Enbridge Energy, Limited Partnership
Line 6B Pipeline Release, Marshall, Michigan

Case No.: 15-1411-CE

Conceptual Site Model – January 2016



Submitted: January 22, 2016

Document ID 5161

Table of Contents

FIGURES

LIST OF ACRONYMS

ABC	Aquatic Background Concentration
ac-ft	acre-feet
Amsl	above mean sea level
ASTM	American Society for Testing and Materials
Bgs	below ground surface
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CL	Cold Lake
Criteria (Criterion)	Part 201 Residential Generic Cleanup Criteria (Criterion)
CSM	Conceptual Site Model,
cSt	centistokes
DCC	Part 201 Generic Residential Direct Contact Criteria
DWC	Part 201 Generic Residential Drinking Water Criteria
DWPC	Part 201 Generic Residential Soil Drinking Water Protection Criteria
Enbridge	Enbridge Energy, Limited Partnership
Facility	Any area, place or property where a hazardous substance from the Enbridge Line 6B Marshall Release in excess of the concentrations that satisfy the cleanup criteria for unrestricted residential use has been released, deposited, disposed of, or otherwise comes to be located, as set forth at MCL 324.20101(1)(s). "Facility" does not include any area, place, or property where the conditions of MCL 324.20101(1)(s) (i)-(vi) have been satisfied.
Ft	feet
ft/mi	feet per mile
g/cm^3	grams per cubic centimeter
Groundwater White Paper	*White Paper: Evaluation of Line 6B Crude Oil PNA and VOC Related Risk to Groundwater Quality,* submitted to the MDEQ on July 24, 2014
GSIC	Part 201 Generic Residential Groundwater Surface Water Interface Criteria
GSIPC	Part 201 Generic Residential Groundwater Surface Water Interface Protection Criteria (for soils)
GVIAIC	Part 201 Generic Residential Groundwater Volatilization to Indoor Air Inhalation Criteria
HMW	High molecular weight
ITRC	Interstate Technology & Regulatory Council
Line 6B	The pipeline owned by Enbridge Energy, Limited Partnership that runs just south of Marshall, Michigan
LMW	Low molecular weight
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
MDEQ Consent Judgment	Consent Judgment so agreed by the Michigan Department of Environmental Quality, Michigan Department of Attorney General, and Enbridge Energy Partners, L.P.; Enbridge Energy, Limited Partnership; Enbridge Pipelines (Lakehead) LLC; Enbridge Energy Management LLC; Enbridge Energy Company, Inc.; and Enbridge Employee Services, Inc. ordered, adjudged, and decreed pursuant to MCL 324.1701, MCL 324.3109, MCL 324.30112, MCL 324.30316, and MCL 324.20137, signed May 13, 2015.
Metals White Paper	*White Paper: Evaluation of Metals in Soil and Groundwater*, submitted to the MDEQ on June 4, 2014.

mg/kg	milligrams per kilograms
mg/l	milligrams per liter
MGP	Manufactured Gas Plant
MP	Mile Post
NAPL	Non-Aqueous Phase Liquid
NAPL White Paper	*White Paper: Evaluation of Line 6B Crude Oil NAPL Risk based on a Weight of Evidence Approach,* submitted to the MDEQ on July 30, 2015.
NFA	No Further Action
Part 201	Part 201 of Michigan's Act 451 of 1994, as amended
Part 211	Part 211 of Michigan's Act 451 of 1994, as amended
Part 213	Part 213 of Michigan's Act 451 of 1994, as amended
Part 31	Part 31 of Michigan's Act 451 of 1994, as amended
PCBs	Polychlorinated Biphenyls
PEC	Probably Effects Concentration
PNAs	Polynuclear Aromatic Hydrocarbons
PSIC	Part 201 Generic Particulate Soil Inhalation Criteria
PSQs	Principle Study Questions
PVOCs	Petroleum Volatile Organic Compounds
R5 ESLs	Region 5 Ecological Screening Levels
RI	Remedial Investigation
RRD	Remediation and Redevelopment Division
Rule 57	Michigan Rule 323.1057
Source Area	Subset of the Spill Area that encompasses the pipeline breach and approximately 5 acres of land where the Line 6B crude oil release emerged onto the ground surface.
Spill Area	A Facility created by the Enbridge Line 6B Marshall Release and also private and public properties that have been disturbed, destroyed, dredged, excavated, or otherwise altered or damaged as a result of the release or Response Activities taken to address the release, including but not limited to vegetation, surface waters, soils, sediments, groundwater, wetlands, floodplains, and overbank areas.
SPLP	Synthetic Precipitation Leaching Procedure
SQT	Sediment Quality Triad
SSLs	Soil Screening Level
SVIAIC	Part 201 Generic Residential Soil Volatilization to Indoor Air Inhalation Criteria
tar patty	Weather surface feature consisting of solidified, Line 6B crude oil residue. Merriam-Webster dictionary defines "tar" as a dark brown or black bituminous usually odorous viscous liquid obtained by destructive distillation of organic material (as wood, coal, or peat). While it is understood that "tar" is not present as a result of the Line 6B crude oil release, the term has been commonly adopted to describe observations of solidified Line 6B crude oil in various forms.
TBC	Terrestrial Background Concentration
TEC	Threshold Effects Concentration
UBC	Urban Background Concentrations
Urban PAH White Paper	*White Paper: Urban PAH Background Evaluation*, submitted to the MDEQ on August 28, 2015.
U.S. EPA	United States Environmental Protection Agency

UV	Ultraviolet
VOCs	Volatile Organic Compounds
WCS	Western Canadian Select

1.0 INTRODUCTION

The Conceptual Site Model (CSM) presented here is a product of over 5 years of remedial and investigative activities. During the project lifespan, the CSM has evolved in accordance with information gained via the extensive data collected, research conducted, and cleanup operations completed. This document was prepared pursuant to the *Consent Judgment so agreed by the Michigan Department of Environmental Quality, Michigan Department of Attorney General, and Enbridge Energy Partners, L.P.; Enbridge Energy, Limited Partnership; Enbridge Pipelines (Lakehead) LLC; Enbridge Energy Management LLC; Enbridge Energy Company, Inc.; and Enbridge Employee Services, Inc. ordered, adjudged, and decreed pursuant to MCL 324.1701, MCL 324.3109, MCL 324.30112, MCL 324.30316, and MCL 324.20137*, signed May 13, 2015 (MDEQ Consent Judgment) (MDEQ, 2015). The opinions, findings, and conclusions expressed are those of Enbridge Energy, Limited Partnership (Enbridge) and not those of the Michigan Department of Environmental Quality (MDEQ).

This CSM is intended to provide a concise, narrative overview of the project and site conditions, such that a reader with minimal technical background and/or no experience at this site can understand the relevant site characteristics and issues. Scientific data has been presented in white paper documents, Remedial Investigation (RI) Reports, and No Further Action (NFA) Reports; which have all been submitted to the MDEQ for a comprehensive review independent from this CSM. The reader is referred to the appropriate published documents for full data disclosure and analytical details, when it is appropriate. For some topics, the definitive report(s) are still under development or yet to be developed. In this case, the reader is referred to appropriate reports that provide partial content and/or the forthcoming reports.

Statements of position and/or conceptual understanding presented in this CSM are based on the most recent data evaluations up to the date of CSM submission.

1.1 Conceptual Site Model Purpose

A CSM, as defined by United States Environmental Protection Agency (U.S. EPA) “should reflect the best interpretation of available information at any point in time.” As captured within the MDEQ document pertaining to Interstate Technology & Regulatory Council (ITRC) training, a CSM is defined as, “an evolving document that will continuously be revised as additional data is collected.” The ITRC further explains that, “The CSM should be maintained and updated as new information is collected throughout the life cycle of the project” (ITRC, 2012). The *Standard Guide for Development of Conceptual Site Models for Contaminated Sites, Contaminated Sites, E1689-95* (ASTM, 2008) has also served as guidance for CSM development. It is, and has been, Enbridge’s intent to act in accordance with these key guiding principles and documents regarding CSM development and usage. Enbridge has used the CSM to determine necessary response and investigation activities to comply with the requirements of Part 201 of Michigan’s Act 451 of 1994, as amended (Part 201).

1.2 CSM Updates and Revisions

Enbridge is submitting this CSM in accordance with the requirements set forth in the MDEQ Consent Judgment. Enbridge will provide supplements to the CSM semiannually in accordance with the MDEQ Consent Judgment. It is intended that each subsequent CSM submittal will act as a stand-alone document that will replace the previous CSM version.

1.3 Geographic Project Layout

Geographic subdivisions with specific project meaning have been established for consistency in communication. All discussion of project related events and findings (past, present, and future) make use of these geographic terms.

Section 324.20101 of Michigan’s Natural Resources and Environmental Protection Act 451 of 1994 (on-line rendering April 23. 2015, effective December 14, 2010) defines a facility as a location where hazardous substances in excess of cleanup criteria exist. However, the MDEQ Consent Judgment defines the Facility as “Any area, place or property where a hazardous substance from the Enbridge Line 6B Marshall Release in excess of the concentrations that satisfy the cleanup criteria for unrestricted residential use has been released, deposited, disposed of, or otherwise comes to be located, as set forth at MCL 324.20101(1)(s). “Facility” does not include any area, place, or property where the conditions of MCL 324.20101(1)(s) (i)-(vi) have been satisfied.” (Facility).

The MDEQ Consent Judgment defines the Spill Area as “the Facility created by the Enbridge Line 6B Marshall Release and also private and public properties that have been disturbed, destroyed, dredged, excavated, or otherwise altered or damaged as a result of the release or Response Activities taken place to address the release, including but not limited to vegetation, surface waters, soils, sediments, groundwater, wetlands, floodplains, and overbank areas.” (Spill Area).

In practice, the Spill Area encompasses the location of the Line 6B crude oil release (Source Area), Talmadge Creek from the Source Area to the Kalamazoo River, and the Kalamazoo River channel and floodplain (within the limits of modeled inundation) from the confluence with Talmadge Creek to the Morrow Lake impoundment (*Figure 1*). Also included in the Spill Area are areas utilized by Enbridge during the extensive cleanup and response activities.

The “Source Area” is a commonly used term that is a subset of the Spill Area and encompasses the pipeline breach and approximately 5 acres of property owned by Enbridge where the Line 6B crude oil release emerged onto the ground surface, flowed over land following the natural topography into Talmadge Creek.

In order to make the presentation, interpretation, and management of data more manageable and easier to relate to the State’s regulatory framework, Enbridge and the MDEQ have agreed to divide the Spill Area into separate geographic sections. These sections are referred to as Reaches. Reaches encompass multiple parcels and typically begin and end at property boundaries. Reach 1 comprises the Source Area and a limited segment of Talmadge Creek. Subsequent Reaches are numbered progressing downstream along Talmadge Creek and the Kalamazoo River to Reach 47 and Reach 48, which encompass Morrow Lake. The numbered Reaches are depicted on *Figure 1*.

1.4 The General Line 6B Crude Oil Release Scenario and Enbridge Response

On July 26, 2010, Enbridge discovered a release of crude oil from the Line 6B pipeline that is located south of Marshall, Michigan. The Line 6B crude oil was released below grade via a break in the Line 6B pipeline at Mile Post (MP) 608 into a scrub-shrub wetland. Approximately 843,000 gallons of Line 6B crude oil was released (U.S. EPA, 2015). The Line 6B crude oil was forced from the pipeline under pressure into the surrounding soils and emerged onto the ground surface. The released Line 6B crude oil flowed over land through the wooded scrub-shrub wetland area, following the natural topography into Talmadge Creek.

At the time of the Line 6B crude oil release, Talmadge Creek and Kalamazoo River discharges were higher than normal due to recent heavy rain, and in many areas, the creek and river had overflowed their banks. The Line 6B crude oil was carried down Talmadge Creek to the confluence with the Kalamazoo River. The river level was high at the time of the Line 6B crude oil release and Line 6B crude oil was observed in the channel, bank, and floodplain areas (see *Figure 2*). Line 6B crude oil was transported, and in some cases, deposited within the channels of Talmadge Creek and the Kalamazoo River during and following the Line 6B crude oil release.

As flood water levels receded, some Line 6B crude oil was carried with water back within the banks of the Kalamazoo River. Line 6B crude oil that did return to the channel in some cases adhered to and/or incorporated fine sediment particles suspended within the water column. This is confirmed from site-specific samples collected of the Line 6B crude oil which exhibit a greater density than unweathered oil and have a composition that is 40% sediment and water. Eventually these oil-sediment mixes settled within depositional areas of the channel such as artificial impoundments, backwater areas, oxbows, and meander cutoffs. Line 6B crude oil was carried down the Kalamazoo River as far as the Morrow Lake Delta near Kalamazoo, Michigan (*Figure 1*). The Line 6B crude oil that returned with floodwaters to the main stem river and creek potentially impacted in-channel sediments and surface water quality in terms of human health and aquatic ecological risk and aesthetics.

Stranding of Line 6B crude oil within the floodplain also occurred during the recession of the flood. As floodwaters receded back to the main channel and percolated downward into the floodplain soils, Line 6B crude oil became trapped within low-relief topographic depressions, cavities, burrows, and other voids within the formerly inundated area. Much of the Line 6B crude oil adhered to vegetation, including emergent herbaceous wetlands and woody plants associated with scrub-shrub wetlands and swamps within the floodplain and along the banks of the river. The Line 6B crude oil that was stranded in overbank areas potentially impacted soils and groundwater in terms of human and terrestrial ecological health risk and aesthetics.

In the immediate aftermath of the release, Shoreline Cleanup and Assessment Technique teams (consisting of Enbridge representatives as well as U.S. EPA and MDEQ personnel) surveyed the extent of oiling over the entirety of the Spill area as well as areas downstream of Morrow Lake and helped guide first response-type removal efforts including cutting and removal of wetland plants with heavy oil adherence. During the first 8 months of response, a substantial amount of oil was recovered via boom, vacuum surface pumping, and excavation within the Spill Area. The extensive removal actions, included dredging, agitation, containment and collection, vacuum removal, and island, bar, and bank excavations recovered an estimated 766,000 gallons (91%) of released Line 6B crude oil (U.S. EPA, 2011).

The spill scenario outlined above resulted in extensive cleanup activities performed in the years following the initial response. These activities included field survey and monitoring of overbank areas for Line 6B crude oil remnants, in-channel dredging and island removal, creek and river bank excavations, dam removal, permanent and temporary well installation, and river sediment and overbank soil core collection. The CSM summarizes 5.5 years of data collected since the release. These data address the following issues in the Spill Area:

- Human use and health risk (in-channel and overbank),
- Aquatic (in-channel) and terrestrial (overbank) ecology and risk,
- Existing and natural non-Line 6B crude oil (natural and urban background) analytes,
- water quality (ground and surface),
- sediments (in-channel),
- soils (overbank),
- Mobility of remnant Line 6B crude oil, and
- Aesthetics (in-channel and overbank).

1.5 Cleanup Criteria and Screening Levels

In any environmental cleanup effort, the recognition of impact magnitude as well as the measurement of remediation success takes place within a regulatory framework of criteria designed to identify contamination that poses risk to human and ecological health. These criteria are typically specific to four environmental media: soil, sediment, groundwater, and surface water. In accordance with the MDEQ Consent Judgment, characterization and response activities within the various reaches have been conducted pursuant to Part 201, Part 201's administrative rules, and Part 201 Residential Cleanup Criteria (Criteria). When Part 201 does not provide specific criteria, alternative criteria derived from the U.S. EPA or other state agencies have been identified. This section summarizes Cleanup Criteria and screening levels used to evaluate analytical data in each type of media encountered in the Spill Area.

1.5.1 Soil

Soil samples were analyzed for one or more of the following parameters pertinent to regulatory criteria:

- Volatile Organic Compounds (VOCs);
- Polynuclear Aromatic Hydrocarbons (PNAs); and
- Metals (beryllium, molybdenum, nickel, and vanadium).

The human health Criteria used to evaluate analytical results for soil are:

- Part 201 Generic Residential Soil Direct Contact Criteria (DCC),
- Part 201 Generic Residential Soil Drinking Water Protection Criteria (DWPC),
- Part 201 Generic Residential Soil Groundwater Surface Water Interface Protection Criteria (GSIPC),
- Part 201 Generic Residential Soil Volatilization to Indoor Air Inhalation Criteria (SVIAIC),
- Part 201 Generic Residential Soil Ambient Air Infinite Source Volatile Soil Inhalation Criteria, and
- Part 201 Generic Residential Particulate Soil Inhalation Criteria (PSIC).

Unlike Human Health Risk, Part 201 does not provide specific criteria for evaluating potential terrestrial ecological risks related to the exposure of plants and animals to impacted soil. Because of this, the U.S. EPA's Region 5 Ecological Screening Levels (R5 ESLs) (U.S. EPA, 2003) and Soil Screening Levels (SSLs) (U.S. EPA, 2014a) are used to screen soil data. The R5 ESLs and SSLs are screening levels only and are not intended for use as specific cleanup criteria. The R5 ESLs and SSLs are appropriate only to identify potential for ecological risks and the need for additional evaluation. Enbridge is using R5 ESLs for VOCs and the SSLs for PNAs.

Comparison of analytical results to R5 ESLs and SSLs identifies potential risks regardless of cause. Therefore, Enbridge has also investigated background concentrations to identify impacts not related to the Line 6B crude oil release. Establishing existing background conditions that existed prior to the Line 6B crude oil release puts the Spill Area analytical results into proper context. Terrestrial Background Concentrations (TBCs) for PNA concentrations and Urban Background Concentrations (UBC) for benzo(a)pyrene, fluoranthene, and phenanthrene were developed using soil data from background overbank areas along the Kalamazoo River upstream of the Line 6B crude oil release.

Lastly, additional soil cleanup concerns, to which the criteria used to evaluate human or ecological risk do not directly apply, have also been evaluated (as directed by the MDEQ) over the course of the last 5 years. Laboratory mobility tests were used to investigate potentially mobile quantities of Line 6B crude oil. The potential for observed Line 6B crude oil constituents in soil to leach (release) contaminants to groundwater was investigated using Synthetic Potential Leaching Procedure (SPLP) testing.

By evaluating risk to human and ecological health within the context of existing background concentrations and potential contaminant mobility, Enbridge is providing a realistic and comprehensive picture of the impact of the Line 6B crude oil release on Spill Area soils.

1.5.2 Groundwater

Groundwater and potable water samples were analyzed for one or more of the following parameters pertinent to regulatory criteria:

- Groundwater – VOCs; PNAs; and, total metals (i.e., unfiltered) - beryllium, molybdenum, nickel, and vanadium.
- Potable water – VOCs; PNAs; pesticides; polychlorinated biphenyls (PCBs); total metals (i.e., unfiltered); total organic carbon; total suspended solids; and, hardness.

The Criteria used to evaluate analytical results for groundwater are:

- Part 201 Generic Residential Drinking Water Criteria (DWC), which include aesthetic conditions based on taste and odor,
- Part 201 Generic Groundwater Surface Water Interface Criteria (for groundwater) (GSIC),

- Part 201 Generic Residential Groundwater Volatilization to Indoor Air Inhalation Criteria (GVIAIC), and
- Flammability and Explosivity Screening Levels for groundwater.

1.5.3 Surface Water

Surface water samples include those from the Kalamazoo River and overbank ponds, wetlands and streams. As dictated by the regulatory criteria the surface water samples were analyzed for VOCs, metals, and PNAs.

Impacts to surface water quality are being assessed according to MDEQ Surface Water Quality Standards as well as the Michigan Rule 323.1057 (Rule 57) Water Quality Values. The Rule 57 Water Quality Values include Final Acute Values, Aquatic Chronic Values, Wildlife Values, Human Cancer Values, and Human Non-cancer Values. Human health and aquatic ecological risks are addressed using these values. The Kalamazoo River is not used as a municipal water supply; therefore non-drinking water values are applicable for human health.

1.5.4 Sediment

In the application of regulatory Criteria to the Spill Area, sediment is differentiated from soil (*Section 1.5.1*) primarily on the basis of its presence within a persisting surface water body. Sediments are completely saturated and are collected from within stream or river channels, overbank ponds, and perennially filled depressions in wetlands. Sediment samples were analyzed for VOCs, PNAs, and metals (beryllium, molybdenum, nickel, and vanadium).

The Criteria used to evaluate analytical results for the overbank sediment are:

- DCC,
- R5 ESLs for sediment,
- Probable Effect Concentrations (PECs),
- UBC, and
- Aquatic Background Concentration (ABC) for total PNAs.

Kalamazoo River sediment (in-channel sediments) analytical data are compared to:

- DCC,
- R5 ESLs,

- Threshold Effect Concentrations (TEC), and
- PECs.

As requested by the MDEQ, all sediment (overbank and in-channel) results are compared to the DCC for human health and R5 ESLs and PECs for ecological health. All of these criteria are intended for screening purposes only. The DCC are originally intended for soil. Since people are exposed to sediment much less frequently than to soil, it is appropriate to use DCC as screening levels only and not as a sediment cleanup criteria. As was the case for soils (*Section 1.5.1*), R5 ESLs are recommended by the MDEQ Remediation and Redevelopment Division (RRD) as screening levels to evaluate the potential ecological impact of the Line 6B crude oil release on sediments. The R5 ESLs are presented in *Appendix A* and *Appendix B* of the MDEQ *RRD Operational Memorandum No. 4 – Attachment 3* (MDEQ, 2006). The R5 ESLs incorporate default TECs from the *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald et al., 2000). *Appendix A* of the *RRD Operational Memorandum No. 4* presents the TECs for PNAs (MacDonald et al., 2000), as summarized by the U.S. EPA (U.S. EPA, 2003). Adverse effects to the benthic community are not likely if concentrations are less than the TECs.

PECs, which also apply to both in-channel and overbank sediments, are concentrations above which adverse impacts to ecological health are expected. The PECs are also derived from *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald et al., 2000) and are further detailed by the Wisconsin Department of Natural Resources (WDNR, 2003).

Because the regulatory criteria available for sediment related human and ecological health impacts provide screening levels only and not concrete cleanup criteria designed to help define site closure and compliance, for in-channel sediments further evaluation of ecological risk using the sediment quality triad (SQT) approach was conducted. As outlined in *Section 4.2.1*, this approach combines the screening levels above with toxicological testing and biological community analysis in Spill Area and upstream reference areas to assess sediment impacts.

In the case of overbank sediment, data are compared to two additional criteria, UBCs and ABCs. The UBC were developed originally as part of the *White Paper: Urban PAH Background Evaluation,* submitted to the MDEQ on August 28, 2015 (Urban PAH White Paper) (Enbridge, 2015a) for overbank soils for three chemicals (benzo(a)pyrene, fluoranthene, and phenanthrene) based on concentrations in overbank soil from background locations upstream of the Line 6B crude oil release (see *Section 4.3.2*).

The ABC value was developed for total PNAs. It is based on total PNA concentrations in background soil from overbank areas along the Kalamazoo River upstream of the Line 6B crude oil release.

1.5.5 Aesthetic Concerns (All Media)

In addition to the Criteria cited above, impacts to all media also include a less tangible (in an analytical sense) aesthetic component. Aesthetic observations are those characteristics of a constituent which are observable (generally through sight or smell) and that may be objectionable to an individual who encounters them but is specifically not detrimental to human health.

Current Part 201 and Part 31 of Michigan's Act 451 of 1994, as amended (Part 31) rules and MDEQ published guidance documents, provide limited direction on what constitutes an aesthetic observation or what aesthetic observations would be considered actionable. Enbridge developed a comprehensive process to identify and categorize aesthetic observations from all available records (e.g., soil boring logs, well construction reports, groundwater sampling logs, and field records). The process summarized below is based on the current MDEQ rules and guidance. Aesthetic observations for groundwater, surface water, and soils were evaluated as follows:

Groundwater: All groundwater analytical results were compared to groundwater DWC, which include aesthetic conditions based on taste and odor.

Surface Water: The narrative water quality standards (Rule 323.1050), which include observations of oil films (or sheens) and odors, apply to surface water only and not to soil or groundwater. The water quality standards are based on visual physical characteristics (turbidity, odor, oil films, floating solids, foams, settleable solids, suspended solids, and deposits) which are or may become injurious to any designated use. The narrative water quality standards are not chemical-specific concentrations.

Soil: Enbridge contacted numerous MDEQ personnel from districts throughout Michigan seeking examples and guidance on the MDEQ position on aesthetics observations and actionable aesthetic impacts. Enbridge did not identify any MDEQ rules that addressed aesthetic observations in soil. However, Enbridge utilized MDEQ web-based resources to identify instances of aesthetic impact notification and the specific aesthetic observation causing the actions. Enbridge also reviewed and considered the MDEQ's *Technical Review Comments - Aesthetic Concerns on the Remedial Investigation Report for Reach 1*, issued on May 14, 2014 (MDEQ, 2014a) and the MDEQ's *Technical Review Comments* within the *Notice of Insufficient Information in Reach 5 No Further Action Report*, issued on August 22, 2014 (MDEQ, 2014b). The compilation of this information was used as the basis for Enbridge's aesthetic evaluation.

