The recognition of the role of headwater streams at controlling the water quality and overall health of downstream waters has lead to an exponential growth in the number of stream restoration projects implemented in the US and in Maryland to improve water quality. Regenerative Stormwater Conveyance (RSC) systems represent an emerging and promising integrative approach to manage stormwater and restore headwater streams in the Coastal Plain region. They offer an alternative to piping and culverts for more effective and eco-friendly stormwater management. RSC construction results in a three dimensional wetlands complex integrated into the landscape around it. Stormwater is conveyed through the site in a non-erosive fashion and surface water flows are directed into a broad, flat, gentle meandering pattern.

Historically, the practice with storm water runoff has been simply to drain it as quickly as possible into receiving streams and tidal waters. But what was a common practice in the mid decades of the 20th century prior to the establishment of Stormwater Regulations in the '80's has turned into a significant environmental problem in the 21st. Erosion throughout the lower western shore watersheds of the Chesapeake Bay has been caused by failed drain pipes that were installed decades ago. In urban environments, it is estimated that a large portion of the sediment (over 65% some cases),[1,2,3] and phosphorus loading[4], comes from stream channel and bank erosion[5]. A substantial proportion of the nitrogen loading is also derived from the baseflow that feeds these streams [6]

Targeted and Strategic Restoration: Targeting environmental restoration is, and will for the foreseeable future, be an exercise in triage, working to find the most cost effective ways to spend very limited dollars in addressing an enormous pollution problem.

In this context, doing work in the upland (installing standard BMPs and parking lot retrofits), aimed at arresting the perceived sources of nutrient and sediment pollution misses perhaps the largest contributor of pollutants to tidal waters. More importantly, even after these BMPs are installed, they still deliver significant volumes and velocities of storm water to a broken network of streams incapable of handling them.

Historical geomorphology – Our Broken Tributaries: In the years between the retreat of the last ice age (About 6,000 years ago) and European colonization, the Chesapeake watershed was almost entirely forested, and when rain fell on the landscape, virtually no sediment runoff was deposited in tidewater. [7] It took only two centuries for colonists to reduce the forest cover in the watershed to just above 40%.

With this massive de-forestation came the inevitable runoff of millions of tons of agricultural soils as the rain fell on the highly erodible sand and clays found through the region. These sediments washed off the landscape and found their way both into our stream valley floodplains and tidewater. The channel form of streams now widespread across the landscape is not, in fact what was a "natural" stream for this area historically[8]. Instead, prior to the pre-colonial land clearing, stream systems were broad, shallow and slow-moving wetland complexes, very well connected to their flood plain.

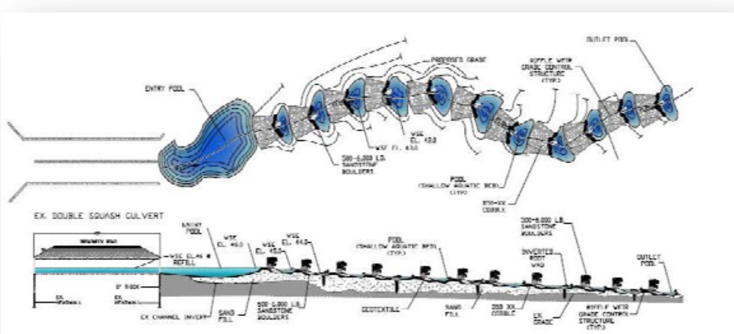
There is considerable research to corroborate this series of events, but locally the US Naval Academy has taken soil cores in the headwaters of Church Creek on the South River which confirm it. In January 2009, researchers took 4 soil borings near where the Route 665 bridge crosses Church Creek in Annapolis. Each of the cores showed the same pattern: 3 to 4 feet of silt, sometimes banded in locations with sand, overlaying a peat horizon, a vestige of the wetland complex that had once been present on the site.[9] This is consistent with the findings of other researchers in the region.[10]

To illustrate these manmade changes in topography, at Church Creek there is presently an 11’ wide, single-threaded channel where once the system was likely 300’+ in width and comprised of acres of high quality wetlands. This undersized channel, carved through “legacy sediments” now actively erodes, contributing nutrients and sediments downstream with every storm event. A similar situation exists at the site of each of the proposed stream and wetland restoration projects locations on Church Creek.   In fact this situation exists throughout the watersheds in Anne Arundel County.

A further variation on these ancient stream patterns was the repeating sequence of beaver ponds and dams which allowed water to be held on the floodplain and forced water to meander through and around these obstacles. The current RSC’s, with their pools and riffle weirs and berms, mimic these ponds and dams. When combined with seepage wetlands which reconnect the floodplain to the streams, they constitute an effective system for material processing, reduction in flood water energy, and even reduction of sediment transported through the systems reminiscent of the wetland systems existent prior to human intervention.

