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Attachment 2

U.S. EPA Volume Estimate for Submerged Line 6B Oil in the Kalamazoo River

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Volume Estimate for Submerged Line 6B Oil in the Kalamazoo River

Subject: Enbridge Energy, Limited Partnership (Enbridge) Line 6B, Mile Post (MP) 608, Marshall, MI, Pipeline Release

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EXECUTIVE SUMMARY

To better understand the effects of the Enbridge Line 6B oil discharge and guide long-term response and remediation activities, the U.S. Environmental Protection Agency (U.S. EPA) requested that its Scientific Support Coordination Group (SSCG) assist in planning a study to quantify the amount of submerged Line 6B oil remaining in the Kalamazoo River. The SSCG is a project-specific assembly of internationally known experts in oil spill science and technology. In response to U.S. EPA's request, the SSCG provided state-of-the-art recommendations covering the following two specific areas for quantification of the Line 6B oil:

1. **Oil fingerprinting analytical methods:** The SSCG identified the latest developments in analytical methods that would enable the identification of Line 6B oil in sediments.

2. **Sediment sample collection:** The SSCG identified improved sampling schemes that would allow an efficient selection of sampling locations and also potentially minimize uncertainty in the overall estimate of the submerged Line 6B oil volume.

Under the direction and oversight of the U.S. EPA, Enbridge implemented these recommendations in conducting its ongoing Submerged Oil Quantification Study. In July and August 2012, Enbridge collected sediment cores from 102 locations along the stretch of the Kalamazoo River affected by the Line 6B oil discharge. Enbridge's laboratory analyzed approximately 400 sediment samples extracted from these cores using U.S. EPA's recommended oil fingerprinting methods. Dr. Gregory Douglas, an expert forensic oil chemist retained by U.S. EPA, interpreted the analytical results and determined concentrations of Line 6B oil in sediment.

Line 6B oil was positively detected in approximately 75 percent of the approximately 400 sediment samples analyzed. The total submerged Line 6B oil volume remaining in the Kalamazoo River as of July and August 2012 was estimated at 180,000 gallons[1]. Overall results for the three impoundment areas (Ceresco Impoundment, Mill Ponds Impoundment, and Morrow Lake Delta) indicate that approximately 12,000 gallons of submerged Line 6B oil was present in the areas with heavy to moderate (H/M) oil

[1] The statistical approach used to estimate submerged Line 6B oil volume also allows for calculation of the uncertainty in the volume estimate. Uncertainty could be reduced through the collection and analysis of additional sediment cores in certain areas of the Line 6B discharge.

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sheening based upon poling[2] observations, with approximately 22,000 gallons present in the Light/None (L/N) areas. The three impoundments contain approximately 80 percent of the Line 6B oil in H/M areas across the entire discharge site.[3]

In summary, the calculated estimate of submerged Line 6B oil quantified in sediment supports other assessment and monitoring results. These multiple lines of evidence indicate that submerged Line 6B oil is present and has migrated into depositional areas along the entire 38-mile-long reach of the Kalamazoo River affected by the July 2010 Line 6B oil discharge.

1.0 INTRODUCTION

This technical memorandum documents the approach developed and methods used to estimate the volume of submerged Line 6B oil remaining in Kalamazoo River sediment as of July and August 2012. For the purposes of this technical memorandum, the Line 6B oil discharge site is defined as the 38-mile-long stretch of the Kalamazoo River with the upstream end at the confluence with Talmadge Creek at Mile Post MP 2.0 and the downstream end at Morrow Dam (MP 39.75).

1.1 Project Background

Enbridge was required to quantify submerged oil remaining in sediment in the Kalamazoo River at the Line 6B oil discharge site as part of the U.S. EPA-approved "Consolidated Work Plan from Fall 2011 to Fall 2012" (2012 CWP). Previous efforts to estimate the remaining quantity of Line 6B oil were hampered by the lack of analytical procedures capable of specifically identifying Line 6B oil. In addition, previous efforts to quantify Line 6B oil did not provide an estimate of the uncertainty associated with the quantification estimate.

To address these concerns, the Federal On-Scene Coordinator (FOSC) requested the SSCG to make recommendations regarding the analytical sampling program, statistical approach to sediment sample location, and sample processing. The SSCG-recommended approach (**Appendix 1**) included the following:

- Sediment core collection procedure
- Laboratory analytical procedure for oil fingerprinting analysis of sediment core samples

[2] Poling is a field technique used to determine whether oil is observable on the water surface after agitation of submerged sediment using a hand-held pole with a 6-inch disc attached to the submerged end.
[3] The Submerged Oil Quantification Study data can only provide very general oil volume estimates for specific areas of the Line 6B discharge site. The Study was not designed to provide detailed maps of oiled sediments in the discharge site area or any portion thereof (such as impoundments). Site poling data for Line 6B oil would be a more appropriate database for detailed mapping of oiled sediments.

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- Generalized Random Tessellation Survey (GRTS) approach for stratified random sampling locations of cores
- Sample processing of core interval samples using Incremental Sampling Methodology (ISM)

Sediment cores were collected in July and August 2012. Shortly after core collection began, U.S. EPA field oversight personnel observed that sediment in the cores exhibited little visual evidence (either under natural or ultraviolet [UV] illumination) of oil sheens, oil droplets, or oil-stained sediments. This observation was problematic because the core processing and core sample interval selection plan was based on visual evidence of oil. Core processing and subsampling activities were halted until a Pilot Test could be conducted to determine if oil was (1) present but undetectable using current visual observation techniques or (2) not present. Core collection continued through August 2012, but the cores were immediately frozen and held in Marshall, MI, to await processing following the findings from the Pilot Test. On November 15, 2012, U.S. EPA reported that the Pilot Test findings demonstrated that visual identification of Line 6B oil in Kalamazoo River sediment cores was not reliable as a method for selecting sampling intervals for laboratory analysis.

On November 20, 2012, U.S. EPA issued a directive to Enbridge to complete the Submerged Oil Quantification Study (Directive). The Directive provided explicit direction regarding the resumption of subsampling and laboratory analysis of the July and August 2012 sediment cores that had been on hold since the start of the Pilot Test, including the following activities:

- Sediment core logging
- Sediment core subsampling
- Sediment sample laboratory oil fingerprinting analysis

The Directive also stipulated that U.S. EPA would provide Enbridge with a methodology for calculating Line 6B oil concentrations in sediment samples based on the oil fingerprinting analysis performed. This methodology subsequently was provided to Enbridge in a letter dated March 1, 2013 (**Appendix 2**).

1.2 2012 CWP Task Summary

As part of the Submerged Oil Characterization task identified in the 2012 CWP, submerged oil quantification was required using information obtained from sediment cores collected after 2011 submerged oil recovery activities were complete. The purpose of the quantification was to assess the volume of oil remaining in sediment in the Kalamazoo River at the Line 6B oil discharge site. Prior submerged oil quantification efforts relied on the measurement of total petroleum hydrocarbons (TPH) as the analytical method to estimate Line 6B oil concentrations in sediment samples. It became apparent that TPH measurements were unsuitable for this task because of (1) the substantial and varying levels of

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interfering organic substances present in Kalamazoo River sediment before the discharge and (2) the inadequate range of hydrocarbons captured by standard TPH analytical methods. An alternative analytical approach was necessary but had not yet been identified.

The 2012 CWP identifies the following basic quantification model to estimate the amount of submerged Line 6B oil:

$$V_{oil_j} = C_{TPH_j}\, \rho_s\, A_j\, D_j\, K\, \rho_{oil}{}^{-1} \qquad \text{(Equation 1)}$$

where

V_{oil_j}	=	Volume of oil for sampling stratum *j*
C_{TPH_j}	=	Representative concentration of oil (TPH) in sediment from stratum *j*
ρ_s	=	Dry bulk density of sediment
A_j	=	Lateral extent of sampling stratum *j*
D_j	=	Depth of oil-impacted layer
K	=	Constant used for unit conversion
ρ_{oil}	=	Bulk density of weathered Line 6B oil

This model is essentially unchanged for the current quantification efforts described in more detail in Section 3.6.

2.0 APPROACH AND METHODS USED TO ESTIMATE VOLUME OF SUBMERGED LINE 6B OIL AS OF JULY AND AUGUST 2012

One major advancement in the methodology provided to Enbridge (**Appendix 1**) for the design of the submerged Line 6B oil quantification effort was the consideration of stratification of the Line 6B oil discharge site into areas of similar sediment type and oiling categories as discussed in Sections 2.1 and 2.2 below. This stratification enabled the efficient selection of sediment core locations (Section 2.3) that allowed site knowledge to be used to generate a statistical characterization of the submerged Line 6B oil volume and that provided for consideration of statistical uncertainty in the volume estimate. Consistent with previous efforts to determine the submerged Line 6B oil volume, sediment coring was selected as the method to provide vertical sediment profiles for the oil fingerprinting samples (Section 2.3). Sediment sample results then underwent oil fingerprinting analysis (Sections 2.4 and 2.5).

2.1 Sediment Types - Geomorphic Framework

The first stratification performed was based on sediment depositional behavior as defined by river

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geomorphology[4]. Tetra Tech, Inc. (Tetra Tech), an Enbridge contractor, first mapped in-channel geomorphic settings in the Kalamazoo River in 2011 for interpreting and predicting areas of sediment and submerged oil deposition (Tetra Tech 2012). The Tetra Tech approach was similar to that used previously for mapping contaminated sediment deposits in other rivers. Geomorphic surface units (GSU) were delineated using a geographic information system (GIS) to facilitate the synthesis of several data sources. In the summer and fall of 2010, Tetra Tech collected channel longitudinal profile and slope data for the Kalamazoo River (Tetra Tech 2011). Fluvial landforms, anthropogenic[5] features, and channel widths were interpreted from aerial orthophotography[6] produced from overflights during leaf-off conditions in April 2011. Streambed sediment type was visually assessed during the Spring 2011 Reassessment poling activities, and observations were classified into eight categories – gravel and larger, sand and gravel, sand, sand and silt, sand over silt, silt over sand, soft sediment, and organic. Water depths measured during the Spring 2011 Reassessment poling were used to guide final refinement of the GSUs. The resultant system of 28 geomorphology-based categories (**Table 1**) was used to delineate areas of the river channel prone to erosion and deposition. Submerged oil occurrence was most frequently associated with depositional GSUs in slower moving areas of the river with soft sediment.

[4] River, or fluvial, geomorphology is the science dealing with the nature of flowing water, sediments, and other products of watersheds in relation to various land forms.
[5] Anthropogenic features have been caused or influenced by humans.
[6] Orthophotography, or orthophotos, have been geometrically corrected to remove distortions caused by terrain, one-point perspective, and to make the scale uniform.

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TABLE 1: GSUs MAPPED BY TETRA TECH IN 2011

Fluvial Setting	Delta and Lake	Anthropogenic Surfaces
Backwater	Delta Bar	Anthropogenic Deposit
Channel Deposit	Delta Island Deposit	Anthropogenic Thalweg
Cut Bank	Distributary Channel	Dam Deposit
Cutoff Channel	Distributary Fan	Engineered Channel
Island	Former Channel	Near bank dam deposit
Island Deposit	Former Floodplain	
Mid-Channel Bar	Former Oxbow	
Near Bank High Energy	Lake Fan	
Near Bank Low Energy	Low Energy Deposit	
Near Bank Moderate Energy	Remnant Terrace	
Oxbow		
Point Bar		
Thalweg		
Tributary		

Tetra Tech mapped approximately 1,200 GSUs along the 38-mile-long stretch of the Line 6B oil discharge site in the Kalamazoo River, from its confluence with Talmadge Creek to the Morrow Lake Dam. The areas of the mapped GSUs ranged from 0.05 to 113 acres, with most areas being less than 0.5 acre.

In 2012, the 28 GSU categories were grouped into nine geomorphic settings for specific application in the submerged oil volume quantification efforts by the USGS and WESTON (U.S. EPA Superfund Technical Assessment & Response Team [START] contractor) (**Table 2**). A smaller number of geomorphic settings was needed for use in a stratified random sampling design for targeting sediment core locations associated with the quantification effort. A simple crosswalk by category was preferred, whereby all mapped GSUs of each category were assigned to a single new setting type, but this approach was not feasible because of the targeted design. (The new delta setting retained spatial collocation with its namesake GSU but was more inclusive geomorphically, being composed from a variety of depositional GSUs that occurred near the original delta GSU.) In the process of the re-grouping, the streambed sediment types were reexamined along with aerial photographs reviewed in a GIS overlay of both data types. This reexamination raised the possibility of some GSUs fitting into more than one geomorphic setting. For example, if a cutoff channel GSU had a gravelly substrate and was connected to the main channel, it was put in the channel deposit setting and not cutoff channel. Regardless of the assigned class in the new grouping, the original line work delineated for mapping the GSUs remained the same and the original GSU category assignments were retained in the GIS attribute table. The nine geomorphic settings used for the submerged oil quantification effort are listed in **Table 2** below. Seven of the settings

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had soft sediment designations as their dominant sediment type: Backwater, Channel Deposit, Cutoff/Oxbow, Delta, Depositional Bar, Impoundment, and Morrow Lake.

TABLE 2: CROSS-WALK BETWEEN GSUs AND GEOMORPHIC SETTINGS

Geomorphic Setting	GSUs Included in Setting
Anthropogenic Channel	Anthropogenic Deposit
Backwater	Backwater, Near Bank Low Energy (Anthropogenic Deposit, Oxbow)
Channel Deposit	Channel deposit, Cut Bank, Cut Off Channel, Delta Island Deposit, Distributary Channel, Near Bank High Energy, Thalweg (Anthropogenic Deposit, Anthropogenic Thalweg, Island Deposit, Mid-Channel Bar, Oxbow, Point Bar)
Cutoff/Oxbow	Cutoff Channel, Oxbow
Delta	Delta Bar, Distributary Fan, Island Deposit, Low Energy Deposit (Backwater, Delta Island Deposit, Distributary Channel, Mid-Channel Bar, Near Bank Low Energy, Near Bank Moderate Energy, Remnant Terrace)
Depositional Bar	Island Deposit, Mid-Channel Bar, Point Bar (Anthropogenic Deposit, Channel Deposit, Cut Bank, Near Bank Low Energy, Near Bank Moderate Energy)
Impoundment	Dam Deposit, Near Bank Dam Deposit (Anthropogenic Deposit)
Morrow Lake	Former Channel, Former Floodplain, Former Oxbow, Remnant Terrace (Anthropogenic Deposit, Island Deposit)
Morrow Lake Fan	Delta (Backwater, Former Channel, Lake Fan, Remnant Terrace, Thalweg)

Note: GSUs listed in parentheses were secondarily grouped in additional strata.

Appendix 3 includes maps of the Line 6B oil discharge site illustrating the distribution of geomorphic settings used in the submerged Line 6B oil volume quantification.

2.2 Oiling Categories - Spring 2012 Reassessment Poling Summary

The second stratification performed was based on field-determined patterns of submerged Line 6B oil released from sediment after agitation. A survey of the relative amount of submerged Line 6B oil sheen and/or globules appearing at the water's surface after agitation had been performed during late Spring 2012 at approximately 7,700 locations using a pole with a 6-inch-diameter disk to agitate sediment. After agitation, observations of oil droplets and sheen released to the water surface were described using previously defined oiling categories of Heavy (H), Moderate (M), Light (L), and None (N). The decision tree diagram for classifying poling observations into these four oiling categories is reported in Enbridge (2011). This poling process included documentation of location coordinates using global positioning system (GPS) units so that the poling information could be accurately mapped.

Poling information from the Spring 2012 Reassessment was compiled, and polygons representing H, M, L, and N areas were identified. **Appendix 3** includes maps of the Line 6B oil discharge site illustrating oiling categories based on the Spring 2012 Reassessment poling information.

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Two further steps were taken. First, the oiling category polygons were overlain on the geomorphic settings to create sampling stratum polygons for the unique combinations of oiling level and geomorphic setting. Second, to provide a larger sample size for descriptive statistics calculations that were later determined to be necessary for handling non-detect results in the oil-concentration data for each sampling stratum, the four oiling categories later were combined into two categories: H/M and L/N. **Appendix 3** includes maps illustrating the final sampling strata based on the overlays of the two oiling categories for each geomorphic setting.

2.3 Sediment Coring

Locations for sediment core samples collected in July and August 2012 were determined using a GRTS design. Prior to field work, core locations were determined randomly within each geomorphic/oiling category or sampling stratum. A total of 102 investigative cores from locations within the Line 6B oil discharge site were collected for oil fingerprinting analysis. **Appendix 3** includes maps showing the locations of the sediment cores collected for the submerged Line 6B oil quantification effort.

At a subset of 32 of the 102 core locations, a paired side-by-side core was collected for bulk density analyses.

Sediment cores for core logging were split and photographed under both visible and UV illumination. Cores were logged for color, texture, and stratigraphic features. At all stages of core logging, the geologist noted any evidence of oil or petroleum in the split core (including globules, sheen, staining, and odors). The top 1 inch of each core was collected for laboratory analysis. Additional vertical core intervals were collected for laboratory analysis, with a preference given to upper stratigraphic layers of soft sediment and also any layer or portion of a layer that exhibited any indication of oil impact. **Appendix 4** provides additional details regarding core locations, subsampling, and processing.

As indicated in Section 1.1, shortly after the start of sediment core logging, U.S. EPA oversight personnel observed little to no visual evidence of oil in the logged sediment cores, which were collected in areas where poling results indicated the presence of submerged Line 6B oil. After completion of a Pilot Test to evaluate visual observation techniques, U.S. EPA concluded that visual observation was unreliable as a guide to select core intervals for laboratory analysis. U.S. EPA's Directive to complete the submerged Line 6B oil quantification included specific instructions for analyzing samples from all upper depositional layers, regardless of the presence or absence of visual evidence of oil. U.S. EPA also selected additional core intervals from previously logged cores for laboratory analysis. These core intervals had been collected and stored frozen at the laboratory pending the results of the Pilot Test. **Appendix 5** includes

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logs for the sediment cores collected for the oil quantification effort. The logs also identify the core intervals collected and submitted for laboratory analysis or for laboratory storage.

2.4 Laboratory Analytical Program

Sediment samples designated for oil fingerprinting analysis were analyzed in accordance with the Analytical Quality Assurance Plan (Enbridge Line 6B MP 608 Marshall, MI, Pipeline Release, Version 2.2, February 28, 2012). Samples were analyzed using the following methods:

- **Polycyclic aromatic hydrocarbons (PAH) and sulfur heterocyclic compounds, including alkyl homologues:** Gas chromatography (GC) with low-resolution mass spectrometry (MS) using selected ion monitoring (SIM)
- **Saturate hydrocarbons:** GC with flame ionization detection (FID)
- **Total extractable hydrocarbons (TEH) representing the total aromatic and aliphatic hydrocarbon content of sample extracts after silica gel clean-up and analysis:** GC/FID
- **Petroleum biomarkers:** GC/MS-SIM

Under contract to Enbridge, Alpha Analytical of Mansfield, MA, performed the laboratory analyses for hydrocarbons and petroleum biomarkers.

2.5 Oil Fingerprinting Data Interpretation

The oil fingerprinting analytical data do not provide a direct measurement of Line 6B oil in sediment. Dr. Gregory Douglas of NewFields, an expert forensic oil chemist, examined the oil fingerprinting data for unique chemical features that would allow Line 6B oil to be distinguished from residual background hydrocarbons in Kalamazoo River sediment (**Appendix 2**). Many potential sources contribute to residual background hydrocarbons in river sediment, including sediment from coal tar sources, runoff containing coal-tar-based road and parking lot sealants and road oils, atmospheric deposition of combustion PAHs, and contributions from non-Line 6B oils. Dr. Douglas determined that the Line 6B oil is enriched in a group of biomarker compounds called triaromatic steroids (TAS). He was able to compare the enriched Line 6B oil to other stable but less discriminating biomarker compounds. Sample-specific biomarker ratios were identified with high stability and resolving power and used to distinguish residual background hydrocarbons from Line 6B oil. This methodology is described in detail in **Appendix 2**.

3.0 QUANTIFICATION VARIABLES

At the foundation of the Line 6B oil volume quantification method are (1) a set of five factors identified as affecting the volumetric quantity of submerged Line 6B oil in a volume of bottom material or bed sediment (Sections 3.1 through 3.5) and (2) the mathematical relationship between these factors and the

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resulting oil volume (Section 3.6). These factors and the mathematical relationship remain conceptually very similar to those reported in Enbridge (2012).

3.1 Line 6B Oil Concentrations in Sediment

An important distinction in the 2012 quantification of oil volume relative to earlier attempts is the availability of a state-of-the-science data set for oil concentrations in sediment samples that distinguishes the Line 6B oil from other types (undifferentiated) of hydrocarbon residues collocated in the sampled bed sediment. Discussion of the various other hydrocarbon compounds and their distinguishing features in the geochemical suite of analytical results or gas chromatographs is beyond the scope of this technical memorandum. "Other residual background hydrocarbons" are defined to include pyrogenic[7] hydrocarbons, plant-derived organics, naturally occurring hydrocarbons from geologic sources in the watershed, and residues from other discharges of hydrocarbon products (whether recent or historical).

The input variable, concentration of Line 6B oil in sediment, refers to the forensic-chemistry determined concentration of Line 6B oil only, as distinguished from other residual background hydrocarbons present in the sediment and expressed as mass of oil per mass of sediment (milligrams [mg] of Line 6B oil per kilogram [kg] of dry sediment). **Appendix 2** provides more details of the forensic and analytical chemistry methods.

Pre-processing of the Line 6B oil concentration data involved two steps. First, the mean value among replicate analyses (usually field duplicates) was computed and retained for further analysis, while replicate records were removed to retain only one concentration per sampled interval of a core. Where the set of duplicates included one censored value (nondetect) and one quantifiable detection, the value of the quantifiable detection was selected; this approach is justified as erring on the side of including all detections. Where all of the replicates were censored values, the value selected was the average of their Line 6B limits of detectability and coded as a nondetection. Second, all censored values were temporarily marked by arbitrarily adding 0.01 to the concentration at the Line 6B limit of detectability. (Uncertainty estimation and subsequent processing of the censored values are discussed in subsequent sections of this technical memorandum.)

Appendix 6 provides the Line 6B oil concentrations for sediment samples collected during this study.

3.2 Sediment Dry Bulk Density

[7] Generated by heat or combustion

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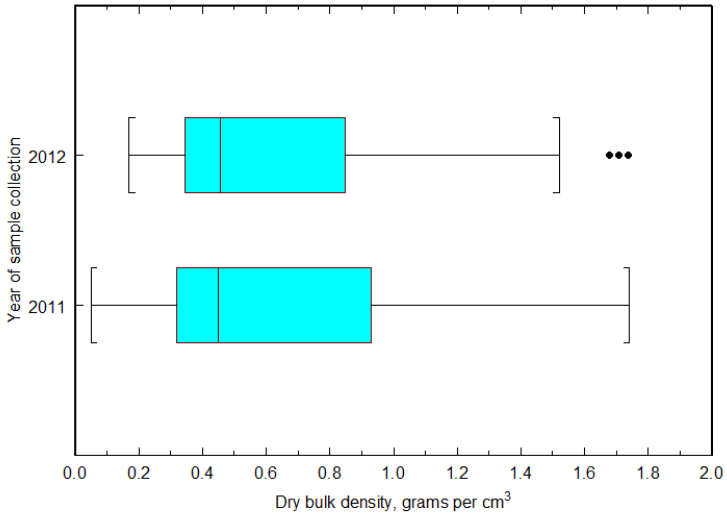
An estimate of the bulk density of the discharged oil at the time of sediment coring is required to convert the estimated quantity of Line 6B oil from mass units to volumetric units. The unit of measure for the input variable, dry bulk density of sediment, is mass per unit volume. The mass unit was converted, if necessary, to correspond to the unit of the denominator in oil concentrations discussed in Section 3.1 resulting from forensic-chemistry analysis of Line 6B oil in sediment sample results, expressed in unit mass of oil per unit mass of dry sediment. Sampled volume can be readily determined from a core interval's physical dimensions. Similarly, if the depth of investigation is known and the areal extent of a sampling stratum is known or calculated, then the sediment volume to which a stratum-mean concentration might be applied also is a straightforward calculation.

The sources of data for dry bulk density estimation were geotechnical laboratory results for cores collected by Enbridge specifically for this purpose in 2011 and 2012. In 2011, there were 110 coring locations, and a paired core was collected at each boring location for bulk density determined by the core method (Colo. State Univ. Soil, Water and Plant Testing Lab., Fort Collins, CO; Grossman and Reinsch, 2002) and for particle-size analyses. In 2012, the paired cores analyzed for bulk density (Driesenga and Assoc., Holland, MI; ASTM D7263) and particle-size determinations were collected at only 32 coring sites. The result for one core from 2011 was considered spurious and was excluded from the data set. Different laboratories analyzed the samples from each year's streambed sediment sampling, so the results were compared between years to verify there was no significant difference between laboratories or between years (**Figure 1**).

FIGURE 1: BOX PLOT DIAGRAMS OF SAMPLING DISTRIBUTION OF DRY BULK DENSITY FOR SHALLOW CORES COLLECTED IN 2011(N = 109) AND 2012 (N = 32)



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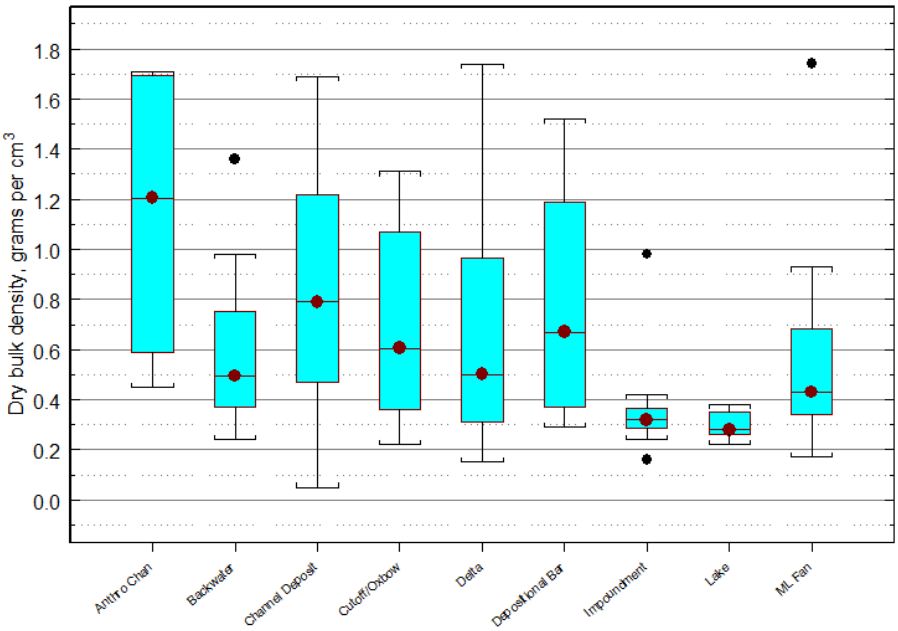
Enbridge's previous oil-quantification calculators had applied a single average dry bulk density of sediment for the entire discharge site, but as expected, there are substantial differences among the geomorphic settings (**Figure 2**).

FIGURE 2: BOX PLOT DIAGRAMS OF FREQUENCY DISTRIBUTIONS WITHIN EACH GEOMORPHIC SETTING (USED FOR 2012 OIL VOLUME QUANTIFICATION STUDY)



Note: Total number of values is 141; see **Table 3** for distribution

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TABLE 3: SUMMARY OF DRY BULK DENSITY OF SEDIMENT FOR NINE GEOMORPHIC SETTINGS

Geomorphic setting	No. of Values (Cores)	Bulk Density, Dry, Mean (MVUE) (g/cm^3)	Bulk Density, Dry, Std. Dev. (MVUE) (g/cm^3)	Bulk Density, Dry, (*predictMVUE* fit) (g/cm^3)
Anthropogenic Channel	4	1.153	0.734	1.105
Backwater	14	0.583	0.289	0.603
Channel Deposit	33	0.937	0.795	0.895
Cutoff/Oxbow	10	0.710	0.465	0.680
Delta	20	0.667	0.499	0.615
Depositional Bar	11	0.767	0.465	0.755
Impoundment	16	0.350	0.131	0.379
Morrow Lake	13	0.296	0.052	0.336
Morrow Lake Fan	20	0.537	0.308	0.538

Notes:
g/cm^3 Gram per cubic centimeter
MVUE Minimum-variance unbiased estimation
Std. Dev. Standard Deviation

Thus, for the 2012 oil-volume quantification, data analysts calculated a representative bulk density for each geomorphic setting. There were no censored values, and the overall sampling distribution was a log-normal frequency distribution, so subsets for each geomorphic setting were analyzed as log-transformed values and descriptive statistics were retransformed using a minimum-variance unbiased estimation (MVUE) algorithm (Quantitative Decisions 2001). Results from the *ln_mvue.xls* calculator were compared with those obtained using an S-Plus function (*predictMVUE*; TIBCO 2008) that fits an analysis of variance (ANOVA) model with variance pooled across all geomorphic strata (**Table 3**).

Although the group mean values obtained by the two methods (ln_mvue.xls and predictMVUE) could be averaged to produce a possibly more robust estimate, the two methods use different procedures to estimate the uncertainty interval for the group mean. These uncertainties cannot be averaged as comparable (one is a parametric estimate [ln_mvue.xls] and the other is a non-parametric estimate). Therefore, the decision was made to stay with one method for both group mean and uncertainty, and the parametric estimates were used to maintain consistency between means and uncertainty estimates. Differences in particle size, organic matter and moisture content generally account for differences in bulk density among sampling strata. No field duplicates were analyzed for bulk density for either the 2011 or 2012 oil-volume quantification investigations.

3.3 Line 6B Oil Density

An estimate of the bulk density of the discharged oil at the time of sediment coring (the weathered oil density) is required to convert the estimated quantity of Line 6B oil from mass units to volumetric units.

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Based on laboratory tests (American Society for Testing and Materials [ASTM] D4052–91, Standard Test Method for Density and Relative Density of Liquids by Digital Density Meter) of Cold Lake blend at 1 °C and 15 °C after 17 percent of initial volume had evaporated (SL Ross Environmental Research 2010; Table 3-3), the average of bulk densities was 0.985 g/cm^3. Enbridge previously reported that about 77 percent of the crude oil released from Line 6B in July 2010 was Cold Lake blend. Diluted bitumen crude oils typically contain more than 17% diluent[8], however, so these laboratory results do not reflect the weathered state of the discharged Line 6B oil.

Oil density varies based on temperature, and the range in density related to a temperature range from 1 °C to 15 °C is 0.008 g/cm^3 for Cold Lake blend (SL Ross Environmental Research 2010).

For the 2012 oil-volume quantification effort, U.S. EPA used 0.985 ± 0.004 g/cm^3 as estimates of the mean and uncertainty of bulk density of Line 6B oil at the time of core collection in Summer 2012. This value is 5.7% larger than the mean oil density value for fresh products discharged from Line 6B (Cold Lake blend [0.9283 g/cm^3] and Western Canadian Select crude [0.9290 g/cm^3]) that was used in previous submerged Line 6B oil volume quantification studies (Enbridge Energy, 2011, 2012).

3.4 Lateral Extent of Sampling Stratum

Oil concentration (mass per mass unit) must be applied to a corresponding sediment mass and volume to produce an oil-volume estimate. The sediment volume is defined by a vertical and lateral extent for each sampling stratum in the stratified study design. The lateral extent of a sampling stratum is a function of the geometric intersection of a geomorphic setting and a submerged-oil category. For the 2011 oil-volume quantification effort, the lateral extent was limited to areas with oil observable on the water surface after agitation of sediment using a hand-held pole (poling); other areas were presumed to contain no (zero) Line 6B oil. In the absence of laboratory analytical data to validate poling results, the Summer 2012 study design included all areas of the Kalamazoo River between its confluence with Talmadge Creek and the Morrow Lake dam (the Line 6B oil discharge site) except the concrete-lined channel reach within Battle Creek, MI.

A stratified-random sampling design produced target coring locations distributed among 34 sampling strata, each of which represented the geometric intersection of a single geomorphic setting (nine types) and a single submerged oiling category (four poling-based classes). Therefore, the lateral extent of a sampling stratum was the summation of the GIS-calculated area of each instance of a unique combination of geomorphic setting and submerged oiling category. The sampling strata generally consisted of

[8] Diluent is a light petroleum (typically natural gas condensate) that is mixed with crude bitumen in order to decrease the viscosity and allow transportation by pipeline.

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multiple, discrete, areal units (having more than one polygon feature). Sampling strata formed as combinations with either the "Morrow Lake" or "Morrow Lake Fan" geomorphic setting were confined to a single, contiguous region of the study area, whereas other sampling strata generally were scattered or located at widely separate locales.

The sources of data for lateral extent were geospatial (digital maps) and included digital maps of geomorphic settings and of submerged oiling category map units (polygons). The two sources for the map of geomorphic settings were (1) the bank lines of the Kalamazoo River digitized by Enbridge contractors from high-resolution, low-altitude aerial orthophotography and (2) the map of geomorphic surfaces also compiled and digitized by Enbridge contractors (Section 2.1, e.g. **Appendix 3**). Use of the map of geomorphic surfaces as is would have resulted in too many categories (that is, would have required too many cores and samples), especially after application of the geospatial intersection analysis with the submerged oiling category map. Therefore, the geomorphic surfaces classification was encompassed by a higher-level stratification of the study area that ultimately produced a map of nine geomorphic settings for use in the sampling design (see Section 2.1). Eleven strata initially resulted but were further collapsed to eliminate two strata (tributary mouth and engineered/concrete-lined channel) that were not areally extensive in order to focus all sampling points within the nine strata having greater extent and importance to the task of submerged Line 6B oil quantification. The mapping accuracy of the geomorphic surfaces is unknown.

The map of submerged oiling categories was obtained as range-classed results from an interpolated surface fit to a numerical recoding of the submerged-oil qualitative observations at poling points. The poling observations were recoded under a scheme where "heavy submerged oil" equals 7, "moderate" equals 5, "light" equals 3, and "none" equals 1. After recoding the points as numeric values, the inverse-distance weighting (IDW) interpolation algorithm was applied using a parameter value, $k = 5$, as the exponent applied to distance. The desktop help reference for the IDW spatial analysis function gives guidance on selection of the exponent value as follows: "An optimal value for the power can be considered to be where the minimum mean absolute error is at its lowest" (ESRI 2011). This guidance suggests two analyses that could yet be undertaken (now that results for 102 cores are available) that could be paired with interpolated estimates to measure the *a posteriori* error rates of the IDW interpolations. In addition, if a subset of the poling observations was reserved as validation data, it could be applied to estimate the root mean squared error (RMSE) or other error measures for IDW-interpolated surfaces constructed for varying values of the distance exponent.

In the absence of data on the mapping accuracy of the geomorphic surfaces and the resulting sampling strata, U.S. EPA selected a method to estimate uncertainty of the lateral extent values based on the

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uncertainty of their linear boundaries inferred based on the scale, density, and quality of source observations. For submerged Line 6B oil category boundaries, sources of uncertainty considered included (1) surveyed point coordinates and (2) field-survey method points (step-out poling points surveyed). The horizontal uncertainty of points surveyed using real time kinetic (RTK) GPS (typically 1 to 2 cm) was considered negligible relative to the other sources affecting lateral extent estimates. The increment used for the step-out poling method was estimated for two areas with a large number of poling observations spread across the river channel: Ceresco Impoundment and the Morrow Lake Delta. GIS spatial analysis ("Near" function in ArcGIS-10) results yielded an estimated "Range-epsilon band width" (as defined by Dunn et al. 1990), or 2 times epsilon, of 38 feet (ft), where epsilon is assumed to equal one-half of typical spacing between points upon which the actual position of the boundary between "included" in versus "outside" of a given submerged oil class was based. It was assumed that a similar ratio of the Range-epsilon to interquartile range (IQR)-epsilon band widths applied to this application as for the Dunn et al. (1990) study, and an IQR-epsilon band width of 5.9 ft (uncertainty ± 2.95 ft) was used. To apply linear uncertainty to polygon area (two dimensions, x and y), Dunn et al. (1990) multiplied the sum of the perimeters of the polygons composing the particular class by the IQR-epsilon band width.

For geomorphic boundaries located at channel bank lines, it was assumed that at the page scale, aerial photomap resolution supported "national map accuracy standards" (an accuracy of 0.02 inch). Then, assuming that channel bank lines were digitized at a scale of 1:600, the linear offset accuracy was calculated to be ± 1.0 ft RMSE. For a theoretical normal distribution, this value corresponds to an IQR of 1.348 ft (± 0.674 ft). By analogy, Dunn et al. (1990) refer to this error, when extended along a full length of bank line, to be the IQR-epsilon band width. For polygon areas between two bank lines, Dunn et al. (1990) indicate that the areal uncertainty equals the bank-formed perimeter times its epsilon band width. (But this does not include additional uncertainty from perimeter segments not formed by channel banks.)

To apply these IQR-epsilon band widths to submerged-oil map units and sampling stratum boundaries, the GIS-measured lengths of all perimeters bounding the set of polygons forming each sampling stratum (34 strata originally; later collapsed to 17 strata) were used. Each line segment also was coded to indicate if it represented a bank line so that the corresponding epsilon band width could be applied to estimate the total areal uncertainty for each sampling stratum.

Table 4 summarizes the results from the analyses and methods discussed above for determining the lateral extent of sampling strata.

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TABLE 4: LATERAL EXTENT OF SAMPLING STRATA USED FOR SUMMER 2012 STUDY

Sampling Stratum	Area of Reporting Stratum (acres)	Area of Sampling Stratum (hectares)	Uncertainty of Area (% of area)	Sum of Perimeters, Channel banks (ft)	Sum of Perimeters, Other (ft)	Uncertainty of Area (hectares)
Anthropogenic Channel – H/M	0.66	0.27	20.7	638.5	1,890.9	0.06
Anthropogenic Channel – L/N	77.31	31.3	1.1	27,224.1	6,541.9	0.35
Backwater - H/M	18.49	7.5	10.2	15,036.8	24,498.5	0.76
Backwater - L/N	77.65	31.4	4.7	67,798.9	38,896.3	1.49
Channel Deposit - H/M	22.59	9.1	18.8	9,990.9	60,556.6	1.72
Channel Deposit - L/N	525.61	212.7	3.3	229,010.9	204,132.4	7.02
Cutoff/Oxbow - H/M	5.62	2.3	9.7	5,376.2	6,835.4	0.22
Cutoff/Oxbow - L/N	19.15	7.8	6.2	20,686.7	12,787.1	0.48
Delta - H/M	34.57	14.0	9.1	9,379.4	44,260.4	1.27
Delta - L/N	43.77	17.7	9.1	16,134.5	55,268.1	1.61
Depositional Bar - H/M	7.95	3.2	16.4	6,461.4	17,751.0	0.53
Depositional Bar - L/N	110.98	44.9	9.1	93,771.5	127,889.4	4.09
Impoundment - H/M	16.36	6.6	7.7	6,059.3	17,191.2	0.51
Impoundment - L/N	43.69	17.7	4.1	11,985.5	23,875.1	0.73
Morrow Lake - L/N	592.67	239.8	0.2	18,600.5	10,449.6	0.40
Morrow Lake Fan - H/M	2.45	0.99	11.5	656.5	4,015.5	0.11
Morrow Lake Fan - L/N	180.20	72.9	0.7	11,537.9	15,109.8	0.49

3.5 Vertical Extent of Investigation

During the 2011 attempt to calculate submerged-oil volume, the depth of investigation was the visually determined depth of oil indications (sheen or globules) observed within the split core examined in the field. For the Summer 2012 study, it was determined that visual indications were not sufficient or reliable for such a determination (K. Lee 2012). Consequently, the vertical extent of investigation was defined for the purposes of the 2012 quantification of submerged Line 6B oil and associated submerged Line 6B oil volume quantification (SOVQ) spreadsheet development to extend to a depth equal to the bottom of the deepest interval where Line 6B oil was detected at a concentration above the Line 6B oil limit of detectability. In tandem with this operational definition, samples from successively greater depths along each collected core were to be analyzed geochemically and forensically until a depth level with an undetectable concentration of Line 6B oil was reached. At the time of preparation of this report, the deepest samples analyzed from numerous cores showed detectable and quantifiable concentrations of Line 6B oil. Across all sampling strata, the mean depth investigated thus far was 1.2 ft; the range among sampling strata mean depths was 0.45 to 1.90 ft.

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The uncertainty of the vertical extent of investigation was estimated using the variance among the several cores collected from within the area of each sampling stratum. That is, if the depths of investigation indicated for the individual cores for a sampling stratum were 1.10, 0.90, 1.30, 1.50, and 0.90 ft, then the mean and standard deviation of the vertical extent of investigation for this stratum would be 1.14 ft and 0.261 ft, respectively.

3.6 Equation for Submerged Line 6B Oil Volume Quantification

As discussed in Section 1.2, the mathematical relation for computing submerged oil volume from the input variables described in this section was consistent with the equation developed for the 2011 submerged-oil volume estimates (Enbridge 2012) as follows:

$$V_{oil_j} = C_{TPH_j}\, \rho_s\, A_j\, D_j\, K\, \rho_{oil}{}^{-1} \qquad \text{(Equation 1)}$$

where

V_{oil_j}	=	Volume of oil for sampling stratum *j*
C_{TPH_j}	=	Representative concentration of oil (TPH) in sediment from stratum *j*
ρ_s	=	Dry bulk density of sediment
A_j	=	Lateral extent of sampling stratum *j*
Dj	=	Depth of oil-impacted layer
K	=	Constant used for unit conversion
ρ_{oil}	=	Bulk density of weathered Line 6B oil

In the 2011 application, Equation 1 was evaluated for the individual vertical increments of uniform thickness (0.1 ft), at least for calculating the representative concentration for each stratum. For the Summer 2012 oil volume quantification study, the following equation was used to estimate the submerged Line 6B oil volume:

$$V_{L6B_j} = \sum_0^{D_j} \left(C_{L6B_{ij}}\, \rho_{s_j}\, A_j\, T_{ij}\, K\, \rho_{oil}{}^{-1} \right) \qquad \text{(Equation 2)}$$

where

V_{L6B_j}	=	Volume of submerged Line 6B oil for the *j*th sampling stratum
$\sum$	=	Summation over the vertical increments, *i*, from *i* = 0 to *i* = D_j; both oil concentration and increment thickness may vary by vertical increment
$C_{L6B_{ij}}$	=	Concentration of oil identified to be from the Line 6B release as distinguished from residual background hydrocarbons for the *jth* sampling stratum

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ρ_{s_j}	=	Dry bulk density of sediment for the *jth* sampling stratum
A_j	=	Lateral extent of sampling stratum *j*
T_{ij}	=	Thickness of a single vertical increment, *i*, of the cores, which does vary (at least at the top of the core)
K	=	Constant used for unit conversion
ρ_{oil}	=	Bulk density of weathered Line 6B oil

There is explicit summation of the right side of the equation across all vertical increments within D_j , the depth of investigation for sampling stratum *j*. An additional change in the equation involves the use of forensic chemistry methods beforehand to provide a concentration, C_{L6B} , that is the oil identified to be from the Line 6B release as distinguished from residual background hydrocarbons. The measurement units were (1) for oil concentration, mg of oil per kg of sediment as dry sediment; (2) for bulk density, g/cm^3; (3) for area, hectares; and (4) for thickness or depth, ft. For these measurement units, and with oil density in grams per cubic centimeter, the value of *K* (constant for unit conversion) is 3.048.

4.0 SUBMERGED OIL VOLUME CALCULATOR SPREADSHEET

An Excel™ spreadsheet tool (the SOVQ spreadsheet) was developed to support attainment of the project objective: a technically sound estimate of the residual volume of spilled, submerged Line 6B crude oil in the Kalamazoo River. The previously existing oil-quantification calculator tool developed for sampling completed in 2011 was not adequate for either the more finely stratified design or the more rigorous analysis of uncertainty in the 2012 study design. Therefore, a new SOVQ spreadsheet calculator was developed specifically for the 2012 study. The scope of SOVQ spreadsheet development was as follows: (1) to retain, to the extent practicable, the concepts embodied in Enbridge's previous oil-quantification spreadsheet (that is, general factors included in the equation for oil volume, the form of the equation, spatially stratified analysis, and use of discrete vertical intervals to standardize treatment of samples across cores within a sampling stratum); (2) to use Line 6B oil concentrations from Dr. Douglas of NewFields that distinguish Line 6B oil from residual background hydrocarbons; (3) to estimate a representative concentration for each sampling stratum by discrete vertical interval; and (4) to estimate a 95-percent confidence interval for the Line 6B oil volume estimates at the sampling-stratum level that takes into account the combined uncertainties for the factors in the equation used for volume estimation.

The SOVQ spreadsheet tool does not calculate the specialized statistics recommended when a data set includes left-censored values (non-detects) among the oil concentrations. Rather, it was presumed that users will apply external statistical analysis software to develop such values, where needed, to refine the required inputs. For the Line 6B volume estimate provided in this technical memorandum, the Kaplan-

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Meier Method was used to address non-detects as implemented in U.S. EPA's ProUCL software (version 4.1, U.S. EPA 2013). See **Appendix 7** for a more detailed discussion.

Procedures embodied in the newly developed SOVQ calculator spreadsheet tool include estimation at the sampling-stratum level of a representative value (and uncertainty) for each of the five factors or terms in the oil volume equation discussed in Section 3.0. In the 2011 calculator, the depth of investigation was the visually determined depth of crude oil indications (sheen or globules) within examined split cores, whereas for the Summer 2012 study, the depth of investigation extends to a depth equal to the bottom of the deepest interval where Line 6B oil was detectable. As was the case in the earlier 2011 calculator spreadsheet, the SOVQ spreadsheet uses multiple vertical intervals ("calculation volumes") as a sampled-depth standardization approach because sediment samples from the various cores for a sampling stratum seldom came from an identical series of depth intervals.

Appendix 7 provides an overview of the various sheets composing the SOVQ spreadsheet calculator workbook. Note that the first section of the workbook is composed of overall summaries of the submerged Line 6B oil volume, and the largest section of the workbook comprises the calculation tables for submerged oil volume and for estimated uncertainty of the oil volume quantities. The latter section contains multiple sheets, one per individual sampling stratum, and (or) one per collapsed stratum in case the user desires a larger sample size per stratum.

The stratum-specific calculation spreadsheets implement Equation 2. **Appendix 7** gives details of the oil volume calculation methods. The concept that both oil concentration and thickness of discrete vertical increment may vary with depth (subscript *i* in Equation 2) is embodied in the spreadsheet by an array of concentrations and a corresponding vector of interval thicknesses. The summation over vertical increments, for *i* equal 1 to D_j (depth of investigation for stratum *j*), is represented in the spreadsheet by a vector of weights applied to the calculated oil volumes vector. The weights restrict the summation to the mean depth of investigation among the cores composing the stratum sample of bottom material.

A combined uncertainty estimate for the submerged-oil volume also was calculated for each discrete vertical interval and for the depth of investigation as a lower and upper 95-percent confidence limit for the estimated Line 6B oil volume. The approach to estimate combined uncertainty for each discrete vertical interval used a modification of the simplified general formula for error propagation, which is a linear combination of the relative variance (that is, the square of the coefficient of variation [CV]). The general formula is as follows (Kirchner 2001):

$$\frac{\sigma_x^2}{x^2} = \frac{\sigma_u^2}{u^2} + \frac{\sigma_v^2}{v^2} + \cdots \frac{\sigma_n^2}{n^2} \qquad \text{(Equation 3)}$$

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Thus, the relative variance in *x* is the sum of the relative variances in each factor, *u*, *v*, etc. A modification of this general approach is needed when covariance between the errors is not negligible. In the case of the 2012 study, results from 30 pairs of detectable concentrations of Line 6B oil and sediment dry bulk density indicated that a significant correlation exists (Spearman's rho = -0.595, p = 0.0014). In this case, the propagation of uncertainty for *x* will include an additional term, to become as follows:

$$\frac{\sigma_x^2}{x^2} = \frac{\sigma_u^2}{u^2} + \frac{\sigma_v^2}{v^2} + 2\frac{\sigma_u \sigma_v}{u \cdot v}\rho_{uv} + \cdots \frac{\sigma_n^2}{n^2} \qquad \text{(Equation 4)}$$

where

ρ_{uv} = Correlation coefficient for the relation between *u* and *v*

To summarize, the combined uncertainty across the multiple discrete vertical intervals and the relative variance results (from Equation 4) for each vertical interval were combined as a weighted-mean relative variance, where the discrete-interval thicknesses were the weights.

5.0 RESULTS

This section discusses the submerged oil volume estimates and uncertainties (Section 5.1), H/M versus L/M oiling categories (Section 5.2), impoundments (Section 5.3), and uncertainty reduction (Section 5.4).

5.1 Submerged Oil Volume Estimates and Uncertainties

Table 5 summarizes the results for submerged Line 6B oil volume estimates for Summer 2012. The total submerged Line 6B oil volume for the discharge site is estimated to have been 180,000 gallons ± 100,000 gallons when summed over all sampling strata. Major contributors to the total volume come from the following strata:

- Channel Deposit – L/N (81,000 gallons)
- Morrow Lake – L/N (46,000 gallons)
- Depositional Bar – L/N (11,500 gallons)
- Morrow Lake Fan – L/N (11,000 gallons)

These four strata are also the four largest strata (on an areal basis) in the discharge site, accounting for approximately 79 percent of the total area.

Depth-averaged, submerged Line 6B oil concentrations in bottom sediment ranged from 76 mg/kg in the Anthropogenic Channel –(L/N stratum) to 1,140 mg/kg in the Depositional Bar –(H/M stratum).

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When standardized for differences in areal extent, the average submerged Line 6B oil volume per acre ranged from 14.7 gallons/acre in the Anthropogenic Channel (L/N stratum) to 218 gallons/acre in the Depositional Bar (H/M stratum).

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TABLE 5: LINE 6B OIL VOLUME ESTIMATES

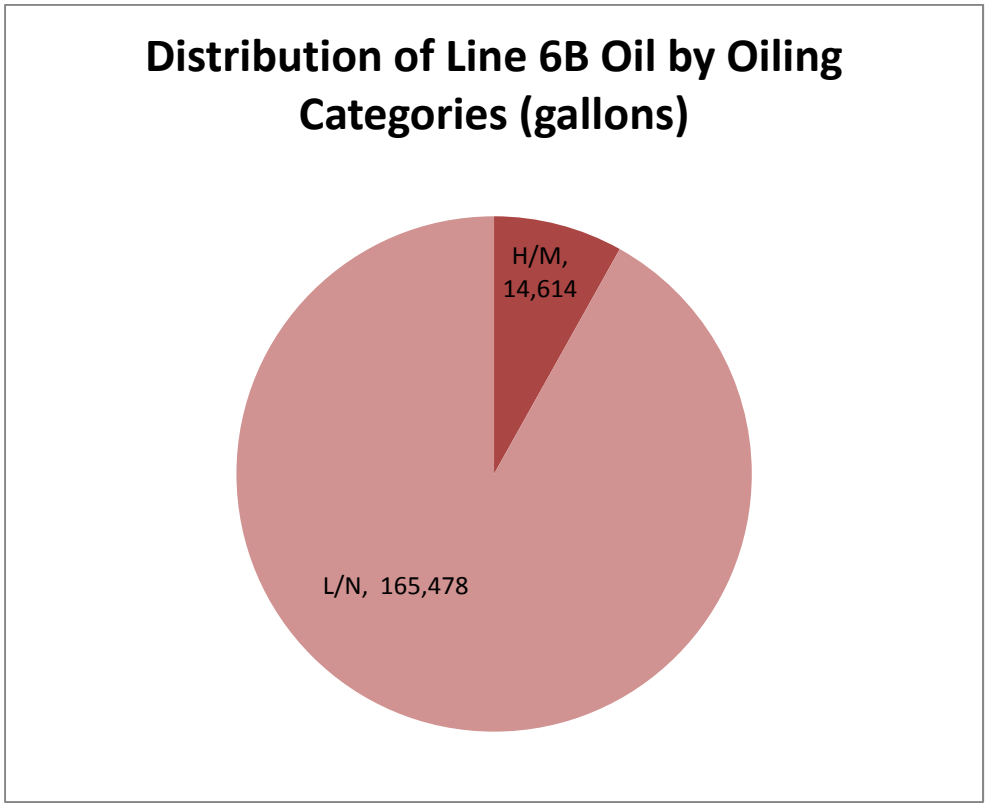
Stratum Name	No. of Cores	Mean Concentration of Line 6B Oil (mg/kg)	Volume of Line 6B Oil (gallons)	Uncertainty of Volume Estimate, Lower-bound (gallons)	Uncertainty of Volume Estimate, Upper-bound (gallons)	Volume of Line 6B Oil (gallons/ acre)	Mean depth of Investigation (ft)	Areal extent (acres)
Anthropogenic Channel – H/M	3	822	110	-51	271	165.6	1.17	0.7
Anthropogenic Channel – L/N	6	76	1,140	-58	2,338	14.7	0.45	77.3
Backwater – H/M	6	249	1,357	175	2,540	73.4	1.12	18.5
Backwater – L/N	6	127	2,400	-1,054	5,853	30.9	1.07	77.7
Channel Deposit - H/M	6	108	1,034	-3,898	5,966	45.8	0.98	22.6
Channel Deposit - L/N	6	279	81,274	-47,193	209,741	154.6	1.30	525.6
Cutoff/Oxbow - H/M	6	200	282	-187	752	50.2	0.77	5.6
Cutoff/Oxbow - L/N	6	173	697	-412	1,805	36.4	0.55	19.2
Delta - H/M	8	428	6,871	-7,319	21,062	198.8	1.36	34.6
Delta - L/N	6	386	6,219	-1,582	14,020	142.1	1.42	43.8
Depositional Bar - H/M	6	1,140	1,735	-1,423	4,893	218.3	0.75	8.0
Depositional Bar - L/N	6	255	11,447	-7,977	30,871	103.1	1.50	111.0
Impoundment - H/M	7	856	3,082	120	6,043	188.4	1.86	16.4
Impoundment - L/N	7	379	4,792	-1,015	10,598	109.7	1.90	43.7
Morrow Lake - L/N	6	957	46,213	9,991	82,436	78.0	1.23	592.7
Morrow Lake Fan - H/M	3	453	142	-24	308	58.1	0.63	2.4
Morrow Lake Fan – L/N	8	710	11,297	-2,120	24,714	62.7	0.89	180.2
Totals	**102**		**180,092**	**77,360**	**282,825**			**1,780**

The vertical extent, or depth of investigation, for which the Line 6B oil volume was calculated may not be finalized as of this writing. The deepest interval analyzed to date from many cores contained a detectable concentration of Line 6B oil, and U.S. EPA potentially could direct that samples from deeper intervals of such cores yet be investigated at the analytical chemistry laboratory. Thus there is potential that additional results for Line 6B oil concentrations in these samples could increase the total estimated volume of Line 6B oil in the Kalamazoo River, but alternatively could decrease the average concentration of oil within a thicker depth of investigation, leading to a decrease in Line 6B oil volume.

5.2 H/M versus L/N Oiling Categories

Figure 3 shows the distribution of Line 6B oil between the two oiling categories (H/M and L/N) summed over all of the geomorphic settings. Approximately 14,600 gallons (8 percent) of Line 6B oil was present in the areas mapped with the H/M oiling category, and approximately 165,500 gallons (92 percent) of Line 6B oil was present in the L/N oiling category areas.

FIGURE 3: SUBMERGED LINE 6B OIL DISTRIBUTION



5.3 Impoundments

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The Line 6B oil discharge site contains three impoundments: the Ceresco Impoundment, Mill Ponds Impoundment, and Morrow Lake Delta. Estimating the submerged Line 6B oil volume for one or all three main-stem impoundments was not an objective of the Summer 2012 sampling design, and none of the sampling strata used for this study exactly corresponds to the extent of the impounded reaches. A set of estimates was prepared based on the sampling stratum-level results as applied to the stratified composition of each impoundment reporting area of interest. However, the estimated Line 6B oil volumes and uncertainty limits developed for the sampling strata could differ from corresponding results based on focused sampling designs and core samples collected from within each impoundment specifically to address these questions.

The distribution of Line 6B oil among the three main-stem impoundments at the Line 6B oil discharge site was summed over all of the geomorphic settings located within the areal extent of each feature. **Appendix 3** provides maps showing the location and extent of each impoundment as used for these summaries. Overall results for the impoundments indicate that approximately 12,000 gallons of submerged Line 6B oil was present in the H/M areas of the impoundments and that approximately 22,000 gallons was present in the L/N areas. The 12,000 gallons represents 82 percent of the site-wide total for H/M areas and 35 percent of the impoundments' overall total volume of submerged Line 6B oil (34,000 gallons). Areally standardized oil volumes in the areas mapped as H/M submerged Line 6B oil were fairly consistent among the three impoundment areas, averaging 155 gallons/acre and ranging from 152 gallons/acre in the Morrow Lake Delta to 164 gallons/acre in the Ceresco impoundment.

Ceresco Impoundment

Within the 53-acre Ceresco Impoundment (**Appendix 3**, MP 4.75 to Ceresco Dam), an estimated 1,500 gallons (28 percent) of Line 6B oil occurred in areas mapped as H/M and an estimated 3,900 gallons (72 percent) occurred in areas mapped as L/N areas. The 1,500 gallons corresponds to 10 percent of all the Line 6B oil in H/M areas across the Line 6B oil discharge site. The "Impoundment" geomorphic setting contained about 94 percent of the Line 6B oil collocated with the H/M submerged Line 6B oil map units at the Ceresco Impoundment and about 62 percent of the Line 6B oil collocated with the L/N map units. With a total Line 6B oil volume of an estimated 5,400 gallons summed over all of the geomorphic settings located within its areal extent, the Ceresco Impoundment contained about 3 percent of the site-wide estimated Line 6B oil volume.

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Mill Ponds Impoundment

Within the 39-acre Mill Ponds Impoundment (**Appendix 3**, MP 14.6 to Kalamazoo Dam), an estimated 2,100 gallons (35 percent) of Line 6B oil occurred in areas mapped as H/M and an estimated 3,900 gallons (65 percent) occurred in areas mapped as L/N. The 2,100 gallons corresponds to 14 percent of all the Line 6B oil in H/M areas across the Line 6B oil discharge site. The "Impoundment" geomorphic setting contained about 79 percent of the Line 6B oil collocated with the H/M submerged Line 6B oil map units at the Mill Ponds Impoundment and about 42 percent of the Line 6B oil collocated with the L/N map units. With a total Line 6B oil volume of an estimated 6,000 gallons, the Mill Ponds Impoundment contained about 3.3 percent of the site-wide estimated Line 6B oil volume.

Morrow Lake Delta

Within the 150-acre Morrow Lake Delta (**Appendix 3**, 35th Street Bridge to Morrow Lake), an estimated 8,300 gallons (39 percent) of Line 6B oil occurred in areas mapped as H/M and an estimated 13,200 gallons (61 percent) occurred in areas mapped as L/N. The 8,300 gallons corresponds to 57 percent of all the Line 6B oil in H/M areas across the Line 6B oil discharge site. The "Delta" geomorphic setting contained about 83 percent of the Line 6B oil collocated with the H/M submerged Line 6B oil map units at the Morrow Lake Delta and about 47 percent of the oil collocated with the L/N map units. With a total submerged Line 6B oil volume of about 21,500 gallons, the Morrow Lake Delta contained about 12 percent of the site-wide estimated Line 6B oil volume.

5.4 Uncertainty Reduction

It is possible to reduce the uncertainty in the overall estimate of submerged Line 6B oil volume by collecting and analyzing additional sediment cores in selected sampling strata where both the magnitude and uncertainty of the estimate are high at present. The uncertainty interval width is inversely proportional to the square root of the number of samples, so increasing the sample size from 4 to 9 samples, for example, is expected to decrease the concentration-related uncertainty by about 33 percent. If some of those additional samples are paired with additional determinations of bulk density of the sediment, additional reduction of the overall combined uncertainty could be realized. If the decision is made to collect and analyze additional cores, emphasis likely would be given also to specific sampling strata where, based on other, independent lines of evidence (such as February 2012 sampling results, sheen observations, site histories, etc.), Line 6B oil volumes were considered to be overestimated or underestimated.

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Another uncertainty issue relates to the apparent presence of Line 6B oil in sediment samples from deeper intervals of cores collected near the downstream end of Morrow Lake. These samples show positive detections of Line 6B oil based on one of the two biomarker ratios used for the calculation of Line 6B oil concentration (ratio of TAS1 and T30). Site information (poling results, absence of spontaneous sheen or globules, absence of oil recovery activities, sampling depth) suggests that samples from this area may be unlikely to contain Line 6B oil. It may be useful to continue the forensic oil investigation of samples from this area to resolve this issue.

6.0 SUMMARY

Previous efforts to estimate the remaining quantity of submerged Line 6B oil were hampered by the lack of specific analytical procedures capable of specifically identifying Line 6B oil. In addition, the previous efforts to quantify submerged Line 6B oil volume did not provide any estimate of the uncertainty associated with the volume estimate. Based on recommendations from the SSCG regarding the analytical sampling program, statistical approach to sediment sampling location, and sample processing, and based on subsequent direction from U.S. EPA, Enbridge developed the 2012 CWP and during Summer 2012 collected 102 sediment cores from the Line 6B oil discharge site to complete the submerged Line 6B oil quantification.

Major advances in the revised approach included in the design of the submerged Line 6B oil quantification effort included (1) application of advanced, higher-resolution analytical chemistry methods and forensic chemical “fingerprinting” to distinguish Line 6B oil from other residual background hydrocarbons, (2) sediment coring locations determined using a model based on probability theory (the GRTS design), and (3) the stratification of the Line 6B oil discharge site into areas sharing similar geomorphic settings and submerged oil poling categories.

The following nine geomorphic settings were used to stratify the discharge site for the submerged oil quantification: Anthropogenic Channel, Backwater, Channel Deposit, Cutoff/Oxbow, Delta, Depositional Bar, Impoundment, Morrow Lake, and Morrow Lake Fan. Seven of the settings had soft sediment designations as their dominant sediment type. The second stratification performed was based on field-measured patterns of submerged Line 6B oil released from discharge site sediments through the poling process. An approximate determination of the relative amount of submerged Line 6B oil had been performed during late Spring 2012 by manually agitating (poling) bottom sediments at numerous locations. After agitation, observations of oil droplets and sheen released to the water surface were described using previously defined oiling categories of Heavy (H), Moderate (M), Light (L), and None

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(N). Two further steps were taken with the stratification of site data. First, Spring 2012 oiling category polygons (developed from poling results) were overlain on the geomorphic settings to create sampling strata polygons for unique combinations of oiling category and geomorphic setting. Second, to support summary statistics calculations that were later determined to be necessary for handling non-detect results in the oil-concentration data for each sampling stratum, the four oiling categories were combined into two categories (H/M and L/N).

Prior to field work, core locations were determined randomly within each geomorphic setting/oiling category or sampling stratum. A total of 102 investigative core locations within the Line 6B discharge site were collected for oil fingerprinting analysis in July and August 2012. Bulk density determinations were paired with 32 of the cores collected for oil fingerprinting determinations. The top 1 inch of each core was collected for oil fingerprinting analysis. Additional core intervals were collected for laboratory analysis, with a preference given to upper stratigraphic layers of soft sediment and also any layer or portion of a layer that exhibited any indication of oil impact.

Many potential sources contribute to residual background hydrocarbons in Kalamazoo River sediment, including nonpoint sources of coal tar, atmospheric deposition of combustion PAHs, road runoff, organic material from decomposed vegetation, and contributions from non-Line 6B petroleum-derived compounds. Sample-specific petroleum biomarker ratios were identified with high stability and resolving power and used to distinguish residual background hydrocarbons from Line 6B oil.

For the Summer 2012 oil volume quantification study, the following equation was used to estimate the submerged Line 6B oil volume:

$$V_{L6B_j} = \sum_0^{D_j} \left(C_{L6B_{ij}}\, \rho_{s_j}\, A_j\, T_{ij}\, K\, \rho_{oil}{}^{-1} \right) \qquad \text{(Equation 2)}$$

where

V_{L6B_j}	=	Volume of submerged Line 6B oil for the *jth* sampling stratum
$\sum$	=	Summation over the vertical increments, *i*, from *i* = 0 to *i* = D_j; both oil concentration and increment thickness may vary by vertical increment
$C_{L6B_{ij}}$	=	Concentration of oil identified to be from the Line 6B release as distinguished from residual background hydrocarbons for the *jth* sampling stratum
ρ_{s_j}	=	Dry bulk density of sediment for the *jth* sampling stratum
A_j	=	Lateral extent of sampling stratum *j*

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T_{ij}	=	Thickness of a single vertical increment, *i*, of the cores, which does vary (at least at the top of the core)
K	=	Constant used for unit conversion
ρ_{oil}	=	Bulk density of weathered Line 6B oil

To implement Equation 2 and supporting calculations, a new SOVQ spreadsheet tool was developed specifically for the Summer 2012 study.

The total submerged Line 6B oil volume for the Line 6B discharge site in 2012 estimated to have been 180,000 gallons ± 100,000 gallons, summed over all sampling strata. Major contributions to the total volume come from the following strata:

- Channel Deposit – L/N (81,000 gallons)
- Morrow Lake – L/N (46,000 gallons)
- Depositional Bar – L/N (11,500 gallons)
- Morrow Lake Fan – L/N (11,000 gallons)

These four strata are also the four largest strata (on an areal basis) in the discharge site, accounting for approximately 79 percent of the total area.

Depth-averaged, submerged Line 6B oil concentrations in bottom sediment ranged from 76 mg/kg in the Anthropogenic Channel – L/N stratum to 1,140 mg/kg in the Depositional Bar – H/M stratum.

Approximately 14,600 gallons (8 percent) of Line 6B oil was present in the areas mapped with the H/M oiling category, and approximately 165,500 gallons (92 percent) of Line 6B oil was present in the L/N oiling category areas.

The Line 6B oil discharge site contains three impoundments: the Ceresco Impoundment, Mill Ponds Impoundment, and Morrow Lake Delta. A set of additional estimates was prepared based on the sampling stratum-level results as applied to the stratified composition of each main-stem impoundment area of interest. Overall results for the impoundments indicate that approximately 11,900 gallons of submerged Line 6B oil was present in the H/M areas of the impoundments. The 11,900 gallons represents 82 percent of the site-wide total for H/M areas. Areally standardized Line 6B oil volumes in the areas mapped as H/M submerged Line 6B oil were fairly consistent among the three impoundment areas, averaging 155 gallons/acre and ranging from 152 gallons/acre in the Morrow Lake Delta to 164 gallons/acre in the Ceresco Impoundment.

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Appendices

1. 8/8/2012 SSCG Recommendations to the FOSC on SOVQ
2. 3/1/2013 Technical Memorandum (G. Douglas, NewFields)
3. Overlay of Geomorphic Settings and Spring 2012 Poling Results, with core locations
4. Enbridge Submerged Oil Volume Quantification (Field Guide)
5. Sediment Core Logs
6. Line 6B Oil Concentrations in Sediment Samples
7. User's Guide for SOVQ Spreadsheet

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Appendix 1

8/8/12 SSC Recommendations to FOSC on SOVQ

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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: Submerged Oil Spring 2012 Volume Quantification
Enbridge Line 6B MP 608, Marshall, MI Pipeline Release

Dear Mr. Dollhopf,

Attached is my recommendation for methodologies to define methods of estimating the quantity of submerged oil present as a result of the Enbridge Line 6B Oil Spill based on the scientific opinions that I have received. The attached document represents additional response to the Federal On-Scene Coordinator's (FOSC) Charge No. 1 to the SSCG (as amended in your letter of March 21, 2012):

> 1. (a) Provide an evaluation of viable analytical and sampling approaches (such as sampling design, sample collection and sample processing/handling) including benefits and disadvantages for each, to quantify the amount of submerged oil in the Kalamazoo River sediments attributable to the Enbridge Oil pipeline Release.
>
> b) Provide a recommendation for the best analytical and sampling approach to accomplish this goal.

Further, the evaluations and recommendations included in the attachments are consistent with the FOSC's charge #1 to SSCG (listed above):

- To quantify the volume of submerged oil, and Line 6B oil fraction thereof, remaining in riverine sediment of the impacted area (cf. CWP, p. 15).
- To quantify the change in oil volume since Fall 2011 sampling (cf. CWP, sec. 3.2.1, p. 11).
- To identify implications of the remaining oil volume for USEPA FOSC's tactical operations plan and Incident response end points, SSCG - Concept white paper, Nov. 17, 2011 [p. 2, Objectives]).

The individual members of the SSCG have provided me with their recommendations for the Spring 2012 submerged oil volume quantification around the following key components of the study design:

- Stratification of impacted area for sampling to quantify Line 6B residual oil.
- Characterization of background hydrocarbons.
- Spatial distribution of sample locations.
- Methods for collecting sample cores.

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- Methods for selecting core-layer samples for analytical chemistry, geotechnical testing, logging, or preservation for potential future use.
- Methods for processing sample cores and core-layer samples.

The attached document represents my synthesis (as a Scientific Support Coordinator) of the applicable opinions and recommendations received from individuals involved with the Chemistry, Fingerprinting and Biodegradation Subgroup of the Scientific Support Coordination Group (SSCG). The individual scientific opinions provided to me are based on each scientist's 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 document, or are otherwise documented in supporting documents maintained in the response files.

I recommend adoption of this technical approach to further develop the understanding of the quantity and sources of submerged oil for the purposes of oil recovery from the Kalamazoo River.

Sincerely yours,

/s/

Thomas Graan, Ph.D.
Scientific Support Coordinator to the FOSC for Enbridge Line 6B Oil Spill
Weston Solutions, Inc., Region 5 S.T.A.R.T. Contractor

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RECOMMENDATION TO THE FOSC

SUBMERGED OIL VOLUME QUANTIFICATION SAMPLING DESIGN AND METHODS FOR SEDIMENT SAMPLING, PROCESSING, AND ANALYSIS

ENBRIDGE LINE 6B MP 608 MARSHALL, MI PIPELINE RELEASE
AUGUST 8, 2012

BACKGROUND

The Federal On-Scene Coordinator-approved Consolidated Work Plan (*CWP; Enbridge Energy, 2011*) recognizes the need for at least two additional studies to re-quantify the volume of residual submerged oil in the impacted area and to attempt to distinguish the oil volume that originated from the Enbridge Line 6B Incident release from unrelated oil. The timing for these studies corresponds to conditions in Spring 2012, following a spring flood but prior to commencement of any submerged-oil recovery efforts, and in Fall 2012 (CWP, p. 21). The quantification of submerged oil is discussed in the CWP as part of the Submerged Oil Characterization, and was described as being critical to understanding submerged oil fate and transport (CWP, sec. 4.0, p. 14). While the Submerged Oil Quantification section of the CWP does call for sediment cores to be collected (CWP, sec. 4.5), the coring methods, core sampling, and associated plans are discussed separately, in the plan's Hydrodynamic Assessment section (CWP, sec. 4.2.4). Collection of new cores in 2012 was explained as a help to not only the effort to quantify submerged oil, but also to determine submerged-oil transport rates and depositional patterns.

The evaluations and recommendations conveyed herein will follow the pattern of the CWP by separating submerged oil quantification and sediment sampling into distinct sections of the document outline. Linkages to both the CWP and the Federal On-Scene Coordinator's (FOSC) charges to the Science Support Coordination Group (SSCG) will be made clear wherever applicable. The overall purposes of the recommendations are to improve upon the methods used to quantify submerged oil in 2011, and to refine the existing protocols for sediment sampling (Enbridge, 2011, SOP EN-202, Nov. 2011) and core processing.

The following principal objectives (linked to the CWP and the FOSC's charge #1 to SSCG) of the planned submerged oil reassessment and re-quantification studies are recommended to remain essentially unchanged:

- To quantify the volume of submerged oil, and Line 6B oil fraction thereof, remaining in riverine sediment of the impacted area (cf. CWP, p. 15).
- To quantify the change in oil volume since Fall 2011 sampling (cf. CWP, sec. 3.2.1, p. 11).

This document represents a synthesis of the applicable opinions and recommendations received from individual scientists and engineers of the SSCG.

SCOPE

Individuals of the SSCG evaluated the protocols used to collect sediment cores and sediment-layer samples for the Fall 2011 submerged oil quantification task. Beyond that evaluation, the FOSC explicitly requested a review of the oil quantification study of Fall 2011 to demonstrate the potential value of incorporating a statistically based design, together with recommendations (FOSC USEPA, written communication, Mar. 21, 2012). The third aspect of the evaluations was to review the previously recommended, general Analytical QA Plan (USEPA-SSCG, 2012). Fourth, the analytical results from the February 2012 sediment samples collected for aquatic acute-toxicity studies were considered.