2.0 PHYSICAL AND BIOLOGICAL CHARACTERISTICS OF THE SPILL AREA

An understanding of the general characteristics of the Kalamazoo river system is necessary as a baseline for understanding the data pertaining to spill impacts, remediation efficacy, site complexities, and cleanup endpoints within the Spill Area.

2.1 Physical Setting: General Hydrology, Geology, and Geomorphology of Talmadge Creek and Kalamazoo River Valley

The Kalamazoo River basin consists of a 2,020 square mile drainage system that flows northwest and ultimately discharges at an average rate of 1,925 cubic feet per second into Lake Michigan. The basin contains 175 miles of main stem drainage (Kalamazoo River), 899 miles of tributary streams, and 287 lakes ranging between 10 acres and 2,661 acres (Wesley, 2005).

Geomorphically the river is a typical meander belt system. Such systems are characterized by a single meandering channel, the sinuosity of which may vary downstream as hydraulic gradients and channel substrates change. Channel depth varies from <2 feet (ft) in shallow reaches to >10 ft in the thalweg (the deepest portion of the channel where the highest flow is concentrated) and deepest portions of artificial impoundments. Within the channel, variance in flow creates areas more prone to deposition than others (such as channel margin backwaters and oxbow/meander cut-offs). The typical bathymetric patterning of pool (deeper water), riffle, and glide (shallowing water) is somewhat muted in the Kalamazoo

River, likely due to high sediment loads and substrate embeddedness (filling of substrate voids with finer grains) as is expected in rivers that pass through areas of high human use. Coarse grained shallow riffles where aeration of waters increases are rare. Functionally speaking, within the Spill Area the main stem of the river can be categorized as high sinuosity, low sinuosity, anthropogenic (highly engineered) channel segments, and artificial impoundments. These functional divisions are discussed further in *Section 2.2* with respect to biological habitats.

Channel gradients of the Kalamazoo River gradually decrease downstream, averaging 3 feet per mile (ft/mi). Between the City of Marshall and Morrow Lake, the channel gradient typically ranges from less than 1 ft/mi to 10 ft/mi (MGDL, 2010), with channel segments with lower gradient being impounded.

Both Talmadge Creek and the Kalamazoo River flow through glacial deposits in Michigan that overlie bedrock at varying depths. These deposits consist variably of glacial outwash sands, coarse end-moraine deposits (sands and gravel), fine end-moraine deposits (silts and clayey sands), ice contact material (sorted sands and gravel), clayey till, and lake plain deposits. The Kalamazoo River basin is dominated by well-drained outwash, coarse end-moraine deposits, and ice contact deposits. These sediments result in higher groundwater yields compared to basins with less permeable deposits (Bent, 1971).

In the well-drained soils of the Kalamazoo River Basin, a large amount of precipitation and snow-melt percolates to the groundwater. Groundwater generally flows to the Kalamazoo River, associated tributaries such as Talmadge Creek, and sub-basin wetlands (Wesley, 2005). While groundwater generally discharges into the Kalamazoo River during most periods of the year, localized exceptions occur where groundwater flows around dams or through tight bends and relict overbank and/or bar deposits protruding into the main stem of the river. In such areas flow from the main channel may drive shallow groundwater flow outward from the main stem (“loosing-stream conditions”). Flow will parallel the general flow of the river, pass across the feature, and then discharge back into the Kalamazoo River downstream.

The unconsolidated glacial deposits and modern alluvium of the Kalamazoo River valley fill overlie bedrock at depth. The primary bedrock units, which can be found exposed at the surface in only a few sparsely distributed locations (sites called outcrops), are Mississippian in age (340 million years old). The primary bedrock formation throughout the Kalamazoo River basin in Calhoun County is the Marshall sandstone. The Coldwater Shale is present in portions of Kalamazoo County (Dorr and Eschman, 1970; WMU, 1981). Depth to bedrock varies within the Spill Area from ground surface at outcrops near Ceresco, to approximately 200 ft below ground surface (bgs) (approximately 700 ft above mean sea level (amsl)). Within the greater Kalamazoo River basin, the bedrock topography ranges from approximately 1,100 ft amsl near the headwaters to 400 ft amsl near Lake Michigan (WMU, 1981). The bedrock units have a slight dip to the northeast (Vanlier, 1966).

2.1.1 Impoundments and Anthropogenic Modifications

There are currently 11 existing dams along the main stem of the river between the river's headwaters and Lake Michigan. At the time of the Line 6B crude oil release an additional impoundment, the Ceresco Dam, was in existence. The Ceresco Dam was notched in October and November 2013 and was completely removed in May through June 2014. This was an activity mutually agreed upon by Enbridge, the U.S. EPA, the MDEQ, and the Michigan Department of Natural Resources in 2013 due to the potential benefits to both the remediation project goals and the overall health of the natural river system. The characteristics of the impoundments that remain in the Spill Area as detailed in Kalamazoo River Assessment (Wesley, 2005) are:

- Mill Pond Dam - 12 ft head; surface area of 4 acres; storage capacity of 3 acre-feet (ac-ft); and, average depth of 0.8 ft, and
- Morrow Lake Dam - 14 ft head; surface area of 1,000 acres; storage capacity of 6,000 ac-ft; and, average depth of 6.0 ft.

At impoundments, dams across the river create a significant and rapid drop in the water elevation. Surface water in the reservoir above the dam will recharge the shallow groundwater flow system and flow parallel to the river in the shallow flow system, essentially bypassing the dam, before discharging back into the Kalamazoo River below the impoundment.

A limited number of alterations to the pre-spill channel morphology are associated with response actions in the Spill Area. Ceresco and Mill Ponds impoundments were affected by dredging (and in the case of Ceresco, by Dam removal). Also, some sediment trap areas (isolated meander cutoffs or channel backwaters) were dredged during the 2013 and 2014 field season. Dredging efforts in Morrow Lake have had minimal impact on flow or circulation characteristics within the Morrow Lake Delta or Morrow Lake. Prior to dredging the same numerical modeling used for estimation of the inundation area was used to infer the influence of the altered channel morphology on water levels at adjacent properties during flood scenarios.

2.1.2 Groundwater

Groundwater is used as a source of drinking water in the rural areas along Talmadge Creek and the Kalamazoo River. The groundwater is generally of good quality, though naturally occurring metals are locally present. Along the majority of the Kalamazoo River groundwater feeds the river (the river is a gaining stream). In some instances, such as tight bends in highly sinuous channel segments or at impoundments flow may be lost temporarily to shallow groundwater.

2.1.3 Precipitation and Trends in River Flow

Annual precipitation generally increases from 32 inches to 36 inches between the headwaters and mouth of the watershed and temperatures are more seasonally moderated closer to Lake Michigan due to lake effects (Wesley, 2005). The highest stream flows are typically in March and April due to snowmelt and storm water runoff flowing over frozen soils. The wettest months with the highest rainfall amounts are June and July. Lower stream flows typically occur in August through October (base flow).

2.2 Biological Habitats and Communities as Related to River Morphology

To understand the biological habitats and communities potentially affected by the Line 6B crude oil release, Enbridge performed a qualitative ecological survey in 2010 (TetraTech, 2010).

Biological habitats are generally linked to fluvial geomorphology as detailed below, however, as a general rule, regardless of geomorphic categorization of a segment of river, quieter and protected areas within river segments may serve as nursery areas for fish species, and populations of frogs and turtles may be expected. Frogs and turtles also ubiquitously frequent shorelines along the main river channel. The Kalamazoo River channel itself has benthic fauna and more sediment dwelling infauna due to the relative absence of coarse grained riffle areas. Silty conditions favor burrowing benthic organisms. These areas are home to species of freshwater mussels. The fish fauna is rich, with many smaller fish (and juvenile fish) in the inlets and backwaters, and larger fish in the open water.

Terrestrial upland habitat and vegetation may reach to the bank. Terrestrial animals may use the Kalamazoo River as a drinking water source and as a source of food.

Wetlands found in overbank and backwater areas likely provide important refuge and habitat for fish and amphibians. Submerged snags are abundant in or near backwaters and provide additional habitat structure.

Low sinuosity, steep-banked, straight river segments include sensitive habitat, especially where the water is shallow. The coarse and well oxygenated substrate is rich in particulate organic matter (i.e., leaf pack) providing a food source for insect juveniles. These in turn are a major food resource for open water, strong swimmer fish species of major economic value such as bass. Aquatic vegetation (floating and submerged) is limited, although encrusting mosses and algae (periphyton) and submerged snags are common. Filtering aquatic mussels also can be found in these segments.

High sinuosity segments can be distinguished from the well-entrenched, more linear segments by an extensive riparian ecosystem, containing a rich biodiversity of wetland, riparian, and aquatic plants and animals. These include semi-aquatic birds and mammals that use the Kalamazoo River and the riparian zone for food and shelter. Bird and mammal use in the high sinuosity segments is likely extensive. Anthropogenic or engineered and channelized sections of the river support limited ecological habitat value. Areas consisting of concrete-lined channels provide no significant ecological habitat, but may have an ecological role as a migration pathway for fish and other aquatic organisms.

River impoundments function largely as lacustrine or lake-like habitats. The sediment is low in biota and may be almost devoid of biota if deep and anoxic. The littoral zone may support a varied fauna. Impoundments are important resting and feeding areas for migratory fowl and shorebirds. Piscivorous birds (e.g., osprey and eagle) may be present. Although the remnant Line 6B crude oil constituents are not bioaccumulative chemicals of concern, these substances can still be a complete exposure pathway for piscivores in impoundments.

The delta areas of larger impoundments contain mudflats, some of which may be extensive. Mudflats may be used by migratory and wading birds. Morrow Lake, the larger impoundment, supports dense stands of submerged aquatic vegetation. The shoreline supports a complex mix of lacustrine (still open water) emergent and palustrine (marsh-like) emergent wetlands. The Morrow Lake Delta contains a large continuous area (approximately 40 acres) of emergent wetlands that reduce velocity of the Kalamazoo River discharge to Morrow Lake. Fish were observed to be relatively abundant in the Morrow Lake Delta and this area appears to represent a good fish nursery and refuge area.

The smaller impoundments also contain mudflats with sparse vegetation. Dense stands of submerged and floating macrophytes are present which provide habitat for largemouth bass, smallmouth bass, and sunfish.

2.3 Human Environment

The Spill Area consists of diverse land use areas and includes many potential human land uses and receptor groups. However, it is a key point that the Kalamazoo River is not used as a municipal water supply.

Human health receptors include recreational users (including boaters, swimmers, hunters, and fishermen) and streamside residents with access to Talmadge Creek and the Kalamazoo River, or who use groundwater extracted within the inundated portion of the Talmadge Creek or the Kalamazoo River floodplains. Human exposure potential is not as strongly tied to geomorphological zones as for ecological receptors. General potential exposure pathways include ingestion, inhalation, and direct contact with contaminated groundwater, soils, and/or volatilized compounds.

Residential communities, including small clusters of homes and cities, are present in specific areas along Talmadge Creek and the Kalamazoo River. Industry is present along the river, primarily in the stretch of the Kalamazoo River that flows through Battle Creek, Michigan. The remainder of the shoreline of the Kalamazoo River is comprised of heavily wooded land, undeveloped land, agricultural land, as well as a number of public parks and river access sites. Farmland is present; however, the vast majority of crops are not grown in the area of the river bank that was impacted by the Line 6B crude oil release via flooding. Hunters (e.g., deer and waterfowl) and recreational users are present in the heavily wooded lands that abut the Kalamazoo River in many places. Most of this property is privately owned and not open to the public. Anglers and recreational boaters also use the Kalamazoo River. Specific exposure pathways are discussed in *Section 4.1.*

The Kalamazoo River basin has a long history of industrial development that predates the Line 6B crude oil release by well over 100 years. Many compounds have impacted the basin, most notably PNAs, but also VOCs, metals, and PCBs.

3.0 CHARACTERISTICS OF LINE 6B CRUDE OIL AND ITS RELEASE TO THE ENVIRONMENT

An understanding of the chemical and physical properties of Line 6B crude oil is important background for any discussions of Line 6B crude oil detection, fate and transport, mobility, and human health and ecological risks.

3.1 Line 6B Crude Oil Chemical Composition

The crude oil release occurred at a time when crude oil in Line 6B was transitioning from a batch of Western Canadian Select (WCS) to a batch of Cold Lake Blend (CL). As a result, the crude oil released was a blend of these two batches. An analysis of composition is detailed in the *White Paper: Evaluation of Line 6B Crude Oil PNA and VOC Related Risk to Groundwater Quality,* submitted to the MDEQ on July 24, 2014 (Groundwater White Paper) (Enbridge, 2014a). The WCS component is a blend of Canadian heavy conventional and bitumen crude oils combined with diluent (added to improve flow characteristics). The CL component is a heavy crude blend of bitumen and diluents.

The chemical composition of the unweathered blend of crude oil present in Line 6B in Marshall, Michigan on July 26, 2010 is based on three Line 6B crude oil samples (as detailed in the Groundwater White Paper). A CL crude oil sample collected upstream of the Marshall Pump Station upon the Line 6B pipeline restart, a WCS crude oil sample collected downstream of the Marshall Pump Station, and a crude oil sample collected by the U.S. EPA from freshly released (1 day later) Line 6B crude oil flowing down the channel of Talmadge Creek.

Laboratory analysis of Line 6B crude oil shows that specific metals are present, albeit at relatively low concentrations compared to the overall organic composition of the oil. As a result, metals are included in laboratory analyses used to characterize the presence of Line 6B crude oil impacts. While a range of metals are present in the Line 6B crude oil, the analyses have focused on four metals, beryllium, molybdenum, nickel, and vanadium which are present in low concentrations ranging from <1 milligrams per kilograms (mg/kg) to <150 mg/kg. VOCs are also not major components of Line 6B crude oil and are attributable primarily to the diluent additive. This is reflected in their low concentrations in the Line 6B crude oil samples which vary from less than 0.35 mg/kg to 4,000 mg/kg of crude oil (less than 0.000035% to 0.4%). Nonetheless, VOCs are one of the primary chemical suites used to evaluate the impact of Line 6B crude oil in the environment. VOCs detected in the Line 6B crude oil include benzene, toluene, ethylbenzene, and xylene (BTEX), 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, isopropylbenzene, n-propylbenzene, n-butylbenzene, sec-butylbenzene, p-isopropyltoluene, and cyclohexane. In some instances the above list of VOCs is shortened by excluding 1,2,3-trimethylbenzene and tert-butylbenzene and the resulting suite of compounds is referred to as petroleum volatile organic compounds (PVOCs). PVOCs are not major components of the Line 6B crude oil, which is important in the context of equilibrium partitioning with groundwater described below.

The primary organic compounds of regulatory concern in the Line 6B crude oil are the less volatile PNAs. The U.S. EPA Priority Pollutant list (U.S. EPA, 2014b) of PNAs is limited to 16 non-alkylated “parent” PNAs. The chemical structure of the parent PNAs consists only of joined aromatic rings and lack side chains attached to these rings. The 16 U.S. EPA Priority Pollutant PNAs plus 2-methylnaphthalene are routinely reported in project analyses of PNAs. Parent PNAs, are minor to trace components of petroleum and the Line 6B crude oil (non-detect to <100 mg/kg), a significant characteristic when evaluating the potential risk of released Line 6B crude oil to soils and groundwater.

Analysis of PNAs allows chemists to distinguish between pyrogenic and petrogenic species. Pyrogenic PNAs are formed by high temperature processes such as combustion of petroleum, wood, coal or the pyrolysis of petroleum or coal to produce creosote, coal tar or other products. Petrogenic PNAs are those associated with petroleum and its original formation. Pyrogenic PNA compositional "patterns" are dominated by the parent-PNAs. Petrogenic PNAs have only minor parent-PNA components (non-detect to <100 mg/kg of petroleum). Instead, PNAs associated with petroleum formation have patterns dominated by alkylated derivatives of the parent PNAs. 2-methyl naphthalene is the only commonly reported alkylated PNA in standard laboratory methods, but many variants or isomers are possible with side chains of various lengths and degrees of branching in their chemical structure. Note that 2-methyl naphthalene is more than twice as abundant in the Line 6B crude oil as the next most abundant parent PNA, naphthalene.

Because the two groups of PNAs are generally distinguishable from one another via chemical analyses, the pattern of PNAs can be used to geochemically ascertain the most likely source (pyrogenic versus petrogenic) of PNAs in a given sample. Analyses show that the Line 6B crude oil blend produces a unique PNA chemical signature in fresh and weathered states (weathering is discussed in *Section 3.3*). The lower graphic on *Figure 3* shows a graphical example of the petrogenic PNA signature of the weathered Line 6B crude oil sample (blue) and an impacted soil sample from the Spill Area with a distinctly different signature (red) indicating an unrelated, likely pyrogenic source. Such analyses were used in a consensus-based development of a unique "fingerprint" reference signature that was presented in two reports submitted to the MDEQ in 2013: *Supplement to the Response Plan for Downstream Impacted Areas commonly referred to as the "Quantification of Submerged Oil Report",* submitted to the MDEQ on March 21, 2013 (Enbridge, 2013a); and, the *Report of Findings for Hydrocarbon Fingerprint Evaluation in Overbank Soil,* submitted to the MDEQ on May 7, 2013 (Enbridge, 2013b). These analyses are expanded upon further in the Urban PAH White Paper.

3.2 Physical Characteristics of Line 6B Crude Oil

This section describes the basic physical properties of Line 6B crude oil impact, mobility, and transport and fate characteristics within the in-channel (submerged) and overbank settings.

3.2.1 Flammability

Unweathered Line 6B crude oil is flammable, while weathered Line 6B crude oil is not flammable (*Section 3.3*). In August 2010, a series of five waste characterization samples were tested for flash point (ignitability) as part of waste characterization. The results are included in the *White Paper: Evaluation of Line 6B Crude Oil NAPL Risk based on a Weight of Evidence Approach* (NAPL White Paper) (Enbridge, 2015b), submitted to the MDEQ on July 30, 2015, and show no flash point below the maximum temperature (200°F) for the test.

3.2.2 Density

The density of six samples of Line 6B crude oil were analyzed using the American Society for Testing and Materials (ASTM) Method D 1963 85 “Standard Test Method for Specific Gravity of Drying Oils, Varnishes, Resins, and Related Materials”. The six samples were segregated into three that were reflective of CL blend (collected upstream of the Marshall pump station) and three that were reflective of WCS blend (collected downstream of the Marshall pump station). Density ranged from 0.92 grams per cubic centimeter (g/cm^3) to 0.93 g/cm^3 as stated in the Groundwater White Paper. These results are consistent with the density measurements made by SL Ross in laboratory experiments on MacKay River Heavy Bitumen and Cold Lake Bitumen diluted with synthetic crude and condensate, respectively (Ross, 2010). The experiments showed that density of Line 6B crude oil approached, but did not exceed water. The near neutral densities of Line 6B crude oil limits the density driven forces which typically exert pressure on a non-aqueous phase liquid (NAPL) to either rise to the surface or to sink through a water column. This data refutes the perception that Line 6B crude oil, in its natural state, sinks after the diluent evaporates.

3.2.3 Viscosity

As previously noted, Line 6B crude oil is a blend of WCS and CL petroleum. The WCS component is a blend of Canadian heavy conventional and bitumen crude oils combined with diluent (added to improve flow characteristics). The CL component is a heavy crude blend of bitumen and diluent. The NAPL White Paper concluded that the average viscosity measurements of these components are as follows:

- CL – 200 centistokes (cSt) at 15°C (59°F), and
- WCS – 196 cSt at 15°C (59°F).

These viscosities can be used to infer the general viscosity range typical for the Line 6B crude oil at the time of release, without the impact of oil weathering or loss of diluent. The viscosities are substantially higher than water (1 cSt) or those associated with light crude oil (<10 cSt) to medium crude oils (<20 cSt). To illustrate by comparison, the released Line 6B crude oil had an original viscosity similar to motor oil (SAE30) or maple syrup.

3.3 Weathering and Residency of Line 6B Crude Oil

The physical and chemical properties of Line 6B crude oil dictate the risk it poses to human and ecological health as well as its persistence within the environment. However, the properties discussed in *Section 3.1* and *Section 3.2* for Line 6B crude oil change with exposure to the environment. These chemical and physical changes are referred to as "weathering."

Immediately upon exposure to water, air, sunlight, and biological factors in the environment outside the Line 6B pipeline (and above grade) initial weathering processes occurred. The degree to which weathering processes acted upon the released Line 6B crude oil is expected to vary depending on if the oil observed was emergent on the surface (the majority of the spilled oil observed in both Spill Area and Source Area) or limited to the subsurface alone (as likely occurred in a portion of the Source Area near the Line 6B crude oil release).

Weathering results in an alteration in composition and a general reduction in contaminant mass and concentration. This occurs through a variety of biological, physical, and chemical processes at work in both the river and stream channels as well as the impacted portion of the floodplain. The processes may act independently or in combination upon the released Line 6B crude oil and include dilution (through advection and dispersion), sorption (to organic debris and/or mineral particles), volatilization, biotic and abiotic transformations, and biological activity (ingestion by microorganisms).

One primary and very early effect of weathering is loss of volatile components of the Line 6B crude oil. During this initial phase VOCs are rapidly lost from the Line 6B crude oil and VOC concentrations are typically reduced to levels below the laboratory reporting limits. This is confirmed by the infrequent detection of these constituents during environmental sampling of Line 6B crude oil exposed to the surface environment following the release (VOCs were detected in less than 1% of the environmental samples collected within the Spill Area). In contrast, the remaining residual oil in the Source Area, which never emerged to the surface and was not exposed to open air or sunlight, exhibited a chemical profile that included lighter aromatic constituents related to the diluent (i.e., BTEX).

In addition to a loss of VOCs early on, weathering generally impacts chemical composition by a reduction of C_9 to C_{37} hydrocarbons, PNAs, and total petroleum hydrocarbons. This is observed directly in samples from the Spill Area via a comparison of relatively fresh, unweathered crude oil samples (two upstream pipeline samples and one Line 6B crude oil release sample) to a weathered sample (located approximately 13 miles downstream of the release site), collected approximately 1.5 years after the Line 6B crude oil release.

Weathering impacts the physical properties of Line 6B crude oil as well (flammability, density, and viscosity). Flammability decreases because the volatile component of the petroleum is reduced, density and viscosity increase due to evaporation and water-in-oil emulsion formation. As stated in a recent study titled *Spills of Diluted Bitumen from Pipelines: A Comparative Study of Environmental Fate, Effects, and Response* (NASEM, 2016), "For any crude oil spill, lighter, volatile compounds begin to evaporate promptly; in the case of diluted bitumen, a dense, viscous material with a strong tendency to adhere to surfaces begins to form as a residue. For this reason, spills of diluted bitumen pose particular challenges when they reach water bodies. In some cases, the residues can submerge or sink to the bottom of the water body. Importantly, the density of the residual oil does not necessarily need to reach or exceed the density of the surrounding water for this to occur. The crude oil may combine with particles present in the water column to submerge, and then remain in suspension or sink."

In general, when sediment becomes entrapped within the weathered crude oil the density of the oil/sediment mixture can become greater than 1 g/cm^3 (Environment Canada, 2013*)*. Weathered oil collected from the overbank over 1 year after the release event had a density of 1.01 g/cm^3, but contained almost 40% sediment and water. As previously stated in *Section 3.2.2*, the density of unweathered oil averaged 0.93 g/cm^3. Therefore, as weathering occurred, it is likely that at least some percentage Line 6B crude oil adhered to sediment particles had the potential to settle to the river bottom in quiescent (depositional) areas of the Kalamazoo River channel or into depressions within inundated portions of the flood plain. Again, this data refutes the perception that Line 6B crude oil, in its natural state, sinks after the diluent evaporates.

However, weathering of the Line 6B crude oil does not always lead to incorporation of sediment and/or settling of oil. In addition to sorbing onto sediments, published results (Ross, 2010) of various physicochemical tests on samples of weathered CL crude oil (a component of the blend released from Line 6B crude oil) indicate that weathered crude oil can also exist as a separate phase fluid or fluid particles. Pour testing indicates weathered CL crude oil is pourable to -12°C (10.4°F) (Ross, 2010).

Therefore, any potential remaining Line 6B crude oil present within the sediments of the main stem channel or overbank areas may be present as oil-mineral (sometimes referred to as oil-particle) aggregates (with a tendency to sink) or as sparse separate fluid phase particle (potentially transported as a globule) with a tendency to rise. These particles become stable and available for subsequent biodegradation. It is likely that sediment agitation (naturally or artificially occurring) creates transitions between the free oil and aggregate states. When oil rises to the water surface via a contrast in density (buoyancy), sheens are generated.

3.3.1 Line 6B Crude Oil in Overbank Settings

Soil borings and excavations from the Source Area and Talmadge Creek indicate that during, and immediately following the Line 6B crude oil release, higher volumes of fresh oil near the release point led to pore-entry pressures that were sufficient to facilitate pore saturation (penetration of oil downward into soils) given the lower viscosities associated with fresh Line 6B crude oil. However, with extensive response actions (excavations) completed in the Source Area and along Talmadge Creek, the vast majority of the Line 6B crude oil has been removed from these areas. Verification of this has been documented through the

Remedial Investigation Report for Reach 1, submitted to the MDEQ on February 28, 2014 (Enbridge, 2014b).

