Stormwater

THE CHALLENGE

Precipitation is a key part of the water cycle, filling our streams and lakes and soaking into the ground to replenish our aquifers. Most moderate rainfall is absorbed by soil, which acts as a natural filter. But, in heavy storms, excess moisture can run off over-saturated ground and impervious surfaces, and that runoff can be excessive. Without the benefit of natural filtration, stormwater flows directly to waterbodies, storm drains, and sewers, taking with it any debris, chemicals, bacteria, soil, and other pollutants it picks up along the way.

While new technologies and green infrastructure help reduce pollutant levels, many solutions are best equipped to handle frequent, low-intensity storms, rather than the sporadic, powerful storms experienced more recently. To compound the problem, population growth and rising water demand have increased dependence on local water sources, including groundwater recharge—raising more concern over potential contaminants.

THE RESEARCH

With more than 130 stormwater projects, WRF's research helps utilities and municipalities manage stormwater and green infrastructure to meet regulations, improve water quality, reduce flooding, enhance climate resilience, and diversify their water supply. WRF research focuses on the big picture—stormwater as part of an integrated approach to water management, helping to promote more adaptable, resilient water infrastructure and sources.

Working collaboratively, WRF conducts technical, economic, and social research that results in innovative technologies and optimized practices. Key partners include the U.S. Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), the Federal Highway Administration (FHWA), the American Public Works Association (APWA), and more.

Water Quality

Exploring the impact of runoff on water quality was among the first stormwater research WRF undertook. WRF research has led the way in identifying microorganisms in stormwater and accurately measuring their true risk. *Development of a Protocol for Risk Assessment of Microorganisms in Separate Stormwater Systems* (03SW2/1137) identifies the waterborne pathogens that pose the greatest risk to human health and measures their concentrations in stormwater. It also outlines a data collection program to assess risk exposure.

WRF has also been a pioneer in helping meet water quality standards, which are often impacted by stormwater. In the early 2000s, WRF published early guidance on developing total maximum daily loads (TMDLs), the required plans for restoring waterbodies to meet standards for various uses. *Navigating the TMDL Process* (00WSM1/1036, 00WSM2/1037, 01WSM1/1072, 02WSM2/1096), a four-volume series, lays the groundwork for a process that is practical, reasonable, and scientifically defensible. This was followed up by the 2010 release of *Drinking Water*

Source Protection Through Effective Use of TMDL Processes (4007), a guide that helps drinking water utilities understand and get involved in the TMDL process.

Management Practices

Beginning in the 1980s, WRF was among the first organizations to provide research on identifying, designing, and implementing best management practices (BMPs) to counteract the negative effects of runoff—and ultimately reduce the demand on wastewater treatment systems. WRF research looks at more effective practices and structural solutions and provides tools to calculate the true cost of projects so realistic numbers can be weighed against potential results.

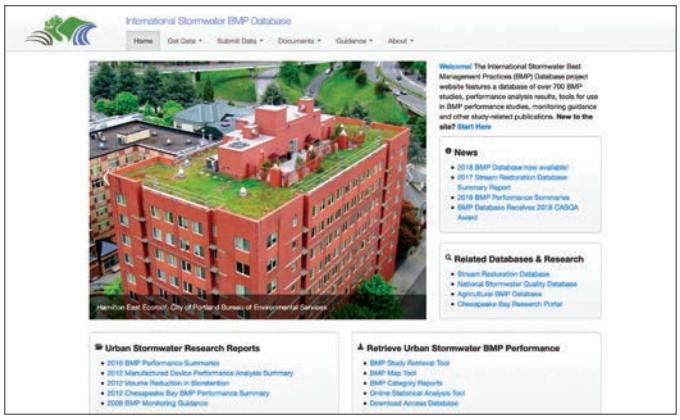
In 1996, WRF partnered with EPA and the American Society of Civil Engineers to launch the International Stormwater BMP Database. The open-access site houses the world's largest collection of field data on stormwater BMP performance, tools, and monitoring guidance—making it easy to see which practices would be the most effective at specific sites. Since then, the website has evolved, adding areas for topics such as agriculture and stormwater quality—and attracted other partners.

