BOLIN CREEK WATERSHED RESTORATION INITIATIVE

FINAL REPORT

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Town of Chapel Hill, NC, Sponsor

Trish D'Arconte, Project Coordinator and Author

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In the following report, "project members", "team members", and "we" generally refers to the Chapel Hill, Carrboro, and NC State University staff that were involved most frequently in implementation. This includes Randy Dodd of Carrboro; Trish D'Arconte, Wendy Smith, and Dave Almond of Chapel Hill; Paul Clark of NC DWQ; and Greg Jennings and Zan Price of NCSU.

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LIST OF ABBREVIATIONS

ASSHTO	American Association of State Highway and Transportation Officials
BMP	Best Management Practice (in this report, those used for stormwater)
CIP	Capital Improvements Project
EPA	Environmental Protection Agency
GIS	Geographic Information System
LID	Low Impact Development
MS4	Municipal Separate Storm Sewer System
NC DENR	North Carolina Department of Environment and Natural Resources
NC DOT	North Carolina Department of Transportation
NC DWQ	North Carolina Division of Water Quality
NC EEP	North Carolina Ecosystem Enhancement Program
NCSU	North Carolina State University
NPDES	National Pollutant Discharge Elimination System
NWIS	National Water Information System
OWASA	Orange Water and Sewer Authority
QAPP	Quality Assurance Program Plan
SCM	Stormwater Control Measure
SVAP	Stream Visual Assessment Protocol
TJCOG	Triangle J Council of Governments
TMDL	Total Maximum Daily Load
UNC	University of North Carolina
URL	Uniform Resource Locator (i.e. web address)
USGS	United States Geological Survey
WECO	Watershed Education for Communities and Officials

EXECUTIVE SUMMARY

Bolin Creek is a fourth order stream flowing through the Towns of Carrboro and Chapel Hill, NC. It is impaired for biological integrity along approximately half its length. Causes of impairment include flashy storm flows, low base flows, stormwater runoff, stream channel scour and erosion, poor habitat quality, and sedimentation. The project team anticipates that through improving physical and chemical stream conditions in Bolin Creek and its tributaries, this will encourage the recolonization and diversification of the stream macroinvertebrate community in Bolin Creek, and thence restore full uses to this impaired stream.

This 319-funded project is expected to be the first of several projects aimed at addressing the complex set of urban stressors impacting Bolin Creek, with the ultimate goal of improving Bolin Creek's biological health. To work towards this goal, the objectives of this project were to:

1. Develop a nine-element Watershed Restoration Plan with significant stakeholder input.
2. Analyze multiple alternative stormwater management methods and costs for a piped urban stream in Chapel Hill (Tanyard Branch), to determine which methods are sufficient to protect the channel downstream from erosion.
3. Install stormwater and erosion control for a tributary to Mill Race in Chapel Hill, repair of two severe gullies, and stream stabilization along an adjacent sanitary sewer line.
4. Restoration of a pair of small streams along a park in Carrboro (Baldwin Park), including energy-dissipating BMPs and riparian enhancement.

Project success was based on reducing effects of stormwater runoff at the implementation sites, determination of feasible alternatives and costs for stormwater retrofit in a dense urban area, and public education about Bolin Creek, its sources of impairment, and methods for its restoration.

The Watershed Restoration Plan was completed after considerable interaction with stakeholders, including a detailed survey of public attitudes towards Bolin Creek. In addition to this public input, the process of implementing the other elements of this project has significantly informed and improved the development of the Plan. This was further supported by the completion of the Tanyard Branch Stormwater Alternatives Analysis, which helped us better understand the comparative benefits and subwatershed needs of distributed versus regional stormwater management approaches in a densely urban area. The analysis has formed the basis of Chapel Hill's implementation steps for restoration of the Bolin Creek Watershed.

Our original restoration and retrofit plans and designs changed in response to landowner cooperation and detailed information about conditions at Baldwin Park and Mill Race tributary. Two streams bracketing Carrboro's Baldwin Park underwent restoration and riparian enhancement, and a bioretention basin was installed to divert street runoff from entering the stream directly. Severe channel erosion has been successfully repaired and riparian forest is now regenerating at this location. This project is very visible to the public and has served very well for public education and outreach. Difficulties with implementing the project elements for the Mill Race tributary meant finding alternative locations that would meet the same water quality benefits. Four alternative project elements were installed on Chapel Hill properties near areas of public foot traffic: restoration of a steep, badly eroded stream (Trinity Court); installation of two bioretention basins (Mitchell Lane and Dickerson Court) treating parking lot and street runoff; and installation of permeable grass pavers to replace a compacted gravel fire lane (Hargraves Community Center). These alternative locations provide much better public education opportunities than the original Mill Race tributary project elements, and provided outreach to staff in other Town Departments.

1. INTRODUCTION AND BACKGROUND

1.1 BOLIN CREEK WATERSHED

Bolin Creek is a fourth order stream draining an area of about 7800 acres, or about 12 square miles. It starts in unincorporated parts of Orange County, NC and flows mostly southeast into first the Town of Carrboro and then into the Town of Chapel Hill. It is one of the major streams draining southern Orange County, as it drains 12 square miles in carving a path through the heart of Carrboro and Chapel Hill (Figure 1). Moving downstream, the watershed transitions from rural to suburban to urban.

When it reaches the confluence with Booker Creek in Chapel Hill the combined streams become known as Little Creek. Little Creek is one of the many streams included in the drainage area known as the "Upper New Hope Arm" of Jordan Lake, which also includes Morgan Creek, New Hope Creek, Northeast Creek, and Third Fork Creek. The Bolin Creek Watershed is shown in Figure X in relation to the drainage area for the Upper New Hope Arm of Jordan Lake, and the combined drainage areas for Little Creek and Morgan Creek.

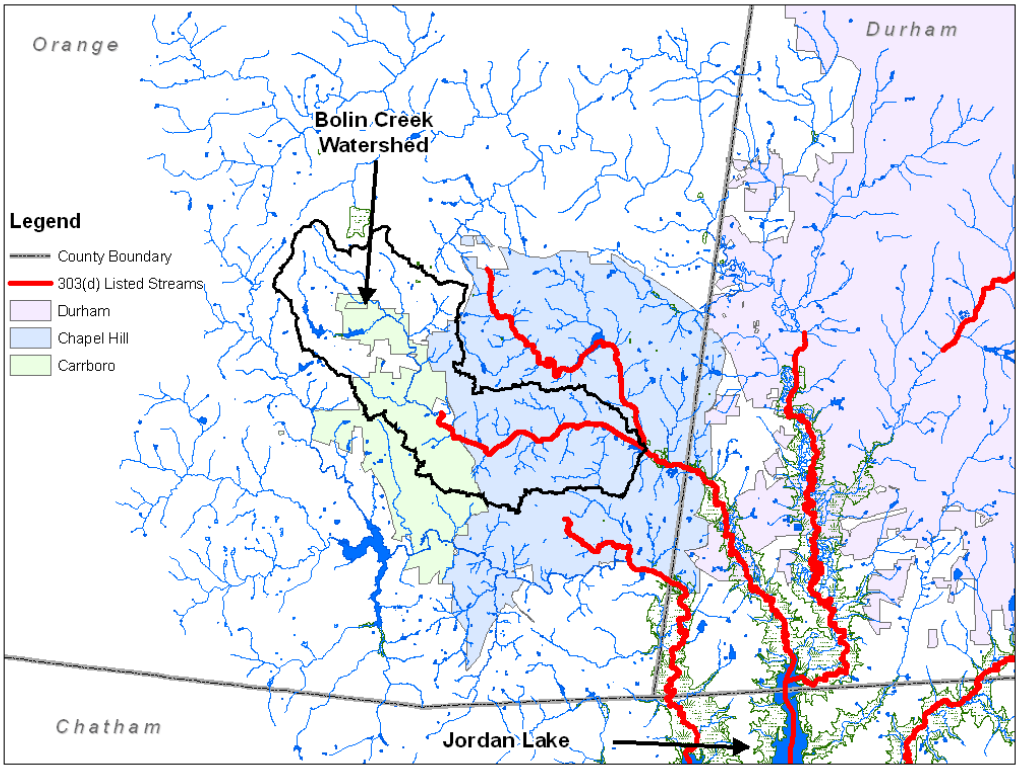


Figure 1: Location of Bolin Creek Watershed

1.2 WATERSHED RESTORATION BACKGROUND

The Division of Water Quality has conducted several rounds of targeted macroinvertebrate collection to better track changing ecological conditions in Bolin Creek. Bolin Creek was found to be meeting its intended uses in 1986, but became impaired by the next round of monitoring in 1993. The length of impaired stream has only increased

since then. As of 2012, Bolin Creek continues to be impaired for biological integrity, the impairment starting about halfway through Carrboro and extending through Chapel Hill. It exhibits a progressive decline in watershed functional health from upstream to downstream, mirroring the increases in land use intensity as you move downstream.

The local community has a fond relationship with the creek, and at the same time, a growing body of evidence over the past several decades has documented that the aquatic life of Bolin Creek and its tributaries is threatened and impaired from the human activity occurring within its watershed. The causes of the impairment are both simple—land disturbance and development—and complex: alterations in hydrology, erosion and sedimentation, introduction of toxic contaminants and other pollutants, and habitat disruption. The bottom line is that the concern is also an opportunity for restoring the creek to a healthier status.

To investigate potential stressors and causes of impairment in the Creek, assessments of the watershed were conducted in 2002 and 2003 by the Watershed Assessment Restoration Program. The study indicated that several effects of urbanization, including habitat degradation, riparian degradation, channel incision, high embeddedness, low base flow, and toxicity, are believed to be the primary factors stressing this watershed. Most of these problems were more prominent as one moves downstream in the watershed. Other potential stressors included temperature (ranges and extremes), high biochemical oxygen demand, nutrients, and cross-connections or leaks from sanitary sewer lines. No streamflow data were taken as part of this study, but scour and related morphological and hydrological modifications were considered a primary contributor to the aforementioned stressors. The study recommended that feasible and cost-effective stormwater retrofit projects be implemented to mitigate the hydrologic and potential toxic effects of existing development.

In 2003 through 2004, the NC Ecosystem Enhancement Program (then Wetlands Restoration Program) undertook a Local Watershed Planning Initiative for the Morgan and Little Creek watersheds. Although the resulting NC EEP report made some recommendations for preservation opportunities, stream restoration projects, and potential stormwater management measure retrofit sites, these were selected based on the particular requirements of the EEP. These requirements are based on the use of the NC EEP as a mitigation bank for the state's Department of Transportation, and selected projects did not target specific identified problem areas or stressors.

Staff from the Carrboro Planning Department, Chapel Hill Stormwater Management Division, the North Carolina Department of Environment and Natural Resources (NC DENR), and the US Environmental Protection Agency (EPA) began meeting in April 2006. Together these organizations formed the Bolin Creek Watershed Restoration Team (BCWRT) to participate in EPA's Watershed Restoration Program in restoring and enhancing Bolin Creek and its tributaries. The Bolin Creek Watershed Restoration Initiative was started to provide organization and support for the Towns of Chapel Hill and Carrboro to participate in EPA's Watershed Restoration Program.

The primary goal of the Initiative is to restore the biological health of the Bolin Creek Watershed. The Initiative focuses on hydrologic modification and habitat degradation by addressing some of the primary causes of these stressors including streambank and streambed erosion, disconnection from stream floodplains, sedimentation, scour, thin or absent forested riparian buffers, the "flashy" nature of urban stream hydrographs, very low base flow, the effects of stream crossings, and purposeful modifications such as channelization and desnagging. Water quality issues related to toxins are expected to be addressed separately by the Towns' respective Illicit Discharge Detection and Elimination programs as part of their Nonpoint Source Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permits.

In 2007, the Bolin Creek Watershed Restoration Team decided a geomorphological analysis of the watershed with would identify projects more likely to have measurable results and directly address the Team's goal. The Team

applied for and was awarded a Clean Water Management Trust Fund (CWMTF) stormwater mini-grant. These funds were used to contract with EarthTech to conduct a geomorphological analysis including surveying the entire watershed and walking the majority of the intermittent and perennial streams in the watershed. During this survey, potential stormwater management measures and stream restoration sites targeted to the worst problems were identified, with a greater focus on the former. This report can be viewed online:

> Carrboro webpage URL for Earth Tech report:
> http://www.ci.carrboro.nc.us/pzi/Env/PDFs/BolinCreek_Report_final_11-6-07.pdf
> Chapel webpage URL for Earth Tech report and related information:
> http://www.townofchapelhill.org/index.aspx?page=1942

EarthTech's report served as an initial guide in the selection of projects for future 319 grant applications. The restoration team has focused its efforts within individual subwatersheds of Bolin Creek in order to concentrate hydrological, morphological, and biological improvements that can be most readily detected as measurable results. The projects funded by this 319 grant are based on this concentrated approach.

1.3 PROJECT OBJECTIVES AND GRANT SPECIFICS

The overarching goal of all Bolin Creek Watershed Restoration Team projects is to restore the aquatic health and water resource quality of Bolin Creek and its tributaries. The Team anticipates that through improving physical and chemical stream conditions in Bolin Creek and its tributaries, this will encourage the recolonization and diversification of the stream macroinvertebrate community in Bolin Creek, and thence restore full uses to this impaired stream. To work towards this goal, the objectives of the 319-funded project described and reviewed in this report were to:

1. Address stream erosion, invasive species, missing riparian forest, and uncontrolled stormwater along a pair of small streams at the mutual boundary of Carrboro and Chapel Hill (known as the "Baldwin Park project").
2. Address stream erosion, invasive species, missing riparian forest, and repair two large gullies in a steep valley in Chapel Hill (known as the "Mill Race tributary project").
3. Conduct an analysis of stormwater management methods for a heavily-urbanized stream suffering severe erosion, to determine whether there are alternatives to installing a wet retention pond in-line on a perennial stream, in support of future downstream restoration.
4. Create an EPA 9-element Watershed Restoration Plan to guide future planning of stream restoration and stormwater retrofit projects across the Bolin Creek Watershed and support future grant applications to fund these projects.

Non-point pollution sources to be addressed included urban runoff/stormwater, habitat modification, hydrologic modification, excess nitrogen excess phosphorus, sedimentation, low dissolved oxygen, and temperature.

Of critical importance was the selection of project areas and restoration methods that were likely to demonstrate improvement within the grant period. Achieving measurable results within the grant period was an objective that was very strongly impressed upon project staff as important to all 319 projects. This is a challenge, given the time required for streams to demonstrate geomorphic stability after restoration construction, and the more extensive time required for stream biological communities to respond to favorable conditions. This is in comparison to the short, three-year grant period for 319 grants, which includes the time set aside for construction when no improvement would be expected.

Project objectives for the Mill Race tributary changed when project staff failed to secure permission from property owners adjacent to the project areas for access. In this very steep terrain access for heavy equipment was severely limited. Project staff identified other areas where projects would meet similar objectives of erosion control and stormwater management at four sites in Chapel Hill: Trinity Court, two locations at Hargraves Community Center, and Dickerson Court. These replacement projects are described in detail under the Mill Race Tributary sections of this report.

ESTIMATES OF LOAD REDUCTIONS

Based on the estimates of the Earth Tech study from which the restoration activities were selected, Baldwin Park stream restoration was proposed to reduce soil erosion by 2400 tons per year, equivalent to reducing export of nitrogen by 4800 pounds per year and phosphorus by 2400 pounds per year (for a 1000 foot segment – extrapolated from a smaller segment calculation). Repair of the two severe gullies at the Mill Race tributary stream was proposed to reduce soil erosion by 1400 tons per year, equivalent to reducing export of nitrogen by 2800 pounds per year and phosphorus by 1400 pounds per year. The load reduction was calculated using the BANCS model (Bank Height Erosion Index combined with Near-Bank Stress).

Because stormwater BMPs for Baldwin Park and stabilization of Mill Race tributary's streambanks were recommended by NCSU after projects were selected from the Earth Tech report, the Team did not have the expertise to calculate the expected load reductions for sediment (eroded soil), nitrogen, or phosphorus.

1.4 DETAILED PROJECT PROPOSALS

BALDWIN PARK STREAM RESTORATION AND STORMWATER RETROFIT

Baldwin Park is a small urban "pocket park" on the boundary between Carrboro and Chapel Hill. A small stream traversing the park, flowing into Tanyard Branch (one of the major, highly-urbanized tributaries of Bolin Creek), it was highlighted as one of the 32 high priority projects in the Earth Tech report. The upper portion of the stream has been put into a pipe, and street runoff drains directly to the stream from a curb inlet. Site reconnaissance identified a tributary to this stream to the east that had scour at the upper end where runoff drains from another street. Both tributaries had instream scour and erosion, poor instream habitat and morphology, minimal to no vegetation on the banks except close-cut grass (Carrboro side) and a few trees (Chapel Hill side) with the exception of the confluence area that was almost entirely Chinese privet.

The conceptual plan for this project was a combination of the Earth Tech recommendations and further additions recommended by NCSU's Water Quality Group. Stream restoration, including changes in channel cross-section, reducing bank slopes, creating a bankfull bench, and improving riffle and pool habitats were proposed for about 300 feet of each of the tributaries. Stream enhancement (vegetating the banks) was proposed for an additional 400 feet of the Chapel Hill tributary. 3 BMPs for handling street runoff would be placed at the upper ends of the streams to prevent degradation of the restored channels. See Appendix 1 for the concept drawings for work proposed at Baldwin Park.

MILL RACE TRIBUTARY STREAM EROSION CONTROL AND GULLY REPAIR

Mill Race is a major tributary of Bolin Creek draining a portion of the Historic District of Chapel Hill. This area is densely urban and largely built-out, rugged with a shallow depth to bedrock, has piped springs and convoluted

storm drainage networks, and sanitary sewer lines running down most stream valleys, with streams pushed against the valley walls. A large tributary to Mill Race was found to have two (later found to be three) severely-eroded gullies, one of which was highlighted as one of the 32 high priority projects in the Earth Tech report.

Further site reconnaissance found the following: a) streambed scour/incision and deposition of the pea-gravel/sand mix (used for sidewalks in the Historic District) below a stormwater outfall at the top of the stream, b) a sanitary sewer line crossing the stream near the bottom of the subwatershed which is being undermined, and c) along the length of the stream a lack of bank vegetation, bank collapse, and heavy instream deposition of "Chapel Hill gravel" (the aforementioned pea-gravel/sand mix) due to the proximity of a sanitary sewer line to the stream and the apparent use of Chapel Hill gravel as fill material to flatten out the easement for vehicle access. (The native soil in this area is a very fine silt-clay, the apparent native stream bed material is boulders and bedrock. This is typical for this area of Town.) Kudzu had also infested the middle portions of the stream valley and was pulling down the tree canopy.

The conceptual plan for this project called for repair of the gullies by adding pipe to the existing stormwater outfalls and bringing the runoff to the bottom of hill and using a BMP to dissipate energy and allow infiltration. The outfall at the top of the subwatershed was to be retrofitted to reduce scour, permeable pavers (and other methods) used to replace the gravel sidewalks in that block to reduce the deposition of sand and gravel in the stream, correcting the undermining of the sanitary sewer crossing (possibly by installation of step-pools), and treatment of the parallel-running sanitary sewer easement to stabilize the streambanks and reduce erosion. See Appendix 2 for the concept drawings for work proposed on the tributary to Mill Race.

ANALYSIS OF STORMWATER MANAGEMENT ALTERNATIVES FOR TANYARD BRANCH

One of the high-priority projects identified by Earth Tech was the bank reshaping, stabilization, and riparian reforesting of an upper segment of Tanyard Branch. By Earth Tech's estimates this deeply incised and severely eroding stream segment contributes over 1900 tons of sediment per year to the Bolin stream system. Further site reconnaissance found potential conflicts with a nearby sanitary sewer line and an existing greenway trail. In addition, Chapel Hill staff were aware of significant erosion occurring upstream of this site just below a large stormwater outfall. The area draining to this outfall is approximately 98% impervious surface (all downtown Chapel Hill), and includes a historically-known spring that has since been piped. Staff concluded (and have observed) that the energy from this drainage could be sufficient to severely degrade any stream restoration or bank stabilization that may be undertaken downstream.

In order to address this in advance of future downstream restoration, Chapel Hill staff inquired with EPA about the use of an in-line BMP to control the flow and volume from this combined spring-stormwater system. Because it would be placed along a perennial stream it would need to meet requirements for 401/404 certification. The primary requirement for such certification would be an analysis of alternatives for the management of runoff flow and volume in this subwatershed, using such methods as cisterns, green roofs, underground storage, etc. that would be appropriate for high-density urban situations, and comparing the costs for implementation of the needed amount of each BMP type to the cost of an in-line BMP at the stormwater outfall.

DEVELOP A WATERSHED RESTORATION PLAN

A comprehensive, coherent watershed restoration plan was suggested as important for successfully winning grant applications for future restoration projects. The Team agreed to develop a nine-element EPA watershed restoration plan including:

1. An information/education component to enhance public understanding of the project and increase public participation.
2. A monitoring component to evaluate the effectiveness of the implementation efforts over time measured against the criteria.
3. An identification of the causes (stressors) and sources or groups of similar sources that need to be controlled to achieve pollutant load reductions estimated in the watershed.
4. An estimate of the improvements associated with the chosen management measures.
5. A description of the measures that will need to be implemented to achieve load reductions as well as to achieve other watershed goals identified in the watershed based plan.
6. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards.
7. An estimate of the amount of technical and financial assistance needed, associated costs and or sources, and authorities that will be relied upon, to implement the plan.
8. A schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious.
9. A description of interim, measurable milestones to track progress in achieving restoration goals.

The aforementioned NC EEP, NC DWQ, and Earth Tech watershed studies already contain a considerable amount of information that could be compiled to meet the nine required elements of a watershed restoration plan. The Bolin Creek Watershed Restoration Plan was proposed to focus on the hydrologically-related stressors identified in these studies, but would also address other water quality issues and develop appropriate solutions and project locations for those solutions.

In addition to the 9 elements, it was proposed to include an analysis of development scenarios, a geodatabase of identified problems and solutions, evaluate local ordinances and capabilities with regard to supporting or inhibiting restoration and preservation efforts, examine future development scenarios and determine Town ordinance and planning needs for protection and preservation of Bolin Creek and its tributaries, catalog other activities in the basin, and ultimately be coordinated with the Towns' Comprehensive Plans and other specific plans such as the Greenways Plan. It was anticipated that detailed studies of individual subwatersheds may be needed to refine the plan where there are complex conditions identified.

1.5 PROPOSED MONITORING

MONITORING GOALS AND APPROACH

In order to demonstrate measurable improvement in these subwatersheds, monitoring of individual project locations around the Baldwin Park stream restoration/BMP sites and sites on the tributary to Mill Race was proposed. Sediment mobilization, water quality and field parameters, stability/quality of stream banks and instream features and habitats, water temperature, dissolved oxygen, and survivorship of desired riparian vegetation were identified as indicators of success. Monitoring was to commence when a Quality Assurance Program Plan had been developed, with the assistance of the NCSU Water Quality Group, at the beginning of the contract period to obtain sufficient data to properly compare pre- and post- conditions at these sites.

COMPLIMENTARY MONITORING

The Towns of Carrboro and Chapel Hill continued ongoing monitoring activities in other parts of the Bolin Creek watershed that are supportive of documentation of measurable improvement, can be used for documenting improvement at future project sites, and provide valuable diagnostic information for addressing impairments in other tributaries of Bolin Creek. Chapel Hill collected base flow water chemistry samples at three points along the mainstem of Bolin Creek from1994 to 2009. Parameters included suspended sediment, turbidity, nitrogen series, phosphorus, fecal coliform, metals, and field parameters. Discharge measurement is not conducted yet but is planned in the near future. Carrboro has conducted, and Chapel Hill proposed to start, annual macroinvertebrate collection at four points along the mainstem of Bolin Creek.

Complimentary to and independent of the Bolin Creek watershed restoration efforts, the Towns had begun conducting stream walks and monitoring activities as part of their NPDES Phase 2 permits to address illicit discharges and connections. The areas that Bolin Creek flows through are both the oldest and most dense parts of both Chapel Hill and Carrboro, and thus are likely to have much higher priority in their respective IDDE programs. It was expected that these activities would address the issue of toxins as contributing stressors as identified in the 2003 Biological Assessment report.

1.6 PROPOSED PUBLIC INVOLVEMENT

The project proposed several ways that project staff would interact with and involve the public in implementation:

- Direct consultation with the Historic District Commission to address the use of highly erodible pea-gravel/sand for sidewalks, and come up with acceptable alternatives or treatments.
- Direct consultation with the Orange Water and Sewer Authority regarding erosion treatments of their streamside sanitary sewer lines.
- Direct consultation with local residents and property owners (and/or their landscapers) to vegetate the projects in a way that is aesthetically pleasing, sufficiently easy to maintain, and meets concerns regarding neighborhood crime (i.e. hiding places), in addition to the usual enhancement goals of bank stability, shade, and native species.
- Following construction we would offer Riparian Plant Maintenance Workshops – intended to allow property owners to learn how to care for the riparian plants they have selected (plant selection by owners helps guarantee care and acceptance) and would serve as prototype for a Stream Steward Program involving riparian planting and maintenance. This may extend to possible targeted eradication of invasive species and subsequent monitoring will also likely involve local garden clubs, the North Carolina Botanical Garden, and Orange County's Master Gardeners.
- Involvement of neighborhood associations local to the projects.
- Construction of two rain gardens in public spaces (in Carrboro) with educational signage.
- "Ribbon cutting" ceremonies involving local officials and the media to publicly present completed projects.
- Educational signage for Baldwin Park.
- Creating a Bolin Creek Watershed Restoration Initiative webpage and email list server to keep interested citizens informed of project status, and offer a venue for continued conversation with Chapel Hill and Carrboro staff.
- Involvement of Friends of Bolin Creek volunteers in collecting water quality samples, annual stream morphology and vegetation monitoring and replenishment.

- Development of the Watershed Restoration Plan was expected to involve a considerable number and variety of stakeholder groups, from Town Departments, UNC-Chapel Hill, Orange Water and Sewer Authority (OWASA), the Federal Railroad Administration, property-owner and neighborhood associations, among others.
- One or two "kickoff" public informational meetings at the beginning of the contract period to update citizens on status of Bolin Creek Watershed effort as well as to gain valuable insight when developing the nine-element watershed restoration plan.

1.7 PROJECT MEASURES OF SUCCESS

Some of the management measures planned for this project were designed to reduce hydrologic impacts of existing developed areas in the watershed. These practices were expected to reduce stormwater volumes and peaks, thus reducing streambank erosion, streambed aggregation and degradation, etc. Other management measures planned for this project were related to improving water quality, particularly in stormwater flows. These water quality management measures were expected to generate some improvements specifically addressing the hydromodification, sediment transport, temperature, and dissolved oxygen stressors.

It was expected that significant improvement in benthic communities is likely to take longer than the three-year duration of this project. The very small size of the project streams also limits the probable maximum diversity that can be expected. However, reducing the impact of these stressors was expected to lead to recovery of benthic communities in the watershed.

Specific improvements expected from this multi-year set of projects include:

- Reduced export of sediment from both Baldwin Park and Mill Race tributary watersheds
- Improved instream habitat for macroinvertebrates
- Reduced levels of nitrogen and phosphorus
- Reduced maximum temperatures in stormwater
- Increased environmental interest and involvement in a lower-income population
- General education of the Towns' populations regarding stream functions, health, protection, restoration
- Demonstration to the local environmentally-oriented population of the Towns' commitment to environmental protection and sustainability
- An alternatives analysis that enables watershed restoration projects with a higher probability of success in a high-density urban area

Possible side effects:

- Increased rainfall infiltration to groundwater throughout the watershed, with the aim to increase the extremely low base flows identified as a potential stressor
- Provide an example of successful watershed restoration to be applied to other officially impaired (and unclassified but imperiled) waterbodies and their watersheds in the Chapel Hill – Carrboro area
- Broader use of Low Impact Development (LID), redevelopment that reduces urban hydrologic effects, and increased environmental sustainability of public and private landowner (and resident) activities

2. METHODS AND EXECUTION

2.1 BRIEF REVIEW OF DELIVERABLES

1. Nine-element Watershed Restoration Plan, integrated with other Town Plans.

The Watershed Restoration Plan has recently been completed. However, integration with other Chapel Hill plans has proven challenging because of the large number of plans, active revisions going on, and competition between plans for the attention of Senior Management for review and implementation. Nevertheless, the Watershed Restoration plan has been integrated with the Chapel Hill Stormwater Management Division's draft Stormwater Master Plan. Watershed restoration activities are part of Chapel Hill's larger Capital Improvements Projects (CIP), and a CIP prioritization scheme is currently in review. This part of the project is addressed in further detail in the following section.

