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Lambert Creek Bacterial Source Identification Study

Draft Monitoring Plan

VLAWMO
Vadnais Lake Area
Water Management Organization

Vadnais Lake Area Water Management Organization

March 2017

Lambert Creek Bacterial Source Identification Study

Draft Monitoring Plan

prepared for

Vadnais Lake Area Water Management Organization

Vadnais Heights, MN

March 2017

prepared by

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LIST OF ABBREVIATIONS

Abbreviation	Term/Phrase/Name
bgs	Below ground surface
BMcD	Burns & McDonnell
BMP	Best management practice
BMU	Burns & McDonnell University
CCTV	Closed circuit television
COC	Chain of Custody
DTG	Depth to groundwater
EPA	US Environmental Protection Agency
MCA	Microbial community analysis
MS4	Municipal separate storm sewer system
QA/QC	Quality Assurance / Quality Control
qPCR	Quantitative polymerase chain reaction
SOP	Standard Operating Procedures
TMDL	Total maximum daily load
VLAWMO	Vadnais Lake Area Water Management Organization

1.0 INTRODUCTION

Lambert Creek is located in the northeast Twin Cities Metropolitan Area of Minnesota in the Upper Mississippi River Basin. The Lambert Creek Watershed covers an area of approximately 25 square miles and includes portions of the Cities of North Oaks, White Bear Lake, Gem Lake, Vadnais Heights, Lino Lakes, and White Bear Township, Minnesota. The watershed falls within the jurisdiction of the Vadnais Lake Area Water Management Organization (VLAWMO) and consists of a mix of urban, open space, parks, and agricultural land uses. A map of the Lambert Creek Watershed is shown in Figure 1-1.

Lambert Creek does not currently meet Minnesota state standards for the indicator bacteria *Escherichia coli* (*E. coli*) and has been placed on the state's 303(d) List of Impaired Water Bodies. As a result, in August 2013, the Minnesota Pollution Control Agency (MPCA) developed a total maximum daily load (TMDL) for *E. coli* in Lambert Creek (Wenck, 2013), which is the total amount of a pollutant that a water body can assimilate without exceeding the established water quality standard for that pollutant.

In response to the TMDL, VLAWMO contracted Burns and McDonnell Engineering, Inc. (Burns & McDonnell) to conduct a bacterial source identification study to identify the sources of *E. coli* in the Lambert Creek Watershed and recommend best management practices (BMPs) that can be implemented to meet the load reduction requirements of the TMDL. This document is the Monitoring Plan that will be used to conduct the source identification study.

1.1 Project Objectives

The Lambert Creek Watershed encompasses the following five contiguous drainages, each with a Primary Monitoring Site at its base: Whitaker, Goose, Oakmede, Country Road F, and Koehler (Figure 1-1). This document provides the Wet Weather Monitoring Plan for two drainages in the watershed: the Goose Drainage, and the Whitaker Drainage. Dry weather assessments were conducted for both the Goose and Whitaker drainages in 2015. Although the TMDL requires bacterial load reductions during both dry and wet weather, this phase of the Source Identification Study will exclusively assess sources during wet weather events (defined for the sake of this plan as approximately 0.25-0.50 inches of precipitation during a 3-hour period).

1.2 Project Team

The Monitoring Plan has been produced by Burns & McDonnell staff for use by staff from VLAWMO, who will conduct the field assessments for the study and coordinate the required laboratory analyses.

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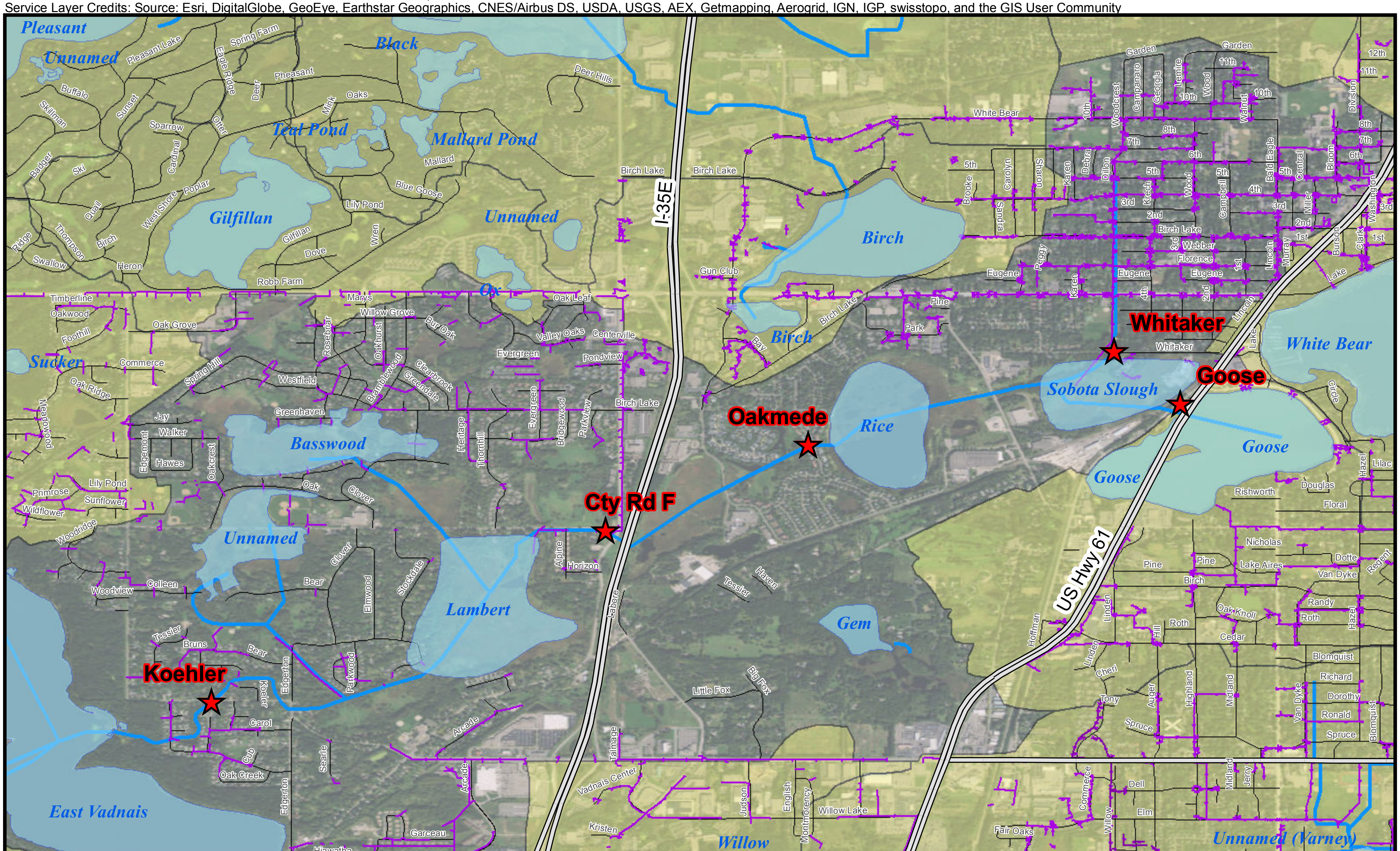
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



