Performance Enhancing Devices for Stormwater BMPs

Internal Water Storage

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Internal Water Storage (IWS)

1. Definition & Applications

Internal Water Storage (IWS) refers to a design alternative that allows water to pond, at least temporarily, within the underdrain and/or soil media layers of bioretention, dry swales, permeable pavement, or other stormwater practice. IWS is usually accomplished by modifying the underdrain configuration so that water ponds above the underdrain.

Research studies that tested IWS targeted enhanced removal of dissolved nitrogen (N), as traditional bioretention has a tendency to leach these forms of N. The dissolved N removal is due to the low-oxygen environment created by the IWS zone, which may lead to denitrification (Hirschman et al., 2017). However, the research also points to IWS as a mechanism to enhance runoff reduction, as the IWS promotes greater exfiltration out the sides and bottom of the practice. Exfiltration and infiltration can be enhanced by 10% to as much as 45% on an average annual basis compared to conventional designs (Winston, 2018). A recent analysis undertaken for the District Department of Energy and Environment indicated that most of the best performing bioretention practices from research studies included IWS, with enhanced runoff reduction serving as a chief pollutant removal mechanism (Hirschman et al., 2018).

IWS has also been recommended for retrofits where limited head is available to outlet the underdrain, such as a shallow catch basin. IWS allows the practice to achieve adequate depths of ponding and soil media, but with a shallower underdrain outlet.

IWS seems to enhance pollutant removal in soils that are somewhat limited for infiltration (clay loam, silt loam, etc.) (Brown & Hunt, 2011). In sandier soils, there may not enough residence time within the IWS for the same level of pollutant removal, but application in sandy soils will enhance runoff reduction.

It should be noted that several existing Chesapeake Bay state stormwater BMP specifications include an option for an enhanced (or Level 2) design using an elevated underdrain overlying a stone sump (D.C., Virginia, West Virginia). This is similar to IWS, but ponding with the sump design takes place below the underdrain versus above the underdrain with the IWS option (see difference between Figures IWS-1 through IWS-4 illustrating IWS versus Figure IWS-5 with the sump). While these design options appear very similar in terms of creating a temporary water storage zone, there are differences in how they function hydrologically and how incoming stormwater may be treated. The IWS option builds up head above the underdrain and may promote increased exfiltration. Also, the IWS design may treat more of the "new" incoming stormwater compared to the sump design.

Finally, some practices use impermeable liners due to high water table, karts, or other site conditions. These practices would not be candidates for IWS.

See Section 8 for a list of qualifying conditions in order for IWS to qualify for enhanced nutrient removal as a performance enhancing device (PED).

2. Creating the IWS Zone

As shown in Figure IWS-1, there are several options for creating IWS in a stormwater design. For purposes of maintenance access, it is advised to have the underdrain outlet in a storm structure (with manhole). The IWS can be achieved by:

1. Putting a weir wall in the storm structure, with the top elevation of the weir wall corresponding with the intended IWS elevation (see below). Note that the underdrain coming into the structure is at a 0% slope, which is a deviation from most current underdrain designs (Figure IWS-1).
2. In lieu of the weir wall, the underdrain outlet in the structure could be fitted with a simple L-fitting and non-perforated vertical extension of the underdrain (open at the top). As with the weir wall, the length of the extension corresponds to the intended IWS depth. This option is sometimes referred to as the "upturned elbow" (Figure IWS-2).
3. An additional option is to have the underdrain from the practice outlet at the invert of the manhole structure, but the pipe leaving the manhole structure set at the intended IWS elevation (Figure IWS-3).
4. For some practices, underdrain outlets may not go to a storm sewer structure. This may occur in less urban settings and/or where the underdrain "runs to daylight" at the ground surface. IWS can still be incorporated into this configuration by using the upturned elbow as the underdrain exits the practice or within the practice itself. For the purposes of marking the location of the upturned elbow for maintenance, it is advisable to put a vertical clean-out pipe with a cap at the location (Figure IWS-4).

