

Overview of Continuous Monitoring and Adaptive Control for Enhancing or Converting Approved Stormwater BMP Types in the Chesapeake Bay Watershed

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There are now reliable, robust, and secure solutions for cost effective continuous monitoring and adaptive control (CMAC) of stormwater infrastructure. These solutions have an important role to play in accelerating the enhancement and conversion of existing stormwater facilities and construction of new facilities. CMAC solutions integrate information directly from field deployed sensors with real-time weather forecast data (i.e., NOAA forecasts) to directly monitor performance and make automated and predictive control decisions to actively manage stormwater storage and flows. The approach is non-proprietary, commercially deployed throughout the county for other stormwater management applications, and the outcomes have been verified by separate independent research efforts.

Specifically CMAC BMPs can improve environmental outcomes by:

- Using a facility's storage volume to detain flow across all storm sizes.
- Dramatically improving water quality from facilities by increasing residence time and/or improving unit process effectiveness (e.g., settling, denitrification).
- Restoring pre-development hydrology and base flows by actively modulating release rates based on forecast information.
- Increasing the volume retained on site.
- Intelligently detaining flows in combined sewer systems for release during dry weather.
- Reduce the frequency of flooding events.
- Enabling durable and adaptable designs that are less dependant on site specific conditions.
- Being adaptable to future climatic conditions or changes in site characteristics without new infrastructure and with only operation changes.

and reduce technical, regulatory, and compliance risk by:

- Providing auditable performance and supporting data without additional cost.
- Increasing uptime of facilities through alerting of operational or maintenance issues.
- Providing direct verification of facility performance.

State of the Practice and Technical Discussion:

Through empirical research, modeling, and widespread field deployments, CMAC solutions have been shown to result in significant increases in the performance of a range of existing stormwater BMPs while reducing operational and outcome risk.

Example Field Deployments and Existing Research:

- **EPA and the Water Environment Research Foundation (WERF)** published a report "*Transforming our Cities: High Performance Green Infrastructure*", which was a pilot level study at eight locations around the country (WERF, 2014). The study concluded that distributed real-time control of green infrastructure can: significantly reduce contributions to combined sewers and mitigate post-storm combined sewer overflows, reduce stormwater runoff, conserve water, with

particular benefits in drought-inclined areas, maximize reuse for irrigation. No other BMP can simultaneously accomplish these goals

- **Center for Research in Water Resources at the University of Texas at Austin and Geosyntec (2015)** showed that a passive dry pond conversion to a CMAC wet pond resulted in a facility that achieved a 73% reduction in Nitrate+Nitrite (Geosyntec, 2015) and a six fold reduction (from an average of 0.66 mg/L to 0.11 mg/L) in Nitrate+Nitrite over the pre-retrofit dry basin.
- **Muchalla et al. (2014)** found that retaining water using real-time rainfall-driven controls resulted in a 48 to 60% increase in removal of small particles from captured stormwater. “The removal efficiency for suspended solids could be significantly increased by all control strategies and the hydraulic peaks were reduced by at least 50%... [CMAC solutions] provide significantly higher removal efficiency for suspended solids and a possible flexible adaptation to future demands”. Increasing retention time without increasing storage volume, such as with a dry pond to wet pond retrofit, has been shown to increase total suspended solids removal from 39 to 90% and ammonia-nitrogen removal from 10 to 84% (Carpenter et al., 2014 and Gaborit et al., 2012).
- **An analysis of the performance of the addition of CMAC on the harvesting systems installed in at USEPA headquarters in Washington DC** greatly improved the system’s ability to mitigate stormwater volumes and flow rates and improve water quality. Total mass reductions estimated from this system during a one year monitoring period indicate removals based on residence time of 89% (TSS), 14% (TP) and 77% (TN), (Debusk, 2015).

Typical Applications in the Chesapeake Bay Watershed:

CMAC of stormwater storage can have a particularly positive impact on the water quality improvement performance of existing approved best management practice (BMP) approaches while also restoring predevelopment flows. CMAC provides a mechanism for achieving both the BMP Conversion and BMP Retrofit categories of retrofits recognized by the Chesapeake Bay Program Expert Panel to Define Removal Rates for Urban Stormwater Retrofit Projects (Scheuler et al., 2012) using existing approved retrofit approaches.