2. Alternatives analysis for inline and/or watershed-wide runoff management in upper Tanyard Branch.

This project was an excellent success, very useful for education of other Town staff and for planning future stormwater retrofitting and stream restoration in the most heavily-developed parts of Chapel Hill. This part of the project is addressed in detail in the following section, and the study is attached as Appendix 3.

3. Quarterly reports and final report.

Quarterly reports were prepared for 15 quarters, plus the final report. Chapel Hill, Carrboro, and NCSU staff all contributed to each report.

4. Construction of three BMPs and stream restoration/enhancement (approximately 1000 feet) in Baldwin Park with signage.

Stream restoration and riparian enhancement were completed along two forks of a stream that bracket Baldwin Park in Carrboro, and on the border with Chapel Hill. A bioretention and an experimental sanitary sewer stream ford crossing were installed at Baldwin Park. This part of the project is addressed in further detail in the following section. Photos and plans are presented in Appendix 1.

5. Repair of two severe gullies, installation of associated BMPs, a BMP reducing sidewalk erosion in Historic District, and treatment reducing streambank erosion along sanitary sewer easement and crossing.

After extensive outreach to property owners through mailings, phone calls, guided stream walks, and invitations to meetings to present engineering design and specifics, all Mill Race project elements had to be dropped due to the lack of cooperation of three property owners (out of 50+) whose properties were situated at critical access locations, which prevented crossing the properties to access other areas in this very steep-sided valley. Photos and plans are presented in Appendix 2.

Mill Race project elements were replaced by a stream restoration at Trinity Court, installation of a bioretention basin at Hargraves Community Center (Mitchell Lane), installation of a bioretention basin at Dickerson Court, and installation of permeable grass-pavers on a fire lane at Hargraves. This part of the project is addressed in further

detail in the following section. Project information and photos are presented in Appendices 4, 5, 6, and 7, respectively.

6. Two Riparian Plant Maintenance workshops.

Carrboro staff coordinated a workshop attended by about a dozen volunteers on riparian plants at Baldwin Park. A similar workshop organized by Chapel Hill for Chapel Hill residents was not well-attended.

A guided project walkthrough and review were held for one of the projects used to replace the Mill Race tributary work (Trinity Court), and was attended by staff from both Towns and OWASA. Carrboro and NCSU staff held training for Carrboro employees to learn how to care for newly-planted riparian zones and for the rain gardens installed in Carrboro.

7. Two "ribbon-cutting" ceremonies with local government officials.

A very-well-attended dedication ceremony was held at Baldwin Park, where the mayors of the two Towns planted a tree in the bioretention area and read a joint proclamation. Pictures and other information related to the event can be found in Appendix 1.

At the request of the Friends of Bolin Creek, the Towns participated in organization of, and presentation at, a half-day Symposium "Can We Heal Our Waterways?" along with presenters from NC DWQ and other organizations. This symposium complemented the Situation Assessment of public attitudes conducted by NCSU's Watershed Education for Communities and Officials (WECO) to address stakeholder vision and collaboration, as described below in the section on development of the Watershed Restoration Plan.

8. Installation of two Carrboro rain gardens (bioretention basins) with signage.

Carrboro staff installed a demonstration bioretention basin by an entrance to Carrboro's Town Hall, and included a brochure box for rain garden handouts. Carrboro staff also contracted the installation of a bioretention basin in a residential subdivision (Tramore West), and provided outreach to the Homeowner's Association. Photos, brochures, and plans can be found in Appendix 8.

9. Creation of a geodatabase containing locations and information on identified stream water quality, morphology, or other problems, and locations and information on proposed stream restoration and stormwater BMP projects.

While systematically storing stream "problem" information in a geodatabase proved to be challenging (problems come in all shapes and sizes and were difficult to represent in anything other than geographic information system (GIS) annotation and stream segment assessment forms), systematically collecting and storing "project" information in a geodatabase has proven very helpful. This part of the project is addressed in further detail in the following section. The list of the project GIS feature class attributes can be found in Appendix 9.

10. Regular updates from staff to public email listserver and webpage.

Public updates throughout the grant period were done through Bolin Creek webpages, each Town hosting its own version for local control. These webpages are still active and not restricted to grant-specific activities; new links and information are posted as we find new studies (local universities are quite active in our area!), present results of new data collection, and conduct other activities in the watershed.

Carrboro's Bolin Creek webpage URL: http://www.ci.carrboro.nc.us/pzi/Env/Water/bcwrt.htm

Chapel Hill's Bolin Creek webpage URL: http://www.townofchapelhill.org/index.aspx?page=1757

Public email listserve updates from Chapel Hill were done the first year and a half as project steps were completed. These were advertised at local events, and we handed out postcards with subscription information. Subsequently the Town's Public Information approach was changed to compile projects and activities of the Stormwater Management Division into a single listserve. We felt it inappropriate to automatically subscribe previous listserve members to this new, much more broadly-themed listserve. In the last year, Chapel Hill staff created an informal, targeted email list of stakeholders (mostly Town staff) for biweekly updates of project details and steps.

In addition to updating their Bolin Creek project webpage, Carrboro activities included posting information on the Town's electronic message board about the project and providing public updates through Board of Aldermen agenda items.

11. Installation of two pressure transducers to measure stream stage and establishment of rating curves for each site.

Pressure transducers for measuring water level were installed as part of the ISCO stormwater sample collecting equipment. Implementation of monitoring is described below, and results of monitoring at Baldwin Park and Mill Race tributary are reviewed in full in the Results and Conclusions Chapter.

12. Installation of two automated storm samplers to collect "first flush" and composite storm samples.

ISCO stormwater sample collectors were installed at Baldwin Park at Mill Race tributary, collecting monthly samples and composite storm samples. After investigation of nitrogen transport in stormflow, it was determined "first flush" was inappropriate for evaluation. Implementation of monitoring is described below, and results of monitoring at Baldwin Park and Mill Race tributary are reviewed in full in the Results and Conclusions Chapter.

13. Pre- and post-construction morphological, erosion, and vegetation survivorship monitoring data for the two subwatersheds.

"As-built" drawings and plant lists were not created by the contractors for any of the riparian enhancements and bioretention plantings, making formal monitoring of vegetation survival difficult. Instead, survival has been monitored informally, with replanting or filling-in occurring as needed. Morphological and erosion monitoring turned out to be inappropriate given the construction techniques used. Changes to this monitoring and reasoning are described below.

14. 72 (36 for each site) monthly base flow and 240 (120 for each site) storm flow samples (approximately 20 storms per year, 2 samples per storm) analyzed for suspended sediment, nitrogen series, and phosphorus.

ISCO stormwater sample collectors were installed at Baldwin Park at Mill Race tributary to collect these samples. Implementation of monitoring is described below, and results of monitoring at Baldwin Park and Mill Race tributary are reviewed in full in the Results and Conclusions Chapter.

15. Continuous temperature and dissolved oxygen measurements for storms before and after project installation.

HOBO temperature probes were installed to measure temperature every 15 minutes. It was determined continuous monitoring of dissolved oxygen would be not provide useful information for the amount of effort required and amount of error likely to affect measurements, and was replaced with benthic macroinvertebrate

monitoring. Implementation of monitoring is described below, and results of monitoring at Baldwin Park and Mill Race tributary are reviewed in full in the Results and Conclusions Chapter.

2.2 IMPLEMENTATION OF SELECTED DELIVERABLES

Some project deliverables had much greater complexity and much more convoluted paths to completion than others and warrant a detailed and comprehensive description. Implementation of the following deliverables will be discussed in detail:

Development of the Watershed Restoration Plan
Development of the Problems and Projects Geodatabase
Tanyard Branch Stormwater Alternatives Analysis
Baldwin Park
Mill Race Tributary
Monitoring

DEVELOPMENT OF THE WATERSHED RESTORATION PLAN

Development of the Watershed Restoration Plan started with guidance from Paul Clark of NC DWQ (our advisor and guide throughout the process) early in the grant period. The project team members primarily involved in writing the Plan include Trish D'Arconte and Wendy Smith of Chapel Hill and Randy Dodd of Carrboro. Initially we held a thorough discussion of the nine elements of an EPA watershed restoration plan, how this may be able to replace the need for development of a Total Maximum Daily Load (TMDL) for Bolin Creek, and how this fit into NC DWQ's Use Restoration Watershed Program. We had several other watershed restoration plans to look at in creating our own, although we learned that every plan is quite unique and really only demonstrates the breadth of watershed restoration planning approaches. A general outline, a schedule for getting sections completed, and who would write which sections were drawn up.

Our initial outline, proposed writing schedule, and writing assignments, while seemingly a good idea, did not make the writing process easier or clearer. Team members had different ideas of what belonged in the plan, how to organize it, the amount to pull from pre-existing plans, and what an implementation section would look like. Thus, multiple versions of plan sections and parts of sections came into being. We expected we would have time to sort out these differences before taking the draft plan to various advisory boards, holding several public hearings, and eventually taking the plan to our governing bodies for adoption in the last year of the grant period.

We were fortunate that several studies and one significant plan had already been done for the larger area. In particular, NC EEP's Local Watershed Plan had extensive data collection, analysis, modeling, risk assessment, and project identification and ranking. A very thorough assessment of current conditions and watershed characterization was incredibly useful, but it became confusing as to how to refer back to this wonderful amount of information, yet still have our own plan that was a complete document in itself. Why rewrite a thorough watershed characterization? Why rerun a thorough analysis of stressors and sources? This uncertainty and indecision diffused writing focus and energy, and contributed to team members' different writing paths and approaches.

Early on, it was recognized that certain entities that controlled significant amounts of land or were responsible for extensive infrastructure would have a disproportionate effect on streams through current activities, which projects could be implemented and how because of how much area they "controlled," or they were likely to undertake or

fund restoration projects themselves. In the Summer of 2010 and 2011 we met with staff from the University of North Carolina (UNC), OWASA, Orange County, NC EEP, NC Division of Transportation (NC DOT), NC Cooperative Extension, and Orange County Soil and Water Conservation District, known as the Bolin Creek Technical Coordinating Committee, to update them on our progress and find out what activities they might have going on in the watershed.

The planning process became complicated in 2009 as Carrboro was creating its Greenways Plan. Generally, the two Towns have taken an approach that uses stream corridors as alternative transportation corridors in addition to being attractive for recreation. The Towns have installed several paved bicycle-pedestrian greenways and generally planned to join them together to improve transportation options for residents. These are designed to AASHTO/NC DOT specifications, being at least ten feet wide with four feet cleared on either side, on a compacted base like a small road. However, many of these are within stream riparian zones. One of the proposed Carrboro greenways was in Bolin Creek's riparian zone as it traversed UNC's Carolina North property, an area treasured by many amateur naturalists, nature-lovers, and others enjoying a walk in the woods.

Residents in the two Towns divided into two very vocal and completely opposed camps, one opposing any greenway paving along Bolin Creek because of the potential negative effects, the other insisting on a paved greenway to encourage more bicycle transportation over car travel and better access for less mobile residents. Websites were created, many letters to the editor were written, every meeting of Carrboro's Environmental Advisory Board (charged with making a greenways recommendation) had large guest attendance and some discussions became very fractious. Carrboro staff were thoroughly consumed with the advisory board meetings and trying to forge some tentative plan.

Early in 2010 this division was so severe that it actually split our local citizens' watershed group, the Friends of Bolin Creek. Their Board of Directors was dissolved and many members left, putting Friends of Bolin Creek (Friends) unofficially in the "anti-paving" camp. Remaining members reorganized and formed a Bolin Creek Watershed Plan Committee to create their own watershed planning document. The purpose as explained to project members was to make a definitive case against greenway paving along Bolin Creek. In Spring 2010 the Friends started holding many discussion and planning meetings regarding creating a watershed plan, and invited staff from the two Towns to present about our 319 projects and development of the Towns' Watershed Restoration Plan.

Our interaction with the Friends regarding its proposed watershed plan diverted Town staff from the process of developing a plan for this 319 grant. Considerable time was spent interacting with Friends of Bolin Creek members to discuss what we were preparing, who it was for, what was its purpose or use, whose goals and views were represented, who had what information for analysis, which one would take precedence (or which one would the Towns follow or implement), and who had the responsibility to create or implement it. Trying to answer the last two questions created considerable disagreement, confusion, distrust, and unwillingness to cooperate between the Towns and Friends of Bolin Creek. There was the fact that the Town of Chapel Hill was obliged to create a plan to meet the requirements of the grant contract. Members of Friends of Bolin Creek felt their organization represented the needs of the watershed and the attitudes of the general public better than local government did.

It became apparent between the earlier strong feelings of many residents regarding the Carrboro greenway, and later distrust between the Towns and Friends of Bolin Creek regarding creation of the Watershed Restoration Plan, that we no longer had a good, working relationship with the citizen watershed organization for Bolin Creek. Nor did we have a good understanding of how citizens viewed natural resources, what they considered important, and

what their environmental goals might be. We became uncertain whether we could develop a Watershed Restoration Plan that would reflect the public's values and priorities and be viewed as legitimate.

In discussing this problem with Paul Clark, we were introduced to NCSU's Watershed Education for Communities and Officials (WECO), an NC Cooperative Extension program that had helped other communities navigate differing values and ideas of their citizens regarding environmental resources. They recommended a Situation Assessment. A situation assessment is built upon a series of interviews and focus group meetings representing residents, businesses, non-profits, local and state government staff, and recreationists from a cross section of interests in a watershed or area of interest. The purpose would be to better understand the interests of watershed stakeholders and organizations, to identify opportunities to engage stakeholders in watershed restoration while meeting multiple interests, and to determine how stakeholders would like to participate in restoration efforts.

Project members considered the lack of communication so severe that a modification of the contract with NCSU to put some of the Mill Race project budget towards a Situation Assessment seemed the best way through conflict and miscommunication, to engage watershed stakeholders, and gain support creation and implementation of a Watershed Restoration Plan. The earlier plan for an extensive, yet measured public outreach process for the watershed plan was no longer workable. Attitudes and opinions had become so polarized that we feared a typical public review process for a local plan (which already can extend well over a year when there is very little that is controversial) could occupy all of the project members' time to the exclusion of completing any other elements of the project.

Stakeholders were identified, interviews were conducted, and the Situation Assessment was produced in February 2011. See Appendix 10 for the full Bolin Creek Watershed Situation Assessment, which includes methods used, stakeholders interviewed, a summary of how respondents viewed Bolin Creek and solutions to water quality problems, and specific recommendations to help the diverse stakeholders in the watershed come together to address watershed restoration.

The Situation Assessment recommendations include:

- Create a multi-organizational, collaborative watershed initiative to serve as the nexus for the watershed.
- Engage an entity with no vested interest in the watershed to coordinate and facilitate the Group (WECO, TJCOG, Dispute Settlement Center of Orange County are organizations who regularly do this work).
- Enlist a neutral party to develop and actively manage an interactive online hub for the watershed community.
- Examine how to more holistically plan and manage water resources across departments and jurisdictions.
- Increase community outreach and engagement on the Carolina North Forest Stewardship Plan.
- Investigate how to raise revenue dedicated to water quality protection and restoration, such as a stormwater utility or other mechanism.
- Continue to work together to address the landfill and groundwater contamination issues in the Rogers Road - Eubanks community.
- Convene a facilitated search for common understanding about ways to connect pedestrian and cyclist routes while also protecting and improving Bolin Creek's riparian corridor.

These results and recommendations contributed to the development of our Watershed Restoration Plan and were referenced therein.

WECO's observations of citizen attitudes did support our understanding that protecting environmental resources was important to the public, and that people perceived that Bolin Creek was impaired ecologically. Interviewees

had a wide variety of views on how to address Bolin Creek's impairments. They perceived a need for education and outreach to develop greater community awareness and clearly expressed a strong desire for more active involvement in watershed planning and management. There was agreement that the proposed Carrboro greenway has divided the community, and that there is a need to develop common natural resource goals and objectives among the many stakeholders beyond simply protecting and restoring Bolin Creek.

In preparing the Plan, we have taken these perceptions and values into consideration. We recognize the need for a neutral party to help the community navigate the many differing uses and visions, and understand that the Towns cannot act in this role. We have thus put much greater emphasis on public education and outreach (presented as "watershed stewardship"), and proposed concrete restoration implementation steps with the understanding that greater public support will be required.

Through the process of the Situation Assessment stakeholder interviews, our relationship with Friends of Bolin Creek was mended such that we were asked to help organize and were invited to speak at their half-day symposium on "Can We Heal Our Waterways?" held in February 2011. Both Carrboro and Chapel Hill staff presented at this symposium, along with presenters from DWQ and other organizations. We laid out the challenges of trying to address multiple stressors in an urban landscape, the need for broad citizen participation to effect changes in watershed conditions, and presented the recommendations of the Situation Assessment. We highlighted the recommendation for the creation of a Watershed Coordinator role as a neutral, stakeholder-supported position to help implement the other recommendations. Our slide presentations are printed in a slide-notes layout in Appendix 11.

Starting in Spring 2011 project members contacted NC EEP staff to confirm the status of their pledged $20,000 grant match activities. NC EEP had no promising projects in the watershed on the horizon, and that information contributed to our request for a contract extension. Later in the summer, when holding a meeting of the Bolin Creek Technical Coordinating Committee, we learned NC EEP was in the process of reorganization and was facing a significant change in how stream mitigation projects were implemented. They were also inquiring with the Army Corps of Engineers whether stormwater BMPs could be counted towards stream mitigation credits. Given that there were very few stream restoration opportunities in the Bolin Creek watershed in general, the potential to install BMPs as a match was something worth investigating. Through 2011 we waited to hear whether NC EEP could find a project to implement, and discussed with them the possibility of installation of a United State Geological Survey (USGS) gage as a replacement for the NC EEP match.

As 2011 progressed Chapel Hill staff became wrapped up in the challenges of implementing the Mill Race tributary projects (described below), and couldn't focus any more attention on plan development until Spring 2012. By this time we had resolved to restate some of what was in NC EEP's Local Watershed Plan in order to have a more complete narrative in the Bolin Creek Watershed Restoration Plan, rather than simply referring the reader to the Local Watershed Plan. Some Team members had already started writing a new, detailed watershed characterization and others had newer and higher resolution data to do a watershed analysis. We decided against throwing away all of this work, and instead focused on blending it together. This may have been a very good decision, simply because this more thoroughly familiarized Team members with watershed conditions, stressors, limitations, and opportunities. Combined with local knowledge of financial, technical, and social realities we were able to propose restoration steps and a timeline that were more realistic for the Towns to implement and more reflective of the fine level of understanding of stressors and sources that could be more readily targeted. The draft was reviewed by Carrboro and Chapel Hill staff and the final version sent on to Paul Clark at NC DWQ.

Between the Situation Assessment and uncertainty over the legitimacy of this planning approach (being led by the Towns, rather than another entity) in the public's eyes, we did not feel we could pursue the same broad, extensive public review that we had originally envisioned. Furthermore, Chapel Hill was still in the process of drafting its own Stormwater Master Plan for its Stormwater Management Program. It was likely that Chapel Hill advisory boards or the Town Council would want the Master Plan completed first, before accepting what would be viewed as an adjunct to the Master Plan. Project members focused simply on completing the document, completing the Plan shortly before final reporting. Integration with other Chapel Hill plans has proved challenging because of the large number of plans, active revisions going on, and competition between plans for the attention of Senior Management for review and implementation. Nevertheless, the Watershed Restoration plan has been written to be integrated with the Stormwater Management Division's draft Stormwater Master Plan. Watershed Restoration activities are part of the larger Capital Improvements Projects, and a CIP project prioritization scheme is currently in review. This part of the project is addressed in further detail in the following section.

The final Bolin Creek Watershed Restoration Plan can be found online at the following webpage URL: http://www.townofchapelhill.org/index.aspx?page=1757

We were very pleased to learn in June 2012 that NC EEP had decided to fund the installation of a USGS gage on Bolin Creek to cover their pledged match. The real-time stream discharge gage on Bolin Creek at Village Drive (Station ID 0209734440) has been installed and is in the process of calibration. Preliminary stage data are online at USGS's NWIS web interface, at URL: http://waterdata.usgs.gov/usa/nwis/uv?0209734440.

DEVELOPMENT OF THE PROBLEMS AND PROJECTS GEODATABASE

The grant application included a proposal for the development of a "problems and projects geodatabase", that is, a geographically referenced database of water quality impairments, stressors, and other problems, potential water quality improvement projects, and information about these "problems" and "projects" that could be used to rank or otherwise evaluate the priority or feasibility of them. The database started with the problems and reparative projects identified by Earth Tech in their study. Earth Tech had created streamwalk field forms for systematic data collection (see Figure 2) and had stored other, less systematic information as a GIS annotation layer that was provided to the staff of the two Towns. This information formed the base of the "problems" part of the problems and projects geodatabase.

From before the beginning of the project, Chapel Hill staff had been developing a Stormwater Master Plan to guide the activity and budgeting of the Stormwater Management Division. As the Bolin Creek project started up, early in 2009, the same town staff involved in that project were also starting detailed assessments of two other subwatersheds in Chapel Hill – Upper Booker Creek and Tracy Branch (aka Ephesus) in preparation of development of subwatershed modeling and detailed plans to be prepared by a contractor. These assessments involved stream walks and measures of channel shape and cross-section, with data collection based on the stream walks conducted as part of the Earth Tech study. Data collection methods were designed to collect stream condition information across Town that was comparable and ultimately could be stored in the same database, saving staff effort in the future. Figure 3 shows the revised stream walk data collection form that was used. These data structures have not yet been systematized in such as way to enable easy summarization in GIS attribute tables for the "problems" part of the geodatabase. This has been partly because of a need to adjust some data collection methods, but largely because of the difficulty of storing water quality problems that have a broad array of geographic presentations. Problems may present as points where pollutants enter or distinct problems are observed, sections of stream bank, stream segments, stream and bank segments, floodplain or riparian areas, and combinations of these. This makes it difficult to determine how to store all this information in a GIS layer, explaining why Earth

Tech wound up storing much of the stream walk notes as an annotation layer, which could accommodate notes and diagrams of all kinds, not dependent on a particular type of feature class. Thus, problems of all sorts are stored in a variety of GIS feature classes. In spite of this, such collection of stressors and problems all into a group of datasets was very useful to stressor analysis in the development of the Watershed Restoration Plan. So while the "problems" part of the geodatabase did not turn out as originally envisioned, the underlying goal of collecting information about stressors and sources in a group of datasets is working out well for Chapel Hill use.

STREAM NAME: UT	**DATE: 5/7/07**	**MAP SHEET #: 1**
PHOTO NUMBERS:	**LANDMARK: W. OF TALBRYN**	**SKETCH ON BACK**

GPS ID START: **DESCRIPTION:**	**GPS ID END:** **DESCRIPTION:**
RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain ☒ None ☐ Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent ☒ Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

SURROUNDING LAND USE: ☐ Industrial ☐ Commercial ☐ Urban/Residential ☒ Suburban/Res ☒ Forested ☐ Institutional ☐ Golf course ☐ Park ☐ Crop ☐ Pasture ☐ Other:

BASE FLOW WIDTH AS % CHANNEL WIDTH ☐ 0-25% ☐ 25-50 % ☐ 50%-75% ☒ 75-100%	**WATER CLARITY** ☐ Clear ☒ Turbid *(suspended matter)* ☐ Stained *(clear, naturally colored)* ☐ Opaque *(milky)* ☐ Other (chemicals, dyes)

DOMINANT SUBSTRATE ☐ Silt/clay (fine or slick) ☐ Sand (gritty) ☒ Gravel (0.1-2.5") ☐ Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**CHANNEL DIMENSIONS AT RIFFLE** **Height**: Low bank ___1_____(ft) **Width**: Bottom ___2_____(ft) Top ___3_____(ft) Water Surface ___2_____(ft) **Depth:** Max BKF _____(ft) **B:H Ratio:** Low bank/Max BKF=_____	**OBSERVED IMPACTS** ☐ Outfall ☐ Confluence ☐ Impacted buffer ☒ Stream crossing- 36" CMP, paved road downstream ☐ Channel mod ☐ Utility impacts ☐ Beaver ☒ Other- Beaver

CHANNEL DYNAMICS ☐ Downcutting ☒ Widening ☒ Headcutting ☐ Aggrading ☐ Bed scour ☐ Bank failure ☒ Bank scour ☐ Sed. deposition ☐ Slope failure ☐ Channelized ☐ Unknown	**NOTES** **WIDENING IS REMNANT** **SHALLOW ROADSIDE DITCH AT CULVERT**
QUALITATIVE IMPAIRMENT RATING: ☐ Low ☒ Moderate ☐ Severe	**CHANNEL EVOLUTIUON STAGE:** ☐ **I** ☐ **II** ☐ **III** ☐ **IV** ☐ **V** ☐ **VI** *(Simon et. al., 2003)*

Figure 2: Example of an Earth Tech Geomorphic Study Field Form

As the modeling of the non-Bolin Creek subwatersheds was progressing, the contractor was also developing a prioritization scheme for Capital Improvements Projects. It had been identified in discussions with staff that Capital Improvements fell into two categories worthy of separate prioritization schemes: Water Quantity CIP (i.e. Flooding and Infrastructure CIP), and Water Quality CIP. Town staff worked with the contractor to come up with a set of information to collect about citizen calls for assistance that led to staff drainage repair recommendations or Capital Improvements Projects. This included a combination of information about problems and recommended solutions (projects). Staff and the contractor teased apart these elements in order to use them more effectively for comparison, splitting problem information from project information, and then again splitting based on its application towards relieving flooding vs. addressing a water quality issue. Information for flooding problems was used as a primary ranking method for flooding Capital Improvements Projects themselves. Ranking for water quality problems or projects was set aside, but the information comparing project information (both types) formed the basis of Chapel Hill's projects portion of the geodatabase. Chapel Hill staff shared this preliminary list of project information with Carrboro staff for comment.

Reach Data:	Reach ID		Climatic condition		Reach Length	
Observers:	Date		Recent Precip		Stream Order	
	GPS Top		Geologic Region		Position in Landscape	
Units: Feet Meters	GPS Bot.		Flow Regime		Slope from Topo	

Riparian Data:	*None, weak, moderate, strong*	Channel Data:	*None, weak, moderate, strong*	Cover Habitats:	*Number*
Overstory Density		Sinuosity		Large Woody Debris	
Understory Density		Pool/Riffle Development		Aquatic Plants	
Groundcover Density		Embeddedness		Aquatic Moss	
Organic/Mulch Layer		Entrenchment		Undercut Banks	
Invasive Dominance		Algae		Overhanging Vegetation	
Floodplain Erosion		Flow		Leaf Packs / Small Debris	
FP Encroachment		Midchannel Bars		Root Mats	
Predom. Land Use		Bank Erosion		Protected Slackwater Areas	
Plant Comm. Type		Channel Modification		Manmade Habitats	
Floodplain Encroachment Types	Trails Roads OWASA Other Utility Fill Structures Other	Modification Type	Riprap Straightened Rerouted Dredged Gabions Concrete Other	Riffle Dominant Substrate	
				Flow Habitats :	*Percent of reach*
				Riffles (fast-shallow flow)	
Invasive Species Present:		Channel Dynamics: Downcutting Widening Sed Deposition Aggrading Headcuts Bank Failure Bank Scour Bed Scour		Runs (fast-deep flow)	
				Pools (slow-deep flow)	
				Glides (slow-shallow flow)	

Channel Measurements	1	2	3	Average
Top of Bank Height				
Top of Bank Width				
Bankfull Height				
Bankfull Width				
Bed Width				
Wetted Width (% of bed width)				
Riffle Water Depth				
Pool Water Depth				

Figure 3: Revised Chapel Hill Stream Walk Field Form

Up to this point, Carrboro had been developing its own structure for the projects portion of the geodatabase. This was based on the project information put together by Earth Tech, and additional projects collected by Carrboro. Chapel Hill started with this spreadsheet and data, and added fields for comparing feasibility in different ways, numbers and types of property owners involved, area covered, potential water quality benefits (calculated using

models in some cases, not able to be modeled in others such as biology), and several other ways to compare the difficulty of implementing projects.

As Chapel Hill staff searched for and implemented projects to replace the elements of Mill Race tributary gully repair and erosion control, more information about projects presented itself as very useful to record for posterity. Some potentially good projects turned out to be infeasible for reasons that required a good deal of information to discover. Rather than let this valuable information about the Infeasibility of a project be forgotten or leave with the staff member that found it, it was recorded in the ever-expanding list of attributes of potential projects.