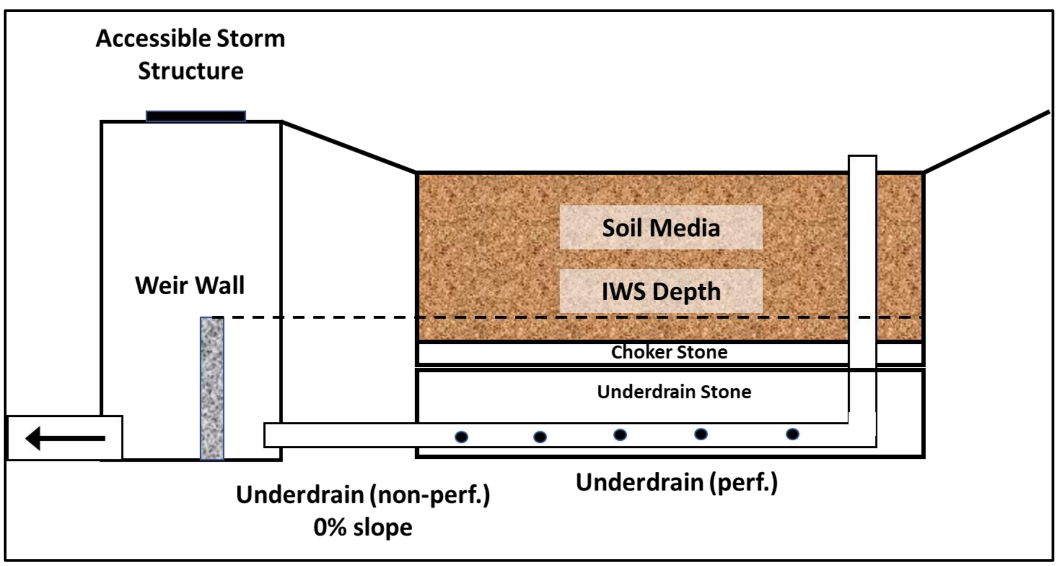

Figure IWS-1. Weir Wall in Storm Structure

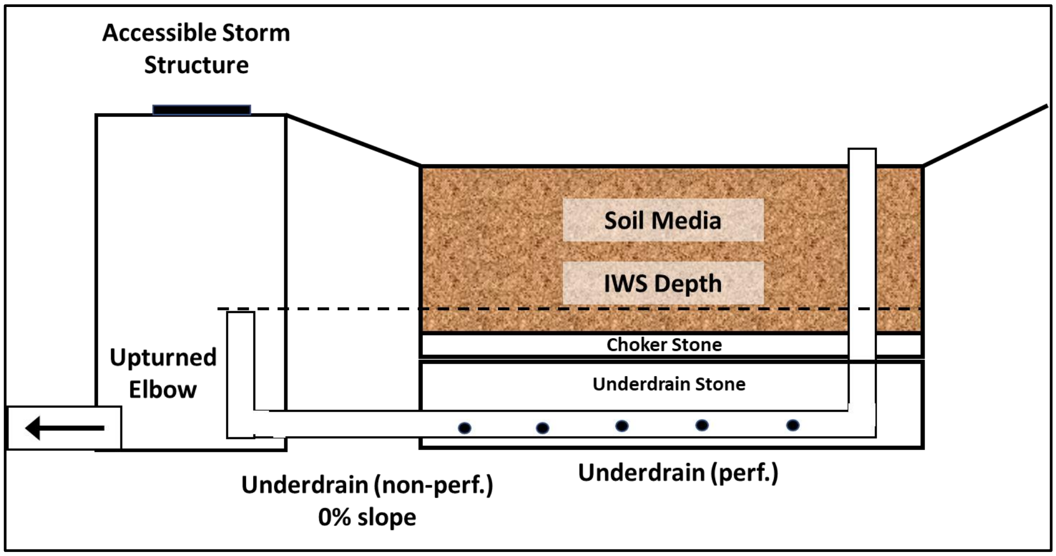

Figure IWS-2. Upturned Elbow in Storm Structure

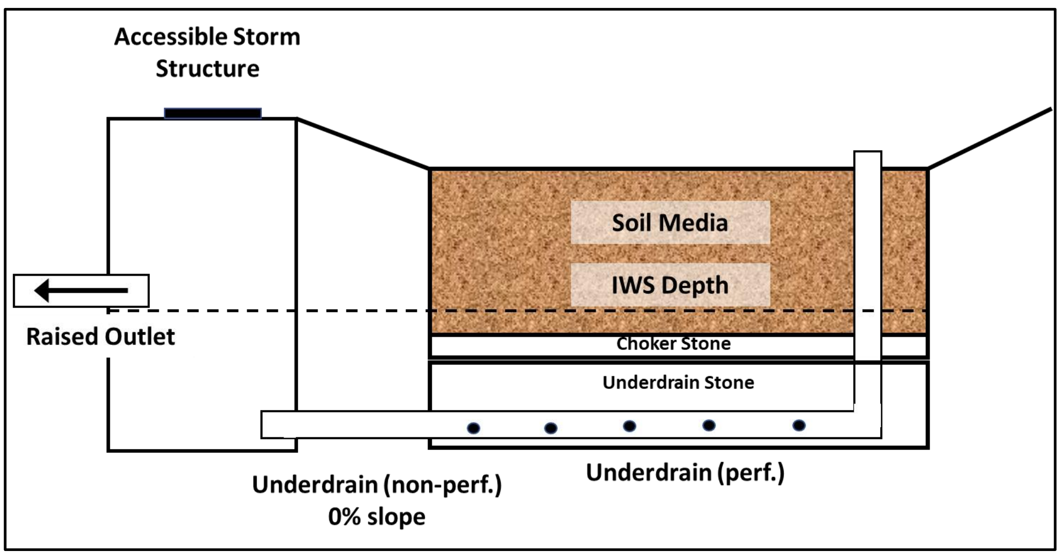

Figure IWS-3. Raised Outlet in Storm Structure

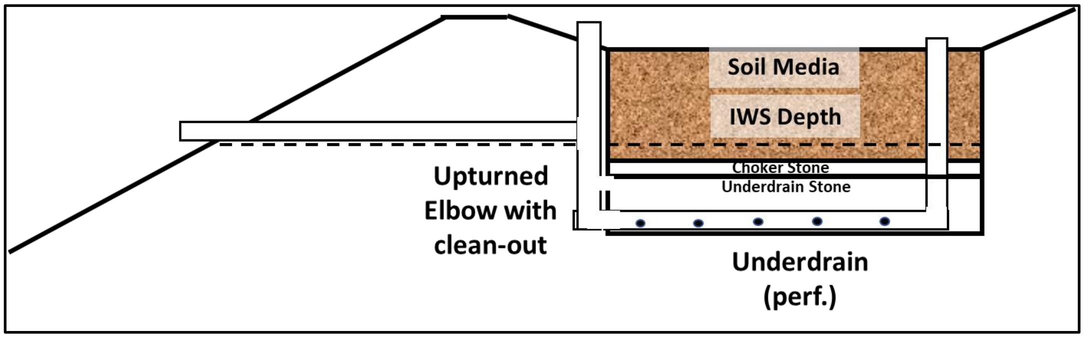

Figure IWS-4. Upturned Elbow in Underdrain that Runs to Daylight

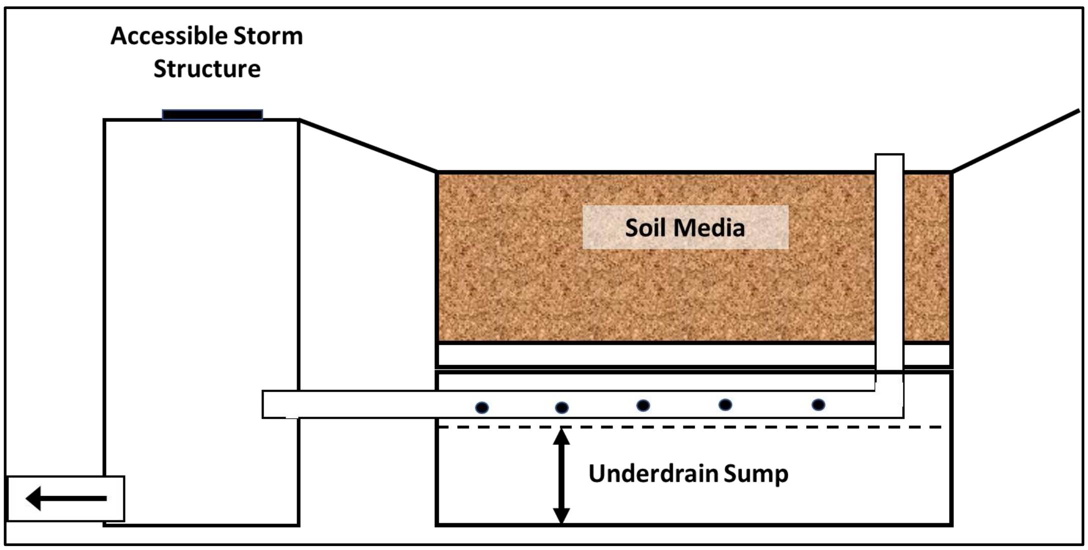

Figure IWS-5. Typical Configuration for Existing Enhanced/Level 2 Design With Underdrain Sump (this graphic is provided for comparison purposes, not as an additional IWS option; see description in "Definition & Applications" section)

3. Depth of IWS

Research does not indicate clearly the depth of the IWS zone. On one hand, if the IWS intercepts too much of the soil media layer, there is a risk that organic material or nutrients may leach out through the underdrain. On the other hand, for denitrification to take place, there must be a carbon source, suggesting that the IWS should intercept some of the soil media and not be confined to just the underdrain stone.

One recommendation that has been adopted in the updated North Carolina Stormwater Design Manual (NCDEQ, 2018; also Brown & Hunt, 2011) is to leave the top 18 inches of soil unsaturated to ensure proper plant growth and root development. That means that the IWS zone would start at least 18 inches below the top of the soil media layer. The resulting depth of IWS then depends on the total depth of the soil media and underdrain layers.

