WRIGHT WATER ENGINEERS, INC.

Resource Guide for Non-standard MS4 TMDL-Related Monitoring

PREPARED FOR COLORADO STORMWATER COUNCIL
NON-STANDARD MS4 SUBCOMMITTEE

April 2026 251-089.000

2490 W. 26th Ave., Ste. 100A
Denver, CO 80211

Resource Guide for Non-standard MS4 TMDL-Related Monitoring

April 2026

Prepared for
Colorado Stormwater Council

251-089.000

Prepared by
WRIGHT WATER ENGINEERS, INC.
2490 W. 26th Ave., Ste. 100A
Denver, CO 80211

WRIGHT WATER ENGINEERS, INC.

ACKNOWLEDGEMENTS

Wright Water Engineers, Inc., prepared this guidance with input from Colorado Stormwater Council members, including:

Authors:

Jane Clary, Wright Water Engineers, Inc.

Chris Olson, P.E., Ph.D., Wright Water Engineers, Inc.

Reviewers and/or Contributors:

Jessica Clayton, City of Colorado Springs

Jacob Moyer, City of Arvada

Jeremiah Unger, E470 Public Highway Authority

Kevin Koryto, P.E., City of Boulder*

Mark Lapham, University of Colorado – Boulder*

Michael Lawlor, City of Boulder*

Candice Owen, P.E., Mile High Flood District*

*Portions of this guidance were adapted from the 2026 update to the Colorado *E. coli* Toolbox prepared for Mile High Flood District by Wright Water Engineers and Geosyntec Consultants, originally issued in 2016. Additionally, portions of the *E. coli* sampling guidance and decision tree were adapted from work previously completed by Wright Water Engineers for the University of Colorado – Boulder. The City of Boulder also contributed input based on field experience from their MS4 monitoring program.

TABLE OF CONTENTS

TABLES

FIGURES

ATTACHMENTS

ACRONYMS

CDPHE	Colorado Department of Public Health and Environment
CDPS	Colorado Discharge Permit System
cfs	cubic feet per second
cfu	colony forming units
Division	Colorado Water Quality Control Division
EPA	U.S. Environmental Protection Agency
FIB	fecal indicator bacteria
gpm	gallons per minute
GIS	geographic information system
IDDE	illicit discharge detection and elimination
LA	load allocation
M&E	monitoring and evaluation
mL	milliliters
MPN	most probable number
MS4	municipal separate storm sewer system
MST	microbial source tracking
qPCR	quantitative polymerase chain reaction
TMDL	total maximum daily load
USGS	U.S. Geological Survey
WLA	wasteload allocation

Resource Guide for Non-standard MS4 TMDL-Related Monitoring

1.0 INTRODUCTION

The Colorado Stormwater Council's Non-Standard Municipal Separate Storm Sewer System (MS4) Committee worked with Wright Water Engineers (WWE) to develop practical monitoring guidance for compliance with *E. coli* and phosphorus total maximum daily load (TMDL)-related requirements in the 2021 Non-standard MS4 Permit. Although five specific TMDLs are referenced in the 2021 permit renewal, CSC anticipates additional future MS4 permit requirements for new TMDLs. This guide is focused specifically on monitoring requirements and includes the following information:

- Initial screening to determine whether outfall monitoring is required.
- Identification of outfalls.
- *E. coli* dry weather outfall monitoring requirements.
- Phosphorus dry weather outfall monitoring requirements in the Barr-Milton TMDL "Datashed.[1]"
- Regional monitoring program options.
- Practical guidance on topics such as flow monitoring, data management and avoiding monitoring surprises.
- Considerations for other types of monitoring, including those not currently required in the Non-standard MS4 permit.

Compliance schedules for completing MS4 outfall monitoring driven by TMDLs vary based on the stormwater permit type as well as by permittee. These deadlines will continue to evolve into the future, but key deadlines for the Non-standard MS4 permittees for whom this guidance was prepared are provided in Table 1.

Table 1. Non-standard MS4 Permittee Monitoring Timelines

Non-standard MS4 Permittee	**Begin Dry Weather Monitoring:**
University of Colorado Boulder	11/2/2022
Boulder Valley School District and Existing permittees affected by the "other TMDLs"	11/1/2026
"New" Non Standard Permittees	11/1/2025
Additional Timelines After Dry Weather Monitoring Begins: E. coli monitoring has to be conducted during the May through October window after the initial dry weather monitoring. Barr-Milton MS4s have to begin phosphorus sampling within 1 year of detecting dry weather flows.	

[1] Because the Barr Milton watershed's physical boundaries extend many miles up tributaries to the South Platte River including the Continental Divide and the Palmer Divide, a pragmatic decision was made during the Barr Milton TMDL model development to map a more manageable "datashed" with boundaries such as the Bear Lake dam, the Cherry Creek dam, Standley Lake dam, and Chatfield dam.

Several appendices are provided, including direct excerpts from the Non-standard MS4 Permit monitoring requirements (Attachment A), an example *E. coli* dry weather outfall sampling plan (Attachment B), flow estimation methods (Attachment C) and TMDL tables and affected permits (Attachment D). For permittees interested in more in-depth *E. coli* source investigation methods such as microbial source tracking (MST), the Colorado *E. coli* Toolbox (accessible at www.mhfd.org) should be referenced.

TMDLs Referenced in 2021 Nonstandard MS4 Permit (with web links)

***E. coli* TMDLs:**

- COSPBD01: Big Dry Creek E.coli TMDL.
- COSPBO02: Boulder Creek from North Boulder Creek to South Boulder Creek, *E. coli* TMDL.
- COSPUS14: South Platte River, Bowles Avenue to Burlington Ditch, Escherichia coli TMDL.
- COARMA04a: Wildhorse Creek, *E. coli* TMDL.

Barr-Milton "Phosphorus TMDL" Documents:

- COSPMS04: Barr Lake and Milton Reservoir, Dissolved Oxygen TMDL: Final.
- COSPMS04: Barr Lake and Milton Reservoir, pH TMDL: Final.
- COSPMSO4:Barr Lake and Milton Reservoir, Implementation Plan for pH TMDL: Final.

CDPHE Weblink for Other TMDLs: https://cdphe.colorado.gov/total-maximum-daily-loads-tmdls

2.0 INITIAL SCREENING TO DETERMINE WHETHER OUTFALL MONITORING IS REQUIRED

To determine whether dry weather outfall monitoring is required, CDPHE provides a flow chart in the permit fact sheet as shown in Figure 1. Attachment D provides a copy of the tables referenced in the flow chart. Simply stated, dry weather outfall monitoring is required for *E. coli* if the Non-standard MS4 has a direct outfall to an *E. coli* TMDL waterbody referenced in the permit. For total phosphorus, dry weather outfall monitoring is required if the there is a direct outfall to a waterbody listed in the Barr Milton "datashed."

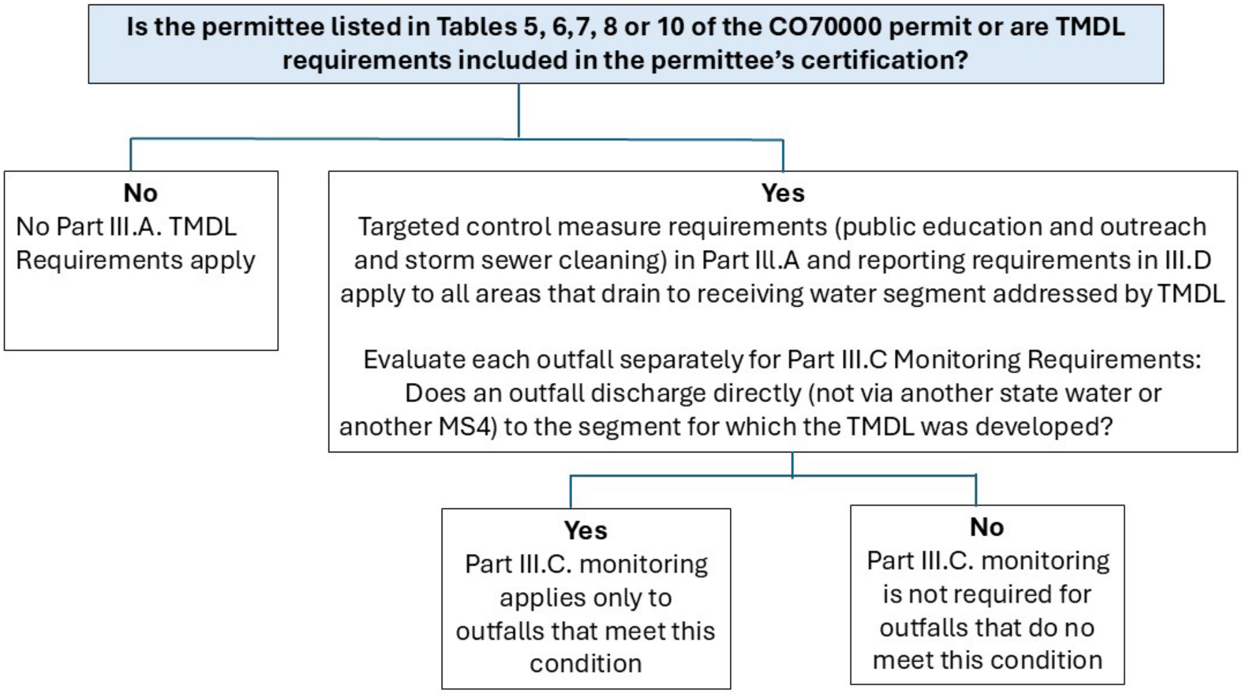


Figure 1. CDPHE's Initial Screening for Monitoring Requirements (Adapted from Nonstandard MS4 Fact Sheet, April 2021)

3.0 IDENTIFICATION OF OUTFALLS

Prior to outfall sampling, a storm sewer system map with outfalls identified is needed. Under the Illicit Discharge Detection and Elimination (IDDE) requirements of the Non-standard MS4 permit (Part 1 E.2.a.i.), permittees are required to prepare a storm sewer map that identified outfalls:

> **Storm Sewer System Map:** The permittee shall maintain a current map of the location of all MS4 outfalls within the jurisdictional boundary, interconnections with other MS4s, and the names and location of all state waters that receive discharges from those outfalls.

The Non-standard MS4 defines an outfall using a combination of these two definitions:

> **Municipal Separate Storm Sewer System Outfall (Outfall):** A point source, as defined herein, at the point where a municipal separate storm sewer discharges to state waters and does not include open conveyances connecting two municipal separate storm sewers, or pipes, tunnels or other conveyances which connect segments of the same stream or other state waters and are used to convey state waters.

> **Point Source:** Any discernible, confined, and discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. Point source does not include irrigation return flow. See 5 CCR 102-61.2(75).

Similar language in the Standard MS4 permit (Part 1 E.2.a.i.) also requires permittees to prepare a storm sewer map and combines all three paragraphs from the Non-standard MS4 permit into one item:

> **Storm Sewer System Map:** The permittee shall maintain a current map of the location of all MS4 outfalls within the permit area, and the names and location of all state waters that receive discharges from those outfalls. A "**municipal separate storm sewer system outfall**" (outfall) is a point source, as defined herein, at the point where a municipal separate storm sewer discharges to state waters. A "municipal separate storm sewer system outfall" does not include the point where a municipal separate storm sewer discharges into an open conveyance connecting two municipal separate storm sewers, or pipes, tunnels or other conveyances which connect segments of the same stream or other state waters and are used to convey state waters. A "**point source**" is any discernible, confined, and discrete conveyance, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. Point source does not include irrigation return flow.