Out of the findings of these evaluations, individuals of the SSCG developed recommendations for the Spring 2012 submerged oil quantification study. These recommendations have implications for key components of the study design:

- Stratification of impacted area for sampling to quantify Line 6B residual oil.
- Characterization of background hydrocarbons.
- Spatial distribution of sample locations.
- Methods for collecting sample cores.
- Methods for selecting core-layer samples for analytical chemistry, geotechnical testing, logging, or preservation for potential future use.
- Methods for processing sample cores and core-layer samples.

STRATIFICATION OF IMPACTED AREA

The application of distinct, mappable geomorphic settings was recognized in the CWP to have value for such tasks as testing the cohesion and erodibility of streambed sediment (CWP, sec. 4.2.2), mapping the extent of areas categorized to have "light" submerged oil (CWP, sec. 4.5.3.3), measurement of current-velocity profiles (CWP, sec. 4.2.3), and monitoring of suspended sediment and associated hydrocarbons being actively transported (CWP, sec. 4.2.5).

Potential calculation of submerged oil volumes within specific geomorphic strata was discussed in the CWP (sec. 4.5.2.1) and an evaluation of various geomorphic surface types as part of the statistical evaluation of TPH results was proposed (sec. 4.5.4). Moreover, up to 10 distinct geomorphic settings were described for the riverine section of the impacted area (CWP, Figure 7.2). Thus, the use of geomorphic mapping information to stratify the impacted area for the purpose of developing an objective, balanced sampling design is not only appropriate but a logical progression from the discussion of options in the CWP.

Evaluations

The statistical value of stratifying a target population for sampling is to reduce the amount of random variation by accounting for a significant fraction of total variance of the primary variable under study that is systematically associated with a supporting characteristic, e.g., spatial or categorical variable. For stratification to be effective, the within-stratum variance should be less than the between-stratum differences. The primary variable under study is the quantity of submerged oil from the Line 6B release that is present in streambed sediment of the impacted area.

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Forensic data should help to separate the background hydrocarbon content from the oil. Until forensic chemistry approaches were first applied to this Incident in February 2012, there were no samples for which analysis had attempted to differentiate Line 6B oil content from total hydrocarbon content. However, the February 2012 samples did not include a sufficient number of oil droplet/globule/sheen samples to allow reliable analysis of the Line 6B oil concentration per unit mass of sediment. Subsequently developed protocols for collecting samples of sheen and globules to document the oil's chemical signatures are being applied to archived samples and have been applied to samples from cores collected in Spring 2012 so that the mass of oil (TPH plus non-chromatographed compounds) may be determined and its source identified with confidence.

In review of Fall 2011 submerged oil quantification (Appendix 1), Zach Nixon (RPI) used GIS overlay analysis with a digital map of geomorphic strata (modified from Enbridge/TetraTech's geomorphic surfaces map) to identify the geomorphic unit type from which each Fall 2011 sediment core was collected. Despite 100 of 110 cores being from areas that, prior to oil recovery work, had shown indications of having "moderate" to "heavy" submerged oil, the uppermost layer of the cores had TPH concentrations that tended to differ among geomorphic strata, although results were not statistically significant overall (ANOVA, $p = 0.20$).

TPH concentrations in Fall 2011 appeared highest on average for four geomorphic strata that are typified as low-gradient and low-velocity environments (impoundments, cutoff/oxbows, backwaters, and anthropogenic channelized reach). These results, together with the recognition that analytical methods used in Fall 2011 did not allow for any within-sample adjustments for level of background hydrocarbons present in the TPH concentration, offer some additional rationale for applying a geomorphic stratification approach to design the Spring 2012 submerged oil quantification. The correspondence of TPH concentration with low-gradient and low-velocity environments was not unexpected, to the extent that both background TPH and submerged oil are preferentially associated with fine sediment (silt / clay) and organic matter, both would be expected to be strongly affected by geomorphic setting. These associations can be exploited during data analysis by normalizing the concentration data to factors (i.e., particle size, organic matter content and bulk density) known to affect sediment-associated organic contaminants.

A second approach to stratification also was evaluated: the use of the surrogate, point-screening results from poling, as generalized and mapped to form polygonal areas, to define two or more strata of expected sediment-oiling intensity. There is available information to suggest this would be an effective stratification approach: the SSCG review of Fall 2011 SO quantification (Appendix 1) reported that the uppermost layer of the cores had TPH concentrations that significantly differed (t-test, $p=0.002$) between two strata, i.e., cores collected from within the polygons delineating area of moderate to heavy poling results, and cores collected from outside those areas.

The recommended alternative for stratification of the impacted area is to use a two-way stratification where ten (10) fluvial geomorphic strata by two (2) Spring 2012 poling categorical strata are applied in combination to define up to 19 total strata as a framework for sampling (table 1). Because the poling results are based only on response from the upper layer(s) of the streambed sediment, samples of deeper layers of sediment should be apportioned using the geomorphic strata alone (table 1). Note that table 1 shows hypothetical scenario for number of cores by stratum that includes only tier-1 counts, i.e., makes the assumption that oil

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concentration variance within each stratum calculated from the tier-1 core-sample results will be small enough to achieve desired precision in confidence interval for each stratum-average concentration. Large hypothetical count for Impoundment stratum is, in part, an expectation that this geomorphic stratum may be expanded to include deeper parts of Morrow Lake, west of the sediment fan (Lake stratum).

	[Values are counts allocated to stratum-category combination; NA, none allocated because combination did not occur within impacted area.]											
		Geomorphic stratum										
Count units	Submerged oil screening category	Impound-ment	Cutoff / oxbow	Deposi-tional bar	Backwater	Channel deposit	Delta	Sediment fan in lake	Lake (beyond fan)	Tributary mouth	Anthropo-genic channel	Total
Cores	Heavy to moderate	10	5	5	5	3	8	5	NA	5	5	51
Cores	Light to none	5	5	4	5	3	3	5	7	5	4	46
Cores	**Subtotal**	15	10	9	10	6	11	10	7	10	9	97
Additional samples from cores included above	Sediment layer >1 ft below water-sediment interface	8	5	4	5	3	6	5	4	5	4	49
Samples	**Total**	38	25	22	25	15	28	25	18	25	22	243

Table 1. Two-way stratification for allocating spatially balanced statistically based sample of streambed sediment across area impacted by Enbridge Line 6B incident. (Core counts are hypothetical tier-1 counts, and do not include cores from upstream reference sampling nor quality-control duplicates. Two samples were assumed would be collected per core from the uppermost 1-ft thickness of sediment. Also, some stratum-category combinations may not actually occur, and core count value then would be "NA")

Whatever analytical chemistry method is selected for quantifying oil in sediment cores in 2012, it is likely that a spatial interpolation method involving strata means/medians and strata dimensions will be used to estimate total amount of oil. Given this expectation, it is important that sampling effort is balanced appropriately to minimize bias and maximize precision.

This section addresses neither the analytical methods proposed for use in oil quantification (see *Analytical Scope* section) nor methods for distinguishing oil in sediments from background (see *Background and Upstream Reference Samples* section), but focuses on spatial sampling design for use with whatever oil chemistry analytical methods are selected. Present understanding of factors affecting the differences in submerged oil concentrations across the impacted area guided the evaluation of sampling strata. Relations between TPH concentration and poling methods informed only the sampling design, and are not a proposed method for Spring 2012 quantification of submerged oil. In all designs proposed for 2012, it is assumed that the selected analytical method will measure oil concentrations separate from background regardless of the relative concentrations of these two values.

A ***model-based approach*** would use existing data to predict oil presence and quantity based on other variable(s) – like space (geostatistical model), geomorphic surface, depth, hydrodynamics, etc. Sampling could be random, but this is not required. To produce a sensitive model, existing data should represent a wide range of possibly related covariates, and sampling often is designed to span the gradient of values for potential predictive covariates. Model-based methods are often

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best when: (1) it is desired to map the property of interest; and (2) a strong correlation exists between the property of interest and covariates.

The total amount of submerged oil is the primary quantity of interest – suggesting a survey-based approach. Understanding how such oil is distributed across space would also be of interest, but the distribution of submerged oil is strongly spatially patterned and appears to be clearly affected by known spatially distributed covariates. The review of 2011 oil quantification efforts (Appendix 1) demonstrated evidence that the amount of submerged oil in 2012 is likely to be strongly related to poling results and to geomorphic surface types. Further, spatial variogram analysis indicated that oil concentrations vary widely over small (<10 m) spatial scales. This result means that pure interpolation approaches would require unrealistically large numbers of samples. To make best use of known covariates to sample efficiently, a hybrid approach known as ***model-assisted survey sampling*** is recommended. The recommended hybrid approach is a ***spatially balanced, stratified Generalized Random Tesselation survey (GRTS) design*** (Stevens and Olsen, 2004). Such a survey design has the advantages of:

- Likely being more efficient than simple random sampling
- Being spatially balanced across the area of interest in the event that geostatistical models (interpolation) are required/helpful
- Leveraging known information about the relationship between covariates and submerged oil presence and quantity
- Having most of the advantageous statistical properties of a simple random sample
- Can include an oversample to accommodate non-response or no-access issues in the field
- Generating data useable for design-based estimates of total submerged oil properties via a variety of frequentist or Bayesian methods

RECOMMENDED STRATIFIED SEDIMENT SAMPLING DESIGN

This approach involves the following two-step process for determining stratification: collecting Spring 2012 Reassessment poling data as per previous years, and generating a stratified GRTS spatial sample using strata based on a combination of (1) 2012 poling results (or spatially interpolated products thereof—e.g., mapped polygons of similar submerged-oil response), and (2) mapped geomorphic surfaces reclassified to better manage the number of two-way strata resulting from the combination. Following the collection of sediment cores at the indicated sampling locations, and use of the selected analytical quantification method to determine hydrocarbon concentrations, the previously approved method (i.e., "calculator") would be applied to estimate median or mean contaminant concentrations (separate from background) within these strata.

Advantages: This approach uses data collected at a stratified sample of all potentially affected locations, so results can be used to derive a more precise and unbiased estimate of remaining subsurface oiling. This approach is also spatially balanced.

Disadvantages: If a method for quantifying oil in sediments directly from poling results is derived, the poling results cannot be considered a sample of all locations. Poling results may be used, but only to stratify sediment sampling for other analysis. Sampling must be performed after poling because sediment sampling is dependent upon poling results. This approach is somewhat logistically complex.

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BACKGROUND AND UPSTREAM REFERENCE SAMPLES

Previous rounds of submerged oil quantification, as well as the preliminary results from samples collected in 2012 for toxicity tests, suggest that concentrations of Enbridge Line 6B oil remaining in the streambed sediment of the impacted area may be of the same order of magnitude as that of background and other anthropogenic hydrocarbons. Possible sources of the background oil include historical industrial releases in the watershed, spills or natural seepage of oil from geologic formations upstream, and runoff containing oil and grease from roads or other surfaces. Atmospheric sources include both local and distant combustion of wood and hydrocarbon fuels that result in release of PAHs and other hydrocarbon emissions that are subsequently deposited on water bodies or other surfaces from which they become entrained by runoff and eventually reach streams.

To achieve the objectives of the submerged oil quantification, distinguishing Line 6B oil from that originating from other sources is necessary. Forensic chemistry-based approaches can be applied to mixing models when the chemical signature of each significant source is sufficiently resolved, and should be able to allocate quantitatively the mixed signature seen in samples from streambed cores among the several sources. Work has already begun using archived samples to address the source signatures, but additional samples may be needed if variation of the chemical signature within a source(s) is large relative to its difference between sources. To better ensure robust resolution of source chemical signatures, it is recommended that (1) duplicate cores be collected at each sampling location, and (2) one of the duplicates be frozen in the vertical position promptly after collection for processing the next day in the field, whereas the other be opened unfrozen at a field processing station, where one-half of that core would be used for core description (protocol enhancements discussed below) and subsequently processed to collect a sample of oil globules, if present, which would be frozen and archived for possible later analysis if needed for the source-resolution purpose; and from the other half of the core a sample would be collected for determinations of total organic carbon (TOC) and particle-size distribution (PSD).

An independent line of evidence for characterizing the background sources' contribution of oil in streambed sediment is possible through sampling of cores representative of analogous riverine environments outside the impacted area and unaffected by the Enbridge Line 6B release. This approach was attempted during the Fall 2011 SO quantification study, but has not previously been used to submit core-interval samples for the high-resolution analyses recommended in the Analytical QA Plan (USEPA-SSCG, 2012).

During the spring 2012 sampling, the effectiveness of the forensic analytical methods with the highly disturbed sediment from impacted areas is being validated, and direct comparison to reference sites (where any hydrocarbons present would be from other sources) is an important aspect of the validation. Therefore, it is recommended that cores be collected for the 2012 SO quantification in about equal numbers from each of the unaffected areas—i.e., Battle Creek and the Kalamazoo River upstream from the impacted area. If this were the primary approach for quantifying background concentrations, it would be important to represent as many of the Table 1 geomorphic strata as occur in the unaffected areas; however, as a secondary line of evidence, and in view that a few previously archived samples might also contribute evidence, a less intensive effort could suffice. Collection of 4 or 5 cores from each of two depositional geomorphic strata, and including some from each stream, is suggested—i.e., a total of 8 to 10

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cores from unaffected areas. The uppermost 2.5-cm interval from each core would be submitted for analytical chemistry, whereas other layers of each core could be archived frozen. Core collection and processing of these "background" cores should be the same as for cores collected from the impacted area. The purpose of these background cores is independent validation that hydrocarbons in non-impacted areas have a signature of alkylated PAHs and biomarkers that is distinct from Line 6B oil. Previously archived samples that potentially could also assist with the purpose of background cores include three samples from each stream collected by Ponar sampler in February 2012; but since those samples are mixtures of the upper 5 to 6 inches, the oil signatures in the initial bulk sediment samples analyzed were less distinct.

SPATIAL DISTRIBUTION OF IMPACTED-AREA SAMPLES

Draft maps of the geomorphic strata developed by USGS and USEPA/START personnel from the previously mapped geomorphic surfaces (Enbridge/TetraTech) are shown as Figure 1 below. The maps show a reclassification of the numerous categories of geomorphic surfaces to produce a set of 13 categories; however, the three categories without a color symbol (Engineered channel, Exclude, and Island) are not within the sampling domain for the Spring 2012 oil quantification study. Thus, there are 10 categories that serve as the geomorphic strata for the two-way stratification of the study area. The concrete-lined Engineered Channel is a reach unsuited for this study and contains few, if any, sediment deposits. Island areas are not submerged at the flow conditions during which cores are collected, and their deposits do not fall within the operational definitions for submerged oil. Neither the Island nor Engineered Channel areas were sampled as part of the 2011 studies undertaken for the purpose of quantification of submerged oil. With the expansion of the impacted area in Spring 2012 to include all of Morrow Lake, additional areas that also were not sampled as part of the 2011 oil-quantification studies are now included in the study design for 2012. As the geomorphic surfaces map units that cover those areas were evaluated and reclassified, one polygon that encompasses an island was identified as not quite fitting into any of the 10 categories. It had been mapped as an Island Deposit with sand and gravel substrate in the geomorphic surfaces map. Clearly it lies beyond the sediment fan which occupies the east end of the lake, but its substrate texture contrasts strongly with the soft sediment of the central and western areas of the lake. Rather than have a single such polygon comprise an eleventh geomorphic stratum, we elected to exclude this unit from the study area.

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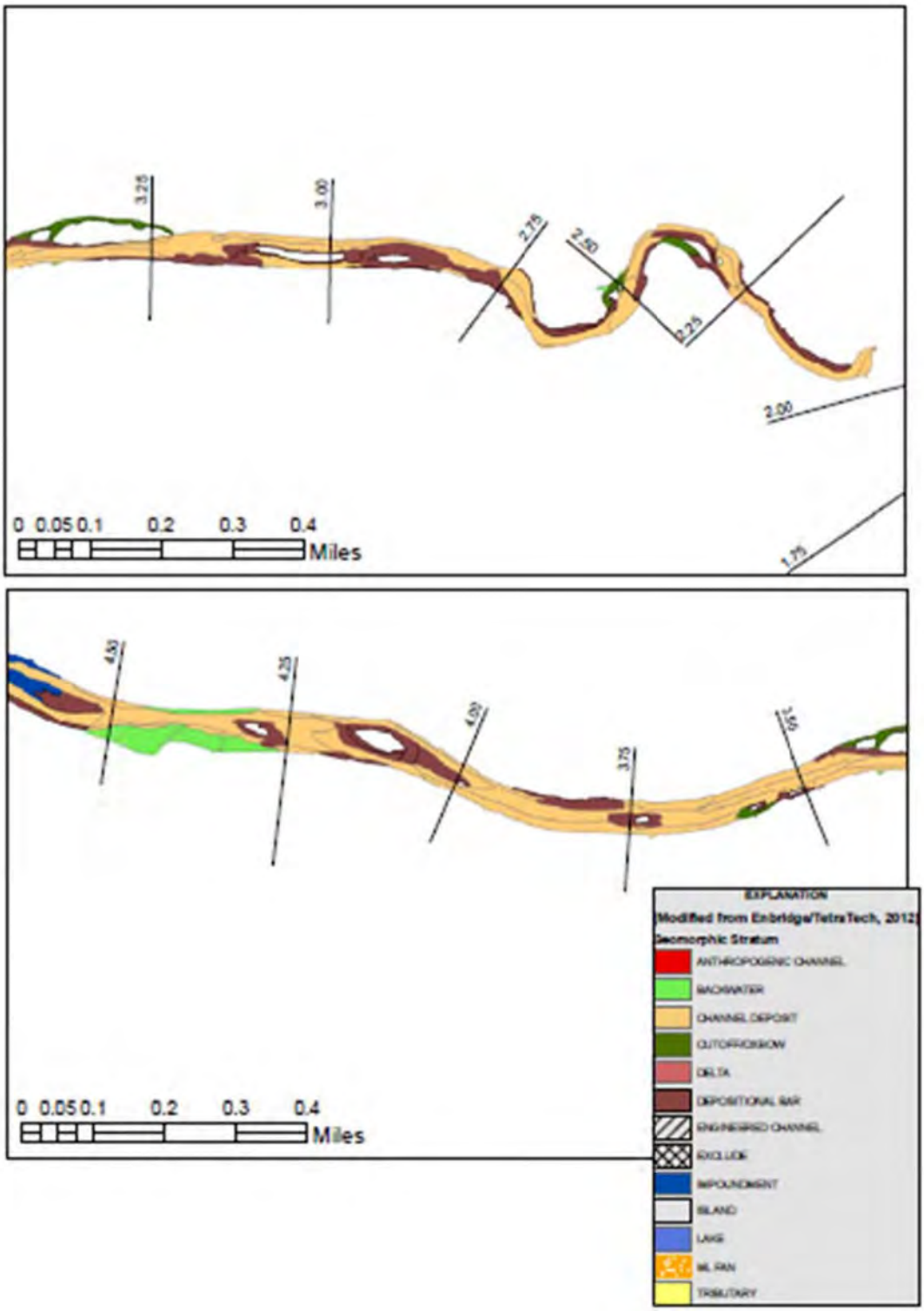

Figure 1. Draft maps of the geomorphic strata developed by USGS and USEPA/START personnel from the previously mapped geomorphic surfaces (Enbridge/TetraTech).

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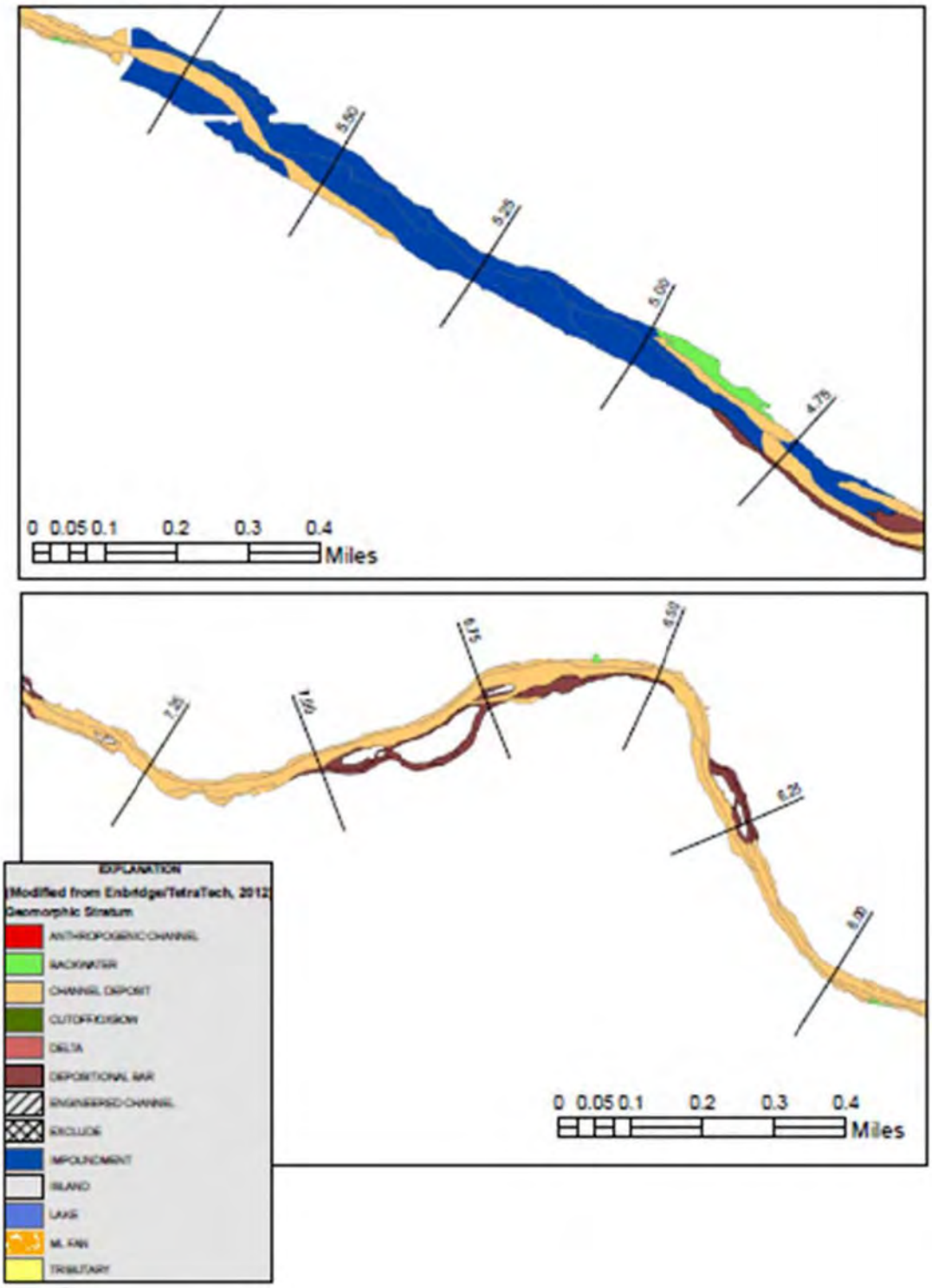

Figure 1 (continued). Draft maps of the geomorphic strata developed by USGS and USEPA/START personnel from the previously mapped geomorphic surfaces (Enbridge/TetraTech).

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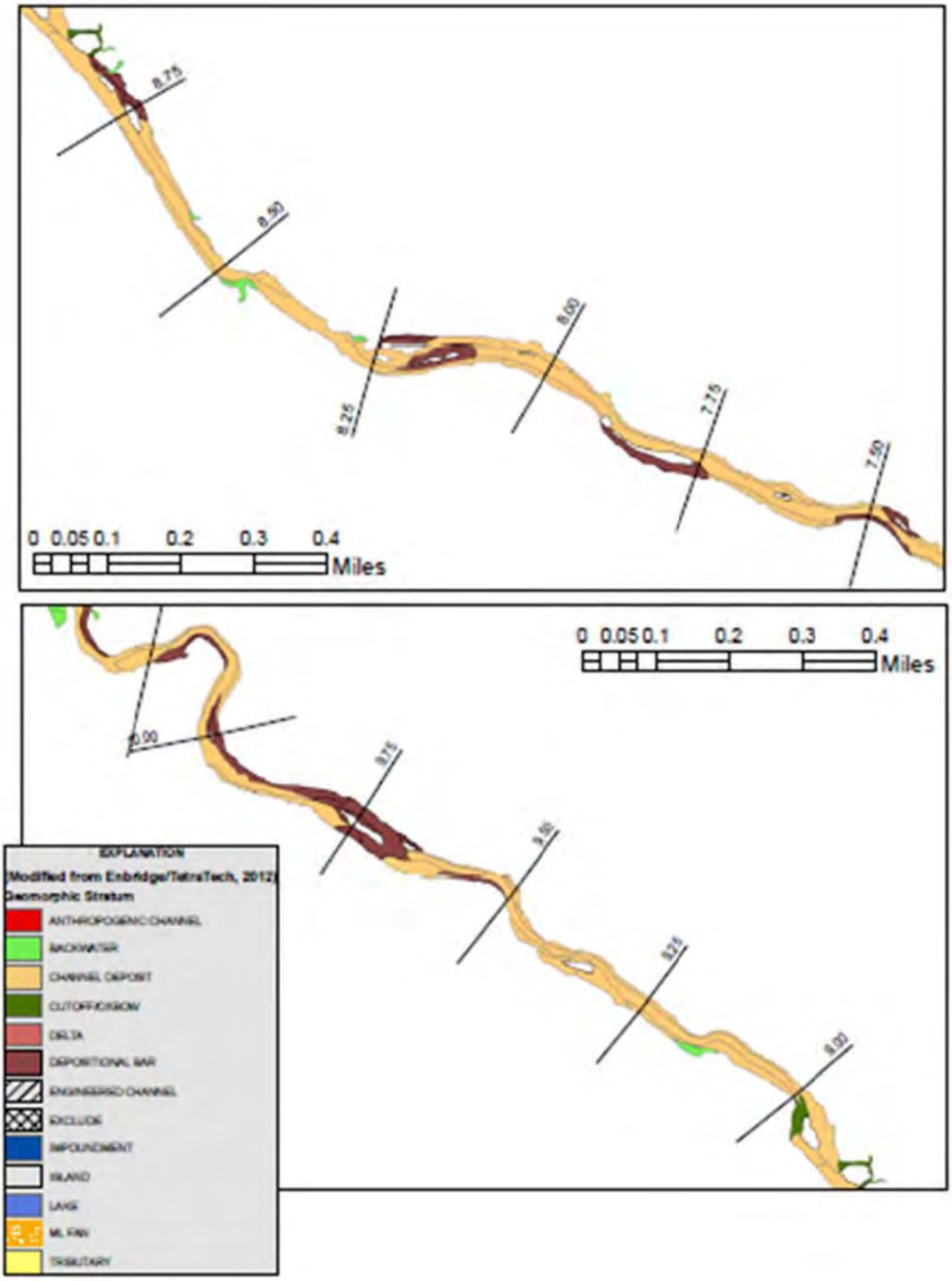
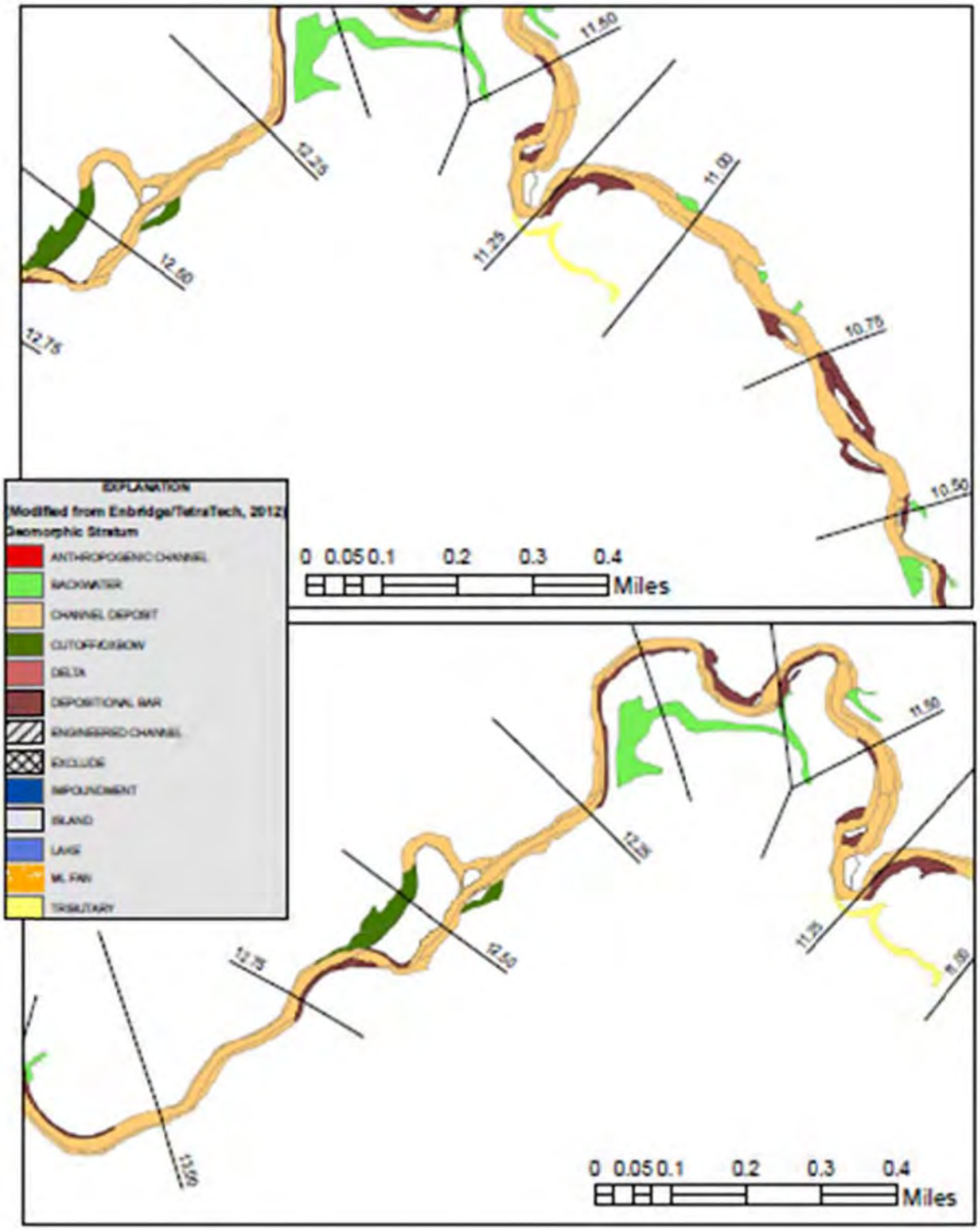


Figure 1 (continued). Draft maps of the geomorphic strata developed by USGS and USEPA/START personnel from the previously mapped geomorphic surfaces (Enbridge/TetraTech).



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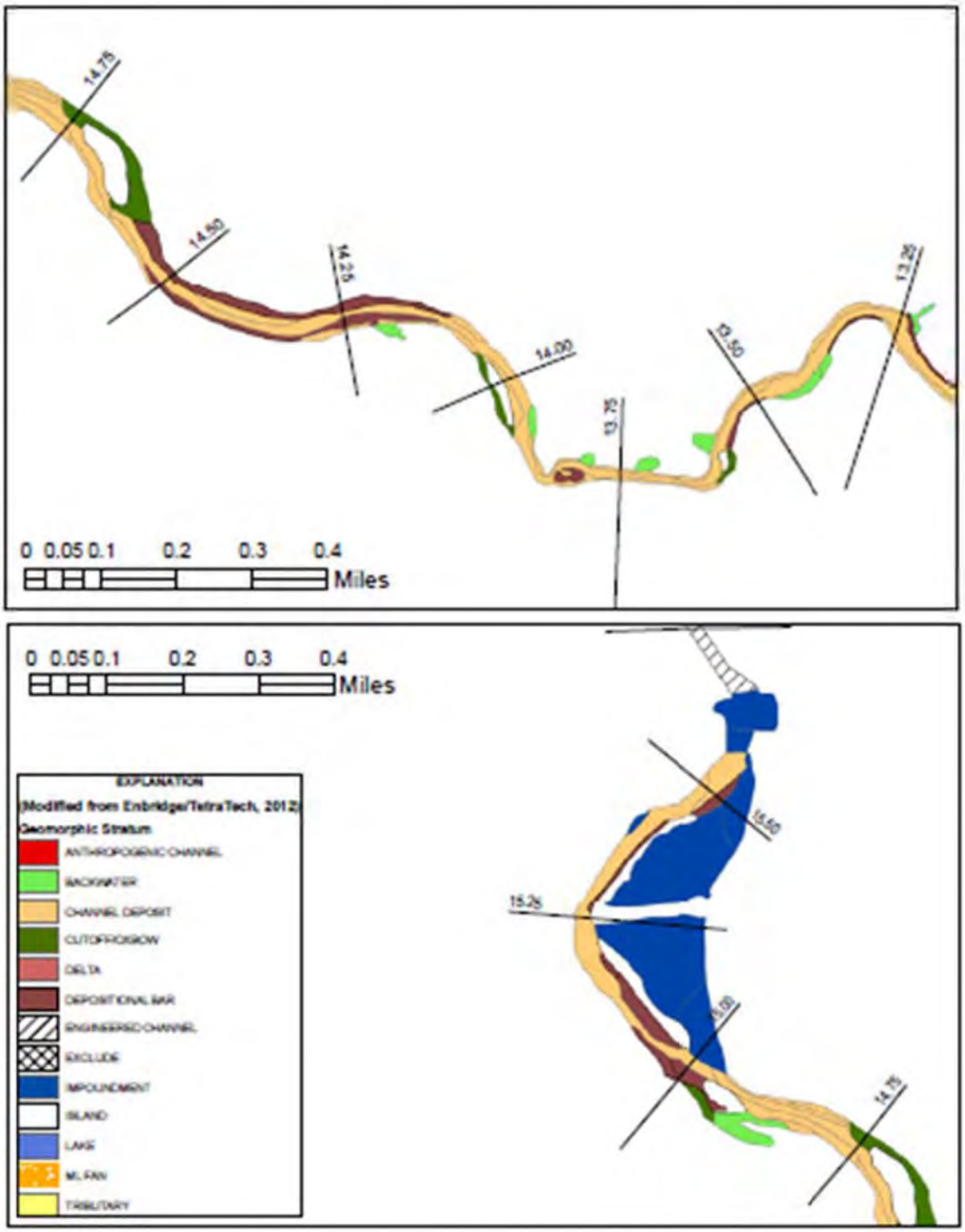

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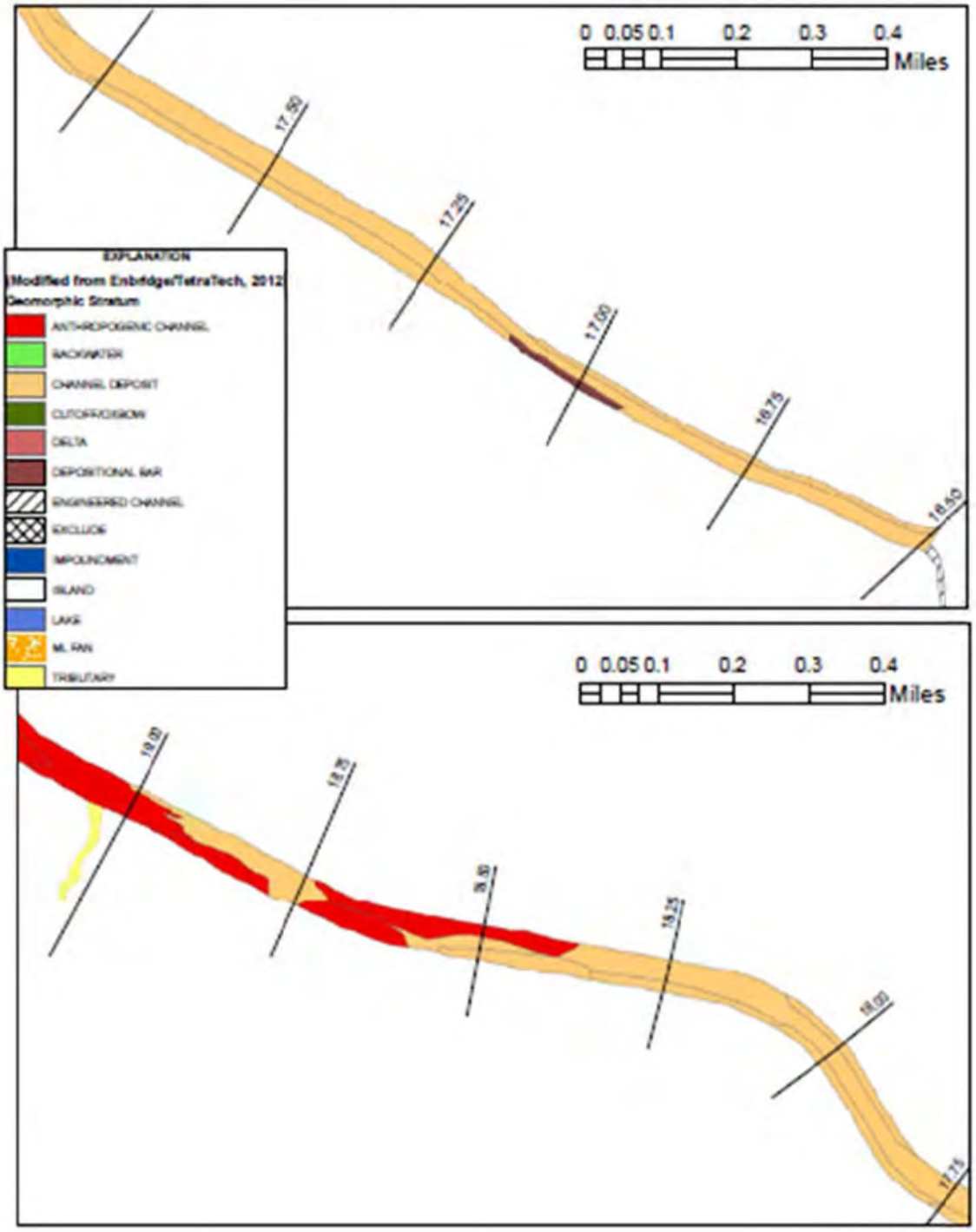

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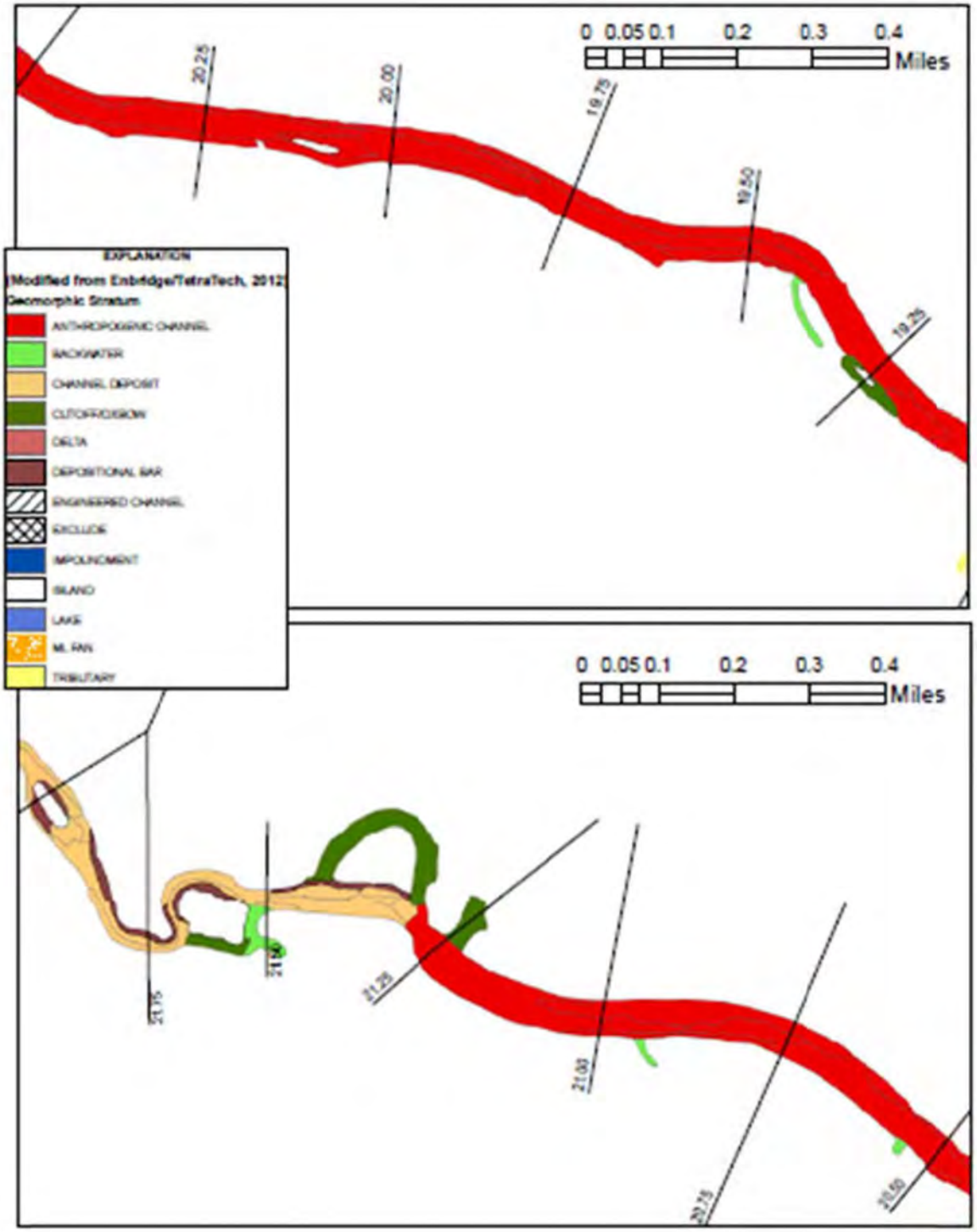

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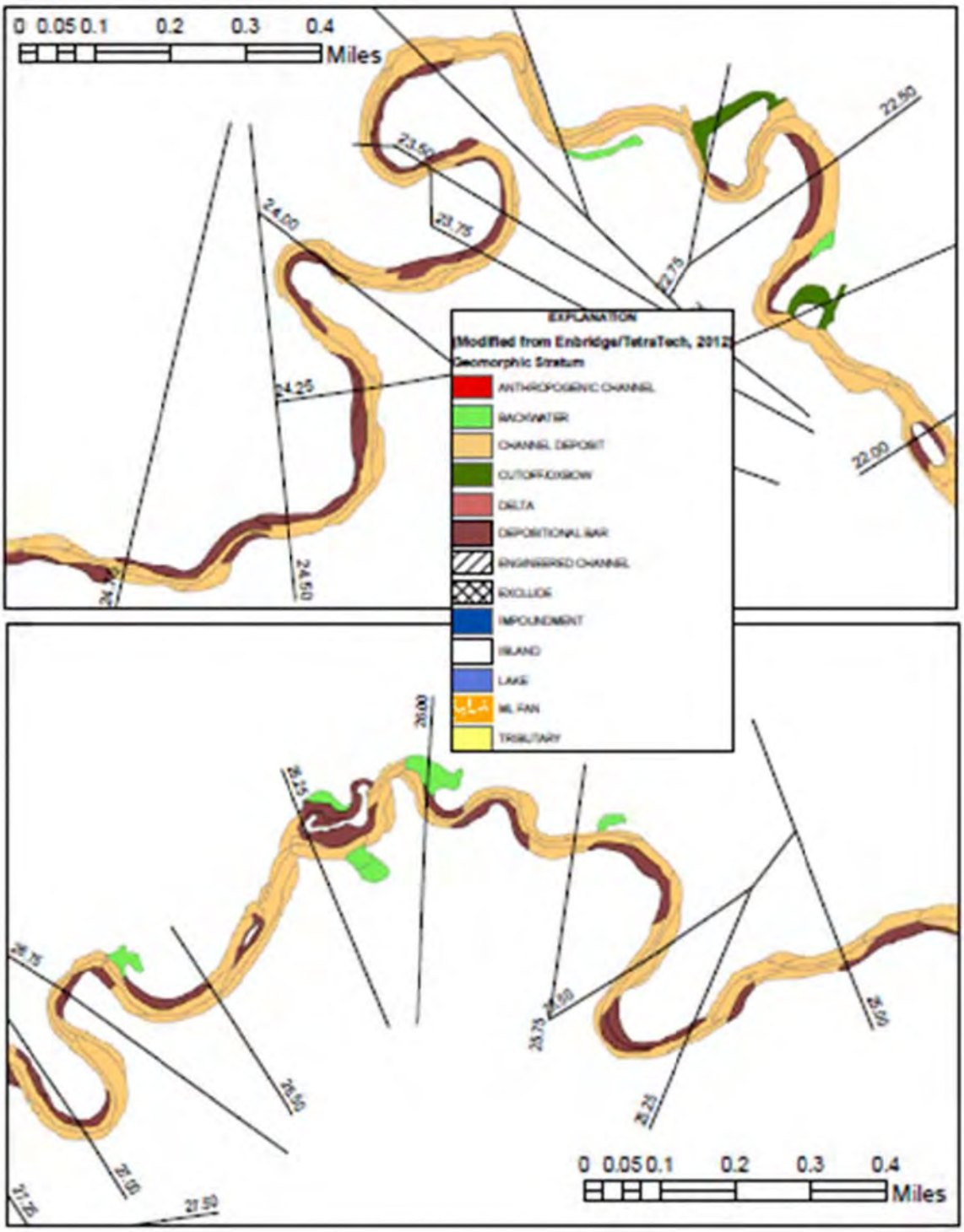

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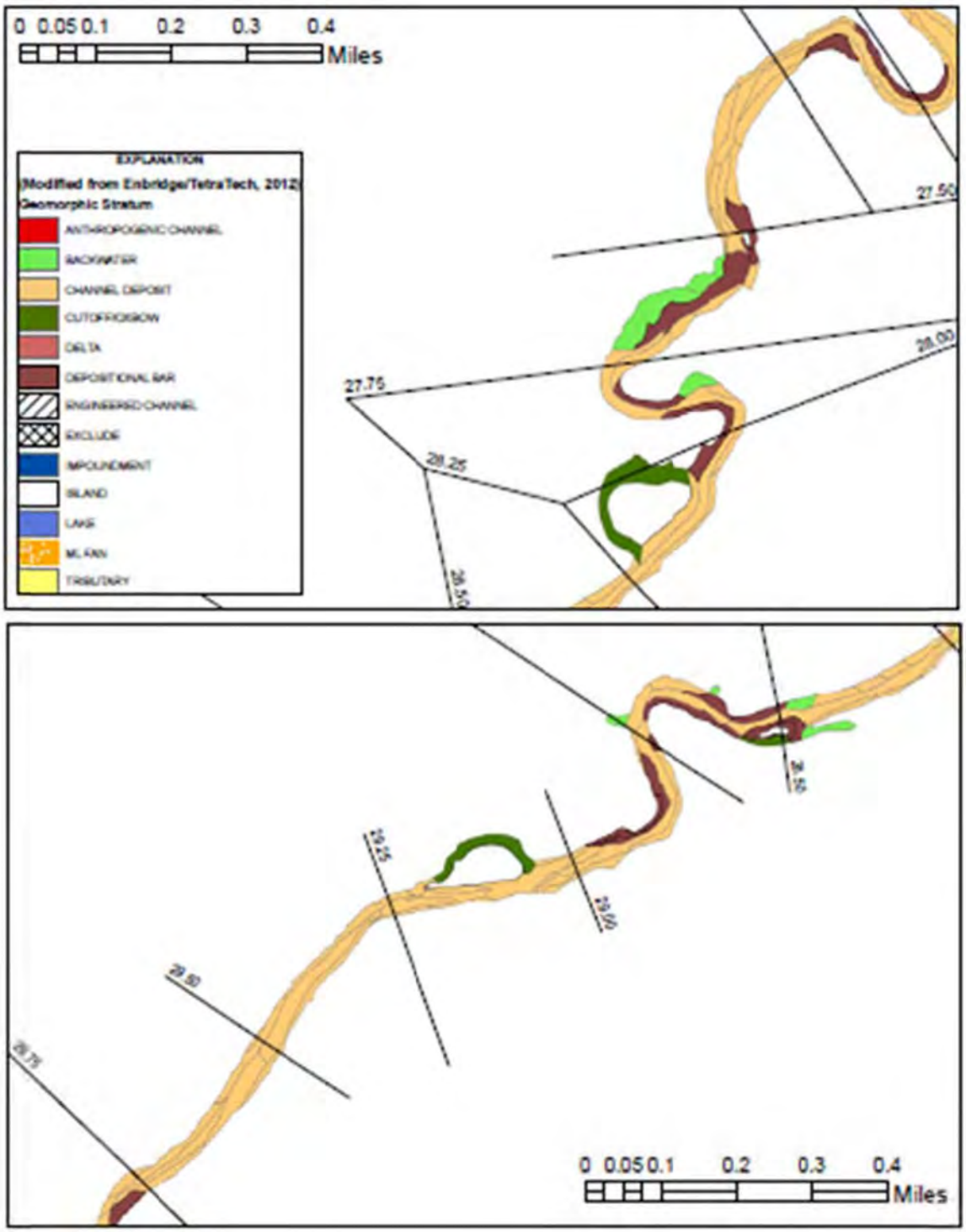

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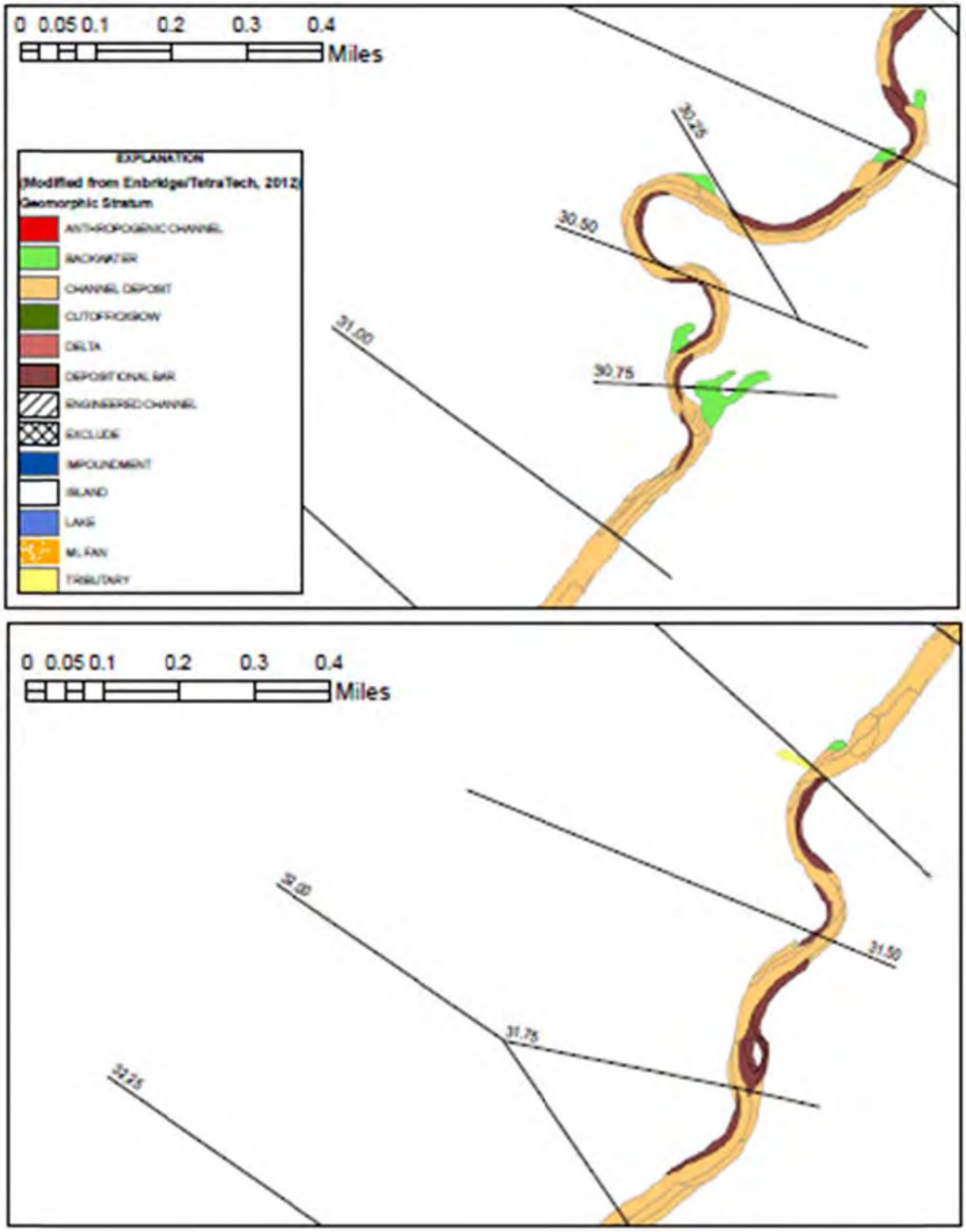

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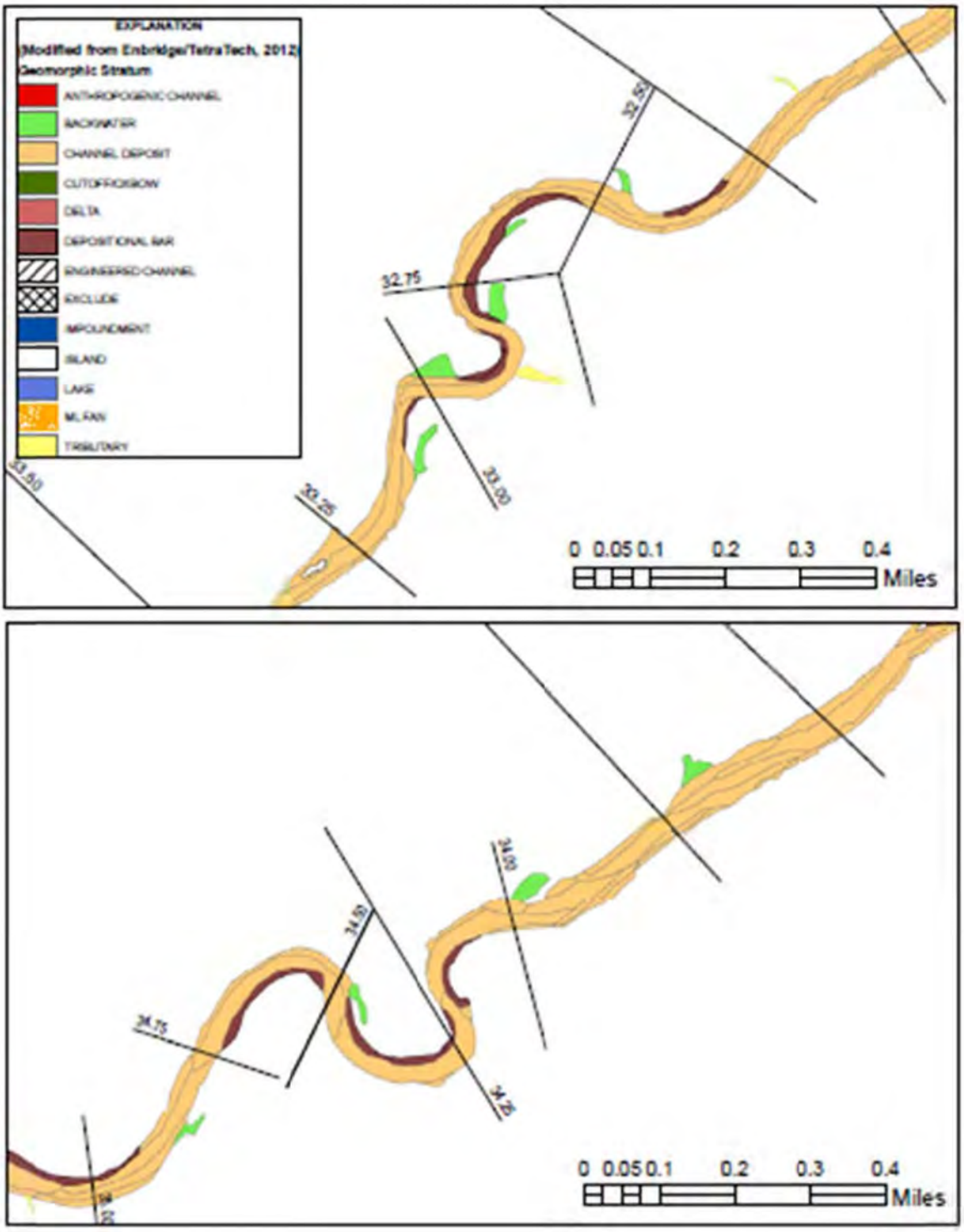

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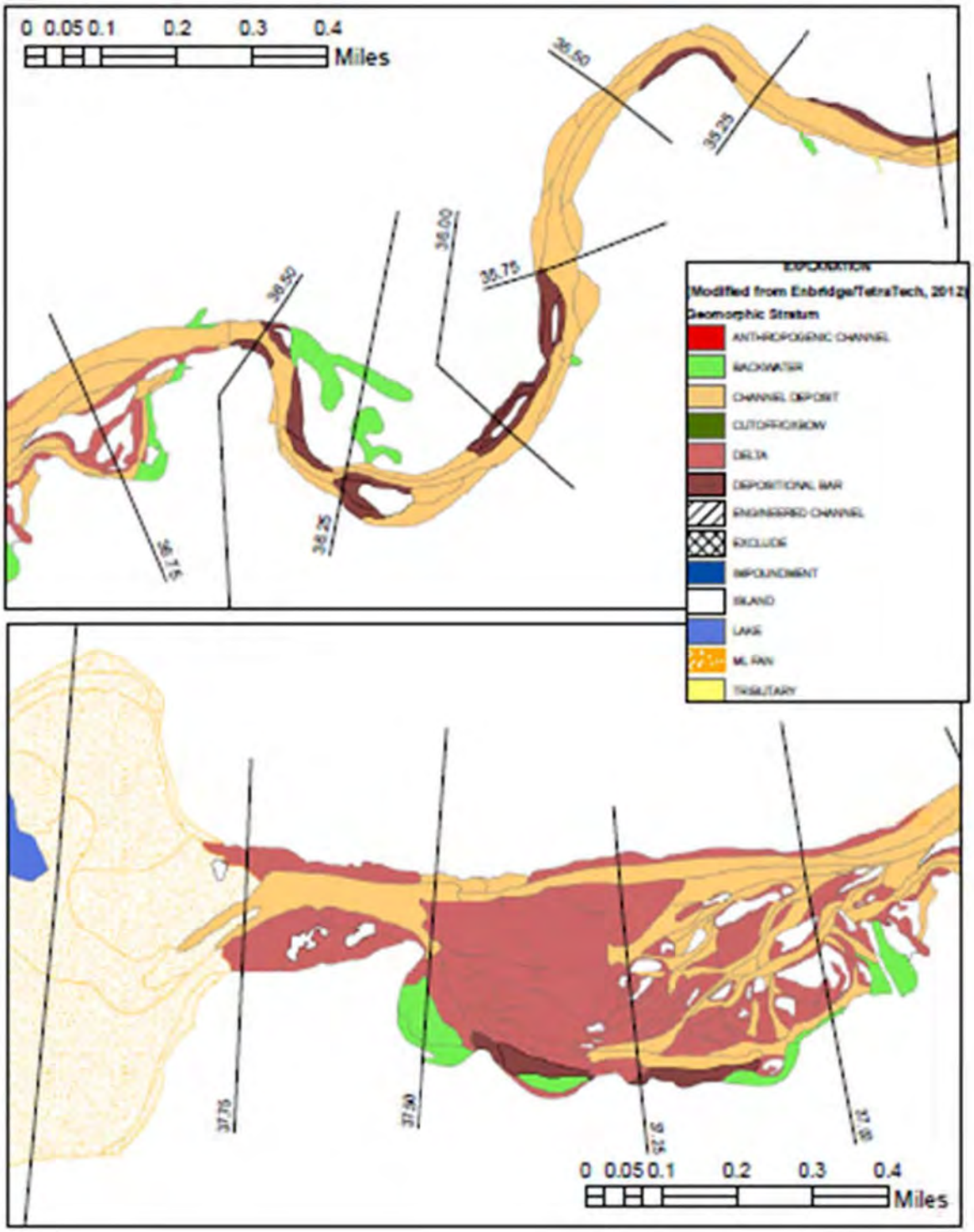

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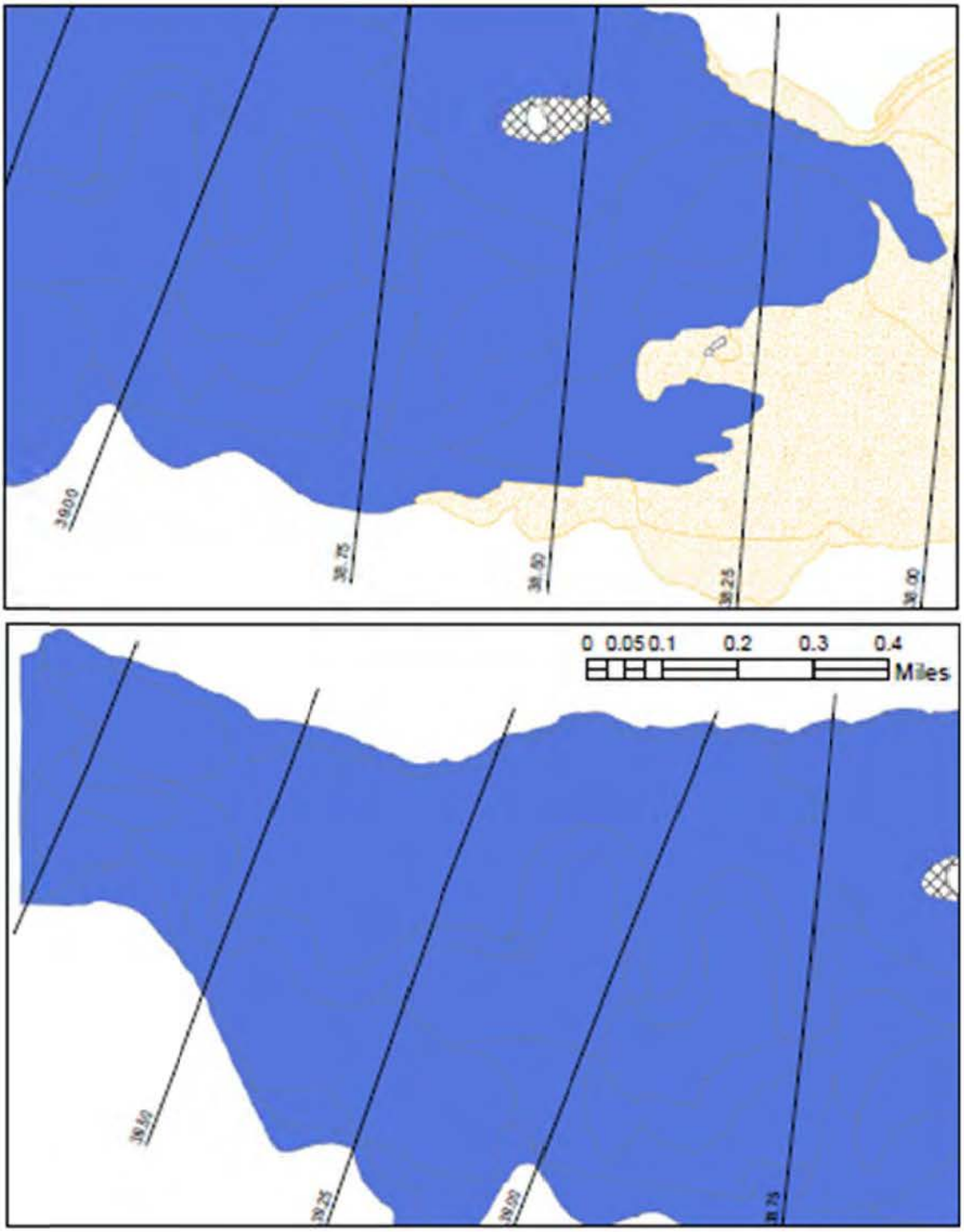

Figure 1 (continued). Draft maps of the geomorphic strata developed by USGS and USEPA/START personnel from the previously mapped geomorphic surfaces (Enbridge/TetraTech).

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Draft maps of the submerged-oil poling categories (heavy, moderate, and light) will be made available following completion of the 2012 Spring Reassessment poling. Those poling categories comprise the second layer of the two-way stratification. Once finalized, the poling categories and geomorphic strata will be processed together using GIS overlay analysis to define up to 19 combinations between the 10-category geomorphic layer and the 2-category submerge oil layer (heavy and moderate poling being combined into a single category, and light and 'absent' poling results comprising the second category).

Each of the 19 or so combination categories comprises one sampling stratum, and from the area corresponding to each, the GRTS software will be used to select a sample of coring locations, with a list of alternates; e.g., perhaps 20-30 locations will be listed per sampling stratum. Maps and tables of the map coordinates and category attributes of each sampling/coring location will be deliverables from the use of the GRTS software. As field teams visit the first tier of sampling/coring locations, if a location is determined in the field to not actually belong to the indicated geomorphic stratum, and a small horizontal offset (say, 10-15 ft) would not permit the location to be shifted into the targeted stratum, then to avoid subjective selection of a replacement, it is recommended that the field team replace the site with the next alternate location from the GRTS-generated list.

ENHANCEMENT OF SAMPLING PROCEDURES

The existing protocols that were used for Fall 2011 coring of streambed sediment and subsequent processing to collect samples for chemical analyses were approved by USEPA for SO quantification prior to compilation of experts within the SSCG. Wherever they do not introduce cause for technical concern, it is accepted that, for consistency and comparability, those methods remain unchanged for the Spring 2012 SO quantification. There are a number of aspects, however, that did raise concerns during evaluation and those are discussed in this section along with recommended alternative methods.

1. Verification of Sampling Location

When the field crew arrives at the projected sampling location, a suitably qualified and experienced fluvial geomorphologist with the U.S. EPA or USGS oversight should verify that the point is "on target" with respect to the study design's stratification categories. That is, the actual observed geomorphic setting, hydraulics and sediment surface should provide mutual agreement with the projected geomorphic stratum; and the presence/absence of sheen and/or globules observed just downstream of the "on target" location should confirm the projected submerged-oil category.

2. Collection of Sediment Cores

2.1 Recommendations

After decontamination, the corer (e.g., check-valve corer head) should be dried, and the core-tube-receiving end then wrapped in foil and kept isolated in clear plastic bags for transport to the sampling site. At the coring site, the corer should be thoroughly rinsed with ambient stream water prior to use. The interior of coring tubes also should be isolated from atmospheric contamination during transport to the coring site.

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Field data to be collected for each core should be expanded from the Fall 2011 SOP to include water temperature and sediment temperature at 1 and 2 ft below the sediment surface, both measured *in situ*. Other field measured parameters from the existing 2011 protocol should remain mandatory data elements for the 2012 protocol.

Cores should be collected with either a check-valve corer or a piston corer; dredge-type samplers should not be used. The bottom end of the core-collection tube should be placed into contact with the sediment surface using a slow descending transit rate to avoid disturbance to any floc layer at the water-sediment interface. For purposes of quantifying submerged oil, the target depth for coring should extend beyond the estimated depth of maximum scour that has occurred since the Line 6B release, whether that scour was introduced by riverine hydraulics or by submerged-oil recovery methods. However, given that collected cores would likely be sub-sampled to even greater depths to acquire particle-size distribution parameters to support data needs of the hydrodynamic assessment and hydrodynamic modeling components of the CWP, the primary recommendation is that recovered material in the primary core be containerized, frozen, and intervals not selected for chemical analysis be archived at the analytical laboratory at -20°C for an indefinite period. The primary core should, in any case, include at least the uppermost 2 ft of the bed sediment profile, unless coring refusal is encountered above that depth.

At each location, it is suggested (at least) two (2) side-by-side cores should be collected. One core would be used for field analysis and sub-sampled for TOC, PSD and oil globules, whereas the other core would be sub-sampled for forensic chemistry in the field with concurrence from an oversight geologist/observer. Because the designation of cores as to destination would not be made until they are inspected at the field processing station, both cores should receive identical treatment at the sampling location and be chilled to 4°C immediately following collection. Additional cores may be collected as dictated by quality-control or other project objectives.

Sheen sampling also is critical to achieve study objectives, because it provides an integrated signature of the oil and degree of environmental weathering and (or) biodegradation at each sampling site without the sediment background interference. Therefore, the field protocol should be revised to specify that immediately after core collection is completed, record a paired observation of sheening response to poling agitation of the streambed adjacent to coring location. Additionally, collect the sheen so produced using a Teflon sheen sampler and following the ***Recommended Oil Globule Sample Collection Procedure*** (4/26/2012).

2.2 Evaluations

Clam-shell-type dredge samplers cause rotation and mixing within the sampled volume of sediment, both as the clam-shell halves close and commonly again as the sample material is emptied from the sampler into an open container of some type. Other types of dredges impose similar hazards of mixing among the layers of sediment. In addition, dredge samplers typically do not collect equal volumes of sediment from each vertical fraction of the streambed material; rather, a sampler-shape induced bias is introduced, typically collected more material from the sediment surface and less from the lowest layers included in the sample. Either the Universal-type push-corer (i.e., check-valve corer) or piston corer are expected to provide a reliable method of collecting undisturbed sediment cores at almost all sampling locations along the impacted section of the river, as long as sampling techniques follow guidance for collecting “acceptable” sediment samples (fig. 2; NewFields, written communication, 2012):

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The following sample-collection guidelines describe a recommended sediment sampling technique.

1) The sampler is lowered at a slow, controlled velocity to minimize the bow wake of the sampler.
2) The sampler is inserted and retrieved at a slow steady rate
3) A minimum sediment depth of 60 cm is recovered in the sample chamber.
4) The core-head check valve closes completely to create a tight seal at the bottom of the sample chamber
5) The sampler is maintained vertically while retrieving and processing activities are conducted
6) A minimum of 1 cm of standing water remains atop the sediment collection chamber.
7) No water is leaking from the sediment collection chamber while the sampler is inspected on the boat
8) The sediment sampler did not over-penetrate the sediments causing sediments to squeeze out of the top of the collection chamber or contact the corer head.
9) The maximum potential volume of standing water is removed from the sample collection chamber without affecting the flocculent material atop the sample.
    - Flocculent material is allowed to settle for a minimum of 1 hour until supernate is clear.
    - Water is removed via a suction bulb turkey baster or small-diameter (~1/4" ID) siphon tubing.
    - Removal of standing water does not remove the flocculent material.
    - Removal of the standing water does not disturb the flocculent material via mixing or mobilization.
    - Potentially 1/8 to 1/4 inch of standing water will remain atop the sample after surface water removal.
10) The sample collection & handling equipment are properly decontaminated.
    - Decontamination activities shall be conducted between each sample attempt.
    - All equipment that contacts sediment surfaces must be decontaminated between each sample attempt.
11) The sample is collected and processed in a "clean environment"
    - Such as maintaining position upwind of any exhaust and with any boat motor turned off.

