Enbridge Line 6B MP 608 Releases

Marshall, MI

Evaluation of Potential Impact of Released Oil

on Groundwater used for Drinking Water

(Hydrogeological Evaluation Report)

Prepared: October 30, 2010

Enbridge Line 6B MP 608 Release
Marshall, MI
Evaluation of Potential Impact of Released Oil on Groundwater used for Drinking Water (Hydrogeological Evaluation Report)

Prepared October 30, 2010

Table of Contents

List of Tables

List of Figures

List of Appendices

List of Acronyms

AMSL – above mean sea level

ATSDR – Agency for Toxic Substances and Disease Registry

bgs – Below Ground Surface

BTEX - Benzene, Toluene, Ethylbenzene and Xylene

CERCLA - Comprehensive Environmental Response Compensation and Liability Act

Company – Enbridge Energy, Limited Partnership

DCE - Dichloroethylene

DRO – Diesel Range Organics

gpm – Gallons Per Minute

FOIA – Freedom of Information Act

GRO – Gasoline Range Organics

HSP – Health and Safety Plan

MDNRE – Michigan Department of Natural Resources and Environment

MP – Mile Post

NAPL – Non-aqueous Phase Liquid

PNA – Polynuclear Aromatic Hydrocarbons

PCB – Polychlorinated Biphenol

PVC – Poly Vinyl Chloride

QAPP – Quality Assurance Project Plan

RI/FS – Remedial Investigation/Feasibility Study

RPDIA – Response Plan for Downstream Impacted Area

SAP – Sampling and Analysis Plan

SAR – Source Area Response Plan

SARA - Superfund Amendments and Reauthorization Act

SARCR – Source Area Response Completion Report

SCAT – Shoreline Clean-up Assessment Technique

SOPs – Standard Operating Procedures

SVOCs – Semi-volatile Organic Compounds

TCE - Trichloroethylene

TDL – Target Detection Limit

TDS – Total Dissolved Solids

TMB – Trimethylbenzene

TPH – Total Petroleum Hydrocarbons

USCOAE – United States Corps of Army Engineers

USCS – Unified Soil Classification System

U.S. EPA – Unites States Environmental Protection Agency

U.S. FWS – United States Fish and Wildlife Service

USGS – United States Geological Survey

VOCs – Volatile Organic Compounds

1.0 Introduction

On July 26, 2010, Enbridge Energy, Limited Partership ("Company") discovered a release of heavy crude oil from Line 6B, a 30-inch diameter line, just west of milepost 608 in the vicinity of its pump station located in Marshall, Calhoun County, Michigan (N1/2, Section 2, T3S, R6WLatitude: 42.2395273 Longitude: -84.9662018). The crude oil originated from the Cold Lake deposit in Alberta, Canada. The oil is designated "heavy" due to its thickness or viscosity. Heavy crude is composed of hydrocarbons, resins, asphaltenes and inorganic fractions. Other light-petroleum fractions, or diluents, were added to the heavy crude to facilitate pumping of the media over long distances. Line 6B is located in an undeveloped rural area, south of Marshall. The Studied Area Location Map is shown on **Figure 1**.

1.1 Background

The release entered Talmadge Creek and subsequently the Kalamazoo River at a time when the river was above flood stage. As a result, oil migrated down the Kalamazoo River and impacted flood plain areas including the shoreline, bank areas, and some overbank areas, upstream of the Morrow Lake Dam. In addition, submerged oil settled in portions of the river bottom upstream from the Morrow Lake Dam. Evaluations performed through the Shoreline Clean-up Assessment Technique (SCAT) process and through evaluations of river sediments, documented the conditions along the river. The SCAT process included manual removal of tarred soil, oiled debris, and pooled oil through low-pressure/high-volume flushing and absorption methods with downstream snare and boom capturer, under the direction of the United States Environmental Protection Agency (U.S. EPA). The results of the SCAT process is documented in the "Oil Recovery Report - Kalamazoo River" dated September 20, 2010.

Response activities completed and/or on-going since the release include, but are not limited to:

- Shut-down of pipeline and closing of isolation valves;
- Installation and operations of flumes (underflow weirs) downgradient of the release area;
- Installation and operation of oil and water containment and recovery systems;
- Development of a system of Mile Post (MP) markers to label all divisions of the river for study;

- Development of plans for remediation of source area (Source Area Response (SAR) Plan) and of downstream impacts (Response Plan for Downstream Impacted Area (RPDIA);
- Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP);
- Sediment and surface water sampling;
- Source Area Response activities as documented in the Source Area Response Completion Report (SARCR);
- Downstream excavation of impacted soil;
- Air monitoring and sampling;
- Sampling and analysis of private and public drinking water wells;
- Shoreline Assessment Technique (SCAT) process; and
- Characterization and remediation activities for submerged oil.

1.2 Purpose and Overview

The purpose of this report, *Evaluation of Potential Impact of Released Oil on Groundwater used for Drinking Water (Hydrogeological Evaluation Report)* is to present the findings from the evaluation of short-term and long-term impacts of the released oil on groundwater that has a potential to be a source of drinking water. This report has been prepared in response to the Supplement to Order for Compliance under Section 311(c) of the Clean Water Act signed on September 23, 2010 (September 23, 2010 Supplement to the Order). The scope of work was conducted in accordance with the final work plan, "Enbridge Line 6B MP 608 Pipeline Release Marshall, Michigan, Supplement to the Sampling and Analysis Plan Referred to as "Work Plan for Evaluating the Potential Impact of Released Oil on Groundwater used for Drinking Water" (Groundwater Evaluation Work Plan), October 3, 2010. This work plan was conditionally approved by U.S. EPA on October 5, 2010.

1.3 Site Setting

The Site Study Area consists of a 38 mile long stretch of river, flood plain and associated areas as shown on **Figure 1** that starts from the release area (milepost 608 in the vicinity of its pump station located in Marshall, Michigan) downstream to the Morrow Dam. The first two miles of impact includes Talmadge Creek. The other 36 miles is along the Kalamazoo River. Land adjacent to the Site is primarily agricultural and woodlands, however, the river also traverses along residential properties and through the urban area of Battle Creek.

Along the stretch of the study the geologic setting is variable but primarily consists of a layer of glacial drift with permeable sands and gravels that contain some clay units overlying bedrock. The upper bedrock consists of Marshall Sandstone in the Marshall Formation (Michigan Department of Environmental Quality, Geological Survey Division, 1987). Groundwater is present in the glacial drift and the underlying bedrock. According to the local health department and Michigan Department of Natural Resources and Environment (MDNRE) Wellogic Database, many residential wells are screened in the bedrock, while others are screened in the permeable sands and gravels above the bedrock.

The Kalamazoo River's role in the water cycle is that of a conduit through which surface water and groundwater drain to Lake Michigan. Available regional groundwater flow data (derived primarily from the United States Geological Survey (USGS) along the Kalamazoo River supports the preliminary conclusion that the river is dominantly a gaining river (http://gwmap.rsgis.msu.edu/viewer.htm). However, certain constraints may cause water from the Kalamazoo River to flow into the surrounding groundwater. Four examples of such constraints are: (1) abrupt increases in the water level of the river during floods which may cause a temporary reversal of the flow, (2) abrupt drops in water levels in the river across dams which can cause localized areas where surface waters flow through the ground around a dam; (3) pumping wells with high discharge rates located adjacent to the river; (4) storm water flow near urban areas where precipitation is channeled directly to the river with minimal groundwater recharge due to surface coverings. These conditions were used to develop goals for assessing oil impact of the river.

1.4 Goals

The primary goal of this study was to determine whether the Kalamazoo River is gaining or losing water at select locations where crude oil was identified during the SCAT process near potable wells. Additional goals included a review of publically available information related to the Kalamazoo River, regional geology and hydrogeology, and investigations and studies previously performed in the Study Area. The evaluation focused on the potential for river water to migrate and transport potential crude oil constituents to groundwater and subsequently drinking water at select locations where crude oil was identified during the SCAT process near potable wells and localized groundwater hydraulics might be complex due to the river configuration (for example tight meandering curves) or at Ceresco Dam. The study did not include long-term monitoring, or a comprehensive study of the whole river

and every outfall. Rather the study focused on eight select areas where the potential for risk to groundwater is the greatest. This report presents the results of these findings.

2.0 Historical Information on the Kalamazoo River

Section 2.0 presents publically available information related to the Kalamazoo River, regional geology and hydrogeology, and investigations and studies previously performed in the investigative areas. Review and presentation of this information was one of the goals of the work plan.

2.1 Kalamazoo River

The Kalamazoo River is a tributary of Lake Michigan and is classified as a navigable water of the United States, within the regulatory jurisdiction of the United States Corps of Army Engineers (USCOAE) Detroit District. The jurisdictional cut-off of the navigable water is at Allegan Dam, approximately 31.5 miles above the confluence with Lake Michigan (USACOE, 2010).

The Kalamazoo River is approximately 123 miles long from the headwaters to the confluence at Lake Michigan. The headwaters originate at Round Lake for the North Branch of the Kalamazoo River, near Hanover, and Mosherville, for the South Branch of the Kalamazoo River. The North and South branches of the Kalamazoo River converge in Albion, Michigan. The main tributaries of the Kalamazoo River include: Talmadge Creek, Rice Creek, Battle Creek River, Wabascon Creek, Gun River, and Rabbit River. Other tributaries are also present. The Kalamazoo River's watershed drains an area of approximately 2,020 square miles, covering portions of ten counties in southern Michigan: Allegan, Barry, Eaton, Van Buren, Kalamazoo, Calhoun, Jackson, Hillsdale, Kent, and Ottawa counties. The drainage basin topography consists of gently rolling hills and the topographic relief is 686 feet from the headwaters to Lake Michigan (Wikipedia, 2010a; Rachol et al., 2005).

The river is classified as a sixth order warm-water stream supporting sport-fish, including trout, sunfish, perch, pike, and other species (Rachol et al. 2005; Wesley, 2005). In 2005, a fishery assessment was performed on the Kalamazoo River by the State of Michigan's Fisheries Division, which is further discussed in Section 2.6. Land-cover within the Kalamazoo River drainage basin is dominated by agricultural (53%) and forested land (27.4%) (Vogelmann et al., 2001). Much of the Kalamazoo River basin was originally forested land and grassland during pre-settlement (early to mid-1800's) times (Comer, 1998).

Within the Kalamazoo River basin, precipitation averages 35.7 inches annually, with greater than 50% of the rainfall occurring from April to September. During winter the average seasonal snowfall is 79.7

inches (Knapp, 1987). A total of twenty-three (USGS) stream-gauging stations are located on the Kalamazoo River drainage basin from Albion to New Richmond, Michigan (Rachol et al., 2005). The Kalamazoo River has a median flow of 352 cubic feet per second at Marshall, Michigan from 2002 - 2009 (USGS, 2010a). By comparison, the river has a median stream flow of 778 cubic feet per second at Battle Creek, Michigan (USGS, 2010b).

Wesley (2005) demarcated the river into five sections: Mouth (from Lake Michigan to Allegan Dam), Lower (Allegan Dam to Otsego), Middle (Otsego to Battle Creek), Upper (Battle Creek to Homer, Albion and Moscow), and the Headwaters (Homer, Mosherville, and Moscow areas). The eight investigative target areas lie within the Upper and Middle portions of the Kalamazoo River (**Figure 2**). The investigative target area locations are defined as follows:

- Target Area 1 Mile Post 2.25 to 3.25
- Target Area 2 Mile Post 5.50 to 6.00
- Target Area 3 Mile Post 15.00 to 15.50
- Target Area 4 Mile Post 22.50 to 23.00
- Target Area 5 Mile Post 26.50 to 27.25
- Target Area 6 Mile Post 34.00 to 34.75
- Target Area 7 Mile Post 36.00 to 36.25
- Target Area 8 Mile Post 36.75 to 37.25

Dams, diversion structures, and channelization have affected sediment deposition along the Kalamazoo River since human settlement in the mid-1880's (Rachol et al., 2005). A total of 111 dams are present along the Kalamazoo River watershed (Wesley, 2005). Within the investigative target areas along the Kalamazoo River, two dams are present at the community of Ceresco and at Morrow Lake. Target Area 2 is located at Ceresco Dam and Target Area 8 is located at Morrow Lake. Numerous environmental studies have been performed at sites along the Kalamazoo River (Simard, 2003) and are summarized in **Appendix A**.

2.2 Regional Geological Setting

Within the investigative area, the primary bedrock units are Mississippian in age and include the Marshall Sandstone throughout the Kalamazoo River basin in Calhoun County, and the Coldwater

Shale in portions of Kalamazoo County (Dorr and Eschman, 1970; WMU, 1981). Depth to bedrock varies within the investigative area from ground surface to approximately 200 feet below ground surface (approximately 700 to 900 feet above mean sea level (amsl)). Within the Kalamazoo River basin, the bedrock topography ranges from approximately 1100 feet amsl near the headwaters to 400 feet amsl near Lake Michigan (WMU, 1981). The bedrock units have a slight dip to the northeast (Vanlier, 1966).

The Marshall Sandstone consists of an upper Napoleon sandstone member and the lower Marshall Sandstone. The upper member is recognizable only in exposures in the southern part of the Michigan basin, including the investigative area. The Napoleon sandstone is locally considered an unconfined aquifer (Apple and Reeves, 2007). Erosional terraces of Marshall Sandstone outcrop at various locations along the Kalamazoo River, including at Ceresco Dam.

The upper surface of the Marshall Sandstone is an erosional contact, which is typically weathered, friable, fractured, and surficially irregular. At depth, the sandstone is a massive bedded unit and grain-size generally decreases with depth (Apple and Reeves, 2007). Generally, the Marshall Sandstone is sparsely fossiliferous, sometimes cross-bedded and rippled, very fine- to coarse-grained sandstone of buff, tan, or gray color. Interbeds of siltstone, sandy shale and shale, are also present at depth. The lower Marshall is mostly fine-grained sandstone with some very fine sand intervals. It is fossiliferous and generally flat-bedded (USGS, 2010c; Apple and Reeves, 2007).

Quaternary geology of the Kalamazoo River watershed from Morrow Lake to Marshall is mapped as glacial outwash sand and gravel and postglacial alluvium (Wesley, 2005; Rachol, et al., 2005). The predominant glacial feature of the area is the Tekonsha Moraine, extending generally parallel to the Kalamazoo River from Morrow Lake, in Kalamazoo County, eastward into the river's headwaters in Jackson and Hillsdale Counties. The Tekonsha Moraine is composed of coarse-textured sandy till, with thin clay layers and discontinuous horizons of sand and gravel (Passero, 1978; Deutsch et al., 1960; Apple and Reeves, 2007).

Glacial geology within the Kalamazoo River basin is described as complex, and lithostratigraphic correlation can be difficult due to lateral and vertical heterogeneity of glacial deposits with a complex depositional history. Modern alluvial sediments present along the river further add complexity and can be difficult to differentiate from glacio-fluvial outwash (Apple and Reeves, 2007).

The main soils types of the Kalamazoo River basin are loam, sand, and muck (Rachol et al, 2005). Within the investigative area the predominant general surficial soil types are sandy loam, fine sand, and sandy clay loam. Wetland areas containing muck are also present.

2.3 Regional Hydrogeology

The Kalamazoo River basin consists of an assortment of glacial outwash sands, coarse end-moraine deposits (sands and gravel), fine end-moraine deposits, ice contact material (sorted sands and gravel), clayey till, lake plain deposits, and post-glacial and modern alluvium. Most of the glacial geology is made up of permeable outwash (41%), whereas lacustrine deposits in the basin are less frequent (6%) (Wesley, 2005). These glacial deposits affect groundwater movement and the behavior of streams and rivers. The Kalamazoo River basin, which is dominated by well-drained outwash, coarse end-moraine deposits, and ice contact deposits have higher groundwater yields compared to basins with less permeable deposits (Bent, 1971).

In these well-drained soils, with Great Lakes temperate climate, a large amount of precipitation and snow-melt percolates to the groundwater and ultimately flows to the Kalamazoo River and associated tributaries and wetlands. In poorly-drained soils, such as fine till deposits, infiltration capacities are low, so most precipitation reaches the river basin as surface runoff. Outwash is the predominant depositional material in the basin, and contributes to moderately high groundwater deliveries to the river system (Wesley, 2005).

Rice Creek, Battle Creek River, and Wabascon Creek are main tributaries feeding the Kalamazoo River along the Study Area. These waterways primarily drain glacial outwash sand and gravel, and postglacial alluvium. Rice Creek drains coarse end moraines and coarse till plains with moderate topographic relief over outwash plains. The result is groundwater flow proximal to the confluence of the Kalamazoo River, near Marshall, Michigan. The Battle Creek River drains medium to fine-textured till plains and low-to-moderate relief end-moraines. Wabascon Creek, midway between Battle Creek and Augusta, Michigan, near Target Area 4, drains from a mixture of moderate-relief coarse end-moraines, coarse till plains, and outwash plains.

In the investigative area, the glacial aquifer consists primarily of outwash and morainal deposits. Hydraulic conductivities of these soils are extremely variable. The estimated hydraulic conductivities of glacial soils at the Verona Well field, in Battle Creek, are 110 ft/day (channel deposits), 70 ft/day

(outwash), 30 ft/day (inter-bedded outwash), and 15 ft/day (till) (Grannemann and Twenter, 1985). Hydraulic conductivities determined during this investigation fall within the published values. The slug test data are further discussed in Section 5.

2.4 United States Geological Survey Studies

Numerous studies along the Kalamazoo River watershed have been prepared by the USGS (USGS, 2010d). Some available studies pertinent to the investigation are presented.

Rachol *et al* (2007), USGS, Lansing, Michigan, prepared "Historical and Simulated Changes in Channel Characteristics of the Kalamazoo River, Plainwell to Otsego, Michigan" in cooperation with U.S. Environmental Protection Agency, Region V, and the Michigan Department of Environmental Quality (MDEQ) now MDNRE. The study was completed to better understand the potential effects of construction and decommissioning of dams on the Kalamazoo River, and to simulate potential channel changes that could result if dams were removed. The study focused on an 80-mile reach from Morrow Dam to the river mouth at Lake Michigan (areas downstream from the investigative areas presented in this report).

The study is significant in identifying that dam impoundments are potentially contaminated-sediment sinks, and that dams can regulate the downstream migration of contaminant-impacted sediments through adjustment of impounded water levels, and incising of bottom-sediments, erosion, avulsion, and transport of sediments. Historical channel change at the mouth of Morrow Lake (Target Area 8) is presented in Appendix C10 of the USGS report (Rachol et al., 2007).

According to a review of a Michigan State University Interactive Map Viewer (http://gwmap.rsgis.msu.edu/), the USGS has three observation wells near the confluence of the Kalamazoo River and Morrow Lake, one observation well north of Augusta, and one observation well north of the Kalamazoo River, near Target Area 4. These wells are summarized below:

USGS Station ID	Location	Lat	Long	Depth (feet)	Depth to Water Range (feet below LS)	Dates
#421614085270801	Miller Drive at Morrow Lake	42.2705979	-85.452223	27	6 to 13.5	1987 - 2005
#421616085262801	Galesburgh Rest Area	42.2711534	-85.441112	47.7	20.8 to 21.6	1987 - 1988
#421713085264601	E. Michigan Avenue, North of Morrow Lake	42.2878196	-85.445279	29	13.2 to 16	1987 - 2005
#422056085211701	N. 42cnd St. North of Augusta	42.3489291	-85.354723	34.8	9.8 to 12	1987 - 2005

USGS Station ID	Location	Lat	Long	Depth (feet)	Depth to Water Range (feet below LS)	Dates
#422207085175501	Michigan Ave, north of Kalamazoo River, near Area 4.	42.3675398	-85.29861	62.5	1.2 to 3.65	1987 - 2002

Review of hydrographs for these observation wells indicates fluctuating water levels, especially at Morrow Lake (USGS Station 421614085270801). Based upon data recorded in 2005, the high water level was approximately 6 feet below ground surface (bgs) in mid-January and March, and low water level was approximately 11 feet below ground surface (bgs) in mid-October and mid-April. USGS hydrographs are included in **Appendix B**.

3.0 Investigation Methods

This section presents the methodology of the study relative to the potential for impacted surface water to impact groundwater and subsequently adjoining potable water wells. To complete this study, eight target areas were defined as previously described. In addition, this study summarizes the results of the potable well sampling.

3.1 Target Areas of Investigation

Eight target areas were selected and evaluated along the Kalamazoo River as part of the investigation. The target areas were selected based on river conditions, hydrogeologic principles, location of potentially vulnerable potable wells, distribution of crude oil observed during the SCAT process, and submerged oil observations. The investigations in each target area were designed to accomplish the following objectives:

- Determine if the Kalamazoo River is gaining or losing at each target area at the time of the study;
- Determine if drinking water aquifer is impacted, or has the potential to be impacted, by released oil;
- Generate information on the hydrogeologic conditions along the Kalamazoo River such as the direction of hydraulic gradients, at the time of the study, and the hydraulic characteristics of the aquifer near the river;
- Install monitoring wells for long term monitoring, and

Monitoring well locations were situated within the target areas based partially on access constraints. The eight target areas, shown in **Figure 2**, were identified for hydrogeological evaluation based on the following criteria:

- Proximity of historic pooled or submerged oil relative to potable wells;
- Areas with potential for demonstrating losing stream characteristics such as at retention areas such as dams (ie. the Ceresco Dam);

- Locations identified where gaining conditions may be less pronounced such as association with tighter meanders in the river, and

- Additional areas near potable wells.

3.2 Point of Reference

Approximately 38 linear miles of surface water and adjacent floodplains have been impacted from the crude oil release. As a method of reference to all areas associated with the crude oil release, a mile post system was developed from the release area to the Morrow Dam area. Due to the level of detail needed to reference each area of the river, the mile posts have been divided into quarter sections (ie. MP 4.25) with a reference to the left (L) or right (R) bank with the downstream flow of the river. The table below summarizes the eight Target Areas of study and their location (mile post), purpose, and number of monitoring wells installed within each of the eight Target Areas.

Target Area	Mile Post Range	Purpose/Objectives	Wells
1	2.25 to 3.25	• Develop conceptual site model (south side) • Document vertical and horizontal gradient near the edge of the river • Document groundwater chemistry	3
2	5.50 to 6.00	• Evaluate groundwater flow at Ceresco Dam on both sides of river. • Document groundwater chemistry	9
3	15.00 to 15.50	• Evaluate if submerged oil impacted groundwater quality. • Document vertical and horizontal gradient near the edge of the river. • Document groundwater chemistry	3
4	22.50 to 23.00	• Evaluate if submerged oil impacted groundwater quality. • Document vertical and horizontal gradient near the edge of the river • Document groundwater chemistry	3
5	26.50 to 27.25	• Evaluate impact of tight river bends on adjacent groundwater flow. • Document the vertical gradient and groundwater chemistry.	3
6	34.00 to 34.75	• Evaluate impact of tight river bends on adjacent groundwater flow. • Document the vertical gradient and groundwater chemistry.	6
7	36.00 to 36.25	• Evaluate if submerged oil impacted groundwater quality. • Documents vertical and horizontal gradient near the edge of the river.	3

Target Area	Mile Post Range	Purpose/Objectives	Wells
		• Document groundwater chemistry.	
8	36.75 to 37.25	• Evaluate if submerged oil is migrating to groundwater. • Document vertical and horizontal gradient near the edge of the river • Document groundwater chemistry.	3

The specific study/drilling locations at each of the target areas were selected based on accessibility within the target areas only. Specific drilling locations are depicted in **Figures 3 through 10.**

Target Area 1 is located upstream away from any historic submerged oil to assess hydraulic conditions near the confluence of Talmadge Creek with the Kalamazoo River.

Target Area 2 is the area of the Ceresco Dam. This area was chosen due to the change in the water level across the face of the dam and the potential for this abrupt change in hydraulic head along the river to cause groundwater to flow outward around the dam.

Four target areas (Areas 3, 4, 7, 8) were selected where submerged oil had been identified along sections of the Kalamazoo River. In these areas, the goal of the groundwater investigation was to investigate surface water/groundwater communication and assess if the oil had impacted groundwater and adjacent potable wells.

Two target areas (Areas 5 and 6) are located on tight meanders within the Kalamazoo River. This study evaluated how tight meanders influenced groundwater and surface water communication in these areas.

3.3 Residential Well Sampling

Residential well sampling was initiated by Enbridge after the release to monitor water quality at potable wells located near the impacted waterways. Wells within 200 feet of the impacted waterway were identified through a combination of direct visual observations of the properties, communication with property owners, communication with local health departments in Kalamazoo and Calhoun Counties, communication with Michigan Department of Community Health, and searching for well locations through publically available sources of information such as Michigan's Well Logic system (http://www.michigan.gov/deq/0,1607,7-135-6132_6828-16124--,00.html). Initially, potable wells

were sampled when owners called in to Enbridge. Soon after the spill, this was converted into a formal process where Enbridge identified wells within 200 feet of the banks of the river. During October, the program expanded to include wells within 200 feet of the high water mark from the storm event that occurred at the time of the spill. The residential water wells have been sampled every other week for metals, total petroleum hydrocarbons (TPH)-oil range organics (ORO), TPH-gasoline ranged organics (GRO), TPH diesel range organics (DRO), volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and polychlorinated byphenols (PCBs). The location of the residential water wells that have been identified within the 200-foot buffer of the high water mark are shown in **Appendix C.**

The initial well water sampling parameter list for the first two sampling events is presented in Table 4.4 of the approved SAP. Many of these parameters are not constituents of crude oil that impacted the site including, but not limited to, arsenic, lead, and PCBs. Once two sampling events at each identified well have no detected constituents related to crude oil, a modified sampling program will be proposed and implemented based upon sampling frequencies.

The results of the residential water sampling is uploaded to SCRIBE nightly and is available to the U.S. EPA, MDNRE, Michigan Department of Community Health, Kalamazoo County Health Department, and Calhoun County Health Department. A summary of the residential well sampling program as of October 26, 2010 is:

- 155 total wells were entered in the sampling program;
- 3 wells in the program could not be sampled because access had not been granted by the owner's representative;
- 27 wells were sampled on one occasion (these were recently added wells); and
- 98 wells were sampled two or more times.

The results of the residential water sampling completed as of October 26, 2010 are presented in **Appendix D**. The data indicate no detections of benzene, ethyl benzene, or TPH in any of the drinking water wells within the program. Two wells have exhibited detectable values of toluene and p,m-xylene. Other constituents potentially related to oil that have been detected in the drinking water

wells include iron (present in most wells), nickel (present in two wells), and naphthalene (present in one sample).

One well reported detectable values of toluene on two sample dates including September 1st during the response phase and October 3 for a re-sample (0.3 and 1.0 ug/L, respectively). This property maintains a polyvinyl chloride (PVC) constructed well with observable PVC glue, of which toluene is a known VOC ingredient. The target detection limit (TDL) for toluene is 1 ug/L. The detectable values are not believed to be of concern as the values are well below the Michigan Part 201Residential Drinking Water Criterion for toluene (790 ug/L, aesthetic). One well displayed a detection for p,m-xylene (0.2 ug/L), also well below the Part 201 Criterion (280 ug/L, aesthetic). Additional sampling performed at this well did not exhibit detectable values of p,m-xylene. The TDL for p,m-xylene is 2 ug/L. As such, this additional hydrocarbon detection is not believed to be of concern or related to the crude oil spill.

Appendix C includes a table displaying the maximum and minimum concentrations of both iron and nickel by township as found in the MDNRE-supplied potable water well data. The Michigan Part 201Residential Drinking Water Criteria for iron and nickel are 0.300 mg/L and 0.100 mg/L, respectively. The minimum and maximum concentrations for iron found among the townships located within the 200-foot buffer are 0.01 to 16 mg/L. Data collected from potable water wells within the program range from 0.02 mg/L to 6.71 mg/L, well within the range of the MDNRE–supplied data. Maximum and minimum concentrations for nickel found among the MDNRE data range from 0.001 to 0.01 mg/L. Nickel concentrations displayed during the residential monitoring program range from 0.005 mg/L to 0.043 mg/L, slightly greater than that of the county data, but not exceeding criterion. It is unlikely that these detections are related to the crude oil spill.

Other constituents detected in potable wells potentially related to oil include naphthalene, present in one sample at 0.1 ug/L. Part 201Residential Drinking Water Criteria for naphthalene is 520 ug/L with a Michigan target detection limit of 5 ug/L. The concentration of naphthalene exhibited at this well is below that of the criterion and the target detection limit, and is unlikely to be related to the crude oil release.

The sampling program of these residential wells closest to the impacted waterways documents that crude oil constituents have not impacted the groundwater that is actually captured by these potable

wells. Although iron has been detected in most wells and nickel in some wells, both are a naturally occurring element and is not attributed to the impacts from the release.

3.4 SAP and QAPP

This hydrogeological study was performed following the methods and procedures outlined in the approved SAP and the QAPP. The SAP was finalized on August 17, 2010 and documents the sampling/analysis and quality assurance programs. In addition, the Drinking Water Well Supplement to the Sampling and Analysis Plan was finalized on September 27, 2010 and was prepared in response to US EPA's Supplement to the Order for Compliance under Section 311(c) of the Clean Water Act (the Order) dated September 23, 2010.

The QAPP was finalized on August 15, 2010. This QAPP provides documentation and direction on the organization, objectives, planned activities, specific quality assurance/quality control procedures for the Company's Response Project. Addendums to the QAPP include the September 3, 2010, Standard Operating Procedures for Check Valve Sampling and Sediment Logging.

3.5 Environmental Sites and Freedom of Information Act (FOIA) Search

Additional studies were reviewed and an on-line literature search performed through Google™ Scholar and U.S.EPA's STORET Database (U.S. EPA, 2010) to evaluate other potential site-specific scenarios where contaminants identified in the Kalamazoo River (or other river systems) impacted groundwater and drinking water wells. No studies were identified along the Kalamazoo River where dissolved contaminants found in the river migrated to drinking water sources.

Studies proximal to the investigative area are presented below.

Albion-Sheridan Township Landfill (ASTL) Site

The Agency for Toxic Substances and Disease Registry (ATSDR) performed a Public Health Assessment at the Albion-Sheridan Township Landfill (ASTL) site, in Sheridan Township, Michigan (ATSDR, 1997). This site is located near Albion, approximately 20 miles upstream of the Study Area. The site is summarized because of biota sampling performed near Ceresco Dam. In July 1987, the MDNR collected fish for tissue analyses from the Ceresco Impoundment, approximately 20 miles downstream from the ASTL site. The collected fish included nine carp, one

largemouth bass, and one smallmouth bass. The highest PCB concentration found was in one of the carp (0.24 ppm) in a skin-off fillet sample. ATSDR concluded that PCBs identified in the carp were at concentration commonly found in fish from Michigan waters, even in areas with no known PCB source.

ATSDR noted that contaminants (elevated concentrations of iron, sodium, potassium, lead, magnesium, calcium, ammonia, total chromium, copper, and zinc) originating on the ASTL site could reach the Kalamazoo River and its associated wetlands via discharge of contaminated groundwater or surface runoff. ATSDR also noted that there was no record of any municipal or private water supply using water directly from the Kalamazoo River.

Other Sources of Contaminant Impact

Anthropogenic and natural sources of contamination exist within the Kalamazoo River basin and associated glacial deposits and bedrock. PNAs are present in crude oil from the Line 6B release; however PNAs are relatively insoluble in water (Neff, 1979). PNAs tend to adsorb onto solid phases in aquatic environments because of their hydrophobic nature and low water solubilities (Neff 1979; NRCC 1983; Eisler 1987).

PNAs are classified by the U. S. EPA as a pollutant of concern under the Lake Michigan Lakewide Management Plan, including Lake Michigan tributaries. PNAs are a group of compounds formed during the incomplete burning of fossil fuels, garbage, or other organic substances. Sources include vehicle exhaust, burning coal, forest fires and agricultural burning, asphalt roads, fossil fuels (crude oil and refined products) and tar.

3.6 Other Studies and Investigations

Michigan Part 201 sites of environmental contamination referenced by Wesley (2005) and as part of a Freedom of Information Act (FOIA) Search are presented in this section. Wesley (2005) identified 189 sites within the Kalamazoo River watershed as being regulated under Part 201 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. Many of these sites are deemed to have high potential for migration of groundwater contaminants to the Kalamazoo River, especially in areas with high groundwater flows (Wesley, 2005). A total of 22 sites are listed as sites under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) of

1980, as amended and the Superfund Amendments and Reauthorization Act (SARA) of 1986. These sites are summarized by river Section in tables in **Appendix A**. Many of these sites are located outside of the Study Area from Marshall to Morrow Lake.

