Appendix H – Long Range BMP, Climate Adaptation and Sustainability Project Solutions

During the development of priority projects in the One Mile Creek subwatershed opportunities were identified to improve the Historic Streamway, but were not feasible for early roll-out. Past experience with permitting agencies has shown the need to improve water quality upstream prior to re-connecting the Historic Streamway with Three Mile Creek. A step towards addressing this is to address the needs of UTTM (CEN). It was determined that the UTTM (CEN) subwatershed was identified as having much the same needs as One Mile Creek subwatershed which are listed below. In adddition future connections to the proposed park facilities to the east are feasible building upon the Phase 1 improvements which will further enhance access to the proposed improvements to the Historic Streamway (See Figure H-1 and H-2). Therefore, these measures are listed below for consideration for the next phase of project implementation. The Phase II BMPs and planning level costs is given in Table H-1. **The total estimated planning level cost range for Phase II is $2,452,000 – $5,502,000.**

Table H-1 Summary of priority BMPs and Planning Level Costs for Phase II Watershed Restoration

Watershed Issue to be Addressed	Priority Projects	Summary Description	Cost
Stormwater	Reduce the amount of trash in and entering the creek and tributaries with a focus on Unnamed Tributary to Three Mile Creek (UTTM (CEN)	1. Identify the outfalls that contribute the most trash (8NS, 10NS, 14NS) 2. Install GPRS in strategic locations (1S, 2S) 3. Citizen involvement and education campaign (7NS, 11NS, 12NS)	$960,000 to $1.41M
Stormwater, Ecology	Remove sediment to increase storage capacity and conveyance of stormwater runoff while improving ecological conditions in Unnamed Tributary to Three Mile Creek (UTTM (CEN)) and Historic Streamway	1. Identify locations of excessive sediment (3NS, 11NS, 12 NS) 2. Remove sediment at strategic locations (4S, 5S, 12S)	$1.082M to $3.42M

Watershed Issue to be Addressed	Priority Projects	Summary Description	Cost
Ecology	Reduce the occurrence of nuisance and/or exotic species with a focus on Three Mile Creek (UTTM (CEN))	1. Map SAV in watershed and Improve management of exotic/nuisance vegetation in wetland and upland riparian areas adjacent to creek and tributaries (6NS) 2. Develop plan for long term management of exotic/nuisance vegetation. (6NS) 3. Utilize previously purchased utility/trash boat/weed harvester (6NS) 4. Remove channel plug and restore historic creek stream channel (14S) 5. (* If purchase of utility/trash boat/weed harvester is required then add $800,000 to this Project (15NS, 16NS)	$154,000 to $285,000
Access	Create a fitness circuit on Historic Streamway	Connect greenway from existing bridge at Martin Luther King Jr. Ave. along Historic Streamway connecting to One Mile Creek and future Hickory Street Landfill Park (1BW, 1GW)	$255,000 to $382,000
Climate Adaptation	Tidal Marsh Restoration/Stream Stabilization	Restore/enhance wetland areas adjacent to historic channel/create living shorelines. (2CA, 4CA, 5CA)	TBD

Note: Cost range does not include the cost of obtaining land or easements if required; surveying and engineering costs; and annual costs associated with operation and maintenance of the completed structural improvements. A 15-20% annual maintenance fee should be added for all structural measures to provide for on-going maintenance.

Figure H-1 Phase 2 Blueway and Greenway Trail alignment anchored by the existing facilities at Tricentennial Park and potential future connections to the planned Hickory Street Landfill park.