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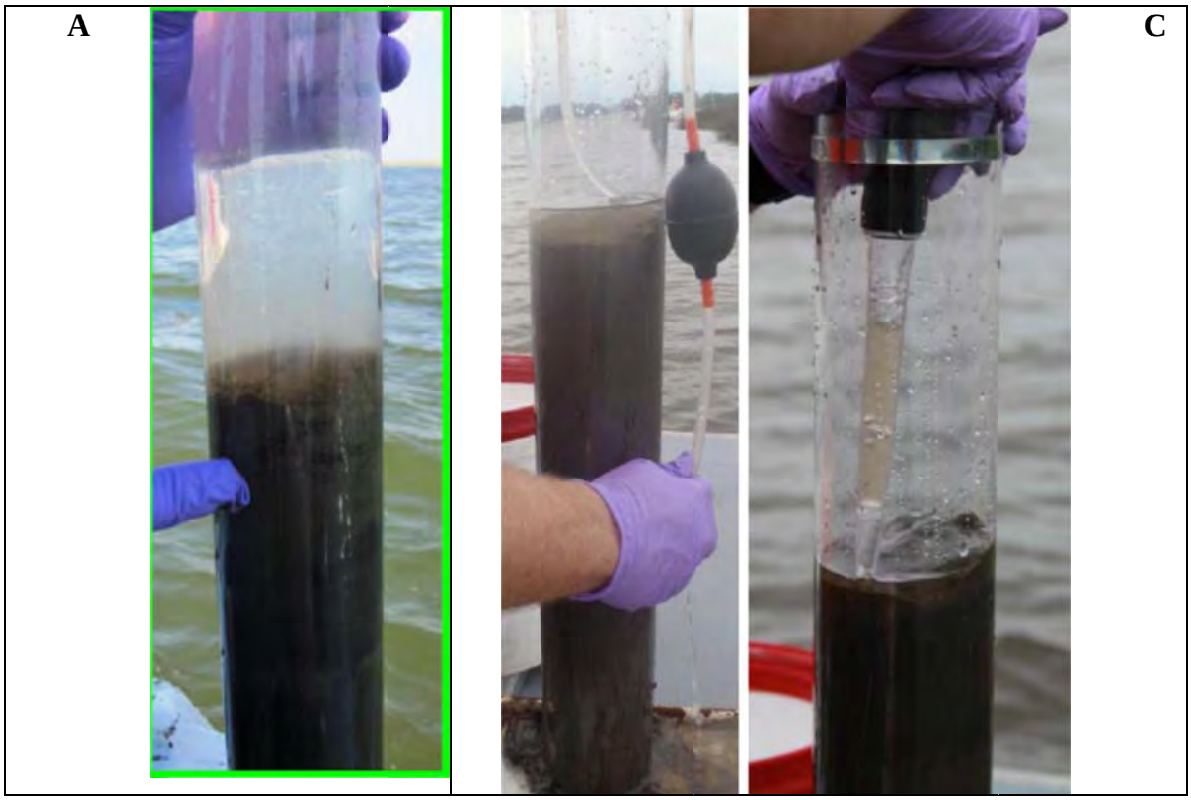

Figure 2. – Photographs showing (A) an acceptable sample that preserved undisturbed the surface flocculent material; and removal of supernatant water by (B) siphoning and (C) suctioning with turkey baster. Note that the technician was cautious not to disturb the flocculent material, and may acceptably leave a shallow depth of supernatant water (1/8 to ¼ inch). Photo source: NewFields.

The sediment deposited since submerged-oil recovery commenced upstream is likely to be present as a low-density layer on the sediment surface. In areas where agitation-based recovery occurred locally, the re-depositing, vertically settling sediment that was suspended by the recovery efforts is expected to occur as an upward-fining sequence. In either situation, the uppermost layer of sediment encountered during core collection could be the most enriched in sediment-associated submerged oil. Thus, a sampling technique that avoids disturbance to that uppermost layer of sediment or floc is strongly preferred.

A 3-inch-diameter piston corer is commonly used by the USGS to collect core samples and paired with a core tube composed of Lexan™ polycarbonate. The corer head is composed of steel. After decontamination, the corer is air dried, covered in foil and transported in clear plastic bags to the sampling site. At the coring site, the corer is thoroughly rinsed with ambient stream water (F.A. Fitzpatrick, USGS, written communication [QAPP for Neopit Millpond], 2004).

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Core length. The scour depth of streambed sediment in the Kalamazoo River generally would be field identifiable using streambed cores, or could be estimated from hydrodynamic simulation of specific hydrologic events. The Fall 2011 thickness of oil impacted sediment generally ranged up to 1.9 ft[1], with a reported average thickness of 0.7 to 0.8 ft for cores with field-detected oil. Previous attempts to quantify the submerged oil volume remaining in the impacted area have used calculation methods that neglected hydrocarbon content below the average thickness of the oil-impacted layer of sediment. Thus, for the objectives only of Spring 2012 oil quantification, there would be little value in collecting cores much longer than the 2-ft maximum expected thickness of the oil-impacted layer. However, collected cores would have uses for other objectives, e.g., they are likely to be sub-sampled to greater depths (perhaps at expected scour depth from 100-year flood) to acquire particle-size distribution parameters for use in the hydrodynamic assessment and hydrodynamic modeling components of the CWP.

3. Processing of Sample Cores

3.1 Recommendations

It is important to preserve undisturbed the uppermost, often "sloppy" or "soupy" *floc* layer at the water-sediment interface (approximately the upper 2.5 cm). Cores collected for field observations and chemical analysis should be maintained in a vertical orientation throughout handling, and transport, except when frozen. Document the quality of each core based on floc thickness, vertical sediment features and sediment recovery. The highest quality core should be reserved for chemical analysis (Core #1), and the remaining core (Core #2) should be used first for collection oil globules and then making the field observations (half A) and collection of PSD and TOC samples (half B). Transport all cores to the core processing station—a "clean" area—while maintaining cores in the vertical position. Allow any sediment in the overlying water settle (approximately one hour), then siphon off the water from both cores *without removing the visible flocculent layer.* Measure and record the sediment thickness in both cores.

Place the chemistry core (Core #1) in the freezer overnight, in a vertical position, to partially freeze the sediment. Process the chilled**,** non-frozen Core #2 by splitting the core liner and laying each half out on a table for processing. Process this core according to the recommendations provided in *Section 3.1.1-Screening method for selecting core subsamples for analytical chemistry***.**

Take photographs of Core #2 under white light and UV illumination (use a specialty camera or film that has particular sensitivity to UV fluorescence is recommended for the latter). The 2012 protocol should give clear instructions on photo documentation of the described core; e.g., prior to any further processing or subsampling, intervals of the opened core should be photographed at an explicit scale (scale/ruler in photo) and under illumination such that sediment general texture and color are well distinguished in the digital image. Then perform a UV-aided visual analysis of the undisturbed exposed sediment, as follows. For each 2-cm interval along the core, record on a core-logging form the presence and relative intensity or frequency of petroleum indicators (i.e.,

[1] Exceptions being 2.5 ft for core SEKR2225C01, and four cores composited from discrete-interval samples collected using a different coring apparatus (Russian peat borer).

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sheen, and number of oil globules, droplets, or tar flecks observed along with size range of the point-type indicators).

The field-analysis core[2] (Core #2) will be opened[3] at a field processing station and one of the core halves would be examined (as in existing 2011 SOP) for field determinations of color (Munsell Color, 1975), UV fluorescence, texture by rubbing sediment between the fingers to classify according to the Unified Soil Classification System (ASTM D-2488-09a), and major stratigraphic units. This half-core also would be processed to collect oil globules (discussed below; see also USEPA-SSCG, ***Recommended Oil Globule Sample Collection Procedure*** [4/26/2012]). Sub-samples of the remaining, undisturbed half of the field-analysis core would be collected for determinations of total organic carbon (TOC) and PSD at a high categorical resolution to support the requirements of the hydrodynamic modeling component of the CWP (see ***Sediment Particle-Size Distribution*** section), as per the existing SOP.

Prior to sub-sampling either core, the sub-sampling equipment should be decontaminated by washing with soapy water, rinsed with tap water and rinsed again with de-ionized water. The sub-sampling equipment is allowed to air dry and stored in aluminum foil. At the core-processing site, the sub-sampling equipment should be thoroughly rinsed, just prior to use, with ambient stream water.

3.1.1 Screening method for selecting core subsamples for analytical chemistry

Selection of the core intervals that will be submitted for chemical analysis should be performed at the field station, with decisions made by qualified personnel knowledgeable about site-specific conditions. The following procedure is recommended: On the day following core collection, remove the partially frozen Core #1 from the freezer. Split the core lengthwise and place each half on a table for observation. Photograph the core under UV illumination, using a specialty camera or film that has particular sensitivity to UV fluorescence. Each subsample of the core selected for chemical analysis should additionally be photographed (at similar scale and illumination) before removal of the core sample from the core.

For all cores, the highest priority sample interval will be the uppermost one-inch (2.5 cm) thick layer, including any flocculent and the most recent deposition. Collect from Core #1 the upper 2.5-cm layer and place into pre-cleaned wide-mouth 8 oz jars (larger if needed). Based on the observations performed on Core #2, collect two additional samples from the chemistry core for analysis/archival (Figure 3).

Additional samples would be selected based on results of a core screening process that depends on both sediment stratigraphy and visible indications of oil presence—data collected as they have been previously under the existing 2011 protocol. The recommended change is that, rather than submitting all distinct sediment strata for laboratory analysis, the SSCG recommends that two additional 4-cm-thick intervals of the primary core would be selected as samples, but only one of those is automatically submitted for chemical analyses. The lowermost 4 cm of the oiled

[2] This sample will be used to define the forensic chemistry sampling intervals.

[3] The core tube is cut on opposite sides, and split in half with the entire length of the sediment core exposed for examination by the field team.

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layer will be selected as the second core interval to be sampled; but if the maximum depth of oil indications is from 2.5 to 6.5 cm beneath the sediment surface, the sampled interval will be less than 4 cm thick. The third interval would be of intermediate depth within the oiled layer, and up to 4 cm in thickness. If maximum depth of oil indications is at least 10.5 cm below the sediment surface, select a 4-cm interval that showed greatest amount of visible indications of oil presence. If oil indications are uniform along the oil-impacted interval, select the interval 2.5 to 6.5-cm from top of core (i.e., the interval immediately below the uppermost, first layer selected). If the described core showed no visible indications of oil presence, or if the maximum depth of those indications did not extend below the bottom of the 2.5-cm thickness of the uppermost interval, then collect as the second and third sub-samples the 2.5 to 6.5-cm and 6.5 to 10.5-cm intervals for archiving—neither is automatically submitted for analysis.

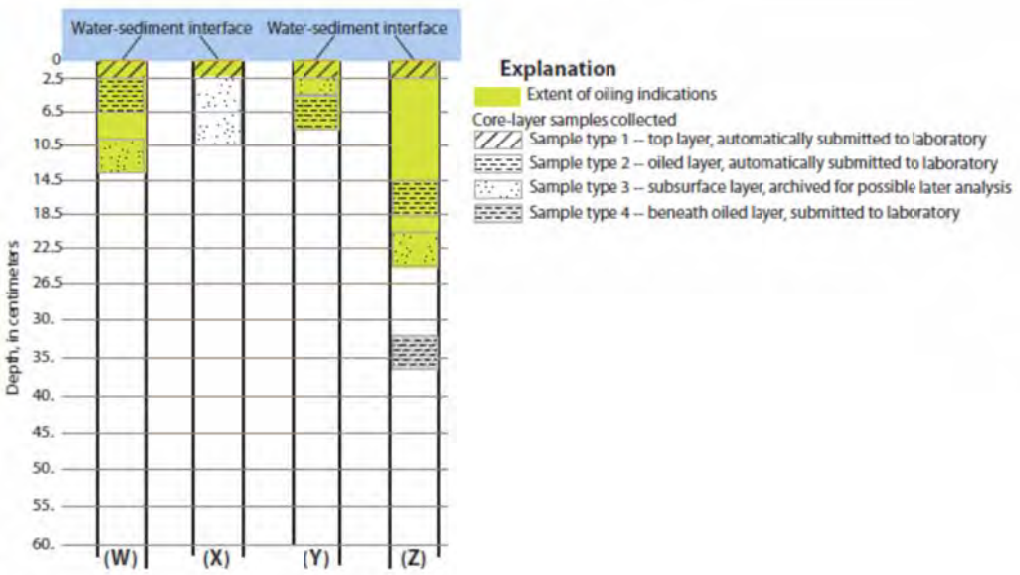

Figure 3.—Diagram illustrating four contrasting scenarios defined by combinations of oil indications depth and consequent intervals that were identified for sample collection [Note that any of the samples not submitted for immediate analysis would be archived (frozen at -20°C); and all extra core material would be archived frozen in core containers that preserve the vertical-position relations intact.] :
Location W has oil indications extending beyond 10.5-cm depth (below water-sediment interface) and the middle sample was designated for initial chemical analysis, along with the top layer that is automatically to be submitted for analysis in all cases; deepest sample would have had less intense visible indication of oil and is to be archived frozen.
Location X has oil indications limited to the top 2.5 cm of the core, and consequently only the top layer is submitted initially; whereas, the two deeper layer samples are archived frozen for possible later analysis.
Location Y has oil indications extending to less than 10.5-cm depth and consequently one of the deeper layer samples is less than 4 cm thick; based on the visible indications of oil, the 4-cm thick deeper layer selected for initial submittal might be either the bottom 4 cm of the oiled layer (as shown) or the 4 cm immediately beneath the top 2.5-cm thick layer. The other deeper layer (not selected for initial submittal) would be archived frozen.
Location Z has oil indications extending well beyond 10.5-cm depth, and additionally was one of the subset of locations selected *a priori* for collection of a deeper sample from below the oiled layer; in the scenario shown, the oiled sample at middle depth was selected for initial analysis based on visible indications of oil, whereas the sample from below the oiled layer was selected from a fine-grained, organic-rich stratigraphic unit. The sample collected at bottom of the oiled interval (not selected for initial submittal) would be archived frozen.

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A fourth interval of the primary core would be submitted for analysis if the sample location is one of those designated for confirming that deeper sediment contains only hydrocarbons that lack the distinctive chemical signature of the Enbridge Line 6B oil. This sample should be collected from the uppermost stratigraphic layer having fine-grained sediment (i.e., predominantly silt or clay), enriched in organic matter, and below the stratigraphic layer that contains the maximum depth of oil indicators (visible sheen or globules under UV illumination). If no deeper layer is both enriched in organic matter and fine-grained sediment, the alternative would be to sample the uppermost deeper interval of fine-grained sediment. If no such deeper layer exists, then the sample would be collected below the maximum depth of oil indicators, but from within the layer that contained the maximum depth of oil indicators. If this, too, is not available, then a pre-determined alternate coring location within the same geomorphic stratum should become the source for this deeper sediment sample.

The intervals to be sampled are determined from logging stratigraphy and indications of oil presence on the non-frozen core examined at the field station. This core is presumed to be representative of the frozen core collected adjacent to the logged core. All samples for forensic chemistry analysis are collected from the semi-frozen core that has been split and opened for visual examination and sample collection. The subsample is removed with a clean stainless steel spoon (wooden tongue depressors may also be used and discarded after each subsample) and placed into a pre-cleaned 8 oz jar. Core subsamples are kept frozen for shipment to the analyzing laboratory. Subsamples may be assigned field identifiers according to the conventions of the existing 2011 protocol, which encodes core location and depth interval information. The remaining intervals of the frozen core should be archived frozen at -20°C for an indefinite period to allow further samples and analysis of any core that chemistry results indicate as challenging to interpret or unusually high in variability along the vertical profile of streambed sediment.

Label each selected subsample of core with sample ID, location identifier, date/time of core collection, and depth interval. Maintain responsible chain-of-custody possession and documentation per applicable EPA-approved SOP.

Evaluations

Vertical orientation of all non-frozen cores is essential to preserve the flocculent or low-density layer at the water-sediment interface. Cores for chemical analysis should no longer be laid in horizontal orientation while they are cut open (unless they are frozen), to prevent the otherwise unavoidable mixing of the flocculent/surface layer with lower layers of sediment within the core. Piston-type incremental core-extruder apparatus is readily available optional equipment for several of the check-valve corers presently available. For the primary sample (to be analyzed for organics), the frozen-core method was considered by SSCG to be the preferred approach.

Sample contamination of sediment samples during collection and subsampling of a core, either by smearing of sediment along the walls of the core tube or by ineffective cleaning of equipment has been shown to be minimal.

Field measurements required by existing SOP include measurement of water depth and core penetration. Sediment temperature, conductivity, and dissolved oxygen or ORP are variables that might be useful to understand environmental controls on degradation. Similarly, nutrients in pore water would be another supporting variable to consider, though more likely determined at a lab. A third core could be used for both bulk density and pore-water concentration of nutrients;

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consider trying this for a subset of sampled locations. NewFields (written communication, 2012) consider it essential for the sampling field crew to note and record any of the following: Any sheens, oil droplets, flecks/specks, or discolorations observed (a) on the water surface within the immediate area of sampling, (b) within the sample-collection chamber (core tube), (c) or within sample compositing/processing container, if used.

Disturbance to extensive parts of the impacted area caused by submerged-oil recovery methods argues against the need to look at very thin intervals of sediment cores. The upper 2 cm is a typical interval selected for chemical analysis of recently deposited oiled-sediment mixture. But for purposes of oil volume quantification, it is recommended to characterize more than the top 2 cm to represent full oiled interval of core; select in addition a middle sample and a bottom sample. Use core logging information to determine bottom of oiled layer, which has frequently been 1 ft or less.

QUALITY-ASSURANCE PROCEDURES

Decontamination

There are numerous sources of hydrocarbon contamination in the field environment, including fuels from boat motors and portable engines, exhaust from boats and vehicles, lubricating oils, cross contamination between sample locations, and vertical cross contamination between shallow and deeper layers of sediment. Thus, field decontamination procedures are crucial to sample/data integrity (NewFields, written communication, 2012).

Prior to each field trip, all sampling equipment will be washed with soapy water, rinsed with tap water and finally rinsed with de-ionized water. At the sampling location, rinse sampling equipment with native water. In the field, the any re-used sampling or sample-processing equipment will be washed between samples with soapy water and rinsed with native water. All non-disposable sampling equipment will be decontaminated after each sample in order to avoid cross contamination between samples or sites. Store sampling equipment in a secure, isolated container during transport to next sampling location (e.g., equipment cooler, tubs or garbage bags). Field crew will wear nitrile gloves whenever there is potential for contact with any sampling equipment or collected sample of sediment or water.

Quality-Control Samples

Equipment Blanks and Blank-Source Water Blank(s)

Prior to beginning environmental sampling for the Spring 2012 study, one (1) equipment blank should be collected with each check-valve coring head to be used in the study. Attach a clean core tube to the coring head. The interior of the tube and check-valve should be rinsed with organic-free blank water, and rinse water collected into a 1-liter glass water-sample bottle. The first 1-liter volume of rinse water is to be submitted as the equipment blank sample. Analyze the equipment blank for PAHs (parent and alkylated homologues) and biomarkers using GC/MS-SIM, and total extractable hydrocarbons using GC/FID at the same laboratory that analyses the core samples. Repeat the equipment blank sample collection at the conclusion of the seasonal study, again collecting one (1) equipment blank per coring head used in the study.

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In addition, collect a 1-liter sample of the blank water from each distinct source lot used for blank sampling (either equipment or trip blanks) during the seasonal study. Collect blank-source water sample in glass bottle and submit

Trip Blanks

A trip blank coring tube should be collected by each field crew daily; the trip blank tube's interior should be exposed to the atmosphere whenever a primary sampling tube is exposed. At the end of the day, the interior of the trip blank tube should be rinsed with organic-free blank water into a water-sample bottle. The collected rinse water becomes the trip blank sample for that day-crew combination, and should be analyzed for PAHs (parent and alkylated homologues) at the same laboratory that analyses the core samples.

Field Duplicate Core Collection

Field duplicates will consist of separate side-by-side cores taken at the same sampling site, one immediately after the other. Duplicates will be contained and labeled separately. A minimum of 10 duplicate cores should be collected. Processing and laboratory analysis for duplicate core should be identical to its paired primary chemistry core.

Opportunistic Duplicate Core Subsample Collection

Additional replicate samples (not cores) should be collected opportunistically when it is evident that more than typical vertical heterogeneity (of oil indications) exists within the oil-enriched interval, if present. Process and analyze a duplicate sediment sample identically as its same-core primary samples.

Sampling Method Quality Performance

An analysis and discussion of data quality assurance shall be included in the final report on Spring 2012 submerged oil volume. The scope of the analysis should include information derived from results of blank samples on contamination sources and how effectively the sampling protocol minimized contamination, and information on sources and magnitude of uncertainty in laboratory determinations that, based on QC replicate sample results, appears attributable to sampling procedures or equipment.

ANALYTICAL SCOPE

Recommendations

The previously recommended Analytical QAP (USEPA-SSCG, 2012) contains the bulk of recommended protocols and evaluations concerning analytes for determining oil content and source identifications. The primary sediment core subsamples will be sent to the Alpha Analytical Laboratory.

Ship to:
Sue O'Neil
Alpha Analytical Laboratory
320 Forbes Blvd
Mansfield, MA 02048
Phone (508-844-4117)

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Primary sediment samples should be analyzed per the Analytical QAP, except that analyses of PIANO compounds and metals may be omitted. An aliquot of each primary sample should be kept frozen and archived for possible later analysis of nutrient, reducible iron, and/or sulfide concentrations in sediment—an aliquot mass of 40 g should be sufficient.

Samples collected from Core #1 (analytical chemistry core from each sampling location) should be analyzed for both wet and dry mass. Together with the core interval thickness and diameter, bulk densities and sediment sample porosity will be calculated. The specific gravity of the various particle types (oil, other organic and inorganic) should be measured using an inert gas (helium) pycnometer (ASTM D5550-94). This method requires an order of magnitude less amount of material (~5 g) than alternate methods of direct measure.

Sediment Particle-Size Distribution

Improved Particle-Size Distribution (PSD) data are needed to support improvements in the hydrodynamic model development as well as to understand and interpret the hydrocarbon chemistry results for sediment-core samples. Organic contaminants in streams are well known to adsorb to the fine-grained fraction of the suspended PSD (Domagalski and Kuivila, 1993). PSD parameters are measurable in many ways, ranging from using sieves, to x-rays, to laser beams. Because a large number of core samples are being proposed for analysis, and improved resolution of the PSD is needed beyond the percentages of sand, silt, and clay fractions (as were determined for previous core samples collected for the Line 6B incident response), the use of an optical laser-diffraction based particle-size analyzer is recommended. The optical Mastersizer (Malvern Instruments, 2012, Mastersizer Particle Size Analyzer) has been suggested (J. Hamrick, TetraTech, oral communication, 2012). However, rather than measuring all particles in a sample, this instrument analyzes a small aliquot (an advantage when sample mass is small), but one that could be biased depending on presence of coarser, fast-settling particles that escape inclusion. Minimum recommended data resolution includes five (5) sand size classes, four (4) silt size classes, and four (4) clay size classes; the total range in phi-scale units is from -1 to 12. A combination approach using sieve analysis for the sand size classes, followed by optical instrument analysis for smaller size fractions, is another option.

Alternative to GC-Based Methods for Screening and Trends Monitoring

A third suggested objective for sediment-core sampling, beyond oil quantification using precise and reliable GC and GC/MS methods (i.e., Analytical QAP) and obtaining needed physical and supporting parameters (bulk density, PSD, TOC, etc.), is to examine the possibility for fluorometry to objectively indicate the extent of the oil-affected layer (and potentially relative concentration of oil) based on oil within the fine-grained pore spaces that is not visible by macroscopic observation. If such a technique is sensitive to and correlates strongly with total extractable hydrocarbons or total PAHs in the fraction of oil from Line 6B, it could potentially be adapted for field application to (a) determine the interval of oil-affected sediment; and (b) track the temporal trend of oil concentrations. If it were successful, such a technique might allow future re-quantifications to be achieved with only a subset of cores needing to have the Analytical QAP suite of laboratory analyses. Because the oil-quantification objectives can be achieved without adoption of this suggested objective, this element of suggested work as optional.

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To test the fluorometry-based approach and validate its use as an acceptable alternative, the SSCG recommends that a first phase be conducted in a laboratory under controlled conditions. If successful, a second phase would be needed to adapt the procedure to a field station and portable fluorometer.

The first phase would be conducted using a subset of core samples (say, 30 or 40 samples), selected to represent a wide range of TEH or TPAH concentrations, and should ideally include replication of this range for more than one level each of sediment coarseness and organic-matter content. Test samples could be selected from archived excess sample material once the initial GC/MS and GC/FID results are known for the core samples. In the analytical laboratory, the pore water contained within an aliquot of each selected sample should be collected and oil extracted using techniques that also could be done at a field laboratory, e.g., extraction by shaken flask with hexane solvent. The extract would then be analyzed by fluorometer (e.g., Kim et al., 2010). Phase I should continue, analyzing pore water from aliquots of selected core sub-samples, until 95% confidence interval for the response curve to oil and/or PAH concentration is accepted as validated as a useful alternative to GC results for trend monitoring by the USEPA, with SSCG advisement.

Evaluations

If the aliquot of each sample sent for chemical fingerprinting analysis is not sieved, there is the potential that sediment samples with large amounts of leaf litter or other plant material may contribute substances (e.g., plant waxes or alkanes) that might interfere with the analysis of petroleum hydrocarbons. To determine whether this plant material was affecting the analysis of PAHs, biomarkers, TEH, and other hydrocarbons, it was previously recommended (letter dated March 2, 2012), and FOSC approved and implemented, a comparative experiment, whereby ten (10) sediment samples were split (from a homogenized composite), and one aliquot sieved using a stainless steel 10-mm mesh sieve. The sieving and analyses were performed at Alpha Analytical laboratory. Results of the comparison (G. Douglas, NewFields, oral communication, 2012) indicated that routine sieving of sediment samples from the Kalamazoo River would not be necessary.

Fluorescence spectroscopy has been widely used for the routine monitoring or characterization of oils, source identification of oil spills, and oil weathering. Fluorometric detection techniques measure the fluorescence intensity from both dissolved and emulsified oil. It has been used as a field-determined surrogate for TPH by GC analysis, particularly in applications where the relative magnitude is sufficient, e.g., for time series monitoring or spatial mapping of relative contamination. Portable fluorometers have been applied to monitor the decline of oil concentrations in pore water of beach sand (Kim et al., 2010).

Laser fluorosensors also have been used for detection of oil (Karpicz et al., 2005), and are able to discriminate remotely between non-fluorescing biogenic oil and petroleum oils (Brown et al., 1996), thus allowing real-time measurement, immediate results, and increased detection ranges.

High-resolution digital photography under UV illumination followed by automated image processing to quantify the amount of fluorescence could be a third approach to using fluorescence as a field-determined surrogate for TPH.

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Fluorescence microscopy is another method that may be suitable and valuable for understanding oil-sediment associations and interactions, but may not be as suitable as a field screening technique.

Strengths: The fluorescence spectroscopy technique is very sensitive to aromatic concentrations (Eastwood, 1981; He et al., 2003). Pore-water samples analyzed by fluorometer will need to be filtered, but have the advantage of relatively short turnaround time (< 1 day) and should be more cost effective than the traditional GC or GC/MS technique, which requires a large amount of solvents, meticulous sample preparation and chromatographic separation (Maher, 1983; Li et al., 2004; Christensen and Tomasi, 2007). By measuring the fluorescence of aromatic compounds using a portable fluorometer, one can obtain insight into the concentrations of TPH. Fluorometric detection of oil can be a good alternative to GC/MS analysis for rapid decision making. Thus, it should provide an objective surrogate measure of TPH that would allow delineation between core intervals that would be submitted for laboratory chemical analyses versus retained intervals.

Limitations: Fluorometric oil analysis may not be a reliable direct surrogate for GC/MS oil measurement because of the complex relation between the chemical composition of oil and its fluorescence signal and because the relative proportion of aromatic hydrocarbons changes as oil degrades (Lambert et al., 2003). In one oil-spill monitoring study (Kim et al., 2010), some samples had high GC–TPH content but low fluorometric oil content, probably because of the preferential loss of relatively labile fluorescent compounds during weathering of oil, while more refractory compounds were still contributing to the GC TPH contents. GC TPH includes extractable fractions of the unresolved complex mixture, especially abundant in highly weathered samples, whereas fluorometric analysis measures only fluorescent aromatic compounds. In addition, the fluorescence response is not linear and increases almost exponentially with increasing number of rings on the PAH molecule. The presence of high TOC may also result in some quenching of the fluorescence response. Generally, this approach is used for screening purposes only.

For fluorometric measurements to be effectively related to GC or GC/MS concentrations and reliably used for quantitative applications (e.g., volume estimation, or comparison with environmental criteria), the fluorometric sensor shall be continuously recalibrated as the condition of oil weathering or oil composition change. Without appropriate recalibration, oil concentrations could be underestimated in heavily weathered samples (Kim et al., 2010).

Finally, fluorometric measurements provide no information regarding identification of the oil source.

Comparison to Fall 2011 protocols. Ultraviolet fluorescence of sheen, globules and flecks was observed visually as part of the routine processing protocol at the field lab. However, there was no use of a fluorometer or fluoresensing instrumentation; thus, the measurement typically was limited to counting the individual fluorescing particles exposed on the plane of core section, and noting the maximum depth at which sheen or globules were observed on the exposed plane. Photographic documentation under UV illumination was part of the protocol, but images were not processed further as a measurement technique.

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APPENDIX 1
REVIEW OF FALL 2011 SUBMERGED OIL QUANTIFICATION SAMPLING PLAN

ENBRIDGE LINE 6B MP 608 MARSHALL, MI PIPELINE RELEASE
JUNE 11, 2012

INTRODUCTION

This document describes the results of the review of the fall 2011 Submerged Oil Sampling Plan for the Enbridge Line 6B release. Specifically, experts evaluated sample locations and results for the 2011 poling and sediment cores used or potentially used in the Fall 2011 submerged oil quantification task. The results of this initial review were then evaluated to complete the following tasks relative to potential approaches for the spring 2012 Submerged Oil Sampling Plan:

- Discussion of pros and cons of various alternative sampling approaches.
- Ranking of recommended alternatives with benefits of each.
- Comparison of recommended alternative to the plan implemented in fall 2011. Identify pros and cons: include discussion of what will be gained in terms of reduced uncertainty, better representation, more applicability to modeling, etc., with the new approaches; and what those gains would cost in terms of additional sampling sites, samples, schedule, or other limitations imposed thereby.

These results are presented below.

The details of the methods used for submerged oil quantification in 2011 can be found in other documents. The following discussion focuses on sampling design recommendations to quantify the submerged oil. . In essence, the quantification method used thus far multiplies the average Total Petroleum Hydrocarbon (TPH) concentration adjusted for sediment bulk density by the planimetric area and thickness of various areal units (areas). These areas are defined by spatial analysis of the poling data wherein areas of "Heavy" and "Moderate" submerged oil sheening or surface-observed globules are manually delineated based upon poling locations and assigned "Heavy" or "Moderate" categorical descriptors; whereas "Light" and "None" areas are delineated via a process of creating and editing Thiessen polygons around "Light" and "None" poling locations. Whatever analytical chemistry method is selected for quantifying oil in sediment cores in 2012, it is likely that a spatial interpolation method involving strata means/medians and strata dimensions will be used to estimate total amount of oil. Given this expectation, it is important that sampling effort is balanced appropriately to minimize bias and maximize precision.

This work does not address analytical methods proposed for use in oil quantification or methods for distinguishing oil in sediments from background, but focuses on spatial sampling design for use with whatever suite of analytical methods is selected. While previous quantification efforts used both TPH and Oil and Grease (O&G) results, alternate or supplemental methods will be used in 2012. Differences in TPH concentrations across areas are evaluated, and the relationship between TPH concentration and poling methods only to inform sampling design, and not as a proposed method for quantification. In all designs proposed for 2012 it was assumed that the selected analytical method will measure concentrations separate from background regardless of the relative concentrations of these two values.

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Fall 2011 Submerged Oil Sampling Plan Description – Poling Results

A total of 7,443 locations on the Kalamazoo River downstream from the release were investigated using a screening assessment of subsurface oil via agitation/poling (hereafter referred to as "poling") in fall 2011 prior to fall remediation activities. These data were collected generally between August and October 2011 with a few supplemental data points from June of 2011 (Enbridge, 2011). A variety of semi-quantitative and quantitative metrics are collected at each screening location (observations of sheen, globules, water depth, etc.), and each location is characterized by a single categorical class describing relative amounts of subsurface oil present at that location: Heavy, Moderate, Light, or None. Statistically speaking, the sampling plan for sediment poling locations can be described as directed sampling in that the poling locations were selected by field practitioners and were not, to our knowledge, a probability sample of all sample locations. Nonetheless, there are evident correlations between the poling results and the geomorphic strata that are proposed for use in 2012.

The poling locations (Figure 1) are spatially widely distributed and cover the Kalamazoo River from the confluence with Talmadge Creek to Morrow Lake. In the area of coverage, poling results are typically collected at points along cross-channel transects with higher densities of poling locations in areas of known current or past subsurface oiling.

These results were evaluated to examine the relationships between the subsurface descriptor and proposed geomorphic strata, as well as the collocated current velocity and sediment type categorical variables also collected at the time of screening for subsurface oil. Results are depicted graphically in mosaic plots (e.g., Friendly, 1994) in Figure 2 below. Chi-squared tests of the relationship between categorical descriptor and these three categorical variables indicate strongly significant ($p < 0.0001$) correlations.

These results indicate that, as expected, categorical descriptor of subsurface oil at poling locations in 2011 are strongly correlated with the proposed geomorphic strata for sampling in 2012 – with heavier oiling generally found in more depositional strata, as well as at locations with lower current velocities and finer sediments.

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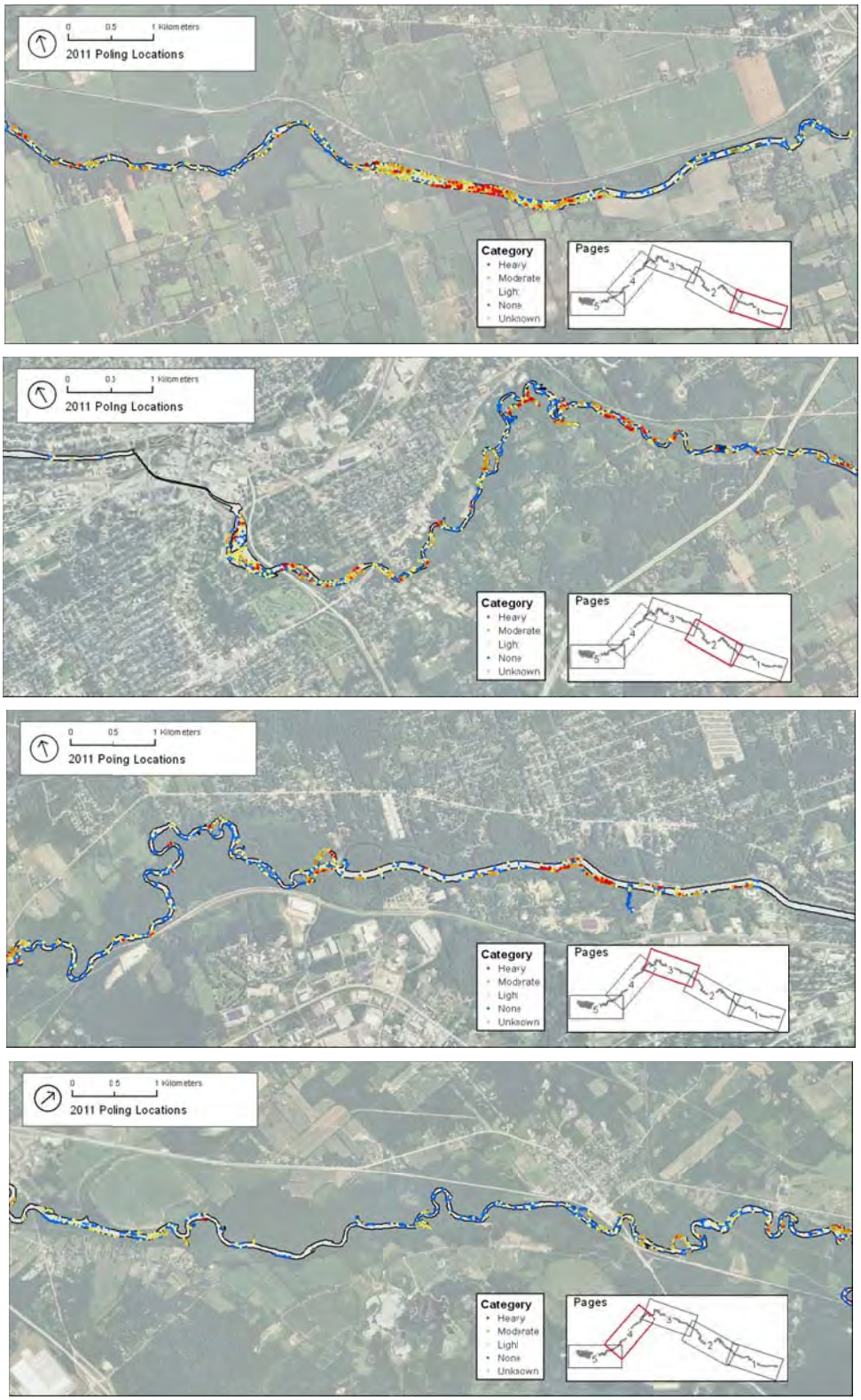

Figure 1. Maps of fall 2011 sediment poling locations by categorical descriptor of subsurface oil

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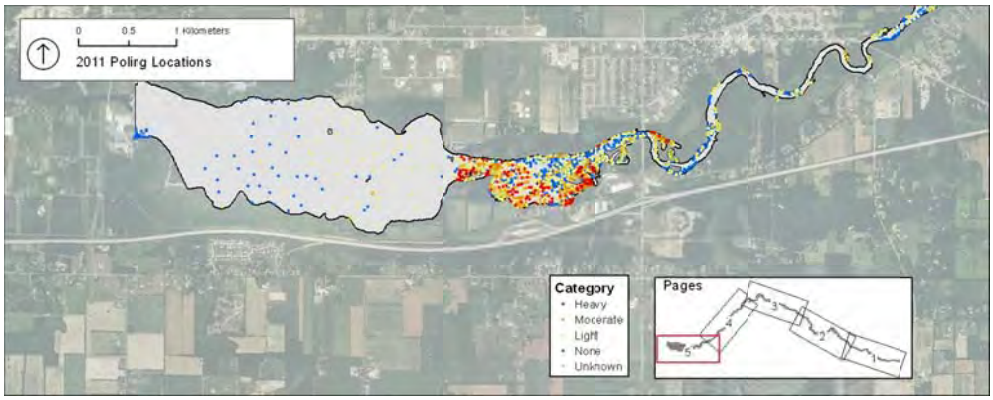

Figure 1 (continued). Maps of fall 2011 sediment poling locations by categorical descriptor of subsurface oil

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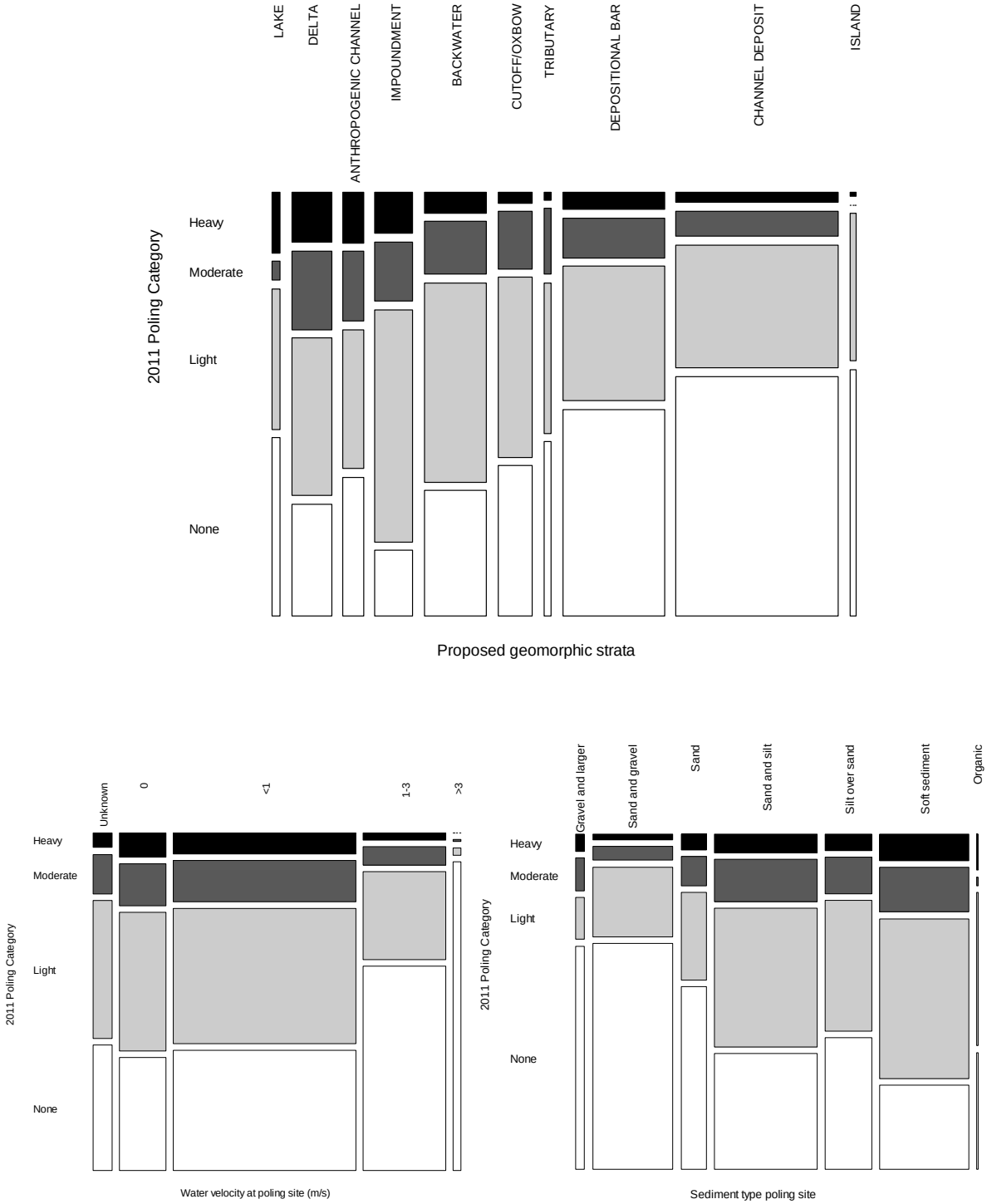

Figure 2. Mosaic plots of contingency tables for categorical descriptor of subsurface oil at poling locations in 2011 proposed geomorphic strata, current velocity and sediment size descriptors. (Dimensions of plotted rectangle correspond to number of samples in the indicated category combination.)

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Fall 2011 Submerged Oil Sampling Plan Description – Sediment Core Surface Total Petroleum Hydrocarbon (TPH) Results

A total of 110 sediment cores were collected from depositional areas located on the Kalamazoo River downstream from the release in 2011. These cores were largely collected within previous oil recovery work areas, and only within depositional areas. Of these, 100 were collected within areas characterized as having "heavy" or "moderate" subsurface oiling via poling at any time in the past. Of these 100 locations, 36 were within areas characterized as having "heavy" or "moderate" subsurface oiling via poling in fall 2011. The remaining 10 cores were collected in areas characterized as "light". These 110 sediment core locations were not co-located with concurrent screening via poling.

Statistically speaking, the sampling plan for sediment samples collected via coring in 2011 can be described as directed sampling, in that the core locations were selected by field practitioners and were not, to our knowledge, a probability sample of all sample locations. Similarly, while the sediment core locations were grouped into categories for the purposes of oil quantification one cannot describe these as sampling strata per se.

The coring locations (Figure 3) are spatially widely distributed and cover most of the Kalamazoo River from the confluence with Talmadge Creek to Morrow Lake. Because the coring locations were intended to be primarily located in areas of previous heavy or moderate poling results, the locations appear clustered at coarse scales within the main stem of the river, and irregularly spaced but spatially balanced in the delta and lake.

The results of the sediment sampling were examined to evaluate the relationships between the surface TPH concentrations (defined as the sum of the oil range and diesel range organics [ORO and DRO] analytical values for the uppermost vertical layer at each core location) and proposed geomorphic strata, as well as the categorical submerged oil descriptor at the nearest 2011 poling location, and whether that sediment core location was inside or outside the Heavy/Moderate polygons as delineated by the 2011 poling data. Each coring location was associated with the nearest poling location. All coring locations were within 500 meters of an adjacent poling location and the median distance between coring location and poling location was 26.5 meters. This analysis was carried out primarily to ensure that quantitative sediment chemistry results display similar relationships to the strata proposed for 2012 as the more descriptive poling results discussed above.

Results are depicted graphically as box plots in Figure 4 below. T-test results indicate evidence for significant ($p=0.069$) differences in log surface TPH concentration between core locations inside and outside the Heavy/Moderate polygons as delineated by the 2011 poling data. Analysis of Variance (ANOVA) results yield significant evidence for differences between log surface TPH concentration by nearest categorical poling result ($p=0.03$) but no real evidence for differences across proposed geomorphic strata ($p=0.21$). There is visual evidence of trends present in both cases, however, with higher TPH values found in more depositional strata as well as at locations with heavier nearby poling categories.

It was also noted that previous work carried out in 2010 has noted similar, and statistically significant, correlations between collocated poling-based categorical oiling descriptor and sediment core TPH values (Enbridge, 2011).

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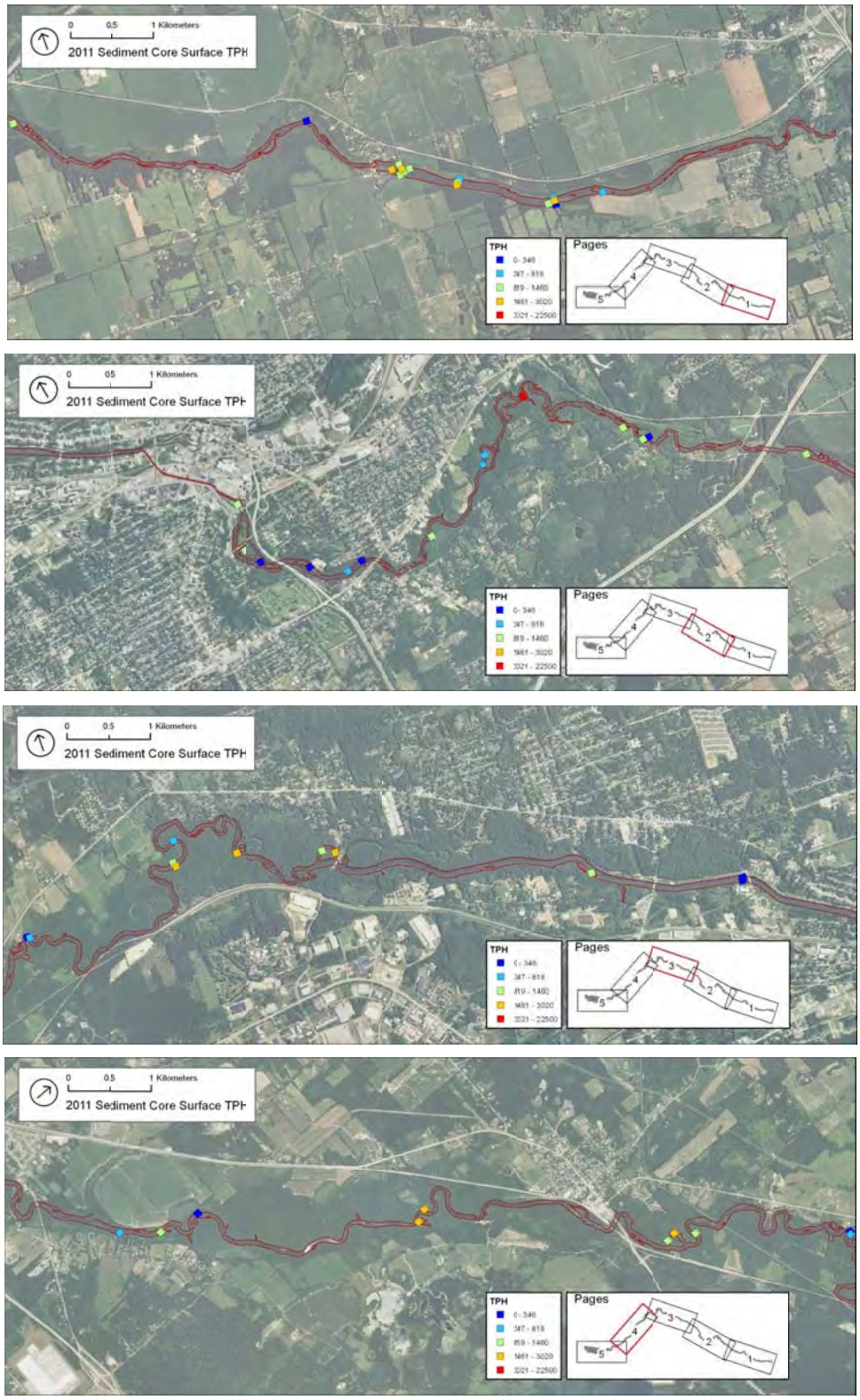

Figure 3. Maps of uppermost sediment-layer TPH concentration ranges (mg/kg) at 2011 sediment coring locations.

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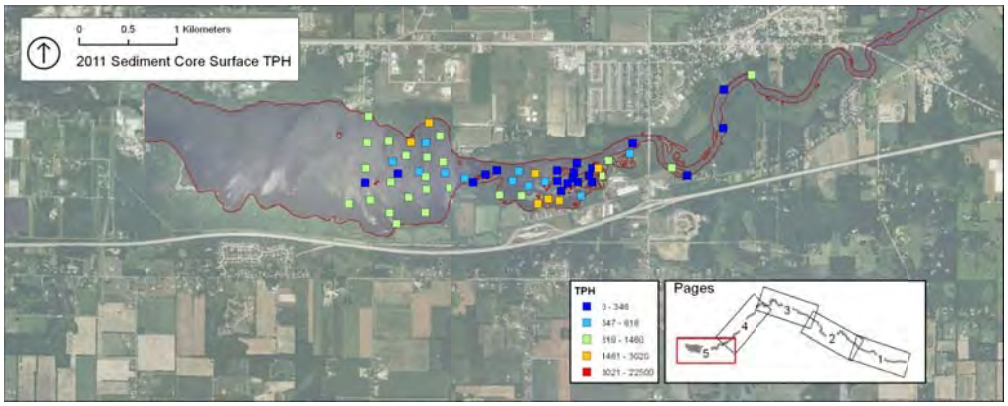

Figure 3 (continued).Maps of uppermost sediment-layer TPH concentration ranges (mg/kg) at 2011 sediment coring locations.

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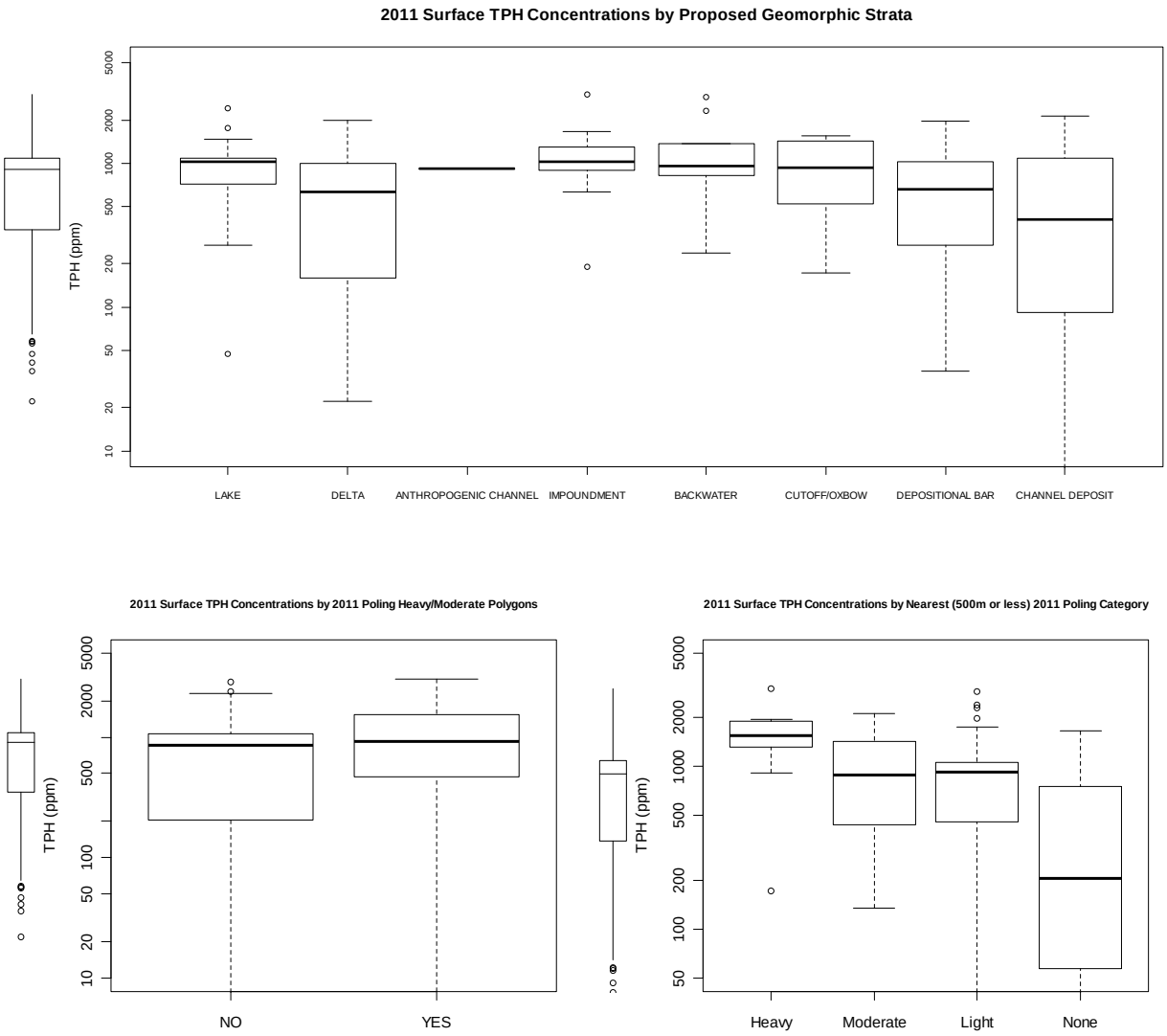

Figure 4. Box plots of surface TPH values (log scale) at 2011 sediment core locations categorized by proposed geomorphic strata (top), Heavy/Moderate poling polygon presence (bottom left) and nearest categorical poling result (bottom right).

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ALTERNATIVE APPROACHES

This document identifies alternative spatial approaches for sample designs for sampling in 2012. The analytical method to be used to quantify oil from the Enbridge Line 6B release in subsurface sediments is unknown at this time. While raw TPH results were analyzed above as part of the investigation of the 2011 sampling design and its relationship to proposed approaches for 2012, it should be stressed that the below-considered approaches involving probability samples, stratification, or leveraging of existing screening results can be applied to any analytical method used to quantify all oil, or oil specifically from the Enbridge Line 6B release, in subsurface sediments. It is assumed that the selected analytical method will measure concentrations separate from background regardless of the relative concentrations of these two values.

There are generally two primary methods for estimation: survey-based and model-based. In this context, a survey-based approach would be to generate a probability sample of the entire domain (river and associated water-bodies), sample these, then estimate the total amount of oil remaining. The design could be a simple random sample or more complex – involving stratification, clustered sampling, or multi-stage or adaptive designs. Design-based methods are often best when: (1) one wants to rigorously estimate statistics of the population (e.g. the mean, median, etc.) and/or conduct hypothesis tests against these statistics; (2) a relatively large number of samples can be afforded, and (3) random sampling is feasible. A model-based approach would be use existing data to predict the relationship of oil presence and quantity based on other variable(s) – like space (geostatistical model), geomorphic surface, depth, hydrodynamics, etc. Sampling could be random, but this is not required. One wants to sample across the range of possibly related covariates so often directed sampling is used to span the gradient of values for potential predictive covariates. Model-based methods are often best when: (1) we want to map the property of interest; and (2) a strong correlation exists between the property of interest and covariates.

The total amount of submerged oil is the primary quantity of interest – suggesting a survey-based approach. Understanding how such oil is distributed across space would also be of interest and that the distribution of submerged oil is strongly spatially patterned and driven by known spatially distributed covariates. The above investigations demonstrate that there is good evidence that the amount of submerged oil in 2012 is likely to be very strongly related to poling results and the geomorphic surface. Further, variogram analysis indicates that oil concentrations vary widely over small (<10 m) spatial scales indicating that pure interpolation approaches would require unrealistically large numbers of samples. In order to make best use of known covariates and sample efficiently, a hybrid approach known as model-assisted survey sampling is recommended. The recommended hybrid approach is a spatially balanced, stratified Generalized Random Tesselation (GRTS) survey design (Stevens and Olsen, 2004). Such a survey design has the advantages of:

- Likely being more efficient than simple random sampling
- Being spatially balanced across the area of interest in the event that geostatistical models (interpolation) are required/helpful
- Leveraging known information about the relationship between covariates and submerged oil presence and quantity
- Having most of the advantageous statistical properties of a simple random sample
- Can include an oversample to accommodate non-response or no-access issues in the field

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- Generating data useable for design-based estimates of total submerged oil properties via a variety of frequentist or Bayesian methods

The approaches considered below (except alternative 1) would involve GRTS sample designs. These designs may or may not be stratified, as detailed below. Potential alternative approaches are summarized and evaluated in the following subsections.

Alternative 1 - Directed sediment sampling:

This approach involves field practitioners collecting spring 2012 poling data as per previous years, collecting sediment cores at locations selected by field practitioners as per previous years, and using a soon-to-be-selected analytical quantification method to estimate median or mean contaminant concentrations separate from background for all locations.

Advantages: Logistically simple. Sampling potentially could be performed within heavy/moderate areas essentially immediately once poling delimits those areas, because the two data collection efforts are not dependent.

Disadvantages: This approach does not constitute a sample of all potentially affected areas, so results cannot be used validly to estimate remaining subsurface oiling in an unbiased way.

Alternative 2 - Sediment sampling design:

This approach involves field practitioners collecting Spring 2012 poling data as per previous years, generating a GRTS spatial sample for sediment coring across all river, delta, and lake areas independent of the 2012 poling results, collecting sediment cores at these sampling locations, and using a selected analytical quantification method to estimate median or mean contaminant concentrations separate from background for all locations.

Advantages: This approach uses data collected at a sample of all potentially affected locations, so results can be used to derive an unbiased estimate of remaining subsurface oiling. This approach is also spatially balanced, and relatively logistically simple. Sampling can be performed at the same time as poling because the two data collection efforts are not dependent.

Disadvantages: This approach ignores other factors known to be correlated with submerged-oil presence and quantity, such as poling results, sediment texture or geomorphic strata.

Alternative 3 - Stratified sediment sampling design (strata from poling only)

This approach involves field practitioners collecting spring 2012 poling data as per previous years, generating a stratified spatial sample using 2012 poling results (or spatial products thereof) after poling is complete, collecting sediment cores at these locations, and using selected analytical quantification method to estimate median or mean contaminant concentrations separate from background within these strata.

Advantages: This approach uses data collected at a stratified sample of all potentially affected locations, so results can be used to derive a more precise and unbiased estimate of remaining subsurface oiling. This approach is also spatially balanced.

Disadvantages: This approach ignores geomorphic information known to be correlated with subsurface presence and quantity. Sampling must be performed after poling because

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sediment sampling is dependent upon poling results. This approach is somewhat more logistically complex.

Alternative 4 - Stratified sediment sampling design (poling and geomorphology)

This approach involves field practitioners collecting Spring 2012 poling data as per previous years, generating a stratified GRTS spatial sample using strata based on a combination of 2012 poling results (or spatial products thereof) and geomorphic surface reclassification, collection of sediment cores at these locations, and use of a selected analytical quantification method to estimate median or mean contaminant concentrations separate from background within these strata. For this alternative and the alternatives below, the 2012 poling data would be used to generate polygonal strata within the, either using methods from previous years as described above, a more automated method (interpolation), or some hybrid approach. These polygons would be used as stratum boundaries.

Advantages: This approach uses data collected at a stratified sample of all potentially affected locations, so results can be used to derive a more precise and unbiased estimate of remaining subsurface oiling. This approach is also spatially balanced.

Disadvantages: If a method for quantifying oil in sediments directly from poling results is derived, the poling results cannot be considered a sample of all locations. Poling results may be used, but only to stratify sediment sampling for other analysis. Sampling must be performed after poling because sediment sampling is dependent upon poling results. This approach is somewhat more logistically complex.

Alternative 5 – Two-phase stratified poling and sediment sampling design

This approach involves generating a stratified GRTS spatial sample for 2012 poling locations using geomorphic surface reclassification and 2011 poling results, collecting Spring 2012 poling data at these locations, then generating a second-phase stratified random sample using geomorphic surface reclassification and 2012 first-phase poling sample, collecting sediment cores at these locations, and using selected analytical quantification method to estimate median or mean contaminant concentrations separate from background within these strata.

Advantages: If a method for quantifying oil in sediments directly from poling results is derived, the poling results can be considered a sample of all locations and can be used directly to derive a more precise and unbiased estimate of remaining subsurface oiling. If not, sediment sampling data are collected at a stratified sample of locations, so these results can also be used to derive a precise and unbiased estimate. This approach is also spatially balanced.

Disadvantages: This approach is significantly more logistically complex than other alternatives because it is a two-phase design. A design must be generated and implemented for spring 2012 poling in a short time. Sediment sampling must be performed after poling because sediment sampling is dependent upon poling results.

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OTHER DESIGN CONSIDERATIONS

There are a few other design options for consideration, detailed below.

Sample Number

It is assumed that overall sampling effort will remain approximately the same or less than that available for fall 2011. In 2011, some 340 samples were analyzed from different vertical strata within sediment cores collected at the 110 sampling locations. It is proposed that samples collected in 2012 be apportioned evenly across strata, or proportional to stratum size with a minimum number per stratum. If one assumes 10 geomorphic strata and 2 different poling polygon strata this would yield up to 20 strata, with n representing either a fixed sample size (e.g., 5 to 10 cores) being the same across strata, or a fixed percentage if samples are apportioned by stratum size.

The sampling potentially could be done in two tiers or phases, where an initial phase collects the minimum number of cores per stratum (e.g., 3-5), these cores are processed to provide oil chemistry results (e.g., for 2 samples per core, or 6-10 samples per stratum), and the variance among the tier 1 results becomes the basis for estimating the number of remaining cores needed to achieve statistical confidence intervals of acceptable width to provide useful estimates of oil volume for each stratum. Tier two would consist of the collection and processing of the remaining number of cores to implement the estimate from tier 2.

Collocation of Poling or Other Screening Techniques

For all of these approaches, sediment coring locations may be collocated with poling locations from 2012. This can be done by re-occupying poling locations if sediment coring is performed after poling, or by field teams performing poling screening at the same time and location as sediment coring.

While the results above relating sediment surface TPH to nearest poling location category indicate some relationships, earlier data from 2010 indicated an even stronger relationship between sediment chemistry and collocated poling category. Collection of collocated data will allow quantification of this relationship and possible development of a poling-based model to refine estimates of amount of remaining subsurface oil.

Timing of Sample Design

Because time is limited and the sampling design for sediment core sampling in impacted areas is dependent upon completion of 2012 poling prior to completion of the design, it is so noted in the following. Some geomorphic types are not widely distributed across the entire impacted area (e.g. the delta) and poling is likely to be completed within them in short time frames. Other geomorphic types (e.g. channel deposits) occur along the entire main-stem of the river and will likely have been surveyed completely via poling only at the end of the entire poling effort. Given this, it is possible to phase the generation of sample locations, with a sample for a given geomorphic stratum generated as soon as poling for that stratum is complete and the poling-derived category boundaries have been mapped.

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PREFERRED ALTERNATIVE APPROACH

I recommend Alternative 4. The primary advantage of the proposed alternative approach is that it constitutes a representative sample of all the sediments within the designated strata, so that estimation of median and mean contaminant concentrations separate from background may be estimated without bias. These unbiased estimates of contaminant concentration, or concentrations above background, may be used to generate an unbiased estimate of the total volume of remaining subsurface oil. Further, there is evidence that analytical sediment chemistry results (or TPH results, in any case) are related to both poling results and proposed geomorphic strata. As such, allocation of sampling effort across strata defined by both poling results and geomorphic class should result in smaller within-strata variances and greater precision in mean or median contaminant concentrations, and resultant total oil quantities.

While it is evident that the poling is valuable as a screening technique and as a method to define strata for sediment sampling, the logistic disadvantages and additional complexity required to implement a two-phase sampling plan for poling and sediment sampling outweigh the potential gains in precision that may be possible with such a design if a suitable technique is devised to relate poling categorical results to subsurface oil quantity.

It is recognized that the conceptual model of subsurface sediment oil contamination source and distribution since the spill may be complex. Specifically, there may be a gradient of contamination as one moves downstream from source areas, and this may have been compounded by subsequent redistribution and removal. However, use of the 2012 poling results as sampling strata essentially allows the system to be considered as static for the purposes of sampling for quantification in 2012. There is ample evidence from 2010 and 2011 that poling, and derivative analysis products, are well correlated with spatially adjacent and contemporaneous sediment chemistry results, and as such provide the best way to account for gross spatial heterogeneity in present-day oil contamination.

It is also recommended to collocate poling at all sediment sample collections. We recommend processing an initial tier of 3 to 5 cores (>10 samples) from each stratum. Given the probable large variations in areas across strata (Table 1), it is likely that additional sample processing in subsequent tiers will take place preferentially in larger strata, or mid-size strata with large variances, resulting in larger sample numbers for larger and more variable strata. Figure 5 depicts a hypothetical GRTS sample generated using the strata defined as in Table 1, by proposed geomorphic classification and 2011 poling-derived Heavy/Moderate delineation areas. A fixed sample size of 20 coring locations was generated for each stratum, regardless of size. The first 5 sample locations in each stratum were assumed to be the first tier of sample processing.

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Strata	Heavy/Moderate Area	Light or None Area
	Acres	Acres
Anthropogenic Channel	6.0	72.6
Backwater	9.8	44.5
Channel Deposit	12.4	501.3
Cutoff/Oxbow	3.6	22.3
Delta	29.5	163.3
Depositional Bar	8.4	132.2
Impoundment	15.2	52.1
Lake	4.3	643.2
Tributary	0.8	2.4
Totals	90.1	1633.9

Table 1. Areas of strata as defined by one possible geomorphic classification and 2011 poling-derived Heavy/Moderate delineation areas. Note that strata for sampling in 2012 will be spatially defined by 2012 poling-derived delineation areas, but 2011 areas provide an estimate of areal extent.

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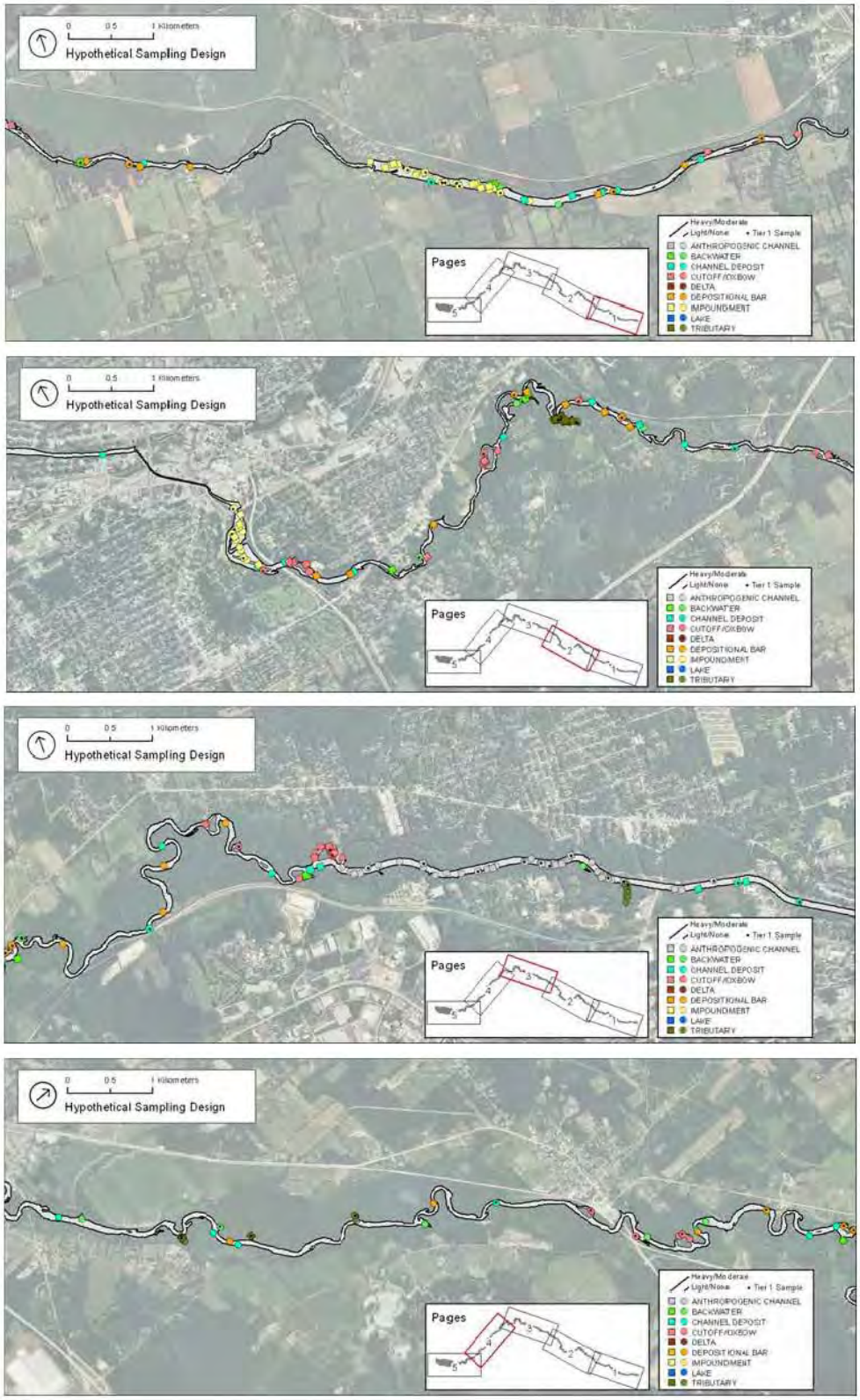

Figure 5. Hypothetical GRTS sample generated using example strata defined as one possible geomorphic classification (9 categories) and 2011 poling-derived submerged-oil indications (2 categories). Note that color indicates geomorphic strata and shape indicates poling derived submerged oil indicators. Tier 1 samples identified with dot.

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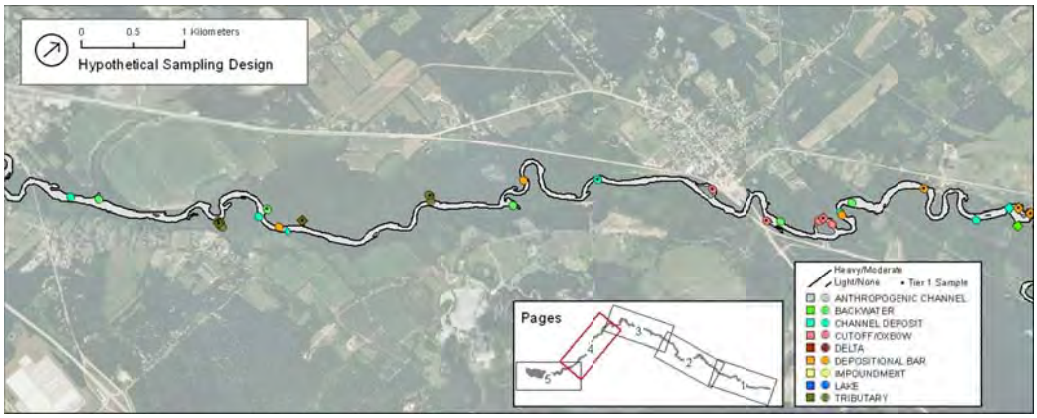

Figure 5 (continued). Hypothetical GRTS sample generated using example strata defined as one possible geomorphic classification (9 categories) and 2011 poling-derived submerged-oil indications (2 categories). Note that color indicates geomorphic strata and shape indicates poling derived submerged oil indicators. Tier 1 samples identified with dot.

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Appendix 2

3/1/2013 Technical Memorandum (G. Douglas, NewFields)

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NewFields

March 1, 2013

Mr. Tom Graan
Weston Solutions, Inc.
750 E. Bunker Court
Vernon Hills, IL 60061

RE: Technical Memorandum – Determination of Line 6B Oil Concentration in Kalamazoo River Sediments.

Dear Mr. Graan,

1.0 Introduction

Line 6B oil is a high viscosity oil sands based bitumen product that is diluted with a gas condensate solvent pipeline flow improver. As such, it exhibits unique physical and chemical properties when released to the river environment. These physical changes include globule and droplet formation in the water column as the lighter condensate evaporates after the release. Re-suspended sediment particles adsorb onto the oil and the oil sinks to the sediment surface. Activities such as oil recovery efforts, natural river turbulence, and recreational activities (e.g., boating) mix the oil laden surface sediments deeper in the sediment core effectively diluting the original surface Line 6B chemical signal within a complex river sediment residual background hydrocarbon (RBH)[1] signature. The ability to forensically identify and quantify the presence of the line 6B oil in these sediments becomes more difficult as oil/sediment dilution increases.

Chemical analysis of Line 6B oil has identified a unique chemical feature which provides a means to distinguish it from the RBH present in the Kalamazoo River sediment. Line 6B oil is enriched in a class of biomarker compounds called triaromatic steroids (TAS)[2] relative to sediment background. Ratios of these compounds to other stable yet less discriminating biomarker compounds (triterpanes) are called source/quantitation ratios (QR) and are used to assist in the identification and quantitation of the Line 6B oil in the sediment.[3] Of the many source/quantitation ratios that have been evaluated, the TAS2/Hopane[4] and TAS1/T30[5] exhibit the highest stability and resolving power within Kalamazoo River sediments.