An additional definition from both stormwater MS4 permits that is part of understanding whether an outfall would need to be sampled under TMDL-related requirements is the definition of an MS4:

> **Municipal Separate Storm Sewer System (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains):**
>
> a. **Owned or operated by a state, city, town, county, district, association, or other public body** (created by or pursuant to state law) having authority over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under state law such as a sewer district, flood control district or drainage district, or similar entity, or a designated and approved management agency under section 208 of the CWA that discharges to state waters;
>
> b. **Designed or used for collecting or conveying stormwater.** For the purposes of this permit, stormwater conveyances also include conveyances that are owned or operated by the permittee through agreement, contract, direct ownership, easement, or right-of-way and are for the purpose of managing flood plains, stream banks, and channels for conveyance of stormwater flows in order for the discharges to be authorized by this permit.
>
> c. Which is not a combined sewer; and
>
> d. Which is not part of a Publicly Owned Treatment Works (POTW). See 5 CCR 1002-61.2(62).

Paraphrasing the definitions above, key points relevant to TMDL-related outfall sampling include:

- The permittee must "own or operate" the outfall – this can be outright ownership or through some type of legal agreement (e.g., easement, right-of-way).
- A stormwater outfall is a place where an MS4 pipe or conveyance discharges stormwater directly into a state water (e.g., stream, lake).
- An outfall is a single, identifiable discharge point, such as the end of a pipe, culvert, channel, or ditch.
- Interconnections from one MS4 into another MS4 are not outfalls. The current Non-standard MS4 permit does not require monitoring at interconnections.[2]

Although in many cases, identification of an outfall is straightforward with clear ownership, there are situations that are less clear—either to identify ownership or to access the outfall for sampling purposes. Even though many MS4s have already completed storm sewer system mapping, sampling-related field work can still be complicated or require additional collaboration with other landowners and jurisdictions, particularly in situations where the ownership and operation involve different entities (private and public). A few examples include:

- An MS4-owned outfall is located on private property and a clear legal agreement defining a storm drainage easement for the purpose of collecting and conveying stormwater either does not exist or requires research of historical legal records to locate.
- The MS4 maintains the outfall as part of a drainage easement, but the outfall is owned by a private entity on private property or owned by another jurisdiction.
- An MS4 outfall serves multiple MS4s with shared operation and maintenance within the storm network, but the outfall portion of the system is owned by a single MS4. In this case, the owner of the outfall would presumably sample the outfall, but if elevated TMDL pollutant concentrations are detected, then follow-up abatement actions ultimately may involve multiple MS4s. In cases of comingled outfalls, early communication and data sharing among MS4s is beneficial.
- In the case of Colorado Department of Transportation (CDOT) drainage easements, the municipality or county MS4 typically is presumed to be the stormwater system operator when the CDOT right of way also conveys municipal or county stormwater, per CRS 43-2-135. Intergovernmental agreements may further define responsibilities. Review of easement conditions and intergovernmental agreements may be needed prior to sampling.

Multiple other scenarios with various combinations of land ownership, drainage easements, MS4 ownership and MS4 operation can occur. When outfall ownership is either unclear or involves an easement on property owned by another entity, sampling access is likely to involve additional steps and time, potentially including legal consultation and a clearly defined intergovernmental agreement.

[2] In 2026 MS4 Permit stakeholder meetings, CDPHE has suggested that monitoring at interconnections may be required for TMDL requirements. See the most current version of your permit to verify requirements.

4.0 NON-STANDARD MS4 MONITORING REQUIREMENTS FOR *E. COLI*

As of 2026, the Non-standard MS4 Permit requires *E. coli* monitoring for Non-standard MS4s with dry weather flows at stormwater outfalls that directly discharge to these stream segments:

- Boulder Creek Segment 2a (portion)
- Big Dry Creek Segment 1
- South Platte Segment 14
- Wildhorse Creek Segment 2

> Dry weather flows are defined in the MS4 Permit as flows greater than 5 gallons per minute (gpm). For comparison, a standard garden hose flows approximately 5-10 gpm, depending on whether it is flowing half full to fully opened.

The Division also has the option to add monitoring requirements for other segments with TMDLs in addition to those listed in the 2021 permit renewal.

Sampling requirements are driven by dry weather flows at outfalls; however, the presence of a dry weather flow does not necessarily mean that the discharge is illicit. Common sources of dry weather flow include groundwater from sump pumps or inflow/infiltration into the storm pipe and irrigation overspray in the summer. Even though these flows are typically not *E. coli* sources, they can transport *E. coli* present in the MS4 to streams. For example, irrigation flow in curb and gutter systems can transport *E. coli* present in wildlife and pet waste. Another common example is raccoons in the MS4 where dry weather flows can transport fecal matter from raccoon “latrines” in pipes and manholes.

In other cases, aging sanitary sewer infrastructure can exfiltrate into the surrounding soil and seep into the storm sewer through cracks under certain conditions. Sanitary leaks in the vicinity of storm pipe joints and cracks can result in elevated dry weather *E. coli* at storm sewer outfalls. In other cases, illegal plumbing configurations may exist where sanitary pipes are erroneously connected to the storm sewer system. Although the Division does not require Microbial Source Tracking used advanced DNA methods to identify sources, human DNA markers such as HF183 and others are available for differentiating human and some animal sources. See the 2026 Colorado *E. coli* Toolbox for more information on when and how to use these methods.

Although dry weather monitoring for *E. coli* does not help with source identification or mitigation, it does help to prioritize outfalls that warrant additional source investigation. The current MS4 permit does not differentiate among sources of *E. coli* in terms of monitoring requirements.

4.1 Monitoring Requirements

Once an MS4 has determined that it “owns and operates” outfalls subject to *E. coli* TMDL monitoring requirements, Figures 2 and 3 provide a decision tree for *E. coli* sampling in accordance with the language in the MS4 permit. As an overview:

- The process begins with determining whether dry weather flows >5 gpm are present at an MS4 owned or operated outfall and whether the source of the flows can be identified and removed.

- If the dry weather flows can be eliminated, then the permittee must complete six rounds of outfall visits (biweekly over three months) to confirm that the dry weather flow has been eliminated. If it has, then *E. coli* monitoring is not required.
- If the dry weather flow returns, then *E. coli* monitoring is required as shown in Figures 2 and 3, *E. coli* Monitoring Part 2.
- The presence of dry weather flows means that a minimum of two years of *E. coli* monitoring will be required with 10 samples during May 1 to October 31 of each year.
- If the seasonal geometric mean of *E. coli* is below 126 cfu/100 mL for both seasons, then sampling can be reduced to one time per year at the outfall. If not, then the 10 samples per season monitoring must continue through the cycle.
- Although several analytical methods can be used for *E. coli*, the most common EPA-approved method currently used on the Front Range for *E. coli* is IDEXX Colilert Quanti-Tray/2000. Hold times for *E. coli* are 8 hours with a 10 °C storage temperature; this includes 6 hours from sample collection to the laboratory, which may require samples to be dropped off by mid-afternoon to meet the 8-hour hold time. In some research contexts, longer hold times may be acceptable (Harmel 2016).

