Appendix G. Adapting Stormwater Management for Climate Change*

Climate change has the potential to affect South Carolina's coast, with impacts including sea level rise and potentially more devastating and intense storm events. However, the exact nature and timeline of these impacts is almost impossible to predict with accuracy. Revising stormwater design parameters such as rainfall depth, intensity, and frequency; initial abstraction; and pollutant loading rates is a fairly straightforward exercise. However, whether these factors change by 3% or 40% creates a dramatically different outcome in terms of conveyance, storage, and treatment capacity. At present, the degree of uncertainty in climate change models, as well as region-specific considerations, make it necessary to consider various scenarios of change in stormwater design factors (Shaw et al. 2005).

Consequently, coastal communities need to adapt to the potential for climate change, but should seek low-cost solutions that can be adjusted over time as more is learned about potential impacts of climate change. This Appendix outlines some cost-effective, adaptable approaches to modify stormwater management techniques in the face of potential climate change.

G.1 Impacts of Climate Change

Some potential impacts of climate change include Sea Level Rise, Increased Storm Intensity, Drought, and Shift in Plant Communities.

Sea Level Rise

The International Panel on Climate Change (Christensen et al., 2007) predicts sea level rises ranging from 6 inches to 2 feet over the next century.[1] In the flat coastal plain of South Carolina, even the low range of this potential sea level rise would be significant. Regional research (Morris et al., 2002) predicted that for the southeastern US, relative sea level rise (RSLR) could be at most 1.2 centimeters per year. Locally, the RSLR was measured to be approximately 1 to 1.5 feet per century at the observing stations at Springmaid Pier (in Myrtle Beach, SC) and Charleston Harbor. Charleston Harbor's RSLR was 10 inches over 80 years, which Tibbetts (2011) reports was 50% faster than NOAA's reported global average.

Climate and sea level change result in the slow and systematic reshaping of the coast by individual hurricanes and storms. South Carolina's coasts are net erosional and the impacts of coastal storms are likely to increase as SLR accelerates (SCDHEC-OCRM, 2010). Increased rates of SLR accelerate rates of coastal erosion and land loss; impair urban infrastructure; and facilitate depletion of coastal habitats, including critical estuarine wetlands that help buffer storm surges. Impacts from higher water levels can include salt water intrusion for drinking water sources and greater extent for storm surge (NRC, 2010).

For stormwater management, some key impacts of sea level rise include:

1. volume in stormwater BMPs lost to sea water;
2. flushing of pollutants from stormwater BMPs during storm surge

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* content based on Hirschman et al., 2011

[1] Reflects range of most likely outcomes across a variety of future scenarios.

3. stormwater conveyance during storm surge
4. effects of salt water intrusion on plants and soil media in stormwater BMPs

Larger, More Intense Storm Events

Over the last century, we have begun to experience more intense storm events, and infrequent storms (e.g., the 100-year storm event) have been occurring more frequently. Climate change models predict that this trend will continue. However, it is uncertain exactly how storm events will change, and over what time period. More frequent above-normal rain events are anticipated in the southeast. Heavy downpours that normally occur once every 20 years are projected to occur every 4 to 15 years by 2100. Increased hurricanes are projected to add 6-18% more rainfall for every 1.8°F increase in tropical sea surface temperature (USGCRP, 2009). After coming off of a 12-year drought, South Carolina's annual precipitation in 2013 was the second heaviest on record on an annual basis, and the wettest summer recorded (Mizzell, 2013). Across the SC, NC, and GA region, there is an increasing trend in fall precipitation. The number of days with precipitation greater than or equal to one inch (as measured at Charleston Airport), shows a slight increasing trend from 1939 to present; similar results were observed by Dai et al. (2013) in their analysis of 60 years of precipitation data from the Santee Experimental Forest in coastal South Carolina. Although precipitation changes seasonally and future predictions are variable (Carbone, 2013), most models indicate that there will be a 5-10% increase in precipitation in the next 40 years.