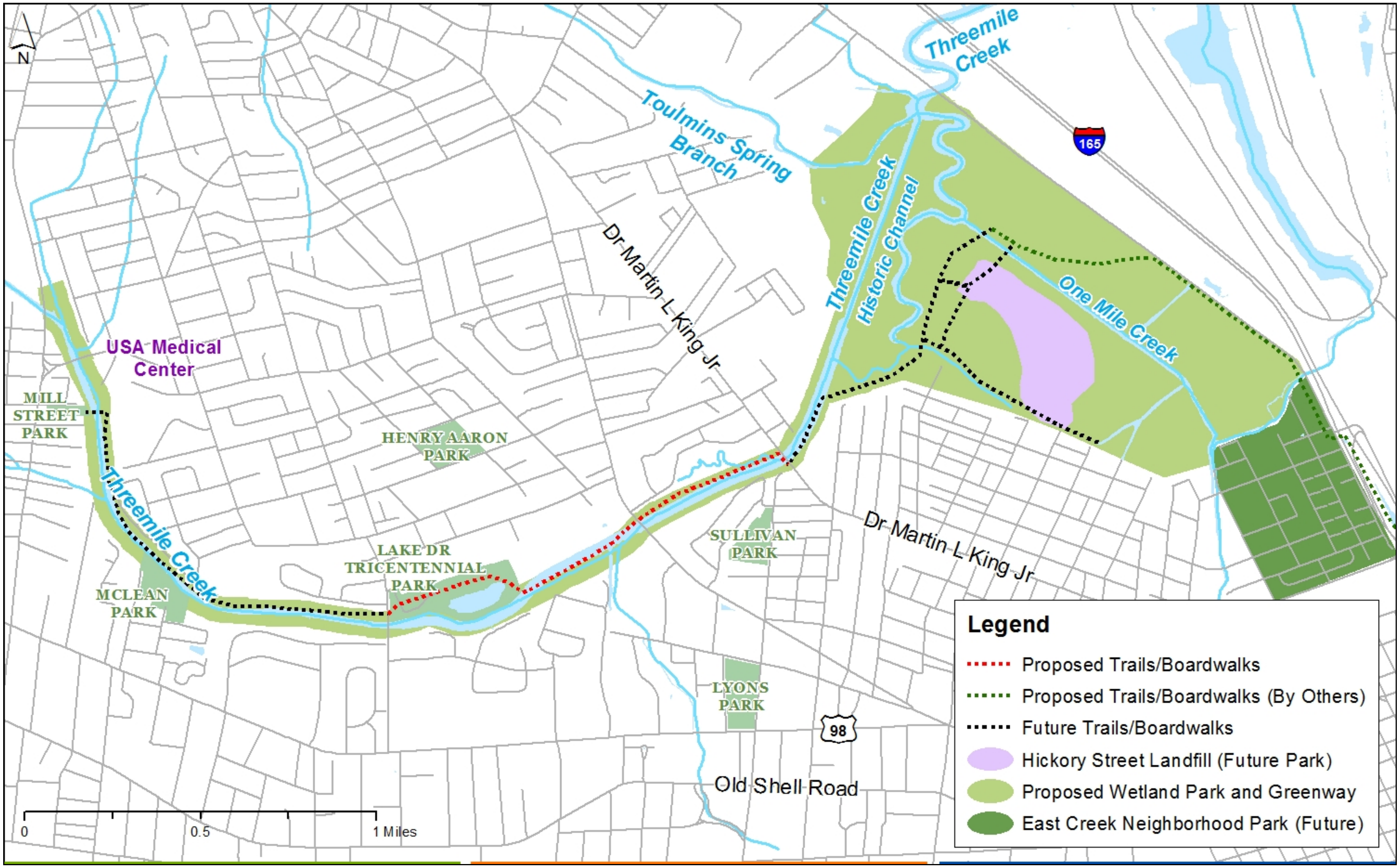
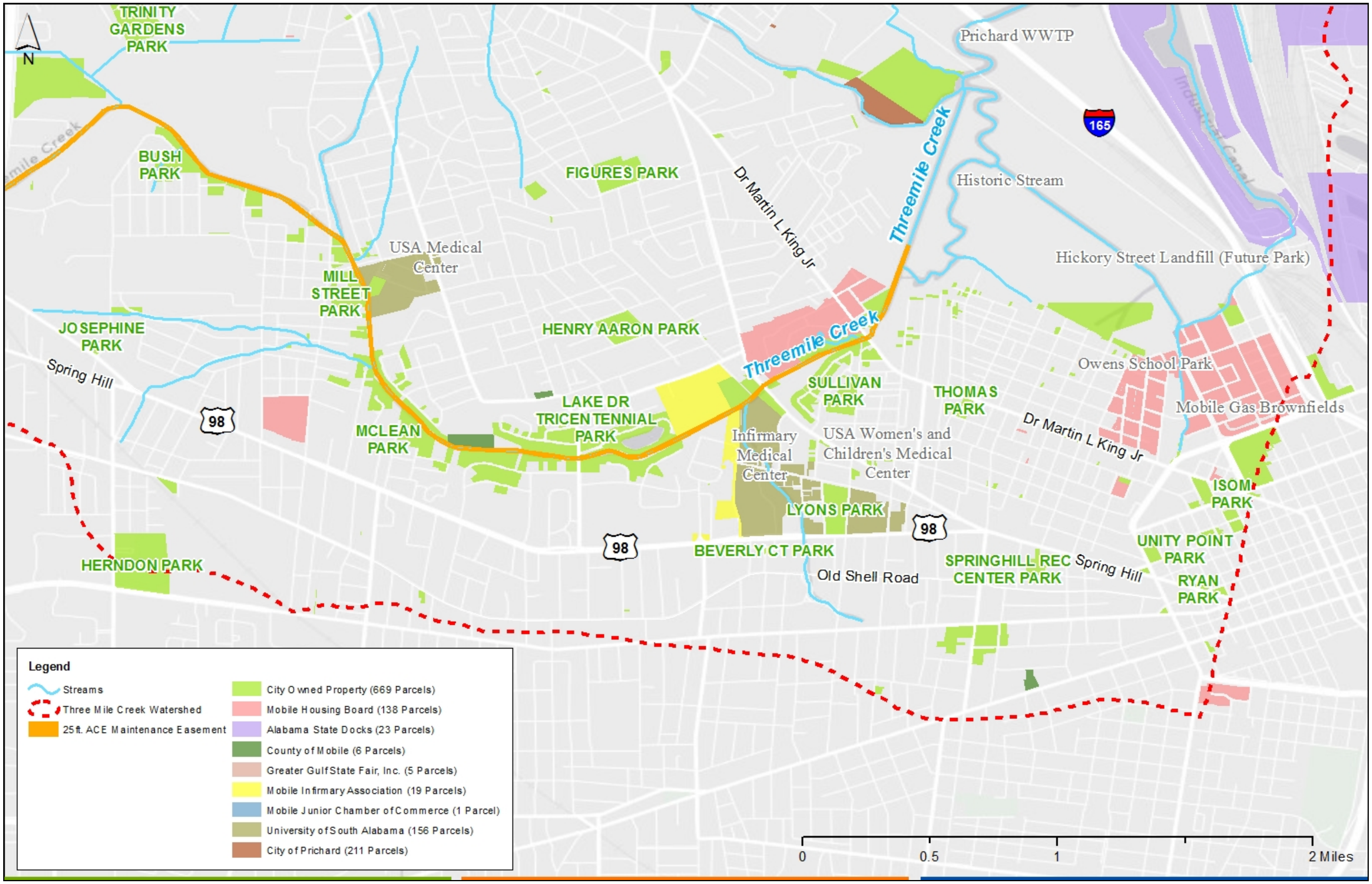