At this point (early 2012), Chapel Hill staff folded in basic information about projects recommended in the EEP Local Watershed Plan, and a preliminary assessment done for NC EEP's predecessor (Wetlands Restoration Program) by KCI. Many of these projects had been investigated for feasibility multiple times, but by different people, each time finding they were infeasible or inappropriate for different reasons. A method of recording these investigations made itself clear in the attributes for Bolin Creek projects. Projects from across both Towns were included, not just in the Bolin Creek Watershed, because it was easier to pull them all in together. However, because of the disparate sources, filling in attributes is a slow, ongoing process, with the highest-priority and most recently investigated having more details entered than other projects. NC EEP helpfully had developed GIS layers for project boundaries, project watershed boundaries, and BMP shapes that formed the basis of the GIS portion of the projects geodatabase (up until that point, everything was all in a spreadsheet). After researching many plans and studies to find any wayward restoration project recommendations, Chapel Hill presented this final list to Carrboro for comment.

As noted above, the problems information proved very useful in the preparation of the Watershed Restoration Plan, especially in the Watershed Analysis of Stressors and Sources. However, the collection of projects and their attributes proved less useful to the development of the Plan's implementation steps and milestones. Both Towns are committed to ongoing geodatabase updates as new projects or project information come to light. For future data collection, during implementation of Chapel Hill's portion of the Bolin Creek Watershed Restoration Plan, this structure may be modified very slightly to accommodate Stream Visual Assessment Protocol (SVAP) measurements with additional NC DWQ habitat measurements in order to be comparable to those methods (as these are commonly used biological assessment methods), but also collect information on other characteristics of interest to Town staff that have shown to be specifically useful for identifying problem areas or problem sources.

For Chapel Hill's part, the small, isolated nature of most of the projects in the dataset did not lend itself to addressing the two biggest (Bolin Creek watershed) problem areas observed: the Tanyard Branch and Mill Race (entire, not tributary) subwatersheds. These areas demonstrated through their poor macroinvertebrate communities that they were in very bad shape ecologically, and staff experience with areas of these subwatersheds made it clear that a subwatershed-wide, systematic approach would be necessary to keep these tributaries from "exporting their problems" to Bolin Creek any further, and possibly beginning to heal.

In comparison, the projects dataset was excellent for comparing individual stream restoration or stormwater retrofit projects, but not adequate for a full subwatershed overhaul, as is needed for Tanyard Branch and Mill Race. The projects dataset will be very useful in the many smaller retrofit opportunities that other organizations may want to cooperate with either Town on. Friends of Bolin Creek, the Orange County Soil and Water Conservation District, and the Carrboro-Chapel Hill City Schools system are looking to be enthusiastic cooperators on isolated stormwater retrofit projects. This comparison of projects allows us to pull out some of the most promising projects when potential cooperators or funding sources make themselves apparent.

The list of the Projects Geodatabase feature class attributes can be found in Appendix 9.

TANYARD BRANCH STORMWATER ALTERNATIVES ANALYSIS

(Tanyard Branch project elements were implemented by Chapel Hill Stormwater Management staff and NCSU engineers. In this section "we" refers strictly to Chapel Hill Town staff.)

As noted in the Introduction, an analysis of stormwater alternatives for Tanyard Branch was proposed as part of the funded project. The uppermost parts of Tanyard Branch once flowed through downtown Chapel Hill, but those segments have been put underground in a pipe over the two centuries of development of the oldest parts of Town. Subsequently the entire drainage network of the area was routed to this piped stream as well, leading to one very large stormwater network that drains an area that is largely covered with impervious surface. The stream and connected drainage open to the surface through two 48 inch pipes north of downtown Chapel Hill in the Northside neighborhood. High amounts of impervious surface and intense networking of stormwater results in very high energy flow that is eroding away a huge area below the outfall.

After crossing Caldwell Street, the stream plunges into a steep, narrow valley that has a small "shelf" on one side where the local OWASA sewer line is run. That stream segment has four to five foot vertical banks, and has cut down to a cobble-bedrock substrate. The bank is composed of a layer of cobble and gravel at the very bottom, with the majority above made of layers of fine silt and clay interspersed with bottles and other trash. We suspect, though have not been able to find proof, that this material is the remnant bottom sediment of a farm pond. We were aware that properties in this neighborhood had been progressively carved out of pasture and farmland over the years. In any case, the severe and continuing erosion demonstrates that the stream channel is out of equilibrium with its flow, a situation which may be exacerbated by deposits of fine sediment. So, while we would like to restore this segment of stream, even if we were able to create a bankfull bench as part of restoration (only if we can move the OWASA line), what remained would still be prone to erosion.

This stream drains a concentrated commercial zone (with associated illicit discharge issues), with occasional storm drainage-sanitary sewer cross-connections (unsurprising because of the amount of abandoned infrastructure below the oldest properties), some of the oldest sanitary sewer lines in Town, and the extensive impervious area, we suspect this stream is considerably more polluted than others. Between the need to reduce the energy and erosivity of storm drainage to allow future downstream restoration, and the need to trap and treat the pollutants, the most logical choice is a stormwater treatment method like a wet retention pond. Since Tanyard Branch is a perennial stream, this requires an analysis of alternative stormwater management methods to determine whether there are methods besides a wet pond that will adequately control stormwater to protect the downstream segment from erosion.

For this analysis, we contracted with Dr. Bill Hunt, of NCSU's Department of Biological and Agricultural Engineering. The grant funded tuition and a stipend for one of his graduate students for two years, and in return the student (Erica Tillinghast) would collect needed data, run models, estimate costs, and produce a report that we could use as an Alternatives Analysis in the future, should we seek permits for installing a stormwater management structure on the uppermost part of Tanyard Branch.

Preparation for analysis included extensive, highly detailed mapping of the entire stormdrainage network leading to the outfall above Caldwell Street. Town staff designed a GIS data structure that would capture details such as pipe sizes, materials, lengths, slopes, and connections; inlet types, "mouth"/grate dimensions, and box dimensions; and information on their condition. Erica then used this detailed information to create a PCSWMM model of the stormdrain network. Erica also collected information on the downstream streambed and bank material sizes, stream cross-sections, and set up a pressure transducer to measure flow in response to rain events.

The analysis modeled nine different stormwater management alternatives, shown in Table 1 (excerpt pulled directly from the report):

Table 1: Description of 9 Scenarios Modeled in PCSWMM		
Scenario	**Areas Treated**	**Description**
1	None	Existing condition
2	Entire watershed (68 ha) with additional 1.2 ha[1]	Undersized wet pond at outlet
3	Entire watershed (68 ha) with additional 2.4 ha[1] (Figure 6)	Full-size wet pond at outlet
4	Residential area only (24 ha)	41 cisterns and 56 rain gardens
5	Residential area + under-sized wet pond (25.2 ha)	48 cisterns, 63 rain gardens, under-sized wet pond from scenario 2
6	Residential + UNC campus (36 ha)	41 cisterns, 56 rain gardens, 4 green roofs (0.49 ha), and 7 permeable pavements (2.45 ha)
7	Residential + UNC campus + under-sized wet pond (37.2 ha)	48 cisterns, 63 rain gardens, 4 green roofs (0.49 ha), 7 permeable pavements (2.45 ha), and under-sized wet pond from scenario 2
8	Residential + UNC campus + downtown (68 ha)	41 cisterns, 56 rain gardens, 10 green roofs (1.01 ha), and 13 permeable pavements (6.5 ha)
9	Residential + UNC campus + downtown + under-sized wet pond (69.2 ha)	48 cisterns, 63 rain gardens, 10 green roofs (1.01 ha), 13 permeable pavements (6.5 ha), and under-sized wet pond from scenario 2

The concluding section of her cost-benefit analysis very neatly sums up the results:

> *Per this cost-benefit analysis, as higher geomorphic stability within a stream is achieved, so, too, do the costs of the project increase. Of 9 retrofit scenarios, scenario 9 (residential + UNC + downtown + under-sized wet pond) would mitigate the disturbances from the heavily impervious watershed the best at an estimated cost of $14 million ($200,000/ha), while scenario 7 (residential + UNC + under-sized wet pond) provided comparable stream stability at 29% of the cost.*
>
> *Both the wet ponds, under-sized and full sized, decreased volume of eroded bedload; however, increased erosional hours from the existing scenario. When used solely, the under-sized wet pond provided minimal mitigation for 1) eroded sediment and 2) nitrogen and phosphorous reduction, negatively impacting ecological services when compared to the other scenarios. While the full sized wet pond had the highest reduction of estimated nitrogen and phosphorous, it also had the highest number of erosional hours, about 2.3 times larger than the existing condition. However, being such a large (68 ha) impervious (60%) watershed, LID practices alone did not provide sufficient benefits (4% and 5% reduction of nitrogen and phosphorous, respectively, and minimal ecological services) for their total appropriate capital costs. To obtain the most benefits in terms of the cost of the project, LID practices are needed with detention SCMs; however alternative methods to reduce nitrogen would be needed regardless of scenario chosen (unless full sized wet pond) to meet current Jordan Lake introduction and phosphorous reduction goals.*

Erica's analysis is presented in two excerpted chapters from her Master's Thesis (the geomorphic analysis and cost-benefit analysis), and an accompanying Appendix, here reproduced together in Appendix 3. A summary of the project, project excerpts, and a link to her entire thesis is available through the Town's webpage at URL: http://www.townofchapelhill.org/index.aspx?page=1889

In the wake of two years of macroinvertebrate monitoring in the area (results described in the Results and Conclusions chapter), Tanyard Branch and Mill Race Branch have been determined to be far and away the most degraded tributaries of Bolin Creek in Chapel Hill. With such poor conditions on these two streams, and being significant sources of pollutants and hydrologic modification, we concluded that a subwatershed-wide restoration of these two had the greatest potential to improve Bolin Creek's condition. This alternatives analysis has been invaluable for identifying and examining our options and what costs we may face, and what benefits we could potentially gain. Thus it has formed the germ of a multi-year implementation plan to install sufficient stormwater management in the Tanyard Branch subwatershed and subsequent stream restoration. This plan is described in detail, with steps and milestones laid out, in the Bolin Creek Watershed Restoration Plan.

BALDWIN PARK

The original Baldwin Park proposal called for stabilization/restoration of about 600 feet of stream bracketing the Park, planting trees along another 400 feet or so, installation of an energy dissipation basin where an ephemeral stream emerged from a stormdrain pipe at the end of Starlite Drive, rerouting street drainage piped along Broad Street to a bioretention above where the stream issued from being piped itself, and stabilization of an eroding path leading from Chapel Hill to Carrboro, crossing the ephemeral stream.

In November 2008, very shortly after the grant contract period started, we organized a stream walk for the neighbors to meet them, introduce them to the project and its goals, and answer any questions they may have. In Summer 2009 the ISCO stormwater sampler was sited on Town property, below the confluence of the two project streams, and installed with little difficulty. After a contract was set up for laboratory analysis, monitoring started to get necessary flow information for engineering design. As with Mill Race tributary, we had calibration problems on the low flow end that we believe have contributed to water level data that has been difficult to interpret.

Through 2009 and 2010, Carrboro staff worked with Carrboro landowners and stakeholders to gain necessary approvals and coordinate with an upcoming community garden project also being sited in Baldwin Park. Carrboro staff coordinated with NCSU on permitting, invasive plant removal, and engineering design of the bioretention basin and the stream segment on the western side of the park.

However, there was significant miscommunication between the Towns regarding roles and responsibilities for the Baldwin Park project elements. Chapel Hill staff included Baldwin Park in the grant application because team members were advised their application would be more favorable if more entities were involved, including projects occurring in both Towns. This seemed reasonable to Chapel Hill staff if Carrboro took the lead on implementing the project. In return, Chapel Hill staff would take care of monitoring for both locations. Carrboro's choice was on the border with Chapel Hill, and some of the problems were on the Chapel Hill side of the park. However, Chapel Hill staff were working under the assumption that Carrboro staff would be doing all the property owner contacting, including for those on the Chapel Hill side (the park did back up to Chapel Hill, and the eastern stream flowed on the border). This was not how Carrboro staff understood the arrangement, and by this time a separate 319 grant project applied for by Carrboro was underway, dividing Carrboro staff time.

As a result, in early 2010 Chapel Hill staff had to scramble to do the necessary outreach for private properties on the eastern side of Baldwin Park, well after concept plans were drawn up and NCSU was ready to get property owner permission for the 401/404 permit. We received passive resistance from some property owners. They would not return messages, would not talk with staff on the phone, or respond to letters. Our attempts to contact property owners through Empowerment (as the closest thing to a homeowners association in Northside that existed), but were informed that the property owners were not interested in talking to us. Finally, after

persistently leaving messages begging for an audience, the owners agreed to meet with us. We provided plan information, maps, and other materials to explain the project, which were ignored. We were told point blank that the owners did not trust the Town because "the Town let Greenbridge go through," meaning the Town let developers continue to convert Northside from a historic black neighborhood to a neighborhood comprised of student rentals. As Town employees, we represented those other actions of the Town, and were denied even an opportunity to revise the project details to meet any concerns they might have. The only concern they would share is their fear the Town would keep them from using their property as a result of the project, a somewhat reasonable concern, given that we would request that the owners not disturb the dissipation basin we proposed to install or the streamside trees we planted. This led to dropping the path stabilization across the stream, the upper energy dissipation basin, and rerouting of the ephemeral channel away from the OWASA easement from the project entirely.

One of the proposed elements of erosion control at the Baldwin Park site was the stabilization of a dirt path that ran down from Craig Street, crossing the stream, and linking up with a cement sidewalk on the Carrboro side. NCSU had recommended that mulch should be sufficient to prevent the path's erosion. As this path runs beside the property of the owners who did not want us to install the upper dissipation basin, we decided we should not aggravate the situation by doing work of any sort in that area, even though it wasn't on the property in question. As it turns out, once the downstream step-pools were installed we saw much less erosion at this site. In the interim, we have discussed the installation of a bridge over the creek and sidewalk from Craig Street with a Boy Scout troop and with Chapel Hill Parks & Recreation staff. This would be a fairly large bridge for an Eagle Scout project, so at this time no scouts have chosen to install a bridge at this crossing.

Fortunately, properties along the stream abutting Chapel Hill, further downstream where the erosion was significant, were primarily rentals and we received little resistance (but little interest) to our proposal for stabilizing the severe erosion there. However, the one owner at the very end, Marva Burnett, was quite interested and cooperative, seeing as how we would move the stream away from her eroding garden area where a fence was being undermined. We are very grateful to her for working with us and keeping in touch with us regularly.

Chapel Hill staff worked through 2010 to keep willing property owners informed of progress, requested NCSU to revise plans as necessary, and get permission forms for 401/404 permit application and construction easement access signed by property owners. In the fall of 2010 Invasive Plant Control treated the extensive amounts of Chinese privet and other invasive plants choking out the understory of the remaining forest area. We received very positive feedback from property owners on removing this scrubby understory.

Construction finally started in late 2010, overseen by NCSU staff with input from project members. The western stream fork was routed away from a very steep bank, where a bend in the stream had been carving progressively deeper into the bank. The eastern stream fork was routed away from a garden and its fence where it had been similarly eroding the streambank, introducing a good meander bend in the process. Along both forks several step-pool structures were installed to absorb and dissipate the energy of flowing water and prevent the stream from eroding down through its bed again. These step-pool structures consisted of two rows of very large rocks (eight feet long, four feet wide) laid perpendicularly to the flow, with rock filled in behind to effectively step the stream down. To reduce the amount of street runoff directly going into the stream, and treat it for pollutants, water from a stormdrain inlet along Broad Street was rerouted to what would become a bioretention basin beside Broad Street. Engineering plans, before and after photos, and other details can be found in Appendix 1. Chapel Hill staff recorded an informational video that was posted to the Town's Vimeo website and advertised with the other video shorts that the Town's Public Affairs office was producing at the time. The URL for the video is: http://vimeo.com/21352340

As construction proceeded, Chapel Hill staff worked with property owners on an acceptable list of trees to plant in the riparian zone on the Chapel Hill side. Most property owners had no concerns, but one did not want us to put trees along the stream, keeping just grass in place. We eventually got agreement to fairly low-density planting of small, attractive trees about ten feet from each bank. In late March of 2011, project members and many volunteers planted a few hundred bare-root trees along both of the restoration segments. On the Carrboro side, trees and shrubs were planted much more densely, and native grass and wildflower seed was sown in the planting area. Meanwhile, project members organized the first tree planting and dedication ceremony of the project (the "ribbon-cutting" referred to in the deliverable language), to be held in early April 2011.

When construction was underway, a contractor for OWASA was constructing an extension of a sanitary sewer main that extended across the larger of the two stream forks, between the restoration area and our monitoring site. We have observed that many OWASA fords are built like small dams, raised up areas of large rock that interrupt the normal flow and transport of water, bed sediment, and woody debris. Depending on the construction, the stream may wind up cutting around the riprap if it obstructs flow too much. Other OWASA crossings have unstable or eroded banks due to equipment traffic and the way the ford was designed. Where small culverts are used for OWASA crossings, we've invariably observed culvert obstruction, either through crushing the pipe or clogging with debris, and rerouting of the stream around the clogged culvert, eroding sediment in the process.

Since we were unable to get the dissipation basin installed above the construction zone, we needed to install a different BMP that would meet similar water quality improvements. For a few years before this, we had wanted to test out alternative methods of constructing OWASA crossings to reduce their effects on stream channels. Both stream forks of the Baldwin Park project site were crossed by OWASA easements, and the smaller stream's OWASA crossing suffered from the kinds of effects we were hoping to avoid with a different ford design. We decided to test a geogrid material that could accommodate cobble-sized rocks in a new OWASA ford so we could see how this would perform compared to the regular riprap ford. While this BMP was not used for dissipation, we believed maintaining stream channel stability and function while allowing a stable crossing for heavy equipment, especially in cases where other crossings have been a problem, was an equitable replacement. In particular, we believed this would mitigate the negative effects that the sewer main construction would have that would be picked up at our monitoring site, confounding our monitoring of the stream restoration.

At the tail end of the small stream's rerouting and stabilization work we observed that the stream was beginning to cut around the riprap and gravel placed on the channel at the OWASA easement. We consulted with NCSU, OWASA, and the construction company putting in the nearby new sewer main and sewer laterals to design a simpler but still less-obstructive ford that would not encourage the stream to cut around the riprap. Being a much smaller stream, we also wanted to test out methods that could be used on the tiniest of streams, where culverts are commonly placed. This required some channel reshaping and extension of rock from where NCSU's work ended at the last-step pool to maintain a bed elevation that would not encourage pooling of water in front of the ford material, and reshaping of the ford material to create a contiguous small channel. As we were unable to do stabilization of the pathway (the third BMP in the deliverable), we felt restructuring the OWASA crossing met or exceeded the water quality benefits the pathway mulching would have provided.

A very-well-attended dedication ceremony was held at Baldwin Park, where the mayors of the two Towns planted a tree in the bioretention basin and read a joint proclamation. This was one of several stops that day on a tour of water quality projects in the two Towns organized by project members, NCSU, and Friends of Bolin Creek. NCSU and Carrboro staff conducted a workshop for Carrboro landscaping employees to properly care for the plants in the riparian zone and bioretention basin. Carrboro staff have since installed signs providing information on the

restoration and the bioretention basin. Pictures and other information related to the event can be found in Appendix 1.

In the year after construction, Carrboro staff have conducted several tours of the project area. Carrboro maintenance staff refrained from mowing along the newly-restored stream segments, and continue maintenance of the bioretention basin. That was a fairly dry summer, and Carrboro staff provided some watering during the worst parts. A lot of the small trees and shrubs along the streams and in the bioretention basin were grazed to nubs by deer. However, when visiting in spring 2012, the riparian zone and bioretention basin were remarkably verdant. We had been advised that many of the native grasses and wildflowers would not germinate until the next spring, which is what appears to have happened. The step-pools and other channel reshaping was completely unchanged and appeared to be stable.

MILL RACE TRIBUTARY

(Mill Race project elements were implemented by Chapel Hill Stormwater Management staff and NCSU engineers. In this section "we" refers strictly to Chapel Hill Town staff.)

In November 2008, very shortly after the grant contract period started, we organized a stream walk for the neighbors to meet them, introduce them to the project and its goals, and answer any questions they had. We requested a response to our mailing, but got interest from only two property owners out of more than 50 who received invitations. Again in March of 2009 we attempted some outreach to property owners with an information brochure, but received response from only one property owner (one of the ones who had responded to us before). Facing difficulty with getting our ISCO samplers up and running at both sites, project staff focused their attention on getting the monitoring underway. During this first year we had difficulties in coordinating all the team members and getting needed steps accomplished in a timely fashion. We started using weekly emailed task lists to team members to get us back on track. Emails had lists of current tasks, due dates, and who was assigned; lists of past tasks and when completed; and a list of upcoming tasks and assignments so team members could plan accordingly.

Installation of monitoring equipment started in Summer 2009. Implementation challenges at Mill Race started with simply trying to site the ISCO sampler inside its metal "bear box" and a pole for its solar cell. The best place for the sampler was downstream of all the construction work, at a culvert that formed a "control point" for setting up discharge measurements. This property was owned by the homeowners association. The nearby property owner was president of the homeowners association, and objected to the placement of the sampler in this location, finding it aesthetically unpleasing. Because of the lack of reliable solar recharging, the sampler's battery ran down on a regular basis, requiring equipment setup and recalibration each time. We believe this contributed to water level data that has been difficult to interpret.

By late 2009/early 2010, we were anticipating getting back to Mill Race outreach. However, as described in the Baldwin Park section, communication problems and changing stakeholder relationships meant Chapel Hill staff could not return attention to Mill Race preparation or property owner outreach and communication until mid-2011. By this point we had requested a one-year extension, figuring that with Baldwin Park experience we should be able to move along faster at Mill Race. But since it was a more complicated project, with extensive invasive plant control, long areas of stream stabilization including incipient gullies on both forks, repair of three huge gullies, replace a blocked stream culvert for an OWASA line with a stabilized ford, LID treatment of the eroding gravel sidewalks that drained to this stream, and stabilization of the stream channel above an encased OWASA line, we planned many more, and more convenient, opportunities for property owners to talk with us about the

proposed project. Given that we still heard from occasional property owners who had some interest in seeing the erosion being corrected, we did not expect the very active resistance that we received.

We announced several meetings and got very little response except those who had already contacted us before. We started to set up a comprehensive invasive management plan while NCSU finalized engineering plans. As these were completed, we sent out much more detailed information with permission forms for the 401/404 permit, treating the invasive species, and conducting the construction on each property (or merely crossing, as was appropriate). In the midst of all this we were attempting to set up an invasive species management contract so that the kudzu could be treated at the most effective time – August and September. We met with several property owners who were uncomfortable with the use of pesticides in order to allay their fears, as we also required permission to control the kudzu.

By mid-August, we were contacting property owners directly by phone in an effort to get permission to go forward with the project. We readily received permission from about 30 properties. Several property owners directed a large amount of abuse at staff on these phone calls. The general tone of these conversations was that all government was incompetent, corrupt, getting in business where it did not belong, including not trying to repair an eroding stream and gullies. The Town was lumped in with all other levels of government in some of these extensive rants. People were very angry at government in general (or maybe at state and federal levels), and we were the only contact they had, their only route to diffuse their anger. For many of these calls, we did not explicitly require access permission because the property only touched the larger project area, and we figured we could just avoid those properties. However, there were three critical properties where the owners refused that forced us to abandon the whole set of Mill Race tributary project elements. One of these properties had the large kudzu field, one of the huge gullies, and one of the two OWASA easements we could use for access for large construction equipment. One of these properties had one of the incipient gullies forming, and the other OWASA access point that would accommodate the large equipment. The third was at the junction of the two stream forks leading to the lower stream segment, along which the OWASA easements followed, through which we would need to travel to get to the other two gullies and the majority of the stream stabilization area. This property also had the crushed culvert that we hoped to replace with a stream ford. We were not merely denied permission to do the project elements on their property, we were denied permission even to cross in order to access other parts of the project. One property owner confused us with OWASA, and was unhappy that we "kept making ruts in her backyard" and she was going to forbid us from entering so there'd be no more ruts. We told her we were offering to repair and stabilize the ruts, and that she could not keep OWASA contractors from entering her property, so there would be more if we did not fix the situation. But she denied us access anyway.

By October 2011, it appeared clear we would not be able to secure the necessary permission from these three property owners, nor would upper levels of Town management agree to contact property owners on our behalf. We regretfully informed property owners of cancellation of the project elements, and set about trying to find replacement projects to cover the many elements of the Mill Race tributary erosion control. Materials related to the Mill Race tributary erosion control project elements can be found in Appendix 2.

Of the many elements we had put together for our final engineering plans, most were add-ons to improve the subwatershed-repair approach and not formally part of the contract. So we looked for replacement projects that could meet the underlying water quality improvement needs that the contracted elements were designed to address. These elements were the LID treatment of the gravel sidewalks to prevent erosion, stabilization of eroding stream segments including an OWASA crossing, and repair of two gullies with associated BMPs. We reviewed over 18 individual project sites in the course of two months to find projects that were feasible, could be completed within the budget, were on Town property (thus removing the need for property owner permission,

and the risk of it being denied), and looked to address the same kind of water quality problem of approximately the same severity. Site investigation involved extensive local storm drainage mapping, identification of construction access, and multiple site visits to each location. It also required extensive meetings with Parks and Recreation staff, as most available sites were managed by this department and would need to meet their needs, or at least not interfere with their activities.

By December we had identified five very promising locations – two potential bioretention areas at Hargraves Community Center, an eroding pea-gravel fire lane suffering lots of flooding and erosion at Hargraves, a bioretention at the end of Dickerson Court, and a stream stabilization at Trinity Court. Given how far in the project timeline we were, we received permission from NC DWQ to proceed with the replacement projects without a contract revision, with the requirement that we explain thoroughly how these projects could match or exceed the water quality benefits of the project elements we could not complete at Mill Race tributary. As these would be installed less than a year before the grant period ended we would be unable to do post-construction morphological monitoring or vegetation monitoring.

Because these sites were managed by the Town's Parks & Recreation department, or adjacent to their facilities, Parks & Recreation staff were very concerned about how our construction would affect their operations and community programming. We consulted and communicated with their staff frequently, sometimes onsite, including sending out weekly stakeholder update emails to keep them apprised of all decisions, activities, and plans.

To replace the stream stabilization and OWASA stream crossing, we found a similarly very steep, badly eroded stream on Town property north of Trinity Court. This intermittent stream connects directly to Bolin Creek opposite the Town's Umstead Park. The pre-construction condition of the stream included steep, very high banks that were eroding, and an otherwise fairly smooth channel that accelerated stormwater down the hillside. Stormwater could not access the floodplain, and the channel contained the most erosive, intensive flows, causing more bank erosion. Erosion was cutting into both sides, but very close along one side ran an OWASA sanitary sewer line, which was threatened by the erosion.

NCSU engineers proposed a similar set of step-pools and OWASA easement stabilization that was proposed for the Mill Race tributary. This would build the streambed up to allow flood flows to get over the banks, and thereby reduce velocity and take advantage of natural floodplain processes of water storage and nutrient processing. Plants were selected for the streambank that would improve stability yet be acceptable to OWASA, since they were right next to the sewer line. This included small shrubs such as yellow buckeye and spicebush, and perennial ferns that create a shallow, yet very fibrous network of roots.

This project got underway fairly quickly early in 2012, with construction completed in 3 days in April, and streamside plantings done shortly afterwards. Construction consisted of installation of several sets of very large rocks to create step-pools. Behind these step-pools was layered erosion control fabric, a sand-wood chip mixture, topped by heavier gravel. This is used to encourage hyporheic (below streambed) flow and the associated nutrient processing and cycling that occurs in the hyporheos, and is called a "regenerative stormwater conveyance." See Appendix 4 for Trinity Court stream restoration engineering plans and before and after photos.

After construction and planting was completed, we held a streamwalk guided by NCSU engineers and invited staff from Chapel Hill (other than Stormwater staff), Carrboro, OWASA, and UNC. Because this project was adjacent to Town public housing, we invited the Housing Director and community advocates from the housing project. We had moderate turnout, but great interest by those who did participate. This area had a significant trash problem

that Town staff and community advocates were made aware of, and this led to the organization of a community-wide cleanup day.