Despite efforts to keep runoff out of waterways, contaminant levels still drive some stormwater managers to look toward stream restoration as a new type of BMP. The BMP Database now has a module on stream restoration practice selection and design, water quality crediting, and performance evaluations. This is complimented by two guidance documents: *Stream Restoration as a BMP: Crediting Guidance* (5075) and *Crediting Water Quality Benefits from Stream Restoration* (4844). The two reports present a framework for measuring benefits of various restoration practices, highlighting those suitable for water quality crediting, and helping practitioners apply crediting guidance to implement stream restoration.

International Stormwater BMP Database: 2020 Summary Statistics (4968) includes new performance studies and analysis categories for manufactured treatment devices used in stormwater management. Data summaries include basic statistics for BMP influent and effluent concentrations, graphical summaries, and hypothesis test results for assessing whether the BMP had an effect on influent concentrations for various pollutant-BMP combinations. This new data will continue to support decision making for integrated stormwater management.

Green Infrastructure

More communities are turning toward natural processes to clean and filter runoff—moving beyond traditional



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infrastructure and incorporating green solutions. The benefits of green infrastructure go beyond just meeting stormwater goals, offering community perks like ponds, parks, and rain gardens. WRF research provides science to improve practices, lower costs, and boost environmental and social benefits by using rainwater to cultivate livable communities.

Often, the first and most complex step in starting a green infrastructure project is calculating the full cost. Through a $1.95M grant from EPA, WRF led a multidisciplinary team to develop a decision support system (DSS) entitled Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs (CLASIC), which was released in April 2021. CLASIC is listed as one of the tools in the EPA's Green Infrastructure Modeling Toolkit. The CLASIC DSS allows users to build and compare multiple stormwater infrastructure options and enables simulation of various climate scenarios. Case studies included in the tool showcase diverse communities from various climate regions in the United States. Varying climate scenario simulations are shown, representing the variety of hydrologic, performance, cost, and co-benefit comparisons that the CLASIC tool can provide to help communities make informed decisions about future stormwater projects.

Because lack of funding and aging infrastructure continue to be a challenge for many stormwater programs, WRF is expanding efforts to measure costs and manage green assets. *Framework and Tools for Quantifying Green*

Infrastructure Co-Benefits and Linking with Triple Bottom Line Analysis (SIWM4T17/4852) helped quantify the benefits of implementing green infrastructure and evaluated the economic, environmental, and social values. This effort supplements other available tools, such as the CLASIC tool and BMP Database, to support a more integrated stormwater management approach.

Urban trees are important components of green infrastructure networks; however, little is known about their ability to regulate runoff quantity and quality. *Incorporating Forestry into Stormwater Management Programs: State of the Science and Business Model Evaluation for Nutrient Reduction and Volume Control* (SIWM12C15/4837) documents the contribution of urban tree systems to stormwater nutrient and volume control in terms of their effectiveness at various scales, cost, desirability, and practicality. The research is a resource for water utilities and the stormwater regulatory, planning, and design communities as they integrate urban tree and forest systems within stormwater regulatory and management frameworks.

Water Supply Diversity

As the demand for water continues to rise, many drinking water facilities are exploring alternative water sources, and WRF research is helping to carve out stormwater's role. Until now, large-scale direct potable reuse of stormwater has been largely non-existent in the United States. WRF is providing the science to change that through projects like *Alternative Water Source Requirements for Conventional Drinking Water Treatment* (4665), which found that stormwater blended with surface water can potentially be treated with conventional drinking water processes with additional disinfection.

In conjunction with this study, WRF released A·SWAT, the Alternative Source Water Assessment Tool, a program that allows users to look at potential water sources and estimate the quality of water that can be produced through treatment. It then ranks the suitability of those sources for drinking. The tool also offers strategies to improve water that falls short of being ready for conventional treatment.

SOLUTIONS IN THE FIELD: Urban Drainage and Flood Control District

The Urban Drainage and Flood Control District (UDFCD) in Denver has a long history of working with metropolitan areas to prevent flooding and the adverse effects. Since 1969, UDFCD has published the *Urban Storm Drainage Criteria Manual*, a handbook that provides guidance to minimize the impacts of runoff. The manual, now a three-volume series, is regarded as the industry-standard reference for BMP selection, and is revised regularly to keep up with the latest advances.

When it came time for the most recent revision, UDFCD turned to the International Stormwater BMP Database, tapping into the extensive data to support its storm drainage criteria recommendations, compare local BMP performance with national data, and estimate achievable effluent concentrations.

