SNOW REMOVAL WASTEWATER DISPOSAL ALTERNATIVES

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Prepared for:

The Ohio Department of Transportation,

Office of Statewide Planning & Research

State Job Number 134629

January 2014

Final Report

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/OH-2013/16		
4. Title and Subtitle		5. Report Date
Snow Removal Wastewater Disposal Alternatives		**January 2014**
		6. Performing Organization Code
7. Author(s)		8. Performing Organization Report No.
Christopher M. Miller, William H. Schneider IV, Marla Kennedy, and Sarah Sullivan		
9. Performing Organization Name and Address		10. Work Unit No. (TRAIS)
The University of Akron **302 Buchtel Common** **Akron, OH 44325-2102**		
		11. Contract or Grant No.
		SJN 134629
12. Sponsoring Agency Name and Address		13. Type of Report and Period Covered
Ohio Department of Transportation		**Final Report**
1980 West Broad Street		14. Sponsoring Agency Code
Columbus, Ohio 43223		
15. Supplementary Notes		
Project performed in cooperation with the Ohio Department of Transportation and the Federal Highway Management Administration		
16. Abstract		
Management of truck wash water generated at DOT maintenance facilities without access to sanitary sewer can be costly. Strategies for managing this waste stream, including collection and direct disposal, reuse with and without treatment, and tying into the sanitary sewer were identified and evaluated. The results of truck wash water quality monitoring at 24 maintenance facilities indicated that heavy metals concentrations exceeded the established reuse limits in Ohio at many garages. Pilot scale testing indicated that media filtration and particulate settling may be adequate to reduce heavy metals concentrations to acceptable levels for reuse of wash water.		
17. Keywords		18. Distribution Statement
winter maintenance, wash water quality, brine, reuse, disposal		**No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161**

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	**Unclassified**		

Form DOT F 1700.7 (8-72) **Reproduction of completed pages authorized**

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January, 2014

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and the U.S. Department of Transportation, Federal Highway Administration

The contents of this report reflect the views of the author(s) who is (are) responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Ohio Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

ACKNOWLEDGMENTS

This project was conducted in cooperation with ODOT and FHWA. The authors would like to thank the members of ODOT's Technical Liaison Committee:

- Mr. Hans Gucker, Office of Environmental Services,
- Mr. Timothy Killeen, Office of Environmental Services, and
- Mr. Jamie Hendershot, District 10 Highway Management Administrator.

The time and input provided for this project by members of the Technical Liaison Committee were greatly appreciated. In addition to our technical liaisons, the authors would like to express their appreciation to ODOT's Office of Statewide Planning and Research and Mr. Mark Griffiths, Portage County Manager, for their time and assistance. We would also like to thank all of the county garage managers that coordinated wash water sample collection and transport to our laboratory for analysis. Finally, we want to acknowledge MAR Systems (Cleveland, OH) for assistance with the start-up and operation of the pilot unit.

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LIST OF ACRONYMS

ANOVA—Analysis of Variance

BDL—Below Detection Limit

DNR—Department of Natural Resources

DOT—Department of Transportation

EPA—Environmental Protection Agency

EUAC—Equivalent Uniform Annual Cost

GAC—Granular Activated Carbon

ICP-OES – Inductively Coupled Plasma – Optical Emission Spectrometry

MBAS—Methylene Blue Active Substance

MCL—Maximum Contaminant Level

MLR—Multiple Linear Regression

OAC – Ohio Administrative Code

ODOT—Ohio Department of Transportation

OMZA – Outside Mixing Zone Average

OMZM – Outside Mixing Zone Maximum

PCA—Principal Component Analysis

POTW—Publicly Owned Treatment Works

ppb – parts per billion

ppm—parts per million

RO—Reverse Osmosis

SHA—State Highway Administration

SOBPs—Synthesis of Best Practices

TAC—Transportation Association of Canada

TDS—Total Dissolved Solids

TMS—Transportation Management System

TOC – Total Organic Carbon

TSS—Total Suspended Solids

UST—Underground Storage Tank

VTRC—Virginia Transportation Research Council

WPCP—Water Pollution Control Plant

WWTP—Waste Water Treatment Plant

LIST OF APPENDICES

APPENDIX A: Results of Survey of Other State DOT

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APPENDIX E: Example Cost Calculation

CHAPTER I

INTRODUCTION

1.1. Problem Statement

Minimizing the effects and impact of deicing chemicals on the environment is an important endeavor and there are many projects and efforts directed at this problem. One area that has received minimal attention includes managing snow removal wastewater (i.e. water generated from washing trucks after deicing-salt operations). Due to a number of factors, effectively managing snow removal wastewater could be a challenge. ODOT currently owns and operates 88 county garages, 132 outposts, and 12 district garages and central office facilities. The wastewater generated from washing equipment is typically disposed of in one of two methods:

1. If the garage or facility is in an area that sanitary sewer is available, the wastewater is drained into an existing sewer system.
2. If sewer is not available, the wastewater is treated via an oil-water separator to remove oil then stored in tanks to be disposed elsewhere or reused to make salt brine.

Storing wastewater for reuse in making salt brine may be a preferred practice; however, the quantity of wastewater generated often exceeds the quantity of salt brine needed. Additionally, the wastewater quality is not well characterized. Therefore, cost effective and environmentally friendly solutions are needed; however, they will likely be district or geographically constrained and require optimization of both technology and logistical operations.

1.2. Objectives and Goals of the Study

To insure this research project would be considered a success, the research team developed the following objectives:

- Objective 1 - Evaluate the current state of practice for handling snow removal wastewater for states outside of Ohio,
- Objective 2 - Evaluate the current state of practice for handling snow removal wastewater in Ohio,
- Objective 3 - Assess commercially viable solutions for handling snow removal wastewater and provide a best-practices recommendation, and
- Objective 4 - Summarize the final results.

1.3. Overview of Approach

To meet the four objectives identified above and to provide a cost effective environmentally friendly management strategy that decreases the impact of wastewater from salt trucks, this research team developed and completed twelve tasks divided across two phases.

1.3.1. Phase I

During Phase I of this research project, seven tasks were identified and completed. The main goal of Phase I was to identify potential wash water management strategies and conduct a preliminary evaluation of wash water quality, wash water treatment, and wash water management costs. Phase I encompassed data from winter season 2011-2012. A brief description of the tasks completed during Phase I is provided below.

Task One: Synthesis of the State of the Practice

Two subtasks, telephone interviews and literature review, were included under Task One of this study. In the first subtask, this research team interviewed state DOTs with the majority of the interviewees from the Midwest. The interview questions specifically addressed:

- Their current day-to-day operations,

- Specific environmental and maintenance challenges,
- What environmental strategies have they incorporated in the past,
- Operating budget,
- What applications do they use their salt brine for, and
- Long-term objectives.

The main goal from the national interview of state DOTs was to learn from their successes and failures. The second subtask within Task One was a comprehensive literature review on this topic. The results from the interviews and the literature review provided a solid foundation of working knowledge which was incorporated into subsequent project task efforts.

Task Two: Evaluate the Current State of the Practice in Ohio

In this task, current practices within the Ohio DOT were evaluated using a combination of an email survey, telephone interviews with the Facilities Mangers in each district, and site visits. The information provided by individual garages on wash water management practices and costs aided in the identification of viable wash water management options.

Task Three: Preliminary Evaluation of Commercially Viable Solutions

Using the information collected under Tasks One and Two, options were identified and evaluated as potential viable alternatives under specific scenarios that addressed both disposal of truck wash water and reuse of wash water for brine production. The feasibility of these options was evaluated based on feedback from other state DOT and the results of truck wash water quality monitoring and media filtration evaluation conducted during Winter 2011/2012.

Task Four: Cost Analysis

The fourth task within this project was the identification of the cost categories and values for the cost evaluation of the wash water management alternatives. Although all of the options identified under Task Three were evaluated to determine their feasibility, only options considered viable from an environmental and cost standpoint were included in the final evaluation. The results of the cost analysis were incorporated into an evaluation and calculation matrix that is described in Task Six.

Task Five: Strategic Meeting with ODOT Technical Liaisons and Project Managers

Strategic meetings with ODOT personnel were conducted to improve the likelihood for successful implementation of the final project. Meetings were conducted to share data and exchange ideas regarding the project data, direction, and focus.

Task Six: Evaluation and Calculation Matrix

In the sixth task, the research team developed an Evaluation and Calculation Matrix tool to calculate wash water management costs at individual ODOT maintenance facilities. The tool was developed using Visual Basic Applications in Microsoft Excel and was designed to incorporate user supplied information into the cost calculation. The tool supports a side-by-side comparison of costs for different management strategies.

Task Seven: Make Preliminary Recommendation

The seventh task was to make an interim recommendation on wash water management approaches for each district and to recommend additional work to be conducted during project Phase II.

1.3.2. Phase II

After the completion of Phase I, an additional five tasks were developed and completed including data collected during the 2012-2013 winter season. The focus of Phase II was to collect additional data regarding wash water quality, conduct a pilot study using filtration media identified during Phase I, and update-streamline the cost analysis tool. A description of each Task completed during Phase II of this research project is provided below.

Task Eight: Update Cost Analysis Tool

The eighth task on this project was to update the cost analysis tool and evaluation matrix to be more user-friendly including the ability to easily customize wash water volume estimates and cost factors (e.g. disposal cost, interest rate, and time period).

Task Nine: Wash Water Quality Analysis

Task ten performed additional wash water quality sample analysis on 24 garage facilities around Ohio. All regulatory compliance regarding disposal or reuse limits and guidelines is based on wash water quality and additional data was needed to establish a higher degree of confidence regarding the expected range of water quality. These wash water quality results were compared to current disposal and reuse limits and guidelines across Ohio.

Task Ten: Wash Water Modeling

Based on the wash water quality analysis (Task 9), logistical regression models were created for traffic metals incorporating wash water quality attributes and garage-specific attributes (e.g. number of winter events).

Task Eleven: Pilot Unit Testing with Filter Media

Task eleven of this project conducted pilot testing with filter media to assess wash water treatment performance using actual garage wash water collected during winter season conditions. In addition, pilot results were used to establish preliminary protocols for wash water treatment at ODOT facilities.

Task Twelve: Final Recommendation

The last task was to make a final recommendation for implementation of the research including managing wash water generated at ODOT maintenance facilities.

1.4. Report Organization

This report is organized into six chapters. Chapter 1 summarizes the goals and objectives of this project as well as the general approach to meeting these objectives. Chapter 2 provides background information including a review of relevant literature and current strategies for managing wash water in Ohio and across the country. Chapter 3 summarizes the results of wash water quality monitoring and modeling conducted from 2011 through 2013, and Chapter 4 presents an analysis of wash water quality treatment via filtration media. Chapter 5 discusses the cost of alternative wash water management strategies and the development of a tool that could be

used to calculate wash water management costs at individual maintenance facilities. Chapter 6 summarizes the results of this research and provides recommendations for implementation.

CHAPTER II

BACKGROUND

2.1. Introduction

An average of 600,000 tons of salt is used to maintain Ohio's 43,000 lane miles each year (ODOT, 2011). Due to the corrosive nature of sodium chloride, salt trucks are washed frequently at ODOT's 88 county and 136 outpost garages during the winter months (Figure 2-1). Waste water generated during routine truck washing can have elevated concentrations of suspended solids, dissolved solids, oil and grease, and heavy metals (Alleman, 2004; Fitch, et al., 2004). In locations where sanitary sewer is available, truck wash water is treated with an oil/water separator and discharged directly. However, at facilities that do not have access to sanitary sewer, truck wash water must be collected and managed, often at significant cost to the DOT. To identify viable strategies for managing truck wash water, a nationwide literature review, a survey of best management practices across other state DOT, and a survey of current management strategies and costs across Ohio were conducted.

2.2. Literature Review

A limited number of studies have examined the quality of truck wash water and the viability of potential management options including reusing the truck wash water for brine and treating the wash water using reverse osmosis to remove dissolved solids. Table 2-1 summarizes the reports included in this literature review.

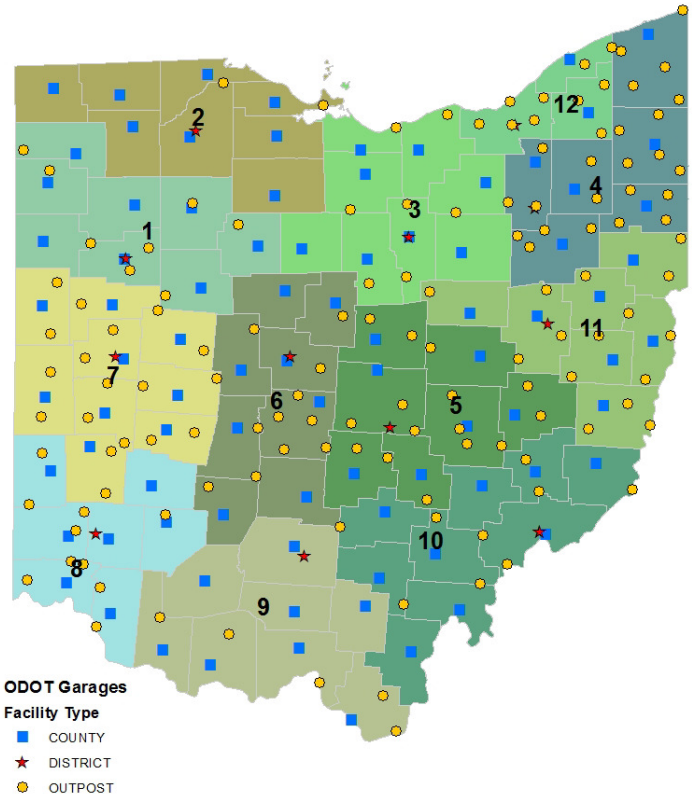


Figure 2-1: ODOT Districts and maintenance facility locations.

Table 2-1: Summary of literature review.

Reference	Result
Alleman, 2004	Assessed truck wash water quality at INDOT maintenance facilities; suggested wash water can be reused for brine production.
Fitch, et al., 2004	Assessed water quality from the retention ponds used to collect truck wash water; recommended RO as a viable treatment technology.
Fitch, et al., 2006	Conducted RO pilot study; concluded that RO would be adequate to treat wash water, but identified potential obstacles to implementing RO including the need for adequate pretreatment and significant system downtime.
Fitch et al., 2008	Conducted reuse pilot; wash water from the retention ponds was converted to brine; concluded that wash water could be reused without filtration. (VDOT does not currently reuse wash water).
Hull and Associates, 2010	Performed study to evaluate reusing wash water for brine in Henry County, Ohio; water quality of the on-site lagoon was assessed.
TAC, 2003	Developed Best Management Practices for handling truck wash water.
Stone, 2010	Evaluated the implementation of truck wash water best management practices provided by TAC 7.

Truck wash water quality monitoring has been conducted by researchers for the Indiana Department of Transportation (INDOT) and Virginia Transportation Research Council (VTRC). Results indicated that, in undiluted truck wash water, chloride ion concentrations ranged from below detection limit (BDL) to 79,000 parts per million (ppm), with an average of 24,679 ppm, total suspended solids (TSS) concentrations ranged from BDL to 4,970 ppm, with an average value of 1,198 ppm, and oil and grease concentrations ranged from BDL to 218 ppm with an average value of 60 ppm (Alleman, 2004). In truck wash water samples collected from a retention pond, after dilution with storm water, chloride ion concentrations ranged from 140 to 3,100 ppm, while TSS concentrations ranged from 3 to 270 ppm and oil and grease concentrations ranged from less than 2 to 193 ppm (Fitch, et al., 2004).

Reported average chloride ion concentrations in undiluted truck wash water exceed the maximum contaminant level (MCL) for chloride of 250 mg/L set by the United States Environmental Protection Agency (USEPA) National Secondary Drinking Water Regulation (U.S. Code, 2002). At these chloride concentrations, the wash water must be collected and managed. Previous researchers have identified several potential management strategies (Alleman, 2004, Fitch, et al., 2004, 2006, 2008), including the use of a National Pollutant Discharge Elimination System (NPDES) permit for direct discharge of treated waste water (Fitch et al., 2004, 2006). Prior to discharge, the water would require collection and treatment to a chloride ion concentration of less than 250 mg/L, or further, depending on local water quality standards (Fitch et al., 2004). Chloride ion concentration reduction would likely require the use of desalination technologies.

Desalination technologies are generally divided into two groups: thermal technologies and membrane technologies. Because of their high energy costs, thermal technologies, such as distillation, are impractical for many state DOT maintenance facilities. Based on preliminary cost estimates, the VTRC identified RO as the most cost effective membrane system for use at the scale of a maintenance facility (Fitch et al., 2004). Pilot studies conducted to assess the ability of reverse osmosis to treat truck wash water revealed several potential issues: (1) it is difficult to treat to less than 25 mg/L chloride, which could be the discharge requirement (per Virginia groundwater standards), (2) the volume reduction of the wastewater was only 50%, and (3) pre-filtering was necessary because of the turbid water (Fitch et al., 2006).

One alternative to treating truck wash water to meet discharge requirements is to reuse the truck wash water for the production of brine that can be placed on the roadways as part of a winter maintenance program (Alleman, 2004; Fitch et al., 2008). The reuse of truck wash water for brine eliminates the need to desalinate the wash water. Because many DOT already use brine as part of their winter maintenance program, reusing the wash water could yield cost savings in the form of reduced disposal and water costs. However, the brine must meet applicable water quality requirements for placement on the roadway.

The Ohio DOT is currently investigating reuse of wash water for brine production at the Henry County Garage in District 2. The wash water is treated with an oil water separator and diluted in an on-site lagoon where it is stored until is needed for brine production. Four water quality samples were collected at the outset of their reuse project: one from the oil/water separator effluent, one from each of the two on-site potable ponds, and one from the storm water catch basin at Henry County Garage. Samples were analyzed for land application metals, cyanide, phosphorus, oil and grease, pesticides and herbicides, and methylene blue active substances (Hull and Associates, 2010). Sampling results indicated that aluminum and oil and grease concentrations exceeded the applicable discharge limits in the sample collected from inside the wash bay. In addition, aluminum, lithium, fluoride, iron, and phosphorus concentrations, which do not have established discharge standards, were reported at detectable levels from the sample collected inside the wash bay. Table 2-2 shows the results of this water quality sampling event.

Table 2-2: Results of water quality sampling conducted at Henry County Garage. Sample SP-4 was collected from the wash bay. Table taken from "Procedural Plan for Beneficial Reuse of Wastewater Pilot Study" prepared by Hull & Associates (2010).

HENRY COUNTY HIGHWAY GARAGE, NAPOLEON, OHIO

TABLE 1

SURFACE WATER SAMPLING RESULTS

Sample Location:								SP-1	SP-3	SP-4	SP-5	FB1
Field Sample ID:	PTI Final Brine Limits based on Surface Water mg/l	PTI Final Brine Limits based on Human Health Non-drinking water mg/l	Ag. Uses Table 7-12 avg*3.11 Conversion to Maximum	Metals mg/l Table 7-5 formulas w/ back ground hardness 288 mg/l OMZM	OMZM mg/l	Human Health Non Drinking Water	Reporting Units	Salt Loading Area DGL017: SP-1:\0050109	On-site Pond Intake Water DGL017: SP-3:\0050110	Truck Wash Water DGL017: SP-4:\0050111	On-Site Pond Intake Water DGL017: SP-5:\0050112	Field Blank DGL017: FB1:\0050113
Sample Date:				OMZM				5/1/2009	5/1/2009	5/1/2009	5/1/2009	5/1/2009
US EPA Method 200												
Aluminum	-^	4.5				4.5	mg/L	0.85	<0.05	5.8	<0.05	<0.05
Arsenic	0.311	0.58	0.311		0.34	0.58	mg/L	0.3	0.0078	0.018	<0.005	<0.005
Beryllium	0.311	1.3	0.311			1.3	mg/L	<0.010	<0.001	<0.001	<0.001	<0.001
Boron	33	200			33	200	mg/L	<3.0	<0.3	<0.3	<0.3	<0.3
Cadmium	0.015	0.73	0.156	0.015		0.73	mg/L	<0.01	<0.001	0.0016	<0.001	<0.001
Chromium	0.311	14	0.311	4.288		14	mg/L	<0.1	<0.01	0.033	<0.01	<0.01
Cobalt	0.22	-^			0.22	-^	mg/L	<0.2	<0.02	<0.02	<0.02	<0.02
Copper	0.038	64	1.555	0.038		64	mg/L	0.21	<0.004	1.3	<0.004	<0.004
Fluoride	6.22	-^	6.220			-^	mg/L	<2.5	0.11	1.2	0.14	0.17
Iron	15.550	-^	15.550			-^	mg/L	5.4	<0.20	22	<0.20	<0.20
Lead	0.311	0.19	0.311	0.470		0.19	mg/L	<0.12	<0.003	0.11	<0.003	<0.003
Lithium	-^	-^				-^	mg/L	<0.10	<0.01	0.022	<0.01	<0.01
Manganese	-	61				61	mg/L	<0.50	<0.05	0.41	<0.05	<0.05
Molybdenum	150	10			150	10	mg/L	<0.50	<0.05	<0.05	<0.05	<0.05
Nickel	0.622	43	0.622	1.148		43	mg/L	<0.20	<0.02	0.031	<0.02	<0.02
Selenium	0.156	3.1	0.156			3.1	mg/L	0.057	<0.005	<0.005	<0.005	<0.005
Vanadium	0.15	-^			0.15	-^	mg/L	0.47	0.037	0.039	<0.004	<0.004
Zinc	0.294	35	77.750	0.294		35	mg/L	<0.50	<0.05	0.76	<0.05	<0.05
U.S. EPA 335 Method												
Cyanide	0.022			0.022		480	mg/L	0.81	<0.005	0.014	<0.005	<0.005
US EPA 365.2 Method												
Phosphorus	0.68					-^	mg/L	0.29	<0.25	31	<0.25	<0.25
US EPA 413.1 Method												
Oil and Grease	10			10		-^	mg/L	<8.0	<8.0	152	<8.0	<8.7
US EPA 608 Method												
Pesticides	-^					-^	mg/L	—	ND	—	ND	ND
US EPA 8151 Method												
Herbicides	-^					-^	mg/L	—	ND	—	ND	ND
US EPA 425.1 Method												
MBAS	0.5					-^	mg/L	—	<0.005	0.036	<0.005	<0.005

Notes:

PTI Final Brine Limits based on Surface Water mg/l

PTI Final Brine Limits Based on Human Health Non-Drinking Water Standards

MBAS= Methylene Blue Active Substances

-^ = Standard has not been established for this parameter

— = Not analyzed for.

ND= Non Detect. U.S. EPA Method 608 and 8081 provide a long list of specific pesticides and herbicides, respectively. Since all of the individual analytes were below the reporting limit, ND was used to show that no analytes were detected above the reporting limit of the analyte.

HULL & ASSOCIATES, INC.
TOLEDO, OHIO

JANUARY 2010
DGL017.100.001.XLS

Several best management practices have been developed by the Transportation Association of Canada (TAC) to reduce the impact of salt on the environment. To date, nine Synthesis of Best Practices (SOBPs) guidance documents have been developed. TAC 7, "Design and Operation of Road Maintenance Facilities," details best management practices for truck wash water. The document recommends that large particulate matter be removed manually from the vehicle prior to washing, that washing be conducted indoors or on an impermeable pad, and that all wash water be treated with an oil grit separator prior to disposal. TAC 7 also indicates that the collection of truck wash water for brine production or disposal is preferred (TAC 7, 2003). To evaluate whether these guidance documents are followed in practice, the University of Waterloo conducted a survey of 432 public officials with knowledge of salt management practices at maintenance garages in Canada. The survey results showed that 43% of respondents followed the guidance provided in TAC 7 regarding the construction of maintenance facilities, 83% reported that wash water is effectively managed at their facility, and 14% stated that they use wash water for brine production (Stone, et al, 2010).

2.3. Current Wash Water Management Strategies Outside of Ohio

During the literature review, several strategies for managing truck wash water, including treatment and reuse as brine, were identified. To gain a better understanding of how truck wash water is managed on a day-to-day basis by state DOT's and to learn about strategies that may have been implemented by other states (successfully or unsuccessfully), state DOT's across the country were surveyed about their best management practices for truck wash water.

Thirty state DOT's were initially contacted by email on November 2, 2011 to request their participation in a survey regarding best management practices for truck wash water management. The survey specifically addressed truck wash water disposal in locations lacking sanitary sewer access, as well the benefits and limitations of reusing truck wash water. After the initial survey results were received, follow-up telephone interviews were conducted. A second request for participation in a survey of current best management practices was sent by email on January 23, 2012 and additional telephone interviews were conducted.

A total of seventeen State DOTs (57%) responded to the survey of best management practices. Table 2-3 lists the name and title of each person contacted for information regarding truck wash water management practices in their state, and Table 2-4 summarizes each state's

general approach to truck wash water management. Detailed summaries of truck wash water management in each state are provided in Appendix A.

Table 2-3: State DOT personnel contacted to survey current wash water management practices.

State	Contact	Title
Indiana	Steve Mcavoy	Manager Office of Facilities Management
Colorado	Theresa Santangelo	Hazardous Waste Management Unit Supervisor
Iowa	James VanSickle	Supervisor, Iowa Ames Garage
Utah	Lynn Bernhard	Methods Engineer
Virginia	Jim Brewbaker	Salem District Equipment Manager
Pennsylvania	Terry Pearsall	Acting Division Chief—Facility Management
Missouri	Douglas Record	GS Facilities Manager
Tennessee	Estel Hagewood	Transportation Manager I
Oregon	Shawna Secord	Clean Water Program Technician
Washington	Norm Payton	Storm water and Environmental Policy Manager
Maryland	Gregory Kennan	Chief, Environmental Compliance Division
Minnesota	Steve Lund	State Maintenance Engineer
Vermont	George McCool	District Manager
Michigan	Andrew Bouvy	Engineer
Delaware	Alastair Probert	Maintenance Engineer
Rhode Island	Joe Baker	Deputy Administrator Division of Highway and Bridge Maintenance
Idaho	Steve Spoor	Maintenance Services Manager

Table 2-4: Summary of alternative (i.e. other than sewer disposal) truck wash water management practices for each state DOT interviewed.

State	Alternative Wash Water Management Strategy	Recommend Reuse?
Indiana	Reuse wash water for brine after treatment with an oil/water separator.	Yes, for brine
Colorado	Reuse wash water for brine or truck washing after treatment with an oil/water separator and ultrafiltration system.	Yes, for brine and truck washing
Iowa	Reuse wash water for brine after treatment with an oil/water separator.	Yes, for brine
Utah	Collect wash water in retention ponds after treatment with an oil/water separator; wash water is reused for brine.	Yes, for brine
Virginia	Wash trucks at commercial facilities when possible. If not possible, trucks are washed over subsurface engineered wash pads, which filter the water before it is allowed to infiltrate.	No; don't reuse for brine because of concerns with oil/grease
Pennsylvania	Reuse wash water for truck washing after treatment with commercially available recycling system.	No; they have some reuse for truck washing, but don't recommend
Missouri	Attempting pilot study to reuse wash water for brine.	Yes, if they can meet oil/grease requirements
Tennessee	Wash trucks at commercial facilities or on a wash pad where wash water can be collected, stored, and disposed of off-site.	No
Oregon	Filter wash water with a GAC filter and discharge directly to the ground surface.	No
Washington	Route wash water to a pond or bioswale after treatment with an oil/water separator where it is allowed to infiltrate.	No; used to reuse for truck washing, but discontinued due to high cost
Maryland	Discharge directly to surface water after treatment with an oil/water separator.	No; used to reuse for truck washing, but discontinued due to high cost
Minnesota	Collect and store wash water for off-site disposal.	No; conducted pilot study to reuse for truck washing, but discontinued to corrosion issues

Vermont	Collect and store wash water for off-site disposal.	Have not tried
Michigan	Collect and store wash water for off-site disposal.	No; tried to reuse for truck washing; pilot was unsuccessful
Delaware	Route wash water to a pond after treatment with an oil/water separator where it is allowed to infiltrate.	Have not tried
Rhode Island	Wash trucks at commercial facilities.	Have not tried
Idaho	Wash trucks near the salt pile. Wash water runs back toward salt pile.	Have not tried

As shown in Table 2-4, several states have successfully implemented programs for reusing truck wash water as brine, after varying levels of treatment. Many states also reported the collection, storage, and off-site disposal of truck wash water as a viable management option. In addition to providing information on current best management practices for truck wash water disposal, the interviews of other State DOTs also led to the discovery of several potential issues with implementing a wash water treatment and reuse program. A number of states indicated that previously tested treatment systems had failed as a result of limited employee buy-in or severe equipment corrosion. Unanticipated costs associated with equipment maintenance and frequent replacement of system components was also problematic. Lastly, no one reported monitoring for heavy metals, which are likely to be present and could be a regulatory concern, in the wash water.

Figure 2-2 depicts eighteen different truck wash water management strategies for disposal or reuse identified through the literature review and interviews with other state DOTs.

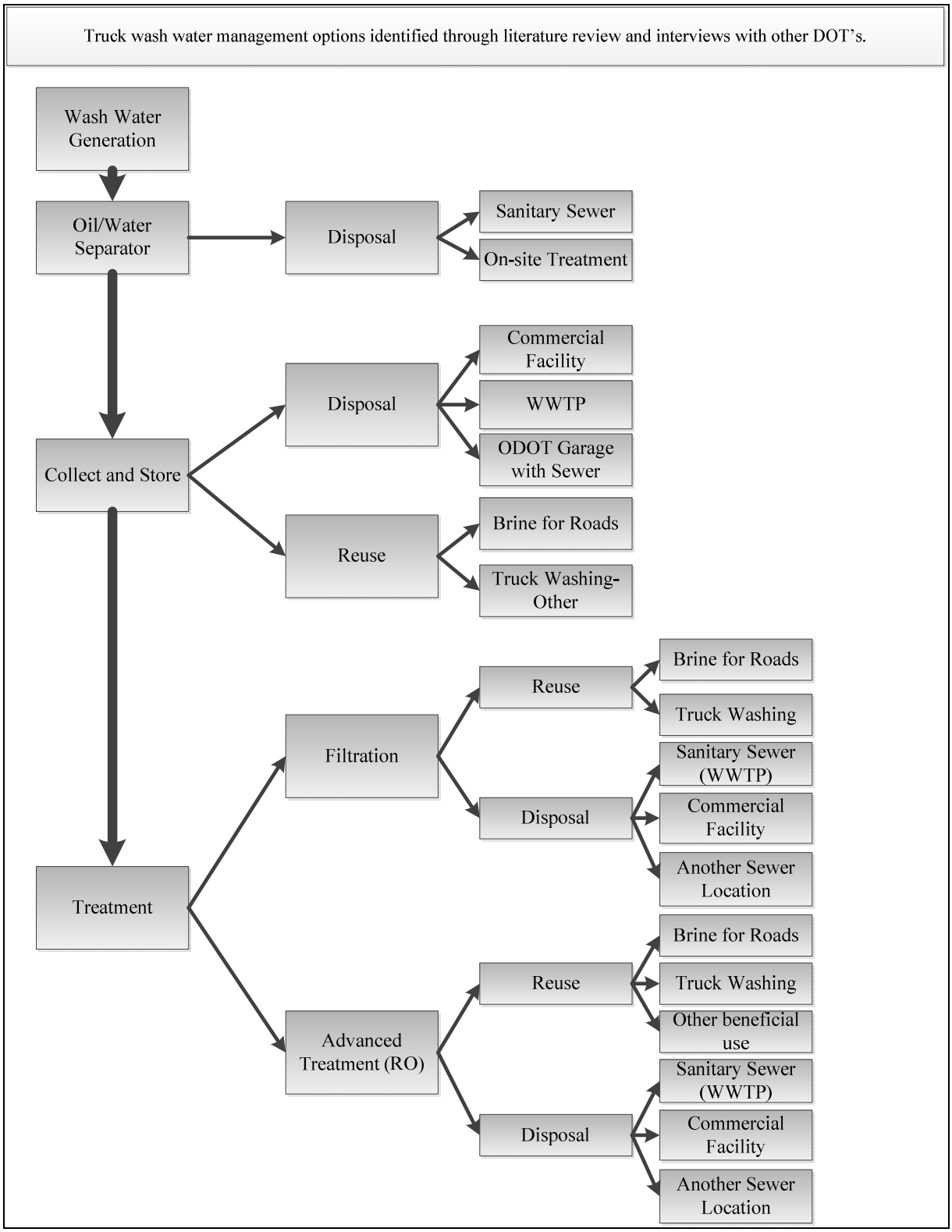


Figure 2-2: Truck wash water management strategies for disposal or reuse.

2.4. Current Wash Water Management Strategies in Ohio

Because the main focus of this research was the identification of alternative wash water management strategies for implementation in Ohio, a detailed assessment of factors contributing to the generation of truck wash water, current wash water management practices, and current wash water management costs in Ohio was conducted. This assessment consisted of five subtasks:

- A preliminary assessment of the number of trucks, lane miles, and snowfall patterns;
- A survey of current practices conducted by email and telephone and follow-up site visits;
- An assessment of brine production and usage in all 12 ODOT districts;
- An evaluation of the volume of wash water generated at each garage; and
- An evaluation of the current costs associated with existing wash water management programs.

2.4.1. Preliminary assessment of trucks, lane miles, and snowfall

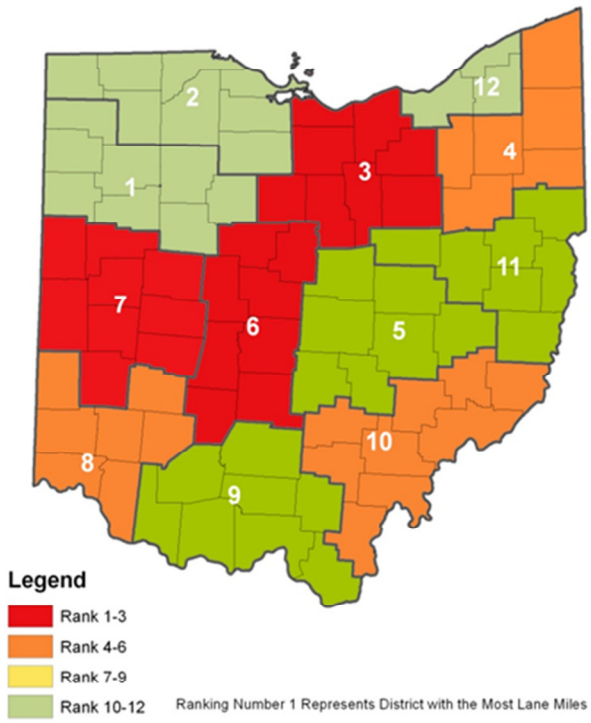
As an initial assessment of which garages would be likely to generate the highest volume of truck wash water, a preliminary investigation of the number of trucks, lane miles, and snowfall patterns for each District was conducted.

The preliminary results of the number of trucks, lane miles, and snowfall patterns for each District are shown in Table 2-5 and Figure 2-3. Based on lane miles alone and corroborated by the number of trucks (see Table 2-5), Districts 3, 6, and 7 would produce the greatest quantity of snow removal wastewater. If snow fall is also considered, then District 3 (lane mile rank 2) or District 4 (lane mile rank 6) could produce the greatest quantity of wastewater. District specific estimates are made in subsequent sections of this report.

Table 2-5: ODOT truck inventory, lane mile, and relative snowfall organized by district.

ODOT District	Trucks	Truck Rank	Lane Miles	Lane Miles Rank	Snowfall
1	119	9	3312	10	Medium
2	123	8	3260	11	Medium
3	147	4	4268	2	Medium
4	147	4	3961	6	High
5	133	6	3592	8	Medium
6	160	1	4977	1	Medium
7	155	2	4047	3	Medium
8	149	3	4038	4	Low
9	112	11	3790	7	Low
10	125	7	4019	5	Low
11	118	10	3329	9	Medium
12	91	12	1766	12	High

ODOT District Ranking Based on Lane Miles



Snow Fall Totals for the State of Ohio in 2009

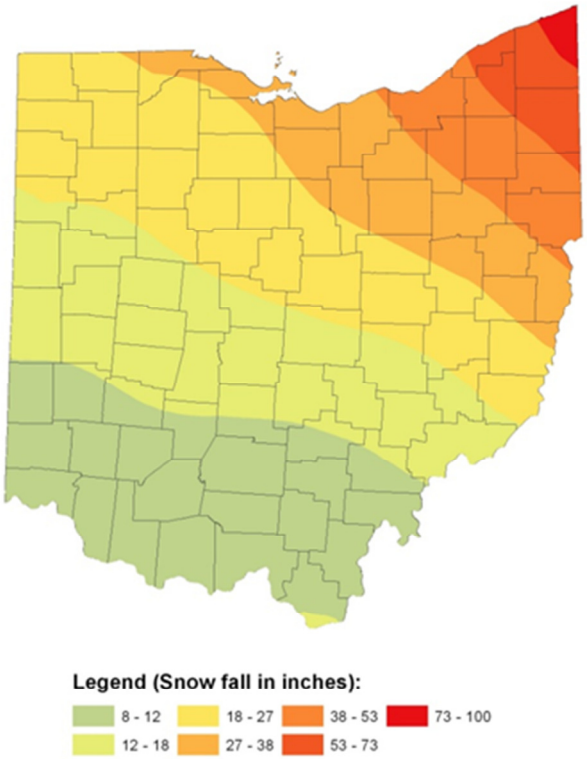


Figure 2-3: ODOT lane miles ranked by district (see Table 2-3) and 2009 Ohio snow fall data. Tables with gradients are developed at The University of Akron.

2.4.2. Survey and Site Visits

Current best management practices for truck wash water disposal across the state of Ohio were evaluated using a combination of an email survey and site visits. The email survey was developed and sent to the District Highway Management Administrator in each of the 12 ODOT Districts on February 7, 2012. The survey was designed to collect information regarding wash water generation and disposal, brine production, and on-site storage volumes, as this information is critical to assessing the cost of treatment, reuse, or disposal of the truck wash water. To confirm the primary method of wash water disposal reported in the survey, the Facilities Managers in 11 of the 12 districts were contacted and interviewed. The primary method of wash water disposal for the garages in District 10 was confirmed during site visits conducted in October 2011, so it was not necessary to contact the Facilities Manager for District 10.

Based on the responses to the District Survey, a list of garages lacking access to sanitary sewer was compiled. This list was used to select 25 garages, with a minimum of one per district, for site visits. Preference for a site visit was given to county and district garages, but in districts where all county and district garages use sanitary sewer for truck wash water disposal, outpost garages were selected. Site visits were used to verify the method of truck wash water disposal and discuss truck washing protocols.

The surveys submitted by each District are provided in Appendix B, and a detailed description of wash water management strategies in each district is presented in Appendix C. In summary, there are currently twelve county garages, one district garage, and 66 outpost garages without access to sanitary sewer. At the time of the survey, it was anticipated that two of the county garages would be tied into the sanitary sewer system during the summer of 2012. Based on the results of the survey, garages without access to sanitary sewer use one of three primary methods for disposal of truck wash water: a holding tank, a class 5 well (septic tank and mound system or leach field), or a storm sewer. All wash water is treated using an oil/water separator prior to storage or discharge.

Many of the Facilities Managers reported that safety washes, rather than full washes of trucks, are conducted at the outpost garages, although the possibility of more extensive washing does exist at these locations. A summary of the garages without access to sanitary sewer is presented in Table 2-6 and Table 2-7. Table 2-8 shows the facilities currently reusing wash

water for brine. Figure 2-4 shows the geographic distribution of garages lacking access to sanitary sewer.

Table 2-6: County and District Garages without access to sanitary sewer for truck wash water disposal.

District	County	Facility Type	Garage Name
D5	Licking	District	District 5 HQ and Garage
D2	Henry	County	Henry
D3	Huron	County	Huron County Garage (HURCG)
D4	Summit	County	Summit County Garage
D5	Licking	County	Licking County--Utica
D5	Muskingum	County	Muskingum County
D6	Madison	County	Madison County
D8	Preble	County	Preble County Garage (PRECG)
D10	Meigs	County	Meigs County
D10	Morgan	County	Morgan County
D10	Vinton	County	Vinton County
D11	Columbiana	County	Columbiana County Garage
D11	Tuscarawas	County	Tuscarawas County - New Philadelphia Garage

Table 2-7: Final list of outpost garages without access to sanitary sewer for truck wash water disposal.

District	County	Facility Type	Garage Name
D1	Wyandot	OP	Carey
D2	Ottawa	OP	Edison
D3	Ashland	OP	Perrysville Outpost Garage (ASDPSO)
D3	Erie	OP	Vermillion Outpost Garage (ERIPNE)
D3	Huron	OP	Plymouth Outpost Garage (HURPSE)
D3	Medina	OP	Burbank Outpost Garage (MEDPSW)
D3	Richland	OP	Lexington Outpost Garage (RICPSW)

D4	Ashtabula	OP	Williamsfield Outpost
D4	Ashtabula	OP	Dorset Outpost
D4	Ashtabula	OP	Rome Outpost
D4	Mahoning	OP	Sebring Outpost
D4	Mahoning	OP	North Lima Outpost
D4	Portage	OP	Yale Outpost
D4	Portage	OP	Drakesburg Outpost
D4	Summit	OP	Interchange Outpost
D4	Summit	OP	Twinsburg Outpost
D4	Trumbull	OP	Brookfield Outpost
D4	Trumbull	OP	Farmington Outpost
D4	Trumbull	OP	Gustavus Outpost
D5	Guernsey	OP	GUE - North Salem
D5	Guernsey	OP	GUE -Old Washington
D5	Licking	OP	LIC -Etna
D5	Licking	OP	LIC -Brownsville
D5	Muskingum	OP	MUS -158- Dresden
D5	Muskingum	OP	MUS -160- Moxahala
D5	Muskingum	OP	MUS -161- Duncan Falls
D6	Fayette	OP	Jeffersonville Outpost
D6	Madison	OP	Mt. Sterling Outpost
D6	Madison	OP	West Jefferson Outpost
D6	Madison	OP	Land Outpost
D6	Union	OP	Richwood Outpost
D7	Champaign	OP	CHP -Mechanicsburg
D7	Champaign	OP	CHP -Saint Paris
D7	Clark	OP	CLA -Harmony
D7	Clark	OP	CLA -Enon
D7	Darke	OP	Fort Jefferson OP

D7	Logan	OP	LOG - East Liberty
D7	Logan	OP	LOG-Old Northwood OP
D7	Mercer	OP	MER - Mercer
D7	Mercer	OP	MER -Cassella
D8	Butler	OP	Middletown
D8	Clinton	OP	68.O.P
D8	Hamilton	OP	Miamitown Outpost Garage (HAMPWE)
D8	Preble	OP	Eaton Outpost Garage (PREPCT)
D8	Warren	OP	Monroe
D10	Hollister	OP	Hollister Outpost Garage (ATHPNO)
D10	Monroe	OP	Duffy Outpost Garage (MOEPSE)
D10	Noble	OP	Belle Valley Outpost Garage (NOBPWE)
D10	Vinton	OP	Wilkesville Outpost Garage (VINPSE)
D10	Washington	OP	Bartlett Outpost Garage (WASPWE)
D10	Washington	OP	Belpre Outpost Garage (WASPSW)
D10	Washington	OP	Macksburg Outpost Garage (WASPNO)
D11	Belmont	OP	Belmont - Barnesville Outpost
D11	Belmont	OP	Belmont - St. Clairsville Outpost
D11	Belmont	OP	Belmont-Shadyside Outpost Yard
D11	Columbiana	OP	Columbiana - Unity Outpost
D11	Columbiana	OP	Columbiana - Apples Corner Outpost
D11	Harrison	OP	Harrison - Freeport Outpost
D11	Jefferson	OP	Jefferson - Toronto Outpost
D11	Jefferson	OP	Jefferson - Bergholz Outpost
D11	Tuscarawas	OP	Tuscarawas County - New Philadelphia Garage
D11	Tuscarawas	OP	Tuscarawas - Zoar Outpost
D12	Geauga	OP	Montville Outpost Garage (GEAPNE)
D12	Geauga	OP	Munson Outpost Garage (GEAPNO)
D12	Geauga	OP	Parkman Outpost Garage (GEAPSE)

D12	Lake	OP	Unionville Outpost Garage (LAKPNE)
D12	Lake	OP	Vrooman Road Outpost Garage (LAKPSE)

Table 2-8: Summary of facilities reusing wash water.

District	Garage Name	Reuse Approach
D2	Henry County	Lagoon/Reuse
D10	Meigs County	Holding Tank/Reuse

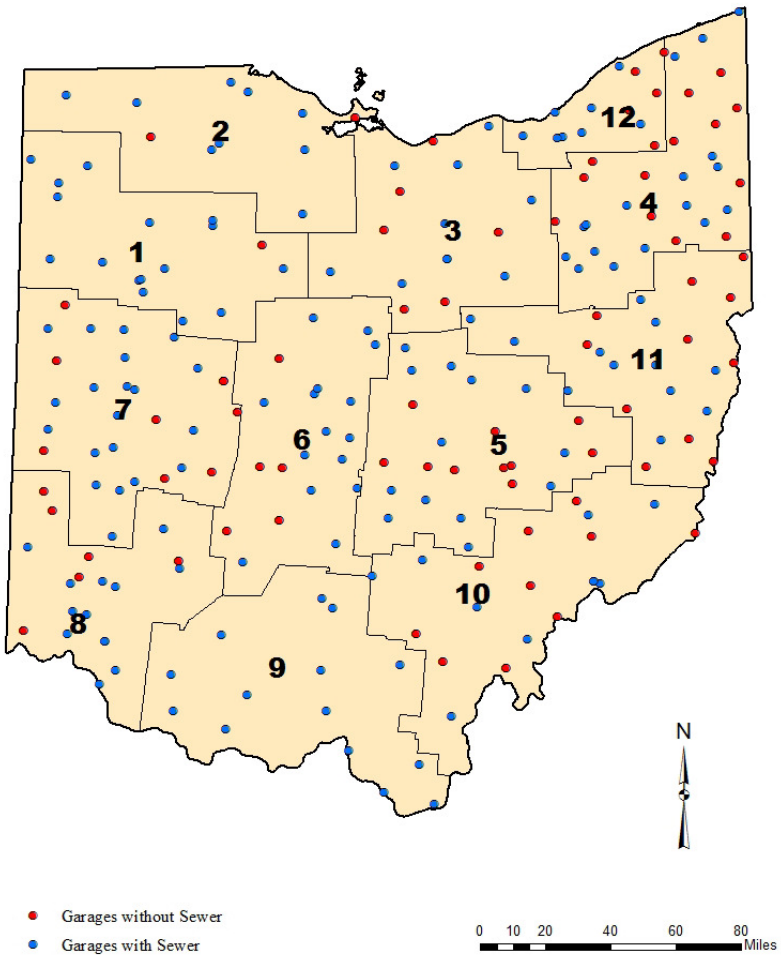


Figure 2-4: Summary of ODOT maintenance facilities lacking access to sanitary sewer.

2.4.3. Evaluation of Current Brine Usage

Because many ODOT districts are already using brine as part of the winter maintenance program, one potential management strategy would be to convert the wash water to a brine solution. To determine whether this would be possible on a volume basis, the volume of brine used by ODOT over the past five winter season was assessed. Data obtained from the Transportation Management System (TMS) was provided to the research team by ODOT personnel.

Figure 2-5 shows the volume of brine made by each of the twelve ODOT districts and the total volume of brine made in Ohio over the last five winter seasons. Table 2-9 shows the volume of salt brine used by each district for pre-treating and pre-wetting. As shown in Figure 2-5 and Table 2-9, District 4 consistently produces and uses the highest volume of brine. Over the past five winter seasons, the average volume of brine used per year in District 4 was 1,792,259 gallons. The total volume of brine used by all twelve ODOT districts over the last five years ranged from a minimum of 5,784,040 gallons (winter 2009/2010) to a maximum of 7,107,050 gallons (winter 2006/2007) with a median volume of 6,565,189 gallons.

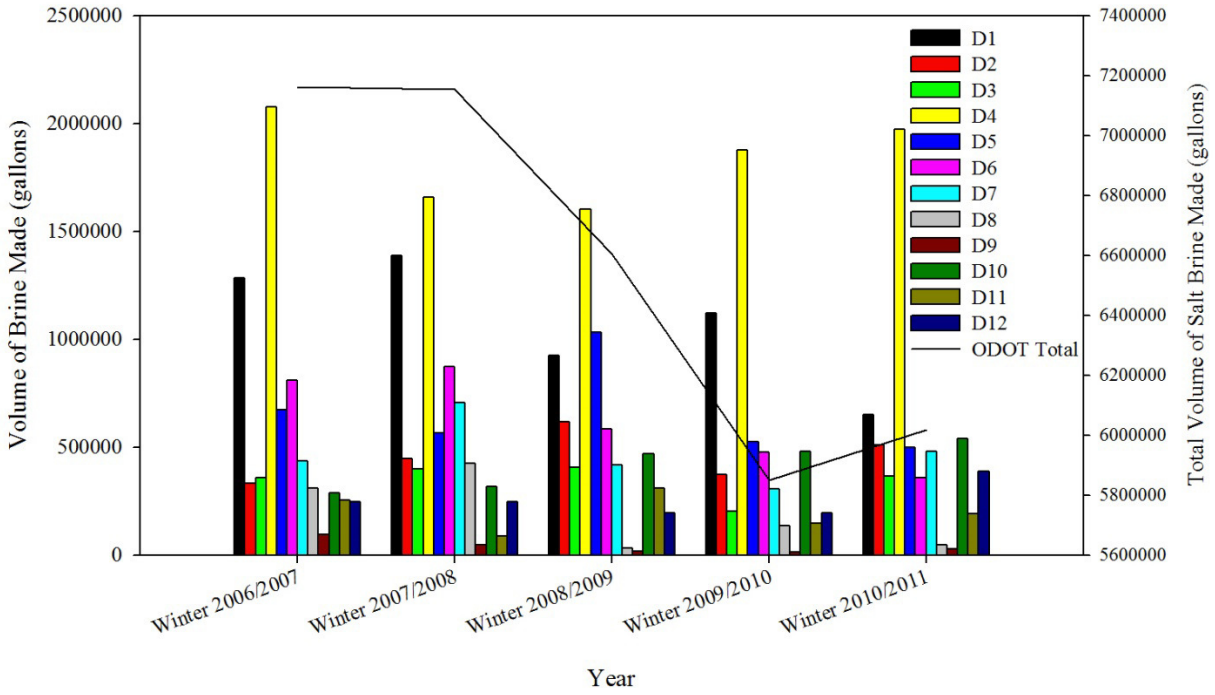


Figure 2-5: Volume of Salt Brine Produced by Each ODOT District and Total Volume of Salt Brine Made by all ODOT Facilities from Winter 2006 through Winter 2011. Data Provided by ODOT Transportation Management System (TMS).

Table 2-9: Volume of Salt Brine Used for Pre-treating and Pre-wetting in each of the Twelve ODOT Districts for Winter 2006 through Winter 2011. All volumes reported in gallons. Data provided by ODOT TMS.

Salt Brine Pre-Treating and Prewetting Usages for Winters 2006/2007 thru 2010/2011

	Winter 2006/2007			Winter 2007/2008			Winter 2008/2009			Winter 2009/2010			Winter 2010/2011		
District	**Pretreat Volume**	**Prewet Volume**	**Total Volume of Salt Brine Used**	**Pretreat Volume**	**Prewet Volume**	**Total Volume of Salt Brine Used**	**Pretreat Volume**	**Prewet Volume**	**Total Volume of Salt Brine Used**	**Pretreat Volume**	**Prewet Volume**	**Total Volume of Salt Brine Used**	**Pretreat Volume**	**Prewet Volume**	**Total Volume of Salt Brine Used**
D01 Totals	926,049	359,529	1,285,578	916,356	462,061	1,378,417	682,085	243,891	925,976	866,452	254,609	1,121,061	373,625	268,231	641,856
D02 Totals	259,246	73,859	333,105	322,303	122,415	444,718	509,329	107,781	617,110	254,443	116,415	370,858	282,490	225,448	507,938
D03 Totals	296,488	62,152	358,640	233,941	155,512	389,452	221,554	183,502	405,057	110,081	92,866	202,947	174,106	189,016	363,122
D04 Totals	1,062,127	971,414	2,033,541	680,916	922,418	1,603,334	457,006	1,126,093	1,583,099	594,941	1,221,362	1,816,303	833,469	1,091,554	1,925,023
D05 Totals	439,798	219,833	659,631	330,034	234,625	564,659	531,538	480,662	1,012,200	163,253	361,373	524,626	206,588	287,003	493,591
D06 Totals	666,363	144,451	810,814	570,612	301,064	871,676	368,213	217,207	585,419	265,476	210,590	476,065	244,873	113,429	358,301
D07 Totals	292,192	143,322	435,514	372,837	334,083	706,920	163,765	254,247	418,012	101,237	205,285	306,522	180,470	268,550	449,020
D08 Totals	268,824	40,405	309,229	405,769	19,463	425,232	28,200	2,250	30,450	126,815	8,275	135,090	39,700	5,000	44,700
D09 Totals	88,060	6,665	94,725	44,280	240	44,520	16,763	160	16,923	14,675	50	14,725	25,551	1,030	26,581
D10 Totals	237,619	48,459	286,078	277,936	39,185	317,121	379,869	85,502	465,371	341,003	138,376	479,379	414,560	125,371	539,931
D11 Totals	200,460	54,155	254,615	68,790	17,759	86,549	211,160	98,227	309,387	111,217	30,265	141,482	144,079	82,722	226,801
D12 Totals	176,431	69,150	245,581	206,351	41,673	248,025	105,400	90,787	196,187	76,634	118,349	194,983	126,640	259,808	386,448
ODOT Totals	**4,913,656**	**2,193,394**	**7,107,050**	**4,430,124**	**2,650,498**	**7,080,622**	**3,674,882**	**2,890,308**	**6,565,190**	**3,026,227**	**2,757,813**	**5,784,040**	**3,046,151**	**2,917,161**	**5,963,312**
ODOT Average	**409,471**	**182,783**	**592,254**	**369,177**	**220,875**	**590,052**	**306,240**	**240,859**	**547,099**	**252,186**	**229,818**	**482,003**	**253,846**	**243,097**	**496,943**
ODOT Median	**280,508**	**71,505**	**345,872**	**326,169**	**138,963**	**434,975**	**294,883**	**145,642**	**441,691**	**145,034**	**128,362**	**338,690**	**193,529**	**207,232**	**417,734**

2.4.4. Wash Water Volume Estimation

The volume of wash water generated influences which management strategies may be viable and is an important factor for assessing management costs. Because this volume is unknown and varies among maintenance facilities based on the number of trucks and winter events, it was estimated for each ODOT maintenance facility using the site specific number of trucks and number of winter events (based on the ODOT definition of a winter event, depending on salt use), which are known historical quantities (Equation 2-1).

Equation 2-1: Estimation of the volume of wash water generated annually

Annual Vol. (gallons) = No. of trucks * Vol. per truck per wash cycle * No. of Wash Cycles

Where:

Volume/Truck = 300 gallons/truck/cycle

Number of Wash Cycles = Number of winter events * 1.1

For the purposes of this analysis, a wash cycle was defined as a cycle consisting of two quick washes and one full wash, where a quick wash lasts approximately 15 minutes and a full wash lasts 30 minutes. Assuming a hose capable of providing five gallons per minute is used for truck washing, approximately 300 gallons of wash water are generated by each truck during each wash cycle. Based on discussions with ODOT personnel, it was assumed that during a typical winter event, each truck goes through one wash cycle, and that approximately 10% of winter events will last multiple days, yielding additional wash cycles for those events. To calculate the annual number of wash cycles, the three year average number of winter events at each facility (as provided by ODOT) was multiplied by 1.1.

To assess the validity of the assumption that 300 gallons of wash water are generated per truck per wash cycle, the annual volume of wash water generated was estimated at each garage in District 10 and the results were compared with the actual water usage as reported on the water bills for the garages in District 10 for July 2010-June 2011. As shown in Figure 2-6, water usage is at its peak during the winter months of December through March, as expected, but there is a background water usage during every month of the year.

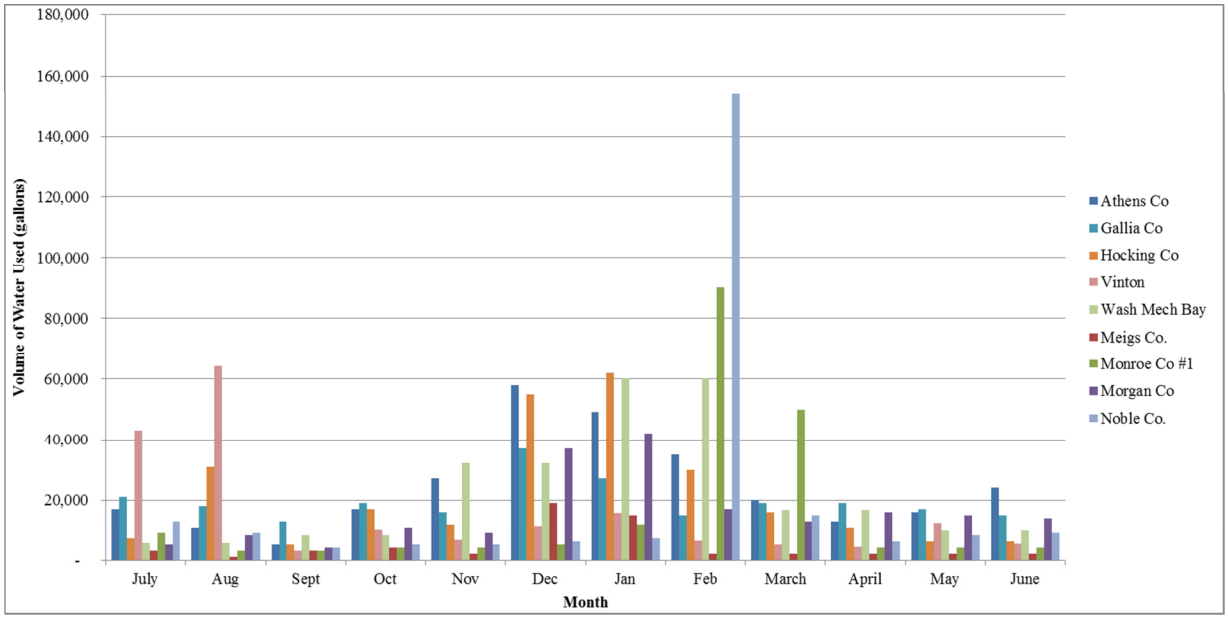


Figure 2-6: Water usage for the county garages in District 10: July 2010-June 2011.

Table 2-10 shows the results of the verification of the estimate of 300 gallons of wash water per truck per event. The annual volume of wash water generated at each garage in District 10 during winter 2010 was estimated using Equation 2-1 and added to the volume of brine made to generate an estimate of the total water usage. This total estimated volume was compared to the actual water usage. This analysis assumes that truck washing and brine production account for the bulk of water usage during the winter months. As shown in Table 2-10, the district total estimated volume of water used during winter 2010 was 1,366,431 gallons. The actual volume of water used during winter 2010 was 1,517,584. This suggests that the 300 gallons per truck per wash cycle estimate is reasonable. In Meigs County, the volume of brine made exceeded the volume of water used because wash water is reused for brine production, and initial brine production for the winter season may begin before October.

Table 2-10: Verification of the estimate of 300 gallons of wash water generated per truck per wash cycle for garages in District 10. Shaded garages lack access to sanitary sewer.

Garage Name	Estimated Volume of Wash Water Generated	Actual Volume of Salt Brine Made	Estimated Total Water Usage (wash water + brine made)	Actual Winter Water Usage from Bill (Oct-Mar)
	gallons	gallons	gallons	gallons
Athens County	63,000	99,730	162,730	206,000
Hollister Outpost Garage	12,600		12,600	8,270
Gallia County	66,300	17,395	83,695	133,000
Hocking County	68,400	57,520	125,920	192,000
Laurelville Outpost Garage	5,700		5,700	
Meigs County	61,200	53,052	114,252	44,000
Tuppers Plains Outpost	15,300		15,300	18,000
Monroe County	81,000	62,314	143,314	165,000
Duffy Outpost Garage	16,200		16,200	
Morgan County	90,000	79,200	169,200	129,000
Noble County	79,200	46,090	125,290	192,063
Belle Valley Outpost Garage	28,800		28,800	40,109
Vinton County	52,800	48,605	101,405	67,800
Wilkesville Outpost Garage	13,200		13,200	5,000
Washington County	93,600	76,025	169,625	218,042
Bartlett Outpost Garage	21,600		21,600	54,600
Belpre Outpost Garage	36,000		36,000	29,200
Macksburg Outpost Garage	21,600		21,600	15,500
District 10 Totals	826,500	539,931	1,366,431	1,517,584

After verifying that the estimate of 300 gallons of wash water per truck per wash cycle was reasonable, the volume of wash water generated at each ODOT maintenance facility was estimated using Equation 2-1. The estimated volumes at each garage within a District were summed to obtain the total estimate for each District, and the District estimates were summed to obtain the estimated total annual volume of wash water generated by ODOT. These volumes were then compared with the five year average volume of brine made in each District to evaluate the viability of reusing truck wash water for the production of brine on a volume basis.

Figure 2-7 shows the estimated volume of truck wash water generated and the five year average volume of salt brine made in each ODOT District. The estimated annual volume of wash water generated by all ODOT Garages for which data were available was 15,403,000 gallons, while the five year average volume of brine made by all ODOT Garages was 6,525,247 gallons.

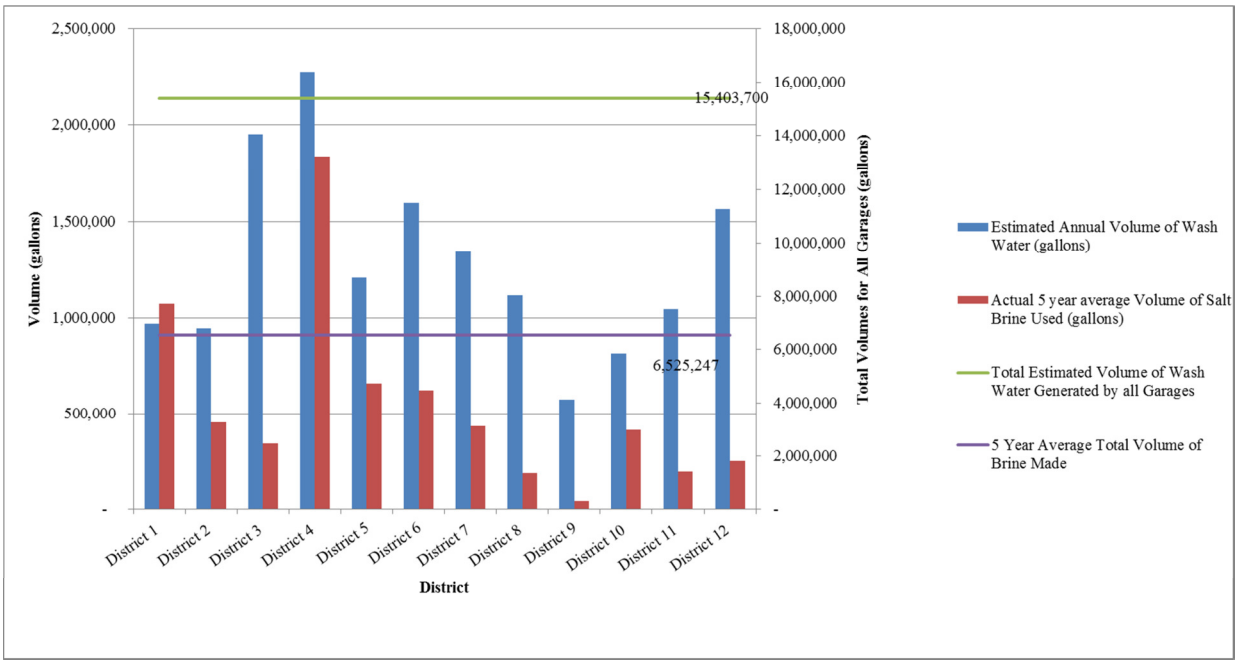


Figure 2-7: Comparison of the estimated annual volume of wash water generated by ODOT garages with the five year average annual volume of brine made in each district. The solid lines represent the total volume of wash water generated and the total volume of brine made. As shown in the figure, it would not be possible for ODOT to reuse all wash water generated for brine; approximately 9 million gallons would still require disposal.

Estimates on the volume of truck wash water generated were incomplete in Districts 8 and 12, with two counties not participating in the survey. Based on these estimates, if truck wash water were reused to produce the volume of brine needed for winter maintenance operations, approximately 6.5 million gallons of wash water could be converted to brine, eliminating the need to use 6.5 million gallons of fresh water for brine production. By reusing these 6.5 million gallons of water, ODOT would save on the cost for disposal of this volume of wash water. However, the estimated volume of truck wash water generated by all ODOT garages exceeds the five-year average volume of salt brine made by almost nine million gallons, and this volume would still need to be managed.

Based on these estimates, it appears that if ODOT were to reuse wash water generated at all ODOT maintenance facilities, the annual volume of brine used would have to be more than double to reuse the total volume of wash water generated. This seems unlikely to be cost effective or practical. However, estimates of the volume of truck wash water generated by ODOT maintenance garages without access to sanitary sewer indicate that the annual volume of wash water produced by these facilities is approximately 3.8 million gallons, which is less than the 6.5 million gallons of salt brine used by ODOT maintenance facilities. Figure 2-8 shows the results of these estimates.

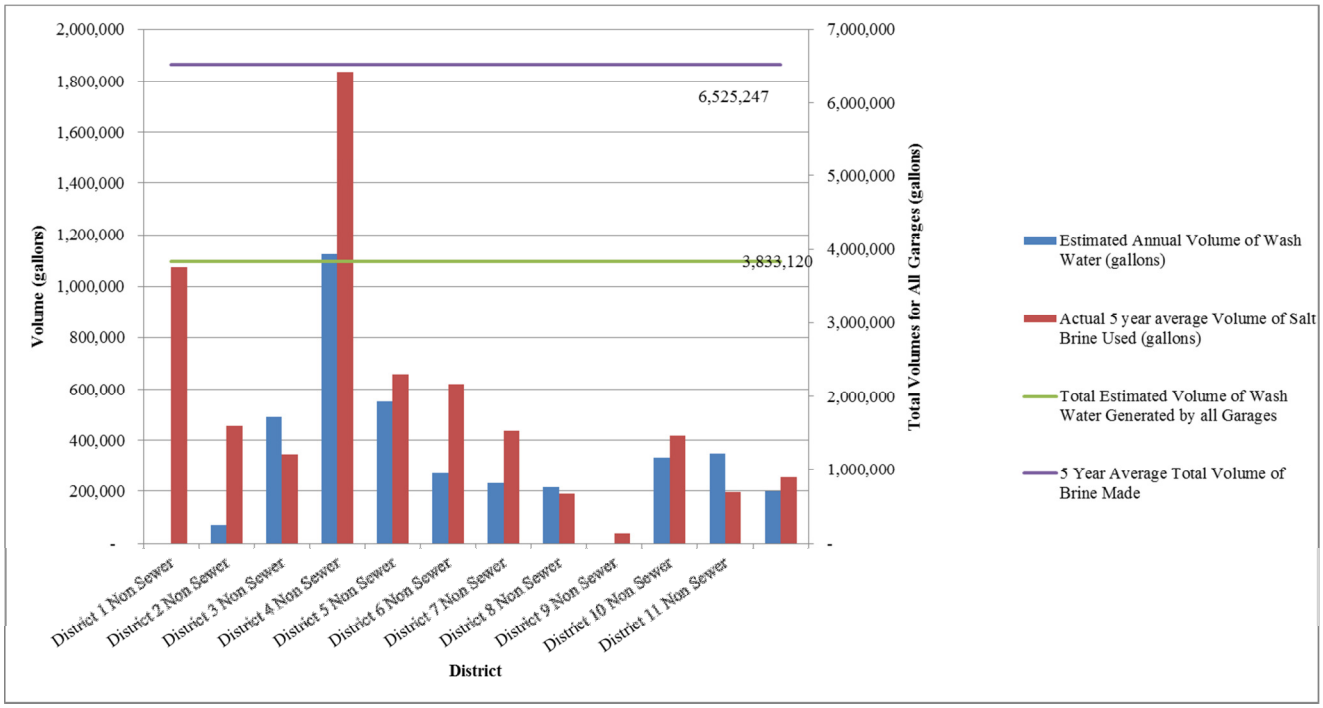


Figure 2-8: Comparison of the estimated volume of truck wash water generated by ODOT maintenance garages without access to sanitary sewer with the 5-year average volume of salt brine made by each district. The solid lines represent the total volumes.