Figure H-2 Public and Non-Profit Owned Property



Future Phases of Watershed Restoration

The watershed segment priorities (see Section 6.4) and associated BMP recommendations provide a road map for the watershed restoration implementation strategy in Three Mile Creek. If possible, it would be preferable to implement all the recommended improvements in a few years and then set about monitoring and measuring watershed response as a whole. However, the typical timeline for funding availability can be slow and unpredictable, and opportunities can arise to implement improvements in areas that do not match the prescribed and prioritized sequence. Therefore, the 10-year timeframe and priority sequence of this WMP are set forth as a management strategy that recognizes the unique conditions and needs of the Three Mile Creek watershed and provides a flexible list of improvements aimed at achieving better water quality. MBNEP should seek to implement all recommended non-structural and structural BMPs as funding is available using the watershed segments to prioritize the use of funds when discretion is allowed.

We recommend continuation of non-structural BMP practices such as ongoing education and outreach program, routine collection of trash and organic debris, as well as street cleaning throughout the implementation of the WMP. The objective of these BMPs is to remove pollutants at their source before they enter the surface water system. It is recommended that local officials should increase enforcement of existing regulations such as the NPDES Construction General Permit and littering violations. MBNEP should closely coordinate with the City of Mobile to encourage enhanced enforcement. Most importantly, monitoring and evaluation stages should be included in each implemented BMP so that BMP effectiveness and efficiency can be tracked and guide future implementation decisions. This adaptive management will not only ensure the most effective application of funds, but also their application in the area of greatest need in the watershed. The following tables provide a summary of management measures as they apply to each of the five identified challenges to Three Mile Creek.

Stormwater

Measure Identification Number	BMP Activity Description	Location	Measure Objectives
3NS, 4S, 5S, 12S	Remove Sediments	USA wet ponds, Langan Park and as needed in the Creek and tributaries	Map of current creek and tributary bathymetry and determine physical and chemical characteristics identified in Data Gaps; assess normal water depths; select locations for sediment removal
4NS, 3S	Disconnect impervious areas/ install Green Infrastructure projects	Public R/W and private lots	Retrofit public areas and partner with private landowners (subwatershed areas of 20 acres or less)
5NS	Revegetate or stabilize bare soil areas to reduce erosion	Public R/W and private lots	Retrofit public areas and partner with private landowners to revegetate of disturbed eroding areas in upland areas
7NS, 11NS	Education and outreach program;	Entire watershed	Partner with schools, churches and community groups to promote issues on water quality improvement; Install road signage and placards (Anti-littering – Drains to Three Mile Creek).
8NS, 1S, 6S, 7S	Improve trash management	Entire watershed	Initiate water borne collection of trash/organic debris; Initiate intensive street cleaning; Install Gross Pollutant Removal Structure (GPRS) on pipe and channel outfalls; Add trash capture at USA pond and Langan Park inflow points
9NS, 10NS	Improve code enforcement	Entire watershed	Develop program of field observation/inspection to identify and reduce litter and pollution sources; Increase frequency of field observation/inspection and enforce NPDES Construction General Permit Requirements (>1 acre disturbance).
14NS	Identify drainage area and pollutant loads from major storm sewer outfalls	Entire watershed	Complete Stormwater and wet weather creek surface water quality monitoring, identify drainage area and pollutant loads for each major storm sewer outfall identified in Data Gaps.
16S, 17S	Construct Energy Dissipaters	Twelve Mile Creek downstream of East Drive and downstream of University Blvd.	Repair erosion and construct an energy dissipater in 2 locations on Twelve Mile creek exhibiting severe scour conditions

Wastewater

Measure Identification Number	BMP Activity Description	Location	Measure Objectives
1NS	Identify and remove sanitary system and septic system leakage/overflows	Focus on TSB and CEN sub-basins and lower portion of watershed.	Field studies and inspection: Identify and remove sanitary system and septic system leakage/overflows into groundwater, creeks and tributaries.
2NS	Identify and remove illicit discharges to stormwater and surface water system	Focus on TSB and CEN sub-basins and lower portion of watershed.	Field studies and inspection: Identify and remove illicit discharges to stormwater and surface water system in watershed.