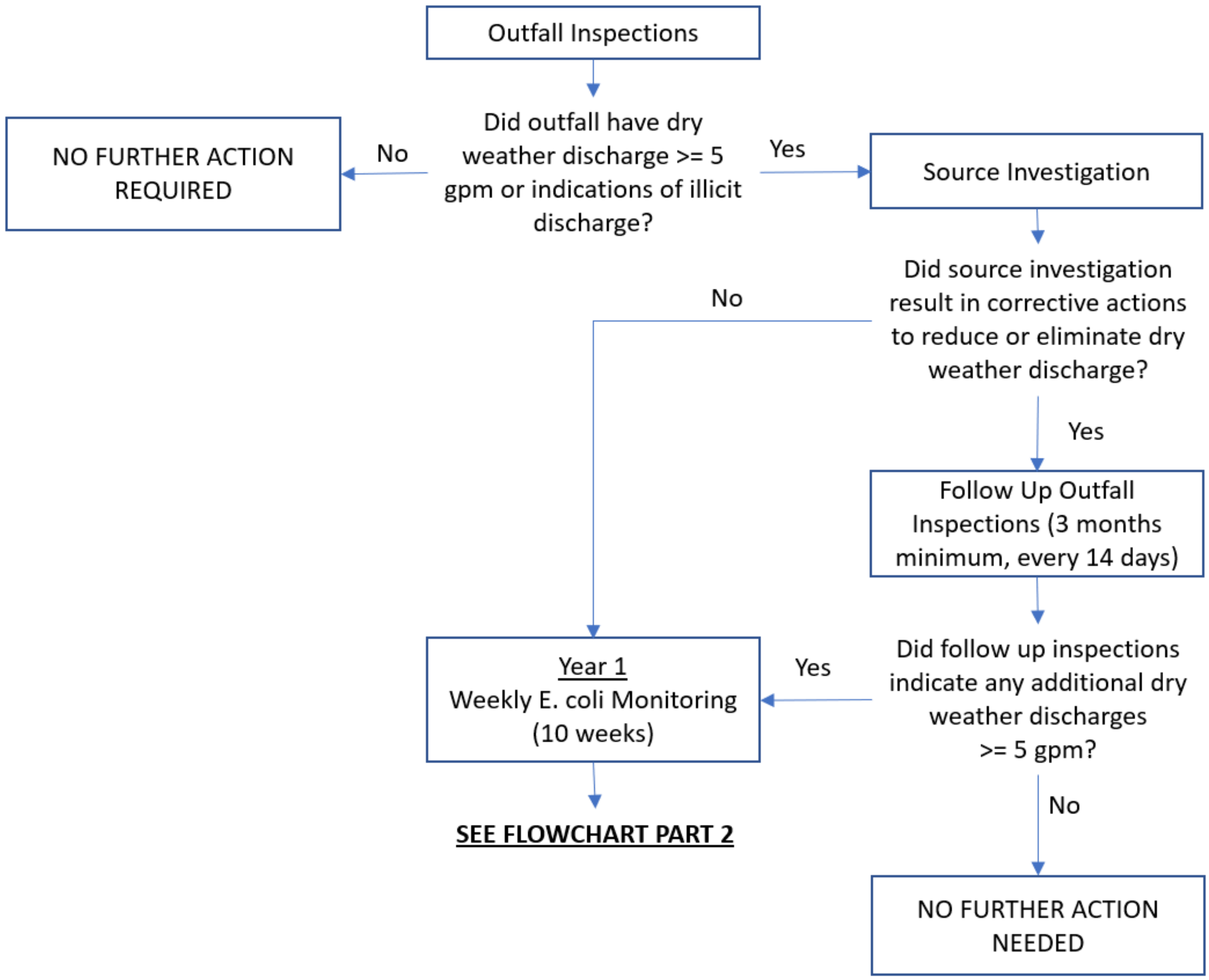


Figure 2. *E. coli* Monitoring Flow Chart Part 1

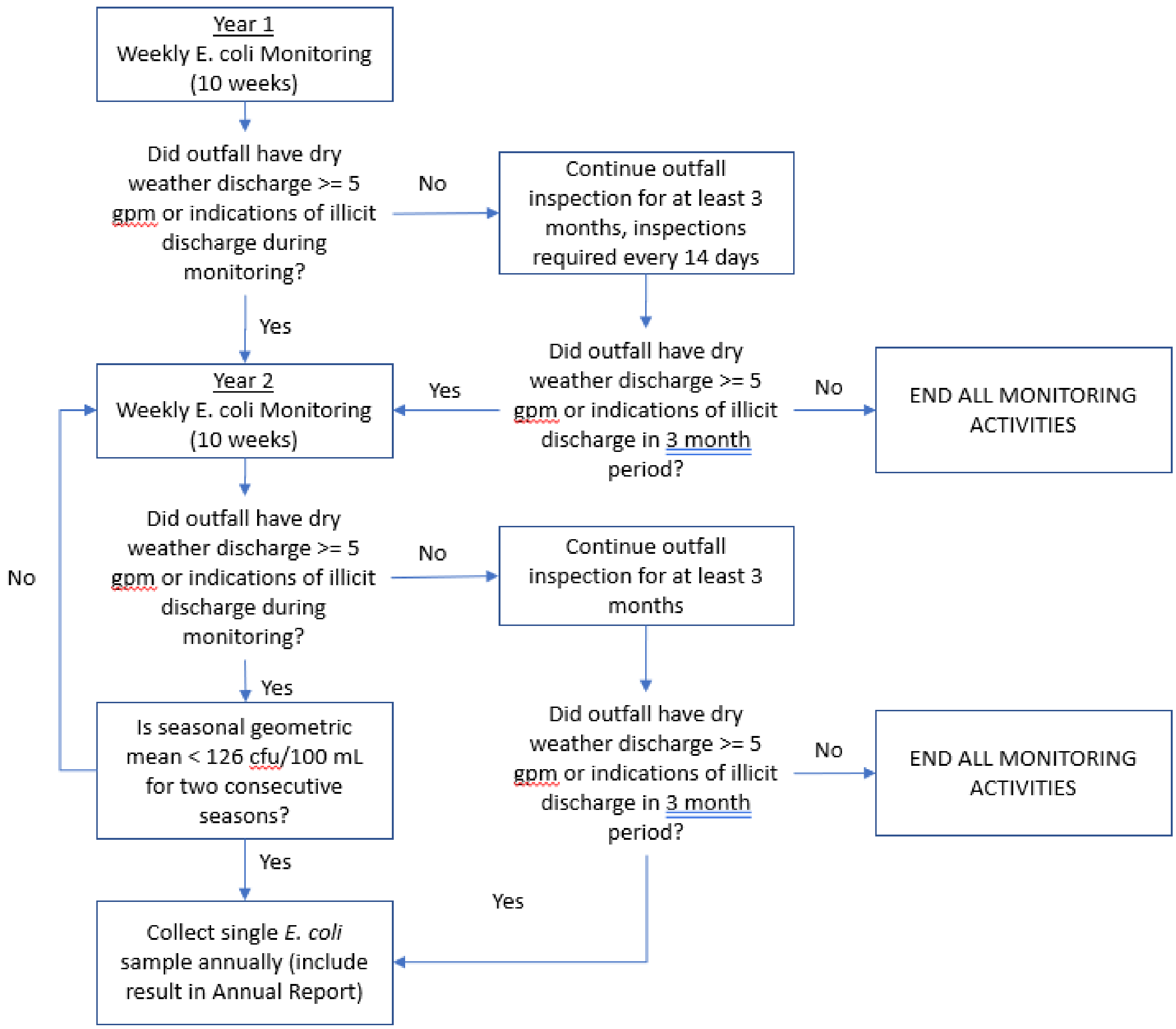


Figure 3. *E. coli* Monitoring Flow Chart Part 2

4.2 Reporting Requirements

Documentation and reporting include the following information for each outfall sampled:

- Event sample results for *E. coli* and flow (cubic feet/day). See Attachment C for flow calculation methods.
- Calculate the seasonal geometric mean for *E. coli* (May 1 – October 31). (This can be done with the @geomean function in Excel.)
- For values below detection limits, substitute the detection limit (e.g., 1 cfu/100 mL) for non-detects to calculate the geometric mean.
- For values exceeding the upper quantitation limit (e.g., 2,419.6 MPN/100 mL for the IDEXX Colilert method), then resampling is required for such “too numerous to count” (TNTC) results. Request

that the lab run a 10X dilution of the sample to increase the upper quantitation limit (e.g., 21,496 MPN/100 mL). Although a 10X dilution is usually sufficient, if a significant sanitary contribution is present, then a 100X dilution may be needed.

5.0 NON-STANDARD MS4 MONITORING REQUIREMENTS FOR TOTAL PHOSPHORUS

The Barr Lake and Milton Reservoir pH TMDL (often referred to as the Barr - Milton Phosphorus TMDL) generates phosphorus-related MS4 dry weather monitoring requirements for MS4 outfalls in the Barr Milton TMDL boundary (also known as the “datashed” as shown in Figure 4).

Phosphorus in urban watersheds originates from multiple sources. For streams that receive discharges from wastewater treatment plants (WWTPs), phosphorus loads have historically been and may still be dominated by WWTP loads; however, significant phosphorus load reductions from WWTPs have occurred in the Barr-Milton watershed, particularly over the last 5-10 years under the Regulation 85 Voluntary Incentive Program for Early Nutrient Reduction. Urban runoff also contributes phosphorus loading originating from sources such as fertilizer, soil erosion and organic matter. Previous work completed for the Colorado Stormwater Council compiled available urban runoff data (WWE and Geosyntec 2013) characterized phosphorus concentrations in urban runoff by land use, as summarized in Table 2 and Figure 5, including recent updates to this data set by the Cherry Creek Basin Water Quality Authority (WWE 2025). Agricultural runoff also contributes phosphorus loading from sources such as fertilizer, manure and soil erosion. Other sources of elevated phosphorus in streams can also include septic systems, channel erosion and runoff from natural areas (CCBWQA 2025). Internal loading of phosphorus from sediments in reservoir bottoms in also a known phosphorus contributor to in the Barr-Milton system.

Phosphorus in dry weather flows from MS4 outfalls can originate from sources similar to those that are transported by wet weather events, although typically at much lower concentrations unless an illicit discharge is present.

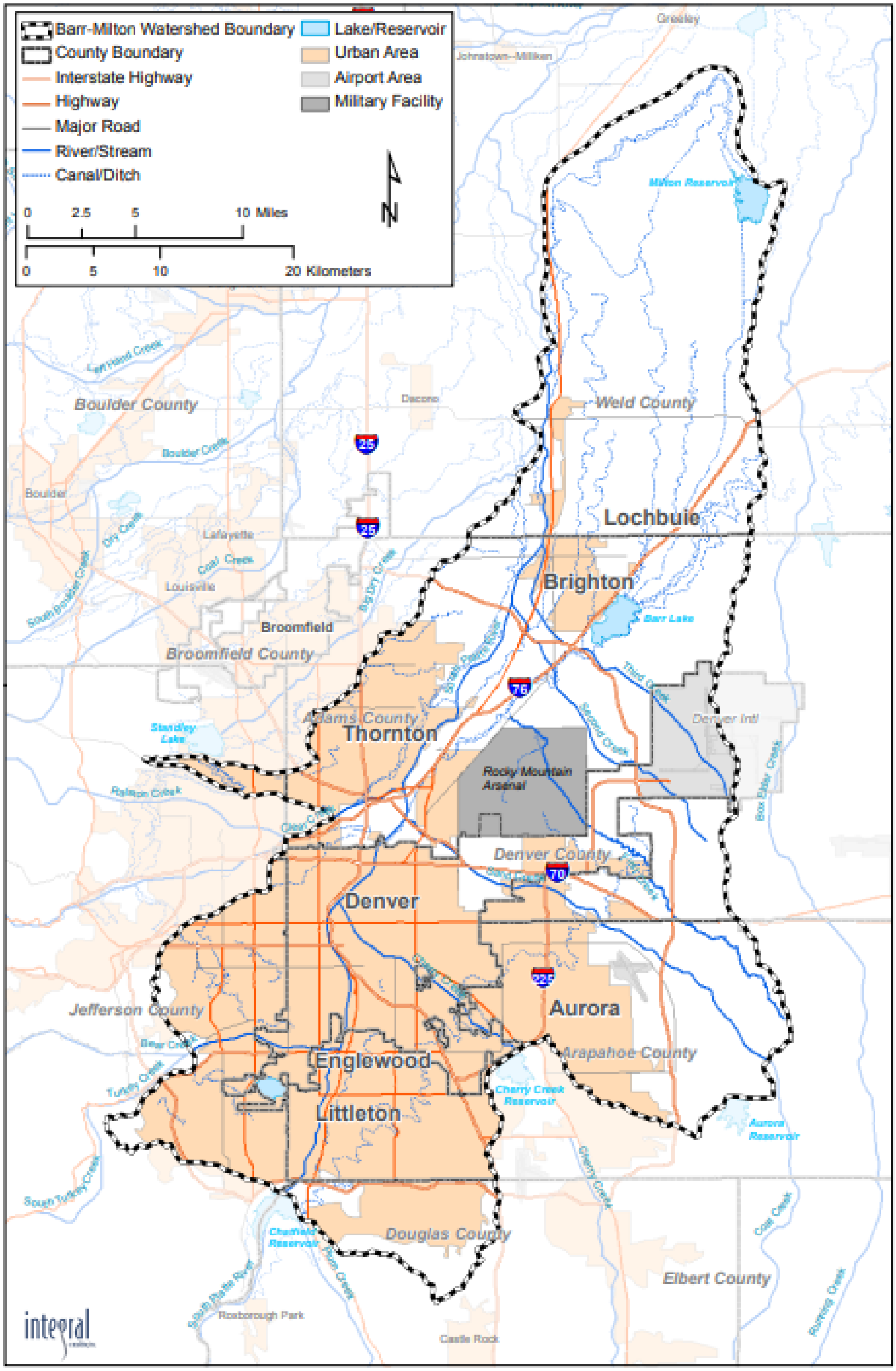


Figure 4. Barr Milton TMDL "Datashed"

Table 2. Phosphorus Concentrations (mg/L) in Urban Stormwater Runoff by Land Use in Colorado

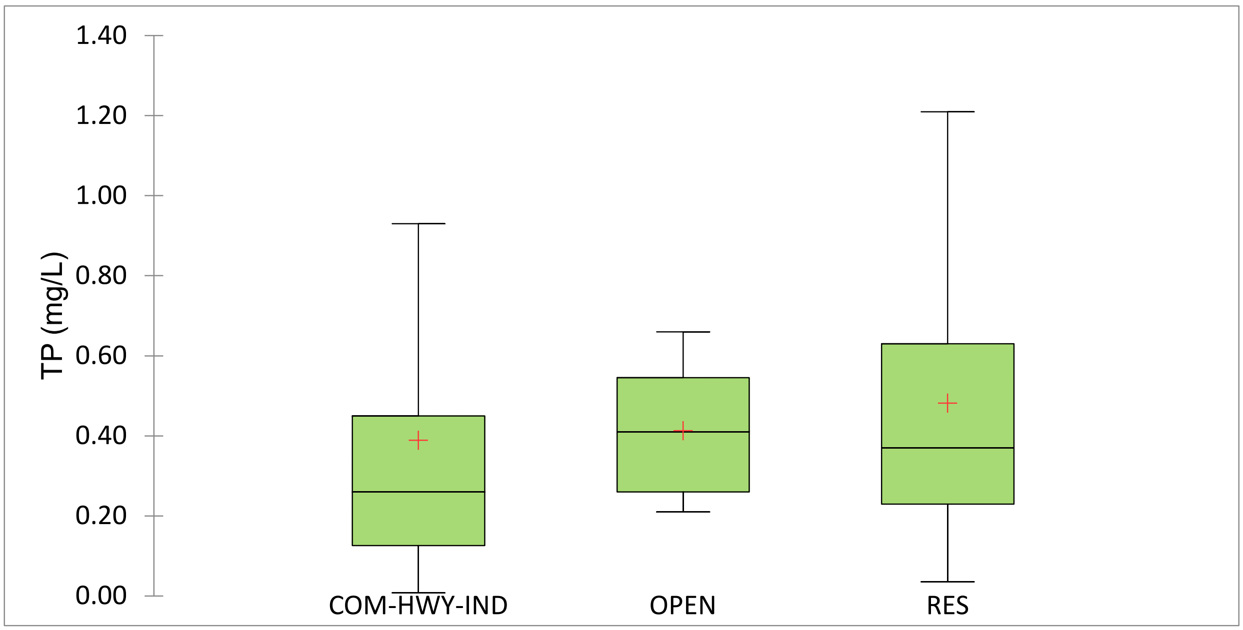
(Source: WWE et al. 2013, updated through 2023 in WWE 2025)

Statistic	Nbr.	Minimum	Maximum	1st Quartile	Median	3rd Quartile	Mean
COM-HWY-IND	487	0.01	6.30	0.13	**0.26**	0.45	**0.39**
OPEN	7	0.21	0.66	0.26	**0.41**	0.54	**0.41**
RES	498	0.04	3.40	0.23	**0.37**	0.63	**0.48**

Notes: COM = commercial; HWY = highway; IND = industrial; RES = residential; Open = open space.