We were unable to find severe gullies similar to the ones at the Mill Race tributary in other locations where we could get permission for projects. We found a potential bioretention site at Hargraves Community Center and another at Dickerson Court. We found a good replacement for the sidewalk LID treatment also at Hargraves. The Dickerson Court area lies directly next to Bolin Creek in the Triassic Basin. The Hargraves projects are in the Upper Tanyard Branch watershed. Among the stormwater management recommendations from the Tanyard Branch Alternatives Analysis, were the subwatershed-wide installation of BMPs which detain/retain runoff to lengthen the hydrologic response time and reduce shear stress on eroding streambanks. While the substitute recommendations from the study projects we wanted to implement did not all address the same suite of pollutants or water quality impact as the projects to be replaced, we believed the projects as a group would result in improvements to water quality equal to or greater than the set of projects we had to replace because they would retain and treat runoff where the original projects do not.

To replace one of the two severe gully repair efforts at Mill Race we looked at several areas we could potentially install bioretention basins at Hargraves Community Center. We looked at trying to capture roof drainage from the buildings, but after extensive investigation found all the drains were deeply buried under walkways and connected directly to the extensive stormdrainage network in the area. We then looked at capturing flow from one or more of the four parking lots on the property. Two very promising bioretention sites were located, and NCSU did surveying and design for both of them. One of the two Hargraves bioretention sites was not feasible because of utility lines under the proposed location that were found after engineering designs were drawn up.

The other site, which would become known as the "Mitchell Lane bioretention basin" had a good, open spot downhill from a parking lot. However, its drainage was linked directly to the extensive network that went through the entire site. We considered whether we could reroute that whole network to this location for treatment, but determined the runoff volume would vastly overfill any bioretention basin we could put in that area. Instead, we decided to try to split the parking lot runoff from the larger stormdrain network.

An NCSU engineer designed a bioretention basin that would treat flow from approximately 50,000 square feet of area in total, approximately 14,000 square feet of untreated impervious surface, mostly parking lot. This setup would divert direct stormwater inputs to the stormdrain system leading to Tanyard Branch into treatment instead. Prior to installing the bioretention basin, we had to capture the parking lot flow. Chapel Hill Stormwater Engineers designed a new stormwater inlet box that would drain the lot, and the old inlet would be closed off. Getting this new box and a pipe to the treatment area was tricky, as we had very limited time before the summertime pool season when we could not have the lot blocked off. Chapel Hill's Stormwater Maintenance Crew installed the box and pipe very quickly in May in time for the pool opening. See Appendix 5 for the Mitchell Lane bioretention basin engineering plans and before and after photos.

Even this location had utilities that challenged our design – an electric guy pole and line used to keep tension on the power lines and poles across the street. This wound up not being moveable, so the bioretention basin was designed around it. A forebay was designed to allow a place for fine material from the lot to settle to avoid clogging the soil media. Construction of the bioretention basin took place in Summer 2012. While it was directed by an NCSU engineer and installed by an NCSU contractor, both required considerable oversight by Chapel Hill Stormwater Engineers because of apparent lack of experience with bioretention design and installation. Construction took a few weeks and required several field revisions.

This location was also beset by many invasive species, including kudzu, English ivy, and wisteria. Town staff had attempted to get professional removal done before construction, but could not get quotes in time nor arrange for Town Landscaping staff to do the work. As a result, Town staff designed a planting plan for the bioretention basin and adjacent steep slope with native species that were fairly aggressive and had a chance of outcompeting the invasive species. Further, being in a fairly urban and well-traveled area, and after consultation with the Town's Landscaping Division, we selected more showy, tidy, low-growing herbaceous species rather than the standard native shrubs and trees commonly planted in bioretention basins. Herbaceous species also ensured we could try to manage the invasive species by annual mowing, which we would not be able to do with shrubs or trees. Because the plantings were almost all herbaceous, a high planting density was selected to ensure good ground cover quickly to fend off colonization by invasive species. To assist the NCSU engineer, commercial sources for these plant species were researched by Town staff and provided with the planting plan.

However, NCSU ordered plants through a different plant vendor that did not carry most of the desired species, and new ones were selected. Town staff learned of this substitution on the planting day. Some of the selected species were acceptable, but others were lacking in either aggressive growth, short stature, showiness, tidy habit, partial shade tolerance, perennial growth, or a multiple of those. The planting density used was appropriate for trees and shrubs, at 400 stems/acre, but inappropriate for herbs and grasses that have a mature maximum spread of 3 feet. With the exception of the three specified small trees used as centerpieces, the layout of the planting plan also was not followed. The stabilizing grass species for the steep hillside had not been ordered nor seed laid down.

Town staff conveyed their specific concerns that inappropriate species had been installed. Since planting at Mitchell had occurred while the other bioretention basin at Dickerson Court was being constructed, an agreement was made that a similar set of species and planting density to that specified in the original Mitchell planting plan would be ordered for Dickerson.

To replace the other Mill Race tributary gully repair, the proposed bioretention basin at the end of Dickerson Court would treat flow from approximately 22,000 square feet of area total, 13,000 square feet of untreated impervious surface, mostly public street. The storm drainage from this street was routed directly to Bolin Creek. This bioretention site would reduce contaminants and flows that would have otherwise gone directly to the creek by intercepting a stormdrain and rerouting it to treatment. While this and the Mitchell Lane bioretention basins were likely not halting the contribution of as much sediment as the Mill Race gullies were, instead we were removing multiple pollutants from inflow, rather than just reducing the erosiveness and sediment load of the inflow.

The NCSU engineer designed this bioretention basin as well, with guidance from Chapel Hill Stormwater Engineers. Rather than constructing a new stormwater collection system, or unearthing the existing one to modify it, the engineers used the existing lay of the street and position of a driveway apron to direct street runoff to the bioretention basin. To convert the existing stormdrain inlet to an overflow device, the engineers designed very careful repaving of the street to make a small rise in front of the inlet that would only overflow at a set amount of water. In late summer 2012 a different and experienced NCSU contractor constructed the bioretention basin fairly quickly and with few problems. The Town hired a contractor to cut down the driveway apron so water would flow directly from the street, and hired the asphalt paving contractor. See Appendix 6 for the Dickerson Court bioretention basin engineering plans and before and after photos.

As noted above, the Dickerson planting plans resembled the original Mitchell plan, and Town staff drew up the planting layout, staked out the site in advance, rounded up volunteers for planting, and directed (and participated in) the planting. Some of the large plants installed at Mitchell were transplanted to Dickerson, and the design used those plants as centerpieces. Planting was completed over two days, and then moved back over to Mitchell to

increase the planting density and get showy grass plugs installed on the hillside. Town Landscaping staff provided planting equipment and additional assistance, and provided watering the first day to get the plants established. After that the Stormwater Maintenance Crew did almost-daily watering to help get the sod and plants established. A comparatively wet summer and fall greatly assisted us in this regard. Lastly, Town staff designed and NCSU ordered educational signage for both bioretention sites that explained how bioretention works, why we use it, and about the plants used.

To replace the LID treatment of the grit sidewalks in the Historic District, draining (and eroding to) the Mill Race tributary, we found a fire lane and hillslope on Town property (Hargraves Community Center) composed of the same "Chapel Hill grit" which is used on the Historic District sidewalks on North Street. Between the action of heavy equipment and informal construction of two bike paths on the slope, the area was beginning to form channels as the ground was compacted and material carried away to nearby stormwater inlets. We found a considerable amount of grit deposited several hundred feet away at the stormwater outfall. We proposed the installation of an LID grass-grid-paver system in the fire lane and fencing to direct traffic to less erodible pathways and away from the eroding hill. We estimated this project area to be very close in size to the LID treatment area on North Street.

The fire lane sits between the gym and ball field, and is on a hill above the Mitchell Lane bioretention site described above. It was composed of fairly compacted "Chapel Hill grit," which is a pea gravel-sand mixture with a considerable amount of finer material. It is both easily compacted and yet easily eroded. This area never drained properly and runoff would pool up along the gym. Addressing this problem was of particular interest to the Town's Parks & Recreation Department, and our installation schedule was designed around the center's programming and activities to inconvenience patrons as little as possible.

This entire area around the gym seems to be made of or covered with Chapel Hill grit, including the hillside above the Mitchell bioretention area. Trees behind the gym had poor soil with no leaf mulch because of a practice of removing fallen leaves. Visitors had been cutting paths directly down the face of the hill, creating a channel which was starting to erode, and we found a considerable amount of this material in the stormwater inlet boxes downhill. Part of the Mitchell Lane project involved placing large boulders excavated from the bioretention site to block travel directly down the hill, and direct it to a more stable, lower sloped path on the hill.

The installation was designed by Chapel Hill Stormwater Engineers, and construction took place in Summer of 2012, conducted by Chapel Hill's Stormwater Maintenance Crew. We considered this a valuable experience to learn to work with this material, as we wanted a demonstration area to present to other Town staff to show how well grass-paver systems could work. See Appendix 7 for the Hargraves fire lane grass-paver engineering plans and before and after photos.

MONITORING

Water level and discharge measurement, water chemistry sample collection, continuous water temperature measurement, rainfall gauging, and care of the ISCO stormwater samplers were carried by Chapel Hill Stormwater Management staff with advice and assistance from Michael Shaffer of NCSU. Biological monitoring was contracted separately through Dave Lenat and Dave Penrose, with assistance from Carrboro and Chapel Hill staff.

A Quality Assurance Program Plan was required to be submitted after the grant was awarded (see Appendix 12 for the approved QAPP). A QAPP helps the monitoring entity organize and plan monitoring in such a way that attention can be paid to monitoring environmental conditions that will measure what you are actually interested

in, making sure that monitoring is done at a sufficient frequency and with an adequate level of quality to detect information of interest.

Water chemistry, stage (water level), discharge, and temperature monitoring were carried out, albeit with challenges. ISCO stormwater samplers are difficult to set up and get running, and a good deal of construction knowledge is required (Mike Shaffer of NCSU was invaluable for this). We had persistent problems with power loss at Mill Race tributary because we were not permitted to put up a solar panel. Thus we had to frequently reset and recalibrate this site. Rating curves for determining loads from water concentration data are easy at moderate flows, but error-prone at low flows and increasingly difficult (and unsafe) at flows at and beyond bankfull. Flows of this amount are also very brief and difficult to "catch in the act" in these flashy, urban drainages. Because of the error we were getting at low flows, we inquired with NCSU as to whether we could install a weir to help us more accurately measure low flows. We were advised that even our smaller watershed, Mill Race Tributary, was much too large for installation of a weir. Thus our rating curves are more limited than we would prefer, and don't work well at either the high or the low end of flow. We must have also had some calibration (or measurement) problem that we still have not determined the cause of, leading to low stage readings that when converted to discharge give a negative number.

In the course of writing the QAPP, it was determined that some information that was proposed to be collected in the grant contract was not appropriate or infeasible. For example, in-situ dissolved oxygen meters can get fouled easily and require servicing every few days to few weeks, making continuous monitoring difficult. The likelihood of detecting significant changes in dissolved oxygen after construction was also doubted because we would not be treating stormwater at either project location in a way that would change effects on dissolved oxygen. We determined that measuring nitrogen in "first-flush" was inappropriate given the solubility and transport characteristics of nitrogen compounds. Further, we were interested in loads as a whole, which could be better calculated with flow-weighted storm composite samples rather than first flush. Fortunately, ISCO samplers could be programmed to collect such samples.

Some changes to monitoring occurred even after the QAPP was submitted upon finding in the field that we would not be able to collect data the way we wanted to. Installation of bank pins was inappropriate given the intensive earth-moving and installation of large rocks done at the stream restoration sites. Before and after construction comparison of bank erosion using bank pins is meaningless if you cannot compare the same section of bank or cannot leave the pins in place. The same goes for habitat conditions in the area of the restoration, when the methods used were installation of step-pools. More general geomorphic data comparison (such as Rosgen channel characteristics) before and after construction was constrained by the fact that we were relying on the contractor (NCSU) to collect preconstruction geomorphic data, but were unspecific on what needed to be collected. Similarly, planting plans were drawn up for planting the Baldwin Park bioretention, and plants selected for riparian planting, but the lack of an accounting of what was actually planted and where plants were placed made evaluation of survival and plant success impossible.

This misunderstanding of roles affected other parts of this project, and points to the importance of having crystal-clear monitoring goals, methods, and roles – ALL of the details – laid out prior to even applying for the grant. Pressure to get "measureable improvements," and therefore to measure everything possible to detect even the smallest improvement may have contributed to an overly-ambitious monitoring plan, which could have been questioned if detailed pre-project scoping of monitoring needs had occurred, including staff time and what are the best, yet simplest methods to detect changes. Such planning would have also prevented the problems in contracting for laboratory analysis (no lab had been selected prior to project commencement; no estimates of lab analysis costs had been included in the budget). Such planning may have also helped Chapel Hill staff avoid being

overwhelmed in trying to get the QAPP written and approved, acquiring necessary equipment (which was complicated separately by miscommunication on budget amendments with Chapel Hill's Finance Department), get necessary monitoring started up, troubleshooting of difficult and testy equipment, setting up a lab analysis contract, etc. This prevented Chapel Hill staff from paying sufficient attention in Year 1 to other aspects of project implementation, such as extensive outreach to property owners in both project areas.

Even for the monitoring we did carry out effectively, the baseflow and stormflow water chemistry samples, it may have been unreasonable to expect changes in anything but sediment loading. As more recent studies are discovering, a restored section of stream may not recover its nutrient cycling and retention capabilities in a short amount of time, if ever. This is because most nutrient retention in eastern streams comes from retention and extensive microbial colonization of leaf litter, rather than capturing nutrients dissolved in the water column. Where leaves are not being retained and allowed time to decompose and their nutrients absorbed into the food chain because of scour or other removal, those nutrients are flushed downstream. Where nutrients are dissolved in the water column, rather than being supplied through leaf litter, only algae (and to a small degree terrestrial plants that can tolerate root saturation) can retain and slow the export of nutrients. This requires a lot of sunlight for algal photosynthesis, and completely changes the stream food web, temperature, dissolved oxygen and pH diurnal patterns, and other physico-chemical characteristics that macroinvertebrates are sensitive to. Essentially, relying on algae to remove nutrients means changing the ecological community type of the stream.

Much of the nutrient reduction was expected through reduction of soil, streambank, and stream channel erosion. This could have been detected strictly through total suspended solids, and measuring nutrients was completely unnecessary for this.

It must be noted that Mill Race tributary sampling was concluded in late 2011 when it became apparent that we could not complete the project in that area due to property owner resistance and technical challenges. Therefore we have fewer than anticipated samples for Mill Race tributary, and none of them are post-construction.

Macroinvertebrate monitoring using NC DWQ methods was added fairly easily since Carrboro was already conducting annual monitoring at several locations as part of its grant match, and Chapel Hill was setting up a contract to do so as well. As it turns out, monitoring benthic macroinvertebrates may have been the most useful method, best able to detect changes and requiring the least amount of project staff time because it was largely contracted out. This is in spite of the fact that macroinvertebrate communities are slow to show improvement after restoration activities, but that may be dependent on where sampling takes place. We sampled below the construction area at Baldwin Park, and at the construction area at Mill Race tributary. To see what benthic macroinvertebrate monitoring told us, see the Monitoring Results section of the Results and Conclusions chapter. The temperature, flow/discharge, and water chemistry information can also be found there.

3. RESULTS AND CONCLUSIONS

3.1 MONITORING RESULTS AND DISCUSSION

WATER LEVEL AND DISCHARGE MONITORING

While we have over 2 years of water level data for Baldwin Park, we had extensive difficulties with the Mill Race sampler and data. At best we were able to get some two- to four-week contiguous periods for Mill Race, and in

joining these we found we had much more time where no readings were taken or they were zero than we had data. This was not caught because we did not have time to thoroughly check every downloaded dataset, but most that we looked at appeared alright. In the future we hope to get much better guidance on using this equipment and how to troubleshoot data problems.

The entirety of Baldwin Park water level data is presented in Figure 4.

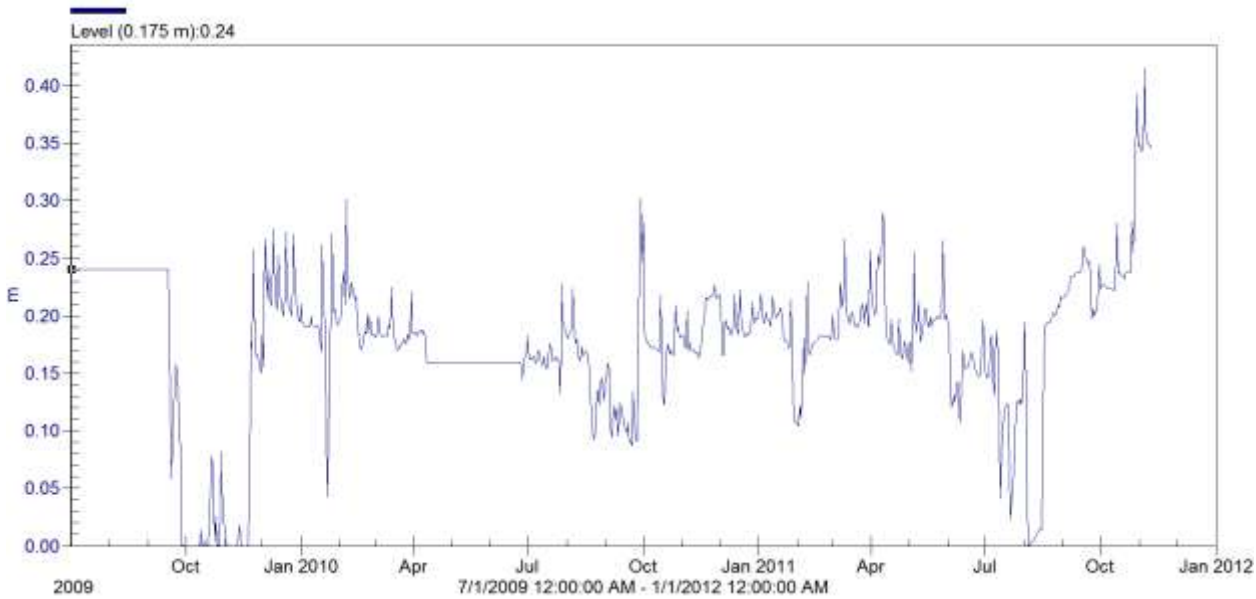


Figure 4: Baldwin Park Water Level Data

As noted in the Methods and Execution Chapter, we had difficulty setting up rating curves for both sites. In particular, when regression equations were applied, the lower ends resulted in negative discharges, which is not what we observed. We believe these were the result of calibration problems. Figures 5 and 6 show the stage-discharge rating curves for the two sites, with 3 different regression equations shown. Each equation had similar problems with generating negative discharges at low flows. We will be consulting with NCSU more extensively to try to diagnose what went wrong with our data collection.

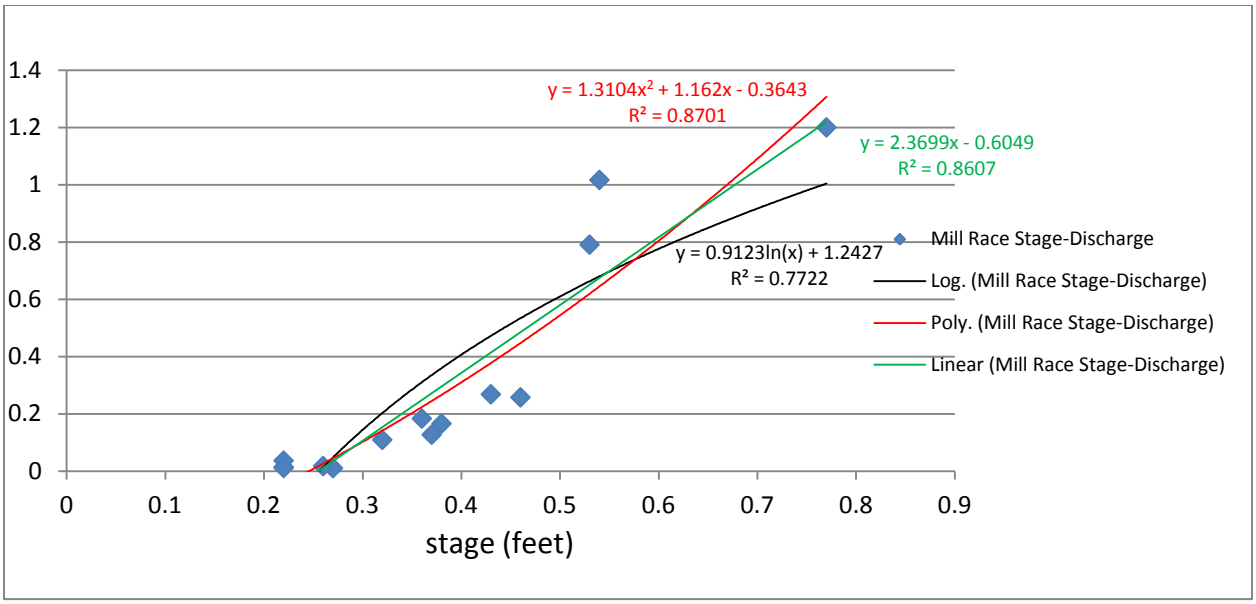


Figure 5: Mill Race Tributary Stage-Discharge

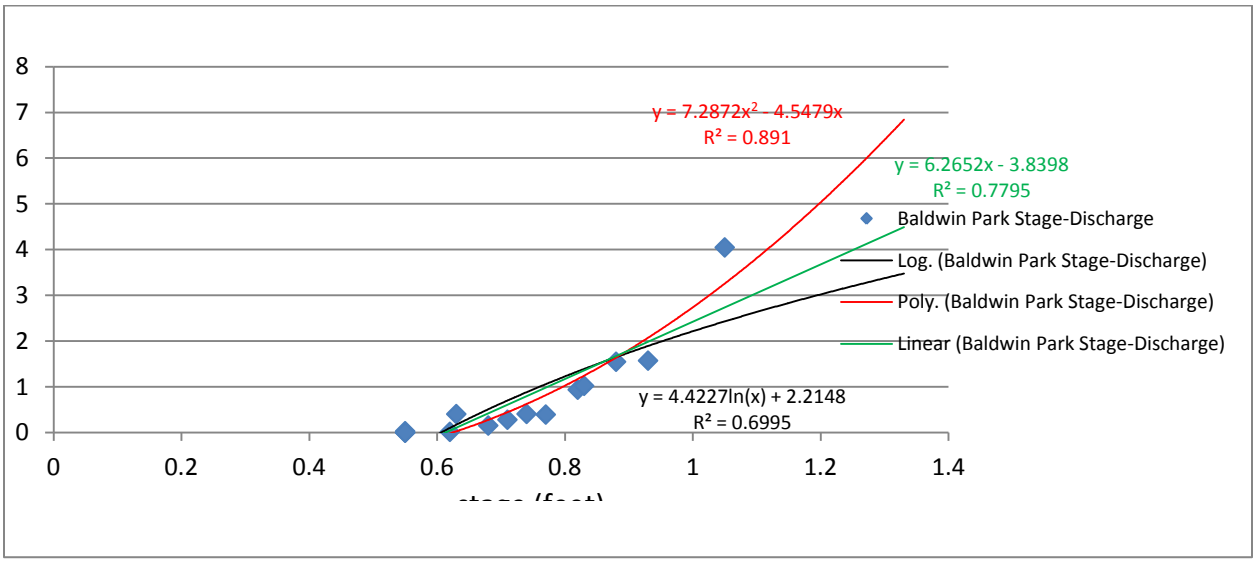


Figure 6: Baldwin Park Stage-Discharge

WATER CHEMISTRY MONITORING

We had much greater success with water chemistry monitoring at Baldwin Park than at Mill Race tributary, not to mention the fact that we could divide Baldwin Park samples into pre- and post-construction samples as proposed, and could not do that for Mill Race tributary. The greater problems with equipment calibration and functioning at Mill Race tributary also limited our sample collection. The data for Baldwin Park are presented in Table 2, and the data for Mill Race tributary are presented in Table 3. Stormwater flow composite samples are shaded to differentiate them from the base flow grab samples.

Table 2: Baldwin Park Water Chemistry Pre- and Post-Construction

TYPE	DATE	total Kjeldahl nitrogen mg/L	ammonia mg/L	nitrate + nitrite mg/L	total phosphate mg/L	ortho-phosphate mg/L	suspended solids mg/L	conductivity µs/cm	Diss. Oxygen mg/L	pH
Pre-Construction										
Baseflow	1/15/2010	0.68	0	1.06	0.24	0.15	21	369	11.63	6.65
Baseflow	2/19/2010	1.03	0.04	1.38	0.22	0.18	27	451	10.76	6.54
Baseflow	2/19/2010	0.43	0.42	0.54	0.79	0.73	1			
Baseflow	3/19/2010	0.37	0.03	0.79	0.19	0.18	11	390	10.23	6.51
Stormflow	3/29/2010	1.54	0.19	0.63	0.23	0.19	189			
Baseflow	4/16/2010	1	0.07	1.03	0.21	0.19	47	430	7.88	6.08
Stormflow	4/26/2010	2.86	0.04	1.04	0.5	0.25	228			
Baseflow	5/21/2010	0.8	0.03	0.92	0.29	0.26	98	438	7.07	7.59
Stormflow	5/22/2010	3.09	0.06	0.45	0.71	0.19	578			
Baseflow	6/11/2010	0.36	0.03	1.39	0.15	0.14	15	420	6.57	7.62
Baseflow	7/16/2010	0.47	0.07	0.58	0.34	0.34	7	383	4.77	7.57
Baseflow	8/27/2010	0.25	0.01	0.64	0.4	0.35	40	393	5.31	7.58
Stormflow	9/28/2010	6.21	0.05	1.29	0.66	0.4	323	458	6.65	7.4
Baseflow	10/18/2010	0.32	0	0.83	0.37	0.16	14	441	7.77	7.43
Stormflow	10/27/2010	2.22	0.07	0.26	0.93	0.34	409	491	6.38	7.27
Baseflow	1/19/2011	0.94	0.02	1.36	0.27	0.16	39			
Baseflow	2/11/2011	0.83	0	1.12	0.21	0.21	4	479	11.52	7.4
Stormflow	3/1/2011	1.77	0.31	0.63	0.63	0.26	974	415	11.56	7.71
Post-Construction										
Baseflow	7/19/2011	0.4	0.03	0.45	0.21	0.13	31		6.19	7.25
Stormflow	9/22/2011	1.98	0.03	1.2	0.31	0.17	76	517	7.43	7.15
Baseflow	11/10/2011	0.23	0.03	1.01	0.19	0.17	6			7.12
Stormflow	11/29/2011	0.58	0.04	1.09	0.15	0.11	2	268	9.21	6.99
Stormflow	12/8/2011	1.89	0.03	0.5	0.24	0.02	218	431	9.66	7.11
Stormflow	1/27/2012	1.58	0.25	0.56	0.21	0.02	41			
Stormflow	3/6/2012	0.35	0	0.6	0.04	0.03	684			
Stormflow	3/24/2012	4.47	0.03	0.29	1.53	0.04	641			

Table 3: Mill Race Tributary Water Chemistry Pre-Construction

TYPE	DATE	total Kjeldahl nitrogen mg/L	ammonia mg/L	nitrate + nitrite mg/L	total phosphate mg/L	ortho-phosphate mg/L	suspended solids mg/L	conductivity µs/cm	Diss. Oxygen mg/L	pH
Pre-Construction										
Baseflow	1/15/2010	0.49	0	2.59	0.28	0.18	2	205.2	11.66	6.59
Baseflow	2/19/2010	0.09	0.01	2.56	0.2	0.16	16	279	10.61	6.72

Baseflow	2/19/2010	0.55	0.48	0.54	0.78	0.74	0.3			
Baseflow	3/19/2010	0.32	0.03	1.61	0.16	0.16	16	231	10.03	6.41
Baseflow	4/16/2010	0.68	0.03	1.68	0.2	0.19	16	236	6.74	6.13
Stormflow	4/26/2010	0.15	0.01	0.01	0.09	0.03	0	239	4.88	6.81
Baseflow	5/21/2010	0.11	0.01	1.4	0.23	0.22	17	220	7.75	7.08
Baseflow	6/11/2010	0.65	0.01	2.06	0.11	0.06	4	228	6.8	7.3
Baseflow	7/16/2010	0.32	0.03	1.54	0.27	0.26	4	224	0.18	7.19
Stormflow	8/27/2010	6.69	2.17	1.42	0.52	0.48	134	232	6.38	7.2
Baseflow	10/18/2010	0.4	0.01	1.55	0.48	0.16	21	220	8.33	7.15
Baseflow	1/19/2011	1.54	0	1.97	0.18	0.17	13			
Stormflow	2/7/2011	3.26	0.1	1.04	0.19	0.18	576	336	10.35	7.17
Baseflow	2/11/2011	0.22	0	1.99	0.24	0.23	13	359	10.73	6.99
Stormflow	4/9/2011	4.02	0.19	0.35	0.66	0.17	491			
Stormflow	4/27/2011	1.04	0.34	1.36	0.2	0.19	61	104.3	6.74	7
Baseflow	7/19/2011	0.76	0.02	1.35	0.19	0.1	19		5.46	6.8
Stormflow	9/22/2011	3.46	0.33	1.56	0.53	0.15	255	202.4	6.09	9.93

Given these limitations, upon examining the results we do not see significant differences in water chemistry at Baldwin Park between the pre- and post-construction periods. The one exception is orthophosphate – dissolved phosphate that is available to plants and algae for uptake (in contrast to other forms of phosphate which are not). This is surprising, as we expected total phosphate to be reduced by adding stormwater BMPs and reducing erosion, not just orthophosphate (which is clearly not the majority of the total much of the time). We don't see a difference in total phosphate or suspended solids, either.