Legend

- Sample Sites
- Watersheds Level 8 HUCs
- Drainage Data
- Streams

NORTH

3,000 1,500 0 3,000

Scale in Feet

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Figure 1-1
Lambert Creek Watershed
and
Five Primary Monitoring Sites

Source: USGS; VLAWMO

Issued: 4/6/2017

2.0 STUDY DESIGN

The study design used in this Monitoring Plan to conduct the Source Identification Study for Lambert Creek is based on similar studies conducted in other regions of the country for identifying sources of indicator bacteria in urban watersheds. The Monitoring Plan is based on three design approaches that have been shown to be effective in identifying sources of bacteria in urban watersheds throughout the country (see SCCWRP, 2013). The study design will be 1) Phased, 2) Tiered, and 3) Adaptive. Each of these design approaches is described briefly below.

2.1 Phased Approach

The Lambert Creek Watershed encompasses approximately 25 square miles (Wenck, 2013), consisting of a diverse mix of urban, open space, and recreational land uses intermixed with numerous creeks, wetlands, and lakes. The TMDL requires that the water quality standards for *E. coli* are met at all monitoring locations within the watershed during both dry and wet conditions. In order to identify the sources of bacteria in this diverse watershed, the study was phased to focus first on dry weather conditions (at least 72 hours following precipitation). Dry weather assessments were conducted for the Oakmede and County Road F drainages in 2014 and the Whitaker and Goose drainages in 2015. In 2016, a wet weather assessment was conducted for the Oakmede and County Road F drainages. The design of the 2017 wet weather assessment will be based on the results of the 2015 dry weather assessment conducted for the Goose and Whitaker drainages.

2.2 Tiered Approach

The Tiered Approach uses a step-wise process of assessing the watershed and identifying sources of bacteria in a prioritized, progressive process. The wet weather assessment for the Goose and Whitaker drainages will be implemented in the sequence described below to focus the assessment on high priority sources of bacteria first, followed by additional steps as the study progresses. A similar study design will be used to identify bacterial sources in the other drainages within the watershed in future iterations of the Monitoring Plan. This tiered approach has been developed from similar monitoring programs (SCCWRP, 2013) with elements specific to the Lambert Creek Watershed.

The 2017 Monitoring Plan will be implemented according to the following tiered steps:

1. Characterize the drainages (Goose and Whitaker) by using infrastructure maps and conducting visual inspections during a site reconnaissance to develop a list of potential locations that may influence bacterial concentrations at the primary monitoring sites during wet weather (e.g.,

stormwater retention ponds, outfalls from urbanized catchments, ephemeral streams that may flow only during storm events, sheet flow from large grassy areas, inlets into perennial wetlands).

2. Based on the characterization, develop a list of Study Questions to be addressed by the assessment that are specific to the conditions within that drainage.
3. Conduct pollutograph monitoring (see definition below) at various sampling locations (including primary monitoring sites) to characterize how bacteria concentrations change over the course of a storm event.
4. Collect spot samples during wet weather events at secondary monitoring locations identified during the field reconnaissance and the dry weather assessment.
5. Collect samples for molecular analyses for human and wildlife genetic markers to help identify sources of elevated bacterial concentrations.
6. Based on findings from the pollutograph and spot sampling, design and implement special studies to identify bacterial sources that may contribute bacteria to the receiving waters during storm events.

The basic steps listed above have been modified to meet the specific characteristics of the Goose and Whitaker drainages (Sections 5 and 6 below). Future iterations of the Monitoring Plan will use this same process to develop specific step-wise investigation elements for other drainages in the Lambert Creek Watershed.

2.3 Adaptive Approach

Source identification studies can be difficult to conduct due to the ubiquitous nature of bacteria in the environment, the multiple sources within a given watershed, and the potential for regrowth of bacteria outside the host animal. For these reasons, source identification studies often do not lend themselves to prescriptive monitoring plans where the details of each monitoring element are determined prior to the initiation of the study. Instead, the most effective source identification studies rely on a basic monitoring framework with elements developed from the tiered approach discussed above. The details of each monitoring element are adaptive, whereby the results of the first element are used to focus the design for subsequent elements in the study. The adaptive approach allows the design of each element of the study to be built upon the results of the previous element, resulting in an increasingly focused approach to identifying the sources of bacteria in the drainage. The end result is a comprehensive and efficient assessment of potential bacterial sources in the drainage, leading to multiple lines of evidence for identifying those sources that have the greatest impact on water quality. These results also allow for focused recommendations on the most effective and efficient BMPs to remediate the bacterial source.

In this Monitoring Plan, study elements have been developed specifically for the Goose and Whitaker drainages and basic monitoring schedules for wet weather monitoring have been provided to answer the drainage-specific Study Questions. When the results from the initial assessments have been analyzed, additional details will be provided for subsequent monitoring. This adaptive approach will maximize the efficiency of limited resources to conduct the study and produce a focused assessment of the sources of *E. coli* in each drainage.

3.0 SAMPLING AND ANALYSIS PROCEDURES

The sampling and analysis procedures that will be used over the course of the study are discussed below.

3.1 Pollutograph Analysis

A pollutograph is a means of depicting the changes in concentrations of a pollutant over the course of a storm event. It is created by plotting the stream hydrograph from the beginning to the end of a storm event. Samples are collected over the course of the storm event (ascending limb, peak, and descending limb of the hydrograph) and the pollutant concentrations are plotted at the time they were collected on the hydrograph. In this way, changes in the pollutant concentrations can be seen as the creek rises, peaks, and falls (as depicted in the hydrograph). Pollutographs can be very helpful in identifying pollutant sources by helping to elucidate when the pollutant enters the receiving waters. They can also be helpful in designing BMPs to reduce pollutant concentrations and loads in the receiving waters because they demonstrate the capacity of the BMP needed to reduce a given load (e.g., as required for TMDLs). An example of a pollutograph is presented on Figure 3-1.