Some specific concerns for stormwater management include

1. safely conveying stormwater during more intense events
2. potential bypass of some practices, such as filter strips, during higher intensity storms
3. practice sizing for both water quality and water quantity

Potential Drought and Shift in Plant Communities

Under the most likely scenario (the A1B scenario)[2] predicted by the IPCC, most of the planet will experience a shift in annual precipitation. In Coastal South Carolina, the annual temperature is predicted to increase between three and six degrees Farenheit over the next century. Higher temperatures increase evaporation and increase the intensity and duration of droughts (USGCRP, 2009). These changes will result in a shift in plant communities, and also create a greater need for irrigation and water reuse.

G.2 Stormwater Strategies to Adapt to Climate Change

Effectively responding to climate change will require broad-based, adaptive approaches. Some measures that can help Coastal South Carolina effectively adapt to climate change include:

1. implementing LID practices at the site scale
2. modifying practices to prevent bypass during intense storm events

[2] This scenario assumes: 1) Rapid economic growth; 2) A global population that reaches 9 billion in 2050 and then gradually declines; 3) The quick spread of new and efficient technologies; 4) A convergent world - income and way of life converge between regions. Extensive social and cultural interactions worldwide; and 5) Reliance on a mix of fossil fuels and other energy sources.

3. periodically revisiting design storms and mapped floodplains
4. creating adaptable planting plans
5. using stormwater as a resource

Implement LID Practices at the Site Scale

Since the level of uncertainty in predicting climate change is high, making it difficult to recommend specific design standards, the design community should focus on broader design principles that build system resiliency for climate change. Designers should rely on approaches that:

1. enhance storage and treatment in natural areas
2. use small-scale storage and treatment
3. provide conveyances that allow for a margin of safety for flood conveyance and water quaity treatment

These design principles reflect current thinking in stormwater design and the low-impact development (LID) design framework.

Taken together, an LID design approach can reduce runoff volumes, thus minimizing the impacts of climate change. For example, in one study in New Hampshire (Ballestero, 2009), LID practices were found to retain 15-22% of design storm runoff on-site, so that resulting runoff volumes were similar to conditions before predicted climate change.

Modify Practices to Prevent Bypass During Intense Storm Events.

Design modifications of individual stormwater practices may also be necessary in response to the climate change factors noted above. Since our understanding of design storms may change, the design community may want to focus on fairly modest modifications of existing designs to better accommodate more intense rainfall events. The following examples provide two illustrations of how individual practices could be modified at relatively low cost.

Example 1: Reallocating Storage in Bioretention

The Issue: Increasing rainfall depths and intensities may force a rethinking about how storage is allocated to the various layers within a bioretention facility. More frequent high-intensity rainfall will lead to increased bypassing of the treatment mechanism, resulting in lower overall performance. The most vulnerable flow path element may be the rate at which water stored on the surface of the filter can effectively percolate down and fill the void spaces within the soil media.

Possible Adaptation: Increasing the surface area allocated for storage above the soil media can create a "holding zone" for water to move down through the soil voids. Importantly, this does not necessarily mean that the surface area (or volume) of engineered soil media needs to increase, as this change could have profound cost implications. The solution may be to have a surface ponding area that is not underlain by soil media, as shown in Figure G.2-1. In fact, this method has already been adopted in existing specifications, such as those on the Virginia Stormwater Best Management Practice (BMP) Clearinghouse, albeit not as a climate change adaptation (Virginia Department of Conservation and Recreation [VADCR], 2013a).