From the high conductivity readings we have reason to believe that Baldwin Park is impacted by illicit discharges or sewer cross-connections, which we do not expect stream restoration or stormwater retrofits to address. Monitoring shows a great deal of suspended solids transport during stormwater flows at both sites. With the very small amount of stormwater treatment that our BMP at Baldwin Park provides to the stream there in comparison to other untreated sources, we might conclude that this one BMP is simply not enough to address systemic watershed erosion problems. Alternatively, the site simply may not have "settled" after the considerable amount of instream construction for the restoration itself, as well as the installation of the stabilized OWASA stream ford in between the restoration area and the monitoring site. It is possible that suspended sediment is not the best constituent to monitor for issues of aquatic health or stream stability. Spot turbidity readings, rather than stormwater composites of sediment, may tell us more about conditions relevant to organisms. Stream stability may be better monitored through cross-section surveys or bank pins and scour chains.

TEMPERATURE MONITORING

Temperature monitoring started in Fall 2009 and went into Summer 2010. Temperature probes were removed for a period to download data, and then to allow construction to proceed. As it appeared construction would not happen at Mill Race tributary, we put the probe back in for a time. Before and after temperature at both Baldwin Park and Mill Race tributary are shown in Figures 7 through 10.

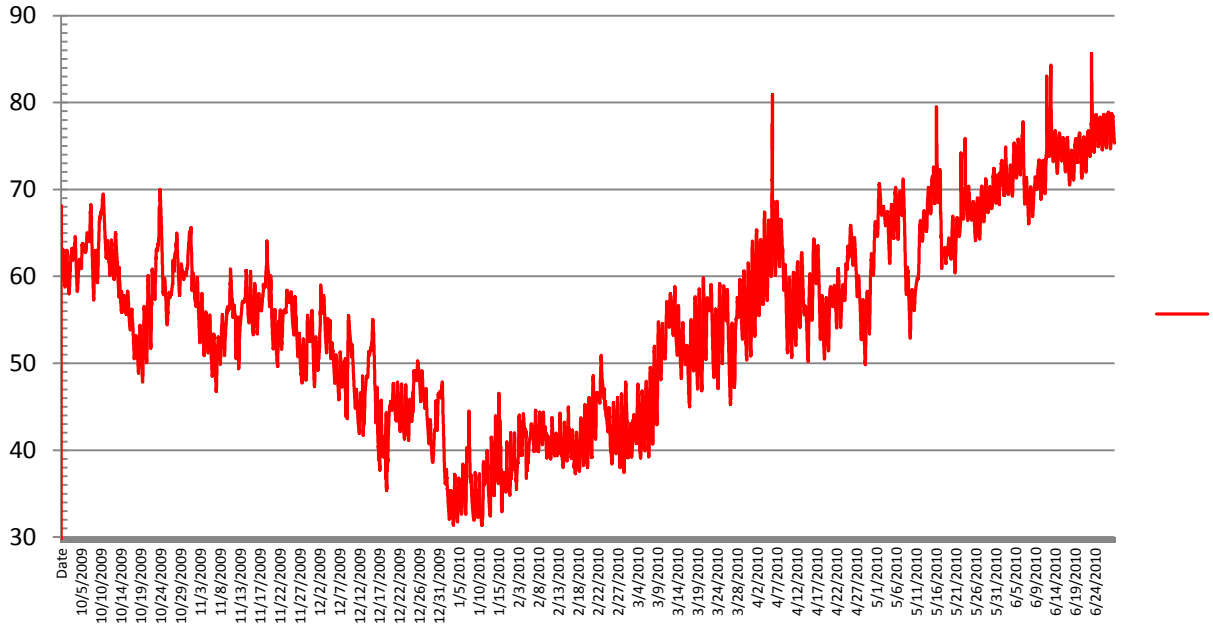


Figure 7: Baldwin Park Temperature (F) Before Construction

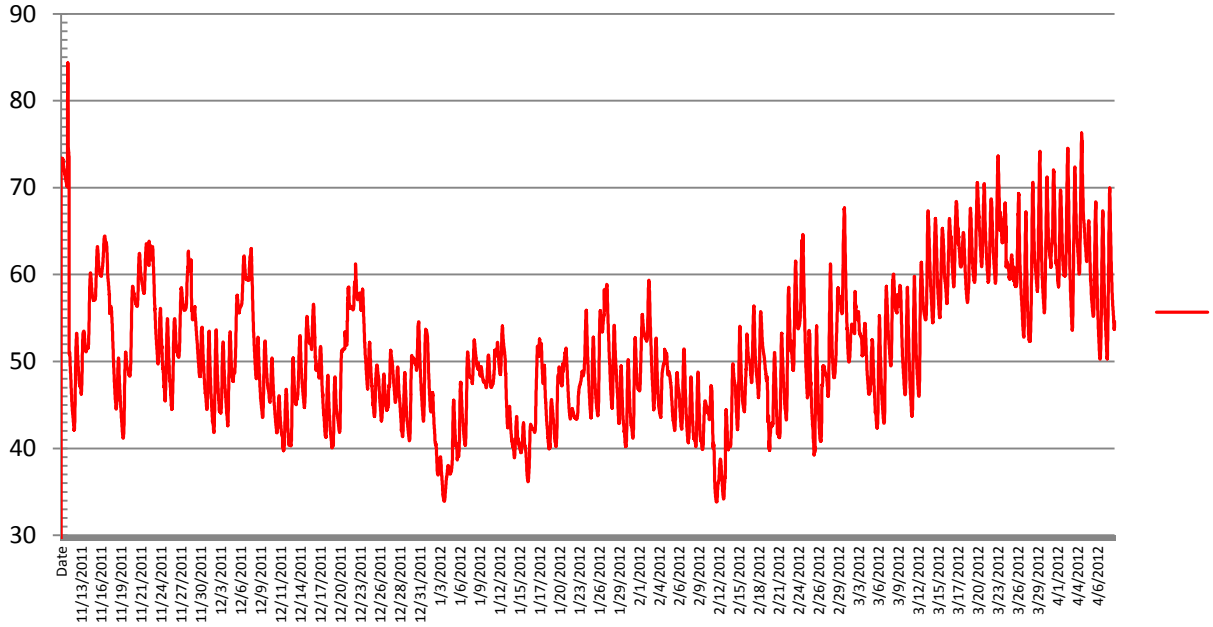


Figure 8: Baldwin Park Temperature (F) After Construction

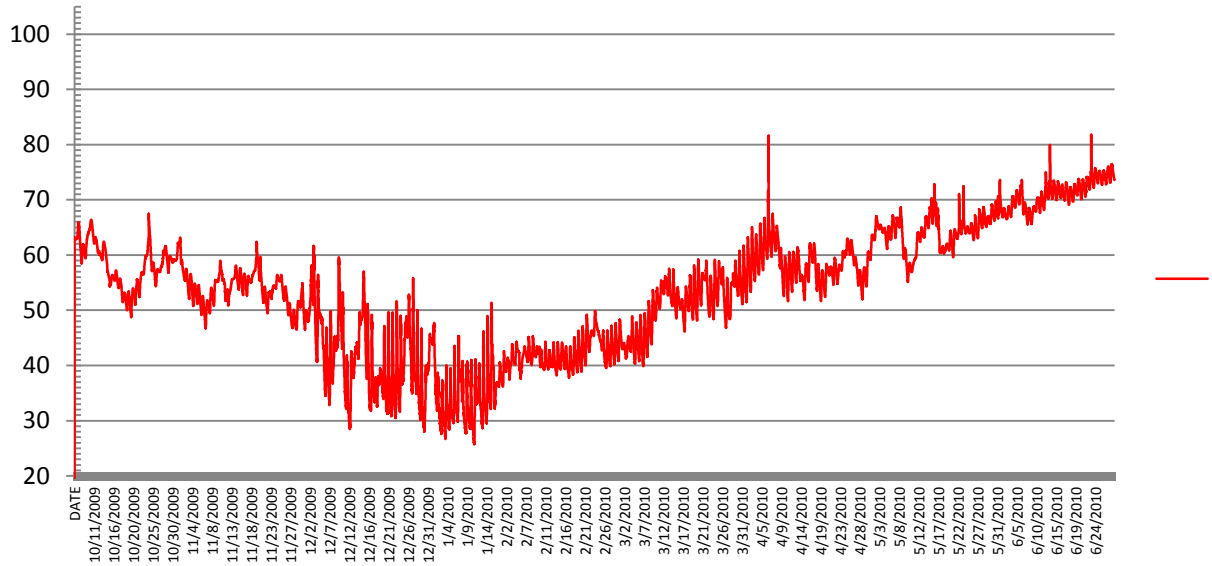


Figure 9: Mill Race Trib Temperature (F) Before Construction

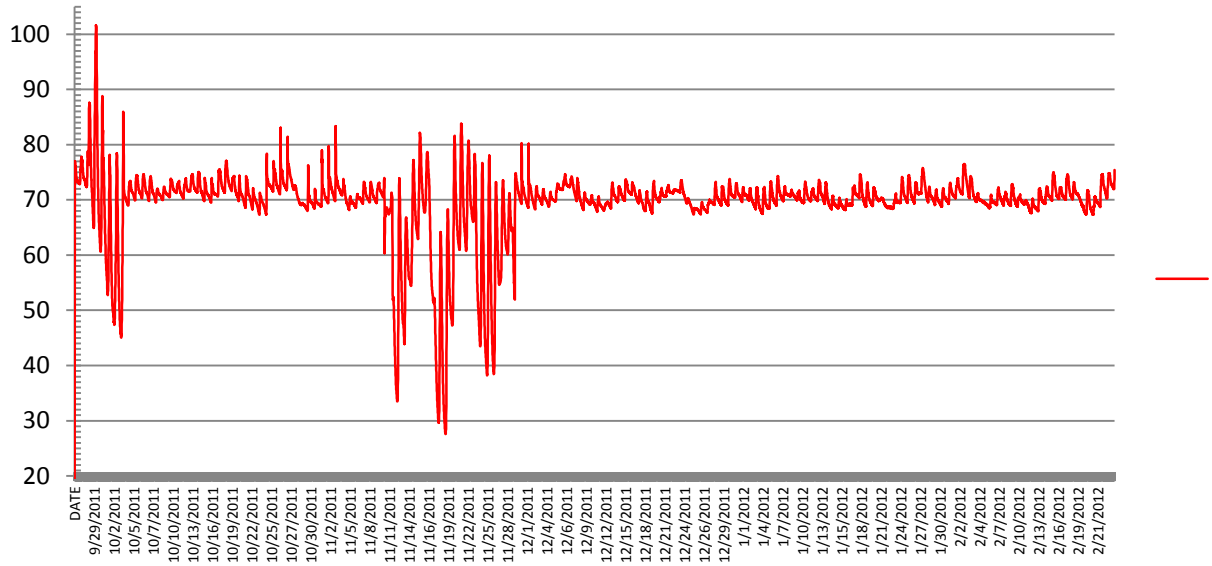


Figure 10: Mill Race Trib Temperature (F) After Planned Construction Period

RAIN GAUGE DATA

Rainfall was monitored from the beginning of the project to assist with modeling of the project subwatersheds and engineering design of the stormwater management structures (BMPs). In the following rainfall hyetograph (Figure

11, we have aggregated rainfall to total daily values. We have a brief period in late 2010 that appears to be very dry. This is when the gauge sensor's battery had run out, and reflects the time it took us to get a new one in.

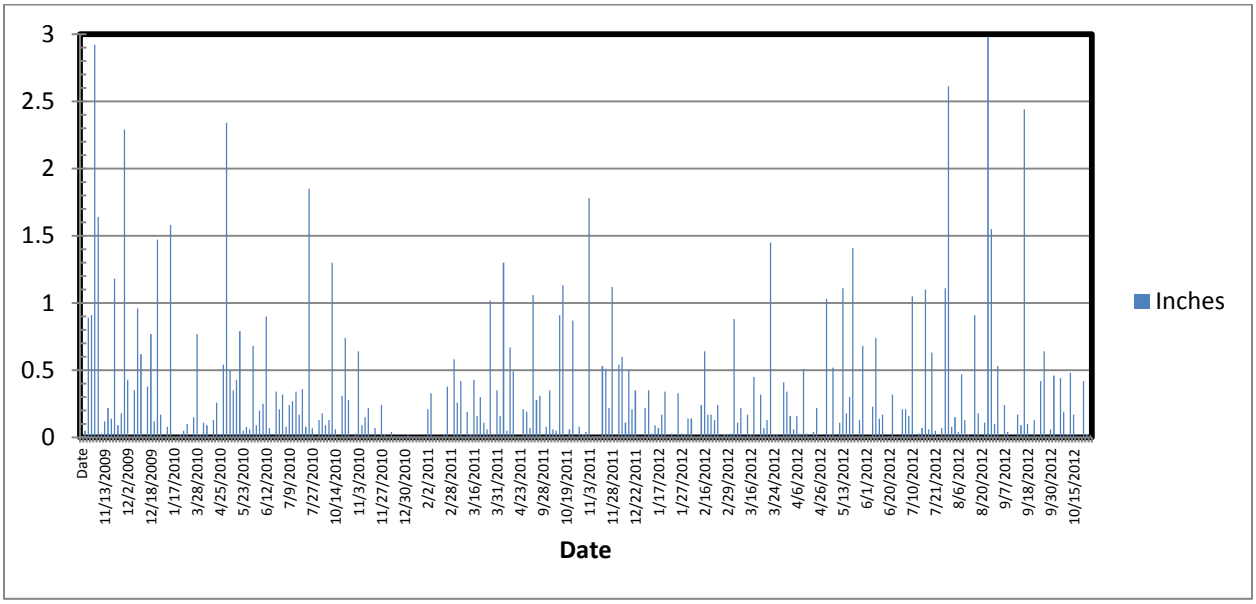


Figure 11: Chapel Hill Town Hall Rain Gauge Data

BENTHIC MACROINVERTEBRATE MONITORING

Benthic macroinvertebrates collected at the two sites are presented in Table 4. Organisms are picked out from a sample roughly in proportion to their abundance, but no attempt is made to remove all organisms. If an organism can be reliably identified as a single taxon in the field, then no more than 10 individuals need to be collected. Some organisms are not picked, even if found in the samples, because abundance is difficult to quantify or because they are most often found on the water surface or on the banks and are not truly benthic. Organisms are classified as Abundant if 10 or more specimens are collected, Common if 3-9 specimens are collected, and Rare if 1-2 specimens are collected.

Table 4: Abundance of Benthic Insects Collected from Baldwin Park and Mill Race Tributary	**Baldwin Park 2009**	**Baldwin Park 2012**	**Mill Race trib 2010**
Taxon	*Abundance*		
Ephemeroptera			
Family Baetidae			
Baetis flavistriga		**A**	
Trichoptera			
Family Hydropsychidae			
Diplectrona modesta			**R**
Cheumatopsyche spp	**A**	**A**	
Hydropsyche betteni	**A**	**R**	
Family Philopotamidae			
Chimarra sp		**R**	

Diptera			
Family Tipulidae			
Tipula spp		**R**	**R**
Family Chironomidae			
Conchapelopia group		**R**	**R**
Natarsia spp			**C**
Paratendipes spp			**C**
Cricotopus annulator group	**C**	**A**	
Cricotopus fugax		**R**	
Cricotopus triannulatus gr		**A**	
Eukiefferiella claripennis group	**A**	**C**	
Orthocladius obumbratus	**R**		
Zavrelimyia spp		**R**	
Corynoneura spp		**R**	
Coleoptera			
Family Dryopidae			
Helichus spp			**R**
Family Dytiscidae			
Hydroporus spp		**R**	**R**
Family Elmidae			
Stenelmis spp			**A**
Family Psephenidae			
Ectopria nervosa			**A**
Odonata			
Family Cordulegasteridae			
Cordulegaster spp			**R**
Family Coenagrionidae			
Argia spp		**C**	**R**
Oligochaeta			
Family Enchytraeidae	**C**	**R**	
Family Lumbricidae			
Lumbriculus spp	**C**		
Family Lumbriculidae			**R**
Family Tubificidae			
Limnodrilus spp (hofmeisteri)	**C**	**C**	
Ilyodrilus templetoni	**R**		
Family Naidiae			
Nais spp	**A**	**C**	
Slavina appendiculata		**C**	
Crustacea			
Family Gammaridae			
Crangonxy spp			**C**
Family Asellidae			

Caecidotea sp (forbesi)	**R**		
Family Cambaridae			
Procambarus acutus	**R**		
Mollusca			
Family Physidae			
Physella sp		**A**	
Abundance codes: A = Abundant, C = Common, R = Rare			

Table 5 presents the tabulated measures of biotic diversity (richness), NC biotic index score, and bioclassification based on NC DWQ's Small Streams Biocriteria:

Table 5: Diversity and Bioclassifications of Baldwin Park and Mill Race tributary

	Baldwin Park 2009	**Baldwin Park 2012**	**Mill Race trib 2010**
TOTAL TAXA RICHNESS	12	21	13
TOTAL EPT RICHNESS	2	4	1
BIOTIC INDEX	7.5	7.8	5.8
BIOCLASSIFICATION	Poor	Poor	Good/Fair

Regarding the benthic monitoring results, Dave Lenat, who did the collections at Baldwin Park noted in 2009:

> *The stream fauna indicated that this stream usually has flowing water, with hydropsychid caddisflies abundant in riffle areas. There was good rocky habitat, although there were few leaves and few good bank areas. Low taxa richness (12), low EPT taxa richness (2) and a high biotic index (7.5) all indicated Poor water quality. Only tolerant species were abundant: Cheumatopsyche, Hydropsyche betteni, Eukiefferiella claripennis group and Nais. Poor water quality is often associated with urban runoff, so this pattern is not unexpected. Restoration efforts should target improvements in water quality, as there is no evidence of existing sedimentation problems in this stream.*

Since considerable sediment was being eroded from segments upstream, we suspect that it is either being carried through or deposited upstream.

And in 2012:

> *This stream drains both residential and commercial areas, with most of the catchment in Carrboro. This site was not sampled during the regular tributary collections in the spring of 2011, but a special collection had been made in March 2009. The latter collection was to establish baseline conditions, prior to mitigation efforts near the park. Although both collections produced a Poor rating, total taxa richness increased from only 12 in 2009 to 21 in 2012; EPT taxa richness increased from 2 to 4 over the same period. The mayfly Baetis flavistriga was especially abundant in this stream segment. Although this small stream has good habitat after the mitigation project, conductivity remains very high (500+ µmohs/cm in 2012).*

We note that the specific conductivity measured at the time of sample collection was 510 µS, nearly twice as high as any of the other 20 sites sampled that year. This indicates considerable dissolved materials in the water, and is a strong indicator of illicit discharges or sewer cross-connections. However, it appears there is some marginal

improvement at Baldwin Park, even though it is not enough to change the Bioclassification. On the other hand, this may be merely because 2012 was a wetter year than 2009.

Habitat was characterized using NC DWQ's methods in 2012, but not in any year prior, so we are unable to compare habitat scores over time or between these sites.

Dave Penrose, who did the collection at Mill Race tributary notes in his report:

> *The fauna was dominated by two species of beetles (Ectopria and Stenelmis) both of which are relatively tolerant. Interestingly the only EPT taxa collected from this site is an intolerant hydropsychidae (Diplectrona modesta). No mayflies or stoneflies were collected at this location. The NC Division of Water Quality (DWQ 2008) has recently developed bioclassification for small streams which is based on the biotic index values of representative taxa – UT of Bolin Creek at this location received a Good/Fair bioclassification based on these criteria.*

A site on the mainstem of Mill Race below the confluence with this tributary has consistently scored a bioclassification of Poor in both 2011 and 2012 sampling. Mill Race's tributary is clearly in much better shape and is mainly exporting a considerable amount of coarse sediment (the pea gravel and sand that is eroding in the valley). It does not appear to be exporting much fine sediment, and so may not be contributing much to the poor water quality conditions at the mainstem Mill Race site. The leads us to reconsider whether the severe erosion noted in the Mill Race tributary valley needs to be addressed in order to restore Mill Race's or Bolin Creek's water quality.

3.2 PROJECT EVALUATION

EVALUATION AGAINST MEASURES OF SUCCESS

Compared to the measures of success proposed in the grant application, how does the project measure up? Did the project elements get implemented as planned? Monitoring? Public outreach?

These were the proposed measures of success:

- Reduced export of sediment from both Baldwin Park and Mill Race tributary watersheds
- Improved instream habitat for macroinvertebrates
- Reduced levels of nitrogen and phosphorus
- Reduced maximum temperatures in stormwater
- Increased environmental interest and involvement in a lower-income population
- General education of the Towns' populations regarding stream functions, health, protection, restoration
- Demonstration to the local environmentally-oriented population of the Towns' commitment to environmental protection and sustainability
- An alternatives analysis that enables watershed restoration projects with a higher probability of success in a high-density urban area

Some of the project elements, public involvement, and monitoring did not get implemented as planned, although we did strive to implement on-the-ground projects that would have equivalent water quality benefits. In retrospect, we have learned that our project vision was simultaneously too vague in some ways and overly specific in others. This contributed to unrealistic expectations, insufficient planning, and lack of coordination. Implementing this project taught all of the project team members, even our NC DWQ team member, some very valuable lessons. These lessons are presented in a set of "Lessons Learned" in the next section, presented in a way that would have been very useful for our team to have seen prior to starting out.

There were indications of improved biological conditions at Baldwin Park, but our original monitoring methods did not pick up significant improvements. However, we have not observed any further erosion going on at Baldwin Park, and recognize that the biological community can take longer than a year to show significant improvement. As with the other project elements, implementation itself presented many opportunities for public interaction and education, and gave project members a better understanding of property owner concerns in this historically African-American neighborhood. Installation of a modified OWASA stream ford crossing was educational for both Chapel Hill staff and OWASA staff, and has opened up discussion on how to minimize geomorphic effects of stream crossing fords.

Since we did not carry out the projects at Mill Race tributary, we did not meet the measures of success for that site in particular. And because we only did pre- and post-construction monitoring for Baldwin Park, we are not able to evaluate whether the replacement projects for Mill Race tributary (Trinity Court Stream Restoration, Hargraves Fire Lane, Dickerson Court Bioretention, or Mitchell Lane Bioretention) resulted in any physical, chemical, or biological changes in receiving waters downstream. However, two of these replacement projects drain directly to Tanyard Branch. The installation of new stormwater management in this built-out area is supported by the results of the Tanyard Branch Alternatives Analysis, which encourages both the use of distributed and regional stormwater retrofits in the subwatershed to address downstream erosion.

These replacement projects were excellent opportunities for outreach to other Chapel Hill Departments and Divisions who are unfamiliar with or skeptical of stormwater retrofit and stream restoration projects. We believe this has opened up a positive and productive dialogue between Departments and Divisions and forms a good base for setting up more retrofit and restoration projects on Town property. Being on Town property in fairly public areas, where there is a lot of foot traffic, these sites offer a better opportunity for public outreach and education than the Mill Race tributary project elements would have. The Mill Race project elements were all situated in property owners' back yards in a deep valley, affording no opportunities for public education beyond the property owners themselves. Our replacement sites are getting signs installed (still in design to make sure they meet the needs of the affected departments), which allows us to share our message passively, rather than requiring tours and other direct staff involvement.

For the Watershed Restoration Plan, we did not have any measures of success other than those related to public education. While the process of writing the Watershed Restoration Plan was difficult due to distraction and division, we now have a very thorough and directed Watershed Restoration Plan for the watershed. Our interactions with the public and environmental organizations have taught us we must place greater emphasis and effort on public outreach and involvement. Our completely unplanned but necessary Situation Assessment told us much more about public attitudes than we could have learned even through direct interaction with the interviewed stakeholders. A third party provided neutrality that we could not. We definitely increased environmental interest and involvement as measured by the amount of interaction we had with Friends of Bolin Creek, the Situation Assessment itself, and the events that had increasing attendance as the project progressed. We have definitely demonstrated to local environmental organizations and environmentally-minded citizens that the town has a commitment to environmental protection and sustainability. We have begun the process of educating the general public on water resources in general, only touching on stream health and functions. In this regard we have a lot more work to do, as this project only interacted with a comparatively small portion of the general public.

We have an excellent alternatives analysis for Tanyard Branch that is serving as the foundation for watershed restoration implementation steps for Chapel Hill that are described in the Watershed Restoration Plan. This study, and the benthic macroinvertebrate monitoring done over the past few years, has crystallized our focus. It suggests that tackling the most degraded streams for comprehensive subwatershed-scale restoration is probably the most effective way to improve Bolin Creek's overall biological health, even though with such high land use intensities such projects will be extraordinarily challenging.

Overall, we do consider the project a success, even if it did not turn out as planned. We have learned a great deal about stream restoration and stormwater retrofit project planning, siting, design, and implementation; things even our professional staff engineers were unfamiliar with. Interaction with different stakeholders and parts of the public has shown us new dimensions on public attitudes that we would not have known about otherwise, including strongly negative feelings and attitudes unrelated to environmental issues that the Towns should pay better attention to. We now have a much better understanding of the kinds and depth of public resistance and support we can anticipate for future projects. We have learned the limitations and boundaries of our own organizations, but also developed deeper cooperation and communication. Environmental organizations that would partner with us now have a better understanding of what they are asking of us, and what environmental objectives are more realistic than others. These experiences will serve us very well as we start down the path of implementing our Watershed Restoration Plan.

GRANT BUDGET SUMMARY

The total proposed project cost was $632,320. The amount of 319 Funds requested was $369,792. The proposed match amount was $185,200 in-kind and $77,328 cash, for a total of $246,528, provided by the Towns of Chapel Hill and Carrboro, NCSU's Water Quality Group, the Friends of Bolin Creek, and the NC Ecosystem Enhancement Program. Match consisted of staff time, installation of demonstration projects, monitoring, website and outreach, reports, project administration, and NC EEP preservation/restoration activities.

Actual total expenditures were a total of $737,826.89, including additional local match activities as described below, including the installation of a USGS real-time stream gage on Bolin Creek. The cost split was 48.65% federal funds, 51.35% non-federal.

Table6 summarizes the actual and budgeted amounts of cash and in-kind match funds.

Table 6: Actual and Budgeted Cash and In-Kind Match Amounts

	Actual	**Budgeted**
Total	*$378,863.89*	*$262,528.00*
Cash	*$87,049.37*	*$77,328.00*
In-kind	*$291,814.52*	*$185,200.00*

Appendix 13 presents final federal and non-federal expenditures broken out by quarter, expenditure type, and the total amount.

MATCH AMOUNTS AND DISCREPANCIES

In preparing our grant application, we were encouraged to include all water quality activities in Bolin Creek watershed as match amounts. On the other hand, we were not advised well on how much staff time implementation would consume or how to budget cash versus in-kind match amounts. Thus, our original match amounts were weighted heavily towards tasks other than project implementation, and our actual match expenditures were weighted much more towards salary and benefits for staff. This also meant that if we spent more in match during the project period that the total project cost would go up. This is an unfortunate side-effect of using activities not part of project implementation as match in this way.

At the time, Chapel Hill staff were doing water chemistry monitoring, and had originally planned on three years of water chemistry monitoring match, $7200 total. In actuality, $10,082.95 was spent for two years of macroinvertebrate monitoring in the watershed, and $2691.50 was spent for water chemistry monitoring.

Similarly, Carrboro's initial match estimate for water chemistry was $5700, and $18,000 for macroinvertebrate monitoring. Their actual match amounts for benthic monitoring were $21,900 and $1350 for water chemistry.

NCSU had originally pledged $45,000 as an in-kind match. In initial cost calculations, project staff mistakenly subtracted this from NCSU's estimate of project engineering and construction costs. NCSU had given us the engineering and construction estimate with the match amount already subtracted, meaning our budgeted amounts in our initial contract were incorrect. As it turns out, NCSU contributed $60,000 as an in-kind match.