Figure 5. Boxplots of Total Phosphorus (mg/L) in Urban Stormwater Runoff in Colorado

(Source: WWE et al. 2013, updated through 2023 in WWE 2025)



*Outliers not displayed on these boxplots. Notes: COM = commercial; HWY = highway; IND = industrial; RES = residential; Open = open space.

The Barr Milton TMDL assigned MS4 permittees a 20 percent reduction in phosphorus loads. The TMDL includes a single wasteload allocation (WLA) for all MS4 permittees within the datashed for three averaging periods shown in Table 3. Determination of whether a Nonstandard MS4 permittee has met this target reduction is outside of the scope of this guidance, and it is presumed that dry weather phosphorus monitoring is required as summarized in Figure 6 once an MS4 has determined that they “own and operate” outfalls subject to phosphorus TMDL monitoring requirements. As is the case with *E. coli*, monitoring is triggered by the presence of dry weather flows > 5 gpm and can be discontinued if those dry weather flows are eliminated and demonstrated by follow-up confirmation with six rounds of observation over a three-month period.

Table 3. Summary of Allowable Total Phosphorus Loads to Barr Lake and Milton Reservoir

Source Wasteload	Target Load (kg/yr	Daily Mean Target Load (kg/day)	Total Max. Daily Load (kg/day)
Barr Lake	1,751	7.3	19.3
Milton Reservoir	362	2.2	4.8

If identified dry weather flows persist, then quarterly phosphorus and dry weather flow monitoring is required for two years. No further actions are specified in the permit. Key considerations for collection of samples for total phosphorus analysis include:

- Phosphorus sampling methods can generally follow the sampling plan in Attachment B with the exception being the test method that can include any total phosphorus method approved under 40 CFR 136 (including EPA 365.1, 365.3, 365.4; SM 4500-P series). The minimum practical quantitation limit is 0.05 mg/L and results should be reported as P.[3]

- Although not specified in the permit, sample preparation includes checking precipitation gauges to confirm that dry weather conditions have been present for at least 48 hours. Some MS4s and other state permits use 72 hours. The intent is to make sure that flows from outfalls are not influenced by storm runoff.

- Reporting requirements for total phosphorus include outfall ID, sample date, sample result & units, qualifier (if any), laboratory method, method detection limits, and flow measurement or estimate.

[3] Total phosphorus results are sometimes reported as PO_4 rather than as P so care should be taken to verify that results are reported as P.

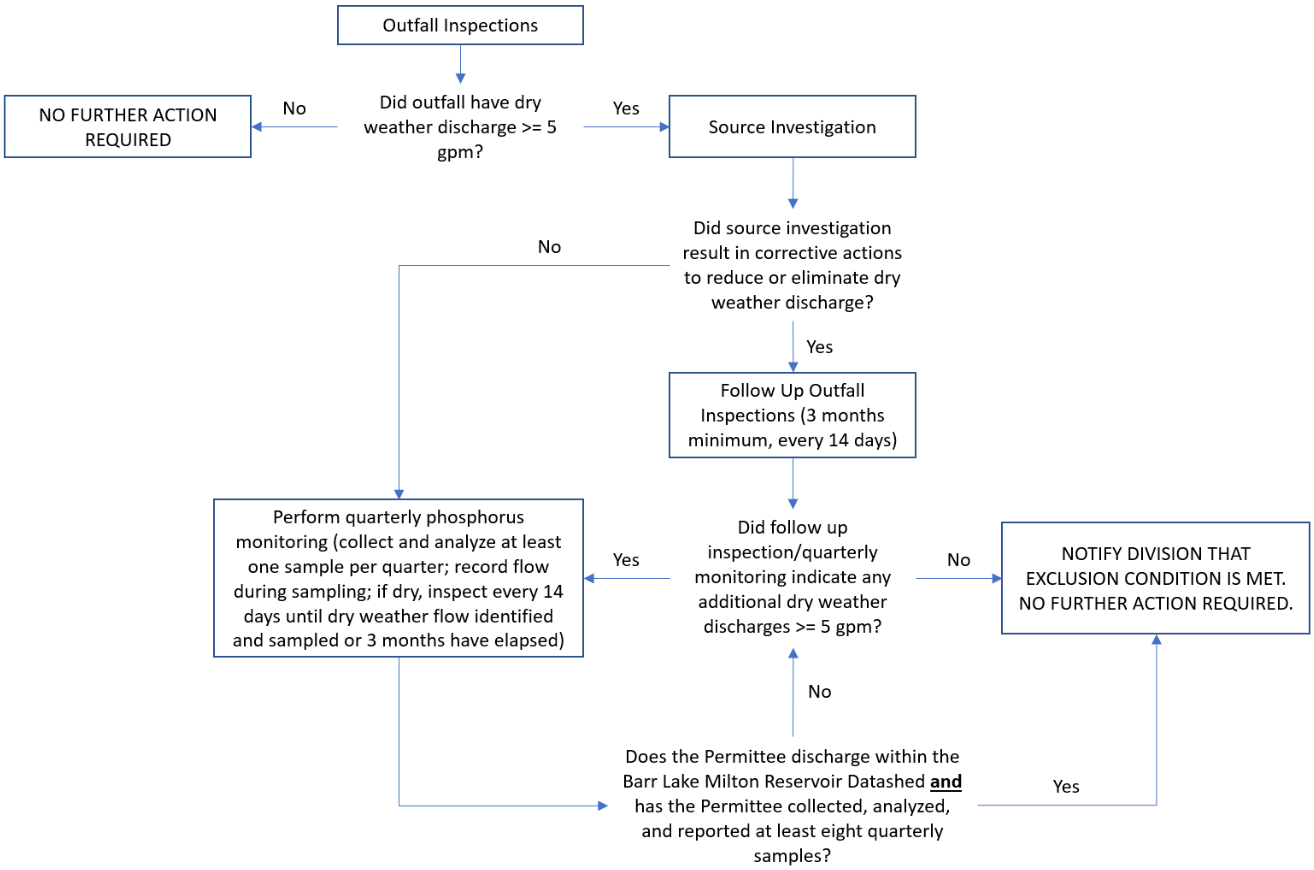


Figure 6. Total Phosphorus Monitoring Flow Chart for Discharges in the Barr Milton TMDL "Datashed"

6.0 REGIONAL MONITORING CONCEPTS

The Non-standard MS4 Permit provides an option for participation in a Regional Monitoring Program instead of conducting the monitoring described in Sections 3 and 4 as stated in the permit:

> *The permittee may be excluded from E. coli* [or phosphorus] *monitoring requirements if they are participating in a Regional Monitoring Program and have notified the division. The Regional Monitoring Program must meet the following criteria:*
>
> - *The program monitors MS4 discharges for pollutants causing the impairment addressed by the TMDL.*
> - *The program has established a monitoring plan that is consistent with the TMDL.*
> - *Monitoring data collected under the program must be quantitatively comparable to TMDL WLAs.*
> - *Monitoring data must include analytical monitoring of discharges representative of the permittee's discharges or the specific type of permittee.*

The Fact Sheet accompanying the permit does not provide more information on how these conditions are met, but the following minimum requirements are evident:

- Samples must be collected and analyzed for the TMDL pollutant from MS4 outfalls with flow estimates/measurements so that loads can be calculated in the units specified in the TMDL. (Note: The Segment 14 MS4 permit requirements are expressed as *E. coli* concentrations under dry weather flow conditions—this TMDL expression is atypical of recent *E. coli* TMDL that are based on loads.)

- A written monitoring plan is required and along with notification to the Division that a regional monitoring approach is being used.

Beyond these minimum requirements, it is less explicit how the regional monitoring scenario should be implemented. A benefit of collaborative or regional monitoring programs is that they provide opportunity for cost-sharing among multiple local governments, either through in-kind staff labor and in-house laboratories or through cost-sharing for consultant contracts. In some cases, the monitoring and analysis is done in-house by staff and a consultant is hired to statistically analyze collected data. Additionally, as a stream crosses multiple municipal boundaries, the monitoring methods and sampling dates are consistent, which can be useful for identifying patterns and trends. Many regional monitoring organizations already exist in Colorado (see inset) and could be potential organizations to contact to determine whether MS4 outfall sampling could be integrated into existing efforts.

Representative Front Range Regional Monitoring Programs

Arkansas Fountain Coalition for Urban River Evaluation (AF CURE)

Barr Milton Watershed Association

Bear Creek Watershed Association

Big Dry Creek Watershed Association

Cherry Creek Basin Water Quality Authority

Joint Task Force – Phase 1 MS4s & MHFD

Keep It Clean Partnership (Boulder County)

Lower Poudre Monitoring Alliance

South Platte Coalition for Urban River Evaluation (SPCURE)

Whether working with an existing organization or forming a new monitoring group, two options that could comply with the framework in the permit include:

- Multiple MS4s discharging to an impaired segment could prepare a joint monitoring plan and hire a contractor to complete dry weather outfall screening and sampling as part of one integrated program for *E. coli* (and phosphorus, if applicable). Local government WWTP labs could conduct in-kind analysis for the program. Alternatively, city staff could collect the samples without hiring a contractor. The benefits of this approach would be an integrated understanding of potential "problem outfalls" for a stream segment. There may be some economies of scale for mobilizing one group of samplers rather than multiple separate efforts. The limitations of this approach are that it doesn't change the minimum sampling requirements, and it could increase coordination/administration costs initially (e.g., combining GIS outfall mapping).

- Another approach that could provide more cost savings in the context of total phosphorus could be to identify a representative set of outfalls for dry weather sampling for phosphorus, thereby decreasing the number of samples that need to be collected. For example, rather than sampling every outfall with dry weather flows, samples could be targeted to representative land uses among all of the MS4s (e.g., commercial, residential, park/open space, highway). This could fulfill the phosphorus dry weather monitoring requirements with fewer samples.

- For permits subject to multiple TMDL monitoring requirements (e.g., *E. coli*, phosphorus, metals), cost efficiencies can be gained by developing a monitoring approach that integrates monitoring for multiple TMDL pollutants.

