Guidance for Reviewing Stormwater Management Practices in Use III and IV Watersheds

Purpose

To establish environmental review criteria for use in evaluating proposed stormwater management treatment facilities that expands resource considerations to include thermal protections in conjunction with sediment and nutrient transport mitigation in Use III and IV watersheds.

Scope

For department use, with recommendations made to Maryland Department of the Environment, Maryland Department of Transportation, State Highway Administration, and other public and private organizations that are involved with the construction or review of stormwater treatment systems in Use III and IV watersheds.

Introduction

Expanding development in Maryland has increased impervious surfaces, creating a greater need for stormwater treatment best management practices (BMPs). The focus of stormwater BMPs have primarily targeted sediment and nutrient reductions, with an expected outcome of reducing sedimentation and eutrophication in downstream water bodies. While these BMPs may be effective in mitigating sediment and nutrient total maximum daily load (TMDL) concerns, other influences on the receiving waters create challenges for the ecological integrity of aquatic resources.

Of particular concern for natural resources management is the protection of the thermal regime of coldwater streams. Many aquatic species have strict thermal limits, where even slight increases to stream temperature can negatively impact reproduction, feeding, and basic biological processes. Protecting the thermal regime is critical to maintaining healthy populations of aquatic species and limiting thermal stress. Stormwater is an important influence on stream temperature. Stormwater that runs off of heated impervious surfaces into receiving waters, may increase temperatures beyond the maximum tolerance threshold for thermally sensitive species.

Stormwater BMPs act as an important layer of protection between impervious surface runoff and receiving waters. In cases where stormwater BMPs are used, stormwater is directed to the treatment system first, where flow rate is reduced, allowing sediments and associated nutrients to settle out before returning to receiving waters. Depending on the practice method, little to no protections to the thermal regime are afforded by sediment and nutrient TMDL BMPs. The standard method for treating sediment and nutrients, slowing flow rate, is contrary to practices needed to maintain or decrease water temperature prior to returning to receiving waters. In treatment methods such as wet ponds, the standing water may receive additional thermal energy from sunlight, further increasing the temperature of receiving waters (Jones and Hunt 2010).

In contrast to surface treatments, subsurface BMPs are more effective at temperature mitigation (UNHSC 2011). These methods of stormwater management function by allowing collected stormwater to infiltrate into the ground and be cooled through geothermal convective processes. Depending on the design, stormwater may pass through a filter system and ultimately recharge groundwater or pass through an underdrain. The runoff is removed from direct sunlight, preventing further heating from solar energy. Contact with subsurface substrate and groundwater may reduce the temperature of runoff through convective cooling. In general, a subsurface approach can yield effluent temperatures similar to groundwater temperatures.

While current methods of encouraging stormwater BMPs incentivize treatment for only sediment and nutrients (EPA 2010), new guidelines to prioritize thermal protection are in development. It has long been the practice of the department to discourage the use of surface stormwater BMPs in Use III watersheds and any watershed that supports thermally sensitive species. Project designers are encouraged to pursue BMPs that provide thermal protection in these watersheds. This document will categorize stormwater BMPs that are considered to be acceptable in Use III and IV watersheds, and any watershed that supports trout populations and/or coldwater benthic macroinvertebrates (i.e., obligates).

Stream Use Classifications and Protection of Aquatic Communities

Maryland has assigned classifications to determine the uses and water quality standards for all water bodies. The use classification establishes a management structure for water bodies by designating the activities and functions of the water body, such as fishing, swimming, and use as a public water supply. The classification determines what water quality standards are assigned to the water body to protect and maintain the designated uses. Water quality standards determine how a water body may be used, particularly with regards to watershed permitting and discharge. The stream use classifications are defined in COMAR (26.08.02.02) as:

- Use I: Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life.
- Use II: Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting.
- Use III: Nontidal Cold Water.
- Use IV: Recreational Trout Waters.

Of particular interest for thermal concerns and stormwater management practices are the Use III and IV classifications. These classifications are intended to protect coldwater aquatic resources, particularly those that support reproducing wild trout populations (Use III) or hatchery trout that are stocked for recreational fishing (Use IV). Both designations have maximum temperature standards to protect the thermal regime of the water bodies. In Use III streams, discharge may not increase the temperature of the surface water above 20ºC outside of the mixing zone. Use IV stream temperatures receiving discharge may not exceed 23.0ºC outside of the mixing zone. These higher levels of protection may be contrasted with a standard of 32ºC in Use I streams.

