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Evaluation of the Virginia Department of Transportation's Current Practices for Tracking Storm Drain Cleaning Operations to Support Pollutant Removal Crediting

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The Virginia Department of Transportation (VDOT) implements a number of different best management practices to meet pollutant load reductions associated with the Chesapeake Bay Total Maximum Daily Load (TMDL) Program. Although commonly implemented best management practices include structural practices such as bioretention filters and extended detention ponds, pollutant load reductions can also be met by reporting information on certain maintenance activities such as storm drain and pipe clean-outs. Storm drain and pipe clean-outs achieve pollutant load reductions by removing pollutant-containing material that has accumulated in the storm sewer system before it can be transported into the Chesapeake Bay or other regulated waters.

In order to claim pollutant load reductions associated with this work, certain information needs to be provided to support these claims. This information includes the mass of material removed from storm drains located in regulated areas, termed "municipal separate storm sewer system (MS4) service areas"; any default values used to calculate pollutant load reductions and how these values were developed; and a standard operating procedure documenting the processes used to collect and report this information.

The purpose of this study was to evaluate VDOT's current practices for conducting these clean-outs, including a review of the contracts established with contracted clean-out crews and the landfills where this material is disposed. The scope of this study was limited to VDOT's Richmond District; however, the findings and recommendations can be readily applied statewide.

The observations made during this study identified a number of key factors in VDOT's current practices that require modification in order to report accurate pollutant load reductions provided by these clean-outs. This included noting when material is removed from specific storm drains during clean-outs and adding the MS4 service area to the geographic database used to schedule and report these activities. A recommendation was made that the VDOT consider increasing the comprehensiveness of its inventory of storm drains across the state since the current inventory is limited to storm drains located on interstate highways.

By use of the current inventory of storm drains and pipes in the Richmond District's MS4 service area and default nutrient enrichment factors developed by the Chesapeake Stormwater Network and other default values from the literature, the pollutant load reductions provided by VDOT clean-outs were estimated assuming annual clean-out of each asset. The load reduction estimates were 416 lb/yr, 2,626 lb/yr, and 168,241 lb/yr for total phosphorus, total nitrogen, and total suspended solids, respectively. Because of the purchase price of an equivalent amount of nutrient credits in the James River Watershed, these load reductions could represent a significant cost savings, from \$4 million to \$5 million per year for total phosphorus alone. Since these clean-outs are already being conducted as part of routine VDOT maintenance, the cost savings would be realized without additional work by VDOT operators or contractors in the field.

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FINAL REPORT

EVALUATION OF THE VIRGINIA DEPARTMENT OF TRANSPORTATION'S CURRENT PRACTICES FOR TRACKING STORM DRAIN CLEANING OPERATIONS TO SUPPORT POLLUTANT REMOVAL CREDITING

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ABSTRACT

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INTRODUCTION

In response to an observed decrease in the overall health of the Chesapeake Bay and a number of its tributaries, the U.S. Environmental Protection Agency established the Chesapeake Bay Total Maximum Daily Load (TMDL) Program. The overall goal of this program is to reduce the amount of pollutants such as nitrogen and phosphorus entering the Chesapeake Bay. In Virginia, this program is monitored by the Virginia Department of Environmental Quality (VDEQ), which issues permits to municipal separate storm sewer systems (MS4s), such as VDOT's, allowing the discharge of stormwater from impervious areas into the surface waters of Virginia. These permits are a part of VDEQ's Virginia Pollutant Discharge Elimination System.

Under VDOT's individual Virginia Pollutant Discharge Elimination System permit, VDOT has committed to reducing the loads of nutrients and sediments discharging from its MS4 in a three-phased approach, with each phase (consisting of an MS4 permit cycle) calling for increased reductions of nitrogen, phosphorus, and total suspended solids (TSS). Phase I required a 5% reduction, Phase II an additional 31% reduction, and Phase III an additional 64% reduction. By the end of Phase III, VDOT will be required to reduce 100% of these discharges, returning the bay to its natural "pollutant diet." Currently, VDOT is in Phase II of this process.

To meet these TMDLs, VDOT implements a number of best management practices (BMPs) to remove nutrients and sediments from stormwater. These BMPS include the development of green infrastructure such as bioretention filters, streambank restoration and stabilization projects, and community outreach efforts, to name a few. However, because of the increased TMDL reductions planned for the future, VDOT is continually working to establish additional practices to implement. One of these additional methods, storm drain cleaning, is of particular interest since this work is already conducted as part of VDOT's general maintenance routine. Storm drain cleaning refers to the removal of accumulated material from the storm drains, drop inlets, catch basins, pipes, and other infrastructure that make up the MS4. For the purposes of this report, inlets, drop inlets, and catch basins are termed "storm drains." Similar to street sweeping, storm drain and pipe clean-outs achieve nutrient and sediment reductions by removing road-deposited sediments, organic matter, trash, and pollutants from the MS4 before they have the opportunity to migrate farther into the system or into surface waters.

Previous research has shown that material accumulated on the surface of the street and, to a greater extent, in the associated storm drains can serve as sinks for pollutants such as heavy metals (Alaska Department of Transportation and Public Facilities, 2000; Florida Department of

Environmental Protection, 2004; Jang et al, 2010; Jartun et al., 2008; Lloyd et al., 2018); hydrocarbons (Alaska Department of Transportation and Public Facilities, 2000; Azah et al., 2015; Florida Department of Environmental Protection, 2004; Jang et al., 2010; Jartun et al., 2008; Lloyd et al., 2018); fine sediments (Azah et al., 2015; Donner et al., 2016; Jartun et al., 2008; Lloyd et al., 2018); and nutrients (Kang et al., 2020; Law et al., 2018). Conducting these clean-outs not only ensures the proper functioning of the MS4 but also prevents this material and the associated pollutants from entering surface waters and contributing to the already observed adverse impacts to the bay and many of its tributaries.

Calculating Nutrient Removal Credits

The material collected during storm drain or pipe clean-outs is typically removed using a vacuum truck (hereinafter "vac truck") that uses pressurized water to loosen accumulated material in the pipe or storm drain followed by a vacuum to remove it when needed. Pollutant removal credits are then calculated for the removed material using the following information: (1) the wet mass of material collected; (2) the fraction of material categorized as sediment, organic matter, or trash; and (3) the moisture content of the material (Donner et al., 2016; VDEQ, 2020a). Using this information and a set of pre-defined enrichment factors (EFs), the pounds of total phosphorus (TP), total nitrogen (TN), and TSS removed from the MS4 service area can be calculated for a given quantity of material.

The EFs used to calculate the pounds of TP, TN, and TSS removed can be derived from laboratory analysis of the material; as an alternative, a set of default values developed by the Chesapeake Stormwater Network (CSN) can be used if necessary. In a 2016 expert panel report, CSN provided default TP, TN, and TSS EFs for sediment and organic matter collected from storm drains. These EFs are provided in Table 1 and are based on a search of the literature conducted as part of CSN's expert panel review. Although CSN provided these default values for use by reporting agencies, they recommended that these values be confirmed and modified periodically based on laboratory analysis of representative samples of the material (Donner et al., 2016).

CSN broke down the process for calculating pollutant removal credits achieved from storm drain clean-outs into five steps: (1) applying a discounting factor to remove large particles; (2) determining how much of the material is sediment or organic matter; (3) converting the mass of material from tons to pounds; (4) converting wet weight to dry weight; and (5) determining the nutrients and sediment removed through storm drain and pipe clean-outs.

Table 1. Enrichment Factors for Material Collected During Storm Drain Clean-Outs

Solid Fraction	Total Phosphorus	Total Nitrogen	Total Suspended Solids
Sediment	0.0006	0.0027	0.3
Organic Matter	0.0012	0.0111	0.3

Data from Donner et al., 2016.

As noted previously, each step except Steps 2 and 3 applies a number of EFs or other default values developed during CSN's expert panel review. Specifically, in Step 1 it is assumed that 30% of the material removed during clean-outs is larger than what can be categorized as TSS; therefore, a discounting factor of 70% is applied to the total mass of the material (Donner et al., 2016). In Step 4, it is assumed that the moisture content of the sediment and organic matter fractions are 30% and 80%, respectively, and in Step 5, the EFs provided in Table 1 are applied to the sediment and organic factions of the material to determine the load reductions of TP, TN, and TSS (Donner et al., 2016).

Although clean-outs of storm drains and pipes are already conducted by VDOT to maintain the proper functioning of the drainage system, VDOT currently does not report these activities for TMDL credits. In order to claim these credits, VDEQ requires that the "removal credit must be supported by data on the measured mass of the nutrient-rich sediment that is physically removed from the storm drain system" as recommended by CSN's expert panel (Donner et al., 2016; VDEQ, 2020a).

Regulated Areas

It is important to note that although clean-outs are conducted throughout the state, only material removed from specific areas can be reported for TMDL credits. As stated in the individual permit, VDOT is required to meet these TMDLs in areas defined as the "MS4 service area." This MS4 service area consists of the acres of right of way and other VDOT property located within the 2010 Census Urban Areas (CUAs), which drain into one of the four tributaries to the Chesapeake Bay in Virginia (VDOT, 2018a). These tributaries include (1) the James River Basin, (2) the Potomac River Basin, (3) the Rappahannock River Basin, and (4) the York River Basin (VDOT, 2018a).