In the rest of the Spill Area, after the subsidence of the flood waters that were present at the time of the Line 6B crude oil release, transport (surface or subsurface) of Line 6B crude oil within floodplain environments has been very limited. At the surface any remaining Line 6B crude oil mineral aggregates, sparse surface residues, and/or tar patties continue to weather with the net effect that they become less malleable and easier to naturally, physically break down over time. Please note, the Merriam-Webster dictionary defines "tar" as a dark brown or black bituminous usually odorous viscous liquid obtained by destructive distillation of organic material (as wood, coal, or peat). While it is understood that "tar" is not present as a result of the Line 6B crude oil release, the term has been commonly adopted to describe observations of solidified Line 6B crude oil in various forms.

Depth of penetration, and/or lateral extent of any Line 6B crude oil remnants in the subsurface of the overbank is very limited due to the fine (finest sands, silt, and clay) grain size associated with the low energy floodplain depositional environment. Secondary porosity potentially exists due to burrowing animals and vegetation (e.g., tree roots). These provided an alternate pathway for oil to enter the soil with increased depth of penetration in the immediate aftermath of the release, but are not likely impacted by any highly weathered remnants remaining in the floodplain. The presence of remaining Line 6B crude oil in secondary macropores is limited, and when encountered it is generally near the Kalamazoo River bank.

3.3.2 Line 6B Crude Oil in In-Channel Settings

Given the physical properties of the Line 6B crude oil and weathering processes it is likely that any unrecovered Line 6B crude oil in Talmadge Creek and the Kalamazoo River channels will be transported as some combination of aggregated oil sorbed to fine grains (clay, silt, fine sands) and as fine globules. It is likely that it is mobilized under a range of flows rather than moving solely as a component of bedload or suspension load. Transient or temporary deposition within the channel is possible as flow conditions vary. Transience of sediment load is common in the fluvial system and relationships between flow and suspension load, bedload, and saltation (bouncing in and out of bedload) can be characterized. Deposition with any meaningful trend of long term Line 6B crude oil accumulation or sequestering is most likely to occur in backwater areas, channel cutoffs, and impoundments.

4.0 PRINCIPLE STUDY QUESTIONS

Section 1.0 through *Section 3.3.2* provided a general, guiding overview of the Line 6B crude oil release and the concepts involved with long term response. However, the details associated with demonstrating compliance, achievement of cleanup goals, as well as ensuring that no human health and/or ecological risks remain within the overbank and in-channel components of a dynamic fluvial system are great in number and scope. As in any scientific endeavor, it is the questions that remain and not necessarily the answers that are known that dictate the path that must be taken forward to reach reasonable conclusions. Therefore, Principle Study Questions (PSQs) have been established throughout the lifespan of the response to guide project efforts.

The PSQs remaining and the answers to them indicated by the most current data are presented below as a means of illustrating the major forces and findings directing Enbridge project efforts and goals. The PSQs related to Line 6B crude oil are:

- Based on analytical results and the location of observed impacts, are there human health risks in the in-channel or overbank areas?
- Based on analytical results and the location of observed impacts, are there ecological risks in the in-channel or overbank areas?
- Which observed impacts in the Spill Area are attributable to urban (non-Line 6B crude oil) contamination and/or background concentrations?
- Are there sufficient Line 6B crude oil related constituents remaining such that migration through media and into new media is possible?
- Has the nature and extent of Line 6B crude oil contamination been adequately defined within both the in-channel and overbank areas?
- Do potentially remaining aesthetic observations in the Spill Area represent an actionable condition?

As demonstrated in this section, the PSQs listed above are largely addressed by the data accumulated to date. Enbridge's position on relevant topics and their relationship to the established PSQs are presented below.

4.1 Human Health: What Risk is Present?

This section summarizes soil, groundwater, surface water, and sediment data for the entire Spill Area in relation to human health risk and the Criteria identified in *Section 1.5*. Because the Spill Area is large and has variable populations, soil types, and river morphology, specific exposure pathways will be identified, described, and further evaluated in increased detail for each reach (see *Section 1.3* for definition of river reaches) as part of the RI Reports and NFA Reports submitted to the MDEQ.

The summary below includes constituents from sources other than the Line 6B crude oil release. Impacts attributable to urban background (non-Line 6B crude oil) are further evaluated in *Section 4.3*, as well as the Groundwater White Paper and the Urban PAH White Paper.

The approximate number of samples in various media evaluated in supporting documents are:

- Drinking water from potable wells: approximately 2,300 samples collected from July 2010 through August 2014 (last sampled date);
- Groundwater from monitor wells: approximately 1,300 samples collected from October 2010 through October 2015, depending on chemical analysis;
- Groundwater from temporary wells: approximately 1,325 samples collected from October 2010 through October 2015;
- Soil: approximately 10,700 samples collected from August 2010 through October 2015;
- Soil analyzed using the SPLP: approximately 300 samples analyzed for VOCs and/or PNAs from November 2011 through October 2015; and
- Surface water: approximately 4,500 samples collected from August 2010 through October 2015.

Human receptors are recreational users, streamside residents with access to Talmadge Creek and the Kalamazoo River, people who use groundwater extracted near Talmadge Creek and the Kalamazoo River for irrigation and/or drinking water, and people who may be exposed to impacted soil. The potential exposure pathways with corresponding Criteria are identified in *Section 1.5.*

Human health risks associated with surface water, sediments, and fish consumption are discussed in *Section 4.1.11* and have also been evaluated by the Michigan Department of Community Health (MDCH) (MDCH, 2012 and MDCH, 2014).

As detailed in this section, potential risks related to PNAs, VOCs other than benzene, and metals (particularly target metals beryllium, molybdenum, nickel, and vanadium) in soil, groundwater, surface water and sediments of the overbank and in-channel areas are low. VOCs “other than benzene” are specified above due to a limited presence of benzene in some Source Area monitoring wells.

4.1.1 Soil Direct Contact

Approximately 2,980 samples of soil from the Talmadge Creek Spill Area were analyzed for VOCs and approximately 3,360 samples were analyzed for PNAs. Approximately 3,330 samples from the greater Spill Area were analyzed for VOCs and approximately 4,880 samples were analyzed for PNAs.

VOC concentrations did not exceed the soil DCC in any of these samples. PNA concentrations exceeded the soil DCC in a relatively small percent of the samples collected. The most frequently detected PNAs were benzo(a)pyrene, fluoranthene, and phenanthrene. Concentrations of benzo(a)pyrene exceeded the DCC in less than 4% of these samples; fluoranthene and phenanthrene did not exceed the DCC.

PNAs are common contaminants of urban soils and urban river sediments (Stout et al., 2004). PNAs were detected in background soil samples collected in overbank areas along the Kalamazoo River upstream of the Spill Area. Benzo(a)pyrene concentrations exceeded DCC in 32% of the background soil samples. The concentrations and frequency of benzo(a)pyrene in the Spill Area soil are consistent with pyrogenic sources and are not related to the Line 6B crude oil release. Concentrations for constituents related to the Line 6B crude oil release are below DCC. Enbridge concludes that human health risk via direct contact with soils in overbank areas is low. The generic DCC are very conservative (low) criteria for the overbank soil. The low frequency of PNA exceedances generally indicates that the concentrations measured will overestimate exposure concentrations since no one would be exposed to a single location for very long. Also, most of the Spill Area is not suitable for residential development because it is in the floodplain of the Kalamazoo River and exposures would be less frequent than assumed by the residential DCC.

4.1.2 Soil Drinking Water Protection and Soil Groundwater Surface Water Interface Protection

Only a limited number of overbank soil samples exceeded DWPC or GSIPC. Less than 1% of overbank soil samples had concentrations of VOCs that exceeded DWPC or GSIPC. In the corresponding SPLP leachate results less than 8% had concentrations of VOCs that exceeded Criteria. Less than 1% of overbank soil samples had concentrations of PNAs that exceeded DWPC or GSIPC. In the corresponding SPLP leachate results less than 9% had concentrations of PNAs that exceeded Criteria.

While trace amounts of Line 6B crude oil constituents may remain in the soil, remaining impacted soil is not a secondary source of these constituents to groundwater. The constituents in soil are not leaching to groundwater at concentrations that exceed DWC and GSIC as evidenced by the SPLP results and groundwater data. Based on the low number (generally less than 1%) of DWPC and GSIPC exceedances for VOCs and PNAs and the associated SPLP analyses that indicate that only a small (between 5% to 30%) subset of this sparse sample population exhibit the potential to leach contaminants to groundwater, Enbridge concludes that human health risk associated with leaching of contaminants from soils in overbank areas is generally low. Further, as discussed below in *Section 4.1.6*, *Section 4.1.7*, and *Section 4.1.8*, contaminant concentrations are identified in a very limited number of groundwater samples and support that risk is generally low.

4.1.3 Soil Volatilization to Indoor and Ambient Air

Concentrations of Line 6B crude oil constituents exceed SVIAC in less than 1% of samples. There are no buildings situated at these locations. None of the groundwater or soil samples had concentrations of Line 6B crude oil constituents that exceed Criteria for protection of ambient air. Human health risk associated with volatilization to indoor and ambient air is very low.

4.1.4 Inhalation of Soil Particulates

None of the soil samples had concentrations of Line 6B crude oil constituents that exceed PSIC.

4.1.5 Soil Saturation Screening Levels

None of the soil samples had concentrations of Line 6B crude oil constituents that exceed the soil saturation screening level.

4.1.6 Drinking Water

Enbridge conducted a visual survey in conjunction with the State of Michigan's database to locate all private drinking water wells located within the 200-ft buffer zone of the Kalamazoo River and Morrow Lake (i.e., 200 ft of the inundation zone), and within 200 ft of Talmadge Creek. These wells, and some concerned landowner's wells located within a reasonable distance from the Line 6B crude oil release area, were included in the drinking water monitoring program. A total of 168 drinking water wells were included in this monitoring program as detailed in the approved *SAP Attachment B Drinking Water Well Supplement to the Sampling and Analysis Plan*, submitted to the MDEQ on April 10, 2013 (Enbridge, 2013c).

The drinking water well data demonstrate that drinking water wells located within 200 ft of the inundation zone have not been impacted by the Line 6B crude oil release. Line 6B crude oil organic constituents were not detected in approximately 2,300 samples collected from these drinking water wells. The MDCH independently evaluated the groundwater data from the drinking water wells and concluded that "no oil-related organic chemicals were found in people's water" (MDCH, 2013).

Nickel and iron concentrations exceeded DWC in some samples, but are attributed to naturally occurring background conditions that existed before the Line 6B crude oil release (MDCH, 2013). Enbridge is in concurrence with this finding and maintains that the presence of a suite of target metals (beryllium, molybdenum, nickel, and vanadium) in soil and groundwater is due to natural factors and not to the Line 6B crude oil release. The *White Paper: Evaluation of Metals in Soil and Groundwater*, submitted to the MDEQ for comment on June 4, 2014 (Metals White Paper) (Enbridge, 2014c) presents multiple lines of evidence from accumulated data in support of this conclusion. A summary of these lines of evidence is provided in *Section 4.3*.

Based on the data, Enbridge concludes that there is no risk to human health via drinking water supply. A formal document entitled A *Request for Discontinuing the Drinking Water Monitoring Program* was submitted to the MDEQ on July 30, 2014 (Enbridge, 2014d).

4.1.7 Groundwater

In addition to the analysis of samples from drinking water supply wells, groundwater was collected throughout the impacted overbank areas via a network of temporary wells and monitoring wells. Approximately 1,300 temporary and monitoring well locations were distributed throughout the Source Area and the greater Spill Area. Groundwater impact can potentially occur via direct contact between pore water and oil or through leaching from impacted soils to the groundwater. The Ground Water White Paper provides a comprehensive overview of results addressing these potential impacts. Samples collected from August 2010 through May 2014 are included in this evaluation.

Very few (less than 3%) exceedances of VOCs and PNAs were observed, which indicated a low general risk to groundwater quality. All VOC exceedances came from the Source Area, and not from the greater Spill Area. Isolated detections occurred within the first mile downstream of the Source Area. PNA exceedances were very infrequent (less than 1%) and only exceeded DWC. Concentrations of benzo(g,h,i)perylene exceeded the DWC in less than 0.5% and a concentration of benzo(k)fluoranthene exceeded the DWC in less than 0.5% of these samples. Concentrations of benzene in less than 3% of samples exceeded the DWC. All of these samples were located in the Source Area.

While limited PNA and VOC related groundwater impacts were observed, there is no evidence of subsurface contaminant mass(es) (i.e., NAPL bodies) in the greater Spill Area, therefore the risk of future impacts to the groundwater from any remaining Line 6B crude oil is low. This assessment was accomplished using fundamental chemical principles (equilibrium partitioning theory), location-specific observations of contaminant concentrations in paired groundwater and soil samples, laboratory assessments of leaching potential, and an analysis of spatial and temporal trends in compound concentrations. The results of this effort, summarized below from the Groundwater White Paper, show the following:

- Based on equilibrium partitioning theory and the composition of the Line 6B crude oil, no PNA groundwater Criteria exceedances are possible based on direct crude-oil-to-water contact.
- Using the same calculations as above, only limited exceedances of VOCs (i.e., BTEX) are possible.

- VOC and PNA concentrations, as measured in all groundwater collected, are consistent with the theory-based calculations and show low numbers of detections and even fewer exceedances, less than 3% of DWC and the GSIC.
- When the ability of PNAs to leach from soils into water were evaluated using the SPLP, most soils (approximately 90%) with significant PNA concentrations did not produce any detectable PNAs in leachate. This low efficiency leaching confirms theoretical expectations based on the very low effective solubility of PNAs in groundwater.
- VOC SPLP analysis yielded similar results. Of the samples that had SPLP leachate analyses less than 3% of samples had leachate concentrations that exceeded the groundwater Criteria (DWC or GSIC).
- Spatially, PNA detections in soil and groundwater are sparsely distributed throughout the Kalamazoo River floodplain with none of the detections occurring along the banks of Talmadge Creek or the Source Area.
- For VOC samples, particularly the BTEX compounds, there is a greater frequency of detection than for PNAs, though still low (less than 3%). Almost 90% of the samples with detected VOCs occur within 1 mile of the Line 6B crude oil release. The general pattern observed for VOC contamination in groundwater is that it is confined to the Source Area.

The results summarized above show a very low risk of groundwater impact from remaining Line 6B crude oil in the Spill Area.

In addressing the potential impact of metals from Line 6B crude oil, Enbridge focused on detections of beryllium, molybdenum, nickel, and vanadium in foreground and background sampling. Enbridge concluded, based on soil and groundwater sampling from 2010 through 2014, that the widespread presence of these four metals, in nearly all groundwater samples, at low concentrations was consistent with a natural background source. Further, SPLP analyses show low likelihood of significant leaching from soil.

4.1.8 Groundwater Surface Water Interface

Concentrations of xylene in less than 0.1% of groundwater samples exceeded the GSIC. Enbridge concludes that human health and ecological risk associated with groundwater exceedances of Criteria are low.

4.1.9 Groundwater Volatilization to Indoor Air

None of the groundwater samples had concentrations of Line 6B crude oil constituents that exceed the GVIAIC.

4.1.10 Acute Hazards

None of the groundwater samples had concentrations of Line 6B crude oil constituents that exceed acute hazard Criteria.

4.1.11 Surface Water and Sediment Direct Contact and Incidental Ingestion

Surface water quality was monitored at weekly to monthly intervals at select locations in the Kalamazoo River and Morrow Lake. Approximately 4,000 surface water samples were collected and analyzed, depending on the constituent. The DWC and Rule 57 Water Quality Values (human non-cancer value, human cancer value, and final chronic value) were used to evaluate the surface water data.

Less than 0.2% of the surface water samples (collected from September 2011 through May 2014) have concentrations that exceed Rule 57 Water Quality Values. The results were summarized in *Request for Discontinuing the Surface Water and Sediment Monitoring Programs,* submitted to the MDEQ on May 29, 2014 (Enbridge, 2014e).

Human health risks associated with direct contact and incidental ingestion of river and other sediments were independently evaluated by the MDCH (MDCH, 2012, and MDCH, 2014). The MDCH found risks are low (MDCH, 2012) and made the following conclusions:

- Contact with sediments containing submerged oil, oil remaining in floodplains and on riverbanks (such as tar patties), or sheen on the water could cause temporary health effects, such as skin irritation,
- Repeated skin contact with and accidently eating small amounts of sediment containing submerged oil will not result in long-lasting health effects, and
- Repeated skin contact with and accidently eating small amounts of sediment containing submerged oil will not result in a higher than normal risk of cancer.

The MDCH also performed an evaluation of the risks associated with recreational exposure to river water and fish (MDCH, 2014). Human health risks associated with direct contact and incidental ingestion of surface water and ingestion of fish from the Kalamazoo River and Morrow Lake are low. The MDCH study concluded that chemicals found in surface water are not expected to cause long-term harm to people's health. Risk to people consisted of potential temporary health effects, such as skin irritation from contact with oil sheen, or tar globules in the water.

The MDCH concluded that Line 6B crude oil-related chemicals found in fish from the Kalamazoo River and Morrow Lake will not harm people's health (MDCH, 2014). The MDCH had previously issued fish consumption guidelines before the Line 6B crude oil release for these waters and most other waters in Michigan due to concentrations of mercury and PCBs found in fish filets. Mercury and PCBs are not related to the Line 6B crude oil release.

4.2 Ecological Health: What Risk is Present?

Ecological risk involves multiple receptors, exposure pathways in both terrestrial (overbank soil) and aquatic (overbank sediment, overbank surface water and in the Kalamazoo River channel) settings. Remaining Line 6B crude oil in soil, water, and sediment may pose a potential risk to ecological receptors via ingestion, direct contact pathways or bio-concentration.

4.2.1 Aquatic Ecological Risk

Aquatic ecological risks for the Kalamazoo River and for surface waters present in overbank areas are evaluated separately. The evaluation of aquatic ecological risks for the Kalamazoo River is complete and is summarized below. The evaluations of aquatic ecological risks in overbank surface waters are being done in NFA Reports or RI Reports for each Reach.

In the *Potential Chronic Effects of Line 6B Residual Oil Report of Findings,* submitted to the MDEQ on April 25, 2014 (Enbridge, 2014f), three lines of evidence (sediment chemistry, sediment toxicity, and benthic macro-invertebrate community structure), collectively known as the SQT were evaluated for evidence that the Line 6B crude oil release has impacted the ecology of the Kalamazoo River sediments. This study focused on depositional areas and the benthic macro-invertebrate community in Kalamazoo River sediments as potential worst-case indicators of impact.

The Kalamazoo River sediment chemistry evaluation concluded:

- When bioavailability of PNAs is considered (as governed by total organic carbon in the sediment), potentially toxic locations are not present in the Line 6B crude oil impacted reaches of the Kalamazoo River. Rather, they are limited to reference locations in the Kalamazoo River upstream of the Spill Area and to the Battle Creek River (also upstream).

The Kalamazoo River sediment toxicity evaluation concluded:

- In 2013, data indicate that toxicity is mostly absent in the evaluated parts of the river. The few significant toxic effects observed:
  - Have low absolute magnitude of toxicity,
  - Are similar to effects seen in reference areas, and
  - Are reduced from the toxicity observed in 2012 at the same locations.

The absolute magnitude of toxic effects is small, and the reductions in growth or survival in samples with statistically significant reductions are small (10% to 15%).

The Kalamazoo River sediment benthic macro-invertebrate community structure evaluation concluded:

- There is no discernible pattern in predicted PNA toxicity, observed significant toxicity, and diversity indices,
- The reduced apparent density of benthic biota in the Kalamazoo River may be an indication of past impact and subsequent recovery in population density. Density differences can also be influenced by non-Line 6B crude oil causes (e.g., sediment substrate type, water quality, temperature, erosion, and sedimentation),
- Benthic invertebrate density actually appears slightly positively correlated with predicted PNA toxicity units, a counterintuitive finding,
- The benthic communities show little evidence of stress or adverse effects, and
- The low sediment toxicity and trends in sediment benthic community metrics in the sampled areas of the Kalamazoo River in 2013 coincide, indicating that significant adverse biological effects from any source are absent.

Bioavailability of contaminants is low, and the impacts of stressors and contaminants unrelated to the Line 6B crude oil release are significant in the Kalamazoo River. Data indicate that any low level biological effects cannot be correlated with Line 6B crude oil constituents.

The overall SQT evaluation of ecological risk concluded that, based on the low levels of toxicity predicted by the sediment chemistry, the low levels of toxicity seen in toxicity tests, and an observed benthic community diversity consistent with reference locations, the remaining Line 6B crude oil does not have significant ongoing adverse impact on the aquatic ecosystem. The MDEQ concurred with the conclusions presented in the evaluation in an email on September 19, 2014, but requested additional data gap sampling. Enbridge submitted the approved *In-Channel Remedial Investigation Work Plan for the Kalamazoo River*, to the MDEQ on December 12, 2014 (Enbridge, 2014g). Results from the additional sampling were presented in the *Addendum to the Potential Chronic Effects of Line 6B Residual Oil Report of Findings*, submitted to the MDEQ on October 30, 2015 (Enbridge, 2015c).

Aquatic ecological risks associated with overbank surface water and sediments from ponds, wetlands and streams are being evaluated in the RI Reports or NFA Reports using Michigan's Water Quality Values presented in *Section 1.5.3* and *Section 1.5.4* respectively.

4.2.2 Terrestrial Ecological Risk

Concentrations of urban background contaminants, naturally occurring background concentrations, and Line 6B crude oil constituents in overbank soil may impact terrestrial ecological receptors such as plants, mammals, soil invertebrates, and birds. Enbridge used the R5 ESLs for VOCs and SSLs for PNAs to screen soil data from Talmadge Creek and the Kalamazoo River overbank areas. UBC (available for benzo(a)pyrene, fluoranthene, and phenanthrene) and TBCs for total low molecular weight (LMW) and high molecular weight (HMW) PNAs were used to identify probable urban impacts unrelated to the Line 6B crude oil release.

The data screened included all saturated and unsaturated soil data through July 2014, from background locations and Spill Area locations, excepting data from excavated soils. Approximately 2,980 samples of soil from the Talmadge Creek Spill Area were analyzed for VOCs and approximately 3,360 samples were analyzed for PNAs. Approximately 3,330 samples from the Kalamazoo River Spill Area were analyzed for VOCs and approximately 4,880 were analyzed for PNAs. Based on this screening Enbridge found the following results:

Talmadge Creek Overbank Areas

- Concentrations of VOCs did not exceed R5 ESLs in the background samples and in less than 1% of the Spill Area samples.
- Concentrations of LMW PNAs (i.e., four rings or fewer) did not exceed SSLs in either Spill Area or background locations.
- Concentrations of HMW PNAs (greater than four rings) did not exceed the SSL in background samples and exceeded the SSL in less than 1% of the Spill Area samples.

Kalamazoo River Overbank Areas

- Concentrations of VOCs did not exceed R5 ESLs in the background samples and less than 1% of the Spill Area samples.
- Concentrations of LMW PNAs did not exceed SSLs in the background samples and less than 1% of the Spill Area samples.
- Concentrations of HMW PNAs exceeded SSLs in 82% of the background samples and 47% of the Kalamazoo River Spill Area samples.

Measureable terrestrial ecological impacts in the Source Area and greater Spill Area related to Line 6B crude oil or urban concentrations are unlikely and low in magnitude. In the Source Area, measurements around Talmadge Creek show residual impacts and risk are unlikely due to the low frequency of concentrations of Line 6B crude oil constituents in soil samples that exceed screening levels. Measurable terrestrial ecological impacts (if any) in the Kalamazoo River Spill Area are likely to be less than or equal to those observed in background (upstream) areas and therefore not related to the Line 6B crude oil release.

4.3 Which Impacts in the Spill Area Are Attributable to Background Conditions and Legacy Contamination?

The analytical results presented above shows that observed impacts and associated risks to human health and the environment are low within the Kalamazoo river channel and floodplain. Pre-existing background analytes have been identified throughout the Spill Area. Background analytes are of concern because they interfere with accurate interpretation of impacts which are truly attributable to the Line 6B crude oil release and obscure the cleanup endpoints for project closure. These background analytes can be divided into two distinct types, those that are naturally occurring (background metals) and those that are associated with historical land use (urban background).

Background metals are those naturally occurring metal constituents that are attributable to bedrock and the glacial substrate through which the river and creeks flow. A targeted subset of metals of concern (beryllium, molybdenum, nickel, and vanadium) has been identified for analysis.

Legacy contamination or urban background refers to impacts to soil, sediment, surface water, and groundwater in the Spill Area that originated from industry, agriculture, or other anthropogenic sources other than the Line 6B crude oil release. The Kalamazoo River basin has a long history of industrial and agricultural development that predates the Line 6B crude oil release by well over 100 years. As a result, a range of compounds have impacted the watershed, most notably PNAs, but also VOCs, metals, and PCBs. Environmental media were impacted before the Line 6B crude oil release and are being evaluated with respect to this historic impact. Enbridge’s primary focus concerning legacy contamination in the Spill Area is those chemicals that are also constituents of Line 6B crude oil.

