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SURFACE WITHDRAWAL AND POROUS BAFFLES: The One-Two Punch for Sediment Basin Success

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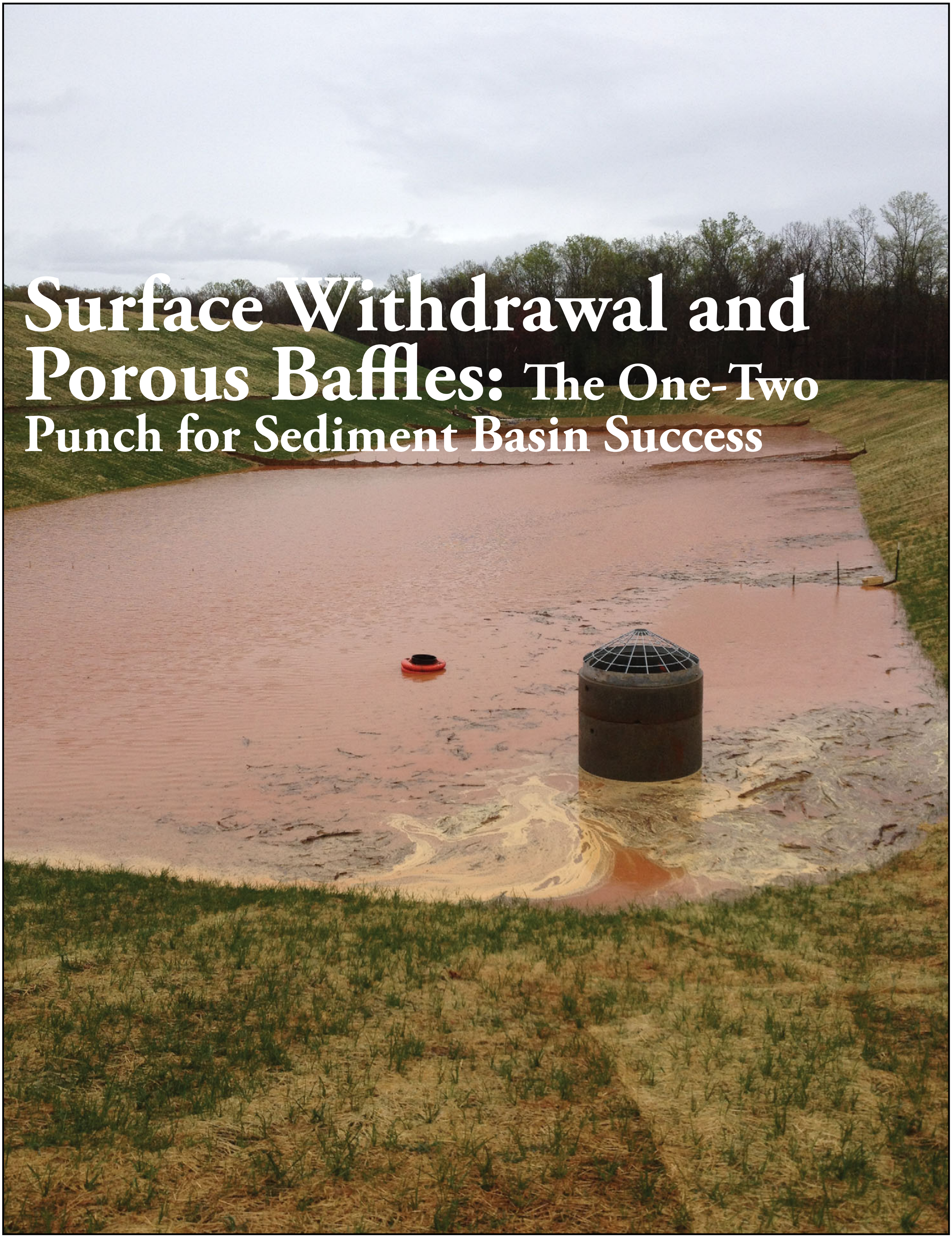
Geomembranes 101

Surface Withdrawal and Porous Baffles: The One-Two Punch for Sediment Basin Success



To improve the water quality in stormwater runoff, the South Carolina Department of Transportation (SCDOT) uses sediment basins for roadway construction projects, one of a number of best management practices (BMP) to control stormwater runoff. In the past, these sediment basins have traditionally featured a perforated riser with a low-flow orifice for dewatering, allowing the detained runoff to be discharged uniformly along the entire depth of the basin.