VDOT's MS4 contains more than 36,000 storm drains and pipes distributed across the state. Of these, only about 7,000 are located in areas designated the MS4 service area. The large size and distributed nature of the system pose a number of challenges associated with tracking storm drain cleaning operations of this infrastructure and quantifying the amount of material removed from the system that is eligible for TMDL crediting. Although the CSN report provided default EFs for nutrients, it did not provide a default value for the amount of material that can be expected to be removed from an individual storm drain. This is likely due to the effects that factors such as density of tree canopy cover, time of year, storm drain geometry, and traffic load can have on the amount of material that can accumulate in a given storm drain or pipe.

PURPOSE AND SCOPE

The purpose of this study was (1) to evaluate VDOT's current practices for conducting clean-outs of storm drains, pipes, and other creditable stormwater infrastructure with a focus on determining what information is collected during these operations; (2) to determine how much of this work is conducted by state forces vs. contractors and how operations conducted by these crews differ; (3) to evaluate the structure of existing contracts between VDOT and the vendors used to conduct this work; and (4) to develop recommendations outlining what key data should be collected during these clean-out operations and identify any modifications that should be made to future contracts.

Although the scope of this study was limited to VDOT's Richmond District, it was hoped that the information provided from this study would be applicable to the other VDOT districts that must meet TMDL reductions. Based on 2010 census data, CUAs are present in all nine VDOT districts. Of these nine districts, seven contain CUAs located within the Chesapeake Bay Watershed, termed "MS4 service areas" for the purposes of this report.

METHODS

Literature Review

An extensive search of the literature was conducted. This included a search of the literature from the scientific community and relevant regulatory agencies and TMDL action plans of other municipalities in Virginia. The tools used to conduct these searches included Web of Science, Google Scholar, and simple Google searches.

The focus of these searches was information on the pollutant and physical characteristics of material collected during these clean-out procedures and how other states and Virginia municipalities are tracking and reporting this work for TMDL purposes. Any guidance documents developed in coordination with the regulators, such as those developed by CSN, were also reviewed to establish what information is required for reporting these activities for credits.

Field Observations

Field observations of active storm drain cleaning operations conducted by both state forces and private contractors were conducted. Information regarding the methods used to clean-out both pipes and storm drains was collected including the type of equipment used and general procedures followed by the crews. Visual observations of the infrastructure being cleaned were also made including the structure type (i.e., cross pipe, driveway pipe, or storm drain) and the general characteristics of the accumulated material (i.e., soil, trash, roots, vegetation, or sediment).

Site visits were also made to decanting sites in the Richmond District to observe the methods used to clean-out vac trucks at the end of the day or service period and to collect grab samples of that material for analysis.

Interviews With Personnel

Maintenance personnel responsible for scheduling storm drain and pipe cleaning, conducting storm drain and pipe cleaning, and monitoring clean-out operations conducted by contractors were interviewed. The purpose of these interviews was to identify the common practices used not only to conduct this work in the field but also to schedule and report its completion. Interviews were also conducted of administrative personnel responsible for managing VDOT contracts with private sector vac truck operators and the landfills that receive the waste generated from this work. These individuals included residency administrators and business administrators, interstate maintenance office (IMO) personnel, vac truck operators, area headquarters (AHQ) superintendents, and maintenance operations managers.

RESULTS AND DISCUSSION

Literature Review

Required Information for Reporting TMDL Credits Associated with Storm Drain Cleaning

Chesapeake Stormwater Network

Practices such as bioretention, extended detention, or other “structural” stormwater treatment practices capable of producing reductions in nutrients and sediments are qualified to receive perpetual TMDL credits (VDEQ, 2020b). This means that the reporting agency can claim a set amount of TMDL credits per practice per year. Reporting requirements generally include proof that the practice is functioning as intended, which is confirmed through inspection records. Comparatively, practices such as street sweeping and storm drain clean-outs are considered non-structural or “annual” stormwater treatment practices in that they achieve stormwater treatment through programmatic changes conducted on an ongoing basis rather than a physical installation. Because of this, these practices are eligible to receive annual credits and require significantly more supporting information both to calculate and to verify the pollutant load reductions they can provide (VDEQ, 2020b**)**.

In 2016, CSN published their *Expert Panel Report to Define Removal Rates for Street and Storm Drain Cleaning Practices* (Donner et al., 2016). As is evident from the title, this report provided the methods used for calculating pollutant reductions provided by street sweeping and storm drain clean-outs. The report also defined the recommended supporting information that localities should provide to verify this information (Donner et al., 2016). This included the following: location of clean-outs (either centroid of jurisdiction or 12-digit hydraulic unit code [HUC] watershed address); how sediments and/or organic matter was measured; supporting documentation for the level of storm drain cleaning effort (e.g., dumpster loads, disposal tickets, tipping fees, or vac truck loads); the equation used to convert wet sediment volumes to dry sediment mass; and the nutrient enrichment ratios applied to the sediment mass (Donner et al., 2016).

The 2016 CSN report also recommended that collection methods for the information be incorporated into a standard operating procedure (SOP) to ensure that storm drain clean-out efforts “have a strong water quality focus” (Donner et al., 2016). An SOP from Baltimore County, Maryland, was referenced in the report as an example of what this SOP should include.

Generally, Baltimore County's SOP was broken into two sections: (1) the tracking of clean-out operations, and (2) the calculation of pollutant load reductions. Tracking of clean-out operations included recording the date of the clean-out and the mass of material removed from the individual storm drain or pipe. Baltimore County established a database where each individual storm drain or pipe has an associated record of when that particular asset was cleaned and the amount of material removed. For pipes, these records include information on the length of pipe cleared, upstream and downstream manhole number, pipe size, and type of debris removed. For storm drains, information on the length, width, and depth of the storm drain before and after cleaning, type of debris removed, and odor before and after cleaning is recorded (Baltimore County Department of Environmental Protection and Sustainability, 2015). In both cases, the arrival time of the clean-out crew and the local weather are also noted. These records are then uploaded to a database called CASSWORKS so that pollutant load reductions can be calculated by the relevant responsible personnel.

Using the tracking data provided by the clean-out crews, Baltimore County calculates pollutant load reductions through a series of excel spreadsheets stored in the CASSWORKS database (Baltimore County Department of Environmental Protection and Sustainability, 2015). Of particular interest here is that the storm drain dimensions before and after cleaning, recorded in the field, are used to calculate the volume of material removed from an individual drain (Baltimore County Department of Environmental Protection and Sustainability, 2015). This volume and a default material density are used to determine the mass of material removed. No guidance was provided on determining the amount of material removed from pipes. In addition, using the provided location information, each clean-out is geocoded in the Excel spreadsheet so that clean-outs conducted outside the MS4 service area are not included in the final calculation of pollutant load reductions for each watershed.

The result of this process is an Excel spreadsheet containing a pivot table that can be used to show the number of storm drains cleaned and volume of material removed per watershed (Baltimore County Department of Environmental Protection and Sustainability, 2015). A discounting factor is applied to the total mass of material to account for the amount of trash (8.9%). In this SOP, TN, TP, and TSS reductions are calculated based on the mass of both sediment and organic matter (OM). Default EFs used by Baltimore County to calculate these reductions are provided in Table 3 later in this report.

VDEQ BMP Verification Plan

VDEQ has adopted many of the tracking requirements laid out in the 2016 CSN report. As part of this effort, VDEQ has developed a BMP Verification Plan, which provides guidance to agencies and localities on how to report these practices properly. In this plan, BMPs are broken up first by "sector" (agricultural, urban, etc.) and then into "verification groups" based on the practice type (annual, structural, etc.), credit duration, program type (i.e., voluntary or regulatory), and risk for failure. Storm drain clean-outs (grouped together with street sweeping) have the following designations: Sector: Urban; Practice Type: Annual; Credit Duration: 1 year; and Program Type: Voluntary/Regulatory (VDEQ, 2020b). As part of the verification plan, VDEQ requires that reports of this practice include weigh station reports indicating the date and weight of material collected or "by vehicle logs documenting the area swept" (VDEQ, 2020b).

Although this guidance makes no mention of providing location information for storm drain cleaning, it should be assumed that it is still needed since VDEQ currently groups street sweeping and storm drain cleaning together in its list of approved practices.

The guidance provided in the BMP Verification Plan was written with the intent of providing the reporting agency with a certain degree of flexibility when developing their verification protocols (VDEQ, 2020b). As stated in the plan, this flexibility is permitted as long as five "verification principles" are incorporated: (1) practice reporting, (2) scientific rigor, (3) public confidence, (4) adaptive management, and (5) sector equity. Detailed definitions of each of these verification principles are provided in VDEQ's BMP Verification Plan (VDEQ, 2020b).