Description of an RSC: These RSCs are especially useful in urban systems as a tool for restoring lost ecosystem functions of the streams and adjacent floodplains and wetlands.

RSC placement in the water train determines the spacing of the weirs and the use of cascades. When located closer to the headwaters and in steeper grades, the technique has been dubbed a **Coastal Plan Outfall**. When located further down in the water train, often at a confluence of stream tributaries or just above the tidal interface, it s known as a **Sand Seepage Wetland**. Although somewhat modified to accommodate grade and terrain, these techniques are two sides of the same RSC coin.



In a RSC, water conveyance and processing is accomplished via a constructed network of sand seepage berms, pools, and cobble weirs. The arrangement of these features forms a new surface topography that, in turn, controls the surface and subsurface hydrology. The physical modifications necessary to establish the sand seepage hydrology most suitable for the establishment of seepage wetlands result in the creation of a series of well vegetated stilling pools, sand seepage beds replete with above and below-ground biomass, and associated flow paths through low areas dominated by native wetland plants. The physical effect of the pools and their many plant stems is to reduce water velocity and facilitate removal of suspended particles and their associated nutrients and/or contaminants.

Uptake of dissolved nutrients and adsorption of oils and greases by the many plant stems present in the pools yields additional benefits.

The cobble weirs set the surface water elevations and establish the current necessary to drive the sand seepage dynamic that supports these plants. In addition, the sand seepage bed supports microbes, fungi, macroinvertebrates, and processes which remove nutrients and contaminants as they pass through the sand bed. Furthermore, the many roots present in the sand take up nutrients and provide sites for microbial attachment, contaminant adsorption, and long-term sequestration in the peat forming layer resulting from annual root formation of the fibric root mat.

Coastal Plain Outfalls utilize added structural stability via stone and sand to eroded ravines or outfall areas expecting increased flows. But just like Sand Seepage Wetlands, the vegetative material planted along the channel and in the bottoms of pools provides an important contribution to project sustainability by tying the system together and increasing the porosity of the pools.

The materials used to achieve these results are taken from the coastal plain. Bank-run gravel and sand are quarried throughout the region and can be readily obtained. The only large stone found in the coastal plain is sandstone (e.g., bog iron, ferracrete). Sandstone's porosity, as well as its ability to retain water, allow it to naturalize quickly, providing habitat for ferns, moss, and other organisms that persist in these systems.

Why this technique?

- **TMDL requirements**: Recent EPA recognition of urban stormwater runoff as a significant source of pollution of the Chesapeake Bay has led to the State's adoption of the Maryland 2011 Milestones to Reduce Nitrogen and Phosphorus and put it on pace to reach its federally mandated Bay restoration goals by 2020. Non-point source pollution now represents the priority restoration targets in order to achieve the TMDL caps which will be set to significantly reduce the pollution levels allowable in our inland waters under the Chesapeake Bay Program.

- **Sediment trapping:** Recent USGS studies estimate that over 50% of the nitrogen in the Bay comes from streams. The western shore of the Chesapeake is a fast developing region with rapidly increasing impervious land coverage. By reconnecting these streams to their floodplains and putting these critically-needed non-tidal wetlands back on the landscape, we are able to set the stage for effective sediment trapping and nutrient processing as well as create habitat on a scale rarely undertaken in urban environments.[11]

- **Nutrient load reductions**: Ongoing scientific measurement of nitrogen processing in streams documents the greater denitrification occurring in integrated stream and wetland restoration projects relative to unrestored streams or streams using "conventional" channel designs. The newer and more physically complex restored streams (i.e. the RSC type in-stream wetlands and step pools) are "significantly more effective at reducing nitrogen loads moving downstream than un-restored streams or streams restored earlier using older designs." [12]

- **Fish species restoration**: Post-restoration fish sampling of RSCs on the western coastal plain of the Chesapeake has also found significant increases in species diversity and abundance compared with pre-restoration conditions[13]

- **Availability of land:** Unlike many other BMPs which require utilization and acquisition of developed land adjoining the streams, RSCs can be built right in the undeveloped floodplains. These areas are often controlled by the local government, making construction easement acquisition and permitting more likely.

- **Strategic flexibility**: The RSC approach provides great flexibility. In situations such as Clements Creek and Saltworks Creeks on the Severn River, the Watershed Action Plans call for utilizing both a headwater Coastal Plain Outfall to be paired with a Sand Seepage Wetland at a confluence located above the tidal interface. This is due to acute situations at the steeper headwaters which required intervention. In Clements, the problem was a seriously eroded ravine caused by a failed storm water outfall which was transporting significant amounts of sediment downstream. In Saltworks, untreated runoff from state and county roadways and commercial and industrial parking lots flows out of a large culvert at a rate sufficient to create a perennial stream which feeds directly into Cabin Branch. In most situations, however, a single treatment located above the tidal interface allows for maximum drainage area to be treated for the greatest return on investment. For example, in Brewers Creek on the Severn River, a Sand Seepage Wetland was built 10 years ago. As referenced above, ongoing studies by CBL and the County indicate that stormflow efficiencies for reducing nitrogen are up to 60%.