While Enbridge has aggressively and comprehensively addressed impacts associated with the Line 6B crude oil release, Enbridge is not responsible for naturally occurring background metals or urban background constituents that are unrelated to the Line 6B crude oil release. The following sections discuss background concentrations detected for metals and urban PNA constituents.

4.3.1 Background Metals

Enbridge analyses show that beryllium, molybdenum, nickel, and vanadium, identified as trace components of Line 6B crude oil, also occur naturally in the Kalamazoo River watershed in soil, sediment, and groundwater in low concentrations and wide geographic distribution. This is detailed in the Metals White Paper. A summary based on the data of the Metals White Paper is included in this section. The detection and occasional exceedance of these target metals (beryllium, molybdenum, nickel, and vanadium) are not attributable to Line 6B crude oil. Three lines of evidence support this finding:

- A review of the stability of the target metals in Line 6B crude oil,
- An assessment of the maximum concentration of the target metals that Line 6B crude oil could contribute to soil samples, and
- An evaluation of the distribution of the metals in soil and groundwater, and their exceedances of Criteria across the Spill Area.

4.3.1.1 Metals Stability

The target metals present in Line 6B crude oil are minor constituents. They are well bound within the bitumen, which is a principle component of Line 6B crude oil. A primary component of bitumen is asphaltene, which can make up to 20% of the bitumen. Asphalatenes consist of insoluble, HMW, aromatic compounds. Heavy metals in asphaltenes, such as vanadium and nickel, occur in organic porphyrin structures. The organic porphyrin structures are very stable and trapped within the asphaltenes. As a result, target metals are not readily weathered into inorganic forms in soil or groundwater under normal, seasonal environment conditions.

Research has shown that these metals can only be released using very high temperatures or other intense methods that do not occur under natural conditions (Health Canada, 2010). As a result, heavy metals in the organic porphyrin complexes, and vanadium in particular, are not significantly leached or weathered from the Line 6B crude oil. Moreover, additional studies show that the partitioning of vanadium and nickel from the oil phase to the aqueous phase is extremely low and that most of the vanadium and nickel in the aqueous phase is primarily in an organic complex form, not an ionic form, which further reduces toxicity concerns (Cantu et al., 2000). Metals are stable within the Line 6B crude oil and are not likely to be leached from the crude to soils or groundwater.

4.3.1.2 Theoretical Maximum Concentration Increases to Soil

While heavy metals are unlikely to leach from Line 6B crude oil because they are chemically bound in the oil, this section evaluates the theoretical maximum if the metals were to become incorporated into the soil. This is done by calculating the maximum increase in target metal concentrations that Line 6B crude oil could contribute to the soil.

This evaluation uses the average concentration of the target metals in Line 6B crude oil. This was obtained from chemical analysis of four samples of Line 6B crude oil collected in August and October 2010. Results show that differences in metal concentrations among the samples were generally low (coefficient of variation is less than 1).

The concentration of beryllium and nickel in the Line 6B crude oil is below the lowest applicable Criteria (DWPC). Therefore, even if a soil sample was 100% Line 6B crude oil, it would not contain enough beryllium or nickel to exceed the Criteria. If a soil sample had a concentration of beryllium or nickel that was marginally below the Criteria, and was then impacted with Line 6B crude oil, the mixing of the oil with the soil sample would proportionately result in an overall decrease in the concentration of beryllium or nickel in the impacted soil sample. Based on this, beryllium and nickel contributions from Line 6B crude oil could not result in Criteria exceedances of soils.

For molybdenum and vanadium theoretical maximum increases in soil concentrations that could be contributed by the Line 6B crude oil were calculated using their average concentrations in Line 6B crude oil. The concentration increases in soil were then calculated as a proportion of Line 6B crude oil in impacted soil. For the purpose of the calculations, the maximum detected Line 6B crude oil concentration of 200,000 mg/kg in soil was assumed. Molybdenum soil concentration increase is 1.0 mg/kg (compare to the DWPC of 1.5 mg/kg), and the vanadium soil concentration increase is 27 mg/kg (compare to the DWPC of 72 mg/kg). These theoretical increases are below their respective Criteria. This shows that even in soil samples impacted by Line 6B crude oil, the contribution from Line 6B crude oil to molybdenum and vanadium concentrations in soil must be below Criteria.

The distribution of Line 6B crude oil was spatially heterogeneous in the Spill Area making theoretical cases such as presented above difficult to apply universally with absolute certainty. However based on the argument above, the small amount of metals in the Line 6B crude oil cannot alone result in metals concentrations in soil in exceedance of Criteria.

4.3.1.3 Distribution of Metals in Soil and Groundwater

If metals exceedances were attributable to the Line 6B crude oil release, certain data relationships and spatial conditions would be expected:

- Samples with the highest target metal concentrations would also have other indicators of the Line 6B crude oil release, such as detections of PNAs and/or VOCs, oil globules, sheen, or fluorescence.
- The target metal concentrations would increase toward the Source Area and would decrease with distance downstream.
- Target metal concentrations would be higher within the Spill Area and significantly lower in unaffected/background areas.

Across the Spill Area over 5,000 soil samples and over 2,000 groundwater samples have been analyzed for the target metals. The following points summarize the trends in metals data throughout the Spill Area:

<u>Soils</u>

- Beryllium results showed no exceedances of Criteria in the overall Spill Area.
- Nickel results showed only two exceedances in the Spill Area at locations 15 miles and 21 miles downstream from the Source Area.
- Molybdenum exceeded Criteria in approximately 1,500 samples across the Spill Area. Of these approximately 1,200 samples were screened for the presence of Line 6B crude oil (visual oil, sheen, or fluorescence) and the vast majority, approximately 78% reported no visual oil, sheen, fluorescence or other indicators of Line 6B crude impact. In the case of the approximately 22% of the samples exceeding Criteria and having an indicator of Line 6B crude oil impact the molybdenum concentrations were generally lower (1.6 mg/kg to 7 mg/kg) than the samples without observations of Line 6B crude oil.

- Molybdenum exceeded Criteria in approximately 55% of the background samples in Talmadge Creek. This included the highest molybdenum concentration detected on the project (67 mg/kg), which was reported in a background sample collected on Talmadge Creek upstream from the Source Area (background sample).
- Molybdenum was evaluated using SPLP in 992 samples across the Spill Area to date, and only 20 of the samples (2%) exceeded the DWC.
- Vanadium exceeded Criteria in 66 samples collected throughout the Spill Area. Of these, 51 samples were screened for the presence of visual oil, sheen, or fluorescence and 50 (98%) reported no visual oil, sheen, or fluorescence. These samples had vanadium concentrations of 74 mg/kg to 360 mg/kg. For the single sample which had a vanadium Criteria exceedance and reported visual oil, sheen, or fluorescence the vanadium concentration was 110 mg/kg. Therefore the samples without observations of Line 6B crude oil exhibited similar or higher concentrations of vanadium than the single sample with reported observations of impact.
- The nine highest vanadium concentrations (170 mg/kg to 360 mg/kg) were all collected in the same area of Reach 9, near the former Ceresco Impoundment. Three of these samples were from the Marshall Sandstone bedrock. The vanadium concentration in these three samples ranged from 170 mg/kg to 300 mg/kg.

In addition to the metals evaluation presented in the Metals White Paper, the MDEQ developed an approach to evaluate if metal exceedances within soils are attributable to Line 6B crude oil. The MDEQ findings determined that metal exceedances along Talmadge Creek were not attributable to Line 6B crude oil. This conclusion is also applicable to metals within the entire Spill Area soils.

No data relationship exists between the Line 6B crude oil release and metals detected in soils. Metals impacts were low, widespread, and showed no spatial pattern in concentrations that suggested anything other than a vanadium hotspot near outcropping Marshall sandstone.

Trends in groundwater are similarly summarized below:

<u>Groundwater</u>

- Only 37 groundwater samples of the over 2,000 samples analyzed in the entire Spill Area to date reported exceedances of beryllium, molybdenum, or nickel. All of these samples reported elevated turbidity and, as a result, the turbidity is attributable to sediment in the samples.
- Across the entire Spill Area only 3% of the detected vanadium concentrations from filtered samples exceeded Criteria (seven samples out of a total of 222 filtered samples). These exceedances occurred at four permanent wells and one soil boring/temporary well. Of these, the locations with the highest vanadium concentrations were measured in two monitoring wells located north and south of the Kalamazoo River immediately upstream of the former Ceresco Dam. Both wells are located outside the inundation zone as well as outside the potential groundwater flow paths related to the Ceresco Dam backwater. Following removal of the Ceresco Dam in 2013, the water elevation in these wells dropped into the bedrock and left only 2 ft to 4 ft of water in the wells. During the December 2014 sampling event, both wells purged dry before they could be sampled. In accordance with the approved *Sampling and Analysis Plan (SAP)*, submitted to the MDEQ on August 30, 2011 (Enbridge, 2011), the wells were allowed to recover and then sampled the following day. The samples for both wells were characterized as cloudy (elevated turbidity) and had vanadium concentrations of 0.840 milligrams per liter (mg/l) and 0.210 mg/l, respectively approximately 5 to 20 times higher than any other vanadium detections. These circumstances indicate that the elevated vanadium concentrations are related to the Marshall Sandstone in the Kalamazoo River watershed.
- In a related line of evidence, there is a tendency to find higher vanadium concentrations in deeper temporary wells. This is contrary to what would be expected if vanadium exceedances were associated with the Line 6B crude oil release, which would have a greater effect on shallower groundwater located near the ground surface.

The MDEQ also developed an approach to determine if metal exceedances in groundwater along Talmadge Creek, primarily vanadium, are attributable to Line 6B crude oil. A total of 10 monitoring wells were installed along Talmadge Creek and one round of groundwater samples was collected. The analytical results reported that all samples were non-detect at the method detection limit. The MDEQ concurred that the metal Criteria exceedances in groundwater observed along Talmadge Creek are not attributable to Line 6B crude oil. This conclusion can be applicable to metals within the entire Spill Area groundwater based on the similar percent of Criteria exceedances observed along Talmadge Creek and the Spill Area.

No data relationship exists between the Line 6B crude oil release and metals detected in groundwater. Metal impacts associated with beryllium, molybdenum, and nickel are nonexistent or occur rarely with no spatial pattern that mirrors the Line 6B crude oil release. Vanadium detections, though more frequent and occasionally above Criteria, more closely reflect conditions associated with groundwater in the Marshall Sandstone or regional groundwater discharge. Overall, there is no indication that the Line 6B crude oil release is the source of target metal Criteria exceedances of groundwater.

These multiple lines of evidence support that the metal detections and exceedances in both soil and groundwater within the Spill Area are not attributable to Line 6B crude oil.

4.3.2 Legacy Contamination

A range of compounds derived from the long history of industrial and agricultural development in the Kalamazoo River Basin have impacted the watershed, most notably PNAs, but also VOCs, metals, and PCBs. Many of the sites of environmental contamination regulated under Part 201 referenced in the *Kalamazoo River Assessment* (Wesley, 2005) are deemed to have high potential for migration of groundwater contaminants to the Kalamazoo River, especially in areas with high groundwater flows.

As described in *Section 3.1*, PNA constituents are likely associated with pyrogenic sources. PNAs are present at low to trace levels in Line 6B crude oil. However, these PNAs are petrogenic in origin and can be differentiated pyrogenic PNA constituents.

PNA concentrations have been detected in background soil samples collected along the Kalamazoo River upstream of the confluence with Talmadge Creek, outside the area impacted by the Line 6B crude oil release. PNAs were detected in 91% of the background soil locations, and 32% of the background locations exceeded Criteria. In these background samples, PNA constituents associated with pyrogenic sources were the primary PNAs detected, while PNAs associated with natural petroleum formation were detected at lower concentrations. The PNAs with concentrations above soil Criteria were primarily pyrogenic in origin. In addition, the geographic distribution and detection frequency of PNAs in soil strongly suggests that Line 6B crude oil is not the source of most PNAs detected in the Spill Area.

The background PNA data were also used to develop UBC, as has been used at other sites in Michigan according to the MDEQ. The UBC were developed for benzo(a)pyrene, fluoranthene, and phenanthrene. All of the Kalamazoo River background samples were used in the calculations to develop the UBC as presented in the Urban PAH White Paper. The calculated UBC for the three PNAs are presented below:

- Benzo(a)pyrene – 13,912 ug/kg,
- Fluoranthene – 30,493 ug/kg, and
- Phenanthrene – 7,853 ug/kg.

As a further line of evidence that Line 6B crude oil is not the source of most PNAs detected in the Spill Area, Enbridge performed a PNA “fingerprinting” assessment that included forensic analyses and other lines of evidence as a prudent course of action that demonstrated that the pyrogenic-sourced PNA constituents detected within the Kalamazoo River Spill Area are primarily derived from historic, legacy impacts unrelated to the Line 6B crude oil release. The results of this analysis were presented in the Urban PAH White Paper.

The Urban PAH White Paper evaluation demonstrates that:

- PNA concentrations found in the majority of soil samples collected from the Kalamazoo River floodplain background, an area that was not impacted by the Line 6B crude oil release, are generally greater than detections in the Spill Area and greater than applicable Criteria;
- PNA concentrations in the Spill Area of the Kalamazoo River floodplain are usually less than the Kalamazoo River background concentrations;
- PNA chemical profiles in Kalamazoo River background soils are frequent matches to PNA profiles from samples collected within the Spill Area, including most samples that have PNA Criteria exceedances; and

- The spatial distribution of PNAs with respect to distance from the river banks, found in both Kalamazoo River Background samples and the Reach 5 Spill Area samples, are consistent with a signature of long-term impacts from background sources rather than the Line 6B crude oil.

Based on the multiple lines of evidence presented above, Enbridge concludes that the source of most PNAs detected in the Spill Area is not the Line 6B crude oil.

4.4 Non-Aqueous Phase Liquid (NAPL): Is there Risk of Migration of Remnant Line 6B Crude Oil into new areas or new media?

NAPL is defined as a liquid, such as gasoline, diesel or other petroleum based fuel, waste oil, or crude oil that contains one or more organic compounds that are relatively insoluble in water (ASTM, 2007; ITRC, 2009; MDEQ, 2014d). In the environment, NAPL exists as a separate phase that is immiscible with water. Line 6B crude oil met the definition of a NAPL in its unweathered state immediately following the release.

NAPL is of concern because if present it not only indicates a significant mass of contaminant which may act as a source of constituents of concern to a wider spread dissolved phase plume (chemical and compositional risk), but also if present in large enough concentrations presents challenges associated with contaminant mobility and contaminant migration (saturational risk). Therefore Enbridge has worked in conjunction with the MDEQ to evaluate potential NAPL mobility (saturational risk), and the ability of any potential NAPL bodies if present to act as a source for dissolved plume impacts to groundwater (compositional risk) within the overbank portions of the Source Area and Spill Area.

Enbridge's full evaluation of potential risks associated with NAPL is detailed in the NAPL White Paper. In short, this effort showed that while low levels of NAPL saturation were present, no NAPL mobility was exhibited. Overall, the NAPL remaining is regarded as *de minimis* and discrete observation (sparse immobile residuals). General findings of this effort are summarized in this section.

4.4.1 Basic NAPL Concepts and Guidance Documentation

Enbridge has adopted recent NAPL guidance provided by the MDEQ, the ASTM, and the ITRC. The evaluation and conceptualization of NAPL presence and potential impact are conducted in accordance with MDEQ's Policy and Procedure document, *Non-aqueous Phase Liquid (NAPL) Characterization, Remediation, and Management for Petroleum Releases* (MDEQ, 2014d), the ITRC's *Evaluating LNAPL Remedial Technologies for Achieving Project Goals* (ITRC, 2009), and the *Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Non-aqueous-Phase Liquids Released to the Subsurface* (ASTM, 2007).

4.4.2 NAPL Observations: Monitoring Wells and Soil Borings

Within the environmental industry, observations and measurements of NAPL as a separate phase in monitoring wells is common practice and a high confidence method used to assess the presence of mobile NAPL. For this reason, Enbridge has routinely used interface probes to evaluate the presence of NAPL as a separate phase in monitoring wells. However, NAPL has never been observed or measured in any of the monitoring wells installed in the Source Area or Spill Area.

Throughout the Spill Area, approximately 6% of soil boring locations (from MP 0.00 to MP 35.25) had some indication of NAPL presence in the subsurface. Direct indications of NAPL (visible oil or globules of oil within the logged soil) were made at approximately 25% of the subset and indirect indicators of NAPL (ultraviolet (UV) fluorescence or sheens) were found in the remaining 75% of the subset. In accordance with the *Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Non-aqueous-Phase Liquids Released to the Subsurface* (ASTM, 2007), sheen is a secondary weight of evidence indicator for the potential presence of NAPL. Sheen observations represent minor, lingering remnants of NAPL and are not by themselves considered a NAPL body or residual NAPL. A NAPL Body, for the purpose of this project, is defined as a contiguous, measureable volume of Line 6B crude oil product in soil or on groundwater or in the soil pore volume, and not discontinuous, isolated and *de minimis* observations of NAPL.

Observation of NAPL in the aftermath of response actions is extremely limited. NAPL has not been directly observed within groundwater monitoring wells in the Spill Area following response actions. Direct observations of NAPL were reported in only 1.5% of all soil borings, while indirect (i.e., UV fluorescence or sheen) observations of NAPL were reported in less than 6% of soil borings throughout the entirety of the Spill Area. Data do not indicate the presence of significant NAPL bodies in the overbank throughout the Spill Area.

4.4.3 NAPL – Mobility Testing (Saturational risk)

While NAPL mobility or the presence of NAPL bodies is not indicated based on current data and observations, the potential mobility of NAPL can be evaluated using known worst case areas. As discussed with and agreed upon by the MDEQ, Enbridge conducted a phased NAPL mobility study to determine the significance of the NAPL observations made within the Spill Area. Enbridge reviewed historic observations and analytical results collected during response actions and the remedial investigations to arrive at a total of 12 “worst case” locations from the Source Area to 13 miles downstream. While the selection process focused on impacted locations that were most likely to have the highest NAPL saturation (i.e., visible oil in soil cores), locations selected also had a range of visual impacts, UV fluorescence, soil type, and saturation. New soil borings were collected at these sites (4 ft bgs), located as close as possible to the boring in which impact was initially observed. The 28 new borings were subjected to petrophysical testing including NAPL pore saturation (using the Dean-Stark Method detailed in the *Recommended Practices for Core Analysis* (API, 1998)) and NAPL mobility using water drive method (PTS Laboratories, Inc. proprietary method).

Notably low levels of NAPL saturation (2.5% to 10.7%) were found. These saturations are nominally below the range for residual NAPL saturations (7% to 16%) of the soil types present within the Spill Area (Carsell and Parish, 1988). NAPL is rarely observed to exhibit significant mobility at saturations below 20% to 25% (Rousseau et al, 2012). Mobility testing of these worst case samples was consistent with this and none of the samples exhibited mobility under the water drive method.

Any NAPL, after 5 years of weathering and due to its very high viscosity, would require substantially higher saturations than those observed before any mobility would be expected. The test results are further supported by the lack of NAPL observed in any monitoring wells and particularly the monitoring wells installed at the locations of NAPL mobility evaluation soil borings. Together, these findings clearly show that any remaining NAPL in the Spill Area is immobile. As a result, there is no saturational risk associated with the remaining *de minimis*, isolated and immobile NAPL.

4.4.4 NAPL-Analytical Testing (Compositional Risk)

In addition to the petrophysical testing, laboratory analytical testing was conducted on soil and groundwater samples collected from worst case locations to assess compositional risk and the potential for the NAPL to leach dissolved phase impacts to groundwater at concentrations in excess of Criteria.

Analytical groundwater and soils data associated with the Spill Area wide evaluation of human health risk (*Section 4.1.2, Section 4.1.6,* and *Section 4.1.7)* provide an additional line-of-evidence to demonstrate that soil and groundwater in the Spill Area reflect minimal impacts from the weathered, isolated, immobile NAPL.

4.4.4.1 Soil Analyses

Chemical analyses, specifically from the 12 worst case locations, showed few exceedances of Criteria for PNAs and VOCs. The selection process focused on impacted locations that were most likely to have the highest NAPL saturation (i.e., visible oil in soil cores).

With the exception of the VOC exceedances in the Source Area, no other SPLP or groundwater samples from temporary wells or monitoring wells where NAPL observations were recorded showed exceedances. Given that these samples were collected from the most impacted areas remaining in the Spill Area, these analytical results demonstrate that the remaining NAPL does not pose a risk of contributing dissolved phase impacts to groundwater. As a result, the residual NAPL in worst case locations does not pose a compositional risk to groundwater.

Analytical results from the subset of Spill Area-wide sample locations exhibiting NAPL observations show a near absence of compositional risk from the Line 6B crude oil. Less than 5% of the locations where NAPL was observed showed a potential for groundwater impact (an exceedance of GSIPC). Most of these locations were accompanied by an SPLP analysis and/or groundwater sample collected from a temporary well or monitoring well. Analytical results show, with one exception in the Source Area, that the residual NAPL did not contribute to groundwater impacts in excess of Criteria.

The one exception in the Source Area was an isolated area of impact that contributed to benzene exceedances of DWC. However, even in this single location, the benzene concentrations reported in quarterly groundwater sampling is clearly trending downward.

4.4.4.2 Groundwater Analyses

The only area of groundwater exceedances of Criteria that can be attributed to residual NAPL occurs within the Source Area. Taken as a whole, the Spill Area-wide groundwater assessment of locations where NAPL was observed provides another line-of-evidence to demonstrate that the residual NAPL from the Line 6B crude oil release does not represent a human health or ecological risk to groundwater.

4.4.5 Conclusions Regarding NAPL Risk

Results summarized here and presented in the NAPL White Paper, show that there is no indication of remnant Line 6B crude oil NAPL bodies within the overbank of the Spill Area (inclusive of Source Area). Assessments of NAPL saturational risk (mobility) from known worst case areas show that risk of migration of Line 6B crude oil remnants through soils and/or into other media (leaching to groundwater) is very low. NAPL compositional risk (chemical impacts observed in soils and/or associated groundwater) is also extremely low, with low risk only observed in isolated portions of the Source Area near the Line 6B crude oil release.

4.5 Has Nature and Extent Been Adequately Defined?

Extensive efforts have been conducted to define the nature and extent of the impacts from the July 2010 crude oil release from the Enbridge Line 6B pipeline in Marshall, MI. As shown in *Figure* 4 and *Figure 5*, the Spill Area has undergone extensive response activities and characterization (approximately 2,425 groundwater samples and 2,300 potable well samples, 10,500 soil samples, 4,000 surface water samples, 6,038 sediment samples, and

300 soil samples analyzed for VOCs and/or PNAs using the SPLP). PNAs and VOCs associated with Line 6B crude oil that exceed Criteria are rare and only exceed Criteria on a limited basis. Only seven Source Area monitoring wells have shown Line 6B crude oil constituents in groundwater that exceed Criteria.

Remaining NAPL impacts in the Spill Area have been delineated using multiple methods and have been documented only in isolated, discontinuous areas over a small scale. Residual NAPL does not contribute to groundwater exceedances of Criteria except within an isolated portion of the Source Area, which Enbridge is committed to addressing. The *de minimis*, isolated, and immobile NAPL associated with the Line 6B crude oil release does not pose a saturational or compositional risk nor should the presence of this residual NAPL be an impediment to regulatory closure.

4.5.1 Conclusions Regarding Adequacy of Data Coverage

Enbridge concludes that the magnitude of the sampling effort to date (in terms of spatial and temporal distribution and number of samples and analyses) has adequately characterized the nature and extent of Line 6B crude oil impacts. This is especially true given the low human health and ecological risks exhibited by remnants of Line 6B crude oil. Enbridge continues to address data gaps as necessary.

4.6 Do Aesthetics Concerns Exist and Are They Actionable?

Enbridge is performing an aesthetics evaluation for remaining Line 6B crude oil observations throughout the entire Spill Area as part of the reach by reach NFA process. The number of instances where aesthetic observations have been identified in the Spill Area have decreased dramatically as a result of response efforts performed to date. However, aesthetic observations, although rare, remain and may be observed in the future. The majority of the remaining aesthetic observations identified are discontinuous and *de minimis* in nature.

4.6.1 Aesthetics Evaluation Process and Summary of findings

The evaluation process to determine whether any of the remaining potential aesthetic observation would require further evaluation includes, but is not limited to, the following:

- Determine if MDEQ rules state the aesthetic observation requires actions (i.e., exceedance of aesthetic groundwater Criteria);

- Evaluate existing MDEQ guidance;
- Evaluate the geographic distribution of aesthetic observations to one another within each Reach (are multiple similar aesthetic observations in immediate proximity to one another or are they isolated);
- Evaluate the depth of the aesthetic observation (is it likely that an individual would come into contact with the aesthetic observation and find it objectionable); and
- Determine if aesthetic observation would be considered *de minimis*.

De minimis is typically defined as lacking significance or importance. *De minimis* aesthetic observations will be identified on a case-by-case basis using best professional judgment supported by multiple lines of evidence.