Sites within the study area having potentially similar contaminants as the Enbridge release include those sites with benzene, toluene, ethylbenzene and xylene (BTEX), some metals, and those that are not specifically categorized by pollutants. These sites include:

Environmental Site	**Location / City**	**Relevant Pollutant**
Calhoun Co Road Commission	Marshall	BTEX
Clark Oil APEX Oil	Marshall	Benzene, Toluene
Consumers Energy	Marshall	PNAs
Residential Well 23 Mile Road	Marshall	Benzene, Toluene, Xylene
American Fibrit	Battle Creek	Heavy Manufacturing / Pollutant not defined
Battle Creek Adventist Hospital	Battle Creek	PNAs
Battle Creek Aquatic Center	Battle Creek	Metals, BTEX, PNAs
Calhound Co Road Commission	Battle Creek	Benzene, Toluene
Cereal City Landfill	Battle Creek	Benzene
East Columbia	Battle Creek	BTEX
Global Paint and Ink	Battle Creek	Xylene
GT Western Railroad	Battle Creek	Diesel Fuel
Kelloggs Kelpaco	Battle Creek	BTEX
Kendall Street	Battle Creek	PNAs
McLeieer Oil	Battle Creek	BTEX, PNAs, Metals
Michigan Paperboard Corp.	Battle Creek	Ethylbenzene, toluene, xylene, naphthalene
Quad L Corp.	Battle Creek	Ethylbenzene, toluene, xylene
Shay Motor Company	Battle Creek	Benzene, toluene

In addition to the sites identified above, a FOIA Search was performed at the MDNRE, Kalamazoo District on several dates in October 2010. A total of 86 sites were identified, evaluated summarized in **Appendix A**. The majority of sites identified are located in Battle Creek, Michigan. The following sites are located within 2,000 feet of the Kalamazoo River or one of the Target Areas:

<u>K-Mart, 200 Capital Avenue SW, Battle Creek</u>

This is a closed Part 213 Site located 1,200 feet northwest of Target Area 3. Historically, BTEX and PNAs were identified at the site. However, impact was not identified in groundwater because groundwater was not encountered during site investigation activities.

Kellogg Foundation, 55 Hamblin Avenue, Battle Creek

This is a closed Part 213 Site located 1,500 feet north of Target Area 3. Historically, petroleum compounds were a concern at the site due to a spill, but no impacts were found in any media. The groundwater flows northwest toward the junction of the Kalamazoo and Battle Creek Rivers. Groundwater is approximately 15-16 feet bgs. This site is upgradient of Target Area 3 (north of the Kalamazoo River) and provides additional supportive documentation that groundwater flow in the vicinity of Target Area 3 is toward the Kalamazoo River.

Leatherman Oil, 455 Upton Avenue, Battle Creek

This is a Part 213 site located 2 miles north of Target Area 3, just south of the Kalamazoo River. Historically, BTEX, lead, and naphthalene were identified at the site in the soil and groundwater. The groundwater is 11-12 feet bgs and flows north-northeast toward the Kalamazoo River. This site provides additional supportive documentation that groundwater flow in the vicinity of Target Area 3 is toward the Kalamazoo River.

Neighborhoods, Inc., W 482 Van Buren, Battle Creek

This is a closed Part 213 site located 7,200 feet north-northwest of Target Area 3 and 1,000 ft northeast of the Kalamazoo River. Historically, lead was identified in site soils but not groundwater. The groundwater is approximately 37 feet bgs, and flows southwest toward the Kalamazoo River. This site provides additional supportive documentation that groundwater flow in the vicinity of Target Area 3 is toward the Kalamazoo River.

P.S. Food Mart, 1344 E Columbia Avenue, Battle Creek

This is a Part 213 site located 500 feet north of the Kalamazoo River and 8,000 feet southeast of Target Area 3. Historically, BTEX has been identified in soil and groundwater at the site. The groundwater flows northeast (away from the Kalamazoo River) at a gradient of approximately 0.01 foot/foot. Groundwater is approximately 37-39 feet bgs.

Former Sears Roebuck, 170 Capital Avenue, Battle Creek

This is a closed Part 213 site located 1,000 feet southwest of the Kalamazoo River and 2,000 feet northwest of Target Area 3. Historically, BTEX and PNAs were identified in the soil. Groundwater is approximately 18 feet bgs. No information is available regarding groundwater flow direction.

Trumbull Service Station, 94 North Avenue, Battle Creek

This is a Part 213 site located 1,000 feet northwest of the Kalamazoo River and 4,000 feet north-northeast of Target Area 3. Historically, BTEX and PNAs were identified in the soil and groundwater. The groundwater flows south-southwest, generally towards the Kalamazoo River. Groundwater is approximately 28 feet bgs. This site provides additional supportive documentation that groundwater flow in the vicinity of Target Area 3 is toward the Kalamazoo River.

Wagner-Flook Builders Inc, 235 Hamblin Avenue, Battle Creek

This is a closed Part 213 Site located less than 100 feet west of the Kalamazoo River and 4,000 feet north-northwest of Target Area 3. Historically, PNAs were identified in the soil. No information is available regarding groundwater flow direction.

W.K. Kellogg Institute, 2 Hamblin Avenue, Battle Creek

This is a closed Part 213 site located 1,000 feet northeast of the Kalamazoo River and 0.5 mile northeast of Target Area 3. Historically, BTEX, Methyl-Tert-Buthyl-Ether (MTBE), and lead were identified in the soil and groundwater. No information is available regarding groundwater flow direction.

Augusta Total Retail, 301 E Michigan Avenue, Augusta

This is a closed Part 213 site located 1.25 miles southwest of Target Area 5, but 600 feet north of the Kalamazoo near the confluence of Augusta Creek. Historically, petroleum compounds were identified in the soil and groundwater. The groundwater flows east-southeast toward the Kalamazoo River at a gradient of 0.001 foot/foot and a flow velocity of 32 feet/year. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

Eaton Corp-Springfield, 463 N. 20th Street, Springfield

This is a Part 201 site located 2.25 miles northwest of Target Area 3 and approximately 2,500 feet south of the Kalamazoo River. Historically, chromium, mercury, and trichloroethylene (TCE), were identified in the groundwater. The groundwater flows northeast toward the Kalamazoo River at a gradient of 0.0072 foot/foot and a velocity of 3.2 feet/day. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

A.K. Zinn/K&M Salvage, 160 S. Kendall, Battle Creek

This is a Part 201 site located 1 mile northwest of Target Area 3, and approximately 1,200 feet south of the Kalamazoo River. Historically, VOCs, chromium, lead, and mercury were identified in the soil and groundwater. The groundwater flows north-northeast toward the Kalamazoo River at a gradient of 0.0033 foot/foot and a velocity of 0.94 feet/day. Groundwater is approximately 14-17 feet bgs. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

W. Dickman/Kellogg Property, Intersection of Brady and W. Dickman, Battle Creek

This is a Part 201 site located 3.25 miles northwest of Target Area 3 and 4 miles southeast of Target Area 4, along the Kalamazoo River. Historically, various metals and PNAs were identified in the soil and groundwater. The groundwater is approximately 22 – 34 feet bgs. Review of Remedial Investigation and Feasibility Study (RI/FS) notes that assumed flow is north toward the Kalamazoo River. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

Former Springfield Elementary School, 383 N 20th Street, Springfield

This is a Part 201 site located 2 miles northwest of Target Area 3. Historically, arsenic, mercury, lead, and selenium were identified in the soil. No water was encountered at the site.

City of Battle Creek, Equipment Division, 350 W Michigan Avenue, Battle Creek

This is a Part 213 site located 500 feet north of the Kalamazoo River. Historically, BTEX and Trimethylbenzenes (TMBs) were identified in the soil and groundwater. The groundwater flows southwest at a gradient of 0.006 foot/foot and a velocity of 0.04 feet/day. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

City of Battle Creek, Police Division, 20 N Division, Battle Creek

This is a Part 213 site located 1,100 feet north of the Kalamazoo River and 400 feet south of the Battle Creek River. Historically, BTEX was identified in the soil and groundwater. The groundwater flows north-northwest toward the Battle Creek River. Groundwater is approximately 9-16 feet bgs.

Battle Creek Gas Com, 165 S Monroe Street, Battle Creek

This is a Part 213 site located less than 500 feet east of the Kalamazoo River, but within the confluence of the Battle Creek River. Historically, BTEX was identified in the soil and groundwater. The groundwater is 10-12 feet bgs and flows north-northwest at a gradient of 0.01 foot/foot and a velocity of 0.10 feet/day. Groundwater flow direction is influenced by the confluence of the Kalamazoo River and the Battle Creek. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

Former Gas Station, 170 Capital Avenue, Battle Creek

This is a Part 213 site is located 200 feet southwest of the Kalamazoo River and 1500 feet northwest of Lower Mill Pond. Historically, PNAs were identified in the soil. Groundwater is approximately 18 feet bgs. No information is available regarding groundwater flow.

Kellogg Institute/BC Transit, 2 Hamblin Avenue/75 Beacon Street, Battle Creek

This is a Part 213 site located 500 feet east of the Kalamazoo River. Historically, BTEX, TMBs, and PNAs were identified in the soil and groundwater. The groundwater flows west-southwest toward the Kalamazoo River. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

Bell Auto Sales, 169 E Michigan Avenue, Galesburg

This is a closed Part 201/213 site located 1500 feet north of the Kalamazoo River. Historically, BTEX and TMBs were identified in the groundwater. The groundwater flows south toward the

Kalamazoo River. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

Titus Construction Company, 12105 E Michigan Avenue, Galesburg

This is a Part 201 site located 300 feet south of the Kalamazoo River. Historically, BTEX was identified in the soil and groundwater. The groundwater flows north-northwest toward the Kalamazoo River. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

Michigan Paperboard, 79 Fountain Street, Battle Creek

This is a Part 201/213 site located less than 500 feet west of the Kalamazoo River. Historically, BTEX and isopropanol were identified in the soil. No information is available regarding groundwater flow.

Western Michigan Refrigeration Warehouse, 1400 S 35th Street, Galesburg

This is a Part 201/213 site located 0.25 mile south of the Kalamazoo River. Historically, BTEX and naphthalene were identified in the groundwater. The groundwater flows northwest toward the Kalamazoo River. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

Texaco, 1540 S 35th Street, Galesburg

This is a Part 201/213 site located 0.25 mile south of the Kalamazoo River. Historically, BTEX, naphthalene, TMBs, and PNAs were identified in the soil and groundwater. The groundwater is approximately 10 feet bgs and flows north toward the Kalamazoo River. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

Mikes Tire Service, 144 W Michigan Avenue, Galesburg

This is a Part 201 site located 0.25 mile north of the Kalamazoo River. Historically, BTEX, TCE, and carbon tetrachloride were identified in the soil and groundwater. The groundwater flows west-southwest at 0.00148 feet/day, towards the Kalamazoo River.

Galesburg-Augusta School, 600 W Michigan Avenue, Galesburg

This is a Part 201 site located 900 feet west of the Kalamazoo River. Historically, BTEX, and naphthalene were identified in the soil and surface water. The groundwater is 5.5 to 9.5 feet bgs and flows north away from the Kalamazoo River.

Davis Oil C-Store, 6 E Michigan Avenue, Galesburg

This is a Part 201 site located 1,000 feet north of the Kalamazoo River. Historically, BTEX was identified in the soil and groundwater. The groundwater is approximately 9 feet bgs and flows south towards the Kalamazoo River. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

Davis Oil #2, 45 W Michigan Avenue, Galesburg

This is a Part 201 site located 1,000 feet north of the Kalamazoo River. Historically, BTEX was identified in the soil and groundwater. The groundwater flows south-southeast toward the Kalamazoo River. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

60 N 12th Street, Springfield

This is a Part 201 site located 1,000 feet south of the Kalamazoo River. Historically, arsenic, lead, and benzo(a)pyrene were identified in the soil. Groundwater is approximately 22 feet bgs. No information is available regarding groundwater flow.

Ronan & Kunzl Main Site, 500 S Kalamazoo, Marshall

This is a Part 201 site located 500 feet north of the Kalamazoo River, several thousand feet upstream from Target Area 1. The site is included due to proximity to the Kalamazoo River. Historically, Dichloroethylene (DCE), TCE, and barium were identified in the groundwater. The groundwater flows south, toward the Kalamazoo River. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

Calhoun County Road Commission-Marshall Facility, 13300 15 Mile Road, Marshall

This is a Part 201 site located 1.5 miles northeast of Target Area 1. This site is included because it is approximately 1,500 feet north of the Kalamazoo River. Historically, chlorinated VOCs, sodium, and chloride were identified in the groundwater. The groundwater flows southwest and southeast, toward

the Kalamazoo River. This site provides additional supportive documentation that groundwater flow in the vicinity is toward the Kalamazoo River.

3.7 Evaluation of Production and Municipal Wells

Industrial/Agricultural production wells and Municipal Supply water wells are located near the Study Area. Pumping wells in vicinity of the Kalamazoo River could potentially influence groundwater flow and direction. This section summarizes potential influences of municipal wells in the study area. A listing of Municipal wells are presented in **Appendix E**.

The Kalamazoo River watershed is rated highest in the State of Michigan in regards to groundwater withdrawals. It also has the second highest number of wells in glacial deposits and bedrock in Michigan. Most of the water withdrawal used is for industrial (43%), public (34%), irrigation (11%), domestic, commercial, agricultural and mining use (12% combined).

Based upon a review of the RS&GIS Interactive Map Viewer, municipal well fields are located near the study area at the following locations and communities:

- Marshall, Michigan, four wells set 100 feet bgs, for combined pumping capacity of 4,840 gallons per minute (gpm);
- Pennfield Township, two wells set 240 and 220 feet bgs, for combined pumping capacity of 2,400 gpm;
- Battle Creek – Verona Well Field, 20 wells set 120 to 150 feet bgs, for a combined pumping capacity of 20,394 gpm;
- Bedford Hills, Michigan, 3 wells set approximately 180 feet bgs, for a combined flow of 5,289 gpm;
- Augusta, Michigan, two wells set approximately 110 feet bgs, for a combined pumping capacity of 1,360 gpm;
- Galesburg, Michigan, two wells set approximately 65 feet bgs, for a combined pumping capacity of 1,500 gpm;
- Kalamazoo Pumping Station at Morrow Lake, one well (depth unknown) pumping at a capacity of 2,600 gpm.

Wells located in Marshall are located on Rice Creek, approximately 2.6 miles upstream and northeast of the confluence of Talmadge Creek. Due to the distance from the Kalamazoo River, pumping from the wells in Marshall are not likely to affect the Kalamazoo River.

Wells located in Pennfield Township are 3.2 miles northeast of the Kalamazoo River. Due to the distance from the Kalamazoo River, pumping from the wells in Pennfield Township do not affect the Kalamazoo River.

The Verona Well Field draws water primarily from the Battle Creek tributary of the Kalamazoo River. Because it is located approximated 2.5 to 3 miles northwest of the Kalamazoo River and wells are screened in the Marshall sandstone, pumping likely does not influence groundwater movement near the closest study Target Area 3.

Wells in Bedford Falls are located approximately 1.3 miles northeast of the Kalamazoo River and several miles from Target Area 4. Due to the distance from the Kalamazoo River, pumping from the wells in Bedford Falls are not likely to affect the Kalamazoo River.

Municipal wells in Augusta are located adjacent to the Kalamazoo River and 0.75 miles east of Study Area 5. The wells are part of a sampling program that includes potable wells within 200 feet of the high water mark. All collected samples had no detectable concentrations of crude oil constituents. The results are included in **Appendix D**. Studies performed in support of the Wellhead Protection Program Plan concluded that the aquifer in which the Village's municipal wells were screened was not directly influenced by the Kalamazoo River, and the municipal well's influence did not extend significantly beneath the Kalamazoo River (Fleis & VandenBrink, 2002).

The well at Morrow Lake is adjacent to Morrow Lake and approximately one-half mile west of Target Area 8. The well was temporarily taken offline as a precautionary measure from the crude oil spill; however, the well is currently being tested at various pumping rates following a reactivation plan approved by the MDNRE. The phases of the plan are outlined below.

- Phase 1 was intitiated by pumping the well to waste and collecting samples for VOCs and PNAs. The pumping was started on October 11th and ran for 72 hours. Water water samples were collected on hours 1, 12, 24, 48, and 72. Preliminary data indicate there have been no detections of VOCs and PNA parameters.

- If no impacts are noted in the validated data from phase 1 the well will be pumped for a maximum of 12hours/day at a maximum output of 628,000 gal/day. This output will be sampled on a daily basis for 30 days. This phase is anticipated to occur in the November/December 2010 time frame.
- Based on no impacts from phase 2, the maximum pumping rate will be increased to 837,000 gal/day, 12 hours/day, with weekly sampling. This is anticipated to occur in the January-March 2011 time frame.
- Based on no impacts noted in phase 3, the maximum pumping rate will be increased to 930,000 gal/day, 12 hours/day, This is anticipated to occur in April, 2011.
- Based on no impacts noted in phase 4, the well will be returned to full operation as needed in May 2011.

It is anticipated that the well will be added to the potable well sampling program.

3.8 Well-Head Protection

Based on a review of the Michigan State University Interactive Map Viewer (http://gwmap.rsgis.msu.edu/), there are five Wellhead Protection Areas along the Kalamazoo River between Marshall and Morrow Lake. The Wellhead protection areas are presented in **Appendix E**.

4.0 Methods

The following methodologies were used to implement the scope of work proposed in the October 3, 2010 "Supplement to the Sampling and Analysis Plan Referred to as Work Plan for Evaluating the Potential Impact of Released Oil on Groundwater used for Drinking Water". Due to the tight timeline, however, some deviations from the Work Plan were presented during an October 5, 2010 meeting with U.S. EPA. These deviations are discussed in Section 4.6.

4.1 Drilling and Well Installation

Sonic drilling technologies were used to install the monitoring wells during the investigation. This method was chosen because sonic drilling allows for continuous observation of soil cores, reduces volume of soil cuttings, and can penetrate bedrock if it is encountered. Soils were logged by a geologist, using the Unified Soil Classification System (USCS). Screened intervals were selected based on anticipated groundwater depths and a review of the sonic core for evidence of saturated zones and fractures in the bedrock. Boring logs are presented in **Appendix F**.

The monitoring wells were constructed of 2-inch diameter, schedule 40, poly vinyl chloride (PVC) casing, with five- or 10-foot long factory-slotted (10-slot) screens. Five-foot long screens were used in the deep monitoring wells and were placed a minimum of 15 feet below the bottom of the shallow screen. In some cases the deep well screens were placed below an underlying confining unit. As a result, water levels rose above the screened interval.

The wells were installed with an annular sand pack that extended a minimum of 1 foot above the top of the well screen. Bentonite grout was placed from the top of the sand pack to 1 foot below the ground surface. The wells were finished with locking caps and bolt-down, flush mount covers. Well construction forms are provided in **Appendix F**.

All monitoring wells were developed to remove fines from the screen interval. The wells were initially developed by removing the greater of three casing volumes or 55 gallons. After subsequent discussions with the U.S. EPA, a vac truck was used to remove an additional amount of water added during drilling which was equivalent to 50 gallons per 10 feet of submerged well.

All monitoring wells and staff gauges were surveyed to the US State Plane 1983 Michigan South

Zone 2113 coordinate system and the North American Datum 1983 international feet. The survey coordinates and elevations are summarized in **Table 1**. Horizontal locations were surveyed to the nearest foot and vertical elevations to the nearest hundredth of a foot.

4.2 Water Level Measurements

Water level measurements were collected from all monitoring wells and staff gauge locations on October 18, 2010, October 20, 2010, and October 22, 2010. The staff gauge locations were located on permanent structures (primarily bridges) that were located as close to each Target Area as possible. Temporary staff gauges located at the surface water sampling locations were considered; however the difficulty in accessing the locations and the temporary nature of the structures (potential for moving between measurements) lead to the use of the permanent structures. A decontaminated oil/water interface probe was used to measure liquid levels to the nearest 0.01 foot. A summary of the water levels is provided in **Table 1**.

4.3 Slug-Testing

Hydraulic conductivity testing was performed on 2 monitoring wells at each of the 8 target areas. A decontaminated PVC slug was used to rapidly change the water levels in the wells while recording the change in water level using an In-Situ Level Troll 700®. Slug testing was conducted using a rising head test on 1 shallow and 1 deep monitoring well at each Target Area. Falling head tests were also performed where the screen was submerged, generally in the deep monitoring well. The hydraulic conductivity testing was intended to provide further information on the potential for groundwater communication with the river and in development of a conceptual site model for future investigations. Data was analyzed using commercially-available curve matching software and applicable hydrogeological solutions (Bouwer and Rice, 1976; or Butler, 1998). A summary table and outputs of the slug tests are provided in **Appendix G**.

4.4 Water Sampling and Analysis

Two types of water samples were collected from each of the 8 Target Areas. Groundwater samples were collected from the monitoring wells and surface water samples were collected from the river. Due to the limited duration of this study, only one round of samples was collected for this study.

The river samples were collected from established surface water sampling locations. This strategy

assisted with the evaluation of whether surface water is venting to groundwater (James, 2002). Data collected as part of the analyses included a major element analyses that was used to construct stiff diagrams that show relationships between the chemistry of the river water and the groundwater. The surface water samples were collected using a peristaltic pump and disposable tubing. Field parameters, including dissolved oxygen, oxidation reduction potential, conductivity, pH, temperature and turbidity were recorded.

Groundwater samples were collected using Low-Flow Minimum Drawdown techniques as described by Puls & Barcelona (1996) as defined in the SAP. The fields parameters listed above were measured during sampling, as provided in the Low-Flow Minimum Drawdown technique. Groundwater samples were collected a minimum of three days after well development. Groundwater samples were analyzed for the parameters in **Table 2**.

All water samples were placed directly into sample bottles provided by the laboratory and sent via laboratory courier under chain-of-custody to the laboratory. The samples were analyzed for the parameters indentified in **Table 2**.

4.5 Data Validation

Laboratory reports were provided by the ALS Holland, Michigan facility with Level II QC data packages containing summaries of batch quality control results. Data validation was performed based on quality control criteria and guidance specified in the U.S. EPA SW846 reference methods, the U.S. EPA National Functional Guidelines for Superfund Organic Methods Data Review (June 2008), U.S. EPA National Functional Guidelines for Inorganic Data Review (October 2004), the Quality Assurance Project Plan, Enbridge Line 6B MP 608, Marshall, Michigan (revised August 15, 2010), the Supplement to the Sampling and Analysis Plan referred to as Work Plan for Evaluating the Potential Impact of Released Oil on Groundwater Used for Drinking Water (revised October 7, 2010), and the laboratory specific standard operating procedures (SOPs). In the absence of QAPP-specified criteria, method or laboratory quality assurance limits were used as appropriate. Level 2 data validation reports, including worksheets and summarized tables of qualified data, are provided in **Appendix D**. Level 4 data validation of 10 percent of the data is still onging.

4.6 Deviations from Work Plan

Discussions were held with the U.S. EPA on October 5, 2010 and October 7, 2010, regarding implementing deviations to the October 3, 2010 revision of the "Work Plan for Evaluating the Potential Impact of Released Oil on Groundwater Used for Drinking Water". It was agreed that deviations to the work plan would be necessary to address site-specific conditions.

The following methodologies were a deviation from the work plan.

- Shallow wells were screened to intersect the water table to detect Light Non-Aqueous Phase Liquids, if present. To account for variations in the water table, the screen length in the shallow monitoring well was increased to 10 feet instead of 5 feet in length.
- At cluster well locations, the top of the screen of the deep monitoring wells was set 15-20 feet below the bottom of the shallow well screen. At locations where the aquifer thickness did not allow 15-20 feet of separation between the well screens (a confined layer was encountered) the deep well screen was set below the confined layer.
- Each deep well boring was advanced below the deep well screen to provide additional hydrogeologic information until the first was encountered: 2 feet into a confined layer, component bedrock, or 100 feet in depth.
- A vacuum truck was used periodically for deep well development.

5.0 Results

The results section has been divided into the eight Target Areas. The results are featured separately because there is a large distance between areas, flow patterns along the river are different, and the geology and geomorphology varies from area to area.

5.1 Target Area 1

Target Area 1 is located on the south side of the Kalamazoo River between Mile Posts MP 2.25 and MP 3.25 (**Figure 3**). Most of the Target Area consists of residential properties with potable wells. Due to limited site access, the Target Area investigation was conducted just to the east of the residential area near Mile Post MP-2.50. No historic submerged oil is present in the vicinity of Target Area 1; however, SCAT-identified areas are located along both sides of the River as shown on **Figure 3**. The monitoring wells were installed linearly, and perpendicular to the river so that a hydraulic gradient could be developed as to whether the river is gaining or losing at Target Area 1.

As presented in the Target Area 1 geologic cross-section (**Figure 11**), the upper 120 feet (greatest depth explored) consists of unconsolidated sediments consisting primarily of sand with an increasing thickness towards the south. The cross-section trends north-south from the Kalamazoo River through MWKR0250L01 (deep well) through MWKR0250L02 (shallow well) and terminates at upgradient well MWKR0250L03. In general, the stratigraphy consists of a sand sequence from approximately 887 feet amsl to 810 feet amsl, with some interbedded clay lenses. In the deep soil boring, a lower till was intercepted at a depth of approximately 810 ft amsl. The till is described as silty clay to clayey silt, with some fine-to-medium sand and rounded gravel. The till was moist to wet. It is not known if the till is laterally continuous in the area.

In-situ hydraulic conductivity tests were conducted at one shallow (MWKR0250L02) and one deep well (MWKR0250L01). The results are summarized below and in **Appendix G**.

Monitoring Well ID	Type of Test	Hydraulic Conductivity (cm/sec)	Hydraulic Conductivity (ft/day)	Type of Soil Around Screen (USCS)	Depth Summary (Screen Interval, bgs)
MWKR0250L01	Falling	1.33E-02	33.89	SP	Deep/74.5-79.5 ft
MWKR0250L01	Falling	4.79E-03	12.17	SP	Deep/74.5-79.5 ft
MWKR0250L01	Rising	4.81E-03	12.21	SP	Deep/74.5-79.5 ft
MWKR0250L01	Rising	4.51E-03	11.46	SP	Deep/74.5-79.5 ft
MWKR0570L02	Rising	4.97E-03	12.62	SP/CL	Shallow/14-24 ft
MWKR0570L02	Rising	6.23E-03	15.81	SP/CL	Shallow/14-24 ft

The mean hydraulic conductivity value is 15.03 ft/day (5.92×10^{-3} cm/sec). These values are consistent with published values (Todd and Mays, 1980).

5.1.1 Hydraulic Gradient

Groundwater and surface water elevation data were collected from wells and nearest staff gauge on October 18, 20 and 22, 2010. The staff gauge is located approximately 2,500 feet upstream. The elevation data, presented in **Table 1** and summarized on **Figure 3**, demonstrate that groundwater is flowing towards the river. The furthest well from the river (MWKR0250L03) has a groundwater elevation approximately 11 feet higher than the well (MWKR0250L02) located immediately adjacent to the river. In addition, the vertical gradient is upward at the well cluster (MWKR0250L02 /L01 (for purposes of clarity the individual wells in each Target Area may be referred to using their last three reference numbers). This further suggests groundwater discharges to surface water at Target Area 1. While the closest staff gauge surface water elevation was slightly higher than the groundwater elevation in the closest well (L02), the staff gauge is approximately ½ mile upstream and, as a result, would be expected to have a higher surface elevation.

5.1.2 Presence of Crude Oil Constituents in Groundwater

Groundwater samples were collected from Target Area 1 on October 14, 2010 from all three monitoring wells. A summary of the samples collected is provided below:

Sample ID	MW ID	Depth Summary (Screen Interval, bgs)
WGC10141640BRH1	MWKR0250L01	Deep/74.5-79.5 ft
WGC10141505BRH1	MWKR0250L02	Shallow/14-24 ft
WGC10141810BRH1	MWKR0250L03	Deep/40-45 ft

The analytical results, methods, and comparison to Part 201 Residential Drinking Water Criteria are summarized in **Table 3** and the analytical laboratory reports are provided in **Appendix D**. The monitoring well locations are shown on **Figure 3**.

Analytical results from the groundwater samples indicate that no PNAs or VOCs were detected in any of the groundwater samples collected from Target Area 1. Dissolved and total iron, a naturally occurring analyte, was detected at concentrations ranging from 0.37 to 1.9 mg/L at each of the monitoring wells.

Given that no other crude oil constituent was detected, and the total iron concentration was the greatest at upgradient well MWKR0250L03 and iron is a naturally occurring analyte, it is likely that the total iron exceedences are not related to the oil release at Target Area 1. This is supported by the water well data collected from residential wells (0.02 to 6.71 mg/L) and MDNRE-supplied analytical data from potable wells in Marshall, Emmett, Battle Creek, Bedford, Ross, Charleston, and Comstock Townships (0.01 to 10.3 mg/L) (**Appendix C**).

5.1.3 Major Cations / Anions

The major ion data are used to construct Piper and Stiff diagrams, which provide a visual representation of groundwater. Concentrations are converted to milliequivalents per liter (meq/L), which take into account the molecular weight and electron charge of the ion species. For Piper

diagrams, the meq/L are converted to percentage of the total charge and plotted. Each point represents the ratio of the ions present in the water sample. Cations (calcium, magnesium, potassium, and sodium) and anions (bicarbonate alkalinity, chloride, and sodium) are plotted on the separate triangles. These points are projected to the diamond that presents the dominant ion configuration for the water sample. Water samples may plot in similar locations on a Piper diagram but have different concentrations.

Stiff diagrams are plots of the meq/L of major ions. The shape of the Stiff diagram varies depending on the dominant cation and anion and the size corresponds to the total dissolved solids (TDS) content of the water sample. Therefore, the size of the Stiff diagram increases as TDS increases. Small, diamond-shaped Stiff diagrams are typical of fresh water that has had minimal contact with soil or rock. Stiff diagrams are compiled by Target Area in **Appendix H**.

For groundwater samples, slight differences in the shapes of Stiff diagrams and sample locations on Piper diagrams may be an indication that water in wells has not fully equilibrated with formation water. Installation of monitoring wells typically has a short-term affect on groundwater chemistry. Therefore, evaluations presented in this summary are preliminary.

As indicated on the Piper and Stiff diagrams, groundwater characteristics exhibited calcium-bicarbonate type and were similar to surface water near this location. Groundwater at deeper well MWKR0250MWL01 is most similar to surface water. Groundwater at wells MWKR0250L02 and L03 are also calcium-bicarbonate type but with greater TDS (Stiff diagrams are larger). These two wells also have relatively large concentrations of sodium and chloride, particularly MWKRO0250L03, which is farther from the riverbank than the other, co-located wells.

A surface water sample (WSC10151555DJJ1) was collected from Target Area 1 on October 15, 2010 at SWKRO250L01. The surface water sample location is shown on **Figure 3** and the analytical data are summarized in **Table 4**

The surface water is almost uniformly calcium-bicarbonate type water. Dividing the Piper diagrams into four diamonds along the 50 percent lines, the points for these water samples are in the right-hand diamond with greater than 50 percent calcium (Ca) + magnesium (Mg) and greater than 50 percent

bicarbonate (HCO3). The similarity in surface water samples is demonstrated by the tight cluster of points on the Piper diagram.

The similarity in surface water samples is demonstrated by the tight cluster of points on the Piper diagram (**Appendix H** of Piper diagram with surface water only). Because all surface water samples were collected over a period of two days, this is not unexpected. This tight cluster of surface water chemistry demonstrates the stability of the surface water major ion chemistry as it flows through this section of the Kalamazoo River.

While surface water is fully oxygenated and slightly alkaline (pH 8.4), shallow groundwater appears to be depleted in oxygen (dissolved oxygen ranging from 0.3 to 1.5 mg/L) and slightly acidic to neutral (pH 6.2 to 7.1). Groundwater at well MWKRO0250L01 (deep monitoring well) is most similar to surface water.