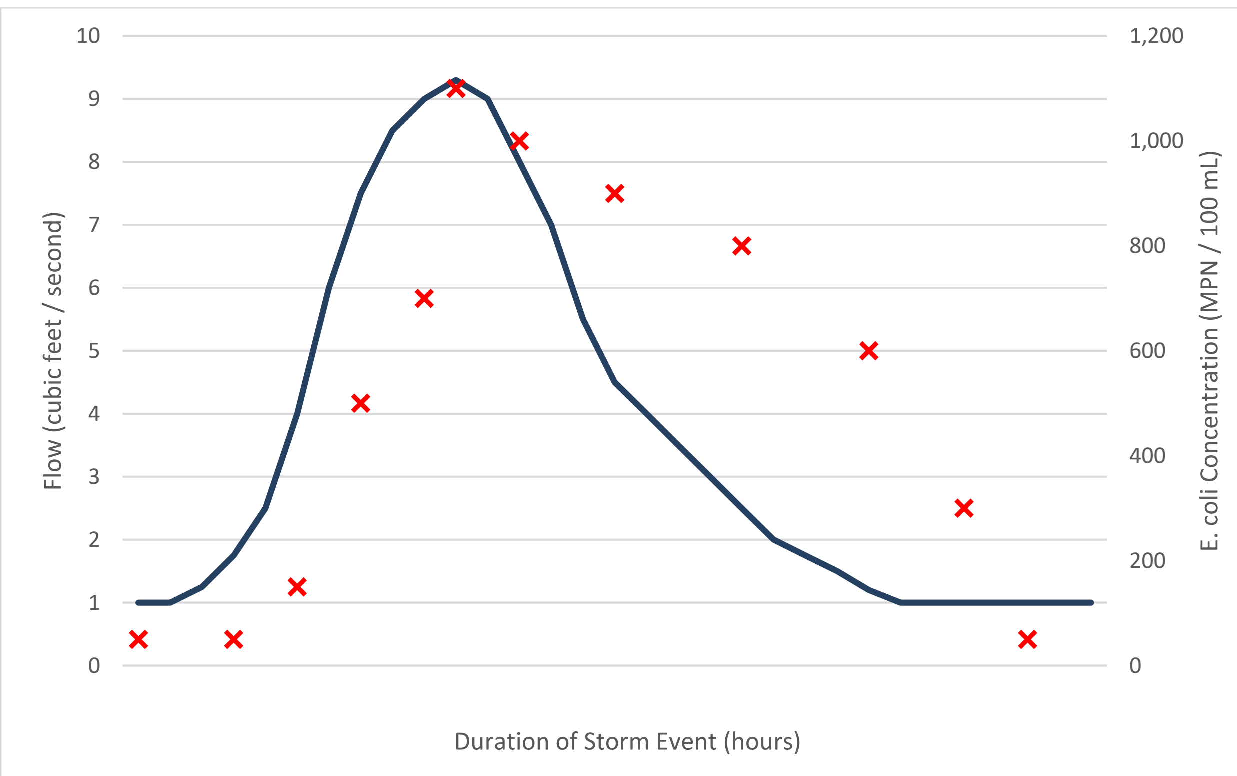

Figure 3-1. Example of a Pollutograph (not based on actual data)

3.2 Flow Monitoring

Flow will be monitored during wet weather events at three sites within the Goose Drainage and five sites within the Whitaker Drainage. The primary monitoring site at the Whitaker Drainage has an established weir with a staff gage already installed. At the other seven locations within both drainages, instantaneous flow will be measured periodically throughout the course of the storm with a Marsh McBirney velocity meter. Flow at each monitoring site will be converted to flow volume using the Manning Equation and known physical dimensions of the creek/culvert at each sampling location. Flow data will be plotted against time for the duration of the storm to produce a hydrograph for each site. Ideally, flow data from at least two storm events (0.25-0.50 inches in less than 3 to 4 hours) will be recorded in this way.

3.3 Visual Observations

Visual observations are a critical component to bacterial source tracking investigations. They provide a direct means of assessing potential anthropogenic and non-anthropogenic bacterial inputs that are often unanticipated or over-looked when a project is designed. In this study, visual observations will be made at each site during every field visit on a Visual Observation Form designed for the Lambert Creek Watershed (see Appendix B). The Visual Observation form contains information for each site visited, including weather, drainage and assessment location, site conditions, evidence of human bacterial sources, evidence of non-human bacterial sources, and evidence of flow or other transport mechanism. Digital photographs of site conditions and suspected bacterial sources will be taken at all sites over the course of each monitoring event to correspond to the visual observations form.

3.4 Sample Collection for Culture Analyses

Grab samples of water will be collected at each sampling location from the center of the channel or storm drain (as applicable). Samples will be collected in sterile, EPA-approved bottles containing sodium thiosulfate (to counteract any chlorine that may be present in the water). Sample containers will be kept in clear Ziploc® bags until use. Just prior to sampling, the bag and sample container will be opened, with both container and lid held face-down to prevent airborne contamination. The bottle will be filled and capped. No sediment or debris will be allowed to enter the sample bottle.

Each field sample will be labeled and identified with the project title, appropriate identification number, the date and time of sample collection, and preservation method. The sample container will then be sealed in the Ziploc® bag. All samples will be stored on ice in the dark from the time of sample collection until delivery to the analytical laboratory. All samples will be delivered to the laboratory in time to meet the required 6-hour holding time.

To verify proper sampling technique, field blanks will be collected at a rate of 5% of the overall samples per field event. Field blanks will be collected using the sampling technique described above except that reagent grade, nuclease-free water will be substituted for the water sample.

For pollutograph monitoring, it is anticipated that six to eight samples will be collected per site over the course of each storm event. Samples will be collected over the course of the storm with the goal of collecting samples during the ascending limb, peak, and descending limb of the hydrograph. The field team will monitor the weather forecast to look for storms that are forecast to drop 0.25 to 0.50 inches of rain over a three to four hour duration. This size and intensity of a storm will provide the best opportunity to generate a discrete hydrograph that is sufficiently long enough to produce flow representative of the entire drainage and short enough to allow for the creek to rise, peak, and fall within a reasonable period of time for the field work to be completed.

3.5 Sample Collection for Molecular Analyses

Field collection procedures for samples that will be analyzed for genetic markers (human or non-human) are detailed in the Standard Operating Procedures (SOP) for the Collection, Storage, and Transport of Samples for Molecular Analysis in Appendix C.

3.6 Laboratory Analyses for Culture Samples

Samples collected for culture analysis will be analyzed by the Saint Paul Regional Water Service (SPRWS) in Saint Paul, Minnesota. All samples collected for culture analysis will be analyzed by Method SM 9223B (Colilert® Quanti-Tray®)-97. The SPRWS is accredited for this analysis under the Safe Drinking Program.

3.7 Laboratory Analyses for Molecular Samples

The samples collected for molecular analyses will be filtered by staff at the Ramsey County Department of Public Works following the protocols described in Appendix D. The processed filters will be shipped to Weston Solutions in Carlsbad, California following the protocols in Appendix D. Laboratory analyses for the human and non-human (*e.g.,* avian and canine) genetic markers (Human Marker and Non-human Marker, respectively) will follow the protocols for quantitative polymerase chain reaction (qPCR) assays described in SCCWRP, 2013.

4.0 SAMPLE HANDLING AND TRACKING

Each sample collected over the course of the study will receive a unique alphanumeric code (sample I.D. number) for tracking. This code will be standard for all samples and contain information as to the monitoring site, sample date, and sample interval number or sequential monitoring event number (as appropriate). Site names identified in the drainage maps provided for the five drainages in the Lambert Creek Watershed (see Sections 5 through 9) will be used to form the first part of the Sample ID, followed by the date of sample collection, and interval or monitoring event number (as appropriate). For example, a sample collected at the Goose Sub-drainage A2 site on June 1, 2017 would have a sample ID number of: Gos-A2-060117. If additional samples are collected in Sub-drainage A, they will be identified as Gos-A2-060117-2. The location should be clearly identified on the Visual Observation forms and photos should be taken for future reference.

