM= SEM-AVS/f_{OC} (µmol/g OC)) were also calculated, but the SEM/AVS ration yielded the most conservative results.

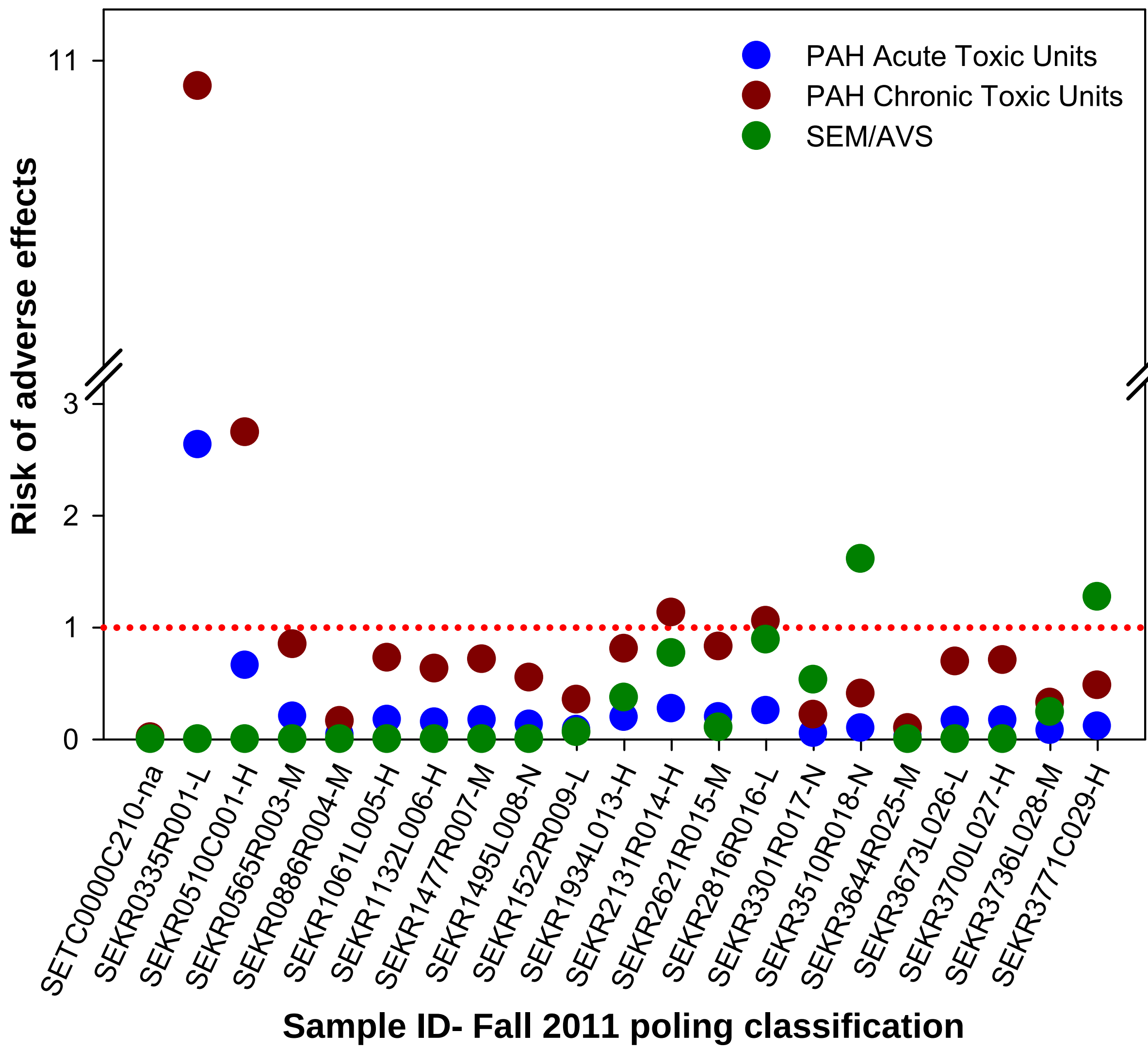


Figure 1. Potential adverse effects to benthic biota from PAHs (PAH acute and chronic Toxic Units) and metals (Simultaneously Extracted Metals/Acid Volatile Sulfide ratio, SEM/AVS) in samples collected for toxicity testing and analyzed for chemical constituents. The x-axis shows the sample ID followed by its corresponding Fall 2011 poling classification. N= No oil, L= Lightly oiled, M= Moderately oiled and H= Heavily oiled. Values >1 indicate the possibility of negative adverse effects from exposures to PAHs and/or metals in the Kalamazoo River samples. The Talmadge Creek sample collected upstream of the oil spill (SETC0000C210) was used as a conservative reference sample (Appendix A2).

Correlation between Toxicity Endpoints and Sediment Metrics

A nonparametric correlation test (Spearman Rank Order Correlation) was used to determine if the toxicological effects observed during the sediment toxicity investigation were associated with the residual oil from the *Enbridge Line 6B* oil spill and/or other confounding variables. The Spearman Rank Order Correlation measures the strength and direction (positive or negative) of association between two variables, in this case, toxicity endpoints for *Chironomus* and *Hyalella,* and all the analytical variables measured in the same sediment samples.

Overall, *Chironomus* percent survival was negatively correlated with most variables potentially associated with the presence of oil residues (low molecular weight and total PAHs, and TEHs), while *Hyalella* percent survival was negatively correlated only with TEHs (Table 1). *Chironomus* percent survival was also correlated with sediment characteristics (TOC, sediment composition). Sub-acute endpoints[2] (growth and biomass) for *Chironomus* were also correlated with explanatory variables associated with the presence of oil residues as well as with silt content. Although statistically significant correlations do not imply causation, this analysis suggests that *Chironomus* was relatively more sensitive than *Hyalella* to many of the variables quantified in the exposure sediments. It is important to note that all of the statically significant correlations were weak to moderate (correlations <0.7), and that many of these variables are highly collinear (e.g., TOC and TEH; Appendix C).

This analysis also suggests that some of the reduced survival observed in *Chironomus* may have been the result of the combined effects of oil residues and sediment characteristics (TOC, sand[3], clay), while only TEHs may have influenced *Hyalella*'s survival (although survival correlations with at least low molecular weight PAHs were similar to those of TEHs, but not statistically significant). In both species, growth may have been influenced by variables unrelated to oil residues from the *Enbridge Line 6B oil spill.*

Table 1. Nonparametric Spearman's Rho correlation coefficients between toxicity test results (GLEC) and analytical variables (ALPHA). Highlighted cells indicate a statically significant correlation at α=0.05.

Variables	*Chironomus dilutus*			*Hyalella azteca*		
	Survival	Growth	Biomass	Survival	Growth	Biomass
Sum LMW-PAH (µg/Kg)*	-0.53	-0.47	-0.51	-0.44	-0.18	-0.17
Sum HMW-PAH (µg/Kg)*	-0.45	-0.36	-0.40	-0.36	-0.20	-0.17
TPAH (µg/Kg)	-0.49	-0.43	-0.47	-0.39	-0.22	-0.21
TEH (mg/kg)**	-0.52	-0.53	-0.54	-0.47	-0.29	-0.39
%TOC	-0.67	-0.35	-0.42	0.04	-0.65	-0.65
% Gravel	-0.08	0.02	0.03	0.01	0.07	0.18
% Sand	0.56	0.40	0.41	0.23	0.41	0.54
% Silt	-0.54	-0.52	-0.52	-0.36	-0.44	-0.55
% Clay	-0.53	-0.21	-0.25	-0.13	-0.41	-0.53

*Low molecular weight (LMW) PAH include Naphthalene to Benzo(b)fluorine (38 analytes), while high molecular weight (HMW) PAHs include Fluoranthene to Benzo[g,h,i]perylene (26 analytes).
** Total Extractable Hydrocarbons (C9-C44; TEH).

Association of Sediment Samples based on their Characteristics

Cluster analysis (hierarchical cluster), by test species, was used to identify groups of sediment samples with similar characteristics based on all biological, chemical and physical variables.

[2] Note that 10 day sediment toxicity test are not appropriate to evaluate chronic impacts (i.e., growth) from residual oil.

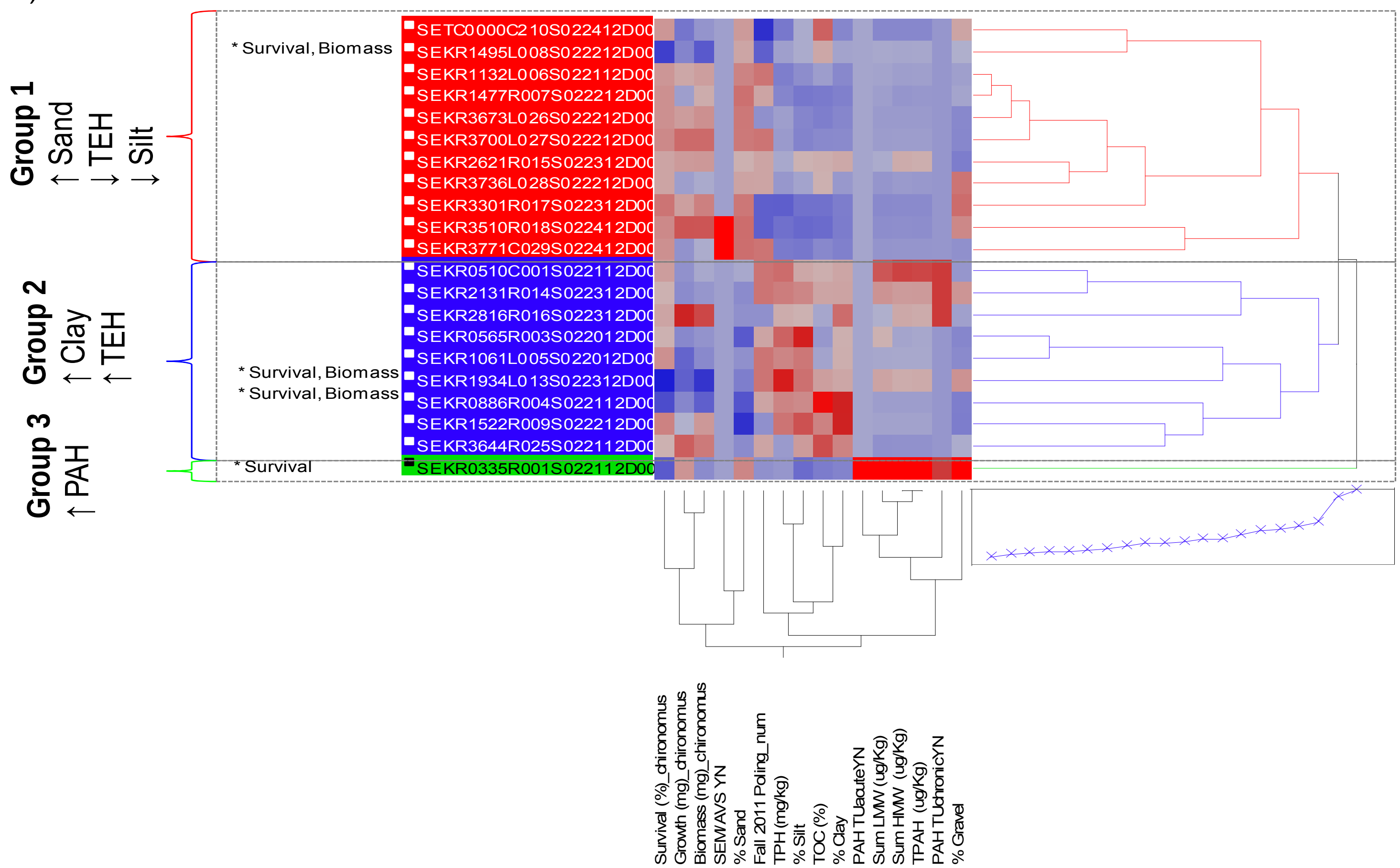
[3] *Chironomus dilutus* requires some sand for building its larval case, indicating that sand is critical in their survival (K. Taulbee, GLEC, pers. comm.)

The analysis for *Chironomus* revealed samples having three distinct groups of chemical/physical characteristics (Figure 2A). Group 1, which includes the field reference sample from Talmadge Creek upstream of the oil spill, is characterized by sediment samples having high sand and low silt contents, and low TEH concentrations. One of the samples (SEKR1495L008) showing effects on survival and biomass and collected from a site observed to be non-oiled is included in this group. Group 2 is characterized by sediment samples having high clay contents, low sand content, and high TEH concentrations. Two of the samples (SEKR0886R004 and SEKR1934L013) showing effects on survival and biomass, and collected from a moderately and heavily oiled site, respectively, are included in this group. Group 3 is comprised of a single sample (SEKR0335R001), a site characterized by extremely high (outlier) concentrations of PAHs. Survival was significantly reduced in this sample.

The analysis for *Hyalella* revealed four distinct groups of samples (Figure 2B). Group 1, which includes the field reference from the Talmadge Creek upstream of the oil spill, is characterized by sediment samples having high TOC content. One of the samples (SEKR3736L028) showing effects on growth and collected from a moderately oiled site is included in this group. Group 2 is characterized by sediment samples having high silt contents, and high TEH concentrations. Two of the samples (SEKR0565R003 and SEKR1061L005) showing effects on survival, and collected from a moderately and heavily oil sites, respectively, are included in this group. Group 3 is characterized by sediment samples having low silt, clay and TOC contents. None of the samples in this group showed significant biological impacts relative to the reference field sample. Group 4 is comprised of a single sample (SEKR0335R001), a site characterized by extremely high (outlier) concentrations of PAHs. This sample did not show significant biological impacts relative to the reference field sample.

The cluster analysis for *Chironomus* suggests that Group 2 (the group with some of higher TEH and PAHs concentrations; excluding SEKR0335R001 for PAHs), is the group most likely to show biological effects from residual oil. Not surprisingly, two of the four samples with reduced survival and biomass were included in this group. However, other sediment samples within this group were collected from heavily oiled sites, but no adverse biological effects were noted. It is important to note that the survival of this species may be positively correlated with sand content. Similarly, the analysis for *Hyalella* suggests that Group 2, the group with some of higher TEH and PAH concentrations (for PAHs excluding SEKR0335R001), is the group most likely to show biological effects that may be attributed to residual oil from the *Enbridge Line 6B* oil spill. Not surprisingly, two samples within this group showed reduced *Hyalella* survival. However, other sediment samples within this group were collected from heavily oiled sites, but no adverse biological effects were noted. These analyses suggest that in some, but not all heavily oiled sites, oil residues may be bioavailable for uptake by *Chironomus* and *Hyalella*, and that other variables may be confounding the observed biological effects. Furthermore, no single sample showed toxicity effects on both species, indicating that *Chironomus* and *Hyalella* exhibit different sensitivities to residual oil from the *Enbridge Line 6B*, as well as to other sediment characteristics.

A) *Chironomus dilutus*



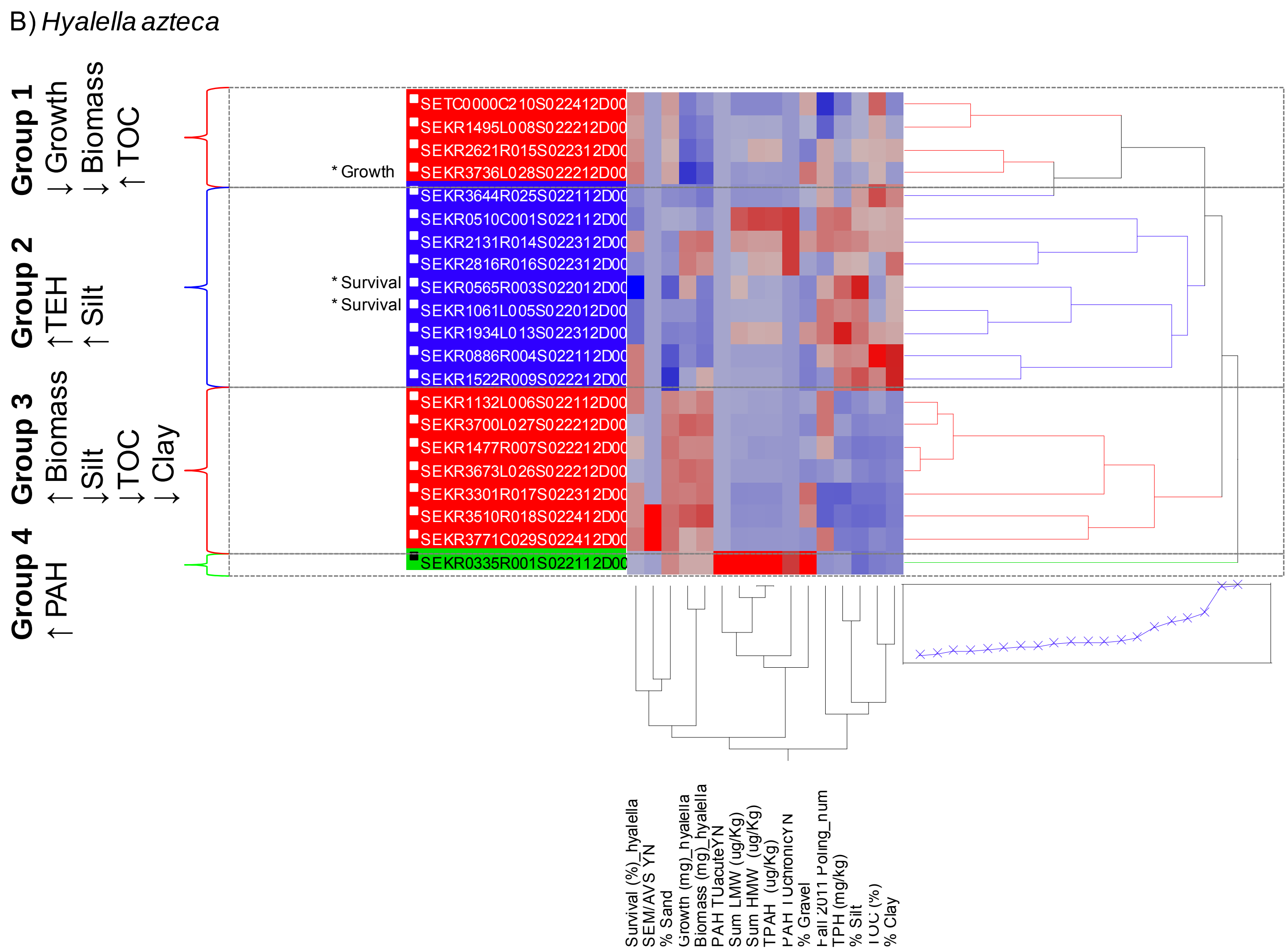


Figure 2. Cluster analysis of all sediment samples by test species. * indicates statistically significant differences compared to the conservative reference sample collected from Talmadge Creek upstream of the oil spill (SETC0000C210; GLEC, 2012). As a reference, warm colors indicate high values (red=highest value), while cold values indicate low values (bright blue= lowest value). The characteristics that separate the different groups are listed on the left (↓ indicates low values, ↑ indicates high values).

__Link between Observed Biological Effects and Residual Oil from the Enbridge Line 6B oil spill__

The information presented above was used to determine, based on weight of evidence, whether or not the observed biological effects can be conclusively linked to the residual oil from the *Enbridge Line 6B* oil spill. A summary of this determination is presented in Table 2. In only one sample (SEKR1934L013) the biological effects observed in *Chironomus* are *probably* associated with residual oil the *Enbridge Line 6B* oil spill. Based on more recent poling data, it appears that one sample initially categorized as having no oil (SEKR1495L008), is surrounded by moderate and heavy oiling, suggesting that the biological effects observed in *Chironomus* are *probably* associated with residual oil the *Enbridge Line 6B* oil spill. In other samples, the biological effects on *Chironomus* or *Hyalella* (SEKR0886R004, SEKR0565R003, SEKR1061L005, SEKR3736L028) *may be related* to residual oil the *Enbridge Line 6B* oil spill, although other sediment characteristics (grain size, TOC) may have also played a role in the observed effects.

Table 2. Descriptive analysis of the link between statistically significant toxicity endpoints (reductions in survival, growth and biomass) and explanatory variables analyzed in the samples collected from selected sites along the Kalamazoo River within the area of influence of the *Enbridge Line 6B* oil spill. Statistically significant endpoints were relative to the conservative field reference from Talmadge Creek sample upstream of the oil spill (SETC0000C210; Appendix A2).

Samples with endpoints statistically significant from the reference	Endpoint	Comments
		Chironomus dilutus
SEKR0335R001	Survival	• Site classified as having low oiling • Highest concentration of low and high molecular weight PAHs, and total PAH across all samples (outlier), but relatively low concentrations of TEHs • Highest gravel content across all samples • Site is in close proximity to a railroad (<0.05 miles) *Conclusion: This site maybe influenced by other sources of contamination. The observed biological effects are likely unrelated to the residual oil from the Enbridge Line 6B oil spill.*
SEKR0886R004	Survival, biomass	• Site classified as having moderate oiling • Relatively lower sand, and higher gravel and silt content than reference • PAH and TEH concentrations comparable to those in other moderately oiled areas • Highest TOC content across all samples

Samples with endpoints statistically significant from the reference	Endpoint	Comments
		Conclusion: The observed biological effects <u>may be related</u> to residual oil from Enbridge Line 6B oil spill, although other confounding variables cannot be ruled out
SEKR1495L008	Survival, biomass	• Site classified as having no oil • Higher clay content than reference • PAH and TEH concentrations comparable to those in moderately and heavily oiled areas, but higher than those in other areas with no oil observed *Conclusion: The observed biological effects at this non oiled site cannot be conclusively attributed to other sources of contamination (e.g., from upstream sources) or to residual oil from Enbridge Line 6B oil spill* *Update: based on the most recent poling data (Spring 2012) the sample location is surrounded by heavy and moderate oiling* *Conclusion: The observed biological effects at this are <u>probably</u> related to residual oil from Enbridge Line 6B oil spill, although other confounding variables cannot be ruled out*
SEKR1934L013	Survival, biomass	• Site classified as having high oiling • PAH and TEH concentrations relatively high and comparable to other heavily oiled areas • Relatively lower sand and higher silt content than reference *Conclusion: The observed biological effects are <u>probably</u> related to residual oil from Enbridge Line 6B oil spill, although other confounding variables cannot be ruled out*
Hyalella azteca		
SEKR0565R003	Survival	• Site classified as having moderate oiling • PAH and TEH concentrations comparable to other moderately oiled areas • Relatively lower sand and higher silt and clay content than reference *Conclusion: The observed biological effects <u>may be related</u> to residual oil from Enbridge Line 6B oil spill, although other confounding variables cannot be ruled out*
SEKR1061L005	Survival	• Site classified as having high oiling

Samples with endpoints statistically significant from the reference	Endpoint	Comments
		• PAH and TEH concentrations comparable to other heavily oiled areas • Relatively higher clay content than reference *Conclusion: The observed biological effects <u>may be related</u> to residual oil from Enbridge Line 6B oil spill, although other confounding variables cannot be ruled out*
SEKR3736L028	Growth	• Site classified as having moderate oiling • PAH and TEH concentrations comparable to other moderately oiled areas • Sub-acute endpoints for this species were correlated with TOC but not with direct indicators of oil residues (PAHs, TEHs) *Conclusion: The observed biological effects <u>may not be</u> related to residual oil from Enbridge Line 6B oil spill. Residual oil and other confounding variables cannot be completely rule out.*

Data Limitations and Uncertainties

This section briefly describes some of the data limitations and uncertainties associated with the analyses presented here.

