

Technical Memo

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Subject: Perforated Pipe Guidelines for Filtration Practices

Introduction

CRWD inspection staff have identified inconsistencies in the drain tile delivered to construction sites for installation in filtration practices compared to what is specified in the approved construction plans. This technical memo aims to provide updated specification guidance for drain tile used in filtration practices for CRWD. The goal of this guidance is to recommend readily available materials that follow accepted specifications to simplify obtaining and installing proper material.

Background

CRWD currently follows guidance from the *Minnesota Stormwater Manual* for underdrain design in filtration practices. Some contractors, however, indicate it is difficult and/or costly to obtain materials from local suppliers that meet these standards. Specific guidance includes:

- Construct underdrains with Schedule 40 or SDR 35 smooth wall PVC pipe
- Use 3/8-inch circular perforations
- Perforation pattern follows ASTM D1785 or AASHTO M278
- Underdrain pipes should have a minimum of three inches of washed #57 stone above and on each side of the pipe (stone is not required below the pipe). Above the stone, two inches of choking stone is needed to protect the underdrain from blockage.

Therefore, this memo will investigate three drain tile properties to potentially offer contractors more material options:

- Perforation pattern to sufficiently convey flow rate from the filter media
- Hole size to correspond with backfill material and prevent migration of material into the drain tile
- Pipe material (Schedule 40, SDR 35, corrugated, etc.) meets the needs of the project and is readily available

Perforation Pattern

Stantec evaluated four different drain tiles to ensure that hole size and perforation pattern combinations can adequately convey flow rate from the filter media. Two of the drain tiles evaluated follow ASTM F758/AASHTO M278 (drain tiles 1 & 3) and one of the drain tiles follows ASTM D1785 (drain tile 2). Stantec found that commercial suppliers commonly list AASHTO M278 and ASTM F758 as being roughly equivalent

standards and thus both routinely appear on specification sheets together (drain tile 1 below). Similarly, suppliers do not commonly carry ASTM D1785 with a 3/8-inch perforation hole as specified in the *Minnesota Stormwater Manual*, but rather 1/2-inch perforations common to sewer pipe specifications. Drain tiles 3 and 4 below are from local suppliers and suggested by contractors working within the watershed at the time of this research.

Drain tiles evaluated:

1. 3/8-inch perforations with ASTM F758 / AASHTO M278 (*Minnesota Stormwater Manual*) (Appendix A.1)
2. 1/2-inch perforations with ASTM D1785 (Appendix A.2)
3. 1/4-inch perforations with ASTM F758 pattern (Appendix A.3)
4. 0.725-inch x 0.04-inch slotted single wall corrugated drain tile (Appendix A.4)

The flow rate for each drain tile specification pattern was solved mathematically over a one-foot length of pipe. Flow calculations assume an orifice flow with 18 inches of head at 1 inch/hour filtration rate (Figure 1).

