Guidance for amending soils with rapid or high infiltration rates

Item 16.16 (https://stormwater.pca.state.mn.us/index.php?title=MN_CSW_Permit_Section_16_Infiltration_Systems#16.16) of the Minnesota Pollution Control Agency (MPCA) Construction Stormwater General Permit (https://stormwater.pca.state.mn.us/index.php?title=2018_Minnesota_Construction_Stormwater_Permit) (CGP) states "This permit prohibits permittees from constructing infiltration systems in areas where soil infiltration rates (including amended soils) are field measured at more than 8.3 inches per hour unless they amend soils to slow the infiltration rate below 8.3 inches per hour".

Item 16.11 (https://stormwater.pca.state.mn.us/index.php?title=MN_CSW_Permit_Section_16_Infiltration_Systems#16.11) states "For design purposes, permittees must divide field measured infiltration rates by 2 as a safety factor or permittees can use soil-boring results with the infiltration rate chart in the Minnesota Stormwater Manual to determine design infiltration rates. When soil borings (https://stormwater.pca.state.mn.us/index.php?title=Understanding_and_interpreting_soils_and_soil_boring_reports_for_infiltration_BMPs) indicate type A soils, permittees should perform field measurements to verify the rate is not above 8.3 inches per hour. This permit prohibits infiltration if the field measured infiltration rate is above 8.3 inches per hour".

The primary concerns with infiltration rates above 8.3 inches per hour are (1) a diminished ability to attenuate pollutants due to the relatively short contact time between the soil and infiltrating stormwater and (2) a higher potential for rapid contaminant transport to groundwater systems (e.g., in the event of chemical spills).

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Example of a coarse-textured soil in which attenuation of pollutants will likely be minimal. Source: USDA (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_053596).

To address these concerns, the MPCA CGP allows for amending soils to slow the infiltration rate to an acceptable level. The approach to amending soils typically involves seeking to accomplish one of two basic objectives: to physically decrease the infiltration rate or to increase pollutant attenuation capacity.

- Physically decreasing infiltration rate: This approach involves designing the soil matrix to achieve a specific permeability that both reduces the speed at which stormwater runoff reaches the groundwater and increases contact time with the soil.
- Increasing pollutant attenuation: This approach does not specifically link to a target infiltration rate. Rather, the soil amendment is done to meet some threshold, such as organic matter content, that satisfies permit requirements. Compost (https://stormwater.pca.state.mn.us/index.php?title=Compost_and_stormwater_management) is commonly used to achieve higher pollutant attenuation capacity.

Caution: Because of the site-specific nature for amending soils, this page offers general guidance on amending soils rather than a specific approach.

Complications

Although slowing infiltration rates to less than 8.3 inches per hour via soil amendments can allow for installation of infiltration systems that help meet permit water quality volume V_{wq} (https://stormwater.pca.state.mn.us/index.php?title=Water_quality_criteria) retention requirements, it also has the potential to create problematic conditions. One of the most common complications of amending soil is decreasing the infiltration rate so much that it becomes unacceptably slow. This is often caused by the introduction of fine-grained materials which become clogged in the native soil. Subsequent consequences of clogging the soil may include failure to meet 48 hour drawdown time requirements and killing vegetation that was not intended for prolonged inundation. Another complication is the potential for the soil amendment to serve as a pollutant source. For example, certain amendment media such as compost can export soluble phosphorus (https://stormwater.pca.state.mn.us/index.php?title=Design_criteria_for_bioretention#Addressing_phosphorus_leaching_concerns_with_media_mixes) in higher concentrations than the incoming stormwater runoff, thus contributing to increased phosphorus loading.

Guide to Developing a Soil Amendment Plan

Designers developing a soil amendment plan to slow the infiltration rate below 8.3 inches per hour should seek to physically decrease the infiltration rate or to increase pollutant attenuation capacity while taking steps to ensure common complications are prevented.

Step 1 – Determine soil conditions

The first step in developing a soil amendment plan involves understanding the baseline conditions of the native soils where the amendment will be performed, including the following.

