Converting dry ponds to wet ponds without excavation

A dry pond in Prince George's County, Maryland, USA, was converted into a wet pond through the addition of continuous monitoring and adaptive control technology. **Jamie R. Lefkowitz** of OptiRTC, Inc. explains how this innovative retrofit achieved the necessary treatment volume at a cost significantly less than a traditional approach involving excavation.

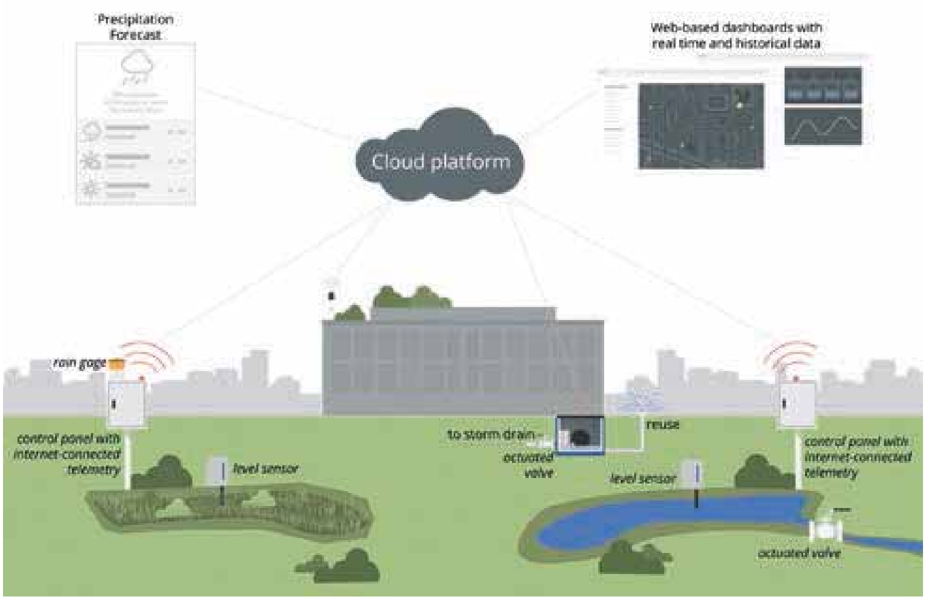
Nearly all traditional stormwater best management practices (BMPs) and green infrastructure systems have been developed as passive systems governed by a fixed control structure designed to achieve a target objective related to water quality, water volume, or both. With recent advances in inexpensive, internet-accessible controller systems and wired and wireless communications, real-time, dynamic controls of BMPs have become viable, cost-effective options for new construction as well as retrofits. By enabling real-time monitoring and control of BMPs via the internet, these technologies represent an especially useful innovation for urban areas, where space and budget constraints often preclude costly retrofits of older facilities to meet current permit requirements.

Stormwater ponds are designed to capture runoff and control flows to prevent damage to downstream waterways. A dry pond controls peak flows from larger storm events but does not hold water to improve water quality, and small events typically pass through unmitigated. By contrast, wet ponds maintain a permanent pool of water at all times, which is gradually replaced during all storm events. Wet ponds retain water in the permanent pool, slowing velocity so that pollutants can settle by gravity or degrade through aquatic biological processes. For this reason, regulated entities facing increasingly stringent water quality requirements may seek to convert existing dry ponds into wet ponds. However, the traditional method for converting a dry pond into a wet pond has involved excavation to create the permanent pool, and the high costs associated with this approach have tended to limit its feasibility. Fortunately, the use of adaptive controls can facilitate such conversions at a cost significantly less than traditional excavation.

The sprawling Chesapeake Bay watershed spans parts of six US states – Delaware, Maryland, New York, Pennsylvania, Virginia and West Virginia – and all of the District of Columbia. The Chesapeake Bay has long been the focus of efforts to reduce sediment and nutrient loads. Faced with strict mandates to reduce pollutant loadings to the Chesapeake Bay, municipalities in the bay's watershed have begun turning to the use of cost-effective real-time controls to convert dry ponds into wet ponds. The first retrofit to enable real-time control of a dry pond for nutrient reduction in the Chesapeake Bay watershed occurred in November 2015. Through the use of continuous monitoring and adaptive control (CMAC) technology, the project added approximately 2,467 cubic meters (m^3) of new water quality treatment volume at an existing dry pond in Prince George's County, Maryland. The facility, which accommodates runoff from a 24-hectare drainage area, now provides 48-hour residence time independent of storm size. Retrofitting the facility with CMAC technology cost far less than the traditional approach of excavating a dry pond to create a permanent pool.