NC EEP had originally pledged $20,000 in Bolin Creek preservation work. However, by Summer 2011 we were uncertain NC EEP would be able to cover their match, as they were having great difficulty finding project sites. This

need to cover their match amount figured into Chapel Hill's decision to use our own crew for some of the Mill Race tributary replacement projects.

In the process of developing our budget, our original subproject budget breakdown (including monitoring, supplies, educational labor and materials, gas, etc.) was approximately:

Administration and contingency:	$42,550
Watershed Plan:	$50,400
Alternatives Analysis:	$50,000
Baldwin Park:	$229,160
Mill Race tributary:	$198.260
Carrboro rain gardens:	$11,050

Calculating actual costs for each part is somewhat more complicated. We did not have a budget item for Town staff labor devoted to implementing Baldwin Park or Mill Race tributary elements. Hence, these wound up being recorded as "Administration." When more Chapel Hill staff were brought in to implement the replacement projects for Mill Race tributary, it did not make sense to mark these as "administration," so these were logged in the same cost category that NCSU match amounts were.

NCSU's match amounts as well as the invoiced contract amounts were also confused by not being clearly tied to particular project elements. Hence, NCSU match amounts were divided evenly between Baldwin Park and Mill Race tributary until 2012, when all NCSU activity at Baldwin Park was truly complete. Furthermore, with $15,000 more contributed in match, it is difficult to know which project element this was spent on. The invoiced contract work suffered the same problem.

There were some specific issues with 319 budgeting and expenditures tracking that tripped us up. The contracting arrangement with NC DWQ required that the Town spend no less than 10% of the 319 funds in the very last quarter of the project, rather than spend it earlier and wait to be reimbursed the last 10% until after the final report was submitted. Attempts to clarify indicated the issue was when 319 funds were *spent*, not when they were *reimbursed*. This was very confusing, as we were using 319 funds for engineering and construction services provided by NCSU. If our project was being executed on time, this meant our design and construction would be completed well before the last quarter. To meet this unexpected spending standard, we set up a payment schedule with NCSU that broke out spending approximately matching when they would be conducting which activities, but drew out payments through the last quarter, including no less than 10% of the 319 funds to be billed by NCSU in the last quarter. This greatly constrained our ability to tie specific work to specific amounts spent in a quarter, and confused just about everyone.

The grant application had estimates of 319 funds spent in each quarter to the closest 5%. We were not instructed by our NC DWQ advisor or NCSU staff on how to come up with milestones for activities or how to estimate amounts to be spent in each quarter, but it did not seem to be a problem for our application. However, when it came time to sign the contract we had to go through extensive and highly detailed revision of the milestone and planned expenditure table, estimate spending to the closest dollar (not closest 10 dollars or 100 dollars) each quarter, and calculate the quarter and cumulative expenditures to hundredths of a percent. These revised numbers were initially pulled from our fixed payment schedule with NCSU (noted above, which went to the closest $1000), but meeting the exact dollar amount took guesswork.

3.3 LESSONS LEARNED

MONITORING

- Create your QAPP prior to applying for grants to get the most out of writing it, including tight estimates of costs, equipment needs, labor needs, quality assurance sample needs, scheduling, identification of the most sensitive parameters, and exclusion of those that will not give you much information. (Treat monitoring as its own project for best results.)
- If you are monitoring a small stream, first-order perennial, intermittent, or ephemeral, consider the installation of a weir to help you measure the smallest flows and provide a pool for your pressure transducer. This has the benefit of giving you a verifiable level that is truly zero flow. This will also allow you to calculate discharge much more reliably for such small streams than trying to measure using a flow meter. The flow meter approach works better on second- to third-order streams where you can find a good control point.
- Select the simplest monitoring approach you can that focuses tightly on the most important, and encompassing, characteristics that are likely to detect what you are most interested in. (Or, contract out for monitoring work to minimize time requirements for project staff.)
- In a three-year grant period you are unlikely to get sufficient pre-construction and post-construction monitoring data where statistical significance or high variability is an issue, such as for water chemistry or flow/discharge.
- In a three-year grant period it is unlikely (but possible, as we learned in our case) that the macroinvertebrate community will have recovered from construction stressors enough to detect improvement. Sample downstream of the project area rather than at the project area.
- Use simpler, more approximate, methods to calculate discharge at very high flows rather than trying to measure discharge directly, unless high data quality is required to detect statistically significant changes. Contract out if higher data quality is required.
- Bank pins are good to use ahead of project proposal and design to get a quantitative measurement of bank erosion, especially in places where you have considerably instability. They are not so useful for monitoring bank erosion after construction if bank or channel reshaping is part of the project. In that case, it is better to get several as-built cross-sections surveyed and resurvey them once a year.
- Ideally, conduct monitoring on tributaries or below areas most likely to receive a stormwater retrofit or stream restoration for a few years prior to applying for a grant to install those projects. This information will get you started faster on engineering design and give you more information to compare post-construction conditions to. A Watershed Restoration Plan can help you identify those tributaries and areas so you can set up a targeted long-term monitoring program. It can also help you better quantify present stressors and their severity, and better quantify expected water quality improvements from a project.

EDUCATION AND OUTREACH

- Set up a list of people who should be privy to the excruciating details of implementation. This should include your potential utility contacts, property owners, contractors, anyone directly affected by the activity, and anyone else who might have advice for or be critical of implementation details. When in doubt add people, noting that you thought they might want to be informed of these details, and instruct them to ask you to remove them if it is too much information. Set up a simple email template to help you

remember what you need to cover in each email and help readers quickly scan it for essential information such as contract number, site, project name, stage in implementation, specific questions for specific recipients, action items for recipients and when due, review of past requested/completed action items, upcoming milestones or steps, critical dates, etc. This is especially important if you are trying to coordinate the activities of many people, or there are certain people who can be a bottleneck in the process if they do not act at the right time. Optimally, set up an actual subscriber-style listserver (rather than email list) to allow participants to control how much they hear from you.

- Plan on a secondary, less information-dense, general public interest listserver or other method to less regularly (perhaps monthly) distribute updates (compared to the higher-frequency stakeholder list). At the start of the project, directly invite journalists/bloggers to subscribe and indicate the volume of email they should expect. Mirror your message across your webpage, Facebook, Twitter, and whatever other hot new social networking tool is in fashion, even phone texts. Each person has a different preferred method of receiving information. Print up business cards with an inviting description of what you are doing for all the different contact methods, then hand them out everywhere.

PLANNING AND PREPARATION

- Have tight, detailed concept plans prior to grant application. Have a clear vision of what you are proposing to construct, and what the interim steps might look like to better describe the final project and project steps to property owners. Review of a site with a fine-toothed comb may be necessary to identify potential pitfalls and problems. Get a utility locate service done when doing the concept plan. Get a professional survey done of the proposed site. Opportunities not perceived from GIS or drive-by surveys may be found when closely observing the site. Review of conditions with the property owners to identify not-easily-viewable or uncommon conditions is essential.
- Have signed construction access agreements prior to applying for a grant. Because properties can be sold in the time it takes to secure a grant for a project, research whether you can get a five-year construction access agreement that is registered with the Register of Deeds, and travels along with the property if it is sold.
- Identify whether some perpetual protection in the form of an easement is required or might be a good idea for a project. Where there is a hazard of a property owner not maintaining a BMP determine whether your organization can take on maintenance, and the property owner may grant a public stormwater easement for that purpose. Alternatively, select designs that require less maintenance or are less likely to fail. Make sure such agreements of maintenance are spelled out clearly in a binding agreement with the property owner.
- Make sure you know ALL of the project implementation steps – every detail, even if not explicitly required in the grant application. This is where a highly detailed concept plan is necessary. When you are contracting work out, review these steps with the contractor to make sure there are no unspoken or assumed steps that need to be scheduled and assigned.
- With a detailed list of implementation steps, review costs thoroughly. What is included in contract work? What outreach activities might you do? Developing a QAPP before grant application will help you in this step immeasurably.
- Contingency planning. Identify possibly pitfalls. Identify points where you have little control over what happens and have alternative plans. Property owner cooperation, weather, proper equipment functioning, cooperation of other departments or agencies, construction challenges, timing and scheduling – all can go in a way not planned on that you have little influence on. Set up an alternative

path for accomplishing deliverables to cover these cases where possible. Do include a contingency amount in your budget, but first discuss what is acceptable with the granting agency.

- Understand your contracting and procurement steps, and do the preliminary setup work for them as soon as you are notified of the grant award. This includes getting quotes, vendor tax information, contractor insurance information, contract details, prepare to setup Purchase Orders, etc.
- Identify needs and requirements of utilities in the area of your project. Find out if they have any plans in the works for that area, or even existing but unused easements. Ask their organization to assign a primary contact for you regarding your project and any activities they may have in the area. Put this person on your regular stakeholder update list.

OTHER ISSUES

- Take lots of photos, ideally, weekly (less frequently before a grant is awarded). Take them from the same locations every time to make comparison over time easier. Make it a habit to download photos immediately upon returning, and write down a short dated note of what is going on to leave in the same directory as the photos. Schedule taking photos (and a general quick site visit) into your calendar. This is especially important if you have considerable administrative or writing duties, or other ongoing projects that may distract you from the passage of time.
- Enlist someone else to take lots of photos at events so you can be open to interacting with the public, and not look busy with other things.
- Identify all steps, roles, and responsibilities of partners. Be very specific. Set out in draft Memoranda of Agreement prior to grant application, and finalized and signed before the grant period starts.
- Consider whether there are stakeholders or partners that you are leaving out, or that would feel insulted if not involved directly in the project. Ask them how they would want to be involved. Make sure their involvement is formalized in a draft Memorandum of Agreement that is signed before the grant period starts.

APPENDIX 1: BALDWIN PARK PROJECT MATERIALS

Stormwater BMP and Stream Stabilization Conceptual Design
Baldwin Park, Chapel Hill & Carrboro, NC

Background

Baldwin Park is a neighborhood park off Broad Street near the boundary between the Town of Carrboro and the Town of Chapel Hill. The park consists of a children's play set, picnic areas, a basketball court (scheduled for expansion), and open fields. A stream, Tanbark Branch, flows along the northern portion of the park. An unnamed ephemeral tributary of Tanbark Branch exists along the eastern boundary of the park. (Note: the NC Division of Water Quality shall determine whether the tributary is ephemeral or intermittent prior to NC and Army Corps permit submittals)

The Department of Biological and Agricultural Engineering of North Carolina State University (NCSU) is working with the Town of Chapel Hill and the Town of Carrboro to implement watershed restoration practices as a component of an EPA 319 grant project in the Bolin Creek Watershed. The purpose is to improve ecosystem health and water quality by restoring natural stream functions and managing stormwater runoff in degraded areas in the watershed.

This report outlines the conceptual stream enhancement and stormwater best management practices (BMP) design for Baldwin Park. The site has been divided into eight areas (see Figure 1). The purpose of this report is make sure town staff and local property owners are agreeable to the proposed project before the design is finalized.

Recommendations

Area 1. Two Tier Bioretention Area

A bioretention area is proposed to treat stormwater runoff generated along Broad Street. Currently, this runoff is directly discharged to Tanbark Branch through a storm sewer pipe. A bioretention area captures runoff from an impervious surface and allows that water to infiltrate through the soil media. As the water infiltrates, pollutants are removed from the stormwater runoff through a variety of mechanisms including adsorption, microbial activity, plant uptake, sedimentation, and filtration. Some of the incoming runoff is temporarily held by the soil of the bioretention area and later "leaves" the system by way of evapotranspiration, exfiltration to the ground water, or discharge from the underdrains. The construction of a bioretention system in clay type soils involves importing a sand/compost mixture (1 – 2 in/hr infiltration rate) and installing perforated underdrains within a gravel layer.

The proposed bioretention area is located in the grassy area between the basketball court and the sidewalk along Broad Street. See photograph below.

Proposed Bioretention Site

The two trees in the above photograph will have to be removed. Stormwater will be intercepted from the existing 15-inch storm sewer along Broad Street. The approximate drainage area to the storm sewer at this location is 1.2-acres (80% impervious, 20% open grassed area). There is not sufficient space in the proposed bioretention area to treat the entire first flush volume from the drainage area due to existing constraints (e.g., basketball pad and sidewalk). Therefore, an adjustable weir shall be installed in the diversion structure such that the initial portion of runoff (typically the dirtiest portion) will be diverted to the bioretention area and excess runoff can pass over the weir and remain in the existing storm sewer that discharges to the creek.

A two-tiered bioretention area will be required due to the steeper topography of the proposed location. Diverted stormwater will discharge to the upper bioretention cell. A grass spillway lined with turf reinforced matting will be designed to convey excess runoff from the upper bioretention cell to the lower cell. An overflow outlet structure will be designed to convey excess runoff from the lower cell to Tanbark Branch. Furthermore, the bioretention underdrains will tie into the overflow structure. See Figure 2 for the proposed bioretention footprint.

Area 2. Tanbark Branch – Park Property

Area 2 is located at the outfall of the main storm sewer pipe by the intersection of Broad Street and Hill Street. The property is owned by the Town of Carrboro (PIN 9778977937). The stream is labeled Tanbark Branch on the USGS map.

There is limited pool habitat in this area, very limited riparian vegetation, and the streambanks are starting to erode.

The following measures are proposed in this area. See attached Figure 3:

- Boulder plunge pool at storm sewer outfall to dissipate energy and reduce erosion downstream
- Invasive plant removal
- Native riparian planting
- Create boulder step pools to improve pool habitat
- Create a bankfull bench and reduce bank slope to stabilize the streambanks

Storm Sewer Outfall

Area 2 Facing Downstream

Area 3. Tanbark Branch - Atwaters

Area 3 is located on the property owned by the Atwaters (PIN 9778987131). The stream is currently eroding the left bank in close proximity to their house. There are two options for this area depending on what the property owner will allow.

Option 1: Leave the stream where it is, reduce the bank slope, remove invasive vegetation, and stabilize the area with coir matting and native riparian vegetation. The property owner will lose a portion of their yard to reduce the bank slope.

Option 2: Relocate the stream away from the eroding bank. Create a new and stable bankfull channel in the floodplain adjacent to the existing channel. Stabilize the area with coir matting and native riparian vegetation. Fill the abandoned channel with material generated onsite. See attached Figure 4.

Area 3 Eroding Streambank

Area 4. Tanbark Branch - Safavis

Area 4 is located on the property owned by the Safavis (PIN 9778987139) and extends to the confluence with the unnamed tributary. The stream is fairly stable in this area. Only invasive vegetation management and native riparian planting are proposed for this area. See attached Figure 4.

Area 4 View Facing Downstream

Area 5. Tributary – Masons & Burnetts

Area 5 is located on the properties owned by the Masons (PIN 9778988271) and the Burnetts (PIN 9778989009) and extends up the unnamed ephemeral tributary approximately 90 feet from the confluence with Tanbark Branch to an existing sewer crossing. The existing channel has been filled with debris and needs to be reshaped to a stable bankfull channel. Invasive vegetation management and native riparian planting are also proposed for this area. See attached Figure 5.

Nothing is proposed for the existing rip rap sewer crossing as OWASA requires this area to remain open and passable for their service vehicles.

Area 5 View Facing Downstream

Area 6. Tributary –Burnetts

Area 6 is located on the properties owned by the Burnetts (PIN 9778989009). The stream is currently eroding the right bank in close proximity to a garden. There are two options for this area depending on what the property owner will allow.

Option 1: Leave the stream where it is, reduce the bank slope, and stabilize the area with coir matting and native riparian vegetation. The property owner will lose a portion of their garden to reduce the bank slope and for riparian plants.

Option 2: Relocate the stream away from the eroding bank. Create a new and stable bankfull channel in the floodplain adjacent to the existing channel. Stabilize the area with coir matting and native riparian vegetation. Fill the abandoned channel with material generated onsite. This option will require relocating the existing footbridge. See attached Figure 6.

Area 6 View Facing Downstream

Area 7. Tributary - Head Cut

Area 7 is located upstream of Area 6. The stream is located close to the property line of the Town of Carrboro park parcels and five Chapel Hill residential properties off Bynum Street. A small head cut is located in this portion of the stream. The area downstream of the head cut is slightly incised. The area upstream of the head cut is currently stable and will not be modified, except for invasive plant removal and riparian planting. See attached Figure 7.

The following measures are proposed in this area:

- Add some fill below the head cut to bring up the downstream portion of the channel and create a stable slope. Create boulder step pool system to stabilize the channel in the head cut area.
- Create a bankful bench where the channel is incised
- Invasive plant removal
- Native riparian planting

Additionally, a footpath leading to the stream in this area will be hardened with a combination of gravel and filter fabric to reduce trail erosion and sedimentation downstream. A small footbridge is proposed where the path crosses the stream.

Area 7 View of Head Cut Facing Upstream

Area 7 Trail Crossing

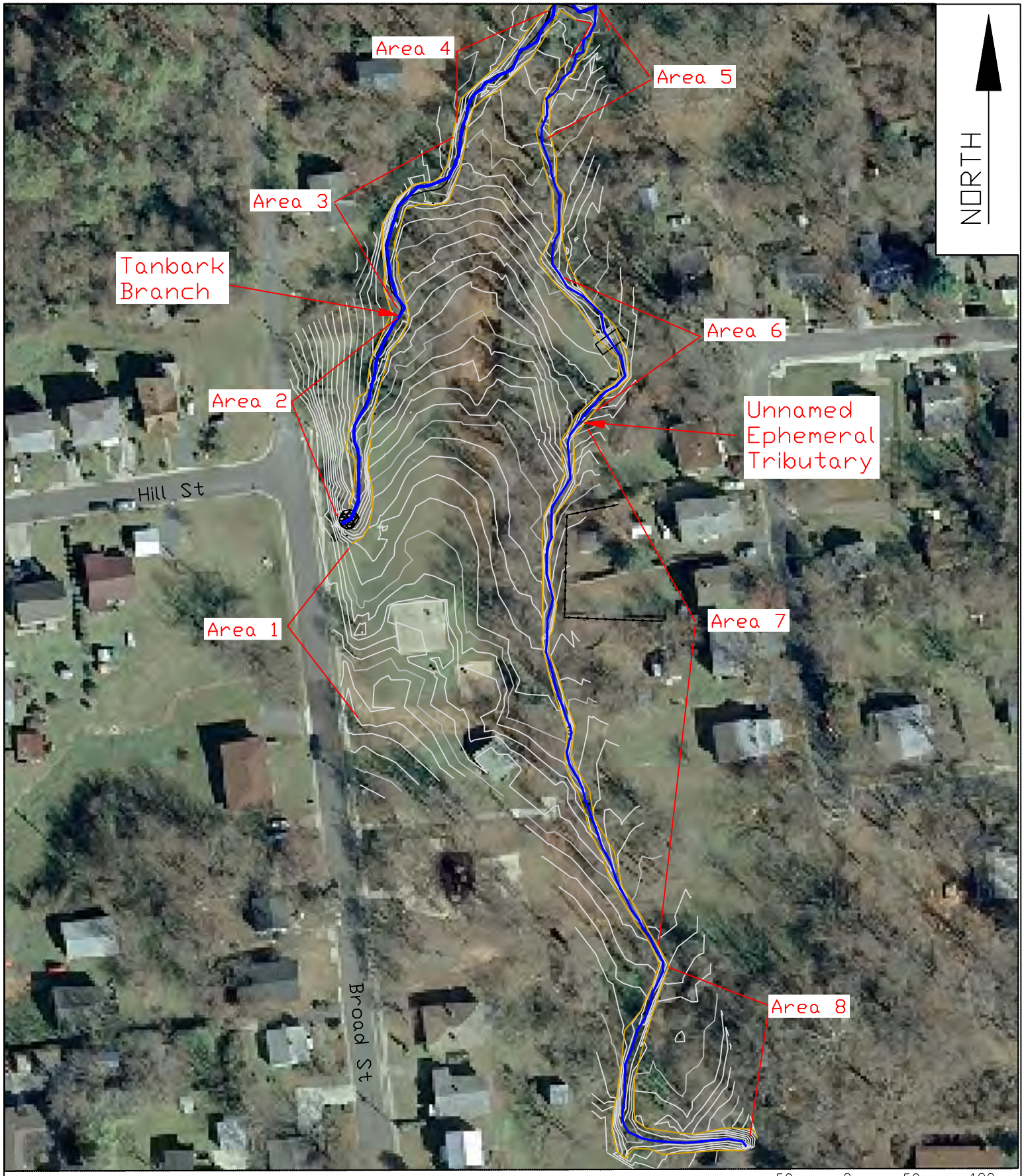
Area 8. Energy Dissipation Basin

Area 8 is located in the most upstream portion of the tributary within the Baldwin (PIN 9788070468) and St. Joseph Christian (PIN 9778979579) properties. The stream is daylighted from a 30-inch culvert at this point and takes a 90-degree turn. There are also two sewer crossing in this area.

The proposed enhancement for this area is to relocate the existing stream to a rock lined energy dissipation basin. The basin would be planted with a native juncus for stabilization and stormwater treatment. The purpose of the basin is to slow down stormwater flow, dissipate energy, and remove sediment to prevent degradation of the downstream restored sections. The new alignment would also avoid the two sewer crossings. Additionally, a swale will be designed to transport runoff to the basin from an existing 15-inch stormwater pipe outfall at the turn on Starlite Drive. See attached Figure 8.

Area 8 View from 30-inch Culvert Outfall

Figures



50 0 50 100

SCALE 1" = 100'

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SHEET NO.	
FILENAME	
PROJECT NO.	
DATE	09/14/09

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FIGURE 1
SITE LOCATION MAP

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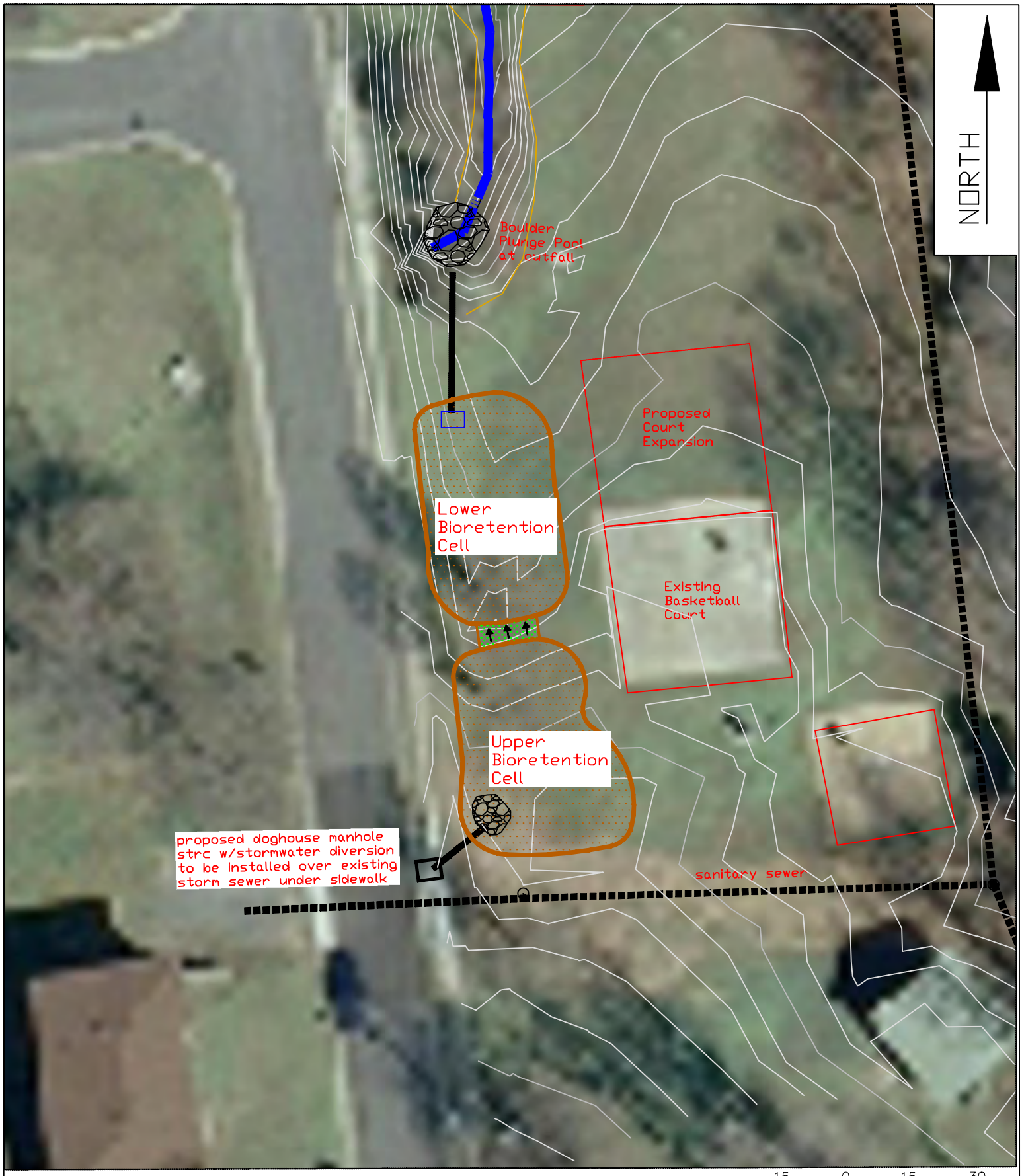

15 0 15 30

SCALE 1" = 30'

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SHEET NO.			
FILENAME			
PROJECT NO.			
DATE	09/14/09		