Ecology

Measure Identification Number	BMP Activity Description	Location	Measure Objectives
6NS, 15NS, 16NS	manage the abundance of invasive species (exotic/nuisance vegetation)	Entire watershed.	Map SAV in watershed and Improve management of exotic/nuisance vegetation in wetland and upland riparian areas adjacent to creek and tributaries; develop plan for long term management. Purchase Conver w/ attachments and trailer and smaller utility boat. Maintain & operate Conver and associated equipment
13NS	manage the abundance of invasive species (invasive animal species)	Three Mile Creek downstream of Langan Park	Coordinate efforts with ACDNR on irradication efforts of the Island Apple Snails and eggs
4NS, 3S	Disconnect impervious areas/ install Green Infrastructure projects	Public R/W and private lots	Retrofit public areas and partner with private landowners (subwatershed areas of 20 acres or less)
5NS	Revegetate or stabilize bare soil areas to reduce erosion	Public R/W and private lots	Retrofit public areas and partner with private landowners to revegetate of disturbed eroding areas in upland areas

Measure Identification Number	BMP Activity Description	Location	Measure Objectives
8S, 9S, 10S 11S,15S	Wetland, Stream and Riparian Buffer Enhancement	Entire watershed	Streambank and Riparian Buffer restoration upstream and within USACE segment; create depressional runoff storage within USACE segment; Restore/enhance wetland areas adjacent to historic channel/create living shorelines.
16S, 17S	Altered creek geomorphology	Twelve Mile Creek downstream of East Drive and downstream of University Blvd.	Repair erosion and construct an energy dissipater in 2 locations on Twelve Mile creek exhibiting severe scour conditions and grade control

Access

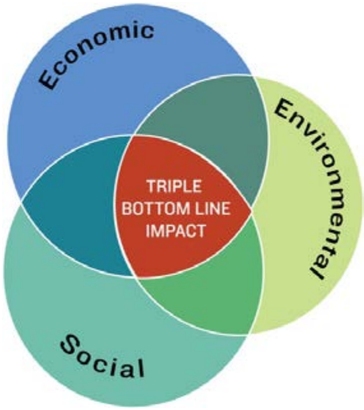
Measure Identification Number	BMP Activity Description	Location	Measure Objectives
1GW,1BW, 3S, 14S, 15S	Improve recreational access to the creek	Lower Watershed	Greenway - 1.7 miles (50% public or non-profit ownership, 50% private easements); Blueway – (3 accesses, 0 portage enhancements); Install green infrastructure retrofits on developed public areas (below Langan Park); Remove channel plug and restore historic creek stream channel; Restore/enhance wetland areas adjacent to historic channel/create living shorelines.
1GW,1BW, 3S, 8S, 9S, 10S, 11S	Improve recreational access to the creek	Middle Watershed	Greenway – 4.2 miles (100% public or non-profit ownership, 0% private easements); Blueway – (2 accesses, 4 portage enhancements); Install green infrastructure retrofits on developed public areas (below Langan Park); Streambank and Riparian Buffer restoration upstream and within USACE segment; create depressional runoff storage within USACE segment; Restore/enhance wetland areas adjacent to historic channel/create living shorelines.

Measure Identification Number	BMP Activity Description	Location	Measure Objectives
1GW,1BW, 4S, 5S, 8S, 9S, 10S, 11S	Improve recreational access to the creek	Upper Watershed	Greenway – 6.8 miles (62% public or non-profit ownership, 48% private easements); Blueway – (1 accesses, 1 portage enhancements); Remove sediment and increase normal water depth/volume at USA wet ponds; Remove sediment and increase normal water depth/volume at Langan Park ponds (assumes 3 ft sediment depth); Streambank and Riparian Buffer restoration upstream and within USACE segment; create depressional runoff storage within USACE segment; Restore/enhance wetland areas adjacent to historic channel/create living shorelines.

Climate Adaptation

Measure Identification Number	BMP Activity Description	Location	Measure Objectives
1CA, 2CA, 3CA, 4CA, 5CA, 6CA, 7CA	Sea Level Rise	Lower Watershed and Middle Watershed downstream of USACE Weirs	Monitoring Plan; Tidal Marsh Restoration; Beneficial use of dredged material; Vegetative planting and marsh nourishment; Land Acquisition; Rolling Easements; Freshwater introduction
8CA, 9CA, 10CA, 11CA	Increased Incidents of Storm Events	Lower Watershed and Middle Watershed downstream of USACE Weirs	Raise Road Levels; Elevate Residential Structures; Flood Proof Non- Residential Structures; Backwater Control Valves; Levees and Floodwalls

BMP Descriptions



During the development of the management measures and the priority projects discussed in Section 6 the Dewberry team followed an Integrated Watershed Approach to pollutant load reduction and restoration in Three Mile Creek. This included:

- Holistic evaluation considering all pollutant sources and loads
- Evaluate life cycle cost per mass pollutant removed
- Triple bottom line analysis – environmental, economic, social

The recommended water quality improvement best management practices include both non-structural and structural practices. In addition long-range sustainability project solutions were discussed to address sea level rise and tidal surge. The following provides a more detailed description of the recommended BMPs from the WMP.

Non-structural

Signs are a smaller-scale project effort which provide great opportunities for sponsorship by local industries/businesses and advertisement of sponsorship to defray costs to the MBNEP. The information below provides additional ideas that could be explored for implementation as part of the objective raise public awareness of environmental education in the TMC watershed.