2.4.5. Current Cost of Wash Water Management

Many ODOT garages without access to sanitary sewer have established truck wash water management strategies. Information regarding the current cost of truck wash water management was obtained from the Henry County Garage in District 2, and the Rome, Dorset, Brookfield,

and Drakesburg Outpost Garages in District 4 to establish a baseline for the cost assessment of viable management alternatives. All five of these garages lack access to sanitary sewer and must collect the total volume of truck wash water generated at each location.

The Henry County Garage in District 2 currently collects truck wash water in an on-site retention pond, where it mixes with storm water-rainfall and is reused to produce brine for winter maintenance. Annual costs associated with this system include, but are not limited to, truck wash water quality monitoring and the disposal of water in excess of the pond's storage capacity. Storm water is frequently pumped and hauled to a waste water treatment plant (WWTP) 20 miles away for disposal using ODOT equipment and personnel. The cost of disposal is $0.05/gallon. During the winter of 2011, 624,800 gallons of wash water/storm water were pumped and hauled to the WWTP for disposal at a cost of $31,240. In addition, there are fuel and labor costs associated with hauling the wash water. Using the actual number of trips made to dispose of the wash water during winter 2011 (as reported by ODOT District 2 personnel), a labor cost of $17/hour, and a fuel cost of $3.50/gallon, the calculated cost to haul wash water to the WWTP during winter 2011 was $21,725. With hauling and disposal, the total cost of wash water disposal during winter 2011 was $52,965. Table 2-11 shows the values used in the cost calculation, while Table 2-12 summarizes the hauling and disposal costs for the Henry County Garage during winter 2011.

Table 2-11: Values used for calculating hauling costs at Henry County Garage. Information provided by Henry County personnel.

Cost of Labor	Cost of Diesel	Distance to WWTP	Fuel Efficiency	Time to load/unload
$17.00/hour	$3.50/gal	20.97 miles	8 mpg	1 hour

Table 2-12: Cost for truck wash water management during winter 2011 for the Henry County Garage. Costs do not include water quality monitoring.

Volume of Water (Winter 2011)	Disposal Costs	Hauling Costs	Total Cost Winter 2011	Unit Disposal Cost
624,800 gal	$31,240	$21,725	$52,965	$0.085/gal

In District 4, there are four outpost garages lacking sanitary sewer access. At these locations, holding tank systems and used to capture truck wash water after treatment with an oil/water separator. ODOT has contracted with Fee Corp, Inc. to pump and haul the wash water for disposal when the tanks are full at an average cost of $0.51/gallon. During the winter of 2011, approximately 116,000 gallons of wash water were generated at these four garages and disposed of at a cost of almost $60,000 dollars. Table 2-13 displays the reported values for the volume of wash water generated at these four outpost garages and the cost of disposal during winter 2011. Data were provided by District 4 personnel.

Table 2-13: Reported volumes of wash water and disposal costs for District 4 outposts.

	Actual Cost Winter 2011		
Garage Name (County)	Gallons of Wash Water	Disposal Cost	Unit Disposal Cost ($/gal)
Brookfield (TRU)	19,500	9,623	0.49
Dorset (AST)	30,000	16,065	0.54
Drakesburg (POR)	36,750	17,906	0.49
Rome (AST)	30,500	16,332	0.54
Total	116,750	59,928	0.51

2.5. Identification of Viable Management Strategies

Based on the results of the literature review, the survey of state DOT, and an assessment of the current practices for wash water management in Ohio, six viable wash water management strategies were identified for potential implementation at ODOT maintenance facilities. These strategies are shown in Figure 2-9, with descriptions of each strategy below.

Tie Into Sanitary Sewer

The preferred management strategy of ODOT is to connect (i.e. tie into) maintenance facilities with an existing sanitary sewer line. The capital costs for construction depend are variable depending on the distance to the sewer line, and this may not be a viable option for

facilities in rural locations. However, tying into the sanitary sewer reduces the need for ongoing collection, storage, and transportation of truck wash water.

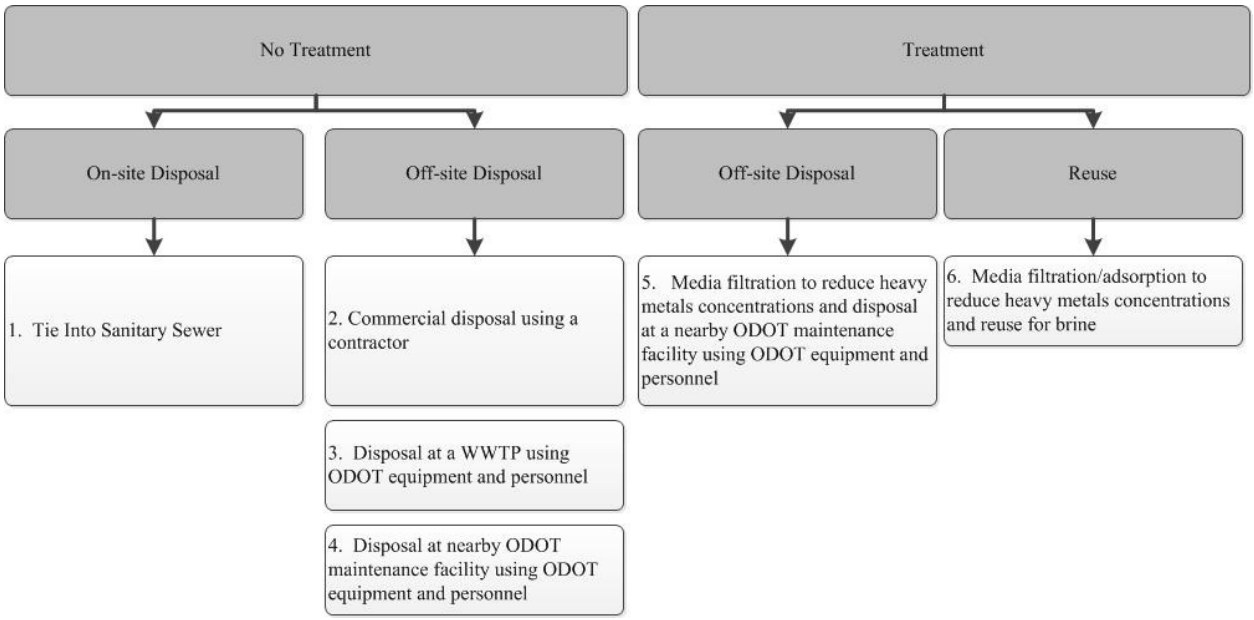


Figure 2-9: List of potential management alternatives included in the detailed cost assessment.

Commercial Disposal

Commercial disposal refers to the use of a commercial contractor for the collection and off-site disposal of wash water. Potential disposal locations include a WWTP or underground injection well. Ohio Department of Natural Resources (ODNR) regulates the disposal of brine in Class II Injection Wells. The map in Figure 2-10 shows the locations of active injection wells in Ohio. These wells may provide a means of disposing of truck wash water generated at ODOT garages in the Eastern part of the state. Because there are very few wells in the western part of the state, it is likely that hauling the truck wash water a long distance would be cost prohibitive. In areas where this option is available, it would have low capital and maintenance costs.

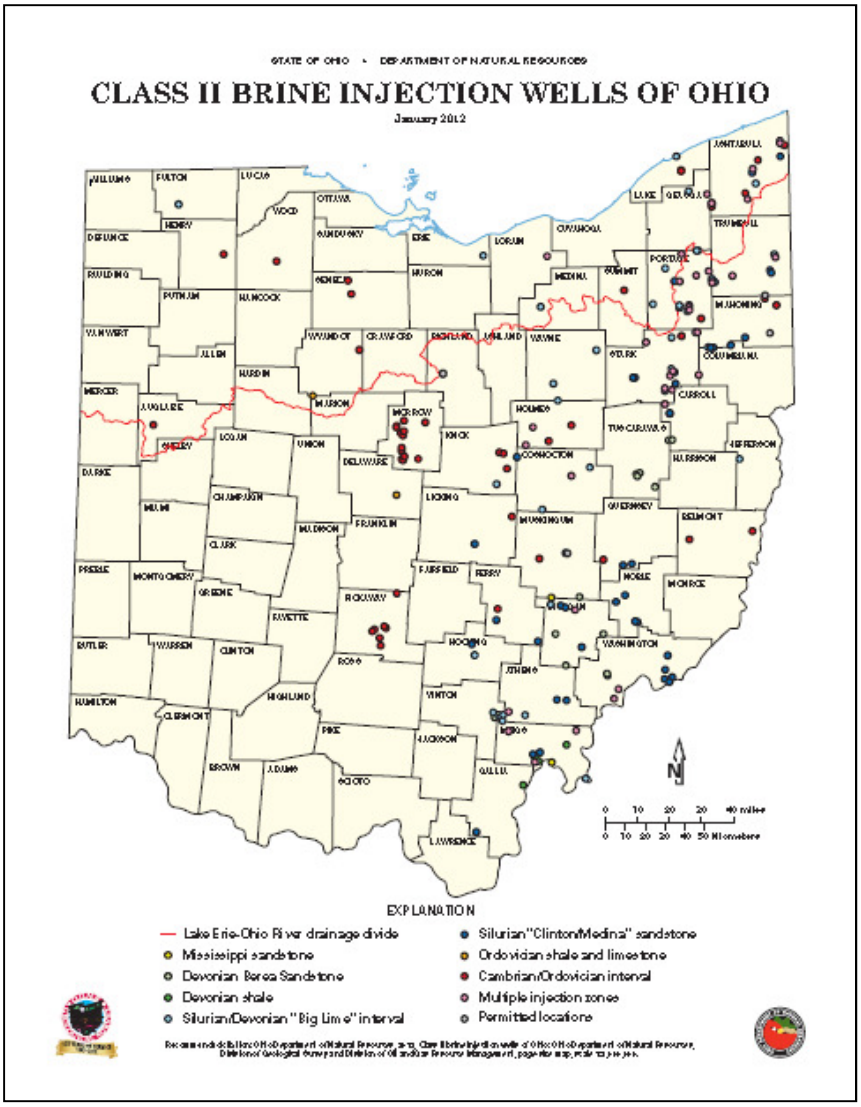


Figure 2-10: Location of permitted Class II Brine Injection Wells in Ohio. Map obtained from Ohio DNR http://www.dnr.state.oh.us/Portals/10/pdf/ClassIIWellsMap.pdf

Haul to WWTP

While there are a large number of WWTP in the state of Ohio (Figure 2-11), the viability of this option would depend on finding a treatment facility willing to accept the wash water, which should not be difficult. The final cost would depend on the monitoring requirements and disposal fees, which are dictated by the individual treatment facilities. Based on the information provided by ODOT garages, the disposal fees may be as low as $0.05/gallon. Baseline water quality monitoring may be required to show that the wash water will not interfere with the

treatment process, and volume limitations may be imposed by the treatment facility. To pursue this disposal option, the individual maintenance facilities would need to locate a treatment plant willing to accept the wash water (based on wash water quality standards or limits) and negotiate disposal fees and volume limitations.

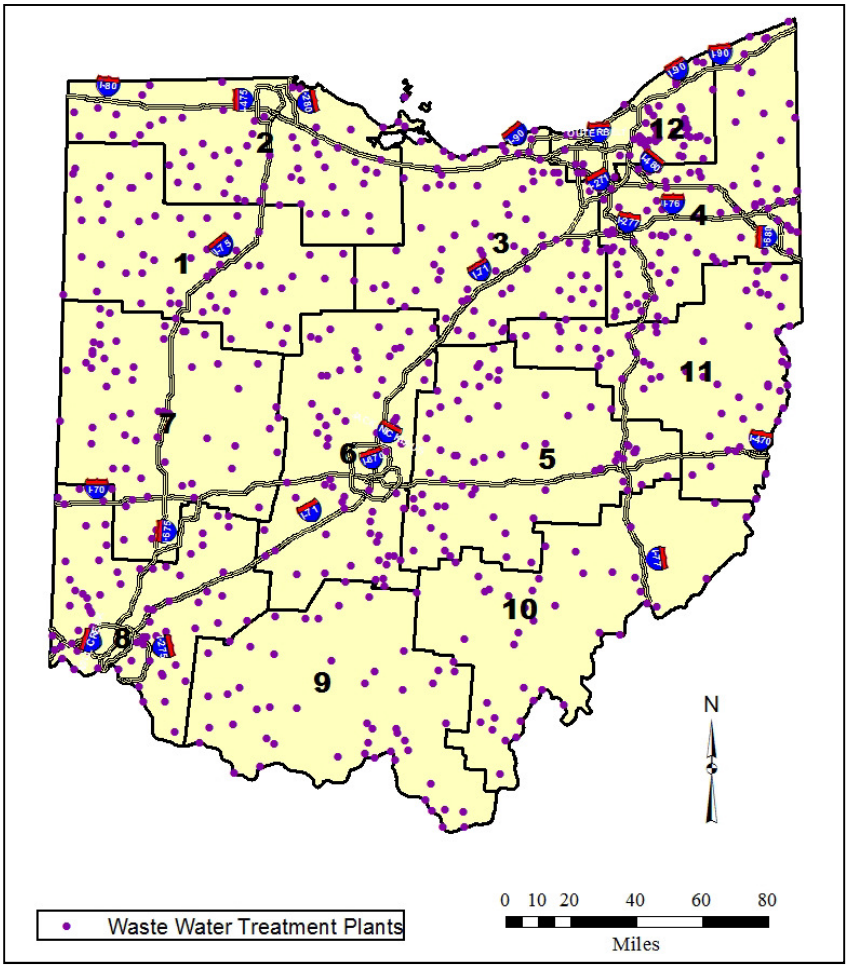


Figure 2-11: Locations of the WWTP in Ohio. Location data obtained from Ohio EPA http://www.epa.ohio.gov/dsw/gis/index.aspx

Haul to ODOT Garage with Sewer Access

Because some sewer districts prohibit hauling waste water from outside the sewer district for disposal, the viability of this option would have to be evaluated on a site-by-site basis by working with local sewer treatment plants. Disposal fees are generally assessed based on water usage, so an agreement regarding payment for the disposal of additional water without additional

water usage would need to be made. Prior to pursuing any of these disposal options, a local WWTP would need to be contacted for their rules and regulations regarding waste water disposal.

Haul to ODOT Garage with Sewer Access and Filtration Unit

Although water quality analysis has shown that the quality of the truck wash water is likely to be adequate for direct disposal, individual treatment facilities have the option of setting water quality limits for specific parameters, like heavy metals. If a facility has a problem meeting their discharge permit requirements for a specific parameter, or is discharging upstream of a sensitive area, they may require that waste water being discharged into the sanitary sewer be treated to reduce contaminant concentrations prior to disposal. This option was included in the cost analysis, but its applicability varies by location.

Haul to ODOT Garage with Filtration and Brine Production Equipment

The option of reusing wash water may not be available to all maintenance facilities. The ability to reuse the wash water will depend on site specific truck wash water quality and regional reuse standards. Truck wash water quality results suggest that the wash water quality may not be adequate for reuse without treatment. However, because each county already has access to brine production equipment and storage, the total cost of reuse would only include hauling, monitoring, and filtration at the county garage (ODOT, 2011).

Summary

Each of these strategies was included in a detailed analysis, which involved an evaluation of wash water quality, an assessment of the use of filtration media for water treatment, and an estimation of management costs for each option. The results of this detailed analysis are the focus of the remaining chapters in this report.

CHAPTER III

WASH WATER QUALITY SAMPLING AND MODELING

3.1. Introduction

To evaluate the viability of each management strategy identified in Section 2.5, a detailed evaluation of the quality of wash water generated at individual ODOT maintenance facilities was needed. This evaluation focused on several potential contaminants of concern including cyanide, oil and grease, and heavy metals. Truck wash water quality monitoring was conducted in two phases. The first phase, which occurred in winter 2011, included the collection and analysis of water quality samples from a limited number of locations. Based on the results achieved during phase one, the sampling effort was expanded to include the collection and analysis of wash water quality samples from 25 maintenance facilities during winter 2012. The water quality data was used to model and identify factors influencing the concentration of heavy metals in truck wash water.

3.2. Wash Water Quality Monitoring

3.2.1. Winter 2011-2012

3.2.1.1. Sampling Protocol

During winter 2011-2012, wash water samples were collected at each of the three selected ODOT locations once per month from January through April 2012. The three locations included: District 2 (Henry County), District 4 (Summit County), and District 10 (Meigs County). Locations were chosen based on geographical diversity. Summit County was selected because of the heavy traffic in the district and Henry Country was chosen because the wash water is being utilized for brine production. The Meigs County Garage presented a unique case in which a

recycled water treatment unit is used to treat wash water. Figure 3-1 shows the wash water quality sampling locations.

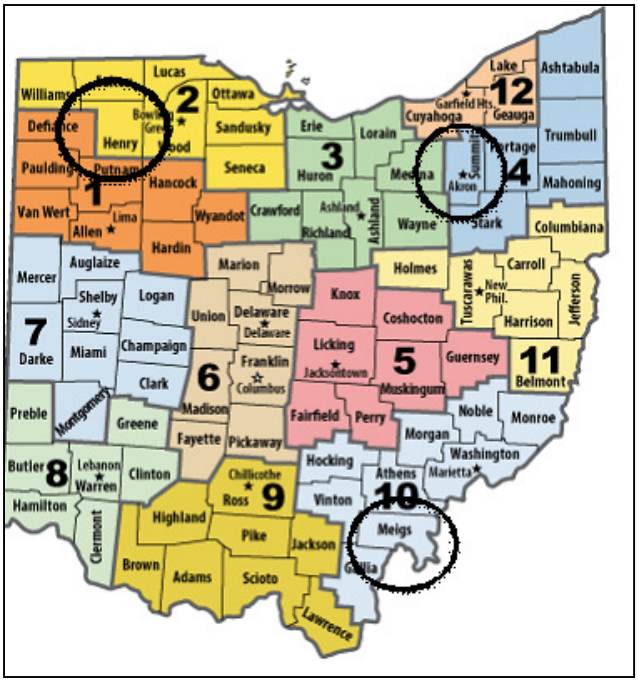


Figure 3-1: ODOT garage wash water sampling locations for samples taken January to April 2012.

The goal of sampling was to obtain wash water samples directly after oil-water separator treatment and characterize the wash water quality. Grab samples were taken directly after the oil/water separator at each of the three sites, as well as one additional location at both Henry County (the pond) and Meigs County (after recycle unit treatment). Figure 3-2 summarizes the wash water sampling effort.

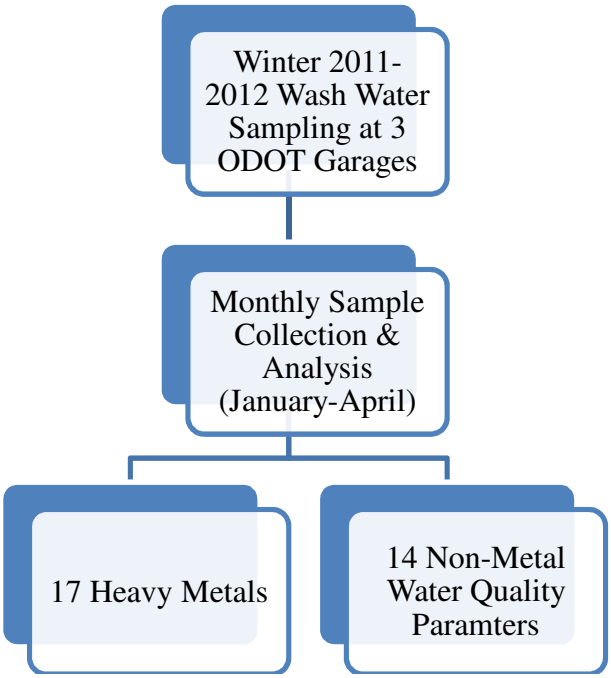


Figure 3-2: Summary of wash water sampling and filter media evaluation program for winter 2011-2012. For the three garages: Henry County – two sampling locations (garage bay sump and retention pond/lagoon), Summit County – one sampling location (effluent from oil-water separator), and Meigs County – two sampling locations (before recycling unit and after recycling unit)

The heavy metals selected for wash water analysis were aluminum (Al), arsenic (As), boron (B), beryllium (Be), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), lithium (Li), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), vanadium (V), and zinc (Zn). Each sample was placed in 0.5 L high density polyethylene bottle, 125ml of the sample was preserved with (1+1) reagent grade nitric acid to a pH<2. The rest of the sample was left unpreserved. The preserved samples were analyzed by an Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES). Wash water also was analyzed for the following:

- Chloride (HACH 8113)
- Conductivity (HACH CO150 Conductivity Meter)
- Cyanide (HACH 8027)
- Fluoride (HACH 8029)
- Herbicides (EPA SW-846 Method 8151A)
- Oil and Grease (EPA Method 1664A)

- Pesticides (EPA Method 608)
- pH (Fisher Scientific AB15 pH Meter)
- Phosphorus (Method 8048)
- Total Dissolved Solids
- Total Organic Carbon (Shimadzu TOC-5000A TOC Analyzer)
- Total Suspended Solids
- Turbidity (HACH 2100Q Portable Turbidimeter)
- Surfactants (HACH 8028)

3.2.1.2. Sampling Results

Heavy metals concentrations are presented in Table 3-1. For discussion purposes, metals are divided into three groups. Group A is comprised of metals that are primarily traffic-related and were detected in greater than 50% of samples. There are 5 group A metals –Cu, Zn, Ni, Cr, and Pb. Group B metals are also detected in greater than 50% of samples. Group C metals are detected in less than 50% of samples. Other non-heavy metal water quality parameters are presented in Table 3-2.

As the focus of the project was wash water quality, discussion of heavy metals focused on the following sampling sites: Summit County Location 1, Henry County Location 1, and Meigs County Location 1. Samples at these locations were taken after an oil/water separator. Of the group A metals at these three sites, Summit County Location 1 samples had the highest average for four of the five metals – Zn, Ni, Cr, and Pb. Meigs County Location 1 had the highest average for Cu. Both Cu and Zn appear at average concentrations greater than 500 ppb at Summit County Location 1. Copper at Meigs County Location 1 also has an average higher than 500 ppb.

Discussion of site differences focuses on sample locations with two sites – Henry County and Meigs County. The focus in this section remains on group A metals. Due to dilution, it was expected that Henry County Location 2 would have lower metal concentrations than Henry County Location 1. Table 3-1 shows that this is not the case. A possible explanation is that the pond (Location 2) receives runoff water from the entire site – including the parking lot, salt

storage, and surrounding grass areas. This runoff effect may cause increased metal concentrations in the pond.

Meigs County Location 2 was expected to have lower concentrations of heavy metals due to the fact that Location 2 is after a recycle unit involving treatment with a clay media. However, Meigs County Location 2 only exhibited lower concentrations for three out of five of group A metals. A possible explanation for this could be that the recycle unit water tank represents a composite of multiple wash cycles.

Concentrations of water quality parameters are presented in Table 3-2. As previously stated, Location 1 samples are the best representation of actual wash water and remain the focus here. Water quality parameters were assessed monthly with the exception of herbicides and pesticides. Herbicides and pesticides were analyzed in April only. April samples were analyzed for 21 pesticides and 8 herbicides. Of those, only one herbicide was detected at one location (Henry County Location 1). There were no detects for pesticides. Oil and grease was detected only in samples from Summit County Location 1 and Henry County Location 1.
Of the three Location 1 samples, Meigs County Location 1 had the lowest average for most nonmetal parameters including: chloride, conductivity, cyanide, surfactants, total dissolved solids (TDS), total organic carbon (TOC), total suspended solids (TSS), and turbidity.

3.2.1.1. Comparison of Results with Water Quality Guidelines

The options for disposing and reusing the wash water based upon water quality guidelines/limits/regulations are displayed in Figure 3-3. There are three disposal methods: allow the wash water to be drained into a local sanitary sewer system, onsite disposal in a leach field, grass field, etc., or haul the water to a local wastewater treatment plant. Each option has different guidelines and limits based on the region. For reusing the water either no limit is required in the permit or the water must meet local aquatic, agriculture, and wildlife standards.

Table 3-1: Total concentrations of heavy metals at ODOT locations for samples taken from January – April 2012.

			Summit County Location 1		Henry County Location 1		Meigs County Location 1		Henry County Location 2		Meigs County Location 2	
Group	Metal	% of samples above detection limit	Range	Avg ± Std Dev	Range	Avg ± Std Dev	Range	Avg ± Std Dev	Range	Avg ± Std Dev	Range	Avg ± Std Dev
A	Cu	100%	275 - 799	555 ± 282	9 - 387	125 ± 176	563 - 858	666 ± 166	10 - 378	144 ± 164	24 - 815	451 ± 415
	Zn	100%	600 - 1,245	884 ± 267	63 - 243	153 ± 92	100 - 1,087	465 ± 541	55 - 975	372 ± 414	62 - 463	249 ± 167
	Ni	100%	21 - 73	42 ± 24	16 - 41	24 ± 12	27 - 34	30 ± 3	13 - 83	34 ± 33	29 - 57	37 ± 13
	Cr	100%	8 - 19	13 ± 5	2 - 8	4 ± 3	1 - 3	2 ± 1	1 - 11	5 ± 4	2 - 4	3 ± 1
	Pb	63%	52 - 188	92 ± 64	28	28 ± 0	41 - 45	43 ± 3	25 - 160	93 ± 95	25 - 64	39 ± 22
B	Al	100%	321 - 1,196	584 ± 411	101 - 524	265 ± 194	34 - 688	411 ± 339	60 - 6,253	1,898 ± 2,927	133 - 244	198 ± 49
	Fe	100%	1,026 - 3,562	1,805 ± 1,181	569 - 2,420	1,327 ±906	305 - 7,195	3,744 ± 3,445	45 - 12,042	3,525 ± 5,712	866 - 2,442	1,835 ± 683
	Mn	100%	281 - 456	347 ± 76	141 - 229	183 ± 41	300 - 869	630 ± 295	2 - 342	103 ± 160	631 - 1,017	804 ± 180
	B	100%	55 - 111	85 ± 23	76 - 161	115 ± 36	40 - 48	45 ± 4	26 - 100	50 ± 34	40 - 78	51 ± 18
	Li	100%	9 - 14	11 ± 2	10 - 95	52 ± 46	7 - 22	13 ± 8	2 - 25	10 ± 10	6 - 26	13 ± 9
	Mo	63%	5 - 12	8 ± 4	2 - 14	8 ± 5	2	2 ± 0	6 - 11	8 ± 2	--	--
C	V	16%	3	3 ± 0	2	2 ± 0	--	--	12	12 ± 0	--	--
	Be	11%	0.7	0.7 ± 0	1.7	1.7 ± 0	--	--	--	--	--	--
	As	5%	15	15 ± 0	--	--	--	--	--	--	--	--
	Se	5%	--	--	123	123 ± 0	--	--	--	--	--	--
	Cd	0%	--	--	--	--	--	--	--	--	--	--
	Co	0%	--	--	--	--	--	--	--	--	--	--

Units: µg/L, ppb

-- no detects

Notes:

1. Summit County Location 1, Henry County Location 1, and Meigs County Location 1 samples were taken directly after an oil/water separator.
2. Henry County Location 2 sample was taken from a pond and Meigs County Location 2 sample was taken after a recycle unit.
3. Samples were taken once per month at each of the five locations. Monthly samples were taken from January 2012 to April 2012 for a total of 19 samples.
4. Metals in group A are traffic related. Metals in Groups B and C were organized based on percent above detection limit.

Table 3-2: Concentrations of various water quality parameters at ODOT locations for samples taken from January – April 2012.

			Summit County Location 1		Henry County Location 1		Meigs County Location 1		Henry County Location 2		Meigs County Location 2	
Parameter	Units	% of samples above detection limit	Range	Avg ± Std Dev	Range	Avg ± Std Dev	Range	Avg ± Std Dev	Range	Avg ± Std Dev	Range	Avg ± Std Dev
Chloride	mg/L as Cl^-	100%	1,400 - 12,300	7,225 ± 4,545	600 - 18,600	7,575 ± 8,490	3,300 - 5,200	4,167 ± 961	500 - 6,000	2,425 ± 2,451	1,400 - 4,800	3,600 ± 1,506
Conductivity	mS	100%	6 - 40	26 ± 14	4 - 62	26 ± 28	16 - 20	18 ± 3	2 - 26	10 ± 11	7 - 20	15 ± 6
Cyanide	mg/L as CN^-	100%	0.009 - 0.036	0.022 ± 0.013	0.011 - 0.087	0.037 ± 0.035	0.003 - 0.007	0.005 ± 0.002	0.002 - 0.113	0.032 ± 0.054	0.004 - 0.015	0.009 ± 0.005
Fluoride	mg/L	100%	0.2 - 1.2	0.8 ± 0.4	0.5 - 0.9	0.6 ± 0.2	0.8 - 1.3	1.0 ± 0.3	0.4 - 1.2	0.6 ± 0.3	0.7 - 1.1	0.9 ± 0.2
Herbicides	µg/L	20%[+]	--	--	336*	336 ± 0	--	--	--	--	--	--
Oil and Grease	mg/L	32%	13 - 120	51 ± 60	9 - 27	18 ± 9	--	--	--	--	--	--
Pesticides	µg/L	0%	--	--	--	--	--	--	--	--	--	--
pH	None	100%	6.4 - 6.9	6.6 ± 0.2	6.3 - 6.8	6.7 ± 0.2	6.8 - 7.0	6.9 ± 0.1	6.6 - 7.4	6.9 ± 0.4	6.8 - 7.0	6.9 ± 0.1
Phosphorus	mg/L as PO_4^-	100%	0.01 - 0.12	0.09 ± 0.05	0.02 - 0.31	0.16 ± 0.14	0.14 - 0.77	0.38 ± 0.34	0.01 - 0.26	0.14 ± 0.12	0.17 - 1.32	0.51 ± 0.54
Surfactants	mg/L	100%	0.04 - 1.91	0.53 ± 0.92	0.08 - 4.13	1.19 ± 1.96	0.04 - 0.05	0.05 ± 0.01	0.02 - 0.05	0.03 ± 0.01	0.03 - 0.10	0.06 ± 0.03
TDS	mg/L	100%	3,510 - 24,490	15,973 ± 8,979	1,950 - 45,260	17,268 ± 20,252	9,120 - 11,460	10,520 ± 1,236	1,340 - 15,740	5,888 ± 6,638	3,670 - 11,460	8,713 ± 3,620
TOC	mg/L	100%	13 - 52	24 ± 19	8 - 64	37 ± 26	7 - 8	8 ± 1	2 - 5	4 ± 1	6 -18	11 ± 5
TSS	mg/L	100%	48 - 397	150 ± 166	76 - 153	108 ± 33	4 - 44	19 ± 22	66 - 2,092	777 ± 1,140	12 - 224	72 ± 102
Turbidity	NTU	100%	47 - 245	108 ± 92	28 - 212	102 ± 80	2 - 91	47 ± 44	< 1 - 1,569	415 ± 770	9 - 26	18 ± 8

-- no detects

*Herbicide detect was for 2,4 - D

[+]This percentage is based on 5 herbicides samples

Notes:

1. Summit County Location 1, Henry County Location 1, and Meigs County Location 1 samples were taken directly after an oil/water separator.
2. Henry County Location 2 sample was taken from a pond and Meigs County Location 2 sample was taken after a recycle unit.
3. Samples were taken once per month at each of the five locations. Monthly samples were taken from January 2012 to April 2012 for a total of 19 samples.

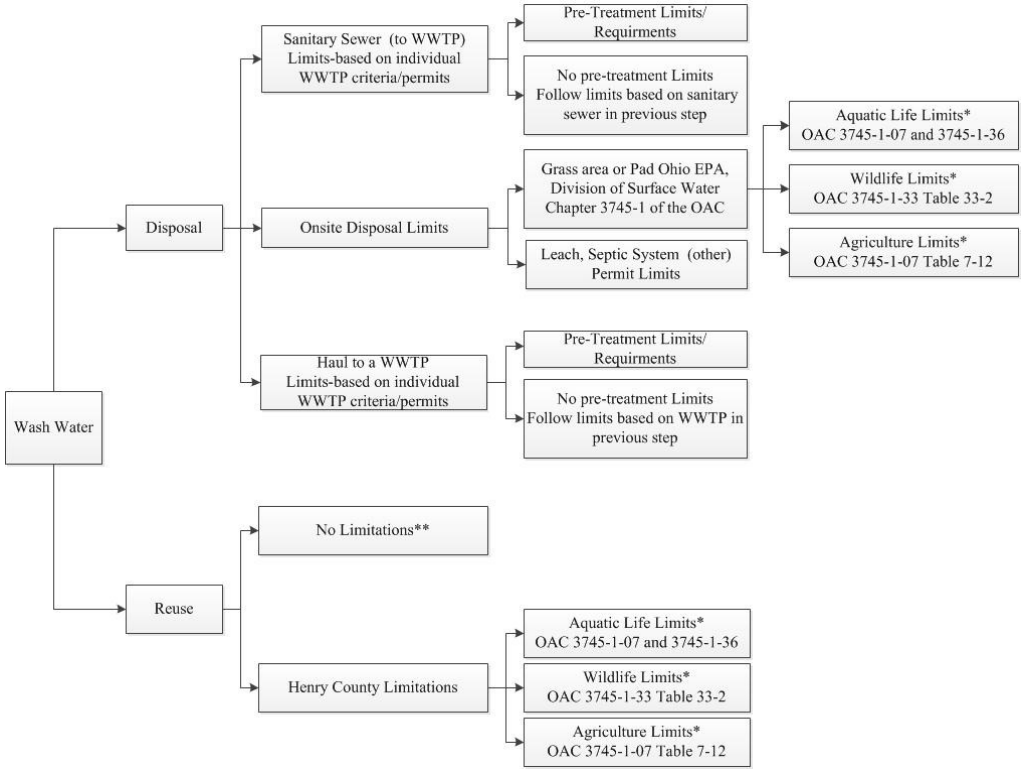


Figure 3-3: Matrix of water quality guidelines and limits for disposal and reuse of wash water (refer to Figure 3-1).

The water quality limits used are regionally dependent. Each county has been evaluated based on the targeted values in that region. The disposal guidance is based on the regions' non-drinking water standards. The non-drinking water standards for Henry County and Summit County were based on the Lake Erie Basin Human Health values Chapter 3745-1 of the Ohio Administrative Code (OAC). For Meigs County, the non-drinking water quality standards were based on the Ohio River Basin Human Health values Chapter 3745-1 of the OAC. A waste water treatment plant (WWTP) may have its own local limits that must be met in order to drain the water into a sanitary sewer system or to haul the water to the plant. Ashtabula County provided guidance to what local limits for each WWTP might look like. The non-drinking water standards (disposal guidance) and local disposal limits provided by Ashtabula County can be seen in Tables 3-3 through 3-7 for each sample location.

In order for brine reuse to occur, the water must meet certain aquatic, agricultural, and wildlife standards after mixing. The reuse limits for Henry County, which have been determined based on a prior permit, are assessed using the most stringent criteria found between several sources including; Lake Erie Basin Aquatic Life Outside the Mixing Zone Maximum (OMZM) from Chapter 3745-1 of the OAC, Statewide Water Quality Criteria for the Protection of Agricultural Uses (Table 7-12 of the State of Ohio Water Quality Standards Chapter 3745-1 of the OAC with a 3.11 times conversion to maximum concentration), Statewide Water Quality Criteria for the Protection of Aquatic Life for Water Hardness Dependent Criteria (Table 7-9 of the State of Ohio Water Quality Standards Chapter 3745-1 of the OAC using OMZM and hardness 288 mg/L), and Lake Erie drainage basin water quality criteria for the protection of human health and wildlife (Table 33-2 of the State of Ohio Water Quality Standards Chapter 3745-1-33 of the OAC using Outside the Mixing Zone Average (OMZA)). The resulting reuse limits for Henry County can be seen in Tables 3-4 and 3-5.

Currently, there are no known reuse limits required for Summit and Meigs County. If this were to change, the projected reuse limits for Summit County are based on the same limits as Henry County with the exception of a potential difference in water hardness change for the aquatic section. The reuse guidance for Meigs County are based on existing targeted values including; Ohio River Basin Aquatic Life OMZM from Chapter 3745-1 of the OAC, Statewide Water Quality Criteria for the Protection of Agricultural Uses (Table 7-12 of the State of Ohio Water Quality Standards Chapter 3745-1 of the OAC with a 3.11 times conversion to maximum concentration), Statewide Water Quality Criteria for the Protection of Aquatic Life for Water Hardness Dependent Criteria (Table 7-9 of the State of Ohio Water Quality Standards Chapter 3745-1 of the OAC using OMZM and hardness dependent), and Lake Erie drainage basin water quality criteria for the protection of human health and wildlife (Table 33-2 of the State of Ohio Water Quality Standards Chapter 3745-1-33 of the OAC using OMZA). While Table 33-2 is a standard for the Lake Erie drainage basin, the OMZA criteria for human health and wildlife are required to be maintained for the entire state. The reuse limitations for Summit County can be seen in Table 3-3 and the reuse limits for the Meigs County locations can be seen in Tables 3-6 and 3-7

The concentrations of each element must be compared to the relevant limit in order to determine if disposal or reuse is a viable option (note: in general the disposal guidance is less

stringent than the reuse limits). Tables 3-3 through 3-7 show each county in comparison with the disposal and reuse limits for that county as well as the local limits provided by the Ashtabula WWTP. The characteristics highlighted in red are those exceeding the limit(s). The following is a description of each characteristic that exceed the guidance(s) in each county.

Aluminum exceeded the non-drinking water limit at Henry County Location 2 in January. This is not seen as an issue because Henry County Location 2 is a retention pond and therefore the grab sample can be considered a composite sample of many different truck washings as well water from rain and drainage. Meigs County Location 1 March sample for copper exceeded the limit. Typically, copper is more than 30% below the non-drinking limitation for Meigs County. All nonmetal parameters were either below the limit or did not possess a limit.

Comparing the characteristics to local reuse limits copper exceeded the limits in 14 out of 19 samples. There were at least two samples from every location and all four samples from Summit County Location 1 that exceeded the limit of 39 ppb. Zinc exceeded the local limits in 8 out of 19 samples. The only sample location that did not have at least one sample exceed zinc was Henry County Location 1. The limit for cyanide was exceeded by Summit County Location 1 (two out of four samples), Henry County Location 1 (two out of four samples), and one sample from Henry County Location 2. No sample from Meigs County exceeded the limit for cyanide. The surfactant guidance was exceeded by one sample from Summit County Location 1 and one sample from Henry County Location 1. Of the six samples above detection for oil and grease, all three samples from Summit County Location 1 exceeded the limit and two out of the three samples exceeded from Henry County Location 1.

Several parameters exceeded the local limits established by Ashtabula WWTP. Out of 19 samples only one copper sample exceeded the local limit of 840 ppb; Meigs County Location 1 April exceeded the limit by only 18 ppb. For TSS 3 out of 19 samples did not meet the limits. Only six samples were above the detection limits for oil and grease, of these six only one did not meet the local limits, it exceeded the limit by 20 ppm. In summary, many samples met disposal guidance; however, far fewer met reuse limits.

Table 3-3: Summit County Location 1 data compared to the disposal and resuse targets.

	Total Concentration				Summit County Standards		
Element	January	February	March	April	Disposal Standard[1], ppb	Local Disposal Limits[2] , ppb	Reuse Standard[3], ppb
Al	1,196	321	441	379	4,500	--	--
As	< 46	15.5	< 46	< 46	580	--	311
B	111	84	91	55	200,000	--	33,000
Be	0.7	< 0.5	< 0.5	< 0.5	130	--	540
Cd	< 1.5	< 1.5	< 1.6	< 1.6	730	74	16
Co	< 6	< 6	< 6	< 6	--	--	220
Cr	19	8	14	11	14,000	2,000	311
Cu	799	349	797	275	64,000	840	39
Fe	3,562	1,026	1,393	1,239	--	--	15,550
Li	9	10	10	14	--	--	--
Mn	330	281	456	322	61,000	--	--
Mo	12	6	5	< 6	10,000	--	190,000
Ni	73	25	49	21	43,000	760	622
Pb	69	61	52	188	--	400	311
Se	< 92	< 92	< 92	< 92	3,100	--	156
V	3	< 1.5	< 1.5	< 1.5	--	--	150
Zn	830	600	1,245	860	35,000	1,460	300
Cyanide	0.036	0.029	0.013	0.009	48	0.250	0.022
Chloride	12,300	8,600	6,600	1,400	--	--	--
Conductivity*	40	30	27	6	--	--	--
Fluoride	0.24	1.23	0.71	0.95	--	--	6
Surfactants	0.12	0.04	0.04	1.91	--	--	0.5
pH[i]	6.4	6.5	6.5	6.9	--	6-11	--
Phosphorus	0.04	0.04	0.06	0.27	--	15	--
TDS	24,490	19,710	16,180	3,510	--	--	--
TSS	397	97	58	48	--	220	--
TOC	52	18	14	13	--	--	--
Turbidity[+]	63	28	107	212	--	--	--
Oil and Grease	120	--*	19	13	--	100	10
Herbicides (various types)	--*	--*	--*	--*	--	--	--
Pesticides (various types)	--*	--*	--*	--*	--	--	--

Notes: Highlighting means the concentration exceeds one or more standard. The standard(s) exceeded is highlighted as well.

Units: µg/L above line mg/L below line unless otherwise noted

* Units: mS

[+] Units: NTU

[i] Unitless

-- No standard provided

--* No detection

[1] Standards based on OAC 3745-1 Human Health non-drinking

[2] Disposal guide for Local Limits provided by Ashtabula Waste Water Treatment Plant

[3]Standards based on OAC 3745-1 aquatic criteria (OMZM) with hardness 288 mg/L, agriculture criteria (OMZM), wildlife criteria (OMZA)

Table 3-4: Henry County Location 1 data compared to the disposal and resuse targets.

	Total Concentration				Henry County Standards		
Element	January	February	March	April	Disposal Standard[1], ppb	Local Disposal Limits[2] , ppb	Reuse Standard[3], ppb
Al	524	131	101	304	4,500	--	--
As	< 46	< 57	< 46	< 46	580	--	311
B	99	161	123	76	200,000	--	33,000
Be	< 0.5	2	< 0.5	< 0.5	1,300	--	311
Cd	< 1.5	< 3	< 1.6	< 1.5	730	74	15
Co	< 6	< 7	< 6	< 6	--	--	220
Cr	4	8	2	4	14,000	2,000	311
Cu	387	38	68	9	64,000	840	38
Fe	2,420	569	597	1,723	--	--	15,550
Li	10	87	95	14	--	--	--
Mn	141	157	229	205	61,000	--	--
Mo	7	9	14	2	10,000	--	190,000
Ni	41	20	16	20	43,000	760	622
Pb	28	< 32	< 16	< 11	1,900	400	311
Se	< 92	< 156	< 92	123	3,100	--	156
V	< 1.5	< 2	< 1.5	2	--	--	150
Zn	243	87	63	221	35,000	1,460	294
Cyanide	0.011	0.013	0.087	0.038	48	0.25	0.022
Chloride	10	19	1	1	--	--	--
Conductivity*	33	62	5	4	--	--	--
Fluoride	0.53	0.9	0.5	0.6	--	--	6.22
Surfactants	4	0.08	0.23	0.34	--	--	0.5
pH[i]	7	6	7	7	--	6-11	--
Phosphorus	0.31	0.25	0.05	0.02	--	15	0.68
TDS	19,050	45,260	2,810	1,950	--	--	--
TSS	153	94	76	110	--	220	--
TOC	64	8	23	53	--	--	--
Turbidity[+]	63	28	107	212	--	--	--
Oil and Grease	--*	27	9	19	--	100	10
Herbicides (various types)	--*	--*	--*	--*	--	--	--
Pesticides (various types)	--*	--*	--*	--*	--	--	--

Notes: Highlighting means the concentration exceeds one or more standard. The standard(s) exceeded is highlighted as well.

Units: µg/L above line mg/L below line unless otherwise noted

* Units: mS

[+] Units: NTU

[i] Unitless

-- No standard provided

--* No detection

[1] Standards based on OAC 3745-1 Human Health non-drinking

[2] Disposal guide for Local Limits provided by Ashtabula Waste Water Treatment Plant

[3]Standards based on OAC 3745-1 aquatic criteria (OMZM) with hardness 288 mg/L, agriculture criteria (OMZM), wildlife criteria (OMZA)

Table 3-5: Henry County Location 2 data compared to the disposal and resuse targets.

	Total Concentration				Henry County Standards		
Element	January	February	March	April	Disposal Standard[1], ppb	Local Disposal Limits[2] , ppb	Reuse Standard[3], ppb
Al	6,253	954	60	325	4,500	--	--
As	< 46	< 57	< 46	< 46	580	--	311
B	47	27	26	100	200,000	--	33,000
Be	< 0.5	< 0.5	< 0.5	< 0.5	1,300	--	311
Cd	< 1.5	< 3	< 1.6	< 1.6	730	74	15
Co	< 6	< 7	< 6	< 6	--	--	220
Cr	11	4	1	4	14,000	2,000	311
Cu	378	10	55	131	64,000	840	38
Fe	12,042	1,527	45	487	--	--	15,550
Li	4	2	8	25	--	--	--
Mn	342	36	2	34	61,000	--	--
Mo	11	9	7	6	10,000	--	190,000
Ni	83	20	13	20	43,000	760	622
Pb	159	< 32	< 16	25	1,900	400	311
Se	< 92	< 156	< 92	< 92	3,100	--	156
V	12	< 2	< 1.5	< 1.5	--	--	150
Zn	975	55	159	299	35,000	1,460	294
Cyanide	0.002	0.003	0.008	0.113	48	0.25	0.022
Chloride	500	1,900	1,300	6,000	--	--	--
Conductivity*	2	5	6	26	--	--	--
Fluoride	0.42	0.53	0.46	1	--	--	6.22
Surfactants	0.015	0.027	0.045	0.033	--	--	0.5
pH[i]	7	7	7	7	--	6-11	--
Phosphorus	0.03	0.02	0.01	0.01	--	15	0.68
TDS	1,340	2,810	3,660	15,740	--	--	--
TSS	2,092	172	2	66	--	220	--
TOC	4	2	3	5	--	--	--
Turbidity[+]	1,596	56	< 1	35	--	--	--
Oil and Grease	--*	--*	--*	--*	--	100	10
Herbicides (various types)	--*	--*	--*	--*	--	--	--
Pesticides (various types)	--*	--*	--*	--*	--	--	--

Notes: Highlighting means the concentration exceeds one or more standard. The standard(s) exceeded is highlighted as well.

Units: µg/L above line mg/L below line unless otherwise noted

* Units: mS

[+] Units: NTU

[i] Unitless

-- No standard provided

--* No detection

[1] Standards based on OAC 3745-1 Human Health non-drinking

[2] Disposal guide for Local Limits provided by Ashtabula Waste Water Treatment Plant

[3]Standards based on OAC 3745-1 aquatic criteria (OMZM) with hardness 288 mg/L, agriculture criteria (OMZM), wildlife criteria (OMZA)

Table 3-6: Meigs County Location 1 data compared to the disposal and resuse targets.

	Total Concentration				Meigs County Standards		
Element	January	February	March	April	Disposal Standard[1], ppb	Local Disposal Limits[2] , ppb	Reuse Standard[3], ppb
Al	NS	688	512	34	--	--	--
As	NS	< 57	< 46	< 46	--	--	311
B	NS	48	45	40	--	--	33,000
Be	NS	< 0.5	< 0.5	< 0.5	280	--	540
Cd	NS	< 3	< 1.6	< 1.5	--	74	16
Co	NS	< 7	< 6	< 6	--	--	220
Cr	NS	3	1	1	--	2,000	311
Cu	NS	563	1,658	858	1,300	840	39
Fe	NS	7,195	3,734	305	--	--	15,550
Li	NS	22	9	7	--	--	--
Mn	NS	722	869	300	--	--	--
Mo	NS	< 8	< 6	2	--	--	190,000
Ni	NS	34	27	31	4,600	760	622
Pb	NS	< 32	45	41	--	400	311
Se	NS	< 156	< 92	< 92	11,000	--	156
V	NS	< 2	< 1.5	< 1.5	--	--	150
Zn	NS	100	208	1,087	69,000	1,460	300
Cyanide	NS	0.004	0.003	0.007	220	0.25	0.022
Chloride	NS	4,000	5,200	3,300	--	--	--
Conductivity*	NS	15.54	19.74	20.10	--	--	--
Fluoride	NS	1.28	0.78	1.06	--	--	6
Surfactants	NS	0.05	0.04	0.05	--	--	1
pH[i]	NS	6.78	6.98	6.91	--	6-11	--
Phosphorus	NS	0.04	0.04	0.15	--	15	--
TDS	NS	9,120	11,460	10,980	--	--	--
TSS	NS	44	10	4	--	220	--
TOC	NS	8	8	7	--	--	--
Turbidity+	NS	91	48	2	--	--	--
Oil and Grease	NS	--*	--*	--*	--	100	10
Herbicides (various types)	NS	--*	--*	--*	--	--	--
Pesticides (various types)	NS	--*	--*	--*	--	--	--

Notes: NS: No January sample was taken for this location

Highlighting means the concentration exceeds one or more standard. The standard(s) exceeded is highlighted as well.

Units: µg/L above line mg/L below line unless otherwise noted

* Units: mS

+ Units: NTU

[i] Unitless

-- No standard provided

--* No detects

[1] Standards based on OAC 3745-1 Human Health non-drinking

[2] Disposal guide for Local Limits provided by Ashtabula Waste Water Treatment Plant

[3]Standards based on OAC 3745-1 aquatic criteria (OMZM) with hardness 288 mg/L, agriculture criteria (OMZM), wildlife criteria (OMZA)

Table 3-7: Meigs County Location 2 data compared to the disposal and resuse targets.

	Total Concentration				Meigs County Standards		
Element	January	February	March	April	Disposal Standard[1], ppb	Local Disposal Limits[2] , ppb	Reuse Standard[3], ppb
Al	187	228	133	244	--	--	--
As	< 46	< 57	< 46	< 46	--	--	311
B	78	44	43	40	--	--	33,000
Be	< 0.5	< 0.5	< 0.5	< 0.5	280	--	540
Cd	< 1.5	< 3	< 1.6	< 1.6	--	74	16
Co	< 6	< 7	< 6	< 6	--	--	220
Cr	3	2	4	4	--	2,000	311
Cu	165	24	815	800	1,300	840	39
Fe	2,442	866	1,905	2,126	--	--	15,550
Li	26	6	12	7	--	--	--
Mn	887	631	1,017	682	--	--	--
Mo	< 6	< 8	< 6	< 6	--	--	190,000
Ni	57	31	29	30	4,600	760	622
Pb	25	< 32	64	26	--	400	311
Se	< 92	< 156	< 92	< 92	11,000	--	156
V	< 1.5	< 2	< 1.5	< 1.5	--	--	150
Zn	203	62	269	463	69,000	1,460	300
Cyanide	0.015	0.004	0.008	0.009	220	0.25	0.022
Chloride	1,400	4,000	4,200	4,800	--	--	--
Conductivity*	7	14	20	20	--	--	--
Fluoride	0.98	1.10	0.68	0.72	--	--	6
Surfactants	0.10	0.03	0.06	0.04	--	--	1
pH[i]	6.97	6.85	6.94	6.80	--	6-11	--
Phosphorus	0.38	0.16	0.11	0.08	--	15	--
TDS	3,650	8,500	11,220	11,460	--	--	--
TSS	34	12	18	224	--	220	--
TOC	18	6	8	11	--	--	--
Turbidity[+]	26	15	23	9	--	--	--
Oil and Grease	--*	--*	--*	--*	--	100	10
Herbicides (various types)	--*	--*	--*	--*	--	--	--
Pesticides (various types)	--*	--*	--*	--*	--	--	--

Notes: Highlighting means the concentration exceeds one or more standard. The standard(s) exceeded is highlighted as well.

Units: µg/L above line mg/L below line unless otherwise noted

* Units: mS

[+] Units: NTU

[i] Unitless

-- No standard provided

--* No detects

[1] Standards based on OAC 3745-1 Human Health non-drinking

[2] Disposal guide for Local Limits provided by Ashtabula Waste Water Treatment Plant

[3]Standards based on OAC 3745-1 aquatic criteria (OMZM) with hardness 288 mg/L, agriculture criteria (OMZM), wildlife criteria (OMZA)

3.2.2. Winter 2012-2013

3.2.2.1. Sampling Protocol

During the first phase of the project (2011-2012 winter season), samples were collected monthly (January-April), from three maintenance facilities: Henry County, Meigs County, and Stark County. For the 2012-2013 winter season samples were collected from the three garages listed above; however Meigs and Henry County were only collecting samples after the oil water separator. In addition to these sample locations, 22 other maintenance facilities were chosen as wash water quality sampling locations, bringing the original total number of sampling locations to 25, with a minimum of one per District. It is noted that Trumbull County could not participate due to not having a viable location to collect water, bringing the actual sampling locations to 24 garages, with a minimum of one per District. The locations of the maintenance facilities collecting wash water quality samples during winter 2012-2013 are shown in Figure 3-4. Table 3-8 gives the garage ID given by the project as well as other pertinent garage information.

During winter 2012-2013, four sampling events were targeted for each location. Each sampling event took place during a full truck wash cycle and included the collection of four wash water grab samples: one at the beginning of the wash cycle, two in the middle, and one at the end. ODOT personnel collected grab samples after the oil/water separator. Each of the four samples was considered to be a sample set. Figure 3-5 summarizes the wash water sampling effort for the 2012-2013 winter season. Table 3-9 summarizes the number of sample sets collected by each of the 24 participating garages. The total number of individual samples collected for the project was 253.

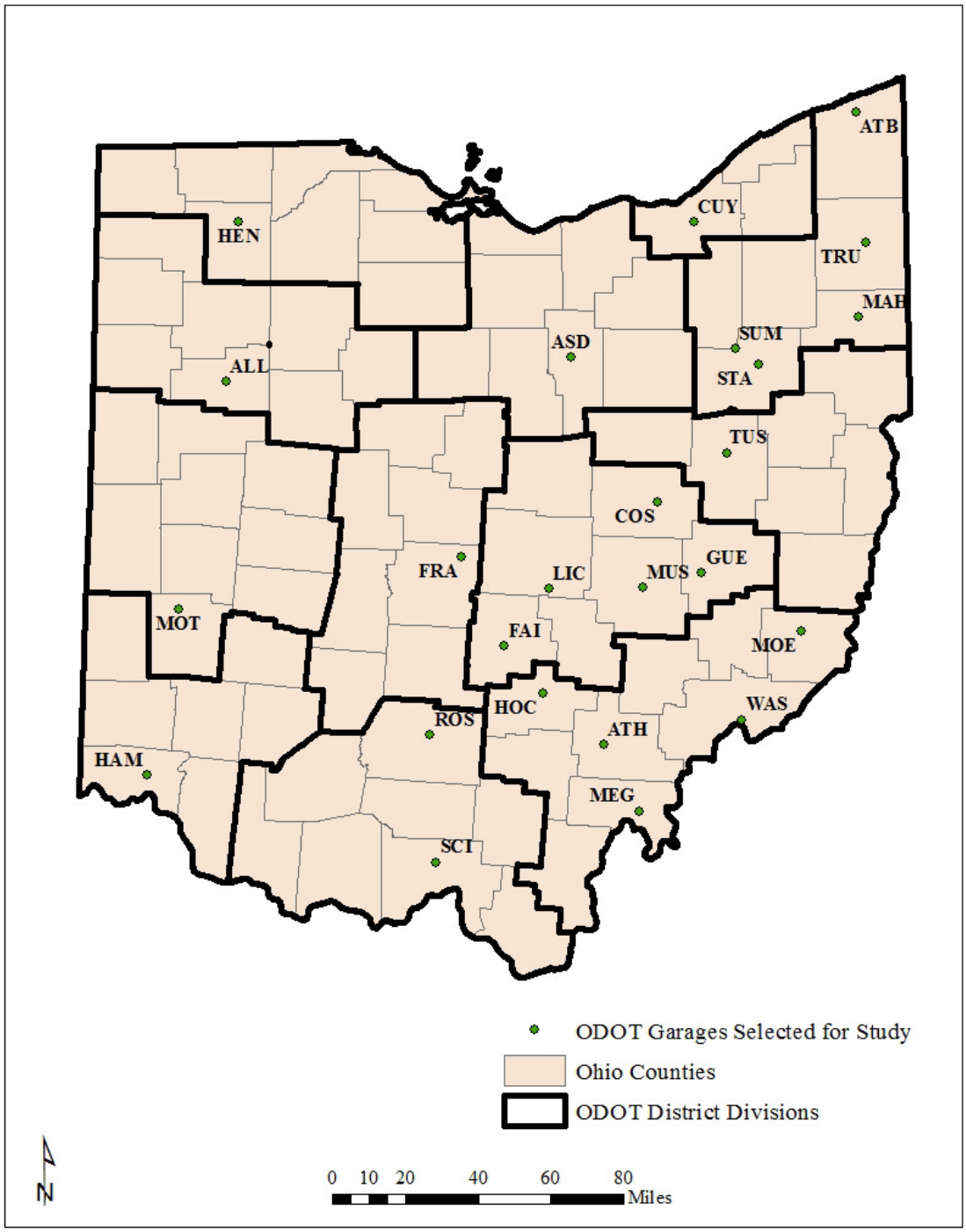


Figure 3-4: ODOT garages selected for the winter 2012-2013 wash water quality sampling.

Table 3-8: ODOT information for the selected garages for the 2012-2013 wash water study. Note: Trumbull County could not participate in the project.

District	Garage Name	Project Garage ID	Garage Code	Address	Facility Type
1	Allen County Garage	1	ALL	123 E Chapman Road, Lima, Ohio 45801	County
2	Henry County Garage	2	HEN	US 6 and SR 110, Napoleon, Ohio 43545	County
3	Ashland County Garage	3	ASD	946 Clark Avenue, Ashland, Ohio 44805	County
4	Greensburg Outpost, Summit County	4	SUM	4377 Mt. Pleasant Rd, North Canton, Ohio 44240	Outpost
4	Ashtabula County Garage	5	ATB	492 Seven Hills Rd., Ashtabula, Ohio 44004	County
4	Mahoning (Canfield) County Garage	6	MAH	401 W. Main St., Canfield, ohio 44406	County
4	Stark County Garage	7	STA	4505 Atlantic Blvd. NE, Canton, Ohio 44705	County
4	Trumbull (Courtland) County Garage	8	TRU	310 Second Street, Cortland, Ohio 44410	County
5	Fairfield County Garage	9	FAI	3265 West Fair Ave., Lancaster, Ohio 443120	County
5	Muskingum County Garage	10	MUS	3399 East Pike, Zanesville, Oh 43701	County
5	Guernsey County Garage	11	GUE	6490 Glenn Hwy., Cambridge, Oh 43725	County
5	Licking County Garage	12	LIC	9600 Jacksontown Rd, Jacksontown, Oh 43030	District Headquarters
5	Coshocton County Garage	13	COS	233 Rivercrest Dr.-Canal Lewisville, Coshocton, Oh 4381	County
6	Franklin County Garage	14	FRA	4730 East Dublin-Granville Road, Westerville, Ohio 43081	County
7	Montgomery County Garage	15	MOT	300 Smith Drive, Clayton, OH 45315	County
8	Hamilton County Garage	16	HAM	1400 East Seymour Ave., Cincinnati, Ohio 45237	County
9	Ross County Garage	17	ROS	255 Larrick Lane, Chillicothe, Ohio 45601	County
9	Scioto County Garage	18	SCI	9187 US Route 23, Lucasville, Ohio 45648	County
10	Meigs County Garage	19	MEG	34449 SR 7, Pomeroy OH 45750	County
10	Athens County Garage	20	ATH	700 W Union Street, Athens OH 45701	County
10	Washington County Garage	21	WAS	1650 Greene St, Marietta, OH 45750	County
10	Hocking County Garage	22	HOC	13176 SR 664, Logan OH 43138	County
10	Monroe County Garage	23	MOE	47028 SR 26, Woodsfield OH 43793	County
11	Tuskawarus County Garage	24	TUS	384 Stonecreek Road SE, New Philadelphia, Ohio 44663	County
12	Independence Outpost, Cuyahoga County	25	CUY	5469 Old Brecksville Road, Independence, OH 44131	Outpost

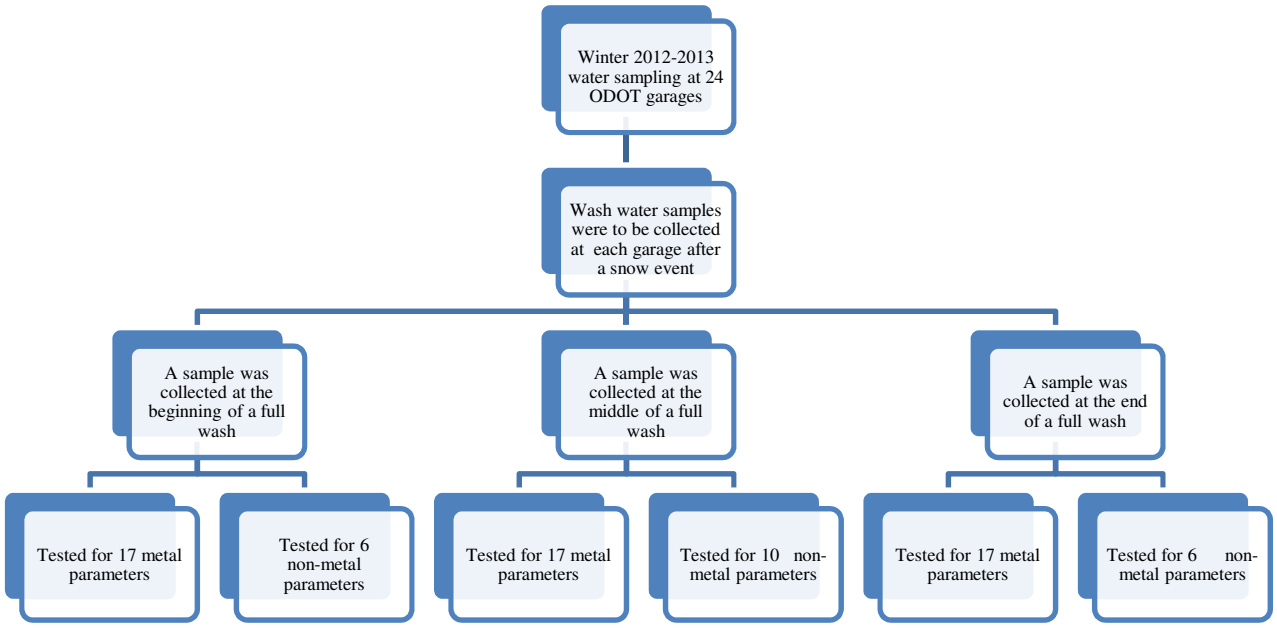


Figure 3-5: A summary of the sampling plan for the 24 garages. Each wash water sampling event included a beginning, middle, and end sample. The middle sample included two containers, one for organics and the other for all other parameters. The samples were to be collected during a full truck washing after a winter event from the oil water separator effluent.

Table 3-9: The number of sample sets collected by each garage during the winter 2012-2013 season.

Garage ID	Number of Sample Sets
1	4
2	3
3	4
4	3
5	4
6	4
7	3
9	4
10	4
11	4
12	4
13	4
14	4
15	3
16	3
17	4
18	4
19	4
20	4
21	4
22	4
23	3
24	4
25	3

Note: A typical sample set should contain three samples. Samples were collected at the beginning (1), middle (1), and end (1) of a wash cycle.

Each of the 253 samples was tested for 17 metal parameters and 6 non-metal parameters. Only one sample in each sample set was tested for cyanide, oil and grease, TSS, and surfactants for a total of 89 samples for those four parameters. The heavy metals and non-metal parameters selected for wash water analysis are in Table 3-10; those non-metal parameters noted with a star were tested on only on sample in each sample set. The methods for each parameter tested were given in section 3.2.1.1 of this report. Each sample was placed in 1 L high density polyethylene bottle, 145 ml of the sample was preserved with reagent grade nitric acid to a pH<2. The organic sample, one of the two

middle samples, was collected in a 1 L amber glass bottle and preserved with a (1+1) regent grade nitric acid to a pH<2. The rest of the sample was left unpreserved. The preserved heavy metal samples were analyzed by an Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES).

Table 3-10: The metal and non-metal parameters analyzed for the samples collected.

Metal Parameters	Non-Metal Parameters
Aluminum	Cyanide*
Arsenic	Surfactants*
Beryllium	TSS*
Boron	TDS
Cadmium	Turbidity
Chromium	Conductivity
Cobalt	Oil and Grease*
Copper	pH
Iron	UV 254
Lead	UV 272
Lithium	
Manganese	
Molybdenum	
Nickel	
Selenium	
Vanadium	
Zinc	

Note: * Analyzed on only one sample in each sample set

3.2.2.2. Sampling Results

The results for the total metals, dissolved metals, and non-metal parameters is organized by garage and by district for reference purposes in Tables 3-11 to 3-13. A brief discussion of individual garages and parameters is given below; further comparison is given later in this chapter.

The total metal form (i.e. dissolved plus particulate) of each of the heavy metals will be the focus of most of the discussion as it is the basis for disposal and reuse guidelines and limits. Of the 17 metals Table 3-11 (a-f) shows that total copper was detected in 98% of the samples and total zinc was

detected in 99.6% of the samples. Total nickel was detected in 100%, total chromium in 82%, total lead in 53%, and total iron was detected 99% of the 253 samples collected. These metals are typically associated with traffic and would be expected to be on the winter maintenance trucks. Iron is a metal that is associated with traffic as well as in the surrounding area.

Looking at individual garages, Allen County has the highest median concentration for total copper, iron, and zinc. It has the second highest median value for total chromium and total lead. Hamilton County garage has the highest median concentration for total chromium and lead, and it has the second highest median value for total copper, iron, nickel, and zinc. Cuyahoga County has the highest median concentration for total nickel. Figures 3-6 and 3-7 demonstrate the median total copper and median total zinc for all 24 garages.

The dissolved metals results can be found in Table 3-12a-f. Of the 17 heavy metals analyzed, nickel and manganese were the only two that were detected in every sample collected. These results indicate the dissolved fraction for the heavy metals was low and the particulate form is predominant. Cuyahoga County had the highest copper, zinc, nickel, chromium, and lead concentrations. Hocking County had the second highest copper and lead concentration. Allen County had the highest iron concentration and Montgomery County had the second highest chromium and nickel concentration. Guernsey County had the second highest zinc concentration and Scioto County had the second highest iron concentration.

There were 10 non-metal parameters analyzed in the wash water samples, as shown in Table 3-10. The results for the non-metal parameters are in Tables 3-13a-h. All parameters had 100% detection except for oil and grease. Tuscarawas County and Meigs County had 0% detection for all samples, meaning that for all samples in these two counties the oil and grease concentration was below 4 mg/L. Coshocton County had the highest median oil and grease concentration at 493 mg/L and Ashtabula County had the second highest at 346 mg/L. Franklin County had the highest median total suspended solids (TSS) concentration at 2682 mg/L and Hocking County had the second highest at 2421 mg/L. All cyanide median cyanide concentrations were below 0.1 mg/L as CN^-.

Table 3-11a-f: Total heavy metal sample results for all 24 garages.