Samples will be kept properly chilled and transferred to the analytical laboratory within holding times to achieve the highest quality data possible. To ensure proper tracking and handling of the samples, documentation will accompany the samples from the initial pickup to the final extractions and analysis. This documentation will be in the form of Chain-of-Custody Forms (provided by VLAWMO and/or participating laboratories). These forms, or equivalent, will be used to track and handle samples. All samples collected will be labeled with the following information:

- Project name
- Date
- Time
- Sampling location name and number
- Preservative
- Collector's initials
- Sample I.D. number
- Analyte(s) to be analyzed

Completed COC forms will be placed in a plastic envelope and kept inside the container containing the samples. Once delivered to the laboratory, the COC form will be signed by the person receiving the samples. The condition of the samples will be noted and recorded by the receiver. COC records will be included in the final reports prepared by the analytical laboratories.

Upon delivery to the laboratory, the laboratory manager will inspect the condition of the samples and reconcile the label information to the COC form. The time of sample collection will be noted and the samples will be stored at the appropriate temperature until analysis is begun, always within the six-hour holding time limitation.

Upon completion of analyses, any remaining sample material will be stored until the holding time expires. At that point, samples will be disposed of.

5.0 GOOSE DRAINAGE

5.1 Review of Existing Information

The Goose Drainage lies south of the Whitaker Drainage and is the smallest of the five drainages in the Lambert Creek Watershed (Figure 1-1). The Drainage is dominated by Goose Lake, which is bisected by US Highway 61, forming East Goose Lake and West Goose Lake (Figure 5-1). The Primary Monitoring Site for the Goose Drainage (Gos-P) lies at the northern end of West Goose Lake. The main inputs into West Goose Lake are from two culverts that extend under Highway 61 and connect West Goose Lake to East Goose Lake (Sites Gos-A1, A2, A3, and A4). In addition, there is a storm drain outfall at the southern end of West Goose Lake that discharges to a small forebay (Site Gos-A5). During the site reconnaissance conducted in May 2014, it was observed that very warm water was flowing from the outfall into the forebay. VLAWMO staff indicated that flows from this outfall were from a permitted discharger just upstream of the outfall. Water in this drainage flows west from East Goose Lake to West Goose Lake (through the two culverts identified above), then north toward the Primary Monitoring Site.

A potential source of *E. coli* that was observed during the site reconnaissance was the canal that discharges to the south side of East Goose Lake. Large grassy areas that go directly to the water's edge are a likely source of bacteria to the canal, which may be transported to West Goose Lake via the southern culvert (Figure 5-1). During the site reconnaissance, several geese were observed along the grassy banks of the canal and large amounts of fecal matter were observed on the grass.

Geese along canal that discharges to East Goose Lake

In addition, there is a restaurant and bar along the northern end of West Goose Lake along the western shore called Don's Little Bar. In the rear of the bar is a grassy bank where geese and goose fecal material were observed during the site reconnaissance. This is a potential source of *E. coli* at the Primary Monitoring Site, which is located approximately 400 feet to the North.

Goose fecal matter along grassy bank at Don's Little Bar on West Goose Lake

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Legend

- Primary Monitoring Site
- Secondary Monitoring Site
- Drainage Data
- Streams

NORTH

680 340 0 680

Scale in Feet

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Figure 5-1
Goose Drainage
Monitoring Sites

Source: USGS; VLAWMO

Issued: 4/6/2017

5.2 Monitoring Locations

Site selection for the bacterial source identification in the Goose Drainage was based on historical data available for the drainage and the results of the site reconnaissance conducted throughout 2014, 2015, and the spring of 2016. The monitoring sites are shown graphically on Figure 5-1and described in Table 5-1.

Table 5-1. Monitoring site IDs, locations, and drainage area descriptions for the Goose Drainage

Site ID	Site Name / Sample Location	Site Drainage Description
Gos-P	Primary Monitoring Site at North end of West Goose Lake	The entire Goose Drainage
Gos-A1	In front of entrance to culvert at northern end of East Goose Lake, which conveys water to West Goose Lake	Inflow from northern portion of East Goose Lake
Gos-A2	In front of exit to culvert at northern end of West Goose Lake, which receives water from East Goose Lake	Outflow from culvert that conveys flow from northern portion of East Goose Lake
Gos-A3	In front of entrance to culvert at southern end of East Goose Lake, which conveys water to West Goose Lake	Inflow from southern portion of East Goose Lake
Gos-A4	In front of exit to culvert at southern end of West Goose Lake, which receives water from East Goose Lake	Outflow from culvert that conveys flow from southern portion of East Goose Lake
Gos-A5	In front of storm drain outfall in forebay at the southern end of West Goose Lake from permitted discharge	Permitted discharge from light industrial facility
Gos-A6	Off the retention basin on the southwest end of Est Goose lake, off Hoffman Road	Parking area for local businesses and drainage off Hoffman Road
Gos-P7	Directly in back of Don's Little Bar at the channel that leads to Gos-P	Grassy area behind Don's Little Bar

Based on the available information, the Monitoring Plan for the Goose Drainage is presented below.

5.3 Study Questions

The following Study Questions related to the Goose Drainage will be addressed in this study:

1. What are the spatial and temporal differences between the *E. coli* concentrations at the entrances to West Goose Lake (Sites Gos-A4 and Gos-A2) and the Primary Monitoring Site (Gos-P) during storm events?
2. Does the *E. coli* in the Goose Drainage during a storm event originate from human sources?
3. Does the *E. coli* in the Goose Drainage during a storm event originate from fecal material from non-human sources?

5.4 Monitoring Elements

The monitoring elements listed in Table 5-2 have been designed to answer the Study Questions listed above for the Goose Drainage. Because the study design for this assessment uses an adaptive approach, whereby the results of the first element are used to focus the design for subsequent elements, the elements will be conducted sequentially as listed in Table 5-2. The adaptive approach allows the design of each element of the study to be built upon the results of the previous element, resulting in an increasingly focused approach to identifying the sources of bacteria in the drainage. The end result will be a comprehensive and efficient assessment of potential sources in the drainage, leading to multiple lines of evidence for identifying those sources that have the greatest impact on water quality. These results also allow for focused recommendations on the most effective and efficient BMPs to reduce bacterial loads in the drainage and meet the load reduction requirements of the TMDL. Each monitoring element is described below.