1. The use of the upstream Talmadge Creek site as a field control (compared to the use of pooled upstream Kalamazoo River field reference samples) is conservative and biased towards over-prediction of risks. Furthermore, because only one upstream Talmadge Creek field control was sampled, additional upstream sampling may be required to determine if this is an appropriate watershed reference site with which to assess the potential impacts of residual oil from the *Enbridge Line 6B* oil spill.
2. Although the sediment samples were analyzed for chemical contaminants possibly related to the residual oil from the *Enbridge Line 6B* oil spill, the presence of additional confounding sources (agricultural chemicals, industrial and municipal discharges atmospheric deposition and other sources of contamination, both organic and inorganic), remains unknown. As discussed above, variables other than residual oil from the *Enbridge Line 6B* oil spill (i.e., particle size distribution, TOC) may have contributed to the observed biological effects, and therefore the documented effects, in most cases, cannot be attributed conclusively to the presence of residual oil from the *Enbridge Line 6B* oil spill. Other unmeasured chemical and physical factors may have also contributed to the observed effects.
3. Based on the chemical analysis, it is clear that this river system is not pristine. Creosote used in timber to support railroads may have contributed to the relatively high levels of

PAHs in one lightly oiled site, as well as in other sites upstream of the Kalamazoo River (4 of 6 samples). Other sources of sediment contamination are also likely. As stated previously, other sources of contamination in this river system remain unknown.

4. Ten-day sediment toxicity test are not appropriate to evaluate chronic impacts (i.e., growth) from residual oil, and therefore chronic effects may have been over- or under-estimated in most sediment samples (primarily in the moderate to heavily oiled sites) evaluated here. Chronic effects from residual oil in this river remain unknown.
5. Assessments based on two test species, which appear to exhibit differences in sensitivity to sediment contaminants and characteristics, may under- or over-estimate risk to other species found in the Kalamazoo River. Therefore, the results of this and similar assessments should be used with caution to avoid over interpretation.
6. The analysis presented here included data from a relatively small number of sites within the *Enbridge Line 6B* oil spill impacted area (3 classified as having no oil, 4 classified as lightly oiled, 6 classified as moderately oiled, 7 classified as highly oiled), and therefore generalizations to the entire impacted area are not appropriate.
7. Most of the samples collected for toxicity testing and physical-chemical analysis were collected from backwater habitats (15 samples), and therefore the results presented here are assumed to be worst-case scenarios (under the assumption of slower oil degradation rates in this habitat). The remaining samples were collected from an impoundment (1 sample) and flowing channel (4 samples) sites.

Conclusions

The use of the Equilibrium Sediment Benchmark Toxic Unit approach for PAHs was helpful in identifying two heavily oiled sites and one lightly oiled site as having concentrations that may have negative acute and chronic effects on benthic organisms. In these three sediment samples, sediment toxicity test results did not show significant reductions in biological endpoints (survival, growth and biomass) relative to the conservative field reference. Based on the benchmark approach for PAHs, we found that some but not all heavily oiled sites (2 out of 7 sites) may pose adverse chronic risks to benthic fauna. However, analysis of the toxicity results in the context of several sediment characteristics (chemical and physical) showed that variables other than those related to oil residues from the *Enbridge Line 6B* oil spill may have influenced survival. Therefore, based on a relatively small sample size, it is difficult to determine with certainty if the observed biological effects were conclusively the result of the presence of residual oil from the *Enbridge Line 6B* oil spill. On the other hand, based on the weight of evidence approach and additional risk metrics, it is possible to conclude that residual oil from the *Enbridge Line 6B* oil spill, particularly in heavily oiled areas, may pose some risks to benthic receptors. However, site-specific characteristics need to be assessed to identify additional potentially confounding sources of toxic contamination. Finally, the results of this analysis are intended to provide support to the NEBA analysis, and using this information to make other response decisions (although not recommended) will require careful consideration.

References

Great Lakes Environmental Center, Inc. (GLEC) 2012. Preliminary 10-day Whole Sediment Toxicity Test Report *Hyalella azteca* and *Chironomus dilutus* Kalamazoo River Sediment Sampling, February 2012 Line 6B Spill, Marshall, Michigan. March 21, 2012

SSCG Ecological Risk and Toxicity Subgroup, 2012. Recommendations to the FOSC for Submerged Oil Toxicity Testing Enbridge Line 6B MP 608 Marshall, MI Pipeline Release. February 16, 2012. 8pp.

USEPA, 2003. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: PAH Mixtures. EPA-600- R-02-013. Office of Research and Development. Washington, DC.

Appendix A

Table A1. Compiled toxicity and analytical data used in the analysis presented in this document. Note that for the purposes of this analysis, the sediment sample collected from Talmadge Creek upstream of the pipeline release (SETC0000C210) was used as the field reference. See original documents for details (GLEC, 2012; ALPHA, 2012).

Sample ID	Fall 2011 Poling (Spring 2012) [3]	NEBA habitats [4]	*Chironomus dilutus* [1]			*Hyalella azteca* [1]			Sediment Characteristics [2]									Risk Metrics		
			Survival (%)	Growth (mg)	Biomass (mg)	Survival (%)	Growth (mg)	Biomass (mg)	TPAH (µg/Kg)	LMW-PAH (µg/Kg) [5]	HMW-PAH (µg/Kg) [5]	TEH (mg/kg) [5]	TOC (%)	Gavel (%)	Sand (%)	Silt (%)	Clay (%)	PAH TU acute [6]	PAH TU chronic [6]	SEM/AVS [7]
SETC0000C210	na		93	0.79	0.72	95	0.11	0.11	1081	189	892	328	8	3	80	15	2	0.0	0.0	0.0
SEKR0000C019	na		76	0.93	0.60	88	0.16	0.14	168737	41425	127312	6130	10	3	74	12	10	0.6	2.4	2.4
SEKR0000C023	na		69	1.15	0.79	79	0.14	0.11	29905	4986	24919	1450	6	0	56	22	21	0.2	0.7	0.0
SEKR0000L020	na		98	1.04	1.01	94	0.12	0.11	18194	5833	12361	1210	5	0	39	43	18	0.1	0.5	0.7
SEKR0000L021	na		96	1.02	0.99	90	0.12	0.11	15979	4540	11439	1560	5	0	25	42	33	0.1	0.4	0.0
SEKR0000R022	na		93	1.13	1.03	96	0.15	0.14	88695	20936	67759	965	7	1	81	12	6	0.4	1.8	0.3
SEKR0000R024	na		99	1.40	1.38	86	0.18	0.15	27500	5141	22359	250	2	0	97	2	1	0.5	2.1	0.0
SEKR0335R001	L (N)	B	71	1.01	0.70	91	0.13	0.12	162937	38710	124227	623	2	10	85	4	1	2.6	10.9	0.0
SEKR0510C001	H (M)	B	91	0.86	0.79	88	0.12	0.11	94283	19679	74604	1570	5	1	70	19	11	0.7	2.7	0.0
SEKR0565R003	M	B	88	0.83	0.72	78	0.13	0.10	20902	6533	14369	1660	3	0	47	43	9	0.2	0.8	0.0
SEKR0886R004	M	B	69	0.83	0.56	96	0.12	0.10	14710	3408	11302	1350	12	0	46	24	30	0.0	0.2	0.0
SEKR1061L005	H	FC	94	0.75	0.69	86	0.12	0.10	21256	4873	16383	1340	4	0	63	27	9	0.2	0.7	0.0
SEKR1132L006	H (M)	B	93	0.96	0.88	96	0.14	0.13	15839	4316	11523	396	4	1	87	10	2	0.2	0.6	0.0
SEKR1477R007	M (M/H)	FC	94	0.89	0.83	93	0.14	0.13	10802	3592	7210	457	2	1	91	6	1	0.2	0.7	0.0
SEKR1495L008	N (L/M/H)	B	66	0.82	0.54	94	0.11	0.10	20626	5033	15593	711	5	2	76	15	6	0.1	0.5	0.0
SEKR1522R009	L (M)	B	96	0.93	0.89	96	0.12	0.12	17633	4131	13502	1490	7	0	35	34	30	0.1	0.4	0.1
SEKR1934L013	H (M)	B	60	0.74	0.43	86	0.11	0.10	32606	8516	24090	2340	5	3	58	28	10	0.2	0.8	0.4
SEKR2131R014	H	B	88	0.84	0.73	95	0.14	0.13	43099	10848	32251	1390	5	3	61	25	11	0.3	1.1	0.8
SEKR2621R015	M	B	90	0.99	0.89	95	0.11	0.10	29832	5380	24452	795	5	0	73	17	10	0.2	0.8	0.1
SEKR2816R016	L	B	90	1.28	1.14	89	0.14	0.13	32245	6048	26197	949	4	1	63	17	19	0.3	1.1	0.9
SEKR3301R017	N (L/M)	FC	99	0.98	0.97	95	0.14	0.13	2822	592	2230	82	2	5	90	5	1	0.1	0.2	0.5

SEKR3510R018	N (N/L)	FC	95	1.16	1.10	95	0.15	0.15	4283	952	3331	250	1	4	92	3	1	0.1	0.4	1.6
SEKR3644R025	M (L)	B	88	1.13	0.98	89	0.12	0.10	7027	1585	5442	649	9	2	62	21	16	0.0	0.1	0.0
SEKR3673L026	L (M)	B	94	0.99	0.92	91	0.15	0.13	12151	2773	9377	700	2	0	89	8	2	0.2	0.7	0.0
SEKR3700L027	H	B	95	1.11	1.03	91	0.15	0.14	14645	3256	11389	659	3	0	89	8	3	0.2	0.7	0.0
SEKR3736L028	M (M/H)	B	90	0.89	0.79	96	0.09	0.09	11532	2230	9303	632	5	4	77	14	5	0.1	0.3	0.2
SEKR3771C029	H (L/M/H)	I	94	0.86	0.80	96	0.13	0.12	9549	2067	7482	350	3	1	92	6	1	0.1	0.5	1.3
SEBC0000L010	na		99	0.79	0.78	94	0.13	0.12	69175	11598	57577	2060	4	3	82	11	4	0.5	2.2	0.7
SEBC0000L012	na		66	0.91	0.58	85	0.15	0.13	51642	21516	30126	2050	10	5	91	3	1	0.2	0.8	0.0
SEBC0000R011	na		25	1.06	0.31	81	0.17	0.13	38244	7104	31140	1040	3	2	84	11	3	0.4	1.5	0.3

1. GLEC, 2012

2. ALPHA, 2012

3. None “N”, Light “L”, Moderate “M”, Heavy “H”, background “na”. Changes relative to Spring 2012 poling noted in parenthesis.

4. Net Environmental Benefit Analysis (NEBA) habitats: Backwaters “B”, Impoundment “I”, Flowing Channel “FC”.

5. Low molecular weight (LMW) PAH include Naphthalene to Benzo(b)fluorine (38 analytes), while high molecular weight (HMW) PAHs include Fluoranthene to Benzo[g,h,i]perylene (26 analytes). Total Extractable Hydrocarbons (THE) includes C9-C44.

6. Potential adverse effects (acute: PAH TU acute, chronic PAH TU chronic) to benthos from 64 coexisting PAHs using the Equilibrium Sediment Benchmark Toxic Unit approach (USEPA, 2003). Values >1 would indicates that negative adverse effects may occur.

7. Potential adverse effects from excess metals using the Simultaneously Extracted Metals/Acid Volatile Sulfide ratio (SEM/AVS). Values >1 would indicates that negative adverse effects may occur.

Appendix A2

The table below describes the rational used in the selection of the reference sample for the assessment of the link between observed biological effects in *Chironomus dilutus* and *Hyalella azteca*, and the residual oil from the Enbridge Line 6B oil spill.

Table A2. Control and reference sites used by GLEC in toxicity testing of sediments with *Chironomus dilutus* and *Hyalella azteca*. Each set of control/reference samples was evaluated for their appropriateness in the analysis undertaken here.

Samples used as control/reference for toxicity testing	Sample ID	Notes
Laboratory Control	NA	Sediment control collected from the Boardman River, a local river that has a primarily forested watershed and undisturbed in the Pere Marquette State Forest This site has been traditionally used as the laboratory control in toxicity assays performed by GLEC Subsamples were not collected for chemical or sediment characterization. However, previous analyses by GLEC[1] showed PAH concentrations below detection limits, and metal concentrations ranging between below detection limits to concentrations much lower than those in field reference sites of the Kalamazoo River watershed. TOC in these samples were also lower than field reference sites of the Kalamazoo River watershed, and were near 0.01%. Particle size distribution (6.4% gravel, 92.2% sand, and 1.4% silt+clay) was similar to the Kalamazoo River samples. *Conclusion: The Laboratory control, does not have associated analytical data to help resolve the link between observed biological effects and residual oil from the Enbridge Line 6B oil spill*
Water Only	NA	Good internal control, but it lacks the sedimentary phase being evaluated here. *Conclusion: The Water Only controls are not suitable for the assessment of the link between observed biological effects and residual oil from the Enbridge Line 6B oil spill*

Samples used as control/reference for toxicity testing	Sample ID	Notes
Kalamazoo River- upstream of the Kalamazoo-Talmadge confluence	SEKR0000C019 SEKR0000C023 SEKR0000L020 SEKR0000L021 SEKR0000R022 SEKR0000R024	Assume to represent background levels of contamination Six and five of the samples had PAH and TEH concentrations, respectively, several times higher than the concentrations measured in areas of the Kalamazoo River with no oil observed (Figure A2_1) Two of the six samples have PAH and TEH concentrations higher than the average concentrations found in heavily oiled areas, while the reminder samples have PAH and TEH concentrations comparable to the average concentrations found in heavily oiled areas. Consequently, some of these samples had chronic exceedances of PAHs compared to the impacted sediments (Figure A2_2) Most of these samples have a grain size composition (particularly clay) are much different than those in areas of the Kalamazoo River with no oil observed These sites are in close proximity to a railroad, suggesting that other sources are possibly increasing contaminant concentrations above reasonable background levels of contamination These reference samples appear to be as or more contaminated than sites along the impacted section of the river *Conclusion: The Kalamazoo River- upstream field sites may not be suitable as “background sites” as these may underestimate the risks associated with residual oil from the Enbridge Line 6B oil spill*
Talmadge Creek- upstream of the impacted area	SETC0000C210	This site appears to be the area least impacted by sources of contamination than other field reference sites

Samples used as control/reference for toxicity testing	Sample ID	Notes
		A good watershed field sample with sediment characteristics similar to the river prior to the spill PAH concentrations are several times lower than the average concentrations measured in areas of the Kalamazoo River with no oil observed (Figure A2_1) TEH concentrations are similar to the average concentrations measured in areas of the Kalamazoo River with no oil observed (Figure A2_1) Only one sample was collected and therefore the variability of contaminants within this system is unknown *Conclusion: Despite lack of sample replication, the Talmadge Creek field site upstream of the oil spill appears to be the best available, and more conservative of all field reference sites (based on sources of contamination). This sample was used to assess the link between observed biological effects and residual oil from the Enbridge Line 6B oil spill*
Battle Creek River sites (not impacted by the spill)	SEBC0000L010 SEBC0000L012 SEBC0000R011	Assume to represent background levels of contamination All three samples had PAH and TEH concentrations several times higher than the concentrations measured in areas of the Kalamazoo River with no oil observed, and higher than the average concentrations found in heavily oiled areas *Conclusion: The Battle Creek River sites may not be suitable as "background sites" as these may underestimate the risks associated with residual oil from the Enbridge Line 6B oil spill*

[1]. Analysis of Boardman River Reference Sediment, Report by RTI laboratories, Inc, submitted to the Great Lakes Environmental Center, February 16, 2011.

Figure A2_1. Comparison of TPAHs (left) and TEHs (right) concentrations by oiling classification (2011 poling) across samples collected for toxicity testing. None "N", Light "L", Moderate "M", Heavy "H", background "na". Note that for the purposes of this analysis, the sediment sample collected from Talmadge Creek upstream of the pipeline release was used as the field reference.

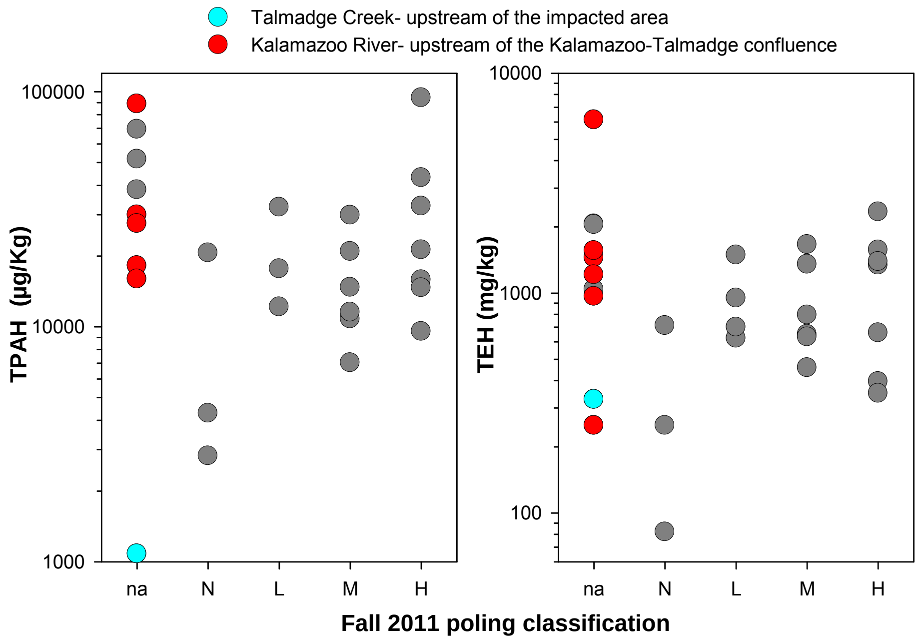
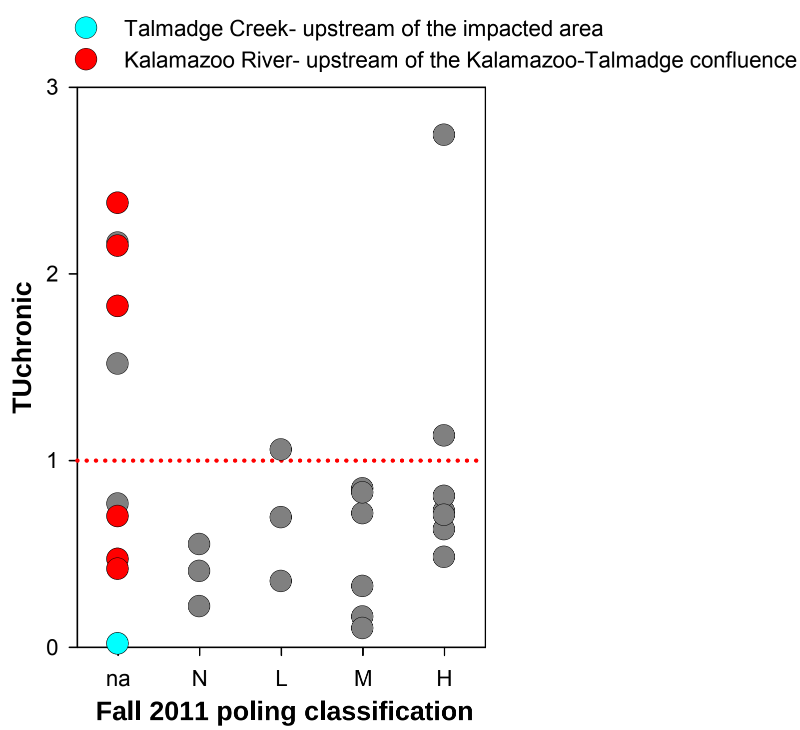


Figure A2_2. Comparison of the estimated chronic risks from TPAHs by oiling classification (2011 poling) across samples collected for toxicity testing. None "N", Light "L", Moderate "M", Heavy "H", background "na". Note that for the purposes of this analysis, the sediment sample collected from Talmadge Creek upstream of the pipeline release was used as the field reference.



Appendix A3

Some of the difficulty in assessing the effects of residual oil from the *Enbridge Line 6B* oil spill is that many of the explanatory variables are highly collinear (Table A3). For instance, all indicators of residual oil (PAHs and TEH) and TOC are negatively correlated with coarse sediment grain (sand), while positively correlated with the finer fractions (clay, silt). Some of these correlations are considered strong (correlations >0.7). Furthermore, there is also a positive correlation between TEH and TOC, making the differentiation between the contributions of naturally occurring organic matter vs. TEHs to decreased survival (particularly to *Chironomus dilutus*) a challenge (Figure A3). Although naturally occurring organic matter is known to interfere with species survival in acute toxicity testing, TEHs are adding organic material to measured TOC (Figure A3) making the link between TOC and survival unclear.

Table A3. Table of correlations among all explanatory variables. Highlighted cells indicate a statically significant correlation at α=0.05.

Correlation Matrix	LMW-PAH	HMW-PAH	TPAH	TEH	%TOC	% Gravel	% Sand	% Silt	% Clay
LMW-PAH	.								
HMW-PAH	0.94	.							
TPAH	0.97	0.99	.						
TEH	0.81	0.78	0.84	.					
%TOC	0.42	0.47	0.50	0.63	.				
% Gravel	-0.23	-0.29	-0.27	-0.40	-0.20	.			
% Sand	-0.57	-0.56	-0.61	-0.85	-0.83	0.35	.		
% Silt	0.65	0.63	0.68	0.89	0.74	-0.37	-0.95	.	
% Clay	0.53	0.60	0.62	0.75	0.89	-0.37	-0.91	0.82	

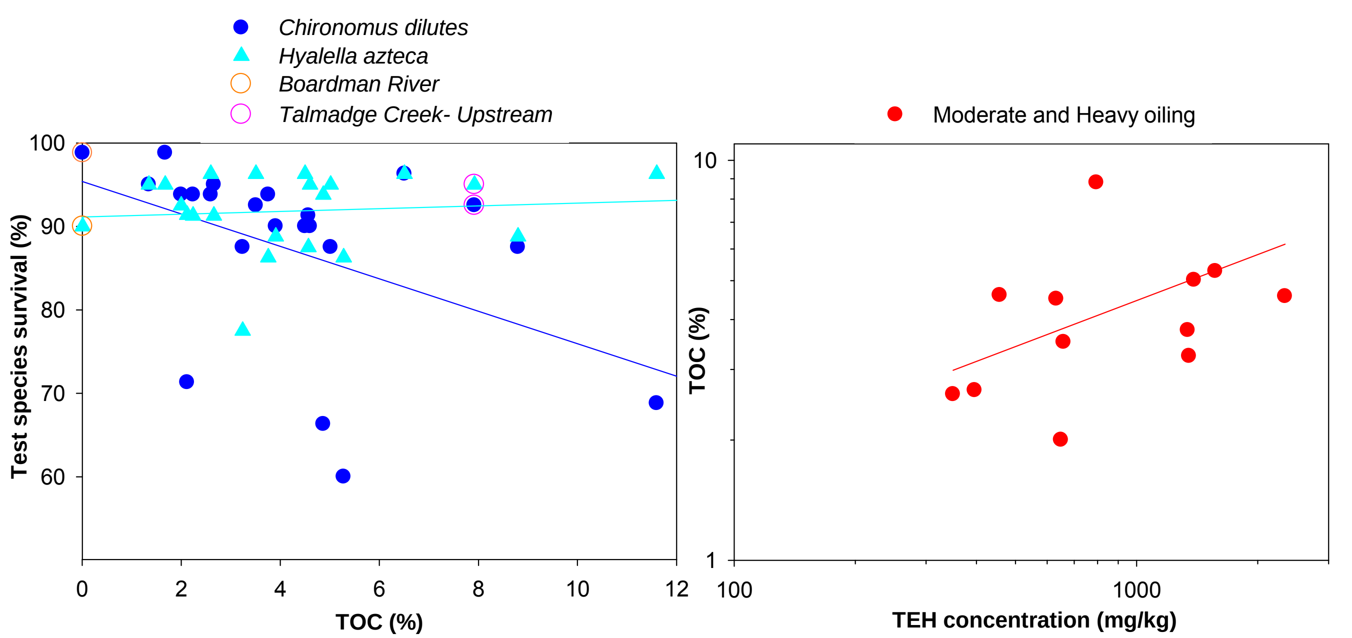


Figure A3. Left- Correlation between survival of *Chironomus dilutus* (dark blue, circles) and *Hyalella azteca* (bright blue, triangles) and total organic carbon (TOC%). Results from the relatively clean field sites are included as a reference. Right- Correlation between total extractable hydrocarbons (TEH) and TOC in moderate and heavy oiled samples (red circles).