	Allen County (D1)				Henry County (D2)				Ashland County (D3)				Summit County (D4)			
Metal	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cu*	100%	256 - 3526.1	1567 ± 1221	1358	100%	20 - 288.68	93 ± 94	60	100%	3 - 79	28 ± 27	16	100%	12 - 58.87	37 ± 15	37
Zn*	100%	469 - 9367.5	3006 ± 2478	2562	100%	138 - 1135.6	423 ± 327	325	100%	87 - 567	332 ± 161	337	100%	117 - 548.7	278 ± 174	181
Ni*	100%	22 - 162	85 ± 44	77	100%	10 - 81	32 ± 23	25	100%	9 - 47	25 ± 12	22	100%	15 - 31	22 ± 7	18
Cr*	100%	10 - 243	64 ± 64	55	88%	7 - 83	34 ± 29	19	83%	0 - 47	12 ± 15	8	57%	9 - 19.99	13 ± 5	12
Pb*	92%	22 - 1130.9	322 ± 335	161	63%	14 - 62	35 ± 21	25	58%	11 - 61	30 ± 19	20	14%	37 - 37	37 ± -	37
Fe*	100%	11877 - 79292	42223 ± 24667	40897	100%	2134 - 33245	11184 ± 10795	6675	100%	155 - 21198	5895 ± 6477	4808	100%	507 - 5420	2539 ± 1518	2388
Al	100%	1705 - 16909	8089 ± 4785	7711	100%	568 - 10296	3066 ± 3393	1549	100%	18 - 4851	1079 ± 1465	327	100%	86 - 8304	1751 ± 2914	660
As	42%	6 - 351	47 ± 96	20	38%	4 - 171	41 ± 57	15	17%	4 - 33	13 ± 10	12	14%	15 - 400	70 ± 145	15
Be	58%	0.1 - 4	1 ± 2	0.2	13%	0.1 - 4	2 ± 1	3	50%	0.04 - 4	2 ± 2	2	14%	1 - 4	3 ± 1	3
B	100%	75 - 442	261 ± 116	280	100%	94 - 293	190 ± 78	176	100%	65 - 247	158 ± 73	159	100%	123 - 268	204 ± 54	192
Cd	75%	1 - 16	5 ± 4	4	13%	0.4 - 4	3 ± 1	3	33%	0.2 - 4	2 ± 1	2	14%	2 - 4	3 ± 1	3
Co	25%	1 - 5	2 ± 2	2	0%	1 - 4	3 ± 1	3	0%	1 - 4	2 ± 1	2	0%	1 - 4	3 ± 1	3
Li	100%	7 - 157	44 ± 44	24	100%	10 - 23	16 ± 6	14	100%	3 - 17	9 ± 4	9	100%	6 - 15	11 ± 3	12
Mn	100%	98 - 997	504 ± 284	424	100%	242 - 752	499 ± 175	488	100%	64 - 668	260 ± 166	202	100%	183 - 457	328 ± 96	307
Mo	100%	8 - 33	21 ± 8	22	88%	4 - 25	13 ± 8	12	83%	2 - 20	9 ± 6	8	43%	4 - 20	10 ± 7	5
Ni	100%	22 - 162	85 ± 44	77	100%	10 - 81	32 ± 23	25	100%	9 - 47	25 ± 12	22	100%	15 - 31	22 ± 7	18
Se	0%	8 - 28	18 ± 8	22	0%	6 - 25	20 ± 8	23	0%	6 - 25	18 ± 9	23	0%	23 - 28	25 ± 2	25
V	92%	3 - 29	14 ± 8	12	50%	3 - 32	10 ± 11	3	42%	0 - 14	3 ± 4	3	14%	3 - 3	3 ± 0.1	3

Units: µg/L, ppb

All concentrations are in total metal form

* denotes a metal that is typically associated with traffic

All non-detect samples were given the concentration of half the detection limit

Samples were taken during the winter months at the beginning, middle, and end of a full truck wash

A total of 253 samples were collected

	Ashtabula County (D4)				Mahoning County (D4)				Stark County (D4)				Fairfield County (D5)			
Metal	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cu*	100%	9 - 256.3	70 ± 88	27	100%	7 - 160.78	66 ± 53	44	100%	19 - 100.28	50 ± 24	48	100%	44 - 323	137 ± 90	108
Zn*	100%	179 - 1341	609 ± 534	336	100%	8 - 1544.2	559 ± 521	462	100%	163 - 928.67	326 ± 242	211	100%	420 - 3831	1194 ± 958	953
Ni*	100%	8 - 34	19 ± 11	15	100%	7 - 119	45 ± 40	27	100%	15 - 59.035	28 ± 13	22	100%	24 - 54.23	34 ± 10	33
Cr*	89%	3 - 39.97	16 ± 10	15	92%	1 - 167	45 ± 52	20	100%	5 - 79.353	21 ± 25	8	100%	12 - 41.4	21 ± 9	18
Pb*	78%	8 - 55	25 ± 20	11	50%	6 - 98	52 ± 31	47	33%	6 - 44.985	19 ± 22	7	50%	28 - 61.12	43 ± 16	40
Fe*	100%	874 - 9368	3356 ± 2881	1984	100%	135 - 44551	12942 ± 15067	6051	100%	671 - 16828	4191 ± 5354	1615	100%	4167 - 13153	6553 ± 2659	5798
Al	100%	152 - 4061	1169 ± 1305	489	100%	39 - 12151	3811 ± 4467	1595	100%	127 - 4463	925 ± 1375	457	100%	1472 - 5791	2860 ± 1281	2617
As	0%	4 - 15	10 ± 5	10	33%	4 - 21	10 ± 6	9	33%	4 - 54	16 ± 15	12	17%	4 - 18	11 ± 5	15
Be	22%	0.02 - 4	1 ± 2	0.1	75%	0.02 - 4	1 ± 1	0.5	44%	0.1 - 3	1 ± 1	0.2	25%	0.1 - 4	2 ± 2	2
B	100%	38 - 576	127 ± 170	64	100%	67 - 262	151 ± 72	141	100%	134 - 561	236 ± 127	211	100%	86 - 366	173 ± 81	168
Cd	56%	1 - 4	2 ± 1	2	42%	0.2 - 4	2 ± 1	1	44%	0.3 - 3	1 ± 1	1	0%	0.2 - 4	2 ± 1	3
Co	0%	1 - 4	2 ± 1	1	8%	1 - 4	2 ± 1	1	0%	1 - 3	2 ± 1	1	0%	1 - 4	2 ± 1	2
Li	89%	1 - 84	16 ± 26	6	100%	4 - 18	10 ± 5	9	100%	5 - 20	10 ± 5	8	100%	3 - 27	9 ± 7	8
Mn	100%	60 - 225	121 ± 57	114	100%	3 - 2674	765 ± 927	253	100%	77 - 1283	347 ± 367	241	100%	77 - 256	149 ± 58	136
Mo	89%	1 - 42	13 ± 14	7	67%	1 - 17	7 ± 5	5	100%	6 - 24	12 ± 6	10	92%	4 - 33	12 ± 9	9
Ni	100%	8 - 34	19 ± 11	15	100%	7 - 119	45 ± 40	27	100%	15 - 59	28 ± 13	22	100%	24 - 54	34 ± 10	33
Se	0%	6 - 25	17 ± 9	22	0%	6 - 25	13 ± 9	6	0%	8 - 28	18 ± 10	23	0%	6 - 25	16 ± 8	16
V	11%	0.2 - 3	2 ± 1	1	67%	0.2 - 35	9 ± 11	4	56%	0.2 - 13	4 ± 5	1	75%	3 - 9	4 ± 2	3

	Muskingum County (D5)				Guernsey County (D5)				Licking County (D5)				Coshocton County (D5)			
Metal	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cu*	100%	20 - 92	43 ± 22	39	100%	24 - 240	86 ± 61	67	100%	13 - 138.3	72 ± 39	62	100%	26 - 968	263 ± 343	84
Zn*	100%	178 - 3519.7	827 ± 1072	349	100%	260 - 17835	3839 ± 6307	1437	100%	236 - 2003	538 ± 486	406	100%	156 - 9716	2527 ± 3411	631
Ni*	100%	16 - 51	26 ± 10	24	100%	10 - 167	51 ± 45	38	100%	16 - 46	29 ± 10	26	100%	17 - 253	57 ± 66	29
Cr*	70%	4 - 41.997	13 ± 13	9	92%	7 - 138	40 ± 35	28	75%	1 - 15.02	7 ± 5	7	100%	13 - 174	45 ± 48	22
Pb*	70%	12 - 64	25 ± 18	20	50%	16 - 127	52 ± 42	46	25%	19 - 28	22 ± 5	20	75%	20 - 561	156 ± 203	72
Fe*	100%	84 - 12023	2622 ± 3554	1754	100%	2635 - 61107	15505 ± 16654	9886	100%	127 - 6632	2676 ± 2582	1799	100%	459 - 77204	19315 ± 21886	10008
Al	100%	81 - 3508	880 ± 1054	628	100%	599 - 26757	5850 ± 7254	3576	100%	25 - 8589	1316 ± 2385	570	100%	218 - 14623	4726 ± 4228	3457
As	0%	4 - 15	10 ± 6	10	8%	6 - 241	34 ± 65	15	8%	4 - 96	19 ± 25	15	0%	4 - 15	13 ± 4	15
Be	30%	0.05 - 4	2 ± 2	2	33%	0.1 - 4	2 ± 2	3	25%	0.1 - 4	2 ± 1	3	25%	0.1 - 4	2 ± 2	3
B	100%	138 - 381	274 ± 93	308	100%	86 - 344	208 ± 92	196	100%	67 - 672	213 ± 181	140	92%	20 - 427	210 ± 115	207
Cd	20%	0.2 - 4	2 ± 1	2	8%	0.4 - 4	2 ± 1	3	42%	1 - 10	4 ± 2	3	42%	1 - 44	9 ± 13	3
Co	0%	1 - 4	3 ± 2	2	0%	1 - 9	3 ± 2	3	17%	1 - 4	3 ± 1	3	8%	1 - 8	3 ± 2	3
Li	100%	3 - 22	11 ± 7	10	100%	2 - 21	13 ± 6	13	100%	17 - 95	43 ± 25	31	92%	1 - 36	14 ± 10	13
Mn	100%	105 - 591	251 ± 137	213	100%	233 - 4414	1058 ± 1161	724	100%	154 - 638	335 ± 154	321	100%	20 - 1831	616 ± 563	393
Mo	80%	3 - 53	12 ± 16	4	33%	1 - 10	5 ± 3	5	92%	4 - 37	14 ± 9	13	58%	3 - 28	9 ± 7	7
Ni	100%	16 - 51	26 ± 10	24	100%	10 - 167	51 ± 45	38	100%	16 - 46	29 ± 10	26	100%	17 - 253	57 ± 66	29
Se	0%	6 - 25	16 ± 10	16	0%	9 - 28	23 ± 5	23	0%	6 - 28	20 ± 8	23	0%	8 - 28	24 ± 6	24
V	30%	0.2 - 3	2 ± 1	3	67%	3 - 50	11 ± 14	5	0%	0.2 - 3	2 ± 1	3	75%	2 - 48	12 ± 13	6

	Franklin County (D6)				Montgomery County (D7)				Hamilton County (D8)				Ross County (D9)			
Metal	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cu*	100%	14 - 769	197 ± 231	98	100%	8 - 259	92 ± 77	85	100%	30 - 1925	598 ± 576	382	100%	8 - 24	17 ± 5	17
Zn*	100%	243 - 5459	1512 ± 1606	766	100%	37 - 1087	414 ± 308	371	100%	140 - 6217	2185 ± 1873	1738	100%	25 - 337	215 ± 106	220
Ni*	100%	8 - 136	41 ± 34	30	100%	21 - 115	71 ± 36	89	100%	23 - 520	181 ± 158	100	100%	11 - 21	17 ± 3	18
Cr*	100%	1 - 146	39 ± 40	32	89%	5 - 80	26 ± 23	22	89%	25 - 379	145 ± 123	129	75%	2 - 11	6 ± 4	3
Pb*	42%	15 - 31	27 ± 7	30	78%	10 - 77	34 ± 23	27	100%	14 - 931	378 ± 297	366	33%	9 - 13	10 ± 2	9
Fe*	100%	838 - 63345	15709 ± 16823	10757.02	100%	604 - 16753	5961 ± 4800	5409	100%	411 - 123074	42505 ± 41289	24247	100%	513 - 5351	2882 ± 1484	3242
Al	100%	269 - 18600	5839 ± 5240	4848	100%	93 - 7188	1831 ± 2203	1150	100%	145 - 35401	12400 ± 11703	7480	100%	39 - 868	348 ± 269	362
As	58%	4 - 30	13 ± 9	11	11%	6 - 34	14 ± 9	15	11%	4 - 34	14 ± 8	15	25%	4 - 36	11 ± 9	8
Be	75%	0.1 - 4	1 ± 1	0.3	0%	0.1 - 3	2 ± 2	3	11%	0.1 - 4	3 ± 1	4	50%	0.04 - 3	1 ± 1	0.2
B	100%	66 - 512	206 ± 112	192	100%	107 - 342	230 ± 85	208	100%	98 - 561	247 ± 142	195	100%	92 - 507	190 ± 125	141
Cd	42%	0.3 - 4	1 ± 1	1	67%	1 - 9	4 ± 3	3	33%	1 - 14	4 ± 4	4	42%	0.2 - 3	2 ± 1	2
Co	0%	1 - 4	2 ± 1	1	0%	1 - 3	2 ± 1	3	0%	1 - 4	3 ± 2	4	0%	1 - 3	2 ± 1	1
Li	100%	1 - 52	22 ± 17	21	100%	2 - 75	32 ± 25	36	89%	1 - 22	8 ± 7	7	100%	4 - 68	17 ± 19	10
Mn	100%	32 - 1721	452 ± 483	269	100%	45 - 400	182 ± 113	172	100%	24 - 4928	1595 ± 1595	1404	100%	107 - 317	212 ± 67	186
Mo	100%	4 - 97	20 ± 25	14	89%	4 - 57	19 ± 17	13	56%	4 - 23	8 ± 7	5	100%	6 - 302	44 ± 83	13
Ni	100%	8 - 136	41 ± 34	30	100%	21 - 115	71 ± 36	89	100%	23 - 520	181 ± 158	100	100%	11 - 21	17 ± 3	18
Se	0%	6 - 28	15 ± 11	8	0%	9 - 28	19 ± 8	23	0%	8 - 25	21 ± 8	25	8%	6 - 27	13 ± 9	9
V	92%	0.2 - 42	10 ± 11	7	56%	1 - 12	4 ± 3	3	89%	2 - 92	30 ± 30	15	42%	0.2 - 3	1 ± 1	1

	Scioto County (D9)				Meigs County (D10)				Athens County (D10)				Washington County (D10)			
Metal	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cu*	100%	2 - 107	29 ± 33	15	55%	53 - 123	72 ± 26	64	100%	14 - 441	92 ± 130	46	100%	24 - 181	71 ± 57	47
Zn*	100%	80 - 2446	662 ± 614	562	91%	33 - 8547	3080 ± 3413	1865	100%	35 - 2896	741 ± 926	321	100%	72 - 1007	426 ± 310	338
Ni*	100%	11 - 62	29 ± 17	24	100%	10 - 40	25 ± 10	25	100%	14 - 173	39 ± 49	20	100%	15 - 110	36 ± 30	24
Cr*	33%	3 - 23	15 ± 9	16	27%	2 - 2	2 ± 0.1	2	82%	1 - 133	20 ± 44	2	100%	5 - 119	27 ± 31	19
Pb*	50%	15 - 48	28 ± 14	21	9%	9 - 9	9 ± -	9	9%	20 - 20	20 ± -	20	83%	15 - 92	43 ± 26	31
Fe*	100%	857 - 80118	12544 ± 22900	4263	82%	159 - 1209	659 ± 353	747.3876	100%	763 - 100260	14846 ± 30801	2352	100%	2482 - 29654	10114 ± 8135	7423
Al	100%	62 - 5154	1217 ± 1873	278	100%	16 - 112	39 ± 28	27	100%	144 - 35424	4450 ± 10660	348	100%	166 - 13261	3124 ± 4132	1748
As	0%	4 - 15	13 ± 4	15	0%	4 - 15	13 ± 5	15	9%	4 - 52	12 ± 14	10	33%	4 - 39	13 ± 11	10
Be	25%	0.1 - 4	3 ± 1	3	0%	0.1 - 3	2 ± 1	3	55%	0.02 - 4	1 ± 2	0.2	50%	0.1 - 1	0.2 ± 0.2	0.1
B	100%	79 - 589	258 ± 136	228	91%	33 - 94	68 ± 18	73	100%	89 - 619	214 ± 167	127	100%	88 - 245	153 ± 58	130
Cd	25%	1 - 4	3 ± 1	3	0%	0.3 - 3	2 ± 1	3	18%	0.2 - 4	1 ± 2	0.4	58%	0.2 - 4	1 ± 1	1
Co	0%	1 - 4	3 ± 1	4	0%	1 - 3	2 ± 1	3	18%	1 - 5	3 ± 2	2	0%	1 - 1	1 ± 0.2	1
Li	100%	7 - 148	63 ± 47	53	100%	1 - 9	3 ± 3	1	100%	4 - 99	20 ± 27	12	100%	5 - 19	11 ± 5	8
Mn	100%	259 - 1817	578 ± 448	443	100%	1636 - 2870	2048 ± 451	1835	100%	149 - 5356	1126 ± 1595	539	100%	193 - 2687	1384 ± 739	1409
Mo	67%	4 - 31	11 ± 8	10	0%	1 - 4	3 ± 1	4	82%	1 - 20	6 ± 6	5	75%	1 - 34	9 ± 9	8
Ni	100%	11 - 62	29 ± 17	24	100%	10 - 40	25 ± 10	25	100%	14 - 173	39 ± 49	20	100%	15 - 110	36 ± 30	24
Se	0%	6 - 25	21 ± 7	24	0%	8 - 23	19 ± 7	23	0%	6 - 25	16 ± 10	22	0%	6 - 28	15 ± 10	9
V	33%	1 - 15	5 ± 5	3	0%	0 - 3	2 ± 1	3	45%	0.2 - 75	9 ± 22	1	100%	1 - 20	5 ± 6	2

	Hocking County (D10)				Monroe County (D10)				Tuscarawas County (D11)				Cuyahoga County (D12)			
Metal	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cu*	92%	9 - 287	113 ± 78	109	100%	4 - 102	38 ± 38	22	100%	2 - 51	22 ± 17	21	100%	157 - 205	185 ± 20	191
Zn*	100%	135 - 2026	675 ± 511	580	100%	23 - 401	167 ± 140	113	100%	50 - 2724	490 ± 744	260	100%	1438 - 1840	1586 ± 169	1544
Ni*	100%	12 - 67	29 ± 16	23	100%	13 - 103	43 ± 33	30	100%	6 - 33	16 ± 7	17	100%	83 - 130	109 ± 17	110
Cr*	75%	3 - 78	19 ± 25	7	100%	3 - 52	19 ± 17	11	67%	0.2 - 4	2 ± 1	3	100%	16 - 51	31 ± 17	20
Pb*	8%	87 - 87	87 ± -	87	33%	21 - 38	27 ± 9	22	17%	23 - 34	29 ± 8	29	100%	37 - 78	51 ± 16	46
Fe*	100%	783 - 12731	4371 ± 4218	2490	100%	907 - 37567	13264 ± 12818	9410	100%	732 - 7559	2867 ± 2111	2306	100%	1359 - 13259	6477 ± 5227	5364.001
Al	100%	75 - 4485	1440 ± 1672	662	100%	332 - 15201	5596 ± 5073	4728	100%	15 - 306	127 ± 107	76	100%	248 - 9505	2894 ± 3848	1496
As	33%	6 - 30	15 ± 7	15	44%	4 - 198	37 ± 63	9	8%	4 - 21	12 ± 6	9	0%	9 - 20	14 ± 4	15
Be	58%	0.1 - 4	1 ± 2	0.2	67%	0.05 - 4	1 ± 2	0.2	50%	0.03 - 1	0.1 ± 0.2	0.1	20%	0.1 - 4	2 ± 2	4
B	100%	45 - 405	200 ± 116	154	100%	49 - 262	147 ± 84	151	100%	94 - 326	190 ± 76	219	100%	158 - 641	305 ± 199	208
Cd	25%	0.4 - 4	1 ± 1	1	22%	0.2 - 4	1 ± 2	0.5	0%	0.2 - 1	0.4 ± 0.2	0.5	40%	2 - 4	3 ± 1	4
Co	33%	1 - 7	3 ± 2	3	0%	1 - 4	2 ± 1	1	0%	1 - 1	1 ± 0.2	1	20%	1 - 4	4 ± 1	4
Li	100%	4 - 23	11 ± 5	10	100%	1 - 26	12 ± 8	14	100%	4 - 69	14 ± 18	8	100%	33 - 824	236 ± 338	59
Mn	100%	151 - 1127	427 ± 266	386	100%	301 - 1725	834 ± 544	528	100%	64 - 814	251 ± 203	178	100%	225 - 934	490 ± 328	278
Mo	67%	3 - 21	7 ± 5	5	56%	1 - 19	7 ± 7	5	75%	3 - 47	12 ± 14	5	100%	34 - 889	381 ± 352	278
Ni	100%	12 - 67	29 ± 16	23	100%	13 - 103	43 ± 33	30	100%	6 - 33	16 ± 7	17	100%	83 - 130	109 ± 17	110
Se	0%	8 - 28	20 ± 9	24	0%	6 - 28	20 ± 11	25	0%	6 - 28	22 ± 8	25	0%	22 - 28	25 ± 2	25
V	58%	1 - 9	3 ± 3	3	89%	0.2 - 25	9 ± 9	5	8%	0.2 - 1	0.4 ± 0.2	1	80%	1 - 4	3 ± 1	3

Table 3-12a-f: Dissolved heavy metal sample results for all 24 garages.

	Allen County (D1)				Henry County (D2)				Ashland County (D3)				Summit County (D4)			
Metal	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cu*	50%	0.4 - 31	5 ± 9	1	38%	0.1 - 13	3 ± 4	1	67%	0.5 - 15	5 ± 5	3	86%	0.1 - 73	17 ± 26	8
Zn*	83%	2 - 3354	585 ± 1054	26	63%	5 - 65	21 ± 23	10	92%	2 - 604	167 ± 170	121	86%	9 - 337	127 ± 115	86
Ni*	100%	11 - 75	31 ± 23	21	100%	6 - 30	18 ± 8	20	100%	11 - 29	21 ± 7	21	100%	12 - 50	24 ± 12	23
Cr*	50%	0.3 - 13	3 ± 4	1	25%	0.4 - 11	2 ± 4	1	67%	0.3 - 3	1 ± 1	1	43%	1 - 2	1 ± 1	1
Pb*	42%	3 - 35	12 ± 11	6	50%	6 - 20	11 ± 6	10	17%	5 - 29	10 ± 8	7	14%	9 - 23	11 ± 5	9
Fe*	100%	515 - 11807	3924 ± 3261	3036	100%	108 - 760	284 ± 212	238	100%	69 - 1033	391 ± 291	331	100%	89 - 1326	491 ± 527	134
Al	92%	3 - 386	77 ± 133	25	88%	3 - 48	19 ± 15	19	100%	18 - 281	72 ± 73	42	100%	22 - 75	47 ± 19	41
As	67%	4 - 353	56 ± 96	27	63%	4 - 184	68 ± 66	66	67%	9 - 169	54 ± 64	24	86%	7 - 105	59 ± 38	61
B	92%	56 - 510	206 ± 174	118	100%	64 - 323	208 ± 118	263	100%	63 - 269	170 ± 81	165	100%	98 - 342	232 ± 99	184
Be	42%	0.02 - 6	1 ± 2	0.1	50%	0.1 - 9	1 ± 3	0	50%	0.1 - 0.3	0.1 ± 0.1	0.1	71%	0.04 - 0.5	0.2 ± 0.2	0.2
Cd	42%	0.3 - 6	1 ± 2	1	13%	0.3 - 10	2 ± 4	1	17%	0.4 - 1	1 ± 0.3	1	14%	1 - 1	1 ± 0.3	1
Co	25%	0.5 - 8	2 ± 3	1	38%	1 - 8	2 ± 2	1	17%	1 - 4	2 ± 1	1	14%	1 - 3	2 ± 1	2
Li	100%	7 - 94	37 ± 25	38	100%	11 - 38	22 ± 10	23	100%	7 - 26	14 ± 6	11	100%	4 - 37	25 ± 11	28
Mn	100%	74 - 653	259 ± 175	242	100%	245 - 666	477 ± 137	473	100%	79 - 483	260 ± 122	222	100%	10 - 515	355 ± 174	353
Mo	92%	2 - 27	14 ± 8	14	100%	8 - 30	16 ± 7	14	92%	1 - 25	11 ± 7	9	86%	3 - 24	13 ± 9	10
Se	25%	7 - 74	23 ± 21	13	0%	8 - 11	9 ± 2	10	17%	7 - 104	18 ± 28	10	0%	10 - 11	10 ± 0.3	10
V	50%	0.3 - 7	2 ± 3	0.5	25%	0.4 - 9	2 ± 3	0.4	33%	0.2 - 2	1 ± 1	0.4	43%	0.2 - 1	1 ± 1	0.4

Units: µg/L, ppb

All concentrations are in dissolved metal form

* denotes a metal that is typically associated with traffic

All non-detect samples were given the concentration of half the detection limit

Samples were taken during the winter months at the beginning, middle, and end of a full truck wash

A total of 253 samples were collected

	Ashtabula County (D4)				Mahoning County (D4)				Stark County (D4)				Fairfield County (D5)			
Metal	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cu*	22%	0.5 - 85	13 ± 28	0.5	100%	5 - 55	21 ± 14	19	100%	1 - 55	14 ± 18	5	58%	0.3 - 132	20 ± 40	1
Zn*	100%	5 - 134	65 ± 38	56	100%	6 - 609	201 ± 177	166	100%	6 - 320	86 ± 99	55	100%	2 - 2664	788 ± 894	449
Ni*	100%	5 - 29	12 ± 9	8	100%	6 - 27	16 ± 7	16	100%	14 - 32	20 ± 7	17	100%	15 - 33	21 ± 5	21
Cr*	33%	0.3 - 1	1 ± 0.4	0.3	17%	0.3 - 10	1 ± 3	0.3	78%	1 - 3	2 ± 1	1	75%	0.3 - 5	2 ± 2	1
Pb*	11%	5 - 22	7 ± 6	5	17%	3 - 27	7 ± 7	5	78%	11 - 28	16 ± 5	14	75%	6 - 32	15 ± 10	13
Fe*	100%	46 - 2086.4	595 ± 753	196	100%	74 - 961	490 ± 290	477	78%	59 - 1379	457 ± 460	262	100%	20 - 2361	810 ± 699	717
Al	100%	15 - 75	42 ± 20	46	100%	25 - 213	64 ± 50	50	100%	20 - 34	27 ± 4	27	83%	1 - 294	68 ± 107	15
As	11%	4 - 14	8 ± 3	9	25%	9 - 34	14 ± 8	9	78%	9 - 191	48 ± 56	32	58%	4 - 36	20 ± 13	26
B	89%	18 - 44	36 ± 8	38	83%	74 - 244	113 ± 49	101	100%	136 - 584	244 ± 156	176	92%	77 - 313	170 ± 85	134
Be	0%	0.1 - 0.1	0.1 ± 0.01	0.1	25%	0.02 - 0.2	0.1 ± 0.04	0.1	33%	0 - 1	0.2 ± 0.3	0.1	67%	0.1 - 1	0.2 ± 0.2	0.1
Cd	0%	0.3 - 0.4	0.4 ± 0.03	0.4	42%	0.3 - 1	1 ± 0.4	0.4	67%	0 - 2	1 ± 0.5	1	58%	0.3 - 2	1 ± 0.5	1
Co	0%	1 - 1	1 ± 0.1	1	8%	0.5 - 2	1 ± 0.3	1	11%	1 - 2	1 ± 0.4	1	33%	0.5 - 2	1 ± 1	1
Li	100%	2 - 46	11 ± 14	5	100%	5 - 20	11 ± 5	9	100%	6 - 35	16 ± 10	16	100%	4 - 218	43 ± 48	11
Mn	100%	58 - 142	91 ± 31	104	100%	2 - 667	268 ± 193	279	100%	154 - 1021	332 ± 264	287	100%	69 - 218	132 ± 43	130
Mo	56%	1 - 8	3 ± 3	3	83%	1 - 14	6 ± 4	5	100%	7 - 24	14 ± 6	11	100%	6 - 27	10 ± 6	8
Se	0%	7 - 9	7 ± 1	7	100%	7 - 66	14 ± 17	7	56%	13 - 64	33 ± 14	29	33%	8 - 44	18 ± 13	12
V	0%	0.2 - 0.4	0.4 ± 0.1	0.4	0%	0.3 - 0.4	0.4 ± 0.1	0.4	56%	0 - 1	1 ± 0.2	1	17%	0.2 - 1	0.4 ± 0.1	0.4

	Muskingum County (D5)				Guernsey County (D5)				Licking County (D5)				Coshocton County (D5)			
Metal	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cu*	70%	0.3 - 47	22 ± 18	24	42%	0.1 - 118	13 ± 34	1	75%	0.1 - 128	38 ± 45	13	50%	0.1 - 27	6 ± 9	1
Zn*	100%	2 - 2399	667 ± 875	304	100%	93 - 7854	2056 ± 2672	871	100%	3 - 1023	367 ± 292	344	100%	4 - 327	105 ± 106	45
Ni*	100%	16 - 37	22 ± 7	21	100%	12 - 632	76 ± 175	26	100%	21 - 45	29 ± 8	25	100%	9 - 34	17 ± 7	15
Cr*	100%	1 - 10	3 ± 3	3	50%	1 - 10	3 ± 3	1	50%	0.3 - 4	1 ± 1	1	50%	0.3 - 2	1 ± 0.5	1
Pb*	30%	4 - 50	13 ± 15	5	25%	4 - 25	10 ± 6	9	17%	4 - 10	7 ± 2	9	25%	4 - 21	9 ± 5	8
Fe*	100%	9 - 405	131 ± 140	81	83%	2 - 1,576	249 ± 479	15	100%	29 - 1636	452 ± 544	229	100%	223 - 6987	1933 ± 1916	1535
Al	90%	4 - 29	20 ± 9	22	100%	13 - 56	34 ± 14	34	100%	14 - 38	25 ± 8	25	100%	9 - 94	41 ± 27	28
As	10%	4 - 18	8 ± 4	8	50%	7 - 51	21 ± 13	20	83%	6 - 90	37 ± 23	35	58%	4 - 37	19 ± 11	20
B	100%	135 - 346	223 ± 79	188	100%	72 - 369	216 ± 93	208	100%	80 - 921	215 ± 225	155	100%	56 - 259	126 ± 57	120
Be	10%	0.1 - 0.1	0.1 ± 0.01	0.1	50%	0.002 - 2	0.2 ± 1	0.1	17%	0.04 - 0.1	0.1 ± 0.02	0.1	17%	0.04 - 0.2	0.1 ± 0.1	0.1
Cd	50%	0.3 - 2	1 ± 1	1	8%	0.4 - 1	1 ± 0.2	1	67%	0.4 - 15	4 ± 4	1	42%	0.3 - 2	1 ± 1	1
Co	40%	1 - 5	2 ± 2	1	92%	2 - 16	7 ± 5	5	50%	1 - 6	3 ± 2	2	25%	1 - 17	3 ± 5	1
Li	100%	5 - 22	12 ± 6	11	100%	2 - 33	18 ± 11	18	100%	18 - 75	44 ± 17	45	100%	6 - 39	18 ± 10	15
Mn	100%	127 - 371	233 ± 79	235	100%	75 - 3084	869 ± 868	567	100%	232 - 561	390 ± 112	394	100%	122 - 1274	535 ± 383	442
Mo	70%	1 - 63	13 ± 20	5	75%	1 - 16	7 ± 4	8	92%	1 - 33	16 ± 10	13	100%	3 - 25	9 ± 6	9
Se	0%	7 - 11	9 ± 2	8	0%	9 - 22	13 ± 5	11	17%	7 - 74	17 ± 20	10	17%	7 - 30	13 ± 8	10
V	0%	0.2 - 0.4	0.4 ± 0.1	0.4	33%	0.2 - 1	0.5 ± 0.2	0.4	33%	0.2 - 1	0.4 ± 0.3	0.4	25%	0.2 - 1	0.5 ± 0.3	0.4

	Franklin County (D6)				Montgomery County (D7)				Hamilton County (D8)				Ross County (D9)			
Metal	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cu*	83%	0.1 - 69	20 ± 20	11	0%	0.1 - 0.3	0.2 ± 0.1	0.1	100%	7 - 93	29 ± 26	20	42%	0.3 - 20	5 ± 7	1
Zn*	83%	9 - 4,022	727 ± 1,087	401	33%	6 - 10	9 ± 1	9	100%	32 - 562	208 ± 170	117	100%	5 - 260	129 ± 93	155
Ni*	100%	5 - 40	18 ± 11	15	100%	18 - 114	77 ± 44	102	100%	14 - 68	28 ± 19	19	100%	11 - 25	17 ± 4	18
Cr*	33%	0.3 - 11	2 ± 3	0.4	67%	1 - 6	4 ± 3	5	33%	0.4 - 13	3 ± 4	1	42%	0.3 - 6	2 ± 2	0.4
Pb*	33%	5 - 15	8 ± 3	8	33%	7 - 16	10 ± 2	9	22%	3 - 46	12 ± 14	6	17%	4 - 12	6 ± 2	5
Fe*	100%	12 - 10230	2036 ± 3212	614	100%	151 - 999	404 ± 327	221	100%	12 - 1143	158 ± 372	18	100%	55 - 2096	654 ± 627	336
Al	100%	5 - 183	51 ± 49	34	100%	14 - 53	34 ± 12	36	89%	3 - 39	14 ± 10	12	100%	3 - 49	26 ± 15	29
As	42%	9 - 45	16 ± 12	10	44%	11 - 28	16 ± 6	11	0%	4 - 11	7 ± 3	7	17%	4 - 24	10 ± 6	9
B	100%	41 - 379	193 ± 112	210	100%	93 - 306	204 ± 81	206	78%	44 - 120	73 ± 21	73	100%	60 - 389	134 ± 90	124
Be	25%	0.04 - 1	0.2 ± 0.3	0.1	11%	0.04 - 0.1	0.05 ± 0.02	0.04	11%	0.02 - 0.1	0.1 ± 0.02	0.1	0%	0.1 - 0.1	0.1 ± 0.01	0.1
Cd	50%	0.4 - 4	1 ± 1	1	33%	1 - 1	1 ± 0.1	1	0%	0.3 - 1	0.4 ± 0.1	0.4	58%	0.3 - 2	1 ± 1	0.4
Co	25%	1 - 4	2 ± 1	1	33%	2 - 3	2 ± 0.4	2	0%	0.5 - 1	1 ± 0.4	1	25%	1 - 2	1 ± 0.4	1
Li	100%	1 - 116	29 ± 32	19	100%	2 - 81	44 ± 33	52	67%	1 - 20	4 ± 6	2	100%	7 - 65	19 ± 18	12
Mn	100%	16 - 1522	463 ± 468	228	100%	49 - 249	155 ± 81	169	100%	1 - 1256	191 ± 404	25	100%	116 - 356	228 ± 90	186
Mo	92%	1 - 70	17 ± 19	10	33%	2 - 10	4 ± 3	3	67%	1 - 28	6 ± 9	3	75%	1 - 318	43 ± 89	13
Se	0%	7 - 13	9 ± 2	8	33%	10 - 136	35 ± 45	10	0%	8 - 13	10 ± 2	11	17%	7 - 101	17 ± 27	7
V	33%	0.2 - 4	1 ± 1	0.4	78%	0.2 - 1	1 ± 1	1	33%	0.3 - 1	1 ± 0.4	0.4	17%	0.3 - 1	0.5 ± 0.2	0.4

	Scioto County (D9)				Meigs County (D10)				Athens County (D10)				Washington County (D10)			
Metal	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cu*	8%	0.5 - 11	2 ± 3	1	73%	1 - 31	14 ± 11	19	91%	1 - 99	24 ± 29	19	83%	1 - 229	25 ± 65	5
Zn*	50%	6 - 491	60 ± 137	13	82%	14 - 7717	2884 ± 3282	245	91%	5 - 4713	644 ± 1362	294	100%	4 - 308	111 ± 89	97
Ni*	100%	16 - 32	23 ± 5	22	100%	11 - 40	27 ± 10	31	100%	12 - 34	18 ± 7	17	100%	11 - 45	20 ± 10	18
Cr*	25%	0.3 - 2	1 ± 0.3	1	36%	0.3 - 2	1 ± 0.5	1	45%	0.3 - 2	1 ± 1	1	17%	0.3 - 2	1 ± 1	0.4
Pb*	8%	5 - 19	9 ± 4	9	0%	4 - 11	8 ± 3	11	27%	3 - 24	9 ± 8	5	8%	4 - 16	6 ± 3	6
Fe*	92%	59 - 34727	6459 ± 11436	1693	64%	5 - 870	148 ± 277	59	100%	12 - 14786	2002 ± 4374	336	100%	13 - 948	142 ± 259	59
Al	100%	10 - 58	32 ± 15	30	45%	1 - 35	10 ± 11	6	91%	3 - 71	31 ± 20	28	100%	5 - 57	26 ± 14	28
As	25%	7 - 32	13 ± 9	9	9%	4 - 21	8 ± 5	9	18%	7 - 34	12 ± 8	9	25%	4 - 32	12 ± 10	7
B	100%	72 - 375	202 ± 78	191	73%	18 - 100	53 ± 28	62	100%	158 - 278	190 ± 36	180	100%	91 - 250	130 ± 47	116
Be	42%	0.03 - 0.1	0.1 ± 0.03	0.1	9%	0.1 - 0.1	0.1 ± 0.02	0.1	36%	0.1 - 0.4	0.1 ± 0.1	0.1	0%	0.1 - 0.1	0 ± 0.01	0.1
Cd	0%	0.4 - 1	0.5 ± 0.1	0.5	0%	0.3 - 0.5	0.4 ± 0.1	0.5	64%	0.4 - 2	1 ± 0.5	1	17%	0.3 - 1	1 ± 0.4	0.4
Co	8%	1 - 6	2 ± 1	1	64%	1 - 7	3 ± 2	3	36%	0.5 - 9	3 ± 3	1	25%	1 - 3	1 ± 1	1
Li	100%	12 - 151	68 ± 48	52	55%	0.3 - 27	5 ± 9	1	100%	6 - 76	22 ± 18	19	100%	4 - 11	8 ± 3	8
Mn	100%	292 - 1342	595 ± 330	479	100%	1975 - 3563	2402 ± 575	2134	100%	39 - 3161	1091 ± 949	710	100%	432 - 1808	1007 ± 487	935
Mo	50%	1 - 31	8 ± 9	3	18%	1 - 3	2 ± 1	3	100%	3 - 14	7 ± 4	5	75%	1 - 51	10 ± 14	6
Se	0%	7 - 28	14 ± 9	11	0%	8 - 28	19 ± 10	28	9%	7 - 17	9 ± 3	7	0%	7 - 11	8 ± 1	8
V	17%	0.4 - 2	1 ± 0.4	0.4	9%	0.2 - 1	0.4 ± 0.2	1	18%	0.01 - 0.4	0.3 ± 0.1	0.4	25%	0.0 - 1	0.4 ± 0.2	0.4

	Hocking County (D10)				Monroe County (D10)				Tuscarawas County (D11)				Cuyahoga County (D12)			
Metal	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cu*	83%	0.5 - 480	137 ± 164	61	100%	5 - 18	11 ± 4	11	67%	0.4 - 53	8 ± 15	4	100%	3 - 164	73 ± 66	80
Zn*	100%	95 - 3220	991 ± 923	677	100%	10 - 131	39 ± 39	25	100%	27 - 5719	743 ± 1610	78	100%	757 - 1600	1269 ± 444	1586
Ni*	100%	10 - 457	83 ± 128	27	100%	10 - 25	14 ± 4	14	100%	8 - 37	21 ± 10	17	100%	106 - 143	126 ± 14	122
Cr*	58%	0.3 - 7	3 ± 2	2	33%	0.3 - 1	1 ± 0.2	1	33%	0.3 - 3	1 ± 1	1	100%	9 - 26	16 ± 7	14
Pb*	75%	5 - 57	30 ± 20	32	0%	3 - 11	6 ± 4	5	25%	5 - 14	8 ± 3	8	80%	11 - 97	46 ± 32	36
Fe*	100%	34 - 2126	578 ± 592	414	100%	56 - 544	228 ± 221	96	100%	116 - 4106	1285 ± 1052	1,301	100%	257 - 14027	5089 ± 6551	534
Al	100%	22 - 153	54 ± 38	44	100%	8 - 50	28 ± 14	24	92%	6 - 60	24 ± 15	19	100%	19 - 674	168 ± 284	34
As	33%	7 - 66	18 ± 19	9	11%	9 - 24	11 ± 5	9	33%	7 - 24	15 ± 7	14	20%	7 - 29	14 ± 10	9
B	100%	121 - 262	198 ± 47	197	67%	43 - 219	114 ± 75	77	100%	133 - 408	226 ± 81	225	100%	153 - 647	291 ± 206	195
Be	83%	0.1 - 3	1 ± 1	0.4	33%	0.1 - 0.1	0.1 ± 0.02	0.1	50%	0.03 - 2	0.3 ± 1	0.1	40%	0.1 - 0.1	0.1 ± 0.0	0.1
Cd	75%	0.4 - 13	3 ± 4	3	22%	0.3 - 1	1 ± 0.3	0.5	42%	0.4 - 3	1 ± 1	1	80%	0.5 - 2	2 ± 1	1
Co	75%	1 - 11	6 ± 3	6	22%	0.5 - 2	1 ± 0.4	1	33%	1 - 6	2 ± 1	1	60%	1 - 4	3 ± 1	3
Li	100%	4 - 33	15 ± 10	11	100%	5 - 31	13 ± 10	10	100%	3 - 45	18 ± 14	14	100%	42 - 902	269 ± 369	58
Mn	100%	188 - 834	480 ± 187	440	100%	218 - 664	533 ± 155	612	100%	53 - 769	405 ± 260	347	100%	220 - 1067	536 ± 374	312
Mo	83%	1 - 24	7 ± 6	6	78%	1 - 35	11 ± 14	4	100%	3 - 68	21 ± 27	7	100%	54 - 762	360 ± 284	338
Se	25%	7 - 38	15 ± 11	11	0%	7 - 28	16 ± 9	13	25%	7 - 32	21 ± 8	22	0%	11 - 28	16 ± 8	11
V	33%	0.4 - 2	1 ± 1	0.4	0%	0.3 - 1	0.4 ± 0.1	0.4	25%	0.3 - 1	1 ± 0.2	0.5	60%	0.4 - 2	1 ± 1	1

Table 3-13a-h: Non-metal parameter sample results for all 24 garages.

		Allen County (D1)				Henry County (D2)				Ashland County (D3)			
Parameter	Units	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cyanide*	mg/L as CN^-	100%	0.002 - 0.1	0.03 ± 0.03	0.02	100%	0.004 - 0.1	0.03 ± 0.03	0.02	100%	0.01 - 0.02	0.01 ± 0.01	0.02
Surfactants*	mg/L	100%	0.1 - 2	1 ± 1	0.4	100%	0.03 - 0.1	0.04 ± 0.02	0.05	100%	0.1 - 0.1	0.1 ± 0.01	0.1
Oil & Grease*	mg/L	100%	70 - 375	196 ± 128	170	100%	8 - 39	18 ± 18	8	100%	13 - 34	22 ± 9	21
TSS*	mg/L	100%	336 - 6354	2274 ± 2797	1203	100%	348 - 8029	2918 ± 4426	378	100%	252 - 1274	524 ± 500	285
TDS	mg/L	100%	379 - 156000	24921 ± 49859	1565	100%	19460 - 29800	24321 ± 2967	24180	100%	2310 - 30200	14103 ± 8036	11700
Turbidity	NTU	100%	78 - 1736	813 ± 620	694	100%	134 - 3952	880 ± 1284	430	100%	37 - 958	305 ± 296	166
Conductivity	mS	100%	1 - 183	41 ± 71	3	100%	34 - 53	43 ± 5	43	100%	5 - 46	24 ± 13	21
pH	None	100%	6 - 7	7 ± 0.4	7	100%	7 - 7	7 ± 0.2	7	100%	6 - 7	7 ± 0.3	7
UV 254	None	100%	0.2 - 3	1 ± 1	1	100%	0.1 - 0.4	0.2 ± 0.1	0.1	100%	0.1 - 1	0.3 ± 0.2	0.2
UV 272	None	100%	0.2 - 3	1 ± 1	1	100%	0.1 - 0.2	0.1 ± 0.1	0.1	100%	0.05 - 0.5	0.2 ± 0.2	0.2

Note: *analysis conducted on only one sample in each sample set
oil and grease non-detect samples were given the concentration of half the detection limit
Samples were collected during the winter months at the beginning, middle, and end of a full truck wash
A total of 253 samples were collected

		Summit County (D4)				Ashtabula County (D4)				Mahoning County (D4)			
Parameter	Units	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cyanide*	mg/L as CN^-	100%	0.01 - 0.1	0.1 ± 0.1	0.04	100%	0.01 - 0.01	0.01 ± 0.002	0.01	100%	0.01 - 0.1	0.04 ± 0.04	0.04
Surfactants*	mg/L	100%	0.1 - 2	1 ± 1	0.1	100%	0.05 - 0.1	0.1 ± 0.05	0.1	100%	0.03 - 0.1	0.04 ± 0.02	0.04
Oil & Grease*	mg/L	66%	2 - 56	32 ± 27	38	100%	113 - 700	376 ± 291	346	100%	8 - 115	59 ± 52	58
TSS*	mg/L	100%	34 - 150	85 ± 59	72	100%	90 - 1168	620 ± 540	610	100%	74 - 6406	1950 ± 2994	660
TDS	mg/L	100%	1110 - 62400	31144 ± 28812	10700	100%	4390 - 18500	9947 ± 5054	8470	100%	6910 - 67200	30208 ± 22213	26565
Turbidity	NTU	100%	44 - 232	100 ± 63	100	100%	35 - 483	152 ± 147	94	100%	30 - 3736	1050 ± 1200	409
Conductivity	mS	100%	2 - 108	54 ± 50	19	100%	8 - 33	18 ± 9	15	100%	13 - 119	53 ± 40	46
pH	None	100%	6 - 7	7 ± 0.3	7	100%	7 - 7	7 ± 0.1	7	100%	6 - 10	7 ± 1	7
UV 254	None	100%	0.1 - 1	0.3 ± 0.2	0.2	100%	0.02 - 1	0.2 ± 0.3	0.1	100%	0.03 - 1	0.2 ± 0.2	0.2
UV 272	None	100%	0.05 - 0.2	0.1 ± 0.1	0.1	100%	0.01 - 1	0.2 ± 0.3	0.05	100%	0.1 - 1	0.3 ± 0.4	0.2

		Stark County (D4)				Fairfield County (D5)				Muskingum County (D5)			
Parameter	Units	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cyanide*	mg/L as CN^-	100%	0.01 - 0.1	0.1 ± 0.04	0.1	100%	0.01 - 0.02	0.01 ± 0.01	0.01	100%	0.01 - 0.03	0.02 ± 0.01	0.02
Surfactants*	mg/L	100%	0.04 - 1	0.4 ± 0.3	0.5	100%	0.01 - 0.2	0.1 ± 0.1	0.1	100%	0.1 - 0.2	0.2 ± 0.1	0.2
Oil & Grease*	mg/L	40%	2 - 16	8 ± 6	10	100%	37 - 61	48 ± 12	46	75%	2 - 15	11 ± 6	13
TSS*	mg/L	100%	3 - 90	48 ± 44	50	100%	35 - 804	476 ± 323	532	100%	204 - 412	274 ± 94	240
TDS	mg/L	100%	20200 - 72000	42789 ± 19640	33600	100%	16300 - 71600	47392 ± 18860	54200	100%	12100 - 43600	25102 ± 12665	18260
Turbidity	NTU	100%	27 - 314	95 ± 86	76	100%	109 - 608	354 ± 152	379	100%	22 - 265	86 ± 75	59
Conductivity	mS	100%	36 - 122	74 ± 32	59	100%	29 - 119	80 ± 31	89	100%	25 - 70	44 ± 18	37
pH	None	100%	7 - 7	7 ± 0.2	7	100%	7 - 7	7 ± 0.2	7	100%	7 - 7	7 ± 0.1	7
UV 254	None	100%	0.05 - 2	1 ± 1	0.1	100%	0.03 - 0.3	0.1 ± 0.1	0.1	100%	0.1 - 0.5	0.2 ± 0.2	0.2
UV 272	None	100%	0.04 - 0.1	0.1 ± 0.03	0.1	100%	0.03 - 1	0.2 ± 0.2	0.2	100%	0.04 - 0.4	0.2 ± 0.1	0.2

		Guernsey County (D5)				Licking County (D5)				Coshocton County (D5)			
Parameter	Units	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cyanide*	mg/L as CN^-	100%	0.01 - 0.1	0.03 ± 0.02	0.03	100%	0.01 - 0.03	0.01 ± 0.01	0.01	100%	0.02 - 0.05	0.03 ± 0.01	0.02
Surfactants*	mg/L	100%	0.04 - 0.1	0.1 ± 0.03	0.05	100%	0.02 - 0.1	0.05 ± 0.04	0.03	100%	0.05 - 1	0.2 ± 0.3	0.1
Oil & Grease*	mg/L	100%	6 - 29	15 ± 10	13	75%	3 - 46	18 ± 20	11	100%	73 - 2667	932 ± 1178	493
TSS*	mg/L	100%	424 - 2602	1462 ± 914	1411	100%	38 - 178	103 ± 62	97	100%	238 - 8804	2665 ± 4120	808
TDS	mg/L	100%	2130 - 139200	32398 ± 40996	14800	100%	13320 - 58800	29131 ± 13096	27300	100%	1560 - 46800	16725 ± 14693	13300
Turbidity	NTU	100%	64 - 3240	1020 ± 1183	344	100%	33 - 247	119 ± 68	115	100%	126 - 1512	489 ± 410	362
Conductivity	mS	100%	4 - 191	53 ± 59	26	100%	19 - 71	49 ± 15	51	100%	3 - 93	31 ± 27	23
pH	None	100%	7 - 7	7 ± 0.2	7	100%	7 - 7	7 ± 0.1	7	100%	6 - 7	7 ± 0.3	7
UV 254	None	100%	0.03 - 0.5	0.1 ± 0.2	0.1	100%	0.1 - 0.4	0.2 ± 0.1	0.2	100%	0.1 - 1	0.3 ± 0.2	0.2
UV 272	None	100%	0.03 - 0.2	0.1 ± 0.1	0.05	100%	0.1 - 0.7	0.2 ± 0.2	0.2	100%	0.1 - 1	0.4 ± 0.2	0.4

		Franklin County (D6)				Montgomery County (D7)				Hamilton County (D8)			
Parameter	Units	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cyanide*	mg/L as CN^-	100%	0.001 - 0.04	0.02 ± 0.02	0.02	100%	0.002 - 0.1	0.02 ± 0.02	0.02	100%	0.01 - 0.01	0.01 ± 0.005	0.01
Surfactants*	mg/L	100%	0.05 - 1	0.3 ± 0.5	0.1	100%	0.2 - 0.2	0.2 ± 0.03	0.2	100%	0.03 - 0.1	0.05 ± 0.02	0.1
Oil & Grease*	mg/L	75%	2 - 143	57 ± 61	41	100%	59 - 213	142 ± 78	156	100%	6 - 575	290 ± 402	290
TSS*	mg/L	100%	226 - 26390	7995 ± 12466	2682	100%	52 - 446	197 ± 217	92	100%	348 - 1932	1128 ± 792	1104
TDS	mg/L	100%	1030 - 138400	54556 ± 42934	51400	100%	2200 - 16300	9971 ± 4957	11700	100%	282 - 3450	1370 ± 1239	759
Turbidity	NTU	100%	16 - 6912	1992 ± 2526	572	100%	63 - 837	257 ± 246	253	100%	168 - 3744	1078 ± 1094	754
Conductivity	mS	100%	2 - 199	90 ± 66	87	100%	4 - 29	18 ± 9	20	100%	1 - 7	3 ± 2	1
pH	None	100%	6 - 8	6 ± 0.4	6	100%	6 - 7	7 ± 0.3	7	100%	7 - 8	7 ± 0.4	7
UV 254	None	100%	0.1 - 1	0.4 ± 0.3	0.3	100%	0.2 - 1	0.4 ± 0.2	0.3	100%	0.03 - 0.3	0.1 ± 0.1	0.1
UV 272	None	100%	0.1 - 2	1 ± 1	0.3	100%	0.2 - 1	0.5 ± 0.2	0.5	100%	0.02 - 0.3	0.1 ± 0.1	0.1

		Ross County (D9)				Scioto County (D9)				Meigs County (D10)			
Parameter	Units	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cyanide*	mg/L as CN^-	100%	0.01 - 0.03	0.01 ± 0.01	0.01	100%	0.02 - 0.1	0.04 ± 0.02	0.04	100%	0.002 - 0.01	0.004 ± 0.004	0.002
Surfactants*	mg/L	100%	0.04 - 0.1	0.1 ± 0.02	0.1	100%	0.01 - 21	5 ± 10	0.1	100%	0.004 - 0.02	0.01 ± 0.01	0.01
Oil & Grease*	mg/L	100%	9 - 74	40 ± 33	37	100%	15 - 6800	1715 ± 3390	22	0%	2 - 3	2 ± 0.1	3
TSS*	mg/L	100%	148 - 252	181 ± 48	161	100%	80 - 19402	4927 ± 9650	113	100%	6 - 14	10 ± 4	10
TDS	mg/L	100%	8840 - 30400	23578 ± 6240	24200	100%	11500 - 19600	16325 ± 2563	16850	100%	34 - 14200	3060 ± 5493	895
Turbidity	NTU	100%	9 - 245	107 ± 69	113	100%	41 - 5928	920 ± 1953	112	100%	1 - 18	10 ± 5	10
Conductivity	mS	100%	1 - 50	35 ± 14	40	100%	20 - 35	29 ± 5	30	100%	1 - 25	5 ± 9	1
pH	None	100%	6 - 7	7 ± 0.3	7	100%	6 - 7	7 ± 0.2	7	100%	7 - 8	7 ± 0.3	7.3
UV 254	None	100%	0.1 - 1	0.3 ± 0.3	0.3	100%	0.07 - 1	0.3 ± 0.2	0.2	100%	0.02 - 0.3	0.1 ± 0.1	0.1
UV 272	None	100%	0.05 - 0.3	0.1 ± 0.1	0.1	100%	0.04 - 1	0.2 ± 0.2	0.2	100%	0.002 - 0.2	0.1 ± 0.1	0.1

		Athens County (D10)				Washington County (D10)				Hocking County (D10)			
Parameter	Units	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cyanide*	mg/L as CN^-	100%	0.02 - 0.097	0.1 ± 0.03	0.04	100%	0.003 - 0.02	0.01 ± 0.01	0.01	100%	0.01 - 0.48	0.2 ± 0.2	0.1
Surfactants*	mg/L	100%	0.04 - 1	0.4 ± 1	0.1	100%	0.03 - 0.04	0.03 ± 0.01	0.03	100%	0.07 - 0.232	0.1 ± 0.1	0
Oil & Grease*	mg/L	100%	11 - 80	33 ± 32	21	100%	11 - 14	13 ± 1	12	100%	16 - 68	32 ± 24	22
TSS*	mg/L	100%	292 - 15394	4134 ± 7507	425	100%	58 - 458	311 ± 174	364	100%	1398 - 3132	2343 ± 717	2421
TDS	mg/L	100%	1190 - 82400	59450 ± 21626.3	61600	100%	1190 - 23000	12862.5 ± 7766	12900	100%	11600 - 2820000	332405 ± 786190	100000
Turbidity	NTU	100%	19 - 11136	1314 ± 3293	243	100%	39 - 1936	354 ± 532	208	100%	69 - 1029	516 ± 376	396.5
Conductivity	mS	100%	2 - 143	103 ± 37	111	100%	2 - 39	23 ± 14	23	100%	21 - 310	157 ± 98	154
pH	None	100%	6 - 8	7 ± 0.3	7	100%	7 - 7	7 ± 0.20845	7	100%	6 - 8	7 ± 0.5	7
UV 254	None	100%	0.1 - 1	0.5 ± 0.4	0.3	100%	0.02 - 0.3	0.1 ± 0.1	0.05	100%	0.004 - 2	0.5 ± 0.5	0.4
UV 272	None	100%	0.04 - 1	0.4 ± 0.4	0.4	100%	0.003 - 0.2	0.1 ± 0.1	0.052	100%	0.01 - 2	0.4 ± 0.5	0.2

		Monroe County (D10)				Tuscarawas County (D11)				Cuyahoga County (D12)			
Parameter	Units	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median	% of samples above detection	Range	Avg ± Std Dev	Median
Cyanide*	mg/L as CN^-	100%	0.001 - 0.02	0.01 ± 0.01	0.007	100%	0.003 - 0.1	0.04 ± 0.04	0.03	100%	0.03 - 0.08	0.05 ± 0.02	0.05
Surfactants*	mg/L	100%	0.01 - 0.05	0.04 ± 0.02	0.05	100%	0.02 - 0.04	0.03 ± 0.01	0.03	100%	0.2 - 2	1 ± 1	1
Oil & Grease	mg/L	66%	2.35 - 25	13 ± 11	12	0%	2 - 3	2 ± 0.1	2	100%	98 - 1163	470 ± 600	150
TSS*	mg/L	100%	1300 - 3374	2078 ± 1130	1560	100%	8 - 72	33 ± 30	25	100%	446 - 1350	793 ± 487	582
TDS	mg/L	100%	10700 - 58800	30944.4 ± 19532.4	26800	100%	690 - 90000	27303 ± 25422	21600	100%	4910 - 31000	13376 ± 10180	10300
Turbidity	NTU	100%	577 - 1892	1396 ± 391	1444	100%	3 - 70	29 ± 22	21	100%	70 - 700	296 ± 245	272
Conductivity	mS	100%	19 - 88	50 ± 29	42	100%	1 - 156	59 ± 60	38	100%	9 - 46	22 ± 14	18
pH	None	100%	7 - 8	7 ± 0.2	7	100%	7 - 8	7 ± 0.3	7	100%	5 - 7	6 ± 1	7
UV 254	None	100%	0.03 - 0.4	0.1 ± 0.1	0.08	100%	0.1 - 1	0.4 ± 0.4	0.3	100%	0.2 - 1	1 ± 0.5	1
UV 272	None	100%	0.007 - 0.5	0.1 ± 0.2	0.04	100%	0.1 - 1	0.4 ± 0.4	0.3	100%	0.5 - 3	1 ± 1	1

Copper and zinc concentrations for all 24 garages, are given in Figures 3-6 and 3-7. The reuse and disposal limits are included in the captions as a reference.

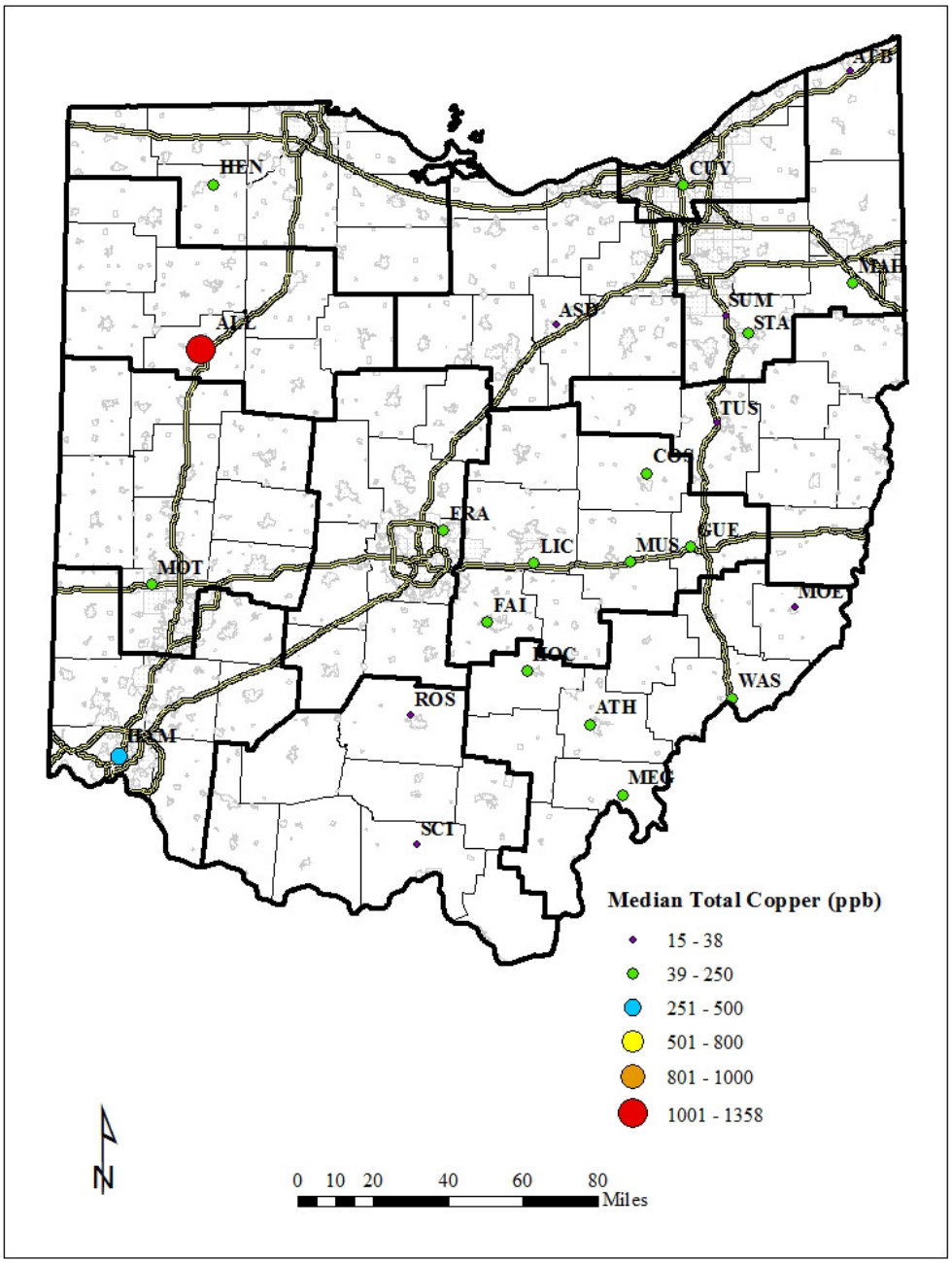


Figure 3-6: Median total copper concentration at each of the 24 garages. The reuse limit for copper is 38 ppb and the disposal guidance is 840 ppb.

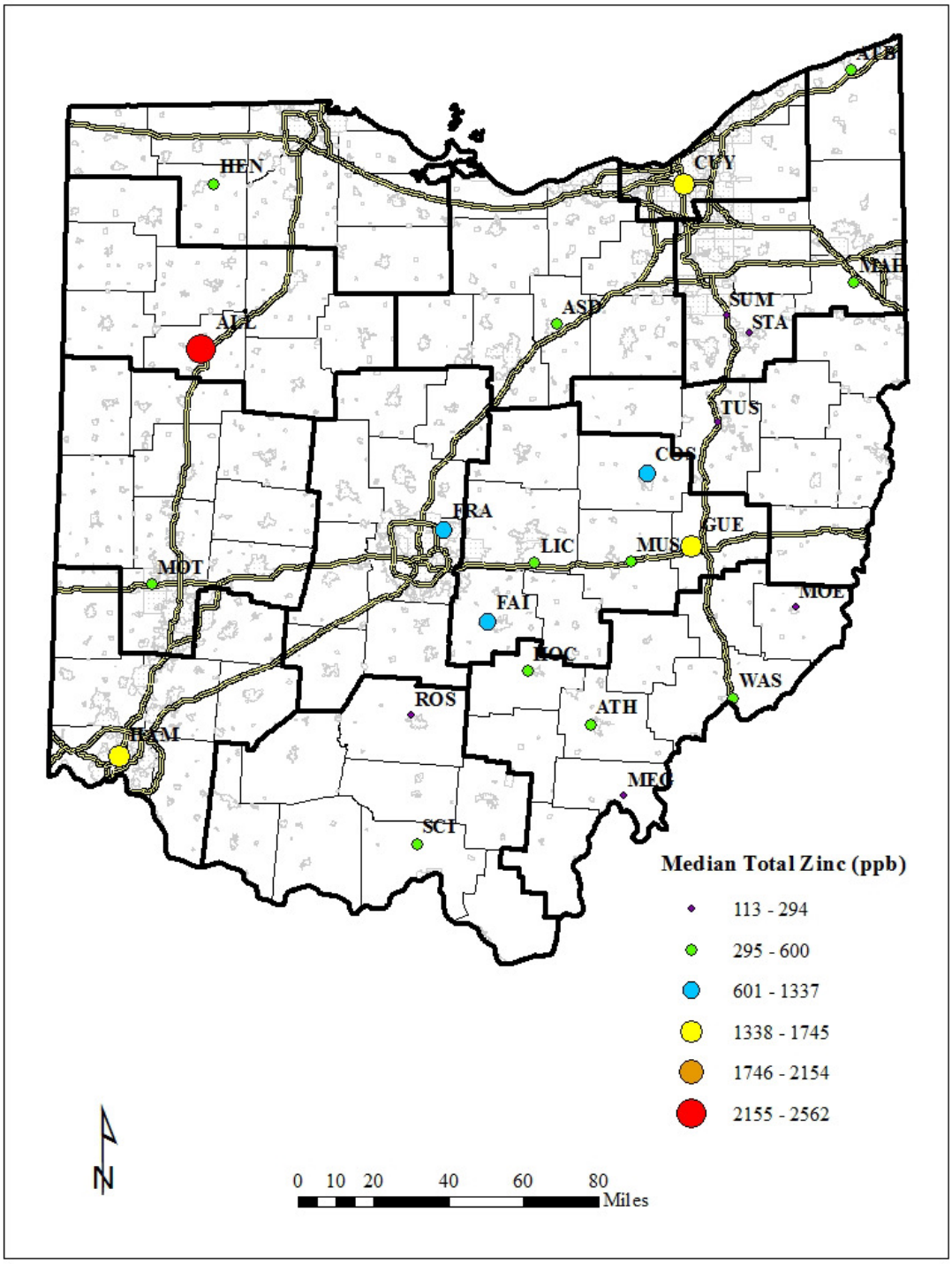


Figure 3-7: Median total zinc concentrations at each of the 24 garages around Ohio. The reuse limit for zinc is 294 ppb and the disposal guidance is 1460 ppb.

Individual sample results for copper and zinc are given in Figures 3-8 to 3-11. In general, as copper increases so does the zinc concentration. This can be seen in Figure 3-8 for the 12 Allen County samples. This would be expected because both are traffic metals. As noted earlier, particulate metal concentrations are much higher than dissolved metal concentrations for the traffic metals. Turbidity measures light scattering caused by the individual particles and could be a good surrogate for particulate metal. Figure 3-8 shows that as turbidity increases so does the total copper and zinc concentration.

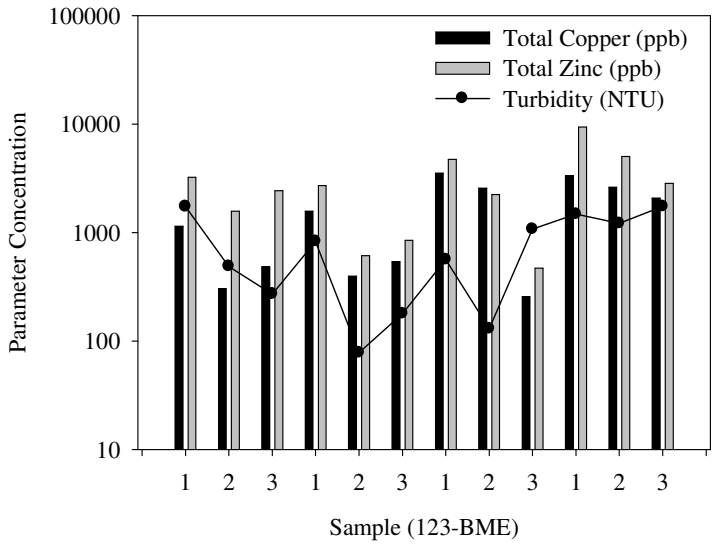


Figure 3-8: A comparison of the trend of total copper, total zinc, and turbidity for all 12 Allen County samples collected for analysis. Note*:* 1=beginning of wash, 2=middle of wash, 3=end of wash. Each new subset of 3 is a new sample set (A-D); *i.e*. the first 1, 2, 3 are sample set A from each garage etc. Total copper, total zinc, and turbidity concentration are in logarithmic scale.

The percent dissolved metal concentrations in comparison to the total metal concentration for the 12 Allen County samples for copper and zinc are shown in Figure 3-9. For many of our samples the percent of dissolved traffic metals is small in comparison to the total metal concentration. For zinc, however, there are several samples where the dissolved fraction was greater than 50% of the sample and could be due to complexation with organic or inorganic species, as well as pH effects. Copper is less impacted than zinc by complexation and pH.