Default Values for Nutrient and Sediment Reductions From the Literature

Default nutrient and sediment EFs or load reduction rates for storm drain clean-out practices have been developed by a number of organizations and localities. As mentioned previously, these default values are typically developed based on representative sampling of the material by the reporting entity. Although these default values lessen the burden placed on those reporting these activities, a large degree of variance between them is apparent. This is likely due to variations in tree canopy cover (Donner et al., 2016; Law et al., 2018; Maryland Department of the Environment [MDE], 2020); traffic load (Donner et al., 2016); land use type (Donner et al., 2016; Law et al., 2018); or time of year (Donner et al., 2016; Kang et al., 2020; Law et al., 2018). In addition, it should be noted that these default values are representative of material removed only from storm drains, not from pipes or concrete-lined conveyance ditches. Specifically, the default values developed by CSN (Donner et al., 2016; Kang et al., 2020; Law et al., 2018) were developed based on sampling material collected only from storm drains, not from these other creditable assets.

The SOP developed by Baltimore County uses default values from two sources:

1. *Default values for the density and fractions of sediment/organic matter and trash were taken from a study by Law et al. (2018).* This study provided the following default values: material density = 331 lb/yd^3, fraction of sediment/organic matter = 91.1%, and fraction of trash = 8.9% based on the total wet mass of material.

2. *Default values for the pollutant load reductions (as opposed to the EFs provided by CSN) were adopted from those developed by MDE.* MDE established these values in 2014 and assumed that 30% of the total weight of the material is water (MDE, 2020). At the time Baltimore County was developing their SOP, MDE did not separate the fractions of sediment and OM when calculating the associated TN, TP, and TSS pollutant load reductions. However, in 2020, MDE updated their guidance and provided the values in Table 2. It should also be noted that MDE permits jurisdictions to "visually determine the predominant material type" (i.e., sediment or OM) when applying these values (MDE, 2020). These load reductions were converted to EFs and are provided in Table 3 for comparison to the EFs developed by CSN and others.

Table 2. Pollutant Load Reductions Provided by the Maryland Department of the Environment (2020)

Solid Fraction	Load Reduced (lb/ton/yr)		
	Total Nitrogen	Total Phosphorus	Total Suspended Solids
Organic Matter	4.44	0.48	400
Sediment	3.78	0.84	1,400

Maryland Department of Transportation State Highway Administration

In 2018, the Maryland Department of Transportation (MDOT) State Highway Administration (SHA) completed a study characterizing the material removed from storm drain clean-outs with the goal of providing "SHA with local data required to justify regulatory credit regarding inlet cleaning practices" (Law et al., 2018). This characterization included a determination of "the mass of pollutants removed by inlet cleaning by removal of stormwater-borne solids" and quantifying "the mass and accumulation rate of target pollutant loads related to gross, coarse, and fine solids entering highway catch basins" (Law et al., 2018). A number of other associated studies were also published and are cited in the study, most notably the study by Kang et al. (2020).

Over a 9-month period, MDOT monitored and sampled a total of 40 storm drains to determine the monthly and annual rates of debris accumulation. Storm drains were selected based on a number of factors, including the land use of the surrounding area, with the goal of selecting storm drains representative of the state (Kang et al., 2020; Law et al., 2018). These land use categories included low, medium, and high density residential, commercial, transportation, and other developed lands (Kang et al., 2020; Law et al., 2018).

Results from the study showed a high degree of variability in the average mass of material removed from the storm drains monitored, with the average total dry weight of material removed per drain ranging from 28 to 1,230 lb (Kang et al., 2020; Law et al., 2018). On average, these dry solids consisted of 67% sediment, 31% organic material, and 4% trash (Kang et al., 2020). As with the total dry solids, a wide range in the percentage of sediment (32% to 85%), OM (13% to 66%), and trash (1% to 14%) was found (Kang et al., 2020).

Prior to this study, MDOT SHA applied a default value for the total (i.e., gross solids) mass of material removed per storm drain per year of 210 lb/drain/yr (Kang et al., 2020). The results from this series of studies indicated an average value of 128 lb/drain/yr, significantly less than what was originally estimated (Kang et al., 2020). The authors noted that the variation between these values was likely due to some assumptions used during the calculation of the original default value, including the assumption that all of the storm drains were full of debris when cleaned (Law et al., 2018). Results from the monitoring period showed that storm drains on average were only 9% full of material and at a maximum were 35% full (Law et al., 2018). These results were further confirmed by a storm drain inventory conducted by MDOT SHA in 2017 of urban storm drains that found that only 8% of the storm drains inspected were at least one-half full and 1% were full (Law et al., 2018).

Along with determining the average accumulation rate of material in storm drains, MDOT SHA determined the pollutant load in the collected material. Specifically, dried solids were analyzed to determine the amount of TN (as Total Kjeldahl Nitrogen, or TKN) and TP in the sediment and organic fractions of material removed during storm drain clean-outs. TP concentrations ranged from 7.1 to 549 mg/kg and 84 to 948 mg/kg in the sediment and OM fractions, respectively. The authors observed that storm drains with a noticeable amount of fresh leaf litter or grass clippings corresponded to increased TP concentrations (Law et al., 2018). Average TP concentrations were 174 mg/kg and 387 mg/kg in the sediment and OM fractions, respectively. Average TN concentrations were 5,358 mg/kg and 40,211 mg/kg in the sediment and OM fractions, respectively. The authors attributed the large increase in TN concentration in the OM fraction to pollen wash-off during the spring leaf-out period (Law et al., 2018). A correlation between this spring phenomenon and increased nitrogen concentration in urban runoff was established in a study by Selbig (2016). When the entire sample (sediment and organic matter combined) was considered, average TP and TN concentrations were 229 mg/kg and 12,438 mg/kg, respectively. Based on this analysis, the authors developed the nutrient EFs provided in Table 3.

In a comparison of the EFs developed by CSN (Donner et al., 2016), MDOT SHA (Law et al., 2018), and MDE (2020), provided in Table 3, a degree of variation was seen. For example, EFs for TN had the greatest amount of variation, particularly in the OM fraction where the relative standard deviation was more than 100%. Relative standard deviations for TP, TN, and TSS EFs in the sediment fraction were approximately 50%.

These results highlight the variability in both the accumulation of material in storm drains and the nutrient load associated with that material. Although VDEQ allows for the use of the default EFs developed by CSN, CSN guidance suggested that users develop their own values based on sampling results. This suggestion is further reinforced by the results from the studies highlighted, which indicated that the application of the CSN default values could significantly under- or overestimate the amount of TMDL credits achieved through this work. This is especially true when the limited number of characterization studies conducted on this material specifically for TMDL crediting purposes is considered.

VDOT Inventory of Stormwater Assets (Highway Maintenance Management System)

VDOT currently maintains one of the largest road networks in the United States. Along with this road network, a substantial drainage system exists to collect and convey stormwater runoff off and away from the road. To keep track of a number of maintenance activities associated with this system, VDOT's Maintenance Division has begun to develop and use the Highway Maintenance Management System (HMMS). This system consists of a database of roadway assets such as retaining walls, guardrails, pipes, and storm drains across the state. For pipes, information including location, geometry (e.g., diameter, length, and depth), construction material (e.g., concrete, metal), design type (e.g., cross), and end type are uploaded into the HMMS and used to schedule and track various maintenance activities across the state. At this time, information on storm drains stored in the HMMS is limited and includes only location information.

Table 3. Nutrient Enrichment Factors Developed by Departments and Organizations in Maryland and the Relative Standard Deviation Between These Factors

Solid Fraction	Chesapeake Stormwater Network (Donner et al., 2016)			Maryland DOT (Law et al., 2018)			Maryland Department of the Environment (2020)			Average ± Relative Standard Deviation		
	TP	**TN**	**TSS**	**TP**	**TN**	**TSS**	**TP**	**TN**	**TSS**	**TP**	**TN**	**TSS**
Sediment	0.0006	0.0027	0.3	0.0002	0.0055	NA	0.00042	0.00189	0.7	0.00041 ± 49%	0.0034 ± 56%	0.5 ± 57%
Organic Matter	0.0012	0.0111	0.3	0.0004	0.0318	NA	0.00024	0.0022	0.2	0.00061 ± 84%	0.015 ± 101%	0.25 ± 28%

NA = not assigned.

Relative standard deviations represent the standard deviation of the average total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) enrichment factors developed by the three studies.

As maintenance issues are reported to the Customer Service Center (CSC), service requests are generated in the HMMS providing information on the location of the issue, type of issue, and type of asset impacted. Figure 1 provides an example service request, termed by the CSC as a “Service Call Form” as it appears in the HMMS. In this case “Drainage Problem_Drop Inlets” was selected from the drop-down list based on the information provided by the customer in the “Description” field.

Once a Service Call Form has been generated in the HMMS, the request can be delegated to the respective residency and AHQ where a work order (WO) is generated. These WOs are received by both the maintenance operations manager at the residency level and the AHQ superintendent. Containing much of the same information as the Service Call Form, these WOs are used both to schedule maintenance and report when it has been completed by the AHQ superintendent. In addition, these WOs can be linked to specific assets based on the Asset ID Number generated in the HMMS; to do this, however, the asset must already exist in the HMMS or be added manually.

Figure 2 is the WO associated with the Service Call Form in Figure 1. As can be seen, upon completion of the work, operators recorded that three pipes totaling 104 linear feet were cleaned out to address the clogged drain under the “Activity Description” of “72206—Pipe/Culvert Clean & Repair.”