Table 5-2. Monitoring element, study question addressed, and monitoring location and frequency for the Goose Drainage bacterial source identification

Element Number	Monitoring Element	Study Question Addressed	Monitoring Location and Frequency
1	Visual Observations	Study Questions 1 through 3	Before, during, and after forecast storm events
2	*E. coli* Monitoring (culture)	Study Questions 1 through 3	Before, during, and after forecast storm events
3	Flow Monitoring	Study Questions 1, 2, and 3	Instantaneous monitoring from July through September
4	Human Origin Assessment	Study Question 3	Two storm events in 2017 and follow up studies as needed
5	Non-human Origin Assessment	Study Question 3	Two storm events in 2017 and follow up studies as needed
6	Microbial Community Analysis	Study Question 3	N/A

Element 1 – Visual Observations

Visual observations are a critical component to bacterial source tracking investigations and may be used to address all six Study Questions for the Goose Drainage. Visual observations will be made at each site during every field visit on a Visual Observation Form designed for the Lambert Creek Watershed (see Appendix B). In addition to documenting flow, conditions during the observations will be made, including observations of any wildlife in the area (individual animals or feces), evidence of trash and debris, foam (e.g., from surfactants), excessive sediment in the water or signs of erosion, runoff from potential sources containing *E. coli* (e.g., animal containment areas), the homeless population, sewage leaks, and any odors that may indicate the presence of a fecal source. Digital photographs will be taken of all potential sources identified and will be stored with the visual observations files.

Element 2 – *E. coli* Monitoring

The purpose of the *E. coli* monitoring is to address Study Questions 1 through 4 for the Goose Drainage. The monitoring sites identified on Figure 5-1 and described in Table 5-1 will be assessed over the course of the study from May through October, 2017, following the schedule and frequency described in Table 5-3. The initial *E. coli* monitoring will consist of colleting samples over the course of a storm event at several sites to create a pollutograph, as described in Sub-section 3.1. A total of two pollutographs will be monitored over the course of the study period at each of three sites in the Goose Drainage (Gos-P, Gos-A4, and Gos-A2).

In addition to pollutograph monitoring, spot samples will be collected at four additional sites that discharge to Gos-P (Gos-A5, Gos-A6, and Gos-P7). The spot samples will be collected on an as-needed basis depending on the nature and extent of flow at the site.

Understanding the spatial and temporal patterns of *E. coli* concentrations during storm events from the primary monitoring site and at locations that discharge to the primary site will allow us to assess the spatial conditions over the course of a storm event that contribute to elevated *E. coli* levels at Gos-P. After the initial assessment, the Monitoring Plan may be adjusted to further identify locations where *E. coli* inputs may be greatest, but it is anticipated that pollutographs will be created from two storm events at sites Gos-P, Gos-A4, and Gos-A2 in 2017 (six pollutographs total).

Table 5-3. Monitoring locations, frequency, and analyses assessed in the Goose Drainage during wet weather

	Site Monitored	Frequency	Culture/Molecular
Pollutograph	Gos-P	2 storms, 6 to 8 samples per storm	3 samples during 1st storm, TBD for subsequent storm events
	Gos-A4	2 storms, 6 to 8 samples per storm	3 samples during 1st storm, TBD for subsequent storm events
	Gos-A2	2 storms, 6 to 8 samples per storm	3 samples during 1st storm, TBD for subsequent storm events
Spot Samples	Gos-A5	As needed, depending on flow conditions	None
	Gos-A6	As needed, depending on flow conditions	None
	Gos-P7	As needed, depending on flow conditions	None

Element 3 – Flow Monitoring

Flow Monitoring will be used to address Study Question 1, 2, and 3 by producing the hydrographs that will be used to create the pollutographs for the initial assessment. Currently, there is no flow meter in place at the Goose Primary Monitoring Site or other sites in the Goose Drainage. However, stream velocity can be monitored at the Goose Weir (Site Gos-P) and converted to flow using the Manning Equation as discussed in Sub-section 3.2. Stream stage will be monitored at Gos-P over the course of all storms monitored in 2017 (pollutographs and special studies). As described in Sub-section 3.2, stage will then be converted to flow by VLAWMO staff and stored electronically. At other locations within each drainage, instantaneous flow will be measured periodically throughout the course of the storm with a Marsh McBirney velocity meter. Estimates of flow will be determined from the velocity data and the channel dimensions. It is not anticipated that sufficient flow data will be collected at sites other than Gos-P to create complete hydrographs, but the instantaneous measurements taken at these sites will be used to help understand the relative contributions to the bacterial load observed at Gos-P over the course of a storm event.

Element 4 – Human Origin Assessment

Element 4 addresses Study Question 3: Does the *E. coli* in the Goose Drainage originate from human sources? To answer this question, samples will be collected and analyzed for the Human Marker at three locations in the Goose Drainage: Gos-P, Gos-A4, and Gos-A2.

For molecular analyses, samples will be collected and composited to represent the ascending limb of the hydrograph (composite of first 2-3 samples of the storm), peak of the hydrograph (composite of middle 2-3 samples of the storm), and descending limb of the hydrograph (composite of final 2-3 samples of the storm). Therefore for each sampling event at sites Gos-P, Gos A4 and Gos-A2, two samples will be collected: one for E. *coli* analysis (which will be stored on ice until delivery to the lab) and one for the Human Marker, which will be stored on ice after collection, then composited with subsequent samples for each phase of the storm.

After assessing the results of the monitoring from the first storm event, additional samples may be collected and analyzed for the Human Marker at other sites in addition to Gos-P, Gos-A4, and Gos-A2. If the Human Marker is detected, additional samples may be needed to verify the presence and location of human fecal matter in the drainage.

Element 5 – Non-human Origin Assessment

The purpose of Element 5 is to address Study Question 6 – Does the *E. coli* in the Goose Drainage originate from fecal material from non-human sources? This element will be conducted for the first storm event in the same manner as the Human Marker assessment described above. The composite samples that represent the ascending limb, peak, and descending limb of the hydrograph that will be assessed for the Human Marker will also be analyzed for the avian and canine makers. The composite samples will be delivered to the laboratory for filtration and the filter from that sample will be sent to Weston Solutions for analyses of the human, avian, and canine markers (see Sub-sections 3.6 and 3.7). Similar to the Human Marker, the results of the non-human markers will be assessed and additional samples may be collected and analyzed at other sites in addition to Gos-P, Gos-A4, and Gos-A2 during subsequent monitoring.

Element 6 – Microbial Community Analysis

MCA is beyond the scope of this current Monitoring Plan for the Lambert Creek Watershed and will not be used to assess bacterial sources in the Goose Drainage under the current Monitoring Plan.

6.0 WHITAKER DRAINAGE

6.1 Review of Existing Information

The Whitaker Drainage lies at the top of the Lambert Creek Watershed (Figure 1-1). The drainage consists entirely of urban land use, primarily single family residential with several large ball fields associated with parks and schools in the upper part of the drainage. There is an extensive municipal separate storm sewer system (MS4) infrastructure in the drainage that conveys storm water flows from the Whitaker Drainage to the Primary Monitoring Site (Wht-P). The MS4 is underground for the entirety of the Whitaker Drainage and there are no surface canals or open ditches where flows in the MS4 are exposed.