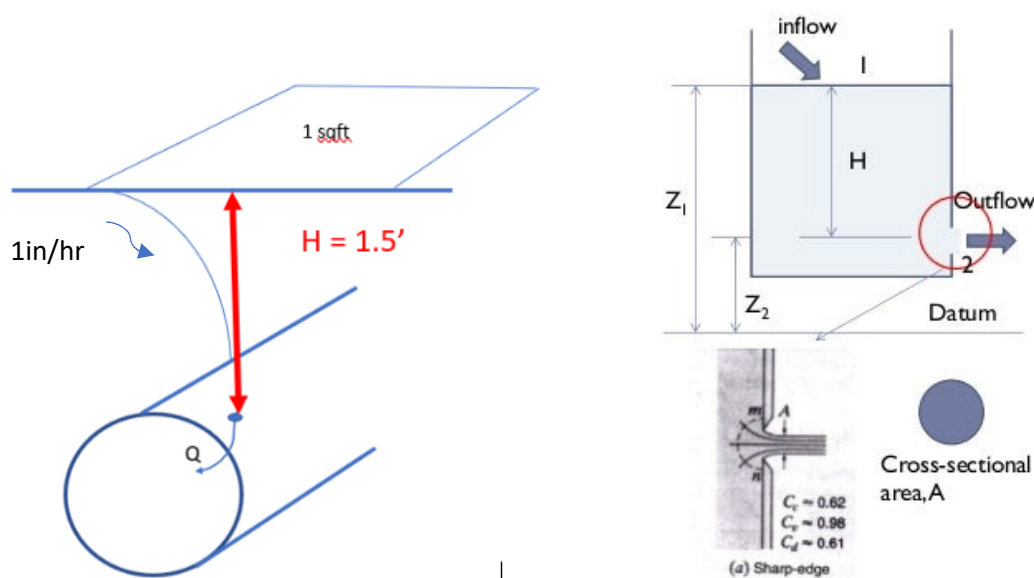


Figure 1. Diagram of flow through a drain tile perforation.

Assumptions:

- 6-inch drain tile diameter (most common drain tile diameter in CRWD)
- Filtration rate through media is 1 inch/hour
- The head (H) related to the flow through a perforation can be directly related to the standard design filtration media depth of 18 inches (1.5 feet)
- 1-D flow through the filtration media
- 50-foot length of pipe per 1,000 ft² of filtration media

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Equation: $Q = C_d A \sqrt{2gH}$ where,

- Q = Flow (cfs)
- C_d = Coefficient of discharge (0.6)
- A = Cross-sectional area of orifice (ft²)
- g = Gravitational constant (~32.2 ft/s²)
- H = Depth of water above orifice centerline (1.5 ft)

Table 1. Perforation patterns and flow rates for drain tile designs.

| Drain Tile | Hole Rows | Hole Size (in) | Spacing (in) | Open Area (in ²)/linear foot | Flow (cfs)/1,000 ft ² (50 feet of drain tile) |
|--|----------------------|----------------|--------------|--|--|
| 1 in/hr Filtration Media | N/A | N/A | N/A | N/A | 0.02 |
| 1 - MN Stormwater Manual - AASHTO M278/ ASTM F758 (Appendix A.1) | 2 @ 90° and 2 @ 160° | 3/8" | 3 | 1.77 | 3.6 |
| 2 - ASTM D1785 (Appendix A.2) | 3 @ 60° | 1/2" | 5 | 1.41 | 2.9 |
| 3 - ¼-inch SDR 35 AASHTO M278/ASTM F758 Pattern (Appendix A.3) | 2 @ 90° and 2 @ 160° | 1/4" | 3 | 0.79 | 1.6 |
| 4 - Slotted Corrugated Drain Tile Pattern A (Appendix A.4) | 4/valley @ 45° | 0.725" x 0.04" | Every Valley | 1.74 | 3.6 |

All hole size and perforation patterns evaluated have sufficient capacity to convey the flow rate from the filter media assuming a long-term filtration rate of 1 inch/hour.

Hole Size

Next, Stantec evaluated perforation hole size to ensure that backfill material does not migrate into and clog the drain tile. The current *Minnesota Stormwater Manual* recommendations indicate 3/8-inch perforation size surrounded by AASHTO #57 rock. However, this combination could allow up to 80% of the AASHTO #57 rock to be smaller than the drain tile size (Table 2). MnDOT Course Filter Aggregate is very similar in gradation to the AASHTO #57 rock but could also allow up to 60% of the rock to be smaller than the 3/8-inch perforations (Table 2).

Table 2. Washed rock size distribution.

| Aggregate | Amount Smaller than Sieve Size | | | | |
|-------------------------------|--------------------------------|--------|-------|------|-------------|
| | 1" | ¾" | 1/2" | 3/8" | #4 (~3/16") |
| AASHTO #57 | 95-100 | N/A | 25-80 | N/A | 0-10 |
| MnDOT Course Filter Aggregate | 100 | 85-100 | 20-60 | N/A | 0-10 |

Stantec explored larger filter rock options, but none were as ubiquitous as AASHTO #57 or MnDOT Coarse Filter Aggregate. Given these rock gradations, a 1/4-inch perforation size is preferred over 3/8-inch since it is smaller and will help to limit migration of rock into the drain tile. Slotted drain tile would also have an advantage of similar flow rates through a smaller width slot to also limit rock migration and drain tile clogging.