4.6.1.1 Surface Water Aesthetics

Enbridge continues to perform sheen monitoring, as allowed by weather conditions, on the Kalamazoo River to identify and collect any sheen observed. Historically (generally when the sheen (oil film) covered 100 square feet or greater), sheen response crews have been dispatched to remove the observed oil sheen. The incidence of these sheen events has decreased over time. Enbridge plans to continue this activity and evaluate trends related to sheen observations.

Enbridge prepared and submitted the approved *Kalamazoo River Residual Oil Monitoring and Maintenance Work Plan* to the MDEQ on July 8, 2014 (Enbridge, 2014h). The objective of this work plan is to monitor and maintain select sediment traps, to monitor historic and newly identified petroleum sheen locations, and to conduct annual poling at selected focused locations. The purpose of monitoring these locations is to visually observe, evaluate, recover (as appropriate), and document occurrences of petroleum sheen to demonstrate compliance with Rule 323.1050 (Physical Characteristics), from the Part 4 Water Quality Standards for Part 31. This information will be used to assess the existence of potential trends in sheen observations.

4.6.1.2 Groundwater Aesthetics

Enbridge has not identified any actionable groundwater aesthetic condition to date. The primary focus of the groundwater aesthetic assessment has been a comparison of groundwater analytical results to groundwater Criteria that are based on aesthetics. This comparison has shown groundwater samples collected to date do not exceed any of the established aesthetic Criteria.

4.6.1.3 Soil Aesthetics

To date, observations of potential actionable aesthetic conditions have been limited in quantity, and the majority of these remaining observations have been discontinuous and *de minimis*. If future observations were to be continuous over a larger area and/or of sufficient quantity such that it would pose an adverse aesthetic condition to the public, Enbridge would consider such observations as an actionable aesthetic condition.

5.0 PROJECT ENDPOINTS

The administrative process for achieving project milestones, endpoints under Part 201 regulations and per the MDEQ Consent Judgment, that represent progress toward regulatory closure for the project, has been established and generally agreed upon by Enbridge and the MDEQ for the Source Area, Talmadge Creek, and overbank areas of the Kalamazoo River affected by the Line 6B crude oil release. These milestones primarily include RI Reports for each Reach (*Figure 1*) and the NFA endpoint documents that incorporate multiple Reaches.

Aggressive and extensive remedial response actions performed to date have minimized the risk to human health and ecological receptors, and any remaining impact from the Line 6B crude oil release continues to be investigated and evaluated through the characterization of the overbank areas. These efforts will culminate in a series of RI Reports organized according to the predetermined (*Section 1.3)* geography of the 48 individual reaches. The RI Reports will focus on issues relevant to the issuance of an NFA determination. The MDEQ has agreed to provide technical comments on each RI Report and subsequently, Enbridge will use the MDEQ technical comments to prepare NFA Reports that will cover a preselected number of reaches to document that conditions are suitable for an NFA determination. In accordance with the MDEQ Consent Judgment, approval of the NFA Reports are the endpoint for the project.

In-channel surface water and sediments within the Kalamazoo River have been addressed through a separate line of reporting in accordance with Part 31, Part 301, and Part 303 of Michigan's Act 451 of 1994, as amended. The *Potential Chronic Effects of Line 6B Residual Oil Report of Findings,* submitted to the MDEQ on April 25, 2014 (Enbridge, 2014f) evaluated sediment chemistry, toxicity and benthic community diversity (SQT), to evaluate ecological risks associated with river sediments. The MDEQ concurred with the conclusions presented in the evaluation in an email on September 19, 2014, but requested additional data gap sampling. Results from the additional sampling were presented in the *Addendum to the Potential Chronic Effects of Line 6B Residual Oil Report of Findings*, submitted to the MDEQ on October 30, 2015 (Enbridge, 2015c). Enbridge is waiting on the MDEQ approval of the addendum document which should represent the endpoint for in-channel issues.

6.0 SCHEDULE AND FORMAT OF FUTURE UPDATES

The CSM will be updated semi-annually in accordance with the MDEQ Consent Judgment. Each update will be a stand-alone, comprehensive, CSM document of a format similar to the one presented here. To a degree, it is intended that each update will replace the previously submitted version of the CSM, thus fulfilling the role of an ongoing record of project understanding and indicator of allocation of effort in the future. Substantive findings will be used in the CSM updates to further develop and present the theories and conclusions reached upon review of these findings. The conceptual model has attained a high level of development over the last 5 years of response, remediation, and investigation. Significant conceptual advancements naturally develop at a slower rate over a project's lifespan and a lower frequency of CSM revision is believed to be appropriate. In the event of new data or observations that require immediate response actions, Enbridge will coordinate and communicate with the MDEQ in a timely manner to address any such actions.

7.0 REFERENCES

API, 1998. American Petroleum Institute; *Recommended Practices for Core Analysis (API RP40).* February 1, 1998.

ASTM, 2007. American Society for Testing and Materials, *Standard Guide for Development of Conceptual Site Models and Remediation Strategies for Light Non-aqueous-Phase Liquids Released to the Subsurface.* E 2531-06. February 2007.

ASTM, 2008. American Society for Testing and Materials, *Standard Guide for Development of Conceptual Site Models for Contaminated Sites.* E1689-95. February 2008.

Bent, 1971. P.C. Bent. 1971. *Influence of Surface Glacial Deposits on Streamflow Characteristics of Michigan Streams*. U.S. Geological Survey, Lansing, MI.

Cantu et al., 2000. Cantu R., Stencel, J.R., Czernuszewicz, R.S., Jaffe, P.R., Lash, T.D. Surfactant-enhanced partitioning of nickel and vanadyl deoxophylloerythroetioporphyrins from crude oil into water and their analysis using surface-enhanced resonance raman spectroscopy. Environmental Science & Technology, vol. 34, p. 192-198. 2000.

Carsell and Parish, 1988. R.F. Carsell and R.S. Parish. *Developing Joint Probability Distributions of Soil Water Retention Characteristics*, Water Resources Research, 24(5), pp. 755-769, 1988.

Dorr and Eschman, 1970. J.A. Dorr and D.F. Eschman. 1970. *Geology of Michigan*: Ann Arbor, Michigan. University of Michigan Press.

Enbridge, 2011. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *Sampling and Analysis Plan (SAP)*, dated August 30, 2011.

Enbridge, 2013a. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *Supplement to the Response Plan for Downstream Impacted Areas commonly referred to as the "Quantification of Submerged Oil Report"*, dated March 21, 2013.

Enbridge, 2013b. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *Report of Findings for Hydrocarbon Fingerprint Evaluation in Overbank Soil,* dated May 7, 2013.

Enbridge, 2013c. Enbridge Line 6B MP 608 Pipeline Release Marshall, Michigan; *SAP Attachment B Drinking Water Well Supplement to the Sampling and Analysis Plan,* dated April 10, 2013.

Enbridge, 2014a. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *White Paper: Evaluation of Line 6B Crude Oil PNA and VOC Related Risk to Groundwater Quality*, dated July 24, 2014.

Enbridge, 2014b. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *Remedial Investigation Report for Reach 1*, dated February 28, 2014.

Enbridge, 2014d. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *White Paper: Evaluation of Metals in Soil and Groundwater,* dated June 4, 2014.

Enbridge, 2014d. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *Request for Discontinuing the Drinking Water Monitoring Program*, dated July 30, 2014.

Enbridge, 2014e. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *Request for Discontinuing the Surface Water and Sediment Monitoring Programs,* dated May 29, 2014.

Enbridge, 2014f. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *Potential Chronic Effects of Line 6B Residual Oil Report of Findings,* dated April 25, 2014.

Enbridge, 2014g. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *In-Channel Remedial Investigation Work Plan for the Kalamazoo River,* dated December 12, 2014.

Enbridge, 2014h. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *Kalamazoo River Residual Oil Monitoring and Maintenance Work Plan*, dated July 8, 2014.

Enbridge, 2015a, Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *White Paper: Urban PAH Background Evaluation*, dated August 28, 2015.

Enbridge, 2015b, Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *White Paper: Evaluation of Line 6B Crude Oil NAPL Risk Based on a Weight of Evidence Approach*, dated July 30, 2015.

Enbridge, 2015c. Enbridge Energy, Limited Partnership Line 6B MP 608 Pipeline Release, Marshall, Michigan; *Addendum to the Potential Chronic Effects of Line 6B Residual Oi Report of Findings*, dated October 30, 2015.

Environment Canada, 2013. Environment Canada, Emergencies Science and Technology, Fisheries and Oceans Canada, Centre for Offshore Oil, Gas and Energy Research, Natural Resources Canada, CanmetENERGY; *Federal Government Technical Report – Properties, Composition and Marine Spill Behavior, Fate and Transport of Two Diluted Bitumen Products from the Canadian Oil Sands*. November 30, 2013.

Health Canada, 2010. Screening Assessment for the Challenge Vanadium oxide (Vanadium pentoxide) CASRN 1314-62-1, Environment Canada, Health Canada, September 2010.

ITRC, 2009. Interstate Technology & Regulatory Council; *Evaluating LNAPL Remedial Technologies for Achieving Project Goals*. Interstate Technology & Regulatory Council LNAPLs Team. December 2009.
http://www.itrcweb.org/GuidanceDocuments/LNAPL-2.pdf.

ITRC, 2012. Interstate Technology & Regulatory Council; *Incremental Sampling Methodology*. ISM-1.Washington, D.C.: Interstate Technology & Regulatory Council, Incremental Sampling Methodology Team.
http://www.itrcweb.org/ism-1/3_1_2_Conceptual_Site_Models.html.

MacDonald et al., 2000. MacDonald, D. D., Ingersoll, C. G., and Berger, T. A. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology 39: 20-31.

MDCH, 2012. Michigan Department of Community Health, Public Health Assessment Final Release. Kalamazoo River/Enbridge Spill: Evaluation of People's Risk for Health Effects From Contact with the Submerged oil in the Sediment of the Kalamazoo River. May 23, 2012.

MDCH, 2013. Michigan Department of Community Health, Public Health Assessment Final Release. Kalamazoo River/Enbridge Spill: Evaluation of Crude Oil Release to Talmadge Creek and Kalamazoo River on Residential Drinking Water Wells in Nearby Communities (Calhoun and Kalamazoo Counties, Michigan). February 27, 2013.

MDCH, 2014. Michigan Department of Community Health, Public Health Assessment Final Release. Kalamazoo River/Enbridge Spill: Evaluation of Kalamazoo River Surface Water and Fish After a Crude Oil Release (Calhoun and Kalamazoo Counties, Michigan). June 2, 2014.

MDEQ, 2006. Michigan Department of Environmental Quality, Remediation and Redevelopment Division; *Operational Memorandum No. 4 – Attachment 3*. August 2, 2006. http://www.michigan.gov/deq/0,1607,7-135-3311_4109_9846-101581--,00.html.

MDEQ, 2006. Michigan Department of Environmental Quality. *Rule 323.1057(8) (Table 5)*. January 13, 2006.

MDEQ, 2014a. Michigan Department of Environmental Quality; Technical Review *Comments – Aesthetic Concerns on the Remedial Investigation Report for Reach 1*. May 14, 2014.

MDEQ, 2014b. Michigan Department of Environmental Quality; *Technical Review Comments* within the *Notice of Insufficient Information in Reach 5 No Further Action Report*. August 22, 2014.

MDEQ, 2014c. Michigan Department of Environmental Quality; *Environmental Mapper*. 2014. (http://www.mcgi.state.mi.us/environmentalmapper/).

MDEQ, 2014d. Michigan Department of Environmental Quality Remediation and Redevelopment Division; *Non-Aqueous Phase Liquid (NAPL) Characterization, Remediation, and Management for Petroleum Releases*. June 2014. (http://www.statescape.com/RegsText/StaticDownloads/72137_112225.pdf).

MDEQ, 2015. Michigan Department of Environmental Quality; *Consent Judgment so agreed by the Michigan Department of Environmental Quality, Michigan Department of Attorney General, and Enbridge Energy Partners, L.P.; Enbridge Energy, Limited Partnership; Enbridge Pipelines (Lakehead) LLC; Enbridge Energy Management LLC; Enbridge Energy Company, Inc.; and Enbridge Employee Services, Inc. ordered, adjudged, and decreed pursuant to MCL 324.1701, MCL 324.3109, MCL 324.30112, MCL 324.30316, and MCL 324.20137*, signed May 13, 2015.

MGDL, 2010. Michigan Geographic Data Library; *River Valley Segments*. (http://www.mcgi.state.mi.us/mgdl/).

NASEM, 2016. National Academies of Sciences, Engineering, and Medicine. 2016. *Spills of Diluted Bitumen from Pipelines: A Comparative Study of Environmental Fate, Effects, and Response.* Washington, DC: The National Academies Press.

Ross, 2010. SL Ross, 2010. *Technical Data Report Properties and Fate of Hydrocarbons Associated with Hypothetical Spills at the Marine Terminal and in the Confined Channel Assessment Area, Enbridge Northern Gateway Project.* SL Ross Environmental Research Ltd. Ottawa, Ontario. Randy Belore, P. Eng., 2010.

Rousseau et al., 2012. Rousseau, Matthew, Cushman, Dave, Klepper, Gary, Pragmatic TPH Screening Values for LNAPL Mobility – Where Does Csat Fit In?, Conestoga-Rovers & Associates, February 14, 2012.

Stout et al., 2004. Stout, S.A., Uhler, A.D., Emsbo-Mattingly, S.D., *Comparative Evaluation of Background Anthropogenic Hydrocarbons in Surficial Sediments from Nine Urban Waterways,* Environmental Science and Technology, vol.38, pp.2987-2994.

TetraTech, 2010. TetraTech; *Ecological Notes Summary for the Characterization of the Kalamazoo River Affected by the Enbridge Oil Spill, Marshall, Michigan, Draft Technical Memorandum*, November 15, 2010.

U.S. EPA, 2003. United States Environmental Protection Agency, *Region 5, RCRA Ecological Screening Levels, August 22, 2003.*
*(**https://www3.epa.gov/region5/waste/cars/pdfs/ecological-screening-levels-200308.pdf**).*
This link was broken. It has been revised in this online document 9/22/2016.

U.S. EPA, 2011. United States Environmental Protection Agency; Cleanup Progress; Plans for Spring Work. Enbridge Oil Spill, Marshall, Michigan Fact Sheet, April, 2011.

U.S. EPA, 2014a. United States Environmental Protection Agency; Ecological Screening Levels. http://www.epa.gov/ecotox/ecossl/. Accessed November, 2014.

U.S. EPA, 2014b. United States Environmental Protection Agency; Priority Pollutants. http://water.epa.gov/scitech/methods/cwa/pollutants.cfm.

U.S. EPA, 2015. United States Environmental Protection Agency; Region 5 Enbridge Oil Spill, ww.epa.gov/Region5/enbridgespill/index.html. Accessed January 20, 2015.

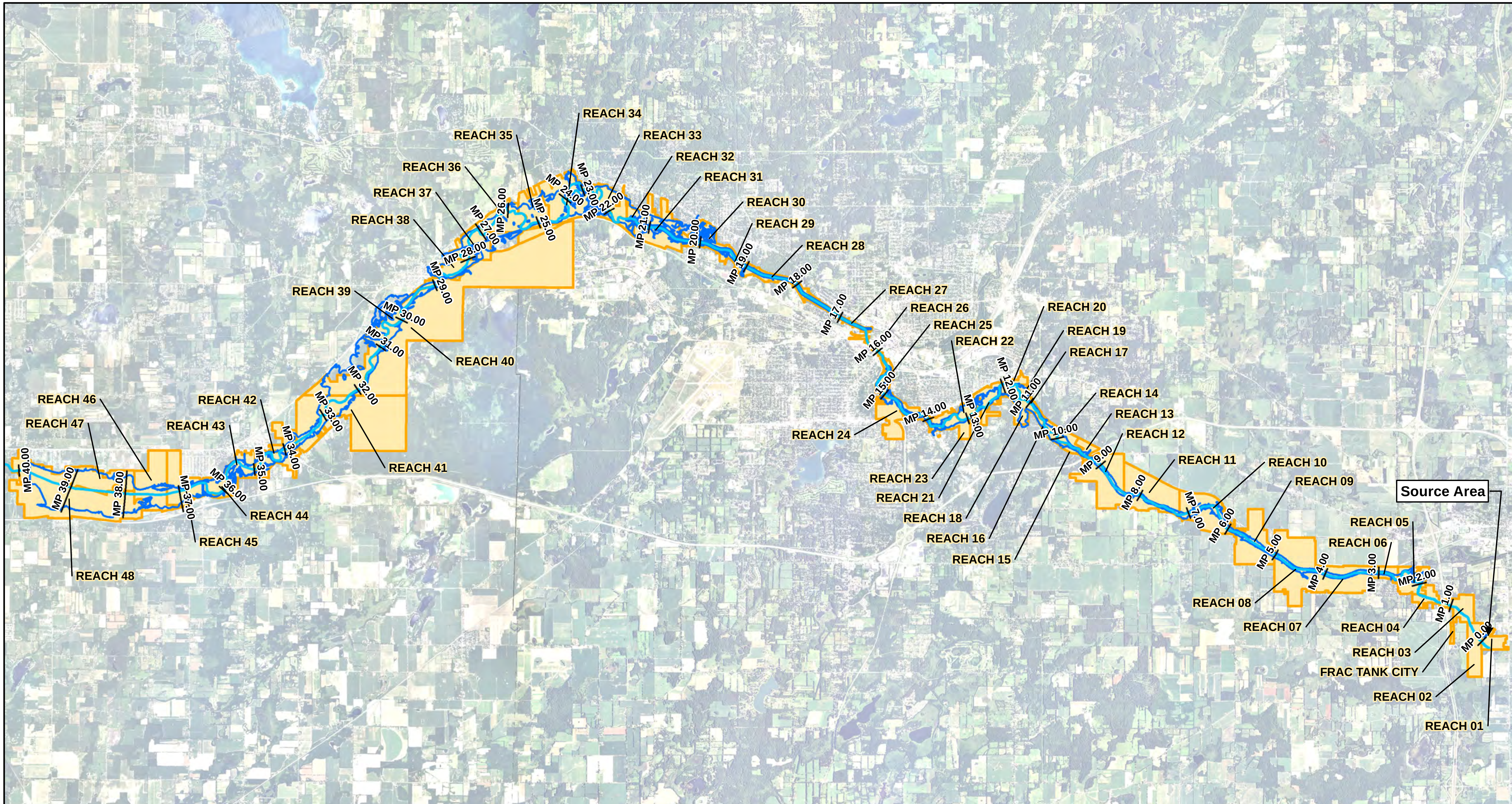
Vanlier, 1966. K. Vanlier. 1966. *Ground-water resources of the Battle Creek area, Michigan*: Michigan Geological Survey Division Report P 21.

WDNR, 2003. Wisconsin Department of Natural Resources. 2003. Consensus-Based Sediment Quality Guidelines. Recommendations for Use & Application Interim Guidance. WT-732-2003.

Wesley, 2005. J.K. Wesley. 2005. *Kalamazoo River Assessment*. State of Michigan, Department of Natural Resources, Fisheries Division Special Report Number 35.

WMU, 1981. Department of Geology, Western Michigan University, *Hydrogeological Atlas of Michigan*, 1981. In cooperation with the United States Environmental Protection Agency, Underground Injection Control Program.

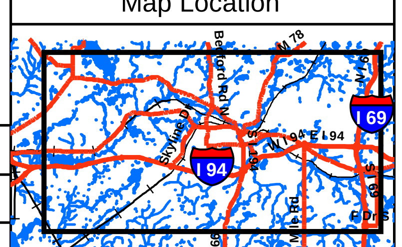
Figures



ENBRIDGE

Drawn:	NS	7/6/2015
Approved:	JC	7/6/2015
Project #:	60339671	

Map Location



Legend

- Reach Boundary
- Kalamazoo River and Talmadge Creek
- Kalamazoo River Flood Inundation Boundary
- One Mile Grid Segments

N

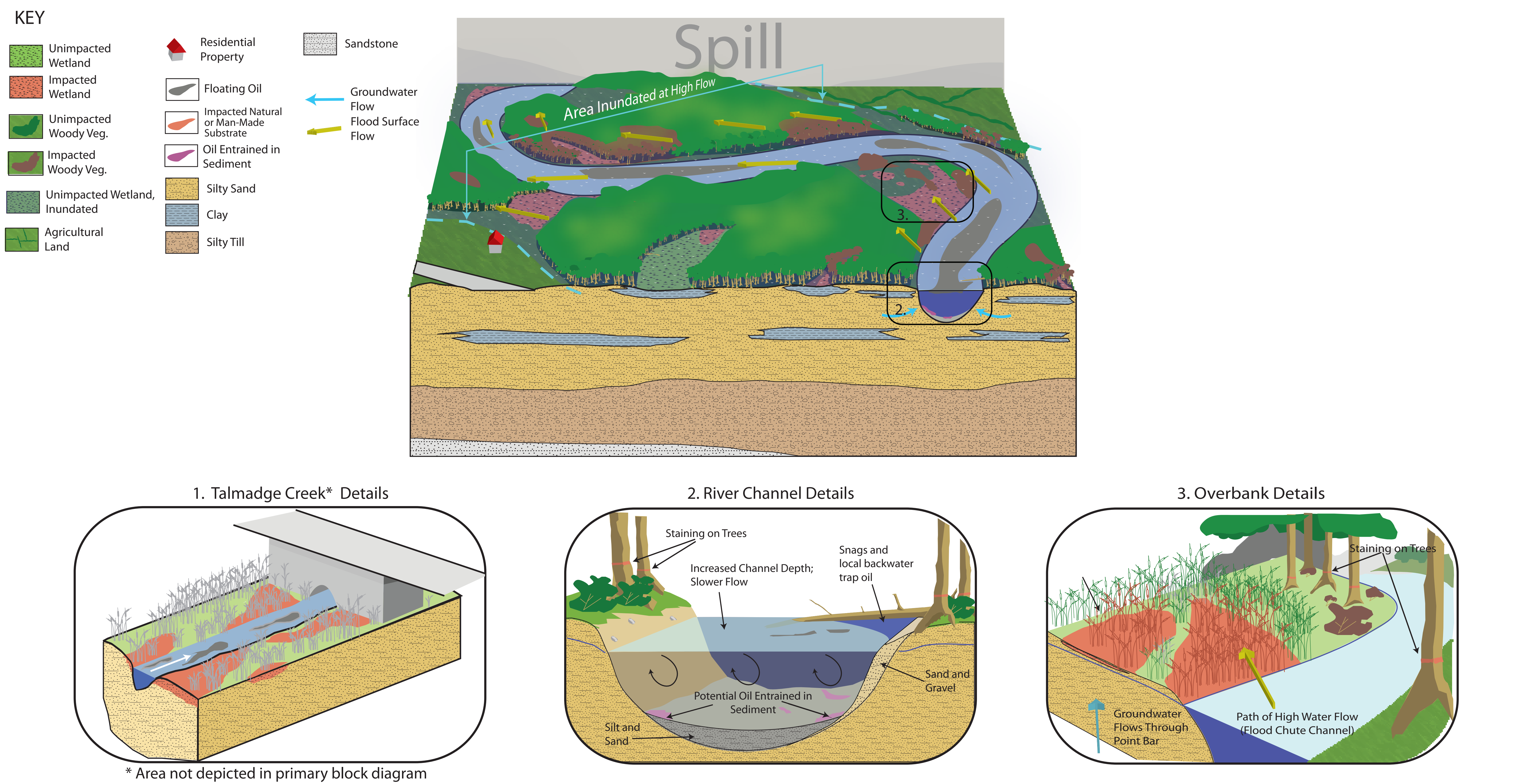
0 1 2 4
Miles

FIGURE 1
SPILL AREA LOCATION MAP

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2014\140710_River_Overview.mxd