Soil media depths in the Bay states range from 18 to 36 inches, depending on the jurisdiction and whether practices qualify for Level 1 (standard) or Level 2 (enhanced) designs. Table IWS-1 provides recommendations for the depth of unsaturated soil above the IWS zone, and thus the total depth of IWS. These recommendations are intended to balance reducing the risk of nutrient leaching while providing enough carbon source for processing of N. IWS is not recommended for soil media depths at or around 18 inches, as there will not be adequate unsaturated soil media to allow the BMP to function.

For the deeper soil media depths (30 to 36 inches; enhanced or Level 2 designs), the table provides a range of values. The recommended depths depend on the type of vegetation (shallow versus deep-rooted) and the BMP's hydrologic and pollutant removal design objectives. In some cases, it will be important to optimize storage within the practice during a storm event, and IWS can temporarily take up some of this storage (suggesting a reduced IWS zone). On other hand, BMP objectives may tend more towards annual runoff reduction and pollutant removal, in which case expanding the IWS should be considered.

Table IWS-1. Recommended Depths of IWS Based on Depth of Soil Media

Soil Media Depth	Underdrain Layer Depth[1]	Unsaturated Soil Media Above IWS[2]	IWS Depth
18 inches	15 inches	N/A	N/A
24 inches	15 inches	18 inches	21 inches
30 inches	15 inches	18 to 24 inches	21 to 27 inches
36 inches	15 inches	24 to 30 inches	21 to 27 inches

[1] 15 inch underdrain layer assumed 12 inches of drainage stone topped with 3 inches of choker stone, which is a standard specification in the Bay states. If the underdrain layer deviates from this assumption, adjust the IWS depth accordingly. 15 inches can be considered the bare minimum for IWS depth, with some intersection of the soil media.

[2] In cases where there is a range, use the shallower unsaturated soil media layer (deeper IWS) for practices that use shallow-rooted vegetation and/or where annual runoff reduction and pollutant removal are primary design objectives. Use the deeper unsaturated soil media layer (shallower IWS) for practices that include some deeper-rooted vegetation and/or where maximizing capture during a fuller range of storm event depths and intensities is a more important design objective.

4. Filter Fabric/Geotextile

Over time, BMP designs have used less of these materials to function as separation barriers. Most Bay state specifications have substituted choker stone as a separation barrier between soil media and underdrain stone. Horizontal planes of filter fabric have been associated with blinding and clogging. It is still common to see filter fabric used along the sides of a BMP excavation, and some practices use a horizontal plane at the bottom of the excavation (not recommended).