7.0 ESTIMATING FLOW RATES: PRACTICAL TIPS FOR DRY WEATHER FLOW MEASUREMENT AND ESTIMATION

For dry weather sampling, simple flow estimation methods are recommended instead of installation of flow measurement instrumentation. There are several approaches for measuring or estimating dry weather flows. The bucket-stopwatch method is the simplest method, but it may not be feasible for large outfalls or outfalls without a drop from the pipe to the stream. Descriptions of these methods include:

1. **Bucket-stopwatch Method:** Equipment needed for this method includes a 5-gallon bucket and stopwatch/timer. Place the bucket under the outfall and calculate the time needed to fill the bucket to calculate a gallons per minute (gpm) estimate then convert results to reporting units. This method is straightforward for dry weather in pipe diameters up to ~ 36 inches. For large pipes or culverts, then this method may not work.

2. **Float Method ("Ping Pong Ball") for Velocity with Flow Depth and Pipe Geometry Measurements:** Where the bucket-stopwatch method doesn't work due to pipe size or other reasons, then a two-step process is needed that estimates velocity and combines it with other outfall characteristics. To estimate velocity, either a hand-held velocity meter can be used or the simpler "ping-pong ball" method can be used. Use of a velocity meter typically requires a minimum of 2 inches of depth. The ping-pong ball method measures the distance a floatable object (e.g., ping pong ball, stick, etc.) moves over a set period of time (e.g., feet per second) using a tape measure and a stopwatch. Once a velocity has been estimated, then several different calculation methods can be used to estimate flows based on pipe geometry and observed flow depth. See Attachment C for calculation methods that can be set up in a spreadsheet once pipe characteristics are documented.

3. **Visual Estimation by Experienced Staff:** In difficult to access locations, a visual flow estimate by experienced staff may be the best estimate of dry weather flow. Similarly, once flow has been measured at a site, subsequent visits may be suited to visual estimation if the same staff are repeatedly visiting the site and the flows are relatively consistent. A useful reference is that a typical garden hose discharges 5-10 gallons per minute, depending on how full it is running. Staff should at least determine if flow is approximately equal to or greater than a garden hose and may be able to estimate the "number of garden hoses" of flow.

Regardless of the method used, dry weather flows will be estimates, subject to significant uncertainty. In-house staff may need additional training to estimate and measure flows, whereas sample collection is relatively straightforward. Practically speaking, it may be most helpful for internal purposes (beyond the MS4 permit requirements) to use the data to rank (or bin) the flows from highest (most significant) to minor (less significant).

For more in-depth dry weather flow investigation or wet weather monitoring, MS4s can also consider installation of instrumentation to measure flow depth (e.g., pressure transducer) or flow depth and velocity (e.g., area-velocity meter). Costs vary depending on the type of instrument, with pressure transducers being on the lower end of the spectrum (e.g., ~$500 for a basic instrument to $2,500+ for more features). An in-depth discussion of this topic is beyond the scope of this guidance; however, pressure transducers are briefly described below because they have been used by Colorado MS4s to support more detailed dry weather investigations at outfalls.

In some circumstances with persistent and significant dry weather flows, it may be worth the time and cost to purchase and securely install a pressure transducer to support flow measurement to better understand flow patterns such as diurnal variations, irrigation or episodic flows. Most pressure transducers require at least 1 to 2 inches of flow depth to measure a depth. These also require frequent maintenance that can significantly increase staff resource needs. Permanent installations are subject to vandalism, theft, damage from large flow events and interference from sediment and debris accumulation. Although a pressure transducer provides the potential benefit of more accurate measurements, the cost and drawbacks described above typically outweigh the benefits for short-term dry weather monitoring that is currently required under the Non-standard MS4 Permit. For sites where an MS4 plans to conduct longer-term monitoring and/or wet weather monitoring that go beyond the current requirements of the Non-standard MS4 Permit, the benefits of pressure transducers and other instruments may outweigh the cost.

8.0 DATA MANAGEMENT

When embarking on a source identification program or routine monitoring program, the importance of data management cannot be overstated. An easily corrected, but common, shortcoming of monitoring programs is lack of systematic data management in a manner that enables future access of study data. Data management protocols should be part of any sampling and analysis plan; however, effective data management is often lacking in practice. Some simple considerations that help to maximize investment in monitoring programs include:

- Provide systematic naming and structure of electronic files supporting the study.
- If an outfall is dry, be sure to report either “dry” or “0” gpm instead of leaving a blank spreadsheet cell. In cases where flow is present but below 5 gpm, <5 gpm should be recorded. This demonstrates that the outfall was inspected and that dry weather flow conditions were documented.
- Conduct timely review of sample results to enable identification and correction of errors or follow-up for unusual results (including explanatory comments when unusual results are observed). Include a notes attribute in spreadsheets or GIS to enable comments or flagging of results.
- Develop a standard spreadsheet or database format that all data entries will follow, regardless of the individual conducting data entry. Usually, a database format with column headers such as location, date, analytical parameter, result, qualifier, detection limit, and comments is needed, along with other explanatory information. If the collected data will be used as model inputs, then storage of the data in a format easily uploaded to a model can also be helpful. The Colorado Data Sharing Network and CDPHE physical and chemical data format can be used as a template and can be used in Excel, Access, or imported to a geospatial database.

- Provide consistent nomenclature for sample locations that carries through various study types, even if different entities are conducting the studies. Changing sample location names from year-to-year causes confusion in data analysis. Include latitude and longitude coordinates for all sampling locations and a narrative name to accompany short location labels (e.g., site 120A is located at 120th Avenue upstream of bridge).

- Ensure staff entering or managing data have clear direction on how to record values above or below quantitation limits. For example, < and > values should be stored as qualifiers with the data. A common problem with *E. coli* data sets is dropping the > qualifier if results exceed the upper quantitation limit.

- Record and store field conditions along with water quality data. These anecdotal observations can be critical components for identifying sources of FIB. In Colorado, seasonal flow regimes related to spring runoff from snowpack, highly managed flow regimes due to reservoir releases and irrigation diversions, and others should be documented.

- Measurements of flow and precipitation records should be stored along with water quality data.

- Obtain copies of electronic records with clear description of contents from consultants conducting special studies. For special research studies, be sure that researchers use the same nomenclature for existing monitoring locations and that the GPS coordinates are provided for special sampling locations.

- Given advances in use of municipal asset management systems and improved storm sewer system mapping in GIS, integration of *E. coli* monitoring program data and metadata with other internal geospatial systems can be a useful tool to better understand trends over time.

9.0 MONITORING PROGRAM DESIGN AND PLANNING LEVEL CONSIDERATIONS FOR VARIOUS TYPES OF TMDL-RELATED WATER QUALITY MONITORING

Although the Non-standard MS4 only explicitly defines requirements for dry weather outfall screening, the MS4 should understand what can and cannot be accomplished by several types of outfall and instream monitoring, as well as have a reasonable understanding of equipment, staffing and experience, and costs. Table 4 briefly summarizes key considerations for various monitoring approaches, with practical tips further described in the remainder of this section.

Table 4. Benefits, Limitations and Relative Cost of Various Types of Water Quality Monitoring
(Source: Colorado *E. coli* Toolbox, 2026 Update)

Types	Benefits	Limitations/ Drawbacks	Relative Cost
Instream (Dry weather or ambient)	Hot spots. Seasonal trends. Temporal trends. Attainment evaluation.	Reflects multiple pollutant sources, not limited to MS4s. WLA Reductions may be in the "noise" for *E. coli.*	Low to Medium (depends on partners)
Dry Weather Outfall	Source ID/control. Prioritize actions. Conducive to phased approach.	Accessibility. Natural sources may be present. Number of outfalls can be labor-intensive.	Low-Medium (depends on phasing)
Wet Weather Outfall	Quantify loads relative to TMDL WLAs.	"Known" information—unlikely to direct new actions. Safety/Equipment/Training.	High
Wet Weather Stormwater Control Measure (SCM) Effectiveness	Identify best performing practices/design improvements.	Skill/equipment/training. Expensive.	High
Wet Weather Instream	Assess whether wet weather attains standard. Trends over time (if long-term monitoring program).	"Known" information—unlikely to direct new actions. Skill/Training. Safety/Equipment.	High

9.1 Dry Weather and Ambient Instream Monitoring[4]

Instream monitoring is not required under the Non-standard MS4 Permit; however, instream monitoring can be helpful for assessing whether the stream itself is progressing toward attainment of TMDL targets. Ultimately, MS4s are responsible for discharges from their outfalls, not the many sources of pollutants in the stream itself.[5] Instream dry weather or ambient monitoring are common among many watershed organizations and collaborative multi-jurisdictional municipal and county programs. Dry weather programs may specify a dry-weather antecedent condition such as 72 hours, whereas ambient programs monitor conditions that happen to occur on the planned monitoring day (e.g., third Thursday of the month). Most of the streams in the Barr-Milton Datashed or with *E. coli* TMDLs on the Front Range are part of such monitoring programs, which typically include *E. coli* and phosphorus (see Section 6). Monitoring frequencies for these programs vary but typically include monthly grab samples during the recreation season, at a minimum. Some programs monitor weekly and others monitor monthly year-round. In some cases, programs have chosen to monitor weekly for limited time period and then reduce

[4] Excerpted from the 2026 Colorado *E. coli* Toolbox.

[5] At a national level, recent litigation reaching the Supreme Court related to San Franciso's MS4/CSO NPDES permits has further defined what MS4s can be held responsible for regarding TMDLs in MS4 permits. Specifically, the U.S. Supreme Court issued a final decision on March 4, 2025, reversing the Ninth Circuit and holding that the Clean Water Act does not allow EPA to impose generic receiving water ("end result") requirements in NPDES permits. The ruling has significant implications for TMDL implementation in permits because it clarified that EPA cannot impose generic receiving water ("end result") requirements in NPDES permits.

the frequency to monthly if no significant new information was being gleaned from the more intensive monitoring frequency.

Instream dry or ambient based monitoring program components typically include grab samples at fixed locations so that trends can be evaluated spatially, temporally and seasonally. As a companion to water quality sampling, flow measurements (either with a flow meter or downloaded from a stream gauge), weather (e.g., precipitation, temperature), field parameters and field observations (e.g., dense geese presence) are important. Additionally, these monitoring programs can be used to identify “hot spots” where pollutant concentrations change spatially or temporally, helping to identify areas warranting more in-depth evaluation. Example sampling and analysis plans, including sample collection procedures are readily available through multiple websites for existing regional monitoring programs (e.g., Keep It Clean Partnership, Big Dry Creek Watershed Association). A written sampling and analysis plan and quality assurance project plan (SAP/QAPP) should be developed and followed for instream monitoring programs.

Topics covered in regional instream monitoring programs (and other types of monitoring programs) should include information on sample locations, sample collection methods, analytical methods and hold times, chain of custody requirements, and quality assurance samples such as field blanks and replicates.

A limitation of instream monitoring programs is that at some point the baseline is characterized and there is a need to shift to outfall sampling or other special studies to identify potential controllable sources. For *E. coli*, it is typically helpful to identify the nature of the source (e.g., human, bird, dog). Once sources are corrected, long-term instream monitoring can also be used to assess how the stream responded to abatement activities.

9.2 Dry Weather Outfall Monitoring (Beyond Minimum MS4 Permit Requirements)

Dry weather outfall monitoring is a key component of assessing whether persistent sources of fecal contamination or phosphorus are originating from stormwater outfalls. Non-standard MS4 dry weather outfall sampling requirements were discussed in Sections 4 and 5. Attachment B provides an example dry weather sampling plan that can be adapted to fit local MS4 needs.