A series of criteria are used to determine the use classification of water bodies in the state. Use III is the more stringent designation, with several methods employed to determine classification status. Data that may be used to apply the Use III designation include temperature data (continuously logged with 90th percentile of temperature data values < 20ºC and the maximum temperature is < 23.8 ºC), presence of reproducing salmonids (presence of young-of-year and multiple year classes), and/or presence of coldwater obligate macroinvertebrate taxa (*Tallaperla maria* and *Sweltsa* spp.). Use IV water bodies must be able to support stocked trout for use as recreational fisheries.

The protection of salmonids in Maryland's streams is of critical importance for fisheries managers. This includes wild brook trout populations, wild and stocked brown trout populations, and wild and stocked rainbow trout populations. Salmonids play an important ecological role in coldwater streams, are a desirable target for anglers, and provide recreational and economic value. Salmonids are highly sensitive to stream temperatures and are extirpated at elevated water temperatures. Tolerance thresholds vary by species and by life history stage, but the critical temperature is 20ºC. Maintaining stream temperatures at or below this standard is essential for maintaining healthy, reproducing trout populations.

Protection of watersheds that support brook trout populations are of greatest concern. Brook trout are Maryland's only native trout species and occur in less than 5 percent of Maryland's streams. Approximately 60 percent of Maryland's historical brook trout populations have been extirpated. In addition, the department's most recent statewide survey (2014-2018) showed another 27 percent loss in brook trout occupied habitat, with a 50 percent loss occurring in the Central region alone (Sell and Heft 2019). The department has made the protection of brook trout a priority for natural resource management. Brook trout have been included in the Maryland Wildlife Diversity Conservation Plan as a species of Greatest Conservation Need. The Brook Trout Fisheries Management Plan (2006) states the goal of "restore and maintain healthy brook trout populations in Maryland's freshwater streams." In addition, protection of brook trout populations and habitat is included as part of the Chesapeake Bay Watershed Agreement. With all of this considered, stormwater management projects that could influence watersheds that support brook trout should make every effort to minimize potential negative impacts.

In addition to salmonids, diversity in aquatic communities are influenced by temperature fluctuations. Several stonefly taxa have been identified as coldwater obligates, including *Sweltsa* spp and *Tallaperla maria*. These taxa have similar temperature requirements to brook trout and are used as coldwater indicators, which is why their presence may be used for Use III designation (Becker et al. 2010). Additionally, there are benthic macroinvertebrates that are slightly less sensitive but prefer cooler temperatures (Becker et al. 2010). Increases to stream temperatures may result in changes to the benthic assemblage and may lead to loss of diversity of the benthic community.

Stormwater Management Guidance

Stormwater BMPs have been grouped into three categories to guide staff in providing comments on stormwater management treatment strategies in Use III and Use IV watersheds. The categories will define treatment strategies as approvable, discouraged but approvable based on design features, and inappropriate practices for Use III and IV watersheds. Category I will include treatment strategies that provide complete or near complete thermal mitigation and are not likely to increase the thermal regime of receiving waters. These treatment strategies will be considered approvable in Use III and IV watersheds and use will be encouraged. Category II includes strategies that do not fully mitigate thermal pollution and should be discouraged in Use III and IV watersheds. Category II treatment strategies may include some useful design features that provide partial thermal mitigation, but they are unlikely to provide enough protection to prevent impacts to the thermal regime of receiving waters. Category III treatment strategies provide no thermal protection and should be avoided in Use III and IV watersheds.

Category I: Approvable Stormwater Treatment Strategies

Category I treatment strategies are considered to be acceptable in Use III and IV watersheds. These treatments have features that have been determined to maximize thermal protection to achieve Use III and IV temperature criteria. These treatment strategies avoid surface pools, minimize sunlight exposure, use subsurface treatments, and frequently employ convective cooling to mitigate temperature pollution (Hunt et al. 2012; Jones and Hunt 2009; Jones and Hunt 2010; Long and Dymond 2013; UNHSC 2011). Examples include:

- Infiltration
- Constructed underdrain systems
- Bioretention systems
- Multicell approaches that use infiltration or underdrains
- Other innovative approaches that demonstrate sufficient thermal protection

Infiltration includes methods that capture and temporarily store stormwater and allow for absorption into soil (Figure 1). Stormwater is directed to the treatment system and is allowed to pass through a series of layers that may include topsoil, pea gravel, a larger stone aggregate, and a sand filter. The water eventually infiltrates through subsoils and may eventually recharge groundwater. As the stormwater filters through the system, sediments and pollutants are trapped. The subsurface storage and treatment reduces heating from surface exposure and brings runoff into contact with cooler subsurface materials.