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FIGURE 2
AREA 1

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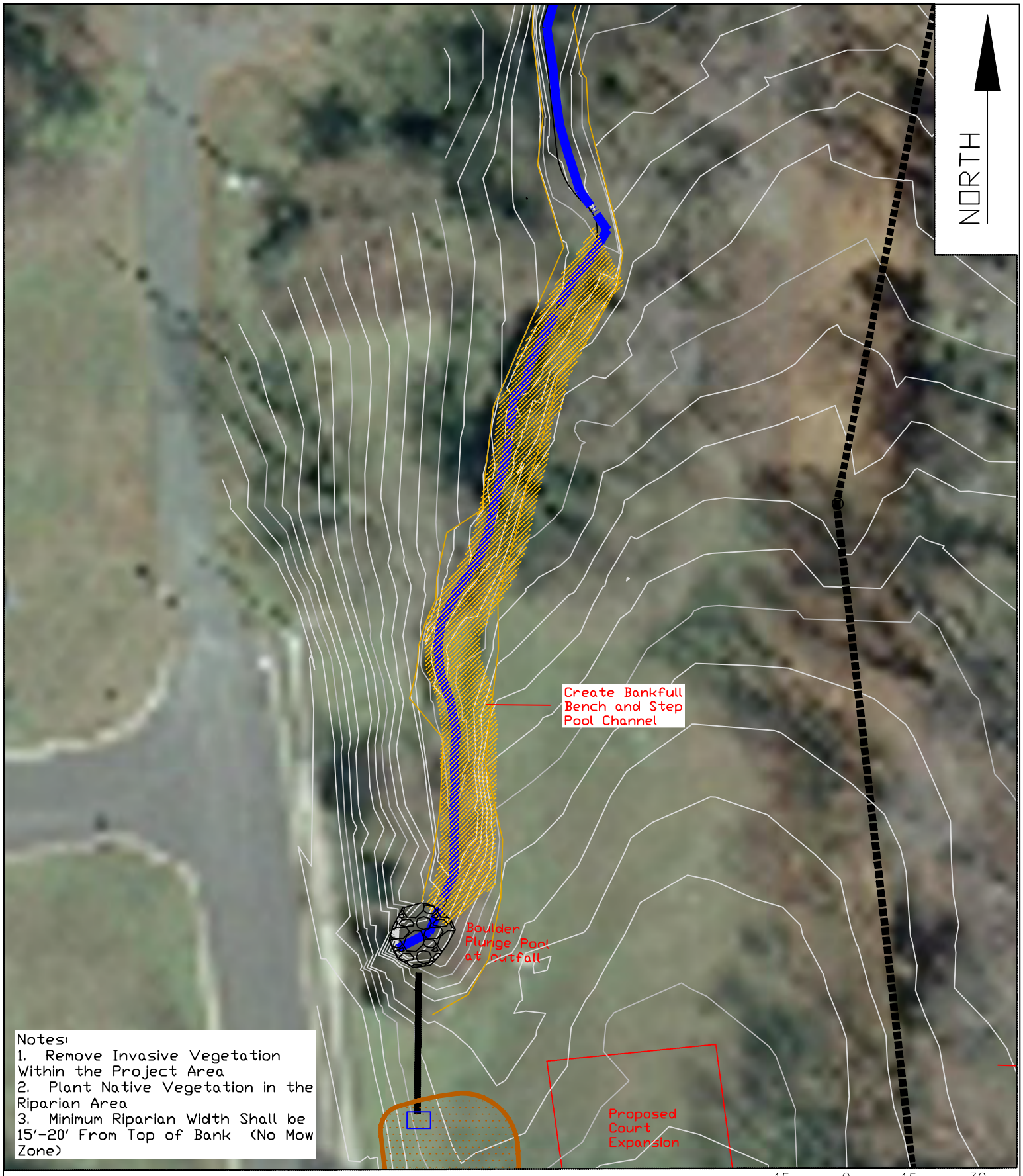
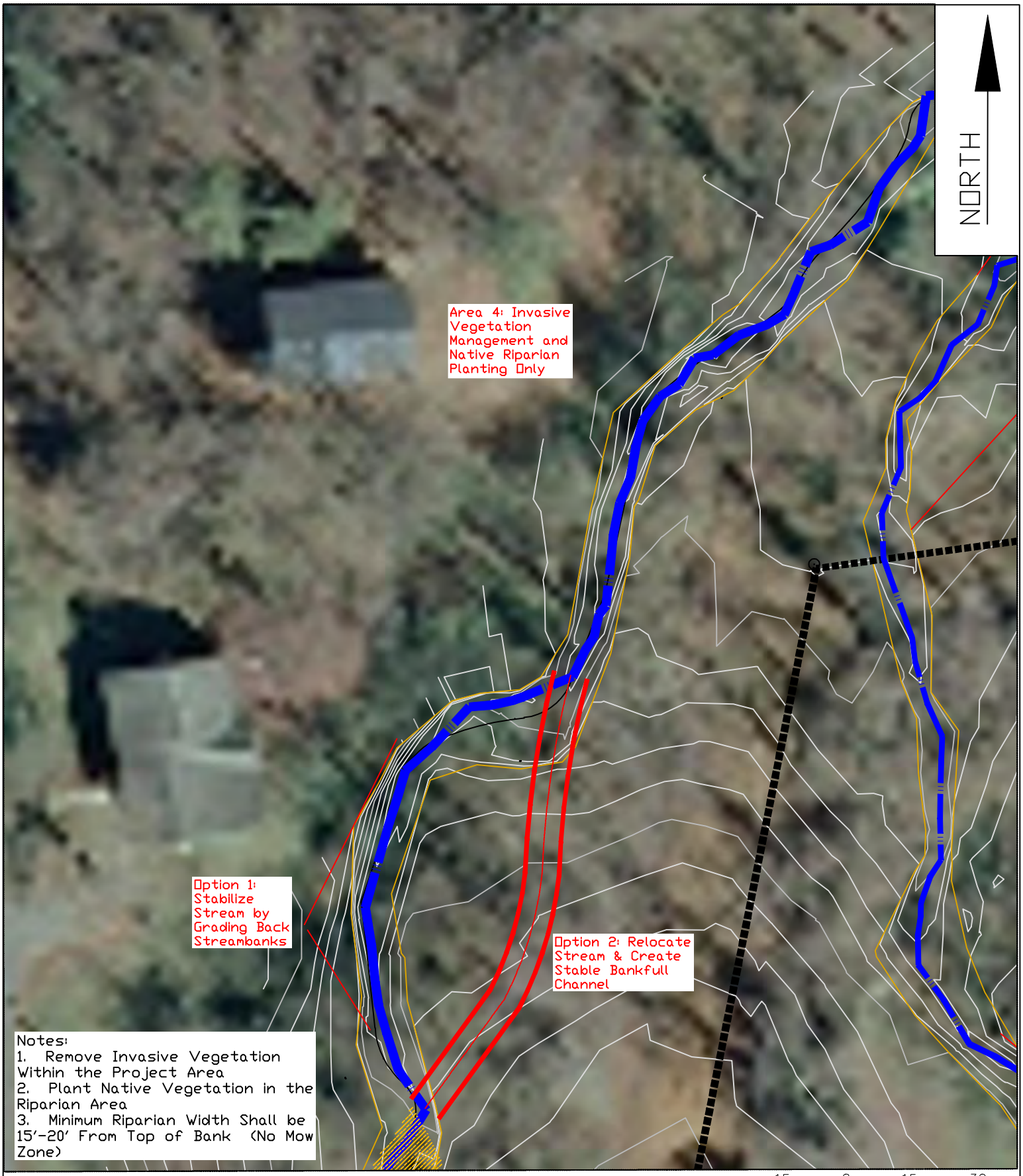


Notes:
1. Remove Invasive Vegetation Within the Project Area
2. Plant Native Vegetation in the Riparian Area
3. Minimum Riparian Width Shall be 15'-20' From Top of Bank (No Mow Zone)

15 0 15 30

SCALE 1" = 30'

DRAWING NO.	SHEET NO.	FILENAME	PROJECT NO.	DATE 09/14/09	Conceptual Design Baldwin Park Carrboro, N.C. FIGURE 3 AREA 2	NC STATE UNIVERSITY BIOLOGICAL & AGRICULTURAL ENGINEERING Weaver Labs Campus Box 7625 North Carolina State University Raleigh, NC 27695	NO / REVISIONS	DRN / CHK / DATE



15 0 15 30

SCALE 1" = 30'

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SHEET NO.			
FILENAME			
PROJECT NO.			
DATE	09/14/09		

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FIGURE 4
AREA 3 & 4

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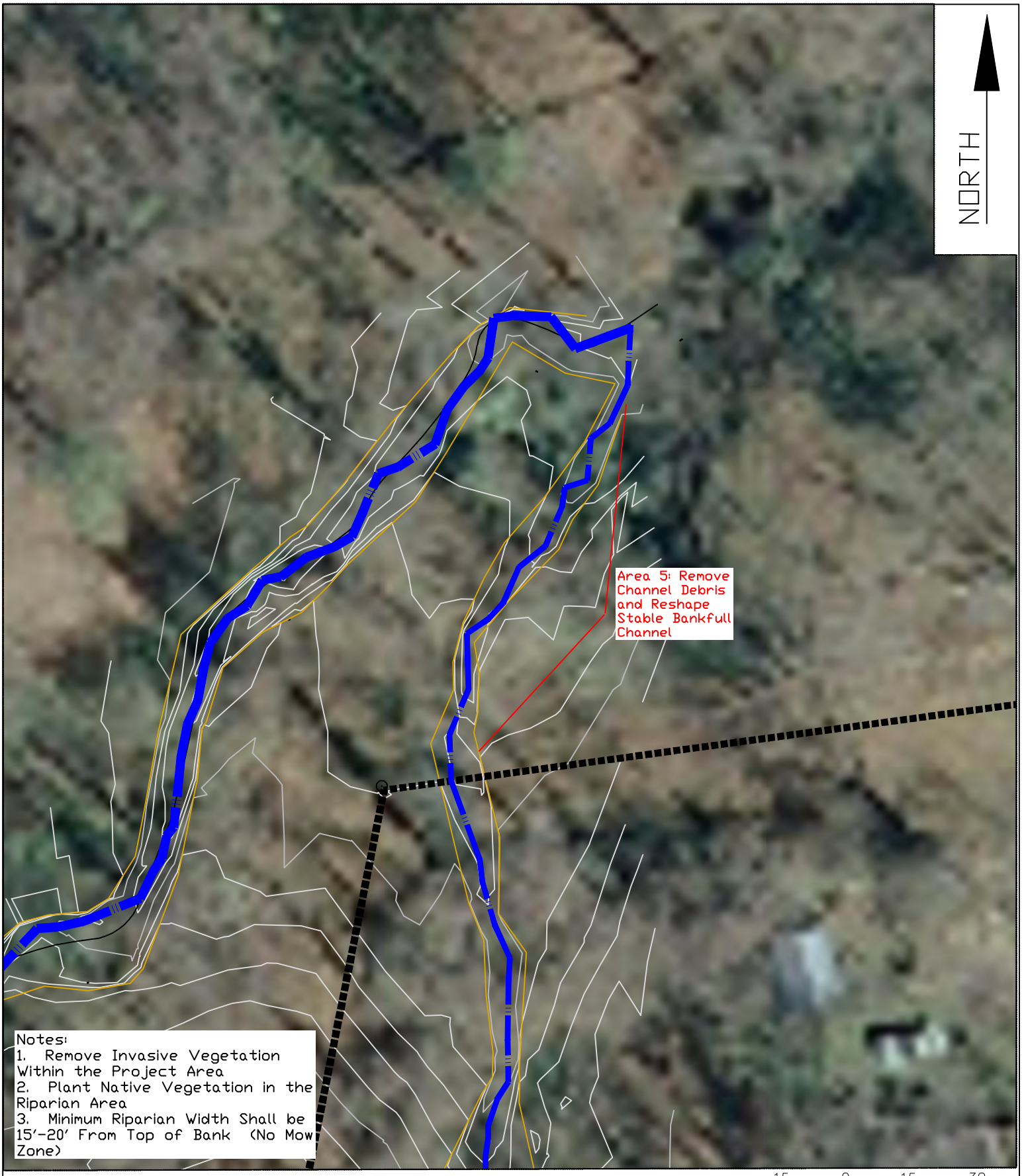

15 0 15 30

SCALE 1" = 30'

DRAWING NO.	SHEET NO.	FILENAME	PROJECT NO.	DATE 09/14/09	Conceptual Design Baldwin Park Carrboro, N.C. FIGURE 5 AREA 5

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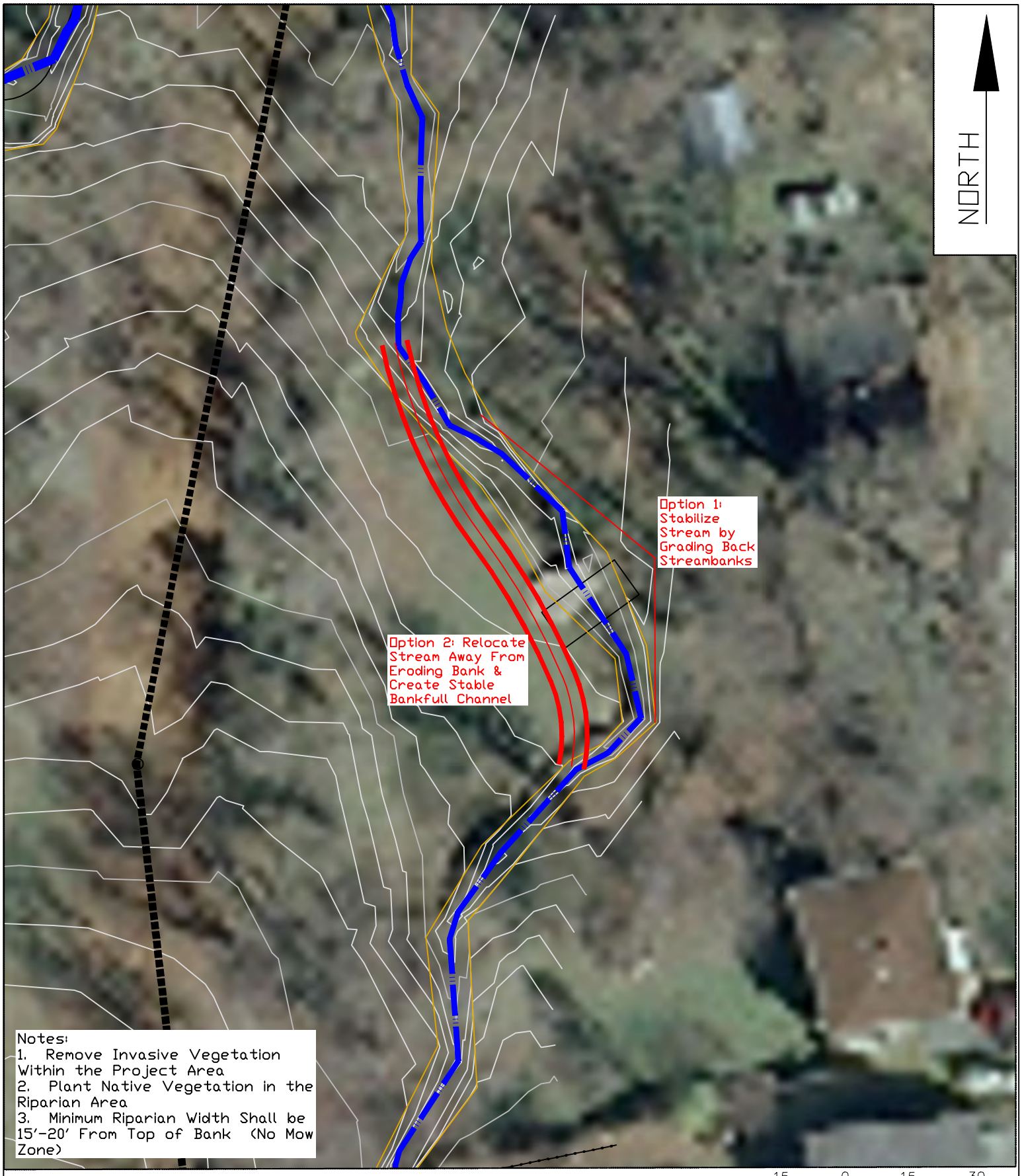
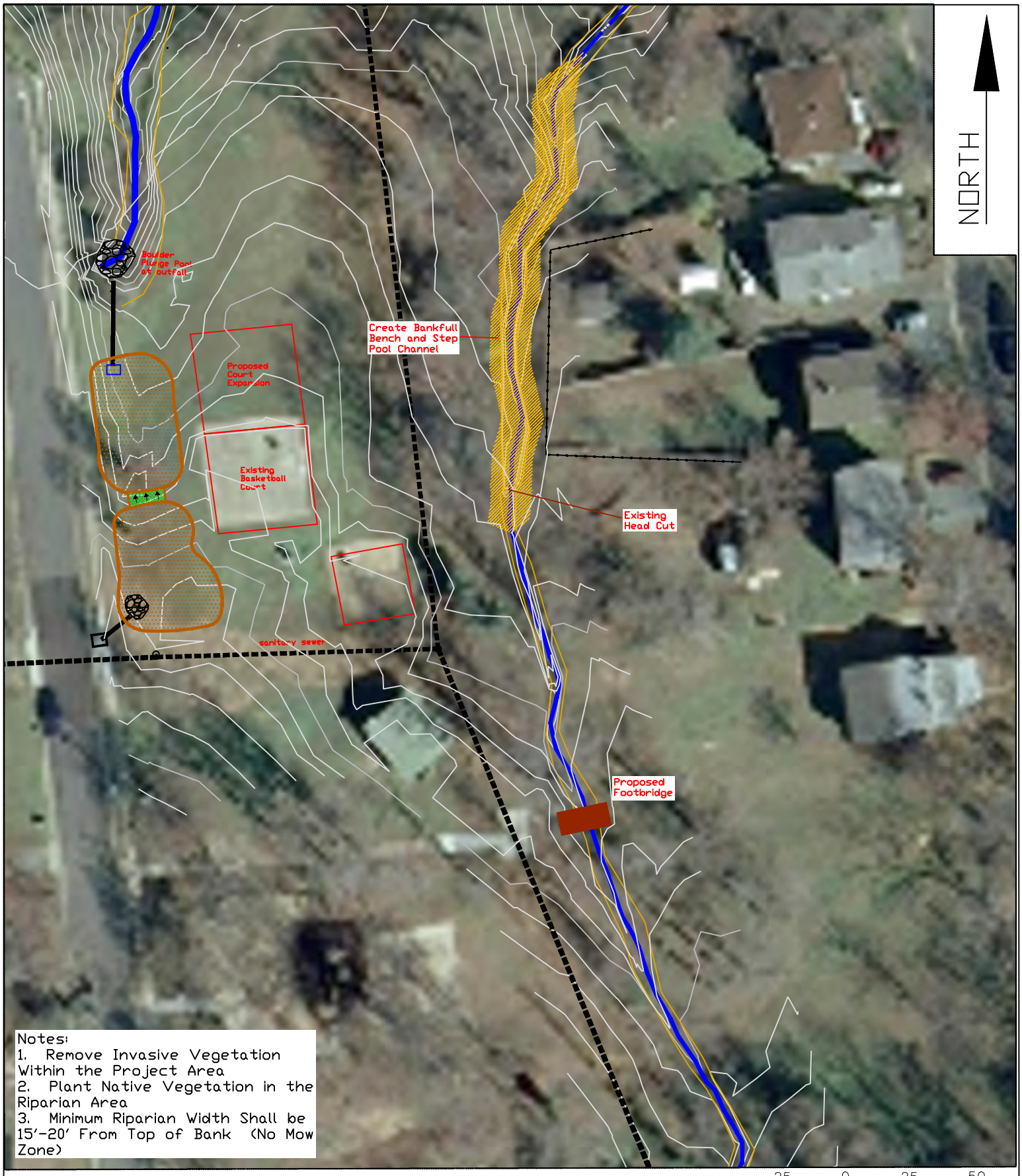


Notes:
1. Remove Invasive Vegetation Within the Project Area
2. Plant Native Vegetation in the Riparian Area
3. Minimum Riparian Width Shall be 15'-20' From Top of Bank (No Mow Zone)

15 0 15 30

SCALE 1" = 30'

DRAWING NO.	SHEET NO.	FILENAME	PROJECT NO.	DATE 09/14/09	Conceptual Design Baldwin Park Carrboro, N.C. FIGURE 6 AREA 6	NC STATE UNIVERSITY BIOLOGICAL & AGRICULTURAL ENGINEERING Weaver Labs Campus Box 7625 North Carolina State University Raleigh, NC 27695	NO	REVISIONS	DRN / CHK / DATE



Notes:
1. Remove Invasive Vegetation Within the Project Area
2. Plant Native Vegetation in the Riparian Area
3. Minimum Riparian Width Shall be 15'-20' From Top of Bank (No Mow Zone)

25 0 25 50

SCALE 1" = 50'

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FIGURE 7
AREA 7

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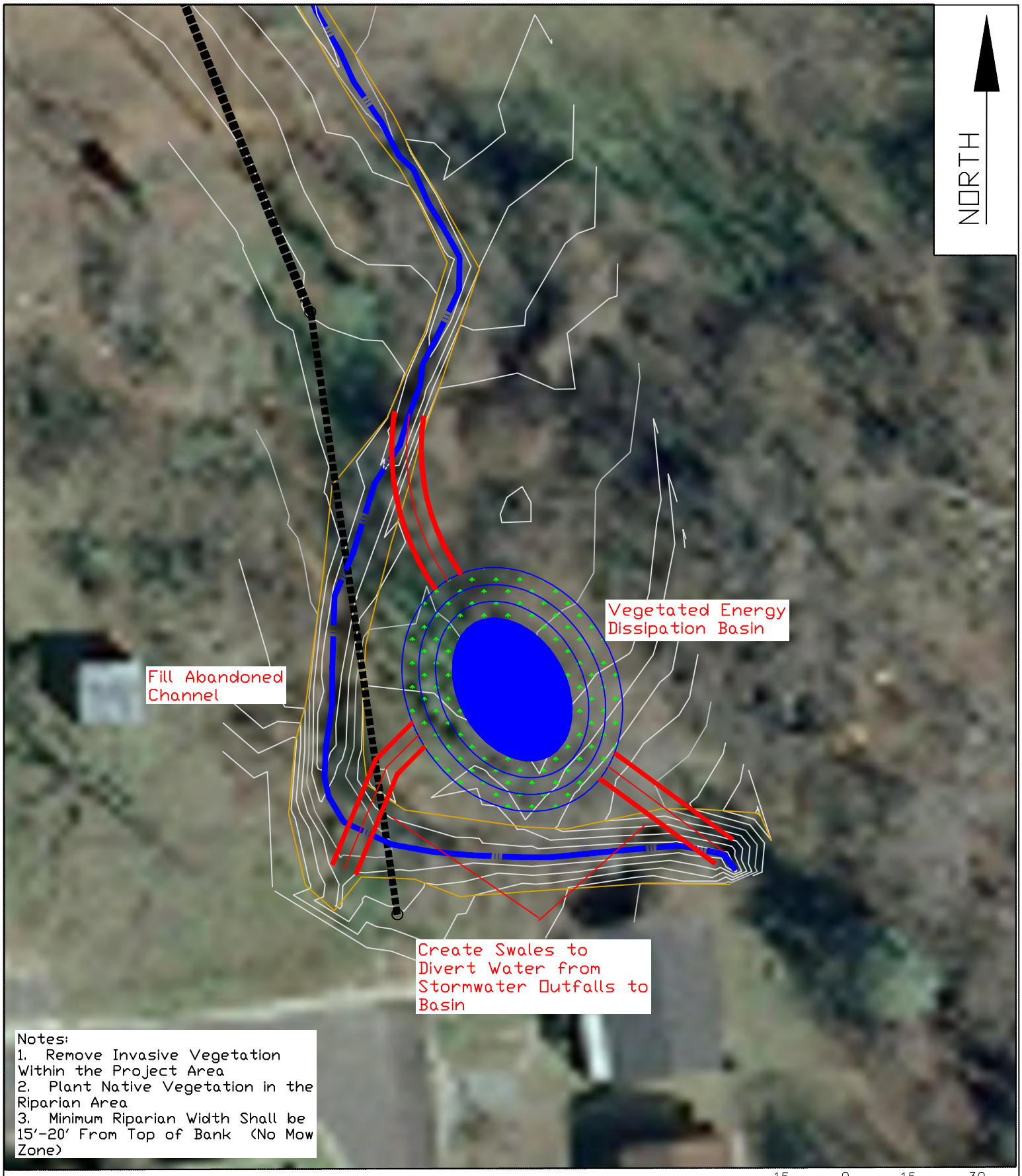

Notes:
1. Remove Invasive Vegetation Within the Project Area
2. Plant Native Vegetation in the Riparian Area
3. Minimum Riparian Width Shall be 15'-20' From Top of Bank (No Mow Zone)

15 0 15 30

SCALE 1" = 30'

DRAWING NO.			
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FILENAME			
PROJECT NO.			
DATE	09/14/09		

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FIGURE 8
AREA 8

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Baldwin Park Rain Garden Design
Carrboro and Chapel Hill, NC
Designer, Zan Price, PE, Extension Associate, NCSU

Site Suitability

Overall, the site appears to be conducive for rain garden placement.

Terrain: Carrboro staff identified a potential rain garden site on the western portion of the property between an existing basketball court and Broad Street. The terrain in this area is gently sloped toward the creek (Tanbark Branch). The site is confined by the basketball court and proposed court expansion to the east, sanitary sewer to the south, sidewalk to the west, and creek to the north.

Existing Vegetation: The proposed area is grassed and two medium sized trees are located within the proposed footprint of the garden. These trees will have to be removed and can potentially be used in the stream enhancement portion of the project.

Education Opportunities: Since the proposed site is a public park, there are lots of opportunities to educate the public on stormwater. An interpretive sign shall be placed adjacent to the garden to inform the public about raingardens.

Water Table: Based on baseflow water levels in the adjacent stream, it appears the seasonally high water table is approximately eight feet below the proposed top of the rain garden. It is recommended that the water table not be within two feet of the bottom of the constructed rain garden. This will allow for at least a three foot rain garden depth plus a gravel underdrain layer.

Runoff Availability: Currently, the proposed area does not receive much stormwater runoff. However, a buried 15-inch stormwater pipe is located under the sidewalk adjacent to the proposed rain garden. This stormwater pipe drains Broad Street through a series of curb inlets. To get runoff to the garden, a diversion structure will be installed over the existing stormwater pipe to divert runoff to the garden. Since the area available for the garden is likely not large enough to treat the entire drainage area, an overflow weir shall be installed in the structure to allow larger runoff events to bypass the area.

Maintenance/Access: Maintenance will be a crucial part of the overall effectiveness of the rain garden. As part of a park system, site maintenance should be available. Access for construction equipment also appears to be acceptable.

Design Summary

The design of the rain garden area (bioretention) at the site consists of the following general steps, which are detailed in the subsequent section.

1. Determine watershed size and characteristic
2. Determine volume of runoff to catch
3. Determine size of bioretention area
4. Set bio-retention area depth and soil type
5. Size underdrain and gravel envelope
6. Assign an overflow device
7. Choose vegetation and a planting plan
8. Construction Sequence
9. Maintenance Schedule

Baldwin Park Rain Garden Design
Carrboro and Chapel Hill, NC
Designer, Zan Price, PE, Extension Associate, NCSU

Design Procedure and Results

Determine watershed size and characteristic: Based on the site map and aerial photography, the watershed draining to the proposed bio-retention area is approximately 50,283 square feet (1.2 acres). The drainage area consists of approximately 53% impervious (i.e. road and sidewalk) and 47% residential (average lot ¼-acre). Based on information obtained from an area soil map, the majority of the drainage area consists of an Iredell soil type, which is a SCS hydrologic soil group D.

A curve number of 98 is appropriate for the impervious portion of the watershed and a curve number of 87 is appropriate for the residential portion of the watershed (residential ¼ acre lots, soil group D).

Determine volume of runoff to catch: Given the goal of improving water quality, the first flush rainfall depth, or one inch, is chosen as the design storm. Using a curve number of 98 and a precipitation depth (P) of 1.0 inches, the runoff can be calculated as $(P – 0.2 S)^2 \div (P + 0.8 S)$, where $S=(1000 \div CN) – 10$. The resulting runoff depth is 0.79 inches.

Using a curve number of 87 and a P of 1.0 inches, the resulting runoff depth is 0.22 inches.

The total volume of runoff is equal to [(0.79 inches) * (50,283 square feet) * 53%] + [(0.22 inches) * (50,283 square feet) * 47%], or 26,253 square foot inches. Thus, the total volume of runoff to treat is equivalent to 2,188 cubic feet.

Determine size of bioretention area: The storage volume of the bioretention area shall be 2,188 cubic feet to capture runoff from 1-inch of rain. An initial ponding depth of 9 to 10 inches is typical of those assigned to bioretention areas. A 10-inch ponding depth will be used here. Thus, the required surface area is (26,253 square feet inches) / (10 inches), or 2,625 square feet. A review of the site plan indicates that the maximum rain garden area available is approximately 1,830 square feet. This is due to the existing site constraints listed above and the existing terrain to obtain 3:1 or flatter side slopes.

The available area is 70 percent of the area needed to store the design storm. However, the method used to determine the bioretention area is a conservative approach as it assumes no infiltration at the beginning of the storm. Therefore, the available area should be able to treat greater than 70 percent of the 1-inch rain runoff. The diversion structure shall be equipped with an adjustable weir so excess runoff can remain in the existing storm sewer and bypass the rain garden. Additionally, the rain garden will be equipped with an overflow structure and emergency spillway.

Set bio-retention area depth and soil type: The onsite soil consists mostly of clay, which should not be used in the rain garden. Thus, soil will be excavated from the site to the design depth and subsequently backfilled (after the placement of underdrain and gravel envelope) with the recommended mix of 85-88% sand, 8-12% silt and clay, and 3-5% organic matter. This soil mix should not be imported from an agricultural site, and should be tested for nutrient concentrations prior to use. Specifically, the P-index for the imported soil should be between 10 and 25. Imported soil should have a permeability of 1-2 inches per hour.

The design depth is based on the project goals and on the type of vegetation required. With the exception of nitrogen removal, water quality benefits generally occur in the top 18 inches of the rain garden. However, aesthetics are important to the park, so plantings of shrubs will be recommended. Shrubs require at least 30-36 inches of rain garden depth. Thus, media depth of

the rain garden is set to 36 inches, which will also help with nitrogen removal. This depth is greater than two feet above the maximum water table depth.

The water drawdown rate can be calculated using Darcy's equation, $Q = (2.3* 10^{-5}) * K * A * \Delta H/\Delta L$, where K is the hydraulic conductivity of the soil, A is the surface area, ΔH represents the driving head of the water, and ΔL represents the fill media depth. K is assumed to be 1 inch per hour, which represents the minimum allowed hydraulic conductivity of the soil; A is 3952 square feet, and $\Delta H/\Delta L$ is set to equal 1 for simplicity. Assuming an initial 10 inch ponded depth of water, the time required to draw water down to two feet below the surface is found in the following manner:

- Find drawdown rate using Darcy's equation: $Q = (2.3*10^{-5})*1*1830*1 = 0.04$ cfs
- Determine ponded volume to drawdown: V = 1830 sq ft * 0.83 ft = 1525 cubic feet
- Find time required to drawdown ponded volume: T = 1525 cubic feet / 0.04 cfs = 36,300 sec = 10 hours
- Find volume of water in top two feet of soil (assume soil porosity, n, = 0.45): V = 0.45* 2 feet * 1830 square feet = 1647 cubic feet
- Find time required to drawdown saturated volume: T = 1647 cubic feet / 0.04 cfs = 41175 sec = 11.5 hours
- Find total time for drawdown of ponded water to 2 feet below surface: T = 10 hrs + 11.5 hrs = 21.5 hrs (***Note:*** This assumes that the surface drawdown and subsurface drawdown occur in discrete time steps. In reality, both will take place simultaneously, resulting in a drawdown time less than 21.5 hours.)