The success of the first pilot project in Prince George's County has led to dry pond conversions throughout the Chesapeake Bay. Three additional retrofits of dry ponds using CMAC technology have been completed in Montgomery County, Maryland; Fairfax County, Virginia; and Lynchburg, Virginia. Twelve additional retrofits are currently in design. The Prince George's County pilot project highlights the potential for this innovative technology to facilitate significant, measurable improvements in BMP performance while greatly reducing the cost associated with such efforts.

Figure 1: Schematic of integrated stormwater controls



What is CMAC technology?

CMAC-based stormwater management systems require an integrated set of hardware and cloud-based software to function. On-site hardware includes an actuated valve, a water level sensor, and an Opti control panel with telemetry and a power source. The systems can operate on line power or batteries recharged by a small solar panel. Figure 1 depicts how these components function together at stormwater management facilities. These components can be installed as a retrofit or in new construction to enhance the functionality of a facility. CMAC technology can enhance many types of green and gray stormwater infrastructure, including bioretention cells, wet ponds, dry ponds, infiltration basins, green roofs, cisterns, rainwater harvesting, and site connection tanks.

Robust hardware components that can function in harsh environmental conditions are a necessity to ensure that service is rarely, if ever, interrupted. As such, solenoid, slide gate, and butterfly valves have shown high reliability for hydraulic control, along with pressure transducers and ultrasonic sensors to measure water levels. As for ensuring access to the cloud-based control system through an internet connection, cellular data connections typically provide the most robust option at distributed locations.

These hardware components communicate through a cellular modem connection at the Opti control panel with cloud-based control software. While the configuration of the logic on these systems can vary, they generally follow this logic sequence:

- Inspect the current 24-hr probability of precipitation and quantitative precipitation forecast from the US National Weather Service.
- Calculate the expected runoff volume into the facility based on watershed characteristics
- Prepare the facility for the incoming runoff by draining stored volume, as needed
- Capture the runoff by modulating the actuated valve to minimize the discharge to avoid overtopping the outlet structure
- Retain captured runoff for 24 to 48 hours after the storm event to improve water quality through settling, infiltration, and biological processes; gradually release water after the retention period
- Continue to inspect the forecast and release stored water early if additional rainfall is predicted.

The software monitors the state of the pond each minute, such that the system can adjust continually to changing forecasts and varying water levels. This process facilitates a robust feedback loop that enables the system to self-correct as the forecast or actual rainfall – and thus the water level in the facility – changes.

Secure automated control system

Another essential aspect of the CMAC system involves the integration of fail-safe features at points where data could be wrong or communication could be lost. The first concerns sensor trust; subroutines can be enabled to change alarms and logic if a sensor provides implausible data. The second addresses the loss of internet connection; local logic in the control panel is always configured to set the valve to a safe state if the system loses its cloud data connection. Finally, in the event of a power loss, the valve returns to a safe state using a battery backup or an auto-return valve.

Essential in all of these applications are data on which to base control decisions, and inherent in the cloud-based systems is access to these data. Data access often takes the form of a web-based dashboard that enables a user to view, explore, and download data. Additionally, these dashboards can facilitate remote, manual control of these systems. Presented on a web-dashboard, these data enable continuous performance monitoring. Additional environmental monitoring sensors, such as rain gages and water quality sensors, are not required for control but can be deployed to stream data for viewing and analysis on the common platform. This feature allows managers to monitor facility performance in real time.

Security is paramount for the complete vertical integration of these systems. Communication between hardware and the cloud-based platform uses hardware-driven, message-level encryption for robust security without consuming excessive amounts of power. The system grants permissions to access data on the web-based interface based on a user's role, enabling granular control and transparency regarding who can view the data and conduct operations remotely. Modern versions of industry-standard Transport Layer Security (TLS) ensure secure communications with the web browser. All of these measures result in a secure, robust automated control system capable of intelligently controlling distributed systems under challenging conditions.