Appendix B

**Review of Potential Ecological Effects of Sediment Agitation
Enbridge Line 6B MP 608 Marshall, MI Pipeline Release**

**In support of the SSCG's Net Environmental Benefit Analysis Subgroup
Prepared by James Chapman, Ph.D., U.S. Environmental Protection Agency
July 13, 2012**

Summary

A literature review of the ecological effects of physical disturbance of sediments indicates that the sediment agitation methods for recovery of submerged oil potentially result in lethal impacts on benthic invertebrates, eggs and larvae of bivalves and fish, and aquatic macrophytes. Direct adverse effects on adult fish are unlikely because of their ability to move away from oil recovery locations. Probably the most severe damage is trauma associated with direct physical impacts of the agitation itself. Eggs and larvae are likely destroyed in the area of agitation and high rates of mortality of benthic organisms are expected. High mortality may also be associated with burial or smothering of eggs, larvae, and benthic organisms by sediment churning in the agitation site, or by downstream deposition of suspended sediments (bedded sediment). Burrowing capability or tolerance of high turbidity do not necessarily correspond to ability to survive burial.

The potential effects of elevated turbidity on adult or juvenile fish, such as gill abrasion by suspended coarse particles or impaired homing or hunting related to light attenuation, appear to present less risk overall as compared to the risks to egg, larvae or benthos associated with direct trauma or smothering. Mobilization of noxious sediment compounds, such as hydrogen sulfide or ammonia, or oxygen-depleting substances, is often localized and of short duration, and, although possibly contribute to mortality in the agitation area, probably do not routinely present significant risk outside the agitation area.

Another potentially large impact to the benthic community is related to the initial removal of instream woody debris to allow access for oil recovery actions.

Recovery of benthic organisms is usually rapid from small-scale disturbances (both temporally and spatially), but the severity of impacts is greater and recovery rates slower for large-scale and repeated disturbances. The rate of benthic community recovery also depends on the proximity of refuges of potential colonizers and their location relative to stream currents.

A limitation of the review is many examples involve marine ecosystems because the effects of sediment disturbance have been extensively studied with regard to navigational dredging, extractive dredging for mineral resources, trawling for demersal fish, and dredging for bivalves. The review does not address impacts associated with removal of riparian vegetation, such as temperature effects from loss of shade, or reduction of carbon and nutrient inputs from leaf and litter fall. The review does not estimate the impacts of indirect effects, such as potential loss of habitats for feeding or reproduction, other than to note that indirect effects may be as, or more significant for some species as direct effects.

Introduction

Options for active recovery of submerged oil in sediments include dredging to remove oil and sediments together, or sediment agitation to release oil to the water column for surface recovery by skimming or with sorbent materials without removing sediment from the water body (although sediments may be displaced within the water body).

<u>Sediment Agitation Toolbox</u>

Three mechanical and four hydrodynamic techniques are included in the sediment agitation toolbox for the Marshall, MI, pipeline release (Enbridge Energy, Limited Partnership 2012):

Mechanical Agitation

Raking – Use a hand held rake with a 3-inch depth penetration to agitate the sediment to release submerged oil.

Hand Held Tiller – Use a hand held, gas powered tiller to agitate the top 6 to 8 inches of the sediment. The hand-held garden tiller has two blades measuring approximately 8 inches in diameter and set approximately 8 inches apart.

Chain Drag – The chain drag apparatus consists of a 5-foot long, 2-inch diameter round metal spreader bar with ¼–inch grade 8 metal chains attached at approximately 6-inch centers. A second spreader bar of the same size is attached to the chains to minimize tangling. The chain drag will be pulled by either a shore mounted system or by a boat following a grid layout to unsure complete coverage of the area.

Hydrodynamic Agitation

Hand Held Stinger – A stinger consists of a hand held discharge wand equipped with river water supply.

Vessel Mounted Water Injector – The vessel mounted subsurface deluge system consists of a spreader bar (6 to8-feet in length) mounted to the front of the vessel. Water will be pushed through the spreader bar and discharged through ports located along the width of the bar, at 45 and 90-degree angles to the bar.

Vessel Mounted Pipe Drag – The vessel mounted bottom drag device consists of an 8-foot long (2-inch diameter) steel horizontal tube with wheels attached on both ends. A boat mounted trash pump injects river water through a threaded fitting near the center of the horizontal tube and the water is released from a series of holes drilled into the horizontal tube. The bottom drag discharges water through holes in the steel pipe.

Rotating Stingers – A set of stingers consists of hand held discharge wands equipped with water supply. The rotating stinger device is constructed using an 8-foot long (1 ½- inch diameter) steel vertical pole with two 6-foot long horizontal steel pipes attached approximately 1-foot from the bottom at 90-degrees to the vertical pole and 180-degrees from each other. The drilled holes are angled toward the bottom where it will agitate and release submerged oil from the sediment. The rotating stinger works best in areas with submerged oil limited to the upper couple inches of sediment. Spreading the flow across 12-feet of pipe through several small holes (increased energy losses) reduces the effective force of the water jets and limits the depth of penetration into the sediment.

All of the agitation techniques involve physical disturbance of sediment to depths of a few to several inches, which includes the biotic zone for benthic organisms, the rooting substrate for aquatic macrophytes, and surface layer stratum for periphyton and biofilms (including epipelon on soft sediment and epilithon on stone). By design, the agitation techniques bring sediments into suspension creating sediment plumes with elevated suspended particulate concentrations and turbidity.

Potential ecological effects associated with the sediment agitation toolbox are described based on a literature review of the effects of analogous processes. The potential effects of instream woody debris removal are also briefly discussed because it is a necessary step before implementing the sediment agitation toolbox.

Models of Potential Effects of Sediment Agitation Methods

Agitation Dredging

Agitation dredging is the closest model of the methods used at the Enbridge oil spill site to release submerged oil to the water column for recovery. In agitation dredging, sediments are brought into suspension by mechanical means (mechanical agitation dredging), by water injection (hydrodynamic dredging or hydraulic agitation dredging), or by directed or undirected propwash, and the sediment plume is removed from the dredge site by water currents.[1] Sidecast dredging similarly depends on water currents for disposing of dredged materials but sediments are initially removed by suction and are pumped without storage through a pipeline or by jetting adjacent to the dredge site. Agitation dredging differs from the submerged oil recovery methods because the extent of the sediment plume is not restricted in any manner and there are no attempts to collect released oil. “If the material is suspended but redeposits shortly in the same area, only agitation (not agitation dredging) has been accomplished” (Richardson 1984).

Reviews of agitation dredging include Richardson 1984, Allen and Hardy 1980, and OSPAR 2004.

Extractive, Navigational, Maintenance, and Construction Dredging and Disposal

Other methods of dredging in which bottom material is excavated and removed from a water body (in contrast to agitation dredging that displaces dredged material within a water body)

[1] Additional methods include vertical mixers and air bubblers that use compressed air for agitation (Richardson 1984).

provide approximate models of potential environmental effects of the submerged oil recovery techniques and recovery from disturbance. Extractive dredging or aggregate extraction refers to removal of mineral resources, primarily sand and gravel, from water body bottoms. The purpose of navigational or maintenance dredging is to maintain desired water depths for passage of ships, recreation, or other activities, and often targets recent unconsolidated sediments. Construction dredging prepares the bottom for engineering purposes. Disposal of dredge spoils in water bodies is another approximate model of disruption of sediment habitat and recovery. These activities differ from the submerged oil sediment agitation recovery techniques in removing large masses of sediment from the dredge site, or adding large masses of sediment to disposal sites, but are similar in presenting severe physical disruption of benthic habitats, with similar potential impacts on areas surrounding the dredge or disposal locations.

Several reviews of potential impacts of dredging and disposal have been performed – examples include Morton 1977, Allen and Hardy 1980, Newell, et al. 1998, OSPAR 2004, Erftemeijer and Lewis 2006, OSPAR 2008, and Foden, et al. 2009.

Demersal Trawling and Bivalve Dredging

Additional models of sediment disturbance and recovery are the effects of various types of heavy fishing gear used to catch dermersal fish (beam and otter trawls) and benthic bivalves (scallop, clam, and mussel dredges). The physical effects on the sea bottom are probably similar to those associated with the chain drag and vessel mounted pipe drag sediment agitation techniques.

Scale

Ecological effects of disturbance are scale-dependent in several ways. Ecological responses and recovery rates or trajectories depend on the intensity (disturbance force) and severity (degree of initial alteration of ecosystem structure or function), frequency (temporal scale), extent (spatial scale), and interactions with other disturbances (Walker 2012).

Woody Debris Removal

The removal of woody debris from the Kalamazoo River to allow access to the sediment bed for oil recovery actions is likely to have significantly reduced habitat quality for aquatic insects. Snags can be “disproportionately important as a substrate” for aquatic insects in lowland rivers because “submerged wood is often the only stable substrate present” (Allan 1995). In one study, invertebrate species richness was 2-fold higher and invertebrate biomass per area 5 to 62 times greater on snags than on mud or sand. Overall, snags represented only 5-6 % of the area of mud or sand habitat, but accounted for more than 50 % of the invertebrate biomass in the river (Allan 1995).

A potentially additional effect of woody debris removal in Talmadge Creek would have been associated with removal of organic debris dams (if present), initiated by large woody debris that trap smaller debris and leaves, which then form pools that collect sediment and organic matter. Macroinvertebrate biomass can be more than 5 times greater in debris dams compared to sediments, and debris dams are "hotspots of heterotrophic activity" with nearly 3-fold higher community respiration compared to undammed sediment (Allan 1995).

Overview of Potential Ecological Effects of Agitation Methods

Potential adverse impacts include direct mortality of benthic life at the agitation site, elevated suspended sediment loads and turbidity, dissolved oxygen (DO) depletion, mobilization of toxic substances such as ammonia or hydrogen sulfide, dispersion of sediment pollutants, release of nutrients (eutrophication), changes in sediment texture (sediment armoring due to enrichment of the coarse fraction when fine sediments are dispersed, or conversely excessive fine sediment accumulation in depositional areas), and alteration of sediment bed topography.

One review stated "The scant available literature on impacts of agitation dredging leads to the conclusion that careful site selection for this technique will impose few environmental hazards if the material is unpolluted" (Allen and Hardy 1980). Reviewers generally report that impacts are minimal, temporary, and often within the range of natural variability (Allen and Hardy 1980, Semmes, et al. 2003, OSPAR 2004). For example, oxygen depletion is "generally limited to the direct surrounding of the dredge site" and sediment loads during storms or high river flows are "frequently similar to or even larger than that which is attained by hydrodynamic dredging" (OSPAR 2004).

However, in a review of 22 examples of agitation dredging projects, only 3 "were monitored fairly completely for environmental effects", that is, included collection of biological data (Richardson 1984). The examples show that agitation dredging can affect benthic communities in the dredge area and downstream, but do not appear to significantly affect adult fish. Impacts appear to scale with the size and frequency of dredging.

Trauma and Burial

The physical impacts of the agitation on bottom organisms probably result in the most severe damage to aquatic biota associated with the submerged oil recovery techniques. Impacts include trauma (wounds, external bodily injury) to bottom organisms (benthic invertebrates, eggs, larvae, periphyton), and indirect effects related to burial.

Dredging removes most of the benthic organisms within a dredge furrow, 75-100 % (Allan and Hardy 1980), and, over a dredged area, can result in 30-70 % reduction of species richness and 40-95 % reduction in individual count and biomass of benthos (Newell, et al. 1998). Quantitative estimates for agitation dredging were not located, but similarly high rates of benthic mortality are likely. For example, abundance of benthic organisms decreased in the dredge area and downstream following propwash agitation dredging in Chinook Channel, Columbia River estuary, but abundance only "recovered somewhat" in the dredge area after 6 months in contrast to the downstream area which fully recovered (Richardson 1984).

An additional line of evidence is the physical effect of seafood harvest gear on non-target species. Mortality of bycatch (unwanted species harvested and discarded) is generally a small contributor to non-target mortality, "and damage or exposure in the trawl track is more important by far" (Bergman and van Santbrink 2000, see also Ball, et al. 2000). Direct mortality of non-target benthic organisms from single passes of beam trawls can be surprisingly high, 20-65 % for bivalves and as much as 49 % for crustaceans (Bergman and van Santbrink 2000). Scallop dredging can result in as much as 43-54 % mortality in non-target benthic megafauna, even though causing much less mortality (2-10 %) in the targeted scallop species (Jenkins, et al. 2001, Gaspar, et al. 2003). Intertidal dredging, involving a level of sediment disturbance approaching that of agitation dredging ("physical removal and resuspension of the substratum in the water column" leaving furrows "tens of centimeters deep") results in mean reductions of abundance by as much as 80 to >90 % and species richness by >70 % depending on habitat according to a meta-analysis (Kaiser, et al. 2006). The subsurface oil agitation methods could have similar initial impacts on benthic organisms as reported for intertidal dredging.

Field investigations of trawled areas show relationships between trawling frequency and severity of benthic impacts (Ball, et al. 2000, Jennings, et al. 2001). Initial impacts of trawling are greater on stable sediment habitats compared to mobile sediment habitats (Kaiser, et al. 1998).

The effects of burial may be relevant to submerged oil recovery actions in two ways: mixing of benthic organisms to lower than optimal depths by mechanical agitation or by heavy sedimentation following agitation. Eggs and larvae are likely destroyed by burial. Sessile animals such as mussels "are killed outright by direct burial", for example, oysters, even though tolerant of elevated suspended sediment, are vulnerable to burial (Morton 1977, see also studies cited in Kaplan, et al. 1974). Many benthic invertebrates are capable of burrowing to the surface if buried, but species differ in survivable burial depths, and the survivable depths decrease with temperature and the presence of anoxic sediment (Morton 1977, OSPAR 2008).

To reduce negative effects on marine benthos, recommendations have been made to limit the thickness of disposed sediment to 15 cm or as much as 20-30 cm, however, some marine epibenthic species do not survive even 5 cm burial (OSPAR 2008). The critical burial depth for two freshwater mussels (fat mucket and pocketbook) was 18 cm, but only 10 cm for a pig-toe mussel (Allen and Hardy 1980). Fluid mud (defined as bulk density <1.3, high water content, and suspended concentration >10 g/l) destroys benthic organisms because it "separates them from the overlying water upon which they depend for respiration and food" (Allen and Hardy 1980). Macrophytes may also be vulnerable to burial, and, as with benthic organisms, there are appreciable species differences in sensitivity – sedimentation critical thresholds for marine seagrasses range from 2 to 13 cm/y (Erftemeijer and Lewis 2006).

See additional discussion of burial under the Suspended and Bedded Sediment (SABS) section.

DO Depletion, Hydrogen Sulfide and Ammonia Release

Sediment disturbance can affect water chemistry through release of oxygen-depleting substances (decaying organic matter, reduced chemicals from anaerobic layers) and toxic substances (such as hydrogen sulfide and ammonia). The available evidence indicates that the effects of such releases are both spatially and temporally limited and therefore appear to be less significant compared to other potential impacts. For example, oxygen depletion associated with agitation dredging is "generally limited to the direct surrounding of the dredge site" (OSPAR 2004).

Propwash agitation dredging resulted in "temporary lowering of dissolved oxygen (D.O.) to marginal, but still acceptable, levels" at the Chinook Channel, Columbia River estuary (Richardson 1984). Small-scale propwash agitation dredging in Tillamook Bay estuary, Oregon, did not increase total sulfides or ammonia in the water column, and caged organisms (not specified) "showed no signs of acute toxicity or other changes" near the dredging site (Richardson 1984). Mechanical agitation dredging in Savannah Harbor was associated with increases in chemical oxygen demand (COD) and ammonia nitrogen "although the data were sufficiently varied so that no conclusive trends could be established" (Richardson 1984). Absence of benthic life in the frequently dredged Savannah Harbor precluded observations of field effects.

An early review stated "The scant available literature on impacts of agitation dredging leads to the conclusion that careful site selection for this technique will impose few environmental hazards if the material is unpolluted" (Allen and Hardy 1980). Reviewers generally report that impacts are minimal, temporary, and often within the range of natural variability (Allen and Hardy 1980, Semmes, et al. 2003, OSPAR 2004).

There are some caveats to directly applying the conclusions regarding agitation dredging to submerged oil recovery actions. One pertains to the aforementioned careful site selection. Hydrodynamic dredging "is restricted to areas where no harmful oxygen depletion and remobilization of contaminants is to be expected" and mechanical agitation dredging to "small harbour areas or other small sedimentation areas that are difficult to access" (OSPAR 2004). In contrast, the locations for oil response actions are determined by the patterns of oil deposition, and the objective is maximal remobilization of oil from sediment into the water column for collection. Agitation dredging requires sufficient current to efficiently remove the displaced sediment from the dredge site, which means the current will also act to mitigate oxygen depression and suspended sediment concentrations. The oil depositional areas targeted in the Enbridge responses do not necessarily have currents similar to those necessary for successful agitation dredging.

One of the recommendations made in a review of agitation dredging, to evaluate sediments "individually for oxygen demand potential, especially during sensitive periods (like hot summer days)" (Semmes, et al. 2003), directly conflicts with the minimum sediment temperature threshold for effective mobilization of submerged oil through sediment agitation.

Suspended and Bedded Sediment (SABS)

Suspended and bedded sediment (SABS) is defined as "organic and inorganic particles that are suspended in, are carried by, or accumulate in waterbodies" (U.S. EPA 2006), thereby encompassing both suspended and deposited (bedded) particles.

Elevation of suspended particulate matter in the water column potentially has multiple adverse effects including gill clogging and abrasion, impaired respiration and feeding (through gill effects or reduced bivalve pumping rates), egg abrasion, retarded egg development and reduced survival, reduced growth and survival of larvae, and disruption of migration, homing, and hunting (Morton 1977, Allen and Hardy 1980, Newcombe and Jensen 1996, Newell, et al. 1998, Wilber and Clarke 2001, Berry, et al. 2003, U.S. EPA 2006, OSPAR 2008). The effects vary with suspended particle size – abrasion with coarse particles (5-240 mm diameter), and clogging with clay (<2 µm) (Newcombe 2003). A meta-analysis showed "Rapid escalation of ill effects on eggs, larvae, and fry" with exposure duration implying "the existence of an abrupt threshold concentration of suspended sediment leading to ill effects in ultrasensitive … life stages" (Newcombe and Jensen 1996).[2] For example, white perch eggs are not affected by sediment layers up to 0.45 mm thick, but 0.5-1.0 mm results in 50 % mortality, and 2.0-mm 100 % mortality (Wilber, et al. 2005). Species differences in sensitivity to suspended sediment show a general relationship with habitat preference, for example, muddy bottom dwellers less and open water species more sensitive, but exceptions occur (Berry, et al. 2003). Limited studies indicate that biota in freshwater river and lake habitats "can be very sensitive to increases in SABS" (Berry, et al. 2003).

In general, egg and larval stages are more sensitive than adults, and filter feeders are particularly sensitive (Morton 1977, Newell, et al. 1998, Wilber and Clark 2001). The greater sensitivity of filter feeders is reflected in a shift in the functional composition of the benthic community in areas with chronic trawling disturbance that includes, in part, reductions in filter feeders and increases in deposit feeders (Tillin, et al. 2006), a pattern also shown in coupled physical-ecological modeling of demersal trawling effects (Allen and Clarke 2007).

Sedimentation "dramatically decreases hatchability and survival" of fish eggs and fry (Allen and Hardy 1980), and "only a few millimeters of deposited sediment" may prevent hatching of demersal eggs (Berry, et al. 2003). The "most probable" suspended sediment dosages (concentration and duration) from dredging operations are projected to result in elevated mortality of eggs and larvae of freshwater and estuarine fish (maximum dosage of 1000 mg/L for 3.5 d) (Wilber and Clarke 2001). Sensitive freshwater fish eggs and larvae exhibit significant mortality (>25 to 75 %) at nearly an order-of-magnitude lower concentration with 2 days exposure; and <25 % mortality is evident with 1 day exposure to tens of mg/L concentrations (Wilber and Clarke 2001 Figure 1).

The adverse effects of sedimentation on fish eggs and fry have been extensively studied with salmonids. Atlantic salmon embryo hatching success abruptly decreases near a threshold of 0.2 % silt and very fine sand by weight in artificial redds (nests) (Levasseur, et al. 2006). Fine sediment affects salmon eggs by reduction of substrate permeability that affects external oxygen levels, and by coating of egg surfaces with clay-sized particles that hinders oxygen uptake (Grieg, et al. 2005a). Clay particles hinder egg oxygen uptake through two proposed mechanisms: blockage of micropores in the egg membrane and formation of a low-permeability seal around the eggs (Grieg, et al. 2005b). Low substrate permeability potentially affects eggs on the sediment surface, but egg coating potentially affects any aquatic eggs located on or above the sediment surface. Additional mechanisms of toxicity of excessive fine sediment include reduction of interstitial flows that cause accumulation of metabolic waste products in demersal eggs, and formation of a physical barrier to fry emergence "with carry-over effects on survival

[2] A data conversion error compromised a model for adult estuarine nonsalmonids in Newcombe and Jensen (1996) (see Wilber and Clarke 2001), but did not affect the remaining models for salmonids, freshwater nonsalmonids, and fish eggs and larvae.

rate, timing of emergence, and posthatch growth of fry" (Louhi, et al. 2011). Low oxygen supply to fish embryos can result in developmental effects that may affect post-hatch survival. Hypoxic conditions delay yolk sac absorption and affect muscle development (Louhi, et al. 2011). High sedimentation resulted in emergence of brown trout fry with larger yolk sacs compared to control fry, which impairs swimming ability "increasing their vulnerability at the transitional stage … to open-water life" (Louhi, et al. 2001).

Centrarchids (including smallmouth and largemouth bass) are more resistant to the effects of sedimentation on nests because of their fanning behavior (assuming the adults are not driven from the nesting location), but "may be severely impacted in their ability to feed by even small increases in turbidity" (Berry, et al. 2003). One-day exposure to as little as 11.4 mg/l suspended bentonite inhibits early life-stage smallmouth bass growth and "may strongly affect year class strength (Berry, et al. 2003).

Disposal of dredge spoils in aquatic environments entails heavy sedimentation that can affect biota not only the intended disposal area, but often over a larger surrounding area from "a few hundred meters" to more than 2 kilometers (Newell, et al. 1998, OSPAR 2008), although some studies report no adverse effects outside of the immediate disposal site (Allen and Hardy 1980). Construction dredging and spoil disposal resulted in near elimination of bivalve larvae in adjacent areas of an estuary as shown by impaired recruitment (maximum of 8 juveniles/m^2 per species at near stations compared to 34-1590 juveniles/m^2 per species at distal stations for the same species) (Rosenberg 1977). The researcher wrote that "pelagic and recently settled larvae were most probably killed by the increased amount of particles in suspension" based on greatly diminished Secchi-disc readings during operations compared to non-dredging periods (0.3-1.5 m and 3-5 m, respectively), and "quite successful" mollusc recruitment in the near stations the year following project completion (Rosenberg 1977).