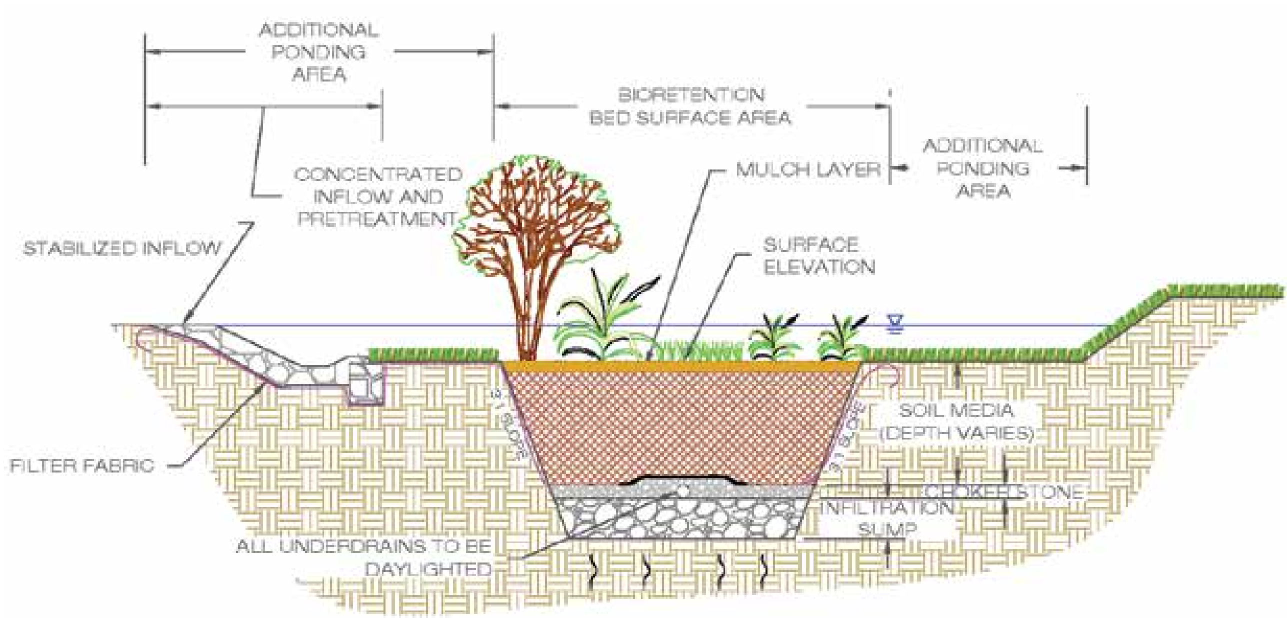

Figure G.2-1. Adaptation of a bioretention facility. Additional surface ponding area has been incorporated while the surface area and volume of soil media remains the same. (Source: VADCR 2013a, figure 9.5 excerpt).

Example 2: Pretreatment for Rainwater Harvesting

The Issue: Rainwater harvesting systems are designed to capture a target amount of water. However, both ends of the spectrum feature designed bypasses—first-flush diverters, vortex filters, and additional pretreatment devices to keep leaves and gross solids out of the storage tank (Figure G.2-2) and bypasses for higher flows once the storage device fills to capacity. With changing rainfall depths and intensities, it is possible that more water than desired will bypass at the front end, resulting in a loss of precious water that could be stored for future use, and overflow at the back end, creating downstream problems.

Possible Adaptation: The efficiencies of vortex filters and other pretreatment devices can be increased so that higher-intensity rainfall events will not lead to excessive bypassing of the storage tank. For instance, some current specifications call for a filter efficiency of 95% for a storm intensity of 25 mm (1 in) per hour (VADCR 2013b). The assumed intensity could be increased to 38 or 51 mm (1.5 or 2 in) per hour. To address more frequent overflows from the tank itself, on-site or off-site downstream infiltration or filtering practices can be coupled with the rainwater harvesting system (Figure G.2-3).

Periodically Revisit Design Storms and Mapped Floodplains

Due to the uncertainty in climate change modeling, it is not clear how, or if, practices need to be sized differently to account for potential larger storm events. Similarly, predicted sea level rise and storm events will likely change the location of mapped floodplains, but we are currently unable to predict the future floodplain or depth to groundwater with any accuracy. Consequently, an Adaptive Management approach, which periodically evaluates storm event data. as well as sea level and groundwater elevation, will allow for gradual readjustment over time. By using this approach, practices would have a useful life before changes occurred, but "new generation" BMPs would be sized and located to consider the effects of climate change as they are learned.