Aerial Photography Date: 2010



ENBRIDGE

Drawn: CP 01/22/2015

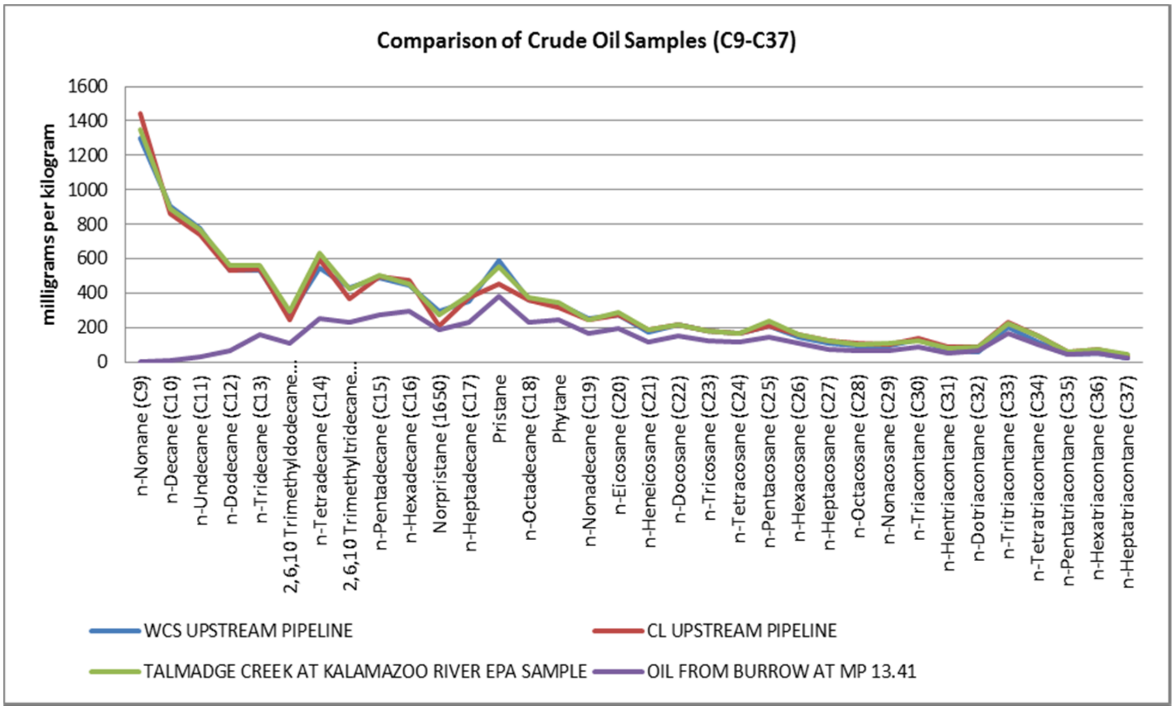
Approved: JC 01/22/2015

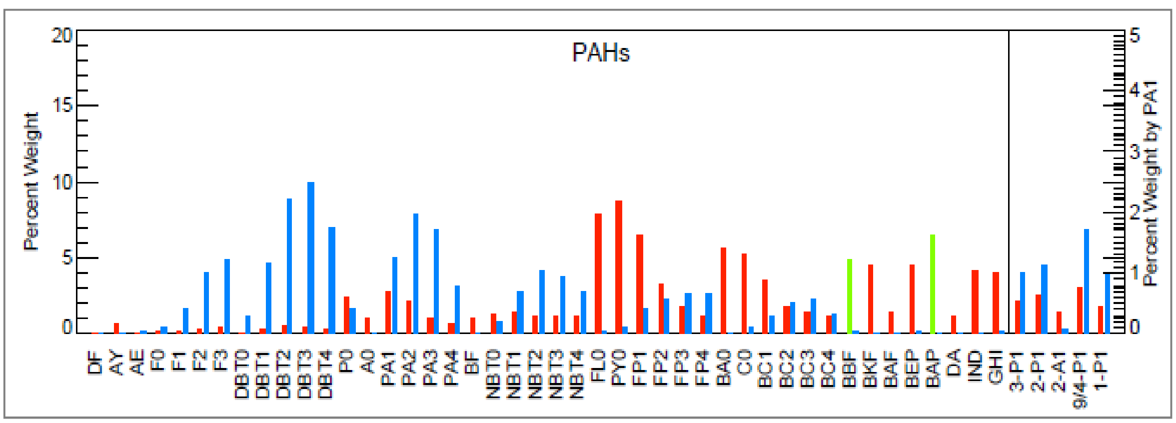
Project #: 60339671

FIGURE 2

CONCEPTUAL RELEASE DIAGRAM

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP





ENBRIDGE

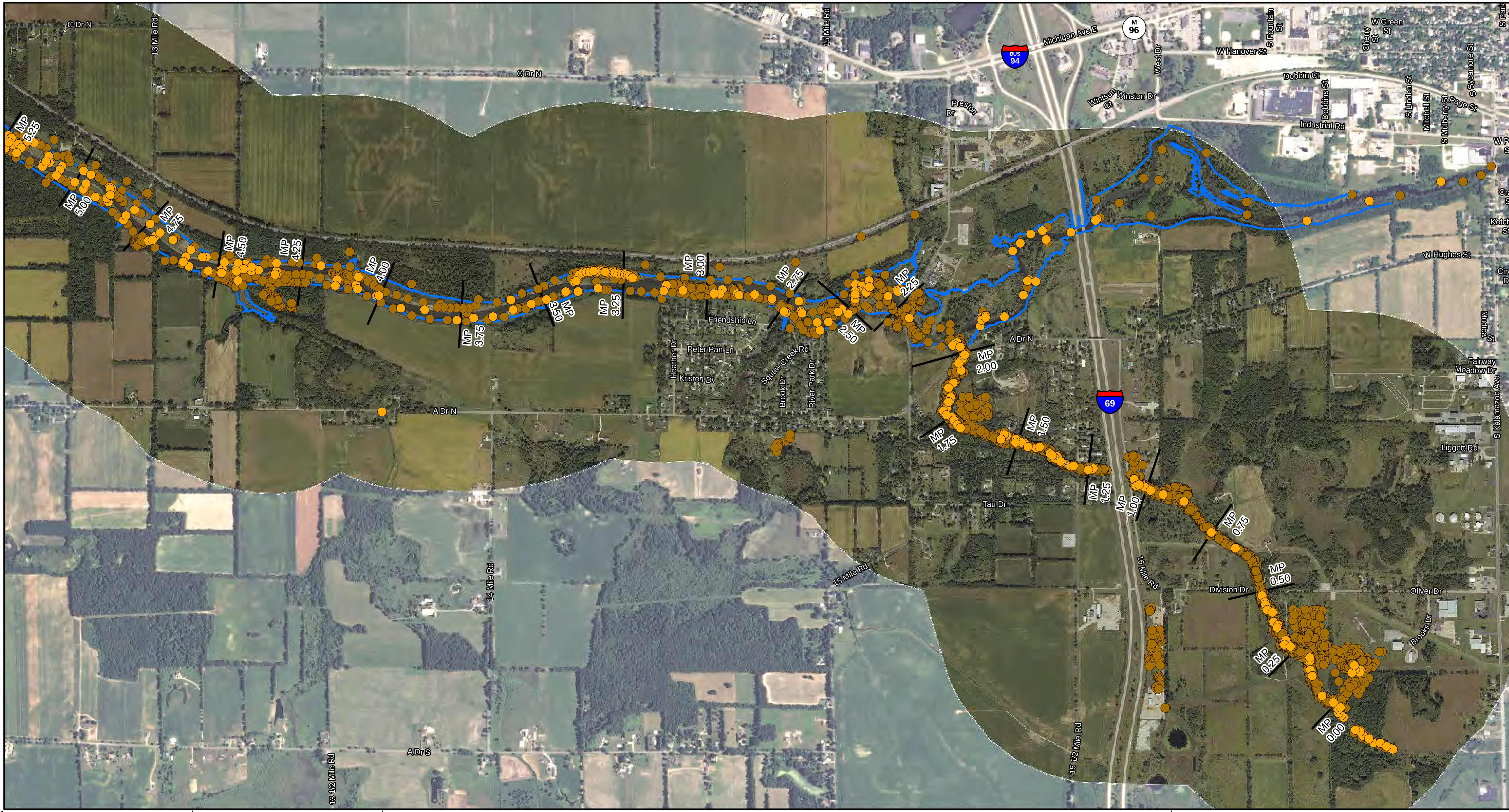
Drawn: CW 07/13/2015

Approved: DD 07/13/2015

Project#: 60339671

FIGURE 3
LINE 6B CHEMICAL SIGNATURE

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY,
LIMITED PARTNERSHIP



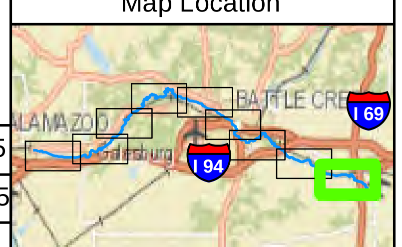
ENBRIDGE

Drawn: NS 12/23/2015

Approved: CP 12/23/2015

Project #: 60339671

Map Location



Legend

- Soil Sample
- Sediment Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

Scale in Feet

FIGURE 4
SOIL AND SEDIMENT SAMPLES
CSM
SHEET 1 OF 9

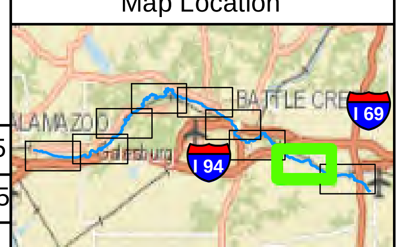
ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\150630_CSM_Soil_and_Sediment_Samples.mxd

Aerial Photography Date: September 2015 over 2010

ENBRIDGE		
Drawn:	NS	12/23/2015
Approved:	CP	12/23/2015
Project #:	60339671	

Map Location



Legend

- Soil Sample
- Sediment Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

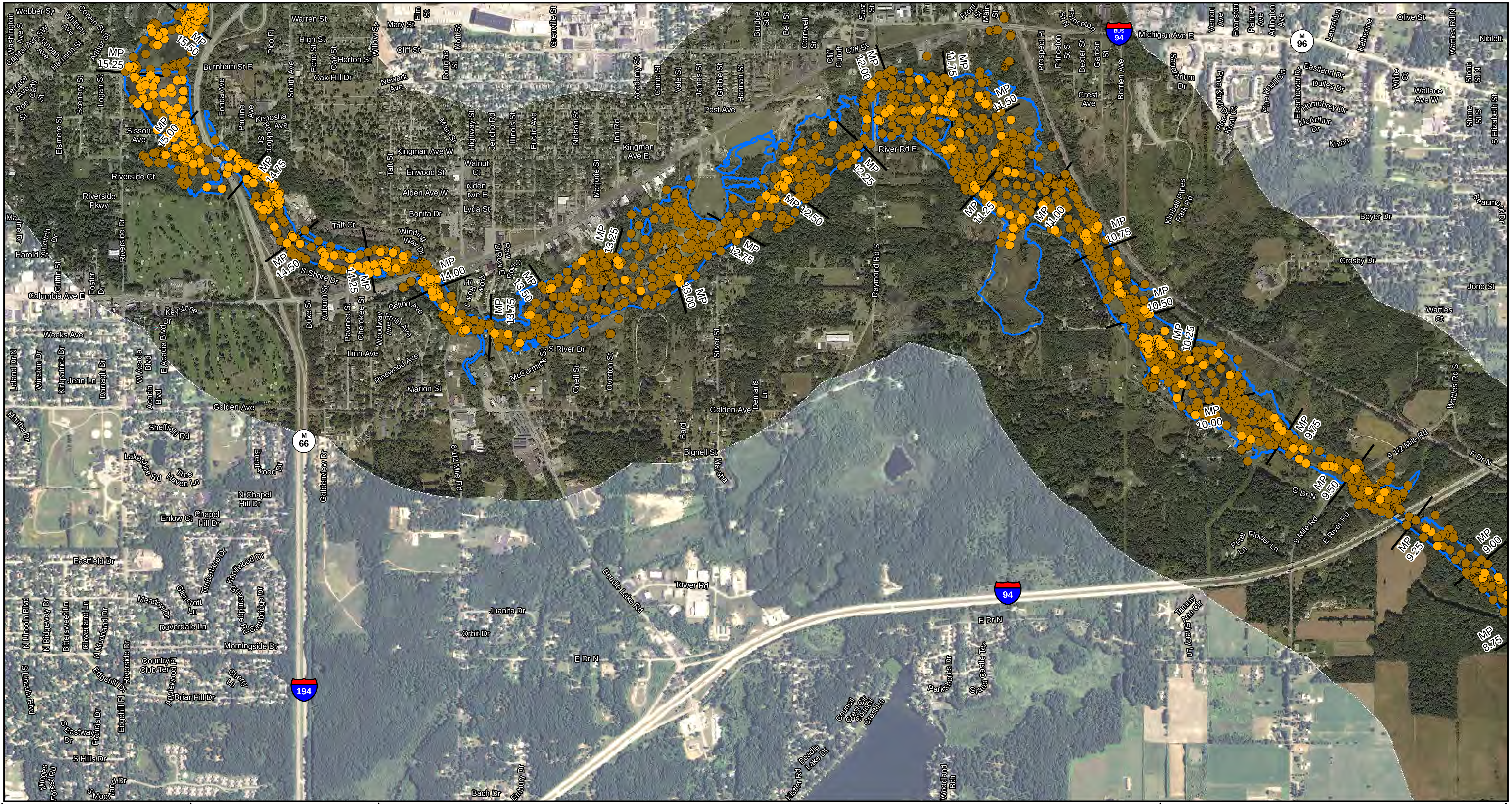
Scale in Feet

FIGURE 4
SOIL AND SEDIMENT SAMPLES
CSM
SHEET 2 OF 9

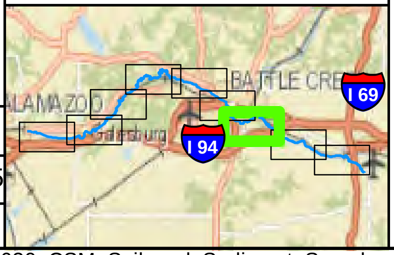
ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\150630_CSM_Soil_and_Sediment_Samples.mxd

Aerial Photography Date: September 2015 over 2010



Map Location



Legend

- Soil Sample
- Sediment Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

Scale in Feet

ENBRIDGE

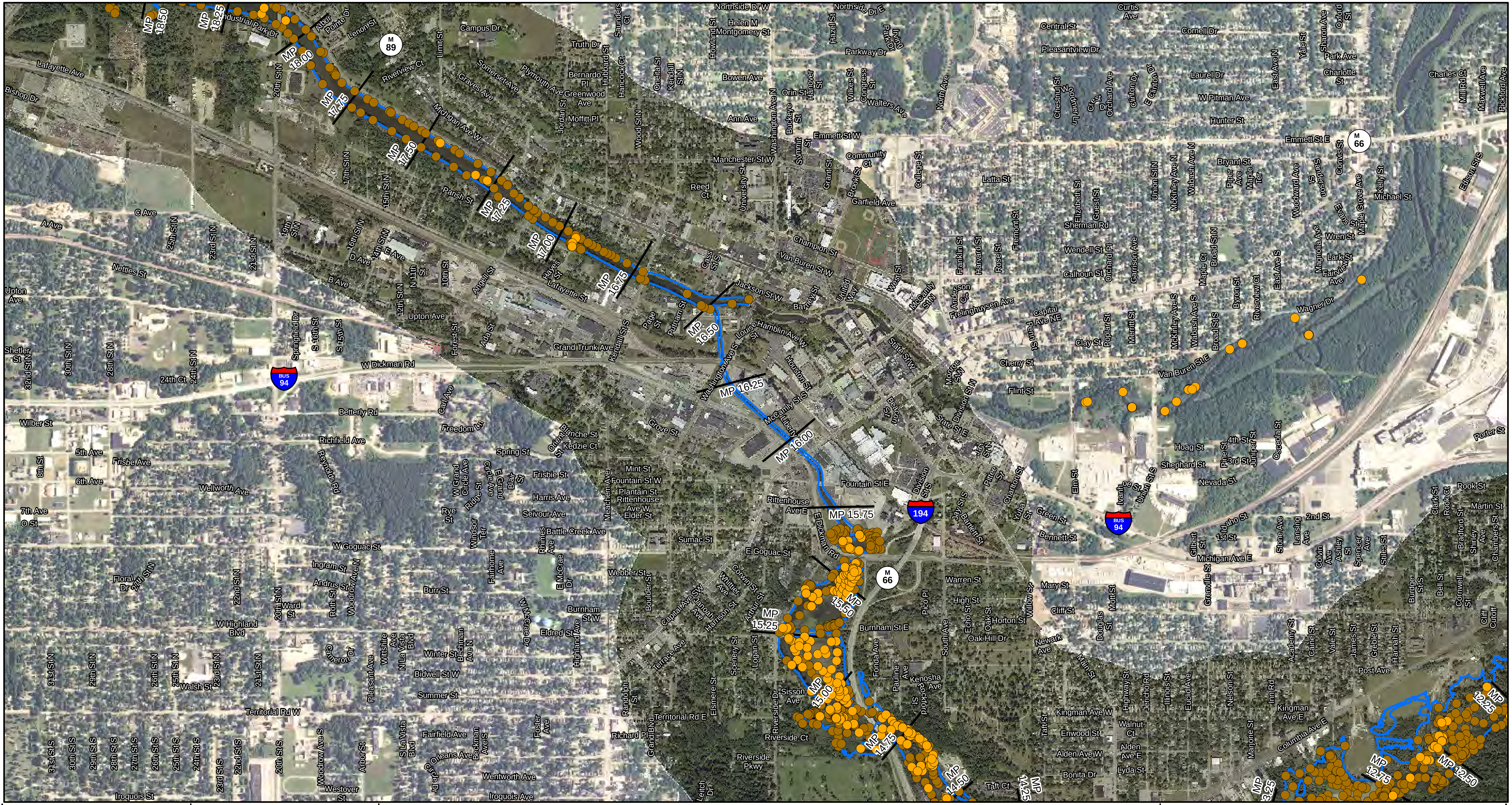
Drawn:	NS	12/23/2015
Approved:	CP	12/23/2015
Project #:	60339671	

FIGURE 4
SOIL AND SEDIMENT SAMPLES
CSM
SHEET 3 OF 9

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\150630_CSM_Soil_and_Sediment_Samples.mxd

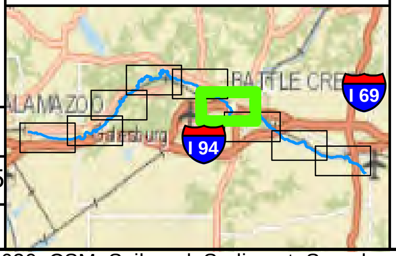
Aerial Photography Date: September 2015 over 2010



ENBRIDGE

Drawn:	NS	12/23/2015
Approved:	CP	12/23/2015
Project #:	60339671	

Map Location



Legend

- Soil Sample
- Sediment Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

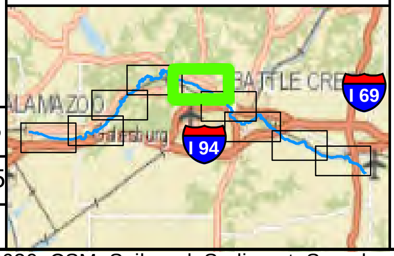
Scale in Feet

FIGURE 4
SOIL AND SEDIMENT SAMPLES
CSM
SHEET 4 OF 9

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\150630_CSM_Soil_and_Sediment_Samples.mxd

Aerial Photography Date: September 2015 over 2010



ENBRIDGE

Drawn:	NS	12/23/2015
Approved:	CP	12/23/2015
Project #:	60339671	

Map Location

Legend

- Soil Sample
- Sediment Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

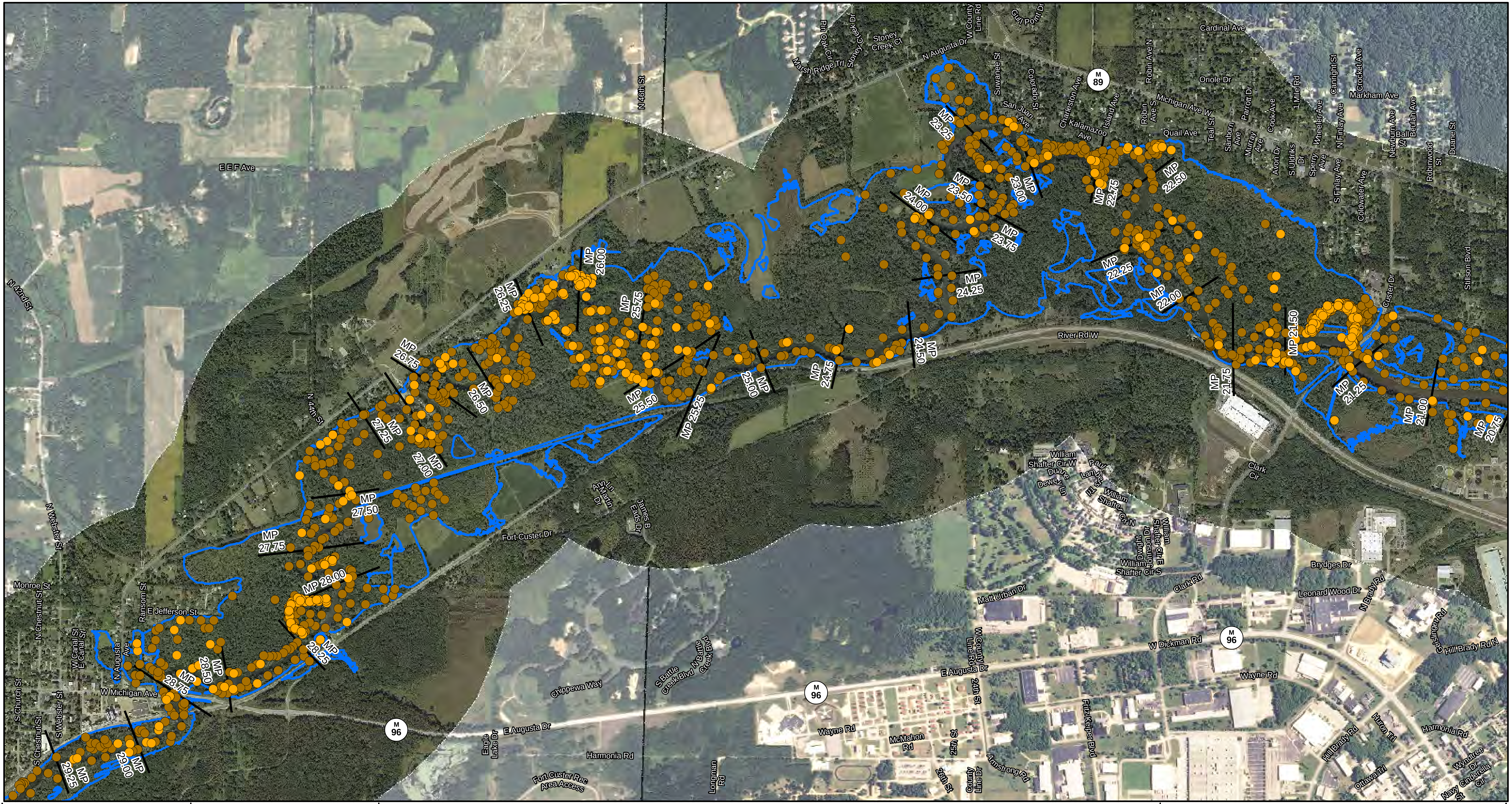
Scale in Feet

FIGURE 4
SOIL AND SEDIMENT SAMPLES
CSM
SHEET 5 OF 9

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

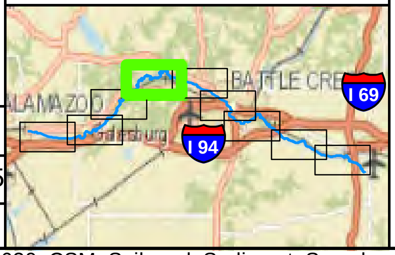
Z:\Work\GIS\CSM\MXD\CSM_2015\150630_CSM_Soil_and_Sediment_Samples.mxd

Aerial Photography Date: September 2015 over 2010



ENBRIDGE	
Drawn: NS	12/23/2015
Approved: CP	12/23/2015
Project #: 60339671	

Map Location



Legend

- Soil Sample
- Sediment Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

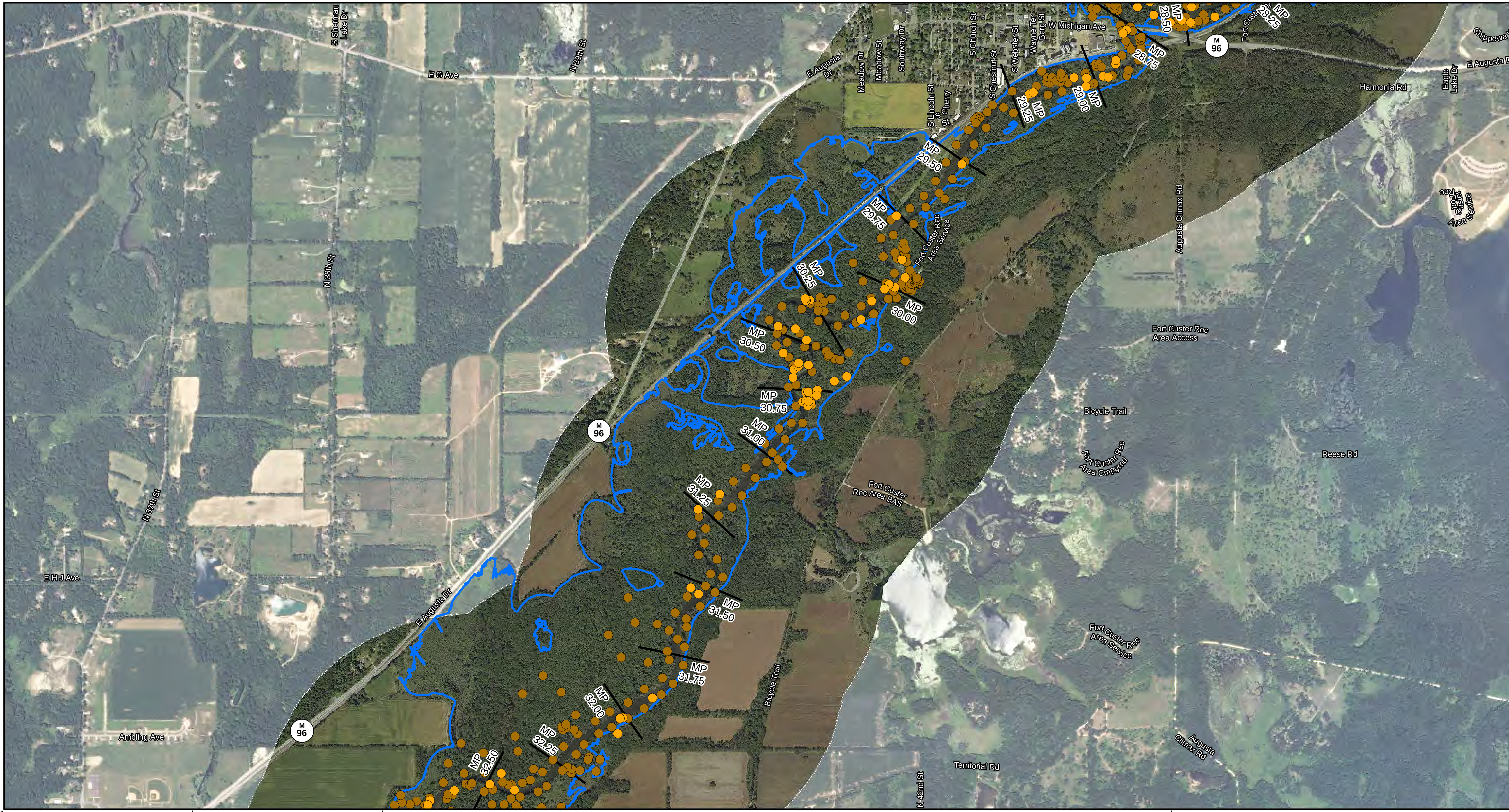
Scale in Feet

FIGURE 4
SOIL AND SEDIMENT SAMPLES
CSM
SHEET 6 OF 9

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\150630_CSM_Soil_and_Sediment_Samples.mxd