Preliminary maps of the MS4 infrastructure within the Whitaker Drainage were created from GIS files made available by VLAWMO. The preliminary maps were used in the field during a site reconnaissance that was conducted on May 15, 2014 in the Whitaker drainage to identify potential sources of bacteria that may be contributing to elevated concentrations at the Primary Monitoring Site. Following the reconnaissance, the preliminary maps were adjusted based on observations of flow and potential inputs to the Primary Monitoring Site. Based on the observations and maps of the MS4 infrastructure, it was determined that within the Whitaker Drainage there are three Major Sub-drainages that each drain to discrete sampling locations. The locations are identified on (Figure 6-1) and described below:

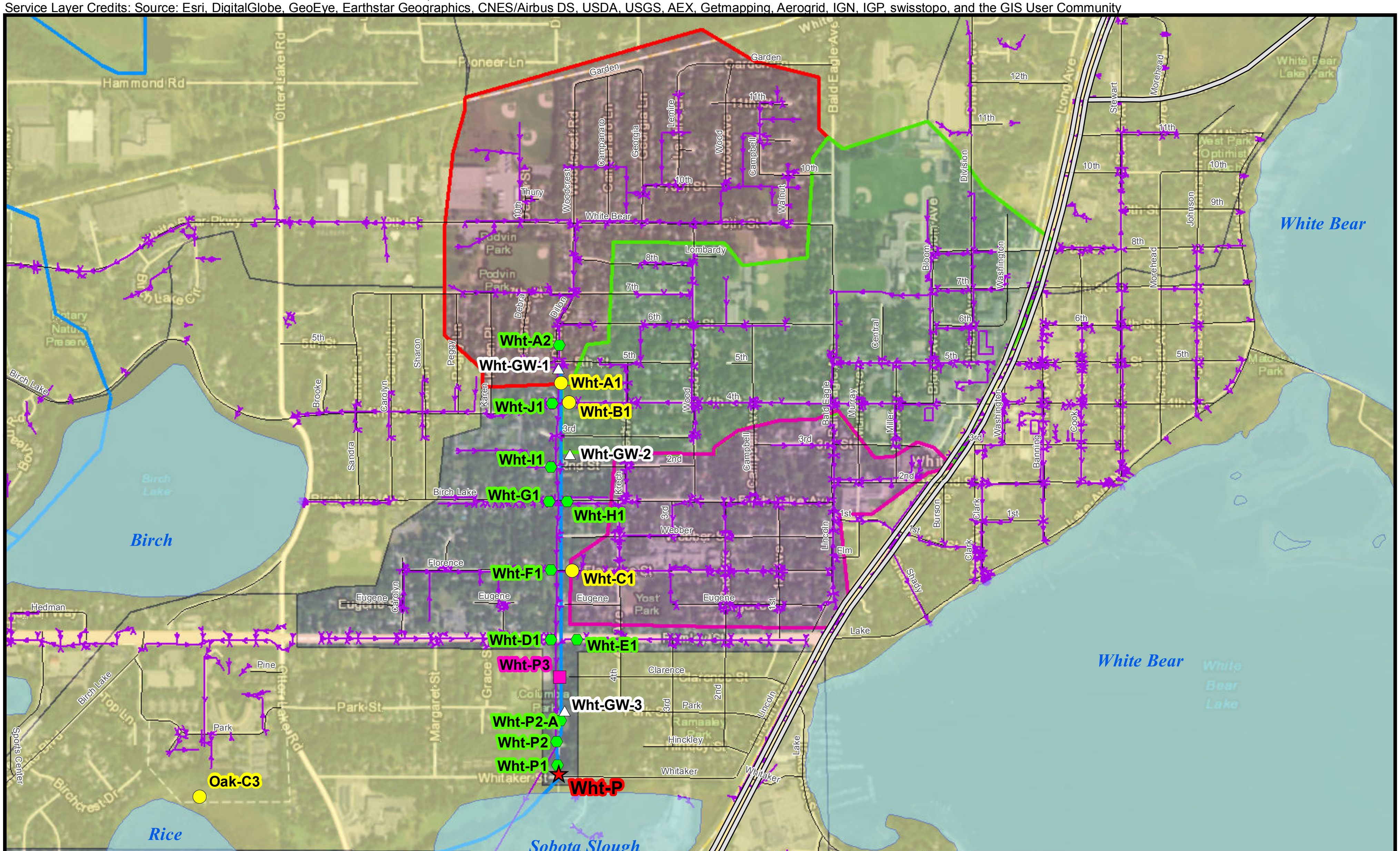
- Major Sub-drainage A – located on Dillon Street, just north of 4th Street;
- Major Sub-drainage B – located on 4th Street at Campbell Avenue; and
- Major Sub-drainage C – located on Florence Street between 4th Street and 2nd Street.

Flows from each of these Major Sub-drainages are directed to the Mainstem MS4, which flows south from 5th Street to the storm drain outfall then discharges to the Whitaker Detention Basin (Figure 6-1). The Mainstem MS4 is designated as a blue-line stream on Figure 6-1 and prior to development of the Whitaker Drainage was an open channel known as the Dillon Ditch. In addition to the Major Sub-drainages A, B, and C, there are a series of smaller MS4 pipes that convey flows to the Mainstem MS4 from the east and west sides of the Whitaker Drainage. These Minor Sub-drainages drain surface streets that run perpendicular to the Mainstem MS4. The location where the Minor Sub-drainages connect to the Mainstem MS4 are designated in green as Minor Sub-drainage Monitoring Sites D through J on Figure 6-1.

Based on the available information, the Monitoring Plan for the Whitaker drainage is presented below.

Path: U:\Users\Current Employees\sgruber\OPPORTUNITES & RFPs\2017\VLAWMO - Lambert Creek Source ID 2017\Monitoring Plan - 2017\GIS\ArcDocs\2017Updates\LambertCreek_SourceID_Monitoring_Figure6-1_WhitakerDrainage.mxd ekriveramelo 4/6/2017

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



Legend

★ Primary Monitoring Site	Basin A
● Major Sub-Drainage Monitoring Site	Basin B
△ Groundwater Monitoring Site	Basin C
● Minor Sub-Drainage Monitoring Site	Drainage Data
■ Flow Monitoring Site	Streams

NORTH

1,250 625 0 1,250

Scale in Feet

BURNS McDONNELL

Figure 6-1
Whitaker Drainage
Monitoring Sites

Source: USGS; VLAWMO

Issued: 4/6/2017

6.2 Monitoring Locations

Site selection for the bacterial source identification in the Whitaker Drainage was based on historical data available for the drainage and the results of the site reconnaissance conducted throughout 2014, 2015, and the spring of 2016. The monitoring sites are shown graphically on Figure 6-1 and described in Table 6-1.