Service Call Form Report

ID: INT-031121-456
Logged By: VUEWorks 03/11/2021 04:30 PM
Ref: 1401661
Type: Maintenance
Division: Customer Service Center (CSC)
Issue: Drainage Problem_Drop Inlets
Group:
Location: 9389 Blakeridge Ave, Mechanicsville, VA 23116
Assigned To: RI-Ashl-Ashland AHQ 03/11/2021 04:30 PM

Status: Closed
Date / Time Occurred: 03/11/2021 04:30 PM
Date / Time Responded To: 03/15/2021 02:50 PM
Response Time: 3 dy 22 hr 20 min
Closed By: Kenneth Gentry
Date / Time Closed: 03/15/2021 02:50 PM
ResolvedTime: 3 dy 22 hr 20 min

Work Area Initial Assignment: RI-Ashl-Ashland AHQ
District: Richmond
Asset Type: Drop Inlets
System or Service Area: 6-Secondary
City/County: Hanover
WA Created By: SaTarra Ford
Assigned User Logon:
Route: Rt. 1465N (Hanover County)
Mile From: 0.06
Mile To: 0.06
Asset Type UOM:

Caller Information
Caller: [redacted]
Address:
Relation to Owner:
Phone: [redacted]
Email:

Description: At 9389 Blakeridge Ave, Mechanicsville, VA 23116 there is a clogged inlet preventing the rain water from flowing. The water is flooding the property. The citizen would like it cleaned out. Please review.

Figure 1. Example Service Request as Shown in the Highway Maintenance Management System

ID WO-031121-1596 **Logged By** VUEWorks 03/11/2021 04:30 PM

Open/ Closed Closed **Priority** 1

Service Request INT-031121-456 **Type** General

Begin Date / Time 03/12/2021 08:00 AM **End Date / Time** 03/12/2021 09:00 AM

Division 111-Maintenance

Activity Description **Group** 0000 - Routine Maintenance

72206 - Pipe/Culvert Clean & Repair

Closed By Kenneth Gentry **Date Closed** 03/15/2021 02:50 PM

Location 9389 Blakeridge Ave, Mechanicsville, VA 23116

Description At 9389 Blakeridge Ave, Mechanicsville, VA 23116 there is a clogged inlet preventing the rain water from flowing. The water is flooding the property.

Assigned To RI-Ashl-Ashland AHQ 03/11/2021 04:30 PM

Assigned/Pending: Assigned

Response to Customer: (Optional)

Disaster ☐ **Contractor Accomplishment** ☐

Open Status Reason (To Customer):

Planned Work ☐

Cancellation Reason:

Closed Status Reason (To Customer): Work completed

Quantity 104.00

UOM Linear Feet

AU1 (If applicable):

No. of Pipes 3

Problem Type: Drainage Problem_Drop Inlets

Department ID 14073 - Ashland Area Hdqtrs

Charge To Department

District Name (Base Map) Richmond

System: 6 - Secondary

AHQ Name (Base Map) Ashland

Residency Name (Base Map) Ashland

County Name (Base Map) Hanover

County Code (FIPS Code): 085

VDOT County Code (Base Map) 042

Duplicate CSC SR IDs

City Name (Base Map)

City Code (FIPS Code):

VDOT City Code (Base Map)

Town Name (Base Map)

Town Code (FIPS Code):

VDOT Town Code (Base Map)

AU2 (Route Number) **Mile Marker (Base Map)** **Federal Structure ID** **State Structure No.**

Figure 2. Example Work Order as Seen in the Highway Maintenance Management System

This is important to note since the CSC reported an issue with a drop inlet; work was actually performed, however, on the associated pipes, as is evident from the "Task Number" provided in the "Activity Description."

Task numbers are used in the HMMS to organize and report WO accomplishments statewide. In the case of clean-outs associated with pipes and storm drains, two task numbers are used: 70104 (Drop Inlet Clean and Repair), and 72206 (Pipe / Culvert Clean / Repair). Using these task numbers, relevant WOs for a given area can be searched in the HMMS.

These data are used by VDOT's Maintenance Division to develop performance metrics for a number of maintenance activities, including pipe and culvert clean-outs and repairs (Task No. 72206). For pipe and culvert clean-outs and repairs, a goal of maintaining 10% of the pipe inventory across the state was set. This created the need to increase the accuracy and comprehensiveness of the inventory of pipe assets in the HMMS. To achieve this, extensive guidance was developed for HMMS users to update or add pipe assets to the HMMS as clean-outs or repairs are conducted. This can be done through either the HMMS web interface or a mobile application, MobileVUE, in the field.

Although performance metrics for a number of other maintenance activities were established, clean-outs of inlets categorized under Task No. 70104 were not included. Because of this, the inventory of storm drains stored in the HMMS is not nearly as comprehensive as that of pipes and culverts. This can readily be seen in Figure 7, where the majority of the drop inlets (highlighted in bright green) recorded in the HMMS are located along interstates and other primaries. The network of pipes, on the other hand, is much more extensive. It should also be noted that the inventory of pipes in the HMMS consists primarily of cross pipes, though future inventories will include driveway pipes.

Performance metrics for pipe clean-outs are reported for clean-outs conducted by both state forces at the AHQ level and contract services at the residency, IMO, or infrastructure level. These reports are created using the WOs attached to the pipe assets stored in the HMMS, which include the feet of pipe cleaned. These metrics are reported via a Tableau database, which is updated daily, though official metrics are provided monthly. These official metrics have gone through a quality assurance /quality control process to ensure the validity of the data. In addition, these metrics provide only a count of the pipes cleaned, not the linear feet of pipe cleaned. As of the time of the writing of this report, the Richmond District had reported 3,715 pipes cleaned out this calendar year as a part of this performance metrics effort.

Field Observations of Storm Drain Cleaning Operations

Contract Work

Since 2015, the Richmond District has maintained a contract with Atlantic Heating & Cooling Service, Inc., to conduct clean-outs of pipes and inlets. Per the terms of the contract, Atlantic Heating & Cooling Service, Inc., is responsible for storm drain and pipe clean-outs in three primary regions: (1) the Ashland Residency, including locations in Goochland, Hanover, Henrico, New Kent, and Charles City counties; the (2) IMO area of operation, including locations in the Ashland Residency, Chesterfield County, and the City of Richmond; and (3) the Petersburg Residency, including Dinwiddie, Prince George, and Nottoway counties.

Pricing is based on the type of infrastructure being cleaned and the duration of work. For example, clean-outs of pipes are charged based on the linear foot, with costs ranging from $3.90 to $4.43 per foot depending on the diameter of the pipe. Clean-outs of storm drains (drop inlets) are charged per each drain cleaned, with costs ranging from $69/drop inlet in the Ashland Residency and IMO regions and $71/drop inlet in the Petersburg Residency. These rates apply to clean-outs conducted within the first 2 hours of work, after which these rates are lowered to $25/drain and $35/drain, respectively.

This pricing breakdown causes VDOT personnel to request clean-out operations only once a sufficient number of storm drains or pipes needing service have been identified to fill a 2-hour period. This is less of a concern for the IMO, since clean-outs of interstate pipes and storm drains are conducted on a routine basis in the spring and fall, almost guaranteeing a sufficient amount of work.

Clean-out operations conducted by contractors were observed in July 2020 and consisted of cleaning storm drains and cross pipes along Route 288 in Chesterfield County. Generally, clean-outs on interstates are grouped based on mile marker. However, in this case, contractors were directed to clean-out infrastructure on Route 288 south of the Route 60 interchange. This section of Route 288 extends about 0.9 miles and consists of a jersey barrier with periodic median inlets and drop inlets connected by cross pipes to convey water off the roadway. The general method used by the vac truck crews begins with a visual observation of the storm drain to identify any obstructions or significant accumulations of sediment. If neither is identified, a pressure washer wand powered by a vac truck is used to spray any dirt or debris built up around the opening into the storm drain. A visual observation is also made of the attached pipe at the bottom of the drain to identify any clogs. If water is found to accumulate in the storm drain, a sewer jet hose is used to break up the material causing the clog, allowing the storm drain and pipe to drain freely. It is important to note that material is removed from a storm drain only if a visible amount has accumulated in the bottom of the drain.

As work progresses, a count of the pipes and storm drains serviced is recorded by both the vac truck crew and the consultant monitor. Because of the consistency in pipe length on interstates, the contractor in this case applied a default value of 100 feet per pipe cleaned out for billing purposes. This information is recorded on a note pad and then reported to the VDOT contract monitor. The VDOT contract monitor then updates the WO in the HMMS and includes the number of storm drains and length of pipe that was serviced.

Once the locations specified on the WO have been serviced or the tank of the vac truck has become full, the vac truck crew hauls the material to the closest dewatering pad. These dewatering pads are discussed further later.

VDOT Forces

Although contractors are used in the areas of the Richmond District specified earlier, the remainder of the district relies on state forces to accomplish this work. Because of limited resources, one vac truck crew is shared with the remaining residencies and counties in the district. Depending on the work load in an area, this crew typically spends about 1 week in each area per rotation.