Additional types of educational signs for future consideration:

- "Don't Dump – Drains to Three Mile Creek": these signs connect potential litter sources on the connection to Three Mile Creek, its tributaries and Mobile Bay. These signs could be placed on bridges and storm drain inlets throughout the watershed to warn against dumping of detergents, oil or other harmful chemicals.
- Environmental educational signs: signs documenting the connections of the watershed to weather, stormwater management, and ecological restoration. These signs can be placed along the greenways and blueways encouraging users to become more knowledgeable about the benefits of Three Mile Creek and learn about the biological richness of the creek with people.
- Historical signage: signs documenting specific moments in local history, historical landmarks and the role Three Mile Creek played (i.e. Civil war battles, baptisms, recreation).

- Positive ownership signs: signs positively connecting residents with the Three Mile Creek watershed (i.e. “Keep Our Creek Clean” or “Creating a Clean Water Future”) instead of a negative connotation such as “Don’t Litter”.
- Maps: signs at launching and park entry points with maps to identify destinations and key markers along the trail.

Structural

The evaluation of potential structural non-point source practices included:

- End-of-pipe treatment for gross solids, sediment
- Traditional treatment practices such as ponds, basins, etc.
- Chemical and wetland treatment
- Green Stormwater Infrastructure practices to reduce runoff volume and promote infiltration and reuse

The recommended structural Best Management Practices for Three Mile Creek include all of the above types of BMPs. The following figures provide examples of each.

LOCATION:
WILMINGTON, NC
SOURCE:
Dewberry design – JEL Wade Wetland

Stormwater Wetlands

Constructed Stormwater wetlands, constructed ecological systems which treat runoff pollutants through physical, chemical, and biological processes, are well suited for coastal areas with high groundwater and available space. Salt tolerant plants may be required depending on proximity to brackish water and tidal fluctuation. Wetlands typically require more space than other SCMs, require critical water balances to properly function and need a rigorous maintenance program.

LOCATION:
Wilmington, NC

Wet Detention Basins

Favored by many developers for their small footprint compared to the treatment volume provided, Wet Detention Basins function well in coastal environments with high groundwater and can be used for the dual purpose of flood storage and water quality improvement. These basins are space efficient since they can stack quality and quantity volumes with minimal depth constraints. Including a perimeter wetland shelf in the design incorporates some of the beneficial aspects of wetlands, increases ascetics and may reduce the need for fencing in public areas. It is noted that ponds that are poorly designed or maintained or placed within contact with brackish water can contribute to Harmful Algae Blooms (HAB).

LOCATION:
CARY, NC
SOURCE:
Dewberry design – Hendrix Auto Sales

Sand Filter Vaults

Sand Filters are surface or subsurface devices that percolate stormwater down through a sand media to provide treatment. These devices are highly effective at removing TSS, BOD, fecal coliform and Phosphorus if maintained properly, but provide limited functionality for peak flow reduction. Sand Filters can be installed in densely developed urban areas with limited space. Sealed vault systems can be installed in fill and as such are not limited by in-situ groundwater conditions. However, buoyancy should be checked in these conditions

LOCATION:
Virginia Beach, VA

Vegetated Buffers

Vegetated buffers, such as restored riparian buffers, are low-maintenance ecosystems adjacent to surface water bodies, where trees, grasses, shrubs, and herbaceous plants function as a filter to remove pollutants from overland stormwater and shallow groundwater flow. Coastal variations include marsh and sound-side shoreline restoration. Vegetated buffers can also reduce the impact of boat wake and storm wave-action erosion. The beneficial effects for stormwater quality improvement increase with contact flow length which typically ranges from 10 to 100 feet.

LOCATION:
Norfolk, VA

SOURCE:
Living Shorelines, Center For Coastal Resources Management, <http://vwrrc.vt.edu/swc/NonProprietaryBMPs.html>.

Living Shorelines

Living Shorelines provide shoreline stabilization with an ecological approach to creating gradual shoreline slopes with sand buffers and native vegetation. Living Shorelines address erosion in lower energy situations by providing long-term protection, restoration or enhancement of vegetated shoreline habitats through strategic placement of plants, stone, sand fill and other structural or organic materials to intercept runoff sheet flow. However, they should include structures, such as dikes or groins, which sever the natural connection between the uplands and aquatic areas. Successful living shoreline implementation can be found at the Hermitage Museum & Gardens in Norfolk, VA. Research is on-going regarding nutrient removal efficiency for this SCM, however preliminary results indicate these systems are similar to wetlands in nutrient removal . (Research from Center for Coastal Resources Management from William & Mary University)7.

LOCATION:
Chapel Hill, NC

SOURCE:
Dewberry design – UNC Botanical Gardens

Bioretention Areas

Bioretention, or bio-infiltration, areas provide high nutrient removal and infiltration capacity, especially when an Internal Water Storage (IWS) Zones are included. However, high water tables present substantial challenges when implementing bioretention retrofits within coastal environments. In order to function as designed, bioretention areas require at least two feet of separation from the Seasonal High Water Table (SHWT). In poorly drained soils the use of underdrains may also be required. With a typical media depth of 3 feet, the overall depth to SHWT should exceed five feet in order to consider using a bioretention area. In certain limited conditions the use of liners and perimeter underdrains can offset high groundwater conditions, but costs may be prohibitive.

LOCATION:
Wilmington, NC

Dry Detention Areas

Dry Detention Basins can provide major flood reduction benefits. These basins typically act as a surge pool attenuating stormwater discharges to meet a pre-development flow condition. However, these facilities provide limited nutrient removal benefits due to their flow through design and are not practical for use in areas with high groundwater.