Least-cost retrofit strategy

Using real-time stormwater control technology to convert dry ponds to wet ponds offers multiple benefits for relatively little cost. Dry ponds typically are designed to capture runoff from large storm events and protect against flooding, but they do not facilitate channel protection nor do they improve water quality. In fact, runoff from small and medium storms passes through such facilities quickly, resulting in short retention times and erosive downstream flows. The traditional method of retrofitting a dry pond into a wet pond involves excavating the pond to establish a permanent pool at a lower elevation than the existing outlet structure. The lower pool provides water quality treatment while the existing upper storage remains available for capturing storm runoff and protecting against floods.

Retrofitting a dry pond with CMAC technology costs much less than the traditional approach because it does not require excavation. A dry pond's outlet structure can be modified with an actuated control valve that, when connected to the system's cloud-based decision software, will draw down the pond in advance of a rain event and maintain a temporary pool in between storms.

Ongoing efforts to improve water quality within the Chesapeake Bay are prompting significant evaluations of methods to reduce nutrient and sediment loads in stormwater across the water body's vast watershed. Inexpensive approaches to improving the performance of existing stormwater management infrastructure will contribute greatly to the goal of boosting environmental conditions within the bay itself and its many tributaries. To this end, using CMAC technology to convert dry ponds to wet ponds offers a way forward for jurisdictions and owners of stormwater management infrastructure seeking a cost-effective solution to achieve tangible progress at a reasonable price.

CMAC benefits proven

Constructed in 1988, the 2467-m^3 dry pond in Prince George's County was retrofit with CMAC technology to provide water quality retention. The pond collects stormwater runoff from a 24-hectare residential development, which is approximately 30 percent impervious. The dry pond is located within the watershed of the Anacostia River, a tributary to the Chesapeake Bay and itself an impaired waterway. The project offers a case study in the benefits associated with using CMAC solutions and demonstrates the extent to which such technology can reduce the cost to

Table 1. Summary of dry pond retrofit by continuous monitoring and adaptive control (CMAC) technology.

Costs (US$)	Traditional Approach	CMAC Approach
Full Design	$60,000	$15,000
Construction, hardware, and installation	$300,000	$31,500
Annual maintenance	$5,000	$5,000
Annual CMAC services	–	$5,000
30-year present value benefits	$446,460	$219,420
Cost per impervious hectare treated	$58,065	$28,536
Water quality benefit	Yes	Yes
Channel protection	Yes	Yes
Low cost	No	Yes
Low impact	No	Yes
Adaptive design	No	Yes

Table 2. Enhanced performance associated with continuous monitoring and adaptive control (CMAC) technology.

	Jan. 12–Feb. 28, 2016 (no control)	March 23–May 12, 2016 (forecast-based CMAC control)
Total rainfall, mm	151	139
Total runoff, m^3	9,528 C=0.23	7,909 C=0.26
Total discharge, m^3	8,661 91% of runoff	5,585 71% of runoff
Total infiltration and evapo-transpiration, m^3	872 9% of runoff	2,309 29% of runoff
Average retention time, hr*	4.0	18.2

*Flow-weighted average retention time of all water discharged from the pond

Figure 2: Above photo shows the dry pond retrofit outlet and control hardware components in Prince George's County, Maryland. Photo by Opti

Figure 3: User interface and control dashboard used to view site data and manually control the valve at a dry pond retrofit in Prince George's County, Maryland

retrofit existing stormwater infrastructure.

Before the retrofit, the dry pond featured an outlet structure with a 305-millimeter (mm)-diameter low-flow orifice and 1.8-meter (m)-tall weir positioned below the water surface elevation associated with a 2-year storm. Discharge from the outlet structure flows into a 914-mm-diameter reinforced concrete pipe. As part of the retrofit, the outlet structure was modified with a weir wall having a 305-mm-diameter actuated valve to maintain the low-flow orifice capacity and raise the next passive overflow elevation from approximately 610 mm to 1219 mm. A water level sensor was installed upstream of the weir wall to provide continuous water level data. The actuated valve and water level sensor were wired to a solar-powered control panel that contains a cellular data connection to Opti cloud-based software.

Funding for the retrofit was provided by the National Fish and Wildlife Foundation and the Metropolitan Washington Council of Governments. The installation of the CMAC technology afforded 2467 m³ of new water quality treatment volume at the facility and enabled it to provide 48-hour residence time independent of storm size. By extending the retention time, the CMAC retrofit increases infiltration and evapotranspiration while providing a mechanism for increased settling and nutrient uptake.