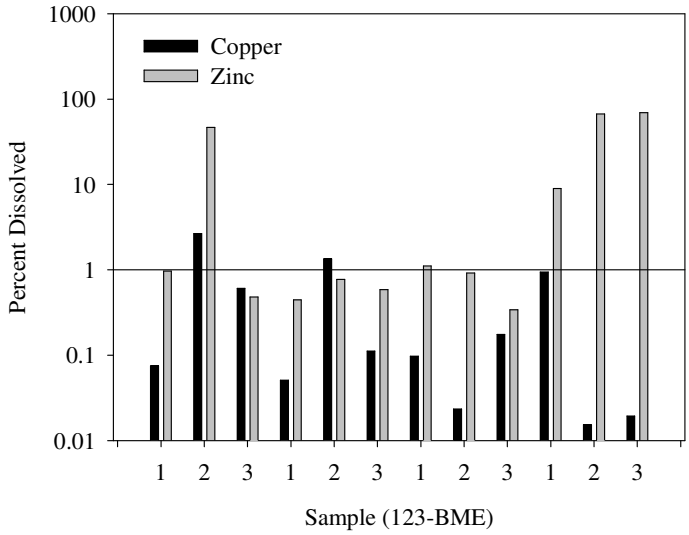


Figure 3-9: The percentage of dissolved copper and dissolved zinc in each of the 12 samples from Allen County. Note: Percentages are in logarithmic scale.

Figure 3-10 is a comparison of the trend of total dissolved solids (TDS) and turbidity for the 12 Allen County samples. The reference line is the typical EPA drinking water standard for TDS. Therefore, this represents the maximum TDS expected from "normal" tap water, thus showing anything above that line could not have come from the water used to clean the trucks, but from the trucks themselves. The TDS coming from the tap water could be much lower than the 500 ppb represented here, this is just a reference to show that when the TDS increases greatly it would be from a salt-covered or dirty truck. The hypothesis is the higher the TDS, the more salt on the trucks during that wash water event. However, this may or may not be an indicator of a higher metal concentration. Figure 3-11 shows the total copper concentration for the 12 Allen County samples. When TDS spikes, the metal concentrations do not always spike. They tend to be higher concentrations, but they do not appear to be correlated. This will be examined later in the modeling section.

Figure 3-11 shows the four sets of samples and the beginning, middle, and end of each set for four garages. This graph demonstrates that often there appears to be a "first flush" (noted by the arrows) effect for total metals where the beginning sample concentration is higher than the

middle and end concentrations. This is not always true due to the high variability nature of an oil water separator which will be analyzed in the three hour study discussed next.

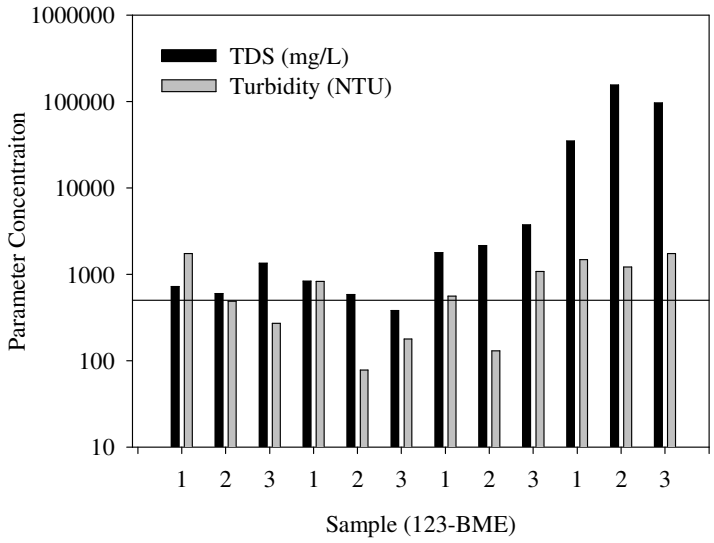


Figure 3-10: Comparison of TDS and turbidity for all 12 Allen County samples. The reference line is at 500 ppb denoting where the maximum TDS concentration can be for the typical EPA drinking water standard. Note: TDS and turbidity concentration are in logarithmic scale.

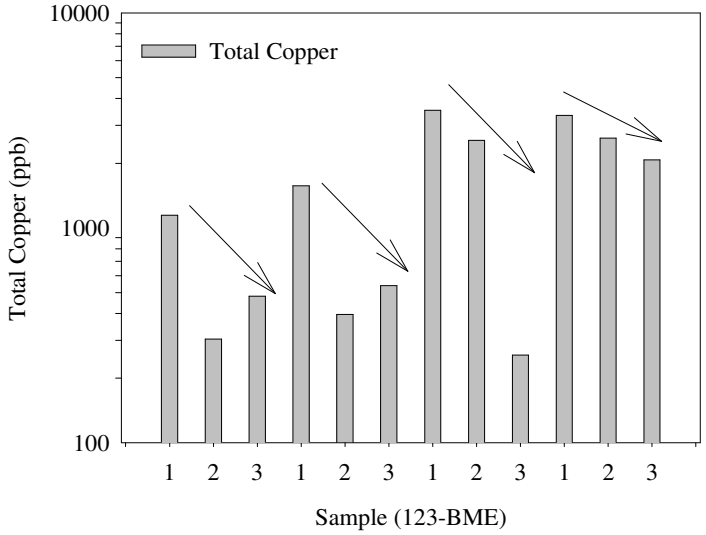


Figure 3-11: A comparison of the total copper at the beginning, middle, and end of a wash cycle for each of the 12 samples for Allen County. Note: Total copper concentration is in logarithmic scale. Arrows indicate generally decreasing copper concentration during the wash cycle.

As the individual garage results were analyzed and reviewed it was decided to conduct an individual garage study to analyze the variability of the oil water separator. A three hour study was conducted at the Stark County ODOT garage (garage ID 7) on April 3rd, 2013 from 7:00 am until 10:00 am. During this time approximately 20 trucks were washed from both the Stark County garage and the Massillon outpost. Grab samples were collected every 15 minutes from the oil water separator. They were collected in 125mL polyethylene bottle and 125mL amber glass bottle. The 13 samples were tested for 17 heavy metals, UV 254 and UV 272, and pH. Three of the samples: one at the beginning (7:00 am), one at the middle (8:15 am), and one at the end (10:00 am) were tested for oil and grease.

Table 3-14 gives the results for the 17 heavy metals during this three hour study. ODOT oil water separators tend to have a high variability of parameter concentrations as a function of time for a full truck wash. In Figure 3-12a one can see as the time of wash changes, so does the concentration of copper and zinc. Copper has a 55% variation above and below the average of 151 ppb and zinc has varies above and below the average of 993 ppb by 63%. Figure 3-12b shows that as the time of wash continues the oil and grease concentration also changes. In this case it actually decreases as a function of time. Overall, all wash water quality parameters exhibit significant variability.

Table 3-14: Three hour full truck washing study conducted at the Stark County ODOT Garage on April 3rd, 2013.

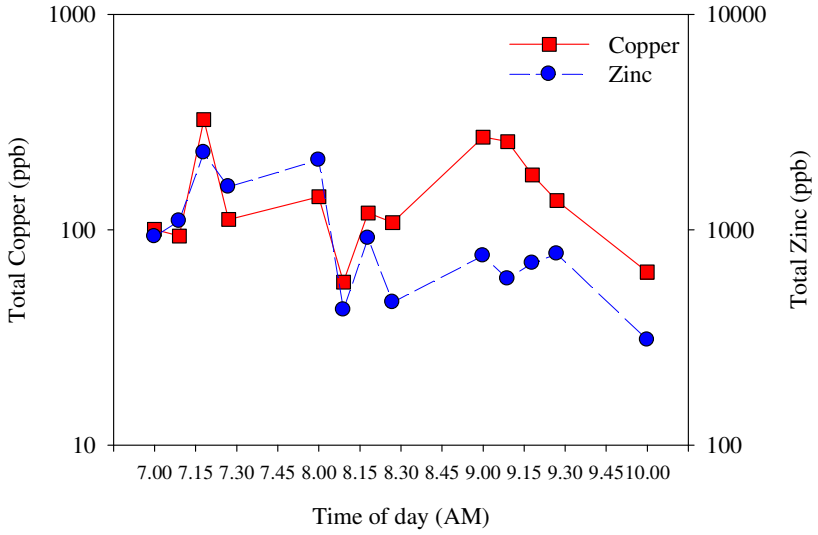
	Concentration at each time segment													For entire data set			
Metal	7:00	7:15	7:30	7:45	8:00	8:15	8:30	8:45	9:00	9:15	9:30	9:45	10:00	Average		Std Dev	Median
Al	4463	4106	4940	3322	3114	546	2768	2058	4723	3784	3418	2749	1358	3181	±	1301	3322
As	22	4	4	4	4	4	4	9	10	4	4	17	4	8	±	6	4
B	206	170	182	168	175	134	181	169	205	185	201	190	178	180	±	19	181
Be	0.3	0.4	0.5	0.3	0.3	0.1	0.2	0.2	0.3	0.3	0.2	0.2	0.1	0	±	0	0.3
Cd	1	1	3	1	2	1	1	1	2	2	2	1	1	1	±	1	1
Co	1	1	1	1	1	1	1	1	1	1	1	1	1	1	±	0	1
Cr	79	132	158	145	152	22	103	70	125	106	118	90	41	103	±	42	106
Cu	100	93	324	111	142	57	120	108	269	257	179	136	64	151	±	83	120
Fe	16828	19733	23329	17741	21929	3752	18571	12740	26345	18805	27431	18547	8667	18032	±	6620	18571
Li	13	10	13	14	6	6	11	12	5	11	11	10	9	10	±	3	11
Mn	1283	1185	1366	1056	944	288	711	529	863	886	861	667	400	849	±	328	863
Mo	15	14	15	12	10	7	11	9	11	11	10	8	6	11	±	3	11
Ni	59	69	112	57	63	28	54	45	64	68	65	62	37	60	±	20	62
Pb	45	44	140	33	60	5	42	32	62	76	41	30	16	48	±	33	42
Se	14	14	14	14	14	14	14	14	14	14	14	14	14	14	±	0	14
V	13	14	16	11	11	1	10	5	14	10	10	8	4	10	±	4	10
Zn	929	1095	2278	1579	2105	423	913	460	756	591	699	771	307	993	±	625	771

Notes: Units: µg/L, ppb

All concentrations are in total metal form

All non-detect samples were given the concentration of half the detection limit

Samples were taken at the Stark County garage on April 3rd, 2013 from 7:00 AM to 10:00AM at 15 minute intervals



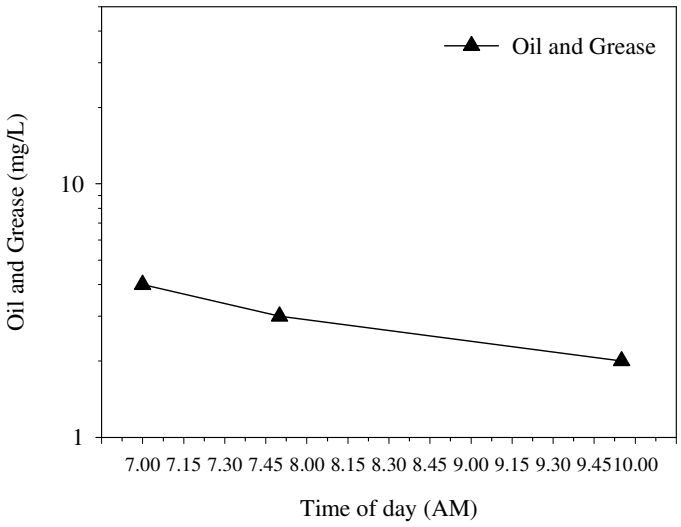


Figure 3-12: a-b: Total copper, zinc, and oil and grease during the three hour truck wash water study conducted at the Stark County garage on April 3, 2013. Note: Total copper, total zinc, and oil and grease concentration are in logarithmic scale.

3.2.2.3. Comparison of Results with Water Quality Guidelines and Limits

Section 3.2.1.3 discusses the origin and reasoning for the disposal and reuse limits and guidance. There are only four of the 24 garages in the Lake Erie Watershed. Those garages are: Allen County, Henry County, Cuyahoga County, and Ashtabula County; the other 20 garages are in the Ohio River Watershed. As discussed previously there are different reuse limits for each watershed and the reuse limits are modified according to the hardness of the water. For the purpose of this discussion the most stringent limits were selected for comparison for the reuse guidance. Disposal limits will also vary for each WWTP around Ohio so we have limited our discussion to the local limit guidance given by the Ashtabula County WWTP.

Table 3-15 compares the median concentration at each garage for each of the 27 parameters to the local disposal guidance. When comparing the medians for each of the 24 garages to the local disposal guidance, copper is exceeded in only 4% of the garages. Zinc exceeds in 13% of the samples, TSS exceeded 67%, and oil and grease exceeds 25% of the samples. All other parameters are below the disposal guidance in all of the samples.

When comparing the medians of all 27 parameters for each of the 24 garages to the most stringent reuse limits, copper exceeds the limit in 71% of the samples. Zinc exceeds 75%, iron exceeds 8%, and oil and grease concentration exceeds 83% of the samples. All other parameters are below the reuse limits in all of the samples (Table 3-16).

Table 3-15: Median concentrations of parameters at each of the garages compared to the local disposal guidance.

Element	Local Disposal Limits[1], ppb	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Exceeding[3]:
Al	--	7711	1549	327	660	489	1595	457	2617	628	3576	570	3457	4848	1150	7480	362	278	27	348	1748	662	4728	76	1496	
As	--	20	15	12	15	10	9	12	15	10	15	15	15	11	15	15	8	15	15	10	10	15	9	9	15	
Be	--	0.2	3	2	3	0.1	0.5	0.2	2	2	3	3	3	0.3	3	4	0.2	3	3	0.2	0.1	0.2	0.2	0.1	4	
B	--	280	176	159	192	64	141	211	168	308	196	140	207	192	208	195	141	228	73	127	130	154	151	219	208	
Cd	74	4	3	2	3	2	1	1	3	2	3	3	3	1	3	4	2	3	3	0.4	1	1	0.5	0.5	4	
Cr	2,000	55	17	4	9	15	18	8	18	5	27	5	22	32	21	116	3	4	3	4	19	6	11	1	20	
Co	--	2	3	2	3	1	1	1	2	2	3	3	3	1	3	4	1	4	3	2	1	3	1	1	4	
Cu	840	1358	60	16	37	27	44	48	108	39	67	62	84	98	85	382	17	15	53	46	47	108	22	21	191	1
Fe	--	40897	6675	4808	2388	1984	6051	1615	5798	1754	9886	1799	10008	10757	5409	24247	3242	4263	596	2352	7423	2490	9410	2306	5364	
Ni	760	77	25	22	18	15	27	22	33	24	38	26	29	30	89	100	18	24	25	20	24	23	30	17	110	
Pb	400	147	17	13	9	10	6	9	19	14	13	9	34	11	25	366	9	12	9	4	29	6	11	8	46	
Li	--	24	14	9	12	6	9	8	8	10	13	31	13	21	36	7	10	53	1	12	8	10	14	8	59	
Mn	--	424	488	202	307	114	253	241	136	213	724	321	393	269	172	1404	186	443	1835	539	1409	386	528	178	278	
Mo	--	22	12	8	5	7	5	10	9	4	5	13	7	14	13	5	13	10	4	5	8	5	5	5	278	
Se	--	22	23	23	25	22	6	23	16	16	23	23	24	8	23	25	9	24	23	22	9	24	25	25	25	
V	--	12	3	3	3	1	4	1	3	3	5	3	6	7	3	15	1	3	3	1	2	3	5	1	3	
Zn	1,460	2562	325	337	181	336	462	211	953	349	1437	406	631	766	371	1738	220	562	190	321	338	580	113	260	1544	3
Cyanide	0.25	0.02	0.02	0.02	0.04	0.01	0.04	0.05	0.01	0.02	0.03	0.01	0.02	0.02	0.02	0.01	0.01	0.04	0.00	0.04	0.01	0.08	0.01	0.03	0.05	
Surfactants	--	0.4	0.05	0.06	0.1	0.05	0.04	0.5	0.1	0.2	0.05	0.03	0.09	0.1	0.2	0.06	0.06	0.1	0.01	0.05	0.03	0.1	0.05	0.03	1.0	
TSS	220	1203	378	285	72	226	660	50	532	240	1411	97	808	2682	92	1104	161	113	10	425	364	2421	1560	25	582	16
TDS	--	1565	24180	11700	10700	8470	26565	33600	54200	18260	14800	27300	13300	51400	11700	759	24200	16850	895	61600	12900	100000	26800	21600	10300	
Turbidity+	--	694	430	166	100	94	409	76	379	59	344	115	362	572	253	754	113	112	10	243	208	397	1444	21	272	
Conductivity*	--	3	43	21	19	15	46	59	89	37	26	51	23	87	20	1	40	30	1	111	23	154	42	38	18	
Oil and Grease	100	170	8	21	38	346	58	10	46	13	13	11	493	41	156	290	37	22	3	21	12	22	12	2	150	6
pH[i]	6-11	7	7	7	7	7	7	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7	
UV 254	--	0.6	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.2	0.2	0.3	0.3	0.1	0.3	0.2	0.1	0.3	0.05	0.4	0.1	0.3	0.6	
UV 272	--	0.5	0.1	0.2	0.1	0.05	0.2	0.1	0.2	0.2	0.05	0.2	0.4	0.3	0.5	0.1	0.1	0.2	0.1	0.4	0.1	0.2	0.04	0.3	1	
	Exceeding[2]:	4	1	1		2	1		1	1	1		2	1	1	3				1	1	1	1		3	

Notes: Highlighting means the concentration exceeds one or more standard.

All samples under the detection limit have been substituted with half the detection limit concentration.

Units: µg/L above line mg/L below line unless otherwise noted

* Units: mS

+ Units: NTU

[i] Unitless

-- No standard provided

[1]Standards based on most stringent OAC 3745-1 aquatic criteria (OMZM) with hardness 288 mg/L, agriculture criteria (OMZM), wildlife criteria (OMZA) standards.

[2]Number of parameters exceeding the disposal guidance per garage.

[3]Number of garages exceeding the disposal guidance per parameter.

Table 3-16: Median concentrations of parameters at each of the garages compared to the most stringent reuse limits.

Element	Reuse Standard[1], ppb	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Exceeding[3]:
Al	--	7711	1549	327	660	489	1595	457	2617	628	3576	570	3457	4848	1150	7480	362	278	27	348	1748	662	4728	76	1496	
As	311	20	15	12	15	10	9	12	15	10	15	15	15	11	15	15	8	15	15	10	10	15	9	9	15	
Be	33,000	0.2	3	2	3	0.1	0.5	0.2	2	2	3	3	3	0.3	3	4	0.2	3	3	0.2	0.1	0.2	0.2	0.1	4	
B	311	280	176	159	192	64	141	211	168	308	196	140	207	192	208	195	141	228	73	127	130	154	151	219	208	
Cd	15	4	3	2	3	2	1	1	3	2	3	3	3	1	3	4	2	3	3	0.4	1	1	0.5	0.5	4	
Cr	311	55	17	4	9	15	18	8	18	5	27	5	22	32	21	116	3	4	3	4	19	6	11	1	20	
Co	220	2	3	2	3	1	1	1	2	2	3	3	3	1	3	4	1	4	3	2	1	3	1	1	4	
Cu	38	1358	60	16	37	27	44	48	108	39	67	62	84	98	85	382	17	15	53	46	47	108	22	21	191	17
Fe	15,550	40897	6675	4808	2388	1984	6051	1615	5798	1754	9886	1799	10008	10757	5409	24247	3242	4263	596	2352	7423	2490	9410	2306	5364	2
Ni	622	77	25	22	18	15	27	22	33	24	38	26	29	30	89	100	18	24	25	20	24	23	30	17	110	
Pb	311	147	17	13	9	10	6	9	19	14	13	9	34	11	25	366	9	12	9	4	29	6	11	8	46	
Li	--	24	14	9	12	6	9	8	8	10	13	31	13	21	36	7	10	53	1	12	8	10	14	8	59	
Mn	--	424	488	202	307	114	253	241	136	213	724	321	393	269	172	1404	186	443	1835	539	1409	386	528	178	278	
Mo	190,000	22	12	8	5	7	5	10	9	4	5	13	7	14	13	5	13	10	4	5	8	5	5	5	278	
Se	156	22	23	23	25	22	6	23	16	16	23	23	24	8	23	25	9	24	23	22	9	24	25	25	25	
V	150	12	3	3	3	1	4	1	3	3	5	3	6	7	3	15	1	3	3	1	2	3	5	1	3	
Zn	294	2562	325	337	181	336	462	211	953	349	1437	406	631	766	371	1738	220	562	190	321	338	580	113	260	1544	18
Cyanide	0.022	0.02	0.02	0.02	0.04	0.01	0.04	0.05	0.01	0.02	0.03	0.01	0.02	0.02	0.02	0.01	0.01	0.04	0.00	0.04	0.01	0.08	0.01	0.03	0.05	
Surfactants	0.5	0.4	0.05	0.06	0.1	0.05	0.04	0.5	0.1	0.2	0.05	0.03	0.09	0.1	0.2	0.06	0.06	0.1	0.01	0.05	0.03	0.1	0.05	0.03	1.0	
TSS	--	1203	378	285	72	226	660	50	532	240	1411	97	808	2682	92	1104	161	113	10	425	364	2421	1560	25	582	
TDS	--	1565	24180	11700	10700	8470	26565	33600	54200	18260	14800	27300	13300	51400	11700	759	24200	16850	895	61600	12900	100000	26800	21600	10300	
Turbidity[+]	--	694	430	166	100	94	409	76	379	59	344	115	362	572	253	754	113	112	10	243	208	397	1444	21	272	
Conductivity*	--	3	43	21	19	15	46	59	89	37	26	51	23	87	20	1	40	30	1	111	23	154	42	38	18	
Oil and Grease	10	170	8	21	38	346	58	10	46	13	13	11	493	41	156	290	37	22	3	21	12	22	12	2	150	20
pH[i]	--	7	7	7	7	7	7	7	7	7	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7	
UV 254	--	0.6	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.2	0.2	0.3	0.3	0.1	0.3	0.2	0.1	0.3	0.05	0.4	0.1	0.3	0.6	
UV 272	--	0.5	0.1	0.2	0.1	0.05	0.2	0.1	0.2	0.2	0.05	0.2	0.4	0.3	0.5	0.1	0.1	0.2	0.1	0.4	0.1	0.2	0.04	0.3	1	
	Exceeding[2]:	4	2	2	1	2	3	1	3	3	3	3	3	3	3	4	1	2	1	3	3	3	1		3	

Notes:

Highlighting means the concentration exceeds one or more standard.

All samples under the detection limit have been substituted with half the detection limit concentration.

Units: µg/L above line mg/L below line unless otherwise noted

* Units: mS

[+] Units: NTU

[i] Unitless

-- No standard provided

[1]Standards based on most stringent OAC 3745-1 aquatic criteria (OMZM) with hardness 288 mg/L, agriculture criteria (OMZM), wildlife criteria (OMZA) standards.

[2]Number of parameters exceeding the reuse standard per garage.

[3]Number of garages exceeding the reuse standard per parameter.

Figure 3-13 shows the garages that meet or exceed the reuse target values and/or disposal guidance for all parameters. Figures 3-14 through 3-16 respectively show where copper, zinc, and oil and grease medians exceed the reuse limits and local disposal guidance around Ohio.

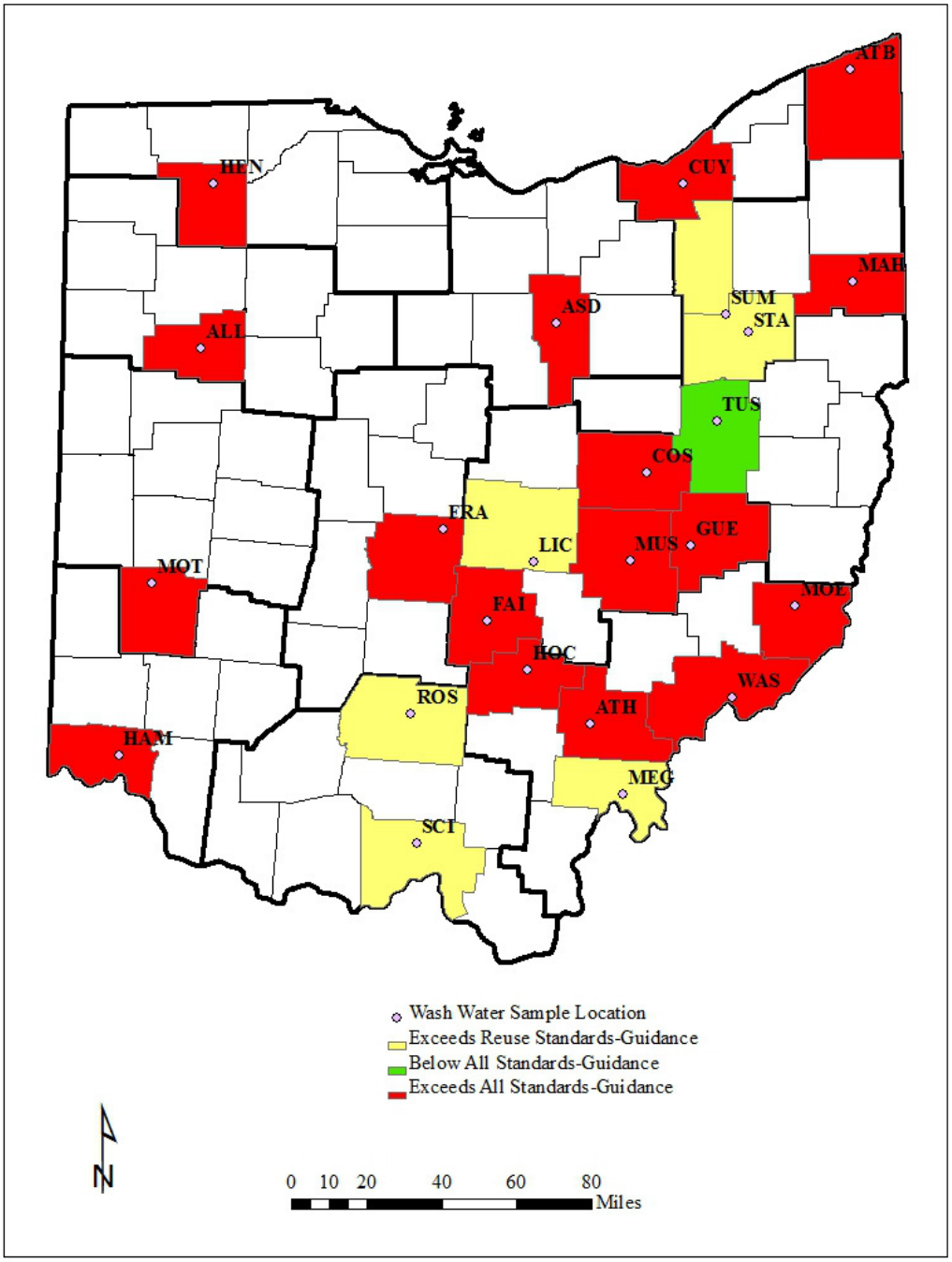


Figure 3-13: Garages meeting or exceeding the reuse limits and/or disposal guidance for all parameters.

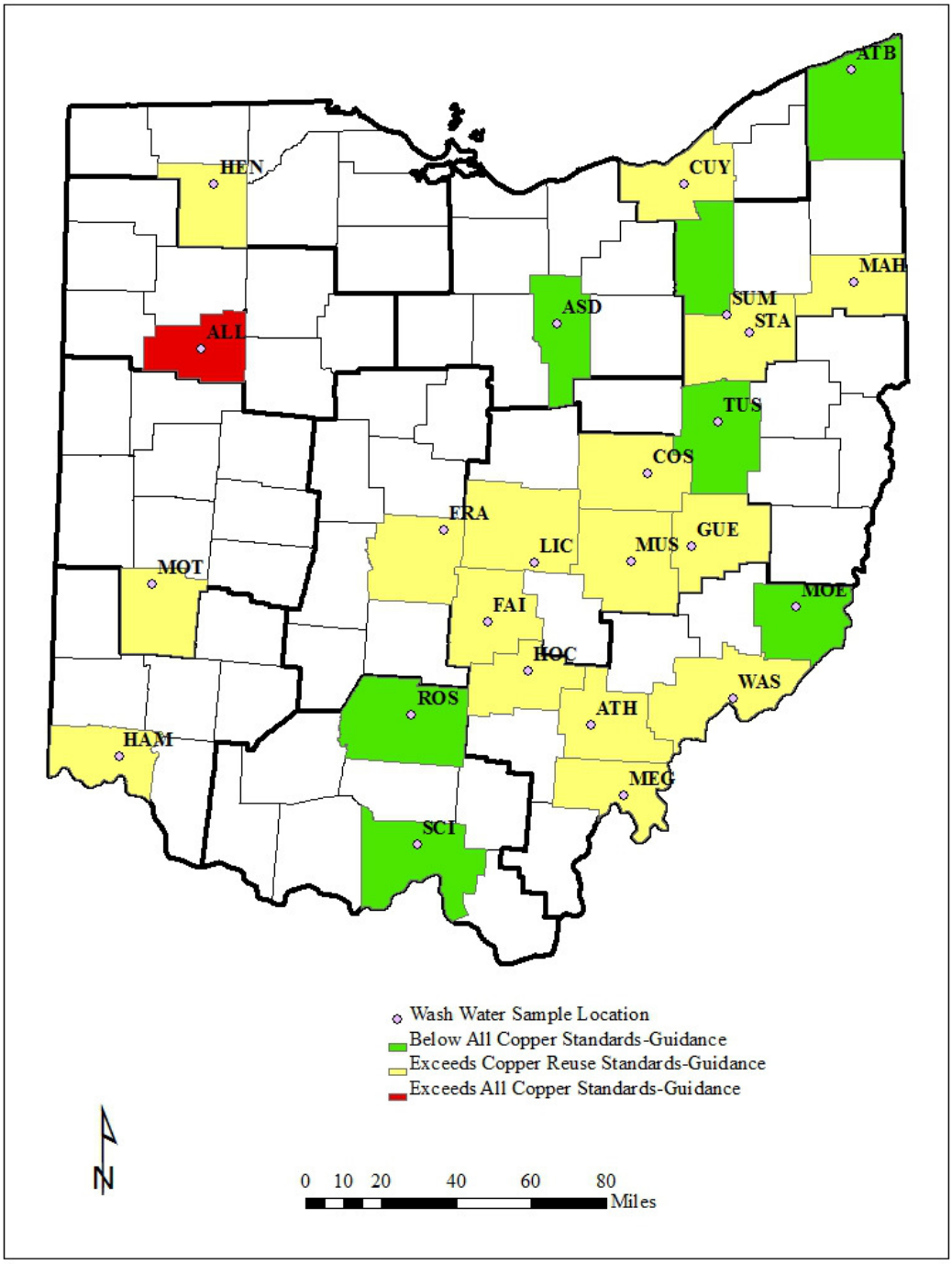


Figure 3-14: Garages meeting or exceeding the reuse limit (39 ppb) and/or disposal guidance (840 ppb) for total copper.

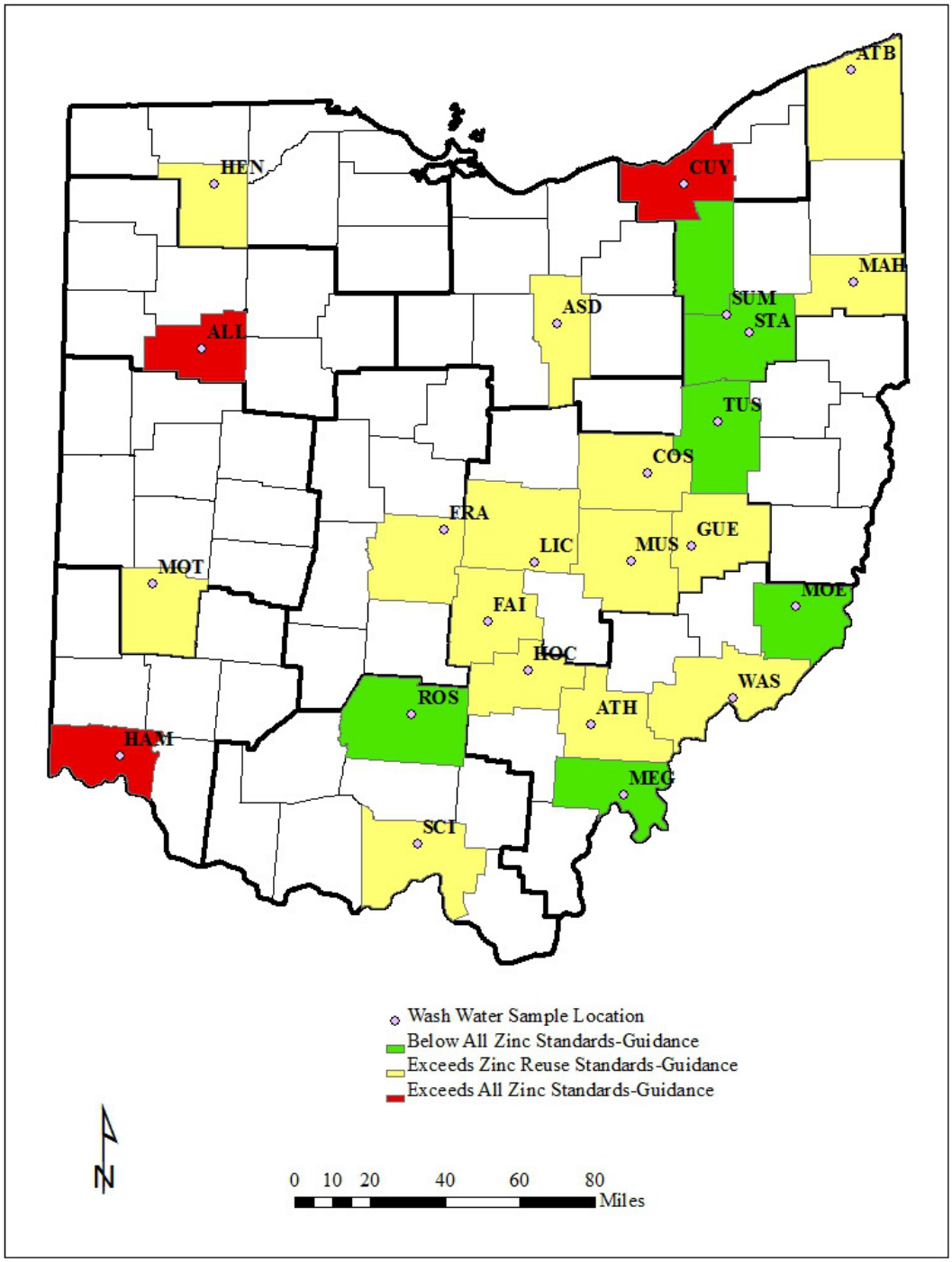


Figure 3-15: Garages meeting or exceeding the reuse limit (294 ppb) and/or disposal guidance (1460 ppb) for total zinc.

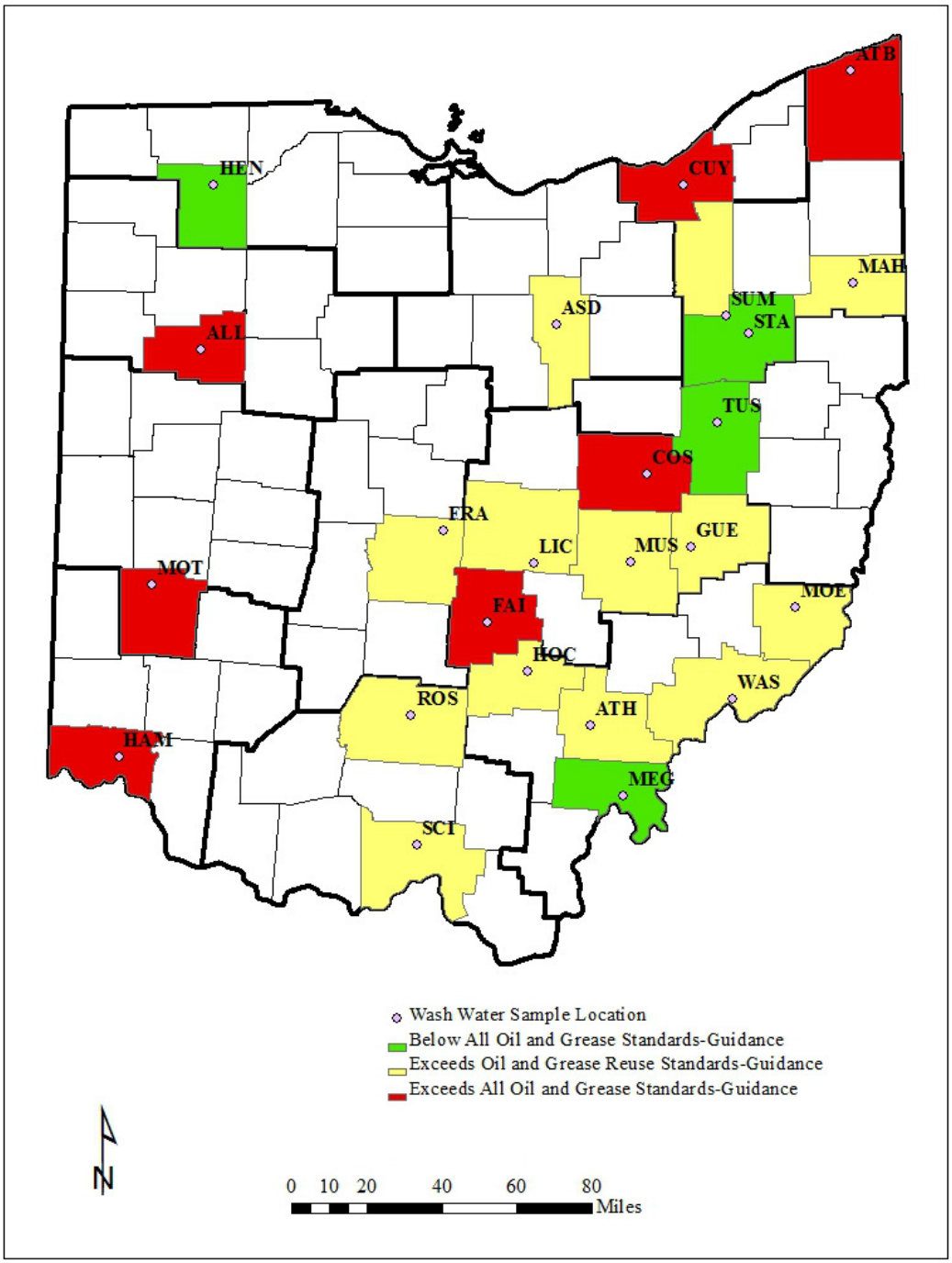


Figure 3-16: Garages meeting or exceeding the reuse limit (10 mg/L) and/or disposal guidance (100 mg/L) for oil and grease.

There were four metal parameters and one non-metal parameter that exceeded the reuse target values and there were two metal parameters and two non-metal parameters that exceeded the local disposal guidance. The percent of garages that exceeded each parameter is summarized in Table 3-17. Table 3-17 also shows the percentage of samples exceeding each of these parameters based on all samples collected. For reuse copper exceeds 59% and zinc exceeds in 66% of the samples. Oil and grease is also noteworthy as it exceeds reuse limits in 74% of the samples. For disposal guidance, TSS has the highest exceedance at 65% of the samples tested. Only 4% of the copper samples and 20% of the zinc sample exceed local disposal guidance, making disposal options feasible.

Table 3-17: Percent of garage medians exceeding reuse limits and local disposal guidance and the percentage of the 253 samples exceeding the limits-guidance.

	Garage Medians		All 253 Samples	
Parameter	% of Garages Exceeding Local Disposal Guidance	% of Garages Exceeding Reuse Limit	% of Samples Exceeding Local Disposal Guidance	% of Samples Exceeding Reuse Limit
Copper	4	71	4	59
Iron	0	8	0	19
Zinc	13	75	20	66
Lead	0	4	4	4
TSS*	67	0	65	0
Oil & Grease*	3	83	20	74

Note: *only 89 of the 253 samples were tested for this parameter. Therefore the percentage is out of 89 not 253. Based on total metal concentrations.

Figures 3-17a-e compares the 24 garage medians versus the reuse limits for each of the five parameters that were greater than the limit. The reference line indicates the reuse limits for each of the parameters shown.

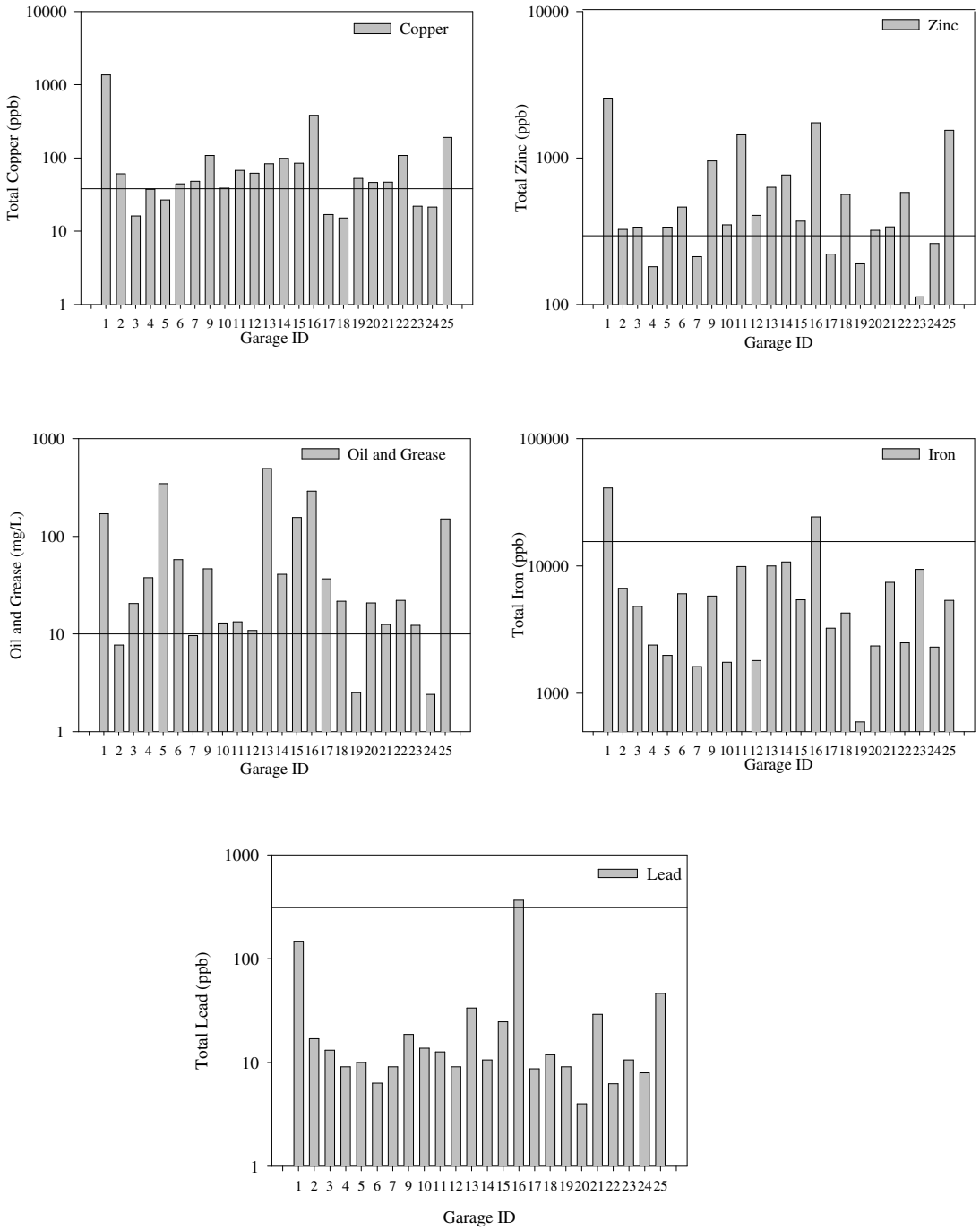


Figure 3-17a-e: Parameter medians for all garages. The line is a reference for the reuse guidance concentration for that parameter. The reuse targeted values can be found in Table 3-16.

Focusing on the reuse target values and the ability to achieve these values is summarized in Table 3-18. This shows the required treatment needed for the average of the 24 garage medians to meet reuse limits. The average total copper requires 78% reduction, total zinc 62% reduction, total iron 52% reduction, total lead 15% reduction, and oil and grease would require a 90% reduction to meet the reuse limits. Treatment options and results will be discussed in Chapter 4 of this report.

Table 3-18: Parameter summary for garages exceeding reuse limits, the average concentration of each garage exceeding a parameter, and the average required treatment needed to meet the most stringent reuse limit.

Parameter	Number of Garage Medians Exceed Reuse Standards	Percent of Garages Exceeding Reuse Standard	Ave ± Std Dev of Garage Medians that are Exceeding Reuse Standard	Required Treatment (%)
Copper	17	71	169 ± 317	78
Iron	2	8	32572 ± 11773	52
Zinc	18	75	779 ± 635	62
Lead	1	4	366 ± 0	15
Oil and Grease	20	83	99 ± 134	90

Note: Based on total metal concentrations
Most stringent reuse limit used for treatment calculations
Required treatment is based off of the average percent removal needed for all garage medians exceeding reuse limits

3.3. Wash Water Quality Modeling

3.3.1. Introduction

Roadway stormwater runoff is considered a major pollution source due to the increasing amount of heavy metals, fuel additives, and hydrocarbons in our water resources (Kayhanian et al., 2007). Heavy metals that are typically related to traffic have been found to pose a threat to human health and impact the environment (Budai and Clement, 2011). As a result of the negative impacts of highway water runoff on water sources, human health, and ecology there have been several studies looking into the characterization and source of heavy metals in the runoff. Additionally, there have been several efforts to incorporate various statistical methods in

attempts to predict, and analyze the impacting factors on metal concentrations in roadway water runoff.

Contributing factors of roadway contamination have reported the following sources: emissions from vehicles, vehicle wear, roadway types, road wear, traffic density, population, fuel additives, pesticides and herbicides, and other pollutant sources (Yong-Chul Jan et al., 2009; Kayhanian et al., 2007; Budia and Clement, 2011; Chi Peng et al., 2013). There have been many studies that have taken sampling data of roadway pollutants (based on sediment and soil sampling adjacent to a roadway) and created models to predict what and how much of a specific pollutant can be found in stormwater runoff. The following is a brief description of a few of these studies. A 2007 study by M. Kayhanian et al, collected stormwater samples from 34 highway sites in California. They characterized the stormwater samples for 7 metals and various non-metal parameters. A multiple linear regression (MLR) model, Spearman's correlation, and ANOVA was used to compare the impact of various site characteristics, storm event parameters, land use, and geographical data to the water quality factors of the samples. One MLR conducted in this paper was to predict copper. The factors found to be significant in this model were: total event rainfall, antecedent dry period, seasonal cumulative rainfall, and average annual daily traffic (Kayhanian et al., 2007).

Lyn B. Irish Jr. et al, in 1998 also used a linear regression model to predict highway stormwater runoff water quality parameters. They sampled at 3 sites along the MoPac Expressway in Austin, Texas. They used event based parameters such as duration, flow, and intensity of the current storm, antecedent dry periods, and total duration of the proceeding storm. They also used several traffic parameters including: average number of vehicles using the highway during the antecedent dry period and average number of vehicles traveling through the current storm. They found that for copper and lead prediction traffic during the storm and during the dry period was the key prediction sources for these two metals. Zinc was found to be dependent on the traffic count as well as the runoff characteristics of the proceeding storm (Lyn B. Irish Jr. et al., 1998). Smith and Shilley in 2009 conducted a monitoring study of a residential car wash water. They analyzed 7 metal parameters and 13 non-metal parameters over a course of 5 weekends at different car wash fundraising events. They used this information to determine the estimated annual mass pollutant discharge from a residential car washing. They determined that residential car washing, not including professional car washing sites, will

contribute 44 lbs. of total copper, 41 lbs. of total lead, and 16,200 lbs. of total suspended solids in one year in the city of Federal Way, WA. They discuss that stormwater will carry these pollutants to urban drainage systems and eventually to surface waters with little or no treatment provided (Smith and Shilley, 2009).

Other studies have been conducted to determine inter-element relationships between water quality parameters. There are several popular models used to demonstrate the associations between parameters. These are multiple linear regression, principal component analysis (PCA), correlation coefficient matrices, and cluster analysis. Copper, zinc, nickel, lead, chromium, and iron have been found to be correlated due to the nature of their traffic based origin. Hjortenkrans et al. in 2006 showed these relationships to be true using Spearman's Rank Correlations (Hjortenkrans et al., 2006). Kayhanian et al., 2007 used MLR to show that Fe was related to Cr, Cu, Ni, Pb, and Zn. Also, TDS is related to chloride concentration and the electric conductivity reading, and TSS and turbidity are correlated (Kayhanian et al., 2007).

Each of these studies added value to our wash water project and modeling effort. However, little information is known about the pollutant emissions from a vehicle washing event. There have been only two known reports, outside of this one, to measure water quality parameters of a vehicle during a wash cycle (Smith and Shilley, 2009; Bakacs et al., 2013). The limitations of these studies are small sampling sizes that may not give an accurate representation of the geospatial variations in large study regions. In order to capture statewide trends in water runoff and vehicle wash data, it is necessary to implement a sampling strategy that will represent a large percentage of the vehicle miles traveled across the state.

The purpose of this modeling effort was to determine what the contributing factors are to the increased levels of total copper, total zinc, total iron, and an urban/rural aspect for the winter of 2012-2013. Recall from earlier in this chapter, there were 24 garages sampled and of those 71% of garage exceeded reuse limits for total copper and 75% exceed total zinc.

3.3.2. Statistical Methodology

In order to determine the contributing factors to the levels of various metals in the winter wash water, four binary logistic regression models are estimated. The basis for logistic regression is simple linear regression where a response, Y, is determined through a relationship with predictor, X. For this research there are four responses, one for each model. Three of the

models include the total concentration of metals as the response including total copper, iron, and zinc. The last model includes an indicator variable for rural or urban garage location. The values of this variable may only be 1 indicating a rural garage, or 0 indicating an urban garage. The equation for the linear regression model may be seen in Equation 3-1 and in Washington et al. (2001);

Equation 3-1: Equation for the linear regression model (Washington et al., 2001).

$$Y_i = \beta_0 + \beta_1 X_1 + \varepsilon_i$$

where Y_i is the response for the set of samples; β_0 is the constant associated with the regression; X_1 is a predictor such as whether or not the sample in question was taken at a rural garage; β_1 is the numeric coefficient associated with attribute X_1; and ε_i is the error associated with the regression.

For many of the metal concentrations and levels, the data ranges within predictable upper and lower limits, resulting in a very few number of samples at extreme values. The use of a logit transformation as seen in Peeters et al. (2012), and in Equation 3-2, linearizes the asymptotic relationship of these relationships.

Equation 3-2: The logit transformation (Peeters et al., 2012).

$$Logit\ (P) = \ln\left(\frac{P}{P-1}\right)$$

In Equation 3-2, P is the probability of success. This varies for the four models run in this research. The probabilities for the metal responses are indications that the number will increase, while the probability of success for the rural/ urban indicator variable is concerning with the chances of the outcome being rural. The final equation for the model may be seen in Kononen et al. (2011) and in Equation 3-3;

Equation 3-3: Model equation from Kononen et al., 2011.

$$ln\left(\frac{P}{P-1}\right) = \beta_0 + \beta_1 X_1 + \varepsilon_i$$

All variable in Equation 3-3 are previously defined in Equations 3-1 and 3-2. The resulting probabilities do not indicate the full effects of the predictors within the model. In order to determine these actual effects, two types of elasticities are determined based on the nature of the predicting variable. The two types of variables in the four models are continuous and indicator, just like the two types of responses being modeled. Continuous variables represent and actual number value and the post estimation equation may be seen in Gkritza and Mannering (2008), as well as in Equation 3-4;

Equation 3-4: Post estimation equation from Gkritza and Mannering, 2008.

$$E_{Xin}^{Pn(i)} = -P(i)\beta_i x_i$$

where all model parameters are previously defined. The other parameter types in the model are indicator variables. As previously described, these parameters take only the value of "1" or "0", and doe to this nature, pseudo-elasticities are developed as seen in Cheng and Mannering (1999) and in Equation 3-5;

Equation 3-5: Equation for the development of pseudo-elasticities from Cheng and Mannering, 1999

$$E_{Xin}^{Pn(i)} = \frac{\exp[\Delta(\beta iXin)]\sum_{\forall I}\exp(\beta iXin)}{\exp[\Delta(\beta iXin)]\sum_{I=In}\exp(\beta iXin)+\sum_{I\neq In} exp(\beta iXin)} - 1$$

3.3.3. Modeling Results

There are four models that are presented in this results section. The first model, model one, is to predict the probability for being over the reuse limit for total copper (39 ppb). Model two is developed for total iron concentration greater than 15,550 mg/l, model three is for total zinc greater than 294 ppb and model four is for estimating the probability based on the various parameters that likelihood for the sampling garage to be located within a rural area. The initial results for the four models including the parameter coefficients, standard errors, t-ratios and p-values are shown in Tables 3-20 through 3-23. In addition to water quality measures, all parameters as described in Table 3-19 were initially selected and were tested for statistical

significance. Only the variables that were within a 95% confidence are included in the four models.

Table 3-19: Garage specific parameters, heavy metal elements, and non-metal parameters selected to be evaluated for inclusion in individual models.

Model Parameter	Parameter Description	Model Parameter	Parameter Description
BME	Timing of the sample: at the beginning of the wash event, middle, or end of the wash cycle	NRT	RTR/TRU for each garage
LOC	The location the sample was pulled from: before, at or after the oil water separator	TW	City or well water
TRU	Number of Trucks owned by each ODOT garage	TLM	ODOT reported: Total Lane Miles
WE	The number of winter event at each garage reported by each garage manager	ULM	ODOT reported: Urban Lane Miles
AWE	The 3 year average of winter event for each garage	RLM	ODOT reported: Rural Lane Miles
VWW	The annual estimate of wash water volume	PUM	Percent Urban Lane Miles to Total Lane Miles
GPO	Specific garage population count: created using CPO within a 15 mile radius of the garage	PLM	Percent Rural Lane Miles to Total Lane Miles
CPO	U.S. Census 2010 population of whole the county for each garage	HML	High, low, or mixed pressure washes
TTR	ODOT reported: 2011 County Daily Vehicle Mile Traveled (DVMT)	RURAL	Bottom 10 rank by population count
UTR	ODOT reported: 2011 County Urban Daily Vehicle Mile Traveled (DVMT)	URBAN	Population count ranked above the bottom 10
RTR	ODOT reported: 2011 County Rural Daily Vehicle Mile Traveled (DVMT)	Total Metal Parameters	17 total heavy metal concentrations previously defined in Table 4-10
NTT	TTR/TRU for each garage	Dissolved Metal Parameters	17 dissolved heavy metalconcentrations previously defined in Table 4-
NUT	UTR/TRU for each garage	Non-Metal Parameters	10 non-metal parameter concentrations previously defined in Table 4-10

Table 3-20: Total copper model.

	Coef.	Std. Err.	t-ratio	p-value
Constant	-3.726	0.645	-5.77	
Total zinc	0.001	0.0003	3.47	0.0005
Total nickel	0.076	0.0247	3.08	0.0021
Total chromium	0.104	0.0288	3.60	0.003
Total dissolved solids	$0.1922*10^{-4}$	$0.69*10^{-5}$	2.76	0.0058
Rural	-0.865	0.400	-2.16	0.0308
Log likelihood function *-85.626* *Restricted log likelihood* *-170.451* *Chi squared [5 d.f.]* *169.65*				
Note: 1) all positive values indicate a higher likelihood for surpassing the total copper reuse limit				

Table 3-21: Total iron model.

	Coef.	Std. Err.	t-ratio	p-value
Constant	-6.078	1.421	-4.28	
Total nickel	0.034	0.139	2.47	0.0135
Total chromium	0.137	0.034	3.97	0.0001
Avg. winter events	-0.076	0.038	-1.98	0.048
Turbidity	0.0007	0.00025	2.77	0.0056
Log likelihood function *-25.156* *Restricted log likelihood* *-119.756* *Chi squared [4 d.f.]* *189.199*				
Note: 1) all positive values indicate a higher likelihood for surpassing the total iron reuse limit				

Table 3-22: Total zinc model.

	Coef.	Std. Err.	t-ratio	p-value
Constant	-1.443	0.4011	-3.60	
Total copper	0.047	0.00902	5.22	0.000
Total iron	0.00013	$0.624*10^{-4}$	2.09	0.0364
Avg. urban lane miles	-1.514	0.571	-2.65	0.0080
Rural	-0.846	0.4053	-2.09	0.0368
Log likelihood function *-93.11* *Restricted log likelihood* *-161.753* *Chi squared [4 d.f.]* *137.279*				
Note: 1) all positive values indicate a higher likelihood for surpassing the total zinc reuse limit				

Table 3-23: Rural garage location model.

	Coef.	Std. Err.	t-ratio	p-value
Constant	8.393	1.28	6.52	
Total copper	-0.005	0.0019	-2.63	0.0086
Total iron	$0.4465*10^{-4}$	$0.2259*10^{-4}$	1.98	0.0481
Avg. winter events	-0.062	0.0179	-3.48	0.0005
Trucks per lane mile	-0.1094	0.0159	-6.85	0.000
Low turbidity	-1.241	0.4032	-3.08	0.0021
Low pH	-1.347	0.645	-209	0.0368
Log likelihood function *-95.169* *Restricted log likelihood* *-172.883* *Chi squared [6 d.f.]* *155.426*				
Note: 1) all positive values indicate a higher likelihood for the garage being designated as rural				

Based on the model results from Tables 3-20 through 3-23, Table 3-24 provides the calculated elasticities and pseudo- elasticities for the statistically significant parameters. In model one, the likelihood for exceeding the total copper reuse limit is presented. Model one includes total chromium, nickel, zinc, total dissolved solids and the rural classification. The results show as the concentrations of chromium, nickel, zinc and total dissolved solids increase so does the likelihood for failing to meet the copper reuse limit. For example in model one, if the concentration of total zinc is 100 ppb, the likelihood for failing to meet the total copper re-use limit increases by 16%. The increase due to total dissolved solids (TDS) may be explained by the truck being relatively dirty (i.e. presence of salt and traffic dust) when washed and could have a large impact on the probability as median TDS can easily exceed 20,000 mg/L and corresponds to increasing the likelihood for failing to meet the copper reuse limit by 4,000%. As anticipated, the rural garage classification lowers the likelihood for copper being above the reuse limit and can be explained by a lower amount of traffic (i.e. exposure to traffic-related metals).

Model two evaluated the likelihood that the total concentration of iron exceeds the reuse limit. There are four parameters of significance which are total chromium, nickel, turbidity and the average number of winter events. The results show as chromium, nickel and turbidity increase so does the likelihood for total iron being above the reuse limit. Like the model for total copper, these results suggest the truck cleanliness (corresponding to turbidity-presence of particulates) could be a factor when sampling. Like TDS, the increase in likelihood for failing to meet the iron due to turbidity could be significant. For example, if the turbidity is 500 NTU, the likelihood for failing to meet the total iron reuse limit increases by 155%.

The third model is developed for total zinc. In this model there are four significant parameters, total copper, iron, average urban lane miles and the rural garage designation. The results suggest as the concentrations of copper and iron increase so does the likelihood that the total zinc will increase. The results also suggest that areas with higher than the average urban lanes miles for all the sample garages are 213%less likely to exceed the total zinc reuse limit.

The final model evaluates the likelihood that the garage will be considered rural. Total iron is the only parameter that increases the likelihood that the garage will be in a rural location. The other parameters, total copper, low turbidity, low pH and average number of winter events all decrease the likelihood for the garage being located in a rural area. The practical

implications of these models will be discussed in our recommendations for implementation of this research.

Table 3-24: Elasticity and pseudo-elasticities for developed models.

Parameter	Model One: Total Copper	Model Two: Total Iron	Model Three: Total Zinc	Model Four: Rural
Total chromium(1)	0.27%	2.56%		
Total copper(1)	--		0.27%	-0.002%
Total iron(1)		--	0.07%	0.30%
Total nickel(1)	0.59%	1.18%		
Total zinc(1)	0.16%		--	
Turbidity(1)		0.31%		
Low turbidity(2)				-90%
Low pH(2)				-121%
Total dissolved solids(1)	0.20%			
Avg. number of winter events(1)		-0.08%		-0.74%
Avg. urban lane miles(2)			-213%	
Trucks per lane mile(1)				-1.74 %
Rural garage location(2)	-74 %		46%	--
Note: (1) Elasticity values (2) Pseudo-elasticity values				

CHAPTER IV

WASH WATER TREATMENT ASSESSMENT

4.1. Introduction

Based on the results of the initial round of wash water quality analysis conducted during the winter season of 2011-2012, it was probable that several heavy metal (i.e. copper and zinc) constituents in wash water could exceed the applicable water quality limits for reusing wash water as brine. To assess the possibility of using a filtration system to reduce heavy metals concentrations to levels acceptable for reuse, bench and pilot scale studies were conducted during winter 2011-2012 and winter 2012-2013. Four types of filter media, all commercially-available were initially assessed to determine their ability to reduce heavy metals concentrations and to identify those that best remove the previously determined heavy metals that exceed water quality limits – Cu and Zn. During the initial assessment, two types of bench scale experiments were conducted: batch and column. One batch study was conducted with all four types of media and two column studies were performed to confirm the findings from batch experiments. For these bench scale tests, metals were analyzed in their dissolved form by ICP-OES. Based on the results of the bench scale tests, the top performing filtration media was selected for use in a full scale pilot study conducted during the winter 2012-2013.

4.2. Bench and Small Column Results

Batch Experiments

Batch experiments were performed to assess four different filter media. Experiments were performed in 65 ml amber glass bottles containing 50 ml of actual wash water taken from Summit County Location 1 in February 2012 along with 300 mg of media. Each bottle was shaken and then left to rest for three hours. After this time, the samples were shaken again and

filtered through a 0.45 µm syringe filter. Analysis focused on the two main group A metals – Cu and Zn.

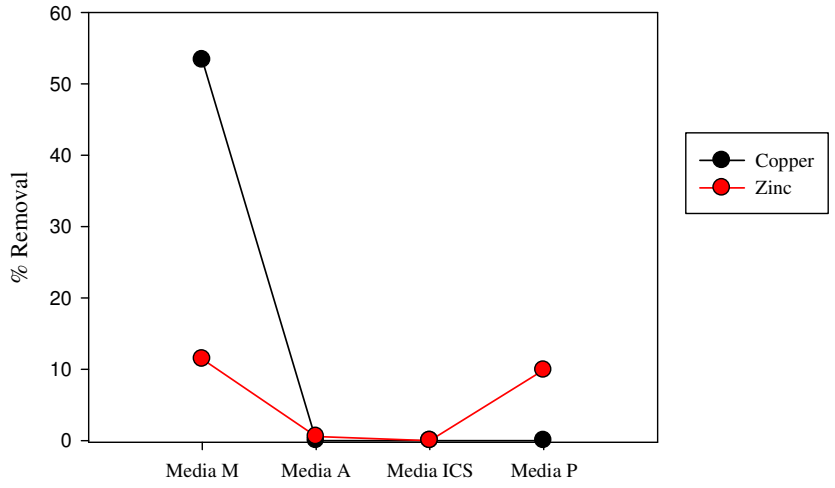


Figure 4-1: Results from batch experiment conducted to assess removal of Cu and Zn from actual ODOT truck wash water from Summit County Location 1 taken in February 2012 (6 g/L, t = 3 hours, Co for Cu = 219 ppb, Co for Zn = 866 ppb).

Figure 4-1 shows the batch experiment results. Media M removed about 50% of Cu and 10% of Zn. Media A and ICS did not remove either metal. Media P removed about 10% of Zn.

Column Experiments

The removal efficiency of three media types on Cu and Zn was also investigated using fixed bed glass columns. Actual wash water from Summit County Location 1 taken in February 2012 was pumped upward into each column. The solution flow rate was monitored using a peristaltic pump. Column dimensions were 29 cm in height by 1 cm in diameter. Bed height and flow rate were held constant at 27 cm and 2 ml/min, respectively. Samples of column effluent were taken at 2.5, 5, 22.5, and 25 hours. Analysis focused on the two main group A metals – Cu and Zn.

Results for the column experiments are shown in Figures 4-2 and 4-3. At 2.5 hours, Media P removes about 70% of Copper and 50% of Zinc. This removal decreases to close to 0%

at 25 hours. No significant removal was found for Media A and Media ICS. Further evaluation may be needed for media P.

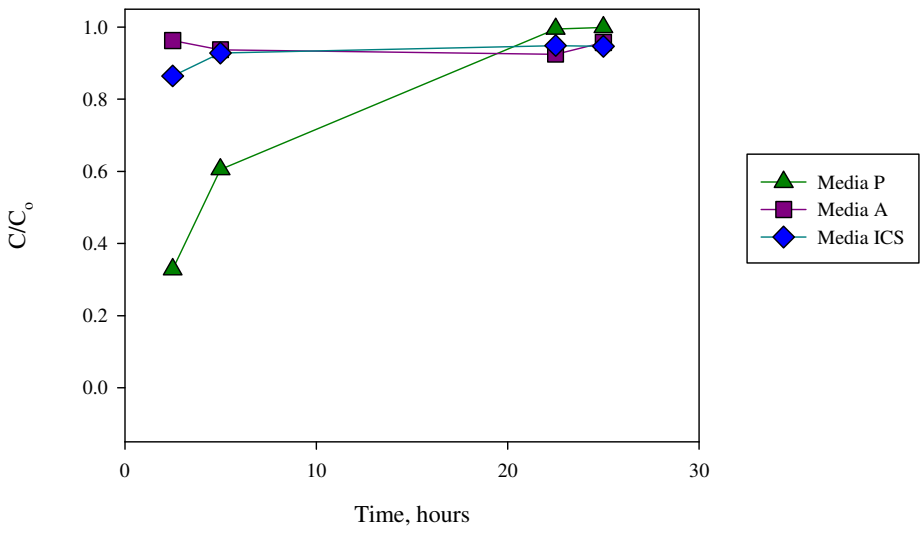


Figure 4-2: Column experiments to assess removal of Cu from actual ODOT truck wash water from Summit County Location 1 taken in February 2012 (I.D. x L: 1 cm x 29 cm, flow rate = 2 ml/min, t = 25 hours, C_o = 700 ppb).

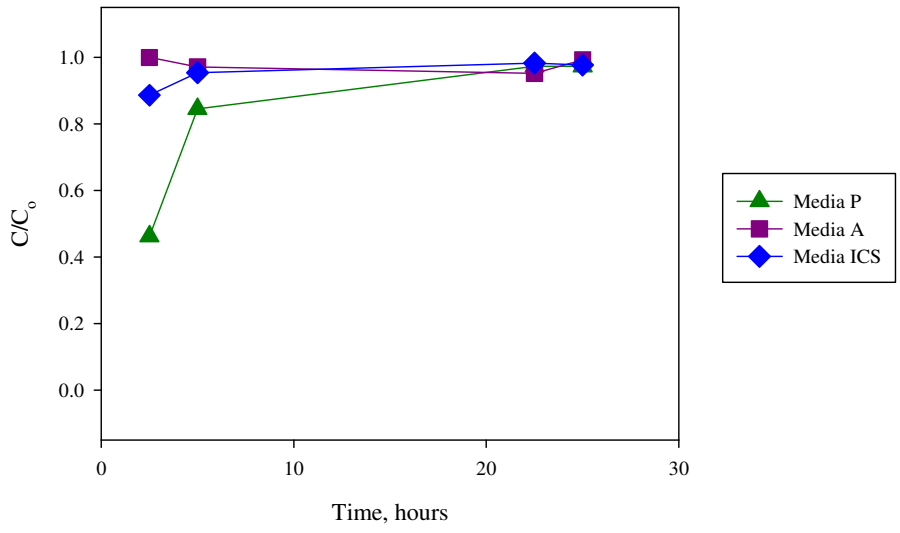


Figure 4-3: Column experiments to assess removal of Zn from actual ODOT truck wash water from Summit County Location 1 taken in February 2012 (I.D. x L: 1 cm x 29 cm, flow rate = 2 ml/min, t = 25 hours, C_o = 643 ppb).

As the batch results showed Media M to have the greatest heavy metal removal, a "larger" column experiment was run for Media M. The same water used in the other column experiments was used for this experiment. However, this experiment used a much larger column measuring 88 cm in height by 2.5 cm in diameter. Flow rate was approximately 20 ml/min and bed height was held constant. Samples of column effluent were taken every hour for 7 hours. Since Media M showed the best batch results, this column experiment focused on all five group A metals.