LOCATION:
Alexandria, VA

Open Sand Filters

Open sand filters are surface devices that percolate stormwater down through a sand media and promote infiltration into the surrounding soil or collect and discharge the treated water through underdrains. These devices are highly effective at removing TSS, BOD, fecal coliform and phosphorus, but provide limited functionality for peak flow reduction. Open systems require undisturbed soil conditions and a one foot separation from the SHWT. In poorly drained soils the use of underdrains below the three media depth may also be required. Therefore, in many cases the depth to SHWT must exceed five feet in order to consider using an open sand filter. In certain limited conditions the use of liners and perimeter underdrains can offset high groundwater conditions, but costs may be prohibitive.

SOURCE:
Suntree Technologies, Inc.
suntreetech.com

Second Generation Baffle Box (Gross Pollutant Removal Device)

The 2nd generation baffle box removes sediment, foliage and litter with minimal head loss. It is considered 2nd generation because of the elaborate mechanical and hydraulic methods used to achieve separation of nutrients from stormwater. Early versions without separation left the organic debris in contact with the stormwater which leads to bacterial build-up

SOURCE:
Brown and Caldwell design for CalTrans

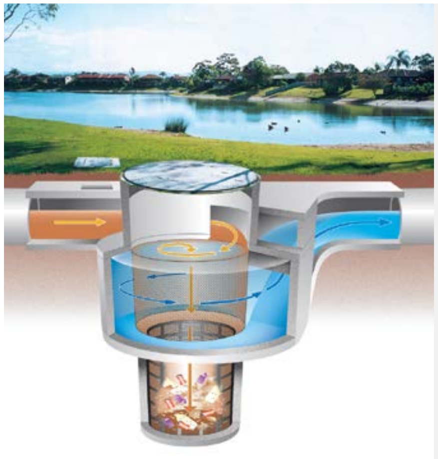
Drum Screen (Gross Pollutant Removal Device)

The drum screen removes foliage and litter with minimal head loss and achieves separation of nutrients from stormwater. The stormwater discharges from a pipe into the interior of the drum. The stormwater then passes through the perforated metal drum (screen), whilst the solids larger than the slot of the screen are retained inside. The retained screenings are captured inside and left to air dry until removed during maintenance.

SOURCE:
Storm Water Systems, Inc.;
sales@stormwatersystems.com

Trash Net (Gross Pollutant Removal Device)

Trash nets are designed to float in waterways in order to capture litter before it flows further downstream by using the current to guide debris into the trap. This floatable control technology continuously operates without mechanical assistance to capture floating litter. It is considered 1st generation because the litter is left in contact with the stormwater until maintenance occurs. For organic debris this wet environment can lead to bacterial build-up.



SOURCE:
CDS
ContechES.com

Pre-cast Vortex/Gravity Driven Devices

Vortex/gravity driven devices are typically installed in line as part of the stormwater collection system. From the surface they often appear to be simply another manhole. These proprietary devices work through creating a vortex within vertical chamber to separate pollutants (sediments and floatable debris). However, similar to many other proprietary devices, limited unit capacity and high design, installation and maintenance cost are typically with these systems. Some manufacturers can use specially designed unit modifications to allow these units to work in high groundwater conditions, but pollutant removal efficiencies may also be reduced.

LOCATION:
Gwinette Co., GA.

SOURCE:
BROWN AND CALDWELL DESIGN - PRIVATE GOLF COURSE

Depression Storage and Infiltration.

Depression storage is typically applied in the overbank area of a stream restoration. Similar to open sand filters these devices that percolate stormwater down through a sand media and promote infiltration into the surrounding soil or collect and discharge the treated stormwater through underdrains. These systems must be designed with accurate knowledge of the SHWT to prevent ponding.

LOCATION:
Wake Forest, NC

SOURCE:
Dewberry Design –NC Ecosystem Enhancement Program – Horse Creek

Stream Restoration

Stream restoration is intended to stabilize natural stream segments and re-establish lost habitat and the benthic health of the stream. Most often stream restoration is needed to offset the impacts by urbanization. Changes in impervious cover and the addition of stormwater collection systems often change the timing, temperature and volume of stormwater delivery to a stream. This can lead to increased shear stresses on the banks, increased volumes, increased stream temperature and excessive velocities in the stream which lead to erosion, bank failure and loss of habitat. Failed streams are typified by excessive bank erosion, down cutting of the streambed, and an imbalance of the sediment transport capacity. A variety of techniques are used to stabilize the stream and balance the sediment transport in the system. Hydraulic models are typically used to simulate stream flow and response in different series of structures that simulate natural conditions such as cross vanes, step pools and riffle-run sequences to achieve equilibrium. Vegetation is also an important component of stream restoration. I t is used to stabilize banks and structures as well as attenuate and filter runoff through vegetated buffers. Stream restorations are most successful when built in combination with vegetated buffers to re-establish the habitat of the natural stream.

Curb Diversion (Green Infrastructure)

Green infrastructure projects include a variety of structural stormwater management practices designed to reduce peak stormwater runoff, increase infiltration and improve water quality. These projects are normally small and distributed throughout the upper portions of the watershed where they can capture runoff from small catchment areas. Projects like this curb diversion are typically implemented as retrofits in older urban areas that were constructed prior to NPDES or local stormwater regulations.