Pipe Material

Lastly, Stantec evaluated pipe material to ensure the specified drain tile meets the needs of the project and is readily available. As noted in the background, the *Minnesota Stormwater Manual* recommends Schedule 40 or SDR 35 smooth wall PVC pipe. Recent supply chain issues have led to limited pipe availability and high cost for PVC pipe and fittings. Stantec looked at strength and functionality of other pipe material options to determine if alternative materials are sufficient for application with filtration practices.

Given that vehicle traffic/loading will be minimal on filtration practices, Schedule 40 or SDR 35 rated pipes may be excessive in terms of strength. Both Prinsco and ADS (common local pipe manufacturers) only require one foot of cover for their single wall corrugated pipe. Since filtration design recommends a minimum of 18-inches of media over the crown of the pipe, the corrugated pipe should have sufficient strength for this application. Through our research, Stantec concluded that pipe strength is not a major factor in determining allowable drain tile material for filtration applications.

When evaluating functionality of drain tile pipes, Stantec noted the benefit of a rigid, smooth wall pipe over a corrugated/flexible pipe. Smooth wall pipes ensure a consistent slope to convey filtered runoff out of the filtration system where corrugated/flexible pipe could introduce swales and dips in the pipe if not installed correctly.

Allowing any material (PVC, HDPE, etc.) with rigid, smooth wall pipes in CRWD would allow for some flexibility from the *Minnesota Stormwater Manual* recommendations without straying too far. The intent in allowing this flexibility is to give contractors a few additional options when installing drain tile for filtration.

Recommendation

Stantec suggests CRWD modify their guidance for drain tile specifications according to:

- Rigid, smooth wall drain tile of all material types
- Perforation pattern (either of the following):
 - 1/4-inch circular perforations following ASTM D1785 or AASHTO M278/ASTM F758 patterns
 - Slotted perforations where slot width is smaller than surrounding rock material
- Five inches of non-carbonate MnDOT Coarse Filter Aggregate surrounding the drain tile
- Perforations orientated down

These new recommendations will allow greater flexibility for contractors to obtain and install drain tile that will meet project needs. See Table 3 for a comparison of past and proposed drain tile specifications.

Table 3. Comparison of past and proposed drain tile specifications.

| Specification | Past Recommendation | Proposed Recommendation |
|-----------------------------|---|--|
| Material | Schedule 40 or SDR 35 smooth wall PVC pipe | Rigid, smooth wall pipe of any material |
| Perforation type | 3/8-inch circular | 1/4-inch circular or slotted |
| Perforation pattern | ASTM D1785 or AASHTO M278 | ASTM D1785 or AASHTO M278/ASTM F758 |
| Rock surrounding drain tile | Three inches AASHTO #57 surrounded by two inches of choking stone | Five inches of non-carbonate MnDOT Course Filter Aggregate |

To further clarify and assist CRWD inspectors, the list below includes items that will not be allowed to satisfy CRWD permit requirements:

1. Carbonate rock such as limestone
2. Drain tile socks
3. Filter fabric between layers or around drain tile
4. 1/2-inch or larger circular perforations
5. Drain tile with perforation open area less than 0.49 in²/ft. For reference, this equates to a minimum of 10 - 1/4-inch perforations per linear foot drain tile.

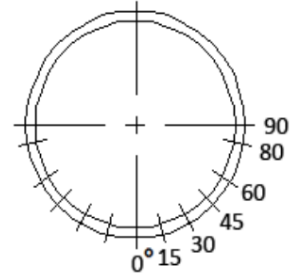
Please see additional information on perforation patterns in Appendix A.

Appendix A: Perforation Patterns

A.1 ASTM F758/AASHTO M278 Pattern from National Pipe and Plastics, Inc.