5.1.4 Summary

Lines of evidence that demonstrate minimal risk to potable wells as a result of the crude oil release include:

- The horizontal and vertical gradient data indicate that groundwater is flowing toward the Kalamazoo River and therefore the Kalamazoo River is a gaining river at Target Area 1.
- PNAs and VOCs were not detected in the three groundwater samples, indicating that residual oil has not migrated to groundwater .
- It is likely that the total iron exceedances are not related to the oil release at Target Area 1 because iron is a naturally occurring analyte, the total iron concentration was the greatest at upgradient well L03, and iron was detected at similar concentrations in nearby potable water wells.
- The concentrations of detected analytes within surface water are within the range of concentrations detected in groundwater, with the exception of the sodium, iron, and chloride concentrations which have lower concentrations than the groundwater samples.
- The groundwater and surface water Piper and Stiff diagrams indicate that cation/anion chemistry of the groundwater and surface water are similar (uniformly calcium-bicarbonate-type water).

- Potential crude oil constituents migrating from the Kalamazoo River via groundwater would be detected in shallow monitoring well MWKR0250L02 prior to detection in a potable well.

5.2 Target Area 2

Target Area 2 is located between Mile Posts MP 5.50 and MP 6.00 in the Ceresco Dam area (**Figure 4**). At this location, both sides of the Ceresco Dam area were evaluated for localized groundwater flow and the potential impact of released oil on groundwater. Most of the investigation was conducted near MP 5.75 for accessibility. The Ceresco Dam area was chosen as a Target Area because it is an area of elevated surface water resulting from the dam's water retention and because of the presence of residential properties with potable wells. Fourteen potable wells were identified within the Target Area boundary. In addition, historic submerged oil has been identified. On the north side of the river (right side going downstream), two transects of monitoring wells were placed perpendicular to the river. A third transect was placed on the south side. This investigation strategy was developed to determine if the elevated water from the dam caused losing conditions.

Figures 12 and 13 present cross-sections of the Target Area. Cross-section trends southwest to northeast from the south side of Kalamazoo River at MWKR0580L03, MWKR0580L02 MWKR0580L01 across the Kalamazoo River to wells MWKR580R01, MWKR580R02 and MWKR580R03 on the north side of the Kalamazoo River. The second cross-section trends west to east on the north side of the Kalamazoo River from MWKR0580R03, MWKR0580R02 and MWKR0580R01 to MWKR0570R01and MWKR0570R02. The wells clustered at MWKR0580R01 were advanced into heavily weathered sandstone. There was evidence of water saturation noted during drilling and therefore, after discussions with the U.S. EPA and MDNRE representatives, wells were installed to intersect the saturated zone. However, water at these wells did not recover to a point that the wells could be sufficiently developed or sampled. As a result, these wells could not be used to evaluate groundwater flow at Target Area 2.

With the exception of MWKR0570R02, the monitoring wells were screened primarily within the sandstone. MWKR0570R02 was screened in sand and gravel above the sandstone. The cross-sections demonstrate that the stratigraphy generally consists of sand and gravel, with interbedded

layers of clay and silt, to the top of the weathered sandstone on the north side of the Kalamazoo River. The top of the weathered sandstone on the north side of the Kalamazoo River varies from approximately 857 to 878 ft amsl, with the highest elevations northwest of the Kalamazoo River at MWKR0570R01 and MWKR0570R02). The bedrock surface elevation slopes to the south and east to approximately 864 ft amsl, with the exception of an anomalous topographic high at MWKR0580L02 as shown on the SW-NE cross-section (**Figure 12**). Above the weathered sandstone south of the Kalamazoo River, interbedded gravel and silt are predominately present (MWKR0580L01, MWKR0580L02, MWKR0580L03) indicating a fluvial depositional environment. The lower bedrock elevation near surface water channels is typical for glacial fluvial environments in southern Michigan.

In-situ hydraulic conductivity tests were conducted at a well screened in sandstone and another in the unconsolidated aquifer the results are summarized below and in **Appendix G**.

Monitoring Well ID	**Type of Test**	**Hydraulic Conductivity (cm/sec)**	**Hydraulic Conductivity (ft/day)**	**Type of Soil Around Screen (USCS)**	**Depth Summary (Screen Interval, bgs)**
MWKR0570R01	Falling	1.21E-01	343.90	Sandstone	Shallow/19-34 ft
MWKR0570R01	Falling	7.82E-02	221.80	Sandstone	Shallow/19-34 ft
MWKR0570R01	Rising	1.05E-01	296.30	Sandstone	Shallow/19-34 ft
MWKR0570R01	Rising	1.17E-01	331.40	Sandstone	Shallow/19-34 ft
MWKR0570R02	Rising	3.48E-02	98.61	SP/GW	Shallow/4-14 ft
MWKR0570R02	Rising	3.48E-02	98.61	SP/GW	Shallow/4-14 ft

The mean hydraulic conductivity of the sandstone and unconsolidated aquifer is 294.18 ft/day (1.04 x 10^{-1} cm/sec) and 98.61 ft/day (6.12 x 10^{-2} cm/sec), respectively. These values are consistent with published values (Todd and Mays, 1980).

5.2.1 Hydraulic Gradient

Static water measurements were obtained from the monitoring wells and staff gauge on October 18, 20, and 22, 2010. The staff gauge is located on the backwater behind Ceresco Dam.

Groundwater and surface water elevation data presented in **Table 1** and **Figure 4** demonstrate that groundwater is flowing away from the Kalamazoo River. The furthest well from the north side of the river (MWKR0570R03) has a ground water elevation approximately 1 foot lower than the recorded level from the staff gauge above the dam. On the south side of the river, the furthest well (MWKR0580L03) has a groundwater elevation approximately 4 feet lower than the staff gauge. The vertical gradient is also downward in the well cluster located at MWKR0580L01 and MWKR0580L02. The observation of a losing water body at this location was anticipated due to the restricted water flow from the dam.

5.2.2 Presence of Crude Oil Constituents in Groundwater

Groundwater samples were collected from six of the nine monitoring wells in Target Area-2 on October 13 and 15, 2010. Groundwater samples could not be collected from wells MWKR0580R01 through MWKR0580R03 since sufficient water was not available in the well screen. A summary of the samples collected is provided below:

Sample ID	MW ID	Depth Summary (Screen Interval, bgs)
WGC10150950DJJ1	MWKR0570R01	Shallow/ 19-34 ft
WGC101501120DJJ1	MWKR0570R02	Shallow/4-14 ft
WGC10130900BAW1	MWKR0570R03	Shallow/9-19 ft
WGC10151310DJJ1	MWKR0580L01	Deep/41-46 ft
WGC10131435DJJ1	MWKR0580L02	Shallow/16-26 ft
WGC10131220BAW1	MWKR0580L03	Shallow/15-25 ft

The analytical results, methods, and comparison to Part 201 Residential Drinking Water Criteria are summarized in **Table 3** and the analytical laboratory reports are provided in **Appendix D**. The monitoring well locations are shown on **Figure 4**.

PNAs and VOCs were not detected in any of the groundwater samples collected from Target Area indicating that the released oil and submerged oil on the south bank has not affected groundwater in the vicinity of the Kalamazoo River. Dissolved and total iron, a naturally occurring analyte, was detected in four samples and ranged in concentration from 0.30 to 15 mg/L. These detections are at or exceed the Part 201 Residential Drinking Water Criterion 0.3 mg/L). As discussed above, iron is a naturally occurring analyte and it is probable that the iron exceedances are not related to the oil release as no other crude oil constituents were detected. The detected iron concentrations are above the maximum detected Enbridge potable water well data (0.02 to 6.71 mg/L). The detected iron concentrations are also above the MDNRE-supplied analytical data from potable wells in Marshall, Emmett, Battle Creek, Bedford, Ross, Charleston, and Comstock Townships (0.01 to 10.3 mg/L) (**Appendix C**).

Dissolved and total vanadium was also detected in three samples and ranged in concentration from 0.0062 – 0.47 mg/L. These detections exceed the Part 201 Residential Drinking Water Criteria (0.0045 mg/L).

Given that total iron and total vanadium concentrations were the greatest in the monitoring well located farthest from the River (MWKR0580L03), and no other crude oil related parameters were detected, it is likely that the iron and vanadium exceedances are not related to the oil release.

5.2.3 Major Cations / Anions

The surface water and groundwater cations and anions chemistry were compared to evaluate the hydraulic communication between the surface water and groundwater. A surface water sample (WSC10151448DJJ1) was collected from Target Area 2 on October 15, 2010 at SWKR0570R01. The surface water sample location is shown on **Figure 4** and summary of the analytical results are provided in **Table 4**. The surface water is calcium-bicarbonate-type water

Monitoring wells were completed in the sandstone bedrock except for MWKR0570R02, which is screened in glacial alluvium. With the exception of MWKR0570R03, groundwater has calcium-

bicarbonate chemistry and is similar in water chemistry and TDS to surface water, as demonstrated by the Stiff diagrams (**Appendix H**). Groundwater at well MWKR0570R03, which is farther from the riverbank, has a calcium-sodium-bicarbonate chemistry. The similarity in water chemistry for wells closer to the river may support the idea that the dam causes local losing conditions adjacent to the river.

5.2.4 Summary

Lines of evidence that demonstrate minimal risk to potable wells as a result of the crude oil release include:

- PNAs and VOCs were not detected in the six groundwater samples indicating the oil organic constituents have not impacted groundwater.
- Although the total and/or dissolved iron and vanadium concentrations exceed the Part 201 Residential Drinking Water Criteria, the maximum iron and vanadium concentrations occur in the well farthest from the River (MWKR0580L03).
- Potential crude oil constituents migrating from the Kalamazoo River via groundwater would be detected in shallow monitoring wells MWKR0570R01, MWKR0570R02, and MWKR0570R03 prior to detection in a potable well.

Groundwater elevations demonstrate that groundwater is locally flowing away from the Kalamazoo River (losing river) due to the elevated surface water behind the Ceresco Dam. Groundwater flow away from the River behind the dam is anticipated based on the hydraulic influence a dam has on local hydraulic conditions. Since there is no indication of migration of petroleum –related compounds into the groundwater, risk to potable wells is unlikely. However, in order to provide a level of assurance that residential wells will not be impacted, additional monitoring will be recommended for this Target Area.

5.3 Target Area 3

Target Area 3 is located between Mile Post MP 15.00 and MP 15.50 in a low-lying area along the east bank of the Kalamazoo River (**Figure 5**). The Target Area is predominately low lying, flat, flood plain which is bordered by the Kalamazoo River to the west and I-194 interstate Highway to the east. Riverside Drive is immediately adjacent to the river on the west side. Burnham Street bisects the

Target Area from east to west with a bridge crossing the river. Historic submerged oil was observed immediately south of Burnham Street and additional SCAT-identified areas are located south of Burnham Street. No potable wells are located in the Target Area.

Figure 14 shows a cross-section of Target Area 3. The cross-section is from the east side of the river. As shown, the stratigraphy consists of approximately 7 feet of fill underlain by approximately 59 feet of silty sand that grades into a courser fine to medium sand with gravel to approximately 66 ft bgs (765.6 ft amsl). At this horizon, the stratigraphy changed to gray sandy silt with gravel. The gradations observed suggest the upper sandy soils were deposited in a fluvial environment and the lower silty clay is a glacial till. At MWKR0580R03, the soils below the fill contain organic material (roots) and had a "swampy" odor.

In-situ hydraulic conductivity tests were conducted at one deep and one shallow well as the results are summarized below and in **Appendix G**.

Monitoring Well ID	**Type of Test**	**Hydraulic Conductivity (cm/sec)**	**Hydraulic Conductivity (ft/day)**	**Type of Soil Around Screen (USCS)**	**Depth Summary (Screen Interval, bgs)**
MWKR1525R01	Falling	7.82-02	221.80	SM	Deep/30-35 ft
MWKR1525R01	Falling	1.26-01	356.20	SM	Deep/30-35 ft
MWKR1525R01	Rising	7.32-02	207.50	SM	Deep/30-35 ft
MWKR1525R01	Rising	1.21-01	344.20	SM	Deep/30-35 ft
MWKR1525R02	Rising	1.17-02	33.27	SM	Shallow/4-14 ft
MWKR1525R02	Rising	1.60-02	45.32	SM	Shallow/4-14 ft

The mean hydraulic conductivity of the shallow and deep unconsolidated soils are 38.8 ft/day (1.37 x 10^{-2} cm/sec) and 274 ft/day (9.67x 10^{-2} cm/sec), respectively. These values are consistent with published values Todd and Mays, 1980).

5.3.1 Hydraulic Gradient

Static water measurements were obtained from the three monitoring wells and one staff gauge (SGTA-3) on October 18, 20, and 22, 2010. The results are presented on **Table 1**. Based on the groundwater elevations of the monitoring wells, groundwater is flowing towards the Kalamazoo River from MWKR1525R03 to MWKR1525R01as shown on **Figure 5**. The surface water elevations at the staff gauge location (SGTA-3 825.96 to 825.95 ft amsl) was approximately 2.7 feet higher than the monitoring wells (823.15 to 823.24 ft amsl). The monitoring wells are located in a low-lying area within the flood plain, so a hydraulic gradient toward the wells would not be unexpected. Over the three events, the horizontal hydraulic gradient between MWKR1525R03 and MWKR1525R02 varied from 0.0004 to 0.0023 ft/ft. These low horizontal gradients are expected since the wells were installed in a low-lying area adjacent to the River. The vertical gradient was assessed at MWKR1525R01 and MWKR1525R02. There was a downward gradient on October 18, and no gradient during the October 20, and 22 gauging events. This suggests static hydraulic conditions in Target Area 3.

5.3.2 Presence of Crude Oil Constituents in Groundwater

Groundwater samples were collected from three monitoring wells in Target Area 3 on October 16, 2010. A summary of the samples collected is provided below:

Sample ID	MW ID	Depth Summary (Screen Interval, bgs)
WGC101601000DJJ1	MWKR1525R01	Deep/30-35 ft
WGC101601000DJJ1	MWKR1525R02	Shallow/4-14 ft
WGC101601000DJJ1	MWKR1525R02 duplicate sample	Shallow/4-14 ft
WGC101601000DJJ1	MWKR1525R03	Shallow/4-14 ft

A surface water sample (WSC10151448DJJ1) was collected from Target Area 3 on October 15, 2010 at SWKR0570R01.

The analytical results, methods, and comparison to Part 201 Residential Drinking Water Criteria are summarized in **Table 3** and the analytical laboratory reports are provided in **Appendix D**. The monitoring well locations are shown on **Figure 5**.

Analytical results from the groundwater samples indicate that PNAs and VOCs were not detected in any of the groundwater samples collected from Target Area 3. Dissolved and total iron, a naturally occurring analyte, was detected at concentrations ranging from 0.42 to 26.0 mg/L at each of the monitoring wells.

Total and dissolved iron concentrations exceed the Part 201 Residential Drinking Water Criterion (0.3 mg/L) for each of the Target Area 3 monitoring wells. As discussed above, iron is a naturally occurring analyte and it is probable that the iron exceedances are not related to the oil release as no other crude oil constituents were detected. The maximum detected iron concentrations exceed the maximum Enbridge potable water well data (0.02 to 6.71 mg/L). The detected iron concentrations also exceed the MDNRE-supplied analytical data from potable wells in Marshall, Emmett, Battle Creek, Bedford, Ross, Charleston, and Comstock Townships (0.01 to 10.3 mg/L) (**Appendix C**).

5.3.3 Major Cations / Anions

A surface water sample (WSC10151712DJJ1) was collected from Target Area 3 on October 15, 2010 at SWKR1525R01. The surface water sample location is shown on **Figure 5** and summary of the analytical results are provided in **Table 4**.

The surface water and groundwater cations and anions chemistry were compared to evaluate the hydraulic communication between the surface water and groundwater. Groundwater has a calcium-bicarbonate chemistry and is similar in water chemistry to surface water. As demonstrated by Stiff diagrams (**Appendix H**), bicarbonate concentrations in groundwater at wells MWKR1525R01 and R02 are about twice the concentration in surface water. Bicarbonate concentration in groundwater at well MWKR1525R03 is intermediate between surface water and groundwater at wells MWKR1525R01 and MWKR1525R02; sodium and chloride are also more elevated in groundwater at well MWKR1525R03.

The differences in groundwater composition may indicate limited communication and local input. MWKR1525R03 is screened near ground surface (4 to 14 ft bgs) and a “swampy odor” was noted

during drilling. The Target Area may be affected by runoff from deicing agents which may contribute sodium and chloride. Elevated bicarbonate in groundwater at wells MWKR1525R01 and -R02 indicates groundwater at these locations is not continuous with surface water or with groundwater at nearby well MWKR1525R03.

5.3.4 Summary

Lines of evidence that demonstrate minimal risk to potable wells as a result of the crude oil release include:

- The direction of groundwater flow is away from the Kalamazoo River based on the staff gauge elevations and towards the River based on the groundwater elevations of the monitoring wells although the horizontal hydraulic gradient is low;
- The static vertical gradient at the shallow/deep well cluster suggest equilibrium conditions at Target Area 3;
- PNAs and VOCs were not detected in groundwater samples indicating the oil organic constituents have not impacted groundwater.
- Although the total and/or dissolved iron are above the Part 201 Residential Drinking Water Criterion for each of the groundwater samples, iron is a naturally occurring analyte and no other crude oil constituents were detected.
- The groundwater and surface water Piper and Stiff diagrams indicate that cation/ion chemistry of the groundwater and surface water are similar (calcium-bicarbonate-type water); however, there were differences (bicarbonate, calcium, sulfate, sodium, and chloride) in groundwater composition that may indicate limited communication and local input.
- Potential crude oil constituents migrating from the Kalamazoo River via groundwater would be detected in shallow monitoring wells MWKR1525R02 and MWKR1525R03 prior to detection in a potable well.

5.4 Target Area 4

Target Area 4 is located between Mile Posts MP 22.50 and MP 22.75 on the west side of the Kalamazoo River as shown on **Figure 6**. The main purpose of the investigation in this area was to evaluate groundwater flow and evaluate the impact of the identified submerged oil area as shown on

Figure 6. In addition, 10 residential wells were located north of the historic submerged oil in the Target Area.

Figure 15 shows cross-section view and stratigraphy at Target Area 4. The cross-section trends northwest to southeast on the north side of the Kalamazoo River from MWKR2275R01 to MWKR2260R01/ MWKR2260R02). This cross-section is north of an oxbow bend in the Kalamazoo River.

The stratigraphy consists of sand from ground surface to approximately 805 ft amsl, grading to a silty sand from 805 ft amsl to approximately 773 ft amsl. The Marshall Sandstone was encountered at approximately 773 ft amsl, or approximately 37 feet bgs. Shallow wells MWKR2260R02 and MWKR2275R01are screened in the upper unconsolidated sand and the deep well MWKR2260R01 is screened approximately 20 feet below the top of the Marshall Sandstone.

In-situ hydraulic conductivity tests were conducted at one well screened in sandstone and one well screened in the unconsolidated aquifer the results are summarized below and in **Appendix G**.

Monitoring Well ID	Type of Test	Hydraulic Conductivity (cm/sec)	Hydraulic Conductivity (ft/day)	Type of Soil Around Screen (USCS)	Depth Summary (Screen Interval, bgs)
MWKR2260R01	Rising	6.17E-03	17.49	Sandstone	Deep/50-55 ft
MWKR2260R02	Falling	4.16E-03	11.79	SP	Shallow/22-27
MWKR2260R02	Rising	5.32E-03	15.08	SP	Shallow/22-27

The mean hydraulic conductivity of the sandstone and unconsolidated aquifer is 13.3 ft/day (4.70 10^{-3} cm/sec). The bedrock hydraulic conductivity is lower than what was found in other areas and the region; however, fracturing of the bedrock (which varies considerably) significantly influences the hydraulic conductivity. The hydraulic conductivity of the unconsolidated formation is consistent with published values (Todd and Mays, 1980).

5.4.1 Hydraulic Gradient

Static water measurements were obtained from the three monitoring wells and one staff gauge (SGTA-4) on October 18, 20, and 22, 2010. The staff gauge is located approximately 2,500 feet east (upstream), at Custer Drive.

The water elevation results are presented on **Table 1**. Based on the groundwater elevations of the monitoring wells, groundwater is flowing towards the Kalamazoo River from MWKR2275R01 to MWR2260R02 as shown on **Figure 6**. The surface water elevations at SGTA-4 (795.99 to 795.92 ft amsl) were lower than the monitoring wells (799.24 to 796.84 ft amsl); suggesting groundwater flow to the river. Since the staff gauge is located up stream of the monitoring well locations, the river elevation at the monitoring well location is likely lower.

Over the three October measurement events, the horizontal hydraulic gradient between MWKR2275R01 and MWR2260R02 was uniformly 0.01 ft/ft. The vertical gradient was assessed at MWKR2260R01 and MWKR2260R02. The vertical gradient was upward from 1.97 to 1.98 on October, 18, 20, and 22. This further suggests that groundwater is discharging to surface water (gaining river) in Target Area 4.

5.4.2 Presence of Crude Oil Constituents in Groundwater

Groundwater samples were collected from three monitoring wells in Target Area 4 on October 16 and 17, 2010. A summary of the samples collected is provided below:

Sample ID	MW ID	Depth Summary (Screen Interval, bgs)
WGD10171520TAS1	MWKR2260R01	Deep/50-55 ft
WGD10171540RWS1	MWKR2260R02	Shallow/22-27 ft
WGD10161730BRH1	MWKR2275R01	Shallow/20-25 ft

The analytical results, methods, and comparison to Part 201 Residential Drinking Water Criteria are summarized in **Table 3** and the analytical laboratory reports are provided in **Appendix D**. The monitoring well locations are shown on **Figure 6**.

PNAs and VOCs were not detected in any of the groundwater samples collected from Target Area 4 indicating that the released oil and submerged oil has not affected groundwater in the vicinity of the Kalamazoo River. Total and/or dissolved iron, a naturally occurring analyte, were detected at concentrations (0.42 to 32 mg/L) exceeding the Part 201 Residential Drinking Water Criteria (0.3 mg/L) in two of the groundwater samples. Total vanadium was also detected at one well (MWKR2275R01) at a concentration of 0.11 mg/L which is above the Part 201 Residential Drinking Water Criteria of 0.0045 mg/L.

Iron and vanadium are naturally occurring analytes, and it is probable that the iron and vanadium exceedances are not related to the oil release at Target Area 4. The maximum iron concentration at MWKR2275R01 is of higher concentration (32 mg/L) than the Enbridge potable water well data (0.02 to 6.71mg/L) and the MDNRE-supplied analytical data from potable wells in Marshall, Emmett, Battle Creek, Bedford, Ross, Charleston, and Comstock Townships (0.01 to 10.3 mg/L). Since MWKR2275R01 is upgradient from the other two monitoring wells, the iron is probably naturally occurring. Vanadium was also only detected in this upgradient well. In addition, groundwater at MWKR2260R01 had the most elevated turbidity and concentrations of total iron and total vanadium. Iron and vanadium were not detected in filtered samples of groundwater. Vanadium is often associated with iron minerals (World Health Organization, 1988).

5.4.3 Major Cations / Anions

A surface water sample (WSC10151448DJJ1) was collected from Target Area 4 on October 15, 2010 at SWKR0570R01. The surface water sample location is shown on **Figure 6** and a summary of the analytical results are provided in **Table 4**.

The surface water and groundwater cations and anions chemistry were compared to evaluate the hydraulic communication between the surface water and groundwater. Groundwater and surface water is calcium-bicarbonate type. Stiff diagrams indicate that TDS is slightly less in groundwater at wells MWKR2260R01 and MWKR2260R02 than in surface water. Chloride, sulfate, and sodium are more elevated in groundwater at well MWKR2260R01.

Chloride, sulfate, and sodium are more elevated in groundwater at upgradient well MWKR2275R01. This likely indicates that wells further from the river are less influenced by river water chemistry. This may be caused by salting of upgradient roads.

5.4.4 Summary

Lines of evidence that demonstrate minimal risk to potable wells as a result of the crude oil release include:

- The horizontal and vertical gradient data indicates that groundwater is flowing toward Kalamazoo River and the Kalamazoo River is a gaining stream.
- The groundwater analytical data indicates that crude oil constituents (PNAs and VOCs) are not present in groundwater thus indicating that residual oil from the submerged oil and SCAT areas has not migrated to groundwater.
- Naturally occurring iron, which was also detected in the crude oil, was detected in all three groundwater samples above the Part 201 Residential Drinking Water Criteria ; however, it is probable that the iron exceedances are not related to the oil release since the highest concentrations were found in the upgradient well. Although the iron concentrations were above the residential well concentrations and the public health department data, the turbidity of the samples may have increased the iron concentrations due to increased particulates. Similarly, vanadium only detected in the upgradient well with elevated turbidity.
- The cation and anion data evaluation via Stiff and Piper diagrams indicate that the chemistry of the surface water and groundwater are of similar type (calcium-bicarbonate type) supporting that the groundwater is discharging to surface water and thus the Kalamazoo River is a gaining stream. The elevated chloride, sulfate, and sodium concentrations in the upgradient well MWKR2275R01 likely indicates that wells further from the river are less influenced by river water chemistry. This may be due to roadway salting of upgradient roads.
- Potential crude oil constituents migrating from the Kalamazoo River via groundwater would be detected in shallow monitoring well MWKR2260R02 prior to detection in a potable well.

5.5 Target Area 5

Target Area 5 is located between Mile Posts MP 26.75 and MP 27.25 at a tight meander on the west side of the Kalamazoo River as shown on **Figure 7**. The main purpose of the investigation in this area

was to evaluate groundwater flow in the vicinity of a tight bend in the Kalamazoo River and potential impact from the crude oil release. Historic submerged oil is present in the vicinity of Target Area 5 as shown on **Figure 7**. In addition, one potable well is located within 100 feet of the monitoring wells in the Target Area.

Figure 16 shows a cross-sectional view and stratigraphy at Target Area 5. The cross-section trends from the southwest to the northeast and traverses an oxbow bend in the Kalamazoo River. Both alluvium, glacial deposits and bedrock are represented in the figure. Three monitoring wells were installed in Target Area 5, MWKR2680R01 located to the northeast, and a two-well cluster (MWKR2700R01/R02) located in a southwesterly direction. In general, a few feet of fill was encountered at wells MWKR2680R01 and MWKR2700R02 in the middle of the oxbow. A thin (approximately 2 feet thick) silty clay horizon is present at MWKR2700R01 at an elevation of 786 ft amsl and at MWKR2680R01 at approximately the same elevation. The silty clay is green to gray in color and a "swamp" odor was noted at MWKR2700R01. The silty clay layer is underlain by a sand sequence to approximately 765 ft amsl. The sandy unit is underlain be a 5-foot thick clayey silt layer which overlies the Marshall Sandstone at an elevation of approximately 761ft amsl. The depositional environment for the upper stratigraphy is interpreted to be fluvial and glaciofluvial with flood plain silty clays sitting on top of point-bar sands and channel deposits near the surface. These fluvial deposits are underlain by glacial till (silty clay).

In-situ hydraulic conductivity tests were conducted at two monitoring wells; one from the shallow and deep unconsolidated aquifers as described below.

Monitoring Well ID	**Type of Test**	**Hydraulic Conductivity (cm/sec)**	**Hydraulic Conductivity (ft/day)**	**Type of Soil Around Screen (USCS)**	**Depth Summary (Screen Interval, bgs)**
MWKR2700R01	Falling	1.26E-01	358.20	Sandstone	Deep/32-37 ft
MWKR2700R01	Falling	8.03E-02	227.50	Sandstone	Deep/32-37 ft
MWKR2700R01	Rising	1.91E-01	541.70	Sandstone	Deep/32-37 ft
MWKR2700R01	Rising	1.12E-01	316.80	Sandstone	Deep/32-37 ft
MMWKR2700R01	Rising	8.18E-02	23.20	SM	Shallow/2-12 ft

Monitoring Well ID	Type of Test	Hydraulic Conductivity (cm/sec)	Hydraulic Conductivity (ft/day)	Type of Soil Around Screen (USCS)	Depth Summary (Screen Interval, bgs)
MWKR0570R02	Rising	6.22E-02	17.63	SM	Shallow/2-12 ft

The geomean hydraulic conductivity of the sandstone and unconsolidated aquifer is 344 ft/day (1.21 x 10^{-1} cm/sec) and 20.2 ft/day (7.13 x 10^{-3} cm/sec), respectively. These values are consistent with published values (Todd and Mays, 1980).

5.5.1 Hydraulic Gradient

Static water measurements were obtained from the three monitoring wells and one staff gauge (SGTA-5) on October 18, 20, and 22, 2010. The staff gauge is located approximately 1.5 miles southwest (down stream) of the monitoring wells.

The water elevation results are presented on **Table 1** and shown on **Figure 7**. Based on the October groundwater elevations of the monitoring wells (MWKR2680R01 and MWKR2700R02, screened from 2 to 12 feet in the unconsolidated soils, and MWKR2700R01 screened in the Marshall Sandstone), shallow groundwater is flowing from MWKR2680R01 to MWKR2700R02, which is roughly parallel to the river channel and consistent with the southwesterly river flow. This shows that at this tight meander bend the shallow groundwater flow did not conform to follow the flow of the river as it did in Target Area 4.

Over the three October measurement events, the horizontal hydraulic gradient between MWKR2680R01 to MWR2700R02 was negligible (0.0001 to 0.0004 ft/ft). The vertical gradient was assessed at MWKR2270R01 and R02. The vertical gradient was upward from 0.01 to 0.09 on October, 18, 20, and 22. This further suggests groundwater discharge to surface water (gaining river) at Target Area 5.

5.5.2 Presence of Crude Oil Constituents in Groundwater

Groundwater samples were collected from three monitoring wells in Target Area 5 on October 16, 2010. A summary of the samples collected is provided below:

Sample ID	MW ID	Depth Summary (Screen Interval)
WGD10161345DJJ1	MWKR2680R01	Shallow/2-12 ft
WGD10161405BRH1	MWKR2700R01	Deep/32-37 ft
WGD101615055BRH1	MWKR2700R02	Shallow/2-12 ft

The analytical results, methods, and comparison to Part 201 Residential Drinking Water Criteria are summarized in **Table 3** and the analytical laboratory reports are provided in **Appendix D**. The monitoring well locations are shown on **Figure 7**.

PNAs and VOCs were not detected in any of the groundwater samples collected from Target Area 5 indicating that the oil released has not affected groundwater in the vicinity of the Kalamazoo River. Dissolved and total iron, a naturally occurring analyte, was detected at concentrations ranging from 0.66 to 4.4 mg/L at each of the monitoring wells.

Total and dissolved iron concentrations are above the Part 201 Residential Drinking Water Criteria (0.3 mg/L) for each of the Target Area 5 monitoring wells. As discussed above, iron is a naturally occurring analyte and it is probable that the iron exceedances are not related to the oil release as no other crude oil constituents were detected. The detected concentrations are below the maximum detected Enbridge potable water well data (0.02 to 6.71 mg/L). The detected concentrations are also below the maximum MDNRE-supplied analytical data from potable wells in Marshall, Emmett, Battle Creek, Bedford, Ross, Charleston, and Comstock Townships (0.01 to 10.3 mg/L) (**Appendix C**).

5.5.3 Major Cations / Anions

A surface water sample (WSD10161450DJJ1) was collected from Target Area 5 on October 16, 2010 at SWKR2700R01. The surface water sample location is shown on **Figure 7** and summary of the analytical results are provided in **Table 4**.

The surface water and groundwater cations and anions chemistry were compared to evaluate the hydraulic communication between the surface water and groundwater. The water chemistry, as indicated on the Piper and Stiff diagrams (**Appendix H**), has a calcium-bicarbonate chemistry, similar to surface water at this and the other surface water locations. Stiff diagrams indicate that TDS is less

in groundwater at the two shallow wells MWKR2680R01 and MWKR2700R02 than in surface water or the bedrock well. The groundwater and surface water samples varied in concentrations for sodium, magnesium, sulfate, and chloride. Concentrations of these parameters were higher in surface water than in groundwater.

5.5.4 Summary

Lines of evidence that demonstrate minimal risk to potable wells as a result of the crude oil release include:

- The horizontal and vertical gradient data indicates that groundwater is flowing toward the Kalamazoo River and the Kalamazoo River is a gaining stream although, as expected, the horizontal gradient is minimal at the tight meandered bend.
- The groundwater analytical data indicate that crude oil constituents (PNAs and VOCs) are not present in groundwater thus indicating that residual oil has not migrated to groundwater.
- The cation and anion data evaluation via Stiff and Piper diagrams indicate that the chemistry of the surface water and groundwater are of similar chemistry (calcium-bicarbonate) supporting that the groundwater is discharging to the Kalamazoo River (gaining river).
- Naturally occurring iron was detected in groundwater samples above the Part 201 Residential Drinking Water Criterion; however, it is likely that the iron exceedances are not related to the oil release as no other crude oil constituents were detected. In addition, the detected iron concentrations are below the maximum Enbridge potable water well data and MDNRE-supplied potable well data.
- Potential crude oil constituents migrating from the Kalamazoo River via groundwater would be detected in shallow monitoring wells MWKR2680R01 and MWKR2700R02 prior to detection in a potable well.