The 2009 EPA Construction and Development Effluent Guidelines and Standards, known as the "C&D" rule, however, prompted the South Carolina Department of Health and Environmental Control (SCDHEC) to create a SCDOT-specific Construction General Permit (CGP) that became effective in January of 2013. The SCDOT CGP established new requirements for the design of sediment basins that require the use of outlet structures that withdraw water from the surface, which eliminated the use of the traditional perforated risers. SCDOT established a design method that utilizes solid non-perforated concrete withdrawal risers with floating skimmers along with porous baffles.

Above: Porous baffles installed in upper state pond. Below: Floating skimmer installed in lower state pond.

Knocking Out Perforated Risers and Baffling Incoming Water

SCDHEC regulations require that SCDOT sediment basins must meet at least one of three of the following criteria for stormwater runoff for the 10-year 24-hour design storm event that drains to a single outlet from land-disturbing activities which disturb 10 acres or more:

The sediment basin shall be designed and constructed to accommodate the anticipated sediment loading from the land-disturbing activity and meet a removal efficiency of 80% suspended solids or 0.5 mL/L peak settable solids concentration or 252 m^3/disturbed hectare (3,600 ft^3/disturbed acre) of storage volume, excluding offsite flows, whichever is less.

Designers may show compliance with the 80% trapping requirement with the use of sediment modeling software. Though it is dependent on the erodible particle size distribution of a given soil, the 252 m^3/disturbed hectare design rule was typically thought to be the more conservative performance requirement, and it was common for engineers to reduce the required basin volume by designing the pond to meet the 80% trapping requirement.

While the SCDOT CGP requires the use of a surface withdrawal riser, new SCDOT design guidelines also require a floating skimmer that drains the basin below the top of the primary riser in 48 hours. For many small rainfall events, the water level never reaches the top of the primary riser and is drained through the skimmer alone, increasing detention time, reducing outflow rates and increasing trapping efficiency.

In addition to the floating skimmer, new SCDOT design guidelines require the use of porous baffles, which spread the flow of incoming water across the entire width of the sediment basin, reducing turbulence and dead space. This increases sediment deposition and retention by allowing smaller eroded particles to be captured.

With the addition of surface withdrawal and baffles, the SCDOT believed the overall storage volume of the basin could be smaller than 252 m^3/disturbed hectare (3,600 ft^3/disturbed acre) and still exceed the 80% trapping compliance, so SCDOT requested engineers at Woolpert investigate this option.

The Matchup: Traditional vs. New

Using the SEDIMOT II modeling software, a comprehensive modeling effort was completed to compare the trapping efficiencies of traditionally designed basins versus basins using the new surface withdrawal design for 10-year 24-hour design storm event. All modeling scenarios for both the traditional design and the new surface withdrawal design used identical watershed and basin inputs. The riser height was set at 4 feet for all model scenarios in order to provide shallow sediment basins with a large surface area to ensure surface withdrawal. The only inputs contrasting the traditional design from the new surface withdrawal design included the outflow withdrawal option, turbulence factor and pond dead space. These inputs were modified to effectively model the impacts that surface withdrawal, floating skimmers and porous baffles have on sediment basin trapping efficiency. Woolpert engineers set these input options in SEDIMOT II to conservatively match each design's withdrawal type, turbulence factor and dead space.