In contrast to the majority of work conducted by contracted crews, clean-outs conducted by state forces are typically in response to customer complaints. For example, a resident might report (via the CSC) that the pipe used to convey water underneath his or her driveway has become clogged and is in need of service. Scheduling of these maintenance tasks is generally conducted by the AHQ superintendent. To avoid long travel times, WOs are typically grouped and scheduled based on proximity to one another. Further, since the vac truck crew is a shared commodity, additional storm drains and pipes can be added to the schedule opportunistically if they are in close proximity to the reported location. An example of a weekly work schedule for the Powhatan AHQ is provided in Figure A1 in the Appendix.

As can be seen on the weekly work schedule (Figure A1), cross pipes and driveway pipes make up the bulk of the work load for this week. Discussions with the vac truck crew indicated that this is common during the summer months and that storm drains typically need servicing during the fall and spring. This observation correlates with the findings in the literature that increased leaf litter in the fall and residuals from the winter maintenance season in the spring can increase the accumulation of material in storm drains (Donner et al., 2016; Jang et al., 2010; Kang et al., 2020; Law et al., 2018; Selbig, 2016).

Field observations of clean-outs conducted by VDOT forces were conducted on August 6 and September 15, 2020. As noted previously, these clean-outs consisted exclusively of driveway pipes. The general procedure followed for these clean-outs begins with a visual observation to determine the cause of the blockage. Material that has accumulated at the opening of the pipe is removed using the vac truck to allow for a clear line of sight down the pipe. As can be seen in Figure 3, this material consists primarily of leaf litter and soil that has washed down the ditch during storm events. If the visual observation indicates that the pipe is free of obstruction, the crew moves on to the next location. If an obstruction is identified, the vac truck crew uses the jet washing attachment on the truck to clear any obstructions and flush the pipe clean. At the same time, the vacuum is used to collect material flushed from the pipe, as seen in Figure 4. This is the same procedure that is followed by contracted clean-out crews when cleaning out driveway pipes.

Figure 3. Removal of Accumulated Debris at the Opening of a Driveway Pipe

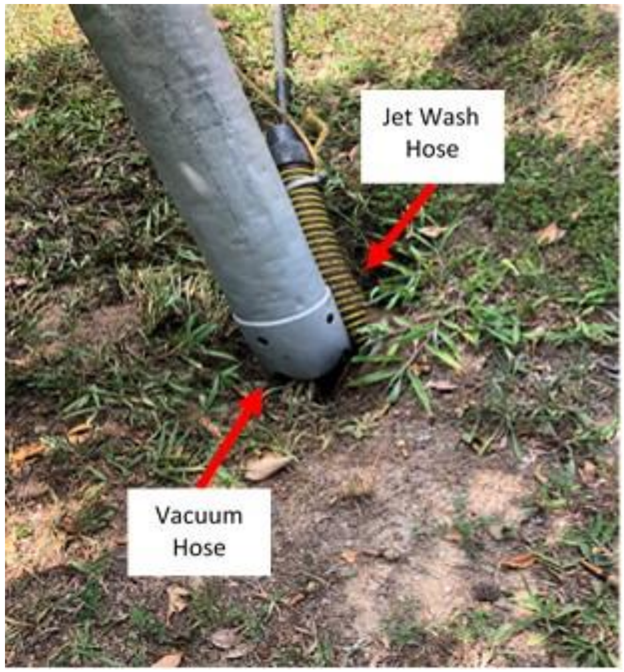

Figure 4. Clean-out of the Driveway Pipe Shown in Figure 3. Here the jet wash hose is used to loosen and flush out material although the vacuum hose collects it.

Dewatering Pads and Disposal

Material collected in the tank of the vac truck has a high water content since large amounts of water are used during clean-outs and the decanting process. Because of this, the material needs to be dewatered prior to disposal. To achieve this, vac trucks transport the material to one of the dewatering pads located across the district (shown in Figure 6). These dewatering pads are designed to allow water to drain from the collected material while retaining any fine suspended sediments. As can be seen in Figure 5, these pads consist of a concrete corral with a slightly sloped floor to direct water through a series of sediment barriers (i.e., a stone berm followed by straw bales) that collect and trap the large majority of suspended sediment. Material collected at these pads is allowed to drain for a period of time until it has dried sufficiently.

A total of six dewatering pads are located across the Richmond District. The locations of these pads are provided in Figure 6. Depending on the location of the work, vac truck crews will use the closest dewatering pad to reduce transportation time. Although state forces use any of the six dewatering pads, contracted crews are directed in the contract to use the West and East End dewatering pads in Henrico County and the IMO pad in Chesterfield County. These locations are identified in green in Figure 6. Once drained, the material is removed from the pad and mixed with other material collected at these sites destined for the landfill.

The Richmond District currently has a contract with Waste Management of Virginia, Inc., to dispose of material at the following locations: the Charles City, Atlantic, and Amelia/Maplewood landfills. A copy of this contract is provided in the Appendix for reference.

Figure 5. A Typical Dewatering Pad Used to Drain Material Collected During Storm Drain and Pipe Clean-Outs

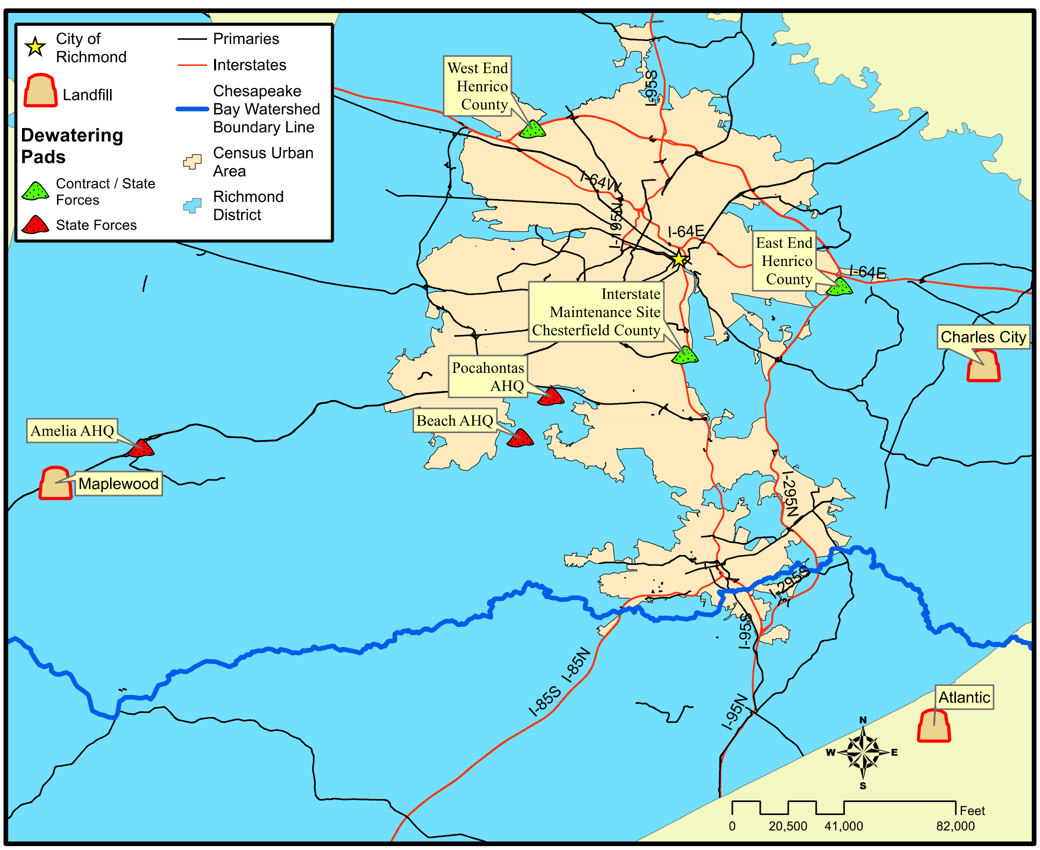

Figure 6. Locations of Dewatering Pads and Landfills in the Richmond District Used for the Collection and Disposal of Material Collected During Storm Drain and Pipe Clean-Outs

The contract contains six line items representing different types of material and the associated cost per ton for disposal. These line items include (1) concrete and asphalt; (2) stumps that are a maximum 36 in, logs up to 5 ft, and brush; (3) “certified” clean dirt billed as debris not otherwise listed (Line 5 if not clean); (4) brush, wood chips (termed “chippings”), and trash; (5) debris not otherwise listed; and (6) disposal of miscellaneous non-hazardous debris. All material is charged at a base price of $40/ton except for “certified” clean dirt that has a base price of $15/ton.

Once a sufficient amount of material has been collected at a dewatering pad site, it is hauled to one of the three landfills listed for disposal. For billing purposes, each truckload of material is issued a ticket by the receiving landfill listing the specific vehicle number, type of material, and weight of material disposed. An example ticket is provided in the Appendix for reference. In this specific case, 2.38 tons of wood-brush was disposed of at the Amelia Landfill under Ticket No. 544760. Every 2 weeks these tickets are summed and an invoice is sent to the respective residency business administrator. An example invoice is provided in the Appendix. As can be seen on the invoice, Ticket No. 544760 is reflected as the second line item.