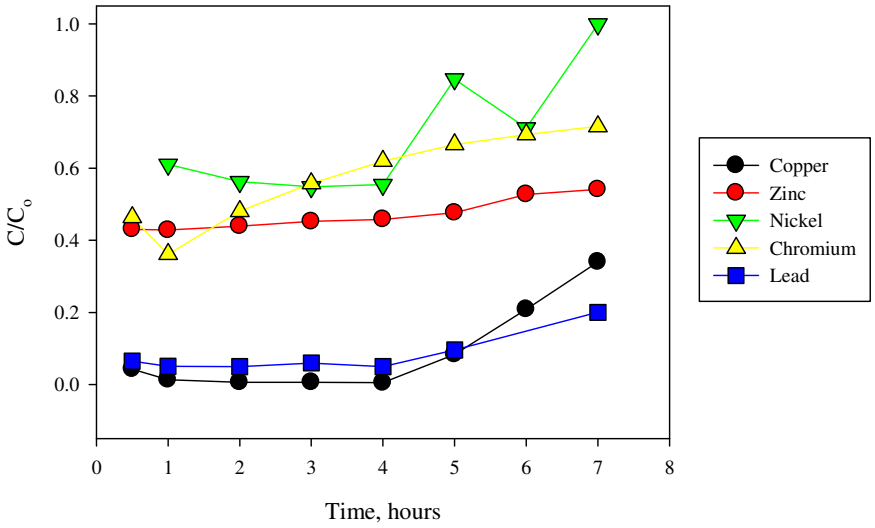


Figure 4-4: Results from column experiment conducted to assess removal by Media M of group A metals from actual ODOT truck wash water from Summit County Location 1 taken in February 2012 (I.D. x L: 2.5 cm x 88 cm, flow rate = 20 ml/min, t = 7 hours, C_o for Cu = 1,550 ppb, C_o for Zn = 1,749 ppb, C_o for Ni = 293 ppb, C_o for Cr = 142 ppb, C_o for Pb = 212 ppb).

Figure 4-4 shows significant removal for Cu and Pb. Media M removes close to 100% for these two metals from hours 0.5 - 4. Removal for the remaining three metals varies between 40-60%.

For Cu and Zn removal, Media M performs very well. Batch results and column results show that this media removes both metals. Media P showed some removal in the batch and column experiments, but overall removal diminishes with time. Discussion with the manufacturers of Media A revealed that Media A must be pre-wet with ethanol for optimum removal efficiency and additional experiments after re-wetting may show better results. As a result of these bench scale studies, Media M was selected for use in a full scale pilot study.

4.3. Pilot Unit Results

The pilot system was purchased through Mar Systems, Incorporated, the M media manufacturer. It was delivered to the University of Akron on January 17th, 2013. The pilot unit contains two 300 gallon vessels for media, each with 225 pounds of gravel and 1,091 pounds of Mar Sorbster media (previously called M media); the media uses a patented, proprietary process to remove metal contaminants from wash water. The media is shown in Figure 4-5 in a barrel prior to being placed in the system. The media was dry loaded into the vessels, backwashed and then put into service. A key operational parameter for the pilot unit was the continuous flow operation, ideally run at 10 gallons per minute; this provides 15 minutes of contact time per vessel, totaling the available contact time for the wash water to be 30 minutes. Figure 4-6 shows the pilot unit in place at The University of Akron. There are two vessels that contain the media in the center with 5 µm filters on the influent pipe to help reduce the amount of suspended solids in the wash water. The effluent (i.e. right hand side of the system) has the option to contain 1 µm filters. According to the manufacturer, the Sorbster media performs across a broad temperature range, typically 32 – 150 degrees Fahrenheit and water with a pH of < 3 should be adjusted to > 3 before pumping it through the pilot unit. In between runs, the media was and should be left in a moist state in order to maintain the reactivity of the media and optimum operation of the pilot unit system.

Figure 4-5: The MAR Systems Sorbster Media before being placed in the pilot unit.

Figure 4-6: A photograph of the pilot unit with the sampling locations identified.

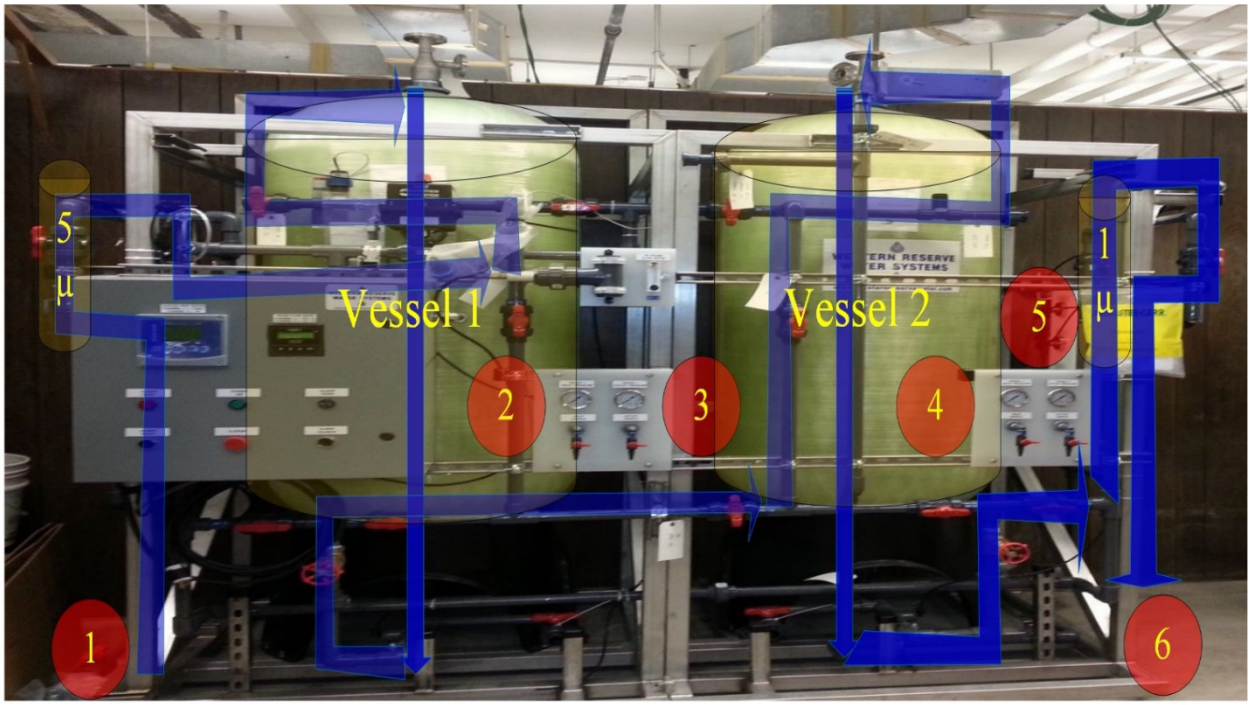


Figure 4-7: Direction of water flow (blue arrows) through the pilot unit with the sampling points labeled. The 1µm filter located at the right of the figure (between points 5 and 6) was not attached for the second and third Stark County pilot unit trials.

Numbering was used in order to identify and track locations for each sample. Samples that were taken at sample port 1, prior to treatment, were regarded as the "initial sample." Based on the size of each vessel, a 10 gallon per minute (GPM) flow rate corresponds to a 15 minute empty bed contact time for the wash water. Since there are two vessels, the total available contact time is 30 minutes at 10 GPM. Figure 4-7 illustrates the flow path of wash water as it is treated by the pilot unit; the illustrated path is a down flow configuration. The pilot unit can be operated in either the up flow or down flow configuration.

Approximately 3,000 gallons of wash water was collected and treated through the pilot unit from the Stark County garage on (Canton, OH). This is garage is located in District 4 as shown in Figure C-4. The wash water was collected from the oil/water separator and pumped using a sump pump into a swap truck. This is shown in Figure 4-8 and Figure 4-9. The wash water was pulled above the sludge at the bottom of the tank, but below the oil layer. It was then brought to The University of Akron loading dock and pumped directly off the truck into the pilot unit. It was pumped out of the bottom of the hopper as shown in Figure 4-9. Figure 4-10 shows

the water being pumped in from the truck, through the recirculation loop, and into the pilot unit inlet. Figure 4-11 shows the reading of approximately 10 GPM through both vessels.

Figure 4-8: Water was collected from the Stark County garage from the oil water separator. Careful placement of the sump pump was needed to avoid the oil/grease at the top and the sediment at the bottom.

Figure 4-9: Stark County ODOT truck connected to the inlet of the pilot unit during pilot unit run 2. (Note: Refer to Table 4-3 for pilot unit run 2 experimental details.)

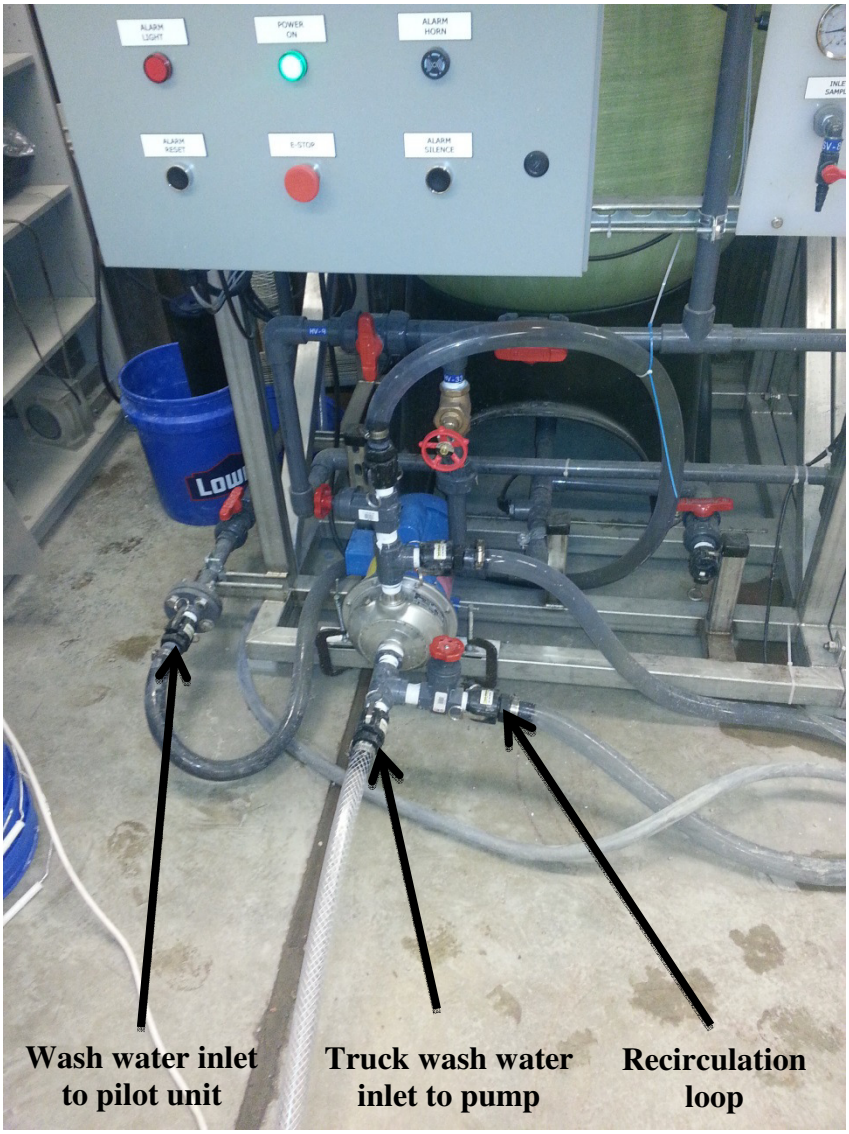


Figure 4-10: Wash water was pumped from the truck using a centrifugal pump at approximately 10 GPM. The water was then pumped into the pilot unit.

Figure 4-11: Flow rate and pH readings at minute 20 of pilot unit run 2 (Stark County run 1). Note: Refer to Table 4-3 and Table 4-4 for details of pilot unit run 2.

Since the four pilot unit experiments were conducted using water drawn from the Stark County garage oil/ water separator, a three hour study was also conducted at the Stark County garage on April 3, 2013. The purpose of the study was to assess the metal and non-metal variability of the garage oil-water separator effluent wash water quality. Table 4-1 shows the results of the study.

Table 4-1: Results from the 3-hour study that was conducted at the Stark County garage on April 3, 2013. All samples below the detection limit have been identified with the less than sign and the detection limit. For the computation of the average, standard deviation, and median, all values below the detection limit were replaced with half the detection limit. Arsenic, cobalt, and selenium values are not shown below because more than half of the samples were below the detection limit. All units are µg/L (ppb).

Time	Al	B	Be	Cd	Cr	Cu	Fe	Li	Mn	Mo	Ni	Pb	V	Zn
7:00	4463	206	0.3	1	79	100	16828	13	1283	15	59	45	13	929
7:15	4106	170	0.4	1	132	93	19733	10	1185	14	69	44	14	1095
7:30	4940	182	0.5	3	158	324	23329	13	1366	15	112	140	16	2278
7:45	3322	168	0.3	1	145	111	17741	14	1056	12	57	33	11	1579
8:00	3114	175	0.3	2	152	142	21929	6	944	10	63	60	11	2105
8:15	546	134	<0.1	1	22	57	3752	6	288	7	28	<21	<1	423
8:30	2768	181	0.2	1	103	120	18571	11	711	11	54	42	10	913
8:45	2058	169	0.2	<0.9	70	108	12740	12	529	9	45	32	5	460
9:00	4723	205	0.3	2	125	269	26345	5	863	11	64	62	14	756
9:15	3784	185	0.3	2	106	257	18805	11	886	11	68	76	10	591
9:30	3418	201	0.2	2	118	179	27431	11	861	10	65	41	10	699
9:45	2749	190	0.2	1	90	136	18547	10	667	8	62	30	8	771
10:00	1358	178	0.1	<0.9	41	64	8667	9	400	6	37	<21	4	307
Average ± Std. Dev.	3181 ± 1250	180 ± 18	0.2 ± 0.1	1 ± 1	103 ± 40	151 ± 80	18032 ± 6360	10 ± 3	849 ± 315	11 ± 3	60 ± 19	48 ± 32	10 ± 4	993 ± 600
Median	3322	181	0.3	1	106	120	18571	11	863	11	62	42	10	771

Four experiments were conducted on the MAR system Sorbster media pilot unit (Table 4-2). The first of the experiments was a 140 gallon wash water volume treated on March 7, 2013; for this run 70 gallons of Stark county garage oil/water separator water was used in combination with 70 gallons of tap water from the University of Akron laboratory. Only the dissolved metals were analyzed through ICP analysis; this run was considered as a test run in order to get the pilot unit running at the right flow capacity. The second pilot run was conducted on March 13, 2013; the volume of wash water treated was 860 gallons which was sourced from the Stark County garage oil/water separator. The third pilot unit run was conducted on April 2, 2013; for this run, 1.92g of $CuSO_4.5H_2O$, 2.03g of ZnO and 3.99g of $PbCO_3$ were spiked into 700 gallons of Stark County garage oil/water separator water. The fourth and final pilot unit run was conducted on April 3, 2013; 1.82g of $CuSO_4.5H_2O$, 3.348g of ZnO and 3.98g of $PbCO_3$ were spiked into 1100 gallons of Stark County garage oil/water separator water. Table 4-2 and Table 4-3 summarize the above described experiment. The emphasis of the spiked experiments were to elevate the

concentration of the target metals Cu, Zn and Pb in order to assess the effectiveness of metal removal by the MAR system Sorbster media. The preceding three pilot unit runs were tested through ICP-OES analysis for both dissolved and total metal content.

Table 4-2: Summary details for each pilot unit experiment. Spiked pilot unit trials occurred when University of Akron personnel increased the metal concentration by spiking Stark County wash water by adding soluble metal compounds prior to transportation to the laboratory. (Note: The 140 gallon trial used 70 gallons of Stark County garage water and 70 gallons of tap water from the University of Akron laboratory.)

Pilot Unit Trial	Title	Date	Total Volume of Water (Gallons)	Source Water	1 µ Filter before the outlet?	Spiked?
1	140 gallon	3/7/13	140	Stark County garage and tap	Yes	No
2	Stark 1	3/13/13	860	Stark County garage	Yes	No
3	Stark 2	4/2/13	700	Stark County garage	No	Yes
4	Stark 3	4/3/13	1100	Stark County garage	No	Yes

Table 4-3: Summary of the spiked pilot unit trials and expected increase to metal concentrations. These samples were not spiked with iron.

		CuSO4.5H2O		ZnO		$PbCO_3$	
Pilot Run	Volume (gallons)	Mass (g)	Theo. Added Cu Conc. (µg/L)	Mass (g)	Theo. Added Zn Conc. (µg/L)	Mass (g)	Theo. Added Pb Conc. (µg/L)
3	700	1.923	699	2.03	2330	3.99	4419
4	1100	1.817	420	3.348	2445	3.98	2805

As illustrated earlier in Figure 4-7, 5 µm filters were installed immediately after the inlet of the pilot unit in order to reduce the amount of suspended solids in the wash water. Two types of filters were used during the pilot runs, namely a “pool like” filter as well as a string wound filter. Characteristic during the pilot unit runs was the constant clogging of the 5 µm filters, with the string wound filter proving slightly less prone to clogging. During the pilot unit run on March 13, 2013 the filter was changed to a “pool like” filter after 15 minutes, changed once more to a string wound filter after 41 minutes and changed for a third time to the same washed

“pool like” filter. An illustration of the used filter is shown in Figure 4-12 with the washed version of the same filter shown in Figure 4-13. This characteristic clogging of the filters due to suspended solids greater than 5 µm led to the introduction of a 5 µm bag attached to the hose from the truck in order to reduce the amount of suspended solids that entered the pilot unit system. Clogged filters resulted in a drop of the flow rate below the recommended 10GPM. In order to increases removal efficiency and reduce the cost of filter replacement, the idea that the majority of the clogging could be remedied by allowing the wash water to sit for an optimal amount of time in order to allow settling of suspended solids in the wash water was investigated and discussed later in this chapter.

Figure 4-12: Photograph of impaired 5 µm filter.

Figure 4-13: Photograph of cleaned 5µm filter.

As mentioned previously, the MAR Systems Sorbster unit was tested on four occasions. However, the analysis of metal concentrations for the first test, the 140 gallon test, was only performed for the dissolved species, not total metal concentration. An unexpected outcome of the pilot unit testing was a very low ratio of dissolved to total metals within the wash water. In many instances, dissolved concentrations were not detected at all. Because of the problematic number of non-detects in the 140 gallon trial, the results for that pilot unit run are not included in Table 4-4 and excluded from all discussion in this section. The raw data from that trial can be reviewed in Table D-1 of Appendix D.

The remaining three trials, Stark 1, Stark 2, and Stark 3, evaluated both dissolved and total metal concentrations. The results from these pilot unit runs are summarized in Table 4-4. The concentrations listed in the table are the average concentrations measured at that sampling point during the experiment. Some values are based off of a single observation, such as influent values, while others include as many as eight observations. The raw data for Stark 1, 2, and 3 pilot unit runs can be found in Tables D-2 thru D-7 of Appendix D. In general and as expected, a

noticeable decrease in average total metal concentrations occurs as the wash water proceeds through the pilot unit.

Observing a trend in dissolved metal concentrations was not straight forward. For example, the average dissolved zinc concentrations at the end of the Stark 2 and Stark 3 pilot unit runs are 17% and 8% of their influent concentrations, showing excellent removal. However, for the dissolved iron in the Stark 2 trial (110ppb→156ppb→105ppb→288ppb) and dissolved zinc in the Stark 1 trial (28ppb→44ppb→15ppb→36ppb→10ppb) the trend was not consistent. Therefore, because of the numerous non-detections (e.g. ~2/3 of all dissolved copper samples for Stark 1, 2, and 3 were non-detects), all further discussions regarding the removal efficiency of the MAR Systems Sorbster Media will focus on total metal concentration.

Table 4-4: Pilot unit average metal concentrations at each sampling location. All samples below the detection limit were given the value of half the detection limit. Only traffic metals where at least one garage median violated the reuse standard have been included in the table. Experimental raw data can be found in Tables D-1 to D-7 of Appendix D. All units are µg/L (ppb).

		Stark 1		Stark 2		Stark 3	
Location	Metal	Dissolved	Total	Dissolved	Total	Dissolved	Total
Influent	Copper	3	98	2	138	2	118
	Zinc	28	282	88	413	78	345
	Iron	268	4016	110	1334	148	1342
	Lead	5	12	0.7	373	0.7	182
After 5µm Filter	Copper	0.6	31	0.6	98	1	33
	Zinc	44	244	47	360	57	160
	Iron	183	2618	156	1599	230	1228
	Lead	4	6	5	257	3	16
After Vessel 1	Copper	10	12	1	34	0.6	22
	Zinc	15	91	29	142	23	91
	Iron	403	908	105	620	145	632
	Lead	4	4	9	46	3	9
After Vessel 2	Copper	0.6	17	2	36	0.6	23
	Zinc	36	76	15	91	6	65
	Iron	894	1098	288	592	235	545
	Lead	0.7	1	5	16	6	6
After 1µm Filter	Copper	0.6	3	-	-	-	-
	Zinc	10	19	-	-	-	-
	Iron	946	526	-	-	-	-
	Lead	4	2	-	-	-	-

When total metal concentrations are evaluated, a clear and consistent pattern is observed for the three pilot unit runs from the Stark County garage. Figure 4-14 and Figure 4-15 display the cumulative removal of copper and zinc as the wash water passes through each stage in the pilot unit. A similar pattern is found for iron and lead. After passing through the pilot unit, the average of all three Stark County trials for total copper removal is 79%. For total zinc, the average removal is 77%. For total iron, the average removal is 63% and for total lead, the average removal is 94%.

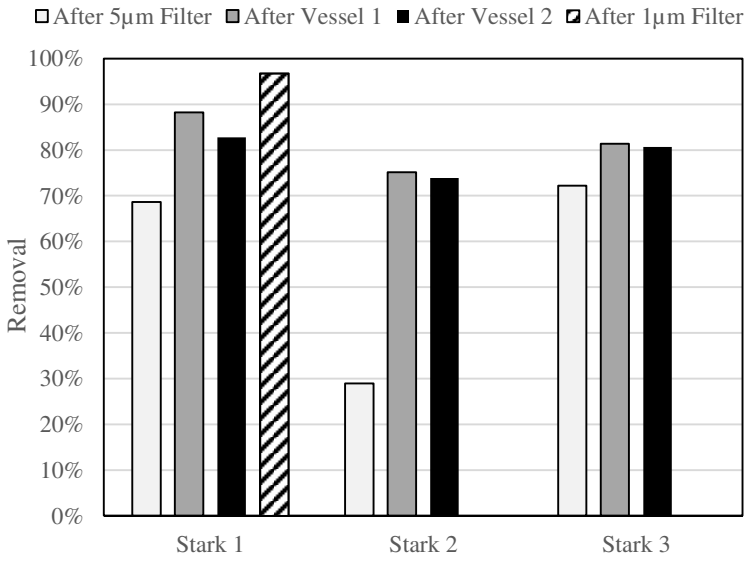


Figure 4-14: Cumulative removal rate of total copper at each stage of the Stark County garage trials. The removal percentage for each location was calculated based on the average concentration across all time periods tested at that location. The second and third trials did not have the optional 1µm filter attached at the end of the unit.

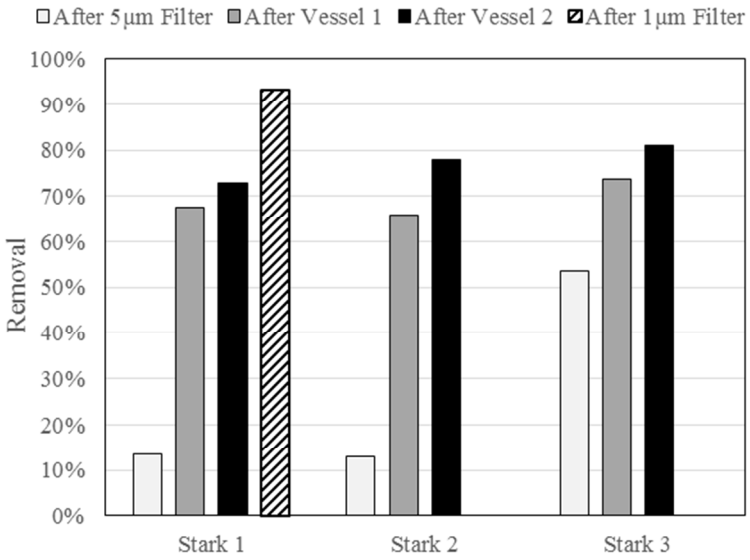


Figure 4-15: Cumulative removal rate of total zinc at each stage of the Stark County garage trials. The removal percentage for each location was calculated based on the average concentration across all time periods tested at that location. The second and third trials did not have the optional 1µm filter attached at the end of the unit.

Applying these removal rates to the garages where the median total metal concentration exceeded the reuse limit-guidelines could result in a significant reduction in the number of these garages. As discussed earlier in this report, 17 of the 24 garages (71%) possessed median total copper concentrations which violated the reuse standard. For zinc, iron, and lead the number of garages are 18 (75%), 2 (8%), and 1 (4%), respectively. The application of the MAR Systems Sorbster Media and its average 79% removal efficiency for total copper would reduce the number of garage exceeding the reuse limit-guideline from 17 to 3. For zinc, iron, and lead, the reductions are also significant: from 18 to 4, from 2 to 0, and 1 to 0, respectively.

Perhaps of greater significance to this study, though, was an observation made after detailed analysis of the pilot unit removal process. A noteworthy portion of the total metal removal is attributed to the 5 µm filter only. Figure 4-16 summarizes the removal of each metal for each of the three Stark County pilot unit runs by the initial 5µm filters. The average removal of total copper, zinc, iron, and lead by just the 5µm filter are 57%, 27%, 8%, and 57%, respectively. When applied to the garage median concentrations, the number of garages exceeding the reuse limits-guidelines (out of 24) would be reduced from 17 to 6 for copper, from 18 to 11 for zinc, and from 1 to 0 for lead. For total iron, the removal by the 5µm filter was not enough to reduce either of the two garage medians to change the outcome. This reduction is not as large as the removal rates found for the entire pilot unit (5µm filter and two vessels of media), but it is important to note the effect of focusing on particles greater than 5µm.

After the 5µm filter, the MAR Systems Sorbster Media is responsible for an appreciable removal of the remaining total metals within the wash water. As exhibited in Figure 4-17, the media within vessels 1 and 2 remove between 30% and 94% of metal particles less than 5µm depending on the pilot unit run and the type of metal. For copper, an average removal of 46% is found for particles less than 5µm. For zinc, the removal percentage is even better at 68%. For iron and lead, the removal percentages are 59% and 79%, respectively. It should also be noted in Figure 4-14 and Figure 4-15 as well as the Tables 3, 5, and 7 in Appendix D, most of that removal is occurring in vessel 1.

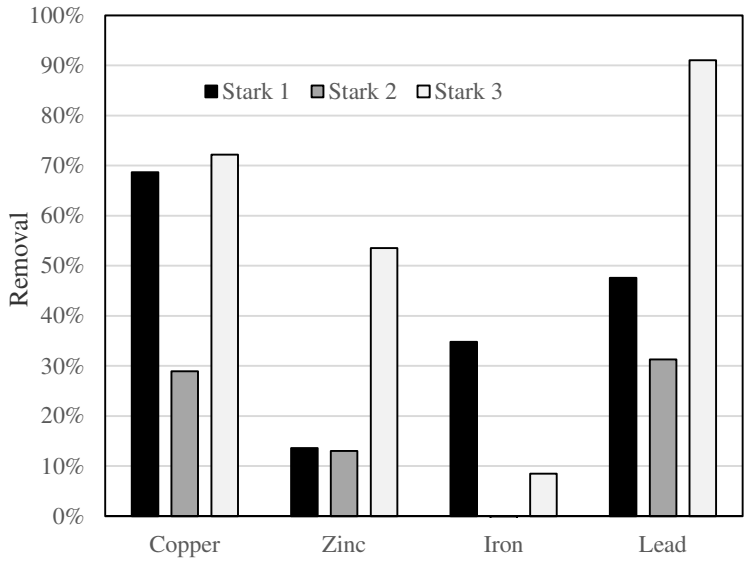


Figure 4-16: Total metal removal due to the 5µm filter. Removal percentage was calculated based on the average concentration after the 5µm filter across all time periods.

In order to further understand the constituent portion of particulate matter (> 5µm) in the total metal concentration an additional experiment was conducted on six samples from different ODOT garages. These garages included Stark County, Allen County, Fairfield County, Guernsey County and Cuyahoga County garages. Referring to Table 3-8 for garage I.D and Table 3-16 for average metal concentrations, these garages were chosen because of their high average metal concentrations. Samples from these garages were taken; 4 and 5 µm paper filters were used to separate the samples into these aforementioned size fractions. The result of which were three different samples per garage; total metal, below five µm and below 4 µm. Analysis of these samples for all six garages was conducted through ICP-OES analysis for a total of 18 samples.

Table 4-5 summarizes the percentage total metal removal by 4 µm and 5 µm filters. For copper, the average removal by the 4 µm filter was 81% while that of the 5 µm filter was 82%. For zinc, the average removal by the 4 µm filter was 64% while that of the 5 µm filter was 60%. For iron, the average removal by the 4 µm filter was 89% while that of the 5 µm filter was 87%. For lead, the average removal by the 4 µm filter was 76% while that of the 5 µm filter was 76%. This indicates that there is a significant portion of the total metal concentration present in the particulate form. Looking at the 5 and 4 µm sizes overall average total metal removal also

indicates that there is not much difference in total metal removal between the two size fractions. Using this, along with the clogging of filters due to suspended solids, the merit of allowing the wash water to settle in order to allow for removal of colloidal metals becomes a viable and efficient option to reduce total metal concentrations. Theoretical settling calculations and their results using Stoke's Law are shown next.

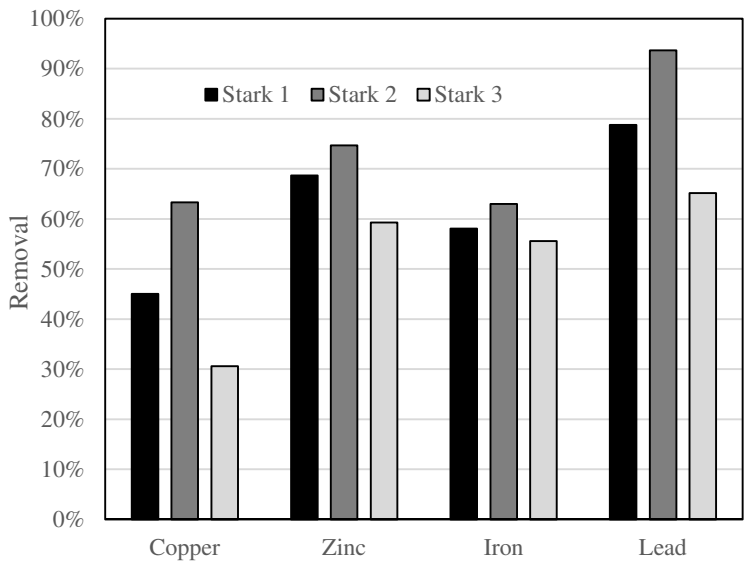


Figure 4-17: Percent removal of total metals performed MAR media on all metals less than 5µm in diameter. Removal percentage was calculated based on the average concentration after vessel 2 for all time periods and the average concentration after the 5µm filter for all time periods.

Table 4-5: Percent total metal removal by a 4µm and 5µm filter for each of the six wash-water samples. Raw data for this calculation can be found in Table D-8 of Appendix D.

	County	Copper		Zinc		Iron		Lead	
Sample	Garage	>5µm	>4µm	>5µm	>4µm	>5µm	>4µm	>5µm	>4µm
1CB	Allen	98	99	82	86	94	95	96	98
7CB	Stark	98	98	93	95	99	100	96	95
7CE	Stark	82	73	72	84	98	99	93	64
9CE	Fairfield	40	46	25	28	87	96	93	87
11DB	Guernsey	99	99	81	82	99	99	99	99
25AE	Cuyahoga	72	73	9	10	44	43	11	17
Six Sample Average		82	81	60	64	87	89	81	76

Settling calculations were conducted for various sized particles of the metals Cu, Zn, Pb and Fe. These metals were chosen because they represented the problematic metals that for one or more instances violated the reuse standards for the ODOT garages. Equation 4-1, Stokes law, was used to calculate the settling velocity for the above stated metals. The acceleration due to gravity was assumed to be 9.81 m/s^2, the diameter of the particles ranged from 1 µm to 5 µm in 1 µm increments. The density for copper was 8960 kg/m^3, for zinc was 7140 kg/m^3, for lead was 11340 kg/m^3 and that of iron was 7874 kg/m^3; the density of water was 1000kg/m3. It was assumed that since the settling tank would be housed indoors the temperature during the settling process would be 40 degrees Fahrenheit; therefore the dynamic viscosity was assumed to be 0.001519kg/m-s.

Equation 4-1: Stokes Law

$$V_s = \frac{g d^2 (\rho_p - \rho_m)}{18\mu}$$

Where:

V_s = settling velocity

g = acceleration due to gravity

d = diameter of particle

ρ_p = density of particle

ρ_m = density of medium

µ = dynamic viscosity

The size fraction raw data analysis can be referenced in Table D-8 of Appendix D.

The settling of copper is shown in Figure 4-18. The size fractions analyzed were 1 – 5 µm; the settling times for 1 µm size fraction ranged from 97.3 hours to 486.3 hours with the depth increasing from 1 m to 5 m, whereas the settling times for the 5 µm size ranged from 3.9 hours to 19.5 hours with the depth increasing from 1 m to 5 m. Figure 4-19 illustrates the settling times for zinc, lead and iron of particle sizes 1 µm and 5 µm; the settling times were varied by depth. For the 1 µm size fraction of zinc, the settling times ranged from 126.1 hours to 630.5

hours as the depth increased from 1m to 5m; for the 5 µm size fraction of zinc, the settling times ranged from 5.0 hours to 25.2 hours as the depth increased from 1m to 5m. The 1 µm size fraction of lead had settling times that varied from 74.9 hours to 374.4 hours as the depth increased from 1m to 5m; the 5 µm size fraction of lead varied from 3.0 hours to 15.0 hours as the depth increased from 1m to 5m. The 1 µm size fraction of iron had settling times that varied from 112.6 hours to 563.1 hours as the depth increased from 1 m to 5 m; the 5 µm size fraction of iron varied from 4.5 hours to 22.5 hours as the depth increased from 1m to 5m. Table 4-6 shows the settling times for copper and zinc for depths of 2 m and 3 m for the size fractions 3 µm and 5 µm. These depths are realistic to the oil water separator and the settling times are manageable with the day to day operations of the garage.

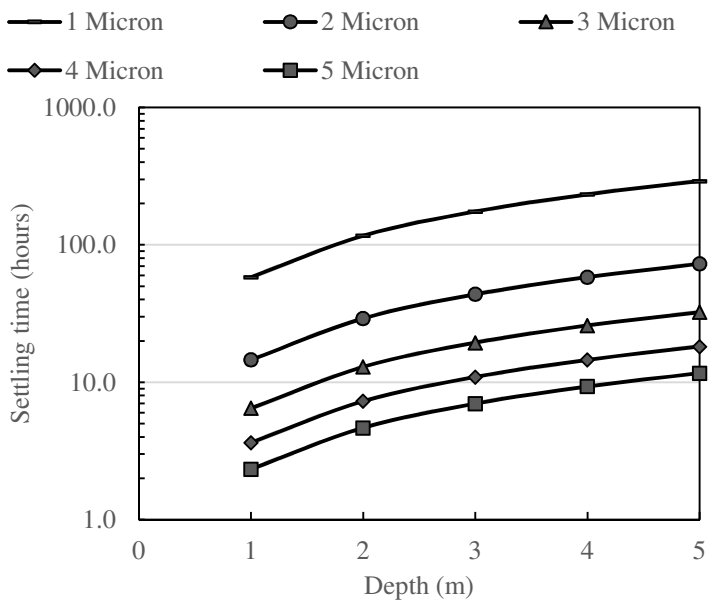


Figure 4-18: Theoretical settling times for copper particles based on Stoke's Law. The assumed dynamic viscosity of water for the equation is 0.001519kg/m-s (40°F). The settling times vary by depth with the different size fraction.

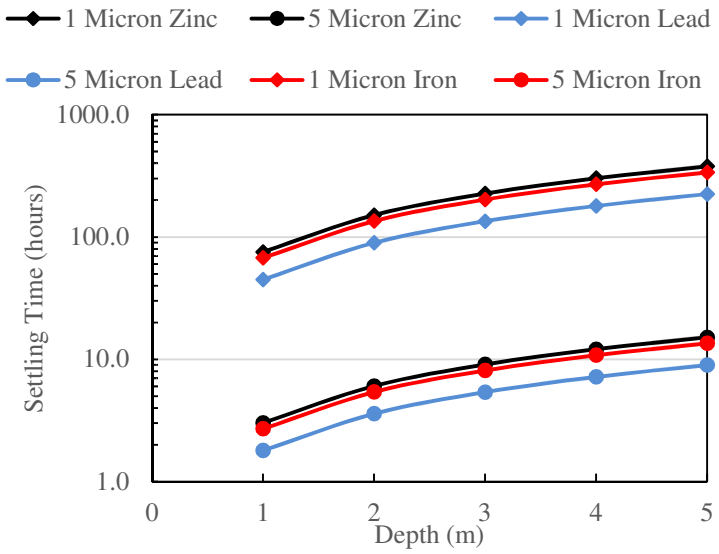


Figure 4-19: Theoretical settling time for zinc, iron, and lead particles based on Stoke's Law. The assumed dynamic viscosity of water for the equation is 0.001519kg/m-s (40°F). The settling times vary by depth, size, and material.

Table 4-6: Summary of theoretical settling times for the significant particle sizes of copper and zinc as a function of depth (i.e. holding tank depth). Times are computed using Stokes Law and assume the dynamic viscosity of water to be 0.001519kg/m-s (40°F). Settling times are in hours.

	5 µm		3 µm	
Metal	2m	3m	2m	3m
Copper	7.8	11.7	21.6	32.4
Zinc	10.1	15.1	28.0	42.0

CHAPTER V

WASH WATER MANAGEMENT TOOL AND COST ANALYSIS

5.1. Introduction

The final component in the detailed analysis of alternative wash water management strategies was to conduct a cost analysis and develop a cost analysis tool that could be used by managers to assess costs based on site specific conditions at individual locations. Each of the six management alternatives identified in Figure 2-9 was included in the cost analysis.

5.2. Annual Cash Flow Analysis

The cost analysis was carried out as an annual cash flow analysis. Annual cash flow analysis is a cost analysis technique that converts costs and/or benefits to a series of uniform annual payments over the expected life of the project, accounting for the time value of money (Newnan, et al., 2009). The equivalent uniform annual cost (EUAC) can be useful when assessing costs as part of an annual operating budget. In this analysis, the EUAC of each of the six management strategies was calculated, and the resulting costs were compared to evaluate the cost effectiveness of various management strategies. Equation 5-1 shows the calculation of the EUAC based on the present value of the capital cost. The total EUAC is the sum of the annual costs and the annualized capital costs (Equation 5-2).

Equation 5-1: Calculation of Equivalent Uniform Annual Costs (EUAC).

$$Annualized\ Capital\ Costs = Capital\ Costs * \left[\frac{i}{((1+i)^n) - 1}\right] + i$$

Where:

i = discount rate

n = number of years

Equation 5-2: Calculation of total annualized costs

$$Annualized\ Costs = Annualized\ Capital\ Costs + Annual\ Costs$$

For the purposes of this analysis, a discount rate of 7% was used (Veneziano, 2010). The value for n was governed by the management option being assessed.

5.3. Preliminary Cost Analysis and Management Tool Development

5.3.1. Determination of Cost Factors

The first step in the cost assessment was to determine values, or processes for calculating values, for the factors contributing to the overall cost of each management alternative. The cost factors identified for each management alternative are shown in Table 5-1 with details below.

Construction

The cost to tie an existing facility into the sanitary sewer line would depend on the distance to an access point. For the purposes of this cost analysis, it was assumed that the capital cost would range between $300,000 and $700,000, based on information provided by ODOT personnel.

Storage

For garages lacking access to sanitary sewer, all of the management options would require that truck wash water be collected on-site using a holding tank system. Based on cost information provided by ODOT District 4, the approximate cost of the installation of an underground storage tank system for the collection of truck wash water is $30,000. This would include a 3,000 gallon fiberglass UST, 500 gallon oil/water separator, and electrical components.

Table 5-1: Identification of the capital and annual operating costs for the truck wash water management strategies included in the cost analysis.

Strategies	Capital	Annual
Sanitary Sewer	Construction	Disposal
Commercial Disposal	Storage	Hauling and Disposal Water Quality Monitoring
Disposal at WWTP	Storage	Hauling Disposal Water Quality Monitoring
Disposal at ODOT Garage with Sewer Access	Storage	Hauling Disposal Water Quality Monitoring
Filtration and Disposal at ODOT Garage with Sewer Access	Storage Filtration Unit	Hauling Disposal Media Replacement Water Quality Monitoring
Filtration and reuse at County Garage	Storage Filtration Unit	Hauling Media Replacement

Filtration

Based on information provided by vendors, the capital cost for a system capable of treating ten gallons per minute would be $30,000 and the annual cost of media replacement would be approximately $4,600. The actual media replacement costs would depend on site specific water quality and quantity and could be determined more accurately through pilot testing.

Disposal

The annual cost of off-site disposal was calculated as the annual volume of wash water generated (Equation 2-1) multiplied by the unit cost for disposal, which would depend on the disposal location: commercial, WWTP, or a nearby ODOT garage with sanitary sewer access. Commercial disposal costs are likely to vary across the state of Ohio and could be as low as $0.08/gallon, or as high as $0.54/gallon, based on estimates provided by independent contractors. Rather than using the best case scenario of $0.08/gallon or the worst case scenario of $0.54/gallon, an average disposal cost of $0.30/gallon was used to calculate commercial disposal costs.

To assess the cost for ODOT to dispose of wash water at a WWTP using ODOT equipment and personnel, a unit disposal rate of $0.05/gallon was used. This is the disposal rate currently paid by the Henry County Garage in ODOT District 2. For disposal at an existing ODOT facility with access to sanitary sewer, a disposal cost of $0.01/gallon was used.

Hauling

Hauling costs depend on the distance to the disposal or reuse location, which varies by maintenance facility. To calculate the hauling costs, the labor cost and fuel costs were calculated separately, based on the distance to the disposal location, and summed. As shown in Equation 5-3, the labor cost was calculated by multiplying an hourly wage of $17/hour by the time of the trip. An additional hour was added to the drive time to account for the time to load and unload the truck (based on reasonable pumping rate). Equation 5-4 shows the calculation of the fuel cost. To calculate the annual number of trips required, which is needed to estimate the total annual hauling cost, it was assumed that a 5,000 gallon tanker truck would be available in each district for hauling wash water. The estimated volume of wash water generated was divided by 5,000 to determine the average annual number of trips. The total annual hauling cost was then calculated as shown in
Equation 5-5.

Equation 5-3: Calculation of labor costs.

$$Labor\ Cost = \$17/hour * (\frac{Distance(miles)}{Average\ Speed\ (mph)} + 1hour)$$

Equation 5-4: Calculation of fuel cost.

$$Fuel\ Cost = \frac{Distance(miles)}{Fuel\ Efficiency\ (mpg)} * fuel\ cost\ (\$/gal)$$

Equation 5-5: Calculation of total annual hauling cost.

$$Total\ Hauling\ Cost = Annual\ Number\ of\ Trips * (Fuel\ Cost + Labor\ Cost)$$

Water Quality Monitoring

It was assumed that water quality monitoring would be required for all of the management options with the exception of tying into the sanitary sewer. The annual cost of wash water quality monitoring was established using information provided by the Henry County Garage in District 2, which has an existing truck wash water quality monitoring program approved by the Ohio EPA. As part of their reuse program, the Henry County Garage is required to monitor for 17 Heavy Metals, phosphorus, cyanide, fluoride, oil and grease, methylene blue active substances (MBAS), pesticides, and herbicides. It is likely that herbicides and pesticides would be monitored on an annual basis, while all other parameters would be monitored quarterly. As shown in Table 5-2, the annual water quality monitoring cost would be $1,385 based on cost estimates provided by TestAmerica (Canton, OH).

Filtration Media

Filtration systems require period media replacement to ensure the equipment is operating efficiently and effectively. Based on information provided by the manufacturer of commercially available filtration media, the annual cost for replacement media would be approximately $4,600. The actual media replacement costs will depend on site specific water quality and quantity and could be determined more accurately by site specific pilot testing. Table 5-3 summarizes the values that were used in the preliminary cost analysis tool.

Table 5-2: Breakdown of laboratory costs for wash water quality monitoring (Pricing from TestAmerica). Costs assume that samples would be analyzed for herbicides and pesticides on an annual basis and all other parameters on a quarterly basis.

Parameter	Cost/Sample	Annual Cost
Metals (excluding lithium)	$120	$480
Lithium	$25	$100
Cyanide	$25	$100
Phosphorus	$30	$120
Oil and Grease	$35	$140
Pesticides	$90	$90
Herbicides	$135	$135
MBAS	$40	$160
Fluoride	$15	$60
Total		**$1,365**

Table 5-3: Cost values used in the assessment of wash water management costs at ODOT maintenance facilities.

Strategies	Capital		Annual	
	Factor	Value	Factor	Value
Sanitary Sewer	Construction	Variable	Disposal	Variable
Commercial Disposal	Storage	$30,000	Hauling and Disposal	$0.30/gal
Disposal at WWTP	Storage	$30,000	Water Quality Monitoring Hauling Disposal	$1,385/yr Variable $0.05/gal
Disposal at ODOT Garage with Sewer Access	Storage	$30,000	Water Quality Monitoring Hauling Disposal	$1,385/yr Variable $0.05/gal
Filtration and Disposal at ODOT Garage with Sewer Access	Storage Filtration Unit	$30,000 $30,000	Water Quality Monitoring Hauling Disposal Media Replacement	$1,385/yr Variable $0.05/gal $4,600/yr
Filtration and reuse at County Garage	Storage Filtration Unit	$30,000 $30,000	Water Quality Monitoring Hauling Media Replacement	$1,385/yr Variable $4,600/yr

5.3.2. Development of Tool for Cost Calculation

Using the values provided in Table 5-3, a preliminary cost analysis tool was developed to calculate the cost of each alternative management option for individual garages. The purpose of this tool was to support individual ODOT districts in the selection of cost effective management strategies. The tool was developed in Microsoft Excel and utilized a combination of user specified information and fixed cost values to calculate the annualized costs of each management strategy. The required user inputs are listed in Table 5-4.

Table 5-4: User inputs for the preliminary cost analysis tool.

Hauling Costs	Sewer Tie In	Construction Cost
Fuel Cost	Existing Storage Volume	Disposal Cost
Distance to nearest garage with sewer	Number of trucks hauling water	
Total distance for disposal at WWTP	Labor Cost	

The tool allowed the user to select garages in their district to include in the cost analysis. After the garages were selected, the user was asked to answer a series of questions about each garage and input site specific information such as the distance to the disposal location, fuel cost, and labor cost. Figure 5-1 depicts the flow of the cost analysis within the tool. After the questions were answered and information was input to the tool, the annualized costs were calculated and displayed on a summary sheet that included the names of the garages and the estimated volume of wash water generated at each garage.

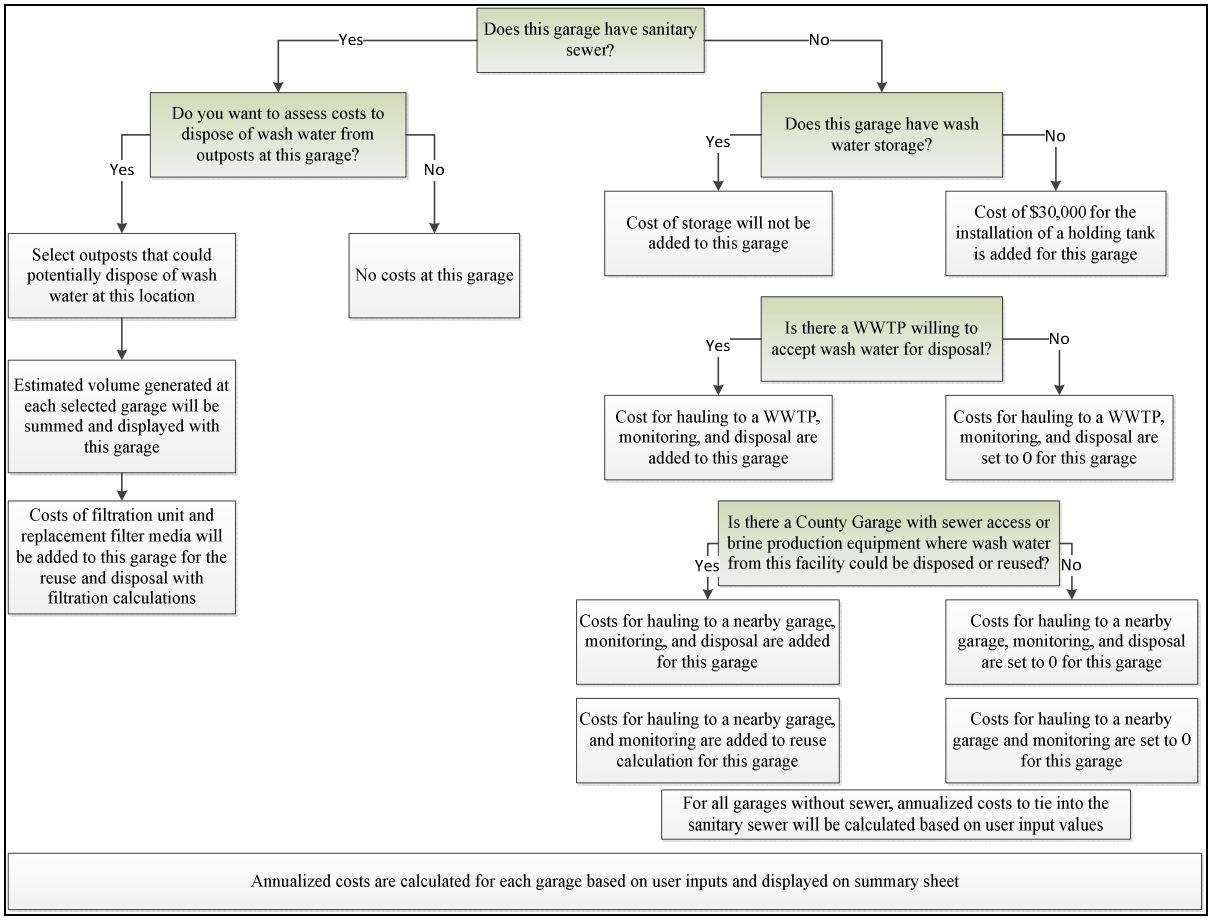


Figure 5-1: Detailed description of the flow of the cost analysis in the preliminary cost analysis tool.

5.3.3. Evaluation of Alternative Management Costs

The preliminary tool was designed to assist in decision making in three different ways:

- By estimating wash water management costs for a single garage;
- By comparing current wash water management costs with the costs of alternative management options; and
- By conducting a district based risk assessment.

Examples of each of these uses are described in detail below.

Single Garage Analysis

To assess wash water management costs at a single (e.g. new garage), 'Single Garage' was chosen from the dropdown menu. For a single garage, the user could input the number of trucks, the annual number of wash cycles, and the volume of wash water generated per truck per wash cycle. The tool calculated the estimated annual volume based on these numbers and allowed the user to enter the site specific information in the same manner as for existing garages. Table 5-5 shows the results of a cost analysis for a hypothetical new garage with 12 trucks. The analysis assumed that the annual number of wash cycles was 33 and the volume of wash water generated per truck was 300 gallons. The cost to tie into the sanitary sewer was estimated at $700,000, and the cost for holding tank at $30,000. As shown in Table 5-5, the annual cost to tie into the sanitary sewer would be $53,694 annually over 40 years, while the annual cost for disposal at a nearby county garage would be approximately $13,512 over 12 years. A step-by-step example the cost calculation is provided in Appendix E.

Table 5-5: Results of cost analysis for a new garage with 12 trucks and an estimated 300 gallons of wash water per truck per wash cycle. Option 1 assumes a tie in cost of $700,000 and a 40 year lifetime; Option 2 and 3 are calculated over a 12 year period. Estimated annual volume of wash water was 118,000 gallons.

	Management Strategy					
Garage	Tie Into Sanitary Sewer	Commercial Facility	WWTP	County Garage with Sewer	Filtration and Disposal	Filtration and Reuse
Single Garage	53,694	40,802	14,557	13,512	13,513	7,573
County Garage with Sewer					8,377	8,377
Total Annual Cost	**53,694**	**40,802**	**14,557**	**13,512**	**21,890**	**15,950**

District 4: Comparing current costs with alternative costs

In District 4, during the winter 2010-2011 season, four outpost garages used holding tanks to collect wash water and then disposed of it using a contractor at an average cost of $0.51/gallon. Using the cost analysis tool, the annual costs of alternative management options were assessed for these four locations. Because these locations already have storage available, capital costs for disposal without filtration were not added to these garages. To assess the cost of disposal or reuse at a nearby county garage, it was assumed that each outpost would dispose of the wash water at the county garage in its county. It was also assumed that a tanker truck would be available at the county garage and that the total distance would be the round trip distance from the county garage to the outpost. Distances were obtained from Google Maps using the addresses of the garages, which are provided in Table 5-6.

Table 5-6: Addresses used to determine distances to potential disposal locations for the cost analysis.

County	Facility Name	Address
Ashtabula County	Ashtabula County Garage	492 Seven Hills Rd, Ashtabula, Ohio
	Dorset Outpost	2325 SR 193, Dorset, Ohio
	Rome Outpost	5451 SR 45, Rome, Ohio
	Ashtabula County WPCP	303 Woodland Avenue, Ashtabula, Ohio
Portage County	Portage County Garage	701 Suite A Oakwood Street, Ravenna, Ohio
	Drakesburg Outpost	9068 SR 88, Windham, Ohio
	Struthers WWTP	530 Lowellville Road, Struthers, Ohio
Trumbull County	Trumbull County Garage	310 Second Street, Cortland, Ohio
	Brookfield Outpost	1590 Brookfield Road, Hubbard, Ohio
	Gustavus Outpost	2979 Kinsman Road, North Bloomfield, Ohio
	Struthers WWTP	530 Lowellville Road, Struthers, Ohio

A second disposal option assessed by the cost analysis tool was disposal at a county garage after media filtration. Again, it was assumed that each outpost would haul wash water to the county garage in its county. The added costs of the filtration unit and annual media replacement were assigned to the three county garages that would be accepting wash water under this scenario.

The option of filtration and reuse at a county garage also assumed that wash water would be hauled to the county garage in the same county as the outpost. Hauling and monitoring costs were assigned to the outpost, while filtration and media replacement costs were assigned to the county garage.

To evaluate the costs for disposal at a WWTP, two non-domestic septage receiving WWTP were identified: Ashtabula County Water Pollution Control Plant (WPCP) and the Struthers WWTP. Based on location, it was assumed that the garages in Ashtabula County would dispose of wash water at the Ashtabula County WPCP, while the garages in Portage and Trumbull County would dispose of wash water at the Struthers WWTP. It was also assumed that the total distance traveled would be the sum of the distances from the county garage to the outpost, the outpost to the WWTP plus the distance to the WWTP, and the WWTP back to the county garage. Again, distances were obtained from Google Maps. Addresses are shown in Table 5-6.

Because the actual volume of wash water generated at these four outpost garages during winter 2010-2011 was known, the volume estimation parameters of the cost analysis tool were modified so that the estimated volume matched the actual volume. This provided a more accurate cost assessment because disposal costs are heavily influenced by volume. For this analysis, it was assumed that 10% of winter events had more than one wash cycle. Using the calculated number of wash cycles, the number of trucks at each outpost, and the actual volume of wash water generated at each location, the volume of wash water generated per truck per wash cycle was calculated and input to the tool. The resulting cost analysis is based on the actual reported volumes of wash water at each outpost. Table 5-7 shows the values used for the volume calculations in this example.

Table 5-7: Use of the preliminary cost analysis tool to obtain accurate volume estimates for four outpost garages in District 4. The actual volumes were used to adjust the volume of wash water generated per truck per wash cycle. This analysis assumed 10% of events have more than one wash cycle. All volumes reported in gallons.

Facility	No. Trucks	Annual Wash Cycles	Vol/Truck/ event	Annual Est. Volume	Actual Vol
Dorset Outpost	4	70.4	106.5	29,990	30,000
Rome Outpost	4	70.4	108.3	30,497	30,500
Drakesburg Outpost	5	52.8	139.2	36,749	36,750
Brookfield Outpost	7	53.9	51.68	19,499	19,500

Cost calculations were carried out over 12 years for all options except tying into sanitary sewer, which was carried out over 40 years. Using the output from the cost analysis tool, the estimated costs for the alternative management options were compared with the current wash water management costs in District 4. As shown in Table 5-8, the estimated annual cost to dispose of truck wash water generated at these outpost garages at a nearby county garage would be $12,738. The actual cost for wash water management at these locations during winter 2010-2011 was $59,928.

Table 5-8: Comparison of the actual annual current management costs with estimated annual management costs for alternative strategies. Actual costs and volumes were reported by District 4 personnel for winter 2011. Option 1 assumes an average tie in cost of $300,000 over a 40 year lifetime; Options 2 and 3 are calculated over a 12 year time period.

	Actual	Estimated					
Garage Name	Commercial Disposal	Tie Into Sanitary Sewer	Commercial Disposal	WWTP	County Garage with Sewer	Filtration and Disposal	Filtration and Reuse
Dorset	16,065	22,803	10,382	3,197	3,145	3,145	1,645
Rome	16,333	22,808	10,534	3,337	3,288	3,288	1,763
Drakesburg	17,907	22,870	12,410	4,415	3,635	3,635	1,798
Brookfield	9,624	22,698	7,235	2,790	2,670	2,670	1,695
Filtration at 3 County Garages						25,131	25,131
District Total	**59,928**	**91,179**	**40,561**	**13,739**	**12,738**	**37,869**	**32,032**

District 10: Risk Assessment

A third possible use for the cost analysis tool was risk assessment. Future regulatory changes may limit the possible management alternatives for truck wash water and may prohibit some of the approaches currently used at ODOT garages. Some garages have already had to make changes at locations where the disposal of truck wash water in leach fields is no longer allowed. The district-based cost analysis tool could be used to assess the potential cost impact of such a regulatory change on a District. District 10 was used to illustrate the risk assessment approach.

The cost analysis tool was used to assess the potential cost to District 10 if the use of leach fields for truck wash water disposal were to become prohibited in the future. The analysis assumed that a 3,000 gallon holding tank system would be installed at each outpost garage at a cost of $30,000. It also assumed that the wash water would be hauled to the county garage in the same county as the outpost for disposal or reuse, that filtration costs would be borne by that county garage, and that the distance to the nearest WWTP classified as 'major' would be using to determine the hauling distance. The names and addresses of the potential disposal and reuse facilities in each county are provided in Table 5-9. These addresses were used to calculate the distances used in this cost analysis.

Table 5-9: Addresses of outpost garages in District 10 currently using leach fields for truck wash water disposal, the nearest county garage, and the nearest 'major' WWTP.

County	Facility Name	Address
Athens County	Athens County Garage	700 West Union Street, Athens, Ohio 45701
	Hollister Outpost	611 at State Route 78 Glouster, Ohio 45732
	Athens WWTP	557 East State Street, Athens, Ohio
Monroe County	Monroe County Garage	47028 SR 26, Woodsfield OH 43793
	Duffy Outpost	SR 7, Duffy, Ohio
	Barnesville WWTP	60235 Cross Road, Barnesville, Ohio
Noble County	Noble County Garage	17229 CR 40, Caldwell, Ohio, 43724
	Belle Valley Outpost	Twp. Rd 108 Belle Valley, Ohio
	Barnesville WWTP	60235 Cross Road, Barnesville, Ohio
Washington County	Washington County Garage	1650 Greene St., Marietta, OH 45750-7816
	Belpre Outpost	399 SR 618 Little Hocking OH 45742
	Macksburg Outpost	20255 SR 821, Dexter City 45727
	Marietta WWTP	440 East 8th Street, Marietta, Ohio

Table 5-10 shows the results of the risk assessment for District 10. This cost analysis shows that if the use of leach fields for truck wash water disposal were to become prohibited in the future, the lowest cost option for District 10 would be to install holding tanks and dispose of the truck wash water at a nearby county garage using ODOT equipment and personnel. The total annual cost to District 10 to implement this option would be approximately $34,000.

Table 5-10: Results of District 10 risk assessment. Option 1 was calculated using an average sewer tie in cost of $300,000 over a 40 year lifetime; Options 2 and 3 were calculated over a 12 year time period. Volumes are reported in gallons, costs reported as annual cost.

			Management Strategy					
Garage Name	Estimated Volume Generated	Volume Disposed	Tie Into Sanitary Sewer	Commercial Facility	WWTP	County Garage with Sewer	Filtration and Disposal	Filtration and Reuse
Athens County Garage (ATHCG)	83,160	13,860					8,377	8,377
Monroe County Garage (MOECG)	104,280	17,160					8,377	8,377
Noble County Garage (NOBCG)	122,100	33,000					8,377	8,377
Washington County Garage (WASCG)	192,720	63,360					8,377	8,377
Hollister Outpost Garage (ATHPNO)	13,860		22,641	9,320	6,088	6,068	6,068	5,375
Duffy Outpost Garage (MOEPSE)	17,160		22,674	10,310	6,569	6,394	6,394	5,536
Belle Valley Outpost Garage (NOBPWE)	33,000		22,833	15,062	7,675	7,114	7,114	5,464
Belpre Outpost Garage (WASPSW)	39,600		22,899	17,042	7,755	7,738	7,738	5,758
Macksburg Outpost Garage (WASPNO)	23,760		22,740	12,290	6,749	6,748	6,748	5,560
Total			**113,787**	**64,024**	**34,836**	**34,062**	**67,570**	**61,201**

5.4. Final Cost Analysis and Management Tool Development

After reviewing the results of the preliminary cost analysis and cost analysis tool, ODOT personnel requested that the tool be modified to streamline the user interface and increase the level of customization in the cost analysis. To achieve this goal, the tool was redeveloped in a Microsoft Excel environment with a focus on calculating wash water management costs at a single garage location. Three subtasks were completed during the redevelopment of the cost analysis tool:

1. The default values used for all cost factors were evaluated and revised as necessary.
2. The user interface was redesigned to improve the user experience and increase the level of customization.
3. A district-based summary of the data collected under Task 2 of this project was created.

5.4.1. Revision of Cost Factors

During the process of redesigning the cost analysis tool, the following values were revised:

1. The default value for the estimated volume of wash water per truck per event was updated from 300 gallons to 330 gallons based on the District 10 water bills.
2. The labor costs were modified to account for salary and benefits by multiplying the average hourly driver wage of $17/hour (ODOT District 2 personnel), by 1.5 (Bureau of Labor Statistics, 2012). This yielded a total hourly cost of $26.35 for a driver.
3. The equipment cost to operate a truck to haul the wash water to a disposal or reuse location was revised to include fuel, depreciation, purchase, insurance, maintenance, and permits. A diesel fuel cost of $4.15 per gallon (U.S. Energy Information Administration, 2013), and an average fuel efficiency of seven miles per gallon (Barnes and Langworthy, 2003) were used to calculate the unit cost of fuel as $0.59/mile. An additional $0.53/mile was added to the fuel cost to account for depreciation, purchase, insurance, maintenance, and permits (Barnes and Langworthy, 2003; Trego and Murray, 2009; American

Transportation Research Institute, 2011), bringing the unit cost to operate a vehicle to $1.12/mile (Table 5-11).

Table 5-11: Calculation of the default value of the cost of operating a truck to haul wash water to a disposal or reuse location.

Parameter	Cost ($/mile)	Reference
Cost of Vehicle	0.235	American Transportation Research Institute, 2011
Insurance	0.06	Trego and Murray, 2009
Repair/Maintenance	0.105	Barnes and Langworthy, 2003
Tires	0.03	Trego and Murray, 2009
Depreciation	0.08	Barnes and Langworthy, 2003
Permits/Licenses	0.023	Barnes and Langworthy, 2003 American Transportation Research Institute, 2011
Subtotal	**0.53**	
Fuel	0.59	US Energy Information Administration, 2013 Barnes and Langworthy, 2003
Total	**1.12**	

All cost factor values from the preliminary cost analysis tool (Table 5-3 above) and as modified above, are included in the revised cost analysis tool. However, rather than being fixed (non-modifiable) as they were in the original tool, the user can choose to use these default values or to modify them. .The purpose of the default cost values is to provide a benchmark to help users estimate unknown cost values. All cost factors can be edited within the tool to suit an individual user's needs. Additional details regarding the calculation of annual wash water management costs can be found in the Appendix E.

5.4.2. Revision of Cost Analysis Tool

User Interface

The revised cost analysis tool is shown in Figure 5-2. Although the number of user inputs has been increased, the streamlined user interface, which has one color-coded column for data entry, enhances the user experience. The user can choose default values for the cost analysis using the button at the left of the screen, or all values can be specified by the user. User inputs in the 'Volume' section, including the number of trucks, events, and volume/truck/event, are used to estimate the volume of wash water generated at a specific garage. In the 'Planning'

section, the user is required to input the interest rate and planning period for both the sanitary sewer and non-sewer options. The 'Sanitary Sewer' section requires an estimated value for the capital cost of tying the specific location into the sanitary sewer line. The 'Other' section requires user input for other factors that influence the cost of wash water management. While the number of user inputs has been increased to allow for a higher level of customization, some of the cost factors, including the 0.01/gallon surcharge for disposal in the sanitary sewer, the capital cost of $30,000 for a filtration unit, and the annual cost of $4,600 for replacement filtration media, remain fixed (non-changeable).

When the required input values have been entered, the annualized costs for each of the six alternative management strategies are calculated and shown in the fields highlighted in green and on the chart at the center of the sheet (Figure 5-2). The fields shaded in yellow show the annual cost savings of each strategy when compared with tying into sanitary sewer. As shown in Figure 5-2, under the conditions of this analysis, disposal at a nearby county garage could yield an annual cost savings of almost $9,500 compared with tying into sanitary sewer for a garage with 12 trucks and 30 winter events.

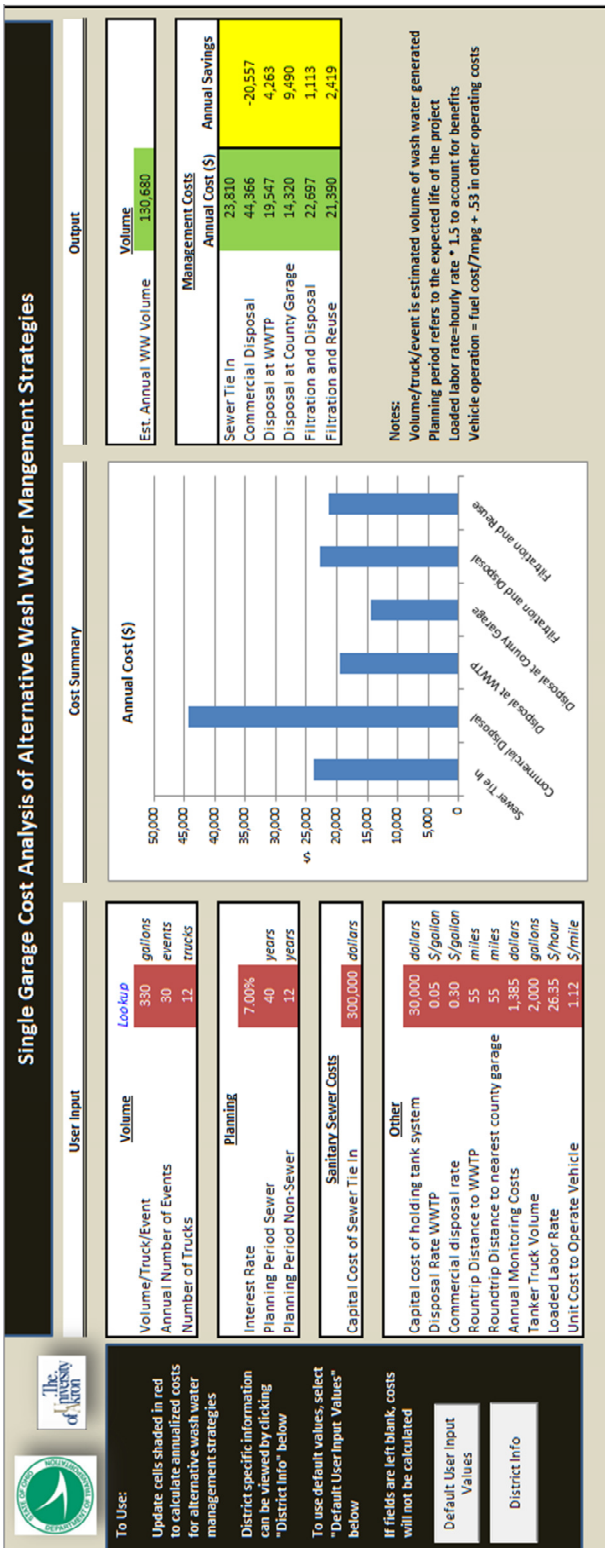


Figure 5-2: Revised cost analysis tool. Fields in red require user input; fields in green and yellow summarize the results of the cost analysis.