The initial modeling effort consisted of 1,215 model scenarios using various input parameters to consider construction projects throughout the state. Three different designs were used:

- Traditional perforated riser with 252 m^3/disturbed hectare storage volume
- Surface withdrawal without porous baffles
- Surface withdrawal with porous baffles

Model scenarios also incorporated multiple watershed sizes varying from 2 hectares (5 acres) to 10 hectares (25 acres) and the following runoff storage volumes per disturbed acre:

- 210 m^3/hectare (3,000 ft^3/acre)
- 168 m^3/hectare (2,400 ft^3/acre)
- 126 m^3/hectare (1,800 ft^3/acre)

SEDIMOT II Option Settings

	Withdrawal Type	Turbulence Factor	Dead Space
Traditional perforated riser	Uniform	1.0	30%
Surface withdrawal w/o porous baffles	Surface	1.0	30%
Surface withdrawal w/ porous baffles	Surface	0.5	10%

Because the upper and lower portions of the state have considerably different soil types, the scenarios included two separate soil classifications—upper state (Piedmont) and lower state (Sand Hill and Coastal Plain)—to match SCDOT project design requirements. And because size distributions of eroded sediment are the most important parameter in determining trapping efficiency (followed by surface area and outflow rates), the models included a varying range of representative erodible particle size distributions.

The Tale of the Tape

A quick glance at the average trapping efficiency from the three storage volumes for either of the two representative soil classifications shows that the combination of surface withdrawal and porous baffles is a clear winner.

Even for the smaller erodible particles of the upper state soils, the average trapping efficiency for the three different storage volumes exceeds the 80% requirement when using surface withdrawal and porous baffles.

For the larger eroded particles of the lower state soils, even the smallest of the three storage volumes (126 m^3/disturbed hectare) provided more than 90% trapping efficiency, regardless of the design. With the more difficult upper state soils, we start to see that surface withdrawal and porous baffles have a positive impact on the trapping efficiency as the storage volume changes.

Pound for Pound, the Winner Is…

Under-designed sediment basins are inefficient and clearly won't perform as needed, particularly during larger rain events. Likewise, over-designed basins waste unnecessary space, can be excessively expensive, and depending on the design, may not have a riser configuration that functions as true surface withdrawal.

SCDOT's modeling study shows that, with the new surface withdrawal and porous baffles design, in certain circumstances, designers can reduce the required runoff storage volume in sediment basins by up to 33% as compared to the traditional method, and still outperform traditional basins at the larger storage volume.

Based on the outcomes of this initial modeling effort, and an additional 850 model scenarios, SCDOT recommended the following for projects in the state in which the entire drainage area to the sediment basin is 100% disturbed:

- Upper state soil projects—three rows of porous baffles and a runoff storage volume of 168 m^3/hectare (2,400 ft^3/acre), a sediment storage volume of 29 m^3/hectare (415 ft^3/acre) resulting in a total basin volume of 197 m^3/hectare (2,815 ft^3/acre).
- Lower state soil projects—one row of porous baffles and a runoff storage volume of 39 m^3/hectare (550 ft^3/acre), a sediment storage volume of 31 m^3/hectare (450 ft^3/acre) resulting in a total basin volume of 70 m^3/hectare (1,000 ft^3/acre).

This modeling study may have implications outside of the state of South Carolina, as it shows that the surface withdrawal and porous baffles combination increases the trapping efficiency of sediment basins, for varying soil types and locations.

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Average Trapping Efficiency			
	Traditional Basin Design	Surface Withdrawal w/o Porous Baffles	Surface Withdrawal w/Porous Baffles
Upper state soils	72.5%	78.9%	82.7%
Lower state soils	92.3%	94.7%	95.8%
All soils	81.0%	85.7%	88.4%

Trapping Efficiency for Upper State Soils			
Runoff Storage Volume	Traditional Basin Design	Surface Withdrawal w/o Porous Baffles	Surface Withdrawal w/Porous Baffles
210 m^3/hectare	74.4%	80.8%	84.4%
168 m^3/hectare	72.6%	79.0%	82.7%
126 m^3/hectare	70.5%	76.9%	80.8%

Trapping Efficiency for Lower State Soils			
	Traditional Basin Design	Surface Withdrawal w/o Porous Baffles	Surface Withdrawal w/Porous Baffles
210 m^3/hectare	93.2%	95.4%	96.5%
168 m^3/hectare	92.5%	94.7%	95.9%
126 m^3/hectare	91.1%	93.9%	95.2%

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