5.6 Target Area 6

Target Area 6 is located between Mile Posts MP 34.00 and MP 34.75 at a tight meander on the east side of the Kalamazoo River as shown on **Figure 8**. The main purpose of the investigation in this area was to evaluate groundwater flow in the vicinity of a tight bend in the Kalamazoo River. No

submerged oil or SCAT areas are present in the vicinity of Target Area 6. Seven residential wells are located within the boundary of the Target Area.

Figure 17 shows a cross-sectional view and stratigraphy at Target Area 6. The cross-section trends from the southeast to the northwest, along Climax Dr and is located to the west of an oxbow bend in the Kalamazoo River. Alluvial and glacial deposits are represented in the figure. Six monitoring wells were installed in Target Area 6, with a two-well cluster to the northwest (MWKR3460L01 and L02) and a four well cluster to the southeast (MWKR3450L04, MWKR3450L03, MWKR3450L01, and MWKR3450L02). At the MWKR3450 monitoring wells, fill was generally encountered to a depth of 5 ft bgs and was underlain by a clay and silt layer, approximately 5 feet thick, to approximately 10 to 12 ft bgs (780 ft to 775 ft amsl). At MWKR3450L01 the clay and silt horizon is underlain by a thick sand sequence from approximately 775ft amsl to 700ft amsl. A gravelly silt glacial till was encountered from 700 ft to approximately 640ft amsl.

In-situ hydraulic conductivity tests were conducted at two monitoring wells; one from the shallow and one from the deep unconsolidated aquifers as described below.

Monitoring Well ID	**Type of Test**	**Hydraulic Conductivity (cm/sec)**	**Hydraulic Conductivity (ft/day)**	**Type of Soil Around Screen (USCS)**	**Depth Summary (Screen Interval, bgs)**
MWKR3450L03	Falling	4.54E-03	12.87	SM	Deep/72-77 ft
MWKR3450L03	Rising	4.35E-03	12.32	SM	Deep/72-77 ft
MWKR3450L04	Rising	9.27E-03	26.28	SP	Shallow/2-12 ft

The mean hydraulic conductivity of the unconsolidated aquifer is 16.1 ft/day (5.68×10^{-3} cm/sec). This value is consistent with published values (Todd and Mays, 1980).

5.6.1 Hydraulic Gradient

Static water measurements were obtained from the six monitoring wells and one staff gauge (SGTA-6) on October 18, 20, and 22, 2010. The staff gauge is located approximately 1,000 feet northwest (upstream) of the monitoring wells.

The results are presented on **Table 1** and shown on **Figure 8**. Based on the October groundwater elevations of the shallow monitoring well clusters (MWKR3460L02, MWKR3450L02 and MWKR3450L04; screened from 6 to 12 ft, 7 to 12 feet and 2 to 12 feet) the shallow groundwater is predominantly flowing from MWKR3460L02 to MWKR3450L02, toward the Kalamazoo River; although the hydraulic gradient was minimal. This shows that at this tight meander bend the shallow groundwater flow did not conform to follow the flow of the river as it did in Target Area 4. In addition, the groundwater elevations in Target Area 6 are approximately 0.3 feet higher than the stream gauge SGTA-6; this also indicates that groundwater is discharging to surface water at Target Area 6.

Over the three October measurement events, the horizontal gradient hydraulic gradient between the northern and shallow well clusters was negligible (0.00005 to 0.0002 ft/ft). The vertical gradient was assessed between MWKR3450L02 (7-12 ft bgs), MWKR3450L03 (72-77 ft bgs) and MWKR3450L01 (137-147 ft bgs). The lower well L01 was a flowing artesian well indicating a strong upward vertical gradient. The vertical gradient between L02 and L03 was upward from 0.14 to 0.15 on October, 18, 20, and 22. This also further suggests groundwater discharge to surface water (gaining river) at Target Area 6.

5.6.2 Presence of Crude Oil Constituents in Groundwater

Groundwater samples were collected from six monitoring wells in Target Area 6 on October 15 and 17, 2010. A summary of the samples collected is provided below:

Sample ID	MW ID	Depth Summary (Screen Interval, bgs)
WGE10171245RWS1	MWKR3450L01	Deep/137-142 ft
WGE10151405BAW1	MWKR3450L02	Shallow/7-12 ft

Sample ID	MW ID	Depth Summary (Screen Interval, bgs)
WGE10171100RWS1	MWKR3450L03	Deep/72-77 ft
WGE10171240TAS1	MWKR3450L04	Shallow/2-12 ft
WGE10151530BAW1	MWKR3460L01	Shallow/7-12 ft
WGE10171041TAS1	MWKR3450L02	Shallow/2-12 ft
WGE10171041TAS2	MWKR3450L02	Shallow/2-12 ft

The analytical results, methods, and comparison to Part 201 Residential Drinking Water Criteria are summarized in **Table 3** and the analytical laboratory reports are provided in **Appendix D**. The monitoring well locations are shown on **Figure 8**.

PNAs and VOCs were not detected in any of the groundwater samples collected from Target Area 6 indicating that the oil released has not affected groundwater in the vicinity of the Kalamazoo River. Dissolved and total iron, a naturally occurring analyte, was detected at concentrations ranging from 0.37 to 5.0 mg/L at each of the monitoring wells.

Total and dissolved iron concentrations are above the Part 201 Residential Drinking Water Criterion (0.3 mg/L) for each of the Target 6 monitoring wells. As discussed above, iron is a naturally occurring analyte and it is probable that the iron exceedances are not related to the oil release as no other crude oil constituents were detected. The detected iron concentrations are below the maximum detected Enbridge potable water well data (0.02 to 6.71 mg/L). The detected iron concentrations are also below the maximum MDNRE-supplied analytical data from potable wells in Marshall, Emmett, Battle Creek, Bedford, Ross, Charleston, and Comstock Townships (0.01 to 10.3 mg/L) (**Appendix C**).

5.6.3 Major Cations / Anions

A surface water sample (WSE10171136BRH1) was collected from Target Area 6 on October 17, 2010 at SWKR3460L0. The surface water sample location is shown on **Figure 8** and summary of the analytical results are provided in **Table 4**.

The surface water and groundwater cations and anions chemistry were compared to evaluate the hydraulic communication between the surface water and groundwater. The water chemistry, as indicated on the Piper and Stiff diagrams (**Appendix H**), is calcium-bicarbonate, similar to surface water at this and the other surface water locations. The groundwater samples varied in TDS concentrations with the two deepest wells having relatively more magnesium, less sulfate, and lower TDS than other wells, as indicated by the Piper and Stiff diagrams. For the four shallow wells, cation and anion concentrations are most similar for wells located in close proximity. Surface water bicarbonate concentrations are lower and chloride and sulfate concentrations are higher than at groundwater wells.

5.6.4 Summary

Lines of evidence that demonstrate minimal risk to potable wells as a result of the crude oil release include:

- The horizontal and vertical gradient data indicate that groundwater is flowing toward Kalamazoo River, indicating the Kalamazoo River is a gaining river.
- The groundwater analytical data indicates that crude oil constituents (PNAs and VOCs) are not present in groundwater, demonstrating that residual oil has not migrated to groundwater.
- The cation and anion data evaluation via Stiff and Piper diagrams indicate that the chemistry of the surface water and groundwater are of similar chemistry (calcium-bicarbonate) supporting that the groundwater is discharging to the Kalamazoo River.
- Potential crude oil constituents migrating from the Kalamazoo River via groundwater would be detected in shallow monitoring wells MWKR3460L01 and MWKR3450L02 and L04 prior to detection in a potable well.

Naturally occurring iron was detected in groundwater samples above the Part 201 Drinking Water Criterion; however, it is likely that the iron exceedances are not related to the oil release as no other crude oil constituents were detected. In addition, the detected iron concentrations are below the maximum Enbridge potable water well data and MDNRE-supplied potable well data.

5.7 Target Area 7

Target Area 7 is located between Mile Posts MP 36.00 and MP 36.25, within a bend on the south side of the Kalamazoo River as shown on **Figure 9**. The main purpose of the investigation in this area was to evaluate groundwater flow in the vicinity of a bend in the Kalamazoo River and evaluate the potential impact of the historic submerged oil. Five residential wells are located within the boundary of the Target Area.

Figure 18 shows a cross-sectional view and stratigraphy at Target Area 7. The cross-section trends from the north to the south and is located to the south of the bend in the Kalamazoo River, and east of Morrow Lake. Three monitoring wells were installed in Target Area 7, with a two-well cluster (MWKR3620L01, deep, and MWKR3620L02, shallow) and another shallow well to the south (MWKR3620L03). Fill and glacial deposits are represented in the cross section. Fill was encountered at all three wells and extends from ground surface to approximately 780 ft amsl. The fill is approximately 3 to 7 feet in thickness. The fill is underlain by a thick 50-foot sand sequence, that grades coarser with depth, to approximately 730 ft amsl. Gravelly silt, a glacial till, was encountered at 730 ft amsl.

In-situ hydraulic conductivity tests were conducted at two monitoring wells; one from the shallow and deep zone of the unconsolidated aquifer above the glacial till as described below.

Monitoring Well ID	Type of Test	Hydraulic Conductivity (cm/sec)	Hydraulic Conductivity (ft/day)	Type of Soil Around Screen (USCS)	Depth Summary (Screen Interval, bgs)
MWKR3620L01	Falling	2.49E-02	70.50	SP	Deep/34.8-39.8 ft
MWKR3620L01	Rising	4.75E-02	134.80	SP	Deep/34.8-39.8 ft
MWKR3620L02	Rising	4.80E-03	13.62	SM	Shallow/10.5-15.5 ft
MWKR3620L02	Rising	4.27E-03	12.11	SM	Shallow/10.5-15.5 ft

The mean hydraulic conductivity of the shallow and deep aquifer values are 12.8 ft/day (4.53×10^{-3} cm/sec) and 97.5 ft/day (3.44×10^{-2}), respectively. These values are consistent with published values (Todd and Mays, 1980).

5.7.1 Hydraulic Gradient

Static water measurements were obtained from the three monitoring wells and one staff gauge (SGTA-7TA8) on October 18, 20, and 22, 2010. The staff gauge is located approximately 1,000 feet northwest (down stream), at the 35th Street Bridge.

The water elevation data are presented on **Table 1** and shown on **Figure 9**. Based on the October groundwater elevations of the shallow monitoring wells (MWKR3620L02 and MWKR3620L03) the shallow groundwater is flowing from MWKR3620L03 to MWKR3620L02, towards the Kalamazoo River. In addition the groundwater elevations in Target Area 7 are approximately 0.4 feet higher than the stream gauge SGTA-7TA8; this also indicates that groundwater is discharging to surface water (gaining river) at Target Area 7.

Over the three October measurement events, the horizontal gradient hydraulic gradient between the northern and shallow wells was consistently 0.0025 ft/ft. The vertical gradient was assessed between MWKR3620L02 (10.5- 15.5 ft bgs) and - MWKR3620L01 (34.8-39.8 ft bgs). The vertical gradient ranged from neutral on October 18 to upward 0.01 and 0.02 on October 20 and 22. The upward gradient, although slight, further suggests groundwater discharge to surface water at Target Area 7.

5.7.2 Presence of Crude Oil Constituents in Groundwater

Groundwater samples were collected from three monitoring wells in Target Area 7 on October 14 and 15, 2010. A summary of the samples collected is provided below:

Sample ID	MW ID	Depth Summary (Screen Interval, bgs)
WGE10141445BAW1	MWKR3620L01	Deep/34.8-39.8 ft
WGE10151050BAW1	MWKR3620L02	Shallow/10.5-15.5 ft
WGE10151050BAW2	MWKR3620L02	Shallow/10.5-15.5 ft
WGE1015935BAW1	MWKR3620L03	Shallow/4.9-14.9 ft

The analytical results, methods, and comparison to Part 201 Residential Drinking Water Criteria are summarized in **Table 3** and the analytical laboratory reports are provided in **Appendix D**. The monitoring well locations are shown on **Figure 9**.

PNAs and VOCs were not detected in any of the groundwater samples collected from Target Area 7 indicating that the released oil and submerged oil on the south bank has not affected groundwater in the vicinity of the Kalamazoo River. Dissolved and total iron, a naturally occurring analyte, was detected only at one well (0.36 and 2.1 mg/L). These detections are above the Part 201 Residential Drinking Water Criterion (0.3 mg/L). As discussed above, iron is a naturally occurring analyte and it is probable that the iron exceedances are not related to the oil release as no other crude oil constituents were detected. The detected iron concentrations are below the maximum detected Enbridge potable water well data (0.02 to 6.71 mg/L). The detected iron concentrations are also below the maximum MDNRE-supplied analytical data from potable wells in Marshall, Emmett, Battle Creek, Bedford, Ross, Charleston, and Comstock Townships (0.01 to 10.3 mg/L) (**Appendix C**).

5.7.3 Cations / Anions

A surface water sample (WSE10151200BAW1) was collected from Target Area 7 on October 15, 2010 at SWKR3690L01. The surface water sample location is shown on **Figure 9** and summary of the analytical results are provided in **Table 4**.

The surface water and groundwater cations and anions chemistry were compared to evaluate the hydraulic communication between the surface water and groundwater. The water chemistry, as indicated on the Piper and Stiff diagrams, is calcium-bicarbonate for groundwater at the wells located close to the riverbank, and sodium-bicarbonate for groundwater at well MWKR3620L03 located about 150 ft from the River. This was the only well with sodium-bicarbonate chemistry and may represent the influence of road salt on roads upgradient from Target Area 7. Alternately, the apparent water chemistry may be an analytical anomaly, as the cation charge is about 15 percent greater than the anion charge at this location.

TDS is variable among the sample locations and is lower in groundwater at shallow well MWKR3620L02, located near the riverbank, than in the nearby surface water sample. Groundwater at the deeper well (MWKR3620L01) is most similar in major ion composition to surface water.

5.7.4 Summary

Lines of evidence that demonstrate minimal risk to potable wells as a result of the crude oil release include:

- The horizontal and vertical gradients indicate that groundwater is flowing towards the Kalamazoo River, indicating the Kalamazoo River is a gaining river.
- The upward vertical gradient is further evidence of a gaining river.
- The groundwater analytical data indicate that crude oil constituents (PNAs and VOCs) are not present in groundwater, demonstrating that residual oil has not migrated to groundwater.
- The cation and anion data evaluation via Stiff and Piper diagrams indicate that the chemistry of the surface water and groundwater are generally of similar chemistry.
- Potential crude oil constituents migrating from the Kalamazoo River via groundwater would be detected in shallow monitoring well MWKR3620L02/ MWKR3620L03 prior to detection in a potable well.

Naturally occurring iron was detected in one groundwater sample above the Part 201 Drinking Water Criterion; however, it is likely that the iron exceedances are not related to the oil release as no other crude oil constituents were detected. In addition, the detected iron concentrations are below the maximum Enbridge potable water well data and MDNRE-supplied potable well data.

5.8 Target Area 8

Target Area 8 is located between Mile Posts MP 36.75 and MP 37.25, within the Morrow Lake Delta as shown on **Figure 10**. The main purpose of the investigation is this area was to evaluate groundwater flow and evaluate the impact of the historic submerged oil area as shown on **Figure 10**. In addition, four potable wells are located within the Target Area boundary.

Figure 19 shows a cross-sectional view and stratigraphy at Target Area 8. This cross-section generally trends south to north on the south side of the Kalamazoo River, at the mouth of Morrow Lake. Alluvial and glacial deposits are represented in the figure. The cross-section includes wells MWKR3680L03, MWKR3680L02, and MWKR3680L01. All wells are screened in the unconsolidated aquifer; however, L01 was screened from at depth (30-35 ft bgs) and L02 and L03 were screened from 3 to 13 ft bgs.

A thick 65-foot sequence of sand was encountered from ground surface to approximately 715 ft amsl and coarsens with depth. The sand is underlain by a 10-foot thick sand and gravel layer to approximately 683 ft amsl and then grades to silty sand to 689 ft amsl. The silty sand is underlain by a silty glacial till. The soils were deposited in a fluvial or glacial fluvial environment.

In-situ hydraulic conductivity tests were conducted at two monitoring wells; one from the shallow and deep zone of the unconsolidated aquifer above the glacial till as described below.

Monitoring Well ID	**Type of Test**	**Hydraulic Conductivity (cm/sec)**	**Hydraulic Conductivity (ft/day)**	**Type of Soil Around Screen (USCS)**	**Depth Summary (Screen Interval, bgs)**
MWKR3680L01	Falling	2.49E-02	143.40	SP	Deep/30-35 ft
MWKR3680L01	Rising	8.81E-02	249.70	SP	Deep/30-35 ft
MWKR3620L02	Rising	8.69E-03	24.65	SM	Shallow/3-13 ft
MWKR3620L02	Rising	1.03E-03	29.20	SM	Shallow/3-13 ft

The mean hydraulic conductivity of the shallow and deep aquifer values are 189 ft/day (6.67x 10-2 cm/sec) and 26.8 ft/day (9.46x10-3), respectively. These values are consistent with published values (Todd and Mays,1980).

5.8.1 Hydraulic Gradient

Static water measurements were obtained from the three monitoring wells and one staff gauge (SGTA-7TA8) on October 18, 20, and 22, 2010. The staff gauge is located approximately 1,000 feet east (upstream), at the 35th Street Bridge.

The results are presented on **Table 1** and shown on **Figure 10.** Based on the October groundwater elevations of the shallow monitoring wells (MWKR3680L02 and - MWKR3680L03) the shallow groundwater is flowing from MWKR3620L03 to MWKR3620L02, toward the Kalamazoo River. In addition the groundwater elevations in Target Area 8 are approximately 0.6 feet higher than the stream gauge SGTA-7TA8; this also indicates that groundwater is discharging to surface water at Target Area 8.

Over the three October measurement events, the horizontal gradient hydraulic gradient between the northern and shallow wells varied from 0.0007 to 0.0012 ft/ft. The vertical gradient was assessed between MWKR3680L02 (3 to 13ft bgs) and MWKR3680L01 (30-35 ft bgs). The vertical gradient ranged from downward 0.01 on October 18 and 22 and upward 0.05 on October 20, 2010. These data indicate a potential for variable surface water and groundwater interaction at Target Area 8.

5.8.2 Presence of Crude Oil Constituents in Groundwater

Groundwater samples were collected from three monitoring wells in Target Area 8 on October 14 2010. A summary of the samples collected is provided below:

Sample ID	MW ID	Depth Summary (Screen Interval, bgs)
WGE10141020BRH1	MWKR3680L01	Deep/30-35 ft
WGE10141200BRH1	MWKR3680L02	Shallow/3-13 ft
WGE10141200BRH1	MWKR3680L02	Shallow/3-13 ft

Sample ID	MW ID	Depth Summary (Screen Interval, bgs)
WGE10141015BAW1	MWKR3680L03	Shallow/3-13 ft

The analytical results, methods, and comparison to Part 201 Residential Drinking Water Criteria are summarized in **Table 2** and the analytical laboratory reports are provided in **Appendix D**. The monitoring well locations are shown on **Figure 10**.

PNAs and VOCs were not detected in any of the groundwater samples collected from Target Area 8 indicating that the released oil and submerged oil has not affected groundwater in the vicinity of the Kalamazoo River. Total iron, a naturally occurring analyte, was detected only at one well (0.30 mg/L). This detection is not above the Part 201 Residential Drinking Water Criterion (0.3 mg/L).

5.8.3 Cations / Anions

A surface water sample (WSE10141155BAW1) was collected from Target Area 8 on October 14, 2010 at SWKR3690L01. The surface water sample location is shown on **Figure 10** and summary of the analytical results are provided in **Table 4**.

The surface water and groundwater cations and anions chemistry were compared to evaluate the hydraulic communication between the surface water and groundwater. The water chemistry, as indicated on the Piper and Stiff diagrams (**Appendix H**), is calcium-bicarbonate but variable in TDS. TDS is lower in groundwater sampled at the three wells compared to the nearby surface water sample. TDS in groundwater at the shallow well near the riverbank (MWKR3680L02) is the lowest of the wells sampled for this evaluation.

5.8.4 Summary

Lines of evidence that demonstrate minimal risk to potable wells as a result of the crude oil release include:

- The horizontal gradient indicate that groundwater is flowing toward s the Kalamazoo River, indicating the Kalamazoo River is a gaining river; however, the vertical gradient was inconclusive with both downward and upward gradients.

- The groundwater analytical data indicate that crude oil constituents (PNAs and VOCs) are not present in groundwater, demonstrating that residual oil has not migrated to groundwater.
- The cation and anion data evaluation via Stiff and Piper diagrams show that the chemistry of the surface water and groundwater are of similar chemistry (calcium-bicarbonate).
- Potential crude oil constituents migrating from the Kalamazoo River via groundwater would be detected in shallow monitoring well MWKR3680L02 and MWKR3680L03 prior to detection in a potable well.

6.0 Discussion

The purpose of this study was to evaluate the potential impacts of the released crude oil on groundwater that is a potential source of potable water. Groundwater immediately adjacent to portions of the Kalamazoo River has the potential to be impacted from the released crude oil. Risk to potable wells was assessed based on multiple lines of evidence developed from publically available information, analytical results from direct samples of potable wells adjacent to the river, and the results of investigations conducted at the eight Target Areas along the Kalamazoo River.

Multiple lines of evidence indicate that the Kalamazoo River is predominantly a gaining river and crude oil impacts to potable water were not evident in the results of the investigation. The potential risk of impact to potable water along the Kalamazoo River is minimal as summarized below:

- Groundwater gradients from 6 of the 8 Target Areas indicate that groundwater is discharging to the Kalamazoo River (gaining river). The groundwater gradient at Target Area 3 is both away and towards the Kalamazoo River in an area where no potable wells were identified. The gradient at Target Area 2 (Ceresco Dam area) is away from the River (losing river) over the area near the impounded water upstream of the Ceresco Dam.

- At the majority of the Part 201 Sites of Contamination located within 2,000 feet of the Kalamazoo River that have groundwater flow direction data, the documented direction of groundwater movement is towards the Kalamazoo River, indicating that the Kalamazoo

River is predominantly a gaining river. Sites where flow is away from the river generally involve a perched aquifer or another surface water body that is closer.

- The analytical results of the sampled potable wells within 200 feet of the Kalamazoo River's high water level indicate that crude oil constituents have not impacted the potable wells. Although iron has been detected in most wells, it is a naturally occurring element and is not attributed to the impacts from the release.

- The analytical results of the sampled monitoring wells at the eight Target Areas indicate that crude oil constituents have not impacted groundwater. The nearest monitoring wells range from approximately 20 feet to 700 feet from the Kalamazoo River with most wells less than 50 feet away. Organic crude oil constituents were not detected in any of the monitoring wells. Although iron and vanadium were detected in some samples; their occurrence is likely attributable to background groundwater quality in the area since elevated iron concentrations were detected in the residential wells as well as in groundwater samples collected in the area by the public health departments. In addition, at several target areas the highest concentrations of iron and vanadium were found in the upgradient wells.

- At Ceresco Dam, Target Area 2, the groundwater flow direction is away from the Kalamazoo River (losing river) and the vertical gradient is downward adjacent to the impoundment upstream from the dam. The abrupt change in water level across the face of the dam creates a hydraulic gradient that can locally cause this flow direction and the downward vertical gradient in this area.

- At Target Area 5, located at a tight meandered bend of the River, the shallow groundwater flow is to the southwest, parallel to the Kalamazoo River channel; however the upward vertical gradient demonstrates the groundwater is still rising from lower formations.

- Surface water and groundwater samples collected during this investigation have almost uniformly calcium-bicarbonate chemistry. The similarity of the major element chemistry of the groundwater and surface water samples is consistent with the conceptual model where the sample event for this study was during base flow conditions for the river when

ground water flow in the river is dominated by groundwater flow into the river. The only area where sharp differences in major element chemistry was observed is for the upgradient groundwater sample collected from Target Area 7 – the major element chemistry for this sample (sodium-bicarbonate) may be due to roadway salting of upgradient roads and is not attributable to any recharge of the groundwater from surface water.

The conceptual site model presented in the work plan has not significantly changed based on the results of the study (**Figure 20**). Geology along the Kalamazoo River consists of a layer of glacial drift (unconsolidated material) with permeable sands and gravels that may also contain some clay units. This glacial drift unit is underlain by bedrock that includes the Marshall Sandstone of the Marshall Formation (Michigan Department of Environmental Quality, Geological Survey Division, 1987). Groundwater is present in the glacial drift and the underlying bedrock. Many residential wells are screened in the bedrock, while others are screened in the permeable sands and gravels above the bedrock.

The Kalamazoo River's role in the water cycle is that of a conduit through which surface water and groundwater drain to Lake Michigan. Groundwater and surface drainage near the Kalamazoo River dominantly flow towards the River. As expected, altered groundwater flow occurs where there are abrupt drops in water levels in the river across dams such as at Ceresco Dam at Target Area 2 where the groundwater locally flows away from the river. At Target Area 3, the low-lying ground surface results in a mixed flow direction, with flow away from the river adjacent to the Kalamazoo River, but flow towards the river at a distance from the river. Also, shallow groundwater flow was documented to migrate with the flow of the river at tight meanders (Target Area 5).

7.0 Recommendations

Results from the Hydrogeological Investigation indicated that the Kalamazoo River is primarily a gaining river where groundwater is flowing into the river. As a result, the potential for crude oil constituents to be transported into the groundwater system is unlikely. A possible exception is at Target Area 2 where the Ceresco Dam water level is higher than the surrounding groundwater causing the groundwater to locally flow (at least seasonally) away from the Kalamazoo River (losing river). In this area, the monitoring wells did not detect hydrocarbons in the groundwater adjacent to the river or in the shallow groundwater farther from the river or the deeper groundwater.

Based on these results, the following recommendations are made:

- Conduct quarterly water level gauging from all monitoring wells to evaluate seasonal groundwater flow patterns;
- Conduct quarterly sampling of select monitoring wells, located closest to the river, that will serve as sentinel monitoring points between the river and potable wells.
- Conduct monthly liquid level gauging for three months and then quarterly, of all monitoring wells at the Ceresco Dam area (Target Area 2) since this area demonstrated the greatest potential for river water migration to groundwater. In addition, collect groundwater sampling monthly at select monitoring wells, located closest to the river;
- Bias the spring and summer quarterly water levels and sampling events for shortly after a high water event in the river to evaluate recharge to the river; and
- Prepare quarterly reports presenting findings and recommendations from each monitoring event.

8.0 References

ATSDR, 1997, Public Health Assessment – Albion-Sheridan Township Landfill.

B.A. Apple and H.W. Reeves. 2007. *Summary of Hydrogeological Conditions by County for the State of Michigan*. Open-File Report 2007-1236. U.S. Department of Interior, U.S. Geological Survey, In cooperation with the State of Michigan, Department of Environmental Quality.

BBL. 1994. Blasland, Bouck and Lee, Inc. *Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site, Remedial Investigation/Feasibility Study, Draft Technical Memorandum 14, Biota Investigation*. July 1994.

D. J. Bedell and R.I. Van Til, 1979 *Irrigation in Michigan 1977*, Water Department Division, Michigan Department of Natural Resources, Lansing, MI. 214 pp.

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

H. Bouwer and R. Rice, 1976, *A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells*: Water Resources Research, Vol. 12, No. 3, p. 423-428.

J.J. Butler, Jr., 1998. *The Design, Performance, and Analysis of Slug Tests*, Lewis Publishers, Boca Raton, 252p.

P.J. Comer, D.A. Albert, and M.B. Austin. 1998. *Digital map of vegetation on Michigan circa 1800 –An interpretation of the General Land Office Surveys: Data from Michigan Natural Features Inventory Report 1995-07*.

M. Deutsch, K.E. Vanlier, and P.R. Giroux. 1960. *Ground-water Hydrology and Glacial Geology of the Kalamazoo Area, Michigan*. State of Michigan Geological Survey Division, Progress Report Number 23, prepared cooperatively with the U.S. Department of Interior Geological Survey.

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

J. Drever, 2002, *The Geochemistry of Natural Waters*. New Jersey: Prentice Hall. pp. 311–322.

R. Eisler, 1987. *Polycyclic Aromatic Hydrocarbon Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. U.S. Fish and Wildlife Service Biological Report 85(1.11). 81p.

Fleis & VandenBrink Engineering, Inc., 2002, *Village of Augusta Wellhead Protection Program Plan*, 48p.

Freedom of Information Act Search, 2010a. MDNRE Kalamazoo District. Final Assessment Report, MDOT – Marshall Maintenance Garage Part 213 Site, 1242 S. Kalamazoo Avenue.

N.G. Grannemann and F.R. Twenter. 1985. *Geohydrology and ground-water flow at Verona well field, Battle Creek, Michigan*: U.S. Geological Survey Water-Resources Investigations Report 85-4056.

GZA-Donahue, June 1990. *Evaluating sediment burial rates and PCB partition coefficients*.

HydroQual, Inc. April 1993, *Attachment 2: Assessment of PCBs discharge to the Kalamazoo River from sources upstream of Morrow Lake Dam*.

B.D. Knapp. 1987. *Soil Survey of Allegan County, Michigan*. U.S. Department of Agriculture, Soil Conservation Service.

J.M. Neff, 1979. *Polycyclic Aromatic Hydrocarbons in the Aquatic Environment: Sources, Fates and Biological Effects*. Applied Science Publishers Ltd., Essex, England. 262 p.

National Research Council of Canada (NRCC). 1983. *Polycyclic Aromatic Hydrocarbons in the Aquatic Environment: Formation, Sources, Fate and Effects on Aquatic Biota*. NRCC Report No. 18981. 209 p.

S. Nicholson, 1999, U.S. Geological Survey's Mineral Resources Program Activities in the Upper Midwest: U.S. Geological Survey

R. Passero (Principal Editor). 1978. *Kalamazoo County Geology and the Environment.* Department of Geology, Geography and Biology, Western Michigan University.

R.W. Puls and M.J. Barcelona, 1996, *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedure*, EPA/540/S-95/504, 12 pp.

Rheaume and others, 2002, *Sediment characteristics and configuration within three dam impoundments on the Kalamazoo River, Michigan*: U.S. Geological Survey Water-Resources Investigation Report 02-4098.

C.M. Rachol, F.A. Fitzpatrick, and T. Rossi. 2005. *Historical and Simulated Changes in Channel Characteristics of the Kalamazoo River, Plainwell to Otsego, Michigan*. Scientific Investigations Report 2005-5044, U.S. Department of Interior, USGS.

A. Simard. 2003. *Annotated bibliography of selected references on PCB and the Kalamazoo River Superfund Site, Michigan, 1982-2002*: U.S. Geological Survey Open-File Report 03-338.

D.K. Todd and L.W. Mays, 1980, *Ground-water hydrology (Second Edition*): John Wiley and Sons, New York, 535 p.

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

P.C. VanMetre, and Callender, E.: 1999, '*Trends in Sediment Quality in Response to Urbanization',in Toxic Substances Hydrology Program*, Technical Meeting Charleston, S.C., March 8–12, proceedings: U.S. Geological Survey.

P.C. Van Metre, B.J. Mahler, and E.T. Furlong, 2000, *Urban sprawl leaves its PAH signature*: Environmental Science and Technology, v. 34, no. 19, p. 4,064–4,070.

J.E. Vogelmann, S.M. Howard, L. Yang, C.R. Larson, B.K. Wylie, and N. Van Driel. 2001. *Completion of the 1990's National Land Cover Data Set for the conterminous United States from the Landsat Thematic Mapper data and ancillary data sources*: Photogrammetric Engineering and Remote Sensing, v. 67.

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

Hydrogeological Atlas of Michigan, 1981. Department of Geology, Western Michigan University. In cooperation with the U.S. Environmental Protection Agency, Underground Injection Control Program.