District Summary

Figure 5-3 shows the District based data summary sheet that has been added to the revised cost analysis tool. The chart at the center shows a comparison of the volume of wash water generated with the average volume of brine made at each garage within a given District, which can be used to evaluate reuse on a volume basis. The user can adjust the volume estimates using the boxes to the far left marked 'Change Vol/Truck/Event' and 'Percent of Events'. When these fields are updated, the estimated volumes will be recalculated and displayed on the chart. The table at the right shows the number of trucks and average number of winter events used in the volume estimation. The user can update the number of trucks as they change over time using the button at the top left marked 'Show/Update Data'. The summary can be shown for another District by selecting a different District from the 'District' dropdown box at the left.

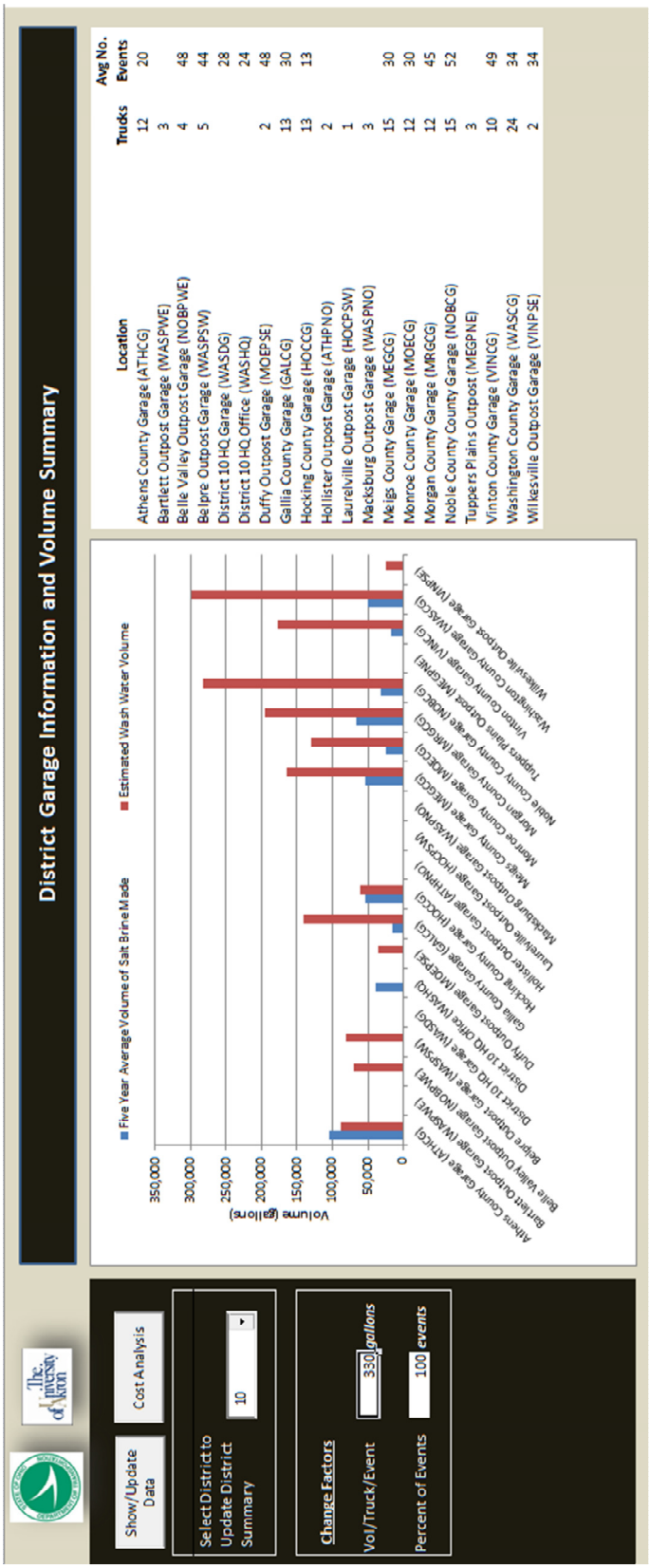


Figure 5-3: District specific data summary sheet of the revised cost tool.

Summary of Cost Tool Enhancements

The following upgrades have been made to the wash water cost analysis tool:

1. The user interface has been streamlined.

2. The number of user inputs has been increased to allow for a higher level of customization in the cost analysis. The revised tool includes user inputs for:

    a. Wash water volume factors: volume of wash water per truck, number of events, number of trucks,

    b. Cost factors: interest rate and planning period,

    c. Capital costs: holding tank system and sanitary sewer, and

    d. Annual costs: monitoring, disposal rate, volume of tanker truck, labor, and truck operating costs

3. The potential annual cost savings that could be achieved by implementing an alternative to tying into the sanitary sewer is evaluated within the tool.

4. A district based summary sheet has been added. This sheet:

    a. Compiles garage data collected under Task 2 of this project,

    b. Compares the five year average volume of brine made with the estimated volume of wash water generated to assess reuse of wash water on a volume basis, and

    c. Allows the user to modify factors influencing the volume of wash water generated to improve the wash water volume estimates

5.4.3. Revised Cost Analysis and Sensitivity Assessment

Using the revised cost factors, the cost impact of site specific conditions, including the volume of wash water generated and the distance to the disposal location, was evaluated. The annualized costs were calculated for each management option using a high, typical, and low estimated volume and a short, typical, and long distance for hauling. The results of this analysis are shown in Tables 5-12 through 5-14. For the volume analysis, the capital cost of tying into the sanitary sewer was held constant at $300,000 and the hauling distance was held constant at 55 miles. The low volume of 4,356 gallons of wash water was calculated for a garage with two trucks and six winter events. The typical volume of 130,680 gallons was calculated for a facility with 12 trucks and 30 winter events, and the high volume of 309,276 was calculated for a garage with 12 trucks and 71 winter events, which was the actual number of winter events at the Ashtabula County Garage during winter 2010. As shown in Table 5-12, disposal at a nearby county garage is the most cost effective option at low volumes, but tying into the sanitary sewer system becomes the most cost effective management strategy at high wash water volumes. This analysis suggests that tying into the sanitary sewer is a cost effective management strategy for larger facilities (i.e. with more trucks), but may not be the best management approach for smaller, outpost garages generating low wash water volumes.

Table 5-12: Evaluation of the impact of the volume of wash water generated on the cost of each alternative management option. All analyses utilized a capital cost of $300,000 to tie into the sanitary sewer. The cost savings was calculated as the annualized cost of sanitary sewer tie in minus the annualized cost of the management alternative; negative values indicate that there is no cost savings by implementing an alternative management strategy.

Management Alternative	Annualized Cost ($)			Cost Savings		
		Volume			Volume	
	Low	Typical	High	Low	Typical	High
Sanitary Sewer	22,546	23,810	25,596			
Commercial Disposal	6,469	44,366	97,945	16,077	-20,556	-72,349
WWTP	5,642	19,557	39,231	16,904	4,253	-13,635
Disposal at ODOT Garage	5,468	14,330	26,860	17,078	9,480	-1,264
Filtration and Disposal	13,845	22,707	35,237	8,701	1,103	-9,641
Filtration and Reuse	13,801	21,400	32,144	8,745	2,410	-6,548

For the volume analysis, the low volume of 4,356 gallons was calculated using 2 trucks and 6 winter events (actual number of winter events at the Athens County Garage during winter 2011); the high volume of 309,276 was calculated using 12 trucks and 71 winter events (actual number of events at Ashtabula County Garage during winter 2010); typical volume of 130,680 was calculated using 12 trucks and 30 events; distance was held constant at 55 miles roundtrip.

For the distance analysis, distances of 25, 55, and 125 miles roundtrip to the disposal location were used. The volume was held constant at 130,680 gallons for the analysis of the costs at a county garage, and 32,670 gallons for an outpost, and the capital cost to tie into the sanitary sewer was held constant at $300,000. Neither the cost of tying into the sanitary sewer nor the cost of commercial disposal are dependent on hauling distance. As expected, at longer hauling distances, off-site disposal and treatment become less cost effective management options (Table 5-13, 5-14). For a typical outpost garage, the lowest cost management option, disposal at a nearby county garage, has a cost of approximately $6,600 at a hauling distance of 25 miles, but the cost increases to $9,400 at a hauling distance of 125 miles (Table 5-13). For a county garage, the lowest cost option, disposal at a nearby ODOT facility, has an annualized cost of approximately $11,000 at a distance of 25 miles, but the annualized cost increases to more than $22,000 at a hauling distance of 125 miles (Table 5-14). When compared with the cost of tying into the sanitary sewer, off-site disposal is always more cost effective than tying into the sanitary sewer for a typical outpost when the hauling distance is less than 125 miles. For a typical county garage, the potential cost savings of off-site disposal at a roundtrip hauling distance of 125 miles may not be large enough to offset the increased complexity in logistics and planning required to pursue this option.

Table 5-13: Assessment of the impact of hauling distance on the annualized cost of alternative wash water management strategies at a typical outpost with 3 trucks and 30 winter events.

Management Strategy	Annualized Cost ($) Distance			Cost Savings Distance		
	Short	Typical	Long	Short	Typical	Long
Sanitary Sewer	22,829	22,829	22,829			
Commercial Disposal	14,963	14,963	14,963	7,866	7,866	7,866
WWTP	7,924	8,761	10,714	14,905	14,068	12,115
Disposal at ODOT Garage	6,617	7,454	9,408	16,212	15,375	13,421
Filtration and Disposal	14,994	15,831	17,785	7,835	6,998	5,044
Filtration and Reuse	14,667	15,504	17,458	8,162	7,325	5,371

Table 5-14: Assessment of the impact of hauling distance on the annualized cost of alternative wash water management strategies at a typical county garage with 12 trucks and 30 winter events.

Management Strategy	Annualized Cost ($) Distance			Cost Savings Distance		
	Short	Typical	Long	Short	Typical	Long
Sanitary Sewer	23,810	23,810	23,810			
Commercial Disposal	44,366	44,366	44,366	-20,556	-20,556	-20,556
WWTP	16,208	19,557	27,371	7,602	4,253	-3,561
Disposal at ODOT Garage	10,981	14,330	22,144	12,829	9,480	1,666
Filtration and Disposal	19,358	22,707	30,521	4,452	1,103	-6,711
Filtration and Reuse	18,051	21,400	29,214	5,759	2,410	-5,404

For the distance analysis, the short distance was 15 miles roundtrip; the typical distance was 55 miles roundtrip; and the long distance was 125 miles roundtrip; the volume was held constant at 130,680 for a county garage and 32,670 for an outpost garage.

To evaluate the impact of the capital cost of tying into the sanitary sewer on the cost effectiveness of this management strategy, the annualized cost of tying into the sanitary sewer was calculated for capital cost values ranging from $100,000 to $800,000. The annualized cost for the sewer tie in at each value was then compared with the annualized cost of each alternative management option calculated for a typical county garage and a typical outpost garage. The hauling distance was held constant at 55 miles for this analysis. To assess the potential cost savings of implementing an alternative to tying into the sanitary sewer, the annualized cost of each management option was subtracted from the annualized cost of tying into the sanitary sewer. As shown in Figure 5-4, at a capital cost of $100,000, tying into the sanitary sewer is the most cost effective management strategy for a typical county garage; however, at a capital cost of $600,000, it is the least cost effective of the management options identified.

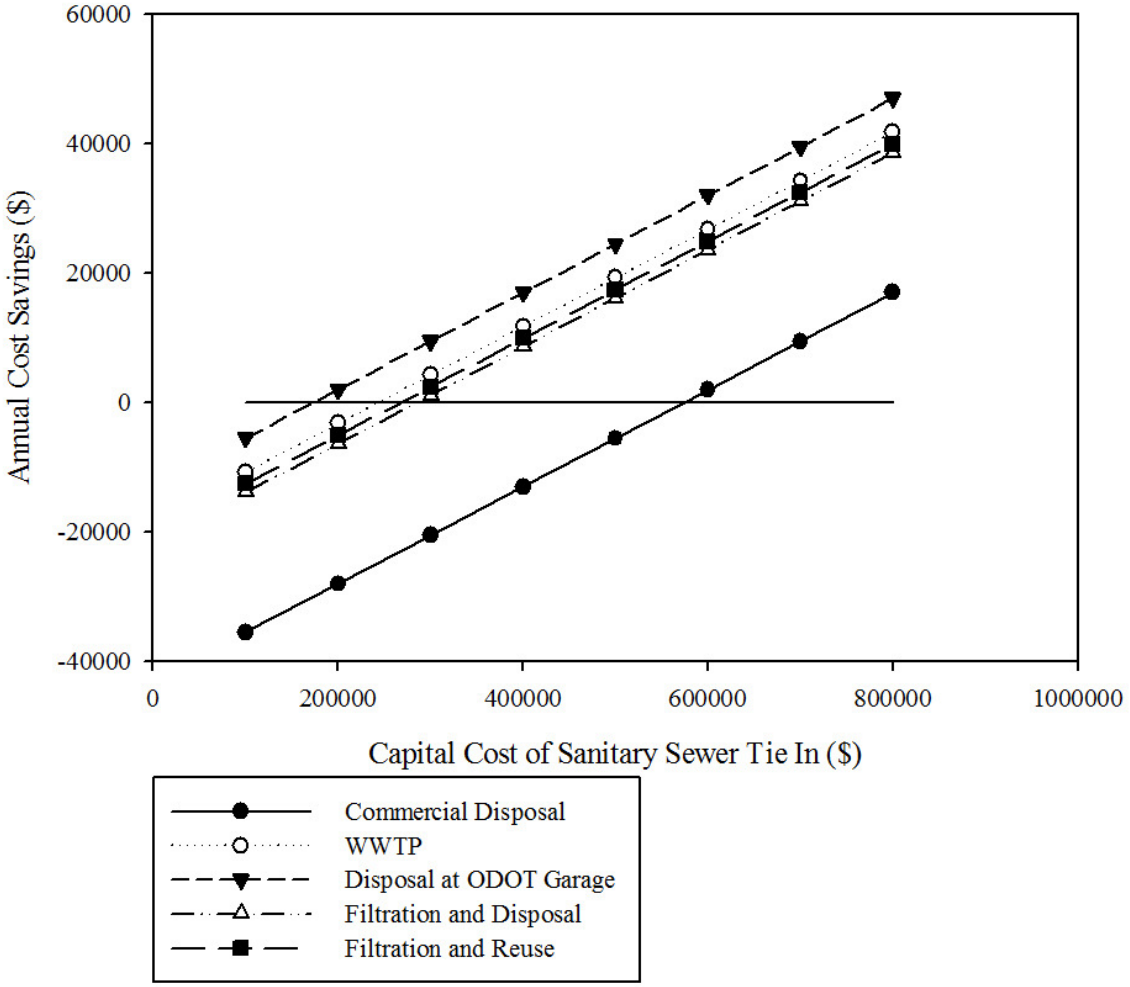


Figure 5-4: Annualized cost savings that could be achieved by implementing an alternative to tying into the sanitary sewer at a typical county garage. Savings was calculated as the annualized cost of tying into the sanitary sewer for different values of capital cost minus the annualized cost for the management option. Values above zero indicate a potential cost savings over tying into the sanitary sewer. Annualized costs for alternative management options were calculated for a typical county garage with 12 trucks and 30 winter events and a hauling distance of 55 miles.

As shown in Figure 5-5, for a typical outpost garage, off-site disposal at a nearby county garage is always more cost effective than tying into the sanitary sewer when the hauling distance is less than 55 miles. When the capital cost of tying into the sanitary sewer is $200,000, all three of the off-site disposal strategies are more cost effective than tying into the sanitary sewer (when hauling distance is less than 55 miles), and at a capital cost of $300,000 to tie into the sanitary

sewer, all of the management options identified are more cost effective than tying into the sanitary sewer under the conditions of this cost analysis. This suggests that for outpost garages, there may be a more cost effective strategy for managing wash water than tying into the sanitary sewer.

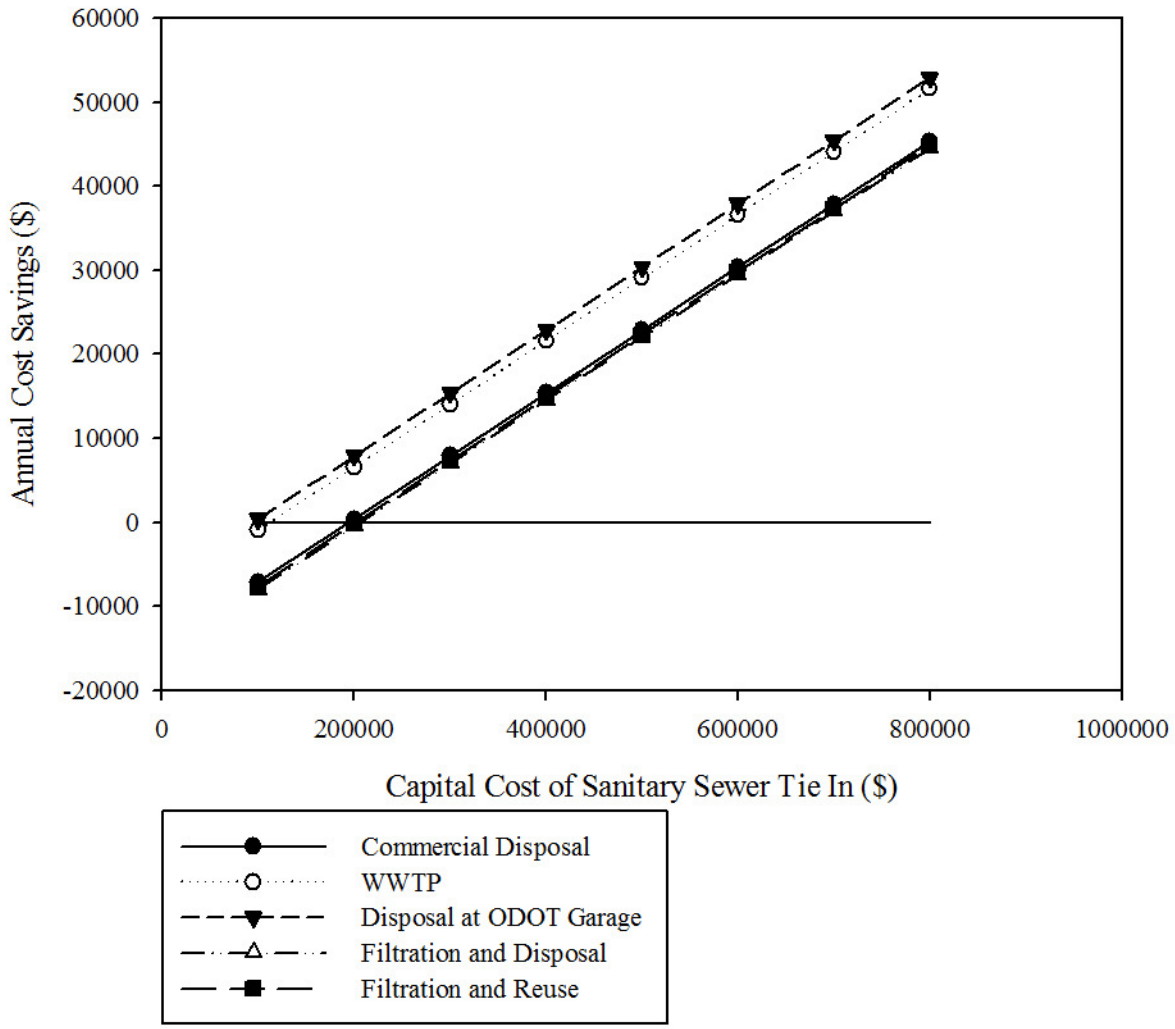


Figure 5-5: Annualized cost savings that could be achieved by implementing an alternative to tying into the sanitary sewer at a typical outpost garage. Savings was calculated as the annualized cost of tying into the sanitary sewer for different values of capital cost minus the annualized cost for the management option. Values above zero indicate a potential cost savings over tying into the sanitary sewer. Annualized costs for alternative management options were calculated for a typical outpost garage with 3 trucks and 30 winter events and a hauling distance of 55 miles.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

This chapter is organized with a section for each results chapter (Chapter 2-Chapter 5), as well as a final section for recommendations for implementation of the research results.

6.1. Current State of the Practice of Wash Water Management

- A comprehensive literature review and interview of seventeen other DOTs was conducted to identify alternative wash water management strategies (Table 2-4). It is clear that wash water management remains a challenge for other DOTs with limited reuse by several states. The challenge is achieving acceptable water quality limits and no other state (except Ohio at the Henry County garage) reported monitoring for heavy metals in the wash water.
- A comprehensive literature review and interview of seventeen other DOTs identified eighteen wash water management strategies for disposal and reuse (Figure 2-2).
- Site visits and a survey of all ODOT Districts was used to document existing wash water management strategies including confirming sites with and without access to sewer, costs, and key factors for estimating the wash water volume generated. All sites were mapped (Figure 2-4).
- Data from the Transportation Management System (TMS) was used to quantify the brine demand for each ODOT District for the last five years (Figure 2-5 and Table 2-9). The median volume for the entire state was approximately 6.6 million gallons.
- Water usage analysis for District 10 (Figure 2-6 and Table 2-10) and survey responses from each District were used to confirm an estimate of 300 gallons of wash water generated per truck per wash cycle.

- Comparing the brine use volume (~6 million gallons) to the wash water generated volume (~ 15 million gallons) estimates, approximately 9 million gallons of wash water would still require disposal or reuse by another municipality.
- The estimate for the total volume of wash water generated by ODOT facilities without sewer access is approximately 3.8 million gallons (Figure 2-8).
- The cost for wash water off-site disposal by ODOT facilities varies significantly ($0.05 to $0.54 per gallon).

6.2. Truck Wash Water Quality

- Wash water quality sampling during January-April 2012 was conducted for three ODOT facilities (Figure 3-1). A number of metals were measured, and copper and zinc (i.e. traffic-related metals) were detected in all samples (Table 3-1). Non-metals parameters (e.g. total dissolved solids) were also measured (Table 3-2).
- Comparison of raw wash water quality results of the January-April 2012 samples from three ODOT garages to disposal and reuse guidelines and limits (Table 3-3 to Table 3-7) showed many samples meeting disposal guidelines; however, many samples would not meet reuse limits.
- In winter 2012-2013, 24 ODOT facilities were sampled during a full truck wash water event (Figure 3-4). There were 17 metals and 10 non-metal parameters analyzed (Table 3-10). Allen County was found to have the highest median concentration for total copper, iron, and zinc.
- Particulate metal concentrations were a significant fraction of the total metal concentration for the traffic metals (Cu, Zn, Ni, Cr, Pb, and Fe), indicating the importance of colloidal metal in the samples. Confirming this was copper and zinc generally increased with increasing turbidity in the sample (Figure 3-8 and 3-9).
- Based on a three hour wash water study conducted at the Stark County garage and individual garage results during wash events (Table 3-14 and Figure 3-12a-b), there is significant wash water quality variability due to mixing and performance of the oil-water separator.

- Very few garages exceeded the disposal guidelines for heavy metals (Table 3-15). Copper was too high in 4% of the garages and 13% of the facilities were too high for zinc.
- Many garages exceeded the reuse limits for heavy metals (Table 3-15). Copper was too high in 71% of the garages and 75% were too high for zinc. When comparing the 24 garage medians to the reuse limits, copper exceed the limit 71% of the time.
- Binary logistic regression models were developed for four parameters (total copper, total iron, total zinc, and rural area) and are summarized in Tables 3-20 through 3-23. The metal parameters were assessed for probability of exceeding reuse limits.
- The total copper binary logistic regression model results show as the concentrations of chromium, nickel, zinc and total dissolved solids increase so does the likelihood for failing to meet the copper re-use limit (Table 3-24). The increase due to total dissolved solids (TDS) may be explained by the truck being relatively dirty (i.e. presence of salt and traffic dust) when washed and could have a large impact on the probability.
- The total iron binary logistic regression model results show as chromium, nickel and turbidity increase so does the likelihood for total iron being above the reuse limits (Table 3-24). Like the model for total copper, these results suggest the truck cleanliness (corresponding to turbidity-presence of particulates) is important in meeting the reuse limits.
- The total zinc binary logistic regression model results show that as copper and iron increase, so does the likelihood that the total zinc will be above the reuse limit (Table 3-24. The results also suggest that areas with higher than the average urban lanes miles for all the sample garages are 213%less likely to exceed the total zinc reuse standard.

6.3. Wash Water Treatment Assessment

- Batch and column experiments performed with filtration media reduced heavy metal concentrations in the wash water including the target metals copper and zinc (Figure 4-1 to Figure 4-4). The reduced levels meet disposal guidance and could increase the likelihood of meeting reuse limits.

- Batch and column test for four different media types were performed to determine metal removal effectiveness. For copper and zinc removal, Media M performed very well. Media P showed some removal in the batch and column experiments, but overall removal diminishes with time. Discussion with the manufacturers of Media A revealed that Media A must be pre-wet with ethanol for optimum removal efficiency and additional experiments after re-wetting may show better results.
- Four trials and nearly 3,000 gallons, testing the metal removal efficiency of the MAR Systems Sorbster media (Media M), were treated through the pilot unit on Stark County garage oil/water separator water. Clogging of the 5 µm filters (Figure 4-12) occurred which resulted in fluctuations in the flow rate and was indicative of a high amount of suspended solids.
- The MAR Systems Sorbster media and pilot unit was effective at reducing the heavy metal concentration of wash water. Average total metal removal efficiencies were 79%, 77%, 63%, and 94% for copper, zinc, iron, and lead, respectively (Figure 4-14 and Figure 4-15).
- A portion of total metal removal by the pilot unit can be attributed to the 5µm filters at the beginning of the pilot unit (Figure 4-16). The average total metal removal by the 5 µm filters were 57%, 27%, 8%, and 57% for copper, zinc, iron, and lead, respectively.
- The total metal removal of the MAR Systems Sorbster media of all particles less than 5 µm was 46%, 68%, 59% and 79% for copper, zinc, iron and lead, respectively, which affirms the removal capabilities of the media (Figure 4-17).
- Additional tests with 5 µm filters on six different garage wash water samples from garages that exceeded the reuse limits (Table 4-5) confirmed the importance of physical separation or settling as a removal alternative. Metal removal efficiencies of 82%, 60%, 87% and 76% were measured for copper, zinc, iron and lead, respectively. This showed that a large percentage of the total metal concentration is in the solid form (greater than 5µm).
- Particle settling estimates (at a temperature of 40 degrees Fahrenheit) showed an average settling time of 11.7 hours and 15.1 hours for 5 µm size particles of copper and zinc, respectively (Table 4-6).

6.4. Cost Analysis

- Based on the literature review, survey data, and wash water quality results, six wash water management strategies (Figure 2-9) and the corresponding cost components (Table 5-1 and Table 5-3) were selected to include in an evaluation matrix tool developed in Microsoft Excel. The evaluation matrix tool is District-based and also allows for a single (e.g. new garage) garage cost analysis.
- Application of the evaluation matrix to an existing situation with four outposts in District 4 identified potential savings of approximately $28,000 per year (Table 5-8).
- An example application of the evaluation matrix to all of District 10 (risk assessment approach if all wash water required collection and disposal) was performed to demonstrate the potential use of the tool to examine District-wide solutions to wash water management.
- The tool was refined based on input from ODOT personnel. The user interface has been streamlined (Figure 5-2), the number of user input values has been increased to allow for a higher level of customization, and a district based summary of trucks and winter events has been added (Figure 5-3). Default values for cost factors were also revised and added to the cost tool to assist users in choosing values for unknown parameters. In addition, the final cost analysis tool includes a calculation of the potential annual cost savings that could be achieved by implementing an alternative to tying into the sanitary sewer.
- Using the revised cost analysis tool and factors, a detailed cost analysis was conducted for each of the six management strategies. The cost analysis indicated that site specific conditions directly impact the cost of alternative management strategies and that tying a facility into sanitary sewer is often the most expensive management strategy. For a typical county maintenance facility with 12 trucks and 30 winter events, four of the five management alternatives identified were more cost effective than tying into the sanitary sewer when the capital cost of tying into the sanitary sewer was greater than $300,000 (Figure 5-4).
- The influence of cost factors, including the volume of wash water generated and the hauling distance, were assessed. The analysis showed that the volume of wash water had a larger impact on the cost than hauling distance (Tables 5-12, 5-13, 5-14). At “lower”

volumes, all of the management options identified would yield a cost savings when compared with the cost of tying into the sanitary sewer.

6.5. Recommendations for Implementation

Figure 6-1 shows a generic flow chart for wash water management monitoring recommendations and approximate heavy metal reduction percentages based on settling and treatment via filtration.

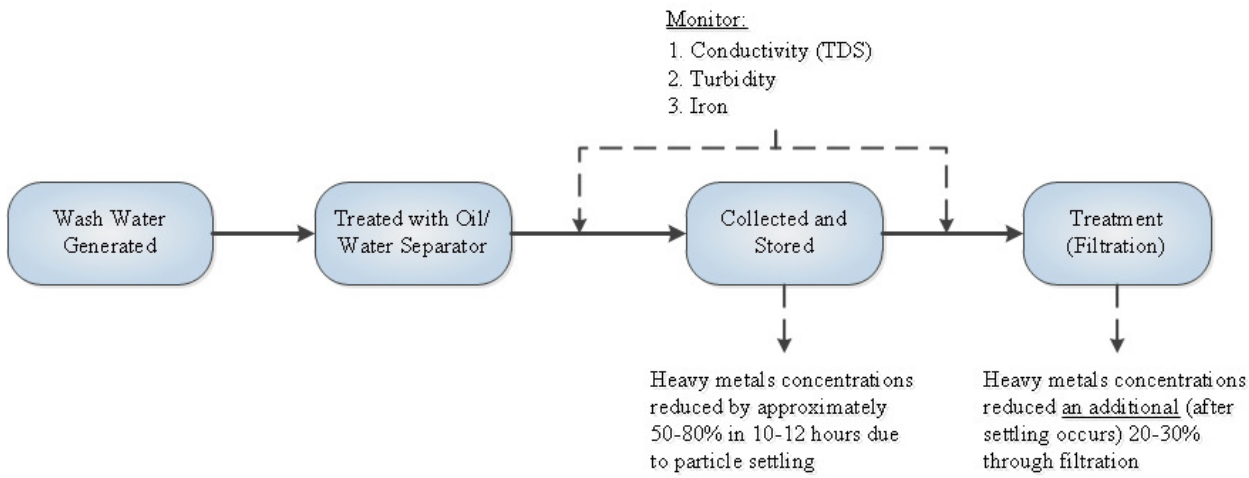


Figure 6-1: Wash water generic management strategy with monitoring recommendations and approximate heavy metal reduction percentages based on settling and treatment via filtration.

Conductivity as a proxy for total dissolved solids (TDS) and turbidity are both relatively simple analytical techniques requiring inexpensive (i.e. less than $1,000) equipment. Based on the models developed in this research, these parameters could be used to assess wash water quality for wash water reuse screening and disposal. Monitoring in this fashion could be confirmed with periodic analysis of the actual metals of concern (i.e. total copper and total zinc). Depending on the level of TDS or turbidity, simply allowing for settling in a collection vessel could reduce many locations to below the reuse limit. For those garages with exceedingly high concentrations of heavy metals (i.e. Allen County), additional treatment may be required and would need to be evaluated on a case by case basis. Finally, the cost analysis tool can be used for an existing

garage to select a cost-effective management strategy and should be used for all locations without access to sanitary sewer.

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APPENDIX A

RESULTS OF SURVEY OF OTHER STATE DOT

Indiana

Mr. Steve Mcavoy, Manager Office of Facilities Management at Indiana DOT (INDOT) provided the following information by email and telephone:

INDOT has a formal program in place for recycling truck wash water into salt brine for winter road maintenance. All new facilities are designed and constructed with this in mind, and a several older facilities have been retrofitted with this capability. The truck washing process at INDOT maintenance facilities is as follows:

1. Large debris is hand removed from the truck prior to entering the wash bay.
2. Any remaining large debris is removed during prewashing, which is conducted over a shallow pit so that the wash water can be collected and drained into the wash bay. The solids remaining in the pit are then collected and reused.
3. Trucks are washed in the wash bay. All wash water is collected and processed through an oil/water separator prior to being pumped into above ground storage tanks in the salt building until it is needed for brine production. If the volume of wash water generated exceeds the volume of storage available, wash water is routed to the sanitary sewer, rather than into the tank. The wash water is used to produce salt brine, as it is needed.

The process is similar in locations without sanitary sewer. Additional storage volume is provided at these locations to minimize the need to pump water out of the storage tanks for off-site disposal. In some cases, water is transported to a nearby maintenance facility to be converted to salt brine when the volume of wash water generated exceeds the volume of storage available. Cost analysis including benefits has not been evaluated.

Colorado

The following information was obtained from email and telephone correspondence with Ms. Theresa Santangelo, Hazardous Waste Management Unit Supervisor for the Colorado DOT: In Colorado, truck wash water is reused for two purposes: brine production and truck washing. Prior to being reused, the wash water is treated to remove volatile organic chemicals, metals, bacteria, oil and grease and to reduce the concentration of dissolved solids. The wash water is then stored until it is needed for truck washing. Because dissolved solids are not removed during

wash water processing, truck washing must be followed by a tap water rinse to ensure that the recycled wash water does not cause vehicle corrosion. In locations where the truck wash water is reused as stock for brine production, the water is treated using an ultrafiltration (UF) system to ensure that the water quality of the salt brine solution used for pre-treating meets applicable standards. UF is used to remove suspended and colloidal particulate matter, but does not remove dissolved solids. After being processed through the UF unit, the treated wash water is stored until it is reused for brine production.

Iowa

The following information was obtained through telephone correspondence with Mr. James VanSickle, Supervisor at the Iowa DOT Ames Garage:

The Ames Garage installed a system to reuse wash water for brine approximately four years ago. Wash water is treated with an oil/water separator prior to being stored on-site until it is converted to brine. The facility has approximately 56,000 gallons of brine storage available on-site. Care is taken to ensure that the brine tanks are nearly empty at the end of the winter season so that all wash water generated during the summer months can be stored and used to make brine in the fall. The on-site storage capacity is such that all wash water generated can be captured. The Ames garage reportedly uses between 800,000 and 1,000,000 gallons of brine in a typical winter. They do not generate enough wash water to produce this volume, and must also use tap water. In addition to producing brine for their own routes, they also produce brine for the City of Ames.

Prior to beginning a reuse program at the Ames Garage, Iowa DOT pilot tested a filtration system designed to treat truck wash water to an acceptable level for discharge directly to the environment. Detailed information regarding this system was not available. However, Iowa DOT no longer uses this system and is moving toward reusing truck wash water for the production of brine at facilities without access to sanitary sewer.

Utah

The following information was obtained from email and telephone correspondence with Mr. Lynn Bernhard, Methods Engineer for Utah DOT:

Utah DOT's standard practice for truck wash water management is to collect and store the wash water in retention ponds until it is reused for the production of salt brine. At the end of each season, retention ponds are sealed and allowed to evaporate. Residual solids are then disposed of as part of an approved waste stream. To address reported problems with seepage and overflow from these retention ponds, concrete liners have been replaced with membrane liners and several retention ponds have been redesigned with greater capacity. While evaporation and disposal is a viable approach to truck wash water management in Utah because of low rainfall totals and high summer temperatures, it is unlikely that this approach would be successful under Ohio's climate conditions.

Virginia

The following information was provided by email and telephone correspondence with Mr. Jim Brewbaker, Salem District Equipment Manager for the Virginia DOT:

In Virginia, truck wash water is managed in one of four ways:

1. When available, wash water is disposed of via sanitary sewer.
2. Wash water is filtered and reused for truck washing. When it can no longer be reused, wash water is disposed of using an evaporator system. Use of these systems has been discontinued in most locations due to the high cost associated with filter replacement and energy to operate the evaporator system. Because of clogging, the filters require more frequent replacement than anticipated. While the intent of these systems was to process the wash water so that it could be reused for truck washing time and time again, truck wash water was only being reused once during the winter season before being evaporated because there were concerns that the salty water would corrode the maintenance vehicles.
3. Wash water is filtered through a subsurface engineered wash pad, which is constructed of alternating layers of sand and stone. After being filtered through the wash pad, the wash water is allowed to infiltrate. Because all materials are excavated and replaced annually, the cost to maintain these wash pads is high.
4. Trucks are washed at commercial facilities when available.

Virginia DOT no longer allows truck wash water to be stored in retention ponds or reused for brine production because of elevated oil and grease concentrations.

Pennsylvania

The following information was obtained by telephone conversation with Mr. Terry Persall, Acting Division Chief—Facility Management for Pennsylvania DOT:
Pennsylvania DOT (PennDOT) does not have a formal plan for reusing truck wash water. Because the first choice for wash water disposal is via sanitary sewer, PennDOT makes a concerted effort to locate new garages in areas with sewer access. When this is not possible, commercially available recycling systems, which process and collect the truck wash water for reuse, are utilized. These systems are known to have high maintenance costs and are ineffective when standard operating procedures for reuse are not followed. Because dissolved solids are not completely removed prior to reuse, a tap water rinse must be the final step in the truck washing process. PennDOT noted that it is difficult to ensure that all maintenance personnel comply with this requirement, but omission of this step can lead to increased costs when maintenance vehicles begin to corrode. PennDOT's final option for truck wash water disposal is to store wash water in a holding tank until it can be properly disposed. PennDOT views this as the least desirable approach, and tries to minimize the use of holding tanks at their maintenance facilities.

Missouri

The following information was obtained through email and telephone correspondence with Mr. Douglas Record, GS Facilities Manager for Missouri DOT:
Missouri DOT attempts to locate new maintenance garages in areas where sewer access is available so that truck wash water may be directed to a Publicly Owned Treatment Works (POTW). In locations where this is not possible, trucks are washed at commercial facilities. Recently, Missouri Department of Natural Resources (DNR) has instructed Missouri DOT to discontinue the practice of using leach fields for truck wash water disposal. In one of these locations, a pilot study is being conducted to evaluate the feasibility of reusing the truck wash water for brine production. The pilot system is designed to collect truck wash water in a sump where oil/water separation begins and solids settle. Wash water is then treated using an oil/water separator prior to being stored in a 6,000 gallon above ground storage tank until it is reused. The pilot study has been unsuccessful to date due to the inability of the existing system to meet Missouri's water quality standards for oil and grease. Oil and grease concentrations in the wash

water storage tank exceeded the limit of 10 mg/L during the first round of sampling. Missouri intends to continue the pilot test using a different cleaning product, which may enhance oil and grease removal, and resample the wash water.

Tennessee

The following information was obtained through email correspondence with Mr. Estel Hagewood, Transportation Manager I for the Tennessee DOT and Tennessee DOT's Standard Operating Procedure for Vehicle Wash Operations:

Tennessee DOT's standard operating procedure for truck washing specifies that trucks must be washed at commercial truck washing facilities or on a designated wash pad. In locations where wash pads are used, wash water passes through an oil/water separator prior to being discharged to the sanitary sewer or collected and stored until it can be transported to a POTW for proper disposal. Some truck wash water treatment units also include a filter paper unit for the removal of suspended solids. The filter paper is periodically changed and properly disposed. In Tennessee, wash water is not recycled.

Oregon

The following information was obtained through email and telephone correspondence with Ms. Shawna Secord, Clean Water Program Technician for the Oregon DOT:

At maintenance facilities without access to sanitary sewer, Oregon DOT's preferred approach is to filter the truck wash water with a granular activated carbon (GAC) filter and discharge the treated water directly onto the ground surface, preferably to a vegetated area. Oregon DOT has a treatment process that includes a vault separator, oil/water separator, or holding tank to remove sediment from the wash water. The wash water is then processed through a bag filter to reduce suspended solids concentrations and finally treated with the GAC filter and discharged. When the units become clogged with solids, the top six inches of media are removed and replaced. At some facilities, the media is replaced each year, while others are able to use the system for several years prior to media replacement. These systems are low maintenance and effective for Oregon DOT.

In locations where discharge to the ground surface is not possible, custom evaporator or closed loop recycling systems are used to minimize the need for wash water disposal. Because of the energy and maintenance requirements, these systems are not preferred.

Washington

The following information was obtained through email correspondence with Mr. Norm Payton, Stormwater and Environmental Policy Manager for Washington DOT:
Washington DOT has a standard operating procedure for truck washing that includes the use of prewash pads, where most of the visible dirt is removed from the trucks using high volume, low pressure washers. This water is processed through a sump, for suspended solids removal, and an oil/water separator prior to being discharged to a sanitary sewer. Additional washing is then conducted in the main wash bay. In the past, Washington DOT installed truck wash water recycling units in approximately five wash bays. However, these are no longer used as they were deemed inefficient and expensive to operate. At facilities that lack sewer access, Washington DOT now routes the wash water to a pond or bioswale, where it infiltrates. In addition, they are considering the use of an Amended Compost Bioswale, which has just been approved by the Washington Department of Ecology for removal of suspended solids and dissolved metals. Additional research may be conducted to ensure that the Amended Compost Bioswale is adequate for oil and grease removal.

Maryland

The following information was obtained through a telephone interview with Mr. Gregory Keenan, Chief of the Environmental Compliance Division with the Maryland State Highway Administration (SHA):

Maryland SHA currently operates six maintenance facilities that do not have access to sanitary sewer for the disposal of truck wash water. With the exception of one location, wash water is treated to remove oil and grease and suspended solids and then discharged directly to surface water with an approved permit. The permit requires monitoring of total suspended solids (TSS) and oil and grease concentrations. Several facilities have had issues meeting the discharge requirements for TSS. To address this concern, treatment systems were upgraded by enlarging the grit chambers inside the wash bay and adding storage volume on-site. However, because

these measures were insufficient to achieve compliance with the TSS discharge limits, these facilities have begun to store the wash water on-site until it can be pumped and hauled to a treatment facility. Maryland SHA has found that the cost for pump and haul is comparable to the cost of monitoring and sampling required for surface water discharge. The location that does not discharge to surface water discharges to ground water with an approved permit. Maryland SHA has considered pursuing groundwater discharge permits for other facilities, but has been unable to do so.

One facility in Carroll County Maryland implemented a system for recycling wash water to use for truck washing a number of years ago, but, due to constant maintenance issues, this operation was discontinued. There is no documentation available on this system. Maryland SHA has also considered the use of an advanced filtration system to address concerns about toxicity from detergents in the wash water. However, there was concern that operation and maintenance of this system would be too difficult and time consuming during the winter season. Instead, they have discontinued the use of detergents at locations that discharge to surface water.

Minnesota

The following information was obtained through telephone interviews with Mr. Steve Lund, State Maintenance Engineer for Minnesota DOT, and Mr. Dave Morisette, Water Resource Engineer for the Minnesota DOT:

In Minnesota, the standard operating procedure for truck wash water disposal in locations without sanitary sewer is to store the wash water on-site until it can be transported to a POTW for disposal. Approximately fifteen years ago, Minnesota DOT conducted a research project to assess the possibility of treating and reusing the wash water for truck washing. Although there is no documentation available regarding this project, Minnesota DOT personnel indicated that the treatment system included filtration, ozonation, and oil and grease removal. The project was abandoned after approximately two years due to limited employee buy-in and issues with equipment corrosion. Minnesota does not currently recycle truck wash water for the production of salt brine.

Vermont

The following information was obtained through a telephone conversation with Mr. George McCool, District Manager for the Vermont DOT:

Truck wash water generated at facilities lacking access to sanitary sewer for disposal is treated with an oil/water separator prior to being discharged directly to a septic system and leach field. At the Central Garage, wash water is stored in an underground storage tank (UST) until it is pumped and hauled off-site for disposal. Vermont DOT has not experimented with wash water reclamation, but indicated that they are always looking for cost savings measures.

Michigan

The following information was obtained through telephone and email correspondence with Mr. Andrew Bouvy, Engineer for the Region Bridge Support Unit of the Michigan DOT: At locations without access to sanitary sewer, Michigan DOT currently treats wash water with an oil/water separator and stores it in a 10,000 gallon UST until it is pumped and hauled off-site for disposal. Most of their facilities only require pumping of the tanks once every two to three months, although one facility reportedly requires pumping and hauling three times per month. Wash water generation is minimized by limiting truck washing activities.

In 2007, Michigan DOT installed a Rowafil wash water reclamation system through Hydro-chemical of Grand Rapids. Because the system did not remove salt from the water, dissolved solids concentrations were elevated to a level that required its disposal as hazardous waste within several cycles. In addition, the equipment showed signs of corrosion in a short amount of time. The project was discontinued and the equipment was auctioned for one quarter of its original price. Michigan DOT does not recommend the use of reclaimed wash water for truck washing.

Delaware

The following information was obtained through a telephone interview with Mr. Alastair Probert, Maintenance Engineer for Delaware DOT:

In Delaware, it is a requirement that truck wash water be disposed of via sanitary sewer when available. In locations where sewer is unavailable, trucks must be washed on an

impervious pad. Wash water is then treated using an oil/water separator and directed overland to an on-site, unlined retention pond. Because the near surface soils in Delaware are sandy, water readily infiltrates, eliminating the need to pump water out of the pond to prevent overflow.

Rhode Island

The following information was obtained by email correspondence with Mr. Joe Baker, Deputy Administrator—Division of Highways and Bridges:

Rhode Island DOT does not conduct truck washing operations at any of their maintenance facilities. Private facilities, which have been pre-approved by the state, are used for all truck washing. The cost ranges from $8-$125 per truck, depending on the size of the truck, and includes wash water disposal.

Idaho

The following information was obtained by telephone interview with Mr. Steve Spoor, Maintenance Services Manager for the Idaho DOT:

Formal best management practices have not been developed for the management of truck wash water in Idaho. Trucks are generally washed with a fire hydrant near the salt pile so that wash water will drain back toward the pile. The first designated truck washing facility in the state is currently under development in Coeur d'Alene, Idaho as a result of concerns regarding storm water management. When completed, the facility will be connected to sanitary sewer. As of January 2012, project specifics remain undefined.

APPENDIX B

OHIO DOT SURVEY RESULTS

District 1

		Number of Trucks Used per Winter Event		Total Lane Miles (per garage or outpost)			
COUNTY GARAGES	Total Number of Dump Trucks	Low End Estimate	High End Estimate	Priority	General	Urban	Total
Allen County	8	4	8	245	178	47	470
Defiance County	13	6	13	46.288	249.626	44.439	340.353
Hancock County	15	8	15	241.69	330.34	50.91	622.94
Hardin County	9	7	8	91	243	0	334
Paulding County	12	4	10	83.78	308.86	0	392.64
Putnam County	15	7	14	106.6	346.85	0	453.45
Van Wert County	15	8	15	103.92	270.6		374.52
Wyandot County	14	4	14	178.2	283.2	15.4	476.8
							0
OUTPOST GARAGES							0
Delphos	3	3	3	245	178	47	470
4th Street	4	4	4	245	178	47	470
Beaverdam	4	4	4	245	178	47	470
Hicksville	1	1	1				0
SR 12 Outpost	6	2	6				0
Roundhead	2	1	2				0
Carey	2	1	2				0

		Estimated Time to Conduct Full Wash of One Truck						Washwater Storage			Washwater Disposal	
	What type of Truck Washing is Conducted at this facility?	Low End Est.	High End Est.	Time to Conduct Quick Wash of one Truck	Type of Hose	Flow Rate from Hose	How was Flow Rate Determined?	Total Oil Water Separator Capacity	Total Sand Trap Capacity	Total Other Storage Capacity	Method	If not using public sewer, estimated Cost for disposal
COUNTY GARAGES	**Select one**	**minutes**	**minutes**	**minutes**		**gpm**		**gallons**	**gallons**	**gallons**	**Select one**	**$/gallon**
Allen County	Full and Quick Wash	30	60	15	Pressure &	P =3.8gpm/	estimated	2000			Sanitary Sewer	N/A
Defiance County	Full and Quick Wash	20	45	20	Pressure Washer	5.5gpm		40	n/a		Sanitary Sewer	N/A
Hancock County	Full and Quick Wash	7 min.	30 min.	7 min	pressure washer @ 4 gal/min			?	n/a	n/a	Sanitary Sewer	N/A
Hardin County	Full and Quick Wash	15	90	15	3/4" high Vol	12 gpm	Timer/Measured	2000 gal	N/A	N/A	Sanitary Sewer	N/A
Paulding County	Full and Quick Wash	15	60	15	high pressure	3	manufacturer	1,500 ga.			Storm Sewer	
Putnam County	Full and Quick Wash	30	120	30	3/8 hp 50'	4.0 gpm	tested 1/11/12	2000	0	2000	Sanitary Sewer	N/A
Van Wert County	Full and Quick Wash	60	120	20	2000 PSI	3.9 GPM	SPECTS	2900			Sanitary Sewer	N/A
Wyandot County	Full and Quick Wash	45	90	15	1"	10	time x gal.				Sanitary Sewer	N/A
-												
OUTPOST GARAGES												
Delphos	Full and Quick Wash	30	60	15	Pressure Wash	p=4gpm/F=	estimated	500			Sanitary Sewer	N/A
4th Street	Full and Quick Wash	30	60	15	Pressure Wash	P=4gpm	estimated	1000			Sanitary Sewer	N/A
Beaverdam	None	na	na	na	na	na						
Hicksville	None											
SR 12 Outpost	Quick Wash Only	7 min.	30 min.	7 min.	fire hose	10		n/a	n/a	n/a	Sanitary Sewer	N/A
Roundhead				do not wash at this facility								
Carey	None									2500	Holding Tank	

						Alternative Deicing Liquids	
	Is Brine Produced at this Location?	What Model of Brine Production Unit is Used?	Estimated Brine Production Rate	Brine Storage Volume	Are Liquids Other than Sodium Chloride Used for Pretreating?	Type	Storage Volume
COUNTY GARAGES	Select one		gallons per day	gallons	Select one		gallons
Allen County	Yes	Self Made	6000	18000	No	CACL	3000
Defiance County	Yes	Homemade	5000	6000	No	Liquid Calcium	9000
Hancock County	Yes	homemade brine maker	10,000	12,000	No		
Hardin County	Yes	ABS-1500 Brine System	2000	8000	No		
Paulding County	Yes	Homemade	375	15,500	No		
Putnam County	Yes	Homemade	12,100 gal	14,400 gal	No	Calcium Chlor	10,000 gal
Van Wert County	Yes	Homemade	9,000 TO 11,000	12000	No		
Wyandot County	Yes	made inhouse	20,000	32,700	No	Beet Heat	6100
-							
OUTPOST GARAGES							
Delphos	No			2000			
4th Street	No			3000			
Beaverdam	No			1500			
Hicksville	No						
SR 12 Outpost	No	n/a	n/a	3000	Yes	Liquid Calcium	3000
Roundhead	No						
Carey	No			9,000	No		

District 2

		Number of Trucks Used per Winter Event		Total Lane Miles (per garage or outpost)			
COUNTY GARAGES	Total Number of Dump Trucks	Low End Estimate	High End Estimate	Priority	General	Urban	Total
Fulton	10	8	10		290		290
Henry	10	4	10	65	324		389
Lucas	16	6	16	171	144	144	459
Ottawa	10	8	10	55	291	12	358
Sandusky	12	8	12	176	158	59	393
Seneca	14	8	14	157	85	168	410
Williams	14	12	14		373		373
Wood	21	11	19	259	389		648
							0
OUTPOST GARAGES							
Northwood	16	8	16	307			307
Edison	4	2	4				0

		Estimated Time to Conduct Full Wash of One Truck						Washwater Storage			Washwater Disposal	
	What type of Truck Washing is Conducted at this facility?	Low End Est.	High End Est.	Estimated Time to Conduct Quick Wash	Type of Hose	Flow Rate from Hose	How was Flow Rate Determined?	Total Oil Water Separator Capacity	Total Sand Trap Capacity	Total Other Storage Capacity	Method	If not using public sewer, estimated Cost for
COUNTY GARAGES	Select one	minutes	minutes	minutes		gpm		gallons	gallons	gallons	Select one	$/gallon
Fulton	Full and Quick Wash	30	45	20	Fire & pressure	2	meter	500			Storm Sewer	
Henry	Full and Quick Wash	10	20	5	pressure	4	5 gal. bucket	500			Sanitary Sewer	
Lucas	None	30	60	15							Leach Field or Mound	
Ottawa	Full and Quick Wash	45	30	20	High Pres.	5	Mnft.Label	2900			Sanitary Sewer	
Sandusky	Full and Quick Wash	8	15	5	High Pres.	4	Mnft.Label	n/a			Storm Sewer	
Seneca	Full and Quick Wash	8	15	5	High Pres.	4	Mnft.Label	2900			Storm Sewer	
Williams	Full and Quick Wash	30	45	20	High Pres.	10	Mnft.Label	2900			Other	.05 pg
Wood	Full and Quick Wash	15	30	5	High Pres.	5	5 gal. bucket	1500			Sanitary Sewer	
-												
OUTPOST GARAGES												
Northwood	Full and Quick Wash	30	60	15	High Pres.	2	Meter reading	500			Sanitary Sewer	
Edison	None										Leach Field or Mound	

						Alternative Deicing Liquids	
	Is Brine Produced at this Location?	What Model of Brine Production Unit is Used?	Estimated Brine Production Rate	Brine Storage Volume	Are Liquids Other than Sodium Chloride Used for Pretreating?	Type	Storage Volume
COUNTY GARAGES	Select one		gallons per day	gallons	Select one		gallons
Fulton	Yes	Snow Equipment	7000	12000	No		
Henry	Yes	Cargill Accubrine	20000	6000	No	Cal. Chlr.	8000
Lucas	No			6000	Yes	Cal. Chlr.	6000
Ottawa	Yes	Home made	10000	16000	Yes	Calc. Chlr.	8000
Sandusky	Yes	Snow Equipment	12000	10000	Yes	Calc. Chlr. & Geomelt	8000 calc. 6000 geo
Seneca	Yes	Snow Equipment	12000	20000	Yes	Calc. Chlr. & Geomelt	8000 cal.c 6000 geo
Williams	Yes	Snow Equipment	10000	6000	Yes	Cal. Chlr.	8000
Wood	Yes	Cargill Accubrine	24000	24400	No	Cal. Chlr. & Geomelt	8000 calc. 9000 geomelt
-							
OUTPOST GARAGES							
Northwood	Yes	Snow Equipment		10000	Yes	Cal. Chlr. & Geomelt	10000 calc. 10000 geomelt
Edison	No						

		Number of Trucks Used per Winter Event		Total Lane Miles (per garage or outpost)			
COUNTY GARAGES	Total Number of Dump Trucks	Low End Estimate	High End Estimate	Priority	General	Urban	Total
Ashland Co. Garage	16	10	14	247	161	136	544
Crawford	14	9	14	89.2	389.4		478.6
Norwalk	13	7	13	136.8	231.7	6.08	374.58
Erie County	12	4	12	189.66	117.29	0	306.95
Lorain County	12	8	12	7.2	376.4		383.6
Richland County	12	9	10	120.86	200.25	0	321.11
Wayne County	17	10	14	216.96	368.92		585.88
							0
							0
OUTPOST GARAGES							0
Perrysville	4	3	4		41	98	139
Nova	0	0	0	0	0	0	0
Plymouth	2	2	2	14	55		69
Vermilion	2	0	2	0	88.33	0	88.33
Avon	6	4	6	124.1	43.1		167.2
Lexington Outpost	8	7	8	182.87	73.13	0	256
							0

		Estimated Time to Conduct Full Wash of One Truck						Washwater Storage			Washwater Disposal	
	What type of Truck Washing is Conducted at this facility?	Low End Est.	High End Est.	Time to Conduct Quick Wash of one Truck	Type of Hose	Flow Rate from Hose	How was Flow Rate Determined?	Total Oil Water Separator Capacity	Total Sand Trap Capacity	Total Other Storage Capacity	Method	If not using public sewer, estimated Cost for disposal
COUNTY GARAGES	**Select one**	**minutes**	**minutes**	**minutes**		**gpm**		**gallons**	**gallons**	**gallons**	**Select one**	**$/gallon**
Ashland Co. Garage	Full and Quick Wash	10	20	5	fire hose	5	fac. Dept	2,000	n/a	n/a	Sanitary Sewer	N/A
Crawford	Full and Quick Wash	60	180	30	fire hose	15	flow rate test	600	0	400	Storm Sewer	
Norwalk	Full and Quick Wash	60	180	30	fire hose	20	flow rate test	1500	0	2500	Holding Tank	0.42
Erie County	Full and Quick Wash	60	90	20	Pressure/3/8	5	per directions	1000	NA	NA	Storm Sewer	NA
Lorain County	Full and Quick Wash	90	120	30	1 1/4 in	15 gal/min	bucket	1000 (in the wash facility bldg)	n/a	n/a	Sanitary Sewer	n/a
Richland County	Full and Quick Wash	15	45	10	Pressure	4	Manufactuer	1000			Storm Sewer	
Wayne County												
-												
-												
OUTPOST GARAGES												
Perrysville	None							250			Leach Field or Mou	$2.50
Nova	None							n/a	n/a		Other	No Plumbing
Plymouth	None											
Vermilion	Quick Wash Only			20	Garden 5/8"	1.66GPM	per directions	1000	NA	NA	Leach Field or Mou	$345per1000gal
Avon	Full and Quick Wash	90	120	30	3/4 in	15 gals/min	bucket	0	n/a	n/a	Sanitary Sewer	n/a
Lexington Outpost	Quick Wash Only			10	Pressure	4	Manufactuer	1000			Leach Field or Mou	

						Alternative Deicing Liquids	
	Is Brine Produced at this Location?	What Model of Brine Production Unit is Used?	Estimated Brine Production Rate	Brine Storage Volume	Are Liquids Other than Sodium Chloride Used for Pretreating?	Type	Storage Volume
COUNTY GARAGES	Select one		gallons per day	gallons	Select one		gallons
Ashland Co. Garage	Yes	Force America	n/a	12,200	No		
Crawford	Yes	Vari-tech	9000	9000	No	Calcuim	6000
Norwalk	Yes	unknown	6000	6000	No	Calcium	6000
Erie County	Yes	VariTech Industries	14,000	12,000	No	Liquid calcium chloride	6,000
Lorain County	Yes	Unknown	10000	14000	No	Calcium Chloride	5500
Richland County	Yes	Pengwyn	4000 as needed	12000	No	calcium	6000
Wayne County							
-							
-							
OUTPOST GARAGES							
Perrysville	No			6,100			
Nova	No						
Plymouth	No			6000	No		
Vermilion	No	NA		6,000	No	Liquid calcium chloride	6,000
Avon	Yes	Unknown	12200	12200	No	Calcium Chloride	6000
Lexington Outpost	No			12000	No	calcium	6000

Revision 3/1/2012		Number of Trucks Used per Winter Event		Total Lane Miles (per garage or outpost)			
COUNTY GARAGES	**Number of Dump**	**Low End Estimate**	**High End Estimate**	**Priority**	**General**	**Urban**	**Total**
ATB - Seven Hills	9	9	9				0
MAH - Canfield	9	6	9				0
PUR - Ravenna	11	9	11				0
STA - Canton	17	14	17				0
SUM - Boston Heights	10	6	10				0
TRU - Cortland	8	7	8				0
							0
							0
							0
OUTPOST GARAGES							
ATB - Conneaut	5	5	5				0
ATB - Dorset	4	3	4				0
ATB - Harpersfield	3	3	3				0
ATB - Rome	4	4	4				0
ATB - Williamsfield	4	3	4				0
MAH - Bailey Rd	4	3	4				0
MAH - North Lima	8	7	8				0
MAH - Sebring	2	2	2				0
PUR - Drakesburg	5	4	5				0
PUR - Rootstown	2	2	2				0
PUR - Yale	4	3	4				0
STA - Massillon	6	6	6				0
SUM - Greensburg	4	4	4				0
SUM - Interchange	7	6	7				0
SUM - Twinsburg	5	4	5				0
TRU - Brookfield	7	6	7				0
TRU - Farmington	4	2	4				0
TRU - Gustavus	6	4	6				0
TRU - Warren	5	4	5				0

		Estimated Time to Conduct Full Wash of One Truck						Washwater Storage			Washwater Disposal	
	What type of Truck Washing is Conducted at this facility?	Low End Est.	High End Est.	Estimated Time to Conduct Quick Wash	Type of Hose	Flow Rate from Hose	How was Flow Rate Determined ?	Total Oil Water Separator Capacity	Total Sand Trap Capacity	Total Other Storage Capacity	Method	If not using public sewer, estimated
COUNTY GARAGES	Only, Full and Quick	minutes	minutes	minutes		gpm		gallons	gallons	gallons		$/gallon
ATB - Seven Hills	Full and quick							3000			Sanitary Sewer	N/A
MAH - Canfield	Full and quick	20	60	10	1" water			3000			Sanitary Sewer	N/A
POR - Ravenna	Quick and full	20	50	10	garden/Fire	10	Bucket Test	N/A			Storm Sewer	N/A
STA - Canton	Full and quick	20	50	5	garden	10	bucket test	1500	0	0	Sanitary Sewer	N/A
SUM - Boston Heights	Full and quick							1500			Leach Field	N/A
TRU - Cortland	Full and quick	20	50	10	fire	10	bucket	1500			Sanitary Sewer	N/A
-												
-												
-												
OUTPOST GARAGES												
ATB - Conneaut								500			Sanitary Sewer	N/A
ATB - Dorset								500		3000	Holding Tank	0.55
ATB - Harpersfield								500			Sanitary Sewer	N/A
ATB - Home								500		6000	Holding Tank	0.55
ATB - Williamsfield								500			Leach Field	
MAH - Bailey Rd	Full and quick	20	60	41,039	1" hose			1000			Sanitary Sewer	N/A
MAH - North Lima	none							1000			Leach Field	
MAH - Sebring	none							1000			Leach Field	
POR - Drakesburg	Quick and full	20	50	10	garden	9	Bucket Test	500		3000	Holding Tank	0.55
POR - Rootstown	Quick only	N/A	N/A	10	Garden	11	Bucket Test	1500			Sanitary Sewer	N/A
POR - Yale	Quick only	N/A	N/A	10	Garden	6	Bucket Test	500			Leach Field	N/A
STA - Massillon	Full and quick	20	50	5	garden	10	bucket test	500 (estimate)	0	0	Sanitary Sewer	N/A
SUM - Greensburg								500			Sanitary Sewer	N/A
SUM - Interchange								1000			Leach Field	
SUM - Twinsburg								500			storm sewer	
TRU - Brookfield	quick only	10	10		fire	10	Bucket Test	500		3000	Holding Tank	0.55
TRU - Farmington	none							500			Leach Field	
TRU - Gustavus	none							500			Leach Field	
TRU - Warren	none							N/A			None	

						Alternative Deicing Liquids	
	Is Brine Produced at this Location?	What Model of Brine Production Unit is Used?	Estimated Brine Production Rate	Brine Storage Volume	Are Liquids Other than Sodium Chloride Used for Pretreating?	Type	Storage Volume
COUNTY GARAGES	Yes/No		day	gallons	Yes/No		gallons
ATB - Seven Hills	YES	Pengwyn PLC-3000SS-HYD		53000		Calcium Chloride	8000
MAH - Canfield	No			12,000 gl		Calcium Chloride	12,000 gl
POR - Ravenna	No			0			
STA - Canton	YES	Homemade	100,000 based on a 24 hour work day	100,000	no, just brine	calcium chloride	12,500
SUM - Boston Heights	YES	Pengwyn PLC-3000SS-HYD		30000		Calcium Chloride	6000
TRU - Cortland	YES	Homemade	1000 gal/hour	12,000		calcium chloride	12,000
-							
OUTPOST GARAGES							
ATB - Conneaut	No			6000		Calcium Chloride	6000
ATB - Dorset	No			6000		Calcium Chloride	6000
ATB - Harpersfield	No			6000		Calcium Chloride	6000
ATB - Rome	No			6000		Calcium Chloride	6000
ATB - Williamsfield	No			12000		Calcium Chloride	6000
MAH - Bailey Rd	YES	Pengwyn PLC-3000SS-HYD		40,000 gl		Calcium Chl./ Beet Juice	16,000/ 10,000
MAH - North Lima	No			12,000 gl		Calcium Chl.	12,000 gl.
MAH - Sebring	No			12,000 gl		Calcium Chl.	6,000 gl
POR - Drakesburg	No			6,000 gl		Calcium Chloide	12,000 gl
POR - Rootstown	YES	Homemade	30,000 gl/24 hr	63,000	just brine	Calcium Chl. or Beet	12,000 gl
POR - Yale	No			6,000		Calcium Chloride	6,000 gl
STA - Massillon	No			24000		Calcium Chloride	6000
SUM - Greensburg	YES	Homemade	2500 gal/hour	36000		Calcium Chloride	12000
SUM - Interchange	No			18000		Calcium Chloride	12000
SUM - Twinsburg	No			18000		Calcium Chloride	12000
TRU - Brookfield	No			6000		Calcium Chloride	6000
TRU - Farmington	No			0		Calcium Chloride	6000
TRU - Gustavus	No			0		Calcium Chloride	6000
TRU - Warren	No			0		Calcium Chloride	6000

COUNTY GARAGES	of Dump Trucks	Number of Trucks Used per Winter Event		Total Lane Miles (per garage or outpost)			
		Low End Estimate	High End Estimate	Priority	General	Urban	Total
Coshocton County	16	10	13	117.17	348.76		465.93
Fairfield County	15	12	14	107.6	294.88	66.86	469.34
Guernsey County	12	7	17	118	180	17	315
Knox County	13	8	12	155.6	183.8		339.4
Licking County							0
Muskingum County	11	6	11	109.748	195.492	29.758	334.998
Perry County	15	10	12		379.02		379.02
OUTPOST GARAGES							
COS - New Castle	0						0
FAI -Baltimore							0
GUE - North Salem	5	3	6	47	89	0	136
GUE -Old Washington	6	3	6	42	118	0	160
KNO -Fredericktown	2	1	2		68		68
KNO -Newcastle in with Main NO Water							0
MUS -158- Dresden	5	2	5	44.872	89.582	3.56	138.014
MUS -160- Moxahala	3	1	3		58.614	5.74	64.354
MUS -161- Duncan Falls	5	2	5		135.474	2.48	137.954
LIC -Etna	7	5	6	168.1	60.6		228.7
LIC -Brownsville	5	3	4	163.5	49.22		212.72
LIC -Utica	6	4	5	154.2	109.82		264.02
LIC -Marne (Salt Reload Only)							0
DISTRICT TOTAL	**108**			**742**	**2,141**	**125**	