Moving beyond the prescriptive requirements in the Non-standard MS4 permit, dry weather *E. coli* sampling is the first step to determine whether more in-depth source identification (e.g., CCTV, DNA markers) is needed in the basin tributary to the outfall. See the Colorado *E. coli* Toolbox (WWE and Geosyntec 2026) for additional guidance on microbial source investigation techniques. Dry weather monitoring can often be staffed internally with consultant support as needed, depending on the scale of the dry weather sampling. For example, some MS4s have only a few outfalls whereas other MS4s may have over 100 outfalls discharging to multiple *E. coli*-impaired or TMDL segments.

The study cost for dry weather outfall screening varies widely but can range from under $10,000 - $25,000 for a limited number of outfalls for water quality sampling and flow estimates only to $100,0000 - $200,000+ if a large number of outfalls are monitored with supporting GIS documentation, report preparation and follow-up sampling for human DNA markers. The mostly commonly used commercially available human DNA marker with an approved EPA method is HF183, although EPA also has an approved method for the HumM2 marker that is also used in combination with HF183 by some communities.[6] Other markers may also be used for research purposes but have less published analysis on corresponding risk based thresholds (RBTs) related to human health.[7]

Factors to consider when budgeting for dry weather screening include: availability of reliable outfall mapping in GIS, staffing approach (internal, consultant, combination), accessibility, number of sampling events and in-house vs. commercial laboratory services. Accessibility of outfalls can increase costs if outfalls are not accessible by bike path or car or have complicated private property access issues. Staff training for grab sample collection is straightforward; however, training is often needed for estimating or measuring flows.

9.3 Wet Weather

Wet weather outfall sampling is not currently required in Non-standard MS4 Permits for *E. coli* and phosphorus. Precipitation-derived runoff will mobilize many of the potential sources that originate on land surfaces and within the collection system. Therefore, results of wet weather sampling will be indicative of sources beyond those captured with dry weather sampling. Urban runoff often has higher concentrations of phosphorus and *E. coli* than dry weather samples (unless an illicit sanitary connection is present) based on instream monitoring conducted along the Front Range for several decades. However, wet weather sampling presents considerably more challenges than dry weather sampling simply because of the unpredictability of the weather and scheduling sampling. Detailed guidance for wet weather sampling is beyond the scope of this guidance; nonetheless, some practical considerations for those considering wet weather sampling include:

- Sampling can be performed using grab samples or automated samplers. Grab samples are collected manually. Single grab samples typically do not provide an accurate representation of concentrations throughout the runoff hydrograph. If more than one sample is required to be collected throughout an event, auto samplers may be more efficient and more representative. The upfront costs of equipment may be less than the long-term costs of labor for manual sampling depending on the particular project.

- Samples can be analyzed individually (discrete) or as composite:
    - Discrete (grab) results will provide a snapshot of concentration at one or more times during the event.
    - Composite sampling provides multiple samples during the runoff event and then composites those samples into a single sample for analysis. The results are more representative of the entire storm event than grab samples. Composite sampling (intended to collect samples representative of the overall storm event) is most effectively conducted using automated samplers. However, auto sampling is very expensive and

[6] Two specific methods approved by EPA for human markers include HF183/BacR287 (Method 1696.1) and HumM2 (human mtDNA) (Method 1697.2). For more information on EPA-approved methods, see https://www.epa.gov/cwa-methods/other-clean-water-act-test-methods-microbiological

[7] See the Colorado *E. coli* Toolbox for more detailed discussion on how quantitative microbial risk assessment (QMRA) has been used to relate concentrations of human markers such as HF183 to human health risk.

specialized. It can take a full monitoring season to "dial in" the equipment, and equipment maintenance is time-intensive.

- Identifying a suitable analytical laboratory and potential hold time constraints (distance from sampling location(s), sample delivery time and day) is important:
    - There are only a few commercial labs on the Front Range that will run *E. coli*. Local government labs (WWTP in-house labs) may be the best option.
    - Most labs will not accept *E. coli* samples after 2-3 pm in the afternoon as the samples must be prepped before closing. Also, some will not accept samples on Fridays as they are closed on Saturdays.
    - Hold times for *E. coli* provide significant constraints. The standard hold time is 6 hours; therefore, samples must typically be collected in the morning/early afternoon. Collecting samples during typical evening storms in the summer would not meet hold times if delivered to the lab the next morning.
- Plan for adequate and redundant staffing. Staff must continuously monitor long-term (72-hr+) weather forecasts and radar on days with high precipitation probability. Staff location(s) in proximity to sampling locations is very important due to unpredictability. Mobilization times from office to sampling location should ideally be less than 1 hour. This also means having all supplies (bottles, coolers, COCs, etc.) pre-prepped and ready.
- Spring (April-early June) is when precipitation events are most predictable (i.e., 48-72 hour forecasts are more reliable) and longer duration (several hours) because they are typically frontal systems.
    - Summer is almost completely unpredictable because they are monsoon systems. Check real-time radar and possibly automated rainfall alerts to determine if rainfall is occurring at the sampling location(s). Rain events can be very short duration (1 hour or less) requiring rapid mobilization.
    - Fall forecasts can be more reliable than summer as frontal systems again begin to dominate over monsoon.
- Using automated sampling, expect to get 5-8 samples during a typical monitoring season (May-October). Although there are usually more rainfall events each year, equipment will fail, rainfall will occur on weekends, etc.
- If collecting grab samples during storm events at multiple locations, it is best to have a team dedicated to each site rather than having one team try to collect samples at multiple locations during the same event. Relatively short (1-2 hours) rain events leave little time to travel between sites, especially if multiple samples must be collected throughout the event.
- Pre-label bottles in a dry location to avoid smearing of ink.

9.4 SCM Monitoring

A general objective of SCM monitoring is to determine if a particular SCM is effective at removing *E. coli* or phosphorus. Monitoring for many SCMs types from around the country is available in the International

Stormwater Best Management Practices (BMP) Database (www.bmpdatabase.org; Clary et al. 2020). Ample total phosphorus data sets are available, with fecal indicator bacteria being more limited.

Inlet and outlet flow and water quality sampling for SCM effectiveness along the Colorado Front Range could expect to collect potentially 5-8 events per year, depending on weather and timing of events relative to lab hours (weekdays) and staff availability. In some years, three events may be realistic based on monitoring experience of MHFD and others. For SCM sampling using a paired inflow-outflow design, then two autosamplers and water level sensors would need to be installed and calibrated, with a 2025 order of magnitude cost estimate of approximately $30,000 per SCM site. Lab analysis costs vary based on constituents analyzed and whether an internal or commercial laboratory is used. *E. coli* analysis alone is typically <$30/sample but the cost for a full suite of analytes and sample collection can often range from $500-2,000 per event, depending on constituents analyzed and lab used. A rule of thumb for SCM monitoring is roughly $60,000/year. To conduct performance and trend analysis, several seasons of monitoring are likely needed to get 15-20 events; therefore, ballpark costs for an SCM study are on the order of ~$200,000+ for a 3-year study.

Most of the considerations for wet weather outfall sampling discussed in Section 8.3 apply to SCM sampling with additional sample collection from both the influent and effluent of the SCM.

- As described in Section 8.3, several different monitoring approaches can be used. Composite, flow-weighted sampling with automated samplers is preferable, especially if results will be compared to other studies in the International BMP Database where most studies collect data using those methods. To evaluate load reduction, inflow/outflow rates and volumes must be monitored in addition to pollutant concentrations; therefore, additional equipment (flumes, pressure transducers, area-velocity sensors) are necessary along with experienced field staff to install, calibrate, maintain and reset automated samplers.

- Due to the large variability in *E. coli* concentrations in wet weather runoff, it can take a large number of samples to assess SCM effectiveness with any statistical significance, typically at least a three-year monitoring period. For more information, see the Colorado *E. coli* Toolbox for a discussion of sample sizes based on guidance from Burton and Pitt (2002).

- Extended drawdown times for water quality capture volume (WQCV)-based SCMs present challenges for meeting *E. coli* hold times. For example, to capture the entire drawdown of an extended detention basin could require collecting samples over a 24-40 hour period, which would not meet a 6- hour hold time for *E. coli*. Therefore, the tradeoffs of a representative hydrograph versus meeting hold times must be considered. Ideally, the sample bottle(s) inside the automated sampler would be on ice throughout the duration of sample collection or a refrigerated sampler would be used.

10.0 SUMMARY

Non-standard MS4s subject to TMDLs have or will have stormwater outfall monitoring requirements. The Colorado Stormwater Council sponsored development of this guidance to support Non-standard MS4s with dry weather monitoring requirements in the 2021 Non-standard MS4 permit for phosphorus and *E. coli*. Permit requirement may change over time; therefore, permittees should defer to their most current CDPHE-issued permit certification and associated MS4 permit for the most current requirements. In addition to permit requirements applicable as of April 2026, this guidance includes practical tips on sample collection, flow estimation, data management and other types of monitoring beyond dry weather outfall monitoring.

As practical lessons are learned by MS4s regarding monitoring, permittees are encouraged to share their experiences with Colorado Stormwater Council and CDPHE to support pragmatic and meaningful monitoring that supports the ultimate goal of water quality protection in local communities.

11.0 REFERENCES

Burton, G.A. Jr., *and* R. Pitt. (2002). *Stormwater Effects Handbook: A Tool Box for Watershed Managers, Scientists, and Engineers*. ISBN 0-87371-924-7. CRC Press, Inc., Boca Raton, FL. 2002. 911 pages. www.epa.gov/ednnrmrl/publications/books/handbook/index.htm

CDPHE (2021). Statewide Non-standard MS4 General Permit (COR070000) and Fact Sheet. Accessible at: https://cdphe.colorado.gov/wq-municipal-ms4-general-permits

CDPHE (n.d.) TMDL webpage: https://cdphe.colorado.gov/total-maximum-daily-loads-tmdls

Center for Watershed Protection and R. Pitt. (2004). *Illicit Discharge Detection and Elimination: A* Guidance *Manual for Program Development and Technical Assessments*. Center for Watershed Protection, Ellicott City, MD, and University of Alabama, Tuscaloosa, AL. http://www.cwp.org/online-watershed-library/cat_view/64-manuals-and-plans/79-illicit-discharge-detection-and-elimination

Clary, J., Jones, J., Leisenring, M., Hobson, P., Strecker, E. (2020). International Stormwater BMP Database: 2020 Summary Statistics. Water Research Foundation: Alexandria, VA. Accessible at: www.bmpdatabase.org

Harmel, R.D., Hathaway, J.M., Wagner, K.L., Wolfe, J.E., Karthikeyan, R., Francesconi, W., McCarthy, D.T. (2016b). Uncertainty in monitoring *E. coli* concentrations in streams and stormwater runoff. *Journal of Hydrology* 534 (2016) 524–533.

U.S. Bureau of Reclamation. (1997). *Water measurement manual* (3rd ed.). https://www.usbr.gov/tsc/techreferences/mands//wmm/

U.S. Environmental Protection Agency. Other Clean Water Act Test Methods: Microbiological. https://www.epa.gov/cwa-methods/other-clean-water-act-test-methods-microbiological

U.S. Geological Survey. Techniques of Water Resource Investigation Reports: https://pubs.usgs.gov/twri/index090905.html

Wright Water Engineers, Inc. and Geosyntec Consultants (2026). Colorado *E. coli* Toolbox, Updated 2026, originally completed in 20216 for Mile High Flood District and City and County of Denver. Accessible at www.mhfd.org

Wright Water Engineers, Inc., Geosyntec Consultants, Robert Pitt and Larry Roesner. 2013. Regulation 85 MS4 Data Gap Analysis. Prepared for the Colorado Stormwater Council and submitted to CDPHE.