Bivalve larvae do not appear to be as sensitive to suspended sediment as fish eggs and larvae in the review by Wilber and Clarke (2001), but this appears to be an artifact of data limitations – larval data are sparse (only 3 species were included in their larval bivalve plot), and egg data even sparser (2 species, both excluded from their bivalve figure). Of the 2 bivalve species with egg data, eastern oyster egg development is adversely affected by 188 mg/L silt concentration (Wilber and Clarke 2001), which indicates relatively high sensitivity to suspended sediment. In a subsequent publication, Wilber, et al. (2005) wrote that "very thin veneers of sediment are known to adversely affect both settlement and recruitment of bivalve larvae".

Elevated suspended sediment also can have sublethal effects on invertebrates including impaired ingestion rates of freshwater mussels, reduced feeding rates in copepods and daphnids, and increase invertebrate drift (at, for example, 120 mg/l) "significantly altering the distribution of benthic invertebrates in streams" (Berry, et al. 2003).

Field studies show no gross effects of dredging and spoil disposal on adult fish including mortality or gill epithelium damage (Morton 1977), consistent with projections that lethal effects are unlikely in adult or juvenile fish or crustaceans exposed to "most probable" suspended sediment dosages from dredging operations (Wilber and Clarke 2001). Adult fish are protected by their mobility. Wilber and Clarke (2001) assumed the maximum suspended sediment exposure to mobile receptors would be 1000 mg/L for 1 day. A caged fish study at a sediment spoil disposal site reported almost no mortality of channel catfish but nearly complete mortality of striped bass (Morton 1977) demonstrating the importance of avoidance behavior, and differences in species sensitivities when avoidance is infeasible.

Another effect of elevated suspended sediment is the increased turbidity and reduced light transmission that potentially can affect forage success and photosynthesis. Behavioral (sublethal) effects of turbidity on fish (for example, feeding success, foraging rate, reaction distance, schooling behavior) are summarized by Anchor Environmental (2003). The 10^{th} percentile for effects is 7.5 nephelometric turbidity units (NTU) and 50^{th} percentile 40 NTU. Bracketing conversion of suspended sediment data at dredging sites to turbidity with low and high suspended sediment-NTU regressions, 10 to 60 % of dredge sediment plumes may exceed the 50^{th} percentile behavioral effect level (Anchor Environmental 2003). This comparison does not take into account spatial extent, duration, or the ecological significance of behavioral effects. The reviewers concluded that “because of the transient nature of dredging induced sediment plumes, more long-term chronic and sublethal effects from resuspended clean sediments are not expected to occur around most dredging operations” (Anchor Environmental 2003). Turbidity from dredging is also considered unlikely to appreciably show adverse effects in the field because of overlap with naturally-induced turbidity (from storms, floods, tides) (Anchor Environmental 2003, OSPAR 2008).

Refined estimates of the potential impact of impaired vision by suspended sediment include exposure duration, and measurement of light attenuation instead of turbidity “because turbidity (a measure of optical side scatter) is poorly correlated with water clarity (maximum sighting range)” (Newcombe 2003). Necombe (2003) presents a semi-empirical model developed for clear water fish, defined as species with life stages always or usually found in clear water systems, defined in turn as systems with black disk (horizontal) sighting range normally >0.55 m most of the year, corresponding to Secchi disk (vertical) sighting range >0.77 m or <7 NTU. In terms of the more commonly used turbidity measures, the model indicates onset of significant impairment of fish growth or habitat between 150-400 NTU or 0.03-0.07 m Secchi depth for short duration exposures (1-7 h), declining to 20-55 NTU or 0.15-0.34 m Secchi depth for 1-6 d exposures.

Suspended sediment can affect photosynthesis through intertwined mechanisms – light attenuation in the water column (turbidity) and deposition of particles on plant surfaces that reduce light absorption (Erftemeijer and Lewis 2006). The effects of turbidity on plants have been extensively studied with marine seagrass. Most species of seagrass have minimum light requirements between 15 to 25 % of surface irradiance (SI), but the overall range for 22 species spans an order-of-magnitude from 2.5 to 37 % SI (Erftemeijer and Lewis 2006). Species also differ greatly in the survivable duration spent below the minimum light requirement, from 2 weeks to several months, related to the size of carbohydrate storage (Erftemeijer and Lewis 2006). As with fish behavioral effects, appreciable impacts of dredging-induced turbidity on aquatic plants are often considered unlikely because of short duration and overlap with natural variability. For example, “the impact of dredged sediment disposal [on] light-dependent organisms due to increased turbidity will most likely not have greater impact than naturally occurring turbidity elevations, induced by floods tides and weather activities” (OSPAR 2008).

The presumed limited impact of dredging on turbidity and the associated biological responses does not necessarily hold in freshwater because of differences in flocculation behavior compared with seawater, or in areas where the dredge spoils are susceptible to resuspension. Saltwater (and hard water with ≥200 mg/l total dissolved solids) "induce flocculation and consequent rapid settling" (Allen and Hardy 1980) thereby limiting the duration and extent of suspended particulate plumes. "Turbidity has the greatest potential for damage in soft freshwater where it is extremely persistent." (Allen and Hardy 1980).

Remobilization of dredge spoils was identified as the cause of large-scale (>150 km^2) loss of seagrass cover in a bay following maintenance dredging. Although the highest light attenuation values were measured immediately after dredging, measureable changes in light attenuation continued for more than 1 year and varied inversely with distance from disposal locations (Onuf 1994). An indirect relationship between dredging and seagrass loss was proposed: "episodes of wind-generated wave action operating on recently deposited dredged material will generate much more turbidity than when operating on the native bottom", and, because dredge materials are more easily mobilized, "resuspension events should be longer lasting and more material should be resuspended for dredge material than the native bottom" (Onuf 1994). Onuf (1994) pointed out that a confluence of conditions resulted in the extensive loss of seagrass: windy area, water depths deep enough to allow wave generation but shallow enough so waves impact dredge spoils, and an unfortunate proximity of spoils and seagrass beds. Seagrass recovery may be prevented altogether in denuded areas with chronic turbidity from resuspended sediment (Erftemeijer and Lewis 2006).

The relevant point for agitation techniques for submerged oil recovery in rivers is that the resettled sediment may be more susceptible to erosion compared with undisturbed sediment, and might result in repeated or extended episodes of high turbidity after cessation of submerged oil recovery efforts.

Indirect effects of heavy sedimentation, such as loss of feeding, cover, or reproduction habitats, "may outweigh the direct effects seen in caged fish" (Newcombe and Jensen 1996). The best studied indirect effect is loss of salmonid spawning habitat by excessive sedimentation (Berry, et al. 2003).

Although this review has mainly focused on the effects suspended sediment, the impacts of deposited sediment may be equally or more important (U.S. EPA 2006):

> In flowing waters, bedded sediments are likely to have a more significant impact on habitat and biota than suspended sediments; while most organisms can tolerate episodic occurrences of increased levels of suspended sediments, impacts can become chronic once the sediment is settled. When sediments are deposited or shift longitudinally along the streambed, infaunal or epibenthic organisms and demersal eggs are vulnerable to smothering and entrapment. In smaller amounts, excess fine sediments can fill in gaps between larger substrate particles, embedding the larger particles, and eliminating interstitial spaces that could otherwise be used as habitat for reproduction, feeding, and cover for invertebrates and fish.

However, our knowledge of impacts of sedimentation rate is less developed than the impacts of suspended sediment (Wilber, et al. 2005):

> The literature available to determine whether elevated sedimentation rates associated with dredging and disposal can result in impacts to sensitive biological resources is generally inadequate. Certain life history stages are known to be particularly sensitive. For example, very thin veneers of sediment are known to adversely affect both settlement and recruitment of bivalve larvae. Some quantitative data on effects are available for demersal fish eggs with respect to layer thickness and changes to particle size composition of the substratum composition. Although there are documented, unambiguous, adverse effects of sedimentation on seagrasses and corals, available data are insufficient to discern thresholds for various levels of effect.
>
> The affect that natural and dredging-induced sedimentation rates have on biological communities needs to be quantified. Data for all habitat types investigated are insufficient to establish dose-response models at scales appropriate to dredging. … Hence predicting potentially harmful rates of sedimentation or establishing technically defensible guidelines for resource protection remains a challenge.

Recovery

Sparse information on benthic recovery following agitation dredging indicates rapid downstream recovery, incomplete recovery in a dredge area after 6 months, and no recovery with repeated agitation. Abundance of benthic organisms decreased both in the dredge area and downstream following propwash agitation dredging in Chinook Channel, Columbia River estuary, but after 6 months “recovered somewhat” in the dredge area, and recovered downstream to greater than pre-dredge values (Richardson 1984). In contrast, the benthic effects of mechanical agitation dredging in Savannah Harbor could not be evaluated because “the areas dredged were virtually devoid of such life” (Richardson 1984). Possible explanations for the absence of a benthic community include frequent dredging, rapid post-dredging sedimentation, toxic sediment pollution, or fluctuating salinity (Richardson 1984). Dredging frequency was as high as 17 times per year per location (Richardson 1984), so it would appear to be a leading explanation for the lack of recovery. In contrast, the effects of agitation dredging on fish and other motile organisms “were projected as insignificant or minimal” (Richardson 1984).

Recovery of the benthic community following dredging is affected by several factors: relative stability of the sediment bed, current strength, spatial scale of disturbance, and temporal scale (frequency). Biological recovery of marine benthic communities following aggregate extraction ranged from 4 to 11 years depending on currents – slower with weak tidal stress and quicker with moderate or strong tidal stress (0-1.8 N m^{-2} and 1.8-4.0 N m^{-2} near-bed tidal stress, respectively) related to bed stability (Foden, et al. 2009) and possibly rate of influx of colonizers to the dredged area. Recovery rates have also been related to sediment texture. A review of benthic recovery from dredging showed quicker rates in muds (3 weeks to >11 months) that are relative unstable and inhabited by opportunistic quick-growing species, and slower rates on coarse-textured sands and gravels (1-12 years) that are relatively stable and therefore can support more complex communities with slower-growing species (Newell, et al. 1998). In contrast, benthic recovery from experimental disturbance (sediment manually dug to 10-cm depth) showed a weak converse pattern – higher rates with greater sand content (Dernie, et al. 2003). Part of the difference appears to be scale-related. Benthic recovery rates in the small experimentally excavated plots (1 x 4 m) strongly correlated with infilling rates, which, in turn, tended to be slower in muddier sites than in sandier sites (Dernie, et al. 2003). Infilling as a mechanism of recolonization of dredged sites would have diminishing influence with increasing size of the dredged area.

Benthic recovery rates are inversely related to frequency of dredging and spatial scale. For example, 4-6 years after cessation of extractive dredging, marine benthic species richness and population density remained significantly lower in areas subjected to high intensity dredging (>10 h dredging/10,000 m^2/y) compared to areas of low intensity dredging (<1 h/10,000 m^2/y) or reference areas; in contrast, species richness in the low intensity area recovered over the same period and population density was intermediate between that of high intensity and reference locations (Boyd, et al. 2005). Foden, et al. (2009) state that benthic recovery rate is inversely related to the size of the dredged area "in sites from 0.1 m^2 to 0.1 km^2, but not in larger sites" related to changes in the ratio of edge to area that affects immigration rate. Relative scale also has a role. Researchers attributed "unusually profound effects" of navigational dredging and spoil disposal in a lagoon, including areas outside of the dredge and disposal footprints, in part to the small size of the lagoon, in contrast to the effects of navigational dredging reported for "creation of channels through relatively large bodies of water" (Kaplan, et al. 1974). Another scale consideration is the initial severity of disruption, for example, in the Columbia River, declines in fish catch and diversity were reported in dredge and disposal areas after 40 days, but increases in catch occurred in areas "only slightly disturbed by dredging" (Allen and Hardy 1980). The differences may be related to initial impacts on the benthic prey base.

In rivers, the rate of recovery of benthic communities is additionally related to the proximity and location of refuges that are sources of recolonization by macroinvertebrates. The benthic communities of rivers with nearby and upstream refuges recovered within 2-5 years after improvements in water chemical quality following pollution control (Langford, et al. 2009). However, benthic community recovery did not occur even 30 years after pollution control in a river with no upstream refuges because they were eliminated by pollution that originated in the headwaters (Langford, et al. 2009). "In the absence of proximate sources of macroinvertebrate organism to act as colonisers, the potential of a historically polluted river to support a richer macroinvertebrate fauna appears constrained not only by water quality but also by colonisation processes." (Lanford, et al. 2009).

Based on literature reviews of field studies in trawled areas, the estimated recovery times for 90 % recovery of benthic numerical abundance by sediment type are 25 d in mud sediment, 111 d sand, 193 d muddy sand, and no recovery in gravel (Hiddinck, et al. 2006). Recovery of benthic biomass following trawling is slower than recovery of numerical abundance, approximately 5 years in the same review (calculated by linear regression for 100 % recovery) (Hiddinck, et al. 2006). Many studies of benthic recovery following experimental dredging have been made, but the reported recovery rates are questionable because of scale issues. As noted in one review, "it appears that the reports of recovery in small-scale experimental studies have been overestimated because this type of [experiment has] immigration rates that are not realistic for real fishing grounds" (Hiddinck, et al. 2006).

Recovery of disturbed seagrass meadows from small-scale disturbance is usually rapid, weeks to months, but from large-scale disturbance commonly requires 2-5 years or more (Erftemeijer and Lewis 2006). Species-specific seagrass recovery rates tend to vary inversely with plant size, quicker recolonization of smaller fast-growing species and slower recovery of larger species

(Erftemeijer and Lewis 2006). This general relationship indicates that recovery of freshwater macrophytes may be more likely to occur within the lower range of seagrass recovery times.

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Appendix C

Analysis of the Potential Ecological Effects of Increased Turbidity from Sediment Agitation in the Kalamazoo River Enbridge Line 6B MP 608 Marshall, MI Pipeline Release

In support of the SSCG's Net Environmental Benefit Analysis Subgroup

Prepared by Adriana C. Bejarano, Research Planning, Inc.

May 10, 2012

Background

Agitation of sediments as an oil removal technique in the Kalamazoo River has the potential to result in adverse ecological effects (summarized in Table 1), concerns that are reflected in the FOSC's Charge No. 4[1]. Sites undergoing oil removal via sediment agitation were monitor for turbidity (Nephelometric Turbidity Units, NTU), and in some instances turbidity data were also collected prior to sediment agitation. This information can provide information on the potential adverse effects of increased turbidity relative to levels of concern.

Table 1. Summary of some of the potential impacts associated with agitation. Not an extensive list of potential impacts.

Agitation Effects	Potential Ecological Impacts
Benthic habitat disturbance	• Removal of important habitat prior to agitation • Direct physical impacts of slow moving/non-motile fauna (including eggs) • Temporary reduction of dissolved oxygen
Increased suspended solids in the water column	• Decreased visibility • Increase respiratory stress • Reduced feeding capacity • Spawning deterrence
Increased sedimentation rates downstream	• Smothering of slow moving/non-motile fauna (including eggs) • Seabed smothering • Increased bottom destabilization

Objectives

The main objective of this analysis is to determine if increased turbidity cause by sediment agitation as a strategy to recover submerged oil from the *Enbridge Line 6B* oil spill in the Kalamazoo River poses adverse ecological risks to fish and other aquatic resources. Note that this assessment does not cover the impacts associated with benthic habitat disturbance, reduction of dissolved oxygen, and increase of sedimentation and smothering downstream of the agitation.

[1] *Identify viable procedures to assess the potential for adverse ecological effects resulting from further oil recovery using sediment agitation ("toolbox") techniques.*

The results from these analyses may inform the Net Environmental Benefit Analysis (NEBA) currently under development by the SSCG, as well as ongoing efforts in response to the FOSC's Charge 4.

Assessment of the Potential Ecological Effects with Data Collected During Agitation

States with water quality standards for turbidity have adopted standards ranging from 10 to 150 NTUs, or standards based on exceedances over background (e.g., ranging from 5 to 50 NTU above background, 10% NTU exceedance above background). These standards vary from State to State, are typically basin/water body-specific, and/or are defined to protect a particular resource (e.g., presence of salmonids). One limitation of these proposed standards is that these typically do not consider exposure duration, which has been demonstrated to be linked to the severity of adverse ecological effects (see Newcombe, 2003; Newcombe and Jensen, 1996).

For the purpose of this assessment, turbidity measurements collected during sediment agitation, were compared to levels associated with various ecological effects based on the models proposed by Newcombe (2003). These models, summarized in Figure 1, were derived based on a large empirical dataset with information on exposure duration, and developed primarily to assess impacts of excessive cloudiness on fish species not adapted to high turbidity conditions (e.g., clear water fish). Because of data limitations on earlier life stages (eggs and larvae), these models are more appropriate to assess effects on juvenile and adult fish. These models categorize ill effects as *no/low* effects, *moderate* including sublethal effects, and *severe* including lethal and paralethal effects.

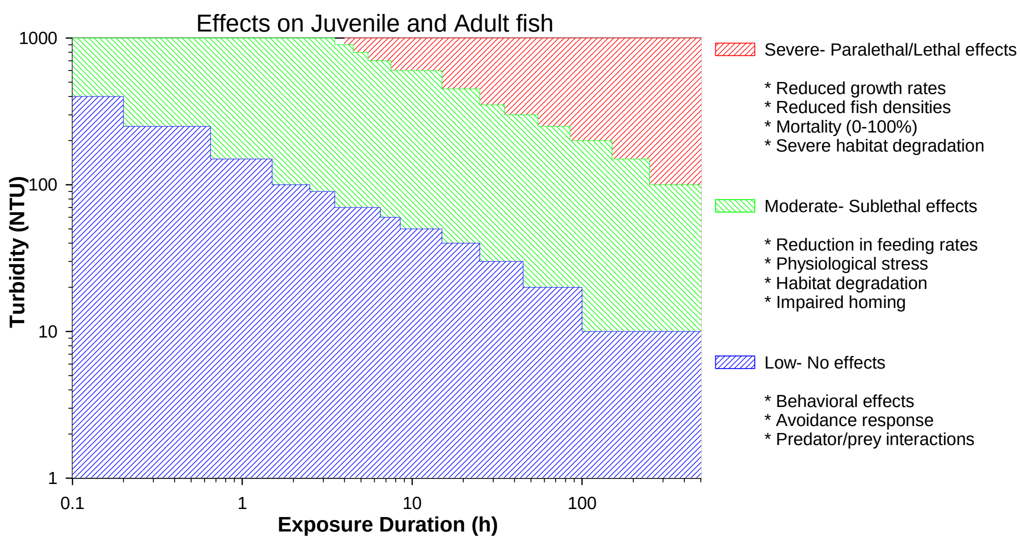


Figure 1. Graphic representation of the potential risk of increased turbidity in the water column on juvenile fish and adults at different exposure durations (Modified from data in Newcombe, 2003).

Data from five sites where turbidity was measured before and during sediment agitation at different locations within each site (upstream, downstream, side gradient and inside work site), (Appendix C1) were compared to the critical thresholds derived from the Newcombe (2003) models. Efforts focused on comparing specific turbidity values: mean background levels (before agitation), mean values downstream and inside the work site during agitation, and maximum turbidity recorded at any site (additional details provided in Appendix C1). Because no temporal duration was recorded in the field, the assumption was made that these turbidity values would last between minutes to several days (Figure 2). Turbidity levels around the mean background (before agitation; 8 NTU) are not expected to cause *severe* effects on fish. By contrast, turbidity levels around the mean downstream and inside work areas during agitation (26 and 43 NTU, respectively), may cause *moderate* effects on fish if these levels continuously persist for 44 and 15 hours, respectively. Turbidity levels around the maximum measured during agitation (501 NTU) may cause *moderate* effects at exposure durations lasting <15 hours, and severe effects at longer exposure durations. However, most of the observations downstream and inside the work area during sediment agitation (90th percentile) were ≤55 NTUs.

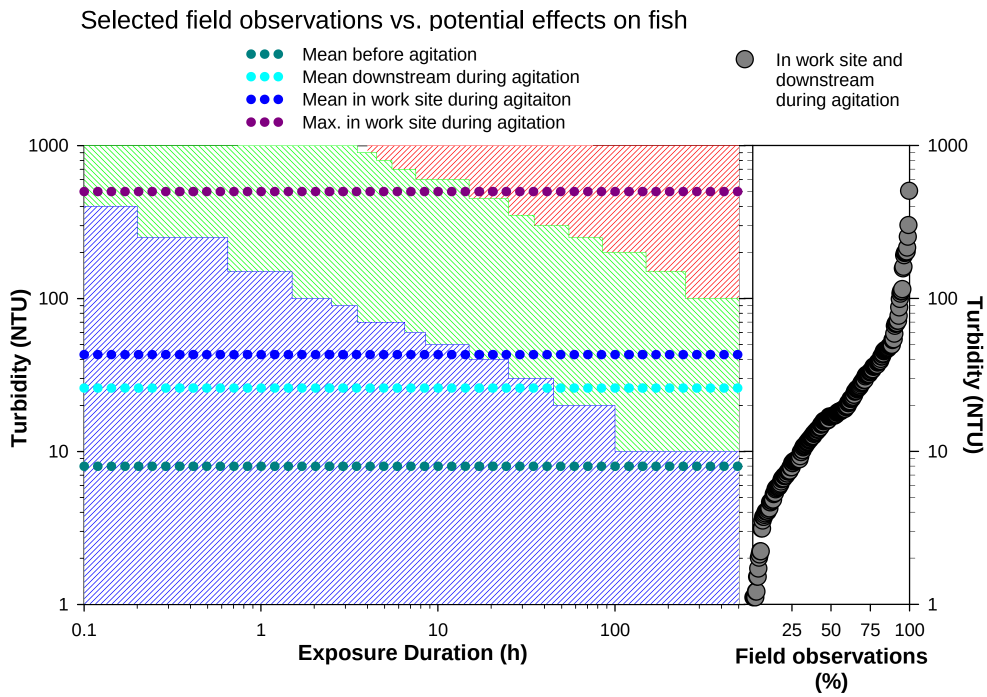


Figure 2. Left panel: Recorded turbidity (NTU) before and during agitation at five selected sites along the Kalamazoo River. The dotted lines represent (from bottom to top) the mean turbidity prior to agitation (background), the mean turbidity at and downstream the work site during agitation, respectively, and the maximum turbidity recorded during agitation. Refer to Figure 1 for details on the three zones with associated ecological effects. Right panel: Distribution of turbidity collected at and downstream of the work site during sediment agitation at these five locations.

Turbidity data were also collected at 248 monitoring areas during sediment agitation along the Kalamazoo River (Appendix C2). The maximum turbidity value recorded at each site was used for further analysis (Figure 3) under assumption of worst-case scenarios of turbidity levels. The 50th percentile of maximum values recorded at each of 248 monitoring sites (48 NTU) may cause *moderate* effects on fish if these levels continuously persist for 15 hours. By contrast, turbidity at the 90th percentile (188 NTU) may cause *moderate* effects on fish if these levels continuously persist between 48 minutes to 150 hours, while severe effects may occur at longer exposure durations. The maximum turbidity of all monitoring data (690 NTU) may cause *moderate* effects at exposure durations <7.5 hours, and severe effects at longer exposure durations. However, all of these values represent the extreme of observations across the entire river system; therefore, the anticipated effects (from turbidity alone) are possibly within the *no/low* effects to *moderate* (sublethal) effects.