Stormwater BMPs with forecast-based adaptive control achieve better pollutant removal and runoff reduction outcomes because, among other benefits, they can increase the amount of time that stormwater remains in the treatment facility without compromising capture rate while also reducing the frequency of erosive flows. Further, the technology used to deploy the CMAC also collects performance continuously, allowing for accurate and precise quantification of a BMP’s actual (not theoretical) performance. Direct continuous monitoring of facility performance should be the gold-standard in the Chesapeake Bay Watershed for quantifying and verifying load reduction credits and verifying implementation plan results. This direct documentation is available using CMAC solutions with approved BMP types.

Considerations for Use of CMAC in the Chesapeake Bay Watershed

CMAC provides a reliable, cost effective means for continuous monitoring and adaptively controlling new and existing stormwater quality facilities. Given that CMAC can provide significant and auditable performance enhancements to approved BMP types, credit should be given for directly demonstrated outcomes. Specifically:

- In the current credit system, a wet pond only gets credit for its volume. However, with CMAC, the precise volume that meets treatment requirements is continuously measured. Therefore, credit can and should be given for the actual treated volume, increasing the credit derived from an existing BMP.

- CMAC is an enhancement to BMPs; therefore, no new BMP types are required to be approved by the expert panel.
- Annual reporting of CMAC integrated project performance should accompany annual compliance reports under implementation plans. These reports should be verified by a professional engineer in the state of record.

Conclusions

Over the past decade, significant advances in hardware, software, communications infrastructure (i.e., the internet) and scalable computing architectures (i.e., cloud computing) have made it cost-effective to deploy reliable, secure, highly intelligent continuous monitoring and adaptive control solutions to help address some of our most challenging water quality issues. We have a significant opportunity to leverage these new technologies alongside the significant existing work of the Working Group and Expert Panel reports to help protect and restore the Chesapeake Bay.

Examples and References

Retrofit Example 1: Dry Pond to Wet Pond Conversion

Forecast-based CMAC provides the most cost-effective method to convert a dry pond to a wet pond, adding quantifiable water quality improvement performance without substantially altering the footprint or structural design of the facility. The retrofit involves modification of the passive outlet structure with a fail-safe actuated valve and installing a level sensor in the pond storage area. In order to evaluate the long-term performance of these systems, continuous simulation modeling has been conducted using 50 years of hourly rainfall data from Baltimore Washington International Airport (OptiRTC, 2015). The model simulates the function of a storage unit sized to capture 1.5 inches of rainfall per impervious acre with an adaptive controlled outlet sized to drain from full in 48 hours, when fully open. The active control logic, designed to maximize retention time by closing the valve except when rainfall is predicted in the 48-hour forecast, achieves:

- 270-hour average retention time of discharged water (the existing dry pond achieves ~12 hours average retention time)
- 74 percent reduction in wet-weather flow volumes
- 70 percent asset volume utilization during wet-weather

These metrics were calculated without assuming any infiltration or evapotranspiration loss from the pond, which would further increase the performance of the system.

Retrofit Example 2: Enhancing the Performance of an Undersized Stormwater Asset

In a recent field study, adaptive control was added to a small legacy wet pond to mitigate post-development erosive flow impacts and improve water quality. The total storage volume equated to just 0.1 inches of rainfall per impervious acre. Analysis of one year of monitoring data resulted in a 25 percent reduction in the duration of channel-forming flows and that approximately 15 percent of total runoff volume was shifted from wet weather to dry weather period (equating to approximately 22 times the active storage volume of the pond). Furthermore, the adaptive control retrofit also inherently provides continuous monitoring data and real-time information on water quality performance indicated by retention time. For example, using readily available readings of water level and discharge rate, the facility reported that 31 percent of the total volume of water discharged from the pond during a 6-month wet-weather season had been retained for 24 hours or more. This type of reporting goes far beyond what is possible or practicable for passive, unmonitored BMPs where monitoring is an afterthought or additional (frequently costly) project. CMAC presents the possibility to bring stormwater permitting and crediting on par with point source discharges - basing compliance on real field collected performance data instead of design criteria and largely uncalibrated site level modeling.

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