The retrofit cost approximately US$46,500 to design and install ($16,500 for hardware, $5,000 for design, $10,000 for modeling, and $15,000 for installation). As a result, the project cost roughly $6,054 per impervious hectare. By comparison, a previous bid for a traditional retrofit by means of excavation of the same facility exceeded more than $300,000, not including design costs. Adding in typical design costs for an excavation project, this approach would have cost approximately $46,950 per impervious hectare.

In terms of capital expenditures, CMAC retrofits of dry ponds cost much less than traditional excavation-based retrofits. Although both approaches require similar annual maintenance, CMAC retrofits also require an annual software subscription service. However, when considering the 30-year lifecycle cost of both options, a CMAC retrofit can still save communities approximately 50 percent over the life of the asset.

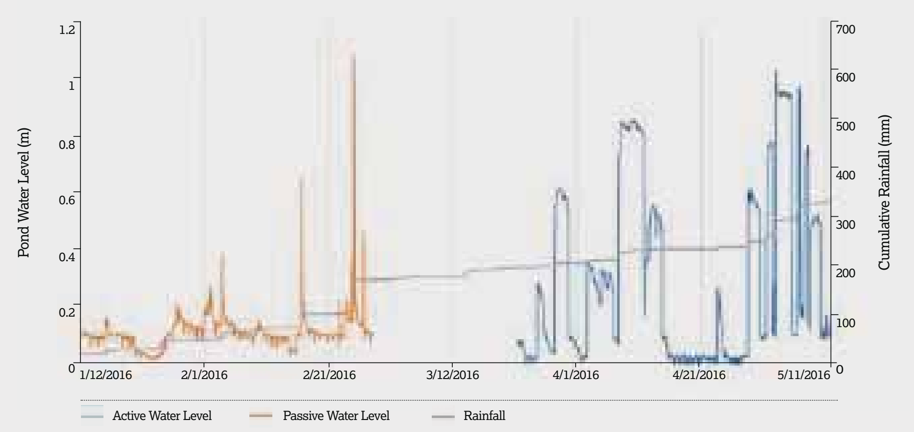
Assessing performance

The CMAC system continuously collects data regarding water levels, weather forecast, and rainfall from the site. A comparison of the retrofitted wet pond's performance during two different periods in early 2016 – one when the CMAC system was monitoring but not controlling releases, and one when the system was monitoring and controlling releases – illustrates the benefits associated with the technology.

This pilot project included an on-site rain gage to collect precipitation data. Approximately 152 mm of precipitation fell on the area served by the converted detention pond between January 12 and February 28, 2016, the period when the CMAC system was monitoring but not controlling releases. Approximately 140 mm of precipitation fell on the area served by the converted detention pond between March 23 and May 12, 2016, the period when the CMAC system was monitoring and controlling releases. Figure 4 shows a time series of water level in the pond, as recorded by the level sensor, during the comparative periods. The data clearly depict the effect of closing the valve during and immediately after wet weather events: The pond with adaptive control spends more time full, optimizing the available storage while still routing storms and avoiding weir overflows. The system performed significantly better during the period with adaptive control: Total discharge from the pond was reduced; total infiltration and evapotranspiration increased, and average retention time increased (see Table 2).

The site has been operating with adaptive control since March 2016. Since the completion of the retrofit, the flow-weighted average retention time of all water discharged through the actuated valve exceeds 30 hours. The NFWF-funded study into the pond's performance will be completed in Summer 2017, and will include the results of water quality grab sampling to compare runoff pollutant reduction rates.

Figure 4. Performance comparison of continuous monitoring and adaptive control (CMAC) technology



Conclusion

This active water management solution is particularly powerful in urban areas lacking the necessary space needed for more traditional stormwater management practices. CMAC technology also helps accommodate tight budgets that may not allow for more costly retrofit methods. Communities facing ever-increasing permit requirements must explore solutions that optimize the use of public funds. CMAC offers a regulator-approved approach to retrofitting dry ponds for much less cost per impervious hectare treated. The flexibility of intelligent, predictive controls is also evident in its adaptive management abilities. Managers of stormwater facilities can monitor, evaluate, and adjust parameters of the system logic to optimize performance over time, a cost-efficient solution in an industry that traditionally has relied on costly construction projects and design modifications.

Author's Note

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