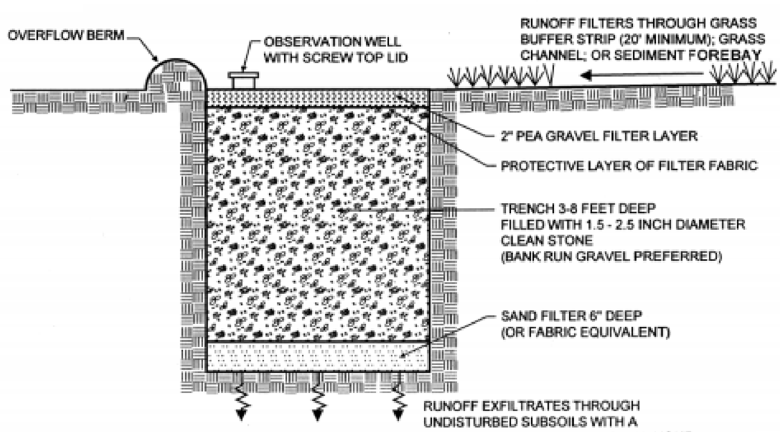

Figure 1. Profile of an infiltration system. Source: Maryland Stormwater Design Manual, MDE

Constructed underdrain systems include a variety of designs that use filtration treatment practices with an underdrain that allows runoff to exit the system. In most of these practices, stormwater runoff is directed to a pretreatment forebay before exiting into a treatment basin. The treatment basin usually acts as a filtration system and contains a substrate that is suitable for treatment. As runoff passes through the system, sediments and pollutants are removed. Runoff collects in the basin under the surface and may eventually be absorbed by soil or be conveyed to surface waters. Temperature is mitigated through subsurface storage in which little heat is gained from solar energy and convective cooling occurs through contact with subsurface materials.

A variety of substrates may be used to achieve both TMDL and thermal treatment. For example, subsurface gravel wetlands have been shown to remove sediments and other pollutants while providing thermal protection (Figure 2). These systems collect runoff in a forebay that removes sediment and other large-sized debris. The runoff exits the forebay and enters the treatment basin, where it percolates into a surface wetland soil layer. Biological treatments occur as pollutants are removed by wetland vegetation and microbial activity. The water collects in a subsurface gravel layer where pollutants and contaminants are further treated. This layer prevents thermal heating and cools through convective processes. An underdrain allows water to exit the system, where infiltration to soil or transport to receiving surface water occurs. Constructed underdrain systems may replace the gravel layer of subsurface gravel wetlands with other substrates, which may include sand filters, peat sand filters, or organic filters. In each case, water is contained in a subsurface treatment facility before exiting the system.

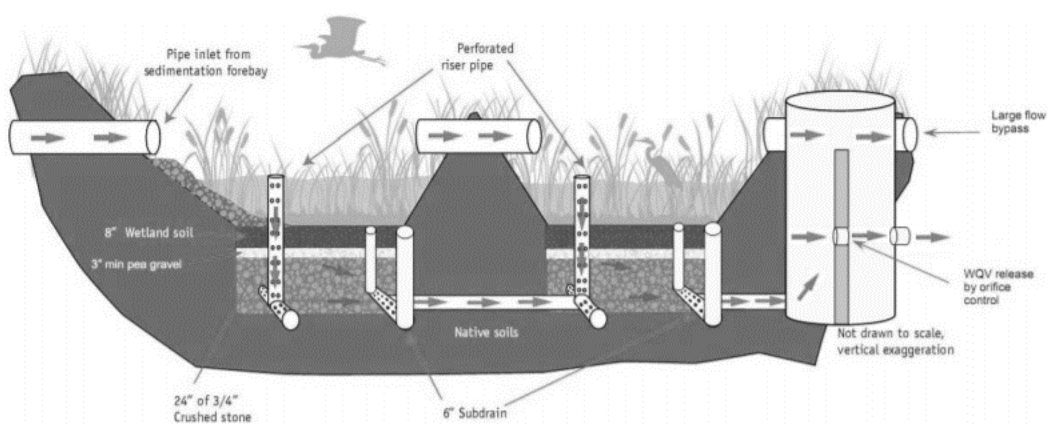

Figure 2. Illustration of a subsurface gravel wetland. Source: UNH Stormwater Center.