Aerial Photography Date: September 2015 over 2010



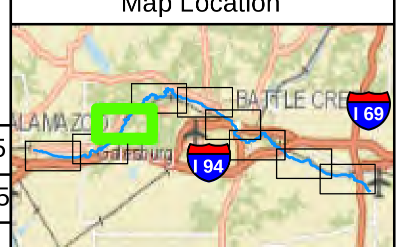
ENBRIDGE

Drawn: NS 12/23/2015

Approved: CP 12/23/2015

Project #: 60339671

Map Location



Legend

- Soil Sample
- Sediment Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

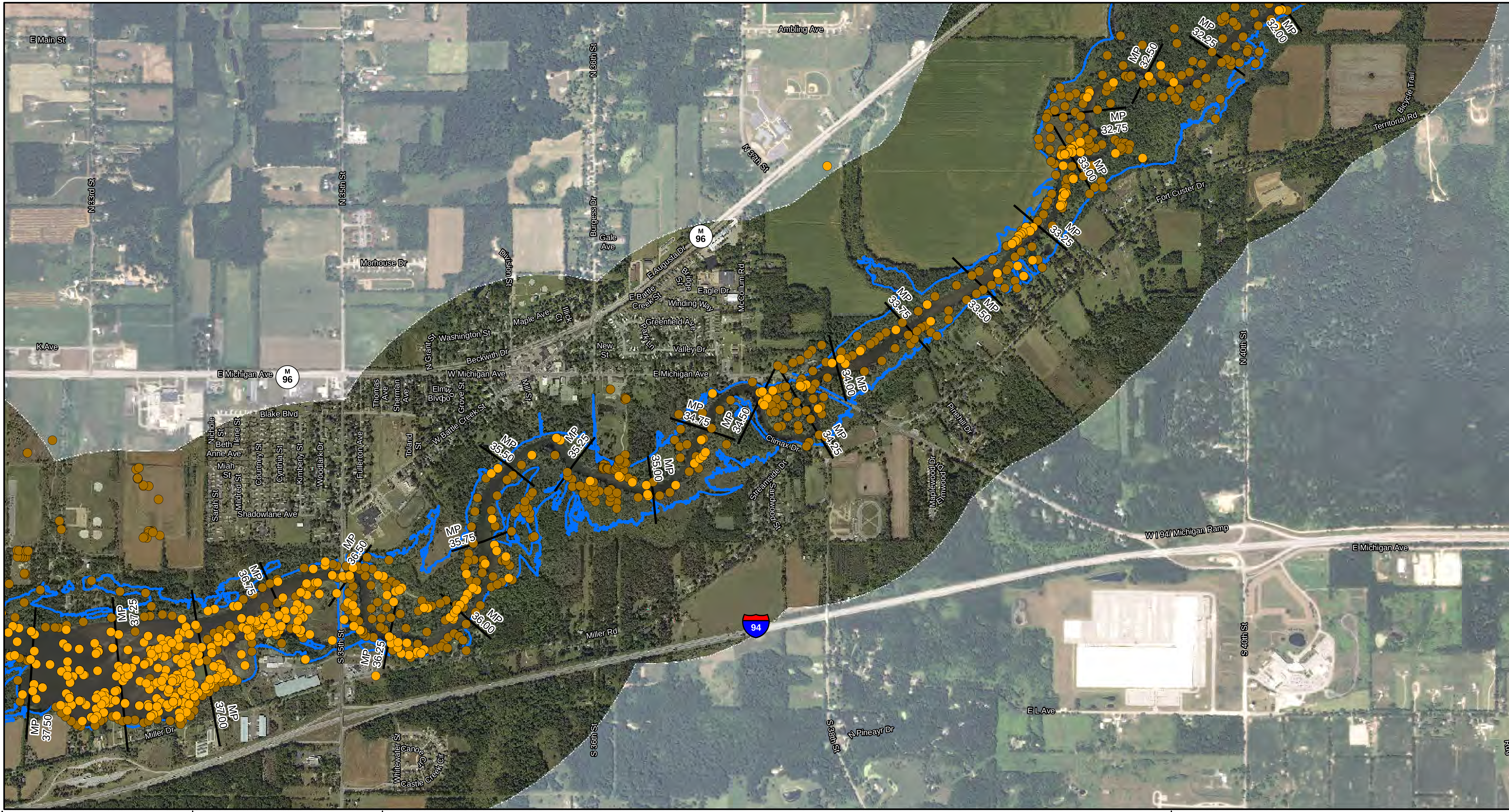
Scale in Feet

FIGURE 4
SOIL AND SEDIMENT SAMPLES
CSM
SHEET 7 OF 9

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\150630_CSM_Soil_and_Sediment_Samples.mxd

Aerial Photography Date: September 2015 over 2010



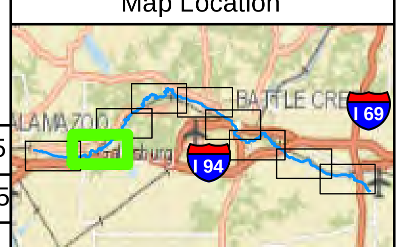
ENBRIDGE

Drawn: NS 12/23/2015

Approved: CP 12/23/2015

Project #: 60339671

Map Location



Legend

- Soil Sample
- Sediment Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

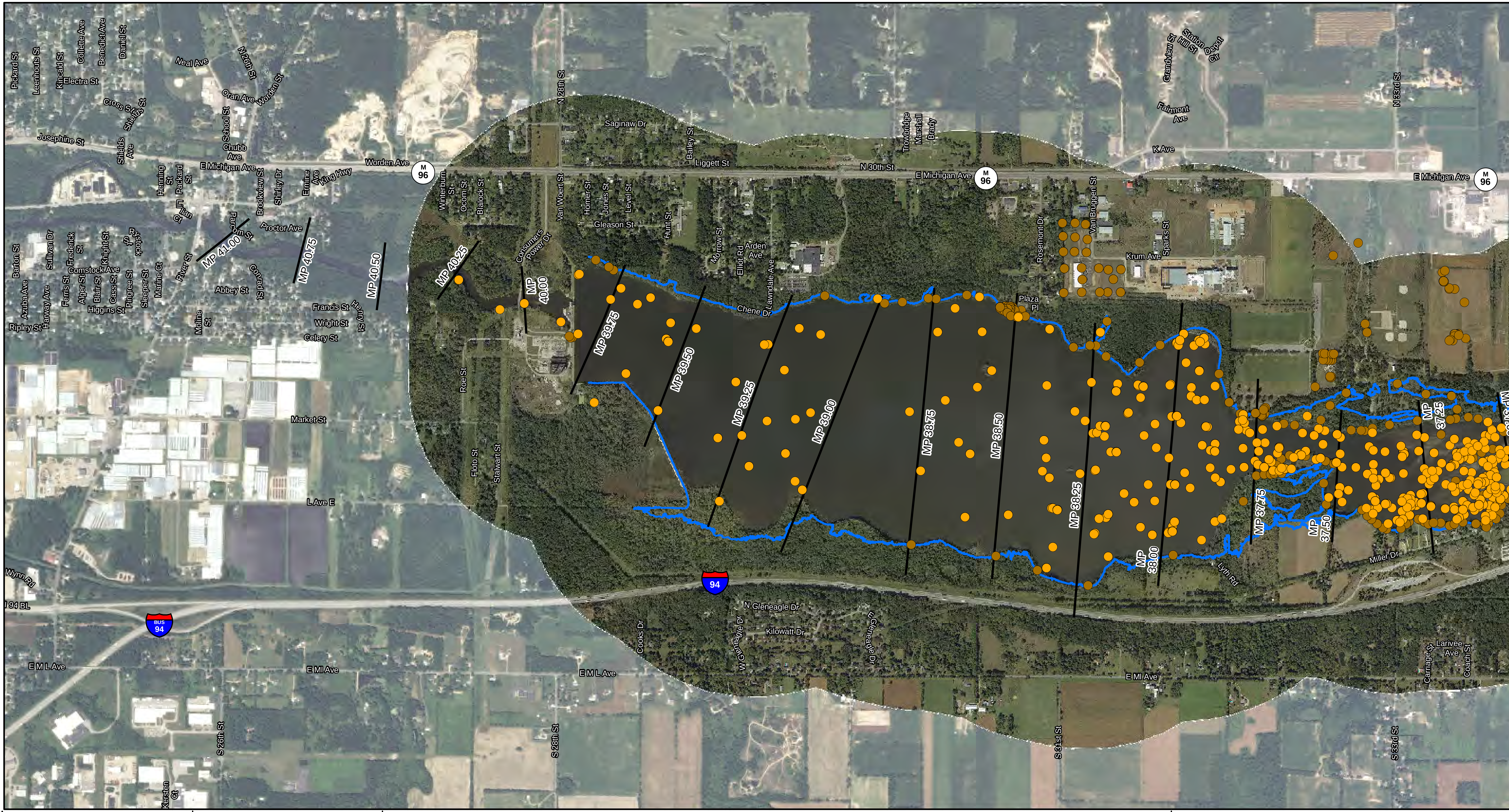
Scale in Feet

FIGURE 4
SOIL AND SEDIMENT SAMPLES
CSM
SHEET 8 OF 9

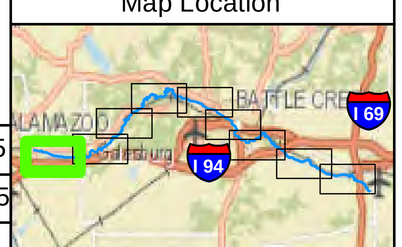
ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\150630_CSM_Soil_and_Sediment_Samples.mxd

Aerial Photography Date: September 2015 over 2010



Map Location



ENBRIDGE

Drawn: NS 12/23/2015

Approved: CP 12/23/2015

Project #: 60339671

Legend
- Soil Sample
- Sediment Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

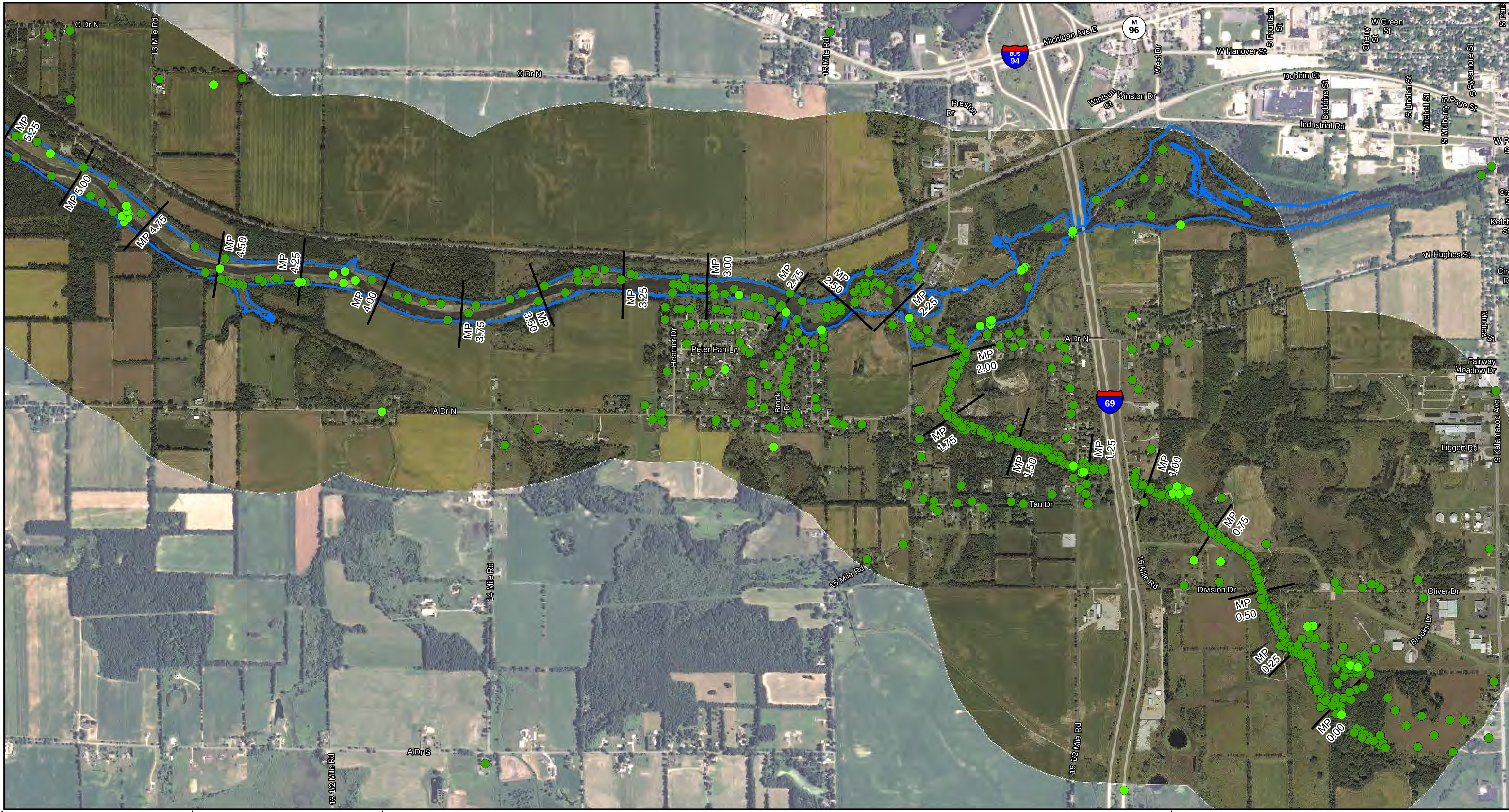
Scale in Feet

FIGURE 4
SOIL AND SEDIMENT SAMPLES
CSM
SHEET 9 OF 9

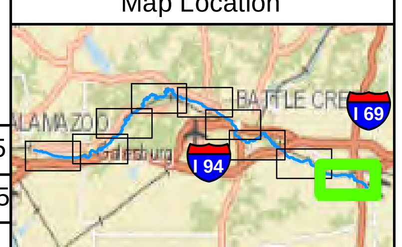
ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\150630_CSM_Soil_and_Sediment_Samples.mxd

Aerial Photography Date: September 2015 over 2010



Map Location



Legend

- Groundwater Sample
- Surface Water Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

Scale in Feet

ENBRIDGE

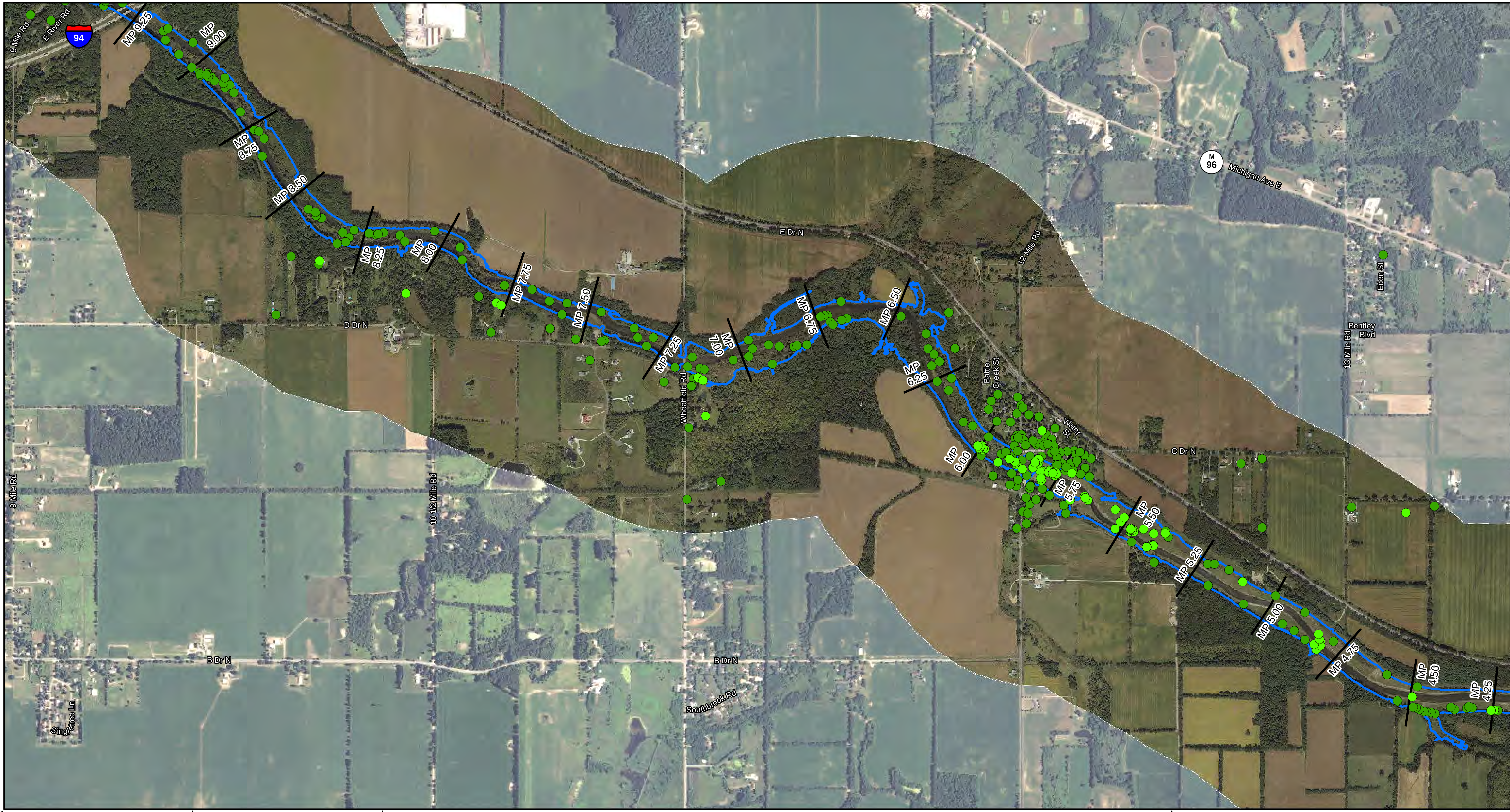
Drawn:	NS	12/23/2015
Approved:	CP	12/23/2015
Project #:	60339671	

FIGURE 5
GROUNDWATER AND SURFACE WATER SAMPLES
CSM
SHEET 1 OF 9

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\151223_CSM_Groundwater_and_Surface_Water_Samples.mxd

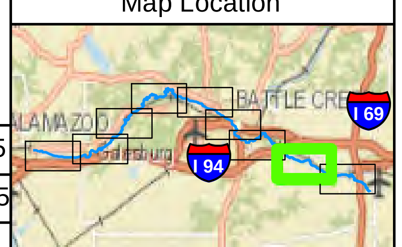
Aerial Photography Date: September 2015 over 2010



ENBRIDGE

Drawn: NS 12/23/2015
Approved: CP 12/23/2015
Project #: 60339671

Map Location



Legend
- Groundwater Sample
- Surface Water Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

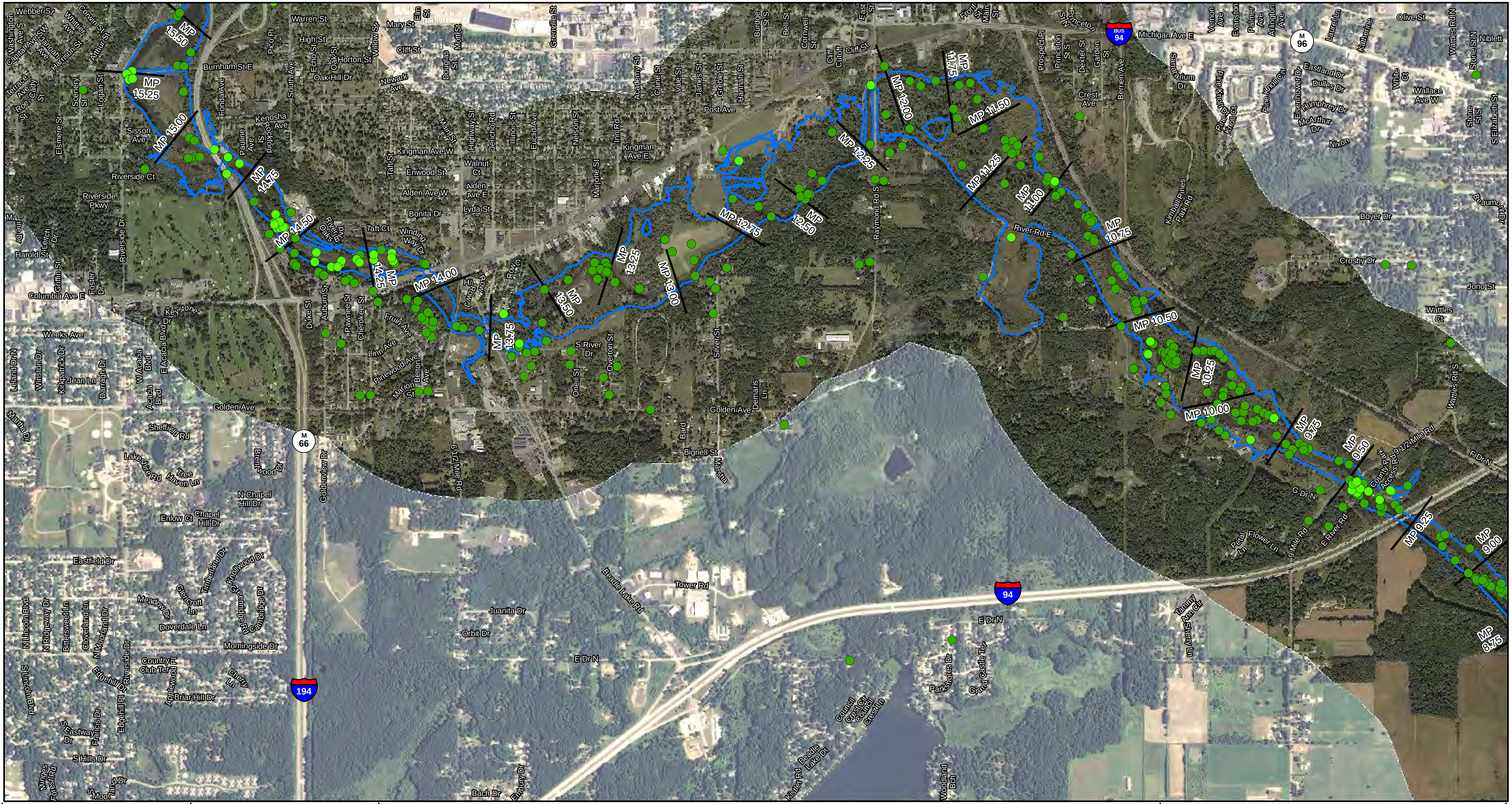
0 750 1,500 3,000
Scale in Feet

FIGURE 5
GROUNDWATER AND SURFACE WATER SAMPLES
CSM
SHEET 2 OF 9

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\151223_CSM_Groundwater_and_Surface_Water_Samples.mxd

