Resilient Design Principles for Stormwater Management

It is recommended that a Chesapeake Bay-wide effort be undertaken to closely evaluate and update stormwater design criteria and floodplain management regulations in the context of projected climate impacts and leading best management practice (BMP) vulnerabilities. This fact sheet will address **six principles of resilient stormwater infrastructure** that provide the potential not only for climate change impact mitigation, but BMP performance improvement.

To provide context for these principles and their importance in stormwater design, here are the latest climate change projections from the Chesapeake Bay Program Partnership:

SUMMARY OF CHESAPEAKE BAY WATERSHED CLIMATE PROJECTIONS:

PRECIPITATION

- More intense downpours and longer dry periods between rain events
- Intensity to increase by 5-35% by 2050
- Volume of annual rainfall to increase in the watershed by approximately 6.5% by 2055
- The 20-year, 24-hour precipitation event could become the 10-year, 24-hour event by 2100

TEMPS/STREAMS/SEA LEVELS

- Approx. 2 feet of sea level rise across the Mid-Atlantic by 2100
- Annual streamflow to increase by 4.5% by 2055
- Temperatures across the watershed to increase by 3.7°F by 2050
- Blue-sky flooding to exceed 30 days per year in over 20 cities in the Northeast by 2050

Stormwater Design and Policy:

Stormwater design criteria should reflect any significant changes in precipitation volume and intensity so that can restoration and public safety functions can be adequately addressed under future climate conditions. The most commonly used dataset of historic precipitation data, Atlas 14, has a period of record that is already twenty years old, while multiple studies suggest that stormwater design based on historic precipitation analysis are likely to underestimate future precipitation. Looking forward, there will be a need for new principles when evaluating infrastructure.

State design standards:

- Most manuals are 5-10 years old
- Standards vary across states and state agencies (ex. transportation/environmental/floodplain)
- Most designers rely on NOAA's Atlas 14, though some still reference older precipitation data sources.

Floodplain management:

- Floodplain boundaries are constantly shifting due to human development and changes in climate.
- Flood maps that show a community's flood zone and floodplain boundaries are not updated uniformly across the watershed.

The following principles are proposed to guide the recommended development of next generation stormwater design standards and specifications.

PRINCIPLES OF RESILIENT STORMWATER DESIGN:

Comprehensive Watershed Management:

In design, it is important to consider the impact to nearby and downstream BMPs. Context must be taken into consideration, including **watershed size, geology, land uses, and impairments**. Working collaboratively across agencies is also a necessity.

Case Study: In 2018, the New York State Department of Transportation revised their highway design manual to account for future projected peak flow in culvert design. Peak flows in some regions of the state (including those falling within the Chesapeake Bay Watershed) were increased by 20%.

Full Cycle Implementation:

Establish specific performance and maintenance targets for new implementation, including an **anticipated design life, removal efficiencies for pollutants of concern, relevant maintenance indicators, and adaptive management for vegetation**. Targets would ideally be tied to assessment timelines and triggers for management actions including repairs or updates.

MAINTENANCE IS KEY!

- Many issues and vulnerabilities can be solved by routine maintenance
- Build maintenance targets & specific performance objectives into design manuals

Sizing:

Design using sizing criteria that provides an acceptable **level of risk under future climate conditions.** There are multiple approaches to resilient sizing criteria, that may include the use of projected IDF curves, adding a "factor of safety" to historic precipitation data, or establishing over-management criterion for quantity and rate control.

Projected IDF curves

Keep the same design criteria, but update the underlying precipitation data used to arrive at the designated storm events

Factor of safety

Rather than use projected IDF curves directly, conduct future precipitation analysis and then add a 20% factor of safety to existing design criteria

Over-management

Rather than trying to predict the future100-yr storm intensity, set criterion that developers release 150-yr post development storm at the 100-yr pre development level

Flow-plains:

Design the conveyance and treatment system to have **capacity for safe overflow** when there is failure. This “**flow-plain**”, similar to a floodplain for a stream or river, is an adaptation of the cloudburst approach to extreme storm event management. When overflow exceeds the capacity of the system, **direct the stormwater to an area that is less vulnerable to flood damage**. For example, directing excess flow to a buffer, forest or designated ballfield to avoid impacts on housing or transportation infrastructure.

Redundancies:

Design with redundancies– both within the practice and across the site and conveyance system. On a site scale, “**treatment trains**” route runoff through a series of BMPs in succession, increasing the opportunity for capture, infiltration, and pollutant removal along the way. Within practices, redundancies and **secondary design elements** that safely pass excess flow if an overflow structure clogs, can provide protection against increased maintenance burdens.

Case Study: Morgan State University’s Center for the Built Environment and Infrastructure Studies uses pervious pavers and a green roof that were constructed with overflow drainage piping conveyed to two separate bioretention facilities that work to provide a combination of BMPs in a series. These redundancies provided added resilience to large storm events.

Performance enhancers:

Design using “performance enhancers” for water quality to provide a buffer against future increases in loads or reduced efficiencies. **Media amendments**, **“smart” BMPs**, and stronger **vegetation guidelines** may all provide improved pollutant removal function under both current and future conditions. Adapting **new standards** for these BMP enhancements may advance water quality goals or, at a minimum, provide a buffer against any decline in performance due to climate change.

Case Study: A “smart” BMP retrofit in Montgomery County, MD uses real-time forecast information from the National Weather Service to determine the timing and expected volume of incoming storm events, and adjust its storage capacity ahead of large events.

Citations: Materials derived from CSN climate change memo series. For full list of citations, see links below:

Further resources:

Memo 1: Summary of Stakeholder Concerns, Current Management and Future Needs for Addressing Climate Change Impacts on Stormwater Management
Memo 2: Review of Current Stormwater Engineering Standards and Criteria for Rainfall and Runoff Modeling in the Chesapeake Bay Watershed
Memo 3: Review of Recent Research on Climate Projections for the Chesapeake Bay Watershed
Memo 4: Vulnerability Analysis and Resilient Design Considerations for Stormwater Best Management Practices MARISA: Projected Intensity-Duration-Frequency (IDF) Curve Data Tool for the Chesapeake Bay Watershed and Virginia