This sparked UDFCD's involvement in a follow-up effort—a cost-tracking protocol and companion report, *Recommended Operation and Maintenance Activity and Cost Reporting Parameters for Stormwater Best Management Practices Database* (SIWM22T17/4851), which are helping to create a better picture of the full cost of operating and maintaining BMPs. UDFCD provided co-funding and peer review, assisting in the development of industry-wide protocols for tracking stormwater BMPs costs and standard maintenance requirements. This information is being incorporated into the BMP Database to create a common ground for budget estimation and maintenance planning.

Because getting started is often the hardest part of integrating stormwater into a balanced water supply portfolio, WRF research is making it easier for utilities to take the first step. A tool that stemmed from the project *Drivers, Hindrances, Planning, and Benefits Quantification: Economic Pathways and Partners for Water Reuse and Stormwater Harvesting* (SIWM8R14/1748), helps utilities weigh the benefits from reuse, like stormwater, and provides resources to jump start projects.

Climate Change and Extreme Weather

As wet weather becomes more severe and flooding more widespread, WRF is helping facilities successfully adapt and protect infrastructure and services. In 2013, WRF teamed up with EPA and NOAA on *Water/Wastewater Utilities and Extreme Climate and Weather Events* (1338-1344). This effort consolidated experiences from watersheds and river basins across the United States and looked at how the water sector, including stormwater utilities, made decisions in response to extreme weather. The report highlights successful, and often concurrent, strategies—underscoring the need for long-term preparedness and emergency response planning that considers multiple risks.

More recently, WRF and several partners convened a workshop to discuss the challenges of climate-resilient planning for urban stormwater and wastewater utilities. The group, including leaders from 15 major metropolitan water utilities, aimed to enhance understanding of current practices, lessons learned, and new ideas for developing actionable rainfall projections and incorporating climate-informed stormwater flows into planning processes. *Climate-Resilient Planning for Urban Stormwater and Wastewater Utilities: Workshop Proceedings* (5001) outlines the findings of the workshop, which centered on the key themes of regulatory and policy requirements, climate scenarios, and modeling and analyses needed to improve and integrate urban stormwater, wastewater, water quality, and flood mitigation planning.

WHAT'S NEXT

As the world faces challenges associated with climate change and water quality standards, the importance of green stormwater infrastructure (GSI) is expanding. Quantifying and monetizing triple-bottom-line benefits from GSI will help utilities and municipalities evaluate future stormwater investments. *Advancing Benefits and Co-Benefits Quantification and Monetization for Green Stormwater Infrastructure: An Interactive Guidebook for Utilities and Municipalities* (5105) is developing comparison case studies for quantifying the benefits and co-benefits of GSI at a national scale, and will identify and prioritize research needs according to GSI benefit and co-benefit categories.

Another ongoing project, *Assessing the Microbial Risks and Impacts from Stormwater Capture and Use to Establish Appropriate Best Management Practices* (5034), will synthesize existing research on stormwater microbial quality and treatment processes to develop a Stormwater Use Roadmap providing pragmatic guidance for design and operation of stormwater use systems by utilities and municipalities.

WRF also has a suite of projects looking at wet weather and flood management. *Exploring Cost-Benefit Analysis of Post Long-Term Control Plan Approaches to Wet Weather Management* (4849) will provide a comprehensive evaluation of experiences, best practices, and costs for combined sewer overflows (CSOs) and wet weather management. Relating to flood management, *Enhancement of Resilience to Extreme Weather and Climate Events: Proactive Flood Management* (4842) will develop an easy-to-use pocket guide focused on proactive risk assessment and flood management. Furthermore, *Holistic and Innovative Approaches for Flood Mitigation Planning and Modeling under Extreme Wet Weather Events and Climate Impacts* (5084) will deliver holistic management approaches to plan for and mitigate climate change impacts, including the use of advanced techniques like artificial intelligence and machine learning. Utilities of all sizes will be able to apply the project results to incorporate climate variability and uncertainty into their holistic flood management approaches.

More guidance is needed on how to integrate capital planning with climate models to ensure new stormwater projects are resilient long into the future. *Integrating Climate Change Impacts with Wet Weather Management, Capital Improvement, and Stream Network Enhancement* (5176) aims to enhance precipitation projection and modeling techniques with risk-based criteria to mitigate risks for utilities (e.g., sewer overflows, flooding, stream network deterioration). It will develop best practices for climate change rainfall statistics and projections by region, improving the adaptability of water infrastructure systems and enhancing the protection of stream networks to meet water quantity and quality requirements under a changing climate.