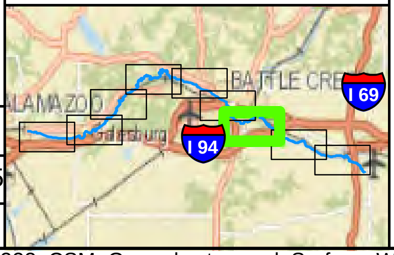
Aerial Photography Date: September 2015 over 2010



ENBRIDGE

Drawn:	NS	12/23/2015
Approved:	CP	12/23/2015
Project #:	60339671	

Map Location



Legend
- Groundwater Sample
- Surface Water Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

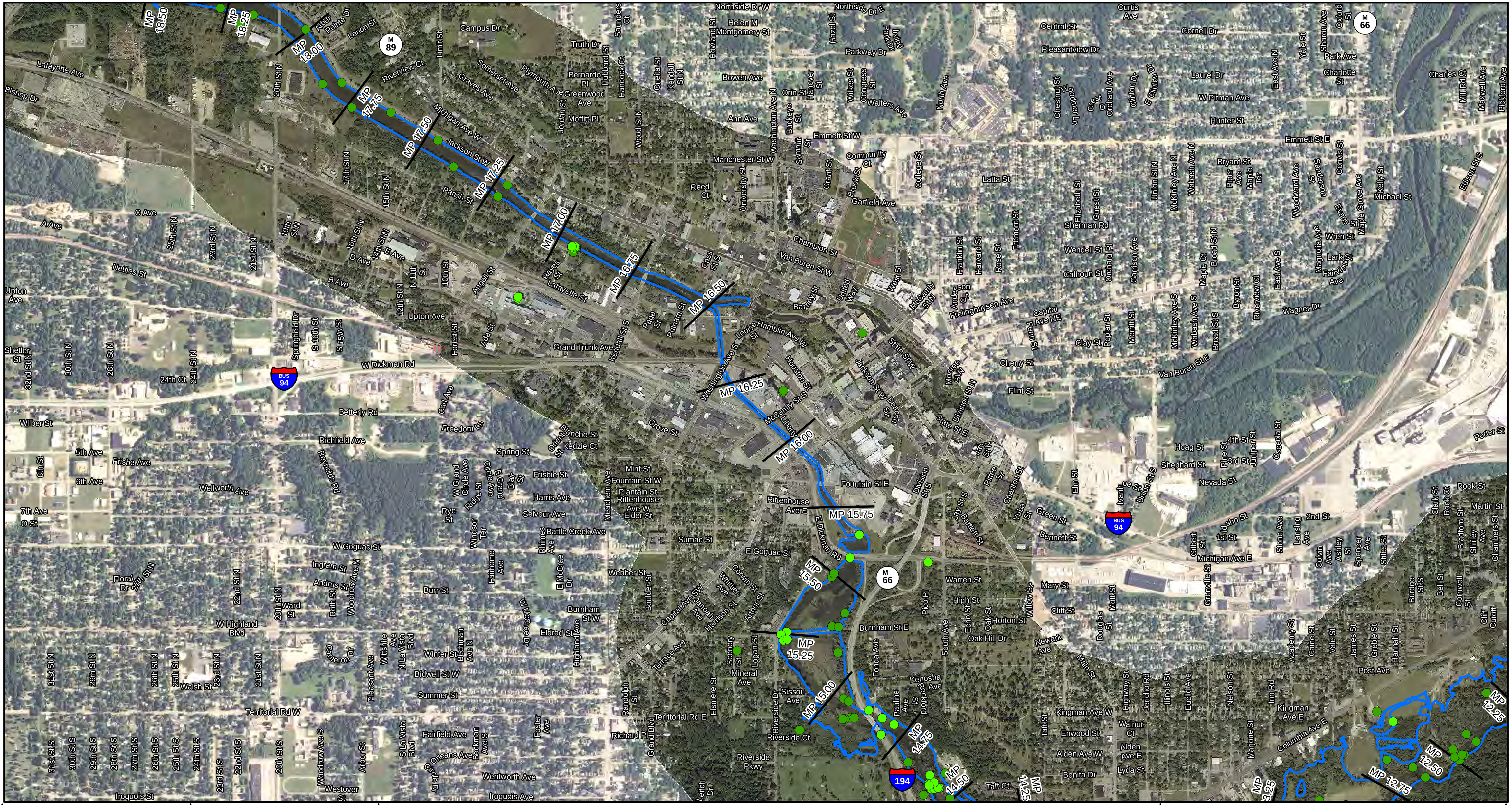
0 750 1,500 3,000
Scale in Feet

FIGURE 5
GROUNDWATER AND SURFACE WATER SAMPLES
CSM
SHEET 3 OF 9

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\151223_CSM_Groundwater_and_Surface_Water_Samples.mxd

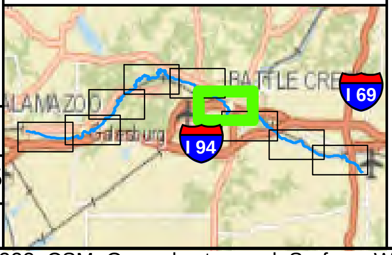
Aerial Photography Date: September 2015 over 2010



ENBRIDGE

Drawn:	NS	12/23/2015
Approved:	CP	12/23/2015
Project #:	60339671	

Map Location



Legend

- Groundwater Sample
- Surface Water Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

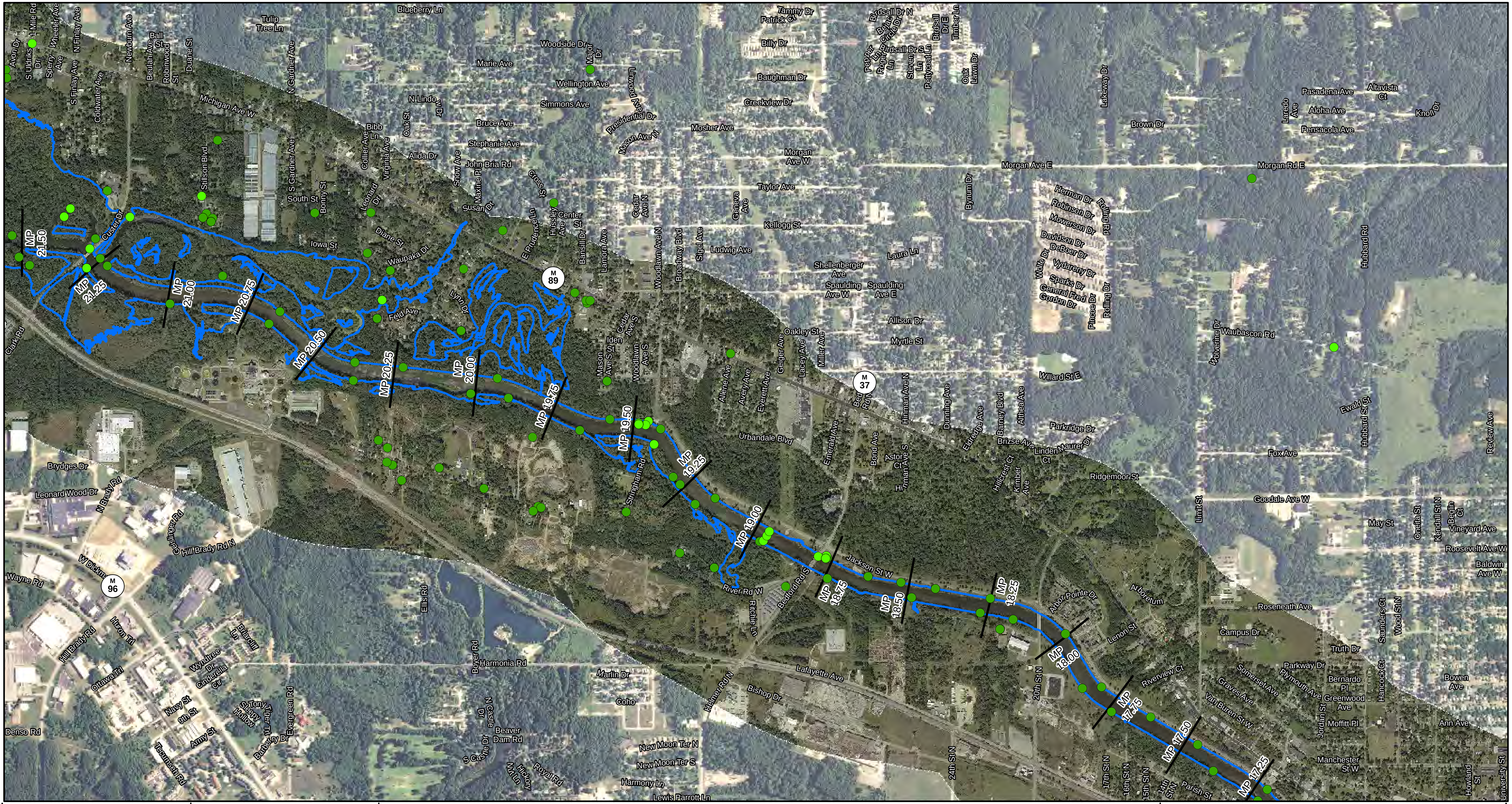
0 750 1,500 3,000
Scale in Feet

FIGURE 5
GROUNDWATER AND SURFACE WATER SAMPLES
CSM
SHEET 4 OF 9

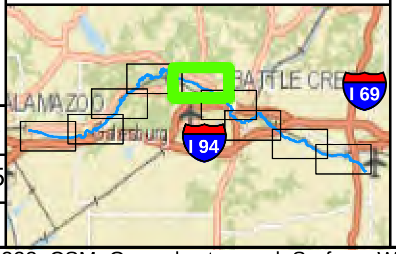
ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\151223_CSM_Groundwater_and_Surface_Water_Samples.mxd

Aerial Photography Date: September 2015 over 2010



Map Location



ENBRIDGE

Drawn:	NS	12/23/2015
Approved:	CP	12/23/2015
Project #:	60339671	

Legend

- Groundwater Sample
- Surface Water Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

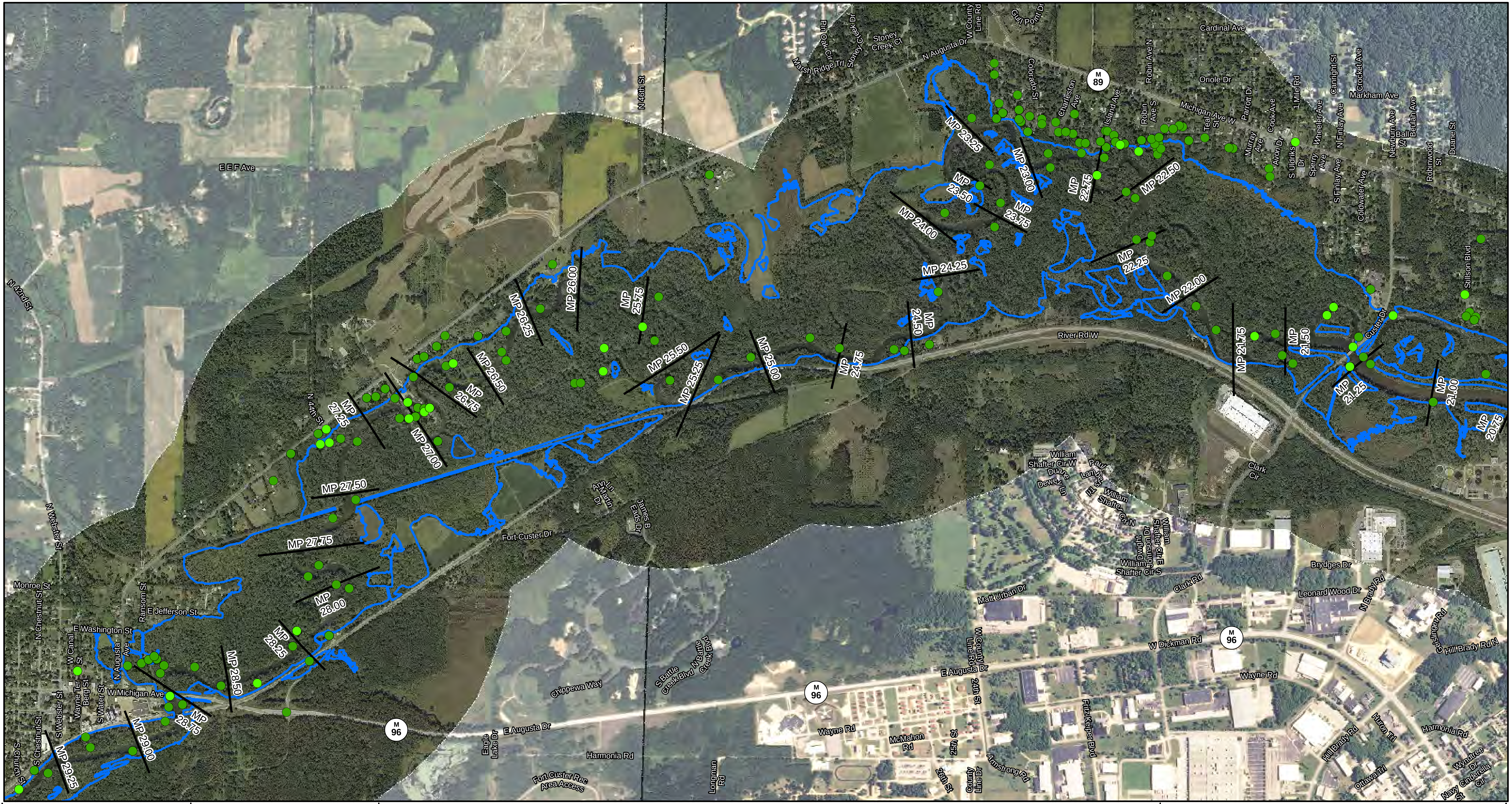
Scale in Feet

FIGURE 5
GROUNDWATER AND SURFACE WATER SAMPLES
CSM
SHEET 5 OF 9

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

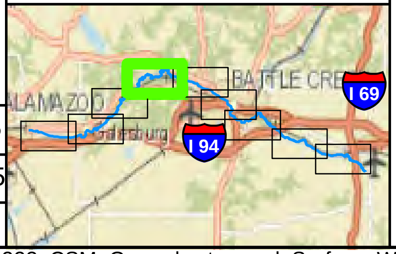
Z:\Work\GIS\CSM\MXD\CSM_2015\151223_CSM_Groundwater_and_Surface_Water_Samples.mxd

Aerial Photography Date: September 2015 over 2010



ENBRIDGE	
Drawn: NS	12/23/2015
Approved: CP	12/23/2015
Project #: 60339671	

Map Location



Legend

- Groundwater Sample
- Surface Water Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

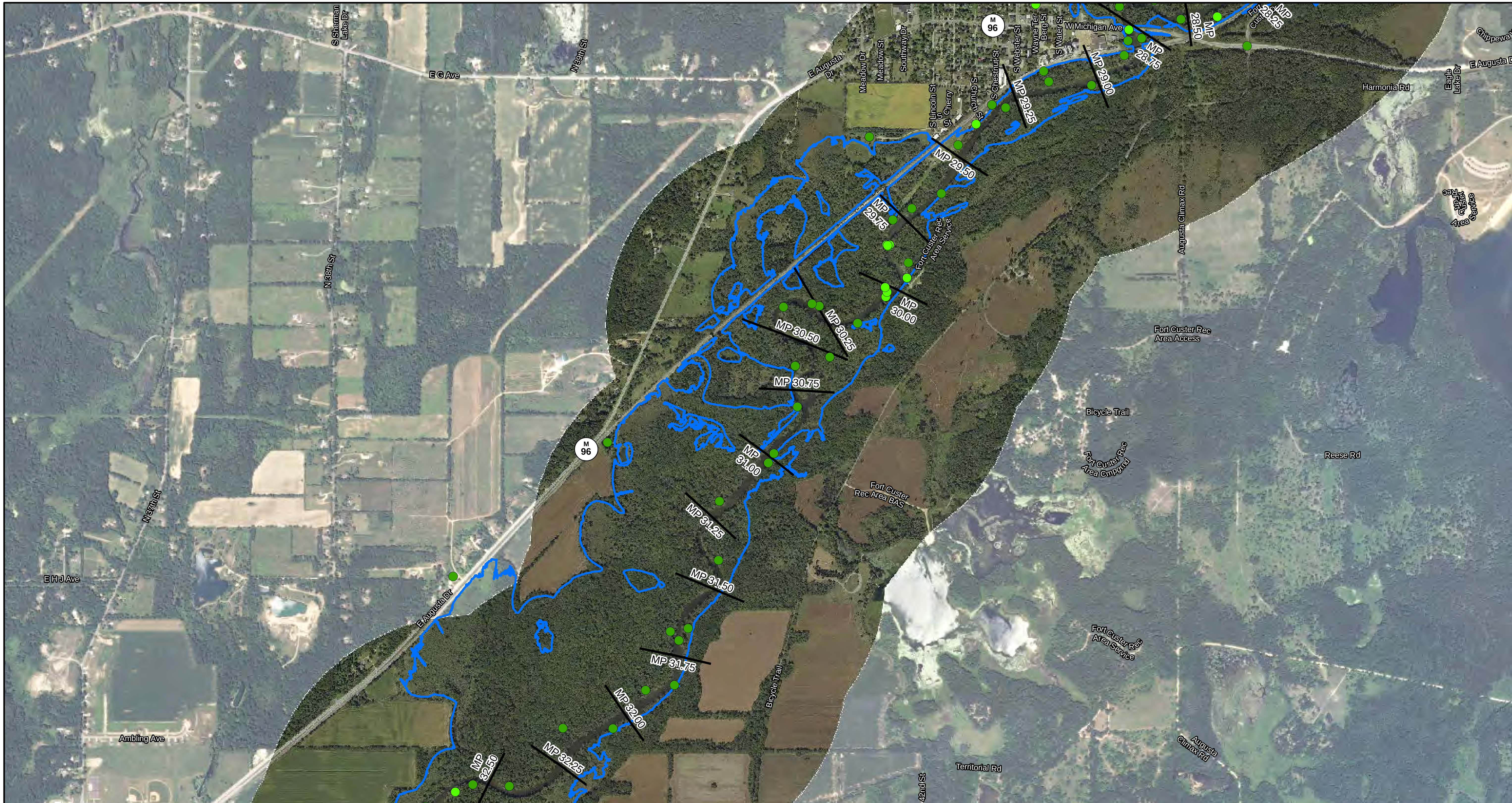
Scale in Feet

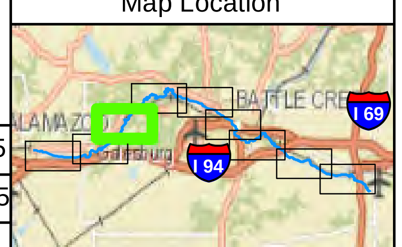
FIGURE 5
GROUNDWATER AND SURFACE WATER SAMPLES
CSM
SHEET 6 OF 9

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\151223_CSM_Groundwater_and_Surface_Water_Samples.mxd

Aerial Photography Date: September 2015 over 2010



Map Location	Legend
	Groundwater Sample Surface Water Sample Kalamazoo River Flood Inundation Boundary Quarter Mile Grid Segments

ENBRIDGE

Drawn: NS 12/23/2015

Approved: CP 12/23/2015

Project #: 60339671

N

0 750 1,500 3,000

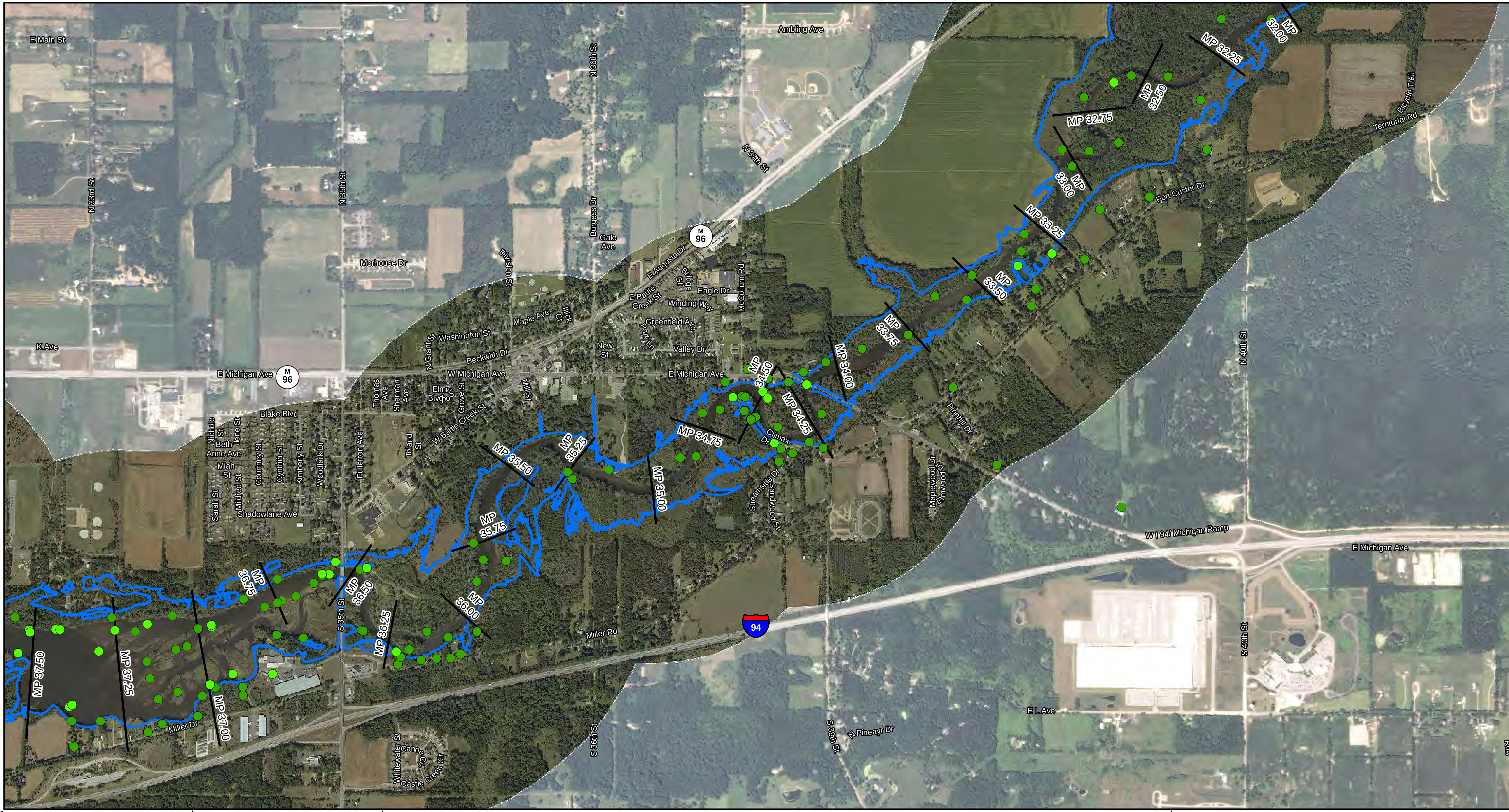
Scale in Feet

FIGURE 5
GROUNDWATER AND SURFACE WATER SAMPLES
CSM
SHEET 7 OF 9

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\151223_CSM_Groundwater_and_Surface_Water_Samples.mxd

Aerial Photography Date: September 2015 over 2010



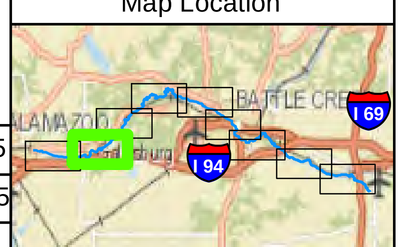
ENBRIDGE

Drawn: NS 12/23/2015

Approved: CP 12/23/2015

Project #: 60339671

Map Location



Legend

- Groundwater Sample
- Surface Water Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000

Scale in Feet

FIGURE 5
GROUNDWATER AND SURFACE WATER SAMPLES
CSM
SHEET 8 OF 9

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\151223_CSM_Groundwater_and_Surface_Water_Samples.mxd

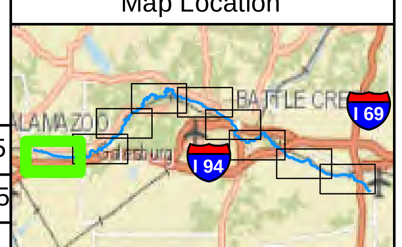
Aerial Photography Date: September 2015 over 2010

FIGURE 5
GROUNDWATER AND SURFACE WATER SAMPLES
CSM
SHEET 9 OF 9

ENBRIDGE

Drawn: NS 12/23/2015
Approved: CP 12/23/2015
Project #: 60339671

Map Location



Legend
- Groundwater Sample
- Surface Water Sample
- Kalamazoo River Flood Inundation Boundary
- Quarter Mile Grid Segments

N

0 750 1,500 3,000
Scale in Feet

ENBRIDGE LINE 6B MP 608
MARSHALL, MI PIPELINE RELEASE
ENBRIDGE ENERGY, LIMITED PARTNERSHIP

Z:\Work\GIS\CSM\MXD\CSM_2015\151223_CSM_Groundwater_and_Surface_Water_Samples.mxd

Aerial Photography Date: September 2015 over 2010