Websites

EPA Kalamazoo River Area of Concern Website http://www.epa.gov/glnpo/aoc/kalriv.html

MDNRE, 2010a. Kalamazoo River Superfund Site page

http://www.michigan.gov/deq/0,1607,7-135-3311_4109_4217-84646--,00.html

USACOE, January 7, 2010. Section 10 Navigable Waters Under USACOE Jurisdiction
http://www.michigan.gov/documents/deq/lwm-jpatm-appx-i_213469_7.pdf

Wikipedia, 2010a. http://en.wikipedia.org/wiki/Kalamazoo_River

USGS, 2010a. Kalamazoo River Stream-Flow Statistics at Station 04103500, Marshall

http://waterdata.usgs.gov/mi/nwis/annual?referred_module=sw&site_no=04103500&por_04103500_1=891496,00060,1,1949,2010&year_type=W&format=html_table&date_format=YYYY-MM-DD&rdb_compression=file&submitted_form=parameter_selection_list

USGS, 2010b. Kalamazoo River Stream-Flow Statistics at Station 04105500, Near Battlecreek.

http://waterdata.usgs.gov/nwis/annual?referred_module=sw&site_no=04105500&por_04105500_1=891505,00060,1,1937,2010&year_type=W&format=html_table&date_format=YYYY-MM-DD&rdb_compression=file&submitted_form=parameter_selection_list

USGS, 2010c. Description of the Marshall Sandstone

http://tin.er.usgs.gov/geology/state/sgmc-unit.php?unit=MIMm;0

USGS, 2010d. List of Publications on File

http://mi.water.usgs.gov/reports/reports.html

Tables

TABLE 1
WATER ELEVATIONS
Hydrogeological Investigation
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

													Observation Date	10/18/2010			10/20/2010			10/22/2010		
Division	Area	Type	Location	Easting	Northing	Ground Elevation (ft amsl)	Measure Point Elevation (ft amsl)	Screen Aquifer	Screen Top Depth (ft bgs)	Screen Top Elevation (ft amsl)	Screen Bottom Depth (ft bgs)	Screen Bottom Elevation (ft amsl)		Depth To Water (ft)	Water Elevation (ft)	Note	Depth To Water (ft)	Water Elevation (ft)	Note	Depth To Water (ft)	Water Elevation (ft)	Note
C	Target Area 1	Staff Gauge	SG 15 MILE ROAD	12952410.8	277034.1	-	882.53	-	-	-	-	-		9.3	873.23		9.13	873.4		9.28	873.25	
C	Target Area 1	MW	MWKR0250L01	12951049.1	276724.8	891.83	891.5	UC	74.5	817.33	79.5	812.33		16.64	874.86		16.58	874.92		16.6	874.9	
C	Target Area 1	MW	MWKR0250L02	12951039.5	276721.4	891.6	891.24	UC	14	877.6	24	867.6		18.61	872.63		18.63	872.61		18.66	872.58	
C	Target Area 1	MW	MWKR0250L03	12951051.8	276492.5	896.3	895.94	UC	40	856.3	45	851.3		12.2	883.74		12.25	883.69		12.32	883.62	
C	Target Area 2	Staff Gauge	SG CERESCO	12935458.28	281252.4	-	876.46	-	-	-	-	-		7.89	868.57		7.9	868.56		7.89	868.57	
C	Target Area 2	Staff Gauge	SGTA2	12935294.2	281431.9	-	879.45	-	-	-	-	-		21.28	858.17		21.29	858.16		21.24	858.21	
C	Target Area 2	MW	MWKR0570R01	12936148.1	281319.4	875.62	875.34	BR	29	846.62	34	841.62		7.49	867.85		7.54	867.8		7.59	867.75	
C	Target Area 2	MW	MWKR0570R02	12936140.2	281326.4	875.32	874.93	UC	4	871.32	14	861.32		6.97	867.96		7.02	867.91		7.09	867.84	
C	Target Area 2	MW	MWKR0570R03	12936213.6	281478.8	882.4	881.97	BR	9	873.4	19	863.4		14.24	867.73		14.27	867.7		14.34	867.63	
C	Target Area 2	MW	MWKR0580L01	12935474.8	281086.7	883.97	883.35	BR	41	842.97	46	837.97		19.99	863.36		20.03	863.32		20.1	863.25	
C	Target Area 2	MW	MWKR0580L02	12935471.5	281081.2	883.77	883.16	BR	16	867.77	26	857.77		19.61	863.55		19.64	863.52		19.73	863.43	
C	Target Area 2	MW	MWKR0580L03	12935464.8	281038.1	884.18	883.78	BR	20	864.18	25	859.18		19.47	864.31		19.51	864.27		19.56	864.22	
C	Target Area 2	MW	MWKR0580R01	12935894.3	281433.5	885.65	885.32	BR	10	875.65	20	865.65		18.32	867		18.37	866.95		18.42	866.9	
C	Target Area 2	MW	MWKR0580R02	12935892.8	281534.7	887.82	887.5	BR	10	877.82	20	867.82		19.25	868.25	Static water level elevation below the screen	19.25	868.25	Static water level elevation below the screen	19.25	868.25	Static water level elevation below the screen
C	Target Area 2	MW	MWKR0580R03	12935847.6	281706.9	892.95	892.62	BR	16	876.95	26	866.95		26.03	866.59	Static water level elevation below the screen	26.03	866.59	Static water level elevation below the screen	26.04	866.58	Static water level elevation below the screen
C	Target Area 3	Staff Gauge	SGTA3	12900847.4	295639.3	-	838.35	-	-	-	-	-		12.39	825.96		12.4	825.95		12.39	825.96	
C	Target Area 3	MW	MWKR1525R01	12901627.4	295799.8	831.6	831.38	UC	30	801.6	35	796.6		8.19	823.19		8.23	823.15		8.32	823.06	
C	Target Area 3	MW	MWKR1525R02	12901625.6	295798.2	831.66	831.31	UC	4	827.66	14	817.66		8.12	823.19		8.16	823.15		8.25	823.06	
C	Target Area 3	MW	MWKR1525R03	12901730.6	295791.8	831.43	831.01	UC	4	827.43	14	817.43		7.77	823.24		7.77	823.24		7.7	823.31	
D	Target Area 4	Staff Gauge	SGTA4	12877622.6	311387.1	-	814.31	-	-	-	-	-		18.32	795.99		18.37	795.94		18.39	795.92	
D	Target Area 4	MW	MWKR2260R01	12873865.1	314746.9	810.32	809.96	BR	55	755.32	60	750.32		11.1	798.86		11.12	798.84		11.14	798.82	
D	Target Area 4	MW	MWKR2260R02	12873867.3	314743.6	810.02	809.63	UC	22	788.02	27	783.02		12.74	796.89		12.76	796.87		12.79	796.84	
D	Target Area 4	MW	MWKR2275R01	12873707.9	314922.7	815.19	814.72	UC	20	795.19	25	790.19		15.48	799.24		15.51	799.21		15.53	799.19	
D	Target Area 5	Staff Gauge	SGTA5	12858743.1	305947.8	-	796.87	-	-	-	-	-		11.12	785.75		11.21	785.66		11.25	785.62	
D	Target Area 5	MW	MWKR2680R01	12862834.7	310490.6	791.59	791.26	UC	2	789.59	12	779.59		3.87	787.39		3.92	787.34		3.93	787.33	
D	Target Area 5	MW	MWKR2700R01	12862693.4	310364.2	790.98	790.65	BR	32	758.98	37	753.98		3.33	787.32		3.33	787.32		3.4	787.25	
D	Target Area 5	MW	MWKR2700R02	12862695.2	310360.9	790.93	790.64	UC	2	788.93	12	778.93		3.33	787.31		3.4	787.24		3.44	787.2	
E	Target Area 6	Staff Gauge	SGTA6	12843253.19	289111.09	-	789.99	-	-	-	-	-		11.08	778.91		11.07	778.92		11.12	778.87	
E	Target Area 6	MW	MWKR3450L01	12842415.7	288548	783.02	782.64	UC	137.2	645.82	147.2	635.82		-		Flowing	-		Flowing			Flowing
E	Target Area 6	MW	MWKR3450L02	12842419.9	288543.5	782.99	782.68	UC	7	775.99	12	770.99		3.4	779.28		3.43	779.25		3.41	779.27	
E	Target Area 6	MW	MWKR3450L03	12842413.1	288551	783.05	782.65	UC	72	711.05	77	706.05		3.22	779.43		3.25	779.4		3.24	779.41	
E	Target Area 6	MW	MWKR3450L04	12842425.1	288538.3	783.07	782.57	UC	2	781.07	12	771.07		3.29	779.28		3.33	779.24		3.35	779.22	
E	Target Area 6	MW	MWKR3460L01	12842307.1	288685	783.67	783.31	UC	6.8	776.87	11.8	771.87		4.02	779.29		4.05	779.26		4.03	779.28	
E	Target Area 6	MW	MWKR3460L02	12842309.6	288681	783.7	783.19	UC	2	781.7	12	771.7		3.9	779.29		3.93	779.26		3.93	779.26	
E	Target Area 7	MW	MWKR3620L01	12836877.8	284792.5	787.41	786.97	UC	34.8	752.61	39.8	747.61		11.32	775.65		11.26	775.71		11.35	775.62	
E	Target Area 7	MW	MWKR3620L02	12836874.6	284793.9	787.42	786.97	UC	10.5	776.92	15.5	771.92		11.32	775.65		11.27	775.7		11.37	775.6	
E	Target Area 7	MW	MWKR3620L03	12836831.2	284673.8	787.23	786.84	UC	4.9	782.33	14.9	772.33		10.89	775.95		10.84	776		10.93	775.91	
E	Target Area 7+8	Staff Gauge	SGTA7TA8	12835904.8	286128.3	-	787.01	-	-	-	-	-		11.75	775.26		11.71	775.3		11.8	775.21	
E	Target Area 8	MW	MWKR3680L01	12834380.5	284322.8	781.68	781.3	UC	30	751.68	35	746.68		5.43	775.87		5.35	775.95		5.44	775.86	
E	Target Area 8	MW	MWKR3680L02	12834381.3	284318.7	781.82	781.47	UC	3	778.82	13	768.82		5.59	775.88		5.57	775.9		5.6	775.87	
E	Target Area 8	MW	MWKR3680L03	12834384.4	284184.4	782.3	781.92	UC	3	779.3	13	769.3		5.94	775.98		5.86	776.06		5.94	775.98	

MW = Monitoring Well
UC = Unconsolidated Well
BR = Bedrock Well
ft amsl = feet above mean sea level
ft bgs = feet below ground surface
- = not applicable

TABLE 2
SAMPLING ANALYSIS SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

Target Area	Monitoring Well/ Surface Water Identifier	Northing (feet)	Easting (feet)	Well Screened Interval (feet below ground surface)	Unconsolidated (UC) or Bedrock (BR) Well	PNAs	VOCs	Metals	Chloride	Sulfate	Bicarbonate	Carbonate	Field Parameters
Target Area 1	MWKR0250L01	276724.8	12951049.1	74.5 - 79.5	UC	X	X	X	X	X	X	X	X
Target Area 1	MWKR0250L02	276721.4	12951039.5	14.0 - 24.0	UC	X	X	X	X	X	X	X	X
Target Area 1	MWKR0250L03	276492.5	12951051.8	40.0 - 45.0	UC	X	X	X	X	X	X	X	X
Target Area 1	SWKR0250L01	276779.2	12951011.9					X	X	X	X	X	X
Target Area 2	MWKR0570R01	281319.4	12936148.1	29.0 - 34.0	BR	X	X	X	X	X	X	X	X
Target Area 2	MWKR0570R02	281326.4	12936140.2	4.0 - 14.0	UC	X	X	X	X	X	X	X	X
Target Area 2	MWKR0570R03	281478.8	12936213.6	9.0 - 19.0	BR	X	X	X	X	X	X	X	X
Target Area 2	MWKR0580L01	281086.7	12935474.8	41.0 - 46.0	BR	X	X	X	X	X	X	X	X
Target Area 2	MWKR0580L02	281081.2	12935471.5	16.0 - 26.0	BR	X	X	X	X	X	X	X	X
Target Area 2	MWKR0580L03	281038.1	12935464.8	15.0 - 25.0	BR	X	X	X	X	X	X	X	X
Target Area 2	SWKR0570R01	281279.2	12936125.9					X	X	X	X	X	X
Target Area 3	MWKR1525R01	295799.8	12901627.4	30.0 - 35.0	UC	X	X	X	X	X	X	X	X
Target Area 3	MWKR1525R02	295798.2	12901625.6	4.0 - 14.0	UC	X	X	X	X	X	X	X	X
Target Area 3	MWKR1525R03	295791.8	12901730.6	4.0 - 14.0	UC	X	X	X	X	X	X	X	X
Target Area 3	SWKR1525R01	295711.8	12900900.2					X	X	X	X	X	X
Target Area 4	MWKR2260R01	314746.9	12873865.1	55.0 - 60.0	BR	X	X	X	X	X	X	X	X
Target Area 4	MWKR2260R02	314743.6	12873867.3	22.0 - 27.0	UC	X	X	X	X	X	X	X	X
Target Area 4	MWKR2275R01	314922.7	12873707.9	20.0 - 25.0	UC	X	X	X	X	X	X	X	X
Target Area 4	SWKR2260R01	314697.5	12873942.8					X	X	X	X	X	X
Target Area 5	MWKR2680R01	310490.6	12862834.7	2.0 - 12.0	UC	X	X	X	X	X	X	X	X
Target Area 5	MWKR2700R01	310364.2	12862693.4	32.0 - 37.0	BR	X	X	X	X	X	X	X	X
Target Area 5	MWKR2700R02	310360.9	12862695.2	2.0 - 12.0	UC	X	X	X	X	X	X	X	X
Target Area 5	SWKR2700R01	310330.1	12862594.5					X	X	X	X	X	X
Target Area 6	MWKR3450L01	288548	12842415.7	137.2 - 147.2	UC	X	X	X	X	X	X	X	X
Target Area 6	MWKR3450L02	288543.5	12842419.9	7.0 - 12.0	UC	X	X	X	X	X	X	X	X
Target Area 6	MWKR3450L03	288551	12842413.1	72.0 - 77.0	UC	X	X	X	X	X	X	X	X
Target Area 6	MWKR3450L04	288538.3	12842425.1	2.0 - 12.0	UC	X	X	X	X	X	X	X	X
Target Area 6	MWKR3460L01	288685	12842307.1	6.8 - 11.8	UC	X	X	X	X	X	X	X	X
Target Area 6	MWKR3460L02	288681	12842309.6	2.0 - 12.0	UC	X	X	X	X	X	X	X	X
Target Area 6	SWKR3460L01	288902.3	12842130.1					X	X	X	X	X	X
Target Area 7	MWKR3620L01	284792.5	12836877.8	34.8 - 39.8	UC	X	X	X	X	X	X	X	X
Target Area 7	MWKR3620L02	284793.9	12836874.6	10.5 - 15.5	UC	X	X	X	X	X	X	X	X
Target Area 7	MWKR3620L03	284673.8	12836831.2	4.9 - 14.9	UC	X	X	X	X	X	X	X	X
Target Area 7	SWKR3630L01	284875.4	12836808.2					X	X	X	X	X	X
Target Area 8	MWKR3680L01	284322.8	12834380.5	30.0 - 35.0	UC	X	X	X	X	X	X	X	X
Target Area 8	MWKR3680L02	284318.7	12834381.3	3.0 - 13.0	UC	X	X	X	X	X	X	X	X
Target Area 8	MWKR3680L03	284184.4	12834384.4	3.0 - 13.0	UC	X	X	X	X	X	X	X	X
Target Area 8	SWKR3690L01	284525.3	12834223.6					X	X	X	X	X	X

** Field parameters are temperature, pH, conductivity, ORP, turbidity
Elevation units: Feet NAVD88
Coordinate System: MI State Plane South NAD83 HARN, international feet

FOOTNOTES
GROUNDWATER ANALYTICAL SUMMARY
HYDROGEOLOGICAL INVESTIGATION
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

Drinking Water Criteria promulgated within the administrative rules for Part 201 of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended.

(A) = Criterion is the state of Michigan drinking water standard established pursuant to section 5 of 1976 PA 399, MCL 325.1005.
(B) = Background, as defined in R 299.5701(b), may be substituted if higher than the calculated cleanup criterion. Background levels may be less than criteria for some inorganic compounds.

(E) = Criterion is the aesthetic drinking water value.

(I) = Hazardous substance may exhibit the characteristic of ignitability.

(M) = Calculated criterion is below the analytical target detection limit, therefore, the criterion defaults to the target detection limit.

(Q) Criteria for carcinogenic polycyclic aromatic hydrocarbons were developed using relative potential potencies to benzo(a)pyrene.

(S) Criterion defaults to the hazardous substance-specific water solubility limit.

(AA) Comparison to these criteria may take into account an evaluation of whether the hazardous substances are adsorbed to particulates rather than dissolved in water and whether filtered groundwater samples were used to evaluate groundwater.

TDL = Target Detection Limit

Bold font indicates chemical detected above laboratory detection limit

Shading indicates a criteria exceedance.

U = The analyte was analyzed, but was not detected above the reported sample quantitation limit.

R = The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control critiera. The presence or absence cannot be verified.

J- = The analyte was positively identified; the associated numerical value is an estimated quantity with a potential low bias.

UJ = The analyte was note detected above the reported sample quantitiation limit. However, the reported quantatation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample

TABLE 3
GROUNDWATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

					Section	Target Area 1	Target Area 1	Target Area 1	Target Area 2	Target Area 2	Target Area 2
					Division	C	C	C	C	C	C
					Location	MWKR0250L01	MWKR0250L02	MWKR0250L03	MWKR0570R01	MWKR0570R02	MWKR0570R03
					Screen Zone	UC	UC	UC	BR	UC	BR
					Date	10/14/2010	10/14/2010	10/14/2010	10/15/2010	10/15/2010	10/13/2010
					Sample	WGC10141640BRH1	WGC10141505BRH1	WGC10141810BRH1	WGC10150950DJJ1	WGC10151120DJJ1	WGC10130900BAW1
Analyte	Method	Fraction	Units	WATER TDL	Part 201 Residential & Commercial I Drinking Water Criteria						
Field Parameters											
DISSOLVED OXYGEN	FIELD	Not applicable	percent		NA	-	-	-	3.22	47.9	-
DISSOLVED OXYGEN	FIELD	Not applicable	mg/l		NA	0.34	1.49	0.32	-	-	-
OXIDATION-REDUCTION POTENTIAL	FIELD	Not applicable	millivolts		NC	-378.2	-136.3	-55.7	69.1	217.3	-
pH	FIELD	Not applicable	su		(E)	6.42	7.09	6.22	7.24	7.22	-
SPECIFIC CONDUCTANCE	FIELD	Not applicable	mS/cm		NC	0.686	1.041	1.412	0.662	0.576	-
TEMPERATURE	FIELD	Not applicable	deg c		NC	13.55	14.47	11.91	11.62	13.61	-
TURBIDITY	FIELD	Not applicable	ntu		NC	10.8	32.7	24.1	0.91	0.39	-
Inorganics (Metals)											
BARIUM	SW6020A	Dissolved	mg/l	0.1	2 (A) (B)	**0.18**	< 0.10 U	**0.11**	< 0.10 U	< 0.10 U	< 0.10 U
CALCIUM	SW6020A	Dissolved	mg/l	1	NC	**74**	**110**	**130**	**91**	**77**	**75**
IRON	SW6020A	Dissolved	mg/l	0.2	0.3 (E) (B)	< 0.20 U	< 0.20 U	< 0.20 U	< 0.20 U	< 0.20 U	***0.49***
MAGNESIUM	SW6020A	Dissolved	mg/l	1	400 (B)	**22**	**27**	**32**	**27**	**22**	**18**
NICKEL	SW6020A	Dissolved	mg/l	0.02	0.1 (A) (B)	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 UJ
POTASSIUM	SW6020A	Dissolved	mg/l	1	NC	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Dissolved	mg/l	1	120	**30**	**59**	**110**	**11**	**10**	**75**
VANADIUM	SW6020A	Dissolved	mg/l	0.004	0.0045	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	**0.0062**
BARIUM	SW6020A	Total	mg/l	0.1	2 (A) (B)	**0.20**	**0.11**	**0.12**	< 0.10 U	< 0.10 U	< 0.10 U
CALCIUM	SW6020A	Total	mg/l	1	NC	**78**	**110**	**140**	**95**	**80**	**77**
IRON	SW6020A	Total	mg/l	0.2	0.3 (E) (B)	***1.9***	***0.41***	***0.37***	< 0.20 U	< 0.20 U	***10***
MAGNESIUM	SW6020A	Total	mg/l	1	400 (B)	**22**	**28**	**32**	**28**	**23**	**19**
NICKEL	SW6020A	Total	mg/l	0.02	0.1 (A) (B)	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	**0.025**
POTASSIUM	SW6020A	Total	mg/l	1	0	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Total	mg/l	1	120	**30**	**62**	**120**	**11**	**11**	**72**
VANADIUM	SW6020A	Total	mg/l	0.004	0.0045	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	**0.034**
Polynuclear Aromatic Hydrocarbons (PNAs)											
2-METHYLNAPHTHALENE	SW8270	Not applicable	ug/l	5	260	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ACENAPHTHENE	SW8270	Not applicable	ug/l	5	1300	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ACENAPHTHYLENE	SW8270	Not applicable	ug/l	5	52	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ANTHRACENE	SW8270	Not applicable	ug/l	5	43 (S)	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
BENZO(A)ANTHRACENE	SW8270	Not applicable	ug/l	1	2.1 (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(A)PYRENE	SW8270	Not applicable	ug/l	1	5 (A) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(B)FLUORANTHENE	SW8270	Not applicable	ug/l	1	1.5 (S, AA) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(G,H,I)PERYLENE	SW8270	Not applicable	ug/l	1	1 (M); 0.26 (S)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(K)FLUORANTHENE	SW8270	Not applicable	ug/l	1	1 (M); 0.8 (S) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CHRYSENE	SW8270	Not applicable	ug/l	1	1.6 (S) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
DIBENZ(A,H)ANTHRACENE	SW8270	Not applicable	ug/l	2	2 (M); 0.21 (Q)	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U

TABLE 3
GROUNDWATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

					Section	Target Area 1	Target Area 1	Target Area 1	Target Area 2	Target Area 2	Target Area 2
					Division	C	C	C	C	C	C
					Location	MWKR0250L01	MWKR0250L02	MWKR0250L03	MWKR0570R01	MWKR0570R02	MWKR0570R03
					Screen Zone	UC	UC	UC	BR	UC	BR
					Date	10/14/2010	10/14/2010	10/14/2010	10/15/2010	10/15/2010	10/13/2010
					Sample	WGC10141640BRH1	WGC10141505BRH1	WGC10141810BRH1	WGC10150950DJJ1	WGC10151120DJJ1	WGC10130900BAW1
Analyte	Method	Fraction	Units	WATER TDL	Part 201 Residential & Commercial I Drinking Water Criteria						
FLUORANTHENE	SW8270	Not applicable	ug/l	1	210 (S)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
FLUORENE	SW8270	Not applicable	ug/l	5	880	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
INDENO(1,2,3-C,D)PYRENE	SW8270	Not applicable	ug/l	2	2 (M); 0.022 (S) (Q)	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U
NAPHTHALENE	SW8260	Not applicable	ug/l	5	520	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
NAPHTHALENE	SW8270	Not applicable	ug/l	1	520	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
PHENANTHRENE	SW8270	Not applicable	ug/l	2	52	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U
PYRENE	SW8270	Not applicable	ug/l	5	140 (S)	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
Volatile Organic Compounds (VOCs)											
1,2,3-TRIMETHYL BENZENE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
1,2,4-TRIMETHYLBENZENE	SW8260	Not applicable	ug/l	1	63 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
1,3,5-TRIMETHYLBENZENE	SW8260	Not applicable	ug/l	1	72 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZENE	SW8260	Not applicable	ug/l	1	5 (A) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CYCLOHEXANE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
CYMENE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 UJ	< 5.0 U
DIMETHYL BENZENE	SW8260	Not applicable	ug/l	3	280 (E) (I)	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U
ETHYLBENZENE	SW8260	Not applicable	ug/l	1	74 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
ISOPROPYLBENZENE	SW8260	Not applicable	ug/l	5	800	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
N-PROPYLBENZENE	SW8260	Not applicable	ug/l	1	80 (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
SEC-BUTYLBENZENE	SW8260	Not applicable	ug/l	1	80	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
TOLUENE	SW8260	Not applicable	ug/l	1	790 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CHEMISTRY											
ALKALINITY, BICARBONATE (AS CACO3)	A2320B	Total	mg/l	10	NC	**250**	**340**	**380**	**300 J-**	**260 J-**	**240**
ALKALINITY, CARBONATE (AS CACO3)	A2320B	Total	mg/l	10	NC	< 10 U	< 10 U	< 10 U	R	R	< 10 U
CHLORIDE (AS CL)	SW9056	Total	mg/l	10	NC	**46**	**97**	**180**	**18**	**11**	**100**
SULFATE (AS SO4)	SW9056	Total	mg/l	1	250 (E)	**37**	**62**	**75**	**35**	**25**	**57**

TABLE 3
GROUNDWATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

					Section	Target Area 2	Target Area 2	Target Area 2	Target Area 3	Target Area 3	Target Area 3
					Division	C	C	C	C	C	C
					Location	MWKR0580L01	MWKR0580L02	MWKR0580L03	MWKR1525R01	MWKR1525R02	MWKR1525R02
					Screen Zone	BR	BR	BR	BR	UC	UC
					Date	10/15/2010	10/13/2010	10/13/2010	10/16/2010	10/16/2010	10/16/2010
					Sample	WGC10151310DJJ1	WGC10131435BAW1	WGC10131220BAW1	WGC10161000DJJ1	WGC10161100DJJ1	WGC10161100DJJ2
Analyte	Method	Fraction	Units	WATER TDL	Part 201 Residential & Commercial I Drinking Water Criteria						
Field Parameters											
DISSOLVED OXYGEN	FIELD	Not applicable	percent		NA	4.1	-	-	3.2	3.1	3.1
DISSOLVED OXYGEN	FIELD	Not applicable	mg/l		NA	-	-	-	-	-	-
OXIDATION-REDUCTION POTENTIAL	FIELD	Not applicable	millivolts		NC	-41.3	-	-	-108.5	-67.9	-67.9
pH	FIELD	Not applicable	su		(E)	7.23	-	-	6.95	6.96	6.96
SPECIFIC CONDUCTANCE	FIELD	Not applicable	mS/cm		NC	0.659	-	-	0.986	1.095	1.095
TEMPERATURE	FIELD	Not applicable	deg c		NC	11.93	-	-	11.98	13.61	13.61
TURBIDITY	FIELD	Not applicable	ntu		NC	3.84	-	-	2.18	3.81	3.81
Inorganics (Metals)											
BARIUM	SW6020A	Dissolved	mg/l	0.1	2 (A) (B)	< 0.10 U	< 0.10 U	< 0.10 U	**0.28**	**0.18**	**0.17**
CALCIUM	SW6020A	Dissolved	mg/l	1	NC	**91**	**81**	**67**	**120**	**130**	**120**
IRON	SW6020A	Dissolved	mg/l	0.2	0.3 (E) (B)	< 0.20 U	***0.43***	***5.8***	***1.8 J***	***1.6 J***	***0.66 J***
MAGNESIUM	SW6020A	Dissolved	mg/l	1	400 (B)	**26**	**22**	**21**	**30**	**28**	**28**
NICKEL	SW6020A	Dissolved	mg/l	0.02	0.1 (A) (B)	< 0.020 U	< 0.020 UJ	< 0.020 UJ	< 0.020 U	< 0.020 U	< 0.020 U
POTASSIUM	SW6020A	Dissolved	mg/l	1	NC	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Dissolved	mg/l	1	120	**11**	**19**	**31**	**16**	**20**	**19**
VANADIUM	SW6020A	Dissolved	mg/l	0.004	0.0045	< 0.0040 U	< 0.0040 U	**0.023**	< 0.0040 U	< 0.0040 U	< 0.0040 U
BARIUM	SW6020A	Total	mg/l	0.1	2 (A) (B)	< 0.10 U	< 0.10 U	< 0.10 U	**0.51**	**0.28**	**0.27**
CALCIUM	SW6020A	Total	mg/l	1	NC	**93**	**77**	**68**	**130**	**130**	**130**
IRON	SW6020A	Total	mg/l	0.2	0.3 (E) (B)	**0.30**	***2.7***	***15***	***26***	***23***	***21***
MAGNESIUM	SW6020A	Total	mg/l	1	400 (B)	**26**	**21**	**21**	**30**	**28**	**28**
NICKEL	SW6020A	Total	mg/l	0.02	0.1 (A) (B)	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U
POTASSIUM	SW6020A	Total	mg/l	1	0	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Total	mg/l	1	120	**12**	**17**	**32**	**16**	**19**	**19**
VANADIUM	SW6020A	Total	mg/l	0.004	0.0045	< 0.0040 U	**0.011**	**0.047**	< 0.0040 U	< 0.0040 U	< 0.0040 U
Polynuclear Aromatic Hydrocarbons (PNAs)											
2-METHYLNAPHTHALENE	SW8270	Not applicable	ug/l	5	260	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ACENAPHTHENE	SW8270	Not applicable	ug/l	5	1300	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ACENAPHTHYLENE	SW8270	Not applicable	ug/l	5	52	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ANTHRACENE	SW8270	Not applicable	ug/l	5	43 (S)	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
BENZO(A)ANTHRACENE	SW8270	Not applicable	ug/l	1	2.1 (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(A)PYRENE	SW8270	Not applicable	ug/l	1	5 (A) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(B)FLUORANTHENE	SW8270	Not applicable	ug/l	1	1.5 (S, AA) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(G,H,I)PERYLENE	SW8270	Not applicable	ug/l	1	1 (M); 0.26 (S)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(K)FLUORANTHENE	SW8270	Not applicable	ug/l	1	1 (M); 0.8 (S) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CHRYSENE	SW8270	Not applicable	ug/l	1	1.6 (S) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
DIBENZ(A,H)ANTHRACENE	SW8270	Not applicable	ug/l	2	2 (M); 0.21 (Q)	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U

TABLE 3
GROUNDWATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

					Section	Target Area 2	Target Area 2	Target Area 2	Target Area 3	Target Area 3	Target Area 3
					Division	C	C	C	C	C	C
					Location	MWKR0580L01	MWKR0580L02	MWKR0580L03	MWKR1525R01	MWKR1525R02	MWKR1525R02
					Screen Zone	BR	BR	BR	BR	UC	UC
					Date	10/15/2010	10/13/2010	10/13/2010	10/16/2010	10/16/2010	10/16/2010
					Sample	WGC10151310DJJ1	WGC10131435BAW1	WGC10131220BAW1	WGC10161000DJJ1	WGC10161100DJJ1	WGC10161100DJJ2
Analyte	Method	Fraction	Units	WATER TDL	Part 201 Residential & Commercial I Drinking Water Criteria						
FLUORANTHENE	SW8270	Not applicable	ug/l	1	210 (S)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
FLUORENE	SW8270	Not applicable	ug/l	5	880	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
INDENO(1,2,3-C,D)PYRENE	SW8270	Not applicable	ug/l	2	2 (M); 0.022 (S) (Q)	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U
NAPHTHALENE	SW8260	Not applicable	ug/l	5	520	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
NAPHTHALENE	SW8270	Not applicable	ug/l	1	520	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
PHENANTHRENE	SW8270	Not applicable	ug/l	2	52	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U
PYRENE	SW8270	Not applicable	ug/l	5	140 (S)	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
Volatile Organic Compounds (VOCs)											
1,2,3-TRIMETHYL BENZENE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
1,2,4-TRIMETHYLBENZENE	SW8260	Not applicable	ug/l	1	63 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
1,3,5-TRIMETHYLBENZENE	SW8260	Not applicable	ug/l	1	72 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZENE	SW8260	Not applicable	ug/l	1	5 (A) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CYCLOHEXANE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
CYMENE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
DIMETHYL BENZENE	SW8260	Not applicable	ug/l	3	280 (E) (I)	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U
ETHYLBENZENE	SW8260	Not applicable	ug/l	1	74 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
ISOPROPYLBENZENE	SW8260	Not applicable	ug/l	5	800	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
N-PROPYLBENZENE	SW8260	Not applicable	ug/l	1	80 (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
SEC-BUTYLBENZENE	SW8260	Not applicable	ug/l	1	80	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
TOLUENE	SW8260	Not applicable	ug/l	1	790 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CHEMISTRY											
ALKALINITY, BICARBONATE (AS CACO3)	A2320B	Total	mg/l	10	NC	**290 J-**	**260**	**240**	**480**	**490**	**490**
ALKALINITY, CARBONATE (AS CACO3)	A2320B	Total	mg/l	10	NC	R	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
CHLORIDE (AS CL)	SW9056	Total	mg/l	10	NC	**33**	**36**	**32**	**33**	**41**	**39**
SULFATE (AS SO4)	SW9056	Total	mg/l	1	250 (E)	**33**	**29**	**55**	< 1.0 U	**4.1**	**3.9**