ASTM F758 / AASHTO M278 Pattern

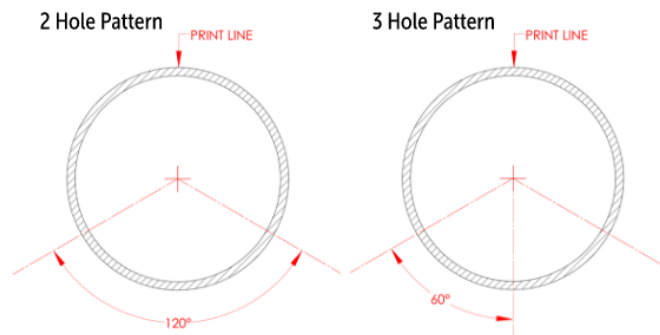
| Nominal Pipe Size | Hole Size | Hole Spacing | Hole Rows |
|-------------------|-----------|--------------|------------------------------------|
| 4" | 3/8" | 3" ± 1/4" | 2 @ 90° (± 3°) |
| 6" - 10" | 3/8" | 3" ± 1/4" | 2 @ 90°, 2 @ 160° (± 3°) |
| 12" - 15" | 3/8" | 3" ± 1/4" | 2 @ 90°, 2 @ 120°, 2 @ 160° (± 3°) |



A.2 ASTM D1785 Pattern from Westlake Pipe

ASTM D1785/D2665 SCH. 40 PVC PRESSURE/DWV PIPE ASTM D1785 SCH. 80 PVC PRESSURE PIPE | Solvent Weld

| D1785 PIPE PERFORATION PATTERNS | | | | | |
|---------------------------------|------------------|------------------------------|--------------------------------|--------------------|---------------------------------------|
| Nominal Size | Perforation Rows | Circumferential Hole Spacing | Longitudinal Hole Spacing (in) | Hole Diameter (in) | Inlet Area (in ² /ft pipe) |
| 4" | 2 | 120° | 5.000 | 0.500 | 0.942 |
| | 3 | 60°-60° | 5.000 | 0.500 | 1.414 |
| 6" | 2 | 120° | 5.000 | 0.500 | 0.942 |
| | 3 | 60°-60° | 5.000 | 0.500 | 1.414 |
| 8" | 2 | 120° | 5.000 | 0.500 | 0.942 |
| | 3 | 60°-60° | 5.000 | 0.500 | 1.414 |



A.3 ASTM F758 Pattern 1/4-inch Hole from Northern Pipe Products Inc.

► HIGHWAY UNDERDRAIN SYSTEMS | ASTM F758 & AASHTO M278

| NOMINAL PIPE SIZE (IN.) | PIPE OUTSIDE DIAMETER (IN.) | MINIMUM WALL (IN.) | LENGTH | ROWS OF PERFORATIONS | HOLE SIZE | HOLE SPACING PER ROW |
|-------------------------|-----------------------------|--------------------|--------|----------------------|-----------|----------------------|
| 4" | 4.215" | .120" | 10' | 4 | 1/4" | 3 |
| 6" | 6.275" | .180" | 10' | 4 | 1/4" | 3 |