Constructed underdrain systems also include ***bioretention systems*** (Figure 3). Bioretention systems, frequently referred to as rain gardens, usually consist of a forebay that collects sediment and a filtration basin. The filtration basin contains a soil mix that can both support vegetation and allow passage of stormwater. Vegetation and microorganisms in the basin soil provide some treatment through biological processes, while physical processes in the soil media will further remove sediments and some pollutants through sorption. As treated stormwater reaches the bottom of the system, it may infiltrate the soil and recharge groundwater or exit through the underdrain to surface waters. Research in North Carolina has shown that bioretention systems are effective at reducing thermal impacts when they comprise 10 percent or more of their contributing watershed (Jones and Hunt 2009).

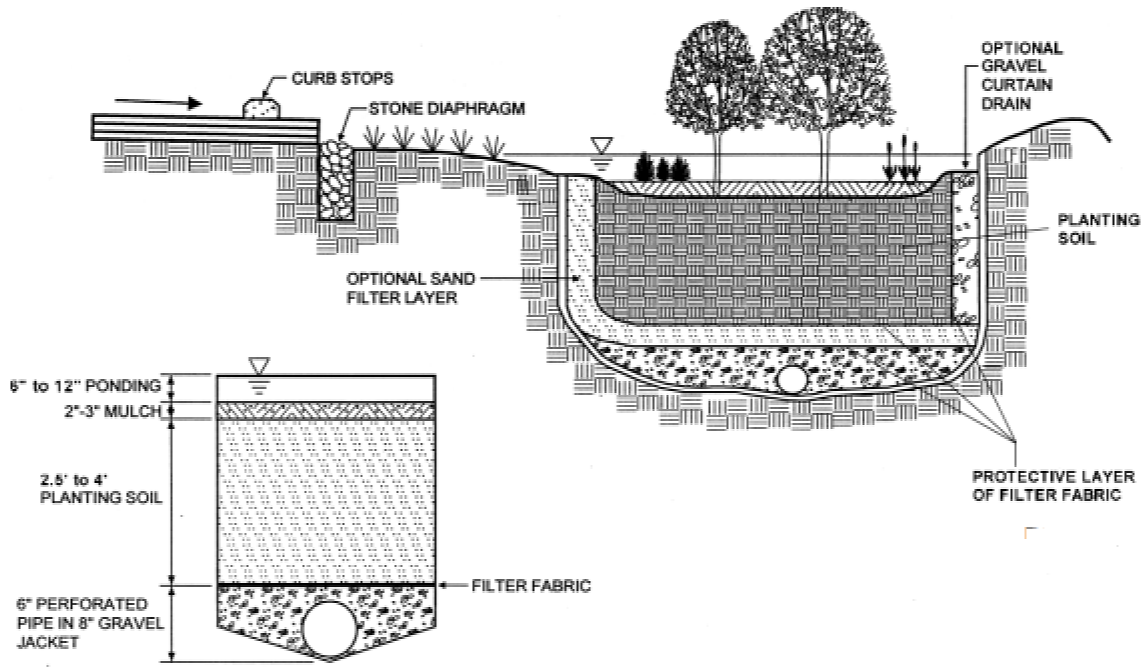

Figure 3. Illustration of the cross section of a bioretention system. Source: MDE Stormwater Manual.