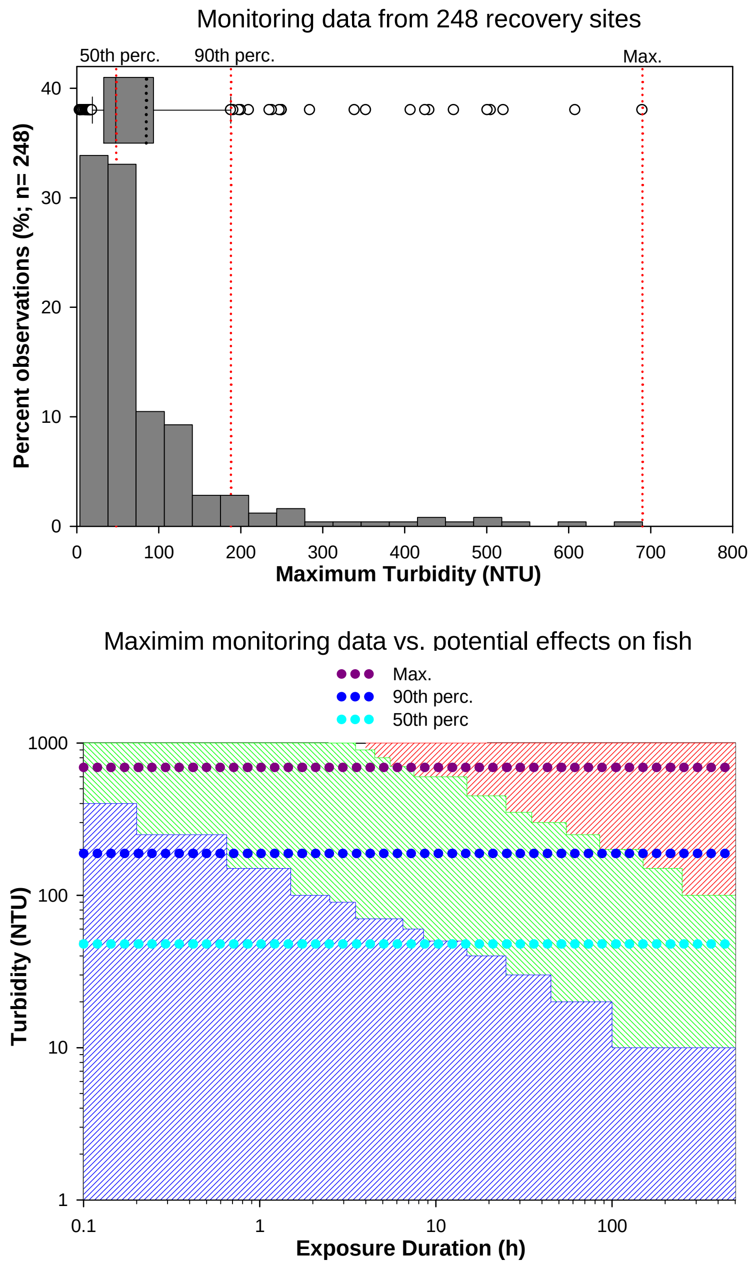


Figure 3. Top panel: Distribution of the maximum turbidity (NTU) recorded at each of 289 monitoring sites during sediment agitation along the Kalamazoo River. The dotted lines represent (from left to right) the 50th and 90th percentiles, and the maximum of all recorded turbidity values. Bottom panel: Comparison of selected turbidity values versus the thresholds of concern. The dotted lines represent (from bottom to top) the 50th and 90th percentiles, and the maximum of all recorded turbidity values recorded during monitoring of agitation sites. Refer to Figure 1 for details on the three zones with associated ecological effects.

The analyses above do not take into account the spatial and/or temporal scale associated with sediment agitation. To address the temporal and spatial scale of increased turbidity from sediment agitation, two pieces of information, for which data are not currently available, are needed. These are the time required for turbidity to reach background levels upon cessation of agitation, and the footprint (particularly downstream) of the potential impacts. These are partially a function of water current velocities (flushing time) and the grain size distribution of the agitated sediment, which determines settling times/distance. Ongoing investigations (Charge 4) may generate such information, which will help fine-tune the analysis presented here.

An alternative approach was used to address the temporal scale of increased turbidity from sediment agitation, which involved the analysis of all the turbidity data collected along the Kalamazoo River. Using georeferenced data on turbidity, selected areas along the Kalamazoo River with high concentration of sediment agitation events within the same timeframe (agitation events occurring during several contiguous/semi contiguous days/weeks) were identified and used to characterize potential ecological effects from continuous exposures to increased turbidity. Exposure duration was assumed to be the sum of the number of days with agitation events. Using this approach, data from ten sites (see Appendix C3 for details) were used in this analysis. Although the spatial scale cannot be directly quantified because turbidity measurements were not recorded upon cessation of agitation, the frequency of agitation events within the area can provide an idea of the potential ecological effects from persistently increased levels of turbidity over several days. This assessment assumes that turbidity will remain elevated until the next agitation event, and that turbidity will remain elevated for the duration of the contiguous days of agitation (both extremely conservative assumptions). Two statistics were used at each site: mean, and mean turbidity plus one standard deviation (worst-case scenario) turbidity during agitation (Figure 4, Table 2). Both statistics are conservative and biased towards overestimation of risk. Using this approach, and compared to the turbidity thresholds from Newcombe (2003), *moderate* effects are expected at all sites and under both exposure scenarios (mean and mean+ turbidity), except for one site (MP2.5-MP4.5; where no effects are expected) (Figure 4).

Newcombe (2003) further described the range of potential effects even within the three ranges of potential effects (no/low effects, moderate, severe). Within the *moderate* category, effects can range from a **Scale 4** (least *moderate* effects: short-term reduction in feeding rates/ feeding success) to a **Scale 8** (worst *moderate* effects: major physiological stress, long-term reduction in feeding rate/feeding success, poor condition). Most sites and scenarios within the Kalamazoo River fell in the **Scale 6** (moderate physiological stress) and **Scale 7** (moderate habitat degradation; impaired homing), and only one site (Ceresco Dam) under the worst-case scenario had a **Scale 8** (Table 2).

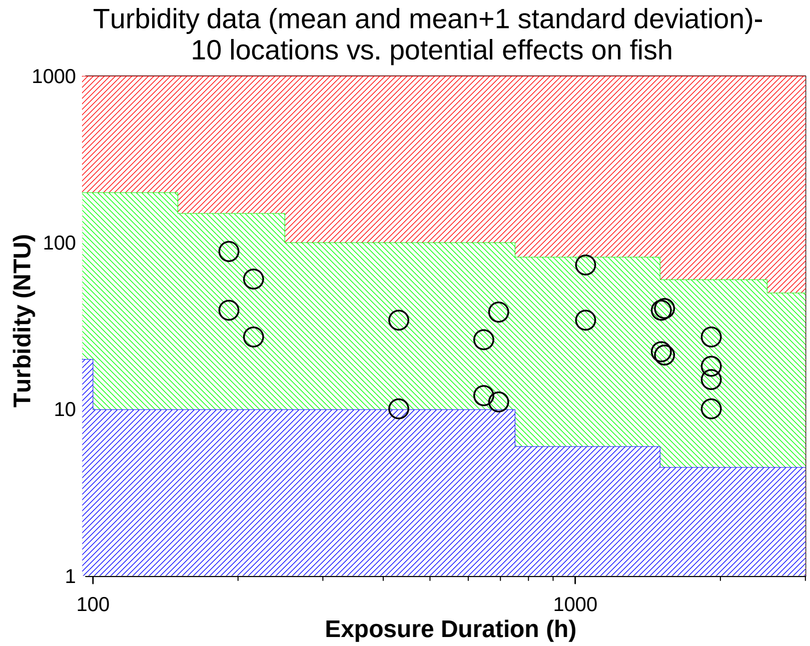


Figure 4. Mean, and mean turbidity plus one standard deviation (worst-case scenario) turbidity during agitation at several locations with high concentration of sediment agitation events (in space and time).

Table 2. Potential adverse ecological effects from turbidity at several locations with high concentration of sediment agitation events (in space and time). Refer to Figure 1 for details. Effects were assessed using the number of sequential days with agitation events, and two statistics of turbidity (mean, mean plus one standard deviation) at each of the sites. Accompanying figures are shown in Appendix C3. The scale of **Moderate** effects was derived from the Newcombe (2003) models and are as follows: **Scale 4:** short-term reduction in feeding rates/feeding success**, Scale 5:** minor physiological stress; increase coughing/respiration rate; **Scale 6:** moderate physiological stress; **Scale 7:** moderate habitat degradation; impaired homing; **Scale 8**: major physiological stress, long-term reduction in feeding rate/feeding success, poor condition.

Sites along the Kalamazoo River with turbidity data during agitation	Number of days with sequential agitation events	Mean NTU	Mean NTU +1 StDev	$\text{Effects}_{\text{Mean NTU}}$	$\text{Effects}_{\text{Mean NTU+1 StDev}}$
Talmadge Creek	27	12	26	Moderate (Scale: 4)	Moderate (Scale: 6)
Kalamazoo River Confluence	29	11	38	Moderate (Scale: 4)	Moderate (Scale: 7)
Island A	8	39	88	Moderate (Scale 5)	Moderate (Scale: 7)
MP 2.5-MP 4.5	18	10	34	No/Low	Moderate (Scale: 6)
Ceresco Dam	31	34	73	Moderate (Scale: 7)	Moderate (Scale: 8)
MP 14.35	9	27	60	Moderate (Scale 5)	Moderate (Scale: 6)
Morrow Lake/Delta*	63	22	39	Moderate (Scale: 6)	Moderate (Scale: 7)
Morrow Lake/Delta**	64	21	40	Moderate (Scale: 6)	Moderate (Scale: 7)
Morrow Lake (fan)***	80	15	27	Moderate (Scale: 6)	Moderate (Scale: 7)
Morrow Lake****	74	10	18	Moderate (Scale 5)	Moderate (Scale: 6)

* 35th Street Bridge and Gabion Basket F; ** Gabion Baskets A, B, E and H; *** Gabion Baskets A-D, F and H and other sites; **** ML6-10 and other sites.

Data on total suspended solid (TSS) concentration were not collected regularly during agitation, and therefore, the effects of TSS on fish were not directly assessed. However, a brief overview of the TSS data relative to historical information (collected at various locations in the Kalamazoo River) is presented in Appendix C4. Overall, TSS concentration does not appear to be higher than the historical record during the post spill sampling period, though clearly TSS in many instances exceeds historical records during sediment agitation.

Data Limitations and Uncertainties

This section briefly describes some of the data limitations and uncertainties associated with the analyses presented here.

1. Although the models from Newcombe (2003) allow the incorporation of exposure duration into the assessment of potential ecological effects of turbidity on fish, these models are more appropriate for juvenile and adult fish; therefore, assessments may not be protective of the most sensitive life stages (eggs and larvae).
2. Although the temporal and spatial scale of the footprint(s) of individual sediment agitation events has not been complete resolved, the approach presented here are generally conservative and biased towards overprediction of risks. Data collected under ongoing investigations may be used to reevaluate the assessments presented here.

Conclusions

Under assumptions of worst- case exposure scenarios, comparison of turbidity data collected during sediment agitation, and turbidity levels associated with ecological effects in fish (Newcombe, 2003), showed that increased turbidity from use of the agitation toolbox response methods in the Kalamazoo River may pose *moderate* (sublethal) effects to juvenile and adult fish species. *Severe* (paralethal/lethal) effects are not likely to occur during typical turbidity levels created by sediment agitation, even over extended periods of agitation (days/weeks).

References

Newcombe, C.P. 2003. Impact Assessment for Clear Water Fishes Exposed to Excessively Cloudy Water. Journal of the American Water Resources Association 39(3):529-544.

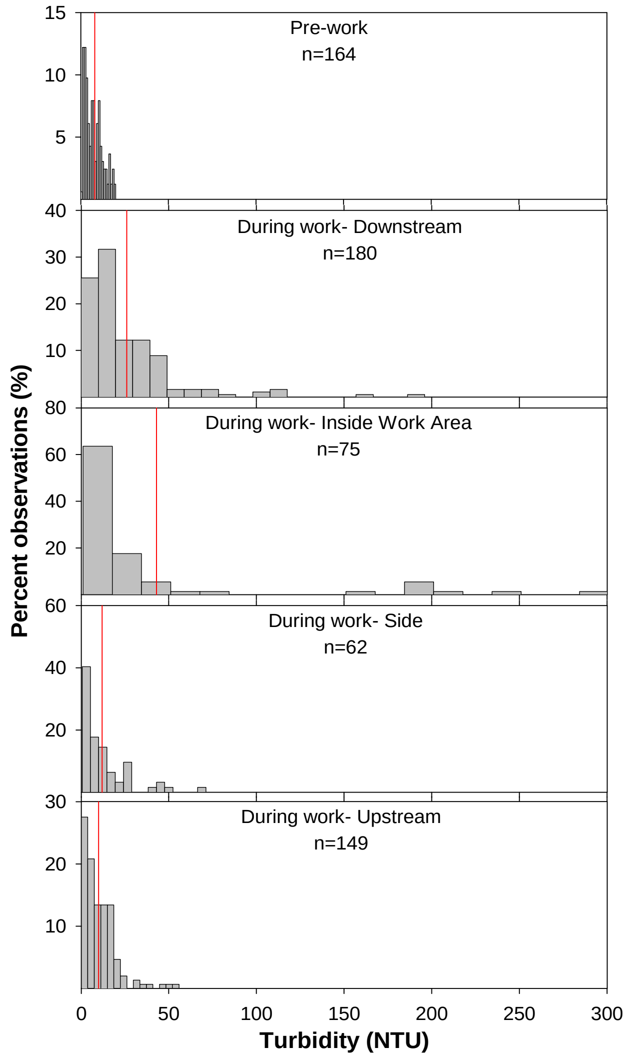
Newcombe, C.P., and J.O.T. Jensen. 1996. Channel Suspended Sediment and Fisheries: A Synthesis for Quantitative Assessment of Risk and Impact. North American Fisheries Management 16: 693-727.

Appendix C1

This appendix contains information on the five selected sites where turbidity data were collected before and during sediment agitation at different locations (inside work area, downstream, upstream and side gradient from work area).

Figure C1. Maps of the five sites with turbidity information before and during agitation

Data plots and summary statistics from all five sites (combined) where turbidity was measured before and during sediment agitation at different locations (inside work area, downstream, upstream and side gradient from work area). The vertical red lines represent the mean value within each location.

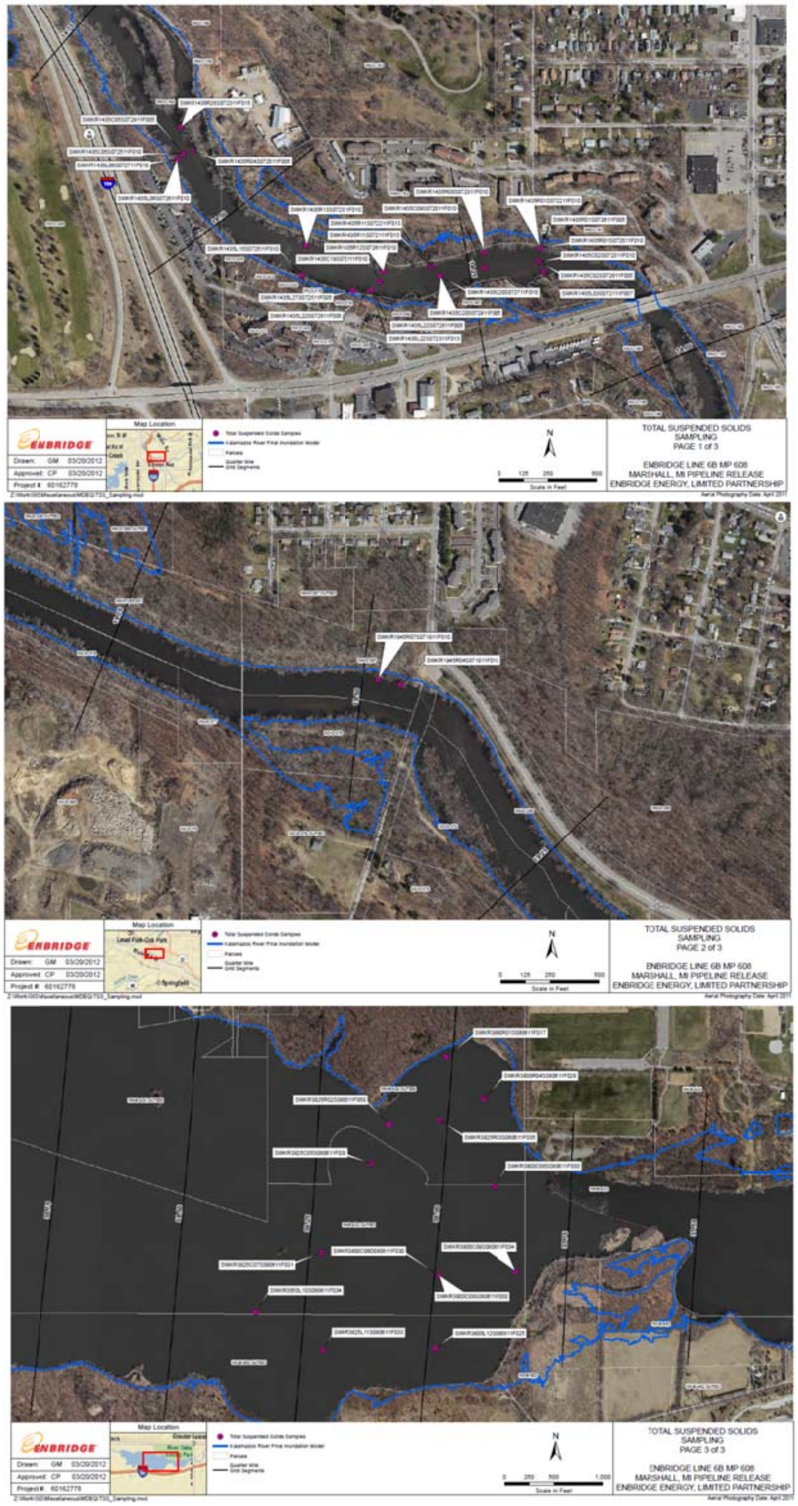


Turbidity (NTU) Statistics	Before Agitation	During Agitation			
		Downstream	In work site	Side gradient	Upstream
Sample size	164	180	75	62	149
Mean (95% CI)	7 (6-8)	26 (22-30)	43 (24-62)	12 (9-16)	10 (9-12)
10th percentile	2	5	3	1	1
50th percentile	7	18	15	8	8
90th percentile	16	49	193	29	20
Maximum	19	196	501	71	56

Appendix C2

This appendix contains information on the 248 monitoring sites with turbidity information.

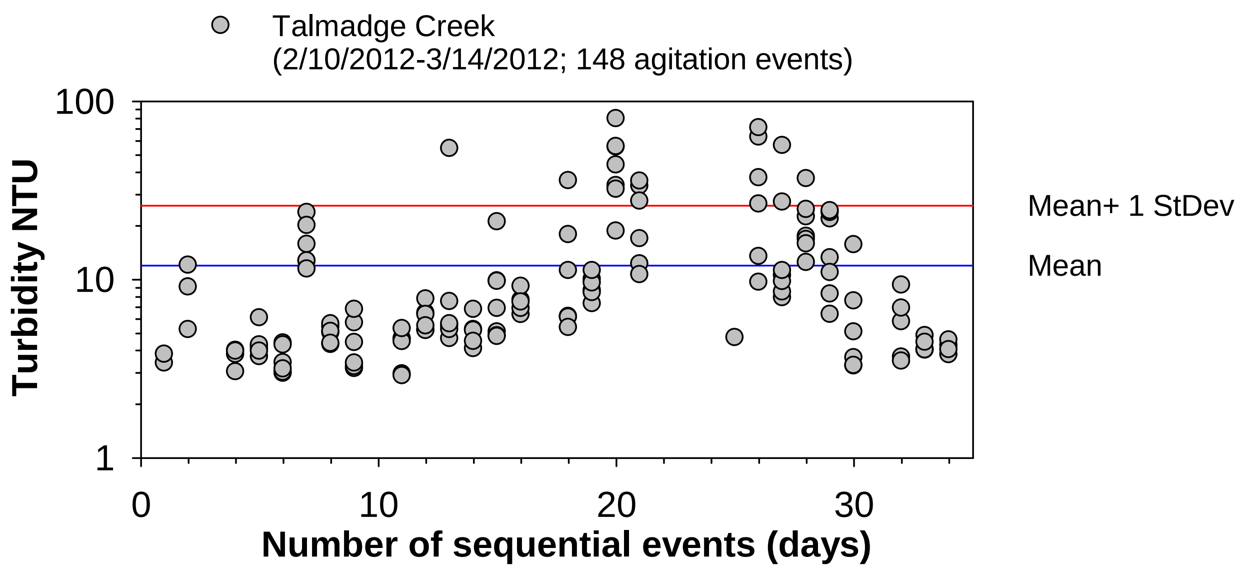
Figure C2. Maps displaying the location of the 248 turbidity-monitoring sites.

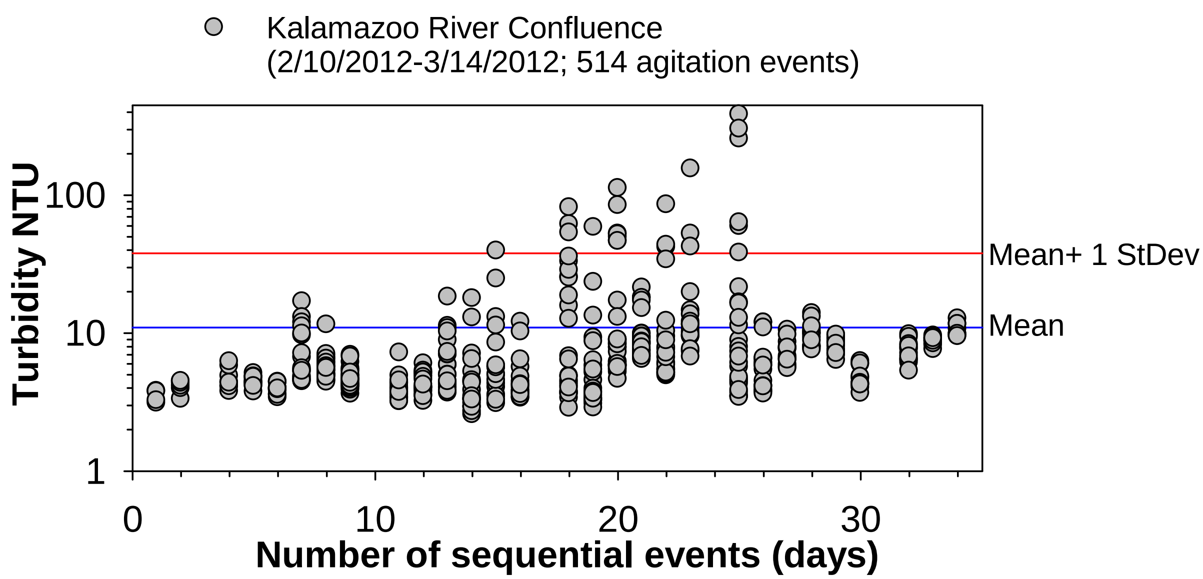


Appendix C3

This appendix contains information on the 10 areas with turbidity information where exposure duration was assumed to depend on the number of days with sequential sediment agitation events.

Figure C3. Distribution of turbidity data within the 10 locations with high concentration of sediment agitation events. The horizontal lines represent two exposure scenarios per site: blue- mean turbidity, and red- mean turbidity plus one standard deviation. Each figure also includes information on the sediment agitation period (start and end dates) and the number of agitation events. Note that scale of the x- and y-axes are location specific.