Figure G.2-2. A vortex filter is an example of a pretreatment device for rainwater harvesting. The vortex filter diverts the first amount of rainfall, which tends to have a lot of solids and vegetative debris. Vortex filters come in different sizes based on efficiency curves for rooftop area treated and rainfall intensity. (Source: VADCR 2011, Figure 6.11)

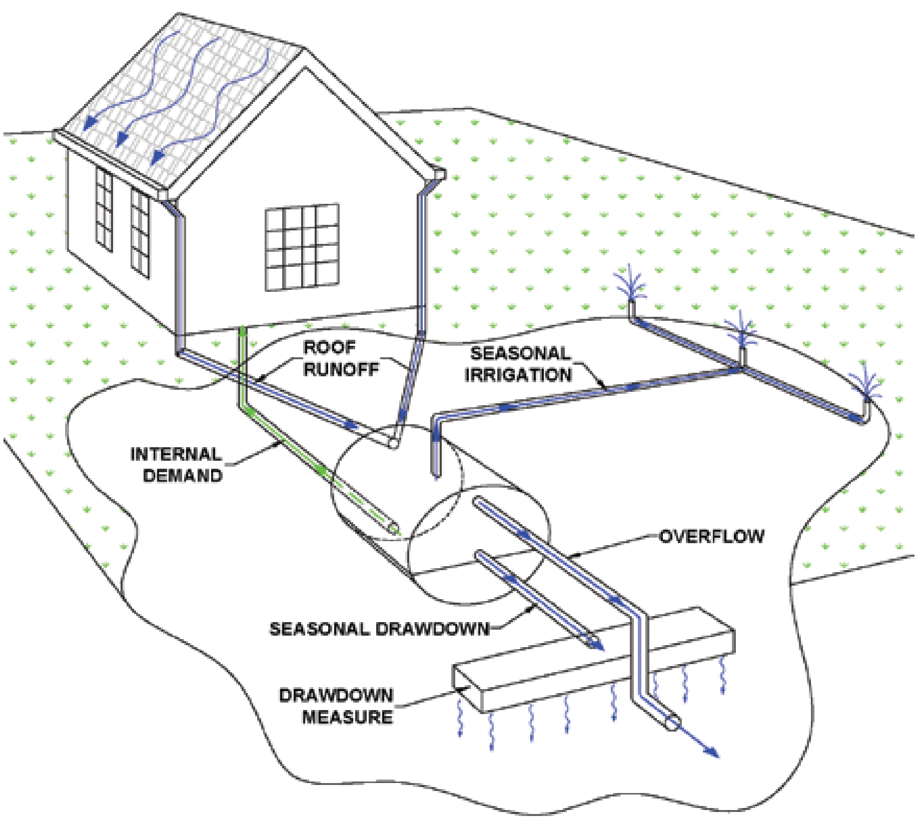

Figure G.2-3. Schematic of a rain-water harvesting system designed for internal use, seasonal irrigation, and treatment in a downstream filtration or infiltration practice during non-irrigation or rainy season months when the tank overflows routinely. (Source: VADCR 2013b, figure 6.3.)

Create Adaptable Planting Plans

Changes in temperature and rainfall patterns will likely combine to change plant communities. The plant lists included in this manual focus on native plants. In the long term, though, these plants may struggle to survive in a changing climate. Consequently, planting plans should be adapted over time so that, as practices are maintained, replacement plants are able to survive in a changing climate. In addition, plant lists in this manual should be reviewed and updated periodically to ensure that they include only plants that continue to thrive in coastal South Carolina.

Use Stormwater As a Resource

If hotter, drier conditions result from climate change, supplying coastal communities with sufficient water to meet both drinking water and irrigation demands may be a challenge. Stormwater management can play an important role in mitigating this problem, either by reducing water demand, or actively storing stormwater for future use. By concentrating ornamental vegetation in stormwater practices such as bioretention, the irrigation demand is far less than it would be in traditional landscaped islands since stormwater directed to these practices provides frequent inundation. Another option is to expand the use of stormwater harvesting practices. By using these practices to provide landscape irrigation and some interior water uses, water demand can be reduced substantially.