Innovative approaches that demonstrate sufficient thermal protection - New and developing strategies for stormwater management should be considered on a case by case basis. Novel designs that address thermal pollution mitigation may be appropriate based on field conditions and receiving waters. While untested strategies should be avoided in Use III or IV watersheds, novel strategies that have demonstrated thermal mitigation may be considered if the risk to aquatic resources is minimal. As a body of evidence develops in support of effective temperature mitigation, more widespread application of the novel strategy may be approved. For example, Maryland Environmental Service is currently developing an underground sinuous system with the goal of achieving traditional TMDL mitigation while also addressing thermal concerns (Figure 4). This design attempts to minimize treatment cost and space resources. The system uses a sinuous trench that is approximately 1.2 meters in depth and 0.3 meters in width. The trench is filled with washed stone or gravel and creates a subsurface channel that acts to cool the heated surface water prior to re-entering the stream. Water may infiltrate into underlying soil or be discharged into receiving waters. While the sinuous design has a sizable footprint, the trenches can be constructed to avoid trees and other desirable landscape features. This trench system can be incorporated into new stormwater BMP designs or used to retrofit existing systems that don't fully mitigate thermal impacts. While use of this method in thermally sensitive watersheds is not appropriate, application in less sensitive watersheds may be considered with a temperature monitoring program. If the data collected during temperature monitoring activities suggests effective thermal mitigation, support for use in more sensitive watersheds may be considered.

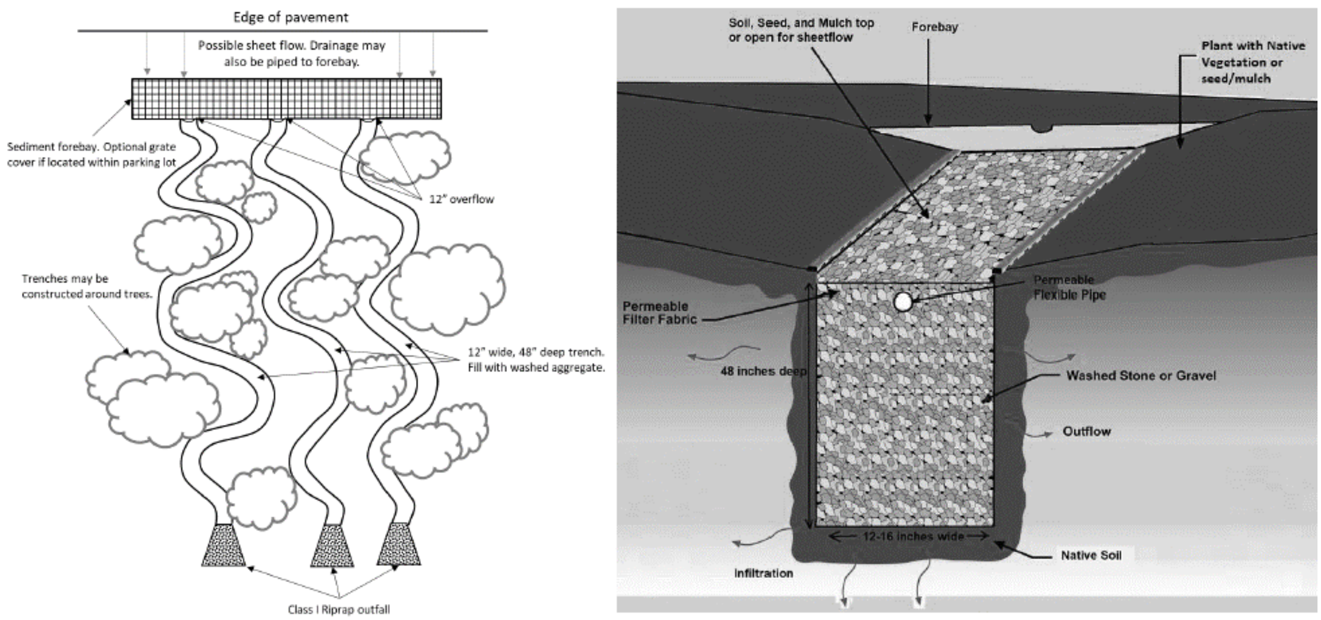

Figure 4. Illustration of a high capacity deep trench outfall. Source: Stauss presentation.

Experimental designs with hypothetically beneficial treatments are best used in Use I watersheds. As evidence is collected that supports efficacy in thermal mitigation, application in Use III or IV watersheds may be considered. Use in watersheds that support wild trout populations should be considered only after clear evidence of thermal protection has been demonstrated.