Using IWS suggests eliminating the fabric along the sides of the excavation, as that is a main surface of exfiltration. Also, there is very little evidence of surrounding soils contaminating the engineered soil media, so the fabric may have limited utility in any case.

5. Construction Process

The construction process for IWS involves only minor modifications during underdrain installation. It may involve setting an additional storm structure with a weir wall or upturned elbow, as illustrated in Figures IWS-1 and IWS-2. Projects that use IWS should provide a record drawing showing as-built conditions and all relevant elevations.

6. Risks

Where Does the Water Go?

As with any practice that puts water into the ground, there may be concern with some of that water moving into basements, road fill, fill slopes, utility trenches, or other places where it is not desired. This is largely a matter of proper site selection and proper field location of wet and dry utilities and other features. With IWS, there will be more water moving through the sides of the practice, especially compared to a conventional underdrain design. Designers should ensure adequate soil mass and travel distance between the practice and any risk areas.

BMP Capacity During Storm Events

Table IWS-1 addresses this issue with regard to the recommended IWS depth. The research indicates that IWS will reduce runoff and associated pollutant loads on an average annual basis. For high intensity storm events, the storage occupied by the IWS zone means that there may be less storage available for incoming runoff versus a design where underdrain flow is activated during the storm event. The consequence is that there can earlier by-pass or flow directed through the overflow structure for certain individual storm events.

BMP design for water quality treatment has moved largely to average annual accounting, but some stormwater programs and/or specific locations may have more of a focus on individual storms (e.g., contain the 1-year or 2-year storm). In these cases, designers should evaluate the trade-offs in average annual and storm event hydrologic performance.

Mosquitos

The designs where the IWS depth is controlled within a storm structure is good for inspection and maintenance access, but, depending on how long water stays within the IWS zone between storms, may provide conditions for mosquito breeding This risk is probably more acute if the IWS draws down to just a few inches and that depth of water sits in the bottom of the structure, as that would be similar to existing storm structures that have a sump below the outlet pipe. This condition should be monitored during the summer months.

Combining IWS with Water Treatment Residuals (WTRs)

There has been some speculation about creating a "super BMP" by combining IWS with reactive media (see the profile sheet on Water Treatment Residuals -- WTRs). This is certainly a possibility. However, there is some risk that saturated soils will lead to increased leaching metals (Aluminum in the case of

WTRs). If this type of combination BMP is used, recommendations include: (1) incorporating WTRs into the soil media only above the IWS zone, or (2) using a treatment train approach, with practices in series using, alternately, IWS and WTRs in whatever order the designer may choose. The second option is preferred, as with #1, the WTRs can migrate down through the soil media to the IWS zone.

7. O&M Considerations

O&M considerations for IWS include the following:

- Monitor the typical time for the IWS to draw down. This will depend on the underlying and surrounding soils. In order to actualize the benefits of IWS, this should not happen too quickly (e.g., within 24 hours), but in most cases should occur prior to the next storm event (obviously, this would not apply for storm events that take place within several days of each other) or within 7 days.
- Monitor success of the vegetation. Vegetative health will depend on many factors aside from IWS. If roots become saturated, vegetation may show symptoms similar to drought conditions: wilting, leaf yellowing, and/or leaf drop. If this occurs, selectively check roots of different species to see if they are becoming saturated. If so, it may be a simple fix to lower the IWS level (e.g., cutting notch in the weir wall or cutting some length off of the upturned elbow). In many cases, IWS may promote plant growth due to providing more water availability between storm events.
- During routine inspections, check the integrity of underdrain clean-outs, upturned elbows, weir walls, and other components of the system.

8. Qualifying Conditions for WTR as a PED

The following conditions summarize the use of IWS to qualify for the PEDs pollutant removal credit:

- Use one of the IWS configurations shown in Section 2, with IWS depth as per guidance in Section 3.
- Eliminate filter fabric along sides of excavation (filter fabric should not be used on bottom of excavation as per most existing BMP specifications).
- Provide record drawing showing as-built IWS configuration and all associated elevations.
- Provide detailed O&M plan that addresses monitoring the drawdown rates of the IWS zone, health of vegetation to include possible signs of root saturation, possible nuisance conditions (e.g., mosquitoes), and structural integrity of underdrain components (see Section 7).

References

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