LOCATION:
SEATTLE, WA

Infiltration Swales (Green Infrastructure)

Treatment swales are shallow open-channel drainage-ways stabilized with grass, herbaceous vegetation or special media designed to infiltrate runoff and filter pollutants. Because they are designed to retain water for less than 24 hours after a storm event, treatment swales can be incorporated within a development to provide an ascetically pleasing conveyance system that is part of the maintained landscape. Treatment swales situated within soils high in silt and clays may require underdrains. Treatment swales can be placed within areas of high groundwater, as long as a minimum separation (~2 ft) is maintained. Treatment swales are typically installed flat to maximize treatment volume per linear foot, but can also be installed in moderately steep terrain with the use of check dams.

LOCATION:
Raleigh, NC

SOURCE:
Dewberry Design – Wake County School Board - Poe Elementary Parking

LOCATION:
Norfolk, VA

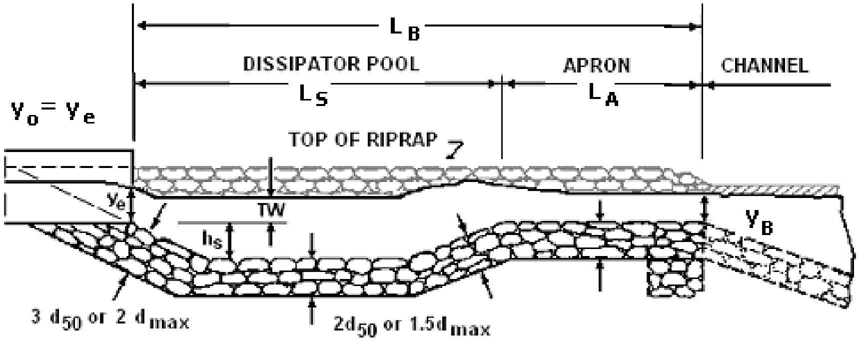
Permeable Pavement (Green Infrastructure)

Permeable pavements are alternative paving surfaces that allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated. A variety of permeable pavement surfaces are available, including pervious concrete, porous asphalt and permeable interlocking concrete pavers, as shown in the graphic. While the specific design may vary, all permeable pavements have a similar structure, consisting of a surface pavement layer, an underlying stone aggregate reservoir layer and a filter layer or fabric installed on the bottom. These facilities can replace traditional paved parking lots and provide some or all of the necessary infiltration capacity to control runoff. As such, they are commonly installed in dense urban areas where land costs offset the high installation costs. The sandy soils of most coastal communities can be ideal as a paving substrate and for providing the required infiltration capacity; however underdrain or soils replacements can also be required where silt or clay soils are present. High maintenance requirements, such as regular vacuum cleaning of the surface, are essential, especially in high wind prone areas, to maintain the infiltration capacity of these systems.

SOURCE:
U.S. Department of Transportation, Federal Highway Administration, Hydraulic Engineering Circular No. 14, Third Edition Hydraulic Design of Energy Dissipaters for Culverts and Channels, Publication No. FHWA-NHI-06-086, July 2006

Energy Dissipater

Energy dissipaters are typically used in channels at outfalls or at grade changes where stream velocities increase causing shear stresses on the channel banks and bed. These can take the form of riprap or concrete lined channel segments where controlled drops and induced hydraulic jumps are used to force turbulent flow and reduce velocities and energy in the stream before flowing back into a natural channel.



Long-Range Sustainability Project Solutions

Additional types of sea level rise adaptation strategies for future consideration:

1. **Strategy: Tidal Marsh Restoration as a Sea Level Rise Adaptation**

   The Bay Institute determined that restoring San Francisco Bay's tidal marshes is one of the best and most inexpensive ways to protect valuable shoreline development from sea level rise during the next several decades. A report by ESA PWA concluded that by using tidal marshes in combination with earthen levees construction and maintenance costs can be reduced by almost 50% (Lowe, Jeremy). This innovative approach is based on a new marsh restoration paradigm that is appropriate in many parts of the Bay and that can provide an interim solution to the problem of tidal marsh inundation and low sediment supply. The new paradigm recommends the addition of an upland ecotone slope of moist grasslands and brackish marshes landward of the existing tidal marsh. The upland ecotone slope would provide both elevation and salinity gradients that would allow the tidal marsh to both move landward and accelerate vertical accretion in order to keep pace with sea level rise. In addition, the new marsh restoration paradigm proposes the use of sediment dredged from nearby flood control channels as construction and maintenance material for the upland ecotone substrate. Reclaimed wastewater effluent from existing public water treatment plants along the shore could be used to irrigate the upland ecotone slope.

Conceptual cross-section of a "horizontal levee", with an upland ecotone slope bayward of a flood risk management levee and landward of a tidal marsh.

By constructing an ecotone slope adjacent to the landward levee, silt from nearby flood control channels could be captured and applied to restoring marshes to build surface elevation. Further, the ecotone slope would function as a self-maintaining levee, building in elevation as root systems grow. Another significant feature of the brackish marsh would be the ability to receive treated wastewater effluent from existing water treatment plants that ring the shoreline. Those plants currently spend considerable sums to pipe, pump and discharge wastewater at distant locations in the bay. Similar brackish, back-marsh networks existed historically throughout the Bay, but were destroyed to make way for development.