Category II: Stormwater Treatment Strategies that are not considered to be full thermal mitigation, but may have beneficial design features

Category II stormwater treatment strategies are treatments that should be avoided in Use III and IV watersheds. Wet ponds (retention ponds; Figure 5) and dry ponds (detention ponds), for example, generally provide little thermal treatment and may negatively influence cold and cool water streams. However, the design of these stormwater facilities may incorporate beneficial features that provide partial thermal mitigation. These features include but are not limited to:

- Mature shading around and downstream of an existing wet pond
- Deep wet ponds with a bottom release, such as reservoirs that undergo frequent maintenance to maintain depth and are monitored for temperature
- Wet ponds with limited volume and multicell approaches

- Permeable pavement

While beneficial design features may provide some thermal protection, it is important to note that full mitigation may not be achieved. Stormwater treatment with these design features should be considered on a case by case basis. Department support for approval of the design should only be granted in cases where there are clear indications that the thermal regime of receiving waters will not be impacted.

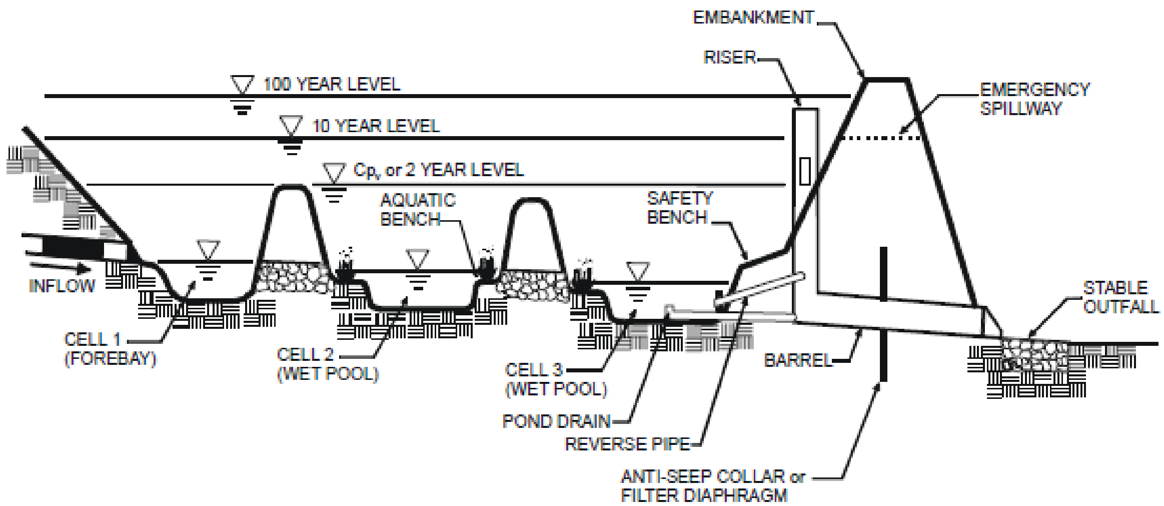

Figure 5. Illustration of a wet pond. This design expresses a multicell wet pond approach. Source: MDE Stormwater Manual.

Careful scrutiny of beneficial design features is needed to consider thermal impacts. For example, a robust ***riparian buffer*** that provides shade for the outfall and tailwater of a wet pond may limit heating and even allow for some cooling. Likewise, riparian planting around the pond may provide shading at the banks. However, riparian planting that provides shading may take 10 to 20 years to grow tall and thick enough to adequately provide shade. It is highly unlikely that full thermal mitigation will be achieved as much of the pond will remain exposed to direct sunlight. Further, it is unlikely that any heat loss will occur through convective processes.

Bottom release is an important strategy used to establish and maintain coldwater resources downstream of larger reservoirs. Water is drawn from the cool water layer at the bottom of the reservoir rather than the warm layer at the surface. While this is an effective method in systems with larger impoundments, there are limitations for wet ponds. Most wet ponds are smaller in size and shallow in depth. If the wet pond is deep enough to allow for a bottom release with sufficiently cooler water, available volume may be limited. There may not be enough cool water to draw from through the entire critical summer period.

A ***multicell*** approach may improve stormwater treatment facilities that otherwise provide little to no thermal mitigation. Multicell designs address stormwater management through a stormwater treatment train, in which stormwater passes through several compartments or facilities in series.

Each compartment may provide a unique treatment or may overlap treatment with other compartments. For example, stormwater runoff may be directed to a wet forebay or a small pond for containment. This compartment in the system will do little to address temperature, but sediments and large particulates will be treated. The stormwater may then flow through a sand filter. This second compartment will further treat sediments and pollutants and will also cool the temperature in the pond caused by solar heating. Finally, the runoff may then enter an underdrain, where it will be further treated for temperature before exiting the system.