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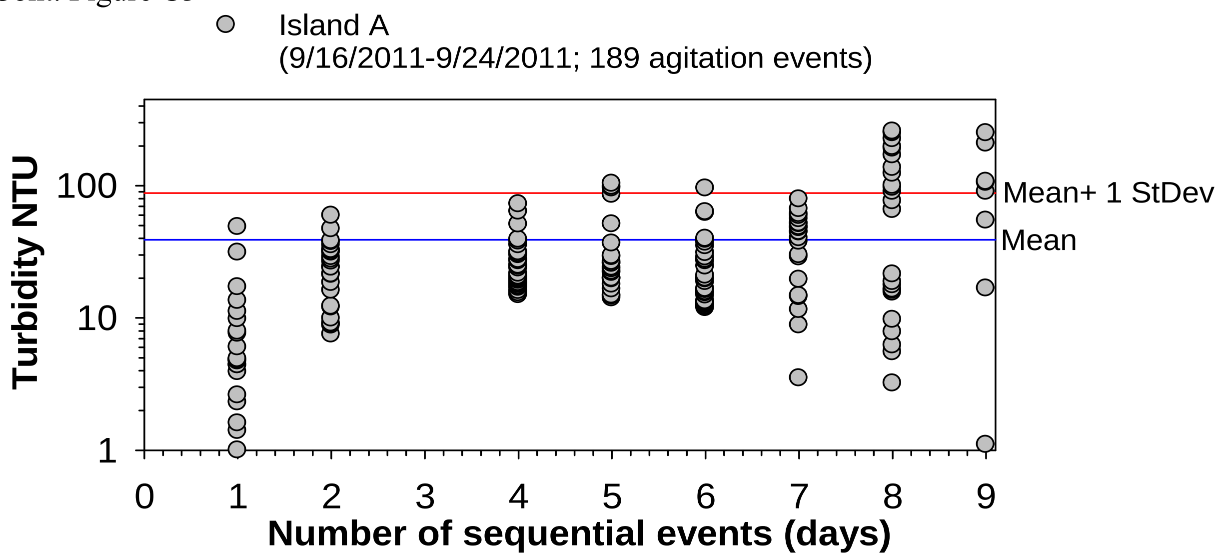

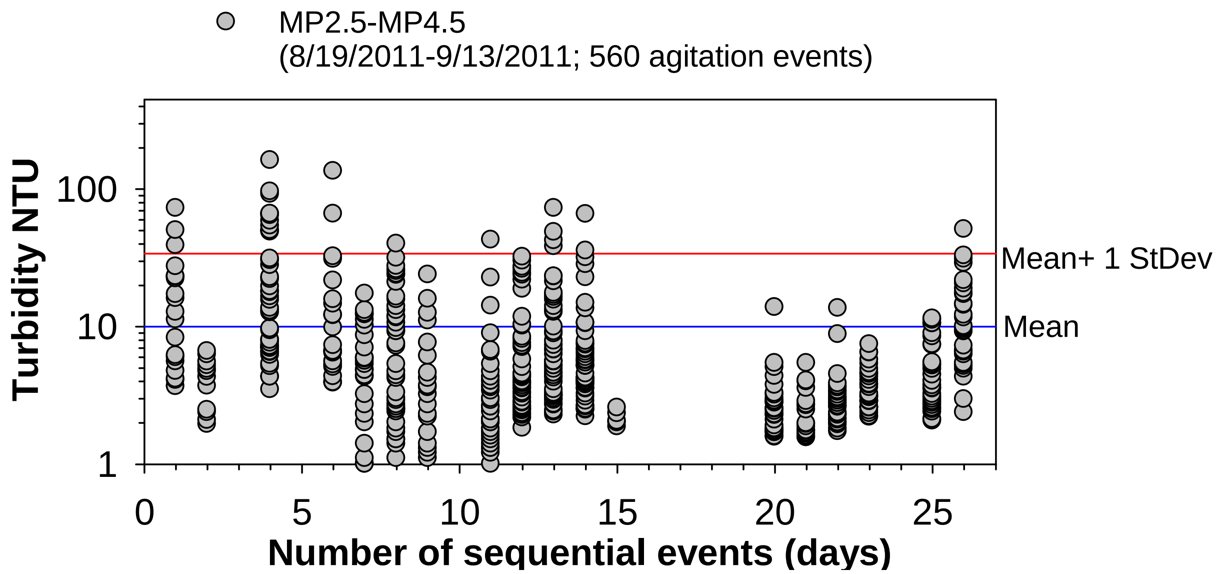

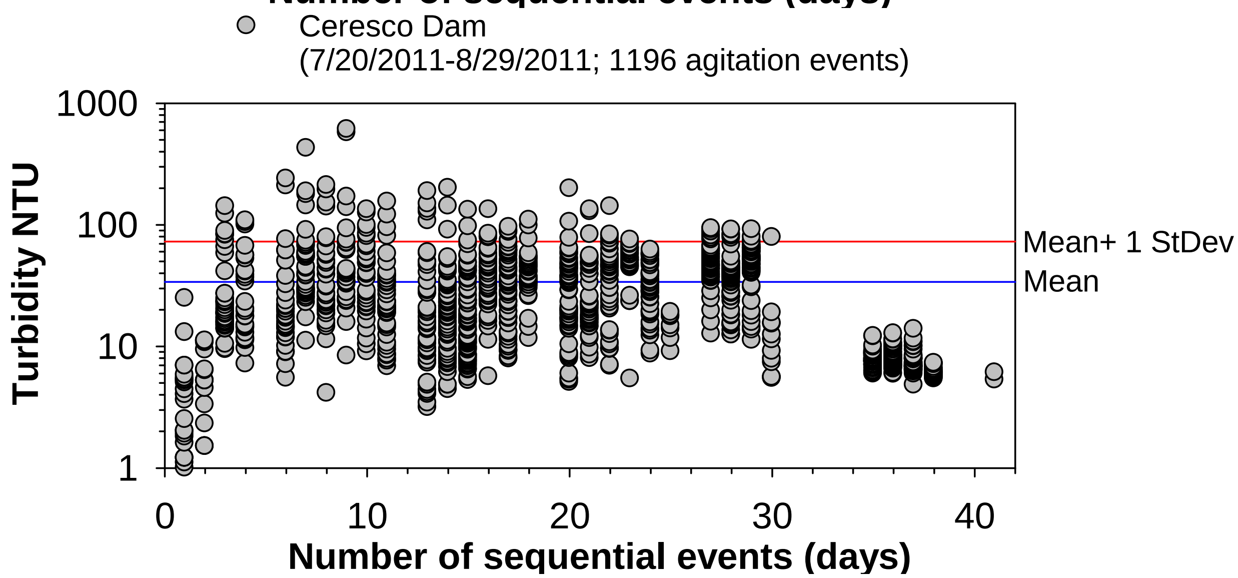

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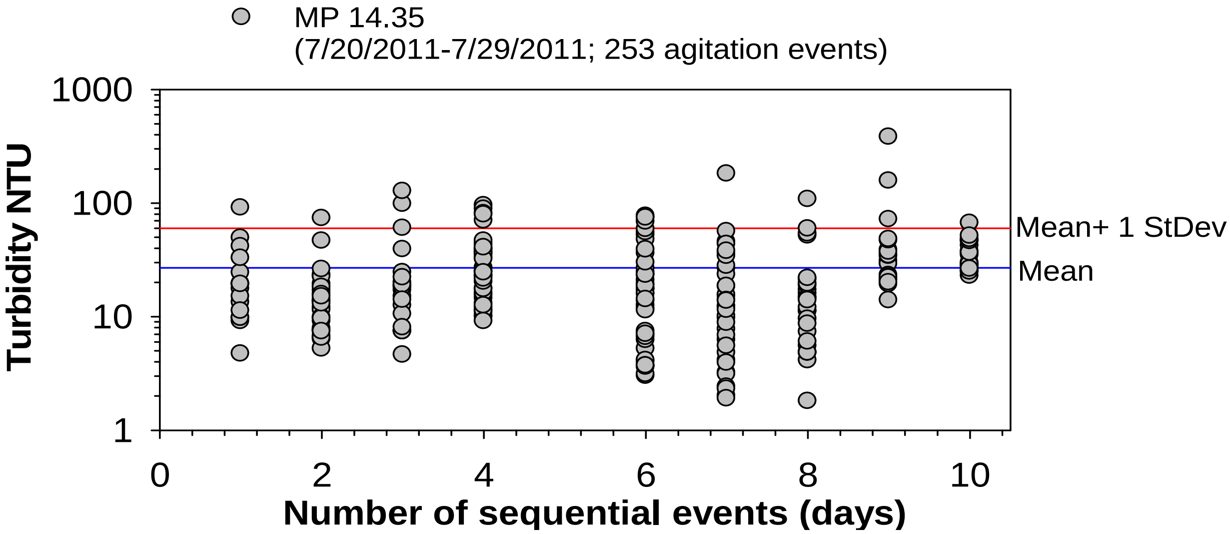

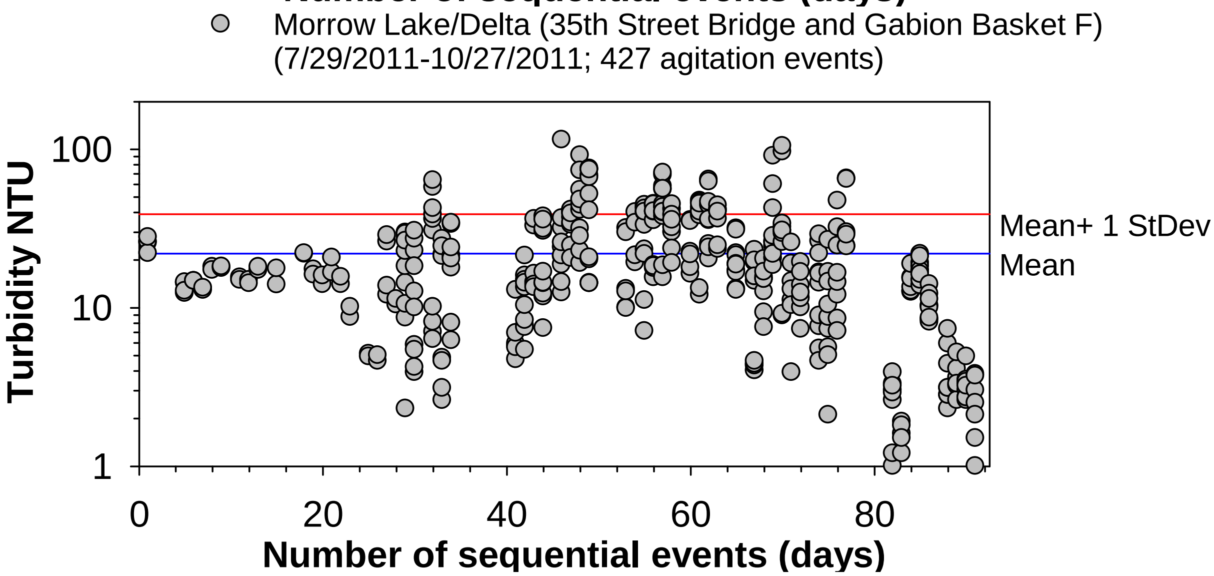

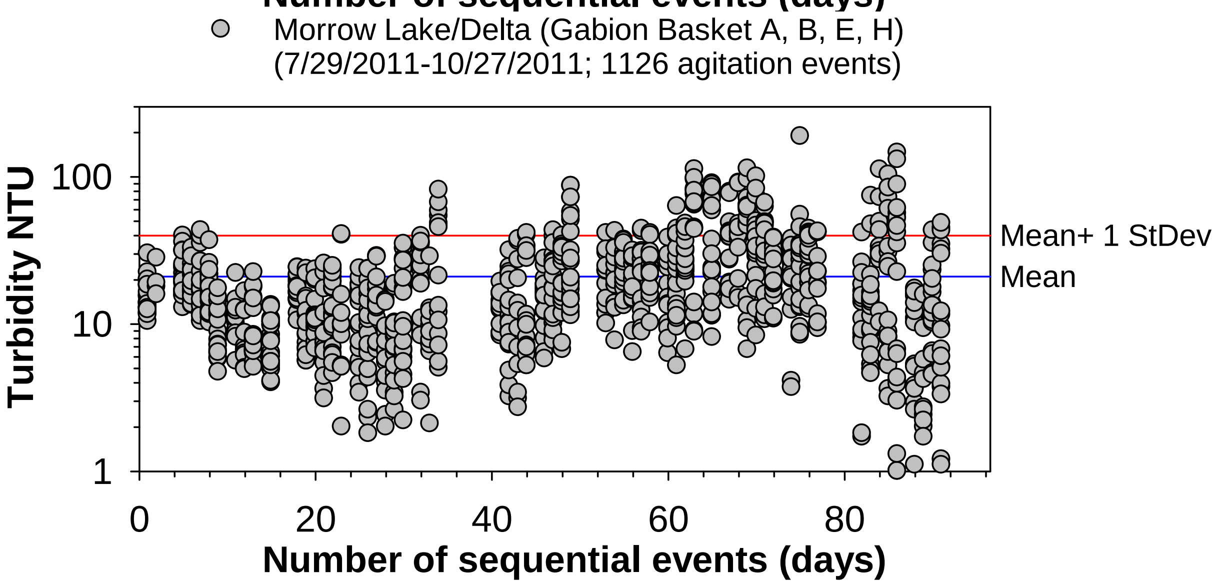

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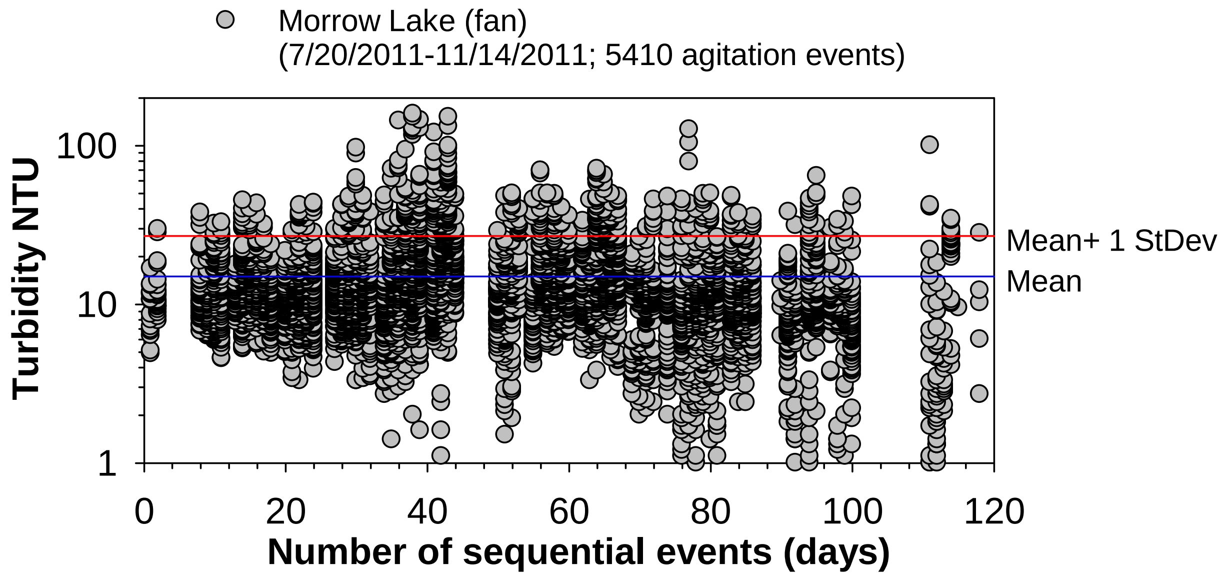
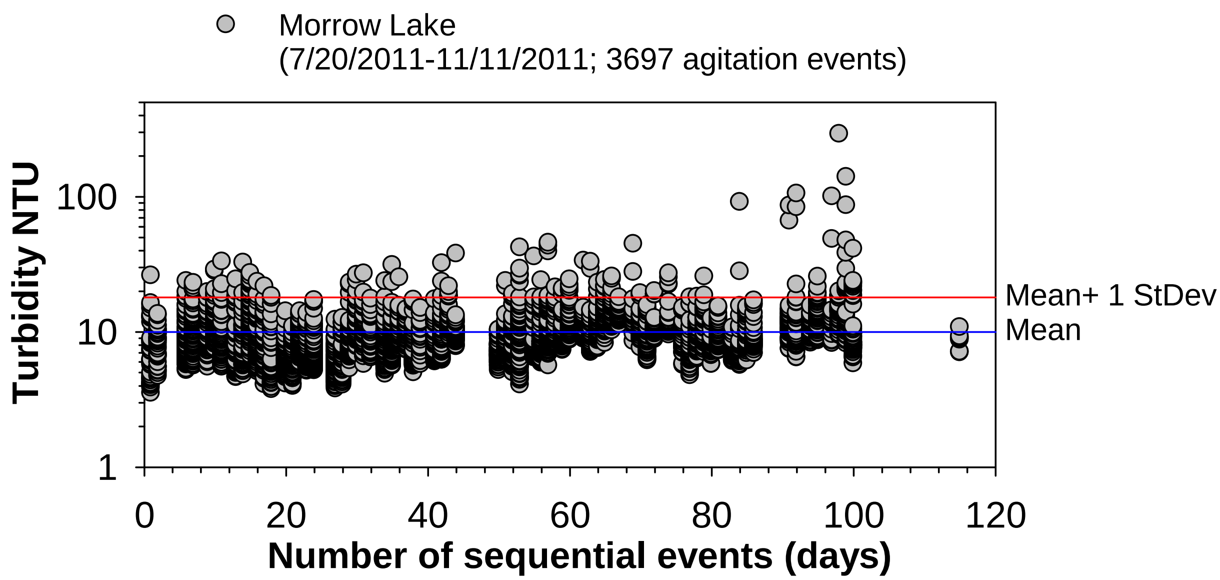


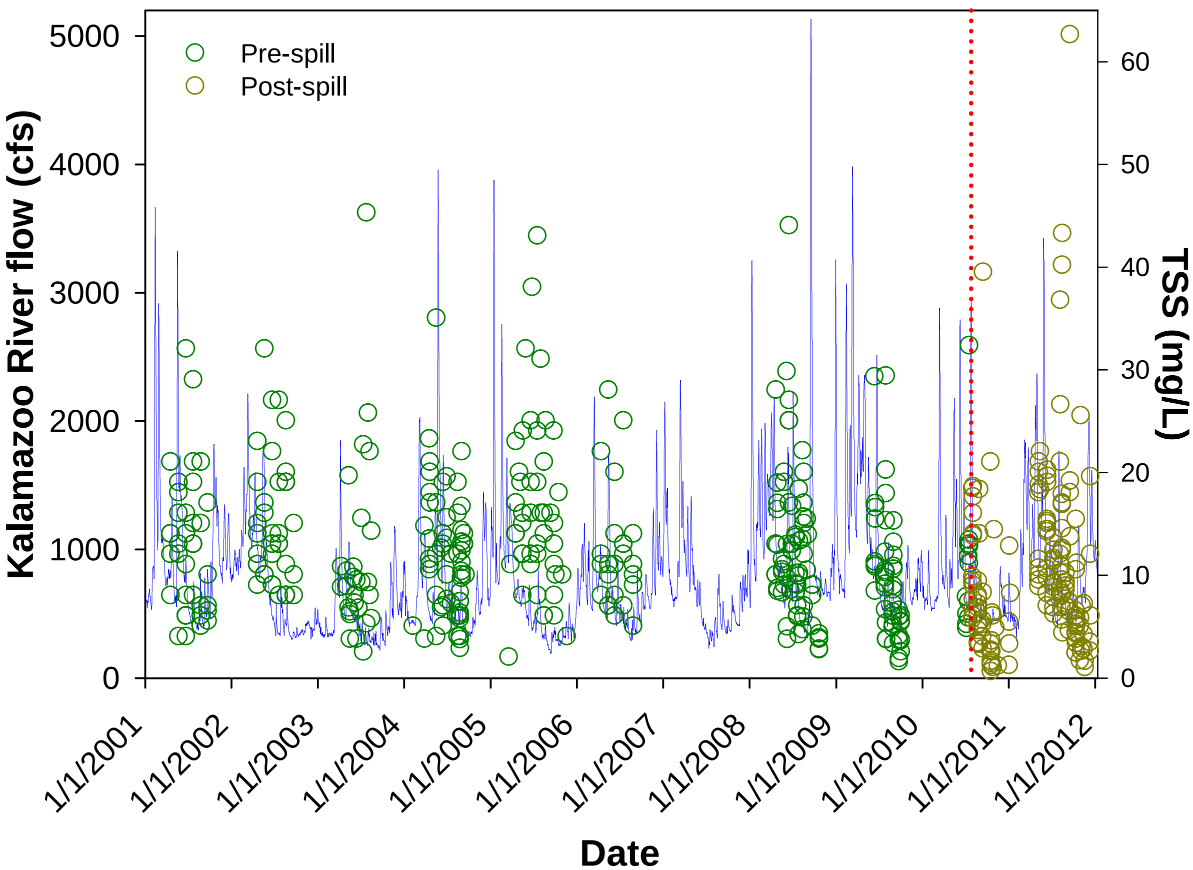


Appendix C4

This appendix contains information on total suspended solid (TSS) concentration (mg/L) in the Kalamazoo from: 1) historical records (2001-2010; S. Hamilton, pers. comm.; MDEQ http://www.kalamazooriver.net/tmdl/krdata/index.htm; n=362); 2) post-spill sampling in the river at several locations (2010-2011; S. Hamilton, pers. comm.; n=157); and 3) turbidity measurements (NTU) collected during sediment agitation (2011-2012; n=36,982).

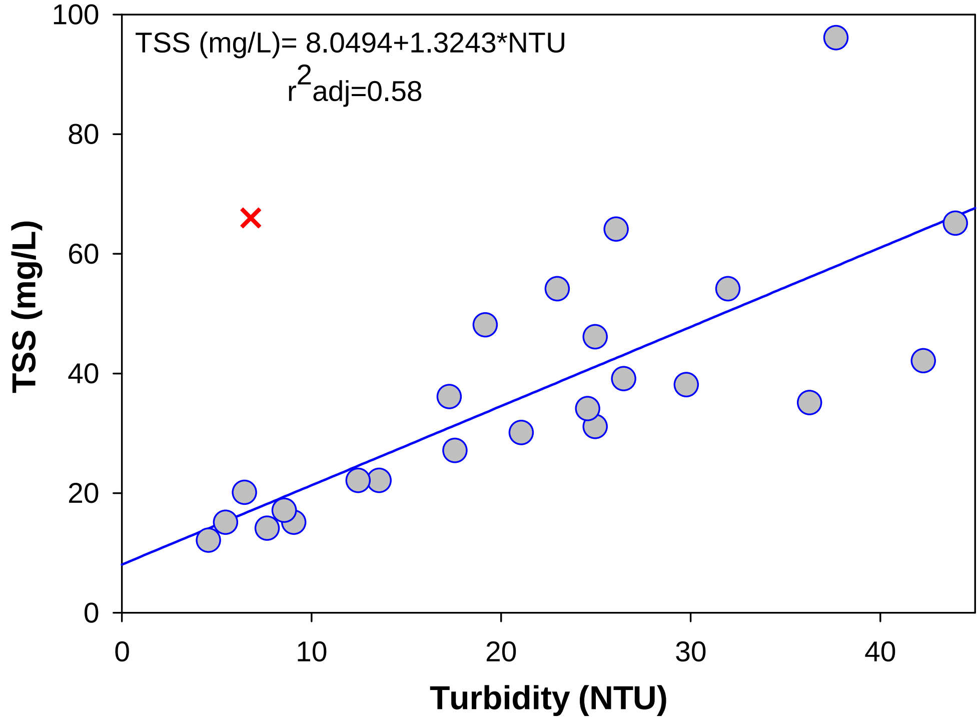
Comparison of pre and post TSS concentration at different locations in the Kalamazoo River shows similar patterns relative to the Kalamazoo River water flow (USGS 04105000). In some cases, high TSS concentrations (≥30 mg/L) were observed during periods of low water flow.