		Estimated Time to Conduct Full Wash of One Truck						Washwater Storage			Washwater Disposal	
COUNTY GARAGES	What type of Truck Washing is Conducted at this facility? Select one	Low End Est. minutes	High End Est. minutes	Estimated Time to Conduct Quick Wash minutes	Type of Hose	Flow Rate from Hose gpm	How was Flow Rate Determined ?	Total Oil Water Separator Capacity gallons	Total Sand Trap Capacity gallons	Total Other Storage Capacity gallons	Method Select one	If not using public sewer, estimated $/gallon
Coshocton County	Wash	30	60	20	Fire	6	Timed	2000	0	0	Holding Tank	0.292
Fairfield County	Full and Quick Was	40	60	20	Power Wash	6	PW Rating	2900	655		Sanitary Sewer	N/A
Guernsey County	Full and Quick Wash	25	45	15	Pressure Washer	4	Pressure Washer	2900	655	0	Sanitary Sewer	
Knox County	Full and Quick Was	45	70	10	Fire Hose/Rinse	12	Timed@ 5min	2000			Sanitary Sewer	N/A
Licking County	Full and Quick Wash	5	30		Pressure Washer	3	On Machine	2500	1000		Other	
Muskingum County	Wash	45	75	10		4		unknown	unknown		Storm Sewer	
Perry County	Full and Quick Was	40	60	20	1.5" Rubber	12	6 gal 30 sec	2000	500		Sanitary Sewer	N/A
OUTPOST GARAGES												
COS - New Castle												
FAI -Baltimore	Wash	40	60	20	Power wash	8	PW Rating	2000	500		Sanitary Sewer	N/A
GUE - North Salem	Quick Wash Only			10	Garden Hose	3	Timed					
GUE -Old Washington	Quick Wash Only			10	Garden Hose	3	Timed					
KNO -Fredericktown	Quick Wash Only			10	Pressure	5	Timed@ 5min.	None	None	None		
Water												
MUS -158- Dresden	Quick Wash Only			10	pressure washer	3	stated on machine	none	none	none		
MUS -160- Moxahala	Quick Wash Only			10	pressure washer	2	stated on machine	none	none	none		
MUS -161- Duncan Falls	Full and Quick Wash	45	75	10	pressure washer	3	stated on machine	unknown	unknown	none	Leach Field or Mound	
LIC -Etna	Quick Wash Only			10	Garden or S	3	On Machine				Sanitary Sewer	
LIC -Brownsville	Quick Wash Only			10	Garden or Small Pressure washer	3	On Machine				Leach Field or Mound	
LIC -Utica	Quick Wash Only			10	Garden or Pressure washer	4	On Machine				Other	

						Alternative Deicing Liquids	
	Is Brine Produced at this Location?	What Model of Brine Production Unit is Used?	Estimated Brine Production Rate	Brine Storage Volume	Are Liquids Other than Sodium Chloride Used for Pretreating?	Type	Storage Volume
COUNTY GARAGES	Select one		gallons per day	gallons	Select one		gallons
Coshocton County	Yes	Pengwyn System	455	10,000	No	Liquid calcium	5000
Fairfield County	Yes	Pengwyn	20,000	10,000	No	Calcium	5,000
Guernsey County	Yes	Pengwyn	16,000	7900	Yes	Calcium	2600
Knox County	Yes	Penguin	6000	6000	No	Calcium	1500
Licking County							
Muskingum County	Yes	Penqwin	10000	16000	Yes	Calcium Chloride	5000
Perry County	Yes	Pengwyn	13,000	6,500	No	Calcium	5,100
OUTPOST GARAGES							
COS - New Castle							
FAI -Baltimore	No			5,000	No		
GUE - North Salem	Yes	Pengwyn	5000	6100	Yes	Calcium	1550
GUE -Old Washington	Yes	Pengwyn	5000	5500	Yes	Calcium	2600
KNO -Fredericktown	No			3000			
KNO -Newcastle in with Main NO Water	No			2000			
MUS -158- Dresden	Yes	Home made	5000	2500	No		
MUS -160- Moxahala	No			1800	No		
MUS -161- Duncan Falls	Yes	Penqwin	6000	5000	No		

		Number of Trucks Used per Winter Event		Total Lane Miles (per garage or outpost)			
COUNTY GARAGES	**Total Number of Dump Trucks**	**Low End Estimate**	**High End Estimate**	**Priority**	**General**	**Urban**	**Total**
D6/DEL	11	2	10	85.88	210.66		296.54
D6/FAY/Wash CH	7	2	6	96.82	116.88		213.7
D6/FRA/Westerville	13	6	12	465.8			465.8
D6/MAD/London	8	4	7	95	133		228
D6/MAR	14	9	14	202	232	0	434
D6/MRW/Mt. Gilead	10	7	10	140.62	183.19		323.81
D6/PIC	15	4	11	238		200	438
D6/UNI/Marysville	10	6	10	174	108.22		282.22
							0
OUTPOST GARAGES							0
D6/DEL/Berkshire	9	2	8	163	96.2		259.2
D6/FAY/Jeffersonville	6	2	5	97.64	149.64		247.28
D6/FRA/5th Ave	15	7	12	541.6			541.6
D6/FRA/Hilliard	13	6	12	283.9	16		299.9
D6/FRA/Grove City	13	5	10	142.7	62.64		205.34
D6/MAD/Mt Sterling	6	3	6	55	118		173
D6/MAD/West Jeff	6	3	5	91	121		212
D6/MRW/Chesterville	4	2	4	80.5	4.23		84.73
D6/UNI/Richwood	6	3	6	40.24	136.66		176.9

COUNTY GARAGES	What type of Truck Washing is Conducted at this facility? Select one	Low End Est. minutes	High End Est. minutes	Time to Conduct Quick Wash of one Truck minutes	Type of Hose	Flow Rate from Hose gpm	How was Flow Rate Determined?	Total Oil Water Separator Capacity gallons	Total Sand Trap Capacity gallons	Total Other Storage Capacity gallons	Method Select one	If not using public sewer, estimated Cost for disposal $/gallon
D6/DEL	Full and Quick Wash	45	75	15	2" fire, 3/4"	9	5 gallon bucket	4394	0	0	Sanitary Sewer	N/A
D6/FAY/Wash CH	Full and Quick Wash	30	60	15	high press.low		nozzle size used	500			Holding Tank	
D6/FRA/Westerville	Full and Quick Wash	8	20	5	Pressure	5		1500			Storm Sewer	
D6/MAD/London	Full and Quick Wash	45	60	20	High Pressu	3	5 gal bucket	1800	0	0	Leach Field or Mou	0
D6/MAR	Full and Quick Wash	60	90	10	garden hose	4	on machine	2000	n/a	n/a	Sanitary Sewer	N/A
D6/MRW/Mt. Gilead	Full and Quick Wash	60	90	10	pressure. Fir	4gpm.\8.5gp	measuring.	3837	?	0	Sanitary Sewer	N/A
D6/PIC	Full and Quick Wash	60	90	15	HP/Fire	8.5 /20	As in example	1250	NA		Sanitary Sewer	N/A
D6/UNI/Marysville	Full and Quick Wash	20	30	15	Pressure Wa	4	Measured				Storm Sewer	
-												
OUTPOST GARAGES												
D6/DEL/Berkshire	Full and Quick Wash	45	75	15	3/4" garden,	4	5 gallon bucket	500	0	0	Sanitary Sewer	N/A
D6/FAY/Jeffersonville	Full and Quick Wash	30	60	15	high press.& low		nozzle size used				Storm Sewer	
D6/FRA/5th Ave	Full and Quick Wash	8	20	5	Pressure	5		1500			Storm Sewer	
D6/FRA/Hilliard	Full and Quick Wash	8	20	5	Pressure	5		1500			Storm Sewer	
D6/FRA/Grove City	Full and Quick Wash	8	20	5	Pressure	5		1500			Storm Sewer	
D6/MAD/Mt Sterling	Full and Quick Wash	45	60	20	Fire Hose	7	5 gal bucket	0	0	0	Storm Sewer	0.01
D6/MAD/West Jeff	Full and Quick Wash	45	60	20	High Pressu	3	5 gal bucket	1000	0	0	Leach Field or Mou	0
D6/MRW/Chesterville	Full and Quick Wash	60	90	10	pressure. Ga	4gpm\6gpm	measuring.	150	?	0	Sanitary Sewer	N/A
D6/UNI/Richwood	Full and Quick Wash	20	30	15	Pressure washer		Measured				Leach Field or Mou	

						Alternative Deicing Liquids	
	Is Brine Produced at this Location?	What Model of Brine Production Unit is Used?	Estimated Brine Production Rate	Brine Storage Volume	Are Liquids Other than Sodium Chloride Used for Pretreating?	Type	Storage Volume
COUNTY GARAGES	Select one		gallons per day	gallons	Select one		gallons
D6/DEL	Yes	Pengyn	6000	9000	No	0	0
D6/FAY/Wash CH	Yes	ABM3000-SS	5500	5500	No	GEOMELT	5500
D6/FRA/Westerville	Yes	Pengwyn	10000	25000	Yes	Geomelt	5000
D6/MAD/London	Yes	Pengwyn	5000	8500	No	Calcium	3500
D6/MAR	Yes	veri tech	12000	12000	Yes	geo melt	6000
D6/MRW/Mt. Gilead	Yes	Pengwyn	24000	18000	No	calcium chloride	5000
D6/PIC	Yes	Pengyn	6400 Gal/Day	5500	Yes	Geo/Calcium	16500
D6/UNI/Marysville	Yes	Pengwyn	10000	14500	No	None	
-							
OUTPOST GARAGES							
D6/DEL/Berkshire	Yes	Pengyn	6000	9000	Yes	Calcium	6000
D6/FAY/Jeffersonville	Yes	ABM3000-SS	5500	5500	No	GEOMELT	5500
D6/FRA/5th Ave	Yes	Pengwyn	10000	20000	Yes	Geomelt	5000
D6/FRA/Hilliard	Yes	Pengwyn	10000	15000	Yes	Geomelt	5000
D6/FRA/Grove City	Yes	Pengwyn	10000	5000	Yes	Geomelt	5000
D6/MAD/Mt Sterling	No		0	5500	Yes	Calcium/ Geomelt	3000/5500
D6/MAD/West Jeff	Yes	Pengwyn	5000	5500	No	Calcium	3500
D6/MRW/Chesterville	No			12000	No		
D6/UNI/Richwood	No			4500	No	None	

		Number of Trucks Used per Winter Event		Total Lane Miles (per garage or outpost)			
COUNTY GARAGES	of Dump Trucks	Low End Estimate	High End Estimate	Priority	General	Urban	Total
Auglaize County - Wapakoneta	17	12	17	136	303		439
Champaign County -Urbana	10	4	9	18.2	269		287.2
Clark County- Springfield Garage	9	4	9	115.57	41.97		157.54
Darke County - Greenville Garage	14	9	14	116.8	263.6		380.4
Logan County - Bellefontaine	10	7	10	59.8	203.44		263.24
Mercer County - Celina	10	6	10	46	132.72		178.72
Miami County - Troy	12	8	11	87.36	234.86		322.22
Montgomery County - Hoke Rd	11	6	10	220.5	21.6		242.1
Shelby County - Sidney	14	10	14	87.96	285.72		373.68
OUTPOST GARAGES							
CHP -Mechanicsburg	3	2	3		89.42		89.42
CHP -Saint Paris	2	1	2		55.88		55.88
CLA -Harmony	4	2	4	76.38	159.62		236
CLA -Enon	5	2	5	94.26	48.6		142.86
DAR - Dawn	5	3	5	16	143.6		159.6
LOG - Lakeview	3	3	3	22	116.3		138.3
LOG - East Liberty	5	3	5	48.8	86.92		135.72
MER - Mercer	3	2	3	71.96	44		115.96
MER -Cassella	3	2	3	14	120		134
MIA - Piqua	5	3	4	77.59	49.88		127.47
MOT - Lyons Road	10	5	8	191.64	0		191.64
SHE - Newport	0	0	0	0	0		0
SHE - Dixie	0	0	0	0	0		0

		Estimated Time to Conduct Full Wash of One Truck						Washwater Storage			Washwater Disposal	
	What type of Truck Washing is Conducted at this facility?	Low End Est.	High End Est.	Estimated Time to Conduct Quick Wash	Type of Hose	Flow Rate from Hose	How was Flow Rate Determined ?	Total Oil Water Separator Capacity	Total Sand Trap Capacity	Total Other Storage Capacity	Method	If not using public sewer, estimated
COUNTY GARAGES	**Select one**	**minutes**	**minutes**	**minutes**		**gpm**		**gallons**	**gallons**	**gallons**	**Select one**	**$/gallon**
Auglaize County - Wapakoneta	Full and Quick Wash	30	60	20	Power Wash	4	unit spec.	1500	200		Sanitary Sewer	N/A
Champaign County -Urbana	Full and Quick Wash	30	60	20	Power Wash	5	Bucket Test	3000			Sanitary Sewer	
Clark County- Springfield Garage	Full and Quick Wash	30	50	25	Fire hose	14	Bucket Test	1200			Sanitary Sewer	N/A
Darke County - Greenville Garage	Full and Quick Wash	45	60	30	5/8" hose	5	Bucket Test	1500			Sanitary Sewer	N/A
Logan County - Bellefontaine	Full and Quick Wash	30	60	20	Fire hose	8	Bucket Test	1500			Sanitary Sewer	N/A
Mercer County - Celina	Full and Quick Wash	30	60	20	Fire hose	8	Bucket Test	1500			Sanitary Sewer	N/A
Miami County - Troy	Full and Quick Wash	30	90	10	1" copper to rubbe	25 gpm	Bucket Test	3000	None	None	Sanitary Sewer	N/A
Montgomery County - Hoke Rd	Full and Quick Wash	10	20	10	Power wash	3	Bucket Test	3000	1000	4000	Sanitary Sewer	N/A
Shelby County - Sidney	Full and Quick Wash	90	120	60	Power wash	3	Bucket Test	3000	0	0	Holding Tank	
OUTPOST GARAGES												
CHP -Mechanicsburg	Full and Quick Wash	30	60	20	Power wash	2	Bucket Test	500		2500	Holding Tank	$0.11
					Fire hose	10	Bucket Test	50				
CHP -Saint Paris	Full and Quick Wash	30	60	20	Power wash	2	Bucket Test	500		2500	Holding Tank	$0.11
					Fire hose	10	Bucket Test	50				
CLA -Harmony	Full and Quick Wash	45	80		Garden hose	4	Bucket Test			1200	Holding Tank	0.38
CLA -Enon	Full and Quick Wash	45	80		Garden hose	4	Bucket Test			1200	Holding Tank	0.38
DAR - Dawn	Full and Quick Wash	45	60	30	5/8" hose	5	Bucket Test	500		2500	Sanitary Sewer	N/A
LOG - Lakeview	Quick Wash Only	60	120	60	Garden hose	5	Bucket Test	500			Holding Tank	
LOG - East Liberty	Quick Wash Only	60	120	60	Garden hose	5	Bucket Test	500			Holding Tank	
MER - Mercer	Full and Quick Wash	30	60	20	Fire hose		Bucket Test	500			Holding Tank	
MER -Cassella	Full and Quick Wash	30	60	20	Fire hose		Bucket Test	500			Holding Tank	
MIA - Piqua	Full and Quick Wash	30	90	10	3/4" garden	10 gpm	Bucket Test	None	None	None	Sanitary Sewer	N/A
MOT - Lyons Road	Full and Quick Wash	10	20	10	Power wash	3	Bucket Test	500	600	1100	Sanitary Sewer	N/A
				10	1.5" hose	10	Bucket Test					
SHE - Newport	None											
SHE - Dixie	None											

						Alternative Deicing Liquids	
	Is Brine Produced at this Location?	What Model of Brine Production Unit is Used?	Estimated Brine Production Rate	Brine Storage Volume	than Sodium Chloride Used for Pretreating?	Type	Storage Volume
COUNTY GARAGES	Select one		gallons per day	gallons	Select one		gallons
Auglaize County - Wapakoneta	Yes	Varitech Industries	3000	6500	No	Calcium	6000
Champaign County -Urbana	Yes	Varitech Industries		6000	No	Calcium	6000
Clark County- Springfield Garage	Yes	Varitech Industries		12000	No	Calcium	6000
Darke County - Greenville Garage	Yes	Varitech Industries	6000	6000	No	Calcium	6000
Logan County - Bellefontaine	Yes	Varitech Industries	3000	12,000	No	Calcium	6000
Mercer County - Celina	Yes	Varitech Industries	3000	6000	No	Calcium	6000
Miami County - Troy	Yes	Varitech Industries	4500	12000	No	Calcium	6000
Montgomery County - Hoke Rd	Yes	Varitech SB600	6000	6000	Yes	Beet Heet	6000
Shelby County - Sidney	Yes	Varitech Industries	400	6000	No	Calcium	6000
OUTPOST GARAGES							
CHP -Mechanicsburg	No			6000	No	Calcium	3000
CHP -Saint Paris	No			6000	No	Calcium	3000
CLA -Harmony	No			6000	No	Calcium	6000
CLA -Enon	No			6000	No	Calcium	6000
DAR - Dawn	No			6000	No	Calcium	3000
LOG - Lakeview	No			3,000	No		
LOG - East Liberty	No			6,000	No		
MER - Mercer	No			6000	No		
MER -Cassella	No			6000	No		
MIA - Piqua	No			6000	No	Calcium	6000
MOT - Lyons Road	Yes	Varitech SB600	6000	5800	Yes	Beet Heet	6000
SHE - Newport	No			3000	No	Calcium	3000
SHE - Dixie	No			6000	No	Calcium	3000

District 8

COUNTY GARAGES	Total Number of Dump Trucks	Number of Trucks Used per Winter Event		Total Lane Miles (per garage or outpost)			
		Low End Estimate	High End Estimate	Priority	General	Urban	Total
Butler	15	8	14	68	278		346
Clermont County Garage	12	5	12	79.42	135.62	91.96	307
Clinton Main Garage	12	10	12	151	209		360
Warren	14	4	14	300	83		383
Greene	14	7	14	246	188		434
Hamilton County	18	9	15	299			299
							0
							0
							0
OUTPOST GARAGES							0
Middletown	3	2	3	6	70		76
Milford Outpost	8	3	8	101.2	158.76		259.96
New Richmond Outpost	7	3	7	67.42	177.22		244.64
68.O.P	5			104	14		118
Monroe	10	4	10	183			183
Huffman Dam	3	1	3	80			80
Blue Ash Outpost	9	5	9	243			243
Miamitown Outpost	8	4	8	276			276

		Estimated Time to Conduct Full Wash of One Truck						Washwater Storage			Washwater Disposal	
COUNTY GARAGES	What type of Truck Washing is Conducted at this facility? Select one	Low End Est. minutes	High End Est. minutes	Estimated Time to Conduct Quick Wash minutes	Type of Hose	Flow Rate from Hose gpm	How was Flow Rate Determined?	Total Oil Water Separator Capacity gallons	Total Sand Trap Capacity gallons	Total Other Storage Capacity gallons	Method Select one	If not using public sewer, estimated Cost for $/gallon
Butler	Full and Quick Wash	30	45	15	garden	5	5 gallon bucket	3000	n/a	n/a	Sanitary Sewer	N/A
Clermont County Garage	Full and Quick Wash	30	60	15	3/4"	8	5 gal bucket	1500		1500	Sanitary Sewer	
Clinton Main Garage	Full and Quick Wash	30	60	15	3/4"	10	5 Gal Bucket	1,500			Sanitary Sewer	
Warren	Full and Quick Wash	15	30	5	Pr washer	5	gallons per min	500	0	0	Sanitary Sewer	
Greene	Full and Quick Wash	10	15	5	1 inch	10	bucket	1500			Sanitary Sewer	N/A
-												
-												
-												
OUTPOST GARAGES												
Middletown	Full and Quick Wash	30	45	15	garden	5	5 gallon bucket	n/a	n/a	n/a	Leach Field or Mo	$525
Milford Outpost	Full and Quick Wash	30	60	15	2"	10	5 gal bucket	1000		1000	Sanitary Sewer	
New Richmond Outpost	Full and Quick Wash	30	60	15	2"	10	5 gal bucket				Sanitary Sewer	
68.O.P	Full and Quick Wash	30	60	15	3/4 "	10	5 Gal Bucket	1500			Storm Sewer	
Monroe	Full and Quick Wash	15	30	5	PR washer	5	gallons per min	300	0	0	Sanitary Sewer	
Huffman Dam	Full and Quick Wash	10	15	5	1 inch	12	bucket	1500			Sanitary Sewer	N/A
Blue Ash Outpost												
Miamitown Outpost												

						Alternative Deicing Liquids	
	Is Brine Produced at this Location?	What Model of Brine Production Unit is Used?	Estimated Brine Production Rate	Brine Storage Volume	than Sodium Chloride Used for Pretreating?	Type	Storage Volume
COUNTY GARAGES	Select one		gallons per day	gallons	Select one		gallons
Butler	Yes	Pengwyn ABM 3000	5000	5000	No	liguid calcium	5000
Clermont County Garage	Yes	Pengwyn	8000	5000	Yes	Calcium Chloride	5000
Clinton Main Garage	No				No	L.Dow	10,000
Warren	Yes	Pengwyn ABM-3000-SS	10000	6000	No	Calcium chloride	5800
Greene		Pengyun	5000	11,000	No	liquid calcium	11,600
-							
-							
-							
-							
OUTPOST GARAGES							
Middletown	No	n/a	n/a	5000	No	liquid calcium	5000
Milford Outpost	No			5000	Yes	Calcium Chloride	5000
New Richmond Outpost	No			5000	Yes	Calcium Chloride	5000
68.O.P	Yes	Snow Equipment	1,350	5000	No	L. Dow	10,000
Monroe	No	none	0	6000	No	Caclium chloride	6000
Huffman Dam						Liquid calcium	5800
Blue Ash Outpost							
Miamitown Outpost							

District 9

		Number of Trucks Used per Winter Event		Total Lane Miles (per garage or outpost)			
COUNTY GARAGES	Total Number of Dump Trucks	Low End Estimate	High End Estimate	Priority	General	Urban	Total
Adams	10	0	10	99.4	381.36		480.76
Brown	10	0	13	111.16	361.66		472.82
Highland	15	0	15	1.56	497.58	23.48	522.62
Jackson	14	0	14	205.68	208.52	27.58	441.78
Lawrence	7	0	12	100.78	322.57	3.04	426.39
Pike	12	0	12	160.14	221.84		381.98
Ross	18	0	18	214.02	344.73	27.94	586.69
Scioto	9	0	13	96.8	345.17	40.07	482.04
							0
OUTPOST GARAGES							
Peebles	3	0	3				0
Whiteoak	3	0	3				0
Wilgus	2	0	2				0
Proctorville	3	0	3				0
Wheelersburg	4	0	4				0

		Estimated Time to Conduct Full Wash of One Truck						Washwater Storage			Washwater Disposal	
	What type of Truck Washing is Conducted at this facility?	Low End Est.	High End Est.	Estimated Time to Conduct Quick Wash	Type of Hose	Flow Rate from Hose	How was Flow Rate Determined ?	Total Oil Water Separator Capacity	Total Sand Trap Capacity	Total Other Storage Capacity	Method	If not using public sewer, estimated
COUNTY GARAGES	Select one	minutes	minutes	minutes		gpm		gallons	gallons	gallons	Select one	$/gallon
Adams	Full and Quick Wash	30	60	30	3/4 in garden	10 gpm	Timer/Measured	600	N/A	N/A	Sanitary Sewer	N/A
Brown	Full and Quick Wash	30	60	30	Pressure	12 gpm	Estimated	1000	N/A	N/A	Sanitary Sewer	N/A
Highland	Full and Quick Wash	60	120	45	3/4 in hose & Pressure	10 gpm	Timer/Measured	1000	N/A	N/A	Sanitary Sewer	N/A
Jackson	Full and Quick Wash	45	90	30	1 in fire hose	12 gpm	Estimated	2500	N/A	N/A	Sanitary Sewer	N/A
Lawrence	Full and Quick Wash	45	90	20	Steam cleaner & 2 in fire hose	12 gpm	Estimated	1500	N/A	N/A	Sanitary Sewer	N/A
Pike	Full and Quick Wash	60	120	45	3/4 in low & Pressure	10 gpm	Timer/Measured	1000	N/A	N/A	Sanitary Sewer	N/A
Ross	Full and Quick Wash	30	60	30	1 in fire hose & Pressure	12 gpm	Estimated	1000	N/A	N/A	Sanitary Sewer	N/A
Scioto	Full and Quick Wash	45	90	20	5/8 garden hose & pressure	10 gpm	Estimated	3000	N/A	N/A	Sanitary Sewer	N/A
-												
OUTPOST GARAGES												
Peebles	Quick Wash Only	30	60	30	Pressure	4 gpm	Estimated	500	N/A	N/A	Sanitary Sewer	N/A
Whiteoak	Quick Wash Only	30	60	30	Pressure	4 gpm	Estimated	500	N/A	N/A	Leach Field or Mound	N/A
Wilgus	Quick Wash Only	45	90	20	Power Washer	4 gpm	Estimated	N/A	N/A	N/A	Other	N/A
Proctorville	Quick Wash Only	45	90	20	Power Washer	4 gpm	Estimated	500	N/A	N/A	Sanitary Sewer	N/A
Wheelersburg	Quick Wash Only	30	60	20	Pressure	4 gpm	Estimated	600	N/A	N/A	Leach Field or Mound	N/A

						Alternative Deicing Liquids	
	Is Brine Produced at this Location?	What Model of Brine Production Unit is Used?	Estimated Brine Production Rate	Brine Storage Volume	Are Liquids Other than Sodium Chloride Used for Pretreating?	Type	Storage Volume
COUNTY GARAGES	Select one		gallons per day	gallons	Select one		gallons
Adams	No	N/A	N/A	N/A	Yes	Calcium Chlor	8000
Brown	No	N/A	N/A	6000	Yes	Calcium Chlor	12000
Highland	No	N/A	N/A	N/A	Yes	Calcium Chlor	8000
Jackson	Yes	Pengwyn	5000	10000	Yes	Calcium Chlor	25000
Lawrence	Yes	Pengwyn ABM-3000-SS	5000	12200	Yes	Calcium Chlor	2000
Pike	Yes	VariTech VAR SB600	5000	5500	Yes	Calcium Chlor	12000
Ross	Yes	Pengwyn ABM-3000-SS	12000	10000	Yes	Calcium Chlor	10000
Scioto	Yes	Pengwyn ABM-3000-SS	375 gal per hour	5500	Yes	Calcium Chlor	4400
-							
OUTPOST GARAGES							
Peebles	Yes	Pengwyn ABM-3000-SS	10000	12000	Yes	Calcium Chlor	4000
Whiteoak	No	N/A			Yes	Calcium Chlor	4000
Wilgus	No	N/A			Yes	Calcium Chlor	1000
Proctorville	No	N/A			Yes	Calcium Chlor	2000
Wheelersburg	No	N/A			Yes	Calcium Chlor	4400

District 10

		Number of Trucks Used per Winter Event		Total Lane Miles (per garage or outpost)			
COUNTY GARAGES	Total Number of Dump Trucks	Low End Estimate	High End Estimate	Priority	General	Urban	Total
ATH	10	7	10	137	191	24	352
GAL	13	7	13	71	368	0	439
HOC	12	6	12	63	257	9	329
MEG	12	9	12	67	355	0	422
MOE	10	8	10	0	401	0	401
MRG	12	4	12	0	377	0	377
NOB	11	5	11	0	380	0	380
VIN	8	5	8	0	258	0	258
WAS	13	8	13	72	235	41	348
OUTPOST GARAGES							
Hollister Outpost Garage (ATHPNO)	2	1	2	0	78	0	78
Laurelville Outpost Garage (HOCPSW)	1	1	1	0	41	0	41
Tuppers Plains Outpost (MEGPNE)	3	1	3	65	36	0	101
Duffy Outpost Garage (MOEPSE)	2	1	2	0	32	0	32
Belle Valley Outpost Garage (NOBPWE)	4	2	4	76	14	0	90
Wilkesville Outpost Garage (VINPSE)	2	2	2	31	42	0	73
Bartlett Outpost Garage (WASPWE)	3	2	3	0	97	0	97
Belpre Outpost Garage (WASPSW)	5	3	5	32	74	4	110
Macksburg Outpost Garage (WASPNO)	3	2	3	55	34	0	89

		Estimated Time to Conduct Full Wash of One Truck						Washwater Storage			Washwater Disposal	
	What type of Truck Washing is Conducted at this facility?	Low End Est.	High End Est.	Time to Conduct Quick Wash of one Truck	Type of Hose	Flow Rate from Hose	How was Flow Rate Determined?	Total Oil Water Separator Capacity	Total Sand Trap Capacity	Total Other Storage Capacity	Method	If not using public sewer, estimated Cost for disposal
COUNTY GARAGES	Select one	minutes	minutes	minutes		gpm		gallons	gallons	gallons	Select one	$/gallon
ATH	Full and Quick Wash	15	25	5	1/2"	4	Per Your Instructions	1100	250	0	Sanitary Sewer	N/A
GAL	Full and Quick Wash	60	180	20	1"	5	Per Your Instructions	1100	1000	0	Sanitary Sewer	N/A
HOC	Full and Quick Wash	45	75	20	1 1/2"	65	Per Your Instructions	1500	750	0	Sanitary Sewer	N/A
MEG	Full and Quick Wash	60	120	45	5/8"	8	Per Your Instructions	1500	1250	10000	Leach Field or Mound	
MOE	Full and Quick Wash	30	60	20	2"	15	Per Your Instructions	2000	750	0	Sanitary Sewer	N/A
MRG	Full and Quick Wash	45	60	20	3/4"	4	Per Your Instructions	1500	1000	10000	Holding Tank	
NOB	Full and Quick Wash	30	60	10	1 1/4"	60	Per Your Instructions	1100	100	10000	Holding Tank	
VIN	Full and Quick Wash	15	30	10	3/4"	4	Per Your Instructions	3000	600	10000	Holding Tank	
WAS	Full and Quick Wash	20	60	15	1 1/2"	65	Per Your Instructions	1500	750	0	Sanitary Sewer	N/A
OUTPOST GARAGES												
Hollister Outpost Garage (ATHPNO)	Full and Quick Wash	15	25	5	1/2"	4	Per Your Instructions	1500	100	0	Leach Field or Mound	
Laurelville Outpost Garage (HOCPSW)	Full and Quick Wash	45	75	20	1/2 "	4	Per Your Instructions		0	0		
Tuppers Plains Outpost (MEGPNE)	Full and Quick Wash	15	25	5	1/2"	4	Per Your Instructions	300	0	0	Sanitary Sewer	N/A
Duffy Outpost Garage (MOEPSE)	Full and Quick Wash	30	60	20	1/2"	5	Per Your Instructions	1500	100	0	Sanitary Sewer	N/A
Belle Valley Outpost Garage (NOBPWE)	Full and Quick Wash	30	60	10	5/8"	8	Per Your Instructions	1500	100	0	Leach Field or Mound	
Wilkesville Outpost Garage (VINPSE)	None						Per Your Instructions			0		
Bartlett Outpost Garage (WASPWE)	Full and Quick Wash	20	60	15	5/8"	4	Per Your Instructions	1500	100	0	Leach Field or Mound	
Belpre Outpost Garage (WASPSW)	Quick Wash Only			15	5/8"	4	Per Your Instructions	500	0	0	Sanitary Sewer	N/A
Macksburg Outpost Garage (WASPNO)	Full and Quick Wash	20	60	15	5/8"	4	Per Your Instructions	1500	250	0	Leach Field or Mound	

						Alternative Deicing Liquids	
	Is Brine Produced at this Location?	What Model of Brine Production Unit is Used?	Estimated Brine Production Rate	Brine Storage Volume	Are Liquids Other than Sodium Chloride Used for Pretreating?	Type	Storage Volume
COUNTY GARAGES	Select one		gallons per day (year round)	gallons	Select one		gallons
ATH	Yes	ABS - 1500	273.23	11000	No	Liquid Calcium Chloride	2600
GAL	Yes	02 Etnyre	47.65	11000	No	Liquid Calcium Chloride	5000
HOC	Yes	02 Etnyre	157.59	5000	No	Liquid Calcium Chloride	5000
MEG	Yes	Veritech / SB 1400	145.35	18000	No	Liquid Calcium Chloride	6000
MOE	Yes	Veritech / HCSB-1400-	170.72	19800	No	Liquid Calcium Chloride	5000
MRG	Yes	ABS - 1500	216.98	16000	No	Liquid Calcium Chloride	5000
NOB	Yes	Veritech / SB 600	126.27	5300	No	Liquid Calcium Chloride	5000
VIN	Yes	Veritech / HCSB 1400 SS	133.16	12000	No	Liquid Calcium Chloride	6000
WAS	Yes	ABS - 1500	208.28	13000	No	Liquid Calcium Chloride	5000
OUTPOST GARAGES							
Hollister Outpost Garage (ATHPNO)	No	N/A	0	0	No	Liquid Calcium Chloride	2500
Laurelville Outpost Garage (HOCPSW)	No	N/A	0	5000	No	None	
Tuppers Plains Outpost (MEGPNE)	No	N/A	0	1800	No	Liquid Calcium Chloride	1500
Duffy Outpost Garage (MOEPSE)	No	N/A	0	6000	No	None	
Belle Valley Outpost Garage (NOBPWE)	No	N/A	0	0	No	Liquid Calcium Chloride	5000
Wilkesville Outpost Garage (VINPSE)	No	N/A	0	6000	No	None	
Bartlett Outpost Garage (WASPWE)	No	N/A	0	0	No	Liquid Calcium Chloride	2000
Belpre Outpost Garage (WASPSW)	No	N/A	0	0	No	Liquid Calcium Chloride	10000
Macksburg Outpost Garage (WASPNO)	No	N/A	0	0	No	Liquid Calcium Chloride	5000

DISTRICT 11		Number of Trucks Used per Winter Event		Total Lane Miles (per garage or outpost)			
COUNTY GARAGES	Total Number of Dump	Low End Estimate	High End Estimate	Priority	General	Urban	Total
Belmont County - Morristown Garage	12	6	12	116	219		335
Carroll County Garage	13	4	13	0	305		305
Columbiana County Garage	14	6	11	126	223	35.2	384.2
Harrison County - Cadiz Garage	8	3	8	111.26	90.76		202.02
Holmes County - Millersburg Garage	10	8	10	131	162		293
Jefferson County - Wintersville Garage	12	6	10	320			320
Tuscarawas County - New Philadelphia Gara	11	5	8	184.5	32.5	35.5	252.5
							0
							0
OUTPOST GARAGES							0
Belmont - Barnesville Outpost	4	2	4	0	150		150
Belmont - St. Clairsville Outpost	7	5	7	94	83	23	200
Carroll - Malvern Outpost	0	0	0		0		0
Columbiana - Unity Outpost	4	2	3		150		150
Columbiana - Apples Corner Outpost	4	2	3		150		150
Harrison - Scio Outpost	3	1	3	0	108.06		108.06
Harrison - Freeport Outpost	3	1	3	10	64.09		74.09
Holmes - Nashville Outpost	3	2	3	0	59		59
Jefferson - Toronto Outpost	3	1	3	118			118
Jefferson - Bergholz Outpost	1	1	1	39			39
Tuscarawas - Dennison Outpost	2	1	2	24	40	0	64
Tuscarawas - Zoar Outpost	2	1	2	33	17	0	50
Tuscarawas - Newcomerstown Outpost	4	2	3	84	32	0	116

		Estimated Time to Conduct Full Wash of One Truck						Washwater Storage			Washwater Disposal	
	What type of Truck Washing is Conducted at this facility?	Low End Est.	High End Est.	Estimated Time to Conduct Quick Wash	Type of Hose	Flow Rate from Hose	How was Flow Rate Determined?	Total Oil Water Separator Capacity	Total Sand Trap Capacity	Total Other Storage Capacity	Method	If not using public sewer, estimated Cost for
COUNTY GARAGES	**Select one**	**minutes**	**minutes**	**minutes**		**gpm**		**gallons**	**gallons**	**gallons**	**Select one**	**$/gallon**
Belmont County - Morristown Garage	Full and Quick Wa	15 Min	30 Min	5 Min	Pressure	5gal/45sec	5 Gal Bucket	2-1500 Gal		3000 Gal		
Carroll County Garage	Full and Quick Wa	15 Min	30 Min	10 Min	1" Fire	20 gal/min	5 Gal Bucket	1500 Gal	0		Sanitary Sewer	N/A
Columbiana County Garage	None											
Harrison County - Cadiz Garage	Full and Quick Wa	15 Min	30 Min	5 Min	Pressure	5 gal/min	5 Gal Bucket	3000 Gal	N/A	None	Sanitary Sewer	N/A
Holmes County - Millersburg Garage	Full and Quick Wa	60 Min	90 Min	15 Min	High Pressu	3 gal/min	Pressure Washe	1000 Gal			Sanitary Sewer	N/A
Jefferson County - Wintersville Garage	Full and Quick Wa	10 Min	30 Min	10 Min	2" Hose	12 gal/min	Bucket Fill	1000 Gal	N/A	N/A	Sanitary Sewer	N/A
Tuscarawas County - New Philadelphia	Quick Wash Only	3 Min	5 Min	4 Min	Garden Hos	6 gal/min	Bucket x Min.	1500 Gal			Holding Tank	
-												
-												
OUTPOST GARAGES												
Belmont - Barnesville Outpost	Quick Wash Only	5 Min	10 Min	5 Min	Garden Hos	5gal/42sec	5 Gal Bucket	1000 Gal		1000 Gal		
Belmont - St. Clairsville Outpost	Quick Wash Only	5 Min	10 Min	5 Min	Garden Hos	5gal/37sec	5 Gal Bucket	1000 Gal		1000 Gal		
Carroll - Malvern Outpost	None											
Columbiana - Unity Outpost	None											
Columbiana - Apples Corner Outpost	Full and Quick Wa	5 Min	15 Min	8 Min	1"	15 gal/min	5 Gal Bucket	1500 Gal			Holding Tank	In house
Harrison - Scio Outpost	Quick Wash Only			5 Min	Garden Hos	10 gal/min	5 Gal Bucket		N/A		Sanitary Sewer	N/A
Harrison - Freeport Outpost	None											
Holmes - Nashville Outpost	Full and Quick Wa	60 Min	90 Min	15 Min	High Pressu	3 gal/min	Pressure Washe	500 Gal		10,000 Gal	Sanitary Sewer	0.17
Jefferson - Toronto Outpost	Quick Wash Only			5 Min	3/4"	4 gal/min	Bucket Fill	N/A	N/A	N/A	Sanitary Sewer	N/A
Jefferson - Bergholz Outpost	Quick Wash Only			5 Min	3/4"	4 gal/min	Bucket Fill	N/A	N/A	N/A	Other	N/A
Tuscarawas - Dennison Outpost	Full and Quick Wa	5 Min	10 Min	10 Min	Hose	6 gal/min	Bucket x Min.				Sanitary Sewer	N/A
Tuscarawas - Zoar Outpost	Quick Wash Only	3 Min	5 Min	5 Min	Garden Hos	6 gal/min	Bucket x Min.	1500 Gal			Holding Tank	

						Alternative Deicing Liquids	
	Is Brine Produced at this Location?	What Model of Brine Production Unit is Used?	Estimated Brine Production Rate	Brine Storage Volume	Are Liquids Other than Sodium Chloride Used for Pretreating?	Type	Storage Volume
COUNTY GARAGES	Select one		gallons per day	gallons	Select one		gallons
Belmont County - Morristown Garage	Yes	Varitech	12,000 Gallons	2-6000 Gal Tank	No	Calcium	5500 Gallons
Carroll County Garage	Yes	Varitech SB600	7500 Gallons	10,500 Gal	No		
Columbiana County Garage	Yes	Varitech SB600	7500 Gallons	10,500 Gal	No		
Harrison County - Cadiz Garage	Yes	Varitech	Varies	5,000 Gal	No	Cal Chloride	11,000 Gallons
Holmes County - Millersburg Garage	No	N/A	N/A	N/A		Liquid Cal	5800 Gallons
Jefferson County - Wintersville Garage							
Tuscarawas County - New Philadelphia Ga	Yes		6000 Gallons	12,000 Gal	Yes	Ice Bite	3000 Gallons
-							
-							
OUTPOST GARAGES							
Belmont - Barnesville Outpost	No	No	None			Calcium	3000 Gallons
Belmont - St. Clairsville Outpost	Yes	Varitech	12,000 Gallons	1-5500 Gal Tank		Calcium	6000 Gallons
Carroll - Malvern Outpost							
Columbiana - Unity Outpost	No						
Columbiana - Apples Corner Outpost	No						
Harrison - Scio Outpost	No					Cal Chloride	8000 Gallons
Harrison - Freeport Outpost	No					Cal Chloride	8000 Gallons
Holmes - Nashville Outpost	No	N/A	N/A	N/A		Liquid Cal	3000 Gallons
Jefferson - Toronto Outpost							

		Number of Trucks Used per Winter Event		Total Lane Miles (per garage or outpost)			
COUNTY GARAGES	Total Number of Dump Trucks	Low End Estimate	High End Estimate	Priority	General	Urban	Total
611 Cleveland Garage	12	5	10	213			213
612 Independence Garage	13	5	11	364			364
613 Mayfield Garage	12	5	11	290			290
614 Riveredge Garage	12	5	10	257			257
615 Warrensville Garage	13	5	11	303			303
BURTON	8	2	6	16	70		86
							0
							0
							0
OUTPOST GARAGES							0
MUNSON	3	2	3	45	57		102
MONTVILLE	3	2	3		93		93
PARKMAN	5	3	5	91	51		142

		Estimated Time to Conduct Full Wash of One Truck						Washwater Storage			Washwater Disposal	
	What type of Truck Washing is Conducted at this facility?	Low End Est.	High End Est.	Estimated Time to Conduct Quick Wash	Type of Hose	Flow Rate from Hose	How was Flow Rate Determined?	Total Oil Water Separator Capacity	Total Sand Trap Capacity	Total Other Storage Capacity	Method	If not using public sewer, estimated Cost for
COUNTY GARAGES	**Select one**	**minutes**	**minutes**	**minutes**		**gpm**		**gallons**	**gallons**	**gallons**	**Select one**	**$/gallon**
611 Cleveland Garage	Quick Wash Only	30	120	30	1.5" in rubber	10	15sec to fill 5gal	Unknown	Unknown	Unknown	Sanitary Sewer	N/A
612 Independence Garage	Quick Wash Only	30	120	30	1.5" in rubber	10	15sec to fill 5gal	Unknown	Unknown	Unknown	Sanitary Sewer	N/A
613 Mayfield Garage	Quick Wash Only	30	120	30	1.5" in rubber	10	15sec to fill 5gal	Unknown	Unknown	Unknown	Sanitary Sewer	N/A
614 Riveredge Garage	Quick Wash Only	30	120	30	1.5" in rubber	10	15sec to fill 5gal	Unknown	Unknown	Unknown	Sanitary Sewer	N/A
615 Warrensville Garage	Quick Wash Only	30	120	30	1.5" in rubber	10	15sec to fill 5gal	Unknown	Unknown	Unknown	Sanitary Sewer	N/A
BURTON	Full and Quick Wa	15	30	10	FIRE	30	ESTIMATED	?			Other	?
-												
-												
-												
-												
-												
-												
-												
-												
OUTPOST GARAGES												
MUNSON	None											
MONTVILLE	None											
PARKMAN	None											

						Alternative Deicing Liquids	
	Is Brine Produced at this Location?	What Model of Brine Production Unit is Used?	Estimated Brine Production Rate	Brine Storage Volume	Are Liquids Other than Sodium Chloride Used for Pretreating?	Type	Storage Volume
COUNTY GARAGES	Select one		gallons per day	gallons	Select one		gallons
611 Cleveland Garage	No		0	0	No	Calcium	12000
612 Independence Garage	Yes	Pengwyn ABS-3000 SS	5600	5600	No	Calcium	11000
613 Mayfield Garage	Yes	Pengwyn ABS-3000 SS	5600	5600	No	Calcium	10000
614 Riveredge Garage	Yes	Pengwyn ABS-3000 SS	5600	12000	No	Calcium	10000
615 Warrensville Garage	Yes	Pengwyn ABS-3000 SS	5600	5600	No	Calcium	18000
BURTON	Yes	PENQWYN	500	5500	Yes	CALCIUM	11000
-							
-							
-							
-							
-							
-							
OUTPOST GARAGES							
MUNSON	No						
MONTVILLE	No						
PARKMAN	No						

APPENDIX C

WASH WATER MANAGEMENT IN EACH ODOT DISTRICT

District 1

Survey

According to the survey submitted by District 1 personnel, District 1 currently maintains approximately 3,400 lane miles with a fleet of 123 trucks across eight counties in northwest Ohio. There are eight county garages and eight outpost garages in District 1. According to the Facilities Manager for District 1, truck washing is only conducted at the county garages, which are all tied into the sanitary sewer system. Of the eight outpost garages in District 1, the only garage with the potential to generate truck wash water that cannot be disposed of via sanitary sewer is the Carey Outpost Garage. Five of the outpost garages are tied into the sanitary sewer and the remaining two have had the floor drains in the wash bays capped (Roundhead and Paulding Outpost Garages). Figure C-1 depicts the locations of all of the maintenance facilities in District 1. Table C-1 summarizes key information regarding the garages in District 1.

Table C- 1: Summary of the number of trucks, lane miles, and current wash water disposal methods for maintenance facilities in District 1. Shading indicates garages without access to sanitary sewer for the disposal of truck wash water.

County	Garage Name	Total Number of Dump Trucks	Lane Miles	Current Method of Wash Water Disposal
Allen County	Allen County	8	470.0	Sanitary Sewer
	4th Street	4		Sanitary Sewer
	Delphos	3		Sanitary Sewer
	Beaverdam	4		Sanitary Sewer
	District 1 HQ			
Defiance County	Defiance County	13	340.4	Sanitary Sewer
	Hicksville	1		Sanitary Sewer
Hancock County	Hancock County	15	622.9	Sanitary Sewer
	SR 12 Outpost	6		Sanitary Sewer

Hardin County	Hardin County	9	334.0	Sanitary Sewer
	Roundhead	2		
Paulding County	Paulding County	12	392.6	Sanitary Sewer
	Paulding County OP			
Putnam County	Putnam County	15	453.5	Sanitary Sewer
VanWert County	Van Wert County	15	374.5	Sanitary Sewer
Wyandot County	Wyandot County	14	476.8	Sanitary Sewer
	Carey	2		Holding Tank
	District 1 Totals	123	3,464.7	

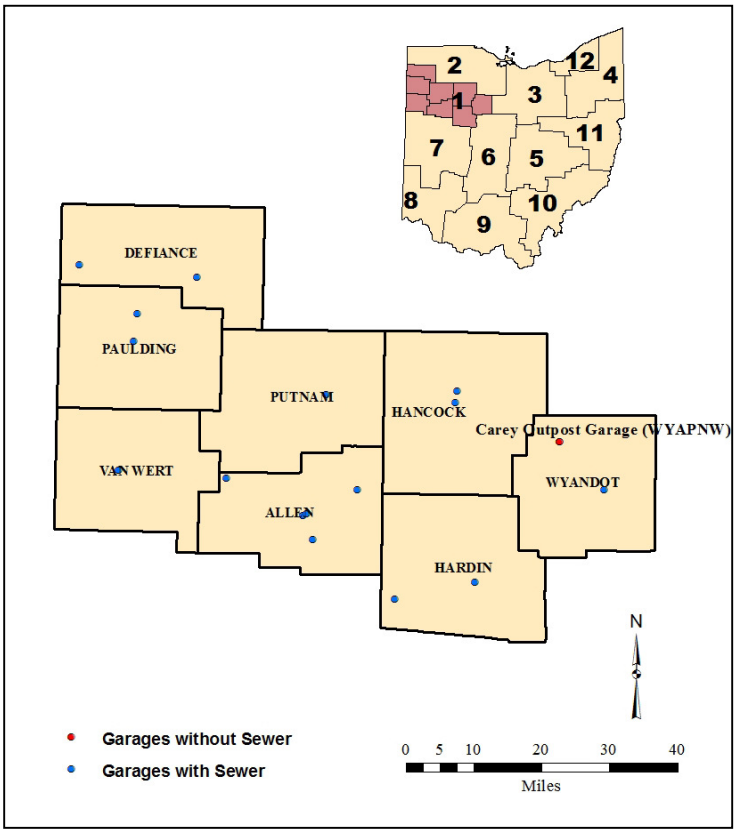

Figure C- 1: Locations of the District, County, and Outpost Garages in District 1. Garages in red lack access to sanitary sewer for truck wash water disposal.

Site Visits

Carey Outpost

Carey Outpost, located in District 1 Wyandot County, does not have access to sanitary sewer for truck wash water. While full truck washing is not conducted at the Carey Outpost Garage, safety washes, which include washing of the truck windows and mirrors, are conducted on an as-needed basis. According to garage personnel, safety washes are conducted at least once per winter event. Wash water generated during safety washes is stored on-site in a 2500 gallon underground storage tank (UST) until it is pumped off-site for disposal. The current disposal cost for this location is approximately $0.15/gallon.

District 2

Survey

District 2, which is headquartered in Bowling Green, Wood County, oversees highway maintenance in Fulton, Henry, Lucas, Ottawa, Sandusky, Seneca, Williams, and Wood counties. The eight county garages and two outpost garages in District 2 maintain approximately 3,300 lane miles with a fleet of 111 trucks. The only county garage in District 2 without access to the sanitary sewer is the Henry County Garage, which collects truck wash water in a lagoon after it is processed through an oil/water separator to be reused for the production of brine. To reuse wash water in this way, the Henry County Garage is required to collect water quality samples from the lagoon annually.

The Edison Outpost Garage is the only other garage in District 2 without access to sanitary sewer. According to Mr. Thomas Richcreek, the Facilities Manager for District 2, truck washing is rarely done at the Edison Outpost Garage. The locations of the garages in District 2 are shown in Figure C-2 with relevant statistics summarized in Table C-2.

Table C- 2: Summary of the number of trucks, lane miles, and current wash water disposal methods for maintenance facilities in District 2. Shading indicates garages without access to sanitary sewer for the disposal of truck wash water.

County	Garage Name	Total Number of Dump Trucks	Lane Miles	Current Method of Wash Water Disposal
Fulton County	Fulton	10	290.0	Sanitary Sewer
Henry County	Henry	10	389.0	Lagoon/Reuse
Lucas County	Lucas	16	459.0	Sanitary Sewer
	Northwood	0	307.0	Sanitary Sewer
Ottawa County	Ottawa	10	358.0	Sanitary Sewer
	Edison	4	-	Leach Field or Mound
Sandusky County	Sandusky	12	393.0	Sanitary Sewer
Seneca County	Seneca	14	410.0	Sanitary Sewer
Williams County	Williams	14	373.0	Sanitary Sewer
Wood County	Wood	21	648.0	Sanitary Sewer
	District 2 HQ			
	District 2 Totals	111	3,320	

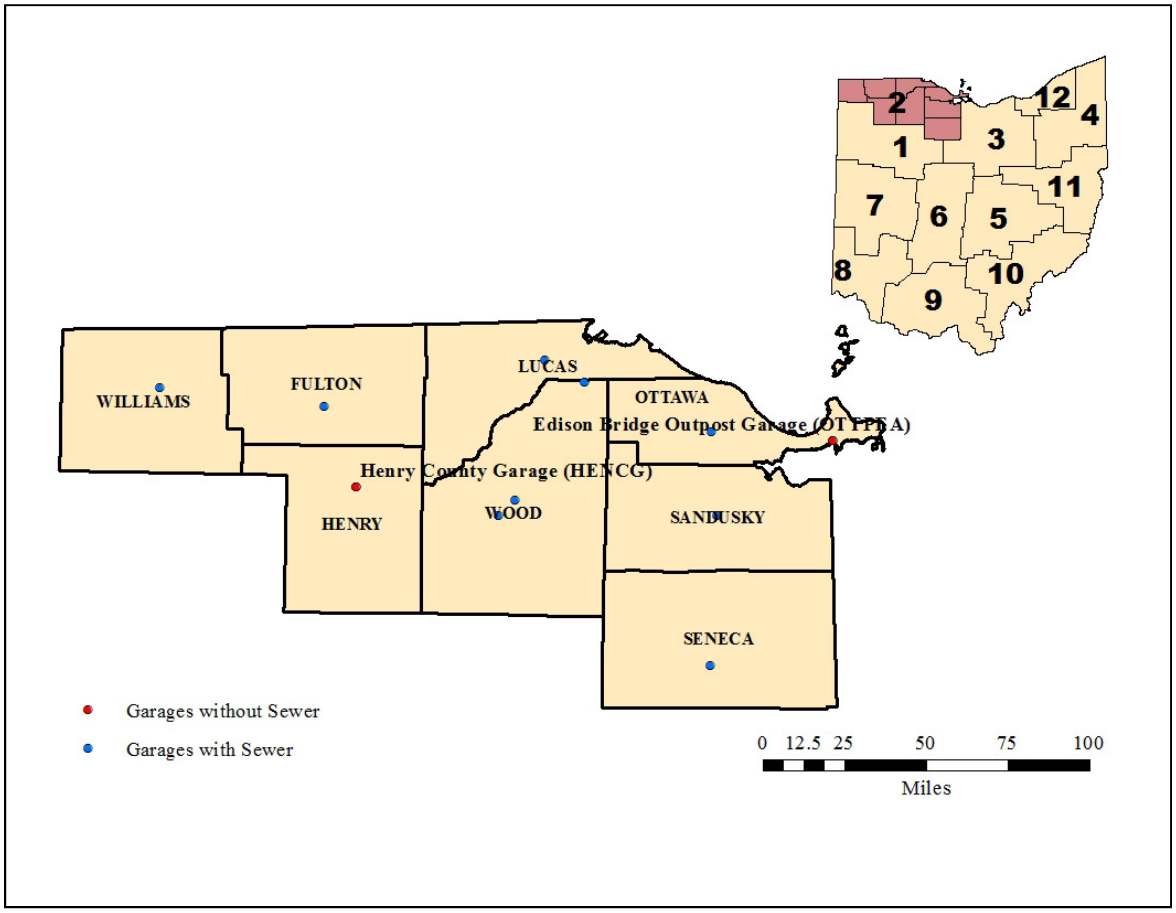

Figure C- 2: Locations of the District, County, and Outpost Garages in District 2. Garages in red lack access to sanitary sewer for truck wash water disposal.

Site Visits

A site visit to the Henry County Garage was conducted in January 2012. Truck wash water generated at the Henry County Garage is processed through an oil/water separator before being routed to an on-site storage lagoon where it is diluted with storm water. The retention pond serves as the source of water for brine production. Henry County personnel noted that water must be frequently pumped from the pond and hauled off-site for disposal to maintain the water level in the pond.

District 3

Survey

ODOT District 3 currently maintains approximately 4,100 lane miles across Ashland, Crawford, Erie, Huron, Lorain, Medina, Richland, and Wayne Counties. District 3 did not participate in the email survey. However, Mr. Richard Feldkamp, Facilities Manager for District 3 confirmed that the Huron County garage is the only county garage in District 3 without access to the sanitary sewer for truck wash water disposal. The Huron County Garage currently manages truck wash water by storing it in a holding tank on-site until it is pumped and hauled to a treatment plant. There are five outpost garages in District 3 without sanitary sewer. Truck washing is not conducted at these outposts. With the exception of the Vermillion Outpost Garage, which has a leach field, the primary means of wash water disposal at the outposts without sanitary sewer is the storm sewer. Figure C-3 shows the locations of the garages in District 3 that do not currently have access to sanitary sewer for truck wash water disposal. Table C-3 summarizes the relevant statistics for District 3.

Table C- 3: Summary of the number of trucks, lane miles, and current wash water disposal methods for maintenance facilities in District 3. Shading indicates garages without access to sanitary sewer for the disposal of truck wash water.

County	Garage Name	Total Number of Dump Trucks	Lane Miles	Current Method of Wash Water Disposal
Ashland County	Ashland County Garage (ASDCG)	16	544.0	Public Sanitary Sewer
	Perrysville Outpost Garage (ASDPSO)	4	139.0	Runoff / Storm Sewer
	Nova Outpost (ASDPNW)	0	-	No Plumbing
	District 3 HQ Office (New) (ASDHQ)			Public Sanitary Sewer
Crawford County	Crawford County Garage (CRACG)	14	478.6	Public Sanitary Sewer
Erie County	Erie County Garage (ERICG)	12	307.0	Public Sanitary Sewer

	Vermillion Outpost Garage (ERIPNE)	2	88.3	Class 5 Well (Septic Tank and Mound System or Leach Field)
Huron County	Huron County Garage (HURCG)	13	374.6	Holding Tank
	Plymouth Outpost Garage (HURPSE)	2	69.0	Runoff / Storm Sewer
Lorain County	Lorain County Garage (LORCG)	12	383.6	Public Sanitary Sewer
	Avon Outpost Garage (LORPNE)	6	167.2	Public Sanitary Sewer
Medina County	Medina County Garage (MEDCG)	22		Public Sanitary Sewer
	Burbank Outpost Garage (MEDPSW)	7		Runoff / Storm Sewer
Richland County	Richland County Garage (RICCG)	12	321.1	Public Sanitary Sewer
	Lexington Outpost Garage (RICPSW)	8	256.0	Runoff / Storm Sewer
Wayne County	Wayne County Garage (WAYCG)	17	585.9	Public Sanitary Sewer
	District 3 Totals	147	3,714.25	

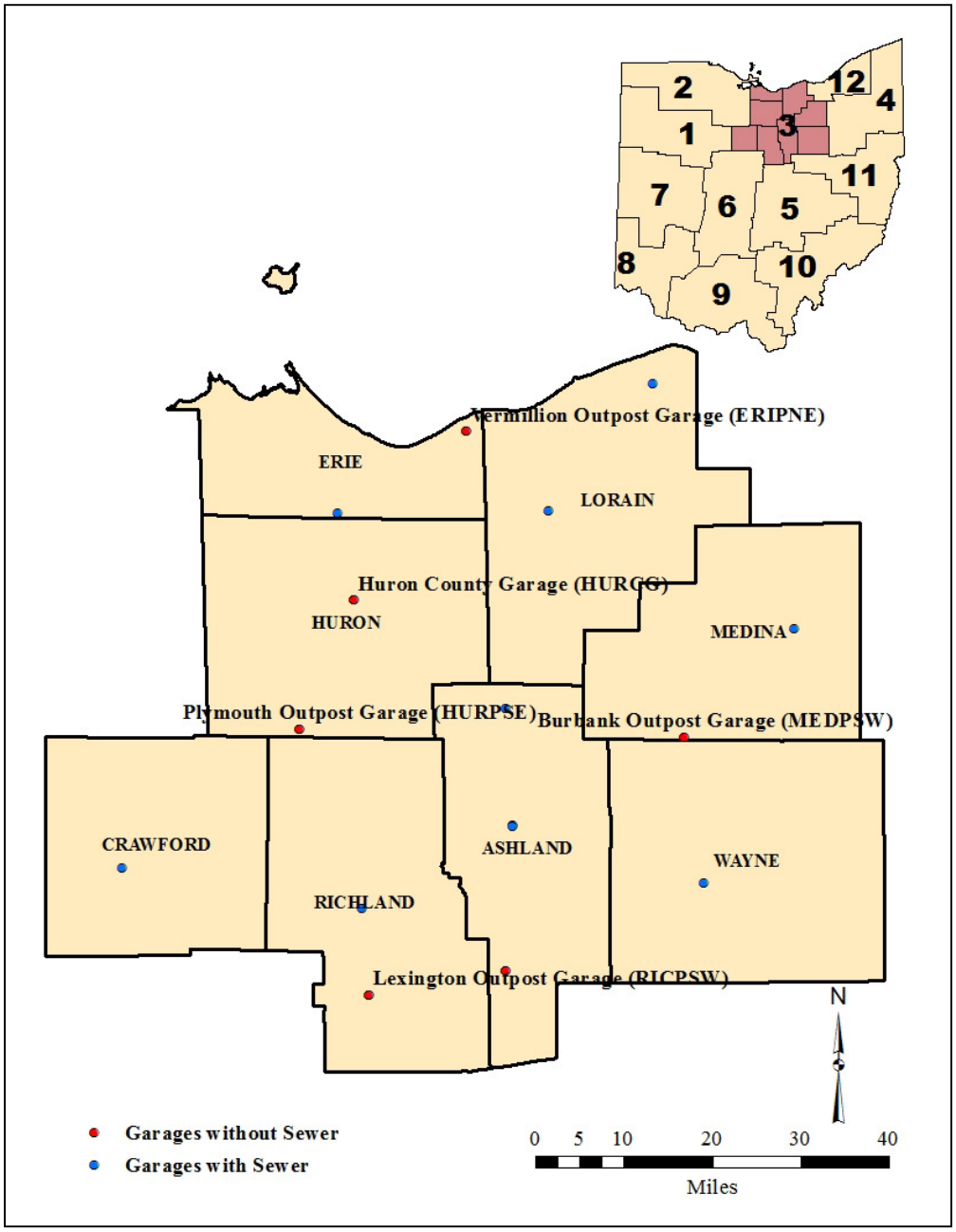

Figure C- 3: Locations of the District, County, and Outpost Garages in District 3. Garages in red lack access to sanitary sewer for truck wash water disposal.

Site Visits

Huron County Garage

The Huron County Garage is the only county garage in District 3 lacking access to sanitary sewer for truck wash water disposal. According to District 3 personnel, the truck wash

water generated during routine maintenance of the 15 dump trucks at this location is stored in a 3,000 gallon underground storage tank (UST) until it is pumped and hauled off-site for disposal. The cost for wash water disposal is approximately $0.42/gallon. Trucks from the Plymouth Outpost are also washed at the Huron County Garage. Brine is produced at the Huron County Garage using tap water.

Plymouth Outpost

The Plymouth Outpost garage is located in Huron County. There are two dump trucks stationed at the Plymouth Outpost. According to District 3 personnel, there is not a wash bay at this facility and trucks are not washed here. Instead, they are driven to the Huron County Garage for washing at the end of each winter event. Wash water is not stored on-site.

District 4

Survey

District 4, which is headquartered in Akron, Ohio, includes Ashtabula, Mahoning, Portage, Stark, Summit, and Trumbull counties. District 4 did not participate in the email survey, however, Mr. Thomas Wathen, Facilities Manager for District 4, was able to provide information regarding wash water disposal methods at each of the garages in District 4. Currently, the only county garage without access to sanitary sewer for truck wash water disposal is the Summit County Garage; however, there are plans to connect this garage to the sanitary sewer during the Summer of 2012.

Over the last year, the Conneaut, Harpersfield, and Greensburg Outpost garages were tied into the sanitary sewer system. There are still 12 outpost garages in District 4 without access to sanitary sewer for truck wash water disposal. Table C-4 summarizes the primary method of wash water disposal for all garages in District 4 and Figure C-4 shows their locations.

Table C- 4: Summary of the number of trucks and current wash water disposal methods for maintenance facilities in District 4. Lane miles were not reported. Shading indicates garages without access to sanitary sewer for the disposal of truck wash water.

County	Garage Name	Total Number of Dump Trucks	Lane Miles	Current Method of Wash Water Disposal
Ashtabula County	Ashtabula County Garage	9		Public Sewer
	Conneaut Outpost	5		Public Sewer
	Harpersfield Outpost	3		Public Sewer
	Williamsfield Outpost	4		Leach Field or Mound
	Dorset Outpost	4		Holding Tank
	Rome Outpost	4		Holding Tank
Mahoning County	Mahoning County Garage	9		Public Sewer
	South Avenue Outpost			No Truck Washing.
	Sebring Outpost	2		Leach Field or Mound
	Bailey Road Outpost	4		Public Sewer
	North Lima Outpost	8		Leach Field or Mound
Portage County	Portage County Garage	11		Public Sewer
	Yale Outpost	4		Leach Field or Mound
	Drakesburg Outpost	5		Holding Tank
Stark County	Stark County Garage	17		Public Sewer
	Alliance Outpost			No Truck Washing or Storage
	Canton Outpost			No Truck Washing or Storage
	Canal Fulton Outpost			No Truck Washing
	Massilon Outpost	6		No Truck Washing
Summit County	Summit County Garage	10		Will connect to sewer--summer 2012
	Interchange Outpost	7		Package Plant
	Kelly Outpost			Public Sewer
	Twinsburg Outpost	5		Storm Sewer
	Greensburg Outpost	4		Public Sewer
	Peninsula Outpost			No Truck Washing or

				Storage
	Richfield Outpost			No Truck Washing or Storage
	District 4 HQ			Public Sewer
Trumbull County	Trumbull County Garage	8		Public Sewer
	Warren Outpost			No Truck Washing.
	Brookfield Outpost	7		Holding Tank
	Farmington Outpost	4		Leach Field or Mound
	Gustavus Outpost	6		Leach Field or Mound
	Trumbull Construction Office			
	District 4 Totals	146		

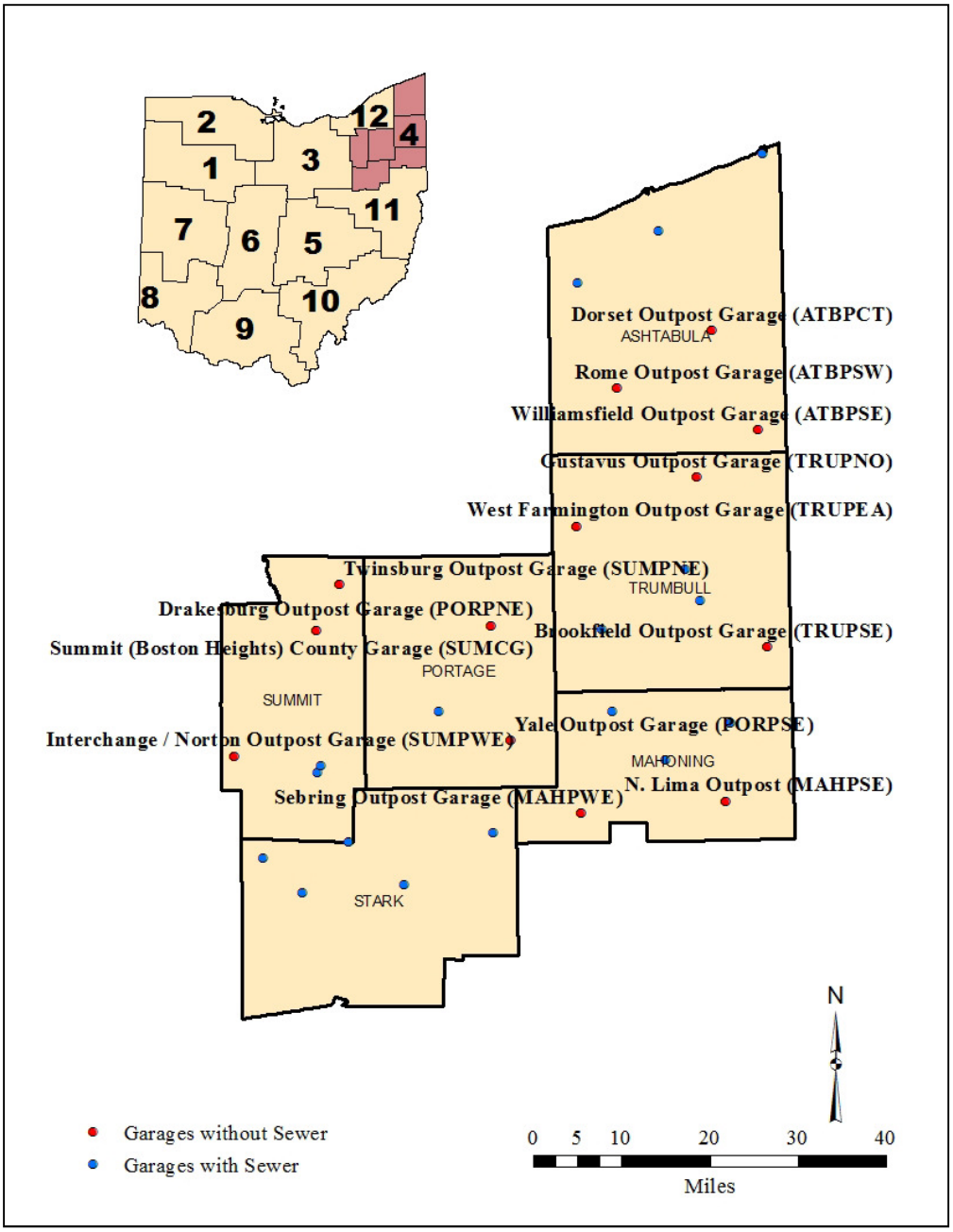

Figure C- 4: Locations of the District, County, and Outpost Garages in District 4. Garages in red lack access to sanitary sewer for truck wash water disposal.

Site Visits

Ashtabula County Garage

Ashtabula County Garage in Ashtabula County, Ohio currently has access to the sanitary sewer for truck wash water disposal. Trucks are washed in a designated wash bay using a

pressure washer and an attachment that slides under the truck to clean the undercarriage. The Ashtabula County Garage produces brine for itself and two outpost garages: Rome and Dorset.

Boston Heights Garage

The Summit County Garage in Boston Heights does not have access to sanitary sewer for truck wash water disposal. Wash water generated at this facility goes into a leach field after being process through an oil/water separator. There are plans for this garage to be tied into the sanitary sewer line in the near future.

Greensburg Airport Outpost Garage

There are four dump trucks assigned to the Greensburg Airport Outpost Garage. Truck wash water generated at this facility is disposed of in the sanitary sewer.