The multicell approach allows for plug in design elements that can expand treatment. A small stormwater pond that provides no thermal treatment may have facilities constructed at the outfall that provides some thermal protection for receiving waters. When considering these methods, it is important to review the sequence of treatment compartments. Runoff that is treated for temperature before entering a ponded facility may provide little to no thermal mitigation. In this case, the thermally treated runoff may increase in temperature as a result of solar heating while in the ponded facility. In most cases, multicell approaches should treat temperature in the last cells before stormwater runoff exits the system. Further research is needed to determine the size of the last cell or thermal treatment in order to cool the water sufficiently prior to entering the coldwater system. Empirical testing should occur in an already compromised system or as a retrofit to an existing pond.

Permeable pavement (Figure 6) may be considered for space-limited locations but careful review is needed. Stormwater collecting on the surface of the pavement infiltrates through porous concrete or asphalt. A filter course under the permeable pavement removes sediments and pollutants as the water passes through the system. Once through, stormwater infiltrates the underlying soil to recharge groundwater or is directed by an underdrain to surface waters. While the subsurface treatment would make this method a viable option in Use III and IV watersheds, concerns for maintenance and upkeep suggest that use should be limited when considering thermal mitigation. Permeable pavement systems are easily obstructed and become ineffective if a blockage occurs. Cleaning and rehabilitating the system is difficult and is required frequently to maintain functionality.

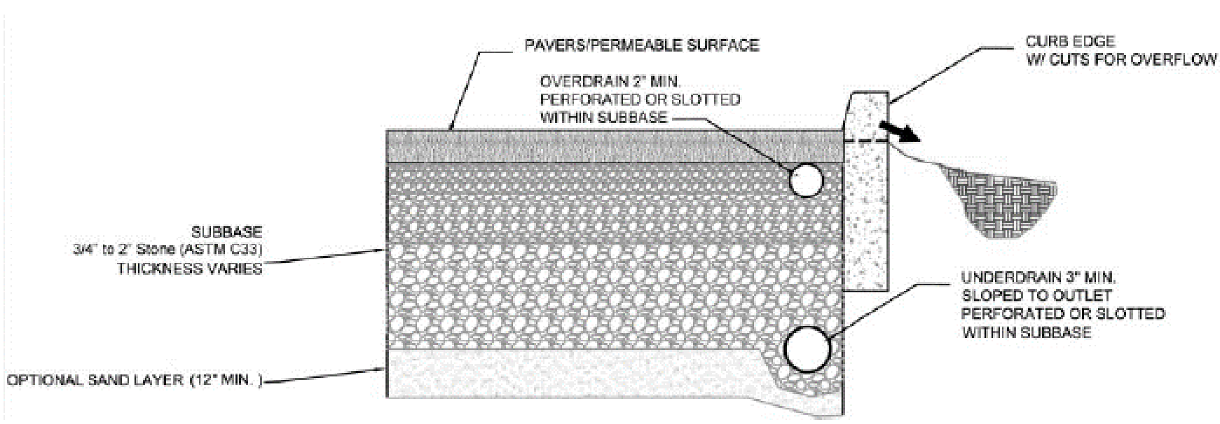

Figure 6. Cross section of a permeable pavement system. Source: MDE Stormwater Manual.

The efficacy of category II features in providing some thermal treatment for stormwater runoff will be heavily dependent on field conditions. It is unlikely that a single feature will be effective in protecting the thermal regime of a Use III or IV stream. However, several of the described features included in a stormwater treatment facility may be enough to limit thermal pollution. The resource, treatment design, and possible complications should all be considered when reviewing these options.

Category III: Stormwater treatment strategies that are not considered to provide any thermal protection on their own and should be avoided in Use III and IV watersheds

As previously stated, wet ponds with no thermal treatment should not be constructed in Use III and IV watersheds. Impacts to the thermal regime of receiving waters will negatively influence the aquatic assemblage. In addition to biological impacts, social and economic impacts may occur due to the loss of desirable sportfishing activities. Reducing angling opportunities limits the economic benefits gained when attracting anglers.

In addition to wet ponds, dry ponds also provide little to no thermal protection and should be avoided in Use III and IV watersheds. Dry ponds, also known as detention ponds, function with no permanent pool of water. The primary function of detention ponds is to slow stormwater runoff by allowing it to pool in the dry basin and empty into receiving waters over an extended time. Depending on the system, stormwater runoff may be discharged over a period of 6 to 48 hours. Because no permanent pool is maintained, stormwater treatment is limited for sediments and nutrients. Little to no thermal protection is achieved without the installation of additional stormwater management features (UNHSC 2011).