A.4 Corrugated HDPE Perforated Pipe from Prinsco

| Pipe Size & Type | Perforation Style | Approximate Slot Length or Hole Diameter | | Approximate Slot Width | | Pattern | Number of Perforations | | Water Inlet Area | |
|------------------|-------------------|--|-------|------------------------|------|---------|------------------------|-----------|---------------------|--------------------|
| | | in | mm | in | mm | | per foot | per meter | in ² /ft | cm ² /m |
| 2" SW | Narrow | 0.725 | 18.42 | 0.040 | 1.02 | H | 36 | 120 | 0.52 | 11.01 |
| 3" SW | Perforated | 0.725 | 18.42 | 0.040 | 1.02 | A | 72 | 240 | 2.09 | 44.24 |
| 3" SW | Narrow | 0.725 | 18.42 | 0.025 | 0.64 | A | 72 | 240 | 1.31 | 27.73 |
| 4" SW/DW | Perforated | 0.725 | 18.42 | 0.040 | 1.02 | A | 72 | 240 | 2.09 | 44.24 |
| 4" SW | Narrow | 0.725 | 18.42 | 0.025 | 0.64 | A | 72 | 240 | 1.31 | 27.73 |
| 5" SW | Perforated | 0.725 | 18.42 | 0.040 | 1.02 | A | 72 | 240 | 2.09 | 44.24 |
| 5" SW | Narrow | 0.725 | 18.42 | 0.025 | 0.64 | A | 72 | 240 | 1.31 | 27.73 |
| 6" SW/DW | Perforated | 0.725 | 18.42 | 0.040 | 1.02 | A | 60 | 200 | 1.74 | 36.83 |
| 6" SW | Narrow | 0.725 | 18.42 | 0.025 | 0.64 | A | 60 | 200 | 1.09 | 23.07 |
| 8" SW/DW/FDW | Perforated | 0.725 | 18.42 | 0.070 | 1.78 | A | 48 | 160 | 2.44 | 51.65 |
| 8" SW/FDW | Narrow | 0.725 | 18.42 | 0.025 | 0.64 | A | 48 | 160 | 0.87 | 18.42 |
| 10" SW/DW | Perforated | 0.725 | 18.42 | 0.070 | 1.78 | C | 72 | 240 | 3.65 | 77.26 |
| 10" SW | Narrow | 0.725 | 18.42 | 0.025 | 0.64 | C | 72 | 240 | 1.31 | 27.73 |
| 10" DW | Perforated | 0.187 | 4.75 | - | - | C | 72 | 240 | 1.98 | 41.91 |
| 12" SW/DW/FDW | Perforated | 0.975 | 24.77 | 0.070 | 1.78 | C | 48 | 160 | 3.28 | 69.43 |
| 12" SW/DW/FDW | Narrow | 0.975 | 24.77 | 0.025 | 0.64 | C | 48 | 160 | 1.17 | 24.77 |
| 12" DW | Perforated | 0.250 | 6.35 | - | - | C | 48 | 160 | 2.36 | 49.95 |
| 15" SW/DW/FDW | Perforated | 0.975 | 24.77 | 0.070 | 1.78 | C | 36 | 120 | 2.46 | 52.07 |
| 15" SW/DW/FDW | Narrow | 0.975 | 24.77 | 0.025 | 0.64 | C | 36 | 120 | 0.88 | 18.63 |
| 15" DW | Perforated | 0.313 | 7.95 | - | - | C | 36 | 120 | 2.76 | 58.63 |
| 18" DW | Perforated | 0.313 | 7.95 | - | - | C | 32 | 104 | 2.45 | 51.86 |
| 18" DW | Narrow | 0.750 | 19.05 | 0.065 | 1.65 | C | 32 | 107 | 0.78 | 16.51 |
| 24" DW | Perforated | 0.375 | 9.53 | - | - | C | 24 | 80 | 2.65 | 56.09 |
| 24" DW | Narrow | 0.750 | 19.05 | 0.065 | 1.65 | C | 24 | 80 | 0.59 | 12.49 |
| 30" DW | Perforated | 0.375 | 9.53 | - | - | C | 24 | 80 | 2.65 | 56.09 |
| 36" DW | Perforated | 0.375 | 9.53 | - | - | C | 20 | 64 | 2.21 | 46.78 |
| 36" DW | Perforated | 0.375 | 9.53 | - | - | C | 24 | 80 | 2.65 | 56.09 |
| 42" DW | Perforated | 0.313 | 7.95 | - | - | D | 30 | 96 | 2.30 | 48.68 |
| 48" DW | Perforated | 0.313 | 7.95 | - | - | D | 30 | 96 | 2.30 | 48.68 |
| 60" DW | Perforated | 0.375 | 9.53 | - | - | D | 24 | 78 | 2.65 | 56.09 |