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[1]Residual background hydrocarbons represent the hydrocarbons present in the sediment from coal tar sources, atmospheric deposition of combustion PAHs, road runoff, and leaks/losses from non-Line 6B oils.
[2]Peters, K. E., Walters, C. C., Moldowan, J.M. 2005. The Biomarker Guide, Volumes1&2. Biomarker and Isotopes in Petroleum Exploration and Earth History. **2005**, Cambridge University Press. Cambridge, UK.
[3]Douglas, G.S. and Hallebone, B.P. 2012. Forensic Identification And Quantification of Oil Sands-Based Diluted Bitumen Released Into a Complex River Environment – The Kalamazoo River Oil Spill. SETAC North America 33rd Annual Meeting.
[4]Wang, Z, and Soutt, S. 2007. Oil Spill Environmental Forensics – Fingerprinting And Source Identification. Academic Press, Burlington, MA. 2007.
[5]TAS1 = C26,20R- +C27,20S- triaromatic steroid, TAS2 = C28,20S-triaromatic steroid, Hopane = 17α(H),21β(H)-hopane, T30 = 30,31-Trishomohopane-22S.

NewFields has been requested by EPA to develop a scientifically sound protocol for the identification and quantitation of Line 6B oil in the Kalamazoo River sediments. Multiple approaches were evaluated during the method development process, including reliance on TPH and gravimetric weight measurements, Line 6B calibrated quantitation relative to a dominant Line 6B compound (e.g., C3-DBT), source double ratio mixing models,[6] and sediment calibration using representative river sediment Line 6B spiking studies (Range Finding Study).

The primary problem identified in these initial studies was the abundance and variability of RBH in the sediments relative to the Line 6B oil chemical fingerprint signal. This problem was first observed in the Toxicity Study[7] sediment samples where Line 6B quantitation estimates were either lower/higher than could be justified by the TPH, gravimetric and forensic chemistry data (e.g., sediment sample MP10.75). To address this issue, sediments representing different background signatures were spiked with Line 6B oil at concentrations ranging from approximately 10 ppm Line 6B to 17,000 ppm Line 6B. These Line 6B calibration samples were then applied geographically from MP2-MP15.75 (SEKR0000R024S092112D004, R025), and from the Battle Creek convergence (MP16.5) to MP39.75 (SEKR3510R018S092112D004, MP35.1) respectively. The primary assumption for this approach was that a similar RBH signature and concentration existed within each of these two sections of the Kalamazoo River.[8] The results for each Range Finding Study (RFS) were reduced to a mathematical equation using accepted curve fitting programs, and directly applied to the respective sediments. These "*Reference*" sediments were selected because they contained moderate amounts of RBH and but did not contain any Line 6B oil. Quantified Line 6B values using these calibration mixtures produced highly variable and generally biased low Line 6B results relative to TPH, Gravimetric, and source ratio measurements.

The Submerged Oil Quantitation Study was designed to collect representative sediment samples both geographically and with sediment depth in the Line 6B spill zone. Sediment cores were collected and processed at selected depths and shipped to the laboratory for analysis. The RFS Line 6B calibration was applied to these samples with limited success. Application of the RFS calibrations to the Submerged Oil Quantitation Study sediments exhibited a wide range of Line 6B sensitivity (spatially and vertically). Line 6B sensitivity is defined as the change in Line 6B oil concentration/change in quantitation ratio (e.g., TAS2/Hopane). Sediments with low Line 6B sensitivity generally have high concentrations of RBH or Line 6B oil. In these sediments, it may take orders of magnitude more Line 6B oil to even detect a change in the Quantitation Ratio relative to a sediment sample with low RBH (e.g., R024). *Only sediments with the same Line 6B sensitivity as the reference samples produce reliable Line 6B quantitation results using the RFS Line 6B calibration method.*

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[6]Douglas, G.S., Stout, S.A., Uhler, A.D., McCarthy, K.J., Emsbo-Mattingly, S.D. 2007. Advantages of quantitative chemical fingerprinting in oil spill source identification. *In:* Oil Spill Environmental Forensics: Fingerprinting and Source Identification. Z. Wang and S.A. Stout, Eds. Elsevier Publishing Co., Boston, MA.

[7]G.M. DeGraeve. 2012. Final Report. *Chironomus dilutus* and *Hyalella Azteca*, 10-day Whole Sediment Toxicity Testing Results, Kalamazoo River Sediment Sampling Line 6B Oil Spill, Marshall, Michigan. Prepared for: Enbridge Energy. June 10, 2012.

[8] River sediments down-stream from the Battle Creek convergence would contain Kalamazoo River RBH and Battle Creek RBH.

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This problem was resolved with the development of a two end member mixing model for each sediment sample. Using this approach, the *calculation of Line 6B oil includes the impact of sample specific RBH within each sample on the behavior of the quantitation ratio (QR).* This sediment sample specific approach is based on the accurate measurements of quantitation ratio compounds (e.g., TAS2, Hopane, TAS1, T30) in each sediment sample and the spilled Line 6B oil (e.g., CL-6B-072223-092710-JPS-KA-001-33_TOPPED, Topped Line 6B Oil). Line 6B oil is added or removed mathematically from the field sample and plotted versus the QR. A QR Critical Value (CV) is defined by the QR of reference samples R024 and MP35.1 above which Line 6B is detected and below which it is not. The slope of these mixing model curves provided a measure of sediment sample-specific Line 6B Detectability (L6BD) and a means to calculate how much Line 6B oil is required to achieve the sample specific QR relative to the reference sample CV. This approach is more accurate than the reference sample curve fitting estimates because it incorporates the impact of differential Line 6B sensitivities within the oil quantitation result. The validity of this approach has been verified in the Line 6B spiked RFS and Method Detection Limit (MDL) sediments where known amounts of Line 6B oil were added to reference sediments R024, MP35.1 and Battle Creek (BC).[9]

This Technical Memorandum describes a field verified Line 6B quantitation methodology for use at the Kalamazoo River Line 6B oil spill zone. The method has been applied to the Submerged Oil Quantitation Study field data and Line 6B concentration, or Line 6B detectability (if L6B = ND) can be calculated for each sediment sample.

2.0 Analytical Methods

Range Finding and Quantitation Study sediment samples were extracted and analyzed according to Enbridge Kalamazoo River Analytical Quality Assurance Plan V2.2 by Alpha Analytical located in Mansfield, Massachusetts. Sediment samples were dried with sodium sulfate, spiked with surrogate compounds, serially extracted with methylene chloride, concentrated to 1 mL and analyzed for extract gravimetric residue weight. The sample extract was then analyzed for alkanes, Total Petroleum Hydrocarbons (TPH), and Total Resolved Hydrocarbons (TRH) by gas chromatography with flame ionization detection (GC-FID). A second aliquot of the extract was analyzed by gas chromatography with mass spectrometer detector (GC-MS) for polycyclic aromatic hydrocarbons (e.g., phenanthrenes), sulfur heterocyclics (e.g., dibenzothiophenes) and their associated alkylated homologs (e.g., C3-dibenzothiophenes). Triterpane, sterane and triaromatic sterane biomarker compounds are also analyzed and reported during this procedure. Due to mass discrimination variability in the TAS analysis, all samples were additionally calibrated with the Line 6B control oil analyzed with each analytical batch. Hopane and T30 were also calibrated with the sample specific Line 6B control oil to minimize analytical variability and improve QR resolution.

A multi-tiered interpretive approach was used to identify the presence or absence of Line 6B oil in the Quantitation Study sediment samples. These included the following interpretive analyses:

1. Comparison of the Line 6B oiled sediment (e.g., MP10.75) GC/FID hydrocarbon signatures to Line 6B oil (Figure 1).

[9] Battle Creek RFS and MDL results are included in this report to document the utility of the mixing model method in different field sediment matrices.

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2. Comparison of reference and oiled sediment PAH distributions to Line 6B oil (Figure 2 and Figure 3).
3. Comparison of reference and oiled sediment Triterpane, Sterane, and Tri-Aromatic Sterane compound distributions to Line 6B oil (Figure 4 and Figure 5).
4. Comparison of field sample QR relative to CV with subsequent quantification of Line 6B inputs or Line 6B detectability.

3.0 Interpretive Line 6B Quantitation Methods

The analytical methods used for Line 6B oil spill provide accurate measurements of key diagnostic hydrocarbons from which interpretive methods were developed to reliably quantify Line 6B oil in the river sediment as follows:

1. Identify Line 6B source and quantitation ratios that provide the highest degree of resolution in the sediment matrix. Line 6B oil chemical fingerprint is unique when compared to sediment background because it contains elevated triaromatic steroids (TAS1, TAS2) relative to the triterpanes (Hopane, T30, Figure 4). Based on extensive analysis and testing, the TAS2/Hopane and TAS1/T30 source/quantitation ratios have been proven superior to all other oil ratios with respect to source specificity, relative abundance to background, and *minimal matrix interferences.*
2. Define the critical values based on the R024 and MP35.1 reference samples (Tables 1 and 2 respectively).
3. Prepare two end member mixing models (TAS2/Hopane and TAS1/T30) for each sediment sample. Use a simple mathematical relationship to calculate Line 6B oil concentration for TAS2/Hopane and TAS1/T30 values > CV. For sediment samples where TAS2/Hopane and TAS1/T30 values < CV, calculate the sample specific Line 6B detectability.[10]
    a. **Positive detections** QR > CV: C = (A-D*X)/(B-E*X) where X = Line 6B concentration (mg/kg). Solving for X: X = (B*C-A)/(E*C-D) **where:**
        A = Sample TAS2 (TAS1) concentration (µg/kg).
        B = Sample Hopane (T30) concentration (µg/kg)
        C = Critical Value of TAS2/Hopane ratio (or TAS1/T30 ratio)
        D = TAS2 (TAS1) concentration in topped L6B oil (g/kg).
        E = Hopane (T30) concentration in topped L6B oil (g/kg).
    b. **Non detects** QR < CV: C = (A+D*X)/(B+E*X) where X = Line 6B detectability (mg/kg). Solving for X: X = (B*C-A)/(D-E*C) **where:**
        A = Sample TAS2 (TAS1) concentration (µg/kg).
        B = Sample Hopane (T30) concentration (µg/kg)
        C = Critical Value of TAS2/Hopane ratio (or TAS1/T30 ratio)
        D = TAS2 (TAS1) concentration in topped L6B oil (g/kg).
        E = Hopane (T30) concentration in topped L6B oil (g/kg)
4. Evaluate the reliability of the two end member mixing model approach using Kalamazoo and Battle Creek River field samples where known amounts of Line 6B oil were added (e.g., Range Finding Study, Figures 6-14, Tables 1-3).

[10] Line 6B detectability is defined as the concentration of Line 6B oil required to reach the Quantitation ratio CV for a specific sediment sample. This estimate is a measure of sediment L6B sensitivity and should be constrained by the gravimetric residue concentrations measured in each sample.

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5. Compare the Line 6B oil quantitation results from the two quantitation ratios and report the results as follows;
    a. If values are reported for both ratios, average and report.
    b. If values are reported for one ratio, but the limit of Line 6 detectability of the second ratio is greater than the reported value, then report the primary value and report ND for the second ratio with the limit of L6B detectability.
    c. If values are reported for one ratio, but the second value Line 6B detectability is less than the reported value, qualify data and evaluate for chemical reasonableness.
    d. **Compare all results to TPH corrected for L6B response and gravimetric weight** for chemical reasonableness.
    e. Evaluate hydrocarbon signature of each sample for chemical reasonableness.
    f. Calculate maximum L6B oil in a sample based on C3-DBT and TAS2.
        i. Calculate the maximum Line 6B oil as follows based on C3-DBT as follows.[11]
            1. $\text{C3-DBT}_{Bkg} = \text{Fluoranthene}_{Sample} \times \text{C3-DBT/Fluoranthene}_{Bkg}$
            2. $\text{C3-DBT}_{Max\ L6B\ Oil} = \text{C3-DBT}_{Sample} - \text{C3-DBT}_{Bkg}$
            3. $\text{Max Line 6B Oil} = \text{C3-DBT}_{Max\ L6B\ Oil} \times \text{Line 6B Oil/C3-DBT}_{L6B}$
        ii. Calculate the maximum Line 6B oil based on TAS2 (TAS1) as follows.
            1. $\text{TAS2}_{Bkg} = \text{Fluoranthene}_{Sample} \times \text{TAS2/Fluoranthene}_{Bkg}$
            2. $\text{TAS2}_{Max\ L6B\ Oil} = \text{TAS2}_{Sample} - \text{TAS2}_{Bkg}$
            3. $\text{Max Line 6B Oil} = \text{TAS2}_{Max\ L6B\ Oil} \times \text{Line 6B Oil/TAS2}_{L6B}$
        iii. Compare maximum Line 6B Oil estimates to mixing model results for chemical reasonableness.

4.0 Results and Discussion

Table 1, Table 2, and Table 3 are the results from the R024, MP35.1 and BC range finding studies, including the TAS2/Hopane and TAS1/T30 quantitation ratios, the amount of Line 6B oil spiked into each sample and the amounts of L6B calculated using the mixing model described above. Figures 6 and 7 are graphical comparisons of measured versus added hopane and TAS2 sediment concentrations in the R024, and MP35.1 range finding studies. The mixing model predicted values are represented by the blue line and show that measured and predicted concentrations agree remarkably well. Figure 8 is a comparison of measured versus added Line 6B oil and QR TAS2/Hopane for R024 and MP35.1 range finding studies. The mixing model predicted values are represented by the blue line and show that measured and predicted concentrations agree remarkably well supporting the use of mixing models to calculate Line 6B oil in Kalamazoo River sediment samples.

The key principles of the Line 6B Quantitation mixing model method are described in plots of Line 6B Oil versus QR and CV for the two range finding studies (Figures 9-14). Figure 9 is a plot of Line 6B oil versus QR for the R024 range finding study (measured QR reported at Line 6B =0) which contain between approximately 10 ppm and 13,000 ppm of spiked Line 6B oil. The curves represent the mixing model calculations for each of the spiked Line 6B range finding sediment samples. When the curve is above the 0 Line 6B oil line (Y axis = 0), Line 6B is being added to the sample by the mixing model. When the curves are below the 0 ppm Line 6B oil line (Y axis =

[11] For this calculation the C3-DBT/fluoranthene and TAS2/fluoranthene (TAS1/fluoranthene) background ratio is derived from the mean of the respective R024 (for MP2 to MP15.75) and MP35.1 (for MP16.5 to MP 39.75) un-spiked reference sediment samples.

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0) Line 6B oil is being removed from the sediment sample. Each mixing model curve represents the mixing model results for the different R024 Line 6B spiking levels as identified in the legend (Figure 9).

Sediment samples that have QRs greater than the CV are positive detections of Line 6B oil. The amount of oil in the sample is represented by the difference in the CV and QR. The larger the QR the greater the amount of L6B (e.g.,"R024 RFS 1327 ppm L6B" has a greater QR than R024 RFS 131 PPM L6B and therefore has greater amounts of L6B"). If all sediments contained the same RBH then the use of a Line 6B calibrated reference sample would apply to all samples.

Figures 9 and 10 show that as more oil is added the R024 sediment, the QR response decreases as indicated by the increasing slopes of the Line 6B oil versus QR for each L6B spiked sample, with the least QR sensitivity in the sample spiked with the most oil (Figure 9, blue arrow). **Because of the dynamic change in L6B sensitivity with amount of L6B oil and RBH, curve fitted calibration of the RFS field results cannot be applied directly the majority of Kalamazoo River sediment samples (Figure 11).**[12]

The advantage of the mixing model approach for Line 6B quantification is that it provides a means to incorporate sample specific L6B sensitivity into each calculation. The impact of differential Line 6B sensitivity is documented in Figures 9 and 10, where the change in QR for the un-spiked R024 sediment is different from the spiked sediments so any additional oil or RBH additions would no longer be accurately reflected by the initial R024 calibration.

Line 6B Quantitation
A more accurate way to determine L6B concentration is to calculate how much Line 6B oil is required to move the field sample QR back to reference sample defined CV. The calculations for this analysis are provided in Section 3 above and graphically presented in Figures 9-14 (and Attachment 1). Given that the Line 6B oil and the field sample QR compounds are accurately measured, mixtures of the two end members and the resultant QR are easily calculated (Figure 9). By calculating how much L6B oil must be removed from the field sample to move the field QR back to the CV a direct measure of the Line 6B oil added to the field sample is derived (Figure 9, Table 1). This approach is verified within the RFS results.

High Concentration Line 6B Quantitation Issues
A second problem with the curve fitting field calibration method was the very limited number of analyses above the 1500 ppm L6B range where the slope of the calibration (and associated Line 6B sensitivity) changed the greatest. RFS calculations of L6B oil above this range were unreliable. This problem was resolved because the two end member mixing model provides high resolution modeling capability in the 1500 PPM and greater range and generates more accurate results than can be obtained the R024 calibrated curve fitting L6B quantitation method (Figures 10, 11, and 14, see Attachment 1 for comparable TAS1/T30 results).

Line 6B Sediment Specific Detectability
Given that L6B sensitivities vary from sediment to sediment, there was no way to estimate the detectability of L6B when the QR was less than the reference sediment CR using the R024 (or

[12] The R024 curve fitting results are most accurately applied to samples with the same Line 6B sensitivity.

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MP35.1) calibrated curve fitting L6B quantitation method. An unsupported value of 10 PPM L6B was used when conceptually it was clear that the ability to detect L6B was much higher in sediment samples with substantial RBH. This issue was resolved when sample-specific calculations were performed and the variable L6B sensitivity was incorporated into the estimate. Figure 12 is a plot of four sediment samples (MP5.5 D016, MP5.5 D006, MP5 DX, MP4.25 DX, which exhibit increasing Line 6B sensitivity respectively and have TAS2/Hopane QRs < CVs. The R024 Range Finding Study field data and the R024 mixing model curves are provided for reference purposes. Sediment sample MP5.5 D016 exhibits the lowest L6B sensitivity (need lots of L6B to move the QR to the CV) and MP4.25 DX has the highest (very little L6B required to move the QR to the CV). These increasing L6B sensitivities are loosely associated with decreasing RBH.

Line 6B Detectability Calculation

For non-detect samples (e.g., QR < CV) the minimum amount of L6B oil that could be in the sample can be calculated using the mixing model method. The calculation for L6B detectability is provided in Section 3 above and graphically in Figure 12. The amount of L6B oil required to move the field measured QR to the CV is dependent on the L6B sensitivity of each samples, and therefore must be calculated for each sample. These estimates should be constrained by the sediment associated gravimetric residue weight for chemical reasonableness. For sample MP5.5 D016 thousands of PPM of L6B oil would be needed before the spilled oil could be detected as compared to sediment samples MP5.5 D006 and MP5 DX where a minimum of 600 ppm and 100 ppm respectively would be required before the spilled oil could be detected in the samples (e.g., QR > CV). Finally, only a small amount of L6B oil would be required to exceed the CV for sample MP4.25 DX (Figure 12).

5.0 Summary

This work defines the optimal procedure for the quantification of Line 6B oil in Kalamazoo River sediments. The foundation of the Line 6B quantitation procedure lies in the production of quality chemical data including total petroleum hydrocarbons by GC/FID, polycyclic aromatic hydrocarbons and sulfur heterocyclic compounds by GC/MS, and triterpane and tri-aromatic sterane biomarkers by GC/MS. The data from Toxicity, Range Finding and Submerged Oil Quantitation studies all indicate that the most reliable source identification and quantitation tools are the TAS2/Hopane and TAS1/T30 ratios (Tables 1-3). Additional graphical analyses are provided in Attachment 1 for the TAS1/T30 Range Finding and Line 6B detectability studies.[13]

Other diagnostic compounds (e.g., C3-dibenzothiophenes, C3-phenanthrenes) and compound classes (e.g., TPH, gravimetric analyses) can be used to confirm/support the identification and quantification of L6B oil in sediments. This interpretive method provides a means to reliably calculate how much Line 6B oil is present in a given sediment, and if not detected, a procedure to estimate on a per sample basis how much Line 6B oil could be present (e.g., Line 6B detectability).

[13] TAS2/Hopane and TAS1/T30 MDL study field verification results are provided in Attachment 1.

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The conclusions in this report are based on currently available data. Should additional data or information become available to me, or if the analytical data is modified as a result of the on-going quality assurance reviews, I reserve the right to update this report as needed.
Please let me know if you have any additional questions concerning the identification and quantification of Line 6B oil in Kalamazoo River sediment samples.

Sincerely,

Gregory S. Douglas, Ph.D.
Sr. Consultant.

Attachment 1: Additional Supporting Data

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Table 1. Spiked and predicted concentrations of Line 6B oil in Kalamazoo Sediment Range Finding Study R024.

R024 Range Finding Study Results - Predicted L6B Versus Spiked Line 6B							
RFS Study ID	R024	R024-14	R024-131	R024-268	R024-677	R024-1328	R024-13394
Line 6B Spiked mg/kg	0	14	131	268	677	1328	13394
TAS2/Hopane QR	0.339	0.366	0.528	0.597	0.688	0.745	0.780
TAS2/Hopane Line 6B Predicted mg/lkg	0	11	134	248	680	1255	12559
TAS1/T30 QR	0.667	0.743	1.987	2.524	3.105	3.634	4.232
TAS1/T30 Line 6B Predicted mg/kg	0	7	147	268	675	1281	13052

Table 2. Spiked and predicted concentrations of Line 6B oil in Kalamazoo Sediment Range Finding Study MP35.1.

MP35.1 Range Finding Study Results - Predicted L6B Versus Spiked Line 6B							
RFS Study ID	MP35.1	MP35.1-17	MP35.1-167	MP35,1-345	MP35.1-843	MP35.1-1654	MP35.1-17094
Line 6B Spiked mg/kg	0	17	167	345	843	1654	17094
TAS2/Hopane QR	0.408	0.441	0.499	0.543	0.641	0.712	0.785
TAS2/Hopane Line 6B Predicted mg/kg	0	76	238	438	1056	2054	17011
TAS1/T30 QR	1.326	1.303	1.829	2.219	2.877	3.417	4.368
TAS1/T30 Line 6B Predicted mg/kg	0	9*	200	417	965	1902	17504
* = Sample reported as ND, value is Line 6B Detectability in PPM.							

Table 3. Spiked and predicted concentrations of Line 6B oil in the Battle Creek Sediment Range Finding Study BC.

Battle Creek Range Finding Study Results - Predicted L6B Versus Spiked Line 6B							
RFS Study ID							
Line 6B Spiked mg/kg	0	16	159	318	795	1569	15749
TAS2/Hopane QR	0.458	0.464	0.495	0.551	0.609	0.678	0.801
TAS2/Hopane Line 6B Predicted mg/kg	0	18	129	400	835	1603	15963
TAS1/T30 QR	1.489	1.835	2.107	2.453	2.705	3.490	4.357
TAS1/T30 Line 6B Predicted mg/kg	0	119	243	479	885	1644	15471

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Figure 1. GC/FID chromatograms of A) topped Cold Lake Oil sample SO092812CL01 CL-6B-072223-092710-JPS-KA-001-33_TOPPED versus sediment sample MP10.75DX (SEKR1075C702S113012DX)

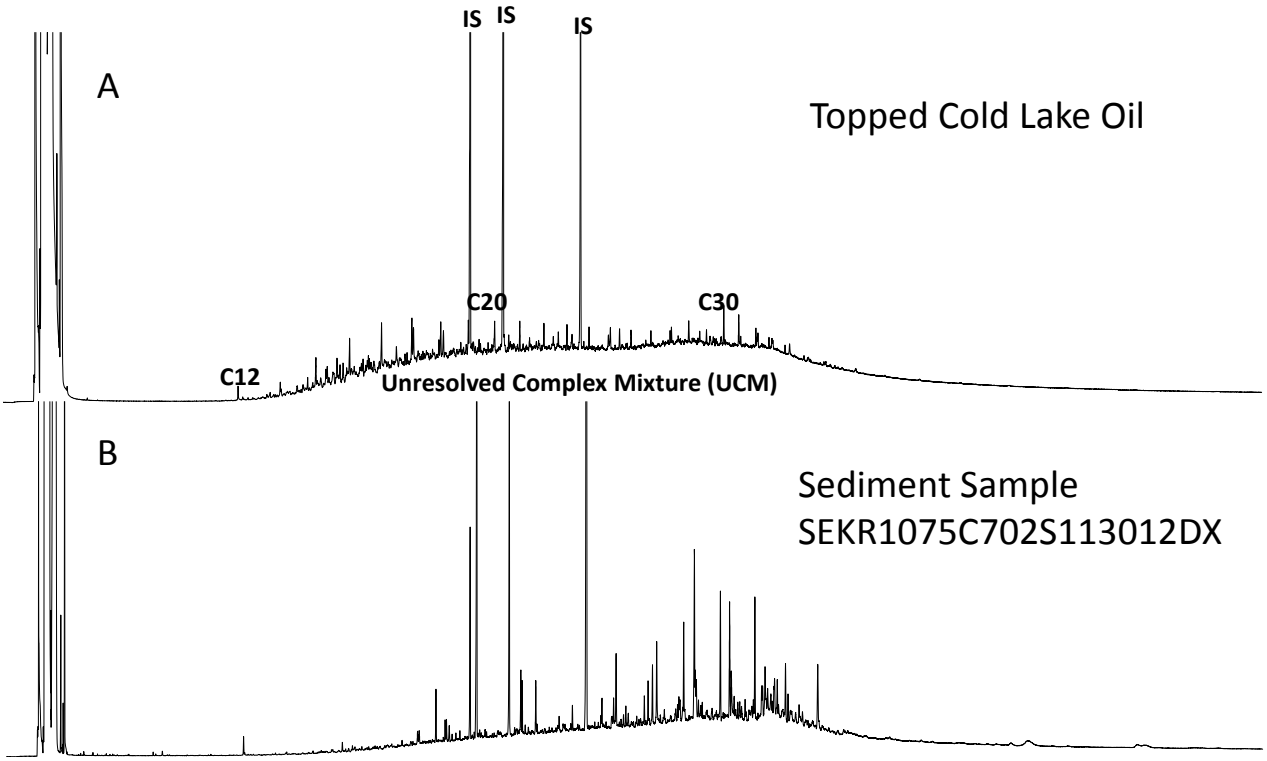

Figure 2. PAH and sulfur heterocyclic distribution plot of topped Cold Lake oil (blue bars) versus RFS sediment sample R024 (red bars) collected above the Talmadge Creek - Kalamazoo River convergence. The Y axis for each sample has been visually adjusted to compare the PAH distributions between the two samples.

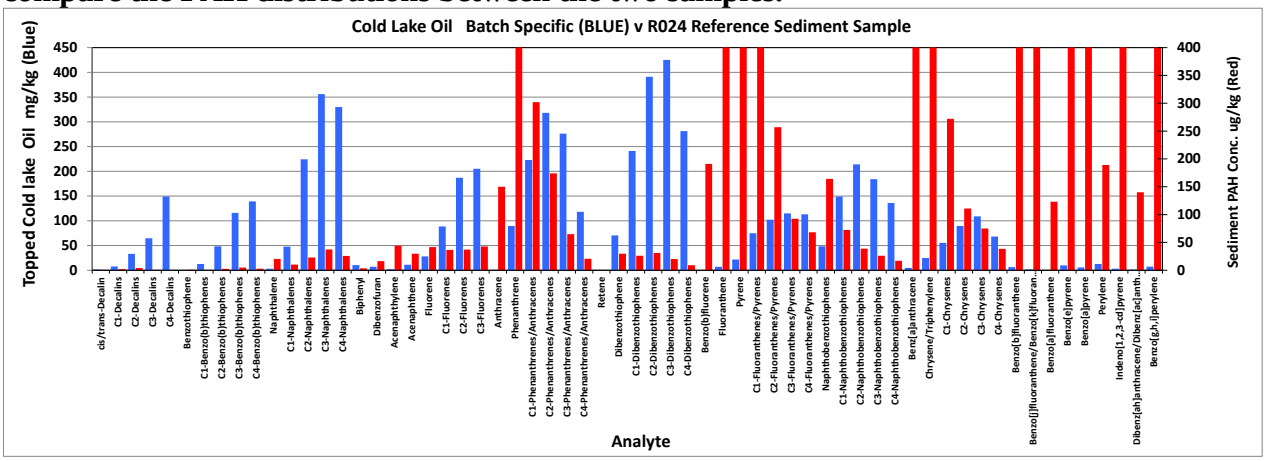

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Figure 3. PAH and sulfur heterocyclic distribution plot of topped Cold Lake oil (blue bars) versus Line 6B oiled sediment sample MP10.75 DX. The Y axis for each sample has been visually adjusted to compare the PAH distributions between the two samples.

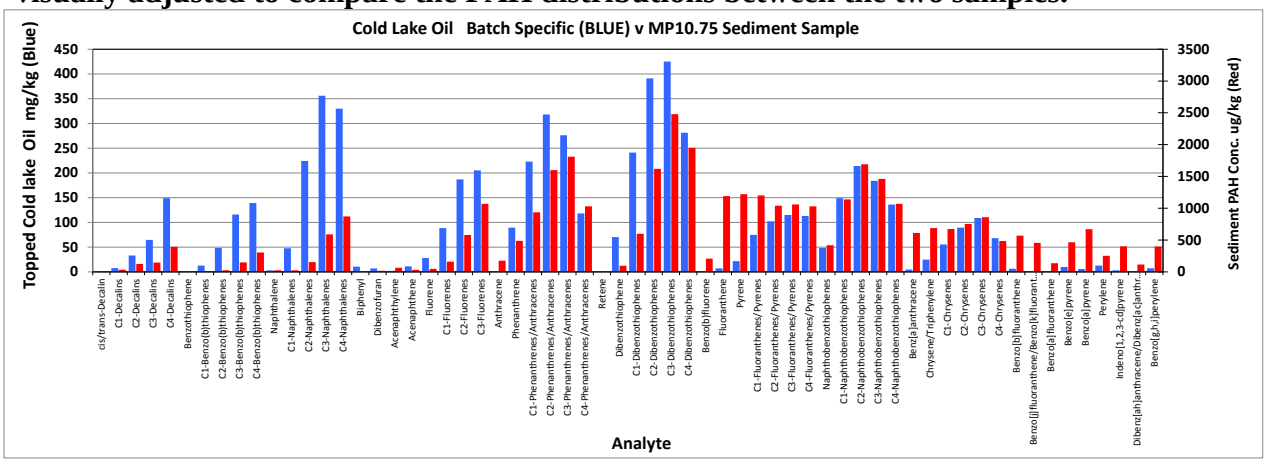

Figure 4. Triterpane, sterane and tri-aromatic sterane (TAS) biomarker distribution of topped Cold Lake oil (blue bars) versus RFS sediment sample R024 (red bars) collected above the Talmadge Creek - Kalamazoo River convergence. The differences in the TAS distributions between the topped Cold Lake Oil and the reference sediment sample provide a means to distinguish between the two sources of hydrocarbons in the Kalamazoo River sediments. The Y axis for each sample has been visually adjusted to compare the biomarker distributions between the two samples.

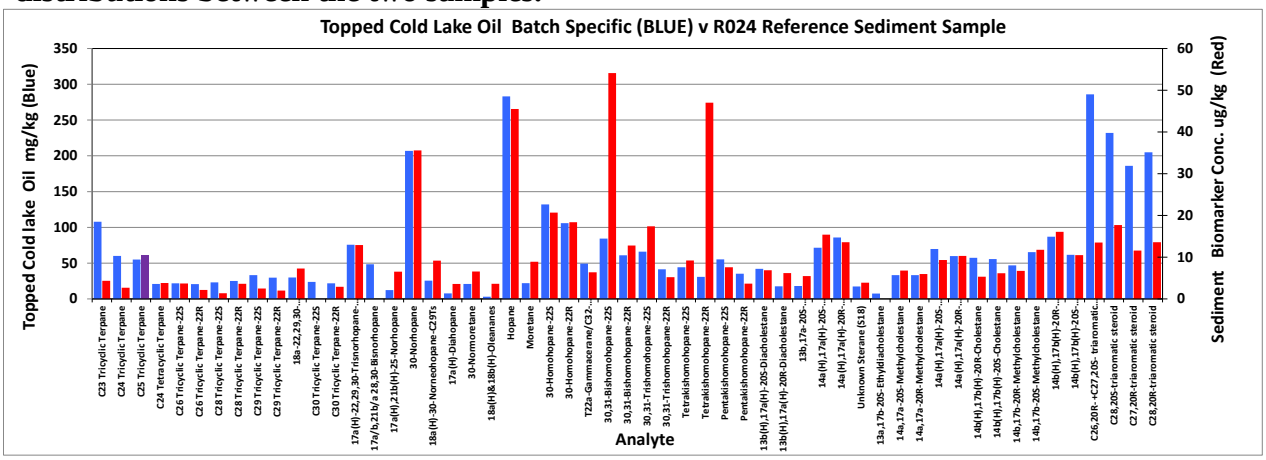

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Figure 5. Triterpane, sterane and tri-aromatic sterane (TAS) biomarker distribution of topped Cold Lake oil (blue bars) versus Line 6B oiled sediment sample MP10.75 DX (red bars) The Y axis for each sample has been visually adjusted to compare the biomarker distributions between the two samples.

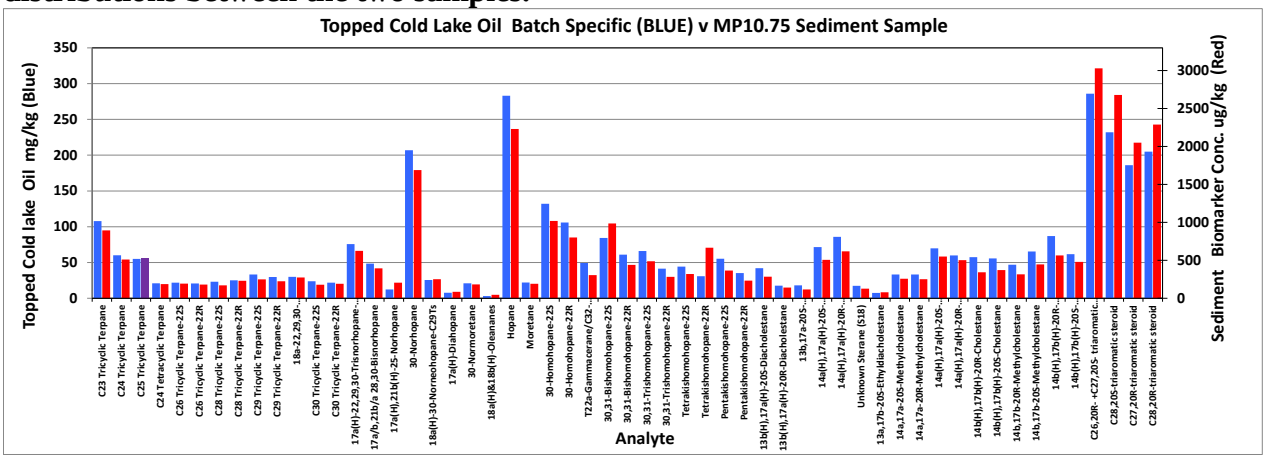

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Figure 6. A&B. Hopane measured versus Hopane added (●) versus mixing model predicted hopane (–) for R024 Range Finding Study. C&D. TAS2 measured versus TAS added (▲) versus mixing model predicted hopane (–). The two end member mixing model approach calculates the Quantitation Ratio compounds remarkably well.

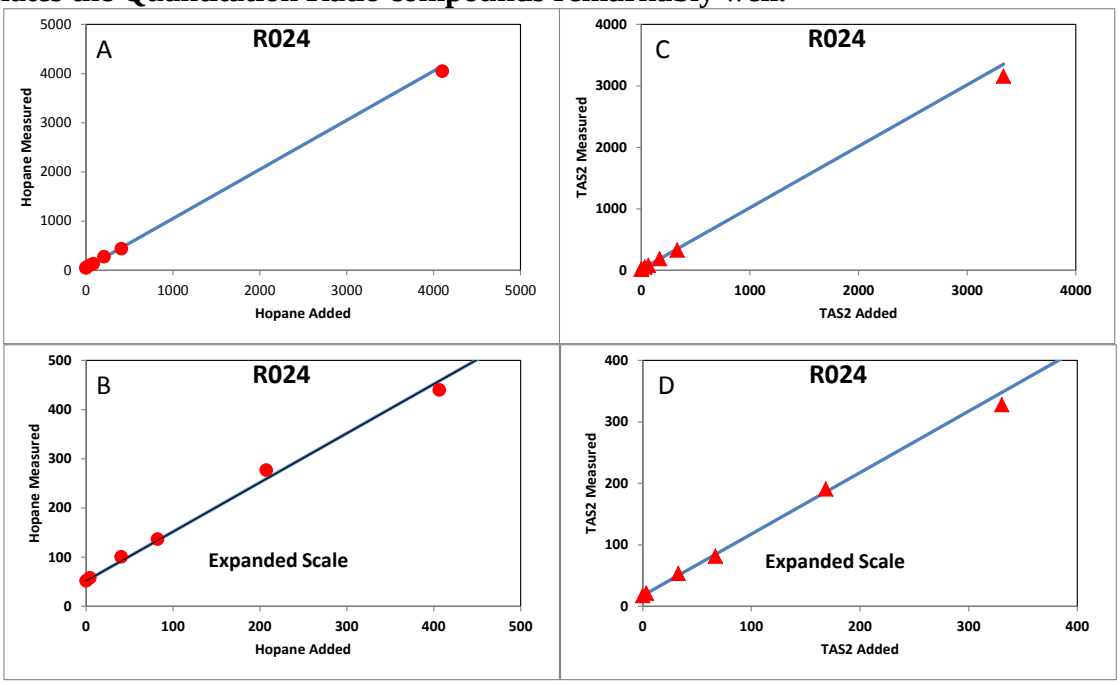

Figure 7. A&B. Hopane measured versus Hopane added (●) versus mixing model predicted hopane (–) for MP35.1 Range Finding Study. C&D. TAS2 measured versus TAS added (▲) versus mixing model predicted TAS (–). The two end member mixing model approach calculates the Quantitation Ratio compounds remarkably well.

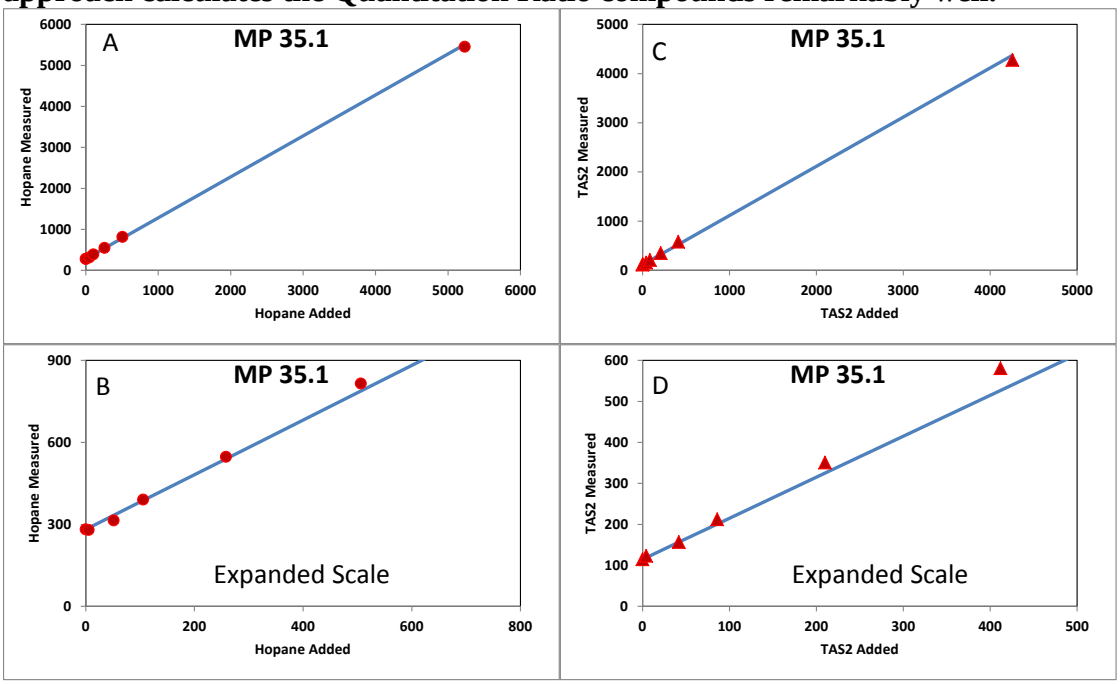

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Figure 8. A&B. Line 6B oil concentration versus measured TAS2/Hopane (●) versus mixing model predicted TAS2/Hopane (–) for R024 Range Finding Study. C&D. Line 6B oil concentration versus measured TAS2/Hopane (▲) versus mixing model predicted TAS2/Hopane (–) for MP35.1 Range Finding Study. The two end member mixing model approach calculates the Quantitation Ratio compounds remarkably well.

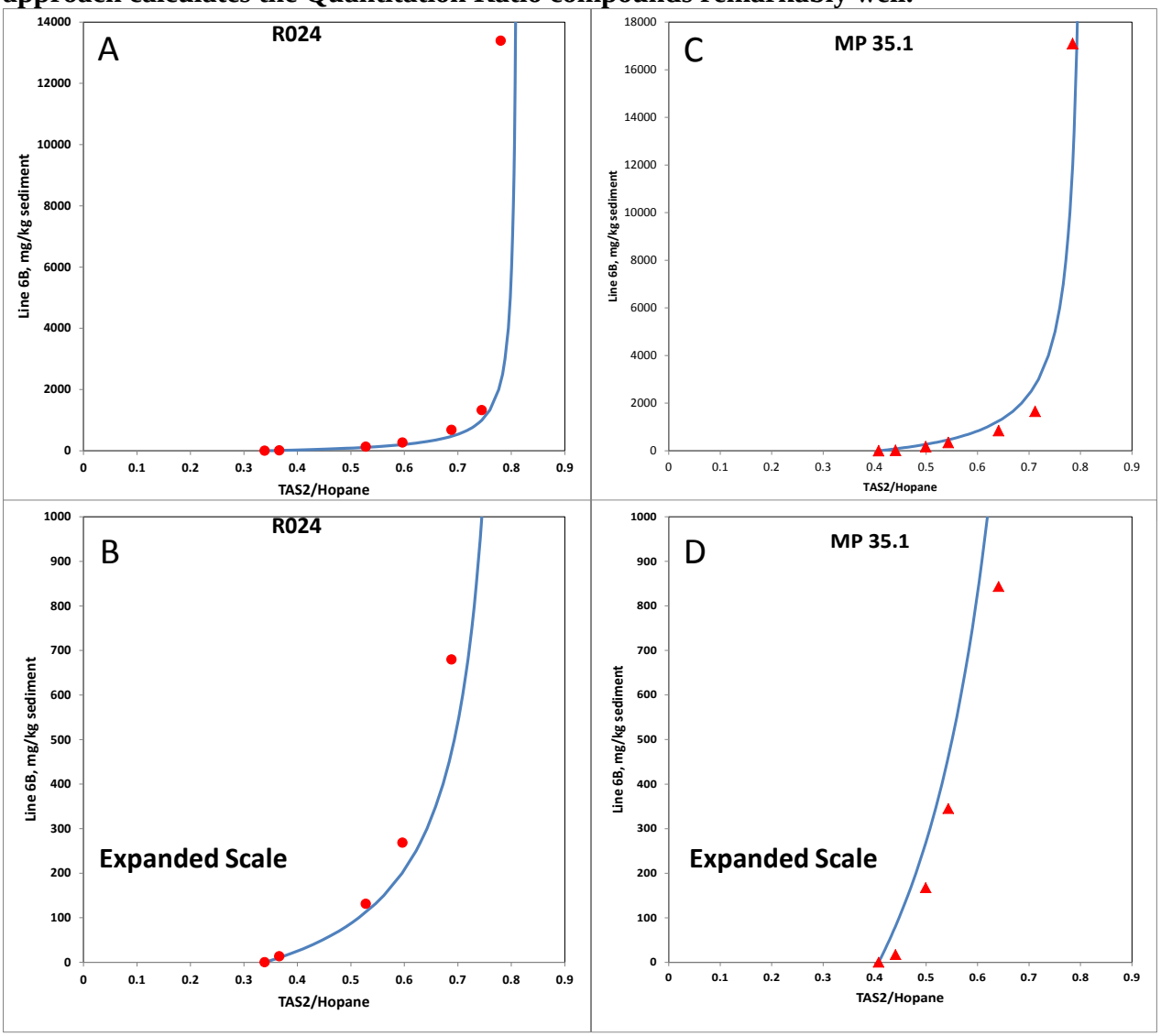

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Figure 9. Line 6B SEKR0000R024S092112D004 (R024) sediment TAS2/Hopane versus Line 6B spiking concentration range finding results. The measured TAS2/Hopane ratio in each spiked (R024) sample is located where the respective curves cross the X axis. Each sample profile is generated using a two end member mixing model based on the TAS2 and Hopane concentrations measured in each spiked sample and the measured TAS2 and Hopane concentrations in topped Line 6B oil (CL-6B-072223-092710-JPS-KA-001-33_TOPPED). Critical Value (CV) is defined by the TAS2/Hopane ratio in the un-spiked R024 reference sediment sample. The R024 results were geographically applied to samples between MP2 and MP15.75. (See Attachment 1 for corresponding TAS1/T30 plots).

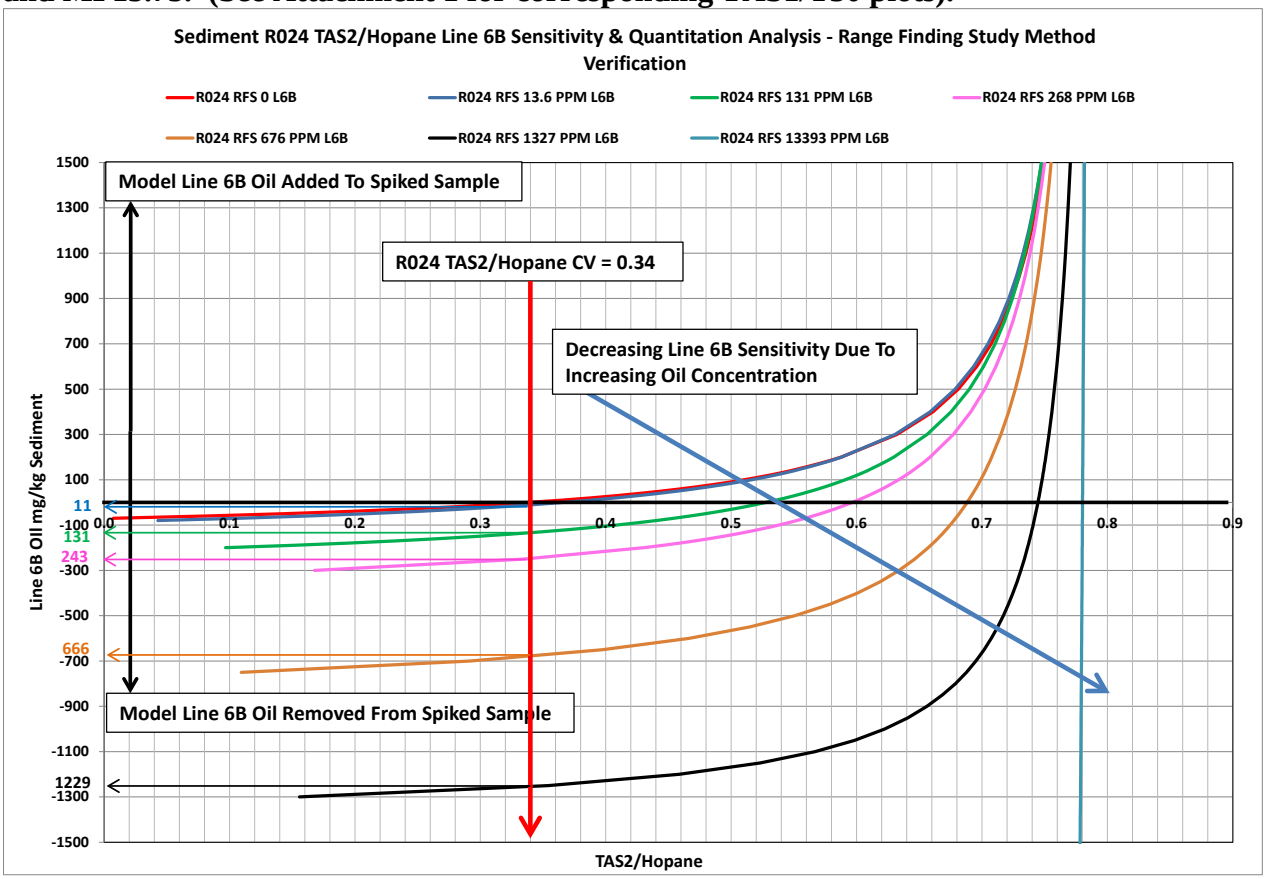

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Figure 10. Line 6B SEKR0000R024S092112D004 (R024) sediment TAS2/Hopane versus Line 6B spiking concentration RFS results. The measured TAS2/Hopane ratio in each spiked (R024) sample is located where the respective curves cross the X axis. Each sample profile is generated using a two end member mixing model based on the TAS2 and Hopane concentrations measured in each spiked sample and the measured TAS2 and Hopane concentrations in topped Line 6B oil (CL-6B-072223-092710-JPS-KA-001-33_TOPPED). Critical Value (CV) is defined by the TAS2/Hopane ratio in the un-spiked R024 reference sediment sample. This figure is an expanded version of Figure 9 designed to compare the highest L6B spiking level in the R024 RFS to the predicted Line 6B oil based on the mixing model method. *The two end member mixing model method provides superior estimates of L6B in high concentration samples.* (See Attachment 1 for corresponding TAS1/T30 plots)

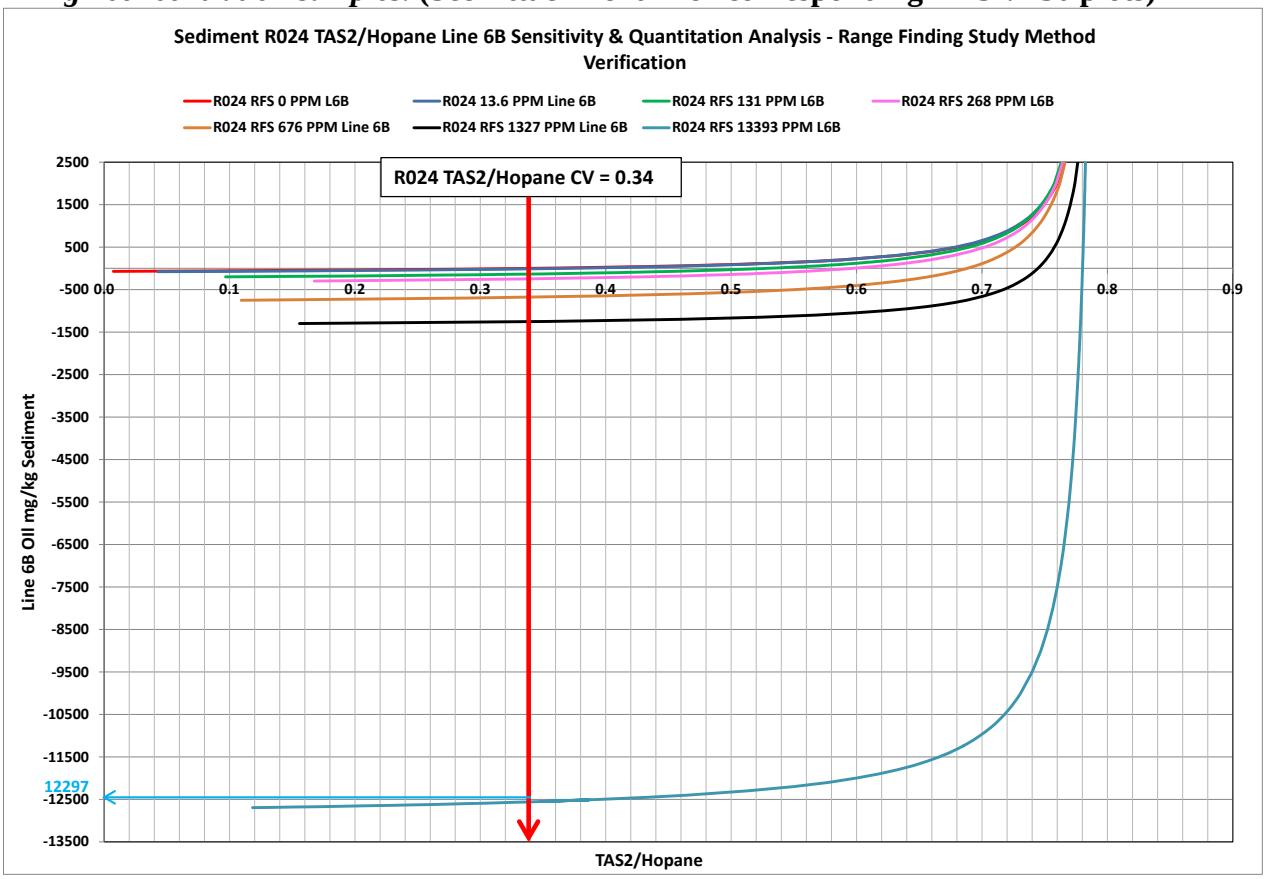

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Figure 11. Example of Curve Fitting and Mixing Model calculations for sediment sample MP10.75 D009 showing how the RFS Curve Fitting method underestimates the concentration of Line 6B oil in the sediment sample.

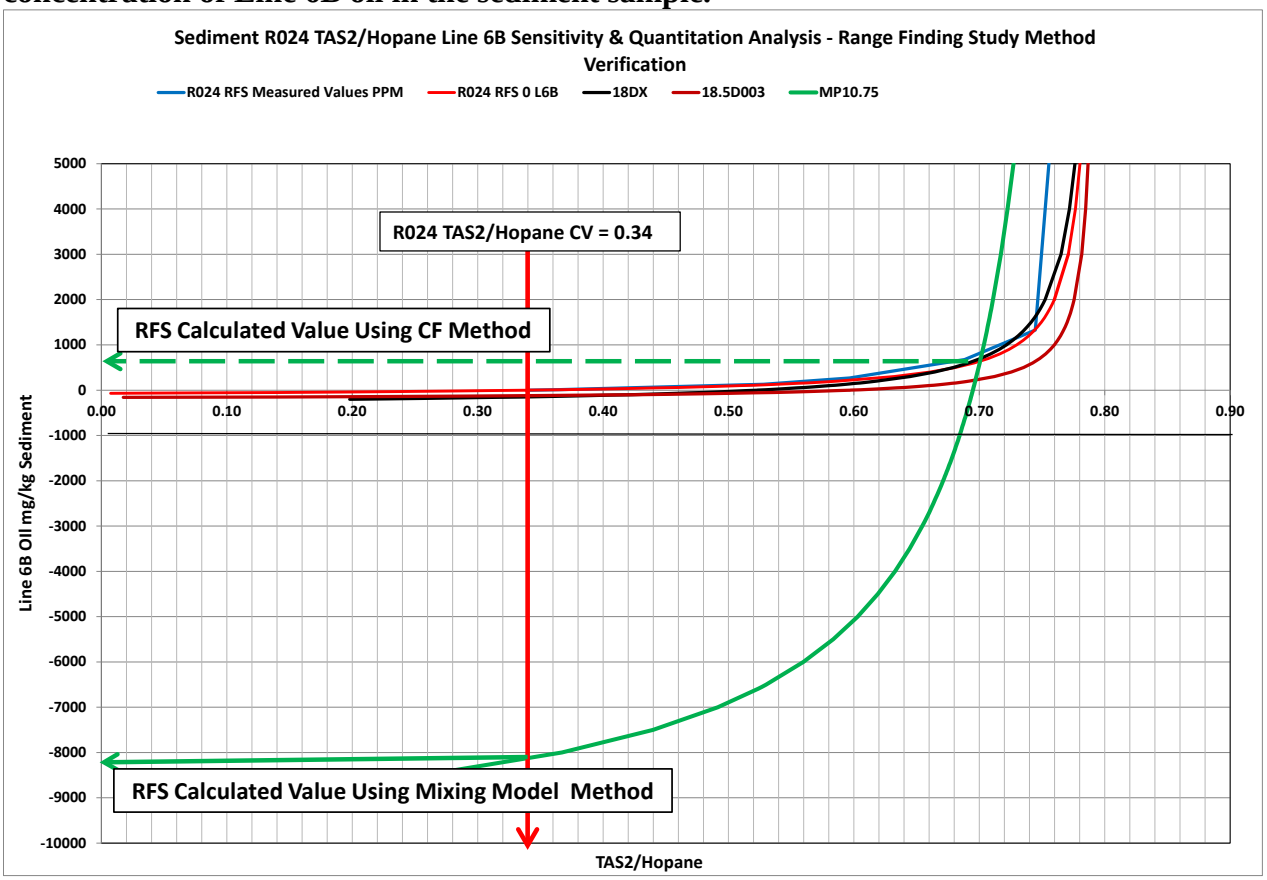

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Figure 12. Measured TAS2/Hopane versus spiked Line 6B oil for RFS sediment sample R024 (blue line with blue circles) and its associated two end member mixing model (red line) showing a close comparison between field data and predicted values. This figure also documents the differences observed in field sample Line 6B sensitivity. Samples MP4.25 DX, MP5.5 D016, MP5.5 D006, and MP5 DX all are non-detects for Line 6B oil (QR < CV). Small amounts of Line 6B oil could be detected in sediment sample MP4.25 DX, however large amounts of Line 6B oil would be required before it could be detected in sediment sample MP5.5 D016. Sediment samples MP5.5 D006 and MP5 DX shows how Line 6 Detectability is calculated at approximately 571 ppm and 77 PPM respectively.

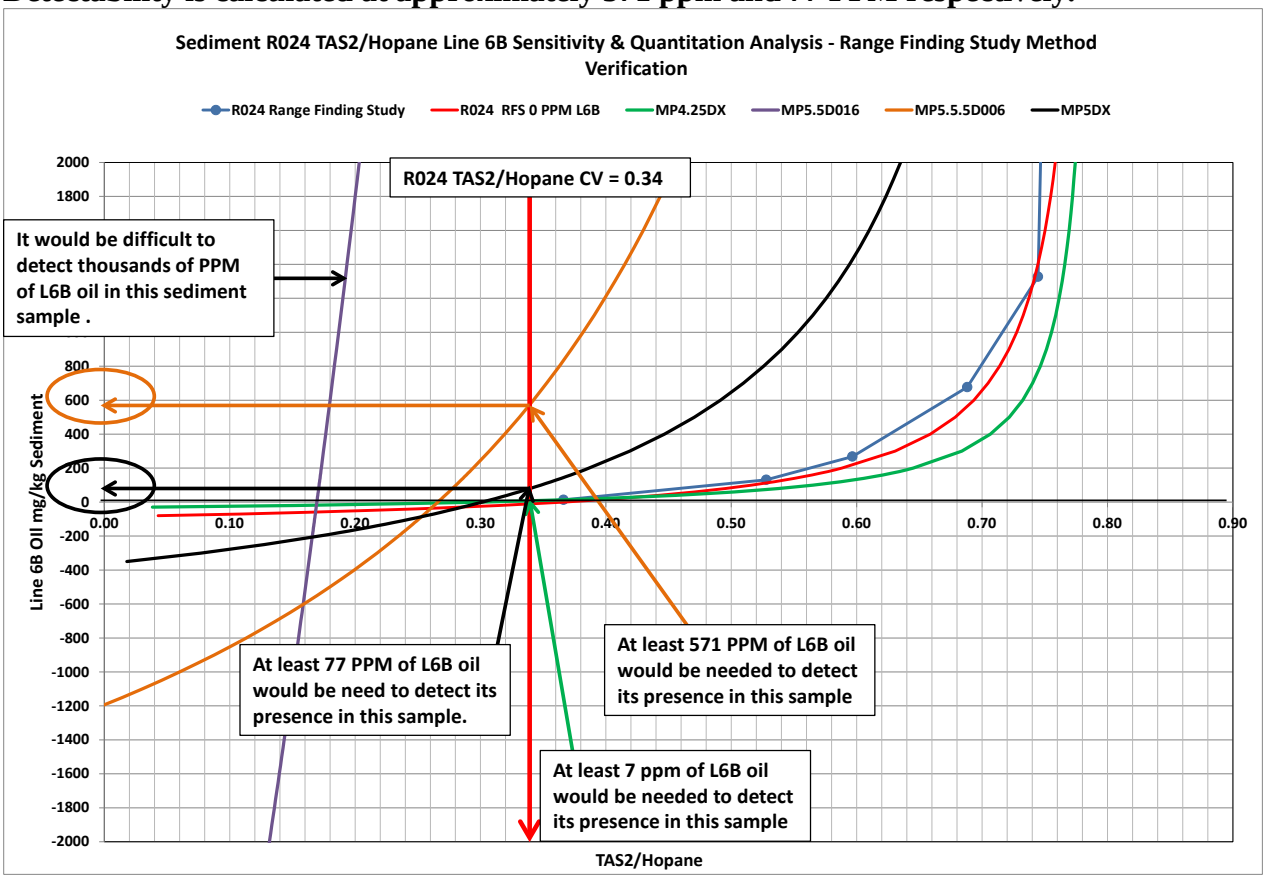

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Figure 13. Line 6B SEKR3510R018S092112D004 (MP35.1) sediment TAS2/Hopane versus Line 6B spiking concentration RFS results. The *measured* TAS2/Hopane ratio in each spiked (MP35.1) sample is located where the respective curves cross the X axis (QR). Each sample profile is generated using a two end member mixing model based on the TAS2 and Hopane concentrations measured in each spiked sample and the measured TAS2 and Hopane concentrations in topped Line 6B oil (CL-6B-072223-092710-JPS-KA-001-33_TOPPED). Critical Value (CV) is defined by the TAS2/Hopane ratio in the un-spiked MP35.1 reference sediment sample. The MP35.1 results were geographically applied to samples between Battle Creek (MP16.5) and MP39.75. (See Attachment 1 for corresponding TAS1/T30 plots)

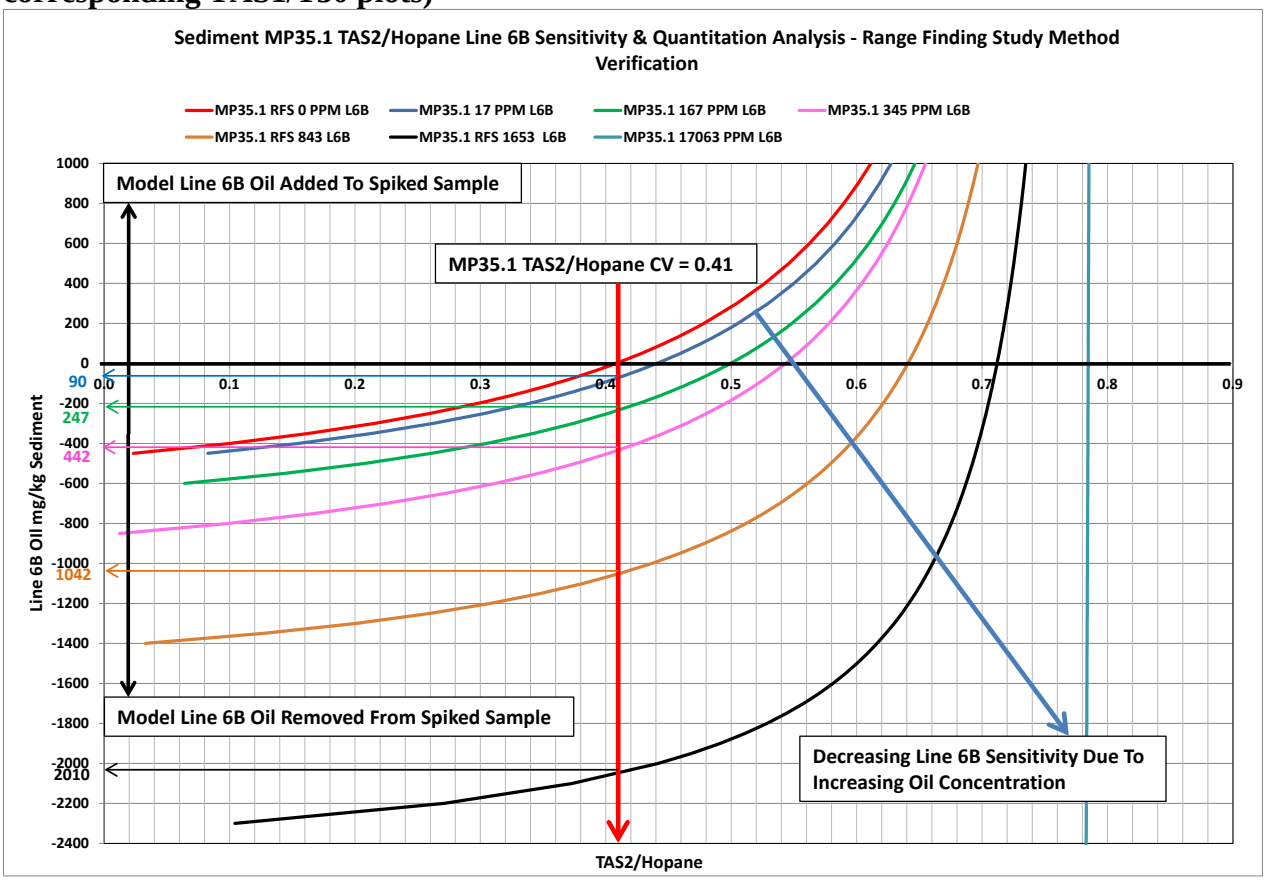

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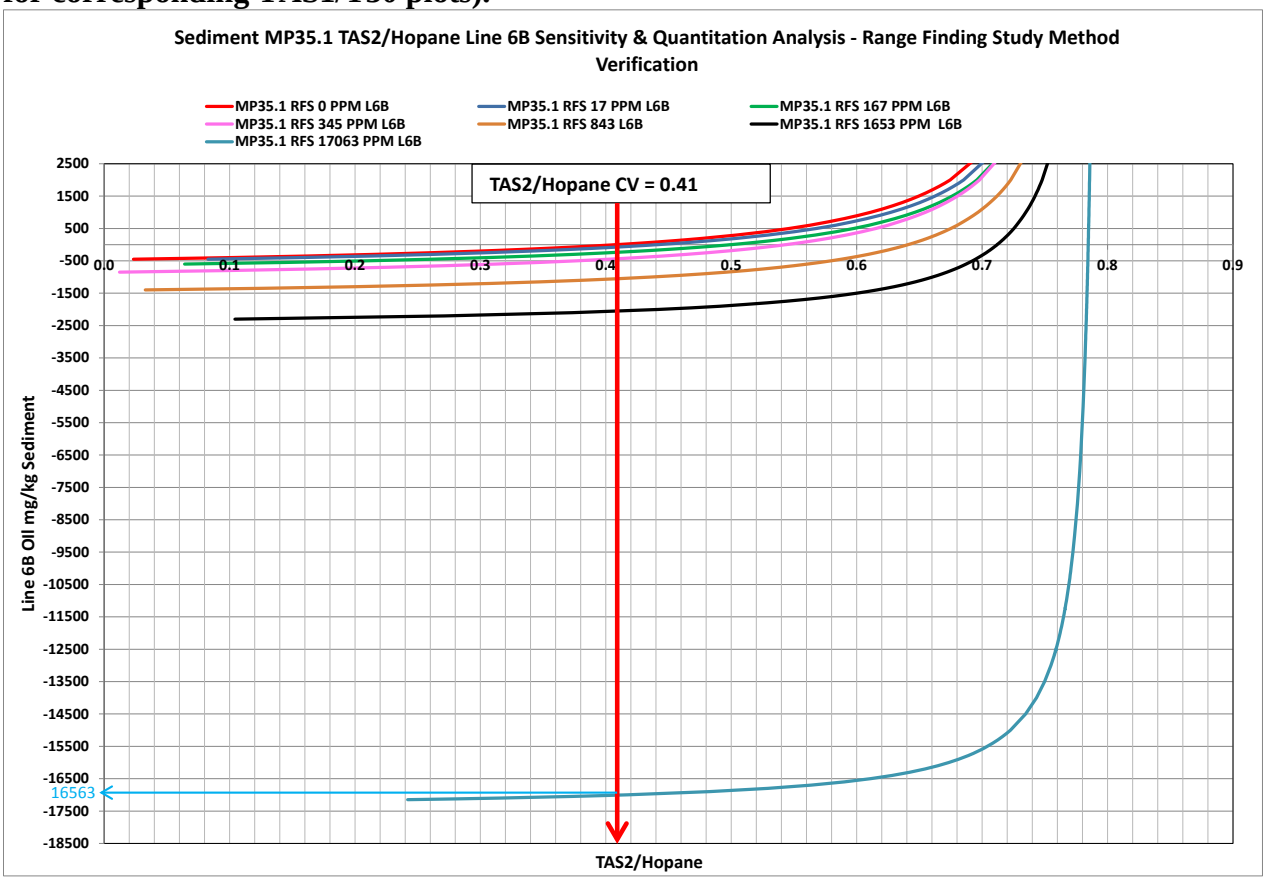
Figure 14. Line 6B SEKR3510R018S092112D004 (MP35.1) sediment TAS2/Hopane versus Line 6B spiking concentration RFS results. The *measured* TAS2/Hopane ratio in each spiked (MP35.1) sample is located where the respective curves cross the X axis (QR). Each sample profile is generated using a two end member mixing model based on the TAS2 and Hopane concentrations measured in each spiked sample and the measured TAS2 and Hopane concentrations in topped Line 6B oil (CL-6B-072223-092710-JPS-KA-001-33_TOPPED). Critical Value (CV) is defined by the TAS2/Hopane ratio in the un-spiked MP35.1 reference sediment sample. The MP35.1 results were geographically applied to samples between Battle Creek (MP16.5) and MP39.75. This figure is an expanded version of Figure 13 designed to compare the highest L6B spiking level in the MP35.1 RFS to the predicted Line 6B oil based on the mixing model method. *The two end member mixing model method provides superior estimates of L6B in high concentration samples.* (See Attachment 1 for corresponding TAS1/T30 plots).



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Attachment 1.
Supporting Information

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Figure A1-1. Line 6B SEBC0000L012S092112D004 (BC) sediment TAS2/Hopane versus Line 6B spiking concentration range finding results. The measured TAS2/Hopane ratio in each spiked (BC) sample is located where the respective curves cross the X axis. Each sample profile is generated using a two end member mixing model based on the TAS2 and Hopane concentrations measured in each spiked sample and the measured TAS2 and Hopane concentrations in topped Line 6B oil (CL-6B-072223-092710-JPS-KA-001-33_TOPPED). Critical Value (CV) is defined by the TAS2/Hopane ratio in the un-spiked BC reference sediment sample.