Main Observations From the Field and Contract Reviews

These field observations provide a number of insights when opportunities for tracking the amount of material removed from storm drains and pipes that are viable for TMDL credits are considered. Current regulations specify that TMDL credits can be calculated only for material collected from storm drains and pipes located within regulated MS4 service areas.

The Richmond District contains one MS4 service area covering about 1,274 km^2. Within this regulated area, VDOT maintains 1,425 pipes and culverts and 1,639 storm drains of the 7,249 and 2,072, respectively, located in the Richmond District, as shown in Figure 7. Because the majority of clean-outs are currently done in response to customer complaints, their scheduling is irregular, with exact clean-out locations grouped together based on proximity to one another. Using the clean-out schedule for Powhatan County provided in Figure A1 in the Appendix as an example, the clean-outs scheduled for Monday consisted of four locations within about a 0.5-mi radius, although Wednesday’s schedule consisted of three locations within approximately a 5-mi radius. In light of how irregularly shaped the MS4 service area is in the Richmond District, this variation in distance from location to location could mean that some clean-out locations were within the regulated area and some were outside of it on a given day.

Another important observation from these site visits was the variability in both the frequency with which material was actually removed from individual storm drains or pipes over the course of a day and the quantity of material removed. For example, during the observations of contracted clean-outs on Route 288, a total of 12 storm drains (and their associated pipes) were inspected and cleaned. Of these 12 locations, material was removed from only 1; the other 11 storm drains were either free of a blockage or cleared with the jet washer. Both of these cases were recorded in the same manner with no note made of when material was removed. It is important to note that this segment of Route 288 had very little, if any, tree canopy cover, which could be contributing to the lack of material collected during these clean-outs.

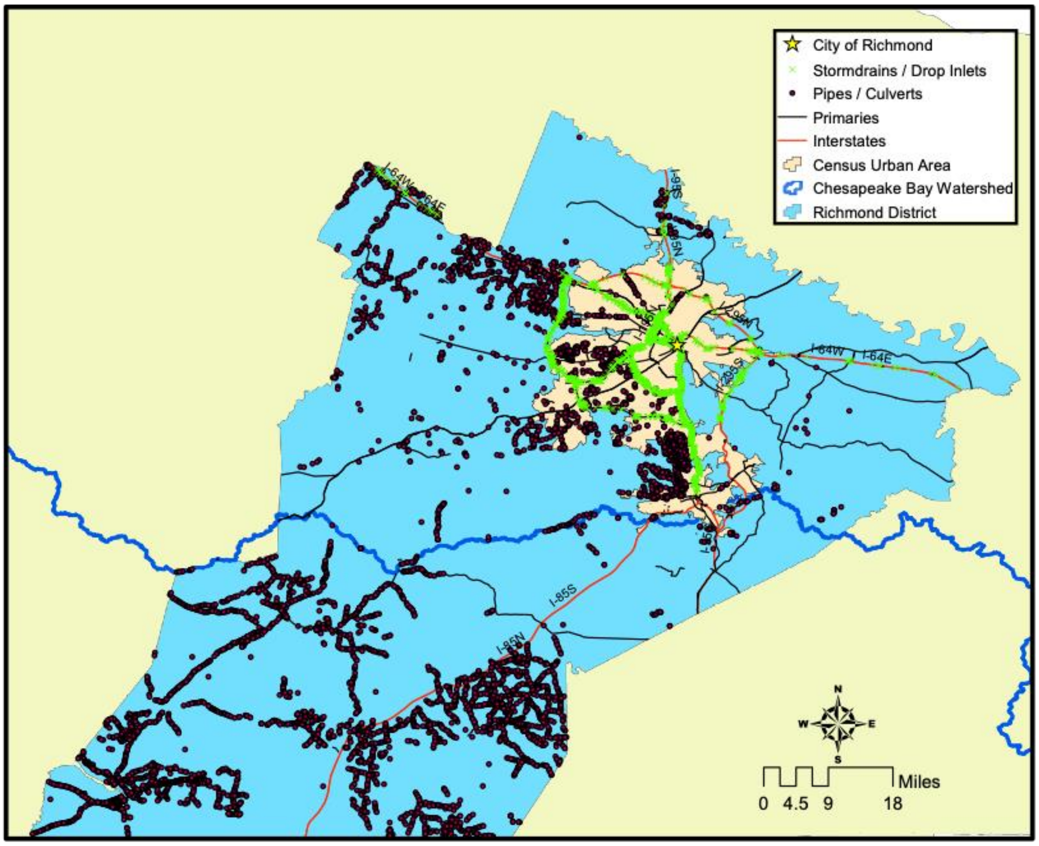

Figure 7. Map of Richmond District Showing Locations of Drop Inlets and Pipes From the Highway Maintenance Management System

Monitoring clean-outs of driveway pipes (conducted by both contracted and state forces) provided different results. As noted, it was common for vac truck crews to remove debris that had accumulated at the opening of the pipe. Since driveway pipes typically connect one earthen ditch to another, this material consisted primarily of leaf litter, soil, traction sand, and other garbage and debris. The guidance provided by the CSN expert panel stated that "solids that are directly removed from storm sewer systems (i.e., storm drains, within storm drain pipes or captured at the storm drain outfall)" are viable for crediting (Donner et al., 2016). However, it was also noted that "sediment removal that occurs during ditch maintenance along open section roads is not currently eligible for this credit" (CSN, 2017; Donner et al., 2016; VDEQ, 2020a). This guidance causes some confusion as to whether the material removed from driveway pipes would be considered eligible for crediting or considered as part of regular ditch maintenance activities. Further, clean-outs of these driveway pipes are often conducted at the same time as routine ditch maintenance and recorded in the HMMS under the same activity code.

Although vac trucks commonly have a system of monitoring the available capacity remaining in the collection tank, this system is rudimentary at best. As can be seen in Figure 8, this gauge provides only an indication of whether the collection tank is full, one-half full, or empty. This does not make using the gauge to track the amount of material removed per storm drain or pipe a viable option, even when accounting for the added water.

Figure 8. Side View of a Typical Vacuum Truck With Available Capacity Indicator Circled in Red

Because TMDL credits associated with storm drain clean-outs are calculated based on the dry mass of material removed from the system, the dewatering pads become the next logical opportunity for collecting this information. However, based on the observations noted, a number of operational changes would need to be made to allow this information to be collected accurately.

First, clean-outs would need to be grouped and scheduled based not only on their proximity to one another but also on whether they are located within the MS4 service area. Current VDOT practices result in material being decanted at dewatering pads from both inside and outside this regulated area. Because of this, the portion of this material that is viable for TMDL credits is unknown. A potential operational change that could be made would be to schedule the clean-outs of storm drains and pipes in regulated areas separately. This could be achieved using certain modifications to the HMMS, notably the addition of an "inside/outside CUA" descriptor category in the information linked to each Asset ID Number.

Second, once the material has sufficiently dried on the dewatering pad, it is mixed with other material on the lot destined for the landfill. This is done to save time and transportation costs. However, again, this practice makes it impossible to know what portion of the material is creditable, removing the ability to use landfill tickets, such as the one provided in the Appendix, as a method of tracking and quantifying the mass of material. This could easily be changed by directing AHQ superintendents to keep these stockpiles separate on the lot and to dispose of them separately. In addition, the contact with Waste Management of Virginia, Inc., could be updated to include a line item specifically for this material. However, this would first require that the noted scheduling issues be addressed. This would also result in additional transportation costs for hauling separate loads of this material to the landfill.

Estimated TMDL Credits

As previously noted, there are more than 3,064 pipes and storm drains located within the MS4 service area of the Richmond District currently recorded in the HMMS. A number of organizations, specifically in Maryland, have developed default values for the amount and characteristics of material removed from individual storm drains. Although the number of storm drains and pipes in the HMMS is likely an underestimate and a significant variation can be seen between the default values, this information can still be used to gain insight into the number of TMDL credits that could potentially be claimed, particularly if VDOT methods for recording clean-outs are adapted for this purpose.

Using the default values developed by Law et al. (2018) for the average mass of material removed per storm drain and the percentage of this material consisting of sediment and organic matter, Table 4 provides the estimated pounds of TP, TN, and TSS removed from the 3,064 storm drains and pipes over the course of 1 year in the Richmond District. These estimates are provided using the EFs developed by MDE (2020); Law et al. (2018); and Donner et al. (2016) (developed for CSN). It should be noted that these estimates assume that the same amount of material was removed from all storm drains and pipes in the Richmond District's MS4 service area.

As can be seen in Table 4, estimates ranged widely depending on which set of EFs was used for the calculations. Load reductions ranged from 139 to 416 lb/yr; 1,101 to 6,566 lb/yr; and 128,523 to 326,365 lb/yr for TP, TN, and TSS, respectively. This comparison highlighted the importance of developing a customized set of EFs based on material sampling. Further, since VDOT's MS4 service area spans a much wider region than the sampling conducted during the development of the EFs noted in this report, more accurate EFs could be developed for particular regions of the state rather than statewide.