- **Cost effectiveness:** In an urban setting, developable land is at a premium, and in areas that have been urbanized for decades, much of it is already being utilized for development purposes. For example, in Church Creek, the South River Federation has been involved in the installation of upland BMPs (e.g. rain gardens, bioretention areas, etc.) in the past and will continue building them in the future. However, it can be extremely time consuming and labor intensive to work with multiple landowners to wrestle away space currently in other uses in order to install a stormwater practice with a relatively small impact. Additionally, the number of upland BMPs required to provide an equivalent stormwater benefit to stream valley restoration is very often several orders of magnitude higher and more expensive.

Table: Volume of Water Captured in the Church Creek Headwaters Restoration – A Comparison of RSC with Conventional BMPs

Restoration Practice	Amount of water stored per installation (cf)	# of installations required
Church Creek Headwaters RSC	91, 476	1
Bioretention Areas[a]	150	610
Living roofs[b]	125	732
Rain Barrels[c]	6.7	13,758

The Anne Arundel County Department of Public Works (DPW) has determined through extensive cost/benefit analyses that the restoration of tidal boundary streams and wetlands using regenerative stormwater conveyance is the most cost effective storm water BMP for reducing sediment and nutrient loads to tidewater, and is also pursuing a restoration strategy based on those findings. For areas smaller than 1-acre, simple bioretention practices may make economic sense, but in the case of treating larger drainage areas, RSCs are far more cost effective.[14] In fact, DPW has declared its intention to make stream restoration using RSCs one of its primary tools to achieve its TMDL reduction goals. RSC will be used both in new development and retrofit opportunities. Their interest in promoting the RSC design has to do with the fact that it is the only BMP to date that can be used inside natural channels without disrupting the

[a] Assumes each practice is 150 sf with 1’ of storage capacity.
[b] Assumes 1,500 sf of roof with 1” of storage capacity.
[c] Assumes 50 gallons of storage.

adjacent natural ecosystem. Its lack of structural disruption and its ability to reconnect the streams with their floodplains makes it an extremely viable technique in the coastal plain physiographic province and erosive soils of Anne Arundel County.

In summary:

- RSC technology is based on the premise that the longer we hold water on our landscape, the better it will be for aquatic and riparian ecosystems. As a result, adjacent floodplains, riparian habitats and associated depressions are more frequently hydrated, extending the temporal and spatial distribution of saturated soils and shallow inundation, extending wetland hydrology, supporting the chemistry of hydric soils, and delivering ecological and social benefits. **The result of these restoration actions will have a direct impact on tidal waters directly below the restoration site.**

- Retaining water on the landscape in this fashion represents an integration of aquatic, wetland and upland habitats that occurs naturally in undisturbed landscapes and needs to be our paradigm for providing high quality riparian and aquatic restoration in the future.

- Restoration of streams and wetlands, especially at the boundary of the tidal area, directly improves the quality of the water transported downstream. These Regenerative Stormwater Conveyance technologies such as Coastal Plain Outfalls and Sand Seepage Wetlands evolved from efforts to restore early stream ecosystems and then use those highly efficient systems as a means for controlling stormwater as well as filtering the pollutants bound in those stormwater pulses by re-introducing wetlands and indigenous ecosystems.

- The projects which use RSC methodology are generally a win-win arrangement, since they are less expensive, provide environmental benefits, are less difficult to permit, and create an aesthetically pleasing environment. This approach has been used to solve other similar problems in Anne Arundel County. The materials used are, to the extent possible, taken from the local region, contributing to the cost effectiveness of the technology. The vegetative material planting along the channel and in the bottoms of pools provides an important contribution to project sustainability by tying the system together and increasing the nutrient load uptake. It is anticipated that unlike the practices of the last century, these innovative practices will not cause more problems than they solve, since once established, these systems are designed to restore the integrity of natural ecosystems and be self-maintaining.

- RSC have performed significantly more effectively at pollution processing than un-restored "reference" reaches or bank stabilization projects.[15]

- Working further down in the landscape, near the tidal boundary, in particular, with restoration methods such as RSC presents the best opportunity to capture and treat the largest amount of the watershed[16], cap "legacy sediments" and return stream valley floodplains to a configuration that mimics their pre-colonial configuration[17], and creates abundant non-tidal wetland habitat for anadromous fish, amphibians, and waterfowl.

This RSC "Fact Sheet" was assembled cooperatively by the South River Federation and the Severn Riverkeeper Program. For more information, contact:

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