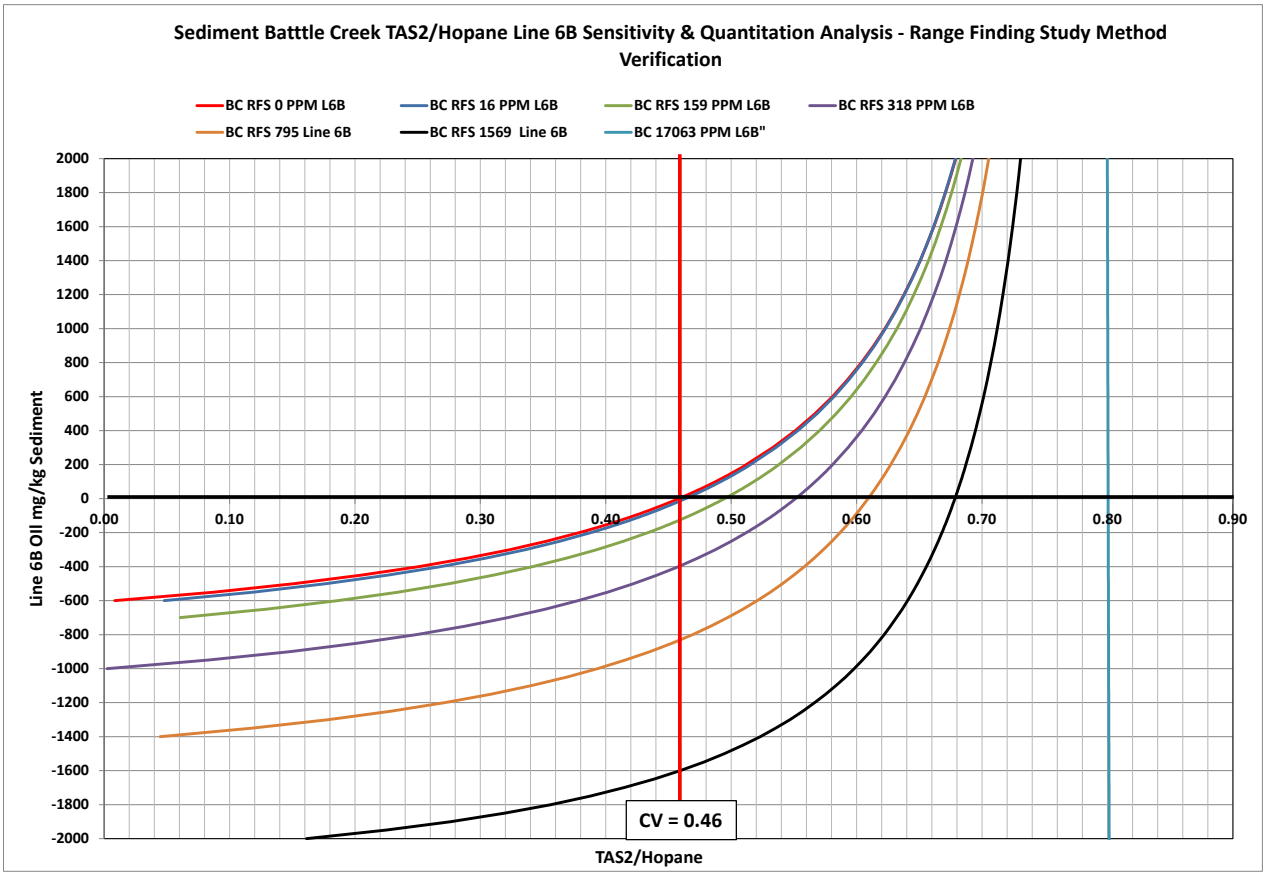

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Figure A1-2. Line 6B SEKR0000R024S092112D004 (R024) sediment TAS1/T30 versus Line 6B spiking concentration range finding results. The measured TAS1/T30 ratio in each spiked (R024) sample is located where the respective curves cross the X axis. Each sample profile is generated using a two end member mixing model based on the TAS1 and T30 concentrations measured in each spiked sample and the measured TAS1 and T30 concentrations in topped Line 6B oil (CL-6B-072223-092710-JPS-KA-001-33_TOPPED). Critical Value (CV) is defined by the TAS1/T30 ratio in the un-spiked R024 reference sediment sample. The R024 results were geographically applied to samples between MP2 and MP15.75.

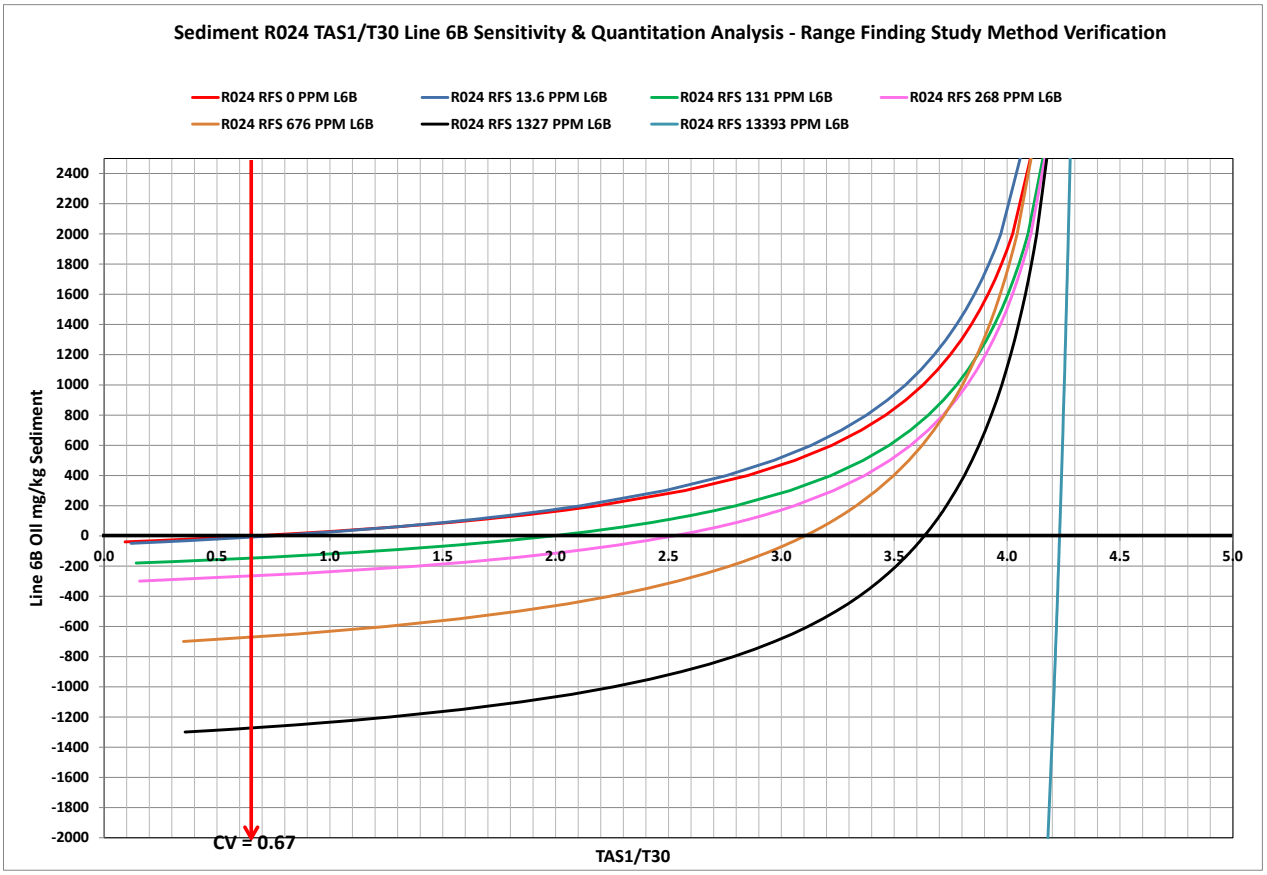

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Figure A1-3. Line 6B SEKR0000R024S092112D004 (R024) sediment TAS1/T30 versus Line 6B spiking concentration RFS results. The measured TAS1/T30 ratio in each spiked (R024) sample is located where the respective curves cross the X axis. Each sample profile is generated using a two end member mixing model based on the TAS1 and T30 concentrations measured in each spiked sample and the measured TAS1 and T30 concentrations in topped Line 6B oil (CL-6B-072223-092710-JPS-KA-001-33_TOPPED). Critical Value (CV) is defined by the TAS1/T30 ratio in the un-spiked R024 reference sediment sample. This figure is an expanded version of Figure A1-2 designed to compare the highest L6B spiking level in the R024 RFS to the predicted Line 6B oil based on the mixing model method. *The two end member mixing model method provides superior estimates of L6B in high concentration samples.*

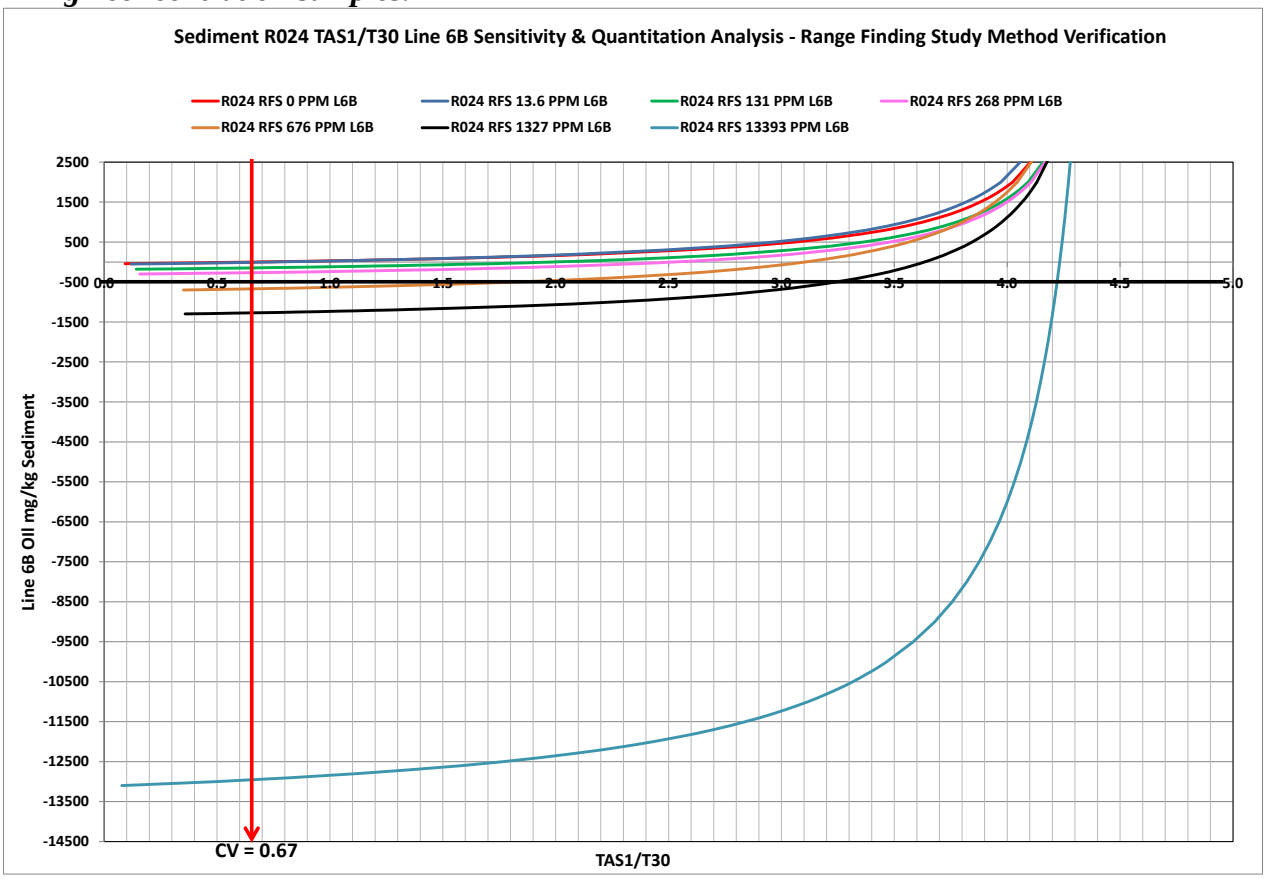

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Figure A1-4. Line 6B SEKR3510R018S092112D004 (MP35.1) sediment TAS1/T30 versus Line 6B spiking concentration RFS results. The *measured* TAS1/T30 ratio in each spiked (MP35.1) sample is located where the respective curves cross the X axis (QR). Each sample profile is generated using a two end member mixing model based on the TAS1 and T30 concentrations measured in each spiked sample and the measured TAS1 and T30 concentrations in topped Line 6B oil (CL-6B-072223-092710-JPS-KA-001-33_TOPPED). Critical Value (CV) is defined by the TAS1/T30 ratio in the un-spiked MP35.1 reference sediment sample. The MP35.1 RFS results were geographically applied to samples between Battle Creek (MP16.5) and MP39.75.

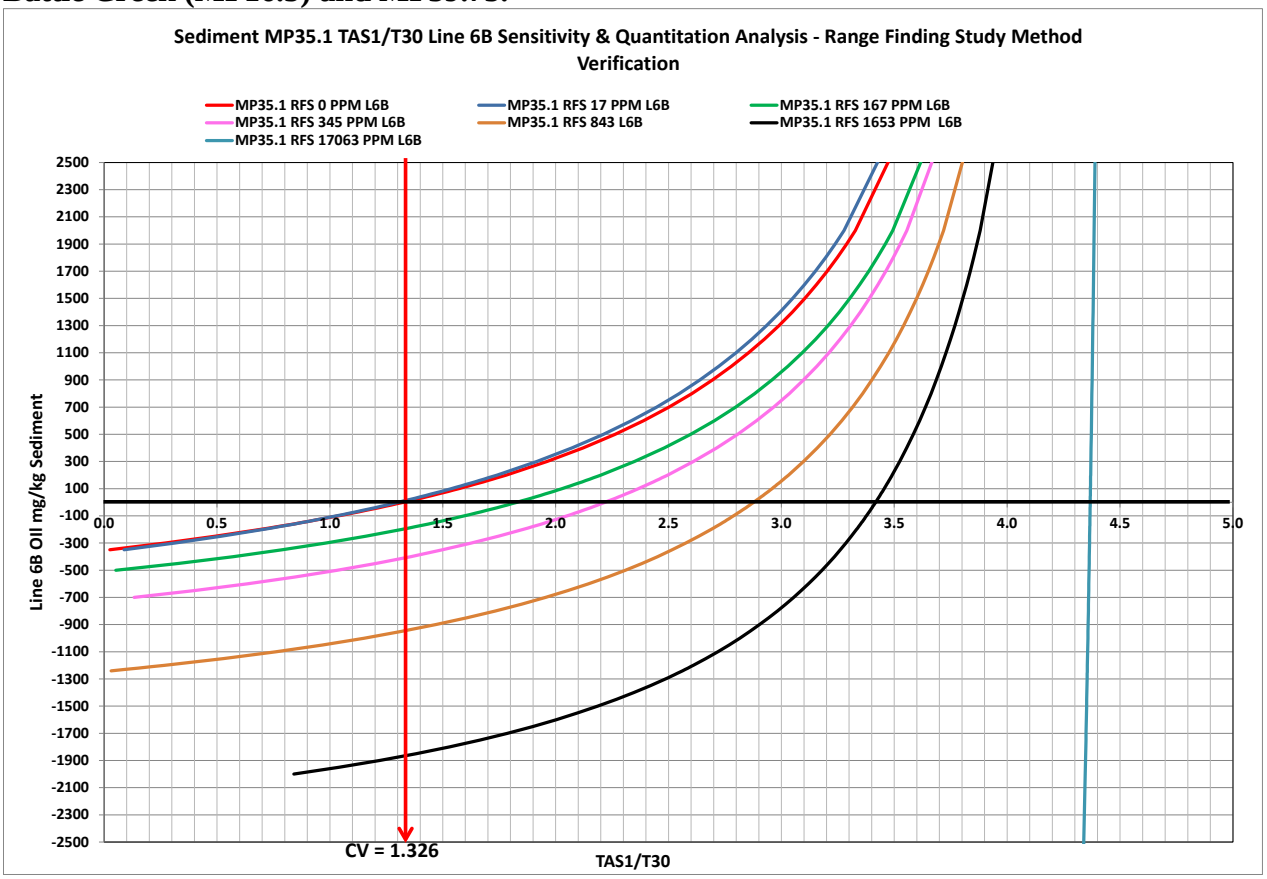

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Figure A1-5. Line 6B SEKR3510R018S092112D004 (MP35.1) sediment TAS1/T30 versus Line 6B spiking concentration RFS results. The *measured* TAS1/T30 ratio in each spiked (MP35.1) sample is located where the respective curves cross the X axis (QR). Each sample profile is generated using a two end member mixing model based on the TAS1 and T30 concentrations measured in each spiked sample and the measured TAS1 and T30 concentrations in topped Line 6B oil (CL-6B-072223-092710-JPS-KA-001-33_TOPPED). Critical Value (CV) is defined by the TAS1/T30 ratio in the un-spiked MP35.1 reference sediment sample. The MP35.1 results were geographically applied to samples between Battle Creek (MP16.5) and MP39.75. This figure is an expanded version of Figure A1-4 designed to compare the highest L6B spiking level in the MP35.1 RFS to the predicted Line 6B oil based on the mixing model method. *The two end member mixing model method provides superior estimates of L6B in high concentration samples.*

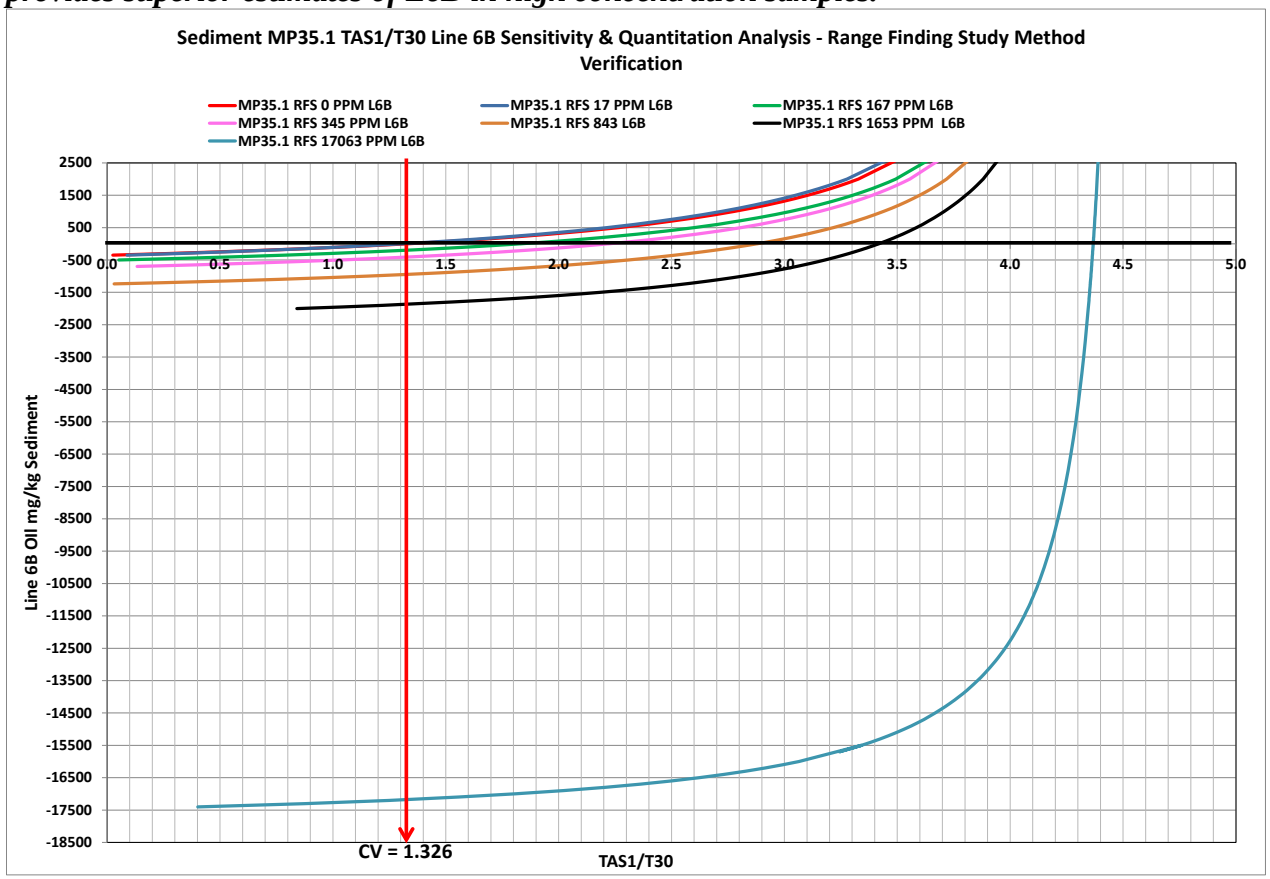

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Figure A1-6. Line 6B SEBC0000L012S092112D004 (Battle Creek) sediment TAS1/T30 versus Line 6B spiking concentration RFS results. The *measured* TAS1/T30 ratio in each spiked (BC) sample is located where the respective curves cross the X axis (QR). Each sample profile is generated using a two end member mixing model based on the TAS1 and T30 concentrations measured in each spiked sample and the measured TAS1 and T30 concentrations in topped Line 6B oil (CL-6B-072223-092710-JPS-KA-001-33_TOPPED). Critical Value (CV) is defined by the TAS1/T30 ratio in the un-spiked BC reference sediment sample.

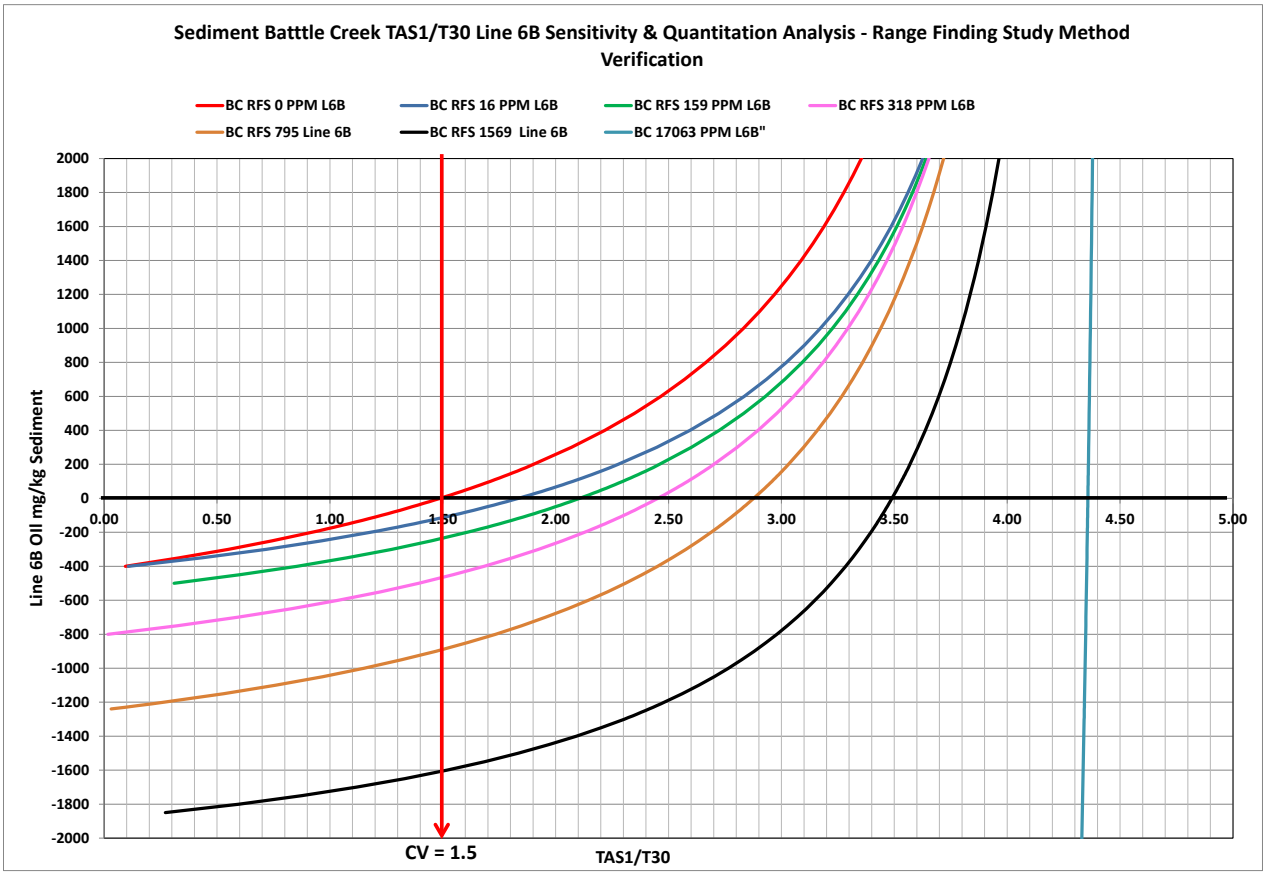

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Figure A1-7 Line 6B SEBC0000L012S092112D004 (Battle Creek) sediment TAS1/T30 versus Line 6B spiking concentration RFS results. The *measured* TAS1/T30 ratio in each spiked (BC) sample is located where the respective curves cross the X axis (QR). Each sample profile is generated using a two end member mixing model based on the TAS1 and T30 concentrations measured in each spiked sample and the measured TAS1 and T30 concentrations in topped Line 6B oil (CL-6B-072223-092710-JPS-KA-001-33_TOPPED). Critical Value (CV) is defined by the TAS1/T30 ratio in the un-spiked BC reference sediment sample. This figure is an expanded version of Figure A1-6 designed to compare the highest L6B spiking level in the BC RFS to the predicted Line 6B oil based on the mixing model method. *The two end member mixing model method provides superior estimates of L6B in high concentration samples.*

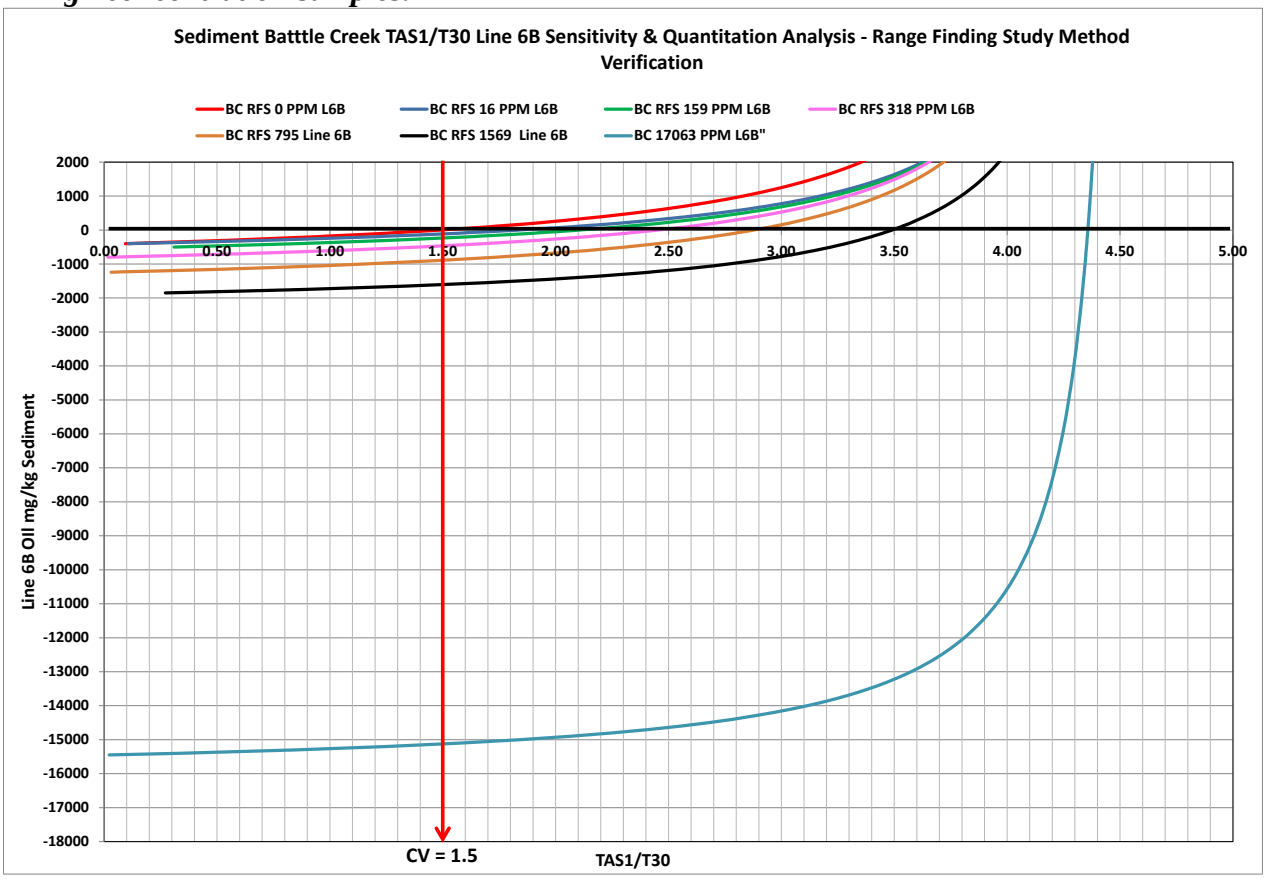

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Figure A1-8. Sediment reference sample SEKR0000R024S092112D004 (R024) TAS2/Hopane Method Detection Limit Study results. These reference sediments were spiked with between 271-272 mg/kg dry wt. Line 6B oil. The MDL study results provide additional information concerning the utility and field verification of the TAS2/Hopane mixing model method to determine the Line 6B oil concentration in Kalamazoo River sediment.

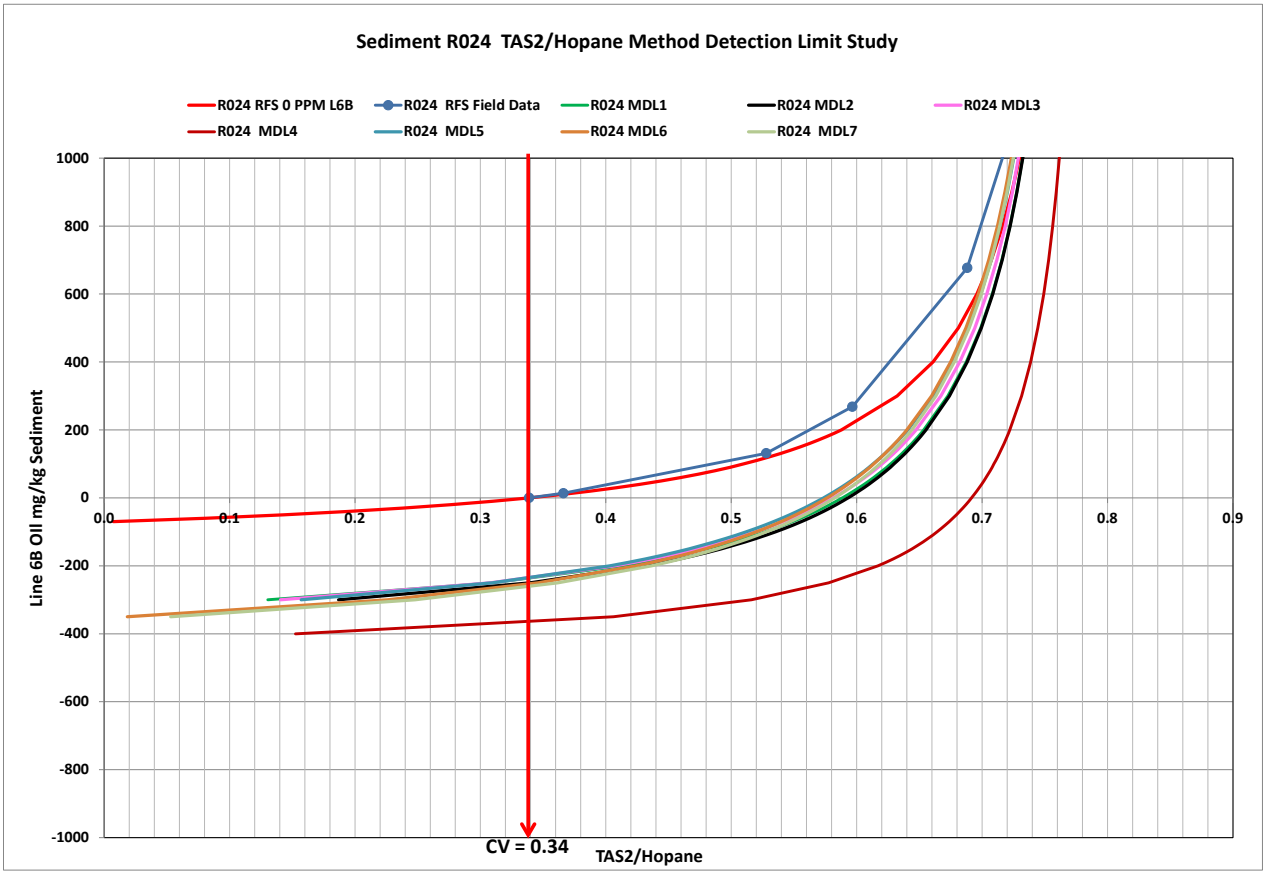

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Figure A1-9. Sediment reference sample SEKR0000R024S092112D004 (R024) TAS1/T30 Method Detection Limit Study results. Sediments were spiked with between 271-272 mg/kg dry wt. Line 6B oil. The MDL Study results provide additional information concerning the utility and field verification of the TAS1/T30 mixing model method to determine the Line 6B oil concentration in Kalamazoo River sediment.

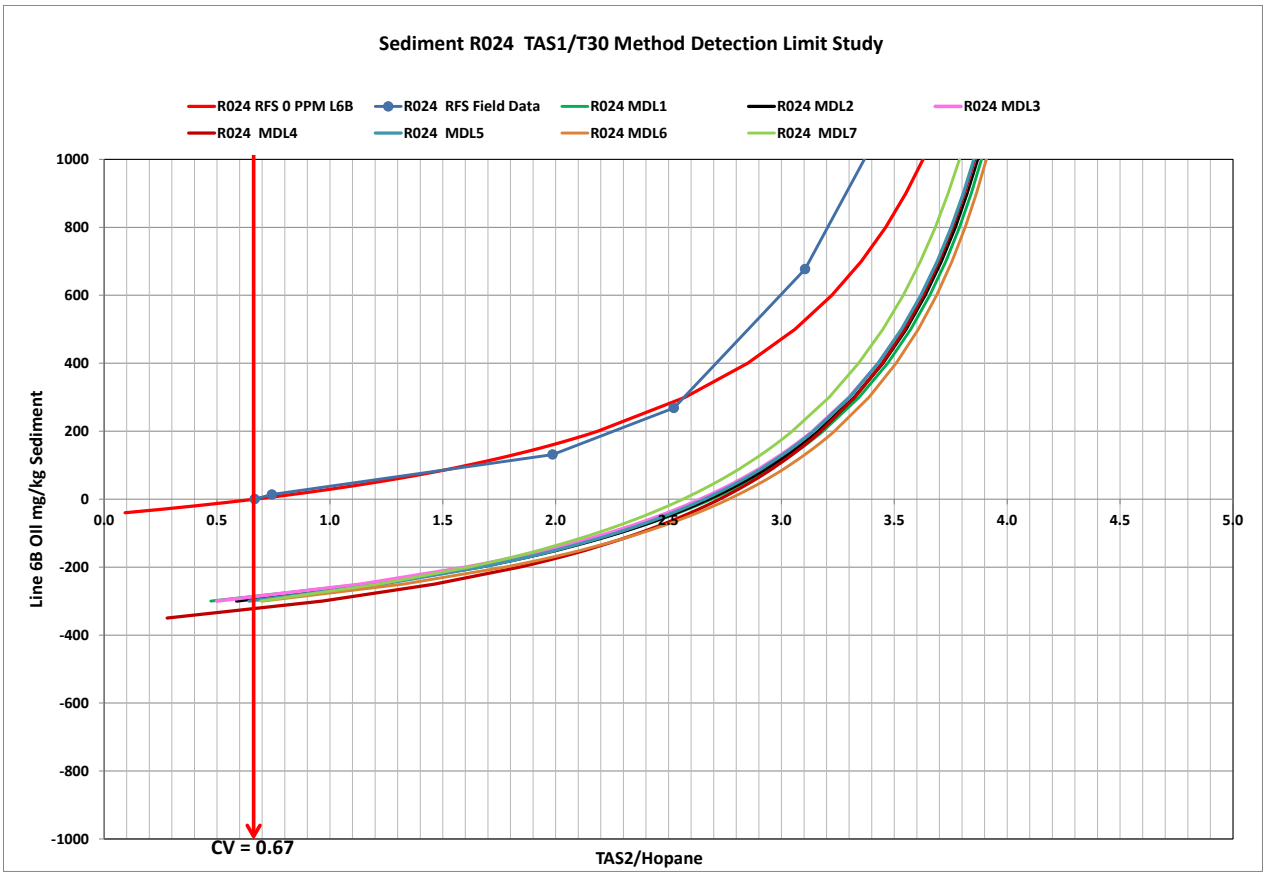

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Figure A1-10. Sediment reference sample SEKR3510R018S092112D004 (MP35.1) TAS2/Hopane Method Detection Limit Study results. Sediments were spiked with between 318-319 mg/kg dry wt Line 6B oil. The MDL Study results provide additional information concerning the utility and field verification of the TAS2/Hopane mixing model method to determine the Line 6B oil concentration in Kalamazoo River sediment.

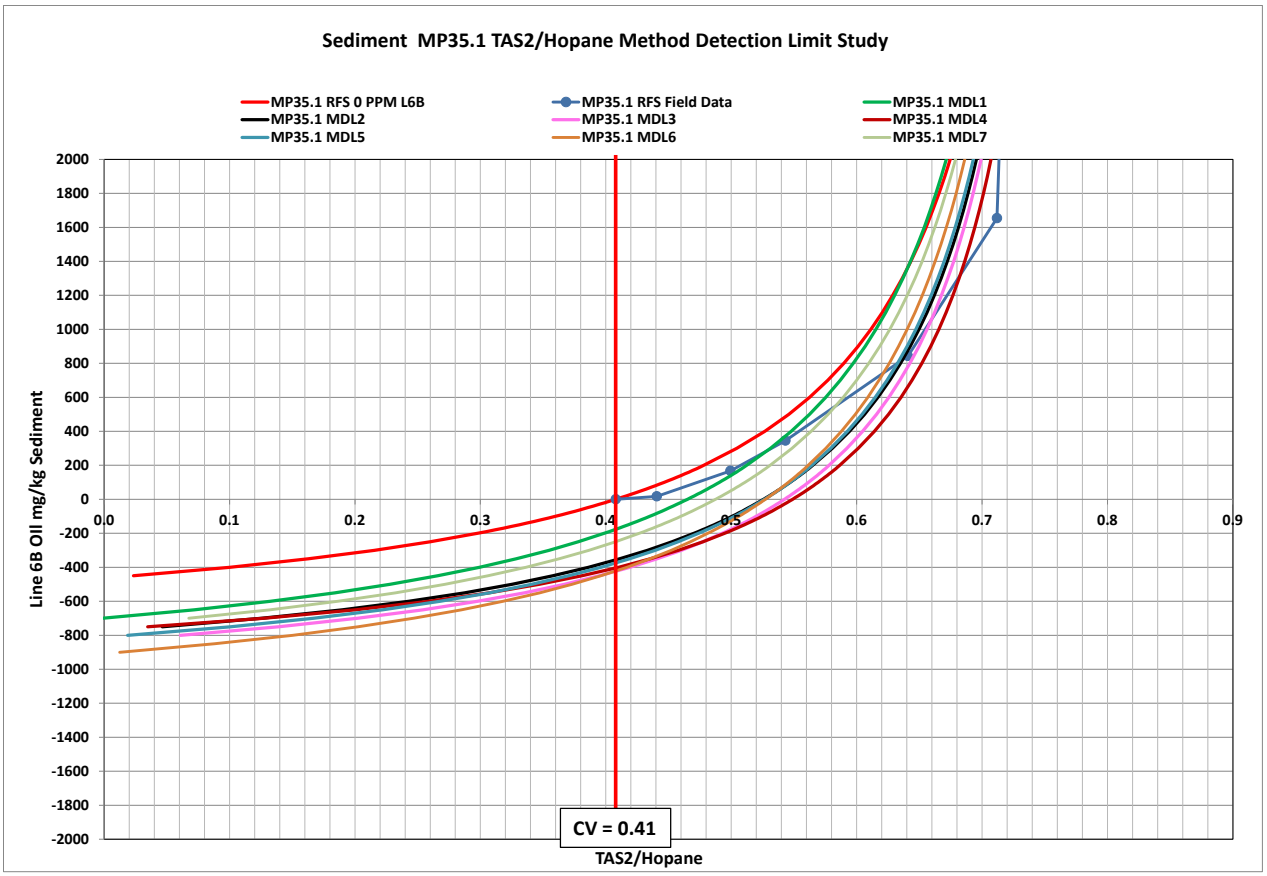

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Figure A1-11. Sediment reference sample SEKR3510R018S092112D004 (MP35.1) TAS1/T30 Method Detection Limit Study results. Sediments were spiked with between 318-319 mg/kg dry wt. Line 6B oil. The MDL study results provide additional information concerning the utility of the TAS1/T30 mixing model approach to determine the Line 6B oil concentration in Kalamazoo River sediment.

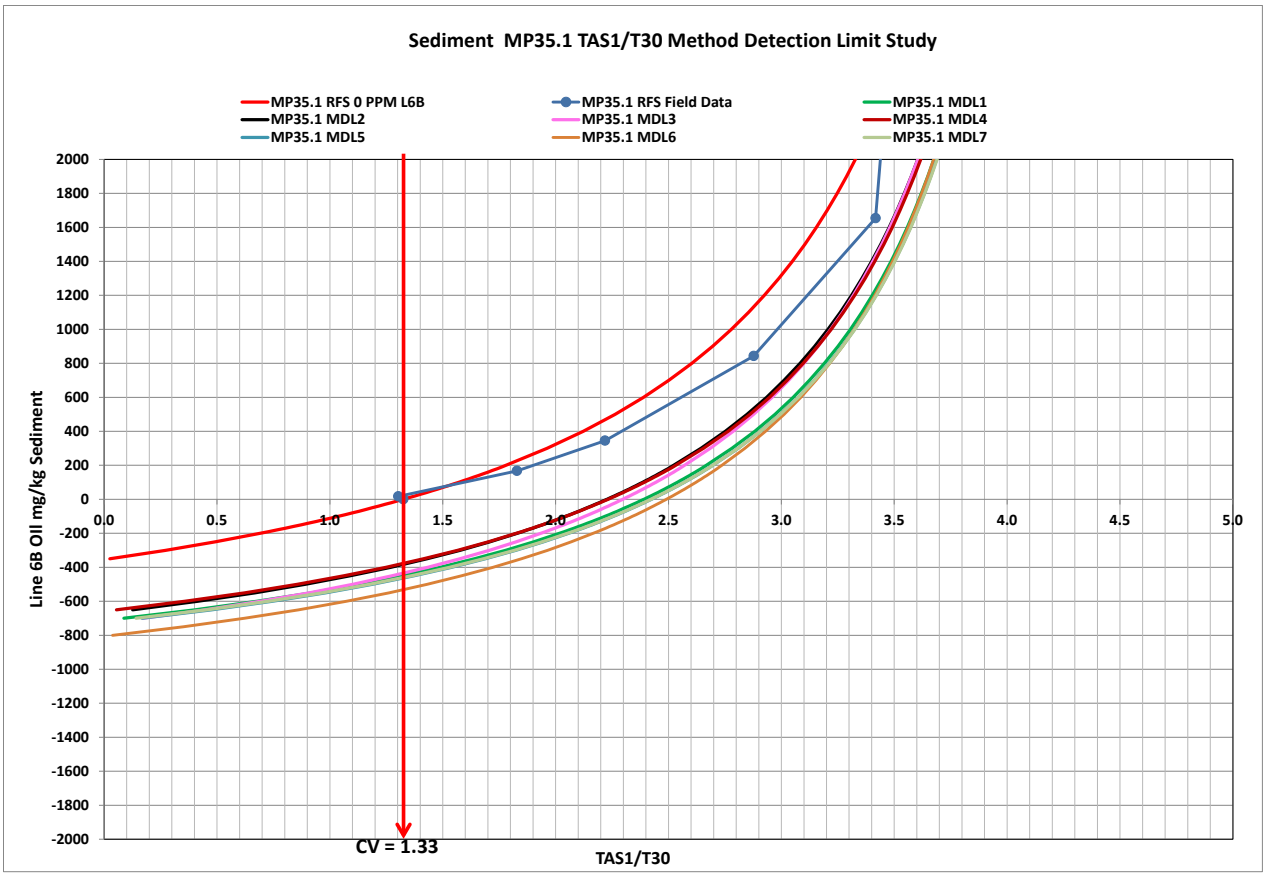

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Figure A1-12. Sediment reference sample SEBC0000L012S092112D004 (Battle Creek) Method Detection Limit Study results. Sediments were spiked with between 345-346 mg/kg dry wt. Line 6B oil. There results provide additional information concerning the utility of the TAS2/Hopane mixing model approach to determine the Line 6B oil concentration in Kalamazoo River sediment.

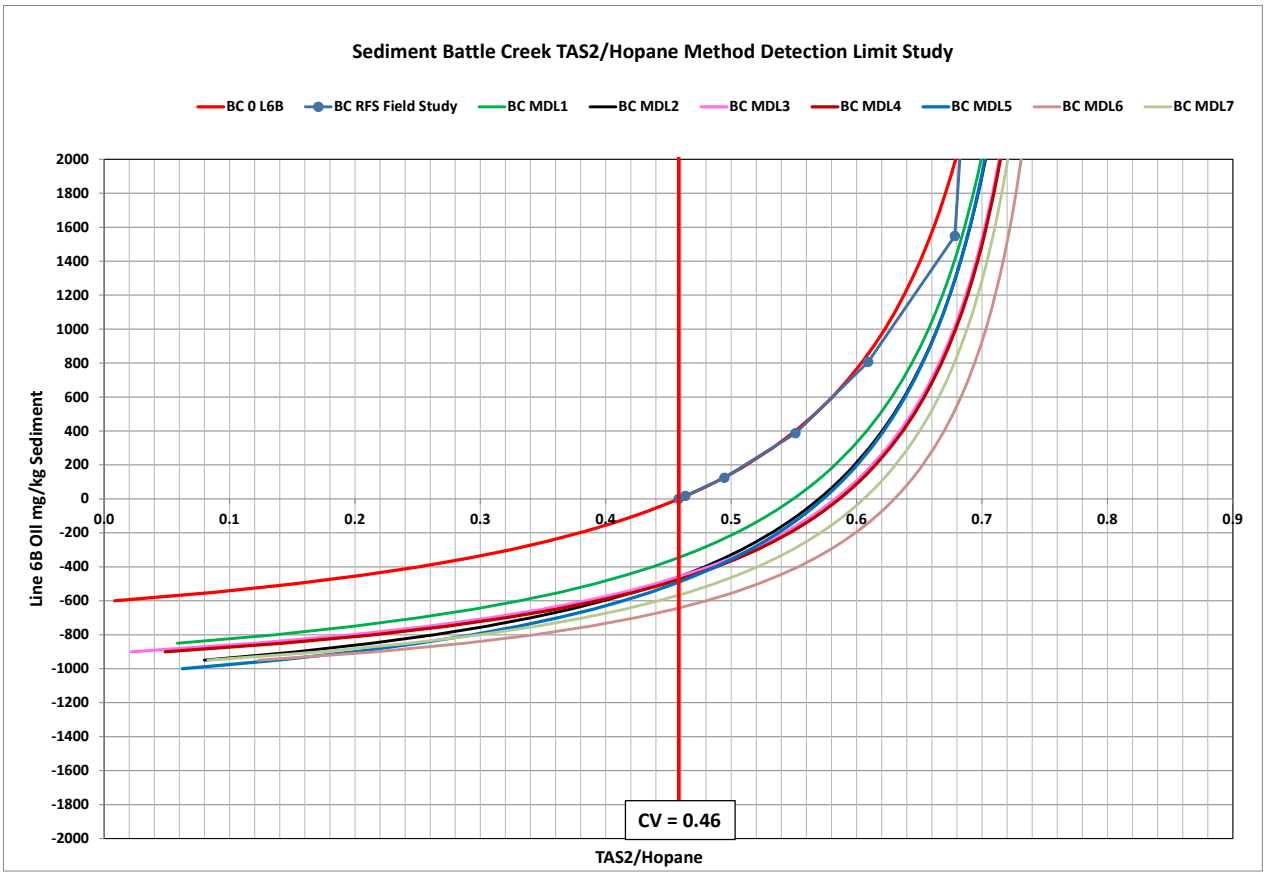

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Figure A1-13. Sediment reference sample SEBC0000L012S092112D004 (Battle Creek) TAS1/T30 Method Detection Limit Study results. Sediments were spiked with between 345-346 mg/kg dry wt. Line 6B oil. The results provide additional information concerning the utility of the TAS1/T30 mixing model approach to determine the Line 6B oil concentration in Kalamazoo River sediment.

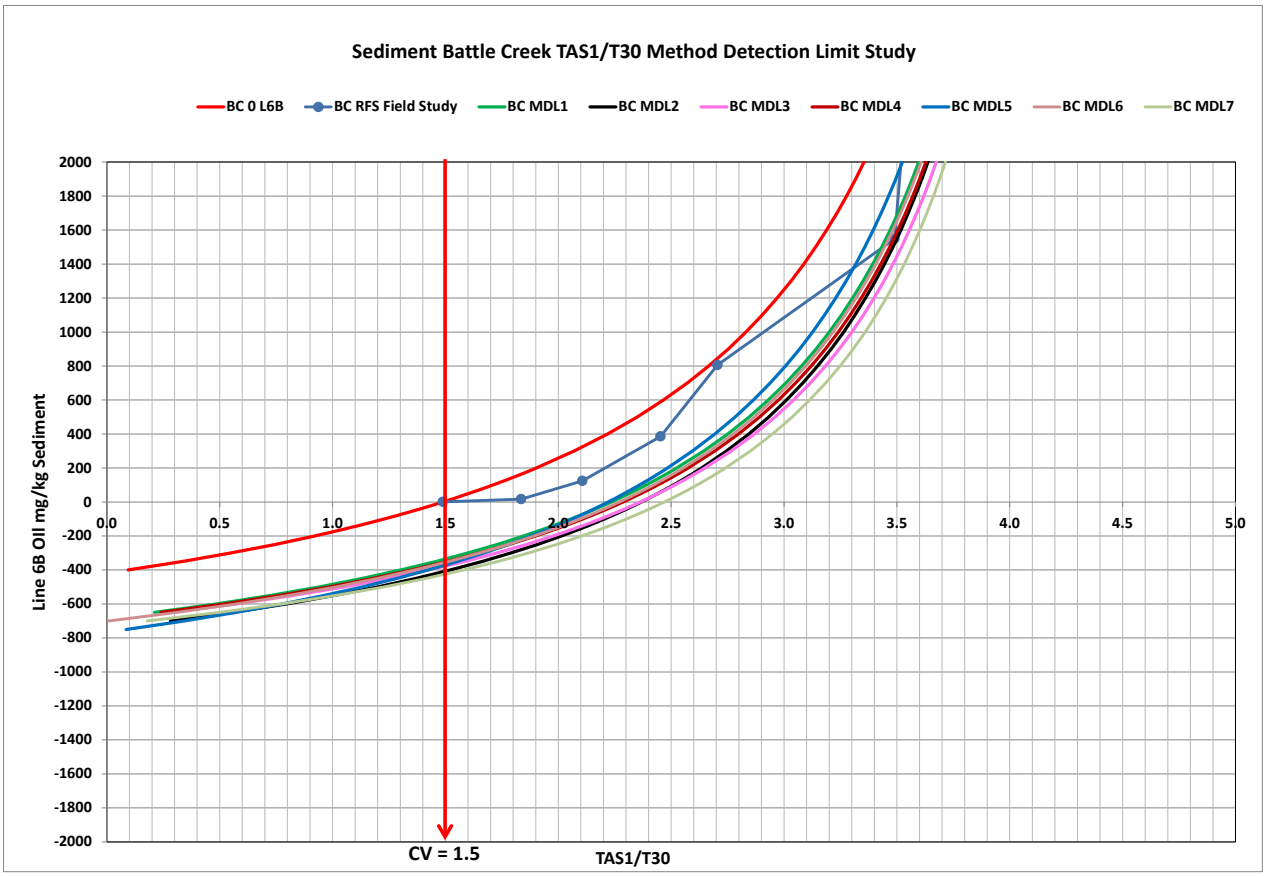

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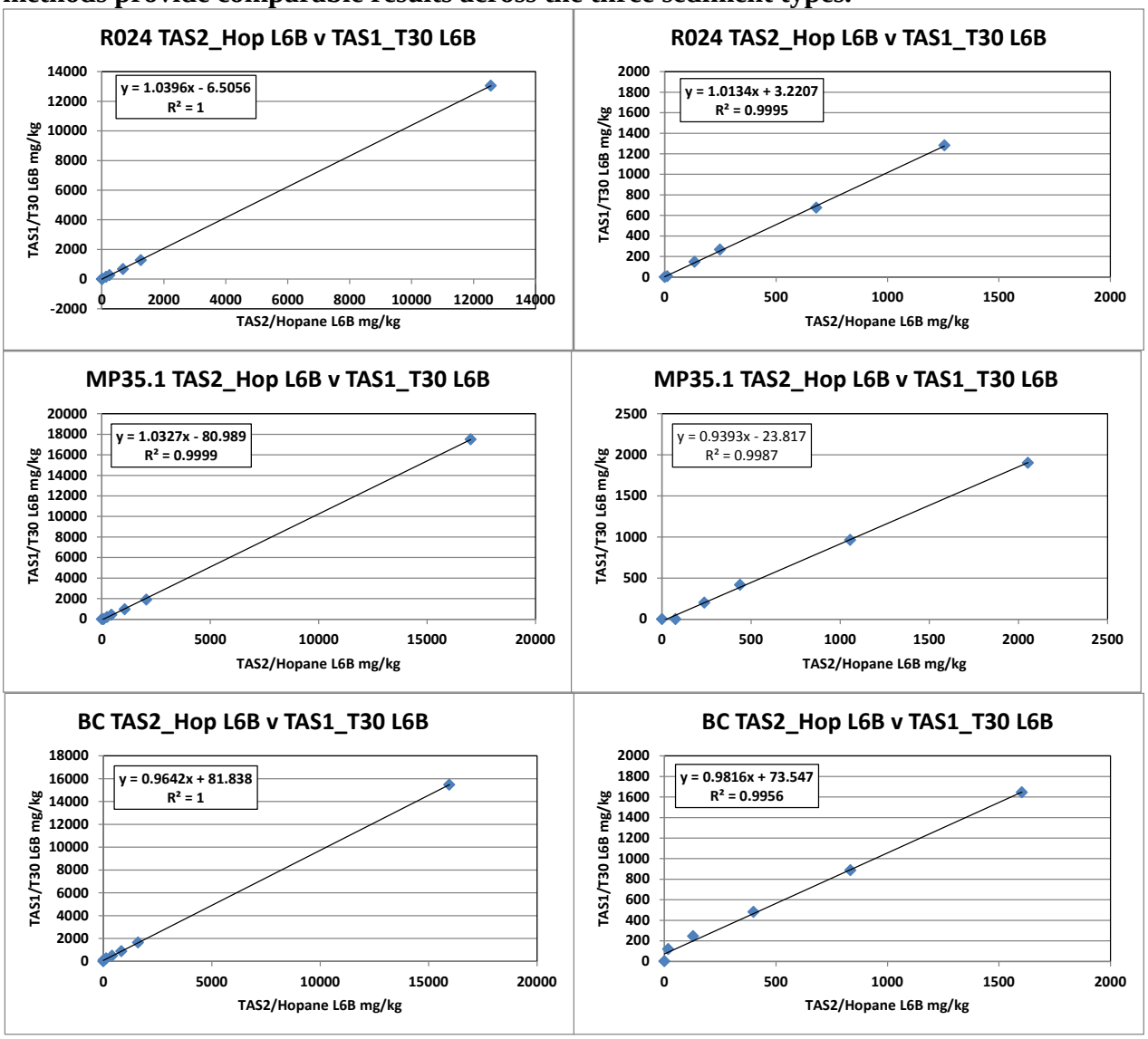
Figure A1-14. Comparison of TAS2/Hopane versus TAS1/T30 predicted Line 6B oil in Range Finding Study samples R024, MP35.1 and Battle Creek. The data show that both methods provide comparable results across the three sediment types.



US EPA ARCHIVE DOCUMENT

Appendix 3

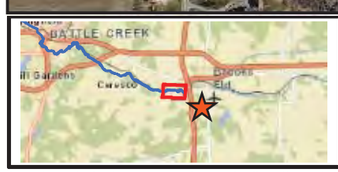
Overlay of Geomorphic Units & Spring 2012 Poling Results,

with Core Locations

US EPA ARCHIVE DOCUMENT

STRATIFIED-303
SEKR0325C701
Cutoff/Oxbow
Expected Poling: None
Actual Poling: Light
Bulk Density: No

3.5
3.25
3
2.75
2.5
2.25
2
1.75



STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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DCN: 1154-4D-AHMS

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STRATIFIED-524
SEKR0550C705
Impoundment
Expected Poling: Light
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-501
SEKR0550C701
Impoundment
Expected Poling: Moderate
Actual Poling: Moderate
Bulk Density: Yes

STRATIFIED-505
SEKR0525C702
Impoundment
Expected Poling: Moderate
Actual Poling: Moderate
Bulk Density: No

5.25

STRATIFIED-542
SEKR0500C702
Impoundment
Expected Poling: None
Actual Poling: Light
Bulk Density: No

5

STRATIFIED-483
SEKR0550C703
Impoundment
Expected Poling: Heavy
Actual Poling: Moderate
Bulk Density: No
Duplicate Core:
SEKR0550C704

4.75

STRATIFIED-121
SEKR0425C701
Backwater
Expected Poling: Light
Actual Poling: Light
Bulk Density: Yes

STRATIFIED-201
SEKR0400C701
Channel Deposit
Expected Poling: Light
Actual Poling: None
Bulk Density: Yes

STRATIFIED-543
SEKR0550C702
Impoundment
Expected Poling: None
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-525
SEKR0500C701
Impoundment
Expected Poling: Light
Actual Poling: Light
Bulk Density: No

STRATIFIED-462
SEKR0425C702
Depositional Bar
Expected Poling: None
Actual Poling: No_Poling_(Dry)
Bulk Density: No

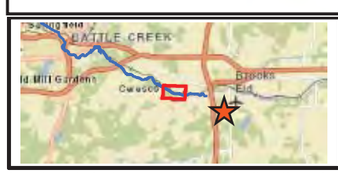
4.25

STRATIFIED-521
SEKR0475C701
Impoundment
Expected Poling: Light
Actual Poling: Light
Bulk Density: No

4

3.75

STRATIFIED-441
SEKR0475C702
Depositional Bar
Expected Poling: Light
Actual Poling: Light
Bulk Density: No



STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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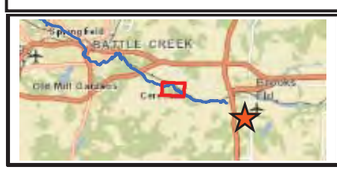

STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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STRATIFIED-261
SEKR0900C702
Cutoff/Oxbow
Expected Poling: Moderate
Actual Poling: Light
Bulk Density: No

STRATIFIED-461
SEKR0900C701
Depositional Bar
Expected Poling: None
Actual Poling: Light
Bulk Density: No

8.75

8.5

8.25

8

7.75

7.5

7.25

STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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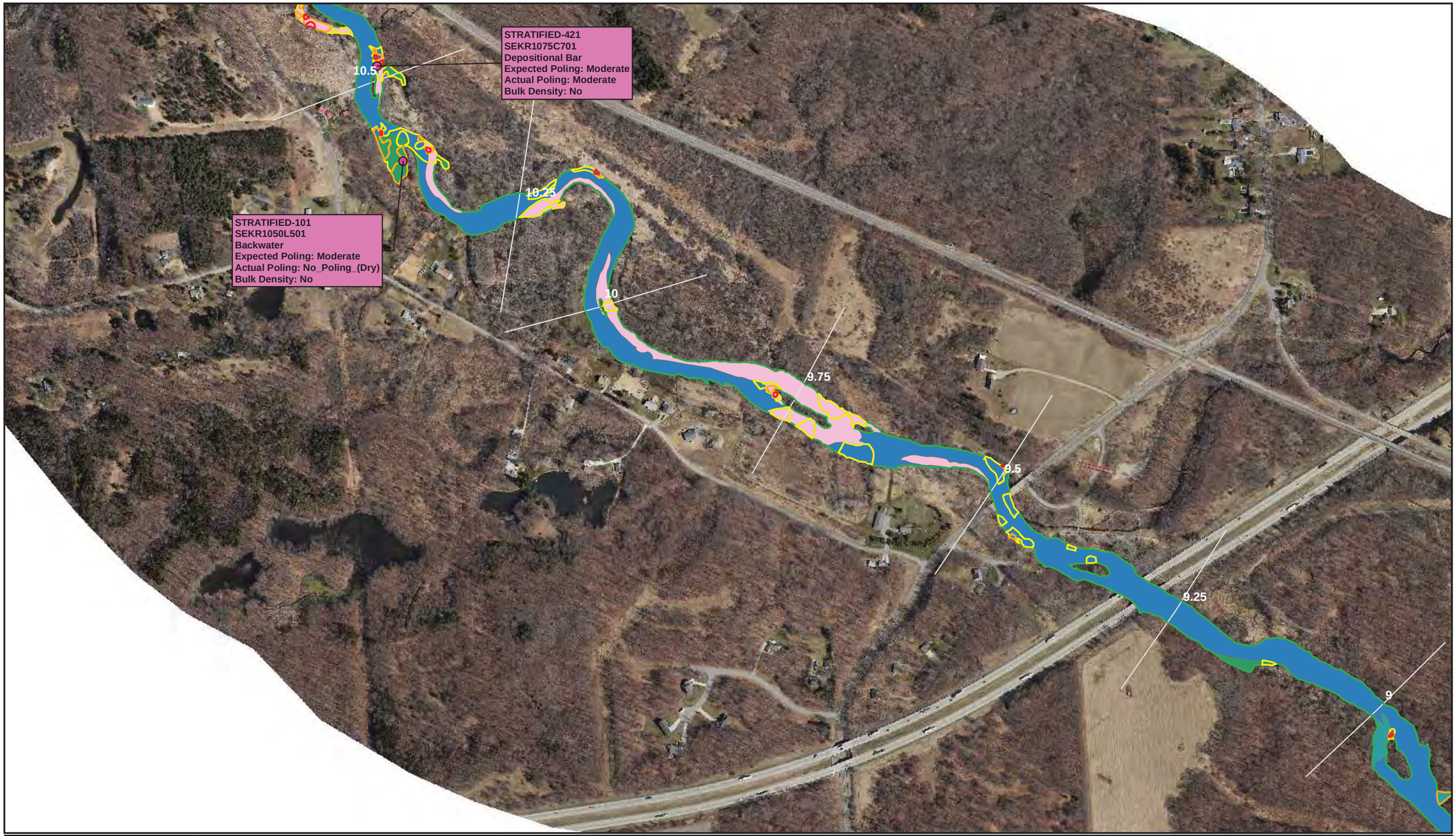

STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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12

11.75

11.5

12.25

STRATIFIED-083
SEKR1200L701
Backwater
Expected Poling: Heavy
Actual Poling: No_Poling_(Dry)
Bulk Density: No

11.25

11

12.5

12.75

STRATIFIED-423
SEKR1100C701
Depositional Bar
Expected Poling: Moderate
Actual Poling: Heavy
Bulk Density: Yes

10.75

STRATIFIED-442
SEKR1075C702/C703
Depositional Bar
Expected Poling: Light
Actual Poling: Heavy
Bulk Density: No

13

STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

Feet
0 125 250 500

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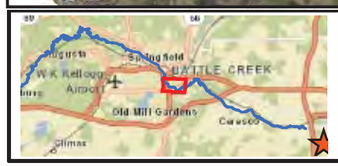
STRATIFIED-202
SEKR1500C701
Channel Deposit
Expected Poling: Light
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-241
SEKR1475C702
Cutoff/Oxbow
Expected Poling: Heavy
Actual Poling: No_Poling_(Dry)
Bulk Density: No

STRATIFIED-221
SEKR1475C701
Channel Deposit
Expected Poling: None
Actual Poling: Moderate
Bulk Density: Yes

STRATIFIED-262
SEKR1425C701
Cutoff/Oxbow
Expected Poling: Moderate
Actual Poling: Moderate
Bulk Density: No

15
14.75
14.5
14.25
14
13.75
13.5
13.25



STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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Date of Aerial Photographs: April 2011

16.25

16

15.75

STRATIFIED-544
SEKR1575C703
Impoundment
Expected Poling: None
Actual Poling: None
Bulk Density: No

STRATIFIED-481
SEKR1575C701
Impoundment
Expected Poling: Heavy
Actual Poling: Heavy
Bulk Density: Yes

15.5

STRATIFIED-482
SEKR1550C701
Impoundment
Expected Poling: Heavy
Actual Poling: Moderate
Bulk Density: Yes

STRATIFIED-503
SEKR1575C702
Impoundment
Expected Poling: Moderate
Actual Poling: Heavy
Bulk Density: No

15.25

STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None

Coring Sample Locations

0 125 250 500 Feet

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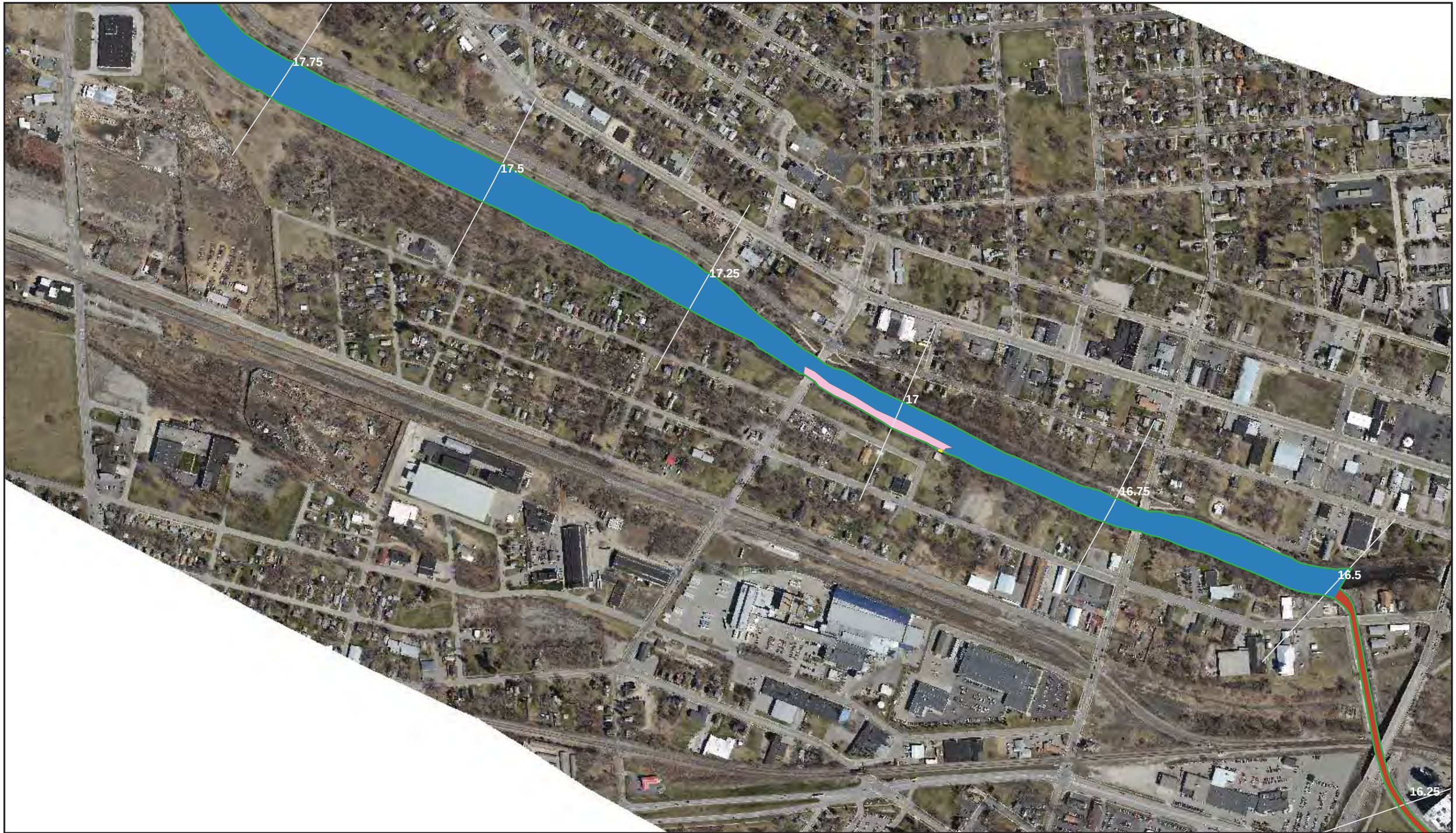

STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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Date of Aerial Photographs: April 2011

19.25

STRATIFIED-061
SEKR1900C701
Anthropogenic Channel
Expected Poling: None
Actual Poling: None
Bulk Density: Yes

19

STRATIFIED-063
SEKR1875C701
Anthropogenic Channel
Expected Poling: None
Actual Poling: None
Bulk Density: No

18.75

STRATIFIED-041
SEKR1850C701
Anthropogenic Channel
Expected Poling: Light
Actual Poling: Light
Bulk Density: Yes

18.5

18.25

18

17.75

STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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Date of Aerial Photographs: April 2011

20.75

20.5

20.25

20

19.75

19.25

STRATIFIED-021
SEKR2000C701
Anthropogenic Channel
Expected Poling: Moderate
Actual Poling: Moderate
Bulk Density: Yes

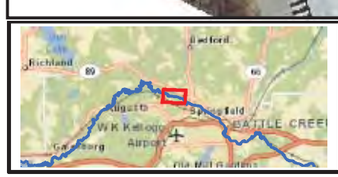
STRATIFIED-062
SEKR2000C702
Anthropogenic Channel
Expected Poling: None
Actual Poling: Heavy
Bulk Density: No

STRATIFIED-042
SEKR1950C701
Anthropogenic Channel
Expected Poling: Light
Actual Poling: Light
Bulk Density: No

STRATIFIED-003
SEKR2025C702
Anthropogenic Channel
Expected Poling: Heavy
Actual Poling: Heavy
Bulk Density: Yes

STRATIFIED-002
SEKR2025C701
Anthropogenic Channel
Expected Poling: Heavy
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-043
SEKR2025C703
Anthropogenic Channel
Expected Poling: Light
Actual Poling: Light
Bulk Density: No



STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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Date of Aerial Photographs: April 2011

STRATIFIED-263
SEKR2300C701
Cutoff/Oxbow
Expected Poling: Moderate
Actual Poling: Heavy
Bulk Density: No

STRATIFIED-302
SEKR2275C701
Cutoff/Oxbow
Expected Poling: None
Actual Poling: Light
Bulk Density: Yes

23

22.75

22.5

23.75

22.25

STRATIFIED-281
SEKR2200C701
Cutoff/Oxbow
Expected Poling: Light
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-222
SEKR2150C702
Channel Deposit
Expected Poling: None
Actual Poling: None
Bulk Density: No

STRATIFIED-443
SEKR2150C705
Depositional Bar
Expected Poling: Light
Actual Poling: Light
Bulk Density: Yes

STRATIFIED-242
SEKR2150C703
Cutoff/Oxbow
Expected Poling: Heavy
Actual Poling: Heavy
Bulk Density: No

22

STRATIFIED-181
SEKR2150C701
Channel Deposit
Expected Poling: Moderate
Actual Poling: Light
Bulk Density: No

STRATIFIED-282
SEKR2125C701
Cutoff/Oxbow
Expected Poling: Light
Actual Poling: Light
Bulk Density: No

STRATIFIED-243
SEKR2150C704
Cutoff/Oxbow
Expected Poling: Heavy
Actual Poling: Heavy
Bulk Density: No

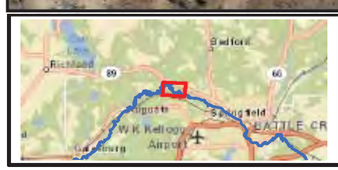
21.5

21.25

STRATIFIED-123
SEKR2175C701
Backwater
Expected Poling: Light
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-143
SEKR2175C702
Backwater
Expected Poling: None
Actual Poling: No_Poling_(Dry)
Bulk Density: No

21



STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

Feet
0 125 250 500

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U.S. EPA REGION V
Contract No.: EP-S5-06-04
TDD: S05-0005-1007-030
DCN: 1154-4D-AHMS

Prepared by:
WESTON SOLUTIONS, INC.
2501 Jolly Road, Suite 100
Okemos, MI

2012 SUB-OIL VOLUME QUANTIFICATION
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KALAMAZOO RIVER, MI
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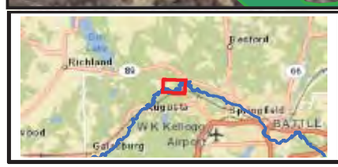
STRATIFIED-401
SEKR2400C701
Depositional Bar
Expected Poling: Heavy
Actual Poling: No_Poling_(Dry)
Bulk Density: No

STRATIFIED-104
SEKR2625C701
Backwater
Expected Poling: Moderate
Actual Poling: No_Poling_(Dry)
Bulk Density: No

STRATIFIED-402
SEKR2475C701
Depositional Bar
Expected Poling: Heavy
Actual Poling: No_Poling_(Dry)
Bulk Density: No

23.25
23
23.5
23.75
24
24.25
24.5
24.75
25
25.5
25.75



STRATA

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- ENGINEERED CHANNEL
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Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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Date of Aerial Photographs: April 2011