2. **Strategy: Acquire property subject to coastal flood inundation and maintain the property as open space in perpetuity.**

States and other government entities can play a critical role in acquiring property that is vulnerable to flooding and adaptively reusing such properties to advance additional complementary goals. By acquiring properties subject to inundation and maintaining them as open space in perpetuity, these floodprone properties can both be removed from the real estate market and add open space for conservation, recreation, or other public purposes. The acquisition of floodprone properties can also further environmental benefits including allowing for marshland migration and reducing non-point source pollution. The City of Mobile has extensive experience with the acquisition of floodprone properties following Hurricane Francis. It is important to note that the property in question may include developed and undeveloped lands.

The ability to map areas under consideration and calculate the costs to acquire the land can be undertaken using available City GIS data coupled with FEMA floodplain boundaries, and other relevant County property assessment data needed to perform the benefit-cost analysis. This strategy must take into account the challenges of identifying willing sellers of their property, determining the cost-effectiveness of properties, acquiring contiguous properties (and avoiding the "checkerboard" effect whereby only some houses in a neighborhood are acquired, which requires the provision of services to remaining households), and the tracking of those bought out to ensure that the funds are used by former property owners to acquire housing outside of areas subject to SLR and coastal flooding. This strategy should draw on the flood hazard data that is readily available as well as lessons learned from the large-scale buyout of floodprone properties that has occurred in the in the mid 1980's.

Areas considered under this strategy should include environmentally sensitive areas; areas prone to flooding, SLR, and coastal erosion; past lands acquired (including differing funding source attributes); and lands prioritized for future purchase by differing groups. A number of pre- and post-disaster hazard-mitigation grant programs provide funding to engage in this effort. Examples include the Hazard Mitigation Grant Program (HMGP, Hazard Mitigation Assistance, Flood Mitigation Assistance, and Severe Repetitive Loss (SRL) Program. In addition, the Department of Housing and Urban Development's Community Development Block Grant Disaster Recovery funds are often used to acquire flood-prone properties after a federally declared disaster.

3. **Strategy: Utilize rolling easements to allow for the migration of wetlands while maintaining public access to the shore.**

The dynamic nature of coastal ecology complicates coastal land use planning, as features like marshes migrate due to oceanographic, hydrological, and meteorological processes. In developed areas, governments and private landowners often attempt to hold back the sea by adding sand to beaches or building hardened structures like sea walls and revetments. Another option to address the natural dynamism of coastal environments, including the migration of coastal wetlands, is to utilize rolling easements. The application of rolling easements has the additional benefit of helping to maintain public access along the State's shores, which also enhances important tourism and recreation-based economies. The EPA recently published a Rolling Easements Primer that outlines a range of approaches to rolling easements and the advantages and disadvantages of pursuing such a strategy (Titus, James G., 'Rolling Easements Primer').

Rolling easements depend on actual, immediate fluctuations in sea level rather than projections. As a result, this strategy sidesteps the inherent uncertainty and disagreements surrounding future levels. As indicated by the protracted debate over NC House Bill 819, much of the State-level opposition to SLR adaptation emanates from groups skeptical to prevailing climate science, which this strategy may help moderate. Developing a policy tied to actual changes may enhance the likelihood of gaining legal standing (e.g., relying on existing State coastal management rules) as well as political support. However, since structures seaward of this line would be removed at the owner's expense, under current State law, it may remain politically objectionable to some property owners. Several States have coastal management programs that employ varied forms of rolling easements. Florida's Coastal Construction Control Line (CCCL) Program provides protection for Florida's beaches and dunes while assuring reasonable use of private property by establishing an area in which more stringent siting and design criteria are applied for construction and related activities. The control line represents the landward limit of a 100-year coastal storm, which could change due to coastal erosion, changes in sea level, or intensification of coastal storms (The Homeowner's Guide to the Coastal Construction Control Line Program). The Texas Open Beaches Act, established in 1959 and amended in 1991, guarantees free public access to beaches on the Texas coast, extending from the mean low tide to the first line of stable vegetation. While litigation is pending to clarify the effects of the Act on beachfront property owners, the Act results in the public easement "rolling" with the vegetation line as long as its movement is gradual/natural and not caused by an event like a hurricane (Texas General Land Office Website). The EPA Climate Ready Estuaries Program encourages the use of rolling easements and may be used to provide broad policy guidance.

4. **Strategy: Allow wetland habitats to move based on changes in sea level rise.**

According to the North Carolina Department of Environment and Natural Resources, habitat corridors such as wetland marshes are essential components of the State's Wildlife Action Plan. In North Carolina, more than 70 percent of the species listed as endangered, threatened, or of special concern depend on wetlands for survival. Thus, a policy of allowing wetland habitats to move as coastal ecologies change as a result of SLR could have significant benefits to flora and fauna; advancing existing wildlife science and policy; and maintaining key nurseries that support important seafood, hunting, and recreational interests in the State.

While it is not hard to imagine this policy boosting coastal economies through tourism and ecosystem services, these benefits likely will prove difficult to quantify. The land acquisition processes required would be similar to Strategy 2 in combination with Strategy 3. At the Federal level, the Coastal Wetlands Conservation Grant Program; Coastal Wetlands Initiative, which identifies and disseminates tools to protect and restore wetland resources; and the Wetlands Reserve Program, which offers landowners the opportunity to protect, restore, and enhance wetlands on their property, could be used to allow wetland migration.