Drakesburg Outpost

Drakesburg Outpost, located in Portage County, Ohio, does not currently have access to sanitary sewer for truck wash water disposal. Because of the lack of sewer access, only safety washing, which includes washing of the windows and mirrors, is conducted at this garage. Each of the four trucks receives a safety wash at the end of every 12-hour shift. At the end of a winter event, the trucks are driven to the nearest county garage for a full wash. Wash water generated during safety washing is processed through an oil/water separator and collected in a 3,000-gallon UST until it can be pumped and hauled by a contractor to the nearest waste water treatment plant for disposal at a cost of $0.49/gallon. During the winter of 2010/2011, the tank was pumped 13 times and 36,750 gallons of wash water were disposed of at a total cost of $17,906.75. This volume of truck wash water was generated over the course of 51 winter events.

Rome Outpost

Rome Outpost in Ashtabula County, Ohio currently utilizes four trucks for snow and ice removal. Because sanitary sewer access is not available at this maintenance facility, wash water generated during safety washes is processed through an oil/water separator and stored in a 6,000-gallon UST until it is pumped and hauled to a nearby waste water treatment plant for disposal at a cost of $0.53/gallon. During winter 2011, with 71 winter events reported in Ashtabula County, a total of 30,500 gallons of wash water were generated at Rome Outpost. The total cost to dispose of the wash water was $16,332.75.

Dorset Outpost

Dorset Outpost in Ashtabula County, Ohio also has four trucks for snow and ice removal. To minimize the generation of wash water at this facility, which does not have access to sanitary sewer, safety washes are conducted at the end of each 12-hour shift during a winter event and the trucks are driven to the nearest county garage with sewer access for a full wash at the end of an event. Wash water is processed through and oil/water separator then stored in a 3,000 gallon UST until it is pumped and hauled to a nearby waste water treatment plant for disposal at a cost of $0.53/gallon. During winter 2011, a total of 30,000 gallons of wash water was generated at Dorset Outpost Garage and disposed of at a cost of $16,065.

District 5

Survey

District 5 maintains approximately 3,700 lane miles with a fleet of 126 trucks distributed throughout seven county and 11 outpost garages. The District 5 Garage currently uses a package plant to manage truck wash water. There are also two county garages without access to sanitary sewer: the Licking County Garage (Utica Outpost) and the Muskingum County Garage currently have leach field systems. However, full truck washing is not conducted at the Licking County Garage, and the Muskingum County Garage currently has a new wash bay under construction and will be connected to the sanitary sewer in the Summer of 2012. There are an additional seven outpost garages without access to sanitary sewer. Table C-5 provides a summary of the lane miles and number of trucks at each maintenance facility in District 5 as well as the current approach to truck wash water management. Figure C-5

Table C- 5: Summary of the number of trucks, lane miles, and current wash water disposal methods for maintenance facilities in District 5. Shading indicates garages without access to sanitary sewer for the disposal of truck wash water.

County	Garage Name	Total Number of Dump Trucks	Lane Miles	Current Method of Wash Water Disposal
Coshocton County	Coshocton County	16	465.9	Sanitary Sewer
	COS - New Castle	0		No water
Fairfield County	Fairfield County	15	469.3	Sanitary Sewer
	FAI -Baltimore			Sanitary Sewer
	US Rt 664			No water
Guernsey County	Guernsey County	12	315.0	Sanitary Sewer
	GUE - North Salem	5	136.0	Leach Field or Mound
	GUE -Old Washington	6	160.0	Leach Field or Mound
	GUE-Cumberland Outpost Garage			Salt Storage/No water
Knox County	Knox County	13	339.4	Sanitary Sewer
	KNO -Fredericktown	2	68.0	Sanitary Sewer
	KNO -Newcastle in with Main NO Water			No water
Licking County	Licking County--Utica	6	264.0	Leach Field or Mound
	LIC -Etna	7	228.7	Leach Field or Mound
	LIC -Brownsville	5	212.7	Leach Field or Mound
	LIC -Marne (Salt Reload Only)			No Water
	District 5 HQ and Garage			Package Plant
Muskingum County	Muskingum County	11	335.0	Leach Field or Mound (new wash bay under construction for summer 2012)
	MUS -158- Dresden	5	138.0	Leach Field or Mound
	MUS -160- Moxahala	3	64.4	Leach Field or Mound
	MUS -161- Duncan Falls	5	138.0	Leach Field or Mound
Perry County	Perry County	15	379.0	Sanitary Sewer
	Shawnee Outpost Garage			Salt Storage/No water
	District 5 Totals	126.0	3,713.4	

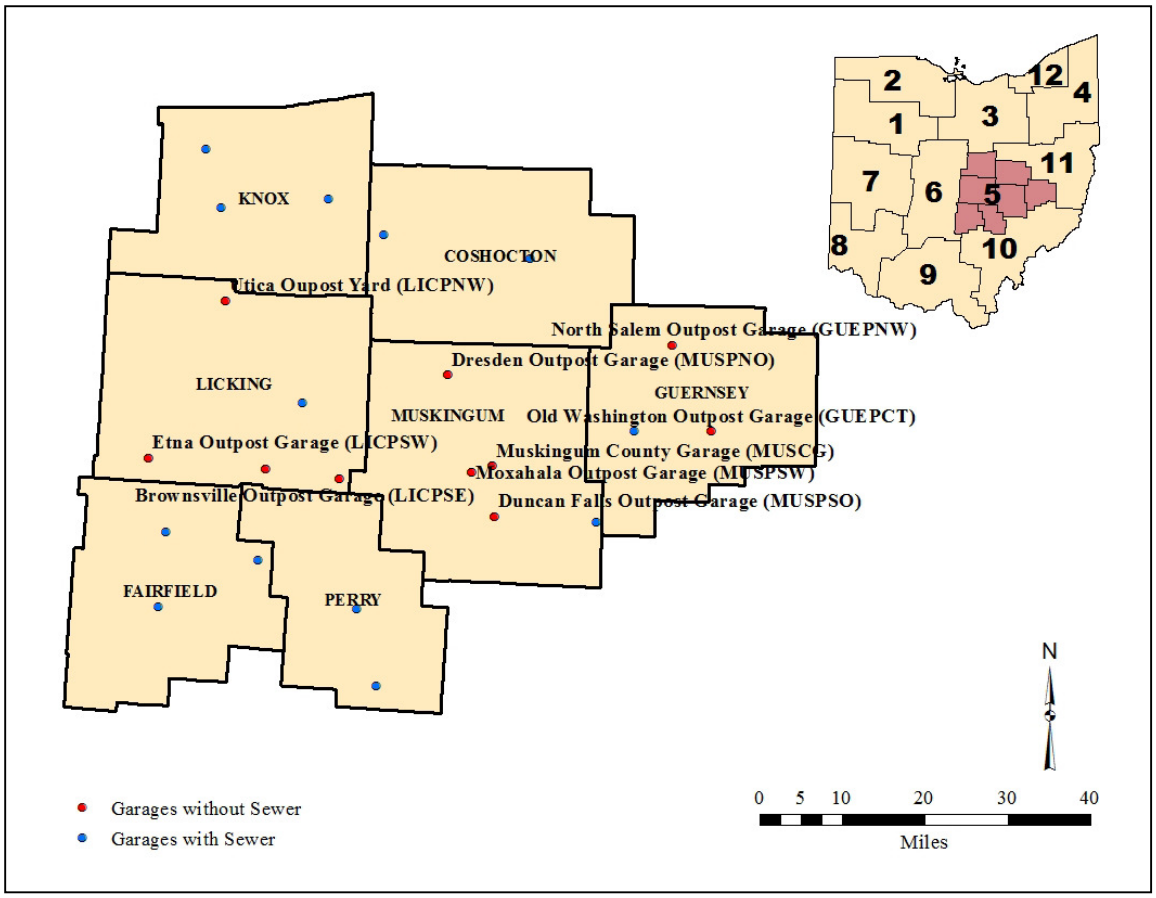

Figure C- 5: Locations of the District, County, and Outpost Garages in District 5. Garages in red lack access to sanitary sewer for truck wash water disposal.

Site Visits

Muskingum County Garage

Truck wash water generated during the routine maintenance of the 11 dump trucks currently stationed at the Muskingum County Garage is disposed of in the sanitary sewer. In addition, the 13 other dump trucks stationed across the three outpost locations in Muskingum County are driven to the Muskingum County Garage for washing at the end of each winter event.

District 6

Survey

District 6 encompasses eight counties in central Ohio. Eight county and nine outpost garages maintain 4,882 lane miles with a fleet of 166 trucks. District 6 has one county and five outpost garages without access to sanitary sewer for truck wash water disposal. Figure C-6 shows their locations with relevant statistics summarized in Table C-6.

Table C- 6: Summary of the number of trucks, lane miles, and current wash water disposal methods for maintenance facilities in District 6. Shading indicates garages without access to sanitary sewer for the disposal of truck wash water.

County	Garage Name	Total Number of Dump Trucks	Lane Miles	Current Method of Wash Water Disposal
Delaware County	Delaware County	11	296.5	Sanitary Sewer
	Berkshire Outpost	9	259.2	Sanitary Sewer
	District 6 HQ			
Fayette County	Fayette County	7	213.7	Sanitary Sewer
	Jeffersonville Outpost	6	247.3	Holding Tank
Franklin County	Franklin County	13	465.8	Sanitary Sewer
	Canal Winchester Outpost Yard			
	5th Avenue Outpost	15	541.6	Sanitary Sewer
	Hilliard Outpost	13	299.9	Sanitary Sewer
	Grove City Outpost	13	205.3	Sanitary Sewer
	Worthington/Wilson Bridge Outpost Garage			
Madison County	Madison County	8	228.0	Leach Field or Mound
	Mt. Sterling Outpost	6	173.0	Storm Sewer
	West Jefferson Outpost	6	212.0	Leach Field or Mound
	Land Outpost			
Marion County	Marion County	14	434.0	Sanitary Sewer
Morrow	Morrow County	10	323.8	Sanitary Sewer

County				
	Chesterville Outpost	4	84.7	Sanitary Sewer
Pickaway County	Pickaway County	15	438.0	Sanitary Sewer
Union County	Union County	10	282.2	Sanitary Sewer
	Richwood Outpost	6	176.9	Leach Field or Mound
	District 6 Totals	166	4,882.0	

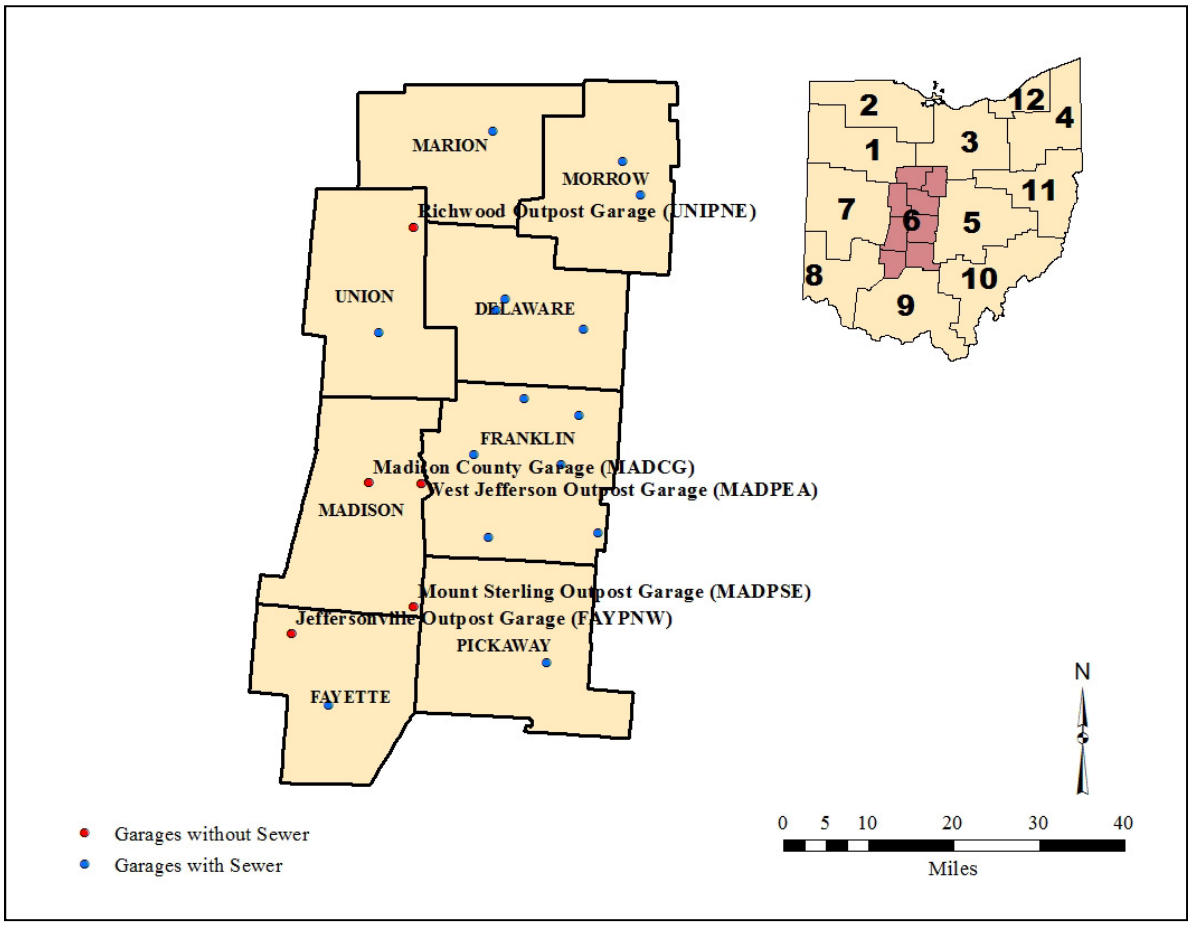

Figure C- 6: Locations of the District, County, and Outpost Garages in District 6. Garages in red lack access to sanitary sewer for truck wash water disposal.

Site Visits

Madison County Garage

A site visit to the Madison County Garage was conducted on March 13, 2012. The visit confirmed that this garage lacks access to sanitary sewer. Wash water generated at the Madison County Garage is treated using an oil/water separator prior to being discharged to a leach field. Wash water is not being reused for brine production.

Franklin County Garage

A site visit to the Franklin County Garage was conducted on March 14, 2012. Wash water generated at the Franklin County Garage is processed through a sedimentation tank and an oil/water separator prior to being discharged to the sanitary sewer.

District 7

Survey

ODOT District 7 oversees maintenance operations in Auglaize, Champaign, Clark, Darke, Logan, Mercer, Miami, Montgomery, and Shelby Counties. All of the county garages in District 7 currently dispose of truck wash water via sanitary sewer. According to Facilities Manager, Mr. Lonnie Falknor, truck washing does not occur at any of the outposts that do not have access to sanitary sewer. There are seven outpost garages in District 7 without sanitary sewer access. Water generated at these facilities is stored in a holding tank until it can be pumped and hauled to the nearest county garage for disposal in the sanitary sewer. Figure C-7 shows the locations of the county garages in District 7 along with all garages lacking access to sanitary sewer. Table C-7 provides a summary the number of trucks and lane miles assigned to each garage, as reported by District 7 personnel in the email survey.

Table C- 7: Summary of the number of trucks, lane miles, and current wash water disposal methods for maintenance facilities in District 7. Shading indicates garages without access to sanitary sewer for the disposal of truck wash water.

County	Garage Name	Total Number of Dump Trucks	Lane Miles	Current Method of Wash Water Disposal
Auglaize County	Auglaize County - Wapakoneta	17	439.0	Sanitary Sewer
	St. Mary's Outpost			Sanitary Sewer
Champaign County	Champaign County -Urbana	10	287.2	Sanitary Sewer
	CHP -Mechanicsburg	3	89.4	Holding Tank
	CHP -Saint Paris	2	55.9	Holding Tank
Clark County	Clark County- Springfield Garage	9	157.5	Sanitary Sewer
	CLA -Harmony	4	236.0	Holding Tank
	CLA -Enon	5	142.9	Holding Tank
Darke County	Darke County - Greenville Garage	14	380.4	Sanitary Sewer
	DAR - Dawn	5	159.6	Sanitary Sewer
	Fort Jefferson OP			0
Logan County	Logan County - Bellefontaine	10	263.2	Sanitary Sewer
	LOG - Lakeview	3	138.3	Sanitary Sewer
	LOG - East Liberty	5	135.7	Holding Tank
	LOG-Old Northwood OP			0
Mercer County	Mercer County - Celina	10	178.7	Sanitary Sewer
	MER - Mercer	3	116.0	Holding Tank
	MER -Cassella	3	134.0	Holding Tank
Miami County	Miami County - Troy	12	322.2	Sanitary Sewer
	MIA - Piqua	5	127.5	Sanitary Sewer
	MIA-Ludlow Falls OP			
Montgomery County	Montgomery County - Hoke Rd	11	242.1	Sanitary Sewer
	MOT - Lyons Road	10	191.6	Sanitary Sewer

	MOT-Shull Road OP			Sanitary Sewer
	MOT-5994 Poe Avenue			0
Shelby County	Shelby County - Sidney	14	373.7	Sanitary Sewer
	SHE - Newport	0	-	
	SHE - Dixie	0	-	
	District 7 HQ			
	District 7 Totals	155	2,644.1	

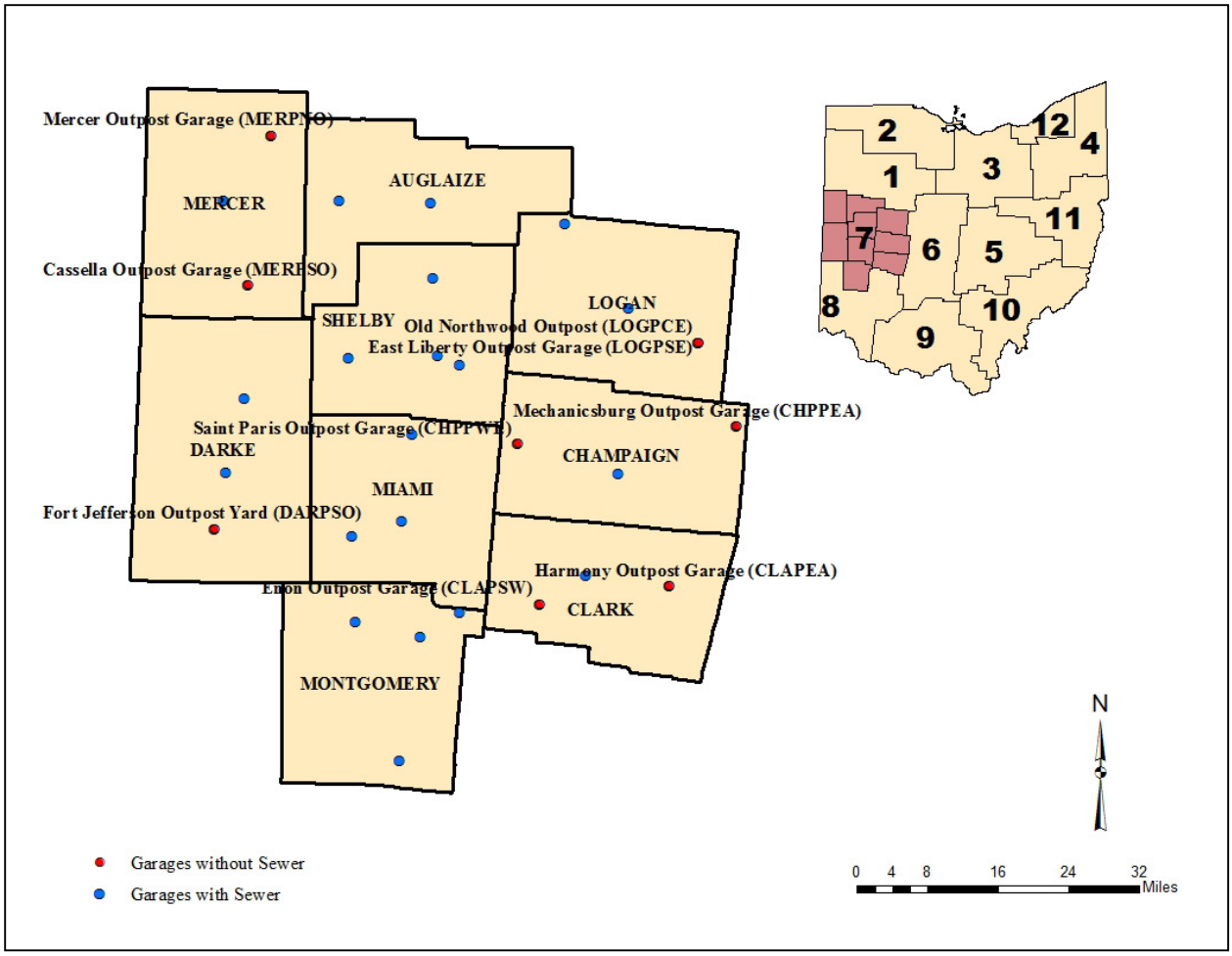

Figure C- 7: Locations of the District, County, and Outpost Garages in District 7. Garages in red lack access to sanitary sewer for truck wash water disposal.

Site Visits

Darke County

The Darke County Garage disposes of truck wash water in the sanitary sewer. There are 19 dump trucks stationed at this garage. Periodically, dump trucks from the Dawn Outpost Garage are brought to the Darke County Garage for washing.

Dawn Outpost

There are five dump trucks assigned to Dawn Outpost. Wash water generated at this garage is disposed of via sanitary sewer.

District 8

Survey

ODOT District 8 oversees maintenance operations in Butler, Clermont, Clinton, Greene, Hamilton, Preble, and Warren Counties. With the exception of Preble County, the email survey was completed by District 8. According to Mr. John Burnie, Facilities Manager for District 8, the only county garage without access to sanitary sewer is the Preble County Garage, which is currently using an aeration system to manage truck wash water. There are a total of five outpost garages without access to sanitary sewer; however, truck washing is not conducted at these locations. Figure C-8 shows the locations of the garages in District 8 highlighting those that lack access to sanitary sewer. Table C-8 summarizes the relevant information regarding District 8.

Table C- 8: Summary of the number of trucks, lane miles, and current wash water disposal methods for maintenance facilities in District 8. Shading indicates garages without access to sanitary sewer for the disposal of truck wash water.

County	Garage Name	Total Number of Dump Trucks	Lane Miles	Current Method of Wash Water Disposal
Butler County	Butler County Garage	15	346.0	Sanitary Sewer
	Middletown	3	76.0	Leach Field or Mound
Clermont County	Clermont County Garage	12	307.0	Sanitary Sewer
	Milford/Old Milford Outpost	8	260.0	Sanitary Sewer
	New Richmond Outpost	7	244.6	Sanitary Sewer
Clinton County	Clinton Main Garage	12	360.0	Sanitary Sewer
	68.O.P	5	118.0	Aeration System
Greene County	Greene County Garage (GRECG)	14	434.0	Public Sanitary Sewer
	Huffman Dam	3	80.0	Public Sanitary Sewer
Hamilton County	Hamilton County Garage (new) (HAMCG)	18	299.0	Public Sanitary Sewer
	Blue Ash Outpost Garage (HAMPNE)	9	243.0	Public Sanitary Sewer
	Miamitown Outpost Garage (HAMPWE)	8	276.0	Leach Field or Mound
	Sharonville Outpost Garage (HAMPNO)			0
Preble County	Preble County Garage (PRECG)			Aeration System
	Eaton Outpost Garage (PREPCT)			Leach Field or Mound
	Morning Sun Outpost Garage (PREPSW)			0
Warren County	Warren County Garage	14	383.0	Sanitary Sewer
	Monroe	10	183.0	Leach Field or Mound
	District 8 HQ Office (WARHQ)			Public Sanitary Sewer
	District 8 Totals	138	2,129.0	

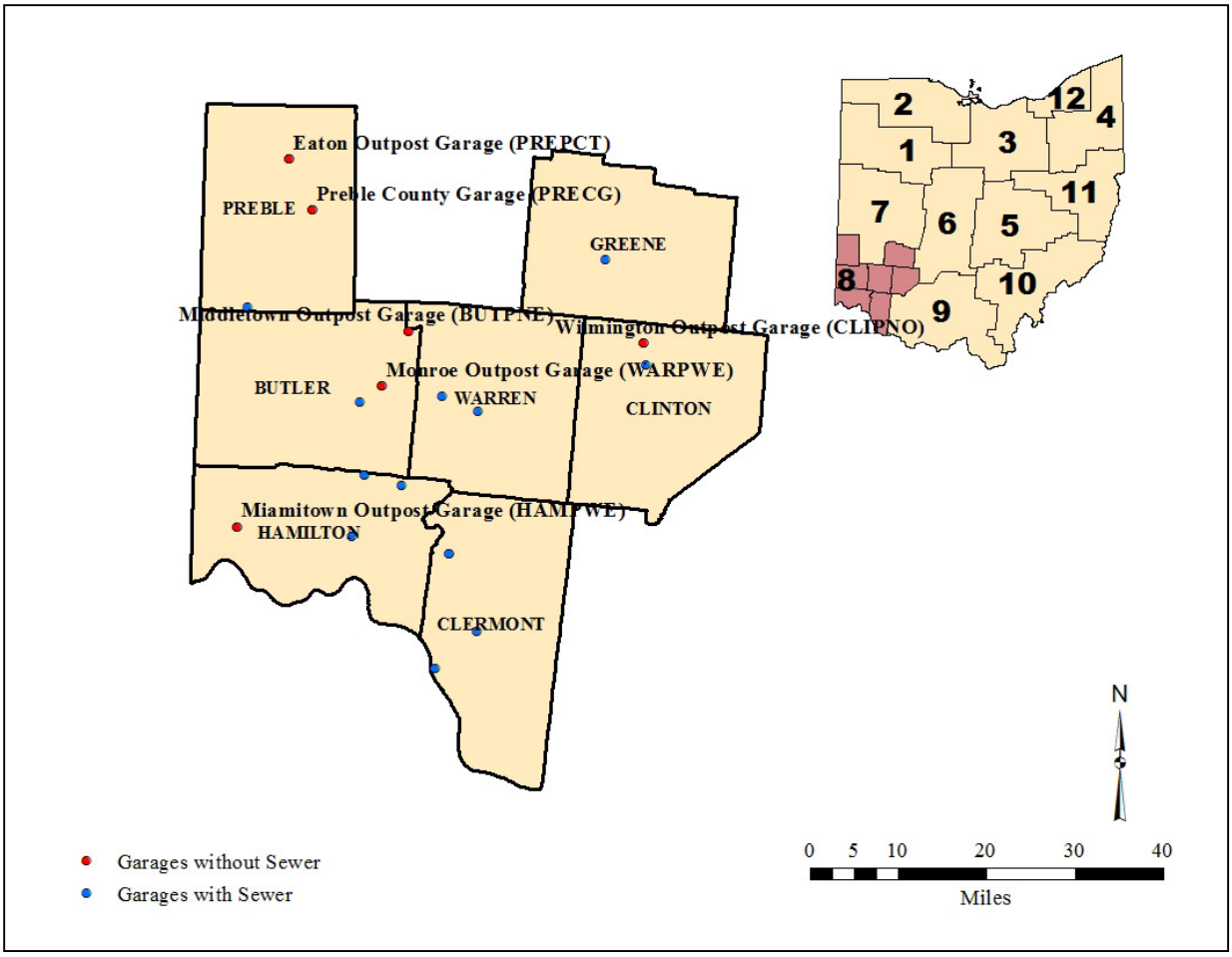

Figure C- 8: Locations of the District, County, and Outpost Garages in District 8. Garages in red lack access to sanitary sewer for truck wash water disposal.

Site Visits

Preble County

The Preble County Garage does not have access to sanitary sewer for truck wash water disposal. Truck wash water generated at this facility is treated using an aeration system. According to district personnel, the aeration system includes a 15,000 gallon tank. Treated wash water drains into a nearby ditch.

District 9

Survey

ODOT District 9 is responsible for approximately 3.900 lane miles in the counties of Adams, Brown, Highland, Jackson, Lawrence, Pike, Ross, and Scioto. According to the Facilities Manager for District 9, during the Summer of 2011, the Jackson County Garage was the last county garage in District 9 to tie in to the sanitary sewer system. All county garages in District 9 now have access to sanitary sewer for the disposal of truck wash water. Neither truck washing nor maintenance is conducted at any of the outpost garages in District 9. Figure C-9 shows the locations of the maintenance facilities in District 9, while Table C-9 summarizes the number of trucks and lane miles for the garages in District 9, as reported by District 9 personnel in the email survey.

Table C- 9: Summary of the number of trucks, lane miles, and current wash water disposal methods for maintenance facilities in District 9. Shading indicates garages without access to sanitary sewer for the disposal of truck wash water.

County	Garage Name	Total Number of Dump Trucks	Lane Miles	Current Method of Wash Water Disposal
Adams County	Adams County Garage (ADACG)	10	480.76	Public Sanitary Sewer
	Peebles Outpost Garage (ADAPNO)	3		0
Brown County	Brown County Garage (BROCG)	10	472.82	Public Sanitary Sewer
	White Oak Outpost Garage (BROPCT)	3		0
Highland County	Highland County Garage (HIGCG)	15	522.62	Public Sanitary Sewer
Jackson County	Jackson County Garage (JACCG)	14	441.78	Public Sanitary Sewer
Lawrence County	Lawrence County Garage (LAWCG)	7	426.39	Public Sanitary Sewer
	Proctorville Outpost Garage (LAWPSE)	3		0
	Wilgus Outpost Yard (LAWPCT)	2		0

Pike County	Pike County Garage (PIKCG)	12	381.98	Public Sanitary Sewer
Ross County	Ross County Garage (ROSCG)	18	586.69	Public Sanitary Sewer
	District 9 HQ Office (ROSHQ)			Public Sanitary Sewer
Scioto County	Scioto County Garage (SCICG)	9	482.04	Public Sanitary Sewer
	Wheelersburg Outpost Garage (SCIPSE)	4		0
	District 9 Totals	110	3,795.08	

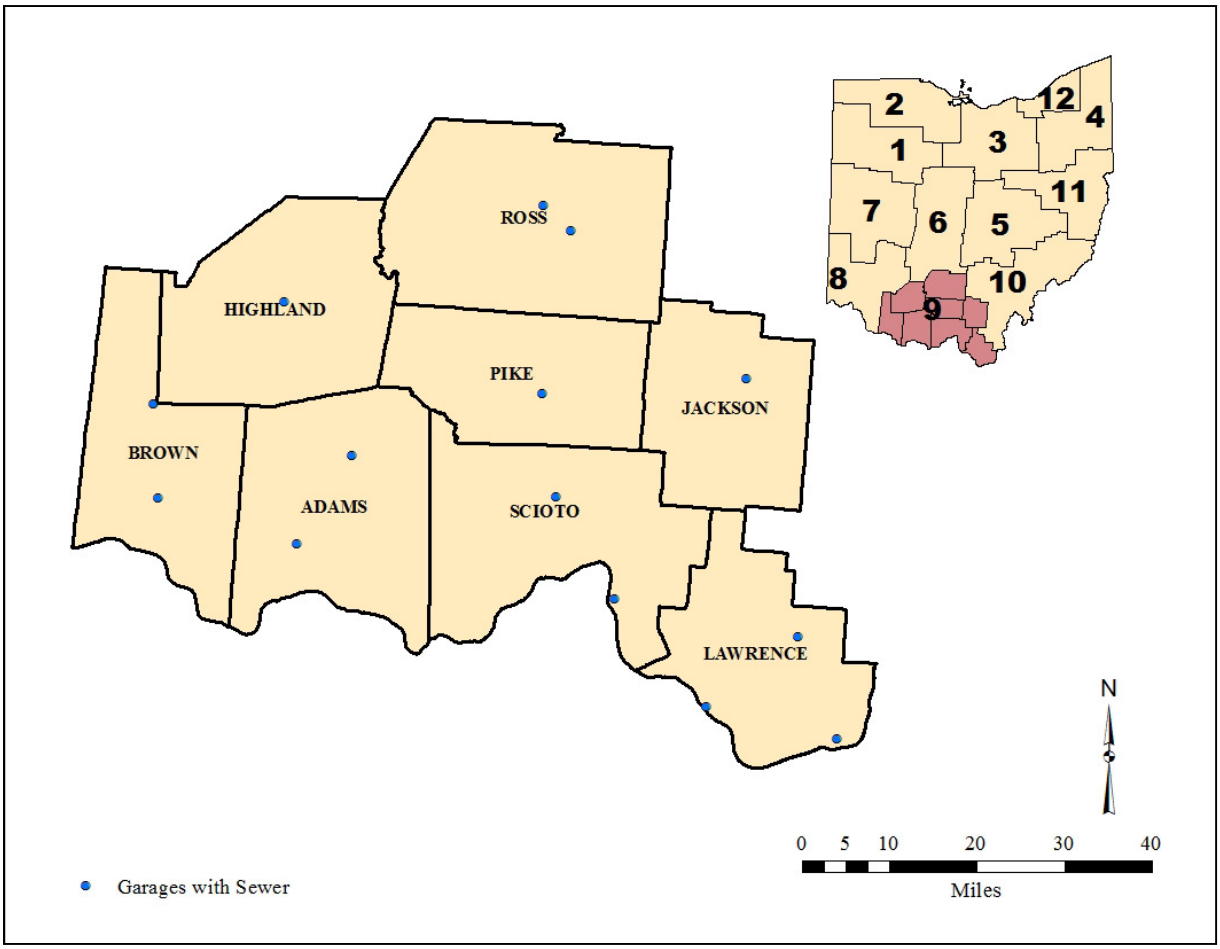

Figure C- 9: Locations of the District, County, and Outpost Garages in District 9. Garages in red lack access to sanitary sewer for truck wash water disposal.

Site Visits

Ross County Garage

The Ross County Garage maintains 587 lane miles with a fleet of 18 dump trucks. According to District 9 personnel, wash water generated at the Ross County Garage is routed to a nearby prison where it is sanitized and reused.

District 10

Survey

District 10 is located in southeastern Ohio and includes Athens, Gallia, Hocking, Meigs, Monroe, Morgan, Noble, Vinton, and Washington counties. The district headquarters is located in Marietta, Washington County. There are nine county garages and nine outpost garages maintaining approximately 4,000 lane miles with a fleet of 126 trucks in District 10. There are three county garages in District 10 without access to sanitary sewer: Meigs, Morgan, and Vinton. Wash water generated at these garages is stored in a holding tank and reused to produce brine. In addition to the three county garages, there are seven outpost garages that lack access to sanitary sewer. Summary statistics for District 10 are tabulated in Table C-10. The locations of the garages in District 10 are shown in Figure C-10.

Table C- 10: Summary of the number of trucks, lane miles, and current wash water disposal methods for maintenance facilities in District 10. Shading indicates garages without access to sanitary sewer for the disposal of truck wash water.

County	Garage Name	Total Number of Dump Trucks	Lane Miles	Current Method of Wash Water Disposal
Athens County	Athens	10	315.90	Sanitary Sewer
	Hollister Outpost Garage (ATHPNO)	2	79.92	Leach Field or Mound
Gallia County	Gallia	13	423.80	Sanitary Sewer
Hocking County	Hocking	12	303.54	Sanitary Sewer

	Laurelville Outpost Garage (HOCPSW)	1	89.52	Sanitary Sewer
Meigs County	Meigs	12	389.58	Holding Tank/Reuse
	Tuppers Plains Outpost (MEGPNE)	3	97.04	Sanitary Sewer
Monroe County	Monroe	10	352.83	Sanitary Sewer
	Duffy Outpost Garage (MOEPSE)	2	83.26	Leach Field or Mound
Morgan County	Morgan	12	379.02	Holding Tank
Noble County	Noble	11	398.34	Sanitary Sewer
	Belle Valley Outpost Garage (NOBPWE)	4	77.20	Leach Field or Mound
Vinton County	Vinton	8	306.72	Holding Tank
	Wilkesville Outpost Garage (VINPSE)	2	45.84	Holding Tank
Washington County	Washington	13	298.36	Sanitary Sewer
	Bartlett Outpost Garage (WASPWE)	3	64.38	Leach Field or Mound
	Belpre Outpost Garage (WASPSW)	5	125.04	Leach Field or Mound
	Macksburg Outpost Garage (WASPNO)	3	136.52	Leach Field or Mound
	District 10 HQ Office			0
	District 10 Totals	126	3,966.81	

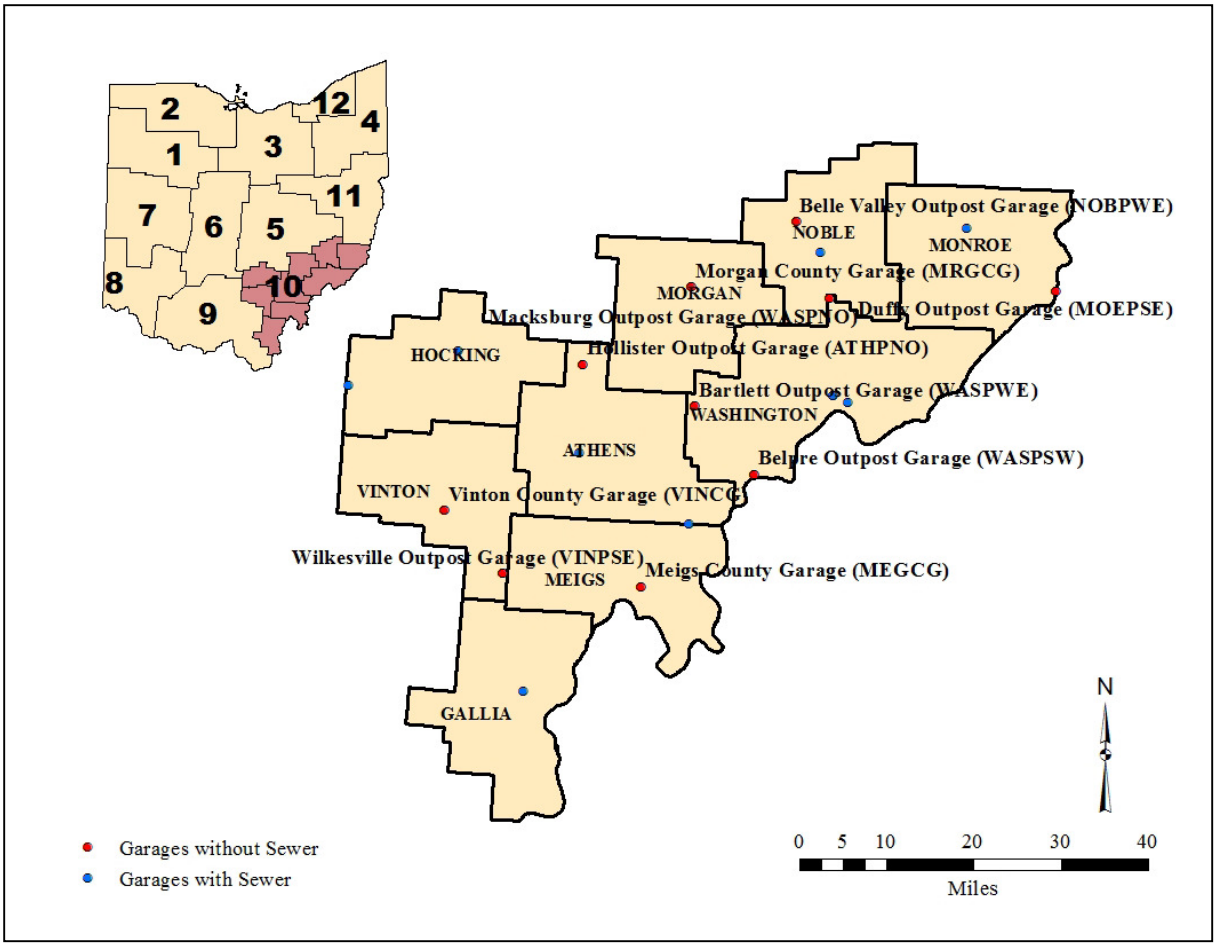

Figure C- 10: Locations of the District, County, and Outpost Garages in District 10. Garages in red lack access to sanitary sewer for truck wash water disposal.

Site Visits

Athens

Ten dump trucks are currently assigned to the Athens County Garage, which has access to sanitary sewer for the disposal of truck wash water.

Meigs

The Meigs County Garage does not have access to sanitary sewer for the disposal of truck wash water. Wash water generated at this facility is filtered and collected in a 10,000 gallon storage tank until it is needed for the production of brine that is used as part of the winter maintenance program. In addition to the 10,000 wash water storage tank, the Meigs County Garage has 18,000 gallon of storage available for brine.

Morgan

The Morgan County Garage does not have access to sanitary sewer for the disposal of truck wash water. Wash water is collected and stored on-site in a 10,000 gallon storage tank.

Vinton

The Vinton County Garage does not have access to sanitary sewer for truck wash water disposal. Instead, wash water generated at the Vinton County Garage is collected on-site in a 10,000 gallon holding tank.

Washington

The Washington County Garage disposes of truck wash water via the sanitary sewer.

District 11

Survey

ODOT District 11 maintains approximately 3,300 lane miles in Belmont, Carroll, Columbiana, Harrison, Holmes, Jefferson, and Tuscarawas Counties. In District 11, there are 2 county garages currently lacking access to sanitary sewer for truck wash water disposal: Columbiana County Garage and Tuscarawas County Garage. According to the Facilities Manager for District 11, Mr. Roy Crawford, full truck washing is not conducted at any facility without sanitary sewer access. Only safety washes, which include cleaning of the windows and mirrors, are permitted at these locations. Holding tanks have already been designed for the Columbiana and Tuscarawas County Garages, and will be constructed during the Summer of 2012. With the exception of the Apples Corner and Nashville Outpost Garages, which each have 15,000 gallon holding tanks for the collection of truck wash water, trucks from outpost garages without sanitary sewer are driven to the nearest county garage for full washing. The holding tanks at Apples Corner and Nashville Outposts are pumped for disposal approximately once per month during the winter and once per quarter during the non-winter season. The locations of maintenance facilities in District 11 are shown in Figure C-11. The number of trucks, lane miles, and current truck wash water disposal methods are summarized in Table C-11.

Table C- 11: Summary of the number of trucks, lane miles, and current wash water disposal methods for maintenance facilities in District 11. Shading indicates garages without access to sanitary sewer for the disposal of truck wash water.

County	Garage Name	Total Number of Dump Trucks	Lane Miles	Current Method of Wash Water Disposal
Belmont County	Belmont County - Morristown Garage	12	335.0	Sanitary Sewer
	Belmont - Barnesville Outpost	4	150.0	Leach Field or Mound
	Belmont - St. Clairsville Outpost	7	200.0	Leach Field or Mound
	Belmont-Shadyside Outpost Yard			Leach Field or Mound
Carroll County	Carroll County Garage	13	305.0	Sanitary Sewer
	Carroll - Malvern Outpost	0	-	0
Columbiana County	Columbiana County Garage	14	150.0	Leach Field/Holding Tank will be installed during summer 2012
	Columbiana - Unity Outpost	4	384.2	Leach Field or Mound
	Columbiana - Apples Corner Outpost	4	150.0	Holding Tank
Harrison County	Harrison County - Cadiz Garage	8	202.0	Sanitary Sewer
	Harrison - Scio Outpost	3	108.1	Sanitary Sewer
	Harrison - Freeport Outpost	3	74.1	Leach Field or Mound
Holmes County	Holmes County - Millersburg Garage	10	293.0	Sanitary Sewer
	Holmes - Nashville Outpost	3	59.0	Sanitary Sewer
Jefferson County	Jefferson County - Wintersville Garage	12	320.0	Sanitary Sewer
	Jefferson - Toronto Outpost	3	118.0	Leach Field or Mound
	Jefferson - Bergholz Outpost	1	39.0	Leach Field or Mound
	Jefferson-Dillonvale Outpost			Sanitary Sewer
Tuscarawas County	Tuscarawas County - New Philadelphia Garage	11	252.5	Leach Field/Holding Tank will be installed during summer 2012
	Tuscarawas - Dennison Outpost	2	64.0	Sanitary Sewer
	Tuscarawas - Zoar Outpost	2	50.0	Holding Tank
	Tuscarawas - Newcomerstown	4	116.0	Sanitary Sewer

	Outpost			
	District 11 HQ			Sanitary Sewer
	District 11 Totals	120	3,369.9	

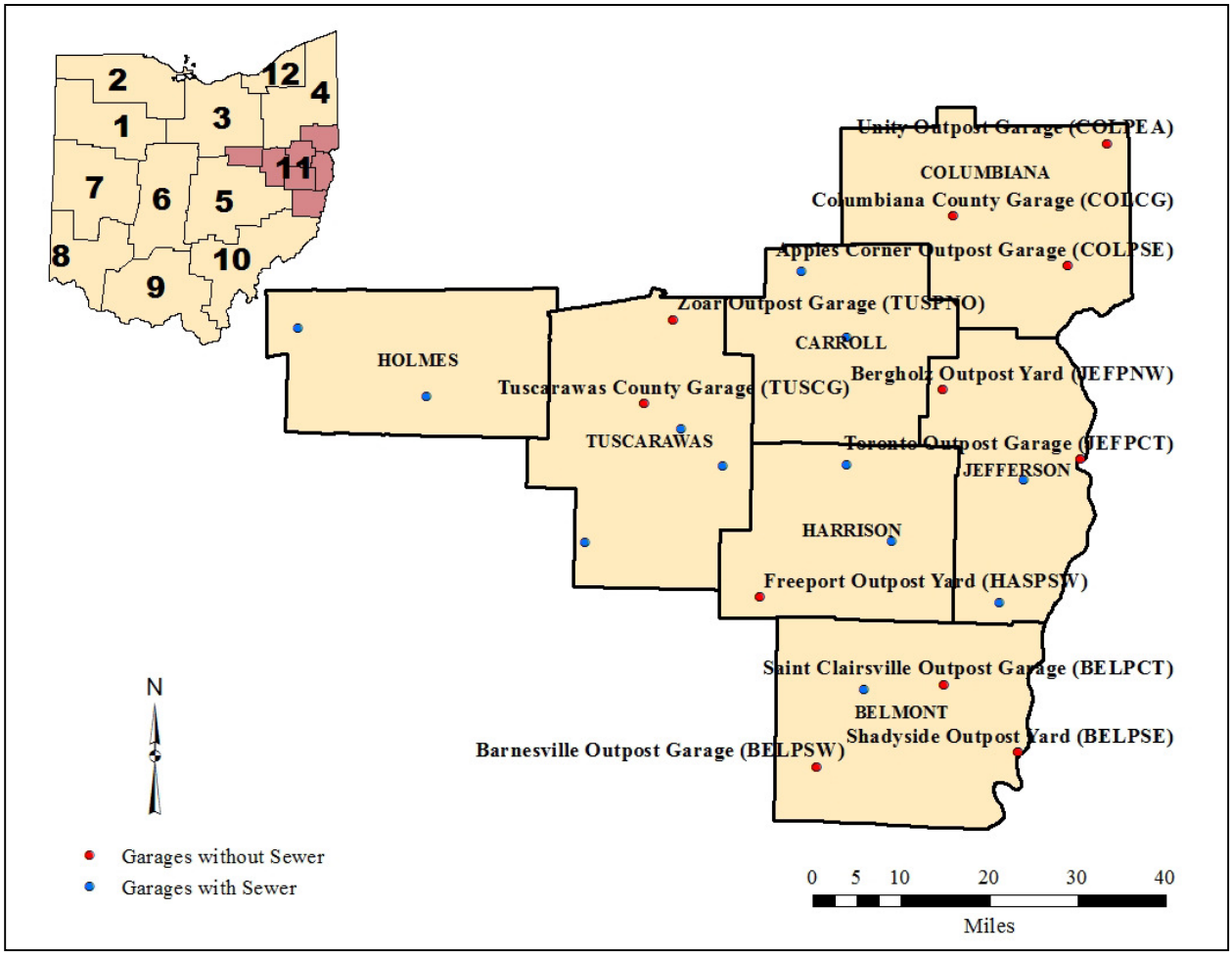

Figure C- 11: Locations of the District, County, and Outpost Garages in District 11. Garages in red lack access to sanitary sewer for truck wash water disposal.

Site Visits

Apples Corner Outpost

The Apples Corner Outpost currently collects wash water in a 10,000 holding tank until it can be pumped and disposed of off-site using ODOT personnel and equipment. According to the current facilities manager, John Migliore, District 5 has previously used a contractor for wash water disposal at a cost of approximately $3,500 to $4,000 per trip. When District 5 began using their own tanker truck and personnel, the cost was reduced to approximately $350 to $400 per trip, excluding labor and fuel costs.

District 12

Survey

District 12, located in northeast Ohio, includes Cuyahoga, Geauga, and Lake Counties and is headquartered in Garfield Heights, Cuyahoga County. All of the county garages in District 12 are currently tied into sanitary sewer for truck wash water disposal; however, there are five outpost locations without sanitary sewer access. According to the Facilities Manager for District 12, these locations manage truck wash water by capturing and storing it on-site in 4,000 gallon cisterns until it is pumped and hauled to a treatment facility for disposal. On average, these tanks require pumping three to four times per year. Table C-12 summarizes survey responses and Figure C-12 shows the locations of the garages in District 12.

Table C- 12: Summary of the number of trucks, lane miles, and current wash water disposal methods for maintenance facilities in District 12. Shading indicates garages without access to sanitary sewer for the disposal of truck wash water.

County	Garage Name	Total Number of Dump Trucks	Lane Miles	Current Method of Wash Water Disposal
Cuyahoga County	District 12 HQ			Sanitary Sewer
	611 Cleveland Garage	12	213.0	Sanitary Sewer
	612 Independence Garage	13	364.0	Sanitary Sewer
	613 Mayfield Garage	12	290.0	Sanitary Sewer

	614 Riveredge Garage	12	257.0	Sanitary Sewer
	615 Warrensville Garage	13	303.0	Sanitary Sewer
Geauga County	Geauga County Garage (GEACG)	8	86.0	Sanitary Sewer
	Montville Outpost Garage (GEAPNE)	3	93.0	Holding Tank
	Munson Outpost Garage (GEAPNO)	3	102.0	Holding Tank
	Parkman Outpost Garage (GEAPSE)	5	142.0	Holding Tank
Lake County	Lake County Garage (New) (LAKCG)			Sanitary Sewer
	Unionville Outpost Garage (LAKPNE)			Holding Tank
	Vrooman Road Outpost Garage (LAKPSE)			Holding Tank
	District 12 Totals	81	1,850	

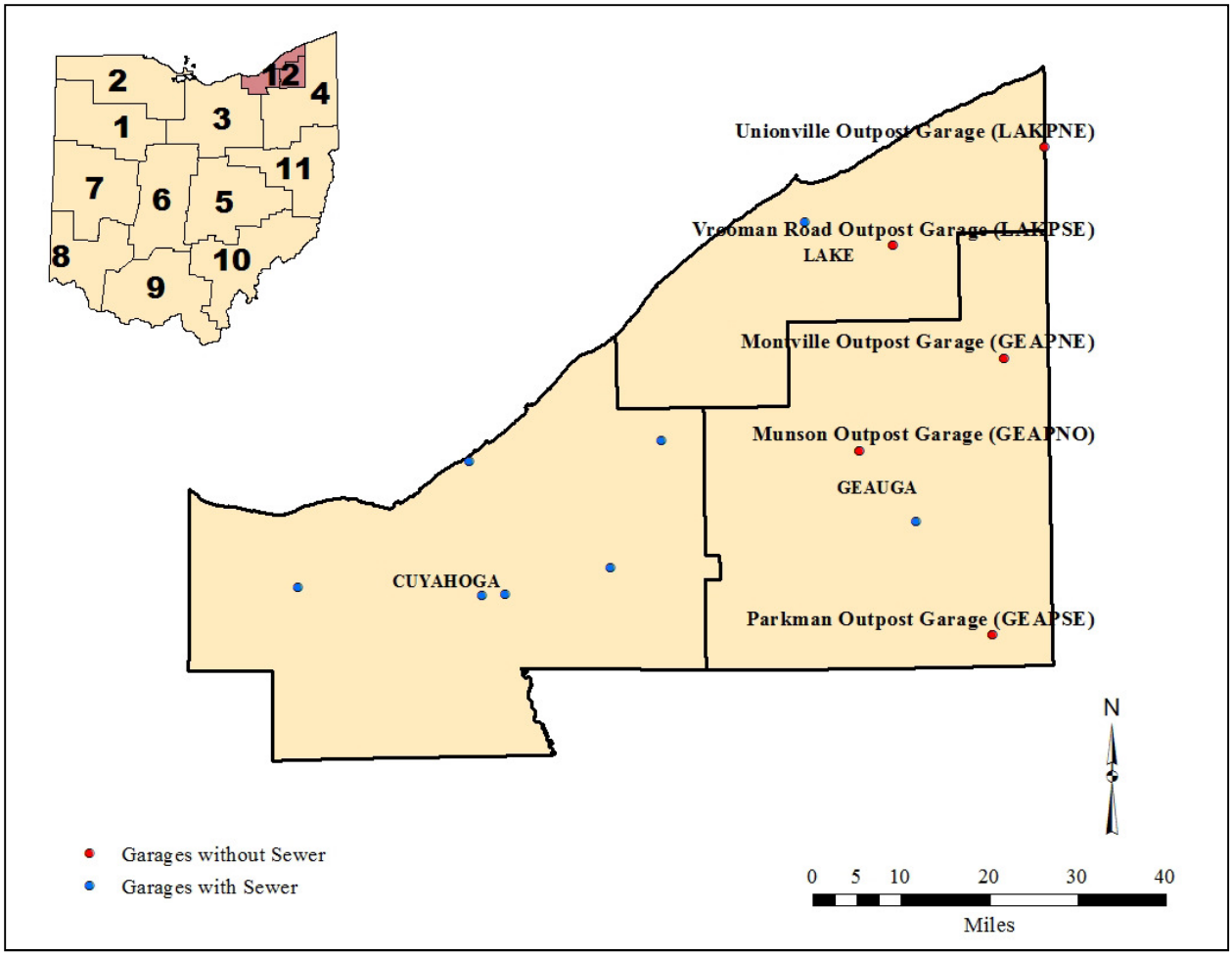

Figure C- 12: Locations of the District, County, and Outpost Garages in District 12. Garages in red lack access to sanitary sewer for truck wash water disposal.

Site Visits

Geauga County Garage

Twenty trucks are currently stationed at the Geauga County Garage. Truck washing occurs in a designated wash bay with a high pressure washing system that includes an undercarriage sprayer. According to the facilities manager, wash water generated during truck washing operations is disposed of in the sanitary sewer.

Munson Outpost Garage

There are three dump trucks stationed at the Munson Outpost Garage. Truck washing activities at this facility only include safety washes. Wash water generated during safety

washing is collected in a holding tank until it is pumped and hauled to a nearby WWTP for disposal. At the end of each event, trucks are driven to the Geauga County Garage for a full wash.

APPENDIX D

RAW DATA FROM PILOT UNIT EXPERIMENTS

Tables D-1 through D-7: All samples below the detection limit have been identified with the less than sign and the detection limit. Only traffic metals where at least one garage median violated the reuse standard have been included in the summarization below. All units are µg/L (ppb).

Table D- 1: Dissolved metal concentrations for the 140 gallon pilot unit run. (Concentrations of the influent at time 0: Copper- <1.2ppb, Zinc- 13ppb, Iron- 658ppb, and Lead- <1.4ppb.)

		Minutes from the Beginning of Trial						
		6	7	8	9	10	11	12
After Vessel 1	Copper	10	17	1	<1.2	<1.2	<1.2	2
	Zinc	3	19	20	3	13	16	15
	Iron	9	20	254	17	123	186	61
	Lead	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4
After Vessel 2	Copper		<1.2			2		
	Zinc		363			31		
	Iron		2307			1178		
	Lead		<1.4			3		
After 1µm Filter	Copper	1	1	2	4	3	1	2
	Zinc	13	11	12	14	17	15	17
	Iron	1431	1281	1215	1203	1150	1158	1148
	Lead	<1.4	<1.4	3	<1.4	2	<1.4	5

Table D- 2: Dissolved metal concentrations from the first pilot unit run of wash-water from Stark County. (Concentrations of the influent at time 0: Copper- 3.2ppb, Zinc- 28ppb, Iron-268ppb, and Lead-4.6ppb.)

		Minutes from the Beginning of Trial						
		10	25	40	55	70	85	97
After 5µm Filter	Copper		<1.2				<1.2	
	Zinc		74				15	
	Iron		195				170	
	Lead		5				3	
After Vessel 1	Copper	<1.2	65	5	<1.2	<1.2	<1.2	<1.2
	Zinc	20	--	17	16	14	9	12
	Iron	475	429	456	389	355	372	346
	Lead	3	9	4	4	<1.4	6	<1.4
After Vessel 2	Copper		<1.2				<1.2	
	Zinc		48				23	
	Iron		1010				779	
	Lead		<1.4				<1.4	
After 1µm Filter	Copper	<1.2	<1.2	<1.2		<1.2	<1.2	<1.2
	Zinc	12	11	10		9	10	9
	Iron	1688	1127	1067		679	580	533
	Lead	4	<1.4	3		5	5	8

Table D- 3: Total metal concentrations from the first pilot unit run of wash-water from Stark County. (Concentrations of the influent at time 0: Copper- 98ppb, Zinc- 282ppb, Iron-4016ppb, and Lead- 12ppb.)

		Minutes from the Beginning of Trial		
		25	55	85
After 5µm Filter	Copper	39		22
	Zinc	361		127
	Iron	3083		2153
	Lead	8		4
After Vessel 1	Copper	11		12
	Zinc	95		88
	Iron	902		914
	Lead	2		6
After Vessel 2	Copper	24		10
	Zinc	86		66
	Iron	1267		929
	Lead	<2.6		<2.6
After 1µm Filter	Copper	3	<0.6	6
	Zinc	21	5	30
	Iron	745	367	465
	Lead	4	<2.6	<2.6

Table D- 4: Dissolved metal concentrations from the second pilot unit run of wash-water from Stark County. (Concentrations of the influent at time 0: Copper- 1.6ppb, Zinc- 88ppb, Iron-110ppb, and Lead- <1.4ppb.)

		Minutes from the Beginning of Trial				
		10	25	40	55	70
After 5µm Filter	Copper	<1.2			<1.2	<1.2
	Zinc	11			64	68
	Iron	114			168	185
	Lead	2			10	2
After Vessel 1	Copper	<1.2	2	3	<1.2	<1.2
	Zinc	29	20	27	42	25
	Iron	100	106	118	100	101
	Lead	2	17	21	<1.4	5
After Vessel 2	Copper	<1.2	<1.2	3	3	1.3
	Zinc	4	17	23	16	13
	Iron	351	325	292	259	210
	Lead	2	<1.4	6	7	7

Table D- 5: Total metal concentrations from the second pilot unit run of wash-water from Stark County. (Concentrations of the influent at time 0: Copper- 138ppb, Zinc- 413ppb, Iron-1334ppb, and Lead- 373ppb.)

		Minutes from the Beginning of Trial				
		10	25	40	55	70
After 5µm Filter	Copper	65			108	122
	Zinc	294			382	402
	Iron	1599			1244	1952
	Lead	180			206	384
After Vessel 1	Copper	49	24	30	30	39
	Zinc	251	98	125	111	123
	Iron	637	689	544	604	629
	Lead	47	35	43	45	59
After Vessel 2	Copper	30	47	29	20	55
	Zinc	101	102	79	62	112
	Iron	554	643	629	531	602
	Lead	12	9	22	20	19

Table D- 6: Dissolved metal concentrations from the third pilot unit run of wash-water from Stark County. (Concentrations of the influent at time 0: Copper- 1.9ppb, Zinc- 78ppb, Iron-148ppb, and Lead- <1.4ppb.)

		Minutes from the Beginning of Trial							
		10	25	40	55	70	85	100	115
After 5µm Filter	Copper	<1.2		2		<1.2			<1.2
	Zinc	30		56		75			66
	Iron	176		235		278			229
	Lead	<1.4		10		<1.4			<1.4
After Vessel 1	Copper	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2
	Zinc	18	20	21	24	30	24	23	21
	Iron	181	153	147	140	156	116	126	139
	Lead	<1.4	<1.4	<1.4	3	4	5	11	2
After Vessel 2	Copper	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2	<1.2
	Zinc	<0.5	2	1	5	7	14	11	11
	Iron	295	278	241	244	211	208	213	193
	Lead	7	2	13	3	12	<1.4	<1.4	8

Table D- 7: Total metal concentrations from the third pilot unit run of wash-water from Stark County. (Concentrations of the influent at time 0: Copper- 118ppb, Zinc- 345ppb, Iron-1342ppb, and Lead- 182ppb.)

		Minutes from the Beginning of Trial							
		10	25	40	55	70	85	100	115
After 5µm Filter	Copper	37		40		39			16
	Zinc	206		198		188			49
	Iron	884		1767		1770			491
	Lead	32		10		11			12
After Vessel 1	Copper	19	31	32	12	37	19	12	14
	Zinc	142	84	95	68	107	84	67	77
	Iron	564	569	662	577	740	723	605	617
	Lead	20	10	11	7	9	<0.7	6	6
After Vessel 2	Copper	21	16	20	19	35	18	17	37
	Zinc	62	26	37	41	64	48	51	193
	Iron	324	347	423	459	480	470	477	1382
	Lead	12	6	7	3	3	5	2	9

Table D- 8: Total metal concentrations from six wash-water samples that were tested without filtering, after a 5µm filter, and after a 4µm filter. All bold numbers indicate that the reading is above the reuse standard as identified in Table 3-16 in Chapter 3. All units are µg/L (ppb).

		Copper			Zinc			Iron			Lead		
Sample	County Garage	Total	After 5µm Filter	After 4µm Filter	Total	After 5µm Filter	After 4µm Filter	Total	After 5µm Filter	After 4µm Filter	Total	After 5µm Filter	After 4µm Filter
1CB	Allen	**4021**	**80**	31	**5929**	**1066**	**829**	**83968**	5278	4109	**1435**	58	34
7CB	Stark	**520**	9	11	**3349**	237	180	**77994**	452	259	182	8	10
7CE	Stark	**97**	17	27	**792**	220	125	11925	193	137	28	2	10
9CE	Fairfield	**335**	**200**	**180**	**2249**	**1683**	**1626**	11201	1481	442	64	4	9
11DB	Guernsey	**1194**	16	15	**37971**	**7069**	**6865**	**173933**	1619	1360	**611**	4	6
25AE	Cuyahoga	**251**	**70**	**68**	**1803**	**1642**	**1616**	13249	7401	7614	63	56	52

APPENDIX E

EXAMPLE COST CALCULATION

For Single Garage with 12 trucks and 30 events; capital cost of sewer tie in of $300,000; hauling distance of 55 miles roundtrip; using revised default cost factors:

Parameter	Equation	Result
Annual Volume	$= \textbf{Number of trucks} * \textbf{Volume/Truck} * (\textbf{Number of Winter Events} * \textbf{1.1})$ Where Volume/Truck = 330 gallons/truck/cycle	= 12 * 330 * 30 * 1.1 =130,680 gallons
Annualized Sewer Tie In Cost	**Annualized Capital Costs = Capital Costs *** $\left[\frac{i}{((1+i)^n)-1}\right]+i$ Where: i = discount rate n = number of years $\textbf{Annual Costs} = \textbf{Volume} * \textbf{Disposal Rate}$ Where disposal rate = 0.01/gallon **Annualized Costs = Annualized Capital Costs + Annual Costs**	= 300,000 * $\left[\frac{0.07}{((1+0.07)^{40})-1}\right]+0.07$ = 22,502.74 = 130,680 *0.01 = 1,306.8 = 22,502.74 + 1,306.8 = 23,810
Commercial Disposal	**Annualized Capital Costs = Capital Costs *** $\left[\frac{i}{((1+i)^n)-1}\right]+i$ Where: i = discount rate n = number of years **Annual Cost = Disposal + Monitoring** **Annualized Costs = Annualized Capital Costs + Annual Costs**	= 30,000 * $\left[\frac{0.07}{((1+0.07)^{12})-1}\right]+0.07$ = 3,777 = (130,680 * 0.30)+ 1,385 =40,589 = 3,777 + 40,589 =44,366

WWTP	**Annualized Capital Costs = Capital Costs *** $\left[\frac{i}{((1+i)^n)-1}\right]+i$	= 30,000 * $\left[\frac{0.07}{((1+0.07)^{12})-1}\right]+0.07$
	Where: i = discount rate n = number of years	= 3,777
	Annual Cost = Disposal + Monitoring + Hauling Where: unit disposal cost = $0.05/gallon Monitoring cost = $1,385 Hauling cost = (labor + truck operation) * annual number of trips Labor rate = $26.35/hour Number of hours = (roundtrip distance / 45mph) + 1 hour to load/unload Operating cost = 0.53/mile + fuel cost/fuel efficiency Fuel cost = 4.15 Fuel efficiency = 7 mpg Annual number of trips = 130,680/2,000 (assuming 2,000 gallon storage tank)	= (130,680 * 0.05) + 1,385 + (130,680/2,000) * [(26.35* ((55/45) + 1)) + ((0.53 + 4.15/7) * 55))] = 15,780
	Annualized Costs = Annualized Capital Costs + Annual Costs	= 3,777 + 15,780 =19,557
Garage with Sewer	**Annualized Capital Costs = Capital Costs *** $\left[\frac{i}{((1+i)^n)-1}\right]+i$	= 30,000 * $\left[\frac{0.07}{((1+0.07)^{12})-1}\right]+0.07$
	Where: i = discount rate n = number of years	= 3,777
	Annual Cost = Disposal + Monitoring + Hauling Where: unit disposal cost = $0.01/gallon Monitoring cost = $1,385 Hauling cost = (labor + truck operation) * annual number of trips Labor rate = $26.35/hour Number of hours = (roundtrip distance / 45mph) + 1 hour to load/unload Operating cost = 0.53/mile + fuel cost/fuel efficiency Fuel cost = 4.15 Fuel efficiency = 7 mpg Annual number of trips = 130,680/2,000 (assuming 2,000 gallon storage tank)	= (130,680 * 0.01) + 1,385 + (130,680/2,000) * [(26.35* ((55/45) + 1)) + ((0.53 + 4.15/7) * 55))] = 10,553
	Annualized Costs = Annualized Capital Costs + Annual Costs	= 3,777 + 10,553 =14,330

Filtration and Disposal	**Annualized Capital Costs = Capital Costs *** $\left[\frac{i}{((1+i)^n)-1}\right]+i$	$= 60{,}000 * \left[\frac{0.07}{((1+0.07)^{12})-1}\right]+0.07$
	Where: i = discount rate n = number of years Capital Cost = Filtration Unit + Storage Filtration Unit = 30,000 Storage = 30,000	= 7,554
	Annual Cost = Disposal + Monitoring + Hauling + Media Replacement Where: unit disposal cost = $0.01/gallon Monitoring cost = $1,385 Hauling cost = (labor + truck operation) * annual number of trips Labor rate = $26.35/hour Number of hours = (roundtrip distance / 45mph) + 1 hour to load/unload Operating cost = 0.53/mile + fuel cost/fuel efficiency Fuel cost = 4.15 Fuel efficiency = 7 mpg Annual number of trips = 130,680/2,000 (assuming 2,000 gallon storage tank) Annual Media Replacement = 4,600	= (130,680 * 0.01) + 1,385 + (130,680/2,000) * [(26.35* ((55/45) + 1)) + ((0.53 + 4.15/7) * 55))] + 4,600 = 15,153
	Annualized Costs = Annualized Capital Costs + Annual Costs	= 7,554 + 15,153 =22,707

Filtration and Reuse	**Annualized Capital Costs = Capital Costs *** $\left[\frac{i}{((1+i)^n)-1}\right]+i$	= 60,000 * $\left[\frac{0.07}{((1+0.07)^{12})-1}\right]+0.07$
	Where: i = discount rate	= 7,554
	n = number of years Capital Cost = Filtration Unit + Storage Filtration Unit = 30,000 Storage = 30,000	
	Annual Cost = Monitoring + Hauling + Media Replacement	= 1,385 + (130,680/2,000) * [(26.35* ((55/45) + 1)) + ((0.53 + 4.15/7) * 55))] + 4,600
	Where: Monitoring cost = $1,385 Hauling cost = (labor + truck operation) * annual number of trips Labor rate = $26.35/hour Number of hours = (roundtrip distance / 45mph) + 1 hour to load/unload Operating cost = 0.53/mile + fuel cost/fuel efficiency Fuel cost = 4.15 Fuel efficiency = 7 mpg Annual number of trips = 130,680/2,000 (assuming 2,000 gallon storage tank) Annual Media Replacement = 4,600	= 13,846
	Annualized Costs = Annualized Capital Costs + Annual Costs	= 7,554 + 13,846 =21,400