Wright Water Engineers, Inc. 2025. Cherry Creek Reservoir Basin Stormwater Control Measure Effectiveness Study. Prepared for Cherry Creek Basin Water Quality Authority. March 29. Accessible at: https://www.cherrycreekbasin.org/scm-effectiveness-study-wwe-2025

https://wrightwater1-my.sharepoint.com/personal/jclary_wrightwater_com/Documents/4-17-26 Draft 2-8-26 CSC Nonstandard MS4 Suppport REV.docx

ATTACHMENTS

Attachment A: *E. coli* and Phosphorus Monitoring Requirements Excerpted from the CDPHE Non-Standard MS4 Permit Issued April 30, 2021

1. **Exclusions**

   a. Removal of Outfalls from dry weather inspection and monitoring requirements: The permittee may remove the outfall from monitoring requirements in Part III.C.2 if they meet one or more of the following conditions:

      i. The permittee has identified and eliminated all sources of the dry weather discharge such that the dry weather flow is less than 5 gpm.

      ii. The dry weather flow has ceased or decreased to below 5 gpm for at least three months, based on a minimum inspection frequency of once per 14 days, or the required sample frequency, whichever is more frequent and there are no indicators present of an illicit discharge.

      iii. For permittees subject to *E. coli* TMDLs for Boulder Creek, Big Dry Creek, and South Platte River, or Wildhorse Creek the seasonal geometric mean remains below the threshold concentrations in Table 11 for two consecutive seasons.

Table 11
Thresholds for Removing an Outfall of Concern

TMDL	Threshold (cfu/100 mL)
Boulder Creek	126
Big Dry Creek	205
South Platte River	126
Wildhorse Creek	126

      For any dry weather discharge that remains after 2 years, the permittees meeting this exclusion must continue to monitor *E. coli* at a frequency of once per year during the period of May 1-October 31.

      iv. For permittees that discharge within the Barr Lake Milton Reservoir Datashed the permittee may discontinue sampling after eight quarterly samples are analyzed and reported.

   b. Permittees must notify the division when an exclusion condition in Part III.C.1 is met.

E. coli Monitoring

e. *E. coli* Monitoring

Where the permittee's certification requires *E. coli* monitoring the permittee must conduct dry weather outfall (i.e., direct discharge to state water that is addressed by the associated TMDL) monitoring as described in i through iv below. To comply with Part III.C.2.e, the permittee may use data collected by another entity as long as it meets requirements of this permit.

The permittee may be excluded from E. coli monitoring requirements in this part (III.C.1.e) if they are participating in a Regional Monitoring Program and have notified the division. The Regional Monitoring Program must meet the following criteria:

- The program monitors MS4 discharges for pollutants causing the impairment addressed by the TMDL
- The program has established a monitoring plan that is consistent with the TMDL
- Monitoring data collected under the program must be quantitatively comparable to TMDL WLAs
- Monitoring data must include analytical monitoring of discharges representative of the permittee's discharges or the specific type of permittee.

i. Within one year of discovering a dry weather discharge, the permittee must begin *E. coli* monitoring at the outfall containing the dry weather discharge. The permittee must collect and analyze for *E. coli* in a minimum of ten discharge samples, spaced one week apart, at each outfall during the period of May 1 through October 31.

ii. The permittee shall either measure or estimate the outfall flow at the time the *E. coli* sample is collected. If flow is estimated the permittee must briefly document the method of estimation.

iii. Following the first sampling event, if flow is absent during a week, the permittee shall document so and shall re-attempt weekly sampling and flow data collection unless the permittee has met conditions for exclusion in Part III.C.1 and notified the division.

Phosphorus Monitoring

f. Phosphorus Monitoring

Where the permittee's certification requires phosphorus monitoring, the permittee must conduct dry weather outfall (i.e., direct discharge to state water) monitoring as described in i through iii below.

The permittee may be excluded from phosphorus monitoring requirements in this part (III.C.1.e) if they are participating in a Regional Monitoring Program and have notified the division. The Regional Monitoring Program must meet the following criteria:

- The program monitors MS4 discharges for pollutants causing the impairment addressed by the TMDL.
- The program has established a monitoring plan that is consistent with the TMDL.
- Monitoring data collected under the program must be quantitatively comparable to TMDL WLAs.
- Monitoring data must include analytical monitoring of discharges representative of the permittee's discharges or the specific type of permittee.

i. Within one year of discovering a dry weather discharge, the permittee must begin quarterly phosphorus monitoring at the outfall containing the dry weather discharge. Quarterly monitoring consists of collecting and analyzing at least one sample per quarter.

ii. The permittee shall either measure or estimate the outfall flow at the time the Total Phosphorus sample is collected. If flow is estimated the permittee must briefly document the method of estimation.

iii. Following the first sampling event, if flow is absent during a quarterly sampling event, the permittee shall document so and shall re-attempt to sample and measure the corresponding flow every 14 days until a sample is obtained for the quarter.

Attachment B: Example *E. coli* Outfall Sample Collection Guidance[8][9]

1. OUTFALL INSPECTION PROCEDURES AND DOCUMENTATION

Outfall inspections will document the presence or absence of dry weather discharges. If dry weather discharges are present, the inspector will measure or estimate the flow rate and perform a visual inspection for any indicators of illicit discharges. Outfalls with dry weather flows greater than or equal to 5 gallons per minute (gpm) will also be monitored for *E. coli*.

Flow Measurement and Estimation

Dry weather flow rates must be measured or estimated in the field by the inspector. For this Plan, "measured" flow rates are those that can be reasonably captured in a device with known volume and "estimated" flow rates are those that cannot.

Measured flow rates will be estimated by using a device with a known volume (e.g., bucket) to capture all of the flow discharging from the outfall and recording the time necessary to fill the device. The flow rate is then calculated as the volume of dry weather discharge collected divided by the time needed to collect that volume. The equation for calculating flow rate in gallons per minute (gpm) is below:

$$Flow\ Rate\ (gpm) = \frac{Volume\ Filled\ (gallons)}{Time\ to\ Fill\ (seconds)} * 60$$

Outfall dry weather discharges that cannot be directly measured must be estimated. Estimated flow rates will be quantified based on the inspector's estimates of average flow depth, width, and velocity across a cross-section of flow. The general equation for calculating flow rate in gpm in the field is below:

$$Flow\ Rate\ (gpm) = D * W * V * Conversion$$

Where:

D = average flow depth (inches)
W = average flow width (inches)
V = average flow velocity (inches/second)
Conversion = 0.26

Where more refined flow estimates are needed, then see Attachment C for equations considering pipe geometry.

For submerged outfalls, observe flow conditions at an alternative location within the MS4, if accessible (e.g., an upstream manhole).

---

[8] Sampling plan adapted from plans prepared by Wright Water Engineers for the University of Colorado Boulder and the Town of Windsor.

[9] This sampling plan can be adapted to include total phosphorus in addition to *E. coli.* Follow sample preservation and hold times for the total phosphorus analysis method in coordination with the analysis laboratory.

Indicators of Illicit Discharge

Indicators of illicit discharges that will be noted, if observed, include the following:

- Presence of human feces and/or sanitary products
- Foul or chemical-like aromas
- Unusual colors or sheens

Outfall Inspection Documentation

Each outfall inspection will be documented and retained in an electronic form. The electronic form will include (at a minimum) the following information:

- MS4 Permit Outfall ID (Tip: use the outfall ID already created in MS4 Asset Management Systems
- MS4 Outfall Common Name (Optional field for orientation, e.g., Eldora Park 1)
- Date of Inspection
- Inspector Name
- Date of last measurable rainfall and name of rain gage
- Dry Weather Discharge Flow Rate (in gallons per minute)
- Dry Weather Discharge Method ("Measured" or "Estimated") – if "Estimated," a brief description of the methodology used to provide the estimate.
- Any indicators of illicit discharges
- Comments (other comments, if needed; e.g., excessive sediment, adjacent encampment, raccoon feces, sump pump surge during sampling)
- Photographs (as appropriate) to support inspection findings

Attachment B-1 is an example outfall inspection form that includes the information above and can be modified as needed and integrated into field applications such as ArcGIS Field Maps or Survey123.

2. DRY WEATHER *E. COLI* OUTFALL MONITORING

E. coli samples will be collected from outfalls with dry weather flows of 5 gpm or greater between May 1 and October 31.

E. coli Sampling Procedures[10]

E. coli sampling under this plan is intended to be representative of dry weather discharges; therefore, sampling events will be conducted at least 48 hours after the last measurable rainfall event.

E. coli grab samples will be collected in sterile bottles provided by the analysis laboratory and immediately placed in a cooler with ice until delivery to the analytical laboratory. Whenever possible, samples will be collected in the morning so that they can be delivered to the analytical laboratory well before close of business hours. Samples will be analyzed by an EPA-approved method (e.g., SM-9223-2016, IDEXX Colilert).

Sample collection methods for *E. coli* at stormwater outfalls include the following:

[10] This sampling plan does not describe techniques for collecting outfall samples; if additional guidance is needed on protocols for sample collection, see: https://www3.epa.gov/npdes/pubs/idde_appendix-g.pdf

Pre-Collection Steps

- Assess safety; avoid confined spaces unless permitted.
- Record flow conditions and visual indicators.
- Label sterile bottles and avoid contamination.

Collect Grab Sample from Outfall Pipe

- Stand to the side of the outfall.
- Extend sterile bottle into center of flow beyond outfall lip.
- Fill bottle to appropriate level (allow headspace).
- Cap immediately and place on ice.
- If direct access is unsafe, use telescoping pole with sterile bottle attached to collect sample.

Avoid Contamination

- Do not touch interior of bottle or cap.
- Keep bottle opening downward until sampling.
- Do not disturb sediment or vegetation in outfall.

Post-Collection Handling

- Immediately chill to ≤10°C by placing in cooler with ice.
- Document outfall ID, date/time, flow, odor, visual indicators.
- Transport to analysis laboratory within 6 hours.

Although CDPHE's Non-standard MS4 Permit does not specify or require quality assurance/quality control samples, collection of field duplicates and field blanks are recommended.[11] These samples are used to indicate the quality of field sampling procedures and analytical results. A field duplicate will be a sample collected at the same time/location as the initial sample and will be indicated on the monitoring form and chain-of-custody (COC) with the Sample ID followed by "DUP."

A field blank is a sample of sterile (distilled[12]) water that is collected at the beginning of daily sample collection activities and is handled in the same manner as other samples. Field blank samples will be recorded on the COC using the Sample ID "DATE"-FB, where "DATE" is the date of sample collection. For example, a field blank for September 15, 2022 will be identified on the COC as "9-15-2022-FB."

For outfalls with a known history of results that were "too numerous to count" (i.e., >2,419.6 MPN/100 mL), follow up samples may be diluted[13] at the laboratory to increase the maximum reporting limit and enable quantification of results.

A complete chain of custody for collected samples will be submitted to analysis laboratory with a copy scanned and stored in the MS4's file directory.

[11] Frequency of sample collection for field blanks and duplicates depends on number of samples and sampling events. A rule of thumb is to collect a set of QC samples representing 5% of the collected samples (e.g., 1 set per 20 samples).

[12] Distilled water can be purchased from local grocery and convenience stores if not provided by the lab.

[13] The dilution ratio may vary based on expected results; however, it is anticipated that a 10:1 dilution ratio will be used during initial sampling periods.