G.3 Conclusion

Climate change has the potential to impact Coastal South Carolina, with potential impacts including sea level rise, frequent and more intense storms, and drought and consequent shift in plant communities. However, it is difficult to predict the precise timing and magnitude of these changes. Consequently, the approach recommended in this appendix is a measured one that highlights low-cost solutions and adaptation over time as more is learned about climate change. The elements of this approach include: implementing LID practices at the site scale; modifying practices to prevent bypass during intense storm events; periodically revisiting design storms and mapped floodplains; creating adaptable planting plans; and using stormwater as a resource.

G.4 Adapting Stormwater Management for Climate Change References

1. Ballestero, Thomas P., Robert M. Roseen, and Iulia A. Barbu. 2009. LID practices as a means of resilience and short-term adaptation to climate change. Paper presented at the 2009 New Hampshire Joint Water and Watershed Conference, Concord, NH.
2. Carbone, G. 2013. Climate Projections for Coastal South Carolina. Presented at the 2013 Climate Stormwater Roundtable, Charleston, SC.
3. Christensen, J., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, K. Kolli,W.T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A.Sarr and P. Whetton P. 2007. Regional Climate Projections in Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007, Cambridge University Press, pp. 847-940.
4. Dai. Z., C.C. Trettin, and D.M. Amatya. 2013. Effects of Climate Variability on Forest Hydrology and Carbon Sequestration on the Santee Experimental Forest in Coastal South Carolina. USDA Forest Service South. Res. Station, Gen. Tech. Rep. SRS-172, 32p

5. Hirschman, D., D. Caraco and S. Drescher. 2011. Linking Stormwater and Climate Change: Retooling for Adaptation. Watershed Sciences Bulletin, Spring 2011: 11-18.
6. U.S. Global Change Research Program (USGCRP). 2009. Global Climate Change Impacts in the United States. Cambridge Universiy Press.
7. Mizzell, H. 2013. Carolina's Climate Report Card: Understanding Climate Trends and Variability. Presented at the 2013 Climate Stormwater Roundtable, Charleston, SC.
8. Morris, James T., P.V. Sundareshwar, Christopher T. Nietch, Bjorn Kjerfve, and D.R. Cahoon. 2002. Responses of coastal wetlands to rising sea level. Ecology 83(10): 2869-2877.
9. National Research Council (NRC). 2010. *Adapting to the Impacts of Climate Change.* The National Academies Press, Washington, DC, USA. Available online at: http://nas-sites.org/americasclimatechoices/sample-page/panel-reports/panel-on-adapting-to-the-impacts-of-climate-change/
10. South Carolina Department of Health and Environmental Control's Office of Ocean and Coastal Resource Management (SCDHEC-OCRM). 2010. Adapting to Shoreline Change: A Foundation for Improved Management and Planning in South Carolina. SCDHEC-OCRM. Charleston, South Carolina.
11. Shaw, H., A. Reisinger, H. Larsen, and C. Stumbles. 2005. Incorporating climate change into stormwater design—Why and how? 4th South Pacific Conference on Stormwater and Aquatic Resource Protection, Auckland.
12. Tibbetts, John H. 2007. Rising tide: Will climate change drown coastal wetlands? Coastal Heritage 21(3): 3-13.
13. Virginia Department of Conservation and Recreation (VADCR). 2011. Design specification no. 6: Rainwater Harvesting. Version 1.9.5. Richmond, VA: Virginia Department of Conservation and Recreation.
14. Virginia Department of Conservation and Recreation (VADCR). 2013a. Design specification no. 9: Bioretention. Version 2. Richmond, VA: Virginia Department of Conservation and Recreation.
15. Virginia Department of Conservation and Recreation (VADCR). 2013b. Design specification no. 6: Rainwater harvesting. Version 2.0. Richmond, VA: Virginia Department of Conservation and Recreation.