TABLE 3
GROUNDWATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

					Section	Target Area 3	Target Area 4	Target Area 4	Target Area 4	Target Area 5	Target Area 5
					Division	C	D	D	D	D	D
					Location	MWKR1525R03	MWKR2260R01	MWKR2260R02	MWKR2275R01	MWKR2680R01	MWKR2700R01
					Screen Zone	UC	BR	UC	UC	UC	BR
					Date	10/16/2010	10/17/2010	10/17/2010	10/16/2010	10/16/2010	10/16/2010
					Sample	WGC10160955BRH1	WGD10171520TAS1	WGD10171540RWS1	WGD10161730BRH1	WGD10161345DJJ1	WGD10161405BRH1
Analyte	Method	Fraction	Units	WATER TDL	Part 201 Residential & Commercial I Drinking Water Criteria						
Field Parameters											
DISSOLVED OXYGEN	FIELD	Not applicable	percent		NA	-	-	-	-	3.3	-
DISSOLVED OXYGEN	FIELD	Not applicable	mg/l		NA	1.01	0.21	0.98	0.62	-	0.18
OXIDATION-REDUCTION POTENTIAL	FIELD	Not applicable	millivolts		NC	-98.3	-282.7	-3.2	-435.9	-73.8	-145.2
pH	FIELD	Not applicable	su		(E)	6.83	7.43	7.09	7.46	7.15	7.25
SPECIFIC CONDUCTANCE	FIELD	Not applicable	mS/cm		NC	0.958	505	0.576	0.674	0.657	0.633
TEMPERATURE	FIELD	Not applicable	deg c		NC	14.4	11.49	11.82	15.06	14.96	13.79
TURBIDITY	FIELD	Not applicable	ntu		NC	4.44	61.74	1.52	623.6	4.81	1.8
Inorganics (Metals)											
BARIUM	SW6020A	Dissolved	mg/l	0.1	2 (A) (B)	**0.11**	< 0.10 U	< 0.10 U	< 0.10 U	< 0.10 U	**0.17**
CALCIUM	SW6020A	Dissolved	mg/l	1	NC	**100**	**64**	**72**	**69**	**100**	**73**
IRON	SW6020A	Dissolved	mg/l	0.2	0.3 (E) (B)	***0.44 J***	***0.42 J***	< 0.20 UJ	< 0.20 UJ	< 0.20 UJ	< 0.20 UJ
MAGNESIUM	SW6020A	Dissolved	mg/l	1	400 (B)	**19**	**19**	**20**	**16**	**13**	**21**
NICKEL	SW6020A	Dissolved	mg/l	0.02	0.1 (A) (B)	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U
POTASSIUM	SW6020A	Dissolved	mg/l	1	NC	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Dissolved	mg/l	1	120	**42**	**5.4**	**13**	**35**	**8.7**	**10**
VANADIUM	SW6020A	Dissolved	mg/l	0.004	0.0045	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U
BARIUM	SW6020A	Total	mg/l	0.1	2 (A) (B)	**0.16**	< 0.10 U	< 0.10 U	< 0.10 U	< 0.10 U	**0.18**
CALCIUM	SW6020A	Total	mg/l	1	NC	**110**	**64**	**71**	**74**	**110**	**77**
IRON	SW6020A	Total	mg/l	0.2	0.3 (E) (B)	***15***	***1.2***	< 0.20 U	***32***	***4.4***	***1.2***
MAGNESIUM	SW6020A	Total	mg/l	1	400 (B)	**20**	**19**	**20**	**20**	**14**	**21**
NICKEL	SW6020A	Total	mg/l	0.02	0.1 (A) (B)	< 0.020 U	< 0.020 U	< 0.020 U	**0.025**	< 0.020 U	< 0.020 U
POTASSIUM	SW6020A	Total	mg/l	1	0	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Total	mg/l	1	120	**44**	**5.3**	**12**	**34**	**9.2**	**11**
VANADIUM	SW6020A	Total	mg/l	0.004	0.0045	< 0.0040 U	< 0.0040 U	< 0.0040 U	**0.11**	< 0.0040 U	< 0.0040 U
Polynuclear Aromatic Hydrocarbons (PNAs)											
2-METHYLNAPHTHALENE	SW8270	Not applicable	ug/l	5	260	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ACENAPHTHENE	SW8270	Not applicable	ug/l	5	1300	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ACENAPHTHYLENE	SW8270	Not applicable	ug/l	5	52	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ANTHRACENE	SW8270	Not applicable	ug/l	5	43 (S)	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
BENZO(A)ANTHRACENE	SW8270	Not applicable	ug/l	1	2.1 (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(A)PYRENE	SW8270	Not applicable	ug/l	1	5 (A) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(B)FLUORANTHENE	SW8270	Not applicable	ug/l	1	1.5 (S, AA) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(G,H,I)PERYLENE	SW8270	Not applicable	ug/l	1	1 (M); 0.26 (S)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(K)FLUORANTHENE	SW8270	Not applicable	ug/l	1	1 (M); 0.8 (S) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CHRYSENE	SW8270	Not applicable	ug/l	1	1.6 (S) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
DIBENZ(A,H)ANTHRACENE	SW8270	Not applicable	ug/l	2	2 (M); 0.21 (Q)	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U

TABLE 3
GROUNDWATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

					Section	Target Area 3	Target Area 4	Target Area 4	Target Area 4	Target Area 5	Target Area 5
					Division	C	D	D	D	D	D
					Location	MWKR1525R03	MWKR2260R01	MWKR2260R02	MWKR2275R01	MWKR2680R01	MWKR2700R01
					Screen Zone	UC	BR	UC	UC	UC	BR
					Date	10/16/2010	10/17/2010	10/17/2010	10/16/2010	10/16/2010	10/16/2010
					Sample	WGC10160955BRH1	WGD10171520TAS1	WGD10171540RWS1	WGD10161730BRH1	WGD10161345DJJ1	WGD10161405BRH1
Analyte	Method	Fraction	Units	WATER TDL	Part 201 Residential & Commercial I Drinking Water Criteria						
FLUORANTHENE	SW8270	Not applicable	ug/l	1	210 (S)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
FLUORENE	SW8270	Not applicable	ug/l	5	880	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
INDENO(1,2,3-C,D)PYRENE	SW8270	Not applicable	ug/l	2	2 (M); 0.022 (S) (Q)	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U
NAPHTHALENE	SW8260	Not applicable	ug/l	5	520	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
NAPHTHALENE	SW8270	Not applicable	ug/l	1	520	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
PHENANTHRENE	SW8270	Not applicable	ug/l	2	52	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U
PYRENE	SW8270	Not applicable	ug/l	5	140 (S)	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
Volatile Organic Compounds (VOCs)											
1,2,3-TRIMETHYL BENZENE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
1,2,4-TRIMETHYLBENZENE	SW8260	Not applicable	ug/l	1	63 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
1,3,5-TRIMETHYLBENZENE	SW8260	Not applicable	ug/l	1	72 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZENE	SW8260	Not applicable	ug/l	1	5 (A) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CYCLOHEXANE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
CYMENE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
DIMETHYL BENZENE	SW8260	Not applicable	ug/l	3	280 (E) (I)	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U
ETHYLBENZENE	SW8260	Not applicable	ug/l	1	74 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
ISOPROPYLBENZENE	SW8260	Not applicable	ug/l	5	800	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
N-PROPYLBENZENE	SW8260	Not applicable	ug/l	1	80 (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
SEC-BUTYLBENZENE	SW8260	Not applicable	ug/l	1	80	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
TOLUENE	SW8260	Not applicable	ug/l	1	790 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CHEMISTRY											
ALKALINITY, BICARBONATE (AS CACO3)	A2320B	Total	mg/l	10	NC	**360**	**230 J-**	**230 J-**	**230**	**320**	**260**
ALKALINITY, CARBONATE (AS CACO3)	A2320B	Total	mg/l	10	NC	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
CHLORIDE (AS CL)	SW9056	Total	mg/l	10	NC	**82**	**12**	**23**	**55**	**19**	**23**
SULFATE (AS SO4)	SW9056	Total	mg/l	1	250 (E)	**3.7**	**31**	**31**	**48**	**13**	**36**

TABLE 3
GROUNDWATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

					Section	Target Area 5	Target Area 6	Target Area 6	Target Area 6	Target Area 6	Target Area 6
					Division	D	E	E	E	E	E
					Location	MWKR2700R02	MWKR3450L01	MWKR3450L02	MWKR3450L03	MWKR3450L04	MWKR3460L01
					Screen Zone	UC	UC	UC	UC	UC	UC
					Date	10/16/2010	10/17/2010	10/15/2010	10/17/2010	10/17/2010	10/15/2010
					Sample	WGD10161505BRH1	WGE10171245RWS1	WGE10151405BAW1	WGE10171100RWS1	WGE10171240TAS1	WGE10151530BAW1
Analyte	Method	Fraction	Units	WATER TDL	Part 201 Residential & Commercial I Drinking Water Criteria						
Field Parameters											
DISSOLVED OXYGEN	FIELD	Not applicable	percent		NA	-	-	-	-	-	-
DISSOLVED OXYGEN	FIELD	Not applicable	mg/l		NA	0.23	0.13	0.26	0.18	-	0.14
OXIDATION-REDUCTION POTENTIAL	FIELD	Not applicable	millivolts		NC	-106.5	-57.4	-85.7	-47.4	-	-52.6
pH	FIELD	Not applicable	su		(E)	7.32	7.64	7.12	7.25	7.06	7.25
SPECIFIC CONDUCTANCE	FIELD	Not applicable	mS/cm		NC	0.508	0.589	0.815	0.644	-	0.683
TEMPERATURE	FIELD	Not applicable	deg c		NC	16.79	11.32	13.94	11.74	-	14
TURBIDITY	FIELD	Not applicable	ntu		NC	2	2.94	2.7	458.1	-	3.2
Inorganics (Metals)											
BARIUM	SW6020A	Dissolved	mg/l	0.1	2 (A) (B)	< 0.10 U	**0.20**	**0.18**	**0.20**	**0.14**	**0.16**
CALCIUM	SW6020A	Dissolved	mg/l	1	NC	**62**	**63**	**120**	**66**	**98**	**90**
IRON	SW6020A	Dissolved	mg/l	0.2	0.3 (E) (B)	***0.66 J***	***0.37 J***	***3.8***	***0.72 J***	***1.8 J***	***0.75***
MAGNESIUM	SW6020A	Dissolved	mg/l	1	400 (B)	**12**	**22**	**20**	**22**	**18**	**23**
NICKEL	SW6020A	Dissolved	mg/l	0.02	0.1 (A) (B)	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U
POTASSIUM	SW6020A	Dissolved	mg/l	1	NC	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Dissolved	mg/l	1	120	**11**	**24**	**23**	**28**	**17**	**12**
VANADIUM	SW6020A	Dissolved	mg/l	0.004	0.0045	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U
BARIUM	SW6020A	Total	mg/l	0.1	2 (A) (B)	< 0.10 U	**0.21**	**0.19**	**0.22**	**0.15**	**0.17**
CALCIUM	SW6020A	Total	mg/l	1	NC	**65**	**65**	**120**	**71**	**100**	**91**
IRON	SW6020A	Total	mg/l	0.2	0.3 (E) (B)	***1.1***	***0.90***	***5.0***	***3.0***	***2.1***	***0.96***
MAGNESIUM	SW6020A	Total	mg/l	1	400 (B)	**13**	**22**	**20**	**24**	**19**	**23**
NICKEL	SW6020A	Total	mg/l	0.02	0.1 (A) (B)	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U
POTASSIUM	SW6020A	Total	mg/l	1	0	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Total	mg/l	1	120	**12**	**24**	**23**	**28**	**18**	**12**
VANADIUM	SW6020A	Total	mg/l	0.004	0.0045	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U
Polynuclear Aromatic Hydrocarbons (PNAs)											
2-METHYLNAPHTHALENE	SW8270	Not applicable	ug/l	5	260	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ACENAPHTHENE	SW8270	Not applicable	ug/l	5	1300	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ACENAPHTHYLENE	SW8270	Not applicable	ug/l	5	52	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ANTHRACENE	SW8270	Not applicable	ug/l	5	43 (S)	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
BENZO(A)ANTHRACENE	SW8270	Not applicable	ug/l	1	2.1 (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(A)PYRENE	SW8270	Not applicable	ug/l	1	5 (A) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(B)FLUORANTHENE	SW8270	Not applicable	ug/l	1	1.5 (S, AA) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(G,H,I)PERYLENE	SW8270	Not applicable	ug/l	1	1 (M); 0.26 (S)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(K)FLUORANTHENE	SW8270	Not applicable	ug/l	1	1 (M); 0.8 (S) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CHRYSENE	SW8270	Not applicable	ug/l	1	1.6 (S) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
DIBENZ(A,H)ANTHRACENE	SW8270	Not applicable	ug/l	2	2 (M); 0.21 (Q)	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U

TABLE 3
GROUNDWATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

					Section	Target Area 5	Target Area 6	Target Area 6	Target Area 6	Target Area 6	Target Area 6
					Division	D	E	E	E	E	E
					Location	MWKR2700R02	MWKR3450L01	MWKR3450L02	MWKR3450L03	MWKR3450L04	MWKR3460L01
					Screen Zone	UC	UC	UC	UC	UC	UC
					Date	10/16/2010	10/17/2010	10/15/2010	10/17/2010	10/17/2010	10/15/2010
					Sample	WGD10161505BRH1	WGE10171245RWS1	WGE10151405BAW1	WGE10171100RWS1	WGE10171240TAS1	WGE10151530BAW1
Analyte	Method	Fraction	Units	WATER TDL	Part 201 Residential & Commercial I Drinking Water Criteria						
FLUORANTHENE	SW8270	Not applicable	ug/l	1	210 (S)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
FLUORENE	SW8270	Not applicable	ug/l	5	880	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
INDENO(1,2,3-C,D)PYRENE	SW8270	Not applicable	ug/l	2	2 (M); 0.022 (S) (Q)	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U
NAPHTHALENE	SW8260	Not applicable	ug/l	5	520	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
NAPHTHALENE	SW8270	Not applicable	ug/l	1	520	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
PHENANTHRENE	SW8270	Not applicable	ug/l	2	52	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U
PYRENE	SW8270	Not applicable	ug/l	5	140 (S)	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
Volatile Organic Compounds (VOCs)											
1,2,3-TRIMETHYL BENZENE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
1,2,4-TRIMETHYLBENZENE	SW8260	Not applicable	ug/l	1	63 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
1,3,5-TRIMETHYLBENZENE	SW8260	Not applicable	ug/l	1	72 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZENE	SW8260	Not applicable	ug/l	1	5 (A) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CYCLOHEXANE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
CYMENE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
DIMETHYL BENZENE	SW8260	Not applicable	ug/l	3	280 (E) (I)	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U
ETHYLBENZENE	SW8260	Not applicable	ug/l	1	74 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
ISOPROPYLBENZENE	SW8260	Not applicable	ug/l	5	800	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
N-PROPYLBENZENE	SW8260	Not applicable	ug/l	1	80 (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
SEC-BUTYLBENZENE	SW8260	Not applicable	ug/l	1	80	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
TOLUENE	SW8260	Not applicable	ug/l	1	790 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CHEMISTRY											
ALKALINITY, BICARBONATE (AS CACO3)	A2320B	Total	mg/l	10	NC	**210**	**280 J-**	**350 J-**	**280 J-**	**330 J-**	**300 J-**
ALKALINITY, CARBONATE (AS CACO3)	A2320B	Total	mg/l	10	NC	< 10 U	< 10 U	R	< 10 U	< 10 U	R
CHLORIDE (AS CL)	SW9056	Total	mg/l	10	NC	**22**	**32**	**26**	**38**	**23**	**22**
SULFATE (AS SO4)	SW9056	Total	mg/l	1	250 (E)	**8.0**	**3.9**	**20**	**12**	**30**	**20**

TABLE 3
GROUNDWATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

					Section	Target Area 6	Target Area 6	Target Area 7	Target Area 7	Target Area 7	Target Area 7
					Division	E	E	E	E	E	E
					Location	MWKR3460L02	MWKR3460L02	MWKR3620L01	MWKR3620L02	MWKR3620L02	MWKR3620L03
					Screen Zone	UC	UC	UC	UC	UC	UC
					Date	10/17/2010	10/17/2010	10/14/2010	10/15/2010	10/15/2010	10/15/2010
					Sample	WGE10171041TAS1	WGE10171041TAS2	WGE10141445BAW1	WGE10151050BAW1	WGE10151050BAW2	WGE10150935BAW1
Analyte	Method	Fraction	Units	WATER TDL	Part 201 Residential & Commercial I Drinking Water Criteria						
Field Parameters											
DISSOLVED OXYGEN	FIELD	Not applicable	percent		NA	-	-	-	-	-	-
DISSOLVED OXYGEN	FIELD	Not applicable	mg/l		NA	0.24	0.24	0.15	5.26	5.26	3.27
OXIDATION-REDUCTION POTENTIAL	FIELD	Not applicable	millivolts		NC	-56.2	-56.2	-85.3	28.2	28.2	38.7
pH	FIELD	Not applicable	su		(E)	-	7.06	7.29	7.8	7.8	7.4
SPECIFIC CONDUCTANCE	FIELD	Not applicable	mS/cm		NC	730	730	1.011	0.648	0.648	0.938
TEMPERATURE	FIELD	Not applicable	deg c		NC	13.92	13.92	12.05	12.63	12.63	13.41
TURBIDITY	FIELD	Not applicable	ntu		NC	7.81	7.81	11.4	0.2	0.2	1.6
Inorganics (Metals)											
BARIUM	SW6020A	Dissolved	mg/l	0.1	2 (A) (B)	**0.13**	**0.13**	**0.13**	< 0.10 U	< 0.10 U	< 0.10 U
CALCIUM	SW6020A	Dissolved	mg/l	1	NC	**89**	**89**	**110**	**75**	**75**	**75**
IRON	SW6020A	Dissolved	mg/l	0.2	0.3 (E) (B)	***1.6 J***	***0.80 J***	***0.36***	< 0.20 U	< 0.20 U	< 0.20 U
MAGNESIUM	SW6020A	Dissolved	mg/l	1	400 (B)	**21**	**21**	**27**	**17**	**17**	**14**
NICKEL	SW6020A	Dissolved	mg/l	0.02	0.1 (A) (B)	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U
POTASSIUM	SW6020A	Dissolved	mg/l	1	NC	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Dissolved	mg/l	1	120	**19**	**19**	**45**	**24**	**23**	**110**
VANADIUM	SW6020A	Dissolved	mg/l	0.004	0.0045	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U
BARIUM	SW6020A	Total	mg/l	0.1	2 (A) (B)	**0.13**	**0.13**	**0.15**	< 0.10 U	< 0.10 U	< 0.10 U
CALCIUM	SW6020A	Total	mg/l	1	NC	**85**	**88**	**130**	**77**	**75**	**76**
IRON	SW6020A	Total	mg/l	0.2	0.3 (E) (B)	***2.1***	***2.2***	***2.1***	< 0.20 U	< 0.20 U	< 0.20 U
MAGNESIUM	SW6020A	Total	mg/l	1	400 (B)	**20**	**20**	**30**	**18**	**17**	**14**
NICKEL	SW6020A	Total	mg/l	0.02	0.1 (A) (B)	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U
POTASSIUM	SW6020A	Total	mg/l	1	0	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Total	mg/l	1	120	**18**	**18**	**49**	**24**	**24**	**110**
VANADIUM	SW6020A	Total	mg/l	0.004	0.0045	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U
Polynuclear Aromatic Hydrocarbons (PNAs)											
2-METHYLNAPHTHALENE	SW8270	Not applicable	ug/l	5	260	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ACENAPHTHENE	SW8270	Not applicable	ug/l	5	1300	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ACENAPHTHYLENE	SW8270	Not applicable	ug/l	5	52	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ANTHRACENE	SW8270	Not applicable	ug/l	5	43 (S)	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
BENZO(A)ANTHRACENE	SW8270	Not applicable	ug/l	1	2.1 (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(A)PYRENE	SW8270	Not applicable	ug/l	1	5 (A) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(B)FLUORANTHENE	SW8270	Not applicable	ug/l	1	1.5 (S, AA) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(G,H,I)PERYLENE	SW8270	Not applicable	ug/l	1	1 (M); 0.26 (S)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(K)FLUORANTHENE	SW8270	Not applicable	ug/l	1	1 (M); 0.8 (S) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CHRYSENE	SW8270	Not applicable	ug/l	1	1.6 (S) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
DIBENZ(A,H)ANTHRACENE	SW8270	Not applicable	ug/l	2	2 (M); 0.21 (Q)	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U

TABLE 3
GROUNDWATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

					Section	Target Area 6	Target Area 6	Target Area 7	Target Area 7	Target Area 7	Target Area 7
					Division	E	E	E	E	E	E
					Location	MWKR3460L02	MWKR3460L02	MWKR3620L01	MWKR3620L02	MWKR3620L02	MWKR3620L03
					Screen Zone	UC	UC	UC	UC	UC	UC
					Date	10/17/2010	10/17/2010	10/14/2010	10/15/2010	10/15/2010	10/15/2010
					Sample	WGE10171041TAS1	WGE10171041TAS2	WGE10141445BAW1	WGE10151050BAW1	WGE10151050BAW2	WGE10150935BAW1
Analyte	Method	Fraction	Units	WATER TDL	Part 201 Residential & Commercial I Drinking Water Criteria						
FLUORANTHENE	SW8270	Not applicable	ug/l	1	210 (S)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
FLUORENE	SW8270	Not applicable	ug/l	5	880	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
INDENO(1,2,3-C,D)PYRENE	SW8270	Not applicable	ug/l	2	2 (M); 0.022 (S) (Q)	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U
NAPHTHALENE	SW8260	Not applicable	ug/l	5	520	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
NAPHTHALENE	SW8270	Not applicable	ug/l	1	520	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
PHENANTHRENE	SW8270	Not applicable	ug/l	2	52	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U
PYRENE	SW8270	Not applicable	ug/l	5	140 (S)	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
Volatile Organic Compounds (VOCs)											
1,2,3-TRIMETHYL BENZENE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
1,2,4-TRIMETHYLBENZENE	SW8260	Not applicable	ug/l	1	63 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
1,3,5-TRIMETHYLBENZENE	SW8260	Not applicable	ug/l	1	72 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZENE	SW8260	Not applicable	ug/l	1	5 (A) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CYCLOHEXANE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
CYMENE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
DIMETHYL BENZENE	SW8260	Not applicable	ug/l	3	280 (E) (I)	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U
ETHYLBENZENE	SW8260	Not applicable	ug/l	1	74 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
ISOPROPYLBENZENE	SW8260	Not applicable	ug/l	5	800	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
N-PROPYLBENZENE	SW8260	Not applicable	ug/l	1	80 (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
SEC-BUTYLBENZENE	SW8260	Not applicable	ug/l	1	80	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
TOLUENE	SW8260	Not applicable	ug/l	1	790 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CHEMISTRY											
ALKALINITY, BICARBONATE (AS CACO3)	A2320B	Total	mg/l	10	NC	**320 J-**	**330 J-**	**260**	**180 J-**	**190 J-**	**310 J-**
ALKALINITY, CARBONATE (AS CACO3)	A2320B	Total	mg/l	10	NC	< 10 U	< 10 U	< 10 U	R	R	R
CHLORIDE (AS CL)	SW9056	Total	mg/l	10	NC	**28**	**28**	**140**	**70**	**69**	**100**
SULFATE (AS SO4)	SW9056	Total	mg/l	1	250 (E)	**22**	**22**	**58**	**22**	**20**	**24**

TABLE 3
GROUNDWATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

					Section	Target Area 8	Target Area 8	Target Area 8	Target Area 8
					Division	E	E	E	E
					Location	MWKR3680L01	MWKR3680L02	MWKR3680L02	MWKR3680L03
					Screen Zone	UC	UC	UC	UC
					Date	10/14/2010	10/14/2010	10/14/2010	10/14/2010
					Sample	WGE10141020BRH1	WGE10141200BRH1	WGE10141200BRH2	WGE10141015BAW1
Analyte	Method	Fraction	Units	WATER TDL	Part 201 Residential & Commercial I Drinking Water Criteria				
Field Parameters									
DISSOLVED OXYGEN	FIELD	Not applicable	percent		NA	-	-	-	-
DISSOLVED OXYGEN	FIELD	Not applicable	mg/l		NA	0.41	0.43	0.43	0.57
OXIDATION-REDUCTION POTENTIAL	FIELD	Not applicable	millivolts		NC	-328.9	-344.1	-344.1	17.3
pH	FIELD	Not applicable	su		(E)	7.6	7.47	7.47	7.57
SPECIFIC CONDUCTANCE	FIELD	Not applicable	mS/cm		NC	0.581	0.354	0.354	0.461
TEMPERATURE	FIELD	Not applicable	deg c		NC	13.23	15.8	15.8	15.56
TURBIDITY	FIELD	Not applicable	ntu		NC	10.5	3.23	3.23	0.7
Inorganics (Metals)									
BARIUM	SW6020A	Dissolved	mg/l	0.1	2 (A) (B)	< 0.10 U	< 0.10 U	< 0.10 U	< 0.10 U
CALCIUM	SW6020A	Dissolved	mg/l	1	NC	**61**	**46**	**46**	**69**
IRON	SW6020A	Dissolved	mg/l	0.2	0.3 (E) (B)	< 0.20 U	< 0.20 U	< 0.20 U	< 0.20 U
MAGNESIUM	SW6020A	Dissolved	mg/l	1	400 (B)	**14**	**11**	**11**	**14**
NICKEL	SW6020A	Dissolved	mg/l	0.02	0.1 (A) (B)	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U
POTASSIUM	SW6020A	Dissolved	mg/l	1	NC	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Dissolved	mg/l	1	120	**29**	**6.5**	**6.5**	**1.7**
VANADIUM	SW6020A	Dissolved	mg/l	0.004	0.0045	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U
BARIUM	SW6020A	Total	mg/l	0.1	2 (A) (B)	< 0.10 U	< 0.10 U	< 0.10 U	< 0.10 U
CALCIUM	SW6020A	Total	mg/l	1	NC	**64**	**50**	**46**	**74**
IRON	SW6020A	Total	mg/l	0.2	0.3 (E) (B)	**0.30**	< 0.20 U	< 0.20 U	< 0.20 U
MAGNESIUM	SW6020A	Total	mg/l	1	400 (B)	**14**	**11**	**11**	**15**
NICKEL	SW6020A	Total	mg/l	0.02	0.1 (A) (B)	< 0.020 U	< 0.020 U	< 0.020 U	< 0.020 U
POTASSIUM	SW6020A	Total	mg/l	1	0	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Total	mg/l	1	120	**29**	**6.6**	**6.2**	**2.4**
VANADIUM	SW6020A	Total	mg/l	0.004	0.0045	< 0.0040 U	< 0.0040 U	< 0.0040 U	< 0.0040 U
Polynuclear Aromatic Hydrocarbons (PNAs)									
2-METHYLNAPHTHALENE	SW8270	Not applicable	ug/l	5	260	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ACENAPHTHENE	SW8270	Not applicable	ug/l	5	1300	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ACENAPHTHYLENE	SW8270	Not applicable	ug/l	5	52	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
ANTHRACENE	SW8270	Not applicable	ug/l	5	43 (S)	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
BENZO(A)ANTHRACENE	SW8270	Not applicable	ug/l	1	2.1 (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(A)PYRENE	SW8270	Not applicable	ug/l	1	5 (A) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(B)FLUORANTHENE	SW8270	Not applicable	ug/l	1	1.5 (S, AA) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(G,H,I)PERYLENE	SW8270	Not applicable	ug/l	1	1 (M); 0.26 (S)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZO(K)FLUORANTHENE	SW8270	Not applicable	ug/l	1	1 (M); 0.8 (S) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CHRYSENE	SW8270	Not applicable	ug/l	1	1.6 (S) (Q)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
DIBENZ(A,H)ANTHRACENE	SW8270	Not applicable	ug/l	2	2 (M); 0.21 (Q)	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U

TABLE 3
GROUNDWATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

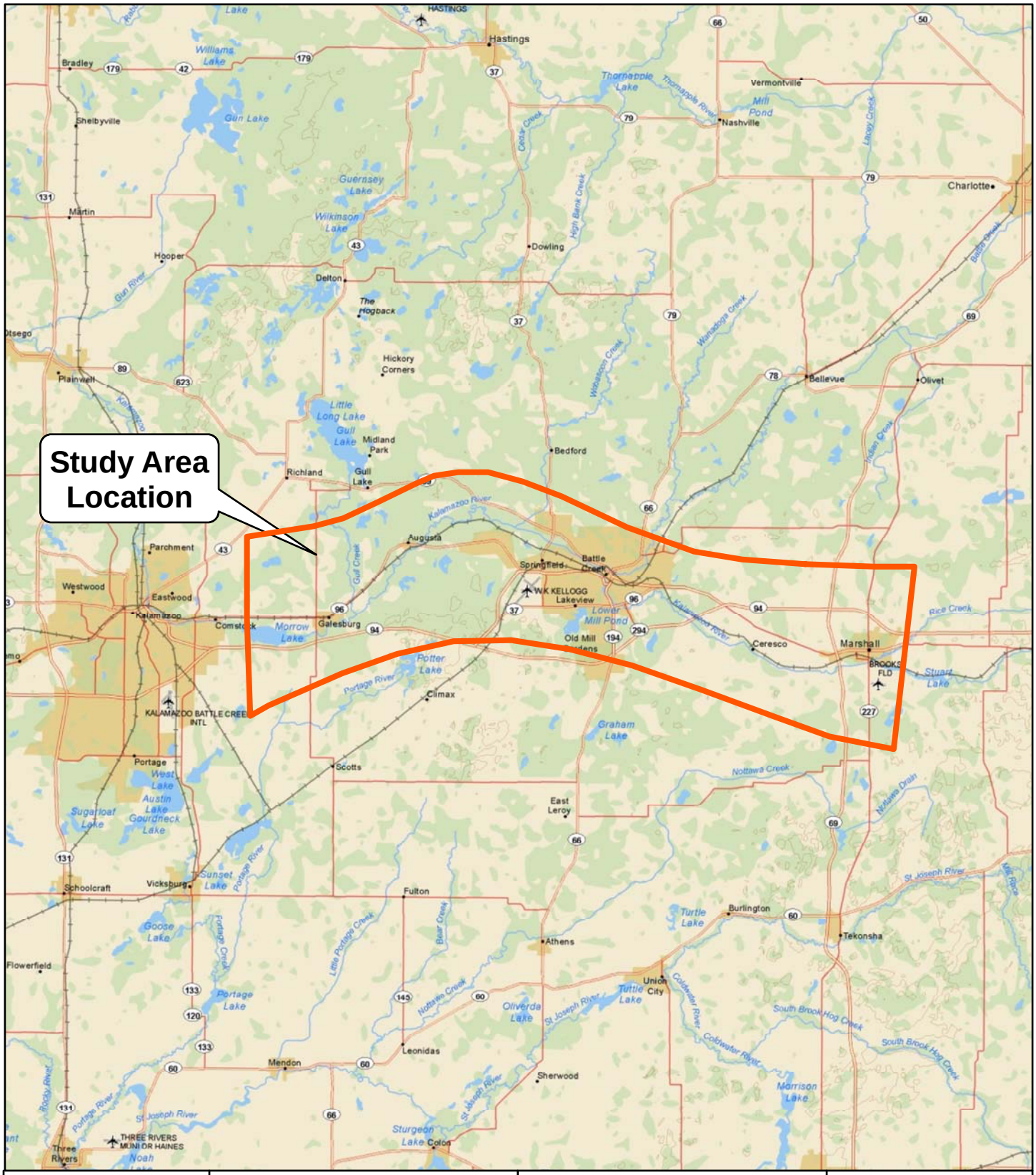
					Section	Target Area 8	Target Area 8	Target Area 8	Target Area 8
					Division	E	E	E	E
					Location	MWKR3680L01	MWKR3680L02	MWKR3680L02	MWKR3680L03
					Screen Zone	UC	UC	UC	UC
					Date	10/14/2010	10/14/2010	10/14/2010	10/14/2010
					Sample	WGE10141020BRH1	WGE10141200BRH1	WGE10141200BRH2	WGE10141015BAW1
Analyte	Method	Fraction	Units	WATER TDL	Part 201 Residential & Commercial I Drinking Water Criteria				
FLUORANTHENE	SW8270	Not applicable	ug/l	1	210 (S)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
FLUORENE	SW8270	Not applicable	ug/l	5	880	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
INDENO(1,2,3-C,D)PYRENE	SW8270	Not applicable	ug/l	2	2 (M); 0.022 (S) (Q)	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U
NAPHTHALENE	SW8260	Not applicable	ug/l	5	520	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 UJ
NAPHTHALENE	SW8270	Not applicable	ug/l	1	520	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
PHENANTHRENE	SW8270	Not applicable	ug/l	2	52	< 2.0 U	< 2.0 U	< 2.0 U	< 2.0 U
PYRENE	SW8270	Not applicable	ug/l	5	140 (S)	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
Volatile Organic Compounds (VOCs)									
1,2,3-TRIMETHYL BENZENE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
1,2,4-TRIMETHYLBENZENE	SW8260	Not applicable	ug/l	1	63 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
1,3,5-TRIMETHYLBENZENE	SW8260	Not applicable	ug/l	1	72 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
BENZENE	SW8260	Not applicable	ug/l	1	5 (A) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CYCLOHEXANE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
CYMENE	SW8260	Not applicable	ug/l	5	NC	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
DIMETHYL BENZENE	SW8260	Not applicable	ug/l	3	280 (E) (I)	< 3.0 U	< 3.0 U	< 3.0 U	< 3.0 U
ETHYLBENZENE	SW8260	Not applicable	ug/l	1	74 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
ISOPROPYLBENZENE	SW8260	Not applicable	ug/l	5	800	< 5.0 U	< 5.0 U	< 5.0 U	< 5.0 U
N-PROPYLBENZENE	SW8260	Not applicable	ug/l	1	80 (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
SEC-BUTYLBENZENE	SW8260	Not applicable	ug/l	1	80	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
TOLUENE	SW8260	Not applicable	ug/l	1	790 (E) (I)	< 1.0 U	< 1.0 U	< 1.0 U	< 1.0 U
CHEMISTRY									
ALKALINITY, BICARBONATE (AS CACO3)	A2320B	Total	mg/l	10	NC	**190**	**160**	**160**	**240**
ALKALINITY, CARBONATE (AS CACO3)	A2320B	Total	mg/l	10	NC	< 10 U	< 10 U	< 10 U	< 10 U
CHLORIDE (AS CL)	SW9056	Total	mg/l	10	NC	**48**	**14**	**13**	< 10 U
SULFATE (AS SO4)	SW9056	Total	mg/l	1	250 (E)	**9.4**	**3.5**	**3.2**	**5.8**