Outfall *E. coli* Monitoring Documentation and Recordkeeping

The Outfall Inspection Form discussed above will be filled out during *E. coli* sampling activities. In addition, laboratory reports and copies of the chain of custodies will also be retained. These records will include:

- Date(s) and time(s) when samples were collected and analyzed.
- Individual(s) who collected the samples.
- Analytical techniques or methods used.
- Results of laboratory analyses with units and qualifiers.
- Dilution applied (if any) (e.g., 10X, 100X).
- Comments

Results will be compiled into an Excel spreadsheet for record-keeping, data analysis, and reporting. In lieu of an Excel spreadsheet. For MS4s with internal "data dashboards" in GIS, lab and field data can alternatively be stored in GIS.

Field Equipment and Materials

Field equipment and materials typically include:

- Sample bottles, bottle labels and chain of custody from lab.
- Cooler with ice.
- Cell phone and/or field tablet, typically with preloaded GIS information in ArcGIS Field Notes or similar program and a functioning camera and stopwatch.
- Chargers/battery backs to support electronic equipment.
- Sharpies.
- Nitrile gloves.
- Hand sanitizer.
- Paper towels.
- Distilled water or deionized lab water for pouring field blanks.
- Tape measure.
- Safety vest.
- Close-toed shoes.
- Garbage bag.
- Hip waders or rubber boots (dependent on site conditions).
- Field notebook.
- Field map (big picture overview to support navigation).
- Extension pole for sample collection (if needed).
- Other personal items: sunscreen, bug spray, water, first aid kit.

Safety

Follow local government safety protocols and standard operating procedures for water sample collection and field work, including any required personal protective equipment and guidance relevant to minimum number of staff for sample collection. Representative considerations include:

- Wear long pants, sleeves and sturdy shoes suitable for scrambling through brush. Some outfalls may require rubber boots or waders if the outfall is only accessible from the stream.
- Practice situational awareness related to tripping hazards and follow precautions related to working in or near waterways. Considerations include weather, drainageway characteristics, flow conditions, property ownership, human encampments, animal inhabitation (e.g., snakes, raccoons), traffic and difficult access conditions.
- Use disposable nitrile or latex gloves for sample collection and change frequently and dispose properly.
- Wash hands thoroughly with soap and water and/or use hand sanitizer in the field after contact with water samples or stream water.
- Avoid touching face, mouth, or eyes during field work.
- Decontaminate equipment following use with soap and water or other equivalent disinfectant.

Outfall Inspection Form

MS4 Outfall ID: ______________________

Inspection Date: ______________ **Inspector Name:** ______________

Date of Last Measurable Rainfall: ______________________

Rain Gage Name: ______________________

Dry Weather Discharge (gpm): ______________________

Discharge Method: Measured: ______________ Estimated: ______________

Discharge Method Notes: ______________________

____

____

Indicators of Illicit Discharges

Type	Yes	No
Human feces or sanitary products		
Foul or chemical-like aromas		
Unusual colors or sheens		

Other (describe): ______________________

____

____

Notes: ______________________

____

____

____

____

____

____

Figure B-1. Example Outfall Inspection Form (Suitable for Integration into a Field App)

Attachment C: Flow Calculation Methods

Flow measurement and estimation at stormwater outfalls can be more challenging than sample collection. Two publicly accessible robust reference for flow measurement include:

U.S. Bureau of Reclamation. (1997). *Water measurement manual* (3rd ed.). https://www.usbr.gov/tsc/techreferences/mands//wmm/

U.S. Geological Survey. Techniques of Water Resource Investigation Reports: https://pubs.usgs.gov/twri/index090905.html

For convenience, equations used to calculate flow based on field observations varying based on pipe type are briefly summarized below. AI tools may be useful for supporting these calculations, provided that the correct input and equation type is used for calculations. Basic data needed to estimate flow include:

Universal Flow Equation

- **A** = flow area (sq ft)
- **V** = average velocity (ft/s)

$$\boxed{Q = A \times V}$$

Where:

- **Q** = flow (cfs)
- **A** = flow area (sq ft)
- **V** = average velocity (ft/s)

Note cfs can be converted to gallons per minute (gpm) (gpm = cfs x 448.83).

Common conversions include:

Flow (cfs)	Flow (gpm)
0.01	4.49
0.1	44.9
0.25	112
0.5	224
1.0	**449**
2.0	898
5.0	2,244
10.0	4,488

Velocity (V) can either be measured by a flow meter or estimated using the float method (“ping pong ball”) method:

$$V = \frac{L}{t}$$

Where:

- **L** = float distance (ft)
- **t** = travel time (sec)

Area (A) calculations to complete the flow calculation require field measurements of flow depth and pipe geometry so that flows can be calculated based on pipe geometry and size. These characteristics should be recorded in a spreadsheet to support calculations. Common stormwater outfall pipe types and sizes include:

Pipe Material / Type	Common Diameters (in)	Typical Use at Outfalls	Notes
Reinforced Concrete Pipe (RCP)	12–72+	Major storm drains, trunk lines	Most common municipal outfall
Corrugated Metal Pipe (CMP)	12–48	Older systems, roadside drainage	Manning n higher due to corrugation
HDPE (Smooth Interior)	12–60	Newer storm systems	Lower roughness, lightweight
PVC (Schedule 40/80)	6–36	Small laterals, private systems	Smooth interior
Box Culvert (Concrete)	2×2 ft to 12×12 ft	High-flow channels, major outfalls	Rectangular geometry
Open Channel / Ditch	Variable	Unpiped outfalls	Treated as trapezoidal/rectangular

Spreadsheets can be set up to enable ease of calculation of flows once basic pipe geometry data (e.g., circular, rectangular) including shape, diameter (D) and/or width (b) are documented.

During each field visit, the unique measurements of flow depth (d) and velocity (V) are needed to calculate flows.

---

1. Circular Stormwater Pipe

A. **Pipe Flowing Full** *(not typically the case for dry weather and water quality events)*

$$A = \frac{\pi D^2}{4}$$

$$\boxed{Q = \frac{\pi D^2}{4} \times V}$$

Where:

- **D** = inside diameter (ft)
- **A** = flow area (sq ft)
- **V** = average velocity (ft/s)

B. Pipe Flowing Partially Full (Depth Observed)

1. Calculate central angle:

$$\theta = 2\cos^{-1}\left(1 - \frac{2d}{D}\right)$$

2. Flow area:

$$A = \frac{D^2}{8}(\theta - \sin\ \theta)$$

3. Flow:

$$\boxed{Q = A \times V}$$

Where:

- **d** = flow depth (ft)
- **D =** pipe diameter (ft)
- **A** = flow area (sq ft)
- **V** = average velocity (ft/s)

---

2. Rectangular Channel or Box Culvert

$$A = b \times d$$

$$\boxed{Q = b \times d \times V}$$

Where:

- **b** = width (ft)
- **d** = depth (ft)
- **V** = average velocity (ft/s)

Common for concrete box outfalls.

---

3. Trapezoidal Channel (Roadside Ditches)

$$A = d(b + zd)$$

$$\boxed{Q = d(b + zd) \times V}$$

Where:

- **b** = bottom width (ft)
- **z** = side slope (H:V)
- **d** = depth (ft)
- **A** = flow area (sq ft)
- **V** = average velocity (ft/s)

4. Manning's Equation (When Velocity Is Not Measured or Estimated)

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

Where:

- **n** = Manning roughness
- **R** = hydraulic radius = A / P
- **A** = cross-sectional area of flow (sq ft)
- **P** = wetted perimeter
- **S** = energy slope (pipe or channel slope) (ft/ft)

Typical **n values**:

- RCP: 0.013
- CMP: 0.022–0.030
- HDPE/PVC: 0.009–0.012

Attachment D: TMDL Wasteload Allocation Tables Referenced in Non-standard MS4 Permit Fact Sheet as of 2026 (Permit Tables 5 – 10)

Table 5 Boulder Creek TMDL Wasteload Allocations for Non-Standard MS4 Permittees					
Permittee	Wasteload Allocations (cfu/day) by Flow Conditions				
	High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flow
University of Colorado	6.85E+10	1.33E+10	4.34E+09	1.28E+09	4.02E+08
Boulder Valley School District	5.53E+09	1.07E+09	3.50E+08	1.03E+08	3.24E+07

Table 6 Big Dry Creek TMDL Wasteload Allocations for Non-Standard MS4 Permittees					
Permittee	Wasteload Allocations (giga cfu/day) by Flow Conditions				
	High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flow
MS4s Upper Reach	201.59	55.61	13.90	6.95	4.17
MS4s Middle Reach	149.14	36.23	4.29	1.60	1.94
MS4s Lower Reach	43.78	18.32	10.20	6.41	0.99

Table 7 South Platte River Segment 14 *E. coli* TMDL Wasteload Allocations for Non-Standard MS4 Permittees		
Permittee	Permit Number	WLAs for Low Flow (cfu/day)
Arapahoe Community College	COR070023	126 cfu/100 ml
Auraria Higher Education Center	COR070048	126 cfu/100 ml
Colorado Rockies Baseball Club	COR070090	126 cfu/100 ml
Denver Health and Hospital Authority	COR070080	126 cfu/100 ml
Denver Public Schools	COR070081	126 cfu/100 ml
Littleton Public Schools	COR070086	126 cfu/100 ml
Metropolitan Football Stadium District	COR070067	126 cfu/100 ml
Regional Transportation District	COR070098	126 cfu/100 ml

Table 8 Wildhorse Creek *E. coli* TMDL Wasteload Allocations for Non-Standard MS4 Permittees		
Permittee	Permit Number	WLA (Giga-cfu/Day)
Pueblo County School District 60	COR070227	0.22[5]

Table 9 Summary of Allowable MS4 Loads for Barr and Milton			
Source Wasteload	Target Load (kg/yr	Daily Mean Target Load (kg/day)	Total Max. Daily Load (kg/day)
Barr Lake	1,751	7.3	19.3
Milton Reservoir	362	2.2	4.8

Table 10 Barr Lake-Milton Reservoir Phosphorus TMDL Wasteload Allocations for Non-Standard MS4 Permittees		
Permittee	Permit Number	TMDL Water Body
Adams 12 Five Star Schools	COR070026	COSPBD01
Adams County School District 14	COR070043	COSPUS16a
Adams County School District 50	COR070074	COSPCL18b
Arapahoe Community College	COR070048	COSPUS14
Auraria Higher Education Center	COR070080	COSPCH03
Aurora Public Schools	COR070059	COSPUS16a
Colorado Department of Corrections	COR070097	COSPUS16a
Colorado Community College System	COR070046	COSPS16c
Colorado Rockies Baseball Club Ltd	COR070090	COSPUS14
Community College of Aurora	COR070047	COSPUS16c
Denver Health and Hospital Authority	COR070081	COSPCH03
Denver Public Schools	COR070086	COSPUS16c
E470 Public Highway Authority	COR070205	COSPUS16c
Fairlake Metro District	COR070072	COSPCH04
Falcon School District	COR0700065	COSPUS16c
Foothills Park and Recreation District	COR070092	COSPUS16c
Highlands Ranch Metro District 1	COR070053	COSPUS16c
Hyland Hills Park and Recreation District	COR070221	COSPUS16c
Littleton Public Schools	COR070067	COSPUS16c
Mapleton Public Schools	COR070036	COSPCH03
Metropolitan Football Stadium District	COR070098	COSPUS16c
Red Rocks Community College	COR070045	COSPUS16c
RTD	COR070023	COSPUS14
Southwest Plaza Metro District	COR070091	COSPUS16c
University of Colorado Denver Anschutz Medical Cam	COR070075	COSPCH03

Resource Guide for Non-standard MS4 TMDL-Related Monitoring

PREPARED FOR

Colorado Stormwater Council

April 2026 251-089.000

WRIGHT WATER ENGINEERS, INC.