Table 6-1. Monitoring site IDs, locations, and drainage area descriptions for the Whitaker Drainage

Site ID	Site Name / Sample Location	Site Drainage Description
Wht-P	Primary Monitoring Site at Base of Whitaker Drainage just upstream of Whitaker Road	The entire Whitaker Drainage
Wht-P1	Downstream side of the Middle Forebay of the Whitaker Detention Basin, upstream of the weir	Upper and Middle Forebays of the Whitaker Detention Basin
Wht-P2	At the Storm drain outfall just upstream of where the MS4 discharges to the Upper Forebay	The entire Whitaker Drainage except the Whitaker Detention Basin
Wht-P3	Mainstem MS4 in Columbia Park off Clarence Street	The entire Whitaker Drainage except the Whitaker Detention Basin and ~ 750 feet upstream of the basin
Wht-A1	On Dillon Street just upstream of 4th Street	Upper northwest corner of the Whitaker Drainage above 4th Street
Wht-B1	East side of the Mainstem MS4 on 4th Street	Upper northeastern and central portion of the Whitaker Drainage upstream of 3rd Street
Wht-C1	East side of the Mainstem MS4 on Florence Street	Lower southeastern portion of the Whitaker Drainage between 3rd Street and Highway 96E
Wht-D1	West side of the Mainstem MS4 at Highway 96E Street	Highway 96E from the western drainage boundary to the Mainstem MS4
Wht-E1	East side of the Mainstem MS4 at Highway 96E Street	Highway 96E from the eastern drainage boundary to the Mainstem MS4
Wht-F1	West side of the Mainstem MS4 at Florence Street	Florence Street from the west side of the drainage boundary to the MS4 Mainstem
Wht-G1	West side of the Mainstem MS4 at Birch Lake Avenue	Birch Lake Avenue from the western watershed boundary to the Mainstem MS4
Wht-H1	East side of the Mainstem MS4 at Birch Lake Avenue	Birch Lake Avenue from the Sub-drainage C boundary to the Mainstem MS4

Site ID	Site Name / Sample Location	Site Drainage Description
Wht-I1	West side of the Mainstem MS4 at 2nd Street	2nd Street from the western watershed boundary to the Mainstem MS4
Wht-J1	West side of the Mainstem MS4 at 4th Street	4th Street from the western watershed boundary to the Mainstem MS4
Wht-GW-1	Groundwater Monitoring Well on the South side of 5th Street at and of Dillon Street	NA
Wht-GW-2	Groundwater Monitoring Well North of 2nd Street along Dillon Ditch	NA
Wht-GW-3	Groundwater Monitoring Well in Columbia Park, just West of Park Street	NA

6.3 Study Questions

The following Study Questions related to the Whitaker Drainage will be addressed in this study:

1. What are the spatial and temporal differences between the *E. coli* concentrations during storm events at the Primary Monitoring Site (Wht-P), the outfall (Site Wht-P2-A), and the outfalls of the three major sub-drainages (Wht-A1, Wht-B-1, and Wht-C1)?
2. Does the *E. coli* in the Whitaker Drainage during a storm event originate from human sources?
3. Does the *E. coli* in the Whitaker Drainage during a storm event originate from fecal material from non-human sources?

6.4 Monitoring Elements

The monitoring elements listed in Table 6-2 have been designed to answer the Study Questions listed above for the Whitaker Drainage. Because the study design for this assessment uses an adaptive approach, whereby the results of the first element are used to focus the design for subsequent elements, the elements will be conducted sequentially as listed in Table 6-2. The adaptive approach allows the design of each element of the study to be built upon the results of the previous element, resulting in an increasingly focused approach to identifying the sources of bacteria in the drainage. The end result will be a comprehensive and efficient assessment of potential sources in the drainage, leading to multiple lines of evidence for identifying those sources that have the greatest impact on water quality. These results also allow for focused recommendations on the most effective and efficient BMPs to reduce bacterial loads in the drainage and meet the load reduction requirements of the TMDL.

Table 6-2. Monitoring element, study question addressed, and monitoring location and frequency for the Whitaker Drainage bacterial source identification

Element Number	Monitoring Element	Study Question Addressed	Monitoring Location and Frequency
1	Visual Observations	Study Questions 1 through 3	Before, during, and after forecast storm events
2	*E. coli* Monitoring (culture)	Study Questions 1 through 3	Before, during, and after forecast storm events
3	Flow Monitoring	Study Questions 1 through 3	Instantaneous monitoring from July through September
4	Human Origin Assessment	Study Question 2	Three storm events in 2017 and follow up studies as needed
5	Non-human Origin Assessment	Study Question 3	Three storm events in 2017 and follow up studies as needed
6	Microbial Community Analysis	N/A	Not conducted in 2017

Each monitoring element is described below.

Element 1 – Visual Observations

Visual observations are a critical component to bacterial source tracking investigations and may be used to address all six Study Questions for the Whitaker Drainage. Visual observations will be made at each site during every field visit on a Visual Observation Form designed for the Lambert Creek Watershed (see Appendix B).

In addition to documenting flow, conditions during the observations will be made, including observations of any wildlife in the area (individual animals or feces), evidence of trash and debris, foam (e.g., from surfactants), excessive sediment in the water or signs of erosion, runoff from potential sources containing *E. coli* (e.g., animal containment areas), the homeless population, sewage leaks, and any odors that may indicate the presence of a fecal source. Digital photographs will be taken of all potential sources identified and will be stored with the visual observations files.

Element 2 – *E. coli* Monitoring

The purpose of the *E. coli* monitoring is to address Study Questions 1 through 3 for the Whitaker Drainage. The monitoring sites identified on Figure 6-1 and described in Table 6-1 will be assessed over the course of the study from June through October, 2017, following the schedule and frequency described Table 6-3. The initial *E. coli* monitoring will consist of colleting samples over the course of a storm event at several sites to create a pollutograph, as described in Sub-section 3.1. A total of two pollutographs will be monitored over the course of the study period at five sites in the Whitaker Drainage (Wht-P, Wht-P2-A, Wht-A1, Wht-B1, and Wht-C1).

Understanding the spatial and temporal patterns of *E. coli* concentrations during storm events from the primary monitoring site and at locations that discharge to the primary site will allow us to assess the spatial conditions over the course of a storm event that contribute to elevated *E. coli* levels at Wht-P. After the initial assessment, the Monitoring Plan may be adjusted to further identify locations where *E. coli* inputs may be greatest, but it is anticipated that pollutographs will be created from two storm events at sites Wht-P, Wht-P2-A, Wht-A1, Wht-B1, and Wht-C1 (ten pollutographs total).