Figure C4_1. Distribution of total suspended solids (TSS) data collected at different locations in the Kalamazoo River before and after the spill relative to the Kalamazoo River water flow (USGS 04105000). The dotted red line represents the date of the spill.



Since the large majority of data collected during the response were reported in NTUs, a calibration equation between NTUs to TSSs (Figure C4_2) was used to allow for comparisons with the historical record. This correlation showed a fair adjusted correlation coefficient (r^2=0.58) typical of these calibration curves, but with relatively moderate prediction capability. Therefore, data interpretation using the conversion equation in Figure C4_2 should be done carefully because of the potential over- under-estimation of TSS concentration.

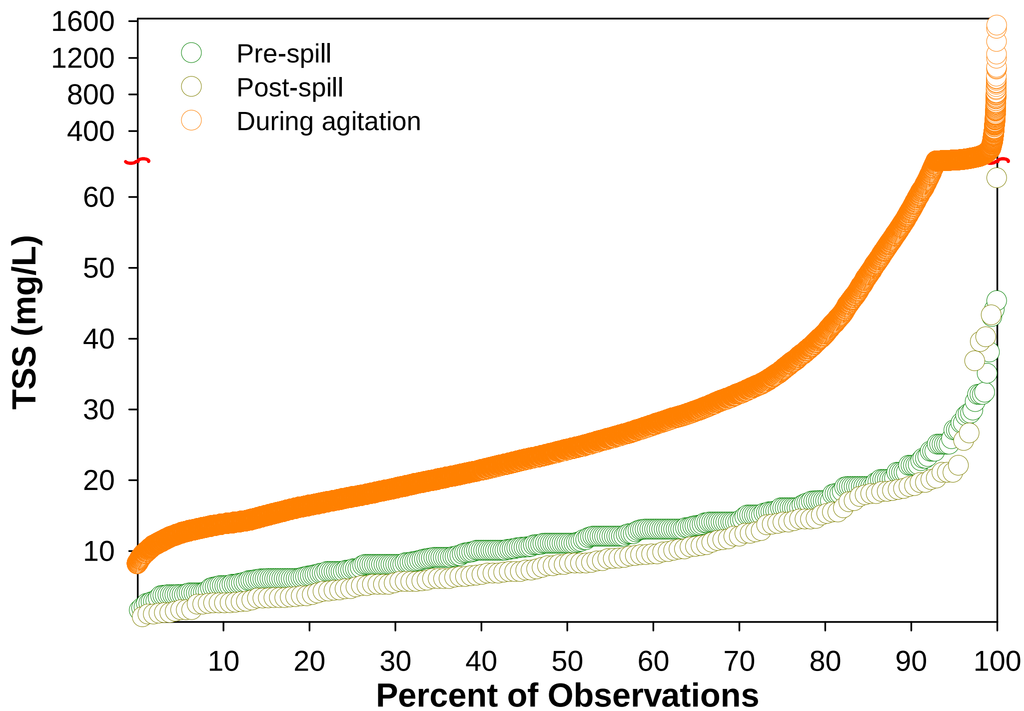
Figure C4_2. Correlation between total suspended solids (TSS) and turbidity (NTU) in water samples collected by Enbridge. The "x" represents an outlier removed during analysis. Note that the correlation coefficient is fair (adjusted r^2=0.58), and that therefore, over- or underestimation of TSS concentrations from NTUs is expected.



The average TSS concentration within the historical record was 13 mg/L, with a maximum of 45 mg/L, and with most observations (90^{th} percentile) falling below 22 mg/L. Similar TSS values were observed in samples collected post spill (average=10 mg/L, maximum= 63 mg/L, 90^{th} percentile=19 mg/L) (Figure C4_3). By comparison, most of the estimated TSS values during agitation (90^{th} percentile= 58 mg/L) were near the maximum reported for pre- and post- spill levels, and a relatively low proportion of samples (3%) had TSS concentrations in the 100-1550 mg/L range. The average TSS concentration during agitation was estimated at 34 mg/L. No attempts were made to assess the effects of TSS on fish and other aquatic organisms because of the uncertainty associated with the conversion from NTUs to TSSs.

Based on the information currently available, there are no apparent differences in the distribution of TSS in the river before and after the spill, but clearly, turbidity measurements taken in the vicinity of sediment agitation operations indicated that TSS is elevated in and around the operations. The duration of this increase (i.e., how long it takes to settle out) is unknown.

Figure C4_3. Distribution of total suspended solid (TSS) concentration (mg/L) in the Kalamazoo before and after the spill, and from turbidity measurements (NTU) collected during sediment agitation and converted to TSS using the equation in Figure C4_2. Note that a split y-axis was used to allow the display of the entire range of estimated TSS concentrations during sediment agitation.



Application and Integration of Net Environmental Benefit Analysis (NEBA) with Spring 2012 Tactical Areas

Kalamazoo River System
Enbridge Line 6B MP 608 Marshall, MI Pipeline Release
Update July 8, 2012

Scientific Support Coordinator: Faith Fitzpatrick (U.S. Geological Survey)

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Background and Overview

A Net Environmental Benefit Analysis (NEBA) was developed in spring 2012 to help decision-makers weigh the environmental risks associated leaving residual submerged oil in place and allowing for natural attenuation as opposed to additional recovery actions such as agitation and dredging. The NEBA relative risk matrix (see NEBA concept document and appendixes) was integrated with the 2012 submerged oil tactical areas previously identified by onsite operations staff. The NEBA integration was first done with the May 2012 tactical areas based on fall 2011 poling reassessment and winter 2011-12 observations and assessments but then revisited in June 2012 after the tactical areas were updated with spring 2012 poling reassessment results. At the time of writing (July 2012) new tactical areas were not yet delineated.

The recommended recovery actions are based on the NEBA risk rankings, site-specific oil recovery history, degree of remaining submerged oil, proximity to previously identified sensitive habitats, potential for oil remobilization, and distance to nearest potential submerged oil/sediment trap.

Recommendations (July 2012)

The SSCG subgroup met with onsite operations staff through web-based conference calls in May and June 2012 before and after the spring 2012 poling reassessment to determine recommendations for recovery actions for each of the tactical approach areas being considered for 2012 response (Table 1). The number of tactical areas increased after the spring 2012 reassessment from about 143 to 240 based on the presence of moderate and heavy poling results in new locations not present during the fall 2011 poling assessment (table 2 excel spreadsheet). At the time that the recommendations were done one large tactical area encompassed the impounded area of Morrow Lake. It is recommended that the area be subdivided into multiple tactical areas in the delta, neck, fan, and lake to help facilitate discussion of recovery actions. With the assistance of GIS technicians, the SSCG subgroup compared poling results from fall 2011 with spring 2012 results. Some of the original 143 tactical areas had less oiling, while others had more. Approximately 40 areas as of May 2012 had no heavy or moderate poling results, only light or none. For these areas, the NEBA recommendation was “no action”.

Individual SSCG comments from conference calls were synthesized into a spreadsheet for each of the approximately 240 tactical areas. Sheen collection was recommended for most of the remaining 200 original and new tactical areas, similar to the May 2012 recommendations (table 2). For existing tactical areas that appeared to stay the same or accumulate more oil over the winter 2011-12 (more moderate and heavy polings observed in spring 2012 compared to fall 2011), the recommendations were to increase monitoring frequency and continue to evaluate for active recovery, similar to recommendations for those with sediment traps. A number of 2011 tactical areas had noticeably more oil accumulation, likely from low flow accumulations in the over the winter and spring 2011-12. Submerged oil accumulations in these areas have a high potential to migrate further downstream during subsequent runoff events. Recommendations for these areas were to consider dredging, hydrovac, or hand scraping now while water remains low and the submerged oil is concentrated, especially in the Morrow Lake delta and Ceresco Impoundment which contain the majority of residual oil with abundant sheening and globs.

Next Steps

The integration of the Kalamazoo River NEBA with the submerged oil tactical areas is an iterative and adaptive process. The site specific recommendations for recovery options for each 2012 tactical area will be reviewed and updated if necessary as more data are generated. The proposed agitation experiment as part of Charge 4 may help distinguish differences in agitation toolbox compared to dredging/hydrovac methods. Recommendations are for the use of the FOSC, MI DEQ and onsite operations for consideration in tactical approaches for residual submerged oil removal and for assisting the FOSC and DEQ in determining cleanup endpoints.

References

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Table 1. Approximate number of tactical areas by habitat and recommended recovery action based on NEBA relative risk matrix, July 2012.

Habitat	No action	Monitored Natural Attenuation	Enhanced Deposition	Agitation toolbox	Dredging/Vacuum Truck	Dewater/Excavate	Sweep push	Scraping	Sheen Collection	Increased monitoring frequency
Impounded waters (no Morrow Lake)	0	0	8	0	3	0	0	0	4	4
Flowing channels	24	1	3	0	0	0	0	2	73	2
Depositional backwaters	15	2	10	0	2	0	0	1	67	8
Bars	0	0	0	0	0	0	0	0	0	0
Emergent wetlands	0	0	0	0	0	0	0	0	1	0
Islands	0	0	0	0	0	0	0	0	0	0
Oxbows	2	0	0	1	0	0	0	0	5	0
Forested scrub wetlands	3	0	0	0	0	0	0	0	0	1

Table 2. Excel Spreadsheet of tactical areas with May 2012 and June 2012 recommended recovery actions based on the NEBA relative risk matrix.

Table 2. DRAFT NEBA recommendations for residual submerged oil recovery in 2012 tactical areas, updated with spring 2012 poling assessments (July 2012).

Eight major recovery actions were considered: monitored natural attenuation, enhanced deposition and recovery (sediment trap), dredging, agitation/toolbox, dewater/excavate, sweep/push, scraping, and sheen collection.

Recommendations are based on poling results, size of tactical area, proximity to high use areas for recreation, potential for disturbance from boating, and potential to remoblize during floods.

"Increased monitoring frequency" was recommended for some tactical areas that were not sediment traps but have a accumulation of oil as determined by moderate/heavy poling results in spring 2012,

or are in high use areas such as boat ramps that have required repeated sheen management. "No action necessary" was recommended for tactical areas with no moderate or heavy poling results in spring 2012.

Because the ecological effects and effectivenessof agitation toolbox for oil recovery were unknown, dredging was the preferred recovery action over agitation effects in most areas.

[May 2012 recommendations were based on fall 2011 oiling conditions. June 2012 recommendations are based on a comparison between fall 2011 and spring 2012 poling results.

June 2012 new tactical areas are shown in blue. Preliminary start on subdivisions of Morrow Lake impoundment tactical area are shown in green.]

Tactical Area Name	River Mile	Area (acres)	NEBA Habitat Type	May 2012 NEBA Primary Recommendation	May 2012 NEBA Secondary Recommendation or Supporting Comment	Number of occurences requiring sheen management (as of 06/26/12)	Toxicity sample and nearby 2012 poling results	Sediment Trap Description (needs to be updated with latest information)	Comparison of fall 2011 with spring 2012 poling assessments	June 2012 NEBA updated recommendation
SO 2.49			Flowing Channel						New tactical area	Sheen collection/monitored natural attenuation
SO 2.64			Backwater/Flowing Channel (mapped as island)						New tactical area	Sheen collection/monitored natural attenuation
SO 3.40 ADDED 6/27			Backwater				SEKRO335 surrounded by nones but some lights and 1 moderate in the backwater/sidechannel	3.25 Passive trap with no structure after model rerun, permit group 2	New tactical area	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery
SO 4.18	4.25	2.4	Flowing Channel	Sheen collection/monitored natural attenuation						Sheen collection/monitored natural attenuation
SO 4.27	4.50	0.1	Flowing Channel	Sheen collection/monitored natural attenuation						Sheen collection/monitored natural attenuation
SO 4.30	4.50	4.1	Flowing Channel	Sheen collection/monitored natural attenuation						Sheen collection/monitored natural attenuation
SO 4.60	4.75	0.4	Flowing Channel	Sheen collection/monitored natural attenuation						Sheen collection/monitored natural attenuation
SO 4.62	4.75	0.0	Flowing Channel	Sheen collection/monitored natural attenuation						Sheen collection/monitored natural attenuation
SO 4.70	4.75	0.2	Flowing Channel	Sheen collection/monitored natural attenuation						Sheen collection/monitored natural attenuation
SO 4.80	5.00	0.1	Impounded waters	Sheen collection/monitored natural attenuation						Sheen collection/monitored natural attenuation
SO 4.81	5.00	0.1	Impounded waters	Sheen collection/monitored natural attenuation						Sheen collection/monitored natural attenuation
SO 4.84 A	5.00	0.1	Impounded waters	Sheen collection/monitored natural attenuation						Sheen collection/monitored natural attenuation
SO 4.84 B	5.00	0.1	Impounded waters	Sheen collection/monitored natural attenuation						Sheen collection/monitored natural attenuation

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SO 5.15	5.25	7.7	Impounded waters	Sheen collection/monitored natural attenuation	Evaluate removal after spring assessment	4- Sheen reponses at C0.5 boat launch	SEKR0510 on a moderate but assorted moderates, lights, and heavy in area		Better -- shifted from mod/heavies to mod/lights	Sheen collection, increase monitoring frequency, continue to evaluate for possible recovery
SO 5.84 A	6.00	12.3	Impounded waters	Sheen collection/monitored natural attenuation	Evaluate removal after spring assessment	1- At 5.35 RDB		Ceresco passive trap, no structure, general permit	both A/B look about the same	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery
SO 5.84 B	6.00	3.4	Impounded waters	Sheen collection/monitored natural attenuation	Evaluate removal after spring assessment	2- at 5.65 LDB		Ceresco passive trap, no structure, general permit	both A/B look about the same	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery
SO 5.84 C	6.00	2.3	Impounded waters	Sheen collection/enhanced deposition w/o removal	Evaluate removal after spring assessment	1- At 5.70 RDB	SEKRO565 @ moderate and surrounded by moderates, lights, and heavies	Ceresco passive trap, no structure, general permit	both C/D worse; high potential to remobilize during next flood	Follow sediment trap monitoring/maintenance plan, consider recovery (dredging)
SO 5.84 D	6.00	3.4	Impounded waters	Sheen collection/enhanced deposition w/o removal	Evaluate removal after spring assessment	4- At Ceresco Control Point		Ceresco passive trap, no structure, general permit	both C/D worse; high potential to remobilize during next flood	Follow sediment trap monitoring/maintenance plan, consider recovery (dredging)
SO 5.89	6.00	0.0	Flowing Channel	Sheen collection/monitored natural attenuation						Sheen collection/monitored natural attenuation
SO 5.90	6.00	0.1	Backwater	Sheen collection/monitored natural attenuation						Sheen collection/monitored natural attenuation
SO 5.92	6.00	0.1	Backwater	Sheen collection/monitored natural attenuation					1 light and 4 nones	Sheen collection/monitored natural attenuation
SO 5.99 North	6.00	0.1	Flowing Channel	Sheen collection/monitored natural attenuation					Better	Sheen collection/monitored natural attenuation
SO 5.99 South	6.00		Backwater						New tactical area 1 moderate	Sheen collection/monitored natural attenuation
SO 6.16	6.25	0.0	Backwater	Sheen collection/monitored natural attenuation					Better, all nones, no submerged oil present	No action necessary
SO 6.24			Flowing Channel						New tactical area, 1 moderate	Sheen collection/monitored natural attenuation
SO 6.41	6.50	0.1	Backwater	Monitored natural attenuation					Worse; 1 moderate in fall, 1 heavy/1moderate in spring	Sheen collection/monitored natural attenuation
SO 6.48	6.50	0.2	Flowing Channel	Monitored natural attenuation					Better	No action necessary

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SO 6.53			Flowing Channel						New tactical area,nothing in the fall, 3 moderates in the spring,	Sheen collection/monitored natural attenuation
SO 6.60	6.75	0.1	Backwater	Monitored natural attenuation					same (nook on north bank)	Monitored natural attenuation
SO 6.72	6.75	0.1	Backwater	Monitored natural attenuation					slightly better	Monitored natural attenuation
SO 6.99	7.00	1.9	Backwater	Sheen collection/monitored natural attenuation					better	No action necessary
SO 7.14			Backwater						new tactical area, fall had nones, spring has 1 moderate + heavy, low flow deposition	Sheen collection/monitored natural attenuation
SO 7.57			Backwater						New tactical area, 1 moderate	Sheen collection/monitored natural attenuation
SO 7.89	8.00	0.8	Flowing Channel	Sheen collection/monitored natural attenuation					Better, swift moving water, not a depositional area	Sheen collection/monitored natural attenuation
SO 8.29	8.50	4.1	Flowing Channel/Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 8.30	8.50	0.1	Backwater	Sheen collection/monitored natural attenuation	Scrape				Better--nones; some poling targets were dry and couldn't be sampled but probably won't go back	No action necessary
SO 8.35	8.50	0.2	Oxbow mapped as Forested/Shrub Wetland	Sheen collection/monitored natural attenuation	Drains high quality wetland				Better -- overbank oil trap in permit process	No action necessary
SO 8.46	8.50	0.0	Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 8.49	8.50	0.4	Backwater	Sheen collection/monitored natural attenuation	Drains high quality wetland	1-			Worse; has boom across opening with heavy poling. Drainage from high quality wetland.	Sheen collection, consider dredging (mudcat or small dredge) [landowner may only be interested in natural attenuation]

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SO 8.60			Backwater						New tactical area, 1 moderate	Sheen collection/monitored natural attenuation
SO 8.83	9.00	1.0	Flowing Channel/Backwater	Sheen collection/monitored natural attenuation	Scrape in backwater				Looks better but heavy/moderate areas dry and couldn't be poled.	Sheen collection, possible scrape in dry areas after further evaluation [landowner may only be interested in natural attenuation]
SO 8.88	9.00	0.1	Backwater	Sheen collection/monitored natural attenuation			SEKR0886 no poling		No poling data,mostly dry	Sheen collection/monitored natural attenuation [based on fall 2011 data]
SO 8.98	9.00	0.6	Flowing Channel	Sheen collection/monitored natural attenuation					Better in side channel but 2 heavies on downstream side of island	Sheen collection/monitored natural attenuation
SO 9.18	9.25	0.2	Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 9.38 C	9.50	0.7	Flowing channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 9.39	9.50	0.0	Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 9.46	9.50	0.2	Flowing Channel	Sheen collection/monitored natural attenuation					Better	Sheen collection/monitored natural attenuation
SO 9.54			Flowing Channel (mapped as "other floodplain -- scale issue)						New tactical area, boat launch; 1 heavy and rest lights/nones	Sheen collection/monitored natural attenuation
SO 9.67	9.75	0.0	Flowing Channel	Sheen collection/monitored natural attenuation					Better, 3 lights	No action necessary
SO 9.82	10.00	1.2	Flowing Channel/Backwater	Sheen collection/monitored natural attenuation	Scrape				Consistent oil deposition on downstream end of island. Island possible source of oil.	Sheen collection; consider containment, dewatering, and scraping or dredging (mudcat).
SO 10.02	10.25	0.2	Flowing Channel	collection/monitored natural attenuation					Better, 1 light	No action necessary

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SO 10.17	10.25	0.1	Flowing channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 10.29	10.50	0.6	Flowing Channel	Sheen collection/monitored natural attenuation					Better, heavies/mod to no heavies/mod	No action necessary
SO 10.42	10.50	0.3	Flowing Channel/Backwater	Sheen collection/monitored natural attenuation	Based on model results, consider enhanced dep			10.4 Passive trap with no structure	Slightly better, natural sediment trap, drying out	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery (dredging/mudcat)
SO 10.45			Backwater/Flowing Channel					10.5L2 Enhanced trap with structure at model rerun stage	New tactical area, sediment trap 10.5L2 working, winter worksite in 2011, agitation summer 2011, more deposition in 2012	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery (dredging/mudcat)
SO 10.56	10.75	0.6	Backwater	Sheen collection/monitored natural attenuation					Same, heavies in channel similar to fall	Sheen collection/monitored natural attenuation, evaluate recovery after next assessment
SO 10.63	10.75	0.4	Backwater	Enhanced deposition and removal	Evaluate removal after spring assessment	2-	SEKR1061 between heavy and moderate sorrounded by heavy, moderate, and lights	10.75 L2 Enhanced trap with X-mas tree structure at downstream end, sedimentation samplers in place since May 2012	Same, sed trap but upstream entrance almost dry	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery (dredging/mudcat)
SO 10.68	10.75	0.3	Backwater	Sheen collection/monitored natural attenuation					Better, just downstream of 10.75	Sheen collection/monitored natural attenuation
SO 10.72	10.75	0.6	Backwater	Sheen collection/monitored natural attenuation					Better	Sheen collection/monitored natural attenuation
SO 10.81			Backwater						New tactical area, 1 moderate in spring 2012	Sheen collection/monitored natural attentuation
SO 10.84	11.00	0.6	Backwater	Sheen collection/monitored natural attenuation	Evaluate removal/sediment trap after spring assess				Better, no heavies and 3 moderates in the spring 2012, not accumulating oil	Sheen collection/monitored natural attenuation
SO 10.90	11.00	0.3	Backwater	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 10.91	11.00	0.0	Flowing Channel/Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 10.95	11.00	0.1	Flowing Channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 11.05	11.25	0.3	Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary

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SO 11.16	11.25	0.0	Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 11.20	11.25	0.0	Forested/Shrub Wetland/Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 11.23	11.25	0.0	Forested/Shrub Wetland/Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 11.25 A	11.25	0.0	Oxbow/Tributary	Sheen collection/monitored natural attenuation	Consider removal /hydrovac after spring assessment		SEKR1132 between 3 moderates and 1 light		Better, A, B, and C combined into one area 11.25. Good access. Overbank sed trap possible (11.21)	Sheen collection/monitored natural attenuation
SO 11.25 B	11.25	0.5	Oxbow/Tributary	Sheen collection/monitored natural attenuation	Consider removal /hydrovac after spring assessment				Better, A, B, and C combined into one area 11.25. Good access. Overbank sed trap possible (11.21)	Sheen collection/monitored natural attenuation
SO 11.25 B	11.25	0.5	Oxbow/Tributary	Sheen collection/monitored natural attenuation	Consider removal /hydrovac after spring assessment				Same	Sheen collection/monitored natural attenuation
SO 11.25 C	11.25	0.1	Oxbow/Tributary	Sheen collection/monitored natural attenuation	Consider removal /hydrovac after spring assessment				Better, A, B, and C combined into one area 11.25. good access. Overbank sed trap possible (11.21)	Sheen collection/monitored natural attenuation
SO 11.30	11.50	0.6	Flowing Channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 11.44	11.50	1.0	Emergent Wetland	shouldnt be on SO list since excav last year					Restored former excavation site, no poling was done	Moving off suboil list
SO 11.60			Oxbow						New tactical area, nothing in fall 2011, 3 moderates in spring 2012	Sheen collection/monitored natural attenuation
SO 11.75 A	12.00	0.8	Backwater	Sheen collection/monitored natural attenuation					High quality wetland; same to worse outside polygon	Sheen collection/monitored natural attenuation
SO 11.75 C	12.00	0.1	Backwater	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 11.75 D	12.00	0.0	Backwater	Sheen collection/monitored natural attenuation	If needed enhanced deposition & hydrovac nr rd				Same	Sheen collection/monitored natural attenuation
SO 11.75 E	12.00	0.4	Backwater	Sheen collection/monitored natural attenuation	If needed enhanced deposition & hydrovac nr rd				Same	Sheen collection/monitored natural attenuation