Similar to detention ponds, vegetated swales provide little to no thermal treatment for stormwater runoff (UNHSC 2011) and only limited treatment for sediments and nutrients. The primary function of vegetated swales is conveyance. Vegetated swales generally consist of a channel that collects water and manages runoff velocity. The channels are usually planted with grass for stabilization. Runoff is directed through the channel and may be slowed before discharge into receiving waters. The exposure of runoff to solar heat and the lack of any method of convective cooling minimizes thermal mitigation before discharge. As with the other surface based stormwater treatment designs, this design is undesirable for Use III and IV watersheds.

Despite similarities with subsurface treatments, underground stormwater storage facilities should be avoided in Use III and IV watersheds. This approach directs stormwater runoff to containment in a subsurface pipe or vault. The stormwater is detained until it exits the system through a restricted flow drain that delays discharge to surface waters. While the subsurface storage minimizes solar heating and contains stormwater in cooler subsurface temperatures, there are no convective processes to further mitigate temperature. The stormwater is slightly cooler when exiting the system, but mitigation does not meet the level needed to protect Use III and IV watersheds (Natarajan and Davis 2010).

Conclusion

Effectively treating thermal pollution is critical to protecting the thermal regime of Use III and Use IV watersheds. When reviewing projects in these watersheds, subsurface treatments should be recommended and encouraged. Treatments should minimize exposure to sunlight and include subsurface convective cooling features. Ideally, increased treatment time should be considered in design features for maximum thermal benefits before discharge to receiving waters.

Surface treatments should be avoided where possible. If unavoidable, additional measures to mitigate thermal impacts, such as mature shading or a treatment train that includes thermal treatment, should be included as part of the design. Stormwater treatment designers should be encouraged to use more than one method of thermal treatment to maximize thermal protection.

Literature Cited

Becker, A.J., S.A. Stranko, R.J. Klauda, A.P. Prochaska, J.D. Schuster, M.T. Kashiwagi, P.H. Graves. 2010. Maryland Biological Stream Survey's sentinel site network: a multi-purpose monitoring program. Maryland Department of Natural Resources, Resource Assessment Service. Annapolis, MD.

Hunt, W.H., A.P. Davis, and R.G. Traver. 2012. Meeting hydrologic and water quality goals through targeted bioretention design. Journal of Environmental Engineering 138: 698-707.

Jones, M., and W. F. Hunt. 2009. Effect of Bioretention on Runoff Temperature in Trout Sensitive Regions. Pages 1–7 World Environmental and Water Resources Congress 2009. American Society of Civil Engineers, Reston, VA.

Jones, M.P. and W.F. Hunt. 2010. Effect of storm-water wetlands and wet ponds on runoff temperature in trout sensitive waters. Journal of Irrigation and Drainage Engineering. 136(9): 656-661.

Long, D.L. and R.L. Dymond. 2013. Thermal pollution mitigation in cold water stream watersheds using bioretention. Journal of the American Water Resources Association 50(4): 977-987.

Maryland Department of the Environment (MDE). 2000. 2000 Maryland stormwater design manual volumes I and II. Maryland Department of the Environment, Water Management Administration, Baltimore, MD.

Natarajan, N. and A.P. Davis. 2010. Thermal reduction by an underground storm-water detention system. Journal of Environmental Engineering. 136: 520-526.

Sell, M. and A. A. Heft. 2019. Current Status and Trends of Brook Trout in Maryland: A 5-Year Assessment (2014-2018). Final Report F-48-R-27, Study III, Job 3. Maryland Department of Natural Resources, Fishing and Boating Services, Freshwater Fisheries Division. Annapolis, Maryland.

Stauss, M. Stormwater treatment alternative with underground sinuous system. Maryland Environmental Service.

U.S. Environmental Protection Agency (EPA). 2010. Chesapeake Bay total maximum daily load for nitrogen, phosphorus and sediment. U.S. Environmental Protection Agency Region 3, Philadelphia, PA.

The University of New Hampshire Stormwater Center (UNHSC). 2011. Examination of thermal impacts from stormwater best management practices. The University of New Hampshire Stormwater Center, Durham, NH.