Table 6-3. Monitoring locations, frequency, and analyses assessed in the Whitaker Drainage during wet weather

	Site Monitored	Frequency	Culture/Molecular
Pollutograph	Wht-P	2 storms, 6 to 8 samples per storm	3 samples during 1st storm, TBD for subsequent storm events
	Wht-P2-A	2 storms, 6 to 8 samples per storm	3 samples during 1st storm, TBD for subsequent storm events
	Wht-A1	As needed, depending on flow conditions	3 samples during 1st storm, TBD for subsequent storm events
	Wht-B1	As needed, depending on flow conditions	3 samples during 1st storm, TBD for subsequent storm events
	Wht-C1	As needed, depending on flow conditions	3 samples during 1st storm, TBD for subsequent storm events
Spot Samples	To Be Determined	As needed, depending on flow conditions	None

Element 3 – Flow Monitoring

Flow Monitoring will be used to address Study Question 1, 2, and 3 by producing the hydrographs that will be used to create the pollutographs for the initial assessment. Stream stage will be monitored at Wht-P3 over the course of all storms monitored in 2017 (pollutographs and special studies) via flow monitoring equipment installed in Columbia Park. As described in Sub-section 3.2, stage will then be converted to flow by VLAWMO staff and stored electronically. At other locations within each drainage, instantaneous flow will be measured periodically throughout the course of the storm with a Marsh McBirney velocity meter. Estimates of flow will be determined from the velocity data and the channel dimensions. It is not anticipated that sufficient flow data will be collected at sites other than Wht-P3 to create complete hydrographs, but the instantaneous measurements taken at these sites will be used to help understand the relative contributions to the bacterial load observed at Wht-P over the course of a storm event.

Element 4 – Human Origin Assessment

Element 4 addresses Study Question 2: Does the *E. coli* in the Whitaker Drainage originate from human sources? To answer this question, samples will be collected and analyzed for the Human Marker at five locations in the Whitaker Drainage: Wht-P, Wht-P2-A, Wht-A1, Wht-B1, and Wht-C1 (Figure 6-1).

For molecular analyses, samples will be collected and composited to represent the ascending limb of the hydrograph (composite of first 2-3 samples of the storm), peak of the hydrograph (composite of middle 2-3 samples of the storm), and descending limb of the hydrograph (composite of final 2-3 samples of the storm). Therefore, for each sampling event at sites Wht-P and Wht-P2-A, two samples will be collected: one for E. *coli* analysis (which will be stored on ice until delivery to the lab) and one for the Human Marker (which will be stored on ice after collection, then composited with subsequent samples for each phase of the storm).

After assessing the results of the monitoring from the first storm event, additional samples may be collected and analyzed for the Human Marker at other sites in the Whitaker Drainage. If the Human Marker is detected, additional samples may be needed to verify the presence and location of human fecal matter in the drainage.

Element 5 – Non-human Origin Assessment

The purpose of Element 5 is to address Study Question 3 – Does the *E. coli* in the Whitaker Drainage originate from fecal material from non-human sources? This element will be conducted for the first storm event in the same manner as the Human Marker assessment described above. The composite samples that represent the ascending limb, peak, and descending limb of the hydrograph that will be assessed for the Human Marker will also be analyzed for the avian and canine makers. The composite samples will be delivered to the laboratory for filtration and the filter from that sample will be sent to Weston Solutions for analyses of the human, avian, and canine markers (see Sub-sections 3.6 and 3.7). Similar to the Human Marker, the results of the non-human markers will be assessed and additional samples may be collected and analyzed at other sites during subsequent monitoring.

Element 6 – Microbial Community Analysis

MCA is beyond the scope of this current Monitoring Plan for the Lambert Creek Watershed and will not be used to assess bacterial sources in the Whitaker Drainage under the current Monitoring Plan. However, future investigations may include this type of analysis if the results of Elements 1 through 5 are insufficient to clearly identify the host origin of bacteria.

7.0 DATA MANAGEMENT AND REPORTING

All field and laboratory data collected will be subjected to QA/QC protocols to assure the data's accuracy and validity. VLAWMO and Burns & McDonnell staff will review and analyze the data compiled under the tasks conducted in the approved Monitoring Plan and prepare a Draft Report for review by VLAWMO staff. After the Draft Report is accepted, a Final Report will be prepared and issued to VLAWMO. The Draft and Final Reports will include the following elements:

- Executive Summary, which will summarize the salient procedures and findings of each of the report sections;
- Introduction, which will introduce the historical background of the area, the history of regulatory issues surrounding the TMDL, and identify the key questions to be answered by the source identification study;
- Materials and Methods, which will detail the Procedures and materials used to conduct the sampling, as well as analytical and statistical approaches used in the assessment of data;
- Results, which will describe in detail the outcome of the source identification study;
- Discussion, which will briefly discuss the findings relative to the TMDL; and
- Recommendations based on the results of the study, which will identify potential BMPs to be considered for implementation based on the findings of the study, data gaps identified, future monitoring activities, and any concerns relative to the monitoring program.

8.0 HEALTH AND SAFETY

Sampling can introduce many potentially dangerous situations, particularly during wet weather. It is imperative that field crews remain alert and aware of the environmental conditions surrounding them at all times. Safety takes top priority while performing any field sampling. The following basic list of potentially hazardous conditions will be reviewed prior to sampling events:

- Roadways can become very dangerous during sampling events involving access to storm drains within right of ways. Caution should be taken any time work is being conducted on or near a roadway. Areas where storm drain or sewer access is needed should be clearly marked off with safety cones or other means to alert oncoming traffic of any potential hazards.
- Samples should be collected by a team of two people so that as one team member collects the sample, the other can watch out for potential hazards.
- Be aware of errant vehicles. Just as the roadways pose a danger to you, they pose the same danger to other drivers. Remain aware of the vehicles around you and general traffic.
- Technicians should never enter a storm drain conveyance without being properly trained and certified in Confined Space Entry.
- Never enter a flowing waterway, conveyance or receiving water during storm water sampling. The depth and speed of waterways can be deceptive, particularly at night. It does not require very much flow to cause people to lose balance and be swept away. During storm water discharge there is typically a high amount of debris that can also cause you to lose balance in otherwise manageable waters.
- Use extra caution during night-time conditions. All potential hazards associated with storm water sampling are heightened during dark conditions.

These are just some basic, common hazards encountered during storm water sampling and are not intended to be a complete list for any and all sites or conditions. VLAWMO staff will be conducting the field work for this project and should refer to their own Health and Safety documents for specific details.

9.0 PROJECT SCHEDULE

Monitoring schedules have been developed for each of the five drainages in the Lambert Creek Watershed (see appropriate sections in this document) except the Koehler Drainage, which will be developed in future iterations of the Monitoring Plan.

10.0 LITERATURE CITED

Wenck, 2013. Vadnais Lake Area WMO Total Maximum Daily Load (TMDL) and Protection Study. Prepared by Wenck Associates, Inc. for Vadnais Lake Area Water Management Organization (VLAWMO).

SCCWRP, 2013. Southern California Coastal Water Research Project. The California Microbial Source Identification Manual: A Tiered Approach to Identifying Fecal Pollution Sources to Beaches.

APPENDIX A - PHOTOGRAPHIC SUMMARY OF SITE RECONNAISSANCE

APPENDIX B – VISUAL OBSERVATION FORM

APPENDIX C - COLLECTION, STORAGE, AND TRANSPORT OF SAMPLES FOR MOLECULAR ANALYSIS

APPENDIX D - FILTRATION PROTOCOL FOR SAMPLES FOR MOLECULAR ANALYSIS

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