STRATIFIED-422
N/A
Depositional Bar
Expected Poling: Moderate
Actual Poling: N/A
Bulk Density: No

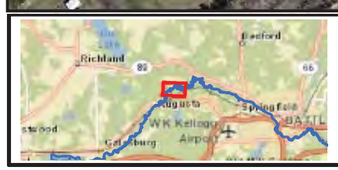
STRATIFIED-104
SEKR2625C701
Backwater
Expected Poling: Moderate
Actual Poling: No_Poling_(Dry)
Bulk Density: No
Duplicate Core:
SEKR2625C702

STRATIFIED-141
SEKR2750C701
Backwater
Expected Poling: None
Actual Poling: None
Bulk Density: No
Duplicate Core:
SEKR2750C702

STRATIFIED-203
SEKR2725C701
Channel Deposit
Expected Poling: Light
Actual Poling: None
Bulk Density: Yes

STRATIFIED-162
SEKR2525C701
Channel Deposit
Expected Poling: Heavy
Actual Poling: No_Poling_(Dry)
Bulk Density: No

26
25.75
25.5
25
26.75
26.5
27.25
27
27.5



STRATA

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- CHANNEL DEPOSIT
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- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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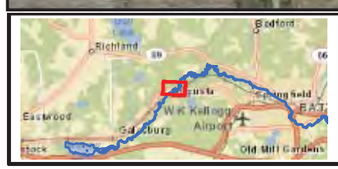
Date of Aerial Photographs: April 2011

STRATIFIED-283
SEKR2800C701
Cutoff/Oxbow
Expected Poling: Light
Actual Poling: Moderate
Bulk Density: Yes

STRATIFIED-142
SEKR2875C701
Backwater
Expected Poling: None
Actual Poling: No_Poling_(Dry)
Bulk Density: Yes

STRATIFIED-301
SEKR2850C701
Cutoff/Oxbow
Expected Poling: None
Actual Poling: None
Bulk Density: No

27.75
28
28.25
28.5
28.75
29
29.25



STRATA

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- BACKWATER
- CHANNEL DEPOSIT
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Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

Feet
0 125 250 500

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- DELTA
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- ENGINEERED CHANNEL
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- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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STRATA

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- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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Date of Aerial Photographs: April 2011

31.75

32

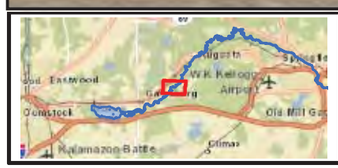
32.25

32.5

32.75

33

STRATIFIED-223
SEKR3250C701
Channel Deposit
Expected Poling: None
Actual Poling: None
Bulk Density: No



STRATA

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- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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Date of Aerial Photographs: April 2011

STRATA

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- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
- DEPOSITIONAL BAR
- ENGINEERED CHANNEL
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- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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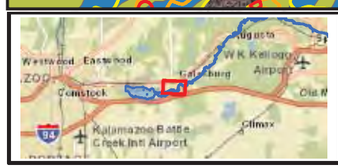
STRATIFIED-365
SEKR3725C706
Delta
Expected Poling: Light
Actual Poling: Light
Bulk Density: No

STRATIFIED-341
SEKR3675C701
Delta
Expected Poling: Moderate
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-081
SEKR3650C701
Backwater
Expected Poling: Heavy
Actual Poling: No_Poling_(Dry)
Bulk Density: No

37
36.25
36
35.75
35.5
35.25



STRATA

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- CUTOFF/OXBOW
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- DEPOSITIONAL BAR
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Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

0 125 250 500 Feet

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Date of Aerial Photographs: April 2011

STRATIFIED-601
SEKR3800C701
ML Fan
Expected Poling: Heavy
Actual Poling: Moderate
Bulk Density: Yes

STRATIFIED-183
SEKR3775C701
Channel Deposit
Expected Poling: Moderate
Actual Poling: Light
Bulk Density: No

STRATIFIED-322
SEKR3750C705
Delta
Expected Poling: Heavy
Actual Poling: Light
Bulk Density: No

STRATIFIED-381
SEKR3725C707
Delta
Expected Poling: None
Actual Poling: None
Bulk Density: No

STRATIFIED-365
SEKR3725C706
Delta
Expected Poling: Light
Actual Poling: Light
Bulk Density: No

STRATIFIED-361
SEKR3725C704
Delta
Expected Poling: Light
Actual Poling: Light
Bulk Density: Yes

STRATIFIED-363
SEKR3750C706
Delta
Expected Poling: Light
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-343
SEKR3775C704
Delta
Expected Poling: Moderate
Actual Poling: None
Bulk Density: No

STRATIFIED-342
SEKR3750C707
Delta
Expected Poling: Moderate
Actual Poling: Light
Bulk Density: Yes

STRATIFIED-362
SEKR3725C705
Delta
Expected Poling: Light
Actual Poling: Light
Bulk Density: Yes

STRATIFIED-645
SEKR3800C706
ML Fan
Expected Poling: Light
Actual Poling: Light
Bulk Density: No

STRATIFIED-161
SEKR3775C702
Channel Deposit
Expected Poling: Heavy
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-163
SEKR3700C701
Channel Deposit
Expected Poling: Heavy
Actual Poling: Moderate
Bulk Density: Yes

STRATIFIED-345
SEKR3750C709
Delta
Expected Poling: Moderate
Actual Poling: Moderate
Bulk Density: No
Duplicate Core:
SEKR3750C710

STRATIFIED-323
SEKR3750C703
Delta
Expected Poling: Heavy
Actual Poling: No_Poling_(Dry)
Bulk Density: No

STRATIFIED-364
SEKR3775C703
Delta
Expected Poling: Light
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-103
SEKR3725C709
Backwater
Expected Poling: Moderate
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-082
SEKR3750C701
Backwater
Expected Poling: Heavy
Actual Poling: No_Poling_(Dry)
Bulk Density: No

STRATIFIED-182
SEKR3725C702
Channel Deposit
Expected Poling: Moderate
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-344
SEKR3750C708
Delta
Expected Poling: Moderate
Actual Poling: Heavy
Bulk Density: Yes

STRATIFIED-321
SEKR3750C704
Delta
Expected Poling: Heavy
Actual Poling: Moderate
Bulk Density: Yes

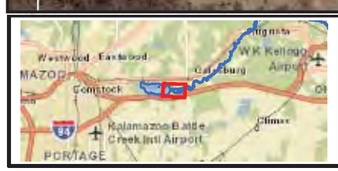
STRATIFIED-424
SEKR3725C708
Depositional Bar
Expected Poling: Moderate
Actual Poling: Moderate
Bulk Density: No

STRATIFIED-403
SEKR3725C701
Depositional Bar
Expected Poling: Heavy
Actual Poling: Moderate
Bulk Density: Yes

38.25

38

36.75



STRATA

- ANTHROPOGENIC CHANNEL
- BACKWATER
- CHANNEL DEPOSIT
- CUTOFF/OXBOW
- DELTA
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- IMPOUNDMENT
- LAKE
- ML FAN

Spring 2012 Sub-Oil Delineations

- Heavy
- Moderate
- Light
- None
- Coring Sample Locations

Feet
0 125 250 500

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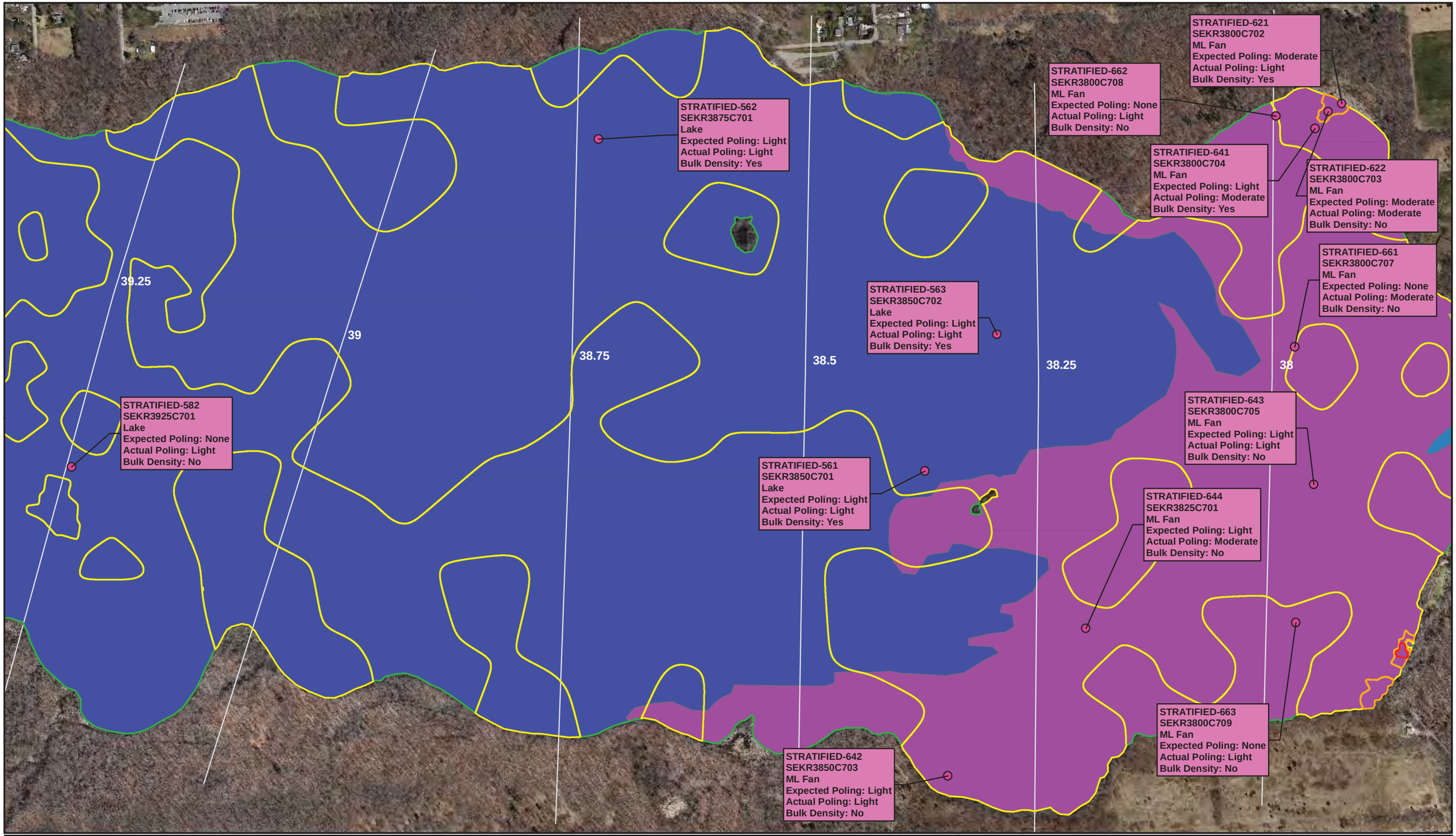

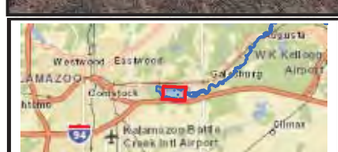

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- Heavy
- Moderate
- Light
- None

Coring Sample Locations

0 125 250 500 Feet

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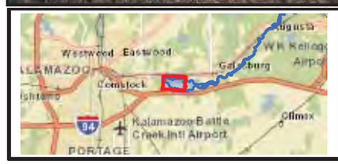
Date of Aerial Photographs: April 2011

STRATIFIED-583
SEKR3950C701
Lake
Expected Poling: None
Actual Poling: None
Bulk Density: No

STRATIFIED-581
SEKR3975C701
Lake
Expected Poling: None
Actual Poling: None
Bulk Density: Yes

STRATIFIED-582
SEKR3925C701
Lake
Expected Poling: None
Actual Poling: Light
Bulk Density: No

39.75
39.5
39.25
39
38.75
38.5



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Feet
0 125 250 500

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Date of Aerial Photographs: April 2011

Appendix 4

Enbridge Submerged Oil Volume Quantification (Field Guide)

US EPA ARCHIVE DOCUMENT

US EPA ARCHIVE DOCUMENT

Enbridge Line 6B MP 608
Marshall, MI Pipeline Release

Submerged Oil Volume Quantification
(Field Guide)

Enbridge Energy, Limited Partnership

August 8, 2012

1.0 INTRODUCTION 1

2.0 STAFF RESOURCES 2

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9.0 DISPUTE MANAGEMENT 9

10.0 SCHEDULE 9

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US EPA ARCHIVE DOCUMENT

LIST OF ACRONYMS

2011 CWP	*Addendum to the Response Plan for Downstream Impacted Areas, August 2, 2010 (Revised August 17, 2010 per U.S. EPA August 17, 2010 letter), Supplement to Source Area Response Plan, and Supplement to Response Plan for Downstream Impacted Areas, Referred to as Operations and Maintenance Work Plan Commonly referred to as "Consolidated Work Plan from Fall 2011 through Fall 2012"* approved by the U.S. EPA on December 21, 2011
Enbridge	Enbridge Energy, Limited Partnership
GPS	Global positioning system
GRTS	Generalized Random Tessellation Survey
Line 6B	The pipeline owned by Enbridge Energy, Limited Partnership that runs just south of Marshall, Michigan
PNA	Polynuclear aromatic hydrocarbon
PSD	particle size distribution
QAPP	Quality Assurance Project Plan
SHC	Saturated hydrocarbons
SOP	Standard Operating Procedure
TPH	total petroleum hydrocarbons
USCS	Unified Soil Classification System
U.S. EPA	United States Environmental Protection Agency
UV	ultraviolet

US EPA ARCHIVE DOCUMENT

1.0 INTRODUCTION

In the summer of 2011, the Unites States Environmental Protection Agency (U.S. EPA) requested that Enbridge Energy, Limited Partnership (Enbridge) quantify the amount of submerged oil remaining in the Kalamazoo River. From early on in the Line 6B response, laboratory analysis of the samples consisted of Total Petroleum Hydrocarbons (TPH) as well as polynuclear aromatic hydrocarbons (PNAs) which are typical target compounds for crude oil investigations. However, TPH and PNA analytical methods detect naturally occurring (non-oil organic material) related materials as well as other hydrocarbons, known to be present in the Kalamazoo River prior to the Line 6B release. In some instances, the median TPH concentrations in samples analyzed from reference locations, in areas not impacted by the Line 6B release, were greater than the median TPH found in sediments impacted by the Line 6B release. Considerable effort ensued to evaluate methods to provide a "more accurate" assessment of crude oil remaining in the river sediments, specifically the identification and quantification of remaining oil within the Kalamazoo River system that originates from the Line 6B release. This effort focuses on identifying very specific compounds unique to the crude oil from the release (not present in other oils present in the river system) and the development of a unique "fingerprint" reference signature that can be used to defensibly determine the presence and relative quantity of Line 6B oil in sediment samples.

The objective of this document is to direct the capture of appropriate data that will be used to defensibly quantify the volume of remaining submerged oil originating from the Line 6B release that is present in the sediments of the Kalamazoo River from the confluence with Talmadge Creek down to Morrow Lake Dam. This analysis will focus on the identified unique characteristics of the Line 6B oil that will allow for the statistically significant determination of the volume of Line 6B oil remaining in the sediments. The submerged oil quantification model and the equations utilized therein are outlined in the *Addendum to the Response Plan for Downstream Impacted Areas, August 2, 2010 (Revised August 17, 2010 per U.S. EPA August 17, 2010 letter), Supplement to Source Area Response Plan, and Supplement to Response Plan for Downstream Impacted Areas, Referred to as Operations and Maintenance Work Plan Commonly referred to as "Consolidated Work Plan from Fall 2011 through Fall 2012"* (Enbridge, 2011a) approved by the U.S. EPA on December 21, 2011 (2011 CWP).

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Characteristics of the sediments and any oil present within the study area that do not pertain to submerged oil quantification of Line 6B oil are not targeted by the following procedures and analyses.

2.0 STAFF RESOURCES

Two sediment coring teams each consisting of:

- Global Positioning System (GPS) technician, and
- Sediment core collecting environmental scientist(s).

One core logging/sampling team consisting of:

- Geologist or equivalent trained in Unified Soil Classification System (USCS) textural classification, and
- Sampler(s) trained in the methodology outlined herein.

One photo logging team consisting of:

- Environmental scientist trained in core preparation, and
- Environmental scientist trained in the use of high-resolution photographic equipment.

3.0 LOCATION AND QUANTITY OF CORE SAMPLES

Locations of the sediment core samples collected during the survey will be pre-determined using a Generalized Random Tessellation Survey (GRTS) design. This is a set methodology that ensures randomly spaced and statistically sound sampling of possible combinations of poling results and geomorphic field areas (referred to as “geomorphic stratum”). A total of 102 sample locations, not including background locations, will be pre-determined using the GRTS design. Care must be taken by field teams to adhere to the sampling plan as closely as possible, only altering sampling location where deemed absolutely necessary (obstruction of coring by riverine debris, etc…). A core location may be adjusted within an approximate 10 foot radius around the proposed point to ensure accuracy. If alteration of the core location within this 10 foot radius still does not allow for obstruction free sampling, then the location is abandoned and the next pre-determined alternative site for the geomorphic stratum being characterized on the list will be selected. Upon verification of the proposed strata, the predetermined amount of cores will be

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collected. After core collection, poling activities will occur at the coring location in line with current practices utilized on the project and the oiling level will be documented. If the proposed location is dry, poling will not be conducted after core collection.

Background and upstream reference samples will also be collected with locations to be pre-determined prior to commencing field activities. The locations will be selected within the Kalamazoo River, upstream of MP 2.00, and from the Battle Creek River. Approximately 10 locations may be initially identified with additional locations added if deemed necessary. The core, sample collection, and analysis procedure for the background cores will follow the same procedures outlined in the following sections.

Once GRTS-selected locations for sediment core collections are determined, field teams will be provided location coordinates via the YUMA GPS units assigned to them. Coring teams will navigate to coring locations by boat, and in some cases by land. The arrival of a coring team at a given sample location will be confirmed in the field by a trained YUMA GPS operator on each team. Sample location and YUMA GPS operation procedures will follow the procedures found in *SOP EN-104* (Enbridge, 2011b).

4.0 CORE COLLECTION

Two (primary) cores will be collected at each coring location. A third core for Bulk Density analysis will be collected from a pre-determined 40 to 50% of locations (approximately 40 to 50 locations total) and a fourth step-out core will be collected at a rate of 1 per 20 (refer to *Section 6.1* for step-out cores). These cores will be located side-by-side at the location. The cores will be separated by minimum distance necessary to ensure that both cores are undisturbed samples representative of site conditions.

Sediment core sample collection *SOP EN-202 Utilization of a Check-valve Sampler* (Enbridge, 2011b) will be as followed:

- Sampler will be inserted slowly to minimize any bow-wake of sample,
- Sampler will be removed at a slow steady rate to minimize mobility of floccules, and
- Cores will be maintained in vertical orientation during transport and storage.

Cores will not exceed a single core barrel in length (4 feet). The minimum core length recovery will be 2 feet unless refusal is reached during coring. Cores will be transported

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(vertically) to refrigerated storage by a team runner to ensure that cores are chilled soon after collection.

Decontamination of coring equipment will take place as outlined in *SOP EN-105 Decontamination of Field Equipment* (Enbridge, 2011b).

5.0 CORE PROCESSING (LOGGING AND SAMPLING)

Collected cores will be opened at a field processing station. Prior to core processing, cores will be labeled Core #1 (primary), Core #2 (primary), and Core #3. Core #1 will be opened, logged, photographed, and sampled for fingerprinting and Particle Size Distribution (PSD). Core #2 will be opened, and sampled for oil globules (if present) under ultraviolet (UV) light. Core #3, when collected, will remain capped and submitted for Bulk Density analysis (4 per strata) and Core #4 (step-out), when collected, will be processed similar to Core #1. In the event that Core #1 does not open in even halves, Core #2 will be used in its place and Core #1 will be used for oil globule sampling.

Prior to opening Core #1, the maximum potential volume of standing water will be removed from the top of the core without impacting flocculent material located above the sediment. The core will be allowed to stabilize for up to one hour to allow flocculent material to settle and ensure water in the core barrel is clear.

- Water will be removed via a suction bulb (turkey baster) or small diameter siphon tubing (Care should be taken to not disturb the flocculent sediment),
- 0.125 to 0.250 inches of standing water may remain, and
- The core will be capped and kept at approximately 32˚ Fahrenheit overnight and allowed to partially freeze.

Upon drainage of excess water and recapping of core #1, the core will be split according to normal procedures *SOP EN-202* (Enbridge, 2011b).

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The processing of Core #1 proceeds as follows:

1. Core #1 will be split, and both halves will be photographed with a scale clearly shown:
    a. Under visible light illumination, and
    b. Under UV illumination.
2. While under UV light, intervals containing any apparent oil will be noted on the core logging sheet (interval beginning and ending, description of petroleum indicator observed, etc.),

3. One half of the core is logged for color, texture, and stratigraphic features *SOP EN-202* (Enbridge, 2011b) including:
    a. Munsell Color Values,
    b. USCS Textural Codes (ASTM D-2488-09a), and
    c. Unit specific notes (woody debris, shell material, anthropogenic matter).

4. Two sampling methodologies will be implemented during this sampling event to meet the requirements of the U.S. EPA and Enbridge. A single core will be used for analytical sampling with one half being designated for each sampling method. All samples will be submitted for laboratory analysis or laboratory "hold" in a manner consistent with the *Quality Assurance Project Plan (QAPP)* (Enbridge, 2010) (QAPP) approved by the U.S. EPA on November 11, 2010.

The cores will be sampled in the following manner:

The processing of Core #1 is as follows:

a. Cores with no evidence of impact.
    i. Enbridge half:
        1. Collect top 1.0 inch for laboratory analysis.
        2. Collect each remaining stratigraphic layer into an appropriately sized sample container (up to 7 inches), place samples on hold.
    ii. U.S. EPA half: No action.

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b. Cores with evidence of impact.
    i. Enbridge half:
        1. Collect top 1.0 inch for laboratory analysis. If impacted interval is inclusive of this interval and only slightly larger (i.e. 2.0 inches) the interval will be expanded to include the impact.
        2. Collect impacted layer into an appropriately sized sample container (up to 7 inches), and submit for laboratory analysis.
        3. Collect each remaining stratigraphic layer into an appropriately sized sample container (up to 7 inches), place samples on hold.
    ii. U.S. EPA half:
        1. Collect top 1.0 inch, place sample on hold.
        2. Collect bottom 2.5 inch interval of impacted interval, place sample on hold.
        3. Collect 2.5 inch interval from area exhibiting greatest impact, place sample on hold.
        4. Collect 1.5 inch layer just below depth of impact and place sample on hold.
        5. Collect all remaining sediment between the bottom of the top 1.0 inch sample and the top of the middle 2.5 inch sample; collect all remaining sediment from the bottom of the middle 2.5 inch sample and the top of the bottom 2.5 inch sample. These samples will be collected in 1.5 inch intervals and placed in a jar sized to hold the entire contents of the interval.

c. Considerations.
    i. If bottom 2.5 inch interval of impacted interval is the interval exhibiting greatest impact, collect a 2.5 inch interval from above which exhibits second greatest impact. Place the sample on hold.
    ii. If bottom 2.5 inch interval of impacted interval is less than 5.0 inches bgs, there will be less than 2.5 inches above. Collect this volume and place the sample on hold.
    iii. Upon review of the logging results, additional sample intervals from below visually impacted intervals will be analyzed at the rate of 1 per

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strata (9 samples). This determination will be made by the Operations Section Chief.

The processing of Core #2 (as necessary) proceeds as follows:

- Half of the core will be observed under UV light for the presence of oil globules. In the event that oil globules are present, they will be collected in accordance with U.S. EPA-SSCG *Recommended Oil Globule Sample Collection Procedure* (April 26, 2012). These cores will be collected at the rate of 100% of total. These samples will be submitted to the laboratory and placed on hold.
- The other half of the core will be sampled for PSD. PSD samples will be collected from the same intervals that were sampled in Core #1. These samples will be submitted to the laboratory and placed on hold.

The processing of Core #3 proceeds as follows:

- The core will be submitted to the lab with instructions to analyze for Bulk Density from either the impacted interval as dictated from the processing of Core #1, or, if no oil is observed, the Bulk Density sample will be collected from the 0.0 to 6.0 inch interval. These cores will be collected at a rate of (40 to 50%) of total.

Refer to *Section 6.1* for the processing of Core #4.

6.0 QUALITY CONTROL SAMPLES

6.1 Step-out Subsample Collection

The step-out cores will be collected at a rate of 1 per 20 and will be collected from each oil category (heavy, moderate, light, none). No more than 2 step-out cores will be collected from the same geomorphic strata. At a location where a step-out core is collected the following will apply:

- The step-out core will be collected within 3 feet of the primary cores, and within the same geomorphic strata and oil category polygon.

- The step-out core is split and photographed. Preliminary visual observations comparing the step-out and primary core lithologies will be conducted. Sediment

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samples from the step-out core will be collected only if lithologies match the primary cores (sample same depth interval if lithology is identical; sample same lithology, and adjust depth interval, if minor variation in lithology are present in the step-out core). If the step-out core lithology is significantly different from the primary core, notify the Ops Section Chiefs to resolve the issues (see *Section 9.0*).

Step-out core materials shall be archived in a manner equivalent to primary cores.

6.2 Duplicate Subsample Collection

Additional replicate subsamples from the primary cores will be collected at a rate of 1 per 20 samples in accordance with the current site specific QAPP.

7.0 ANALYTICAL

Samples collected from the cores at each location will be submitted for the following analyses:

Core #1:

- Alkylated PNAs and biomarkers,
- Saturated hydrocarbons (SHC), and
- PSD (placed on hold).

Core #2:

- Oil globule collection (place on hold).

Core #3:

- Bulk Density.

Chains of custody will be maintained according to *SOP EN-102 Chain of Custody Procedures* (Enbridge, 2011b).

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8.0 EVALUATION OF RESULTS

The quantification of submerged oil will be accomplished utilizing the model and equations outlined in the approved 2011 CWP. Input variables necessary for this model are:

- Alkylated PNAs and biomarkers, and SHC analysis,
- Sediment bulk density,
- Lateral extent of oil-impacted sediment,
- Vertical extent of oil-impacted sediment, and
- Density of released oil, adjusted for weathering.

As stated in the 2011 CWP, "*The models shall utilize a spreadsheet to calculate the volume of impacted sediment. Once calculated, the mass of oil impacted sediment shall be determined from the impacted volume and sediment bulk density. These volume calculations shall be performed separately for different sub-regions of the total oil-impacted river system*…" (i.e. 10 specific geomorphic settings and poling delineated areas). *"Subsequently, the mass of oil present in each stratum shall be calculated based on a representative concentration value*…" (alkylated PNAs and biomarkers, and SHC analysis). "*Finally, the volume of submerged oil shall be calculated from an approximation of the density of the weathered crude."*

Data collected from the proposed sampling and analysis event will be used to supplement data collected during the Spring 2012 sediment sampling assessment to achieve the objectives stated above.

9.0 DISPUTE MANAGEMENT

If during the investigation, concurrence cannot be reached for any reason, a call will be immediately made the Operations Section Chiefs. The Operations Section Chiefs will mobilize to the location of the dispute to make the determination.

10.0 SCHEDULE

It is anticipated that the field activities will take approximately two weeks to collect cores/samples from all GRTS-generated and background locations. The analysis of sediment samples will be complete approximately three weeks following completion of the

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field activities. All available data collected during the investigation will be compiled and reviewed. In the event that data gaps are discovered, additional samples may be collected to fill those gaps.

11.0 REFERENCES

Enbridge, 2010. Enbridge Line 6B MP 608 Marshall, MI Pipeline Release; *Quality Assurance Project Plan (QAPP)*. November 11, 2010.

Enbridge, 2011a. Enbridge Line 6B MP 608 Marshall, MI Pipeline Release; *Addendum to the Response Plan for Downstream Impacted Areas, August 2, 2010 (Revised August 17, 2010 per U.S. EPA August 17, 2010 letter), Supplement to Source Area Response Plan, and Supplement to Response Plan for Downstream Impacted Areas, Referred to as Operations and Maintenance Work Plan Commonly referred to as "Consolidated Work Plan from Fall 2011 through Fall 2012"*. December 21, 2011

Enbridge, 2011b. Enbridge Line 6B MP 608 Marshall, MI Pipeline Release; *Sampling and Analysis Plan (SAP)*. August 30, 2011.

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Appendix 5

Sediment Core Logs

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Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0325C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12947598.5 **Y:** 277693.5	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 3.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/24/2012 15:00	**Water Depth (ft):** +0.1	**Core Diameter (in):** 2.75
Date Core Logged: 7/25/2012		**Field Recovery:** 1.7 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR325C701S072512DX SEKR0325C701S072512D002	SM	Very dark gray (10YR 3/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR325C701S072512D006	SP	Dark gray (10YR 4/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, trace fine gravel, trace coarse sand, trace organics, trace shells	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR325C701S072512D010 SEKR0325C701S072512D014	CL	Very dark gray (10YR 3/1) LEAN CLAY (CL), wet, low plasticity, cohesive, bedded, trace roots	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR325C701S072512D017	SW-SM	Dark grayish brown (10YR 4/2) WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM), wet, non-plastic, non-cohesive, bedded, little fine to coarse gravel, few silt	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0					End of boring at 3 ft.				
3.5									
4.0									

Coring Comments:

Logging Comments: Cutoff/Oxbow
Poling=Light

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0400C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12943105.3 **Y:** 277792.8	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 4	**Target Depth (ft):** 4
Date/Time Core Collected: 7/24/2012 13:55	**Water Depth (ft):** +0.5	**Core Diameter (in):** 2.75
Date Core Logged: 7/25/2012		**Field Recovery:** 2.1 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0400C701S 072512DX / SEKR0400C701S 072512D003	GW-GM	Dark grayish brown (10YR 4/2) WELL GRADED GRAVEL WITH SILT (GW-GM), wet, non-plastic, non-cohesive, bedded, trace organics	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0400C701S 072512D008	CL	Dark grayish brown (10YR 4/2) LEAN CLAY (CL), wet, low to moderate plasticity, cohesive, bedded, little to some silt, trace to few fine sand, trace fine gravel, trace shell material, trace woody debris	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR0400C701S 072512D013						
1.5			SEKR0400C701S 072512D017	ML	Very dark gray (10YR 3/1) to very dark grayish brown (10YR 3/2) SILT (ML), wet, non-plastic, non-cohesive to cohesive, thickly bedded, trace to few peat, few plant/root material	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR0400C701S 072512D021						
2.5									
3.0									
3.5					End of boring at 3.3 ft.				
4.0									

Coring Comments: Channel Deposit; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR0400C701S072512D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0425C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12942002.1 **Y:** 277709.5	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 4.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/24/2012 16:40	**Water Depth (ft):** +0.5	**Core Diameter (in):** 2.75
Date Core Logged: 7/25/2012		**Field Recovery:** 2.2 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0425C701S 072512DX	ML	Very dark brown (10YR 2/2) SILT (ML), wet, non-plastic, non-cohesive, bedded, few fine sand, trace organics	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0425C701S 072512D007						
1.0			SEKR0425C701S 072512D011	CL	Very dark gray (10YR 3/1) LEAN CLAY (CL), wet, low plasticity, cohesive, bedded, trace fine sand	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR0425C701S 072512D016						
			SEKR0425C701S 072512D020	ML	Very dark gray (10YR 3/1) SILT (ML), moist, non-plastic, non-cohesive, bedded, trace fine sand	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR0425C701S 072512D022	SM	Brown (10YR 4/3) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine sand	No sheen or oil	0	No oil fluorescence	0
2.5									
3.0									
3.5					End of boring at 3.3 ft.				
4.0									

Coring Comments: Backwater; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR0425C701S072512D005-Bulk Density

Checked By: JTC **Date:** 7/25/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0425C702	
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12944022. **Y:** 277316.2	**Boring Contractor:** AECOM	**Number of Attempts:** 2	
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 4.25	**Target Depth (ft):** 4	
Date/Time Core Collected: 8/8/2012 13:45	**Water Depth (ft):** NA	**Core Diameter (in):** 2.75	
Date Core Logged: 11/28/2012		**Field Recovery:** 2.8 ft	
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0425C702S 112812DX	SP	Pale brown (10YR 6/3) to gray (10YR 5/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine to medium sand, trace coarse sand, trace shell material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0425C702S 112812D005						
			SEKR0425C702S 112812D009						
1.0			SEKR0425C702S 112812D014	OH	Very dark gray (10YR 3/1) ORGANIC SILT (OH), wet, non-plastic, non-cohesive, thickly bedded, trace fine sand, trace plant/root material	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR0425C702S 112812D019						
2.0			SEKR0425C702S 112812D024						
2.5			SEKR0425C702S 112812D028						
3.0									
3.5									
					End of boring at 3.8 ft.				
4.0									

Coring Comments: Sheen in hole after coring

Logging Comments: Depositional Bar; Poling= No poling (dry point)

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0475C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12940548. **Y:** 278296.3	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 4.75	**Target Depth (ft):** 4
Date/Time Core Collected: 7/25/2012 10:35	**Water Depth (ft):** +1.2	**Core Diameter (in):** 2.75
Date Core Logged: 7/26/2012		**Field Recovery:** 1.9 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0475C701S 072612DX	CL	Very dark gray (10YR 3/1) LEAN CLAY (CL), wet, low to moderate plasticity, cohesive, bedded, few silt, trace to few fine sand, trace fine gravel, trace organics fine to medium sand at surface from 0.0 to 0.01 ft	No sheen or oil	0	No oil fluorescence	0
			SEKR0475C701S 072612D004						
0.5			SEKR0475C701S 072612D008						
1.0			SEKR0475C701S 072612D012	ML	Gray (10YR 5/1) to very dark gray (10YR 3/1) SANDY SILT (ML), wet, non-plastic, cohesive, bedded, fine sand, trace organics 1/2" layer of light brownish gray (10YR 6/2) fine sand at 0.85 ft several thin (1/16") fine sand striations from 0.9 to 1.2 ft	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR0475C701S 072612D017						
			SEKR0475C701S 072612D019	GW	Gray (10YR 5/1) to light gray (10YR 7/1) WELL GRADED GRAVEL WITH SAND (GW), wet, non-plastic, non-cohesive, bedded, fine to coarse sand, trace silt	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5					End of boring at 2.6 ft.				
3.0									
3.5									
4.0									

Coring Comments: Impoundment
Poling=Light

Logging Comments:

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0475C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12941229.8 **Y:** 277926.3	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 4.75	**Target Depth (ft):** 4
Date/Time Core Collected: 7/25/2012 11:00	**Water Depth (ft):** +0.3	**Core Diameter (in):** 2.75
Date Core Logged: 7/26/2012		**Field Recovery:** 2.5 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0475C702S 072612DX	SP-SM	Dark gray (10YR 4/1) POORLY GRADED SAND WITH SILT (SP-SM), wet, non-plastic, non-cohesive, thickly bedded, fine sand, few silt, few medium sand, trace coarse sand, trace fine gravel, trace shell material trace organics in top 0.05 ft very dark gray (10YR 3/1) silt layer from 0.55 to 0.65 and 1.2 to 1.25 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0475C702S 072612D005						
			SEKR0475C702S 072612D009						
1.0			SEKR0475C702S 072612D013						
1.5			SEKR0475C702S 072612D019	CL	Grayish brown (10YR 5/2) and very dark gray (10YR 3/1) LEAN CLAY (CL), wet, low plasticity, cohesive, bedded, some silt, trace fine sand, trace shell material	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR0475C702S 072612D023	ML	Gray (10YR 5/1) with brownish yellow (10YR 6/6) and light gray (10YR 7/1) SANDY SILT (ML), wet, non-plastic, cohesive, bedded, fine sand	No sheen or oil	0	No oil fluorescence	0
2.5			SEKR0475C702S 072612D025	SW-SM	Light gray (10YR 7/2) with gray (10YR 5/1) LAYERED WELL GRADED SAND AND SILT (SW-SM), wet, non-plastic, non-cohesive, bedded, trace fine gravel, few carbonates	No sheen or oil	0	No oil fluorescence	0
3.0									
3.5					End of boring at 3.5 ft.				
4.0									

Coring Comments: Depositional Bar
Poling=Light

Logging Comments:

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR0500C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12940026.5 **Y:** 278586.3	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 5	**Target Depth (ft):**	4
Date/Time Core Collected: 8/7/2012 13:50	**Water Depth (ft):** +1.3	**Core Diameter (in):**	2.75
Date Core Logged: 11/29/2012		**Field Recovery:**	1.3 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0500C701S 112912DX	ML	Black (10YR 2/1) to very dark gray (10YR 3/1) SANDY SILT (ML), wet, non-plastic, non-cohesive, thickly bedded, fine to medium sand, some organics, trace plant/root material, trace woody debris, trace shell material medium to coarse sand layer from 0.5 to 0.6 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0500C701S 112912D006						
1.0			SEKR0500C701S 112912D012						
1.5									
2.0									
2.5									
3.0									
3.5									
4.0					End of boring at 3.8 ft.				

Coring Comments: Impoundment; Poling=Light

Logging Comments:

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0500C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12939743.6 **Y:** 278795.1	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 5	**Target Depth (ft):** 4
Date/Time Core Collected: 8/8/2012 13:10	**Water Depth (ft):** +2.0	**Core Diameter (in):** 2.75
Date Core Logged: 11/28/2012		**Field Recovery:** 1.8 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0500C702S 112812DX	SM	Grayish brown (10YR 5/2) SILTY SAND (SM), wet, non-plastic, non-cohesive, thinly bedded, few fine gravel, trace shells	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0500C702S 112812D007	PT	Very dark brown (10YR 2/2) PEAT (PT), wet, non-plastic, non-cohesive, bedded	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR0500C702S 112812D013						
1.5			SEKR0500C702S 112812D018	CL	Dark gray (10YR 4/1) LEAN CLAY (CL), wet, low plasticity, cohesive, bedded, few fine gravel	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
					End of boring at 2.7 ft.				
3.0									
3.5									
4.0									

Coring Comments: Impoundment; Poling=Light

Logging Comments:

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR0525C702	
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12938813.9 **Y:** 279423.2	**Boring Contractor:** AECOM	**Number of Attempts:** 2	
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 5.25	**Target Depth (ft):** 4	
Date/Time Core Collected: 8/7/2012 14:20	**Water Depth (ft):** +0.8	**Core Diameter (in):** 2.75	
Date Core Logged: 11/28/2012		**Field Recovery:** 2.4 ft	
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0525C702S 112812DX	OL	Black (10YR 2/1) ORGANIC SOIL (OL), wet, low plasticity, cohesive, thickly bedded, trace silt, few organic material UV= two 2 mm flecks from 0.5 to 0.65 ft	No sheen or oil	0	No oil fluorescence	0
			SEKR0525C702S 112812D006						
0.5				OL	Same as above	No sheen or oil	0	Trace Fluorescence	2
			SEKR0525C702S 112812D011	OL	Same as above	No sheen or oil	0	No oil fluorescence	0
1.0									
			SEKR0525C702S 112812D016						
1.5				OL	UV=One 2 mm fleck at 1.6 ft	No sheen or oil	0	Trace Fluorescence	<1
			SEKR0525C702S 112812D020	OL	Same as above	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR0525C702S 112812D024						
2.5									
3.0									
3.5									
					End of boring at 3.8 ft.				
4.0									

Coring Comments: Impoundment; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0550C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12937904.7 **Y:** 279848.6	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 5.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/25/2012 08:50	**Water Depth (ft):** +3.0	**Core Diameter (in):** 2.75
Date Core Logged: 7/26/2012		**Field Recovery:** 1.9 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0550C701S 072612DX	ML	Very dark gray (10YR 3/1) and black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, few fine sand, few organics, trace shell material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0550C701S 072612D005						
			SEKR0550C701S 072612D010						
1.0			SEKR0550C701S 072612D014	CL	Grayish brown (10YR 5/2) LEAN CLAY (CL), wet, moderate plasticity, cohesive, bedded, few to little silt	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR0550C701S 072612D019	ML	Very dark gray (10YR 3/1) SILT (ML), wet, non-plastic to low plasticity, cohesive, bedded, few clay, trace fine sand, trace shell material	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0									
3.5					End of boring at 3.3 ft.				
4.0									

Coring Comments: Impoundment; Poling=Moderate

Logging Comments: 0.0-0.5 ft-SEKR0550C701S072612D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0550C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12937569.2 **Y:** 279958.2	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 5.5	**Target Depth (ft):** 4
Date/Time Core Collected: 8/7/2012 16:00	**Water Depth (ft):** +3.8	**Core Diameter (in):** 2.75
Date Core Logged: 11/29/2012		**Field Recovery:** 1.9 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0550C702S 112912DX	OL	Black (10YR 2/1) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, bedded, few roots/organics	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0550C702S 112912D006						
1.0			SEKR0550C702S 112912D011						
1.5			SEKR0550C702S 112912D015						
2.0			SEKR0550C702S 112912D019						
2.5					End of boring at 2.2 ft.				
3.0									
3.5									
4.0									

Coring Comments: Impoundment; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No		**Location ID:** SEKR0550C703
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12937996.1 **Y:** 279703.	**Boring Contractor:** AECOM	**Number of Attempts:** 2	
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 5.5	**Target Depth (ft):** 4	
Date/Time Core Collected: 8/8/2012 09:30	**Water Depth (ft):** +1.7	**Core Diameter (in):** 2.75	
Date Core Logged: 11/27/2012		**Field Recovery:** 2.2 ft	
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0550C703S 112712DX	OH	Very dark grayish brown (10YR 3/2) ORGANIC SILT (OH), wet, non-plastic, non-cohesive, thickly bedded, trace fine sand, some plant/root material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0550C703S 112712D006						
1.0			SEKR0550C703S 112712D011						
1.5			SEKR0550C703S 112712D016						
2.0			SEKR0550C703S 112712D019						
			SEKR0550C703S 112712D022						
2.5									
3.0									
3.5									
					End of boring at 3.8 ft.				
4.0									

Coring Comments: Impoundment; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 11/28/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR0550C704
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12938000.9 **Y:** 279708.3	**Boring Contractor:** AECOM	**Number of Attempts:** 1
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 5.5	**Target Depth (ft):** 4
Date/Time Core Collected: 8/8/2012 09:35	**Water Depth (ft):** 1.7	**Core Diameter (in):** 2.75
Date Core Logged: 11/28/2012		**Field Recovery:** 2 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0550C704S 112812DX	OL	Black (10YR 2/1) ORGANIC SOIL (OL), wet, low plasticity, cohesive, thickly bedded, little plant material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0550C704S 112812D006	OL	UV flourescence of 2mm flecks at 0.4 ft	No sheen or oil	0	Trace Fluorescence	<1
1.0			SEKR0550C704S 112812D011	OL	Same as above	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR0550C704S 112812D016	OL	UV flourescence of 2mm flecks at 1.5 ft	No sheen or oil	0	Trace Fluorescence	<1
2.0			SEKR0550C704S 112812D020	OL	Same as above	No sheen or oil	0	No oil fluorescence	0
2.5									
3.0									
3.5									
4.0					End of boring at 3.8 ft.				

Coring Comments: Impoundment; Poling=Moderate

Logging Comments: Sheen noted in tray water 1x 2mm x 1cm

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0550C705
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12937609.8 **Y:** 280231.2	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 5.5	**Target Depth (ft):** 4
Date/Time Core Collected: 8/8/2012 10:15	**Water Depth (ft):** +1.0	**Core Diameter (in):** 2.75
Date Core Logged: 11/27/2012		**Field Recovery:** 3.1 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0550C705S 112712DX	PT	Very dark brown (10YR 2/2) PEAT (PT), wet, non-plastic, non-cohesive, thickly bedded	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0550C705S 112712D006						
1.0			SEKR0550C705S 112712D011						
1.5			SEKR0550C705S 112712D016						
2.0			SEKR0550C705S 112712D020						
2.5			SEKR0550C705S 112712D025						
3.0			SEKR0550C705S 112712D028	ML	Very pale brown (10YR 7/4) SILT (ML), wet, non-plastic to low plasticity, cohesive, bedded, trace sand, few organics	No sheen or oil	0	No oil fluorescence	0
3.5			SEKR0550C705S 112712D031						
4.0					End of boring at 3.8 ft.				

Coring Comments: Impoundment; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 11/28/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0575C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12935922.6 **Y:** 280934.	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 5.75	**Target Depth (ft):** 4
Date/Time Core Collected: 7/25/2012 09:35	**Water Depth (ft):** +1.1	**Core Diameter (in):** 2.75
Date Core Logged: 7/26/2012		**Field Recovery:** 1.9 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0575C701S 072612DX	ML	Very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, cohesive, thickly bedded, trace clay, trace organics, trace woody debris slight odor from 1.2 to 1.9 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0575C701S 072612D007						
1.0			SEKR0575C701S 072612D013						
1.5			SEKR0575C701S 072612D019						
2.0									
2.5									
3.0									
3.5									
					End of boring at 3.8 ft.				
4.0									

Coring Comments: Impoundment
Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0575C702	
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12936874.4 **Y:** 280652.4	**Boring Contractor:** AECOM	**Number of Attempts:** 3	
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 5.75	**Target Depth (ft):** 4	
Date/Time Core Collected: 8/7/2012 15:22	**Water Depth (ft):** +0.4	**Core Diameter (in):** 2.75	
Date Core Logged: 11/27/2012		**Field Recovery:** 2.8 ft	
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0575C702S 112712DX	ML	Black (10YR 2/1) SILT WITH SAND (ML), wet, non-plastic, non-cohesive, thickly bedded, fine sand, some organics, trace plant/root material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0575C702S 112712D006						
			SEKR0575C702S 112712D011						
1.0									
			SEKR0575C702S 112712D016						
1.5									
			SEKR0575C702S 112712D020						
2.0			SEKR0575C702S 112712D023	OH	Very dark grayish brown (10YR 3/2) ORGANIC SILT (OH), wet, non-plastic, non-cohesive, bedded, trace fine sand, trace to few shell material	No sheen or oil	0	No oil fluorescence	0
			SEKR0575C702S 112712D027						
2.5			SEKR0575C702S 112712D028	OL	Black (10YR 2/1) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, bedded, some plant/root material, trace woody debris	No sheen or oil	0	No oil fluorescence	0
3.0									
3.5									
					End of boring at 3.8 ft.				
4.0									

Coring Comments: Impoundment; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR0575C702S080712D005-Bulk Density

Checked By: JTC **Date:** 11/28/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR0900C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12923118.9 **Y:** 286832.8	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 9	**Target Depth (ft):**	4
Date/Time Core Collected: 8/6/2012 10:57	**Water Depth (ft):** +0.7	**Core Diameter (in):**	2.75
Date Core Logged: 11/29/2012		**Field Recovery:**	1.6 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0900C701S 112912DX	ML	Very dark grayish brown (10YR 3/2) SILT WITH SAND (ML), wet, non-plastic, non-cohesive, bedded, fine sand, some organics	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0900C701S 112912D006	GW	Very pale brown (10YR 8/2) with light gray (10YR 7/1) to very dark gray (10YR 3/1) with very pale brown (10YR 8/2) WELL GRADED GRAVEL WITH SAND (GW), wet, non-plastic, non-cohesive, thickly bedded, fine to coarse sand, trace silt, trace shell material trace organics from 1.5 to 1.6 ft	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR0900C701S 112912D011						
1.5			SEKR0900C701S 112912D016						
2.0					End of boring at 1.9 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Depositional Bar; Poling=Light

Logging Comments: Sample from 0.0 to 0.15 ft obtained due to only 2" of soil in top depositional layer

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR0900C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12922844.9 **Y:** 287338.	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 9	**Target Depth (ft):** 4
Date/Time Core Collected: 8/6/2012 13:40	**Water Depth (ft):** +0.1	**Core Diameter (in):** 2.75
Date Core Logged: 11/27/2012		**Field Recovery:** 2.4 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR0900C702S 112712DX	OH	Very dark grayish brown (10YR 3/2) ORGANIC SILT (OH), wet, non-plastic, non-cohesive, thickly bedded, trace fine sand, trace fine gravel, some plant/root material, trace to few woody debris, trace shell material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR0900C702S 112712D006						
			SEKR0900C702S 112712D011						
1.0			SEKR0900C702S 112712D014						
1.5			SEKR0900C702S 112712D017						
			SEKR0900C702S 112712D019	GW	Very pale brown (10YR 8/2) with gray (10YR 6/1) WELL GRADED GRAVEL WITH SAND (GW), wet, non-plastic, non-cohesive, bedded, fine to coarse sand, trace shell material	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0									
					End of boring at 3.2 ft.				
3.5									
4.0									

Coring Comments: Cutoff/Oxbow; Poling=Light

Logging Comments:

Checked By: JTC **Date:** 11/28/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR1050C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12917146.1 **Y:** 291323.5	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 10.5	**Target Depth (ft):** 4
Date/Time Core Collected: 7/24/2012 18:08	**Water Depth (ft):** NA	**Core Diameter (in):** 2.75
Date Core Logged: 7/25/2012		**Field Recovery:** 0.9 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0									
	Push 1		SEKR1050C701S 072512DX / SEKR1050C701S 072512D003	ML	Black (10YR 2/1) with very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, trace to few fine sand, trace fine gravel, trace organics	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR1050C701S 072512D007	SM	Black (10YR 2/1) SILTY SAND WITH GRAVEL (SM), wet, non-plastic, non-cohesive, bedded, fine to coarse sand, fine to coarse gravel, trace organics, trace woody debris 1/8" wide woody debris chunk at 0.55 ft	No sheen or oil	0	No oil fluorescence	0
1.0					End of boring at 1.1 ft.				
1.5									
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Backwater; No poling

Logging Comments:

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR1075C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12917048.5 **Y:** 291885.8	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 10.75	**Target Depth (ft):** 4
Date/Time Core Collected: 8/6/2012 08:40	**Water Depth (ft):** +0.6	**Core Diameter (in):** 2.75
Date Core Logged: 11/28/2012		**Field Recovery:** 2.2 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1075C701S 112812DX	OH	Black (10YR 2/1) ORGANIC SILT (OH), wet, non-plastic, non-cohesive, bedded, trace fine gravel, trace fine sand, trace plant/root material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR1075C701S 112812D005	SW	Dark gray (10YR 4/1) with very pale brown (10YR 8/2) WELL GRADED SAND WITH GRAVEL (SW), wet, non-plastic, non-cohesive, bedded, fine to coarse gravel, trace silt	No sheen or oil	0	No oil fluorescence	0
			SEKR1075C701S 112812D009	OH	Very dark gray (10YR 3/1) ORGANIC SILT (OH), wet, non-plastic, non-cohesive, bedded, trace fine sand, trace plant/root material UV Fluorescence- approx. 8 pinhead globules, possible trace of sheen on water in soil from 0.5 to 0.9 ft	No sheen or oil	0	Trace Fluorescence	3
1.0			SEKR1075C701S 112812D014	SW	Gray (10YR 5/1) with very pale brown (10YR 8/2) to dark gray (10YR 4/1) and very dark gray (10YR 3/1) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, thickly bedded, trace fine gravel, trace silt, trace shell material organic silt layer from 1.3 to 1.35 ft	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR1075C701S 112812D019						
2.0									
2.5									
					End of boring at 2.6 ft.				
3.0									
3.5									
4.0									

Coring Comments: Depositional Bar; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR1075C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12916628.1 **Y:** 292667.8	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 10.75	**Target Depth (ft):** 4
Date/Time Core Collected: 8/6/2012 14:40	**Water Depth (ft):** +0.7	**Core Diameter (in):** 2.75
Date Core Logged: 11/30/2012		**Field Recovery:** 0.7 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1075C702S 113012DX SEKR1075C702S 113012D006	ML	Very dark grayish brown (10YR 3/2) SANDY SILT (ML), wet, non-plastic, non-cohesive, bedded, fine sand, some organics, few plant/root material UV Fluorescence is 1.2mm globules (multiple) throughout the soil from 0.0 to 0.6 ft	No sheen or oil	0	Fluoresced Globules	20
0.5									
1.0					End of boring at 0.9 ft.				
1.5									
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Depositional Bar; Poling=Heavy
Sheen in area. The first core had globules on water surface inside the core. Globules ranged in size from BB to Quarter.

Logging Comments: 2" thick layer of smeared oil on inside of tube which is 0.6ft above top of soil

Checked By: JTC **Date:** 12/1/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR1100C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12916123.1 **Y:** 293078.3	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 11	**Target Depth (ft):**	4
Date/Time Core Collected: 8/6/2012 10:01	**Water Depth (ft):** +0.7	**Core Diameter (in):**	2.75
Date Core Logged: 11/29/2012		**Field Recovery:**	1.3 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1100C701S 112912DX SEKR1100C701S 112912D005	SM	Very dark grayish brown (10YR 3/2) to very dark gray (10YR 3/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine sand, few organics, trace plant/root material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR1100C701S 112912D009 SEKR1100C701S 112912D013	GW	Grayish brown (10YR 5/2) to very dark gray (10YR 3/1) WELL GRADED GRAVEL WITH SAND (GW), wet, non-plastic, non-cohesive, bedded, fine to coarse sand, trace shell material	No sheen or oil	0	No oil fluorescence	0
1.0									
1.5					End of boring at 1.5 ft.				
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Depositional Bar; Poling=Heavy

Logging Comments: 0.0-0.5 ft-SEKR1100C701S080612D005-Bulk Density

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR1200C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12913816.9 **Y:** 295073.9	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 12	**Target Depth (ft):** 4
Date/Time Core Collected: 7/24/2012 17:18	**Water Depth (ft):** +0.05	**Core Diameter (in):** 2.75
Date Core Logged: 7/25/2012		**Field Recovery:** 1.6 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1200C701S 072512DX	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, thickly bedded, few fine sand, few organics, material very sloppy/loose	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR1200C701S 072512D006						
1.0			SEKR1200C701S 072512D011						
1.5			SEKR1200C701S 072512D016	SW	Dark gray (10YR 4/1) WELL GRADED WITH GRAVEL (SW), wet, non-plastic, non-cohesive, bedded, few coarse gravel	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
					End of boring at 2.6 ft.				
3.0									
3.5									
4.0									

Coring Comments: Backwater; No poling

Logging Comments:

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR1425C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12905653.3 **Y:** 292314.3	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 14.25	**Target Depth (ft):**	4
Date/Time Core Collected: 8/7/2012 08:30	**Water Depth (ft):** +2.7	**Core Diameter (in):**	2.75
Date Core Logged: 11/30/2012		**Field Recovery:**	1.8 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1425C701S 113012DX	ML	Very dark brown (10YR 2/2) SANDY SILT (ML), wet, non-plastic, non-cohesive, bedded, fine sand, few organics, trace plant/root material	No sheen or oil	0	No oil fluorescence	0
			SEKR1425C701S 113012D004	SP	Pale brown (10YR 6/3) with dark grayish brown (10YR 5/2) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine to medium sand, trace coarse sand, trace silt	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR1425C701S 113012D010	ML	Dark gray (10YR 4/1) to very dark gray (10YR 3/1) SANDY SILT (ML), wet, non-plastic, non-cohesive, bedded, fine sand, little organics, few plant/root material	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR1425C701S 113012D013	SW	Very pale brown (10YR 7/4) and gray (10YR 5/1) and yellowish brown (10YR 5/8) WELL GRADED SAND WITH GRAVEL (SW), wet, non-plastic, non-cohesive, bedded, fine to coarse gravel	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR1425C701S 113012D016						
			SEKR1425C701S 113012D018	SP	Pale brown (10YR 6/3) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine to medium sand, trace coarse sand	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0					End of boring at 3 ft.				
3.5									
4.0									

Coring Comments: Cutoff/Oxbow; Poling=Moderate

Logging Comments: 0.0 to 0.15 ft sample selected due to the small size of the depositional layer

Checked By: JTC **Date:** 12/1/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR1475C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12903038.8 **Y:** 293575.	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 14.75	**Target Depth (ft):** 4
Date/Time Core Collected: 7/25/2012 13:35	**Water Depth (ft):** +1.0	**Core Diameter (in):** 2.75
Date Core Logged: 7/26/2012		**Field Recovery:** 2.4 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1475C701S 072612DX	ML	Dark grayish brown (10YR 4/2) to very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, trace to few organics, trace woody debris grades with trace fine sand at 0.9 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR1475C701S 072612D006						
1.0			SEKR1475C701S 072612D011						
			SEKR1475C701S 072612D014	SP-SM	Gray (10YR 6/1) POORLY GRADED SAND WITH SILT (SP-SM), wet, non-plastic, non-cohesive, bedded, fine sand	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR1475C701S 072612D019	SP	Gray (10YR 5/1) and black (10YR 2/1) to very dark gray (10YR 3/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, thickly bedded, fine to medium sand, few coarse sand, trace fine gravel, trace silt, trace shell material few silt from 1.7 to 1.9 ft	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR1475C701S 072612D024						
2.5									
3.0									
					End of boring at 3.3 ft.				
3.5									
4.0									

Coring Comments: Channel Deposit; Poling=Moderate

Logging Comments: 0.0-0.5 ft-SEKR1475C701S072612D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR1475C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12903238.5 **Y:** 293574.3	**Boring Contractor:** AECOM	**Number of Attempts:** 1
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 14.75	**Target Depth (ft):** 4
Date/Time Core Collected: 7/25/2012 14:10	**Water Depth (ft):** 0	**Core Diameter (in):** 2.75
Date Core Logged: 7/26/2012		**Field Recovery:** 2 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1475C702S 072612DX	CL	Dark grayish brown (10YR 4/2) LEAN CLAY (CL), wet, moderate plasticity, cohesive, bedded, little silt, trace fine sand, trace organics surface grass with roots	No sheen or oil	0	No oil fluorescence	0
			SEKR1475C702S 072612D004						
0.5			SEKR1475C702S 072612D007						
			SEKR1475C702S 072612D009	ML	Black (10YR 2/1) and very dark gray (10YR 3/1) SILT WITH SAND (ML), wet, non-plastic, non-cohesive, bedded, fine sand, trace organics	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR1475C702S 072612D013	ML	Very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, cohesive, bedded, trace fine sand, trace fine gravel, trace clay, trace organics, trace shell material	No sheen or oil	0	No oil fluorescence	0
			SEKR1475C702S 072612D015	SP	Dark gray (10YR 4/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, trace silt, trace shell material	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR1475C702S 072612D019	SM	Very dark gray (10YR 3/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine sand, trace shell material	No sheen or oil	0	No oil fluorescence	0
			SEKR1475C702S 072612D020	SW-SM	Very dark gray (10YR 3/1) WELL GRADED SAND WITH SILT (SW-SM), wet, non-plastic, non-cohesive, bedded, few silt, trace fine to coarse gravel, trace shell material	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0									
3.5									
					End of boring at 3.7 ft.				
4.0									

Coring Comments:

Logging Comments: Cutoff/Oxbow
Poling=No poling done

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:**	SEKR1500C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12902582.4 **Y:** 294295.6	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 15	**Target Depth (ft):**	4
Date/Time Core Collected: 7/25/2012 17:00	**Water Depth (ft):** +0.6	**Core Diameter (in):**	2.75
Date Core Logged: 7/26/2012		**Field Recovery:**	2.8 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1500C701S 072612DX	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, thickly bedded, few sand, few organics	No sheen or oil	0	No oil fluorescence	0
			SEKR1500C701S 072612D003	ML	Same as above	No sheen or oil	0	Trace Fluorescence	5
0.5			SEKR1500C701S 072612D006						
			SEKR1500C701S 072612D009						
1.0			SEKR1500C701S 072612D013	ML	Same as above	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR1500C701S 072612D019	SW	Black (10YR 2/1) to gray (10YR 5/1) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, trace fine grasvel, trace shells	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR1500C701S 072612D024						
2.5			SEKR1500C701S 072612D028	SW-SM	Black (10YR 2/1) WELL GRADED SAND WITH SILT (SW-SM), wet, non-plastic, non-cohesive, bedded, few fine to coarse gravel	No sheen or oil	0	No oil fluorescence	0
3.0					End of boring at 3.2 ft.				
3.5									
4.0									

Coring Comments: Channel Deposit: Poling=Moderate
SEKR1500C701S072612PX= 1 (3/16") globule collect at 1.4 ft from Core 2

Logging Comments: 0.1-0.3 ft-SEKR1500C701S072612D003-E; 0.3-0.4 ft-SEKR1500C701S072612D004-E
0.4-0.6 ft-SEKR1500C701S072612D006-E; 0.6-0.7 ft-SEKR1500C701S072612D007-E
0.7-0.9 ft-SEKR1500C701S072612D009-E; 0.9-1.1 ft-SEKR1500C701S072612D011-E

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:**	SEKR1550C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12901298.7 **Y:** 296118.	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 15.5	**Target Depth (ft):**	4
Date/Time Core Collected: 8/7/2012 09:45	**Water Depth (ft):** +0.3	**Core Diameter (in):**	2.75
Date Core Logged: 11/28/2012		**Field Recovery:**	2.6 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1550C701S 112812DX	OL	Black (10YR 2/1) to very dark brown (10YR 2/2) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, thickly bedded, few roots, trace shells Five 2mm globules under UV light from 0.0 to 0.65ft few fine sand from 0.65 to 1.6 ft	No sheen or oil	0	Trace Fluorescence	<2
0.5			SEKR1550C701S 112812D006						
1.0			SEKR1550C701S 112812D011	OL	Same as above	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR1550C701S 112812D016						
2.0			SEKR1550C701S 112812D021						
2.5			SEKR1550C701S 112812D026						
3.0									
3.5									
4.0									

End of boring at 4 ft.

Coring Comments: Impoundment; Poling=Moderate

Logging Comments: Two 1mm globules noted in tray under UV light
0.0-0.67 ft-SEKR1550C701S080712D007-Bulk Density

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:**	SEKR1575C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12901987.6 **Y:** 296720.7	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 15.75	**Target Depth (ft):**	4
Date/Time Core Collected: 7/25/2012 15:20	**Water Depth (ft):** +0.1	**Core Diameter (in):**	2.75
Date Core Logged: 7/26/2012		**Field Recovery:**	1.9 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1575C701S 072612DX	ML	Very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, non-cohesive to cohesive, thickly bedded, trace fine sand, little organics	No sheen or oil	0	Trace Fluorescence	2
0.5			SEKR1575C701S 072612D007						
1.0			SEKR1575C701S 072612D013						
1.5			SEKR1575C701S 072612D019						
2.0				ML	Same as above	No sheen or oil	0	No oil fluorescence	0
2.5									
3.0									
3.5									
4.0					End of boring at 3.8 ft.				

Coring Comments: Impoundment; Poling=Heavy
SEKR1575C701S072612PX-Globule sample collected

Logging Comments: 0.08-0.2 ft-SEKR1575C701S072612D002-E
0.0-0.5 ft-SEKR1575C701S072612D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR1575C702	
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12901938. **Y:** 296597.5	**Boring Contractor:** AECOM	**Number of Attempts:** 2	
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 15.75	**Target Depth (ft):** 4	
Date/Time Core Collected: 7/25/2012 16:20	**Water Depth (ft):** +0.1	**Core Diameter (in):** 2.75	
Date Core Logged: 7/26/2012		**Field Recovery:** 1.9 ft	
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1575C702S 072612DX	OL	Black (10YR 2/1) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, bedded, few silt, some organics	No sheen or oil	0	No oil fluorescence	0
			SEKR1575C702S 072612D005						
0.5			SEKR1575C702S 072612D010						
1.0			SEKR1575C702S 072612D015	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, cohesive, bedded, few clay, trace sand, little organics	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR1575C702S 072612D019						
2.0									
2.5									
3.0									
3.5									
					End of boring at 3.8 ft.				
4.0									

Coring Comments: Impoundment; Poling=Heavy
SEKR1575C702S072612PX- 6 (1/16") globules collected down to 1 inch from Core 2

Logging Comments: 0.1-0.2 ft-SEKR1575C702S072612D002-E

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR1575C703
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12901893.1 **Y:** 297067.7	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 15.75	**Target Depth (ft):**	4
Date/Time Core Collected: 8/7/2012 12:40	**Water Depth (ft):** +5.8	**Core Diameter (in):**	2.75
Date Core Logged: 11/28/2012		**Field Recovery:**	2.2 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1575C703S 112812DX	SP	Yellowish brown (10YR 5/4) to grayish brown (10YR 5/2) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, thickly bedded, fine to medium sand, trace coarse sand, trace silt, trace shell material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR1575C703S 112812D006						
1.0			SEKR1575C703S 112812D012						
1.5			SEKR1575C703S 112812D017	OH	Black (10YR 2/1) to very dark gray (10YR 3/1) ORGANIC SILT (OH), wet, non-plastic, cohesive, thickly bedded, trace fine sand, trace plant/root material, trace shell material	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR1575C703S 112812D022						
2.5					End of boring at 2.4 ft.				
3.0									
3.5									
4.0									

Coring Comments: Impoundment; Poling=None

Logging Comments:

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR1850C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12891044.7 **Y:** 306003.7	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 18.5	**Target Depth (ft):**	4
Date/Time Core Collected: 7/23/2012 13:50	**Water Depth (ft):** +1.8	**Core Diameter (in):**	2.75
Date Core Logged: 7/24/2012		**Field Recovery:**	2.7 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1850C701S 072412DX / SEKR1850C701S 072412D003	SW	Grayish brown (10YR 5/2) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, trace fine gravel	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR1850C701S 072412D008	SP	Dark gray (10YR 4/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, trace fine gravel	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR1850C701S 072412D015	SP	Very dark gray (10YR 3/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, thinly bedded, trace shells	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR1850C701S 072412D020	SP	Pale brown (10YR 6/3) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, thickly bedded, trace fine gravel	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR1850C701S 072412D027						
2.5									
3.0									
3.5					End of boring at 3.4 ft.				
4.0									

Coring Comments: Anthropogenic Channel; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR1850C701S072412D005-Bulk Density

Checked By: JTC **Date:** 7/25/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR1875C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12890439.4 **Y:** 306066.8	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 18.75	**Target Depth (ft):** 4
Date/Time Core Collected: 7/24/2012 10:53	**Water Depth (ft):** +2.2	**Core Diameter (in):** 2.75
Date Core Logged: 7/25/2012		**Field Recovery:** 1.7 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1875C701S 072512DX / SEKR1875C701S 072512D003	SW	Grayish brown (10YR 5/2) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, few fine to coarse gravel	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR1875C701S 072512D008	SM	Dark gray (10YR 4/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine to medium sand, few fine to coarse gravel	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR1875C701S 072512D010	SW-SM	Gray (10YR 6/1) WELL GRADED SAND WITH SILT AND GRAVEL (SW-SM), wet, non-plastic, non-cohesive, bedded, fine to coarse gravel, few silt	No sheen or oil	0	No oil fluorescence	0
			SEKR1875C701S 072512D014	SP	Light gray (10YR 7/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR1875C701S 072512D016	SW	Light gray (10YR 7/1) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, trace fine to coarse gravel	No sheen or oil	0	No oil fluorescence	0
2.0					End of boring at 1.9 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments:

Logging Comments: Anthropogenic depositional
Poling=None

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR1900C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12888444.1 **Y:** 306851.8	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 19	**Target Depth (ft):**	4
Date/Time Core Collected: 7/24/2012 09:54	**Water Depth (ft):** +1.8	**Core Diameter (in):**	2.75
Date Core Logged: 7/25/2012		**Field Recovery:**	1.9 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1900C701S 072512DX	SP	Light yellowish brown (10YR 6/4) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine to medium sand, few coarse sand, trace fine gravel thin black (10YR 2/1) organic layer at surface (0.01 ft thick) fine to coarse sand layer at 0.85 to 0.90 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR1900C701S 072512D005						
			SEKR1900C701S 072512D009						
1.0			SEKR1900C701S 072512D012	SM	Dark gray (10YR 4/1) to gray (10YR 6/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine sand, trace fine gravel	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR1900C701S 072512D017	SP-SM	Light brownish gray (10YR 6/2) POORLY GRADED SAND WITH SILT (SP-SM), wet, non-plastic, non-cohesive, bedded, fine sand, little medium sand, trace coarse sand, few silt, trace fine to coarse gravel dark gray (10YR 4/1) silt nodules from 1.4 to 1.7 ft	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5					End of boring at 2.5 ft.				
3.0									
3.5									
4.0									

Coring Comments: Anthropogenic deposition; Poling=None

Logging Comments: 0.0-0.5 ft-SEKR1900C701S072512D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR1950C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12886558.7 **Y:** 308439.3	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 19.5	**Target Depth (ft):** 4
Date/Time Core Collected: 7/23/2012 14:25	**Water Depth (ft):** +0.2	**Core Diameter (in):** 2.75
Date Core Logged: 7/24/2012		**Field Recovery:** 0.9 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR1950C701S 072412DX	OL	Black (10YR 2/1) to very dark gray (10YR 3/1) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, bedded, trace to few fine to medium sand, trace fine to coarse gravel, some plant/root material, trace woody debris	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR1950C701S 072412D006						
			SEKR1950C701S 072412D008	GW	Grayish brown (10YR 5/2) WELL GRADED GRAVEL WITH SAND (GW), wet, non-plastic, non-cohesive, bedded, fine to coarse sand, trace shell material	No sheen or oil	0	No oil fluorescence	0
1.0									
					End of boring at 1.2 ft.				
1.5									
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Anthropogenic Channel; Poling=Light

Logging Comments:

Checked By: JTC **Date:** 7/25/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2000C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12883948.1 **Y:** 309191.4	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 20	**Target Depth (ft):** 4
Date/Time Core Collected: 7/23/2012 17:00	**Water Depth (ft):** +0.1	**Core Diameter (in):** 2.75
Date Core Logged: 7/24/2012		**Field Recovery:** 2.8 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2000C701S 072412DX	OL	Black (10YR 2/1) to very dark gray (10YR 3/1) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, thickly bedded, few fine to medium sand, trace fine gravel, few to little plant/root material, trace shell fragments, trace woody debris grades with little fine to medium sand at 1.0 ft	No sheen or oil	0	No oil fluorescence	0
			SEKR2000C701S 072412D005						
0.5			SEKR2000C701S 072412D010						
1.0			SEKR2000C701S 072412D014						
1.5			SEKR2000C701S 072412D016	SP	Gray (10YR 6/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, trace fine gravel	No sheen or oil	0	No oil fluorescence	0
			SEKR2000C701S 072412D020	ML	Dark gray (10YR 4/1) SILT (ML), wet, non-plastic, cohesive, bedded, trace fine sand, trace fine gravel, trace clay slight petroleum odor	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR2000C701S 072412D023						
2.5			SEKR2000C701S 072412D028	SW	Grayish brown (10YR 5/2) WELL GRADED SAND WITH GRAVEL (SW), wet, non-plastic, non-cohesive, bedded, fine to coarse gravel	No sheen or oil	0	No oil fluorescence	0
3.0									
3.5									
					End of boring at 3.6 ft.				
4.0									

Coring Comments: Anthropogenic Channel; Poling=Moderate

Logging Comments: 0.0-0.5 ft-SEKR2000C701S072412D005-Bulk Density

Checked By: JTC **Date:** 7/25/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2000C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12884614.4 **Y:** 308994.3	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 20	**Target Depth (ft):** 4
Date/Time Core Collected: 7/24/2012 10:25	**Water Depth (ft):** +1.0	**Core Diameter (in):** 2.75
Date Core Logged: 7/25/2012		**Field Recovery:** 1.7 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2000C702S 072512DX SEKR2000C702S 072512D002	ML	Very dark brown (10YR 2/2) SILT (ML), wet, non-plastic, non-cohesive, bedded, few fine sand, little organics	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2000C702S 072512D006 SEKR2000C702S 072512D011	SW	Dark gray (10YR 4/1) WELL GRADED SAND WITH GRAVEL (SW), wet, non-plastic, non-cohesive, thickly bedded, fine to coarse gravel	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR2000C702S 072512D013						
1.5				SW	Yellowish brown (10YR 5/4) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, few fine gravel	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5					End of boring at 2.1 ft.				
3.0									
3.5									
4.0									

Coring Comments:

Logging Comments: Anthropogenic deposition
Poling=Heavy

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR2025C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12883115.4 **Y:** 309266.5	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 20.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/23/2012 10:45	**Water Depth (ft):** +1.1	**Core Diameter (in):** 2.75
Date Core Logged: 7/24/2012		**Field Recovery:** 0.7 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2025C701S 072412DX	OL	Black (10YR 2/1) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, bedded, few to little fine to medium sand, trace fine gravel, little plant/root material	No sheen or oil	0	Trace Fluorescence	5
0.5			SEKR2025C701S 072412D007	OL	grades with some pale brown (10YR 6/3) fine to medium sand and few fine to coarse gravel with trace shell material at 0.6 ft Same as above	No sheen or oil	0	No oil fluorescence	0
1.0									
1.5									
2.0					End of boring at 1.7 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Anthropogenic Deposit; Poling=Heavy

Logging Comments: 0.17-0.3 ft= SEKR2025C701S072412D003-E

Checked By: JTC **Date:** 7/25/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2025C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12882683.9 **Y:** 309319.7	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 20.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/23/2012 12:00	**Water Depth (ft):** +1.4	**Core Diameter (in):** 2.75
Date Core Logged: 7/24/2012		**Field Recovery:** 2 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2025C702S 072412DX SEKR2025C702S 072412D005	ML	Very dark brown (10YR 2/2) SANDY SILT (ML), wet, non-plastic, non-cohesive, bedded, some fine sand	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2025C702S 072412D007	SW	Dark gray (10YR 4/1) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, trace gravel	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR2025C702S 072412D011	SP	Gray (10YR 5/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR2025C702S 072412D017	SW	Brown (10YR 5/3) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, few fine to coarse gravel, trace wood	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR2025C702S 072412D020						
2.5				SP	Yellowish brown (10YR 5/4) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded	No sheen or oil	0	No oil fluorescence	0
3.0									
3.5					End of boring at 3.4 ft.				
4.0									

Coring Comments: Anthropogenic Deposit; Poling=Heavy

Logging Comments: 0.0-0.5 ft-SEKR2025C702S072412D005-Bulk Density

Checked By: JTC **Date:** 7/25/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2025C703
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12883404.1 **Y:** 309166.9	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 20.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/23/2012 16:00	**Water Depth (ft):** +0.8	**Core Diameter (in):** 2.75
Date Core Logged: 7/24/2012		**Field Recovery:** 0.7 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0									
	Push 1		SEKR2025C703S 072412DX SEKR2025C703S 072412D004	OL	Very dark gray (10YR 3/1) GRAVELLY ORGANIC SOIL WITH SAND (OL), wet, non-plastic, non-cohesive, few plant material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2025C703S 072412D007	CH	Gray (10YR 5/1) FAT CLAY (CH), wet, high plasticity, cohesive, bedded	No sheen or oil	0	No oil fluorescence	0
					End of boring at 0.8 ft.				
1.0									
1.5									
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Anthropogenic Channel
Poling=Light

Logging Comments:

Checked By: JTC **Date:** 7/25/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2125C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12877702.1 **Y:** 311752.2	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 21.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/23/2012 14:21	**Water Depth (ft):** +1.5	**Core Diameter (in):** 2.75
Date Core Logged: 7/24/2012		**Field Recovery:** 1.9 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2125C701S 072412DX	SM	Very dark gray (10YR 3/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, trace plant material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2125C701S 072412D006						
1.0			SEKR2125C701S 072412D010	SP	Gray (10YR 5/1) to brown (10YR 5/3) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, trace shells, trace plant material	No sheen or oil	0	No oil fluorescence	0
			SEKR2125C701S 072412D014						
1.5			SEKR2125C701S 072412D020	GW	Brown (10YR 5/1) WELL GRADED GRAVEL WITH SAND (GW), wet, non-plastic, non-cohesive, fine to coarse sand several coarse gravel in bottom of core, trace shells	No sheen or oil	0	No oil fluorescence	0
2.0					End of boring at 1.9 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Cutoff/Oxbow; Poling=Light

Logging Comments:

Checked By: JTC **Date:** 7/25/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR2150C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12876326.2 **Y:** 311708.2	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 21.5	**Target Depth (ft):** 4
Date/Time Core Collected: 7/24/2012 10:45	**Water Depth (ft):** +0.5	**Core Diameter (in):** 2.75
Date Core Logged: 7/25/2012		**Field Recovery:** 2.7 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2150C701S 072512DX	SM	Black (10YR 2/1) and gray (10YR 5/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine sand, trace medium sand, trace organics, trace shell material 1/8" thick organic layer at top; fluorescence due to several small globs at surface of core thin black (10YR 2/1) silt layers at 0.3, 0.5 and 0.7 ft	No sheen or oil	0	Fluoresced Globules	1
			SEKR2150C701S 072512D004	SM		No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2150C701S 072512D008		Same as above				
1.0			SEKR2150C701S 072512D012	SW	Gray (10YR 5/1) WELL GRADED SAND WITH GRAVEL (SW), wet, non-plastic, non-cohesive, bedded, fine to coarse gravel, trace shell material	No sheen or oil	0	No oil fluorescence	0
			SEKR2150C701S 072512D014	SP	Gray (10YR 5/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, trace shell material	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR2150C701S 072512D020	SW	Gray (10YR 6/1) WELL GRADED SAND WITH GRAVEL (SW), wet, non-plastic, non-cohesive, thickly bedded, fine to coarse gravel 1/8" black (10YR 2/1) organic layer at 1.4 ft small chunk of woody debris at 2.25 ft	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR2150C701S 072512D026						
2.5									
3.0									
3.5									
4.0					End of boring at 4 ft.				