TABLE 4
SURFACE WATER ANALYTICAL SUMMARY
TARGET AREA 1 THROUGH 8
ENBRIDGE LINE 6B MP 608
MARSHALL, MICHIGAN

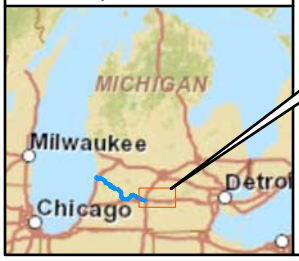
			Section	Target Area 1	Target Area 2	Target Area 3	Target Area 4	Target Area 5	Target Area 6	Target Area 7	Target Area 8
			Division	C	C	C	D	D	E	E	E
			Location	SWKR0250L01	SWKR0570R01	SWKR1525R01	SWKR2260R01	SWKR2700R01	SWKR3460L01	SWKR3630L01	SWKR3690L01
			Date	10/15/2010	10/15/2010	10/15/2010	10/16/2010	10/16/2010	10/17/2010	10/15/2010	10/14/2010
			Sample	WSC10151555DJJ1	WSC10151448DJJ1	WSC10151712DJJ1	WSD10161640DJJ1	WSD10161450DJJ1	WSE10171136BRH1	WSE10151200BAW1	WSE10141155BAW1
Analyte	Method	Fraction	Units								
CHEMISTRY											
ALKALINITY, BICARBONATE (AS CACO3)	A2320B	Total	mg/l	**290 J-**	**260 J-**	**260 J-**	**260**	**260**	**260 J-**	**240 J-**	**270**
ALKALINITY, CARBONATE (AS CACO3)	A2320B	Total	mg/l	R	R	R	< 10 U	< 10 U	< 10 U	R	< 10 U
CHLORIDE (AS CL)	SW9056	Total	mg/l	**37**	**36**	**37**	**46**	**50**	**48**	**44**	**45**
SULFATE (AS SO4)	SW9056	Total	mg/l	**37**	**37**	**35**	**35**	**38**	**36**	**35**	**34**
FIELD PARAMETERS											
DISSOLVED OXYGEN	FIELD	Not applicable	mg/l	**-**	**-**	**-**	**-**	**-**	**10.47**	**8.95**	**9.07**
DISSOLVED OXYGEN	FIELD	Not applicable	percent	109.7	95.7	102.2	73.9	101.2	-	-	-
OXIDATION-REDUCTION POTENTIAL	FIELD	Not applicable	millivolts	94.2	69	69.2	29	-5.4	135	34.5	44.4
pH	FIELD	Not applicable	su	8.38	8.23	8.28	7.82	8.28	8.01	8.25	8.01
SPECIFIC CONDUCTANCE	FIELD	Not applicable	mS/cm	0.643	0.647	0.639	0.666	0.687	0.716	0.687	0.705
TEMPERATURE	FIELD	Not applicable	deg c	14.08	16.43	15.5	14.03	14.17	12.13	12.51	12.97
TURBIDITY	FIELD	Not applicable	ntu	3.4	3.02	25.4	1.31	2.18	0.97	1.3	1.4
INORGANICS (METALS)											
CALCIUM	SW6020A	Total	mg/l	**81**	**88**	**85**	**74**	**78**	**79**	**83**	**86**
IRON	SW6020A	Total	mg/l	**0.23**	**0.28**	**0.84**	**< 0.20 U**	**0.23**	**0.24**	**0.22**	**0.23**
MAGNESIUM	SW6020A	Total	mg/l	**24**	**26**	**24**	**21**	**23**	**23**	**24**	**25**
POTASSIUM	SW6020A	Total	mg/l	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U	< 10 U
SODIUM	SW6020A	Total	mg/l	**16**	**17**	**17**	**22**	**22**	**23**	**23**	**23**

Notes
NA = Not applicable
Bold = detected above method detection limits
- = not recorded
U = The analyte was analyzed, but was not detected above the reported sample quantitation limit.
R = The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control critiera. The presence or absence cannot be verified.
J- = The analyte was positively identified; the associated numerical value is an estimated quantity with a potential low bias.

Figures



Map Location



0 2 4 8

Miles

N

KALAMAZOO RIVER HYDROGEOLOGICAL INVESTIGATION STUDY AREA LOCATION MAP

ENBRIDGE LINE 6B M608 PIPELINE RELEASE MARSHALL, MI

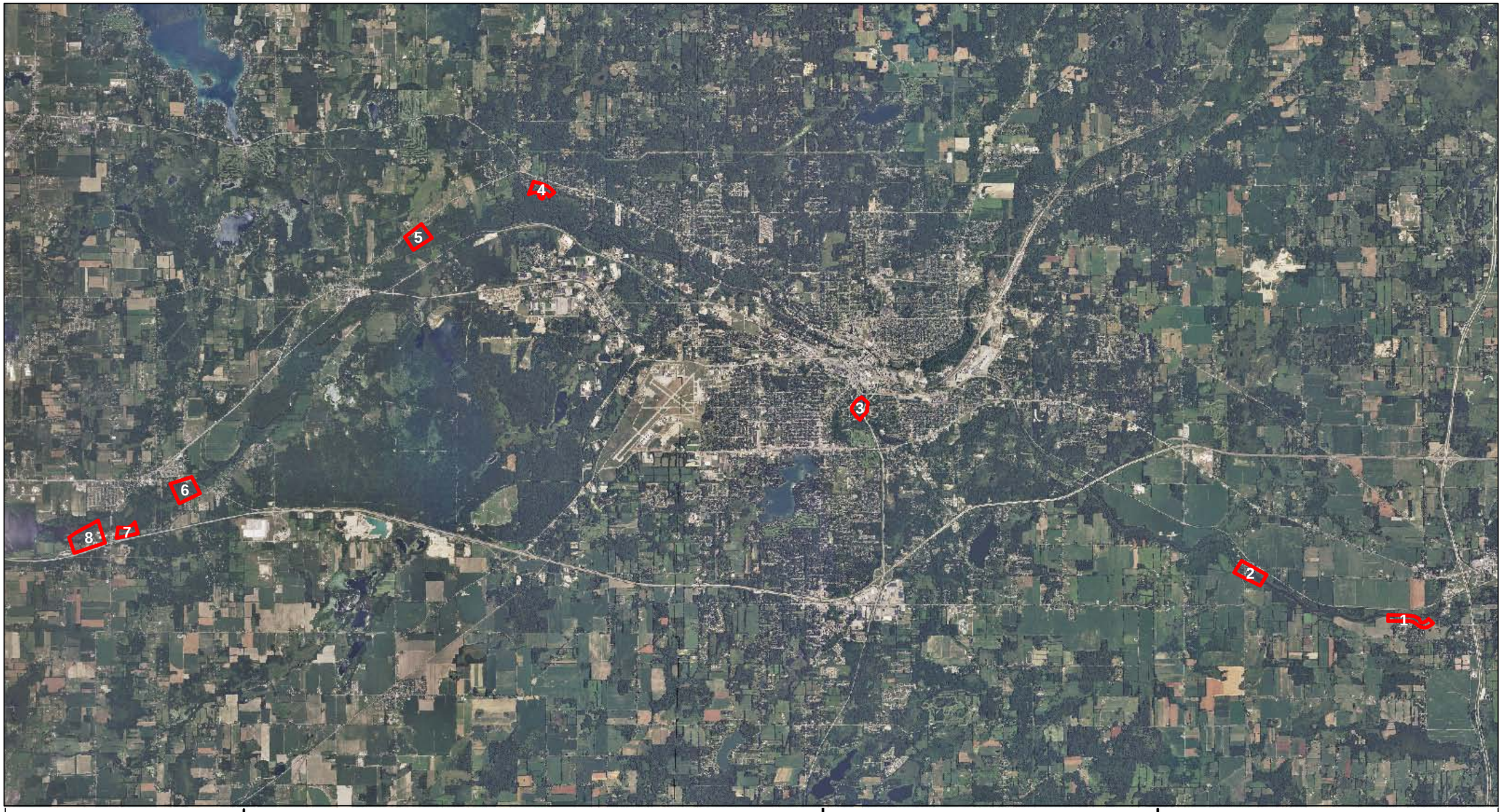
ENBRIDGE

AECOM

Map Name: HydroGeoStudy_SiteMap.mxd

October 2010

Figure 1



ENBRIDGE

AECOM

October, 2010

0 1 2 4

Miles

Legend

Target Area Boundary

Figure: 2

KALAMAZOO RIVER HYDROGEOLOGICAL STUDY

TARGET AREA OVERVIEW MAP

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE

MARSHALL, MI

ENBRIDGE

AECOM

October 2010

N

0 250 500

Scale in Feet

LEGEND:

Location ID - MWKR0250L01

Water Elevation (Ft. above mean Sea Level)

18-Oct Event - 874.86

20-Oct Event - 874.92

22-Oct Event - 875.12

Vertical Gradient

Upward U

Downward D

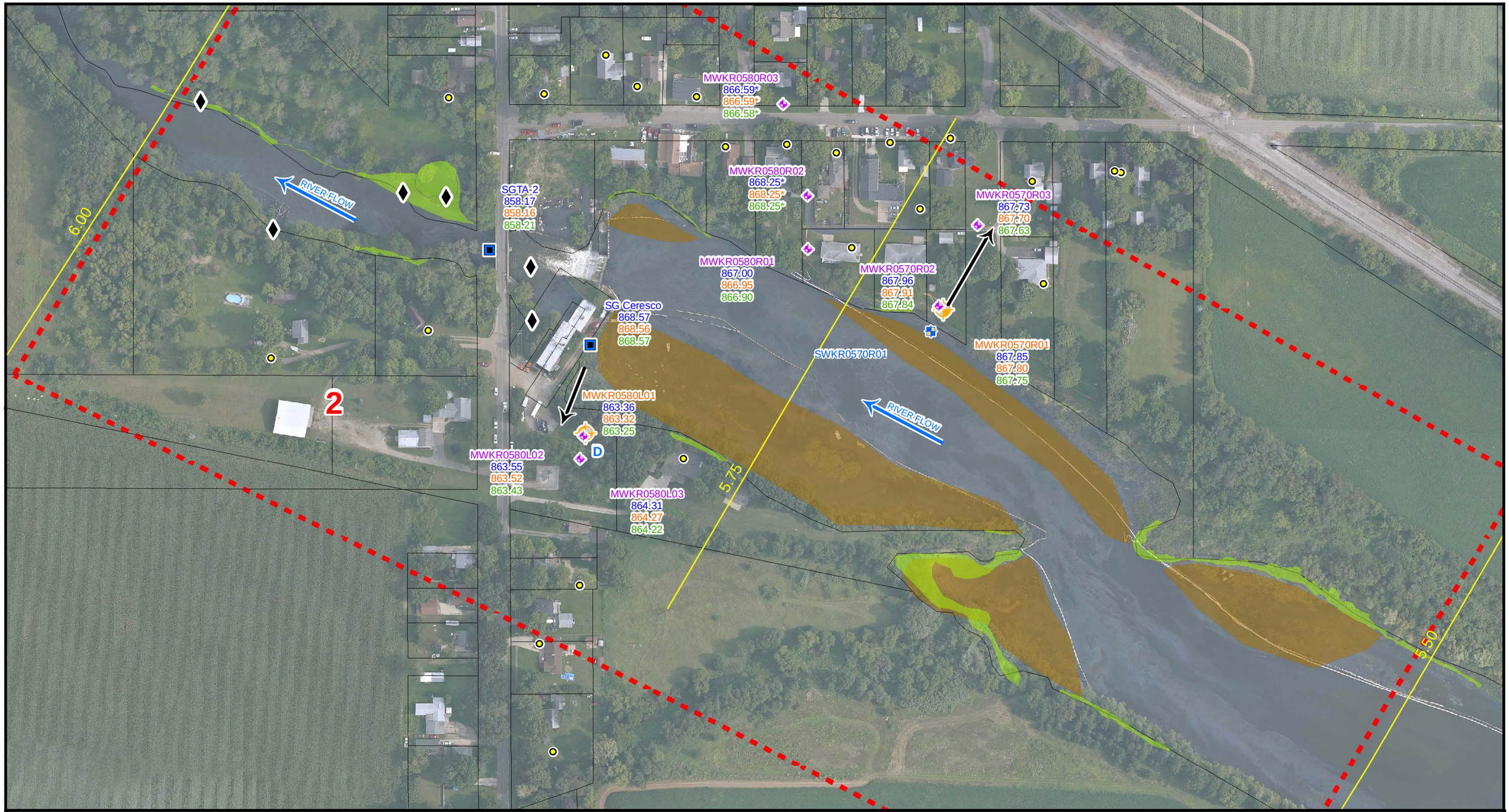
No Gradient N

- Deep Monitoring Well
- Shallow Monitoring Well
- Staff Gauge
- Surface Water Sample
- O&M SCAT Point
- Potable Well
- .25mile Grid Segments
- Target Area Boundary
- SCAT Area
- Groundwater Flow Direction

Figure: 3

GROUNDWATER ELEVATION, FLOW DIRECTION AND VERTICAL GRADIENT. TARGET AREA 1

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE
MARSHALL, MI



ENBRIDGE

AECOM

October 2010

0 165 330

Scale in Feet

LEGEND:

Location ID - MWKR0250L01

Water Elevation (Ft. above mean Sea Level)

18-Oct Event - 874.86

20-Oct Event - 874.92

22-Oct Event - 875.12

Note: * Does not represent a true groundwater elevation

Vertical Gradient

Upward U

Downward D

No Gradient N

Deep Monitoring Well

Shallow Monitoring Well

Staff Gauge

Surface Water Sample

O&M SCAT Point

Potable Well

.25mile Grid Segments

SCAT Area

Historic Submerged Oil

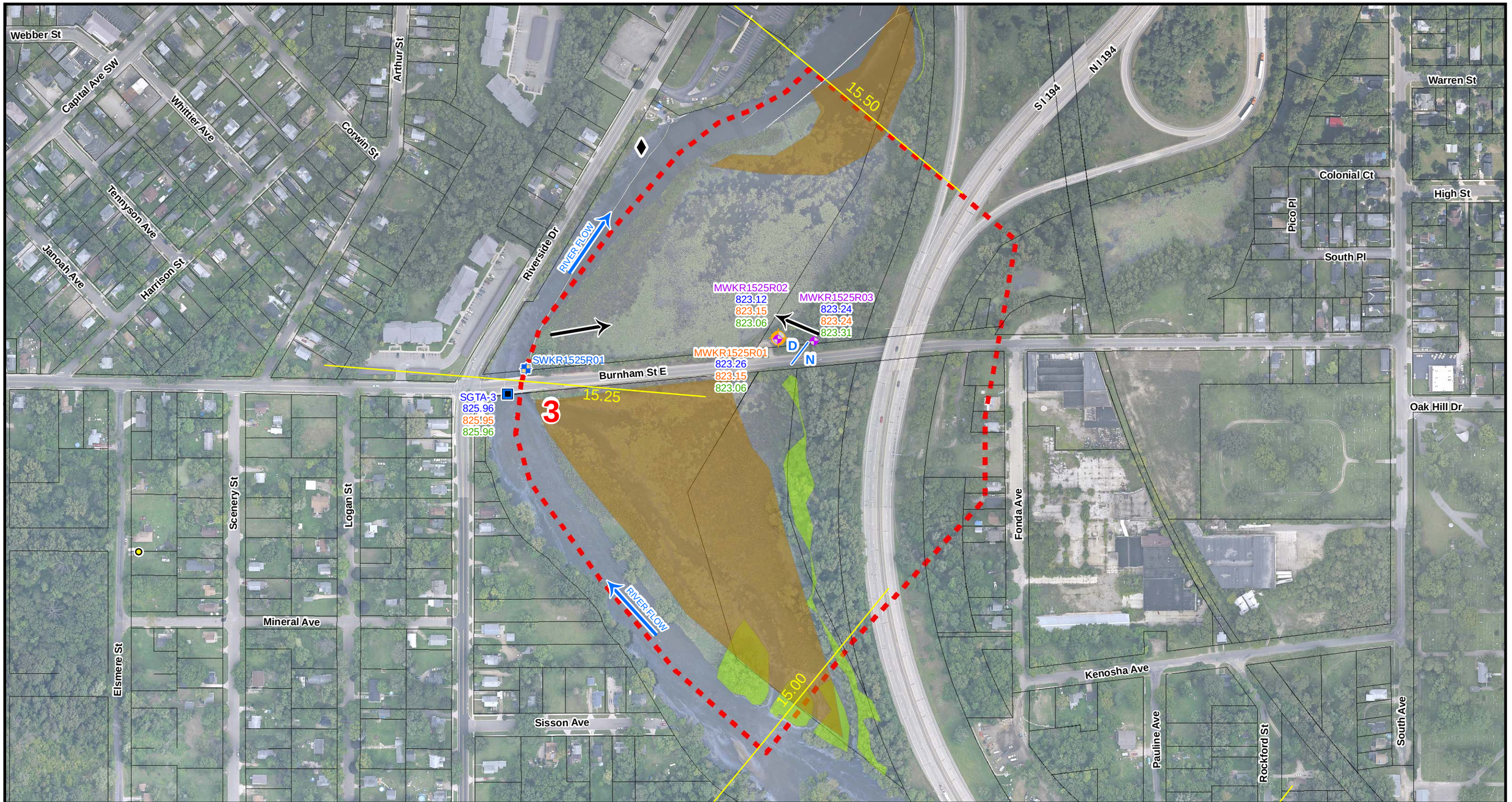
Target Area Boundary

Groundwater Flow Direction

Figure: 4

GROUNDWATER ELEVATION, FLOW DIRECTION AND VERTICAL GRADIENT. TARGET AREA 2

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE MARSHALL, MI



ENBRIDGE

AECOM

October 2010

0 250 500

Scale in Feet

LEGEND:

Location ID - MWKR0250L01

Water Elevation (Ft. above mean Sea Level)		Vertical Gradient	
18-Oct Event -	874.86	Upward	U
20-Oct Event -	874.92	Downward	D
22-Oct Event -	875.12	No Gradient	N

- Deep Monitoring Well
- Shallow Monitoring Well
- Staff Guage; Staff Gauge
- Surface Water Sample
- O&M SCAT Point
- Potable Well
- .25mile Grid Segments
- Historic Submerged Oil
- SCAT Area
- Target Area Boundary
- Groundwater Flow Direction

Figure: 5

GROUNDWATER ELEVATION, FLOW DIRECTION AND VERTICAL GRADIENT. TARGET AREA 3

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE MARSHALL, MI

ENBRIDGE

AECOM

October 2010

0 250 500

Scale in Feet

LEGEND:

Location ID - MWKR0250L01

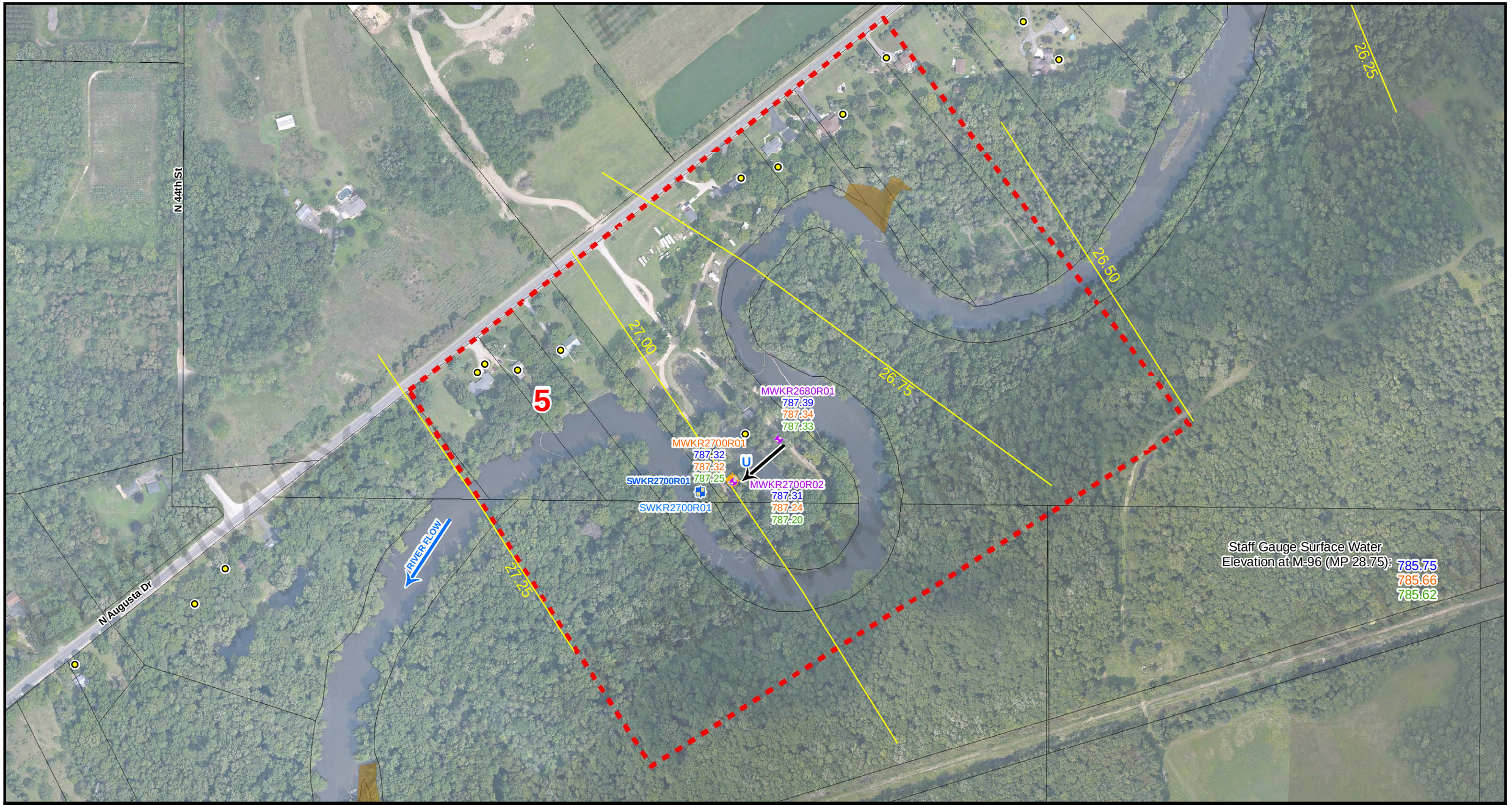
Water Elevation (Ft. above mean Sea Level)		Vertical Gradient	
18-Oct Event -	874.86	Upward	U
20-Oct Event -	874.92	Downward	D
22-Oct Event -	875.12	No Gradient	N

- Deep Monitoring Well
- Shallow Monitoring Well
- Staff Guage; Staff Gauge
- Surface Water Sample
- O&M SCAT Point
- Potable Well
- .25mile Grid Segments
- Historic Submerged Oil
- SCAT Area
- Target Area Boundary
- Groundwater Flow Direction

Figure: 6

GROUNDWATER ELEVATION, FLOW DIRECTION AND VERTICAL GRADIENT. TARGET AREA 4

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE MARSHALL, MI



ENBRIDGE

AECOM

October 2010

0 250 500

Scale in Feet

LEGEND:

Location ID - MWKR0250L01

Water Elevation (Ft. above mean Sea Level)		Vertical Gradient	
18-Oct Event -	874.86	Upward	U
20-Oct Event -	874.92	Downward	D
22-Oct Event -	875.12	No Gradient	N

- Deep Monitoring Well
- Shallow Monitoring Well
- Staff Guage
- Surface Water Sample
- O&M SCAT Point
- .25mile Grid Segments
- Historic Submerged Oil
- SCAT Area
- Target Area Boundary
- Groundwater Flow Direction

Figure: 7

GROUNDWATER ELEVATION, FLOW DIRECTION AND VERTICAL GRADIENT. TARGET AREA 5

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE MARSHALL, MI

ENBRIDGE

AECOM

October 2010

N

0 250 500

Scale in Feet

LEGEND:

Location ID - MWKR0250L01

Water Elevation (Ft. above mean Sea Level)

18-Oct Event - 874.86

20-Oct Event - 874.92

22-Oct Event - 875.12

Vertical Gradient

Upward U

Downward D

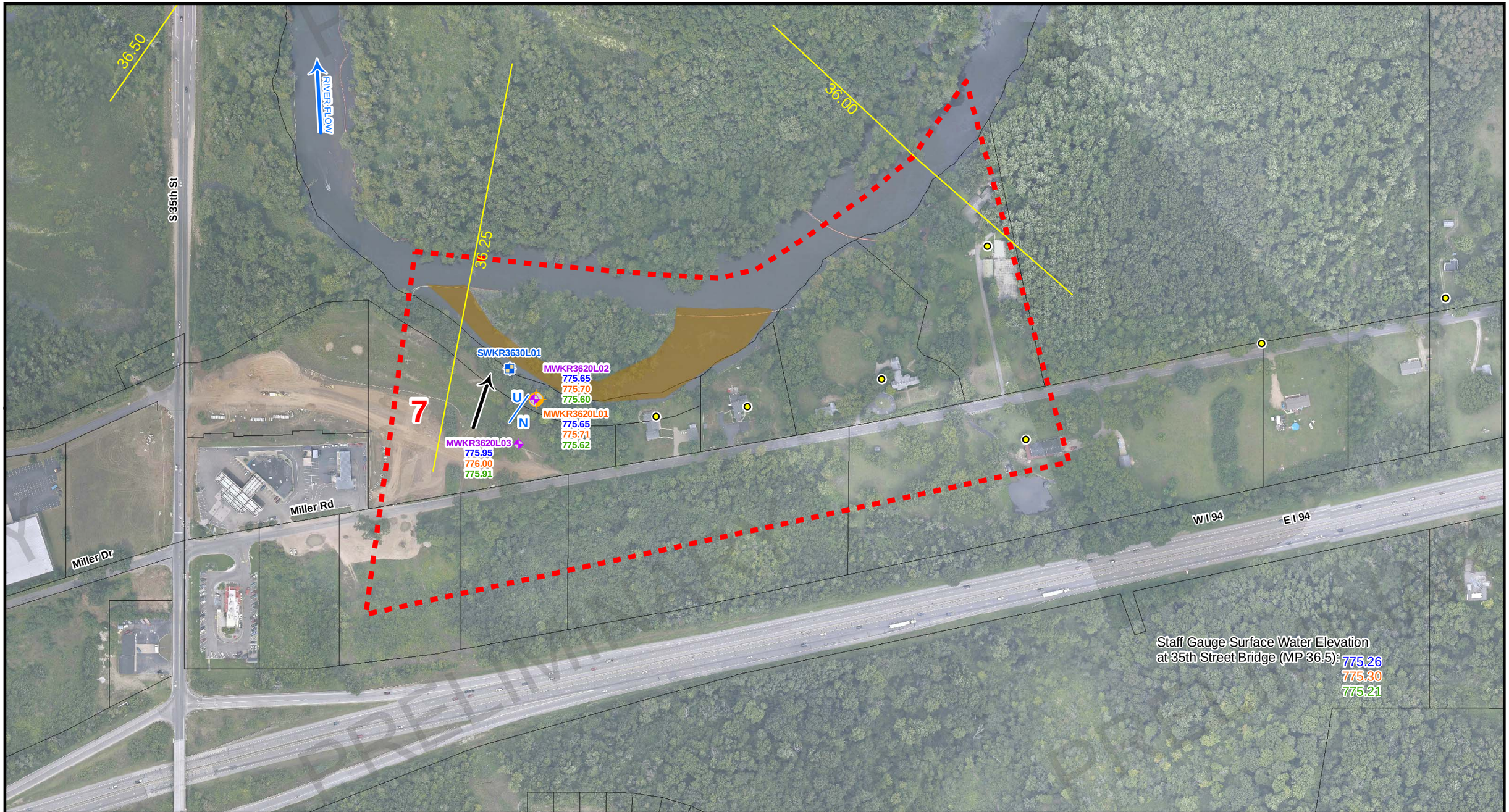
No Gradient N

- Deep Monitoring Well
- Shallow Monitoring Well
- Staff Gauge
- Surface Water Sample
- O&M SCAT Point
- Potable Well
- .25mile Grid Segments
- Target Area Boundary
- Historic Submerged Oil
- SCAT Area
- Groundwater Flow Direction

Figure: 8

GROUNDWATER ELEVATION, FLOW DIRECTION AND VERTICAL GRADIENT. TARGET AREA 6

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE MARSHALL, MI



ENBRIDGE

AECOM

October 2010

0 200 400

Scale in Feet

LEGEND:

Location ID - MWKR0250L01

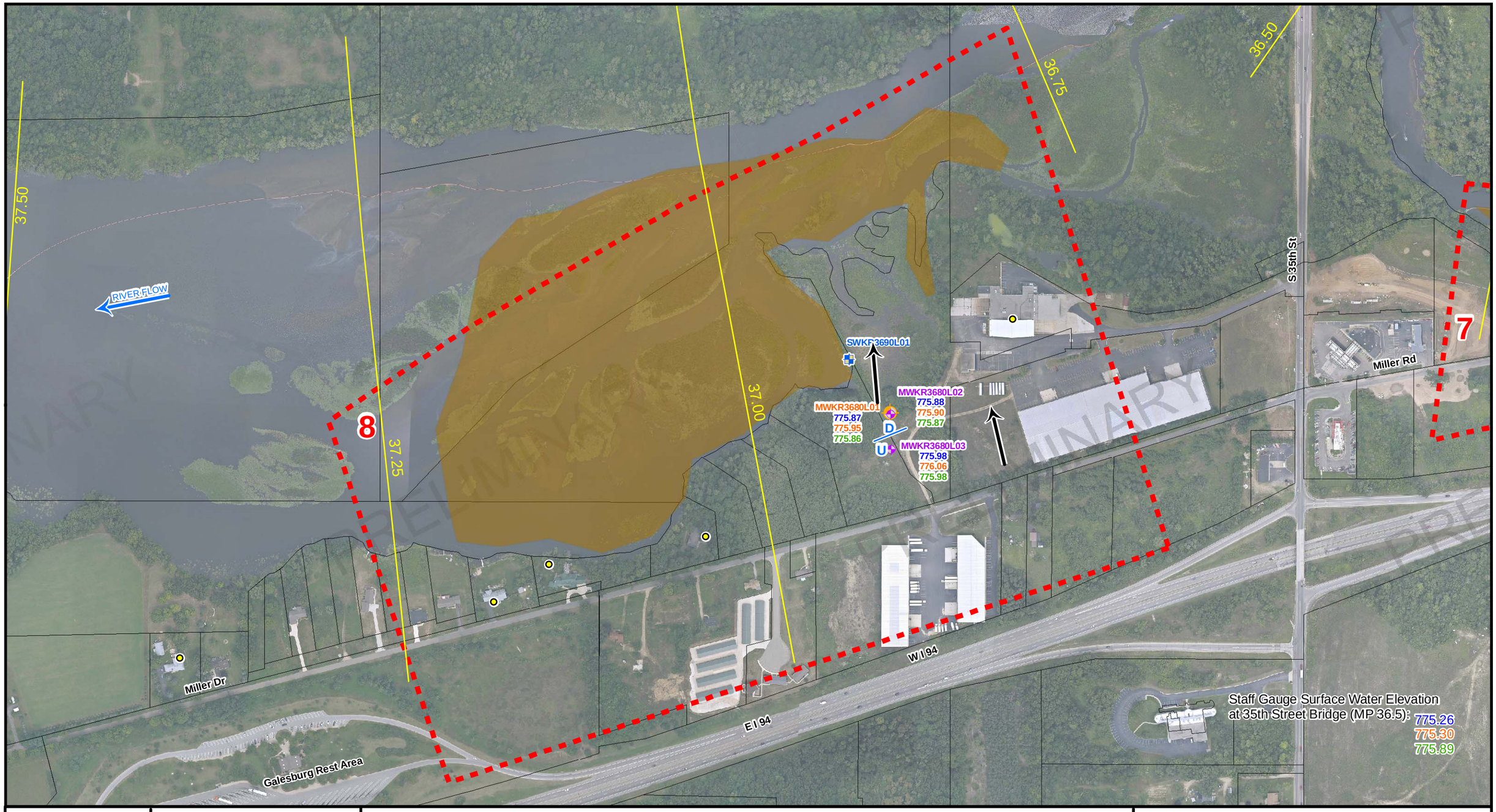
Water Elevation (Ft. above mean Sea Level)		Vertical Gradient	
18-Oct Event -	874.86	Upward	U
20-Oct Event -	874.92	Downward	D
22-Oct Event -	875.12	No Gradient	N

- Deep Monitoring Well
- Shallow Monitoring Well
- Staff Gauge
- Surface Water Sample
- O&M SCAT Point
- Potable Well
- .25mile Grid Segments
- Target Area Boundary
- Historic Submerged Oil
- SCAT Area
- Groundwater Flow Direction

Figure: 9

GROUNDWATER ELEVATION, FLOW DIRECTION AND VERTICAL GRADIENT. TARGET AREA 7

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE MARSHALL, MI



ENBRIDGE

AECOM

October 2010

0 265 530

Scale in Feet

LEGEND:

Location ID - MWKR0250L01

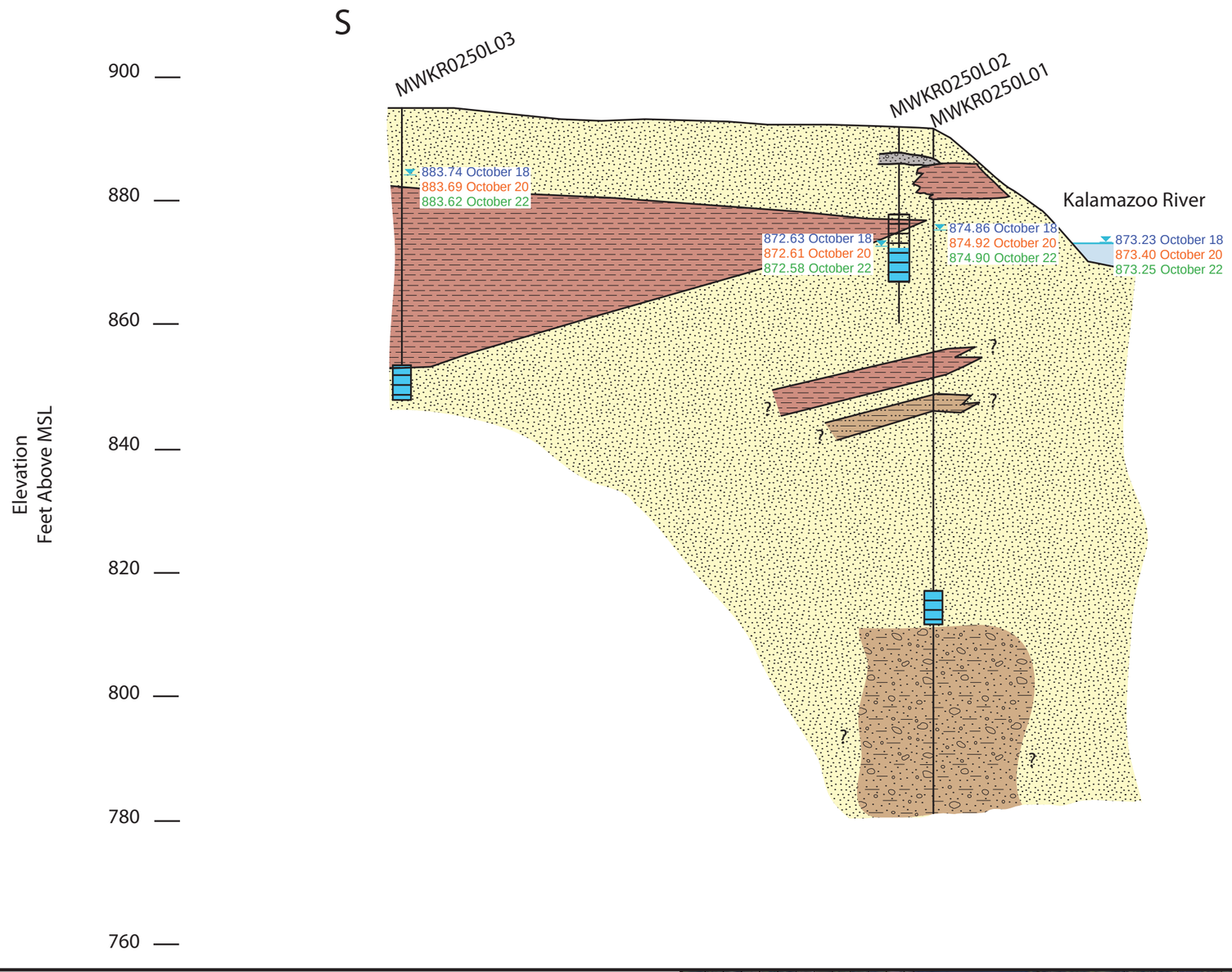
Water Elevation (Ft. above mean Sea Level)			Vertical Gradient	
18-Oct Event	-	874.86	Upward	U
20-Oct Event	-	874.92	Downward	D
22-Oct Event	-	875.12	No Gradient	N

- Deep Monitoring Well
- Shallow Monitoring Well
- Staff Guage
- Surface Water Sample
- O&M SCAT Point
- Potable Well
- .25mile Grid Segments
- TargetAreas
- Historic Submerged Oil
- SCAT Area
- Groundwater Flow Direction

Figure: 10

GROUNDWATER ELEVATION, FLOW DIRECTION AND VERTICAL GRADIENT. TARGET AREA 8

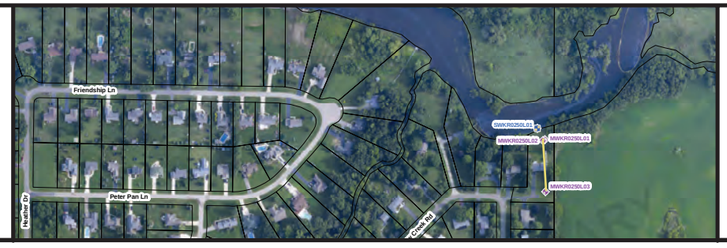
ENBRIDGE LINE 6B M 608 PIPELINE RELEASE
MARSHALL, MI



0 25 50
HORIZONTAL SCALE IN FEET

0 10 20
VERTICAL SCALE IN FEET
VERTICAL EXAGGERATION = 2.5X

Gravel
Sand
Silt
Clay
Sandstone
Silt (TILL)
Well Screen
Fill
Water Level



ENBRIDGE

AECOM

October 2010

Figure: 11

TARGET AREA 1
CROSS SECTION

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE
MARSHALL, MI

SW

NE

Elevation
Feet Above MSL

900
890
880
870
860
850
840
830

MWKR0580L03
MWKR0580L02
MWKR0580L01
MWKR0580R01
MWKR0580R02
MWKR0580R03

Kalamazoo River

-- October 18
868.56 October 20
868.57 October 22

864.31 October 18
864.27 October 20
864.22 October 22

863.36 October 18
863.32 October 20
863.25 October 22

863.55 October 18
863.52 October 20
863.43 October 22

867.00 October 18
866.95 October 20
866.90 October 22

868.25 October 18
868.25 October 20
868.25 October 22

866.59 October 18
866.59 October 20
866.58 October 22

ENBRIDGE

AECOM

October 2010

0 50 100
HORIZONTAL SCALE IN FEET

0 5 10
VERTICAL SCALE IN FEET
VERTICAL EXAGGERATION = 10X

Gravel
Sand
Silt
Clay
Sandstone
Silt (TILL)
Well Screen
Fill
Water Level

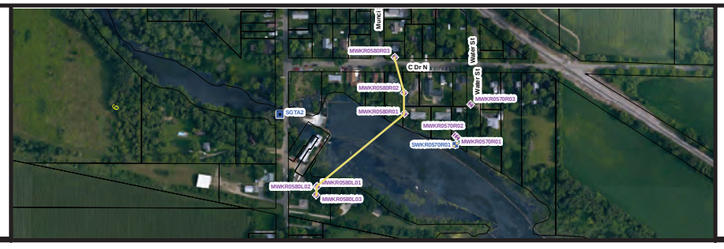


Figure: 12

TARGET AREA 2
CROSS SECTION-A

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE
MARSHALL, MI

W

E

Elevation
Feet Above MSL

900
890
880
870
860
850
840
830

MWKR0580R03

MWKR0580R02

MWKR0580R01

MWKR0570R01

MWKR0570R02

866.59 October 18
866.59 October 20
866.58 October 22

868.25 October 18
868.25 October 20
868.25 October 22

867.00 October 18
866.95 October 20
866.90 October 22

867.85 October 18
867.80 October 20
867.75 October 22

867.96 October 18
867.91 October 20
867.84 October 22

0 50 100
HORIZONTAL SCALE IN FEET

0 5 10
VERTICAL SCALE IN FEET
VERTICAL EXAGGERATION = 10X

Gravel
Sand
Silt
Clay
Sandstone
Silt (TILL)
Well Screen
Fill
Water Level

ENBRIDGE

AECOM

October 2010

Figure: 13

TARGET AREA 2
CROSS SECTION-B

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE
MARSHALL, MI

W

E

850

830

810

790

770

750

730

710

Kalamazoo River

825.99 October 18
825.95 October 20
825.96 October 22

MWK1525R01
MWK1525R02
MWK1525R03

823.19 October 18
823.15 October 20
823.06 October 22

823.24 October 18
823.24 October 20
823.31 October 22

823.19 October 18
823.15 October 20
823.06 October 22

ENBRIDGE

AECOM

October 2010

0 50 100
HORIZONTAL SCALE IN FEET

0 10 20
VERTICAL SCALE IN FEET
VERTICAL EXAGGERATION = 5X

Gravel
Sand
Silt
Clay
Sandstone
Silt (TILL)
Well Screen
Fill
Water Level

Figure: 14

TARGET AREA 3
CROSS SECTION

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE
MARSHALL, MI

NW

SE

MWKR2275R01

MWKR2260R01

MWKR2260R02

820

810

800

790

780

770

760

750

799.24 October 18
799.21 October 20
799.19 October 22

798.86 October 18
798.84 October 20
798.82 October 22

796.89 October 18
796.87 October 20
796.84 October 22

Kalamazoo River

795.99 October 18
795.94 October 20
795.92 October 22

?

?

ENBRIDGE

AECOM

October 2010

0 12.5 25
HORIZONTAL SCALE IN FEET

0 5 10
VERTICAL SCALE IN FEET
VERTICAL EXAGGERATION = 5X

Gravel

Sand

Silt

Clay

Sandstone

Silt (TILL)

Well Screen

Fill

Water Level

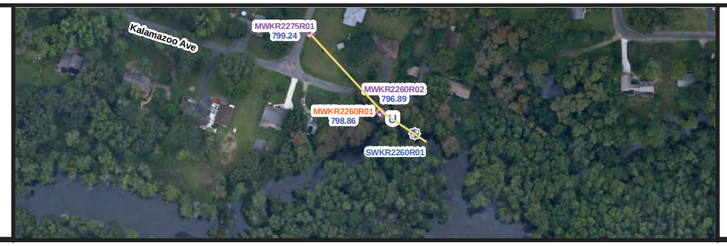


Figure: 15

TARGET AREA 4
CROSS SECTION

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE
MARSHALL, MI

SW

NE

800

790

780

770

760

750

Kalamazoo River

785.75 October 18
785.66 October 20
785.62 October 22

MWKR2700R01
MWKR2700R02

787.32 October 18
787.32 October 20
787.25 October 22

787.31 October 18
787.24 October 20
787.20 October 22

MWKR2680R01

787.39 October 18
787.34 October 20
787.33 October 22

Kalamazoo River

785.75 October 18
785.66 October 20
785.62 October 22

0 25 50
HORIZONTAL SCALE IN FEET

0 5 10
VERTICAL SCALE IN FEET
VERTICAL EXAGGERATION = 5X

Gravel
Sand
Silt
Clay
Sandstone
Silt (TILL)
Well Screen
Fill
Water Level

ENBRIDGE

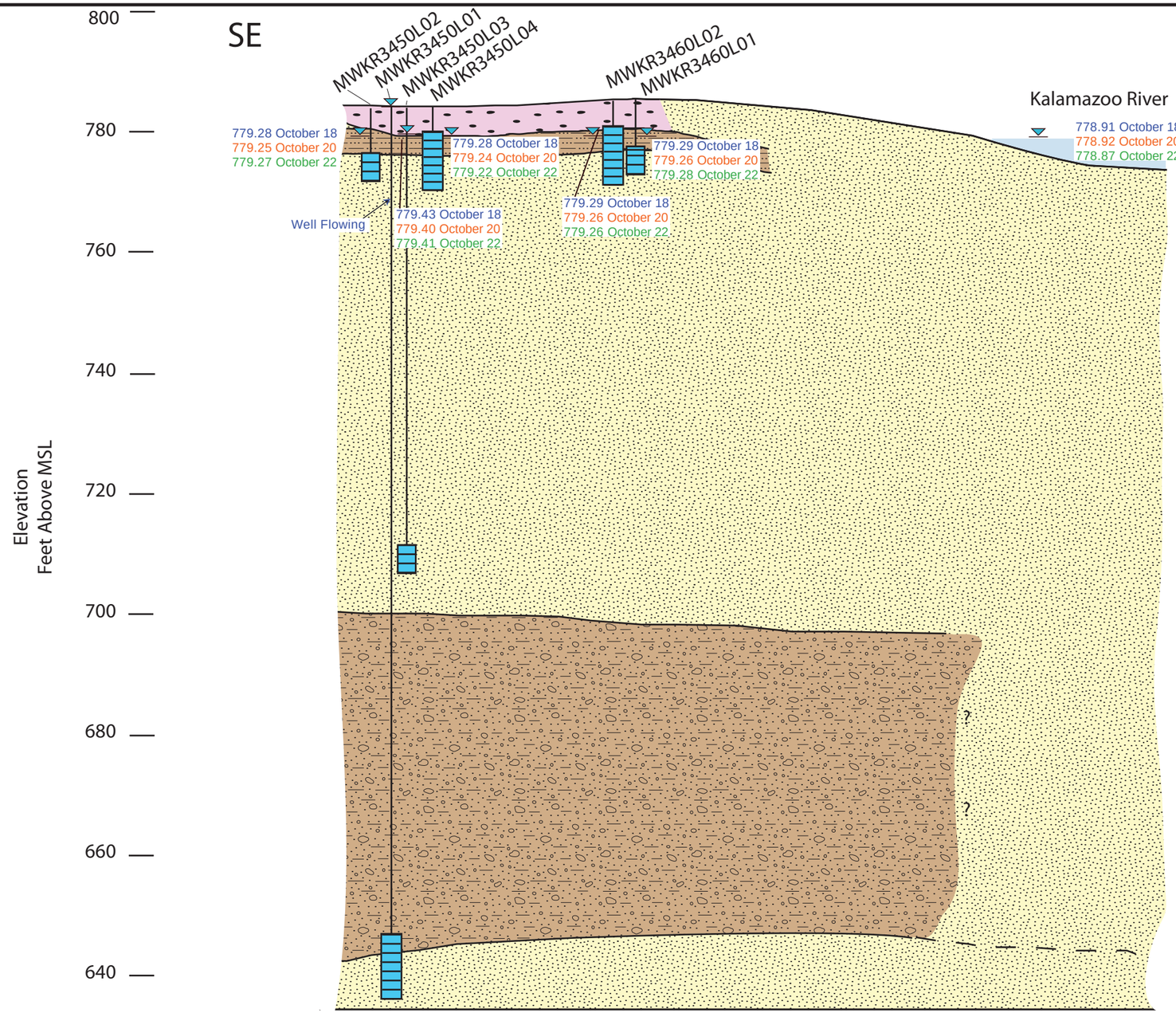
AECOM

October 2010

Figure: 16

TARGET AREA 5
CROSS SECTION

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE
MARSHALL, MI



ENBRIDGE

AECOM

October 2010

0 25 50
HORIZONTAL SCALE IN FEET

0 10 20
VERTICAL SCALE IN FEET
VERTICAL EXAGGERATION = 2.5X

Gravel
Sand
Silt
Clay
Sandstone
Silt (TILL)
Well Screen
Fill
Water Level

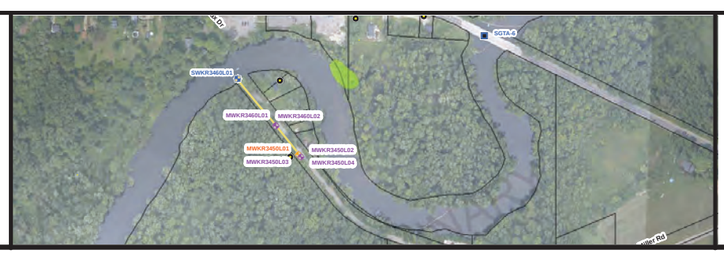
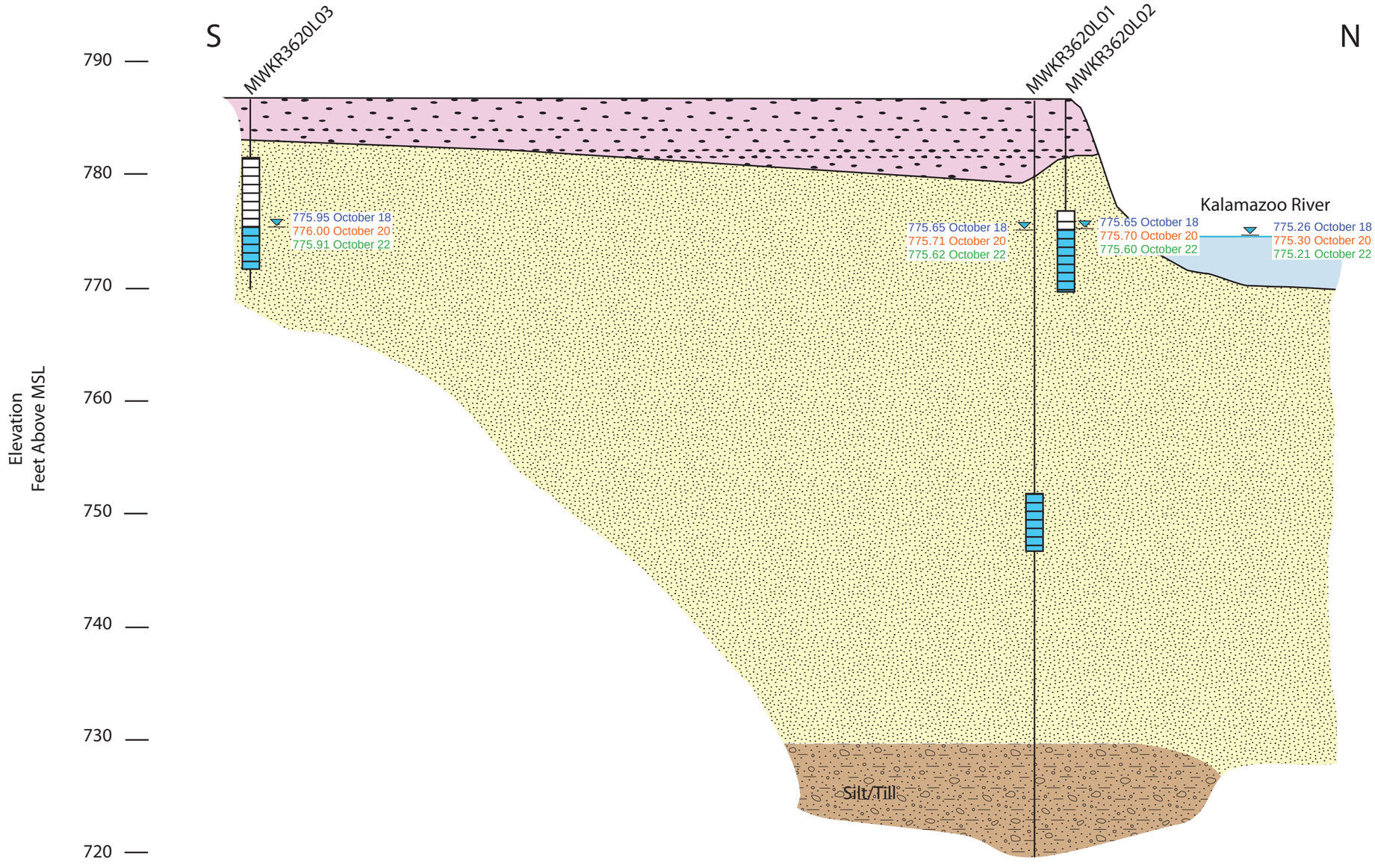


Figure: 17

TARGET AREA 6
CROSS SECTION

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE
MARSHALL, MI



ENBRIDGE

AECOM

October 2010

0 12.5 25
HORIZONTAL SCALE IN FEET

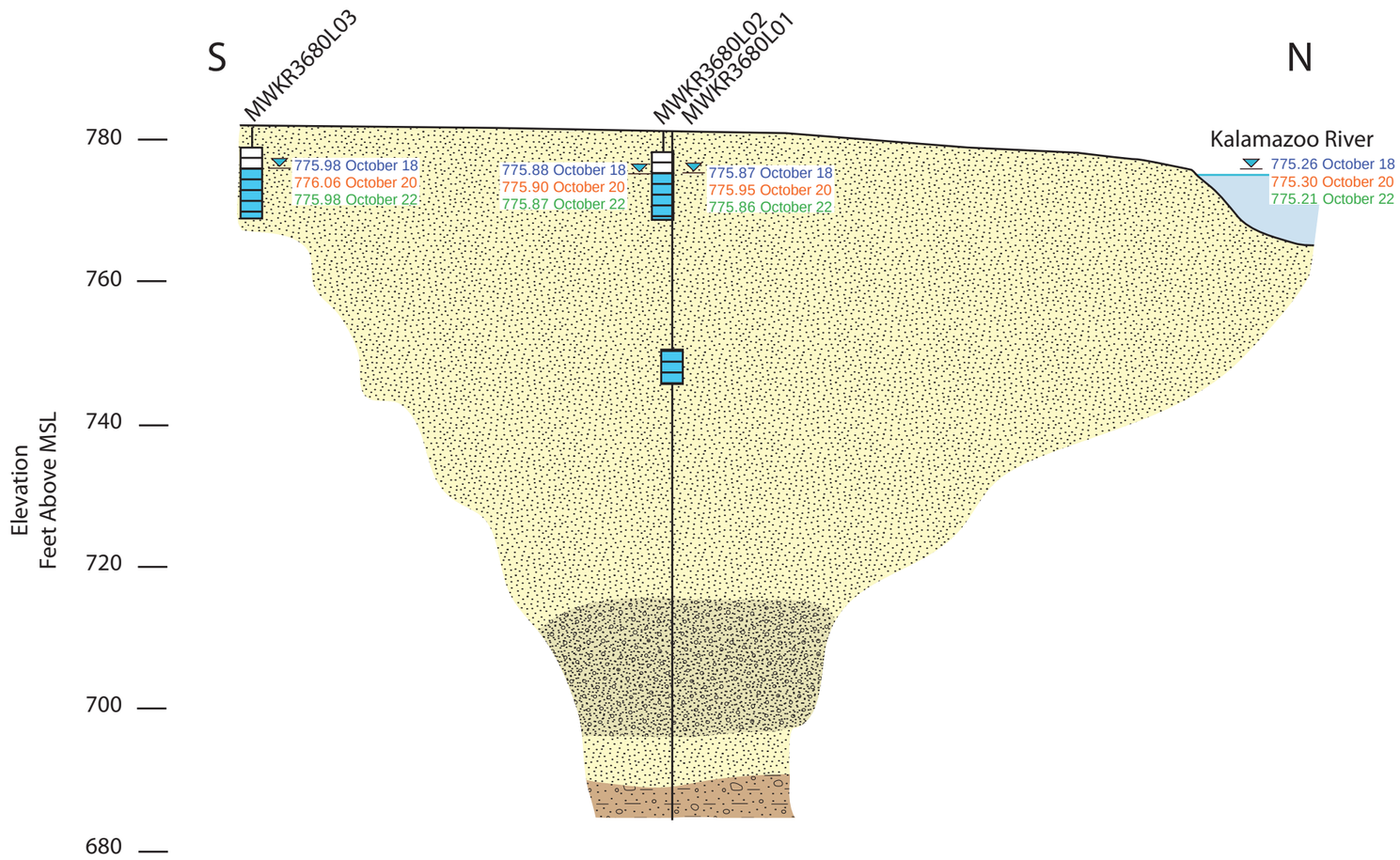
0 5 10
VERTICAL SCALE IN FEET
VERTICAL EXAGGERATION = 5X

Gravel
Sand
Silt
Clay
Sandstone
Silt (TILL)
Well Screen
Fill
Water Level

Figure: 18

TARGET AREA 7
CROSS SECTION

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE
MARSHALL, MI



ENBRIDGE

AECOM

October 2010

0 25 50
HORIZONTAL SCALE IN FEET

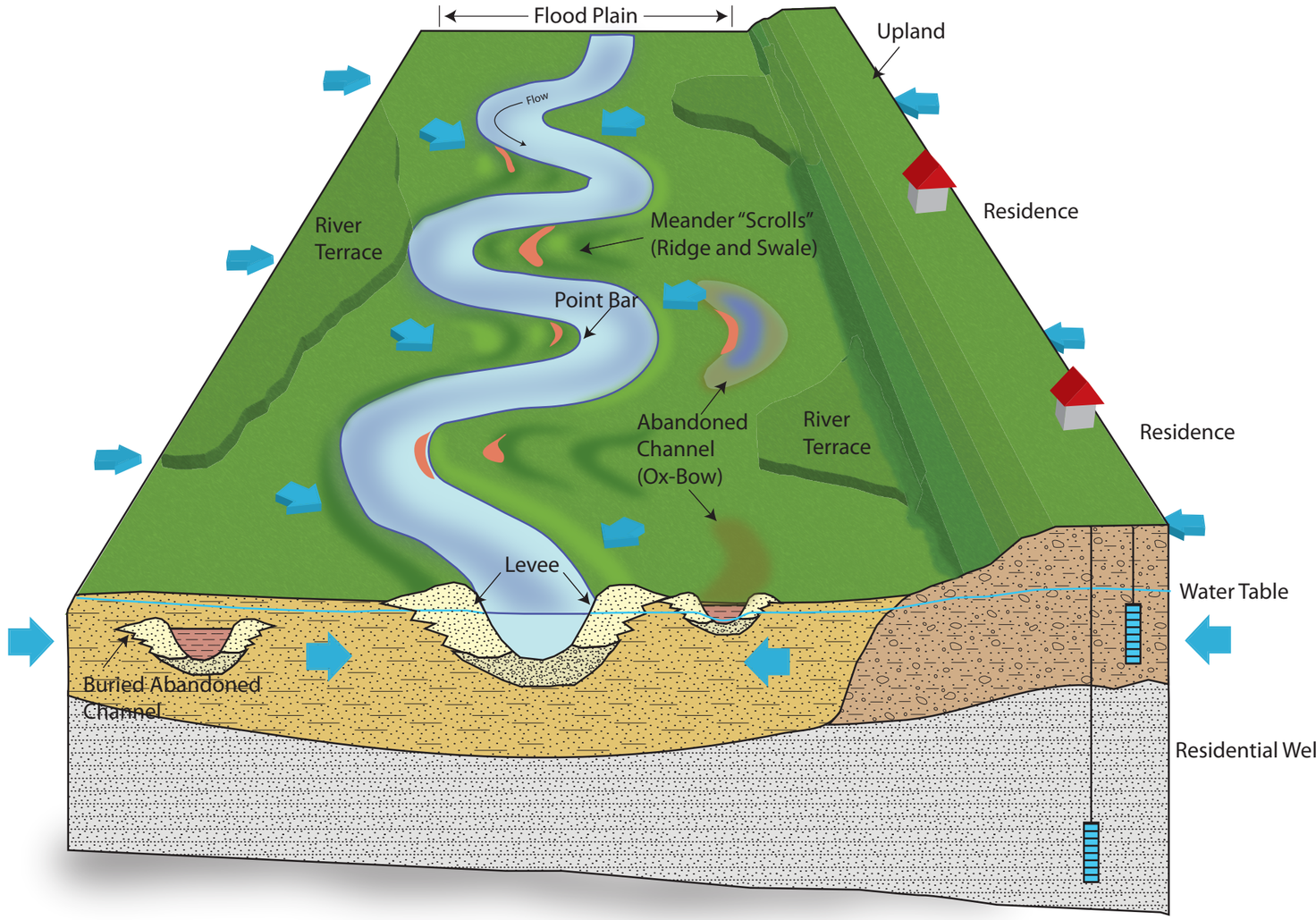
0 10 20
VERTICAL SCALE IN FEET
VERTICAL EXAGGERATION = 2.5X

Gravel
Sand
Sand and Gravel
Clay
Sandstone
Silt (TILL)
Well Screen
Fill
Water Level

Figure: 19

TARGET AREA 8
CROSS SECTION

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE
MARSHALL, MI



Based on: Fitzpatrick, F.A., Knox, J.C., and Whitman, H.E., 1999, The Effects of historical land-cover changes on flooding and sedimentation, North Fish Creek, Wisconsin: U.S. Geological Survey Water Resources Investigations Report 99-4083, 12 p.

ENBRIDGE

AECOM

October 2010

Gravel
Silty Sand
Well Screen
SCAT Area, Historic Submerged Oil and Overbank Areas
Sand
Clay
Silty Till
Sand and Gravel
Sandstone
Groundwater Flow

Figure: 20

Conceptual Site Model

ENBRIDGE LINE 6B M 608 PIPELINE RELEASE
MARSHALL, MI