Table 4. Estimated Pollutant Load Reductions of Total Phosphorus (TP), Total Nitrogen (TN), and Total Suspended Solids (TSS) Removed From Storm Drains and Pipes in the Richmond District MS4 Service Area Using the Enrichment Factors Developed by Donner et al. (2016); Law et al. (2018); and the Maryland Department of the Environment (2020)

	Chesapeake Stormwater Network (Donner et al., 2016)			Maryland Department of Transportation (Law et al., 2018)			Maryland Department of the Environment, 2020		
Fraction	TP (lb/yr)	TN (lb/yr)	TSS (lb/yr)	TP (lb/yr)	TN (lb/yr)	TSS (lb/yr)	TP (lb/yr)	TN (lb/yr)	TSS (lb/yr)
Sediment	257	1,157	128,523	86	2,356	NA	180	810	299,886
Organic Matter	159	1,470	39,719	53	4,210	NA	32	291	26,479
Total	416	2,627	168,242	139	6,566	NA	212	1,101	326,365

Estimates assume each storm drain or pipe contains 189.6 lb of dry material consisting of 4% trash, 31% organic matter, and 67% sediment as defined in Law et al. (2018). These estimates do not include driveway pipes in the Richmond District.

For comparison, in 2017, VDOT reported TP, TN, and TSS reductions of 605 lb/yr, 2,360 lb/yr, and 254,947 lb/yr, respectively, for street sweeping activity conducted in the entire MS4 service area (VDOT, 2018). These pollutant load reductions achieved by street sweeping are consistently greater than the estimated load reductions provided by storm drain clean-outs listed in Table 4.

Last, the guidance provided by CSN and adopted by VDEQ provided the following guidance regarding the specific types of stormwater infrastructure where clean-outs are viable for TMDL credits:

> The Expert Panel Report provides a sediment and nutrient reduction credit for solids that are directly removed from catch basins, within storm drain pipes or captured at the storm drain outfall. The credit also applies to sediment removal from concrete-lined conveyance channels, but does not apply to sediment removal during ditch maintenance along open section roads (VDEQ, 2020a).

Although this guidance provided some clear definitions of the relevant types of infrastructure for this BMP, further clarification is needed with regard to "ditch maintenance along open section roads" (Donner et al., 2016; VDEQ, 2020a). For example, a portion of the pipe clean-outs conducted by VDOT are in response to blocked driveway pipes. In the majority of these cases, these pipes connect one earthen ditch to another, allowing runoff to flow under the driveway. Although these driveway pipe clean-outs are commonly scheduled in sequence with ditch maintenance, the material collected by the vac truck crew comes directly from the pipe. Ditch clean-outs are typically conducted with a separate piece of equipment, and the collected material is not stored on dewatering pads.

Based on the information provided in Section 1, Appendix G, of CSN's *Recommendations of the Expert Panel to Define Removal Rates for Street and Storm Drain Cleaning Practices* (Donner et al., 2016), it is believed that the term "open section roads" applies to roadways without a curb and gutter system. If so, this would mean that clean-outs of driveway pipes are not viable for crediting. This definition also introduces uncertainty with regard to concrete-lined conveyance channels. Again, based on the information provided in Section 1, Appendix G, of the CSN report (specifically the response to Comment No. 2), "these channels are located downstream of storm drains and provide an additional opportunity to capture pollutant loads before reaching the urban stream network" (Donner et al., 2016). In many instances, VDOT uses concrete-lined ditches along stretches of road with no curb and gutter.

Clean-outs of storm drains and pipes provided a modest pollutant load reduction in comparison to the other BMPs implemented by VDOT to meet TMDL reductions in the Chesapeake Bay Watershed. However, considering the fact that these clean-outs are already conducted as part of VDOT's regular maintenance routine, tracking the pollutant load reductions associated with this work can only benefit VDOT. Because VDOT has a relatively robust system for tracking maintenance efforts statewide though the HMMS, simple modifications to this system could be made to track these clean-out activities regularly with a focus on determining pollutant load reductions.

CONCLUSIONS

- *Based on a review of clean-out procedures, neither state nor contracted vac truck crews report the amount of material removed from individual pipes or storm drains or the total amount of material removed over the course of a day.* Vac trucks are not equipped with an accurate method of determining the volume of material removed per storm drain or pipe cleaned. In addition, not all clean-outs of pipes and storm drains involve the removal of material and no record is made of when material is removed by either state or contractor clean-out personnel.

- *TP, TN, and TSS EFs developed by CSN and other organizations vary widely.* Variability in these EFs ranges from 28% to 101%, with the greatest variability seen in TN and TP EFs applied to the organic fraction of this material (101% and 84%, respectively). In addition, the literature indicates similar trends regarding the accumulation rate of material in storm drains.

- *The HMMS houses information on the location and physical characteristics of pipes and storm drains maintained by VDOT across the state.* This information is continually updated, with a current effort being made to inventory pipe assets as they are maintained. These updates can be made by operators in the field via the MobileVUE web application. Although this database currently has extensive data on pipe assets, limited information regarding storm drains is available at this time.

- *The HMMS is used both to distribute service calls from the CSC and to report completed WOs.* Types of work are designated in the HMMS using activity description codes. Activity Codes 72206 and 70104 are associated with the clean-out or repair of pipes and storm drains, respectively. By use of these codes, relevant WOs can be retrieved from the HMMS.

- *Clean-outs conducted by state forces in the Richmond District use one vac truck and crew*. This truck and crew is shared between the residencies that do not use contractors for this work on a weekly rotating schedule. Upon completion of a day's work, this crew reports the specific locations that were serviced to the relevant AHQ maintenance superintendent. This superintendent then updates the associated WO in the HMMS, listing it as completed, still open, or on hold.

- *Clean-outs are currently scheduled based on proximity to one another.* Because of this, the total mass of material collected over the course of a day cannot be reliably used to represent the mass of material removed from a particular MS4 service area.

- *Material collected during clean-out operations is transported to one of six dewatering pads in the Richmond District.* Once dewatered, this material is mixed with other material and taken to the landfill for disposal. Because of this, records of tipping fees and landfill invoices are not a reliable source of information regarding the mass of material removed from storm drains or pipes.

- *Based on the Richmond District's contract with Atlantic Heating & Cooling Service, Inc., clean-outs for storm drains are billed per drain and pipes are billed based on the length of pipe cleaned.* As stated in the contract, contractors are required to include the contract number, purchase order number, itemized quantities, unit price, and extended costs based on the contract pricing schedule on invoices associated with this work.

RECOMMENDATIONS

1. *VDOT's Environmental Division should initiate discussions with VDOT's Maintenance Division to determine the steps required to (a) update the structure of HMMS WO forms to include a field for maintenance personnel to note when material is removed from a storm drain or pipe; (b) update the geographic dataset in the HMMS to include MS4 service areas across the state; (c) establish a work accomplishment report that provides a count of the number of clean-outs in an MS4 service area where material was physically removed from a storm drain or pipe; and (d) update the current contracts to include requirements for recording the number and individual locations of storm drain and pipe clean-outs conducted where material was removed in any MS4 service area.*

2. *VDOT's Environmental Division should initiate discussions with VDOT's Maintenance Division and VDOT's Location and Design Division to assess the level of effort required to increase the comprehensiveness of the storm drain inventory in the HMMS.* This inventory should include information on the location and dimensions (i.e., diameter and depth) of storm drains under VDOT's jurisdiction.

IMPLEMENTATION AND BENEFITS

Implementation

With regard to Recommendation 1, VDOT's Environmental Division will initiate these discussions with VDOT's Maintenance Division by December 1, 2021. These discussions will involve a determination of the level of effort and time requirements to make these modifications and methods of lessening any additional burden associated with reporting this information on maintenance personnel.

With regard to Recommendation 2, VDOT's Environmental Division will initiate these discussions with the Maintenance Division and the Location and Design Division by December 1, 2021. Recent efforts initiated by the Maintenance Division to increase the inventory of pipe assets in the HMMS will be used as a framework for this effort, including the guidance documents associated with those current efforts.

Benefits

Implementing Recommendation 1 would begin the process of modifying VDOT's current practices and contract language to collect the necessary information to calculate any pollutant load reductions associated with these clean-outs. The development of a Work Accomplishment Report would also fulfill one of the TMDL credit reporting requirements developed by CSN: the creation of a centralized database for this information. Further, current rates for TP nutrient credits range from $9,599 to $11,743 per pound in the James River Watershed. Based on this study's estimates of potential pollutant load reductions calculated using CSN EFs (see Table 4), storm drain and pipe clean-outs could provide the equivalent of up to $5 million per year in TP nutrient credits alone.

Implementing Recommendation 2 would increase the accuracy of the HMMS inventory and very likely the amount of TMDL reductions VDOT would be able to report for pollutant removal crediting. In addition, increasing the comprehensiveness of VDOT's inventory of storm drains in the HMMS will provide the Maintenance Division with additional benefits related to the scheduling of maintenance activities and identifying storm drains in need of repair or replacement. Because of the increased regulatory requirements for TMDL reductions in future years, implementation of this recommendation could relieve VDOT from a significant financial burden associated with the purchase of nutrient credits.