Coring Comments: Channel Deposit; Poling=Light
SEKR2150C701S072512PX- globules collected from surface of core

Logging Comments: 0.08-0.2 ft-SEKR2150C701S072512D002-E

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2150C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12876744.2 **Y:** 311595.7	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 21.5	**Target Depth (ft):** 4
Date/Time Core Collected: 7/26/2012 13:35	**Water Depth (ft):** +3.9	**Core Diameter (in):** 2.75
Date Core Logged: 7/27/2012		**Field Recovery:** 1.9 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2150C702S 072712DX	GW	Gray (10YR 5/1) WELL GRADED GRAVEL WITH SAND (GW), wet, non-plastic, non-cohesive, bedded, little fine to coarse sand, trace shells, trace organic material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2150C702S 072712D005						
1.0			SEKR2150C702S 072712D010						
1.5			SEKR2150C702S 072712D015						
2.0			SEKR2150C702S 072712D021	SP-SM	Dark gray (10YR 4/1) POORLY GRADED SAND WITH SILT (SP-SM), wet, non-plastic, non-cohesive, bedded, fine sand, trace medium to coarse sand piece of wood at 1.5 ft	No sheen or oil	0	No oil fluorescence	0
2.5					End of boring at 2.6 ft.				
3.0									
3.5									
4.0									

Coring Comments: Channel Deposit; Poling=None

Logging Comments: 0.0-0.5 ft-SEKR2150C702S072712D005-Bulk Density

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR2150C703
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12877566.8 **Y:** 312062.8	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 21.5	**Target Depth (ft):** 4
Date/Time Core Collected: 7/26/2012 14:00	**Water Depth (ft):** +1.0	**Core Diameter (in):** 2.75
Date Core Logged: 7/27/2012		**Field Recovery:** 1 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2150C703S 072712DX SEKR2150C703S 072712D005	OL	Black (10YR 2/1) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, bedded, few silt, trace fine sand, some organics	No sheen or oil	0	Trace Fluorescence	<1
0.5			SEKR2150C703S 072712D010	SP	Dark grayish brown (10YR 4/2) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, trace fine gravel, trace coarse sand	No sheen or oil	0	No oil fluorescence	0
1.0									
1.5					End of boring at 1.4 ft.				
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Cutoff/Oxbow; Poling=Heavy
SEKR2150C703S072712PX- 1 (1/16") globule collect at 0.5 ft from Core 2

Logging Comments: 0.1-0.3 ft-SEKR2150C703S072712D003-E; 0.3-0.5 ft-SEKR2150C703S072712D005-E
0.5-0.7 ft-SEKR2150C703S072712D007-E

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:**	SEKR2150C704
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12877681.7 **Y:** 311701.	**Boring Contractor:** AECOM	**Number of Attempts:**	1
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 21.5	**Target Depth (ft):**	4
Date/Time Core Collected: 7/26/2012 14:50	**Water Depth (ft):** +2.3	**Core Diameter (in):**	2.75
Date Core Logged: 7/27/2012		**Field Recovery:**	1.3 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2150C704S 072712DX	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, trace sand, few organics	No sheen or oil	0	No oil fluorescence	0
			SEKR2150C704S 072712D003	SP	Dark gray (10YR 4/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand	No sheen or oil	0	No oil fluorescence	0
			SEKR2150C704S 072712D005	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, trace fine sand, some organics	No sheen or oil	0	No oil fluorescence	0
				ML	Same as above	No sheen or oil	0	Trace Fluorescence	<1
0.5			SEKR2150C704S 072712D010	ML	two small pinhead globules at 0.4 ft under UV Same as above	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR2150C704S 072712D013	SP	Dark gray (10YR 4/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, few fine to coarse gravel	No sheen or oil	0	No oil fluorescence	0
1.5					End of boring at 1.7 ft.				
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Cutoff/Oxbow; Poling=Heavy
0.35-0.45 ft-SEKR2150C704S072712D005-Bulk Density; SEKR2150C704S072712PX- 3 (1/16") globules collect from 0.1 to 0.3 ft from Core 2

Logging Comments: 0.1-0.2 ft-SEKR2150C704S072712D002; 0.2-0.3 ft-SEKR2150C704S072712D003
0.3-0.5 ft-SEKR2150C704S072712D005; 0.5-0.7 ft-SEKR2150C704S072712D007

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2150C705
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12876911.1 **Y:** 311691.9	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 21.5	**Target Depth (ft):** 4
Date/Time Core Collected: 8/6/2012 15:44	**Water Depth (ft):** +2.0	**Core Diameter (in):** 2.75
Date Core Logged: 11/29/2012		**Field Recovery:** 1.2 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2150C705S 112912DX	SM	Black (10YR 2/1) to very dark gray (10YR 3/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, thickly bedded, fine to medium sand, trace coarse sand, trace organics, trace shell material some organics with few plant/root material from 0.0 to 0.5 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2150C705S 112912D006						
1.0			SEKR2150C705S 112912D011						
1.5									
2.0					End of boring at 1.8 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Depositional Bar; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR2150C705S080612D005-Bulk Density

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:**	SEKR2175C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12876431. **Y:** 311291.9	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 21.75	**Target Depth (ft):**	4
Date/Time Core Collected: 7/26/2012 15:40	**Water Depth (ft):** +0.9	**Core Diameter (in):**	2.75
Date Core Logged: 7/27/2012		**Field Recovery:**	1.9 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2175C701S 072712DX	SM	Very dark gray (10YR 3/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine sand, trace organics	No sheen or oil	0	No oil fluorescence	0
			SEKR2175C701S 072712D002	SM	Same as above 2 small pinhead globules from 0.2 to 0.5 ft in UV	No sheen or oil	0	Trace Fluorescence	<1
			SEKR2175C701S 072712D005	SM	Very dark gray (10YR 3/1) SILTY SAND WITH GRAVEL (SM), wet, non-plastic, non-cohesive, bedded, little fine gravel, trace organics	No sheen or oil	0	Trace Fluorescence	<1
0.5			SEKR2175C701S 072712D006	SM	Same as above	No sheen or oil	0	No oil fluorescence	0
			SEKR2175C701S 072712D010	SW	Dark grayish brown (10YR 4/2) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, few fine gravel, trace silt	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR2175C701S 072712D014						
1.5			SEKR2175C701S 072712D017	SP	Brown (10YR 5/3) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, trace silt	No sheen or oil	0	No oil fluorescence	0
2.0					End of boring at 2.2 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Backwater; Poling=Moderate
SEKR2175C701S072712PX- 5 (1/16") globules collect from 0.0 to 0.3 ft from Core 2

Logging Comments: 0.1-0.2 ft- SEKR2175C701S072712D002-E; 0.2-0.4 ft- SEKR2175C701S072712D004-E
0.4-0.5 ft- SEKR2175C701S072712D005-E; 0.5-0.7 ft- SEKR2175C701S072712D007-E

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2175C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12876434.3 **Y:** 311378.1	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 21.75	**Target Depth (ft):** 4
Date/Time Core Collected: 8/6/2012 16:12	**Water Depth (ft):** NA	**Core Diameter (in):** 2.75
Date Core Logged: 11/29/2012		**Field Recovery:** 0.9 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2175C702S 112912DX	ML	Very dark gray (10YR 3/1) SILT WITH SAND (ML), moist to wet, non-plastic, bedded, fine sand, trace shells	No sheen or oil	0	No oil fluorescence	0
			SEKR2175C702S 112912D004						
0.5			SEKR2175C702S 112912D007						
			SEKR2175C702S 112912D009	SW	Dark grayish brown (10YR 4/2) WELL GRADED SAND WITH GRAVEL (SW), wet, non-plastic, non-cohesive, bedded, fine gravel, trace roots	No sheen or oil	0	No oil fluorescence	0
1.0					End of boring at 1.1 ft.				
1.5									
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Backwater; Poling=No Poling (Dry Location)

Logging Comments:

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2200C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12874336. **Y:** 313090.8	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 22	**Target Depth (ft):** 4
Date/Time Core Collected: 7/23/2012 13:33	**Water Depth (ft):** +0.4	**Core Diameter (in):** 2.75
Date Core Logged: 7/24/2012		**Field Recovery:** 3.6 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2200C701S 072412DX						
			SEKR2200C701S 072412D005	OL	Very dark gray (10YR 3/1) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, bedded, trace to few fine to medium sand, trace fine gravel, few plant/root material, trace woody debris	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2200C701S 072412D008						
1.0			SEKR2200C701S 072412D013	SP	Dark gray (10YR 4/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, thickly bedded, fine sand, trace fine gravel, few shell material black (10YR 2/1) sandy silt from 2.0 to 2.1 ft	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR2200C701S 072412D018						
2.0			SEKR2200C701S 072412D022						
			SEKR2200C701S 072412D026	SW	Dark gray (10YR 4/1) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, few fine to coarse gravel	No sheen or oil	0	No oil fluorescence	0
2.5			SEKR2200C701S 072412D028	SP	Gray (10YR 6/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand	No sheen or oil	0	No oil fluorescence	0
3.0			SEKR2200C701S 072412D034	GW	Gray (10YR 6/1) and dark gray (10YR 4/1) WELL GRADED GRAVEL WITH SAND (GW), wet, non-plastic, non-cohesive, bedded, fine to coarse sand, trace silt, trace woody debris 0.1 ft wide wood chunk at 3.2 ft	No sheen or oil	0	No oil fluorescence	0
3.5									
4.0									

Coring Comments: Cutoff/Oxbow; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 7/25/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2275C701	
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12873550.7 **Y:** 314441.4	**Boring Contractor:** AECOM	**Number of Attempts:** 2	
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 22.75	**Target Depth (ft):** 4	
Date/Time Core Collected: 7/24/2012 11:25	**Water Depth (ft):** +0.7	**Core Diameter (in):** 2.75	
Date Core Logged: 7/25/2012		**Field Recovery:** 2.2 ft	
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0									
	Push 1		SEKR2275C701S 072512DX	SM	Very dark gray (10YR 3/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine sand, trace organics	No sheen or oil	0	No oil fluorescence	0
			SEKR2275C701S 072512D002	SP	Gray (10YR 5/1) to light gray (10YR 7/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, thickly bedded, fine sand, trace silt, trace medium sand few very pale brown (10YR 7/3) medium sand from 0.2 to 0.35 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2275C701S 072512D007						
1.0			SEKR2275C701S 072512D012						
1.5			SEKR2275C701S 072512D017						
2.0			SEKR2275C701S 072512D022						
2.5					End of boring at 2.5 ft.				
3.0									
3.5									
4.0									

Coring Comments: Cutoff/Oxbow; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR2275C701S072512D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2300C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12873479.4 **Y:** 314459.6	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 23	**Target Depth (ft):** 4
Date/Time Core Collected: 8/7/2012 11:04	**Water Depth (ft):** +1.9	**Core Diameter (in):** 2.75
Date Core Logged: 11/30/2012		**Field Recovery:** 1.1 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2300C701S 113012DX / SEKR2300C701S 113012D003	ML	Very dark grayish brown (10YR 3/2) SANDY SILT (ML), wet, non-plastic, non-cohesive, bedded, fine sand, some organics, few plant/root material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2300C701S 113012D007	SW	Dark gray (10YR 4/1) with dark grayish brown (10YR 4/2) WELL GRADED SAND WITH GRAVEL (SW), wet, non-plastic, non-cohesive, bedded, fine to coarse gravel grades with trace silt at 0.9 ft	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR2300C701S 113012D011						
1.5									
2.0					End of boring at 1.9 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Cutoff/Oxbow; Poling=Heavy

Logging Comments:

Checked By: JTC **Date:** 12/1/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2400C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12870660.3 **Y:** 313522.5	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 24	**Target Depth (ft):** 4
Date/Time Core Collected: 7/24/2012 12:00	**Water Depth (ft):** 0	**Core Diameter (in):** 2.75
Date Core Logged: 7/25/2012		**Field Recovery:** 1.5 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2400C701S 072512DX	ML	Brown (10YR 5/3) SILT (ML), wet, non-plastic, non-cohesive, bedded, few fine sand	No sheen or oil	0	No oil fluorescence	0
			SEKR2400C701S 072512D004	SP	Yellowish brown (10YR 5/4) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, trace fine gravel, trace roots	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2400C701S 072512D008	SP	Very dark gray (10YR 3/1) to dark gray (10YR 4/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, few roots	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR2400C701S 072512D012						
			SEKR2400C701S 072512D015	SP	Grayish brown (10YR 5/2) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, trace fine gravel	No sheen or oil	0	No oil fluorescence	0
1.5									
					End of boring at 1.8 ft.				
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments:

Logging Comments: Depositional Bar
Poling= No poling occurred

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2475C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12869416. **Y:** 311422.2	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 24.75	**Target Depth (ft):** 4
Date/Time Core Collected: 7/24/2012 12:30	**Water Depth (ft):** 0	**Core Diameter (in):** 2.75
Date Core Logged: 7/25/2012		**Field Recovery:** 1 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2475C701S 072512DX	ML	Very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, trace fine sand, few organics some woody debris from 0.4 to 0.7 ft few fine sand from 0.6 to 0.7 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2475C701S 072512D004						
			SEKR2475C701S 072512D007						
1.0			SEKR2475C701S 072512D010	SP	Gray (10YR 5/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine to medium sand, few coarse sand, trace fine gravel, trace shell material	No sheen or oil	0	No oil fluorescence	0
					End of boring at 1.2 ft.				
1.5									
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Location on dry mud flat with sheen on surface

Logging Comments: Depositional Bar
Poling=No poling occurred

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2525C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12867418. **Y:** 310820.4	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 25.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/27/2012 14:07	**Water Depth (ft):** NA	**Core Diameter (in):** 2.75
Date Core Logged: 11/29/2012		**Field Recovery:** 1.2 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2525C701S 112912DX	ML	Very dark gray (10YR 3/1) SILT WITH SAND (ML), wet, non-plastic, non-cohesive, bedded, fine sand, few roots	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2525C701S 112912D006						
1.0			SEKR2525C701S 112912D012						
1.5									
2.0									
2.5									
3.0									
					End of boring at 3.1 ft.				
3.5									
4.0									

Coring Comments: Back Channel; Poling=No Poling (Dry Spot)

Logging Comments:

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2625C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12864805.5 **Y:** 311901.6	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 26.25	**Target Depth (ft):** 4
Date/Time Core Collected: 8/7/2012 13:19	**Water Depth (ft):** NA	**Core Diameter (in):** 2.75
Date Core Logged: 11/29/2012		**Field Recovery:** 1.1 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2625C701S 112912DX	ML	Very dark grayish brown (10YR 3/2) to very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, non-cohesive to cohesive, thickly bedded, trace fine sand, trace organics, trace organics, trace woody debris some organics, few woody debris from 0.0 to 0.6 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2625C701S 112912D006						
1.0			SEKR2625C701S 112912D011						
1.5									
2.0									
2.5					End of boring at 2.5 ft.				
3.0									
3.5									
4.0									

Coring Comments: Backwater Channel; Poling=No Poling (Dry Spot)

Logging Comments:

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2625C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12864806.9 **Y:** 311898.9	**Boring Contractor:** AECOM	**Number of Attempts:** 1
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 26.25	**Target Depth (ft):** 4
Date/Time Core Collected: 8/7/2012 13:27	**Water Depth (ft):** NA	**Core Diameter (in):** 2.75
Date Core Logged: 11/29/2012		**Field Recovery:** 1 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2625C702S 112912DX	ML	Very dark brown (10YR 2/2) SILT (ML), wet, non-plastic, non-cohesive, bedded, trace fine sand, few roots	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2625C702S 112912D005						
			SEKR2625C702S 112912D010						
1.0									
1.5									
2.0									
2.5					End of boring at 2.2 ft.				
3.0									
3.5									
4.0									

Coring Comments: Backwater Channel; Poling=No Poling (Dry Spot)

Logging Comments:

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2725C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12862757. **Y:** 310018.8	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 27.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/26/2012 16:40	**Water Depth (ft):** +3.3	**Core Diameter (in):** 2.75
Date Core Logged: 7/27/2012		**Field Recovery:** 2.6 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2725C701S 072712D007	SW	Dark grayish brown (10YR 4/2) to grayish brown (10YR 5/2) WELL GRADED SAND WITH GRAVEL (SW), wet, non-plastic, non-cohesive, thickly bedded, fine to coarse gravel, trace silt, few to little shell material few dark gray (10YR 4/1) silt from 0.5 to 0.8 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2725C701S 072712D007						
1.0			SEKR2725C701S 072712D013						
1.5			SEKR2725C701S 072712D019						
2.0			SEKR2725C701S 072712D022						
2.5									
					End of boring at 2.7 ft.				
3.0									
3.5									
4.0									

Coring Comments: Channel Deposit; Poling=None

Logging Comments: 0.0-0.5 ft-SEKR2725C701S072712D005-Bulk Density

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR2750C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12861378. **Y:** 310075.2	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 27.5	**Target Depth (ft):** 4
Date/Time Core Collected: 8/6/2012 12:18	**Water Depth (ft):** +4.2	**Core Diameter (in):** 2.75
Date Core Logged: 11/29/2012		**Field Recovery:** 2 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2750C701S 112912DX						
			SEKR2750C701S 112912D006	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, thickly bedded, trace clay, trace fine sand, trace roots	No sheen or oil	0	No oil fluorescence	0
0.5				ML	UV Fluorescence= one 2mm globule at 0.65 ft	No sheen or oil	0	Trace Fluorescence	<1
			SEKR2750C701S 112912D011	ML	Same as above	No sheen or oil	0	No oil fluorescence	0
1.0									
			SEKR2750C701S 112912D016						
1.5									
2.0				SW	Brownish yellow (10YR 6/8) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, few fine gravel, trace silt	No sheen or oil	0	No oil fluorescence	0
2.5									
					End of boring at 2.8 ft.				
3.0									
3.5									
4.0									

Coring Comments: Back Channel; Poling=None

Logging Comments: Recovery 1.6 ft at logging station, 2.0 ft recovery recorded in field

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2750C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12861379.4 **Y:** 310072.5	**Boring Contractor:** AECOM	**Number of Attempts:** 1
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 27.5	**Target Depth (ft):** 4
Date/Time Core Collected: 8/6/2012 12:30	**Water Depth (ft):** +4.2	**Core Diameter (in):** 2.75
Date Core Logged: 11/30/2012		**Field Recovery:** 0.8 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0									
	Push 1		SEKR2750C702S 113012DX SEKR2750C702S 113012D005	ML	Black (10YR 2/1) to very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, trace fine sand, some organics few plant/root material from 0.0 to 0.3 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2750C702S 113012D007						
1.0									
1.5				SP	Brownish yellow (10YR 6/8) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, trace medium to coarse sand, trace fine to coarse gravel	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5					End of boring at 2.5 ft.				
3.0									
3.5									
4.0									

Coring Comments: Backwater; Poling=None

Logging Comments:

Checked By: JTC **Date:** 12/1/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR2800C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12860685.2 **Y:** 307171.7	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 28	**Target Depth (ft):** 4
Date/Time Core Collected: 7/23/2012 16:49	**Water Depth (ft):** +0.7	**Core Diameter (in):** 2.75
Date Core Logged: 7/24/2012		**Field Recovery:** 1.7 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2800C701S 072412DX	SM	Black (10YR 2/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, thickly bedded, few roots/wood	No sheen or oil	0	Fluoresced Oil	30
0.5			SEKR2800C701S 072412D007	SM	Same as above	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR2800C701S 072412D012						
1.5			SEKR2800C701S 072412D017	SP	Black (10YR 2/1) to dark grayish brown (10YR 4/2) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded	No sheen or oil	0	No oil fluorescence	0
2.0					End of boring at 2 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Cutoff/Oxbow; Poling=Moderate
SEKR2800C701S072412PX- 4 (1/16") globules collect from upper 2 inches from Core 2

Logging Comments: 0.1-0.2 ft- SEKR2800C701S072412D002-E
0.0-0.5 ft-SEKR2800C701S072412D005-Bulk Density

Checked By: JTC **Date:** 7/25/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR2850C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12859468.3 **Y:** 306010.8	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 28.5	**Target Depth (ft):** 4
Date/Time Core Collected: 7/23/2012 17:34	**Water Depth (ft):** +2.3	**Core Diameter (in):** 2.75
Date Core Logged: 7/24/2012		**Field Recovery:** 1.7 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2850C701S 072412DX SEKR2850C701S 072412D003	OL	Very dark brown (10YR 2/2) SANDY ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, bedded, fine sand, trace fine gravel, trace cobble, trace shell material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR2850C701S 072412D007	SP-SM	Light yellowish brown (10YR 6/4) POORLY GRADED SAND WITH SILT (SP-SM), wet, non-plastic, non-cohesive, thickly bedded, fine sand, few silt 0.5" fine to coarse sand layer at 0.75 ft				
1.0			SEKR2850C701S 072412D011						
1.5			SEKR2850C701S 072412D016						
2.0					End of boring at 1.7 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Cutoff/Oxbow; Poling=None

Logging Comments:

Checked By: JTC **Date:** 7/25/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR2875C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12859235.1 **Y:** 306388.4	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 28.75	**Target Depth (ft):**	4
Date/Time Core Collected: 8/6/2012 10:11	**Water Depth (ft):** NA	**Core Diameter (in):**	2.75
Date Core Logged: 11/28/2012		**Field Recovery:**	1.6 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR2875C701S 112812DX	ML	Very dark brown (10YR 2/2) with yellowish brown (10YR 5/8) to dark gray (10YR 4/1) with gray (10YR 5/1) and yellowish brown (10YR 5/8) SILT (ML), wet, non-plastic, cohesive, bedded, trace fine sand, few to little organics, few to little plant/root material	No sheen or oil	0	No oil fluorescence	0
			SEKR2875C701S 112812D004						
0.5			SEKR2875C701S 112812D008						
1.0			SEKR2875C701S 112812D012	SP	Dark gray (10YR 4/1) to gray (10YR 5/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, thickly bedded, fine sand, trace medium sand, trace shell material	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR2875C701S 112812D016						
2.0					End of boring at 2.1 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Backwater; Poling= Not Completed (dry location)

Logging Comments: 0.0-0.5 ft-SEKR2875C701S080612D005-Bulk Density

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR3075C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12853588. **Y:** 300580.	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 30.75	**Target Depth (ft):**	4
Date/Time Core Collected: 7/26/2012 11:00	**Water Depth (ft):** N/A	**Core Diameter (in):**	2.75
Date Core Logged: 7/27/2012		**Field Recovery:**	2.5 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3075C701S 072712DX SEKR3075C701S 072712D005	ML	Very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, trace fine sand, little organics	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3075C701S 072712D009 SEKR3075C701S 072712D012	ML	Very dark gray (10YR 3/1) SILT (ML), wet, non-plastic to plasticity, cohesive, bedded, few fine sand, trace organics	No sheen or oil	0	No oil fluorescence	0
1.0									
1.5			SEKR3075C701S 072712D016 SEKR3075C701S 072712D021 SEKR3075C701S 072712D025	SP	Grayish brown (10YR 5/2) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, few medium sand, trace coarse sand seams of medium sand at 1.75 and 2.0 ft large piece of wood from 1.3 to 1.4 and 2.4 to 2.5 ft some fine gravel from 2.3 to 2.4 ft gradually changing to light yellowish brown (10YR 6/4) at 2.4 ft	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0									
3.5									
4.0					End of boring at 3.9 ft.				

Coring Comments: Backwater; Poling=dry location

Logging Comments:

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR3075C702
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12853747.3 **Y:** 300601.3	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 30.75	**Target Depth (ft):**	4
Date/Time Core Collected: 8/7/2012 09:43	**Water Depth (ft):** +0.3	**Core Diameter (in):**	2.75
Date Core Logged: 11/27/2012		**Field Recovery:**	2.5 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3075C702S 112712DX	SP	Brown (10YR 5/3) to dark gray (10YR 4/1) POORLY GRADED SAND (SP), moist to wet, bedded, non-plastic, non-cohesive, fine sand, trace fine gravel, trace shells some organics from 1.1 to 1.3 ft large piece of wood from 2.2 to 2.3 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3075C702S 112712D006						
1.0			SEKR3075C702S 112712D011						
1.5			SEKR3075C702S 112712D016						
2.0			SEKR3075C702S 112712D020						
2.5			SEKR3075C702S 112712D025						
3.0					End of boring at 2.9 ft.				
3.5									
4.0									

Coring Comments: Depositional Bar; Poling=None

Logging Comments: 0.0-0.5 ft-SEKR3075C702S080712D005-Bulk Density

Checked By: JTC **Date:** 11/28/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3250C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12849098. **Y:** 293880.3	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 32.5	**Target Depth (ft):** 4
Date/Time Core Collected: 8/7/2012 09:07	**Water Depth (ft):** +1.2	**Core Diameter (in):** 2.75
Date Core Logged: 11/29/2012		**Field Recovery:** 1.4 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3250C701S 112912DX	SP	Brown (10YR 4/3) to very pale brown (10YR 7/3) to gray (10YR 5/1) with grayish brown (10YR 5/2) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, thickly bedded, fine to medium sand, trace coarse sand	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3250C701S 112912D006						
			SEKR3250C701S 112912D010						
1.0			SEKR3250C701S 112912D014						
1.5									
2.0					End of boring at 1.9 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Channel Deposit; Poling=None

Logging Comments:

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR3650C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12836238.8 **Y:** 285213.1	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 36.5	**Target Depth (ft):**	4
Date/Time Core Collected: 7/24/2012 13:35	**Water Depth (ft):** 0	**Core Diameter (in):**	2.75
Date Core Logged: 7/25/2012		**Field Recovery:**	2 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3650C701S 072512DX	ML	Very dark brown (10YR 2/2) SILT (ML), wet to moist, low plasticity, cohesive, thickly bedded, trace fine sand, some roots	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3650C701S 072512D006						
			SEKR3650C701S 072512D010						
1.0			SEKR3650C701S 072512D015	ML	Dark yellowish brown (10YR 4/4) SILT WITH SAND (ML), wet, low plasticity, cohesive, thinly bedded, trace roots	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR3650C701S 072512D019						
2.0			SEKR3650C701S 072512D021	SP	Yellowish brown (10YR 5/6) POORLY GRADED SAND WITH GRAVEL (SP), wet, non-plastic, non-cohesive, bedded, fine to medium sand, few fine gravel, trace coarse sand	No sheen or oil	0	No oil fluorescence	0
2.5									
3.0									
					End of boring at 3.3 ft.				
3.5									
4.0									

Coring Comments: Backwater; Poling=No poling occurred

Logging Comments: 0.0-0.5 ft-SEKR3650C701S072512D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3675C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12835267.9 **Y:** 285526.4	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 36.76	**Target Depth (ft):** 4
Date/Time Core Collected: 7/27/2012 11:45	**Water Depth (ft):** +0.4	**Core Diameter (in):** 2.75
Date Core Logged: 11/27/2012		**Field Recovery:** 2.1 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3675C701S 112712DX SEKR3675C701S 112712D006	ML	Dark brown (10YR 3/3) SANDY SILT (ML), wet, non-plastic, non-cohesive, bedded, fine sand, some plant/root material, some organics, trace woody debris	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3675C701S 112712D011	ML	Very dark brown (10YR 2/2) SILT WITH SAND (ML), wet, non-plastic, cohesive, bedded, fine sand, trace plant/root material, trace woody debris	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3675C701S 112712D014 SEKR3675C701S 112712D017	SM	Gray (10YR 5/1) and dark gray (10YR 4/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine sand, trace plant/root material	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR3675C701S 112712D021	SP	Dark gray (10YR 4/1) and gray (10YR 5/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, thickly bedded, fine sand, trace medium sand, trace silt, trace shell material	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0									
3.5									
4.0					End of boring at 3.8 ft.				

Coring Comments: Delta; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 11/28/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR3700C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12834022.2 **Y:** 284504.3	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37	**Target Depth (ft):**	4
Date/Time Core Collected: 7/27/2012 11:50	**Water Depth (ft):** +1.2	**Core Diameter (in):**	2.75
Date Core Logged: 11/27/2012		**Field Recovery:**	2 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3700C701S 112712DX	ML	Very dark grayish brown (10YR 3/2) SILT (ML), moist, non-plastic, cohesive, bedded, few organics few fine sand from 0.4 to 0.6 ft	No sheen or oil	0	No oil fluorescence	0
			SEKR3700C701S 112712D005						
0.5			SEKR3700C701S 112712D008						
			SEKR3700C701S 112712D010	CL	Dark gray (10YR 4/1) CLAY (CL), moist to wet, low plasticity, cohesive, bedded	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3700C701S 112712D015	SP	Light yellowish brown (10YR 6/4) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, medium sand with layers of fine sand, trace shells	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR3700C701S 112712D020						
2.0									
2.5									
3.0									
3.5									
					End of boring at 3.8 ft.				
4.0									

Coring Comments: Sheen & globs while coring
Channel Deposit; Poling=Moderate

Logging Comments: 0.0-0.5 ft-SEKR3700C701S072712D005-Bulk Density

Checked By: JTC **Date:** 11/28/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3725C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12832968.8 **Y:** 283880.7	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/24/2012 15:08	**Water Depth (ft):** +2.1	**Core Diameter (in):** 2.75
Date Core Logged: 7/25/2012		**Field Recovery:** 2 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3725C701S 072512DX	OL	Very dark brown (10YR 2/1) and very dark grayish brown (10YR 3/2) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, thickly bedded, some plant/root & decomposed organic matter	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3725C701S 072512D007						
1.0			SEKR3725C701S 072512D013						
			SEKR3725C701S 072512D015	SM	Grayish brown (10YR 5/2) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine sand, trace fine gravel	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR3725C701S 072512D020	SP	Pale brown (10YR 6/3) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, trace medium sand, trace fine gravel	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0									
					End of boring at 3.2 ft.				
3.5									
4.0									

Coring Comments: Depositional Bar; Poling=Heavy

Logging Comments: 0.0-0.5 ft-SEKR3725C701S072512D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR3725C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12833055.7 **Y:** 283930.2	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/26/2012 15:38	**Water Depth (ft):** +1.8	**Core Diameter (in):** 2.75
Date Core Logged: 7/27/2012		**Field Recovery:** 2.6 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3725C702S 072712DX SEKR3725C702S 072712D004	ML	Very dark brown (10YR 2/2) to very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, non-cohesive, thickly bedded, trace to few fine sand, trace clay, trace peat, little to some organics UV several pinhead globules	No sheen or oil	0	Trace Fluorescence	<1
0.5			SEKR3725C702S 072712D010	ML	Same as above	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3725C702S 072712D015						
1.5			SEKR3725C702S 072712D019	SP	Very pale brown (10YR 7/3) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, trace medium sand, trace to few shell material	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR3725C702S 072712D022	SW	Very pale brown (10YR 7/3) WELL GRADED SAND WITH GRAVEL (SW), wet, non-plastic, non-cohesive, bedded, fine to coarse gravel, little shell material	No sheen or oil	0	No oil fluorescence	0
2.5			SEKR3725C702S 072712D026						
3.0									
3.5					End of boring at 3.5 ft.				
4.0									

Coring Comments: Channel deposit; Poling=Moderate
0.30-0.40 ft-SEKR3725C702S072712D004-Bulk Density

Logging Comments: 0.08-0.2 ft- SEKR3725C702S072712D002; 0.2-0.4 ft- SEKR3725C702S072712D004
0.4-0.5 ft- SEKR3725C702S072712D005

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR3725C704
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12832570.9 **Y:** 284903.3	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 37.25	**Target Depth (ft):**	4
Date/Time Core Collected: 7/27/2012 09:00	**Water Depth (ft):** +0.5	**Core Diameter (in):**	2.75
Date Core Logged: 11/28/2012		**Field Recovery:**	3 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3725C704S 112812DX	SP	Yellowish brown (10YR 5/6) with gray (10YR 5/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, thickly bedded, fine to medium sand, trace coarse sand, trace shell material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3725C704S 112812D006						
1.0			SEKR3725C704S 112812D011						
1.5			SEKR3725C704S 112812D017						
2.0			SEKR3725C704S 112812D021	SM	Dark gray (10YR 4/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine sand, trace woody debris, trace shell material	No sheen or oil	0	No oil fluorescence	0
			SEKR3725C704S 112812D025	ML	Very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, cohesive, bedded, trace fine sand	No sheen or oil	0	No oil fluorescence	0
2.5			SEKR3725C704S 112812D030	CL	Very dark gray (10YR 3/1) LEAN CLAY (CL), wet, low to moderate, plasticity, cohesive, bedded, few silt, trace fine sand	No sheen or oil	0	No oil fluorescence	0
3.0									
3.5									
					End of boring at 3.8 ft.				
4.0									

Coring Comments: Delta; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR3725C704S072712D005-Bulk Density

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR3725C705
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12832911.3 **Y:** 284284.6	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/27/2012 09:47	**Water Depth (ft):** +0.8	**Core Diameter (in):** 2.75
Date Core Logged: 11/28/2012		**Field Recovery:** 1.9 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3725C705S 112812DX	SW-SM	Brown (10YR 4/3) to yellowish brown (10YR 5/4) WELL GRADED SAND WITH SILT (SW-SM), moist, non-plastic, non-cohesive, bedded, trace roots Three 1mm globules from 0.0 to 0.3 ft color change to very dark gray (10YR 3/1) at 0.9 ft	No sheen or oil	0	Trace Fluorescence	1
0.5			SEKR3725C705S 112812D006	SW-SM	Same as above	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3725C705S 112812D010						
			SEKR3725C705S 112812D013						
1.5			SEKR3725C705S 112812D019	CL	Very dark gray (10YR 3/1) LEAN CLAY (CL), moist, medium plasticity, cohesive, bedded, trace roots	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5					End of boring at 2.5 ft.				
3.0									
3.5									
4.0									

Coring Comments: Delta; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR3725C705S072712D005-Bulk Density

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR3725C706
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12833455.6 **Y:** 285182.2	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/27/2012 10:04	**Water Depth (ft):** +0.1	**Core Diameter (in):** 2.75
Date Core Logged: 11/29/2012		**Field Recovery:** 1.5 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3725C706S 112912DX	SP	Brown (10YR 5/3) to gray (10YR 5/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, trace shells little leaves/plant material from 0.0 to 0.2 ft UV fluorescence on organic material and in sand from 0.2 to 0.4 ft	No sheen or oil	0	No oil fluorescence	0
			SEKR3725C706S 112912D002	SP		No sheen or oil	0	Fluoresced Oil	10
			SEKR3725C706S 112912D004	SP	Same as above	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3725C706S 112912D005	ML	Same as above Very dark gray (10YR 3/1) SILT (ML), wet, low plasticity, cohesive, bedded, few roots/organics UV fluorescence mainly on root from 1.2 to 1.3 ft	No sheen or oil	0	No oil fluorescence	0
			SEKR3725C706S 112912D010						
1.0			SEKR3725C706S 112912D013	ML	Same as above	No sheen or oil	0	Trace Fluorescence	<1
			SEKR3725C706S 112912D015	PT	Dark brown (10YR 3/3) PEAT (PT), wet, non-plastic, non-cohesive, bedded, little roots	No sheen or oil	0	No oil fluorescence	0
1.5									
2.0									
2.5									
3.0					End of boring at 3 ft.				
3.5									
4.0									

Coring Comments: Delta; Poling=Light

Logging Comments: Sampling procedure modified in accordance with conservations with Brian Albig (Enbridge) and Marc Wahrer, Dan Zahner, and Rex Johnson of U.S. EPA

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3725C707
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12832425.3 **Y:** 285147.4	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 37.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/27/2012 09:16	**Water Depth (ft):** +0.1	**Core Diameter (in):** 2.75
Date Core Logged: 11/27/2012		**Field Recovery:** 1.6 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3725C707S 112712DX	SP	Yellowish brown (10YR 5/4) POORLY GRADED SAND (SP), moist, non-plastic, non-cohesive, bedded, trace fine gravel, trace fine sand layers of dark brown (10YR 3/3) medium sand from 0.0 to 0.1 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3725C707S 112712D006						
			SEKR3725C707S 112712D010						
1.0			SEKR3725C707S 112712D013						
1.5			SEKR3775C707S 112712D016	SP	Dark gray (10YR 4/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded fibrous matted plant material from 1.3 to 1.4 ft	No sheen or oil	0	No oil fluorescence	0
2.0					End of boring at 2.1 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Delta; Poling=None

Logging Comments:

Checked By: JTC **Date:** 11/28/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3725C708	
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12832931.4 **Y:** 283850.5	**Boring Contractor:** AECOM	**Number of Attempts:** 2	
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.25	**Target Depth (ft):** 4	
Date/Time Core Collected: 8/8/2012 14:28	**Water Depth (ft):** +2.3	**Core Diameter (in):** 2.75	
Date Core Logged: 11/29/2012		**Field Recovery:** 1.1 ft	
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3725C708S 112912DX SEKR3725C708S 112912D005	ML	Very dark brown (10YR 2/2) SILT WITH SAND (ML), wet, non-plastic, non-cohesive, bedded, fine sand, trace shells, trace roots large piece of wood from 0.0 to 0.2 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3725C708S 112912D009	PT	Very dark brown (10YR 2/2) PEAT (PT), wet, non-plastic, non-cohesive, bedded, little roots	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3725C708S 112912D011	SW	Very pale brown (10YR 7/4) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, some shells	No sheen or oil	0	No oil fluorescence	0
1.5									
2.0									
2.5									
					End of boring at 2.6 ft.				
3.0									
3.5									
4.0									

Coring Comments: Depositional Bar; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3725C709
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12833539.4 **Y:** 284041.5	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.25	**Target Depth (ft):** 4
Date/Time Core Collected: 8/8/2012 14:07	**Water Depth (ft):** +1.0	**Core Diameter (in):** 2.75
Date Core Logged: 11/30/2012		**Field Recovery:** 1.8 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3725C709S 113012DX	ML	Black (10YR 2/1) and very dark gray (10YR 3/1) SANDY SILT (ML), wet, non-plastic, non-cohesive, bedded, fine sand, some organics, some plant/root material, trace shell material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3725C709S 113012D005						
			SEKR3725C709S 113012D008						
1.0			SEKR3725C709S 113012D011	PT	Black (10YR 2/1) with very dark brown (10YR 2/2) PEAT (PT), wet, non-plastic, non-cohesive, bedded, trace fine sand, trace silt, some plant/root material, trace woody debris	No sheen or oil	0	No oil fluorescence	0
			SEKR3725C709S 113012D015						
1.5			SEKR3725C709S 113012D018	SP	Gray (10YR 5/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine to medium sand, trace coarse sand, trace shell material	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0									
					End of boring at 3.1 ft.				
3.5									
4.0									

Coring Comments: Backwater; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 12/1/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR3750C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12831989.2 **Y:** 283835.4	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.5	**Target Depth (ft):**	4
Date/Time Core Collected: 7/24/2012 14:37	**Water Depth (ft):** +1.9	**Core Diameter (in):**	2.75
Date Core Logged: 7/25/2012		**Field Recovery:**	2.2 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0									
	Push 1		SEKR3750C701S 072512DX						
0.5			SEKR3750C701S 072512D006	ML	Very dark brown (10YR 2/2) SILT (ML), wet, non-plastic, non-cohesive, bedded, little organic material	No sheen or oil	0	No oil fluorescence	0
			SEKR3750C701S 072512D010						
1.0			SEKR3750C701S 072512D014	GW	Brown (10YR 5/3) WELL GRADED SAND (GW), wet, non-plastic, non-cohesive, bedded, trace silt	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR3750C701S 072512D019	SM	Brown (10YR 4/3) SILTY SAND (SM), wet, low plasticity, cohesive, thinly bedded, trace gravel	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR3750C701S 072512D022	SP	Light yellowish brown (10YR 6/4) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine to medium sand, few gravel	No sheen or oil	0	No oil fluorescence	0
2.5					End of boring at 2.5 ft.				
3.0									
3.5									
4.0									

Coring Comments: Backwater; Poling=Heavy
SEKR3750C701S072512PX- 1 globule collected from Core 2

Logging Comments: 0.1-0.2ft-SEKR3750C701S072512D002-E
0.0-0.5 ft-SEKR3750C701S072512D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR3750C703
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12833419.2 **Y:** 284259.8	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 37.5	**Target Depth (ft):**	4
Date/Time Core Collected: 7/27/2012 10:45	**Water Depth (ft):** NA	**Core Diameter (in):**	2.75
Date Core Logged: 11/28/2012		**Field Recovery:**	2.8 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3775C703S 112812DX	OL	Dark brown (10YR 3/3) ORGANIC SOIL (OL), moist, non-plastic, non-cohesive, thinly bedded, little roots	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3750C703S 112812D007	SP	Yellowish brown (10YR 5/6) POORLY GRADED SAND (SP), moist, non-plastic, non-cohesive, bedded, fine to medium sand	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3750C703S 112812D012						
1.5			SEKR3750C703S 112812D017	ML	Yellowish brown (10YR 5/8) to dark yellowish brown (10YR 3/4) SILT WITH SAND (ML), wet, non-plastic to low plasticity, cohesive, thinly bedded	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR3750C703S 112812D022						
2.5			SEKR3750C703S 112812D028						
3.0									
3.5									
4.0					End of boring at 3.8 ft.				

Coring Comments: Delta; Poling=No Poling (Dry Spot)

Logging Comments:

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3750C704
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12832394.7 **Y:** 284265.7	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.5	**Target Depth (ft):** 4
Date/Time Core Collected: 7/27/2012 08:50	**Water Depth (ft):** +1.7	**Core Diameter (in):** 2.75
Date Core Logged: 11/27/2012		**Field Recovery:** 3.1 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3750C704S 112712DX SEKR3750C704S 112712D006	ML	Very dark grayish brown (10YR 3/2) SILT WITH SAND (ML), wet, non-plastic, non-cohesive, bedded, fine sand, some organics, some plant/root material	No sheen or oil	0	No oil fluorescence	0
0.5									
1.0			SEKR3750C704S 112712D011 SEKR3750C704S 112712D016	ML	Dark yellowish brown (10YR 3/6) to yellowish brown (10YR 5/6) and gray (10YR 5/1) SANDY SILT (ML), wet, non-plastic, non-cohesive, bedded, fine sand, trace shell material fine sand from 1.0 to 1.1 ft	No sheen or oil	0	No oil fluorescence	0
1.5									
2.0			SEKR3750C704S 112712D021 SEKR3750C704S 112712D025 SEKR3750C704S 112712D029	SM	Light yellowish brown (10YR 6/4) with yellowish brown (10YR 5/8) and gray (10YR 5/1) to dark gray (10YR 4/1) and very dark gray (10YR 3/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, thickly bedded, fine sand, trace woody debris, trace shell material	No sheen or oil	0	No oil fluorescence	0
2.5									
3.0			SEKR3750C704S 112712D031	SP	Grayish brown (10YR 5/2) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine to medium sand, trace coarse sand, trace fine gravel, trace silt, trace shell material	No sheen or oil	0	No oil fluorescence	0
					End of boring at 3.3 ft.				
3.5									
4.0									

Coring Comments: Delta; Poling=Moderate

Logging Comments: 0.0-0.5 ft-SEKR3750C704S072712D005-Bulk Density

Checked By: JTC **Date:** 11/28/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR3750C705
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12831801.6 **Y:** 284921.5	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.5	**Target Depth (ft):** 4
Date/Time Core Collected: 7/27/2012 09:30	**Water Depth (ft):** +2.1	**Core Diameter (in):** 2.75
Date Core Logged: 11/28/2012		**Field Recovery:** 1.6 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3750C705S 112812DX	ML	Very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, non-cohesive to cohesive, thickly bedded, some organics, few plant/root material, trace woody debris, trace shell material, grades with trace fine sand	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3750C705S 112812D006	ML	UV Fluorescence consists of six scattered globules, pinhead to 1mm in size from 0.2 to 0.8 ft petroleum odor from 0.2 to 1.6 ft	No sheen or oil	0	Trace Fluorescence	2
1.0			SEKR3750C705S 112812D011		Same as above				
1.5			SEKR3750C705S 112812D016						
2.0				ML	Same as above	No sheen or oil	0	No oil fluorescence	0
2.5									
3.0									
3.5					End of boring at 3.5 ft.				
4.0									

Coring Comments: Delta; Poling=Light

Logging Comments:

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR3750C706
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12831801. **Y:** 284585.4	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 37.5	**Target Depth (ft):**	4
Date/Time Core Collected: 7/27/2012 11:25	**Water Depth (ft):** +1.2	**Core Diameter (in):**	2.75
Date Core Logged: 11/29/2012		**Field Recovery:**	1.2 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3750C706S 112912DX	ML	Black (10YR 2/1) with very dark gray (10YR 3/1) SANDY SILT (ML), wet, non-plastic, non-cohesive, thickly bedded, fine sand, some organics, few plant/root material, trace woody debris, trace shell material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3750C706S 112912D006						
			SEKR3750C706S 112912D009						
1.0			SEKR3750C706S 112912D012						
1.5									
2.0									
2.5									
3.0									
3.5									
					End of boring at 3.8 ft.				
4.0									

Coring Comments: Delta; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3750C707
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12831653.7 **Y:** 284386.9	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.5	**Target Depth (ft):** 4
Date/Time Core Collected: 7/27/2012 13:45	**Water Depth (ft):** +1.9	**Core Diameter (in):** 2.75
Date Core Logged: 11/28/2012		**Field Recovery:** 2.1 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3750C707S 112812DX	OH	Very dark gray (10YR 3/1) ORGANIC SILT (OH), wet, non-plastic, non-cohesive, bedded, little plant/root material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3750C707S 112812D006						
			SEKR3750C707S 112812D010						
1.0			SEKR3750C707S 112812D013	SW	Gray (10YR 5/1) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, trace fine gravel, trace silt, trace shell material	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR3750C707S 112812D016						
			SEKR3750C707S 112812D021	ML	Very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, cohesive, thickly bedded, trace fine sand, some organics petroleum odor present	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0									
3.5					End of boring at 3.4 ft.				
4.0									

Coring Comments: Delta; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR3750C707S072712D005-Bulk Density

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR3750C708
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12832280.6 **Y:** 284123.6	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.5	**Target Depth (ft):**	4
Date/Time Core Collected: 8/7/2012 15:23	**Water Depth (ft):** +0.8	**Core Diameter (in):**	2.75
Date Core Logged: 11/29/2012		**Field Recovery:**	2.6 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3750C708S 112912DX	SM	Very dark gray (10YR 3/1) to gray (10YR 5/1) with brownish yellow (10YR 6/8) SILTY SAND (SM), wet, non-plastic, non-cohesive, thickly bedded, fine sand, trace medium sand, trace plant/root material some organics with plant/root material and trace woody debris from 0.0 to 0.7 ft woody debris at 2.2 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3750C708S 112912D006						
1.0			SEKR3750C708S 112912D011						
1.5			SEKR3750C708S 112912D016						
2.0			SEKR3750C708S 112912D021						
2.5			SEKR3750C708S 112912D026						
3.0									
3.5									
4.0					End of boring at 3.8 ft.				

Coring Comments: Delta; Poling=Heavy

Logging Comments: 0.0-0.5 ft-SEKR3750C708S080712D005-Bulk Density

Checked By: JTC **Date:** 11/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3750C709
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12831219. **Y:** 284310.9	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.5	**Target Depth (ft):** 4
Date/Time Core Collected: 8/7/2012 15:50	**Water Depth (ft):** +1.9	**Core Diameter (in):** 2.75
Date Core Logged: 11/27/2012		**Field Recovery:** 1.6 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3750C709S 112712DX	ML	Very dark brown (10YR 2/2) SILT (ML), wet, non-plastic, non-cohesive, thickly bedded, trace fine sand, few organics	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3750C709S 112712D006						
1.0			SEKR3750C709S 112712D011						
1.5			SEKR3750C709S 112712D016	CL	Dark gray (10YR 4/1) LEAN CLAY (CL), wet, medium plasticity, cohesive, bedded, trace fine sand, few roots	No sheen or oil	0	No oil fluorescence	0
2.0					End of boring at 2.1 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Delta; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 11/28/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3750C710
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12831215.8 **Y:** 284310.2	**Boring Contractor:** AECOM	**Number of Attempts:** 1
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.5	**Target Depth (ft):** 4
Date/Time Core Collected: 8/7/2012 15:58	**Water Depth (ft):** +1.9	**Core Diameter (in):** 2.75
Date Core Logged: 11/28/2012		**Field Recovery:** 1.8 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3750C710S 112812DX	OL	Black (10YR 2/1) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, bedded, trace organics	No sheen or oil	0	No oil fluorescence	0
			SEKR3750C710S 112812D005						
0.5			SEKR3750C710S 112812D008						
1.0			SEKR3750C710S 112812D012	SP	Very dark gray (10YR 3/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine to medium sand, trace shells	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR3750C710S 112812D018	CL	Very dark gray (10YR 3/1) LEAN CLAY (CL), wet, medium plasticity, cohesive, bedded, few roots/organics	No sheen or oil	0	No oil fluorescence	0
2.0					End of boring at 2.1 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Delta; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR3775C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12830681.1 **Y:** 285178.	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.75	**Target Depth (ft):** 4
Date/Time Core Collected: 7/26/2012 16:18	**Water Depth (ft):** +6.0	**Core Diameter (in):** 2.75
Date Core Logged: 7/27/2012		**Field Recovery:** 1.3 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3775C701S 072712DX SEKR3775C701S 072712D006	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, few organic material 7 globules (1/16") from 0.0 to 0.3 ft	No sheen or oil	0	Trace Fluorescence	<1
0.5			SEKR3775C701S 072712D007	ML	Same as above	No sheen or oil	0	No oil fluorescence	0
			SEKR3775C701S 072712D009	SP	Very dark gray (10YR 3/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, trace silt	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3775C701S 072712D011	SM	Very dark gray (10YR 3/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine sand	No sheen or oil	0	No oil fluorescence	0
			SEKR3775C701S 072712D013						
1.5									
2.0									
2.5				SW	Dark grayish brown (10YR 4/2) WELL GRADED SAND (SW), wet, non-plastic, non-cohesive, bedded, trace fine gravel, few shells	No sheen or oil	0	No oil fluorescence	0
3.0									
3.5									
4.0									

Coring Comments: Channel deposit; Poling= Light
SEKR3775C701S072712PX- 7 (1/16") globules collect from 0.0 to 0.3 ft

Logging Comments: 0.1-0.3 ft- SEKR3775C701S072712D003-E; 0.3-0.4 ft- SEKR3775C701S072712D004-E
0.4-0.6 ft- SEKR3775C701S072712D006-E; 0.6-0.7 ft- SEKR3775C701S072712D007-E

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3775C702
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12829804.4 **Y:** 284925.8	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 37.75	**Target Depth (ft):** 4
Date/Time Core Collected: 7/26/2012 16:45	**Water Depth (ft):** +5.2	**Core Diameter (in):** 2.75
Date Core Logged: 7/27/2012		**Field Recovery:** 1.2 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3775C702S 072712DX	ML	Very dark gray (10YR 3/1) to black (10YR 2/1) SILT (ML), wet, non-plastic, cohesive, bedded, trace organics gray (10YR 5/1) fine sand layer from 0.55 to 0.60 ft some decomposed plant material from 0.7 to 0.9 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3775C702S 072712D005						
			SEKR3775C702S 072712D009						
1.0			SEKR3775C702S 072712D012	SP-SM	Very dark gray (10YR 3/1) POORLY GRADED SAND WITH SILT (SP-SM), wet, non-plastic, non-cohesive, bedded, fine sand, trace coarse gravel, trace woody debris	No sheen or oil	0	No oil fluorescence	0
1.5									
2.0									
2.5					End of boring at 2.2 ft.				
3.0									
3.5									
4.0									

Coring Comments: Channel Deposit; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR3775C703
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12829785.7 **Y:** 284717.1	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.75	**Target Depth (ft):** 4
Date/Time Core Collected: 7/27/2012 11:00	**Water Depth (ft):** +2.3	**Core Diameter (in):** 2.75
Date Core Logged: 11/28/2012		**Field Recovery:** 1.5 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3775C703S 112812DX	OL	Black (10YR 2/1) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, thickly bedded, few organics	No sheen or oil	0	No oil fluorescence	0
				OL	thin black (10YR 2/1) clay, medium plasticity, cohesive, thinly bedded, trace fine sand layer from 1.15 to 1.3 ft UV Fluorescence=One 3 mm glob at 0.2 ft	No sheen or oil	0	Trace Fluorescence	<1
0.5			SEKR3775C703S 112812D006						
1.0			SEKR3775C703S 112812D011						
			SEKR3775C703S 112812D015	OL	Same as above	No sheen or oil	0	No oil fluorescence	0
1.5									
2.0					End of boring at 2 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Delta; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 11/29/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR3775C704
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12829864.5 **Y:** 285272.	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 37.75	**Target Depth (ft):**	4
Date/Time Core Collected: 7/27/2012 14:15	**Water Depth (ft):** +3.4	**Core Diameter (in):**	2.75
Date Core Logged: 11/27/2012		**Field Recovery:**	2 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3775C704S 112712DX	ML	Very dark grayish brown (10YR 3/2) to dark gray (10YR 4/1) SILT (ML), moist, non-plastic, non-cehesive, thickly bedded, trace gravel	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3775C704S 112712D007						
1.0			SEKR3775C704S 112712D012						
1.5			SEKR3775C704S 112712D016	SP-SM	Dark grayish brown (10YR 4/2) POORLY GRADED SAND WITH SILT (SP-SM), wet, non-plastic, non-cohesive, bedded, fine sand, trace fine gravel, trace wood	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR3775C704S 112712D020						
2.5									
3.0					End of boring at 2.8 ft.				
3.5									
4.0									

Coring Comments: Delta; Poling=None

Logging Comments:

Checked By: JTC **Date:** 11/28/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3800C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12829660.9 **Y:** 285216.2	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 38	**Target Depth (ft):** 4
Date/Time Core Collected: 7/25/2012 16:03	**Water Depth (ft):** +2.9	**Core Diameter (in):** 2.75
Date Core Logged: 7/26/2012		**Field Recovery:** 1.7 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3800C701S 072612DX / SEKR3800C701S 072612D003	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, trace roots	No sheen or oil	0	No oil fluorescence	0
			SEKR3800C701S 072612DX	SM	Black (10YR 2/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3800C701S 072612D010	CL	Very dark gray (10YR 3/1) LEAN CLAY (CL), wet, low to moderate plasticity, cohesive, bedded	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3800C701S 072612D015						
1.5			SEKR3800C701S 072612D017	ML	Very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, little clay, few fine sand	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0					End of boring at 3 ft.				
3.5									
4.0									

Coring Comments: Morrow Lake Fan; Poling=Heavy

Logging Comments: 0.0-0.5 ft-SEKR3800C701S072612D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR3800C702
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12828930. **Y:** 286717.9	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 38	**Target Depth (ft):**	4
Date/Time Core Collected: 7/25/2012 16:32	**Water Depth (ft):** +0.2	**Core Diameter (in):**	2.75
Date Core Logged: 7/26/2012		**Field Recovery:**	0.8 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0									
	Push 1		SEKR3800C702S 072612DX	OL	Black (10YR 2/1) ORGANIC SOIL (OL), wet, non-plastic, non-cphesive, bedded, few silt	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3800C702S 072612D005						
			SEKR3800C702S 072612D009						
1.0									
1.5									
2.0									
2.5									
3.0									
3.5									
					End of boring at 3.6 ft.				
4.0									

Coring Comments: Morrow Lake Fan; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR3800C702S072612D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3800C703	
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12828854.2 **Y:** 286680.9	**Boring Contractor:** AECOM	**Number of Attempts:** 2	
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 38	**Target Depth (ft):** 4	
Date/Time Core Collected: 7/25/2012 16:52	**Water Depth (ft):** +2.0	**Core Diameter (in):** 2.75	
Date Core Logged: 7/26/2012		**Field Recovery:** 1.3 ft	
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3800C703S 072612DX	OL	Black (10YR 2/1) ORGANIC SOIL (OL), wet, non-plastic, non-cohesive, bedded, few silt, trace clay	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3800C703S 072612D007						
1.0			SEKR3800C703S 072612D010	CL	Black (10YR 2/1) LEAN CLAY (CL), wet to moist, low to medium plasticity, cohesive, bedded, little silt, trace fine sand, little organics	No sheen or oil	0	No oil fluorescence	0
			SEKR3800C703S 072612D014						
1.5									
2.0									
2.5									
3.0					End of boring at 2.8 ft.				
3.5									
4.0									

Coring Comments: Morrow Lake Fan; Poling=Moderate

Logging Comments:

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3800C704
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12828780.4 **Y:** 286596.5	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 38	**Target Depth (ft):** 4
Date/Time Core Collected: 7/26/2012 10:45	**Water Depth (ft):** +1.5	**Core Diameter (in):** 2.75
Date Core Logged: 7/27/2012		**Field Recovery:** 1.4 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3800C704S 072712DX SEKR3800C704S 072712D006	ML	Very dark gray (10YR 3/1) with black (10YR 2/1) SILT (ML), wet, non-plastic, cohesive, bedded, trace fine sand, trace organics	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3800C704S 072712D011	SM	Very dark grayish brown (10Yr 3/2) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine sand	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3800C704S 072712D014	SP	Light yellowish brown (10YR 6/4) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded streaks of very dark gray (10YR 3/1) silty sand throughout	No sheen or oil	0	No oil fluorescence	0
1.5					End of boring at 1.7 ft.				
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Morrow Lake Fan; Poling=Moderate

Logging Comments: 0.0-0.5 ft-SEKR3800C704S072712D005-Bulk Density

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:**	SEKR3800C705
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12828630.9 **Y:** 284589.3	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 38	**Target Depth (ft):**	4
Date/Time Core Collected: 7/26/2012 11:42	**Water Depth (ft):** +2.9	**Core Diameter (in):**	2.75
Date Core Logged: 7/27/2012		**Field Recovery:**	1.5 ft
Logged By: GMK			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3800C705S 072712DX	ML	Dark gray (10YR 4/1) with very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, cohesive, bedded, trace fine sand, trace fine gravel, trace organics	No sheen or oil	0	Trace Fluorescence	<1
			SEKR3800C705S 072712D002	ML	several small globules fluoresced	No sheen or oil	0	No oil fluorescence	0
			SEKR3800C705S 072712D004		Same as above				
0.5			SEKR3800C705S 072712D009	SM	Dark gray (10YR 4/1) SILTY SAND 9SM), wet, non-plastic, non-cohesive, bedded, fine sand, trace woody debris	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3800C705S 072712D014	CL	Dark gray (10YR 4/1) LEAN CLAY (CL), wet, moderate plasticity, cohesive, bedded, little silt, trace fine sand	No sheen or oil	0	No oil fluorescence	0
1.5					End of boring at 1.5 ft.				
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Morrow Lake Fan; Poling= Light
SEKR3800C705S072712PX- several small globules at surface and 1 at 0.15 ft collected

Logging Comments: 0.08-0.15 ft- SEKR3800C705S072712D002-E; 0.15-0.25 ft- SEKR3800C705S072712D003-E

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3800C706
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12829486.4 **Y:** 285272.7	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 38	**Target Depth (ft):** 4
Date/Time Core Collected: 7/26/2012 13:26	**Water Depth (ft):** +1.8	**Core Diameter (in):** 2.75
Date Core Logged: 7/27/2012		**Field Recovery:** 2.5 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3800C706S 072712DX SEKR3800C706S 072712D004	ML	Very dark gray (10YR 3/1) SANDY SILT (ML), wet, non-plastic, non-cohesive, bedded, fine sand, trace organics	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3800C706S 072712D009	SM	Grayish brown (10YR 5/2) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine to medium sand, trace fine gravel	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3800C706S 072712D014	ML	Brown (10YR 5/3) to reddish brown (5YR 4/4) SANDY SILT (ML), wet, non-plastic, non-cohesive, thickly bedded, fine to coarse sand, few fine to coarse gravel	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR3800C706S 072712D020						
2.0			SEKR3800C706S 072712D025						
2.5					End of boring at 2.6 ft.				
3.0									
3.5									
4.0									

Coring Comments: Morrow Lake Fan; Poling=Light

Logging Comments:

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:**	SEKR3800C707
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12828574.1 **Y:** 285378.1	**Boring Contractor:** AECOM	**Number of Attempts:**	2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 38	**Target Depth (ft):**	4
Date/Time Core Collected: 7/26/2012 13:46	**Water Depth (ft):** +3.5	**Core Diameter (in):**	2.75
Date Core Logged: 7/27/2012		**Field Recovery:**	2 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3800C707S 072712DX	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, cohesive, bedded, trace fine gravel, trace fine sand, trace roots 1 pinhead globule with UV at 0.3 ft	No sheen or oil	0	No oil fluorescence	0
			SEKR3800C707S 072712D004	ML	Same as above	No sheen or oil	0	Trace Fluorescence	<1
0.5			SEKR3800C707S 072712D009	ML	Same as above	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3800C707S 072712D014						
1.5			SEKR3800C707S 072712D020	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, trace sand, little roots	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0									
3.5									
4.0					End of boring at 3.9 ft.				

Coring Comments: Morrow Lake Fan; Poling= Moderate

Logging Comments: 0.1-0.2 ft- SEKR3800C707S072712D002-E; 0.2-0.4 ft- SEKR3800C707S072712D004-E
0.4-0.6 ft- SEKR3800C707S072712D006-E

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR3800C708
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12828558.1 **Y:** 286682.6	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 38	**Target Depth (ft):** 4
Date/Time Core Collected: 7/26/2012 14:15	**Water Depth (ft):** +1.8	**Core Diameter (in):** 2.75
Date Core Logged: 7/27/2012		**Field Recovery:** 2.2 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3800C708S 072712DX	ML	Very dark grayish brown (10YR 4/2) SILT (ML), wet, non-plastic, cohesive, thickly bedded, trace fine sand, trace to few organics	No sheen or oil	0	Trace Fluorescence	1
0.5			SEKR3800C708S 072712D005	ML	Same as above	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3800C708S 072712D010						
1.5			SEKR3800C708S 072712D014						
2.0			SEKR3800C708S 072712D018	PT	Very dark brown (10YR 2/2) with very dark gray (10YR 3/1) PEAT (PT), wet, non-plastic, non-cohesive, bedded, trace to few silt, some plant/root material	No sheen or oil	0	No oil fluorescence	0
2.5			SEKR3800C708S 072712D022						
3.0									
3.5									
4.0					End of boring at 3.7 ft.				

Coring Comments: Morrow Lake Fan; Poling= Light

Logging Comments: 0.08-0.2 ft- SEKR3800C708S072712D002-E

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3800C709
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12828472.8 **Y:** 283811.4	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 38	**Target Depth (ft):** 4
Date/Time Core Collected: 7/26/2012 14:38	**Water Depth (ft):** +2.0	**Core Diameter (in):** 2.75
Date Core Logged: 7/27/2012		**Field Recovery:** 2.2 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3800C709S 072712DX	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, thickly bedded, trace fine sand, trace organics	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3800C709S 072712D006						
1.0			SEKR3800C709S 072712D011						
			SEKR3800C709S 072712D013	SM	Black (10YR 2/1) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR3800C709S 072712D019	CH	Very dark greenish gray (GLEY1 5GY 3/1) FAT CLAY (CH), moist, high plasticity, cohesive, bedded, trace silt	No sheen or oil	0	No oil fluorescence	0
2.0			SEKR3800C709S 072712D022	ML	Dark grayish green (GLEY1 5GY 4/2) SILT (ML), moist, low plasticity, cohesive, few clay, few sand	No sheen or oil	0	No oil fluorescence	0
2.5					End of boring at 2.2 ft.				
3.0									
3.5									
4.0									

Coring Comments: Morrow Lake Fan; Poling=Light

Logging Comments:

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR3825C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12827278.5 **Y:** 283864.2	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 38.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/26/2012 23:53	**Water Depth (ft):** +3.5	**Core Diameter (in):** 2.75
Date Core Logged: 7/27/2012		**Field Recovery:** 1.5 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3825C701S 072712DX SEKR3825C701S 072712D003	ML	Very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, cohesive, thickly bedded, trace fine sand, trace organics slight odor throughout	Sheen	1	Trace Fluorescence	2
0.5			SEKR3825C701S 072712D009	ML	visible sheen (1/8" diameter) at 0.3 ft; UV-small globs at surface and 1 globule at 0.3 ft	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3825C701S 072712D015						
1.5									
2.0					Same as above				
2.5									
3.0									
3.5									
4.0									

End of boring at 4 ft.