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SO 12.29			Flowing Channel						New tactical area with lights and moderates	Sheen collection/monitored natural attenuation
SO 12.49	12.50	0.1	Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 12.65	12.75	3.2	Backwater	Sheen collection/monitored natural attenuation	Possible enhanced deposition				Better, heavies and moderates to mainly lights, upstream end has lots of blowdown and woody	Sheen collection/monitored natural attenuation
SO 12.69			Flowing channel						New tactical area; moderates and 1 heavy in the spring 2012	Sheen collection/monitored natural attenuation
SO 12.75	12.75	0.0	Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 12.94	13.00	0.0	Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 13.19			Backwater						New Tactical area; 1 moderate	Sheen collection/monitored natural attenuation
SO 13.25	13.25	0.3	Flowing Channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 13.28	13.50	0.0	Flowing Channel	Sheen collection/monitored natural attenuation					Fast moving; near winter 13.40 overbank excavation, still has 1 heavy	Sheen collection/monitored natural attenuation
SO 13.48	13.50	0.9	Backwater	Sheen collection/monitored natural attenuation					Worse; sediment deposition, oil accumulation area; multiple agitation toolbox done previously, high potential to rembolize during next flood	Sheen collection, increased monitoring frequency, consider recovery (dredging/mudcat)
SO 13.52			Flowing Channel						New tactical area with 2 moderates	Sheen collection/monitored natural attenuation
SO 13.60			Backwater						New tactical area with 1 heavy	Sheen collection/monitored natural attenuation
SO 13.62	13.75	0.3	Flowing Channel	Sheen collection/monitored natural attenuation	Consider removal /hydrovac after spring assessment				Better; at launch of Paddlers Grove legacy site	No action necessary
SO 13.73			Forested/Shrub Wetland						New tactical area; overbank ponds not connected during low flow, landowner issues unknown	Sheen collection, increased monitoring frequency, continue to evaluate for possible future recovery
SO 13.84	14.00	0.0	Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 13.85	14.00	0.6	Flowing Channel/Backwater	Sheen collection/monitored natural attenuation	Consider removal after reassesment				Better but fewer poling points	No action necessary

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SO 13.95	14.00	0.1	Flowing Channel	Sheen collection/monitored natural attenuation					Worse (migrated from 13.84 and 13.85?) across main channel. Low flow deposition. Slope drop from Battle Cr dam. Oil will likely move	Sheen collection/natural attenuation; increased monitoring, continue to evaluate for possible recovery
SO 13.97	14.00	0.2	Backwater	Sheen collection/monitored natural attenuation					Better, but less poling along bank with moderates is now dry	No action, but maybe sheen collection/natural attenuation needed if dry area produces moderates
SO 14.09			Backwater						New tactical area, side channel	Sheen collection, increase monitoring frequency, continue to evaluate for possible future recovery
SO 14.17			Backwater						New tactical area	Sheen collection, increase monitoring frequency, continue to evaluate for possible future recovery actions
SO 14.29	14.50	0.8	Backwater	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 14.49	14.50	0.4	Flowing Channel	Sheen collection/monitored natural attenuation					Same to possible a little worse	Sheen collection/monitored natural attenuation
SO 14.56	14.75	2.3	Flowing Channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 14.60	14.75	0.5	Flowing Channel	Sheen collection/monitored natural attenuation					Worse, especially upstream end	Sheen collection/monitored natural attenuation
SO 14.64	14.75	0.0	Backwater	Sheen collection/monitored natural attenuation					Slightlly better	Sheen collection/monitored natural attenuation
SO 14.68	14.75	0.0	Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 14.81	15.00	2.3	Flowing Channel	Sheen collection/monitored natural attenuation	Enhanced deposition	6- Around C5 boat launch	SEKR1477 between heavies and moderates, surrounded by heavies, moderates, and lights	14.75 Enhanced trap with X-mas tree structure at downstream end, sedimentation samplers in place since May 2012	Worse especially downstream of sed trap structure. Downstream of structure natural sediment trap with repeated deposition, many sheen reports at C5	Follow sediment trap monitoring/maintenance plan and consider recovery using dredging/hydrovac (easy road access), especially in oiled area downstream of trap
SO 14.83	15.00	0.1	Backwater	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 15.10	15.25	2.9	Backwater	Sheen collection/monitored natural attenuation			SEKR1495 between moderate, light, and heavy, sourrunded by the same		Much worse against left bank limited fall poling; [BC storm sewer exits into this area and has had oil spills]	Sheen collection, increase monitoring frequency, continue to evaluate for possible future recovery actions
SO 15.23	15.25	10.3	Impounded waters	Sheen collection/monitored natural attenuation		1- At 14.98 Island	SEKR1522 between 2 moderates and a heavy, surrounded by moderates and lights		Worse, high quality vegetation, some sheen reports from downstream end	Sheen collection, increased monitoring frequency, natural attenuation, possibly no other recovery because of high quality vegetation

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SO 15.25			Flowing Channel						New tactical area	Sheen collection/monitored natural attenuation
SO 15.35	15.50	0.3	Backwater	Sheen collection/monitored natural attenuation					Worse	Sheen collection/monitored natural attenuation
SO 15.45	15.50	0.5	Flowing Channel/Backwater	Sheen collection/monitored natural attenuation					Better, control point (surface boom) not there anymore	No action necessary
SO 15.56 LDB			Flowing Channel						New tactical area	Sheen collection/monitored natural attenuation
SO 15.56 RDB	15.75	5.2	Impounded waters	Sheen collection/monitored natural attenuation					Same	Sheen collection, increased monitoring frequency, continue to evaluate for possible future recovery
SO 15.65			Impounded waters			3- Just above Battle Creek Dam			New tactical area, deposition in basin along both sides between road and dam	Sheen collection, increased monitoring frequency, continue to evaluate for possible future recovery (dredging/hydrovac)
SO 16.95	17.00	0.0	Flowing Channel	Sheen collection/monitored natural attenuation	Protection of water intake	1- Rock Tenn			Removal and cleaning of intakes in spring 2012	No action necessary
SO 18.29	18.50	1.7	Flowing Channel	Sheen collection/monitored natural attenuation					Better	Sheen collection/monitored natural attenuation
SO 18.59	18.75	1.2	Flowing Channel	Sheen collection/monitored natural attenuation		3- At Jackson Linear Park Boat Launch			Better	Sheen collection/monitored natural attenuation
SO 18.70	18.75	0.7	Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 18.83	19.00	2.2	Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 18.88	19.00	0.1	Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 18.97	19.00	0.1	Flowing Channel	Sheen collection/monitored natural attenuation					Slightly better	Sheen collection/monitored natural attenuation
SO 19.43	19.50	2.8	Backwater	Sheen collection/monitored natural attenuation	Enhanced deposition with hydrovac	1-	SEKR1934 between and surrounded by lights	X-mas tree structures at downstream end, sedimentation samplers in place since May 2012	Need to check	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery (dredging/hydrovac)

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SO 19.52	19.75	0.4	Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 19.73	19.75	2.6	Flowing Channel	Sheen collection/monitored natural attenuation	Consider removal after assessment				Better	Sheen collection/monitored natural attenuation
SO 19.98			Flowing Channel						New tactical area	Sheen collection/monitored natural attenuation
SO 20.23	20.25	2.9	Flowing Channel	Sheen collection/monitored natural attenuation					Worse; migrated from 19.73(?), or more dense polings	Sheen collection, increased monitoring frequency, continue to evaluate for possible future recovery
SO 20.64	20.75	0.4	Flowing Channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 20.65			Backwater						New tactical area and wwtp outfall "blind channel"	Sheen collection/monitored natural attenuation
SO 21.14	21.25	0.6	Flowing Channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 21.45	21.50	5.7	Backwater/Oxbow	Sheen collection/monitored natural attenuation		9-	SEKR2131 between 2 heavy, 2 moderate, and 1 light and surrounded by similar	21.5 no structure, passive oxbow trap at model rerun stage,sedimentation	Worse	Follow sediment trap monitoring/maintenance plan and evaluate for possible recovery (agitation toolbox?)
SO 21.48	21.50	3.4	Flowing Channel	Sheen collection/monitored natural attenuation					Better	Sheen collection/monitored natural attenuation
SO 21.55	21.75	1.1	Backwater	Sheen collection/monitored natural attenuation					Same to slightly better	Sheen collection/monitored natural attenuation
SO 21.56	21.75	0.2	Flowing Channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 22.16			Flowing Channel						New tactical area	Sheen collection/monitored natural attenuation
SO 22.17			Flowing Channel						New tactical area	Sheen collection/monitored natural attenuation
SO 22.22			Backwater/Flowing Channel						New tactical area, natural deposition area during low flow	Sheen collection, increase monitoring frequency, continue to evaluate for possible future recovery
SO 22.26	22.50	0.3	Backwater	Sheen collection/monitored natural attenuation					Worse	Sheen collection/monitored natural attenuation
SO 22.43			Backwater						New tactical area	Sheen collection/monitored natural attenuation

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SO 22.57			Flowing Channel/Backwater						New tactical area adjacent to 22.82	Sheen collection/monitored natural attenuation
SO 22.82	23.00	1.6	Backwater	Sheen collection/monitored natural attenuation	Consider sediment trap after reassessment				Same; not very depositional. No sediment trap needed.	Sheen collection/monitored natural attenuation
SO 23.0			Flowing Channel						New tactical area	Sheen collection/monitored natural attenuation
SO 23.15			Flowing Channel			1-			New tactical area, more poling coverage	Sheen collection/monitored natural attenuation
SO 23.60	23.75	0.4	Flowing Channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 23.85	24.00	0.4	Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 23.97			Backwater						New tactical area	Sheen collection/monitored natural attenuation
SO 24.39			Flowing Channel						New tactical area	Sheen collection/monitored natural attenuation
SO 24.65	24.75	0.6	Flowing Channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 24.85			Flowing Channel						New tactical area, 5 heavies along north side	Sheen collection/monitored natural attenuation
SO 24.86	25.00	0.1	Backwater	Sheen collection/monitored natural attenuation					Better, Check poling in GIS against suboil list	No action necessary?
SO 24.92	25.00	0.1	Flowing Channel	Sheen collection/monitored natural attenuation					Worse CHECK GIS	Sheen collection/monitored natural attenuation
SO 25.18			Flowing Channel						New tactical area, 4 heavies along north side	Sheen collection/monitored natural attenuation
SO 25.49			Backwater						New tactical area, 1 moderate	Sheen collection/monitored natural attenuation
SO 25.73	25.75	0.5	Backwater	Sheen collection/monitored natural attenuation					Worse	Sheen collection/monitored natural attenuation

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SO 25.87			Flowing Channel						New tactical area	Sheen collection/monitored natural attenuation
SO 25.90			Flowing Channel						High quality wetland with off river oxbow channel; add'l work part of DEQ RI	Natural attenuation; good place to study natural attenuation and toxicity in the future, need more info on landowner
SO 26.05	26.25	1.2	Backwater	Sheen collection/monitored natural attenuation		2-		26.0RDB (Proposed) Phase II enhanced trap w X-mas structure downstream end, model rerun stage	poling limited because dry	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery (dredging)
SO 26.17	26.25	0.4	Backwater	Sheen collection/monitored natural attenuation					Worse	Sheen collection/monitored natural attenuation
SO 26.19	26.25	0.4	Backwater	Sheen collection/monitored natural attenuation					Same, Possible hydrologic connection heavy oxbow area of SO 26.90	Sheen collection/monitored natural attenuation, good place to study connection to oxbow
SO 26.30	26.50	2.0	Backwater	Sheen collection/monitored natural attenuation	(no sediment trap)	6-	SEKR2621 between 2 lights, 1 moderate and 1 heavy,s surrounded by heavies, moderates, and lights		Grouping of heavies in downstream section; Not on the current sed trap list, structure causes backwater effects, natural low flow oil deposition in downstream section, houses nearby	Sheen collection, increased monitoring frequency, need to split polygon, continue to evaluate for possible future recovery (dredging/mudcat) in downstream section
SO 26.37			Flowing Channel						New tactical area	Sheen collection/monitored natural attenuation
SO 26.68	26.75	0.5	Backwater	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 26.90	27.00	0.3	Flowing Channel	Sheen collection/monitored natural attenuation					Worse, moderate area expanded	Sheen collection/monitored natural attenuation
SO 26.96			Oxbow						New tactical area, Shady Bend Campground ponds with moderates and 1 heavy, Enbridge owned, tool box done in the fall, flooded over the winter(?), check overflights	No action necessary, good place for natural attenuation or mesocosm study, potential restoration area
SO 27.08	27.25	0.4	Flowing Channel	Sheen collection/monitored natural attenuation		1- At shady bend boat launch			Better	Sheen collection/monitored natural attenuation
SO 27.13	27.25	0.2	Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 27.39			Flowing Channel						New tactical area with moderates	Sheen collection/monitored natural attenuation
SO 27.40			Flowing Channel						New tactical area with moderates	Sheen collection/monitored natural attenuation

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SO 27.47			Flowing Channel						New tactical area with moderate	Sheen collection/monitored natural attenuation
SO 27.51			Backwater						New tactical area with moderates	Sheen collection/monitored natural attenuation
SO 27.53			Backwater						New tactical area with moderates and 1 heavy	Sheen collection/monitored natural attenuation
SO 27.65			Backwater						New tactical area with moderates and heavies, natural low flow oil deposition	Sheen collection/natural attenuation; increased monitoring frequency, continue to evaluate for possible future recovery
SO 27.74			Flowing Channel						New tactical area with moderate	Sheen collection/monitored natural attenuation
SO 27.94	28.00	0.5	Backwater	Sheen collection/monitored natural attenuation					Worse, natural low flow oil deposition	Sheen collection, possibly increased monitoring frequency, re-evaluate after more assessment
SO 28.14	28.25	0.4	Flowing Channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 28.22	28.25	1.8	Backwater	Sheen collection/monitored natural attenuation		2-	and lights with 1 heavy nearby, otherwise surrounded by nones and lights	28.25 RDB no structure, passive oxbow trap, sdimentation samplers in place since May 2012	Same, had plans for removal previously, no toxicity except chronic toxic unit, some buildup of heavies on downstream end	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery (dredging)
SO 28.28	28.50	0.2	Backwater	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 28.34	28.50	0.2	Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 28.38	28.50	0.2	Backwater/Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 28.48	28.50	0.5	Backwater	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 28.51	28.75	0.2	Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 28.53			Flowing Channel						New tactical area with one moderate	Sheen collection/monitored natural attenuation
SO 28.65	28.75	0.0	Flowing Channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 28.68			Flowing Channel						New tactical area with moderates	Sheen collection/monitored natural attenuation

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SO 28.73	28.75	0.2	Backwater	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 28.81			Backwater/Flowing Channel						New tactical area with moderates and heavy, natural low flow deposition	Sheen collection/monitored natural attenuation
SO 28.97			Flowing Channel						New tactical area with moderates and heavies, natural low flow deposition	Sheen collection/monitored natural attenuation
SO 29.01	29.25	0.5	Flowing Channel	Sheen collection/monitored natural attenuation					Same	Sheen collection/monitored natural attenuation
SO 29.06			Flowing Channel						New tactical area, GIS check, with moderates	Sheen collection/monitored natural attenuation
SO 29.18			Flowing Channel						New tactical area, GIS check, with moderate and heavy	Sheen collection/monitored natural attenuation
SO 29.21			Backwater						New tactical area, with moderates accumulating on upstream end above Augusta Creek	Sheen collection/monitored natural attenuation
SO 29.51			Backwater						New tactical area with moderates	Sheen collection/monitored natural attenuation
SO 29.70			Backwater						New tactical area with moderate and heavy	Sheen collection/monitored natural attenuation
SO 29.80			Backwater						New tactical area with moderates	Sheen collection/monitored natural attenuation
SO 29.95			Backwater/Flowing Channel			4- At Fort Custer boat launch			New tactical area with moderates and heavies; Fort Custer boat launch, natural oil deposition	Sheen collection, possibly increased monitoring frequency, consider recovery (hand scraping)
SO 30.08			Backwater						New tactical area with moderate, mudflat with oligacetes (sp.)	Sheen collection/monitored natural attenuation
SO 30.33			Backwater/Flowing Channel						New tactical area with moderates and heavy, natural low flow deposition	Sheen collection/monitored natural attenuation
SO 30.44			Flowing Channel						New tactical area with moderate	Sheen collection/monitored natural attenuation
SO 30.71	30.75	0.7	Backwater	Sheen collection/monitored natural attenuation		1-			Same	Sheen collection/monitored natural attenuation
SO 30.83			Backwater			1-		30.8 LDB (Proposed) passive trap with no structure	New tactical area, worse, natural oil deposition, dry areas	Follow sediment trap monitoring/maintenance plan and evaluate for recovery (scrape or dredging/mudcat).
SO 31.09			Backwater						New tactical area with moderate	Sheen collection/monitored natural attenuation
SO 31.28	31.50	0.9	Backwater	Sheen collection/monitored natural attenuation					Same or slightly worse	Sheen collection/monitored natural attenuation
SO 31.31			Flowing Channel						New tactical area with moderates and heavy, natural low flow deposition, no poling in fall 2011	Sheen collection/monitored natural attenuation

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SO 31.42			Backwater/Flowing Channel						New tactical area with heavy, natural low flow deposition, no poling in fall 2011	Sheen collection/monitored natural attenuation
SO 31.61			Backwater						New tactical area with moderate	Sheen collection/monitored natural attenuation
SO 31.79			Backwater						New tactical area with moderate and heavies, natural low flow oil deposition	Sheen collection/monitored natural attenuation
SO 32.16	32.25	0.0	Tributary/Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 32.68	32.75	0.3	Backwater	Sheen collection/monitored natural attenuation					Unknown -- heavies from fall may have dried up in spring	Sheen collection/monitored natural attenuation, potential for hand scrape after further evaluation
SO 32.89	33.00	0.1	Tributary/Backwater	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 33.03			Flowing Channel/Backwater			1-	SEKR3301 between 2 lights and 1 moderate surrounded by lights, moderates, and nones	33.0A (Proposed) Phase II enhanced trap w X-mas structure downstream end (CHECK)	New tactical area; Sediment trap, no structure; toxicity sample showed effect	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recvoery (dredging)
SO 33.20	33.25	1.0	Backwater	Sheen collection/monitored natural attenuation	Consider removal after spring assess and monitor			33.0B (Proposed) Enhanced trap with structure at model rerun stage	Worse, re-oiled after 2011 removal, natural low flow oil deposition	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recvovery (dredging)
SO 33.36			Flowing channel						New tactical area with moderates and heavy	Sheen collection/monitored natural attenuation
SO 33.50			Flowing channel						New tactical area with moderates	Sheen collection/monitored natural attenuation
SO 33.56			Flowing channel						New tactical area with moderates	Sheen collection/monitored natural attenuation
SO 33.97			Backwater						New tactical area with moderate NEED GIS check or combine w/ 34.03	Sheen collection/monitored natural attenuation
SO 34.03			Backwater						New tactical area with moderates and heavy, similar to spring 2011, natural low flow oil deposition	Sheen collection/monitored natural attenuation
SO 34.22			Backwater						New tactical area with heavy	Sheen collection/monitored natural attenuation
SO 34.53	34.75	0.5	Backwater	Sheen collection/monitored natural attenuation					Same to maybe worse -- more poling coverage in 2012	Sheen collection/monitored natural attenuation
SO 34.72			Flowing Channel						New tactical area with moderate	Sheen collection/monitored natural attenuation
	MP 35.15 RDB					2- At E-3 boat launch	SEKR3510 between a light and a none surrounded by lights and nones		New tactical area?	Sheen collection/monitored natural attenuation

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SO 35.38			Flowing Channel						New tactical area with moderate	Sheen collection/monitored natural attenuation
SO 35.62			Flowing Channel						New tactical area with moderate	Sheen collection/monitored natural attenuation
SO 35.82			Backwater						New tactical area with moderates	Sheen collection/monitored natural attenuation
SO 35.91	36.00	1.2	Flowing Channel	Sheen collection/monitored natural attenuation					Better	No action necessary
SO 36.05			Backwater					36.1 Enhanced trap with X-mas tree structures, sedimentation samplers in place since May 2012	New tactical area with moderates and heavies, possible migrated from SO 35.91	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery (dredging)
SO 36.08			Backwater						New tactical area with moderate and heavy downstream of 30.1 sed trap	Sheen collection/monitored natural attenuation
SO 36.22			Backwater						New tactical area with moderate	Sheen collection/monitored natural attenuation
SO 36.23	36.25	0.0	Backwater	Sheen collection/monitored natural attenuation					Location looks off, should be part of 36.22?	Sheen collection/monitored natural attenuation
SO 36.27			Backwater/Flowing Channel						New tactical area with moderates and heavies downstream of an island, natural oil deposition area	Sheen collection, increased monitoring frequency, continue to evaluate for possible future recovery
SO 36.42			Emergent Wetland						New tactical area with heavies, natural oil deposition area, probably high quality wetland	Sheen collection/monitored natural attenuation
SO 36.51	36.75	4.0	Backwater	Sheen collection/monitored natural attenuation		1-	SEKR3644 between two lights, surrounded by lights and nones		Possibly better, High quality wetland, sheen coming out of wetland into river, toxicity sampled showed no effects	Sheen collection/monitored natural attenuation
SO 36.53			Flowing Channel						New tactical area with moderates, natural oil deposition area	Sheen collection/monitored natural attenuation
SO 37.75 Islands			Impoundment -delta				SEKR3771 at ds side of islands between 1 moderate and 3 lights, surrounded by mix of lights, modertes, heavies, and 1 none	37.75 Islands passive trap, no structure	Natural oil deposition area	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery

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SO 38.40	38.50	316.3	Impounded waters	Sheen collection/monitored natural attenuation	Consider agitation after reassessment	11- within Morrow Lake Delta and neck 6- within Morrow Lake	SEKR3673 downstream of Delta A between 2 moderates and 1 light, surrounded by mostly moderates and a few lights		Includes all delta, fan, and lake, 4 toxicity samples -- 1 of 4 samples had effects on biomass and growth, need 3-D HD model [is agitation toolbox only possible recovery action]	Subdivide into subareas, evaluate recovery actions after subarea delineations, follow existing sediment trap monitoring and maintenance plan, for heavy oiled areas consider recovery (dredging)
Delta A			Impoundment - delta					Delta A passive trap no structure	Redeposition of oil	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery
Delta EE			Impoundment - delta						Redeposition of oil, high potential to mobilize during flood, most sheen seen during kayak trip of whole river	Sheen collection; consider recovery (dredging) and making an enhanced (deepened) sediment trap
Delta Z -- south shore			Impoundment -delta				of delta, between 3 heavies, 1 mderate, and a light, surrounded by mostly heavies and few moderates	Delta Z passive trap, boom/curtain arrangement	Redeposition of oil, migrated closer to south shore	Follow sediment trap monitoring/maintenance plan and evaluate for possible future recovery.
Delta F			Impoundment -delta				SEKR3700 east of delta F, between 2 moderates and 1 heavy, surrounded by moderates, heavies, and lights		Need to check	Needs further evaluation
Delta SW corner of basin			Impoundment - delta						Had boom/curtain arrangement during 2011 agitation but now has heavy/moderate oil deposition	Needs further evaluation
Neck			Impoundment - neck						Need to check	Needs further evaluation
Fan			Impoundment - fan						Need to check	Needs further evaluation
Lake			Impoundment - lake						Need to check	Needs further evaluation