- **Infiltration rate**: Measure infiltration rates using appropriate methods and number of measurements. Link here for guidance (https://stormwater.pca.state.mn.us/index.php?title=Determining_soil_infiltration_rates).
- **Soil gradation (grain-size distribution)**: Grain-size (particle-size) distribution provides an indication of the presence of fine-grained material (e.g. clay) which can slow infiltration and attenuate pollutants. Samples for grain size analysis are typically collected with soil borings (https://stormwater.pca.state.mn.us/index.php?title=Understanding_and_interpreting_soils_and_soil_boring_reports_for_infiltration_BMPs). Sieve analysis is commonly used to determine grain size distribution, although other methods (e.g. hydrometer) are available. For more information, see [1] (http://home.iitk.ac.in/~madhav/expt4.html), [2] (https://www.astm.org/Standards/D6913.htm), [3] (http://www.environment.nsw.gov.au/resources/soils/testmethods/psa.pdf), [4] (http://www.ce.memphis.edu/1101/notes/filtration/sieve_analysis.pdf).
- **Soil type**: This can be determined once the grain-size distribution is known. Link here (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054167) for more information.
- **Organic matter content**: Soil organic matter (or organic carbon) affects both soil infiltration rate and attenuation of many potential pollutants in stormwater runoff (e.g. metals, organic chemicals, certain forms of nitrogen and phosphorus, bacteria, etc.). Several methods, including field and lab methods, are available for determining soil organic matter content. These are described at these links: [5] (https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051917.pdf), [6] (https://static.tti.tamu.edu/tti.tamu.edu/documents/5-5540-01-P4.pdf), [7] (http://www.nrm.uk.com/files/documents/routine_estimation_of_the_organic_matter_content_of_soils_by_loss_on_ignition.pdf), [8] (https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/aesa8493)
- **Degree of compaction**: Compacted soils will have reduced infiltration rates. Similarly, infiltration rates in uncompacted soils can be decreased by compacting soils. Several methods are available to evaluate soil compaction, including penetration tests and measuring soil bulk density. For description of some methods, see these links: [9] (https://extension.psu.edu/diagnosing-soil-compaction-using-a-penetrometer-soil-compaction-tester), [10] (http://www.vertekcpt.com/blog/soil-compaction-test-intro#.WsJ0Y2cuCGQ), [11] (http://www.multiquip.com/multiquip/pdfs/Soil_Compaction_Handbook_low_res_0212_DataId_59525_Version_1.pdf), [12] (http://gadi.agric.za/articles/Agric/simple.php).

Soil samples should be taken in close proximity to the infiltration test locations.

Step 2 – Develop site plan and select amendment application option(s)

Depending on the site-specific conditions determined from the first step, the soil amendment plan should define one or more of the following.

- Areas where native soil will be retained in place due to sufficient infiltration rates.
- Areas where native topsoil or subsoil will be amended in place.
- Areas where native topsoil will be stripped and stockpiled prior to grading for reapplication.

Step 3 – Identify available material source

Compost and topsoil are the most commonly used soil amendment media. Minnesota's specifications for use of these materials should be followed:

- MnDOT Grade 2 compost (See Specification 3890, page 685 (https://www.dot.state.mn.us/pre-letting/spec/2018/2018-spec-book-final.pdf)) is recommended. Note this compost has a relatively low concentration of nitrogen and phosphorus, which is desirable for soils with rapid infiltration rates.

- Topsoil texture shall be a naturally produced soil of loam, sandy loam to sandy clay loam, within the parameters described in MnDOT Specification 3877, page 699, Sections B and C (https://www.dot.state.mn.us/pre-letting/spec/2018/2018-spec-book-final.pdf#%5B%7B%22num%22%3A1141%2C%22gen%22%3A0%7D%2C%7B%22name%22%3A%22XYZ%22%7D%2C69%2C720%2C0%5D), and suitable for the germination of seeds and the support of vegetative growth.

Step 4 – Calculate amendment volume

When calculating the volume of soil amendment material needed, the following should be taken into consideration.

- Desired infiltration rate of the amended soil
- Desired pollutant attenuation capacity
- Amendment material characteristics (density, gradation, organic matter, etc.)
- Desired depth of amendment
- Degree to which native soil will be mixed with amendment material

Step 5 – Specify construction procedures

Implementation of the soil amendment construction procedure needs to ensure the appropriate volume of amendment is used and that the mixing process results in a consistent, heterogeneous media across the entire site to the proper depth (typically 12 to 18 inches). The mixing process can be accomplished by either:

- blending the native and amendment materials in place with tilling equipment, or
- excavating the native soil, mixing with the amendment material, and reapplying the mixture to achieve the desired depth and gradation.

The specified construction procedure must also ensure that common complications are prevented, and may include the following.

- Avoid layering – creating two or more soil layers that can (1) create voids in the soil profile which would not fill with water unless under saturated conditions (short-circuiting), or (2) result in leaching of fine media materials between layers causing plugging.
- When leaching of nutrients could be harmful to a receiving water, take the compost source into consideration

Step 6 – Specify final inspection procedures

The soil amendment plan should specify post-soil amendment infiltration testing, which is critical to ensuring the amended soil performs as expected (that the new infiltration rates are not too high, too low, or uneven throughout the site). In addition to ensuring the amendment plan and implementation was successful, all infiltration areas that are part of the permanent stormwater management system must be tested for infiltration rates after they are completed in order to submit the NPDES Notice of Termination. It is HIGHLY RECOMMENDED that all infiltration areas are tested prior to project close out, even if an NPDES permit is not required. MnDOT projects require at least five tests per acre of infiltration area and a minimum of five tests per infiltration area. Infiltration rates shall meet or exceed double the design rate assumed. The test results from a MnDOT project must be submitted to MnDOT.

What rate should I use if I follow the procedure?

If the above procedure is followed, we recommend one of the following:

- Use an infiltration rate of 2 inches per hour

- Conduct field tests to determine the infiltration rate (https://stormwater.pca.state.mn.us/index.php?title=Determining_soil_infiltration_rates)

References

- US Army Corps of Engineers. EM 1110-2-2300. 2004. General Design and Construction Considerations for Rock-Fill Dams – Appendix B (http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-2300.pdf).
- US Army Corps of Engineers. EM 1110-2-1901. 1986. Seepage Analysis and Control for Dams – Appendix D (http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1901.pdf). 1986.