Coring Comments: Morrow Lake Fan; Poling=Moderate
SEKR3825C701S072712PX- globule collection sample

Logging Comments: 0.08-0.3 ft- SEKR3825C701S072712D003-E; 0.3-0.4 ft- SEKR3825C701S072712D004-E

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3850C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12826441.9 **Y:** 284821.9	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 38.5	**Target Depth (ft):** 4
Date/Time Core Collected: 7/25/2012 08:50	**Water Depth (ft):** +4.0	**Core Diameter (in):** 2.75
Date Core Logged: 7/26/2012		**Field Recovery:** 1.9 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3850C701S 072612DX	ML	Very dark brown (10YR 2/2) SILT (ML), wet, non-plastic, non-cohesive, thickly bedded	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3850C701S 072612D007						
1.0			SEKR3850C701S 072612D013						
1.5			SEKR3850C701S 072612D019	CL	Very dark brown (10YR 2/2) LEAN CLAY (CL), wet, low plasticity, cohesive, thickly bedded, trace roots	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0									
3.5					End of boring at 3.4 ft.				
4.0									

Coring Comments: Morrow Lake Fan; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR3850C701S072612D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3850C702	
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12826899.7 **Y:** 285555.8	**Boring Contractor:** AECOM	**Number of Attempts:** 3	
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 38.5	**Target Depth (ft):** 4	
Date/Time Core Collected: 7/25/2012 10:05	**Water Depth (ft):** +4.4	**Core Diameter (in):** 2.75	
Date Core Logged: 7/26/2012		**Field Recovery:** 2.1 ft	
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3850C702S 072612DX	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, bedded, trace fine sand, trace fine gravel sand and gravel concentrated from 0.8 to 1.0 ft	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3850C702S 072612D006						
			SEKR3850C702S 072612D010						
1.0			SEKR3850C702S 072612D014	SM	Brown (10YR 5/3) SILTY SAND (SM), wet, non-plastic, non-cohesive, bedded, fine to medium sand, trace fine gravel, trace coarse sand	No sheen or oil	0	No oil fluorescence	0
1.5			SEKR3850C702S 072612D017	CL	Very dark gray (10YR 3/1) LEAN CLAY (CL), moist, medium plasticity, cohesive, thickly bedded	No sheen or oil	0	No oil fluorescence	0
			SEKR3850C702S 072612D021						
2.0									
2.5									
3.0					End of boring at 2.9 ft.				
3.5									
4.0									

Coring Comments: Morrow Lake; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR3850C702S072612D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** Yes	**Location ID:** SEKR3850C703
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12826446.2 **Y:** 283083.	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 38.5	**Target Depth (ft):** 4
Date/Time Core Collected: 7/26/2012 11:12	**Water Depth (ft):** +1.8	**Core Diameter (in):** 2.75
Date Core Logged: 7/27/2012		**Field Recovery:** 1.5 ft
Logged By: GMK		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3850C703S 072712DX	ML	Dark gray (10YR 4/1) to very dark gray (10YR 3/1) SILT (ML), wet, non-plastic, cohesive, bedded, trace organics	No sheen or oil	0	Trace Fluorescence	1
			SEKR3850C703S 072712D002	ML	grades with: few grayish brown (10YR 5/2) lean clay several small globs at contact of soil surface and ice and 1 glob at 0.2 ft in soil under UV	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3850C703S 072712D005						
			SEKR3850C703S 072712D009		Same as above				
1.0			SEKR3850C703S 072712D015	ML	Very dark brown (10YR 2/2) SILT (ML), wet, non-plastic, non-cohesive, bedded, some peat, some organics	No sheen or oil	0	No oil fluorescence	0
1.5									
2.0					End of boring at 2.0 ft.				
2.5									
3.0									
3.5									
4.0									

Coring Comments: Morrow Lake Fan; Poling= Light
0.15-0.25 ft-SEKR3850C703S072712D003-Bulk Density; SEKR3850C703S072712PX- Globule collection sample

Logging Comments: 0.08-0.2 ft- SEKR3850C703S072712D002-E; 0.2-0.3 ft- SEKR3850C703S072712D003-E

Checked By: JTC **Date:** 7/30/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:**	SEKR3875C701
Site Location: Kalamazoo River	**Project Number:** 60246209		
Coordinates: X: 12824729.1 **Y:** 286814.4	**Boring Contractor:** AECOM	**Number of Attempts:**	3
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 38.75	**Target Depth (ft):**	4
Date/Time Core Collected: 7/25/2012 09:17	**Water Depth (ft):** +4.9	**Core Diameter (in):**	2.75
Date Core Logged: 7/26/2012		**Field Recovery:**	1.7 ft
Logged By: RLF			

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3875C701S 072612DX	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, thickly bedded, trace fine sand, trace organic material	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3875C701S 072612D006						
1.0			SEKR3875C701S 072612D012						
1.5			SEKR3875C701S 072612D017						
2.0									
2.5									
3.0									
3.5					End of boring at 3.5 ft.				
4.0									

Coring Comments: Morrow Lake; Poling=Light

Logging Comments: 0.0-0.5 ft-SEKR3875C701S072612D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3925C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12821632.4 **Y:** 285179.2	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 39.25	**Target Depth (ft):** 4
Date/Time Core Collected: 7/25/2012 11:46	**Water Depth (ft):** +6.7	**Core Diameter (in):** 2.75
Date Core Logged: 7/26/2012		**Field Recovery:** 1.7 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3925C701S 072612DX	ML	Black (10YR 2/1) SILT (ML), wet, low plasticity, cohesive, bedded	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3925C701S 072612D006						
			SEKR3925C701S 072612D010	SM	Very dark gray (10YR 3/1) SILTY SAND (SM), wet, non-plastic, cohesive, bedded, trace roots	No sheen or oil	0	No oil fluorescence	0
1.0			SEKR3925C701S 072612D015						
1.5			SEKR3925C701S 072612D017	SP	Gray (10YR 5/1) POORLY GRADED SAND (SP), wet, non-plastic, non-cohesive, bedded, fine sand, trace silt	No sheen or oil	0	No oil fluorescence	0
					End of boring at 1.8 ft.				
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Morrow Lake; Poling=Light

Logging Comments:

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3950C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12820912.4 **Y:** 286869.3	**Boring Contractor:** AECOM	**Number of Attempts:** 2
Collection Method: Check-valve sampler, drive hammer used	**Mile Post:** 39.5	**Target Depth (ft):** 4
Date/Time Core Collected: 7/25/2012 15:24	**Water Depth (ft):** +7.2	**Core Diameter (in):** 2.75
Date Core Logged: 7/26/2012		**Field Recovery:** 1.7 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3950C701S 072612DX	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, thickly bedded	No sheen or oil	0	No oil fluorescence	0
0.5			SEKR3950C701S 072612D007						
1.0			SEKR3950C701S 072612D013						
1.5			SEKR3950C701S 072612D018	CL	Very dark gray (10YR 3/1) LEAN CLAY (CL), wet, medium plasticity, cohesive, bedded, trace fine sand, trace wood fragments	No sheen or oil	0	No oil fluorescence	0
2.0									
2.5									
3.0									
					End of boring at 3.2 ft.				
3.5									
4.0									

Coring Comments: Morrow Lake; Poling=None

Logging Comments:

Checked By: JTC **Date:** 7/27/2012

Client: Enbridge Energy, Limited Partnership	**Free Oil and/or Oil Fluorescence Observed :** No	**Location ID:** SEKR3975C701
Site Location: Kalamazoo River	**Project Number:** 60246209	
Coordinates: X: 12820305.9 **Y:** 285571.8	**Boring Contractor:** AECOM	**Number of Attempts:** 3
Collection Method: Check-valve sampler, hand driven	**Mile Post:** 39.75	**Target Depth (ft):** 4
Date/Time Core Collected: 7/25/2012 10:52	**Water Depth (ft):** +8.0	**Core Diameter (in):** 2.75
Date Core Logged: 7/26/2012		**Field Recovery:** 1.4 ft
Logged By: RLF		

SOIL CORE COMPLETION DETAIL

Depth (ft)	Run Interval	Settled Recovery	Sample ID	USCS	MATERIALS: Color, CLASSIFICATION (USCS - ASTM D2488), moisture, plasticity, cohesiveness, sedimentary structure, secondary grain size, other.	Core Under Visible Light	Percent %	Core Under UV Light	Percent %
0.0	Push 1		SEKR3950C701S 072612DX	ML	Black (10YR 2/1) SILT (ML), wet, non-plastic, non-cohesive, thickly bedded	No sheen or oil	0	No oil fluorescence	0
			SEKR3950C701S 072612D005						
0.5			SEKR3950C701S 072612D010						
1.0			SEKR3950C701S 072612D015						
1.5									
2.0									
2.5									
3.0									
3.5									
4.0									

Coring Comments: Slight sheen while coring, 1%
Morrow Lake; Poling=None

Logging Comments: 0.0-0.5 ft-SEKR3975C701S072612D005-Bulk Density

Checked By: JTC **Date:** 7/27/2012

Appendix 6

Line 6B Oil Concentrations in Sediment Samples

US EPA ARCHIVE DOCUMENT

Table 1
Line 6B Oil Concentrations in Oil Quantification Sediment Samples
Enbridge Line 6B MP 608 Marshall, MI Pipeline Release

Client ID	Lab ID	TAS2/Hopane Line 6B Oil Conc. mg/kg Sed	TAS2/Hopane Line 6B Oil LOD mg/kg Sed	TAS1/T30 Line 6B Oil Conc. mg/kg Sed	TAS1/T30 Line 6B Oil LOD mg/kg Sed	Line 6B Oil Reported Value
SEKR0325C701S072512DX	1209019-18	ND	6	14	NA	14
SEKR0325C701S072512D002	1211038-07	ND	49	47	NA	47
SEKR0400C701S072512DX	1209019-19	ND	24	6	NA	6
SEKR0400C701S072512D003	1211038-08	391	NA	520	NA	455
SEKR0425C701S072512DX	1208009-14	667	NA	879	NA	773
SEKR0425C701S072512D007	1208009-15	303	NA	473	NA	388
SEKR0425C702S112812DX	1212031-11	ND	7	7	NA	7
SEKR0425C702S112812D005	1212031-12	ND	104	32	NA	32
SEKR0425C702D112812D005	1212031-13	ND	57	42	NA	42
SEKR0425C702S112812D009	1212031-14	ND	14	22	NA	22
SEKR0425C702S112812D019	1212052-03	ND	492	1167	NA	1167
SEKR0475C701S072612DX	1209020-06R	ND	29	ND	18	ND, LOD = 24
SEKR0475C701S072612D004	1211039-03	18	NA	ND	---	18
SEKR0475C701S072612D008	1211039-04	22	NA	ND	---	22
SEKR0475C701S072612D017	1212052-11	12	NA	ND	14	12
SEKR0475C702S072612DX	1209020-09R	ND	64	11	NA	11
SEKR0475C702S072612D005	1211039-09	ND	5	23	NA	23
SEKR0475C702S072612D009	1211039-10	ND	52	30	NA	30
SEKR0475C702S072612D013	1211039-11	ND	103	71	NA	71
SEKR0500C701S112912DX	1212034-03	ND	231	135	NA	135
SEKR0500C701D112912D006	1212034-05	ND	214	279	NA	279
SEKR0500C701S112912D006	1212034-04	ND	415	405	NA	405
SEKR0500C701S112912D012	1212034-06	ND	585	1313	NA	1313
SEKR0500C702S112812DX	1212031-02	ND	77	112	NA	112
SEKR0500C702S112812D007	1212031-03	14	NA	ND	507	14
SEKR0500C702S112812D013	1212031-04	ND	14	ND	368	ND, LOD = 193
SEKR0500C702D112812D013	1212031-05	ND	8	ND	368	ND, LOD = 193
SEKR0525C702S112812DX	1212032-02	1618	NA	1914	NA	1766
SEKR0525C702S112812D006	1212032-03	290	NA	633	NA	461
SEKR0525C702S112812D011	1212032-04	ND	2078	900	NA	2078
SEKR0525C702S112812D016	1212032-05	ND	8030	2223	NA	8030
SEKR0525C702S112812D020	1212032-06	ND	6873	3258	NA	6873
SEKR0525C702S112812D024	1212032-07	1165	NA	1800	NA	1483
SEKR0550C701S072612DX	1209020-02R	ND	177	218	NA	218
SEKR0550C701S072612DX	1212028-19	ND	151	415	NA	415
SEKR0550C701S072612D005	1211038-11	ND	26	502	NA	502
SEKR0550C701S072612D010	1211038-12	62	NA	ND	25	62
SEKR0550C702S112912DX	1212034-07	ND	194	585	NA	585
SEKR0550C702S112912D006	1212034-08	ND	301	647	NA	647
SEKR0550C702D112912D006	1212034-09	12	NA	1087	NA	549
SEKR0550C702S112912D011	1212034-10	ND	2621	426	NA	426
SEKR0550C702S112912D015	1212034-11	ND	10872	4216	NA	4216
SEKR0550C702S112912D019	1212034-12	ND	2113	857	NA	857
SEKR0550C703S112712DX	1212028-09	128	NA	582	NA	355
SEKR0550C703S112712D006	1212028-10	ND	768	182	NA	182
SEKR0550C703S112712D011	1212028-11	ND	1467	526	NA	526
SEKR0550C703S112712D016	1212028-12	ND	12954	2524	NA	2524
SEKR0550C703S112712D019	1212028-13	ND	5233	1225	NA	1225
SEKR0550C703S112712D022	1212028-14	ND	289	1512	NA	1512
SEKR0550C704S112812DX	1212031-06	366	NA	845	NA	605
SEKR0550C704S112812D006	1212031-07	ND	558	659	NA	659
SEKR0550C704S112812D011	1212031-08	ND	5194	1490	NA	1490
SEKR0550C704S112812D011	1212031-08D	ND	4823	1272	NA	1272
SEKR0550C704S112812D016	1212031-09	ND	12731	4314	NA	4314
SEKR0550C704S112812D020	1212031-10	ND	1700	1471	NA	1471
SEKR0550C705D112712D016	1212030-08	27	NA	ND	369	27
SEKR0550C705S112712DX	1212030-04	ND	214	55	NA	55
SEKR0550C705S112712D006	1212030-05	0	NA	128	NA	64
SEKR0550C705S112712D011	1212030-06	78	NA	80	NA	79
SEKR0550C705S112712D016	1212030-07	25	NA	ND	310	25
SEKR0550C705S112712D020	1212030-09	7	NA	ND	368	7
SEKR0550C705S112712D025	1212030-10	19	NA	ND	393	19
SEKR0550C705S112712D030	1212052-01	39	NA	ND	300	39

LOD = Limit of Detectability
ND = Nondetect
NA = Not applicable
--- = Biomarker was not detected

US EPA ARCHIVE DOCUMENT

Table 1
Line 6B Oil Concentrations in Oil Quantification Sediment Samples
Enbridge Line 6B MP 608 Marshall, MI Pipeline Release

Client ID	Lab ID	TAS2/Hopane Line 6B Oil Conc. mg/kg Sed	TAS2/Hopane Line 6B Oil LOD mg/kg Sed	TAS1/T30 Line 6B Oil Conc. mg/kg Sed	TAS1/T30 Line 6B Oil LOD mg/kg Sed	Line 6B Oil Reported Value
SEKR0575C701S072612DX	1209020-04R	ND	443	625	NA	625
SEKR0575C701S072612D007	1211038-16	ND	843	1206	NA	1206
SEKR0575C701S072612D013	1211038-17	ND	2202	461	NA	461
SEKR0575C701S072612D019	1211038-18	ND	2315	976	NA	976
SEKR0575C702S112712DX	1212028-01	ND	350	404	NA	404
SEKR0575C702S112712D006	1212028-02	ND	537	412	NA	412
SEKR0575C702S112712D011	1212028-03	ND	265	515	NA	515
SEKR0575C702S112712D016	1212028-04	ND	1686	500	NA	500
SEKR0575C702S112712D016	1212028-04D	ND	2030	480	NA	480
SEKR0575C702S112712D020	1212028-05	ND	3819	1340	NA	1340
SEKR0900C701S112912DX	1212037-02	56	NA	305	NA	181
SEKR0900C701S112912D006	1212037-03	ND	8	13	NA	13
SEKR0900C701S112912D006	1212037-03X	ND	12	ND	13	ND, LOD = 13
SEKR0900C701S112912D011	1212037-04	ND	0	ND	---	ND, LOD = 0
SEKR0900C701S112912D016	1212037-05	1	NA	9	NA	5
SEKR0900C701S112912D016	1212037-05X	ND	1	ND	---	ND, LOD = 1
SEKR0900C702D112712D011	1212028-18	ND	1514	57	NA	57
SEKR0900C702S112712DX	1212028-15	1321	NA	1038	NA	1179
SEKR0900C702S112712D006	1212028-16	24	NA	495	NA	259
SEKR0900C702S112712D011	1212028-17	ND	1669	30	NA	30
SEKR0900C702S112712D014	1212029-01	ND	984	127	NA	127
SEKR0900C702S112712D017	1212029-02	ND	120	178	NA	178
SEKR1050C701S072512DX	1209019-14	ND	147	287	NA	287
SEKR1050C701S072512D003	1211038-02	43	NA	388	NA	215
SEKR1075C701S112812DX	1212030-18	ND	33	67	NA	67
SEKR1075C701S112812D005	1212030-19	270	NA	310	NA	290
SEKR1075C701S112812D009	1212031-01	7982	NA	8574	NA	8278
SEKR1075C701S112812D014	1212052-02	261	NA	313	NA	287
SEKR1075C702S113012DX	1212038-02	2100	NA	2390	NA	2245
SEKR1075C702S113012D006	1212038-03	2858	NA	2949	NA	2903
SEKR1100C701S112912DX	1212035-17	608	NA	536	NA	572
SEKR1100C701S112912D005	1212035-18	236	NA	373	NA	304
SEKR1200C701S072512DX	1209019-13	177	NA	525	NA	351
SEKR1200C701S072512D006	1211037-18	235	NA	707	NA	471
SEKR1200C701S072512D011	1211038-01	526	NA	621	NA	574
SEKR1425C701S113012DX	1212037-15	252	NA	359	NA	306
SEKR1425C701S113012D004	1212037-16	132	NA	129	NA	130
SEKR1475C701S072612DX	1209020-11R	260	NA	299	NA	279
SEKR1475C701S072612D006	1211039-13	823	NA	1060	NA	941
SEKR1475C701S072612D011	1211039-14	1142	NA	1470	NA	1306
SEKR1475C702S072612DX	1209020-14R	920	NA	696	NA	808
SEKR1475C702S072612D004	1211039-17	ND	985	37	NA	37
SEKR1475C702S072612D007	1211039-18	ND	701	181	NA	181
SEKR1500C701S072612DX	1209020-16R	467	NA	647	NA	557
SEKR1500C701S072612D003	1211040-02	410	NA	708	NA	559
SEKR1500C701S072612D006	1211040-03	1709	NA	2258	NA	1984
SEKR1500C701S072612D009	1211040-04	791	NA	909	NA	850
SEKR1500C701S072612D013	1211040-05	ND	51	52	NA	52
SEKR1500C701S072612D028	1212052-12	70	NA	41	NA	56
SEKR1550C701S112812DX	1212033-07	746	NA	1469	NA	1107
SEKR1550C701S112812D006	1212033-08	1915	NA	2570	NA	2242
SEKR1550C701S112812D011	1212033-09	224	NA	510	NA	367
SEKR1550C701S112812D016	1212033-10	ND	137	51	NA	51
SEKR1550C701S112812D021	1212033-11	150	NA	50	NA	100
SEKR1550C701S112812D026	1212033-12	199	NA	8	NA	103
SEKR1575C701S072612DX	1208010-05	609	NA	1002	NA	805
SEKR1575C701S072612D007	1208010-06	739	NA	1043	NA	891
SEKR1575C701S072612D013	1208010-07	ND	204	347	NA	347
SEKR1575C701S072612D019	1208010-08	ND	743	186	NA	186
SEKR1575C701S072612D019	1208010-08D	ND	690	133	NA	133
SEKR1575C702S072612DX	1208010-02	684	NA	1297	NA	990
SEKR1575C702S072612D005	1208010-03	803	NA	1007	NA	905
SEKR1575C702S072612D010	1208010-04	ND	351	103	NA	103

LOD = Limit of Detectability
ND = Nondetect
NA = Not applicable
--- = Biomarker was not detected

US EPA ARCHIVE DOCUMENT

Table 1
Line 6B Oil Concentrations in Oil Quantification Sediment Samples
Enbridge Line 6B MP 608 Marshall, MI Pipeline Release

Client ID	Lab ID	TAS2/Hopane Line 6B Oil Conc. mg/kg Sed	TAS2/Hopane Line 6B Oil LOD mg/kg Sed	TAS1/T30 Line 6B Oil Conc. mg/kg Sed	TAS1/T30 Line 6B Oil LOD mg/kg Sed	Line 6B Oil Reported Value
SEKR1575C703S112812DX	1212031-15	52	NA	68	NA	60
SEKR1575C703S112812D006	1212031-16	29	NA	27	NA	28
SEKR1575C703S112812D012	1212031-17	20	NA	28	NA	24
SEKR1575C703S112812D022	1212052-04	104	NA	ND	86	104
SEKR1850C701S072412DX	1209019-03	111	NA	51	NA	81
SEKR1850C701S072412D003	1211037-05	104	NA	52	NA	78
SEKR1875C701S072512DX	1209019-11	88	NA	21	NA	54
SEKR1875C701S072512D003	1211037-15	103	NA	44	NA	74
SEKR1900C701S072512DX	1208009-05	159	NA	49	NA	104
SEKR1900C701S072512D005	1208009-06	164	NA	69	NA	117
SEKR1900C701S072512D005	1208009-06D	115	NA	33	NA	74
SEKR1900C701S072512D009	1208009-07	ND	72	ND	21	ND, LOD = 47
SEKR1950C701S072412DX	1209019-04	ND	15	ND	550	ND, LOD = 283
SEKR1950C701S072412D006	1211037-06	ND	164	ND	180	ND, LOD = 172
SEKR2000C701S072412DX	1209019-02	37	NA	ND	152	37
SEKR2000C701S072412D005	1211037-02	ND	233	ND	479	ND, LOD = 356
SEKR2000C701S072412D010	1211037-03	ND	691	ND	877	ND, LOD = 818
SEKR2000C701S072412D010	1211037-03D	ND	908	ND	796	ND, LOD = 818
SEKR2000C701S072412D014	1211037-04	ND	551	ND	201	ND, LOD = 376
SEKR2000C701S072412D020	1212052-08	ND	1509	1623	NA	1623
SEKR2000C701S072412D023	1212052-09	ND	353	1856	NA	1856
SEKR2000C702S072512DX	1209019-09	85	NA	ND	791	85
SEKR2000C702S072512D002	1211037-13	21	NA	ND	267	21
SEKR2025C701S072412DX	1209019-01	290	NA	ND	67	290
SEKR2025C701S072412D007	1211037-01	45	NA	ND	586	45
SEKR2025C702S072412DX	1208009-01	1302	NA	382	NA	842
SEKR2025C702S072412D005	1208009-02	ND	125	ND	559	ND, LOD = 342
SEKR2025C703S072412DX	1209019-05	ND	25	ND	426	ND, LOD = 226
SEKR2025C703S072412D004	1211037-07	100	NA	ND	193	100
SEKR2125C701S072412DX	1209019-06	569	NA	583	NA	576
SEKR2125C701S072412D006	1211037-08	462	NA	565	NA	514
SEKR2150C701S072512DX	1209019-16	36	NA	ND	167	36
SEKR2150C701S072512D004	1211038-03	ND	210	ND	241	ND, LOD = 226
SEKR2150C701S072512D008	1211038-04	ND	182	38	NA	38
SEKR2150C702S072712DX	1209021-04	ND	1	ND	17	ND, LOD = 9
SEKR2150C702S072712D005	1211040-11	148	NA	57	NA	102
SEKR2150C702S072712D010	1211040-12	42	NA	16	NA	29
SEKR2150C702S072712D015	1211040-13	15	NA	3	NA	9
SEKR2150C703S072712DX	1209021-06	364	NA	47	NA	205
SEKR2150C703S072712D005	1211040-16	325	NA	31	NA	178
SEKR2150C704S072712DX	1209021-08	707	NA	187	NA	447
SEKR2150C704S072712D003	1211041-02	74	NA	53	NA	64
SEKR2150C704S072712D005	1211041-03	122	NA	345	NA	234
SEKR2150C704S072712D010	1211041-04	ND	101	245	NA	245
SEKR2150C705S112912DX	1212035-04	ND	148	407	NA	407
SEKR2150C705S112912D006	1212035-05	ND	71	607	NA	607
SEKR2150C705S112912D011	1212035-06	ND	204	21	NA	21
SEKR2175C701S072712DX	1209021-12	218	NA	131	NA	174
SEKR2175C701S072712D002	1211041-12	605	NA	417	NA	511
SEKR2175C701S072712D005	1211041-13	ND	6	ND	37	ND, LOD = 22
SEKR2175C701S072712D006	1211041-14X	ND	3	ND	25	ND, LOD = 14
SEKR2175C702S112912DX	1212036-06	ND	28	ND	35	ND, LOD = 23
SEKR2175C702S112912DX	1212036-06X	ND	4	ND	24	ND, LOD = 23
SEKR2175C702S112912D004	1212036-07	ND	48	ND	57	ND, LOD = 53
SEKR2175C702S112912D007	1212036-08	ND	154	ND	427	ND, LOD = 291
SEKR2200C701S072412DX	1209019-07	641	NA	271	NA	456
SEKR2200C701S072412D005	1211037-09	345	NA	349	NA	347
SEKR2200C701S072412D008	1211037-10	171	NA	194	NA	182
SEKR2275C701S072512DX	1209019-10	387	NA	311	NA	349
SEKR2275C701S072512D002	1211037-14	127	NA	77	NA	102
SEKR2300C701D113012D003	1212038-01	1203	NA	503	NA	853
SEKR2300C701S113012DX	1212037-17	1176	NA	843	NA	1009
SEKR2300C701S113012D003	1212037-18	1595	NA	1156	NA	1376

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--- = Biomarker was not detected

US EPA ARCHIVE DOCUMENT

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Line 6B Oil Concentrations in Oil Quantification Sediment Samples
Enbridge Line 6B MP 608 Marshall, MI Pipeline Release

Client ID	Lab ID	TAS2/Hopane Line 6B Oil Conc. mg/kg Sed	TAS2/Hopane Line 6B Oil LOD mg/kg Sed	TAS1/T30 Line 6B Oil Conc. mg/kg Sed	TAS1/T30 Line 6B Oil LOD mg/kg Sed	Line 6B Oil Reported Value
SEKR2400C701S072512DX	1209019-15	104	NA	ND	2	104
SEKR2475C701S072512DX	1209019-17	271	NA	ND	327	271
SEKR2475C701S072512D004	1211038-05	559	NA	422	NA	491
SEKR2475C701S072512D007	1211038-06	20	NA	ND	235	20
SEKR2525C701D112912D006	1212036-11	ND	305	ND	361	ND, LOD = 333
SEKR2525C701S112912DX	1212036-09	123	NA	ND	119	123
SEKR2525C701S112912DX	1212036-09X	119	NA	ND	238	119
SEKR2525C701S112912D006	1212036-10	ND	29	ND	76	ND, LOD = 53
SEKR2525C701S112912D012	1212036-12	ND	462	ND	86	ND, LOD = 274
SEKR2625C701S112912DX	1212035-01	357	NA	ND	69	357
SEKR2625C701S112912D006	1212035-02	621	NA	ND	17	621
SEKR2625C701S112912D011	1212035-03	ND	876	583	NA	583
SEKR2625C702S112912DX	1212036-13	713	NA	231	NA	472
SEKR2625C702S112912D005	1212036-14	802	NA	ND	476	802
SEKR2625C702S112912D010	1212036-15	ND	574	219	NA	219
SEKR2725C701S072712DX	1209021-13	ND	7	ND	10	ND, LOD = 9
SEKR2725C701S072712D007	1211041-15X	14	NA	34	NA	24
SEKR2725C701S072712D007	1211041-15XD	58	NA	43	NA	50
SEKR2750C701S112912DX	1212036-16	ND	22	ND	553	ND, LOD = 288
SEKR2750C701S112912D006	1212036-17	ND	75	ND	571	ND, LOD = 323
SEKR2750C701S112912D011	1212036-18	ND	2	ND	157	ND, LOD = 9
SEKR2750C701S112912D011	1212036-18D	9	NA	ND	95	9
SEKR2750C701S112912D016	1212037-01	136	NA	ND	---	136
SEKR2750C702S113012DX	1212037-09	ND	23	ND	919	ND, LOD = 471
SEKR2750C702S113012D005	1212037-10	3	NA	ND	77	3
SEKR2800C701S072412DX	1209019-08	1020	NA	ND	167	1020
SEKR2800C701S072412D007	1211037-11	106	NA	41	NA	73
SEKR2800C701S072412D012	1211037-12	ND	81	ND	67	ND, LOD = 74
SEKR2850C701S072412DX	1208009-03	ND	1	ND	42	ND, LOD = 22
SEKR2850C701S072412D003	1208009-04	39	NA	ND	79	39
SEKR2875C701D112812D004	1212033-05	ND	883	ND	585	ND, LOD = 734
SEKR2875C701S112812DX	1212033-03	ND	644	ND	611	ND, LOD = 628
SEKR2875C701S112812D004	1212033-04	ND	1069	ND	683	ND, LOD = 805
SEKR2875C701S112812D008	1212033-06	ND	36	ND	88	ND, LOD = 628
SEKR2875C701S112812D016	1212052-06	16	NA	ND	---	16
SEKR3075C701S072712DX	1209021-02	ND	342	ND	470	ND, LOD = 406
SEKR3075C701S072712D005	1211040-07	ND	63	191	NA	191
SEKR3075C701S072712D012	1212052-13	9	NA	170	NA	90
SEKR3075C702D112712D020	1212029-13	6	NA	5	NA	6
SEKR3075C702D112712D020	1212029-13D	ND	13	2	NA	2
SEKR3075C702S112712DX	1212029-08	7	NA	2	NA	5
SEKR3075C702S112712D006	1212029-09	8	NA	4	NA	6
SEKR3075C702S112712D011	1212029-10	38	NA	17	NA	28
SEKR3075C702S112712D016	1212029-11	17	NA	ND	29	17
SEKR3075C702S112712D020	1212029-12	32	NA	44	NA	38
SEKR3075C702S112712D025	1212029-14	ND	11	ND	2	ND, LOD = 7
SEKR3250C701S112912DX	1212033-18	9	NA	9	NA	9
SEKR3250C701S112912D006	1212033-19	2	NA	ND	0	2
SEKR3250C701S112912D010	1212034-01	11	NA	ND	---	11
SEKR3250C701S112912D014	1212034-02	7	NA	ND	---	7
SEKR3250C701S112912D014	1212034-02D	9	NA	ND	---	9
SEKR3650C701S072512DX	1208009-08	ND	131	ND	507	ND, LOD = 319
SEKR3650C701S072512D006	1208009-09	ND	267	ND	704	ND, LOD = 486
SEKR3650C701S072512D010	1208009-10	ND	212	ND	642	ND, LOD = 427
SEKR3650C701S072512D019	1212052-10	11	NA	ND	---	11
SEKR3675C701D112712D006	1212028-08	ND	1354	946	NA	946
SEKR3675C701S112712DX	1212028-06	ND	787	ND	242	ND, LOD = 515
SEKR3675C701S112712D006	1212028-07	ND	1133	212	NA	212
SEKR3700C701S112712DX	1212030-15	1032	NA	466	NA	749
SEKR3700C701S112712D005	1212030-16	94	NA	ND	55	94
SEKR3700C701S112712D008	1212030-17	ND	4	ND	140	ND, LOD = 72
SEKR3725C701S072512DX	1209019-12	ND	35	ND	203	ND, LOD = 119
SEKR3725C701S072512D007	1211037-16	48	NA	166	NA	107

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Table 1
Line 6B Oil Concentrations in Oil Quantification Sediment Samples
Enbridge Line 6B MP 608 Marshall, MI Pipeline Release

Client ID	Lab ID	TAS2/Hopane Line 6B Oil Conc. mg/kg Sed	TAS2/Hopane Line 6B Oil LOD mg/kg Sed	TAS1/T30 Line 6B Oil Conc. mg/kg Sed	TAS1/T30 Line 6B Oil LOD mg/kg Sed	Line 6B Oil Reported Value
SEKR3725C701S072512D013	1211037-17	71	NA	ND	254	71
SEKR3725C702S072712DX	1209021-11	407	NA	69	NA	238
SEKR3725C702S072712D004	1211041-09	542	NA	134	NA	338
SEKR3725C702S072712D010	1211041-10	10	NA	ND	149	10
SEKR3725C702S072712D015	1211041-11	27	NA	ND	31	27
SEKR3725C704S112812DX	1212032-18	42	NA	29	NA	36
SEKR3725C704S112812D006	1212032-19	32	NA	ND	63	32
SEKR3725C704S112812D011	1212033-01	42	NA	19	NA	30
SEKR3725C704S112812D017	1212033-02	19	NA	3	NA	11
SEKR3725C705D112812D006	1212033-15	ND	49	ND	15	ND, LOD = 32
SEKR3725C705S112812DX	1212033-13	ND	94	62	NA	62
SEKR3725C705S112812D006	1212033-14	ND	58	39	NA	39
SEKR3725C705S112812D006	1212033-14D	21	NA	28	NA	25
SEKR3725C705S112812D010	1212033-16	ND	195	ND	35	ND, LOD = 115
SEKR3725C705S112812D013	1212033-17	ND	398	209	NA	209
SEKR3725C706S112912DX	1212034-13	ND	6	7	NA	7
SEKR3725C706S112912D002	1212034-14	3	NA	13	NA	8
SEKR3725C706S112912D004	1212034-15	633	NA	571	NA	602
SEKR3725C706S112912D005	1212034-16	75	NA	63	NA	69
SEKR3725C706S112912D010	1212034-17	ND	476	ND	270	ND, LOD = 373
SEKR3725C706S112912D013	1212034-18	ND	4227	8081	NA	8081
SEKR3725C706S112912D015	1212052-07	162	NA	225	NA	193
SEKR3725C707S112712DX	1212029-15	2	NA	ND	11	2
SEKR3725C707S112712D006	1212029-16	32	NA	14	NA	23
SEKR3725C707S112712D010	1212029-17	66	NA	22	NA	44
SEKR3725C707S112712D013	1212029-18	58	NA	22	NA	40
SEKR3725C708D112912D005	1212035-09	27	NA	17	NA	22
SEKR3725C708S112912DX	1212035-07	ND	48	ND	26	ND, LOD = 37
SEKR3725C708S112912D005	1212035-08	38	NA	ND	77	38
SEKR3725C709D113012D008	1212037-14	ND	35	ND	7	ND, LOD = 21
SEKR3725C709S113012DX	1212037-11	ND	74	ND	170	ND, LOD = 122
SEKR3725C709S113012D005	1212037-12	18	NA	38	NA	28
SEKR3725C709S113012D008	1212037-13	667	NA	643	NA	655
SEKR3725C709S113012D008	1212037-13D	678	NA	584	NA	631
SEKR3750C701S072512DX	1208009-11	321	NA	ND	379	321
SEKR3750C701S072512D006	1208009-12	ND	92	ND	349	ND, LOD = 221
SEKR3750C701S072512D010	1208009-13	ND	391	ND	453	ND, LOD = 422
SEKR3750C703S112812DX	1212031-18	ND	777	ND	2827	ND, LOD = 1802
SEKR3750C703S112812D007	1212031-19	ND	35	ND	22	ND, LOD = 29
SEKR3750C703S112812D012	1212038-18	12	NA	2	NA	7
SEKR3750C703D112812D012	1212032-01	0	NA	2	NA	1
SEKR3750C703S112812D022	1212052-05	5	NA	ND	---	5
SEKR3750C703S112812D022	1212052-05D	5	NA	ND	---	5
SEKR3750C704S112712DX	1212029-03	1058	NA	480	NA	769
SEKR3750C704S112712D006	1212029-04	259	NA	33	NA	146
SEKR3750C705S112812DX	1212032-13	437	NA	504	NA	471
SEKR3750C705S112812D006	1212032-14	ND	611	2955	NA	2955
SEKR3750C705D112812D006	1212032-15	ND	572	3125	NA	3125
SEKR3750C705S112812D011	1212032-16	ND	579	5000	NA	5000
SEKR3750C705S112812D016	1212032-17	ND	55	1632	NA	1632
SEKR3750C706D112912D009	1212036-04	260	NA	135	NA	198
SEKR3750C706S112912DX	1212036-01	ND	259	ND	251	ND, LOD = 255
SEKR3750C706S112912D006	1212036-02	ND	101	ND	279	ND, LOD = 190
SEKR3750C706S112912D009	1212036-03	ND	296	ND	365	ND, LOD = 331
SEKR3750C706S112912D012	1212036-05	ND	360	2246	NA	2246
SEKR3750C707D112812D006	1212030-13	153	NA	ND	40	153
SEKR3750C707S112812DX	1212030-11	175	NA	98	NA	137
SEKR3750C707S112812D006	1212030-12	221	NA	79	NA	150
SEKR3750C707S112812D010	1212030-14	ND	995	ND	315	ND, LOD = 655
SEKR3750C708D112912D011	1212035-13	ND	13	ND	5	ND, LOD = 9
SEKR3750C708S112912DX	1212035-10	355	NA	138	NA	247
SEKR3750C708S112912D006	1212035-11	57	NA	ND	35	57
SEKR3750C708S112912D011	1212035-12	ND	8	ND	30	ND, LOD = 20

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Table 1
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Enbridge Line 6B MP 608 Marshall, MI Pipeline Release

Client ID	Lab ID	TAS2/Hopane Line 6B Oil Conc. mg/kg Sed	TAS2/Hopane Line 6B Oil LOD mg/kg Sed	TAS1/T30 Line 6B Oil Conc. mg/kg Sed	TAS1/T30 Line 6B Oil LOD mg/kg Sed	Line 6B Oil Reported Value
SEKR3750C708S112912D011	1212035-12D	ND	7	ND	35	ND, LOD = 20
SEKR3750C708S112912D016	1212035-14	16	NA	ND	---	16
SEKR3750C708S112912D021	1212035-15	16	NA	ND	6	16
SEKR3750C708S112912D026	1212035-16	20	NA	ND	41	20
SEKR3750C709D112712D006	1212030-02	318	NA	398	NA	358
SEKR3750C709S112712DX	1212029-19	ND	88	ND	38	ND, LOD = 63
SEKR3750C709S112712D006	1212030-01	259	NA	166	NA	213
SEKR3750C709D112712D006	1212030-02D	308	NA	528	NA	418
SEKR3750C709S112712D011	1212030-03	49	NA	22	NA	36
SEKR3750C710S112812DX	1212037-06	165	NA	32	NA	98
SEKR3750C710S112812D005	1212037-07	250	NA	262	NA	256
SEKR3750C710S112812D008	1212037-08	584	NA	452	NA	518
SEKR3775C701S072712DX	1209021-14	ND	263	159	NA	159
SEKR3775C701S072712D006	1211041-16	527	NA	561	NA	544
SEKR3775C701S072712D007	1211041-17	ND	597	ND	305	ND, LOD = 451
SEKR3775C702S072712DX	1208010-16	151	NA	219	NA	185
SEKR3775C702S072712D005	1208010-17	608	NA	362	NA	485
SEKR3775C702S072712D009	1208010-18	ND	158	ND	311	ND, LOD = 235
SEKR3775C703D112812D006	1212032-10	261	NA	ND	384	261
SEKR3775C703D112812D006	1212032-10D	79	NA	ND	193	79
SEKR3775C703S112812DX	1212032-08	ND	13	ND	195	ND, LOD = 104
SEKR3775C703S112812D006	1212032-09	ND	47	ND	391	ND, LOD = 219
SEKR3775C703S112812D011	1212032-11	ND	960	ND	34	ND, LOD = 497
SEKR3775C703S112812D015	1212032-12	ND	332	135	NA	135
SEKR3775C704S112712DX	1212029-05	954	NA	890	NA	922
SEKR3775C704S112712D007	1212029-06	10	NA	ND	53	10
SEKR3775C704S112712D012	1212029-07	17	NA	ND	37	17
SEKR3800C701S072612DX	1209020-10R	41	NA	265	NA	153
SEKR3800C701S072612D003	1211039-12	ND	93	320	NA	320
SEKR3800C702D072612DX	1209020-13R	3963	NA	2615	NA	3289
SEKR3800C702S072612DX	1209020-12R	5611	NA	2689	NA	4150
SEKR3800C702S072612D005	1211039-15	ND	59	ND	608	ND, LOD = 334
SEKR3800C702S072612D009	1211039-16	ND	432	ND	588	ND, LOD = 510
SEKR3800C703S072612DX	1209020-15R	76	NA	569	NA	323
SEKR3800C703S072612D007	1211040-01	ND	432	444	NA	444
SEKR3800C704S072712DX	1209021-01	ND	531	89	NA	89
SEKR3800C704S072712D006	1211040-06	ND	654	ND	247	ND, LOD = 451
SEKR3800C705S072712DX	1209021-05	449	NA	459	NA	454
SEKR3800C705S072712D002	1211040-14	105	NA	103	NA	104
SEKR3800C705S072712D004	1211040-15	ND	46	ND	21	ND, LOD = 34
SEKR3800C706S072712DX	1209021-09	37	NA	79	NA	58
SEKR3800C706S072712D004	1211041-05	51	NA	31	NA	41
SEKR3800C707S072712DX	1208010-09	258	NA	113	NA	186
SEKR3800C707S072712D004	1208010-10	ND	95	53	NA	53
SEKR3800C707S072712D009	1208010-11	ND	606	ND	218	ND, LOD = 412
SEKR3800C707S072712D014	1208010-12	ND	956	2545	NA	2545
SEKR3800C708S072712DX	1209021-10	ND	1614	624	NA	624
SEKR3800C708S072712D005	1211041-06	ND	1482	625	NA	625
SEKR3800C708S072712D005	1211041-06D	ND	1526	312	NA	312
SEKR3800C708S072712D010	1211041-07	ND	2096	821	NA	821
SEKR3800C708S072712D014	1211041-08	ND	1960	691	NA	691
SEKR3800C709S072712DX	1208010-13	ND	169	ND	237	ND, LOD = 203
SEKR3800C709S072712D006	1208010-14	ND	265	ND	203	ND, LOD = 234
SEKR3800C709S072712D011	1208010-15	ND	671	ND	151	ND, LOD = 411
SEKR3825C701S072712DX	1209021-07	ND	348	ND	7	ND, LOD = 178
SEKR3825C701S072712D003	1211040-17	ND	701	ND	222	ND, LOD = 462
SEKR3825C701S072712D009	1211040-18	ND	1068	ND	384	ND, LOD = 726
SEKR3825C701S072712D015	1211041-01	ND	3451	1867	NA	1867
SEKR3850C701S072612DX	1209020-01R	ND	976	ND	389	ND, LOD = 683
SEKR3850C701S072612D007	1211038-09	ND	1562	ND	693	ND, LOD = 1128
SEKR3850C701S072612D013	1211038-10	ND	4450	1793	NA	1793
SEKR3850C702S072612DX	1209020-05R	ND	382	ND	359	ND, LOD = 371
SEKR3850C702S072612D006	1211039-01	ND	875	ND	656	ND, LOD = 766

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Enbridge Line 6B MP 608 Marshall, MI Pipeline Release

Client ID	Lab ID	TAS2/Hopane Line 6B Oil Conc. mg/kg Sed	TAS2/Hopane Line 6B Oil LOD mg/kg Sed	TAS1/T30 Line 6B Oil Conc. mg/kg Sed	TAS1/T30 Line 6B Oil LOD mg/kg Sed	Line 6B Oil Reported Value
SEKR3850C702S072612D010	1211039-02	ND	262	116	NA	116
SEKR3850C702S072612D010	1211039-02D	ND	275	77	NA	77
SEKR3850C703S072712DX	1209021-03	ND	943	ND	382	ND, LOD = 663
SEKR3850C703S072712D002	1211040-08	ND	1046	ND	480	ND, LOD = 763
SEKR3850C703S072712D005	1211040-09	ND	1020	ND	687	ND, LOD = 911
SEKR3850C703S072712D005	1211040-09D	ND	1230	ND	730	ND, LOD = 911
SEKR3850C703S072712D009	1211040-10	ND	1344	ND	555	ND, LOD = 950
SEKR3850C703S072712D015	1212052-14	ND	313	ND	691	ND, LOD = 502
SEKR3875C701S072612DX	1209020-03R	ND	1128	ND	516	ND, LOD = 822
SEKR3875C701S072612D006	1211038-13	ND	2193	ND	922	ND, LOD = 1583
SEKR3875C701S072612D006	1211038-13D	ND	2439	ND	776	ND, LOD = 1583
SEKR3875C701S072612D012	1211038-14	ND	4028	347	NA	347
SEKR3875C701S072612D017	1211038-15	ND	2081	2169	NA	2169
SEKR3925C701S072612DX	1209020-08R	ND	955	ND	575	ND, LOD = 765
SEKR3925C701S072612D006	1211039-08	ND	826	ND	371	ND, LOD = 599
SEKR3950C701S072612DX	1208009-16	ND	1344	ND	1264	ND, LOD = 1304
SEKR3950C701S072612D007	1208009-17	ND	2402	ND	1443	ND, LOD = 1923
SEKR3950C701S072612D013	1208010-01	ND	4578	776	NA	776
SEKR3975C701S072612D005	1211039-05	ND	1224	ND	645	ND, LOD = 935
SEKR3975C701S072612D010	1211039-06	ND	2052	ND	679	ND, LOD = 1366
SEKR3975C701S072612D015	1211039-07	ND	4879	820	NA	820

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Appendix 7

User's Guide for SOVQ Spreadsheet

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SOVQ Calculator Spreadsheet Users Guide, version 1.0 (Feb. 27, 2013)

Abstract

Introduction

An Excel™ spreadsheet calculator tool developed to support a technically defensible estimate of the residual volume of spilled and now submerged heavy crude oil in the Kalamazoo River is documented herein. This tool automates much data processing and several calculations to hopefully minimize the opportunity for data entry or transcription errors; applies estimates of uncertainty for each of the factors involved in the calculation of oil quantity, and calculates a combined, propagated uncertainty. It does not handle estimation of imputed values for left-censored data on the oil concentration in bed sediment, instead presuming that the user will have used external statistical analysis software to develop and apply any such substitute values, if desired, to the input data entered into the SOVQ spreadsheet tool.

Background

U.S. EPA directed Enbridge Energy to collect and analyze sediment cores to develop an estimate of the quantity of submerged Line-6B oil remaining in the Kalamazoo River following the July 2010 rupture and spill of heavy, bitumen-based crude oil from its Line 6B pipeline near Marshall, Michigan. Samples of streambed sediment were collected, processed, and analyzed using forensic chemistry approaches in accordance with work plans and analytical QA plans developed during winter to spring 2012 (Enbridge Energy, 2011; U.S. EPA, 2012). Samples collected during July to August 2012 were allocated among 9 targeted geomorphic environments and at least 2 submerged-oil intensity categories per geomorphic environment. This 2-way system of stratifying the study area was developed with the aim of estimating the residual submerged-oil quantity for each individual stratum in the system, along with the uncertainty associated with each estimated quantity.

Subsequently, when it was apparent that the previously existing quantification calculator tool developed for estimates based on sampling completed in 2011 was not adequate for either the finely stratified design or the more rigorous analysis of uncertainty expected in 2012, a new spreadsheet calculator was developed specifically for the summer 2012 submerged oil volume quantification (SOVQ)

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study, under the overall direction of the Federal On-Scene Coordinator (FOSC) and his staff at the Incident Command Post, Marshall, Michigan.

Purpose

The goal was for the SOVQ spreadsheet tool to produce sound estimates of the residual submerged oil volume for each sampling stratum, based on a limited number of samples consisting of finite vertical intervals along each core collected using a stratified-random areal survey design. The soundness of estimates depends on a number of factors, many beyond control of the data analyst, not least of which is an adequate number of cores and samples per sampling stratum. One feature of this calculator, that was present as well in the earlier spreadsheet calculator used with 2011 sediment core samples, is the use of multiple vertical intervals as a sampled-depth standardization approach for the typical instance where sediment samples from different cores seldom come from the identical depth interval. Because the immediate purpose of the calculator was to support quantification of the summer 2012 residual submerged oil based on the specifics of the study design and sampling plan developed for summer 2012 at the Kalamazoo River study area, the limited attempts to build in general applicability are not likely adequate to give this tool broad applicability, as is, to other studies with contrasting designs and sampling plans.

Methods

At the foundation of the volume quantification method are (1) the set of factors identified as affecting the volumetric quantity of submerged oil in a volume of bottom material or bed sediment, and (2) the mathematical relation between these factors and the resulting oil volume. These remain conceptually very similar to those from the 2011 spreadsheet and as reported in Enbridge Energy (2012).

- Concentration of oil in sediment, which for the primary calculation is referring to the forensic-chemistry determined concentration of Line 6B oil only, as distinguished from other hydrocarbons present in the sediment. The Line 6B oil concentrations were reported to the oil-volume data analyst as resulting from two independent lines of evidence from forensic analysis of laboratory analytical chemistry results. Although details of the forensic and analytical chemistry methods are beyond the scope of this manual, the interested reader is referred to (NewFields, written commun., 2013).

- Dry bulk density of sediment. An estimate of the bulk density of dry sediment is needed for determination of the mass of sediment within a sampled volume, or within a sampling stratum as a whole. Sample volume is readily determined from a core interval's physical dimensions. Similarly, if

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the depth of investigation is known and the areal extent of a sampling stratum is known or calculated, then the sediment volume is a straightforward calculation. But sediment concentrations are reported in mass-per-unit-mass dimensions, so the mass density of bulk sediment is needed to allow those concentrations to be applied volumetrically.

- Lateral extent of the sampling stratum. In the 2011 calculator, the lateral extent was limited to the area in which indications of submerged oil were observable on the water surface following agitation of the sediment with a hand-held pole (poling); and other areas were presumed to contain zero Line 6B oil. Having no scientific evidence that poling was a robust and unbiased method for determining the presence or absence of Line 6B oil at analytically detectable concentrations, the summer 2012 study included all areas of the Kalamazoo River between its confluence with Talmadge Creek and the Morrow Lake dam (except the concrete lined channel reach within Battle Creek, Mich.). A stratified-random sampling design produced target coring locations distributed among 34 sampling strata, each of which represents the geometric intersection of a single geomorphic environment (9 types) and a single submerged oil indications intensity category (4 poling-based classes). The lateral extent is the GIS-calculated area of each sampling stratum, which consisted of multiple discrete areal units (i.e., polygon features) in most cases.

- Vertical extent of calculation volume. The calculation volume is an artificial construct used within the calculator to provide standardization across cores within a common sampling stratum; i.e., uniform weighting of samples per discrete vertical increment for calculation of stratum-average concentrations. Such an approach (used in 2011 as well) is suitable when samples are collected from non-standardized intervals vertically along cores, in most cases. However, one standardized sampling interval was collected in 2012 as a distinct sample from each core-- the uppermost 1-inch interval.

- Bulk density of weathered oil. An estimate of the bulk density of the spilled oil at the time of sediment coring is required to convert the estimated residual quantity of Line 6B oil from mass units to volumetric units.

- Depth of investigation. Whereas in the 2011 calculator the depth of investigation was the visually determined depth of crude oil indications (sheen or globules/flecks) within the split core examined in the field, for the summer 2012 study it was determined that visual indications were not a sufficient and reliable basis for such a determination (K. Lee, written commun., 2013). Consequently, the depth of investigation was presumed, for the purposes of the SOVQ and spreadsheet development, to extend

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to such depth equal to the bottom of the deepest interval where Line 6B oil was detected at a concentration above the method detection limit (MDL).

The mathematical relation for computing submerged oil volume from these inputs was given for the 2011 calculator spreadsheet (Enbridge Energy, 2012) as

$$V_{oil_j} = C_{TPH_j}\, \rho_s\, A_j\, D_j\, K\, \rho_{oil}{}^{-1} \qquad (1),$$

where V_{oilj} is the volume of oil for sampling stratum j, C_{TPH} is the representative concentration of oil in sediment from stratum j, ρ_s is the dry bulk density of sediment, A_j is lateral extent of sampling stratum j, D_j is the depth of oil-impacted layer, ρ_{oil} is the bulk density of weathered Line 6B oil, and K is a constant used for units conversion. When actually applied, however, equation 1 was evaluated for a single vertical increment of the depth (0.1 ft), at least for calculating the representative concentration for each stratum. For the summer 2012 oil volume quantification spreadsheet, T_i is defined to be the thickness of a single vertical increment, i, of the cores, which does vary (at least at the top of the core), and there is explicit summation of the right side of the equation across all vertical increments within D_j, the depth of investigation for sampling stratum j. An additional change in the equation involves the use of forensic chemistry methods beforehand to provide a concentration, C_{L6B}, which is the oil identified to be from the Line 6B release, as distinguished from other residual background hydrocarbons. Thus, the 2012 SOVQ calculator implements as its primary calculation, for residual oil volume from Line 6B,

$$V_{L6B_j} = \sum_0^{D_j} \left(C_{L6B_{ij}}\, \rho_{s_j}\, A_j\, T_{ij}\, K\, \rho_{oil}{}^{-1} \right) \qquad (2),$$

where V_{L6Bj} is the volume of submerged Line 6B oil for vertical increment, i, and both oil concentration and increment thickness may vary by vertical increment. Other terms are as defined above. but there are some additional differences between the 2011 and 2012 spreadsheet calculators, as discussed in the following sections.

Before delving into the inner workings of the spreadsheet calculator, a brief overview of the collection of spreadsheets composing the SOVQ workbook is provided. The user will find it helpful to have a copy of the workbook open while reading the following sections of the *Users Guide*.

Overview of workbook sheets

- **Summary.** The first sheet in the workbook is the Summary sheet, in which the estimated volume and associated uncertainty interval for each sampling stratum is pulled forward from its stratum-specific sheet and tabulated together to provide overviews of the results for the entire study area (Table A-1).

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- **Uncertainty.** On this important sheet are tabulated the considered set of sources of uncertainty affecting each of the factors. Table B-1 lists the general approach to uncertainty based on consideration of the various types and number of sources of uncertainty, and then summarizes in separate cells the specific method used for each source of uncertainty, or whether it was considered a negligible source for the purposes and data quality requirements for site-wide submerged oil volume quantification. Consider variable 2 as a straightforward example, dry bulk density of sediment. Two potential sources of data were identified that could yield insight on the uncertainty of the parameter estimates. (Estimates were compiled only for each geomorphic setting, because the U.S. EPA science team assumed that this parameter's value would not vary between subareas where residual oil indications were heavy and light.) Generally, multiple cores contributed samples from each geomorphic setting, allowing variance and uncertainty to be estimated for each geomorphic setting. For the second potential source of uncertainty data, Table B-1 records that replicate analyses, if present, would support a pooled estimate of the at-a-site uncertainty per each seasonal survey (or overall); however, no split-replicate samples were collected for the Summer 2012 survey. Of note, most of the Fall 2011 core samples that were analyzed for dry bulk density passed an initial QC filter, were assessed for statistical similarity between years overall and by geomorphic setting, and then included in the combined data set for estimation of this parameter and its associated uncertainty for the 2012 SOVQ study.
- **SiteParams.** The third sheet in the workbook stores parameter values and metadata for parameters that are treated in the SOVQ calculator as invariant between sampling strata.
    - First, the replicate values for Line 6B oil concentration in replicate samples or from replicate cores, presumed to have been pooled across all sampling strata, are summarized as uncertainty results for the entire site for the summer 2012 survey (Table C-1).
    - Next, replicate values for sediment bulk density, if present, would be used to populate a similar table of uncertainty (Table C-2).
    - For uncertainty of lateral extent, research by Dunn et al. (1990) suggest that a relatively simple estimation method, by analogy to digitizing lines from maps, might be applied to the mapped boundaries of sampling strata. Linear uncertainty for GIS-based manual capture of bank lines was estimated from the DOQ resolution, likely working scale for digitizing (1:600), and feature contrast (typically tree-lined banks of Kalamazoo River), to have a RMSE of not less than 1.0 ft. Linear uncertainty of boundaries between poling point locations recorded using RTK-GPS was presumed to be a function chiefly of the average or typical spacing between poling points ($\geq$38 ft [median 35.8 ft spacing in MP 05.25 to 5.875 reach, and median 40.9 ft spacing in MP 36.5 to 37.8 reach, with mean of 39 ft for each area];

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Enbridge Energy, unpub. data, 2012). By assuming the ratio of IQR to Range would be similar to that measured for digitizing boundaries from aerials (Dunn et al., 1990), the uncertainty band width (IQR-epsilon based) was estimated to be 5.9 ft (Table C-3). Additional error attributable to effects of chosen method and parameters for interpolation algorithm was assumed to be negligible (more recent research by Leung et al. [2004] on covariance-based errors and error-propagation analysis suggests this is a generous assumption).

- The **user is urged to exercise great caution** and deliberation before changing the parameters in Table C-4-A, because any change to the discretization of the vertical interval of investigation will affect resulting calculations of mass and volume for all sampling strata. Only if there needs to be a change to this framework caused by change in core processing or sub-sampling should this be contemplated.
- Uncertainty of oil density is treated in Table C-5. The similarity of physical properties between the two products released from Line 6B, and the reported dominance of Cold Lake Blend (CLB) relative to Western Canadian Select in the released volume led to the presumed applicability of laboratory tests of changes in the bulk density of CLB with loss of evaporable fractions (SL Ross, 2010, table 3-3). Uncertainty in the estimate of weathered oil density was assumed to be limited to that caused by changes in temperature, but Enbridge Energy may have other information to justify either a wider range of uncertainty or a greater degree of weathering-caused increase in oil density.

- **StratumParams.** Parameters that vary with sampling stratum are tabulated on this sheet. Parameter values calculated using GIS spatial analyses include mapped stratum area, sum of mapped polygon perimeters (2 types), and calculated uncertainty estimate for area (lateral extent). Parameter values calculated using results from statistical methods include:
    - Dry bulk density of sediment cores [generally the uppermost 0.5 ft], from which geomorphic setting-specific mean densities were calculated using log-transformed data, but then back-transformed using minimum-variance unbiased estimation (MVUE) methods. Two types of MVUE were applied—a parametric method, as implemented in Excel (ln_mvue.xls); and a nonparametric method, as implemented in S-plus (predictMVUE function). The parametric method uses stratum-specific variance, but can produce confidence intervals extending into negative values. The nonparametric method uses pooled variance (pooled across all strata), but avoids negative values in the confidence intervals.

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- Covariance between concentrations of Line 6B oil and dry bulk density, and between concentrations of total oil and dry bulk density. The correlation coefficient values will be determined once the complete set of analytical and forensic chemistry results have been received.

- **CoreParams.** Values for all collected sediment cores for the summer 2012 SOVQ study are stored on this sheet. Users should review this sheet to ensure that correct values are listed for number of cores collected and number of samples submitted.
- **SampleParams**. The column (W) with heading, "Depth at bottom of interval" contains the only data the user is likely to need to edit. An attempt was made to populate this column automatically by extracting this depth value from the sample Field ID (col. D), but the user should verify the accuracy of the depth values.
- **Concentrations.** As indicated by the dark gray-shaded columns versus non-shaded column of cells on this spreadsheet, the only column which the user needs to alter is where the final concentration of Line 6B oil is entered on the row corresponding to the respective sediment-core sample.
- **Stratum (*nn*).** There will be multiple sheets of this form, one per sampling stratum, within the workbook. This form contains the calculation equations that implement the Line 6B residual submerged oil volume quantification symbolized by equation 2. More details on the contents and use of these sheets follow in later sections.

Procedural Steps

The following steps, if carefully executed in the sequence indicated, will result in a fully parameterized calculator tool. The use of lookup operations to find many of the needed parameters on the several "*cccc*Params" spreadsheets, where "*cccc*" is the respective prefix in the sheet name (appearing in the Excel workbook tabs), necessitates a careful entry of core codes (Field ID values) and sample codes (Sample ID values), as described in the *Data Input Steps*.

If the existing set of stratum-specific "Stratum (*nn*)" sheets, is not sufficient to the user requirements, first use the "Move or Copy Sheet" option on the sheet-tab menu (right mouse-button) to insert another sheet that is a copy. Then enter the sampling stratum name in cell "C1" being careful to match exactly the naming as given on the StratumParams (col. A) or CoreParams (col. C) sheets. (Suggestion: copy the desired stratum name from either one of those sheets and paste it into cell "C1" of the target sheet.)

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Parameter Input Steps

The SOVQ calculator's Set-up Parameters Block displays the set-up parameters on each sampling stratum's respective "Stratum (*nn*)" sheet, in the block of cells from Z4 to AM20. No data values should need to be entered in this block. The user may wish to review the values for the respective stratum to gain insight on the calculations of oil volume and associated uncertainty for the particular stratum being processed on this sheet. If the standard deviation (std. dev.) for any of the variables is shown as zero, that would indicate that parameter values are missing or incorrectly entered on either the StratumParams or SiteParams sheets.

Additional abbreviations used in the Set-up Parameters Block are as follow: no., number; coeff., coefficient; C.oil, concentration of oil; DBD.sed, dry bulk density of sediment; QC, quality control; RPD, relative percent difference; mg, milligram; g, gram; kg; kilogram; cm3, cubic centimeter; ha, hectare; ft, feet; Low 95%CL, lower limit of 95%- confidence interval; Upp 95%CL, upper limit of 95%-confidence interval; conf., confidence; sub oil, submerged oil; GIS, geographic information system; .M., missing value; NA, not analyzed.

Data Input Steps

There is one area for data input located on each "Stratum (*nn*)" sheet—the "Cores and Samples Input Block"—which extends from cell B4 to cell X48. The other data input block is located on the Concentrations sheet and is located in column L. As such, the oil concentration results need to be entered only on the one sheet, whereas cores and samples identities must be input on each "Stratum (*nn*)" sheet in the workbook. Cells where the user enters data are not shaded (except for cell C1 on each "Stratum (*nn*)" sheet). The user should not need to enter data in cells shaded dark gray or black, many of which will display values from lookup operations or calculated values.

1. On each "Stratum (*nn*)" sheet—Input the core identifiers of all cores collected for the single sampling stratum indicated in cell C1. Enter one core identifier per cell in row 8 (columns E to N) using the "Site ID" from the stratified sampling survey design (i.e., site identifiers start with "STRATIFIED-"). It is **important** that the input cell contents **matches** one of the cells in Column A on sheet **CoreParams**, so it is suggested that the user copy the value of "Site ID" for the applicable core of interest from the CoreParams sheet.

Although no more than five (5) cores were planned for collection from any of the sampling strata, some collapsing of strata is likely to occur to have adequate sample sizes for computing variability and

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uncertainty of the SOV estimates for all groupings in a final report. The spreadsheet allows up to 10 cores to be input on each "Stratum (*nn*)" sheet. Once a value is input in one of the cells in Row 8, a lookup function finds the corresponding "Location ID" value for the core and displays it in Row 7.

2. On each "Stratum (*nn*)" sheet—Input the sample identifiers of all primary samples collected from each core collected for the single sampling stratum indicated in cell C1. Sample identifiers (Field ID) **must match** the Column D value of its corresponding row listed in the **SampleParams** sheet. Proceed core by core in Columns O through X (as needed), where the core identifiers you entered in step 1 will now already appear in header Rows 7 and 8. For each core, enter the unique sample identifier code for each sample in vertical sequence down the core, beginning with shallowest sample in Row 9, next shallowest in Row 12, next in Row 15, and so on, until you enter the identifier for the deepest sample collected for that core.

Once a sample identifier is entered in Columns O to X, a lookup operation will find the depth of the base of the vertical interval of this sample, in the **SampleParams** sheet, and copy it to the corresponding column of the "Sampled INTERVALS" area (columns E to N). From those values, the thickness of the sampled vertical interval is calculated and also displayed in the "Sampled INTERVALS" area.

3. On the "Concentrations" sheet—Input the concentrations of Line 6B oil in Column L, for each sampled interval from each core collected for the SOVQ study. Ensure that sample identifiers (Field ID) **must match** between the Column D value and the data transmission row in the source document or file providing the concentration results.

If the user has decided to use an average concentration value from each pair of replicates, that substitution of the average value in place of the reported value for the primary sample needs to occur by the time of concentration data input. (That is, the SOVQ calculator was not programmed to recognize replicate pairs or to apply any special operations for them.) Similarly, the handling of censored values must occur outside the SOVQ calculator tool. Whatever estimation or substitution approach is selected (preferably one that is based on recent findings and recommendations from applicable scientific studies; e.g., Helsel [2005]), its application to the data set must have occurred by the time of concentration data input. Note as well that the units of concentration values must be milligrams of oil per kilogram of sediment, as dry sediment.

The layout of Columns C through V of the **Concentrations** sheet mimics that of the spreadsheet used for sample tracking. This was a QA device to ensure (hopefully) that all samples collected were

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represented in the Concentrations spreadsheet. Similarly, the **SampleParams** sheet, columns C to V, mimics the tracking spreadsheet . If the version of the tracking spreadsheet used turns out to be incomplete, it should be straightforward to replace the contents of columns C to V in both affected sheets of the SOVQ calculator workbook (but taking care to preserve column L in Concentrations sheet, if practical). Note that the version of the sample tracking spreadsheet was stored in cell Y3 of both the Concentrations sheet and SampleParams sheet.

Once the Concentrations sheet and other Data Input steps are complete, the SOVQ calculator's "Depth-Interval Concentrations Block" will have all needed information, and should now be displaying on the corresponding "Stratum (*nn*)" sheet the final oil concentration values for each vertical discretization interval of the core(s) identified in Columns I to J. Line 6B oil concentrations will be listed in Columns N to N. The displayed values result from a lookup procedure that requires a match of the sample identifier and a check that the sample's base of sampled interval equals or exceeds the discretization-interval's midpoint depth.

Calculation Outputs

There are two areas where calculated output values are located on each "Stratum (*nn*)" sheet—the "SOVQ Calculation Outputs Block for Line 6B Oil"—which extends from cell Z50 to cell AI101; and the "SOVQ Univariate Uncertainty Calculation Outputs Block"—which extends from cell AK47 to BB101. On each "Stratum (*nn*)" sheet in the workbook, the user may review the calculation results for SOVQ for each discrete vertical interval. <u>No further data inputs are needed in these output blocks.</u> The user will note that sampling-stratum totals are displayed in selected cells of Row 101, with the key results highlighted in yellow cells.

1. Turning first to the columns of the output block for Line 6B oil, Column Z contains the oil concentration determined to represent the indicated sampling stratum at the indicated discretization interval. As long as at least one core has a numeric concentration (i.e., in columns E to N) for the indicated discretization interval, the calculator reports a result. Column AA displays the number of cores having a numeric concentration value for the indicated discretization interval. Column AB displays the mass of sediment for the indicated discretization interval and sampling stratum, as the product of thickness of the interval, areal extent of the sampling stratum, and dry bulk density of the sediment. Column AC displays the mass of Line 6B oil for the indicated discretization interval and sampling stratum, as the product of the representative oil concentration (from column Z) and the mass of sediment (from column AB). Column AD converts the oil mass into volumetric units by dividing

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the mass by the estimated bulk density of weathered product released from Line 6B. Before summing the oil volume across all vertical discretization intervals, a weight stored in column AF is applied to represent the depth of investigation, which as the average for multiple cores, typically does not match the deepest depth of investigation; that is, a single core from this sampling stratum might cause an oil mass/volume result to be displayed (in columns AC, AD) for discrete intervals deeper than the average depth of investigation. Column AH stores the results from applying the weights in column AF, and the sampling-stratum total volume of Line 6B oil is displayed in cell AH101. The uncertainty of this submerged-oil volume estimate is indicate by the confidence interval limits displayed in columns AG and AI; its determination is discussed later in this section.

2. In the columns of the outputs block for univariate uncertainty calculations, there are four subsections corresponding to uncertainties for separate factors involved in the SOVQ calculation.

    a. The uncertainty of the lateral extent (i.e., stratum areal extent) is indicated in columns AK and AL. As indicated, there is no data to support varying the lateral extent for different depths below the sediment surface. The effect of the estimated amount of uncertainty in the lateral extent of this sampling stratum, with other uncertainties held constant at zero, is indicated by the values in Row 101 of these two columns.

    b. The uncertainty of the vertical extent (i.e., depth of investigation) is indicated in columns AQ and AR. As summarized in cells AC18 to AF19 , and implemented in columns AO and AP, the data to support uncertainty of the vertical extent come from multiple cores per sampling stratum, and was applied in a univariate assessment by adjusting the weights for inclusion or exclusion of the different discretization intervals below the sediment surface. The effect of the estimated amount of uncertainty in the vertical extent for this sampling stratum, with other uncertainties held constant at zero, is indicated by the values in cells AQ101 and AR101. In addition, **this source of uncertainty is not reflected in the combined uncertainty interval** (cells AG101 and AI101), because for oil volumes calculated using the discrete vertical intervals approach, the thickness of each interval is known with certainty.

    c. The uncertainty of the Line 6B residual submerged oil concentration is indicated in columns AV to AY. As indicated by column headings, standard deviations among concentrations from multiple cores per sampling stratum support the estimation of uncertainty in the concentration at different depths below the sediment surface. Column

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AV lists the standard error-based uncertainty (one-half the 95%-confidence interval); columns AW and AX list the confidence limits for oil concentration; and in column AY the confidence interval of concentration is converted to the corresponding volume of oil. The effect of the indicated amount of uncertainty in the Line 6B oil concentration on the estimated volume of Line 6B oil for this sampling stratum, with other uncertainties held constant at zero, is indicated by the value in cell AY101.

d. The uncertainty of the dry bulk density of sediment is indicated in columns BA and BB. As indicated, there is no data to support varying the bulk density for different depths below the sediment surface. The effect of the estimated amount of uncertainty in the dry bulk density of sediment for this sampling stratum, with other uncertainties held constant at zero, is indicated by the values in Row 101 of these two columns.

Having explained the calculation of the oil volume estimates for submerged residual oil from the Line 6B release, and having explained estimates of the uncertainty in four of the factors contributing to those estimates, we now return to the calculation of a combined uncertainty of each submerged-oil volume estimate. The results of a combined uncertainty calculation are displayed in columns AG and AI. As indicated in the previous section, the particular approach taken to its determination is less than comprehensive, in that variability in the sampling stratum-level estimate for depth of investigation is neglected. In brief, the general approach taken was to estimate combined uncertainty for the oil-volume calculation for each discrete vertical interval (equation 1) using a modification of the simplified general formula for error propagation in x (where x is the product of u and v) by combining the relative variance in x^2, defined as

$$\frac{\sigma_x^2}{x^2} \qquad (3),$$

that is, the variance relative to the squared measured value of the variable. Many readers will recognize this expression (3) as the square of the coefficient of variation (CV). The general formula (Daley, 2009) is

$$\frac{\sigma_x^2}{x^2} = \frac{\sigma_u^2}{u^2} + \frac{\sigma_v^2}{v^2} + \cdots \frac{\sigma_n^2}{n^2} \qquad (4).$$

Thus, the relative variance in x^2 is the sum of the relative variances in each factor, u, v, etc. Now, a modification of this general approach is needed when covariance between the errors is not negligible. In the case of the present SOVQ study, results from 2011 for TPH concentrations and dry bulk density of sediment give cause to expect that correlation between the 2012 forensically determined oil

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concentrations and dry bulk densities will be significant. In this case, the propagation of uncertainty for x will include an additional term into what equation 4 showed, to become

$$\frac{\sigma_x^2}{x^2} = \frac{\sigma_u^2}{u^2} + \frac{\sigma_v^2}{v^2} + 2\frac{\sigma_u \sigma_v}{u \cdot v}\rho_{uv} + \cdots \frac{\sigma_n^2}{n^2} \qquad (5),$$

where ρ_{uv} is the correlation coefficient for the relation between u and v. This approach was implemented to calculate the values given in rows 53 to 100 of columns AG and AI.

What remains to explain is the method used to "sum up" the combined uncertainty across the multiple vertical discretization intervals. The uncertainties are not independent but spatially autocorrelated in the vertical dimension. Therefore, the relative variance results from applying equation 5 to each vertical interval (stored in column AE) were combined as a weighted mean of the relative variance, where the discrete-interval thicknesses were the weights. Finally, the weighted-mean relative variance is applied to the sampling-stratum estimate of oil volume (AH101) to calculate the confidence interval (cells AG101 and AI101) for the oil volume estimate at the sampling-stratum level.

Summary

This guide pertains to a calculator tool developed to support a technically defensible estimate of the residual volume of spilled and now submerged Line 6B crude oil in the Kalamazoo River. The scope of the data analysis task comprised four parts: (1) apply, to the extent practical, the concepts embodied in Enbridge Energy's previous oil-quantification spreadsheet tool (i.e., general factors included in the equation for volume estimation; form of equation; spatially stratified analysis; and use of discrete vertical intervals to standardize treatment of samples across cores within a sampling stratum); (2) determine Line 6B oil concentrations by applying forensic analysis methods (NewFields, this volume) to the analytical chemistry results that distinguish Line 6B oil from other residual hydrocarbons; (3) estimate a representative oil concentration for each sampling stratum and discrete vertical interval by applying statistical techniques developed specifically to properly handle censored data (cf. Helsel, 2005); (4) develop and apply the SOVQ calculation tool, described herein, to estimate the oil volume and 95-percent-confidence interval, or equivalent measure of uncertainty, for the Line 6B oil volume estimates at the sampling-stratum level, that takes into account the combined uncertainties of each factor in the equation used for volume estimation.

Procedures for implementing the sub-tasks were developed consistent with the study design and Summer 2012 sampling plan (U.S. EPA, this volume). Depending on the data analyst's objectives, either the *a priori* allocation of samples among 9 targeted geomorphic environments and at least 2 submerged-oil intensity categories per geomorphic environment were applied to produce estimates for 34 sampling strata, or strata were collapsed (combining the heavy/moderate oil-intensity categories and/or the light/none oil-intensity categories for selected geomorphic environment types, where needed), to achieve statistical analysis requirements for larger sample sizes.

To calculate Line 6B oil volume per discrete vertical interval at the sampling-stratum level, the SOVQ tool requires inputs for a representative value (and uncertainty) for each of the following factors or terms in the volume equation: (1) Line 6B oil concentration per sampled vertical interval; (2) dry bulk density

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of sediment; (3) lateral extent of the sampling stratum; (4) vertical extent, or depth of investigation, to define the sediment volume to which representative oil concentration applies; and (5) the bulk density of the spilled oil at the time of sediment coring to support conversion of estimated mass of oil to volumetric units. Whereas in the 2011 calculator the depth of investigation was the visually determined depth of crude oil indications (sheen or globules) within examined split cores, for the Summer 2012 study, the core-specific depth of investigation extends to a depth equal to the bottom of the deepest interval where Line 6B oil was detected and quantified.

For the summer 2012 oil volume quantification spreadsheet, T_i is defined to be the thickness of a single vertical increment, i, of the cores, which does vary (at least at the top of the core), and there is explicit summation of the right side of the equation across all vertical increments within D_j, the depth of investigation for sampling stratum j. The additional change in the equation involves the use of forensic chemistry methods beforehand to provide the concentration, C_{L6B}, of the oil identified to be from the Line 6B release. Thus, the 2012 calculator implements as its primary calculation of oil volume:

$$V_{L6B_j} = \sum_0^{D_j} \left(C_{L6B_{ij}} \, \rho_{s_j} \, A_j \, T_{ij} \, K \, \rho_{oil}{}^{-1} \right) \qquad (1),$$

where V_{L6B_j} is the volume of submerged Line 6B oil for vertical increment i, A is planimetric area of sampling stratum j, K is a constant for units conversion, and other symbols are as defined above or in Enbridge Energy (2011). Range of uncertainty was estimated analytically in the spreadsheet calculator using linear combination of relative variance, but alternatively can be estimated using error propagation analysis by simulation (Monte Carlo methods). Uncertainty estimation also can take into account covariance between concentrations of Line 6B oil and other factors (e.g., dry bulk density) in equation 1 that are significantly correlated with oil concentration. The spreadsheet calculator implements an analytical solution for uncertainty that allows the user to enter the correlation between oil concentration and dry bulk density of sediment.

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