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APPENDIX

EXAMPLE DOCUMENTS

+THE POWHATAN WEEKLY WORK SCHEDULE

The VDOT Chesterfield Residency weekly plan maintenance for Powhatan County

Maintenance Items

Accomplishments for the week of July 27th 2020 thru July 31st 2020

Monday- ***Continue secondary mowing north and south side of county.. Pick up any debris and dead animals on primary and secondary routes(2)deer. Started tree trimming on Georges Rd but equipment broke down.***

Tuesday – ***Continue secondary mowing north and south side of county. Hauled #26 stone and #3 stone to lot for stock pile. Hauled tree debris and dirt to approved dump site. Cardwell received more on the job training to get his CDL. Fixed stop sign Old Church Rd and placed no outlet sign at Villiage pool Rd. Request from county. Change message boards for bridge closure.***

Wednesday – ***Continue secondary mowing north and south side of county. Dig out on Genito West Circle placing asphalt. 2309 Dorset Ridge way ditching 50'. Fixed shoulder at New Dorset Rd and Dorset Rd with crush and run. Removed small tree on Blenheim Rd. Straightened and day lighted sign at Ballsville Rd and route 60. Cardwell training for CDL in Chester.***

Thursday – ***Secondary mowing north of 60. Patching potholes with hot box Pine View Rd, Moyer Rd, Blenhiem Rd and Ridge Rd. Cardwell training for CDL in Chester. Working shoulders on route 60 Anderson Highway. Cardwell CDL training Chester. Fixed stop sign that was down in Lake Shawnee, Removed tree that was called in by TOC.***

Friday- ***Continue working shoulders on Route 60. Continue mowing north side and south side of county.***

Planned work for week of –August 3rd thru August 7th 2020

Monday- Sewer Jet crew 2120 Red Lane Rd cross pipe cleaning, 2405 Mountain View Rd pipe cleaning, 2924 Edith lane pipe cleaning, and 2010 Georges Rd. Ditching crew if needed behind sewer jet crew. Secondary mowing continues.

Tuesday- Sewer Jet 3170 and 3030 Judes Ferry Rd Pipe cleaning.1247 Dorset Rd pipe cleaning. Ditching crew if needed behind sewer jet crew. Secondary mowing continues

Wednesday- Sewer Jet crew 1401 Page Rd 2843 and 2850 Huguenot Trail cleaning driveway pipes. Ditching crew if needed behind sewer jet crew. Secondary mowing continues.

Thursday- Sewer Jet Ridge View Rd cross pipe clean out. 135 Petersburg Rd driveway clean out. Ditching crew if needed behind sewer jet crew. Secondary mowing continues

Friday- Sewer Jet Powhatan Est. concrete ditch. Old Tavern Rd concrete ditch. Ditching crew if needed behind sewer jet crew. Secondary mowing continues

All PMs are done for month.
2nd round of primary mowing completed
2nd round secondary mowing 80% completed.

Figure A1. Powhatan County Weekly Work Schedule for the Week of July 27 to 31, 2020.

CONTRACT

VA Dept of Transportation
VDOT Central Office
1201 E Broad St
Richmond VA 23219
USA

Dispatch via Print

Contract ID	Version		Page
0000000000000000000047828	1		1 of 3
Contract Dates	**Currency**	**Rate Type**	**Rate Date**
09/01/2019 to 08/31/2021	USD	CRRNT	PO Date
Description:		**Contract Maximum**	
FOB Landfill Services		0.00	
Contract Officer Name		**Phone**	
Lewis, Cheryl A. (VDOT)		804/524-6029	

Supplier 0000019469
Waste Management of Virginia Inc
Rob Clendenin
1405 GORDON AVENUE
VA10003034
EVAAD46428
RICHMOND VA 23224
USA
14033 - CA Vicki Rebuck 757/558-6149

FOB Landfill Services - Richmond District

Contract award a result of IFB #155553 - All specifications and general and special terms and conditions shall apply.

Initial contract period from 9/1/19 to 8/31/20 with four (4) optional one (1) year renewals.

Vendor service areas: Charles City Landfill, Atlantic Landfill and Amelia Maplewood Landfill.

Vendor contact - Brian McClung (804)240-8157 - bmcclung@wm.com

7/16/2020 Contract renewed for one (1) additional one (1) year period from 9/1/2020 to 8/31/2021, there are three (3) renewals remaining - cal

Contract Lines:

Line #	Item ID / Category	Item Desc	UOM	Minimum Order Qty	Minimum Order Amt	Maximum / Open Qty	Maximum / Open Amt
1	9884650800	LANDFILL SERVICES LANDFILL SERVICES, TON	LTN	0.00	0.00	0.00	0.00

Pricing Agreement: Pricing Date: PO Date
Pricing Quantity: PO Date
Quantity Type: Quantity To Date

Adjustments: Sum All Adjustments

Contract Base Pricing 40.00000 LTN MAIN

Seq	Ship To	Min Qty	Max Qty	Method	Adj Pct	Adj Amount	Adj Price	Adj Rules
1		1.00	999999999.99	Amt	-2.44%	-1.00	39.00000	

Concrete and asphalt

Line #	Item ID / Category	Item Desc	UOM	Minimum Order Qty	Minimum Order Amt	Maximum / Open Qty	Maximum / Open Amt
2	9884650800	LANDFILL SERVICES LANDFILL SERVICES, TON	LTN	0.00	0.00	0.00	0.00

Pricing Agreement: Pricing Date: PO Date
Pricing Quantity: PO Date
Quantity Type: Quantity To Date

Adjustments: Sum All Adjustments

Contract Base Pricing 40.00000 LTN MAIN

Seq	Ship To	Min Qty	Max Qty	Method	Adj Pct	Adj Amount	Adj Price	Adj Rules
1		1.00	999999999.99	Amt	-2.44%	-1.00	39.00000	

Stumps - maximum 36" and logs up to 5' and brush

Final = The price is final after adjustments
Hard = Apply adjustments regardless of other adjustments
Skip = Skip adjustments if any other adjustments have been applied

[redacted]

Figure A2. Contract Between VDOT's Richmond District and Waste Management of Virginia, Inc., for the Landfill Disposal of Waste Material Generated in the District

WM
WASTE MANAGEMENT

Amelia Landfill
20221 Maplewood Rd
Jetersville, VA, 23083
Ph: (804) 561-5787

Original
Ticket# 544760

Customer Name VDOT RICHMOND DISTRICT STRUC
Ticket Date 04/15/2020
Payment Type Credit Account
Manual Ticket#
Hauling Ticket#
Route
State Waste Code
Manifest
Destination
PO 50100-0001183563
Profile ()
Generator

Carrier VDOT Richmond
Vehicle# R15020
Container
Driver
Check#
Billing # 0002012
Gen EPA ID
Grid

Volume

	Time	Scale	Operator	Inbound		
In	04/15/2020 09:24:23	Inbound	belliot4		Gross	30100 lb
Out	04/15/2020 09:52:13	Outbound	belliot4		Tare	25340 lb
					Net	4760 lb
					Tons	2.38

Comments

Product	LD%	Qty	UOM	Rate	Fee	Amount	Origin
1 WBRS-Wood - Brush	100	2.38	Tons				VA

111600000-041-70151-14662

Total Fees
Total Ticket

Driver's Signature D Belcher III

Figure A3. Example Disposal Ticket Issued per Truck Load When Disposing of Material Providing the Type and Mass of Material

WASTE MANAGEMENT

Page 3 of 3

Customer ID: 20-76021-33007

Customer Name: VDOT RICHMOND DISTRICT STRUC & BRIDGE

Service Period: 04/01/20-04/15/20

Invoice Date: 04/16/2020

Invoice Number: 0040387-0041-7

Details for Service Location:
Vdot Richmond District Struc & Bridge, 2430 Pine Forest Dr, South Chesterfield VA 23834-5317

Customer ID: 20-76021-33007

PO#: 50100-0001183563

Description	Date	Ticket	Quantity	Unit of Measure	Rate	Amount
Ticket Total						**84.00**
Vehicle#: r07160	04/14/20	544709				0.00
Po#:50100-0001183563						0.00
Msw tons			1.20	TON	40.00	48.00
Manifest#: # 1202726						0.00
Ticket Total						**48.00**
Vehicle#: r15020	04/15/20	544760				0.00
Po#:50100-0001183563						0.00
Wood - brush			2.38	TON	40.00	95.20
Ticket Total						**95.20**
Vehicle#: r15020	04/15/20	544797				0.00
Po#:50100-0001183563						0.00
Msw tons			1.65	TON	40.00	66.00
Ticket Total						**66.00**
Total Current Charges						**359.20**

Support – Non – DSBSD – Micro – Small: # 19469

LAND FILL FEE FOR POCAHONTAS

Contract # 47828 Exp Date 8/21/2020

PO # 1202726 Receiver # 2199493, 2199118

Amt	Acct	Dept	CSC	Task	FIP	
$ 359.20	50153130	14062	11160000	7051	041	Dump

GRD 4/15/2020

Appproved for Payment

D. Kinton

Debby Kinton, RBA

THINK GREEN.

Printed on recycled paper.

Figure A4. Example Invoice From Waste Management, Inc., to the VDOT Richmond District for Landfill Material Disposal. Note that the ticket number provided in Figure A3 is reflected in this invoice.