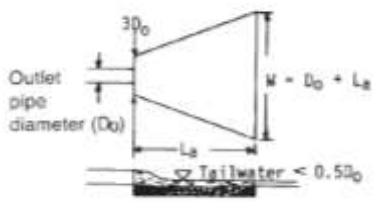
Size underdrain and gravel envelope: A rearranged version of Manning's equation, $N*D = 16 *(Q*n/s^{0.5})^{3/8}$, can be used to determine the required size of the underdrain piping (N = number of pipes and D = diameter of pipe). A safety factor of 10 is applied to the known flow rate. Thus, Q=0.4 cfs for use in underdrain sizing. Let Manning's n=0.015, a representative value for corrugated plastic pipes. Assume an internal slope of 0.5%. Therefore, $N*D = 16*(0.4*0.015/0.005^{0.5})^{3/8}$, or N*D = 6.3. Therefore, one 6 inch pipe would be marginally acceptable. However, given the potential for pipe clogging, two 4 inch corrugated plastic pipes should be installed. A cleanout should be installed for each pipe. Additionally, a 6 inch gravel envelope (2 inches above the pipes) should be used.

Recent research has shown the presence of an internal water storage zone can help with pollutant removal efficiencies and increase infiltration. An internal water storage zone can be achieved by upturning the underdrain outlets. For this project, the underdrains will be connected to the overflow structure and the discharge point of the underdrains will be set at an elevation to achieve a 1-foot internal water storage zone in the lower portion of the bioretention mix.

Assign an overflow device: While bioretention areas are generally not designed to mitigate the peak flow of larger rainfall events, the runoff will need to be routed through the bioretention area. In this case, a diversion structure will be used to keep some excess runoff in the existing storm sewer to avoid the bioretention area. To be conservative, the overflow device will be designed as if there was no diversion structure routing runoff away from the bioretention area. A round overflow structure and emergency spillway, modeled as a weir, are recommended to carry flows up to the 10-year, 24-hour design storm peak flow. Due to safety and stability concerns, it is desired that the water not exceed an elevation of 2 inches above the crest of the emergency spillway. Given this, the overflow device is sized in the following manner:

Baldwin Park Rain Garden Design
Carrboro and Chapel Hill, NC
Designer, Zan Price, PE, Extension Associate, NCSU

- Find peak flow using Rational Equation, Q=CIA: C is set at 0.74, composite C assuming the impervious area (53%) is 0.95 and the residential area (47%) is 0.50 (Rooney Malcom); I is set to the 10-year, 24-hour rainfall intensity for Chapel Hill, or 7.3 inches per hour (***Note:*** obtained from the NOAA Precipitation Frequency Estimate for Chapel Hill assuming a 5 minute time of concentration.); A is equal to 1.2 acres. Thus, Q=6.5 cfs.
- Find weir length using weir equation, $Q= C_W*L*H^{1.5}$: The weir coefficient is set at 3.0; H is set to 2 inches, or 0.17 feet. Thus, L can be calculated to be 31 feet.
- Choose overflow device: A PVC bullhead riser tee shall be located on the north end of the bioretention area. The crest of the inlet should be set at a height of 10 inches above the surface of the bioretention area. In addition to the primary outlet, an emergency spillway (length = 30 - 35 feet) lined with turf reinforced matting shall be cut into the surrounding raingarden berm. The crest of the spillway shall be set at a height of 11 inches above the surface of the bioretention area.
- Size riprap outlet protection for 15" RCP discharging to bioretention area. Assume minimum tailwater conditions since the flow will be able to spread out in the area.



	Minimum TW
	Figure 8.06a
Riprap d_{50}, (ft.)	0.4
Minimum apron length, L_a (ft.)	8
Apron width at pipe outlet (ft.)	3.75
Apron width at outlet end (ft.)	9.25
Max Stone Diameter, dmax (ft.)	0.6
Apron Thickness(ft.)	0.9

Choose vegetation and a planting plan: The rain garden has been designed to accommodate plants sized up to shrubs. Vegetation should be able to tolerate short periods of inundation, as well as periods of drought. Potential rain garden plants are listed below. A mix of 8 – 10 different plants from this list will be chosen for the garden based on availability from local nurseries.

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Carrboro and Chapel Hill, NC
Designer, Zan Price, PE, Extension Associate, NCSU

Shrubs

Deciduous

Chokeberry (1,3) – *Aronia arbutifolia*
Beautyberry (2) – *Callicarpa americana*
Sweet Shrub (2) – *Calycanthus floridus*
Buttonbush (3) – *Cephalanthus occidentalis*
Pepperbush (2) – *Clethra alnifolia*
Strawberry Bush (2) – *Euonymous americanus*
Winterberry (3) – *Ilex verticillata*
Virginia Willow (3) – *Itea virginica*
Spicebush (2) – *Lindera benzion*
Possumhaw (3) – *Viburnum nudum*

Evergreen

Inkberry (2) – *Ilex glabra*
Wax Myrtle (1,2) – *Myrica cerifera*

Perennials

Blue Star (3) – *Amsonia tabernaemontana*
Lady Fern (2) – *Athyrium felix-femina*
Butterflyweed (1) – *Asclepias tuberosa*
Swamp Milkweed (3) – *Asclepias incarnata*
Climbing Aster (3) – *Aster carolinianus*
False Indigo (1,2) – *Baptisia species*
Boltonia (3) – *Boltonia asteriodes*
Turtlehead (3) – *Chelone glabra*
Green and Gold (2) – *Chrysogonum virginianum*
Mouse Ear Coreopsis (2) – *Coreopsis auriculata*
Tickseed (1,2) – *Coreopsis lanceolata*
Swamp Coreopsis (2) – *Coreopsis rosea*
Joe Pye Weed (3) – *Eupatorium dubium*
Swamp Sunflower (3) – *Helianthus angustifolius*
Swamp Mallow (3) – *Hibiscus moscheutos*
Texas Star (3) – *Hibiscus coccineus*
Blue Flag Iris (3) – *Iris virginica*
Cardinal Flower (3) – *Lobelia cardinalis*
Cinnamon Fern (3) – *Osmunda cinnamomea*
Royal Fern (3) – *Osmunda regalis*
Garden Phlox (2) – *Phlox paniculata*
Moss Pinks (1,2) – *Phlox subulata*
Rudbeckia (1,2) – *Rudbeckia fulgida*
Green Headed Coneflower (3) – *Rudbeckia laciniata*
Goldenrod (3) – *Solidago rugosa*
Ironweed (3) – *Vernonia novaboracensis*

Ornamental Grasses

River Oats (1,3) – *Chasmanthium latifolium*
Muhly Grass (1,2) – *Muhlenbergia capillaris*
Panic Grass (1,3) – *Panicum virgatum*
Indiangrass (1,2) – *Sorghastrum nutans*

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Sedges and Rushes

Lurid Sedge (3) – *Carex lurida*
Fringed Sedge (3) – *Carex crinita*
White-topped Sedge (3) – *Rhynchospora latifolia*
Woolgrass (3) - *Scirpus cyperinus*

1. **Plants that, once established*, can withstand considerable drought (3-4 weeks without rainfall)**
2. **Plants that grow best in moist to average soils and will only tolerate short periods (1-2 days) of flooding.**
3. **Plants that will tolerate longer periods of flooding (3-5 days), but will also grow in moist to average soils.**

Construction Sequence:

- Pre-construction meeting on site with NCSU, Carrboro and Chapel Hill representatives, and Contractor
- Locate and mark all underground utilities for the project area.
- Install silt fence per the site plan
- Onsite construction supervision provided by NCSU engineer.
- Since exact invert elevations of the existing buried 15" storm sewer is not known, excavate area for proposed doghouse diversion structure to confirm pipe elevations. Final location of proposed doghouse structure shall be approved by the onsite NCSU engineer.
- Install diversion structure per the plan sheet and associated details. Do not install diversion weir until the bioretention area is completed and stabilized.
- Excavate the bioretention area per the plans.
- Provide orange safety fence for all open excavations.
- Install the primary overflow outlet structure in the bioretention area.
- Line the excavated bioretention area with a permeable geotextile fabric.
- Install gravel layer (washed #57 stone) and underdrains per the plans
- Install 2" choking stone layer and 2" pure sand layer above the #57 stone.
- Place approved bioretention media above the sand layer in 12-18 inch lifts without compaction.
- Install 15" reinforced concrete pipe with flared end section from diversion structure to bioretention area. Plug pipe in diversion structure until area is stabilized.
- Install rip-rap apron at pipe outlet.
- Install sod filter strip on 3:1 side slopes surrounding the bioretention area.
- Install turf reinforced matting along the emergency spillway.
- Install bioretention vegetation per a planting plan provided by the engineer. This will depend on plant availability from the vegetation list above. A mix of 8 – 10 different species will be planted.
- Install 3" double or triple shredded hardwood mulch in the bioretention area.
- Irrigate the area per the maintenance plan below.
- Install diversion weir in the diversion structure per the detail sheets.

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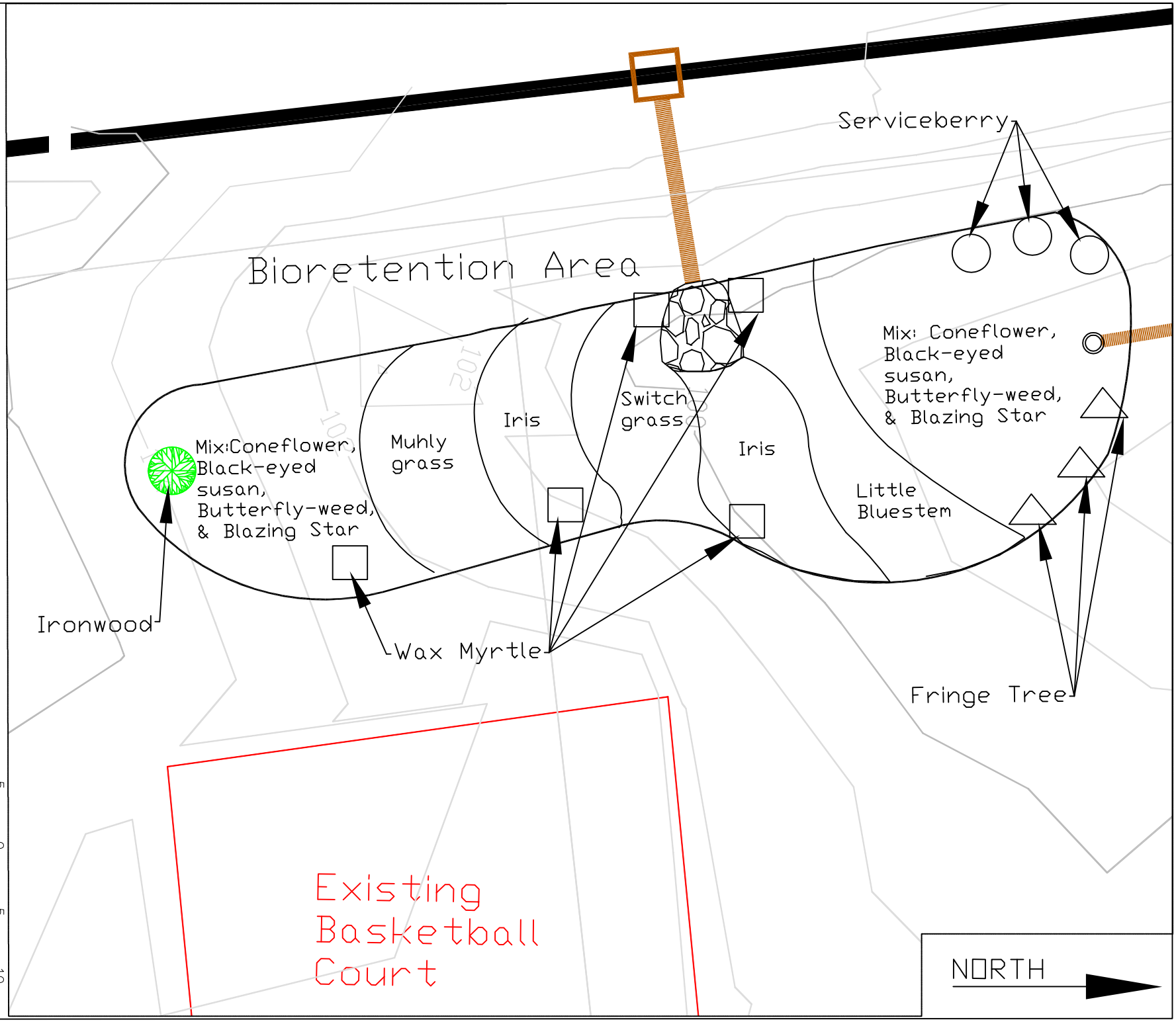
Carrboro and Chapel Hill, NC
Designer, Zan Price, PE, Extension Associate, NCSU

Bioretention Maintenance Schedule:

Task	Frequency	Maintenance Notes
Pruning	1 - 2 times / year	Nutrients in runoff often cause vegetation to flourish
Mulching	1 time/ year	Use shreaded hardwood mulch
Mulch removal	1 time / 3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time / 2 - 3 days for first 1 - 2 months. Sporadically after establishment	If droughty, watering after the initial year may be required.
Fertilization	1 time initially	One time spot fertilization for "first year" vegetation
Remove and replace dead plants	1 time / year	Within the first year, 10 percent of plants may die. Survival rates increase with time.
Miscellaneous upkeep	12 times / year	Tasks include trash collection, spot weeding, and removing mulch from overflow device.



SCALE 1" = 10'

5 0 5 10

Baldwin Park
Carrboro, N.C.

Bioretention Area
Planting Plan

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Raleigh, NC 27695

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DATE 4/4/11
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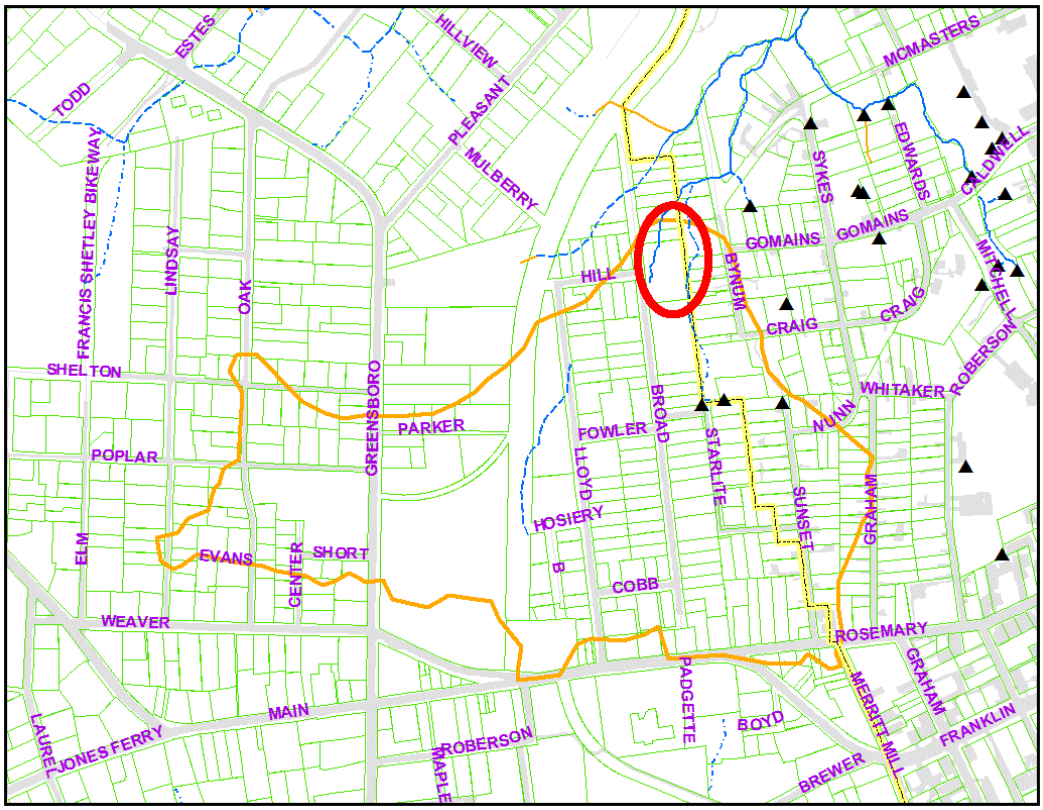
FILENAME
SHEET NO.
DRAWING NO.



The project location

Erosion on the east side of the park, before construction

Erosion on private property to the north – pre-construction

Erosion on the west channel in Baldwin Park – pre-construction

Erosion on the east channel – pre-construction

The stream gage below the project area

The autosampler below the project area

The giant(8’x4’x4’) rocks used to create the step-pools

Placement of the giant rocks perpendicular to the channel to create the step-pools

Creating the new channel on the east side

Creating the new channel on the west side

Installing more giant rocks to create step-pools

Laying the filter fabric and hooking up the pipes in the bioretention

Installing the bioretention basin

More work on the bioretention basin

Construction of the eastern channel is complete

Upper part of the eastern channel with higher gradient

Laying coir matting on the western channel after construction

The western channel after grass has started to grow

Close-up of a step-pool – there is a giant rock under there, but you can see only about 3 feet

Step-pool close-up on the eastern side

The OWASA crossing done incorrectly

View of the tree-planting ceremony and bioretention planting from Broad Street

Donna Bell (CH Councilwoman) introduces a special speaker – Howard Baldwin

Project team members

Carrboro and Chapel Hill VIPs planting the tree

The western stream a year later

Most of the plants in the bioretention basin have survived the winter and grazing by deer

Western stream one year later

The OWASA crossing redone – this time correctly

The upper part of the eastern channel one year later

Town of Chapel Hill

Proclamation

Whereas, the Towns of Chapel Hill and Carrboro are active participants in the Bolin Creek Watershed Restoration Initiative, and the Towns are committed to pursuing watershed restoration opportunities; and

Whereas, the Towns have worked on restoration activities with State and Federal Agencies including the US Environmental Protection Agency, the North Carolina Division of Water Quality, the Ecosystem Enhancement Program, the Clean Water Management Trust Fund, and community groups and members, and understand that restoration efforts require broad collaboration and will take many years; and

Whereas, the Towns have been specifically working together and with North Carolina State University and contractors on a grant received in 2008 under Section 319 of the Clean Water Act to pursue Bolin Creek watershed restoration projects; and

Whereas, one of the projects under the 319 grant has involved restoration efforts on two streams flowing through Baldwin Park, including stream stabilization and enhancement, invasive plant management, native plant establishment, and stormwater management; and

Whereas, these efforts will also result in the establishment of a more beautiful and enjoyable park; and

Whereas, volunteers and residents are supporting these efforts by helping to establish native vegetation;

Now I, Mark Kleinschmidt, Mayor of the Town of Chapel Hill, in honor of Earth Action Day, do hereby additionally proclaim April 9, 2011 as

Therefore

"Bolin Creek Action and Appreciation Day"

in the Town of Chapel Hill and offer sincere appreciation to EPA, the North Carolina Division of Water Quality, North Carolina State University staff, contractors, and to the community members who are supporting the restoration and enhancement of Baldwin Park and its streams.

Given under my hand and the seal of the Town of Chapel Hill on this the 9th day of April in the year 2011.

Mark Kleinschmidt, Mayor

RAIN GARDENS

Treating Stormwater Runoff

In conventional ***Stormwater Management***, runoff from impervious surfaces, such as paved areas, travels through storm drains and is not treated before it is discharged into streams and rivers. Stormwater runoff often has elevated concentrations of pollutants and sediment, an increased temperature, and can scour streambanks, which degrades water quality.

Stormwater treatment practices such as **Rain Gardens** are a more sustainable way to treat runoff before it is discharged to streams and rivers. As water infiltrates through the rain garden, large pollutants such as sediment and trash are filtered, and metals and excess nutrients are reduced by the soil layers. The best plants to use in rain gardens are native grasses, flowers, and shrubs that can withstand both extended wet and dry conditions. For more information on rain gardens, contact the Town of Chapel Hill Stormwater Management Division, or Carrboro Planning Department or visit:
http://townofchapelhill.org/Modules/ShowDocument.aspx?documentid=9320

Rough grading: excavated the existing low infiltration soil

During construction: lined with geotextile fabric, added a gravel layer with underdrains, and several feet of high infiltration soil

Post construction: elected officials, volunteers, and residents installed native plants

The ***Baldwin Park rain garden*** receives stormwater runoff from a portion of Broad Street. Before the rain garden installation, untreated runoff rapidly discharged directly to the stream. Currently, runoff is diverted from the road storm sewer to the rain garden. The water infiltrates down through the soil layers of the rain garden where it is slowed, cooled, and treated prior to discharging to the adjacent stream.

Can I build my own rain garden?
Yes! Rain gardens are a fun and inexpensive way for you to improve water quality and beautify your yard. To find out more about installing your own rain garden, contact the Carrboro Planning Department

What are other ways to treat stormwater naturally?
Other stormwater treatment practices include stormwater wetlands, bioswales, green roofs, and permeable paving. These are designed to treat stormwater near the source.

NC STATE UNIVERSITY

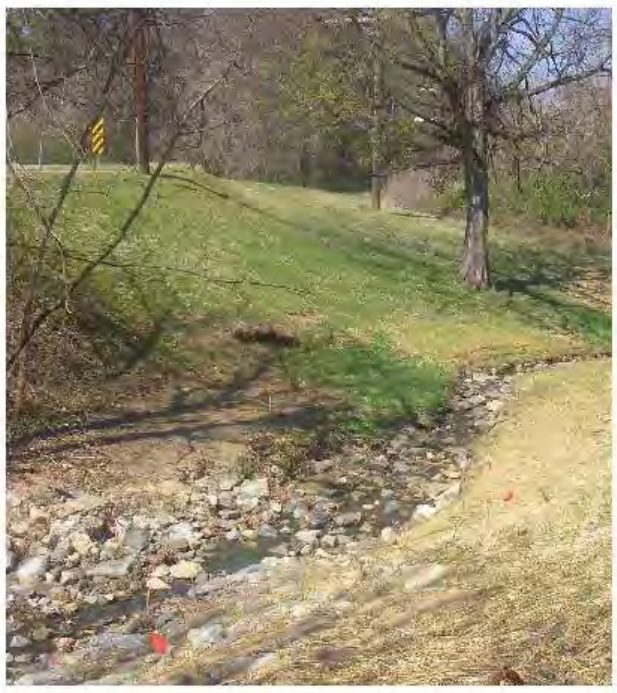
Originally 3’ by 4’

Bolin Creek Watershed Restoration Project
Baldwin Park ♦ Carrboro/Chapel Hill, NC

Project Description: Funding from EPA 319 grant to the Town of Chapel Hill in partnership with the Town of Carrboro and the NC State University Stream Restoration Program for design, construction, materials, and plants to repair stream erosion, enhance in-stream habitat and dissolved oxygen levels, improve overall water quality in Bolin Creek, and eliminate invasive plant species in the stream buffer. This project is one of three restorations in Carrboro and Chapel Hill to improve water quality in the Jordan Lake Watershed.

Before the project, **EROSION** created large cuts in the streambed and bank, destroying property and sending tons of sediment into Bolin Creek. Sediment harms stream habitat, carries pollutants, clogs gills of aquatic life and can increase water temperatures.

BANK RESHAPING angles the banks back to reduce the energy of water during high flows, and prevents further erosion of the banks. After reshaping, stream banks were covered with natural fiber matting to prevent erosion, then planted with native trees and bushes.



A series of in-stream "step-pools" were constructed with large granite blocks to reduce erosion on the banks and to improve in-stream habitat by providing riffles and pools to support a diversity of aquatic life.

Stormwater from the street's drains will flow into a **BIORETENTION CELL**, or engineered rain garden, instead of directly into the creek. This will reduce erosion, slow water, recharge groundwater, and allow pollutants to be filtered through soil and plants. ►

▲**INVASIVE PLANTS** outcompete native trees and vegetation so were removed from the restored area. Native species were planted to stabilize banks, provide shade to reduce water temperature, and offer specific food sources for aquatic life. Native plants will also provide privacy for homeowners while requiring little maintenance.

NC STATE UNIVERSITY Bio&Ag ENGINEERING Stream Restoration Program

Originally 2' by 3'

APPENDIX 2: MILL RACE TRIBUTARY PROJECT MATERIALS

Aerial photo of the tributary to Mill Race (Mill Race is to the left)

At the bottom of Mil Race trib, the banks of an OWASA easement crossing are caving in

Bank erosion is cutting into the OWASA easement along the length of the stream

The “mystery outfall” – we have no idea what it’s connected to

Lots of sediment is accumulating in the lower reaches

There’s a 15ft deep gully back in here!

There’s another deep gully hidden back in here

All along the OWASA easement the streambanks are caving in

More high, eroding streambanks

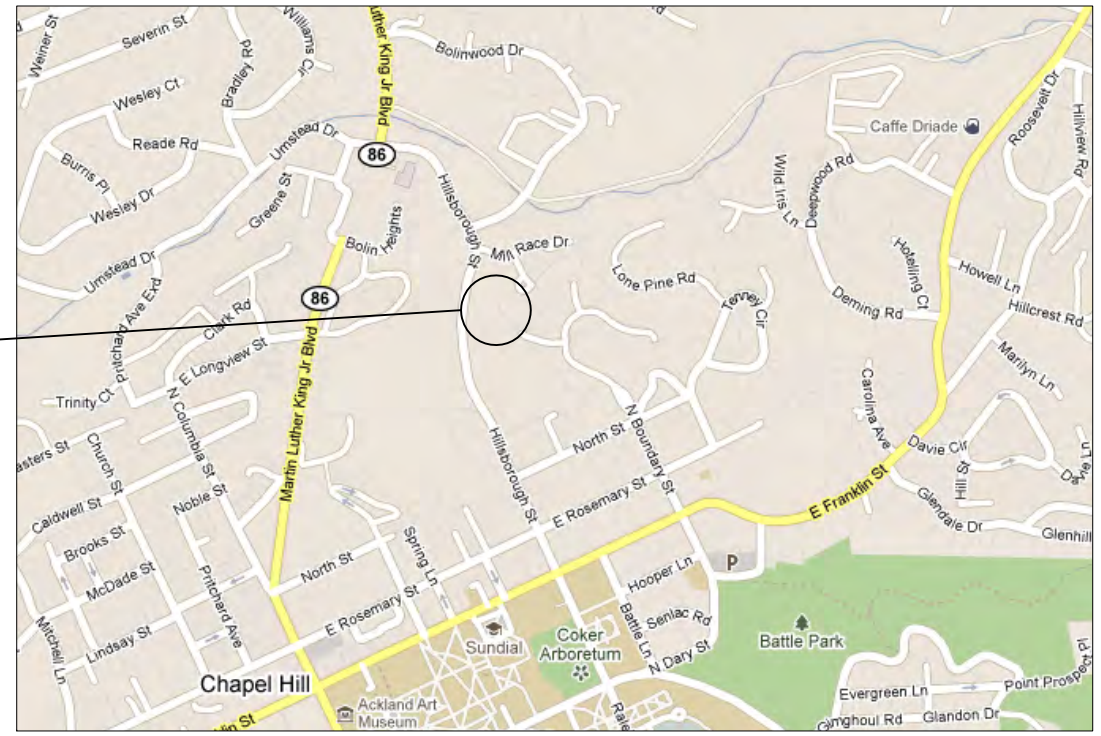
Incipient gullies forming

Kudzu is tanking down the riparian forest

There’s a third huge gully hiding under this kudzu field

MILL RACE STREAM ENHANCEMENT AND EROSION CONTROL PROJECT CHAPEL HILL, NC

SITE



PREPARED FOR:
TOWN OF CHAPEL HILL, NC

SHEET INDEX

1. TITLE
2. SITE OVERVIEW
3. SITE OVERVIEW W/ AERIAL
4. REACH 1A
5 REACH 1B
6. REACH 1C
7. REACH 1D
8. REACH 2A
9. REACH 2B

CONCEPTUAL PLAN: NOT FOR CONSTRUCTION

NO	REVISIONS	DRN	CHK	DATE
1	CONCEPTUAL DESIGN	ZP	GJ	06/30/11

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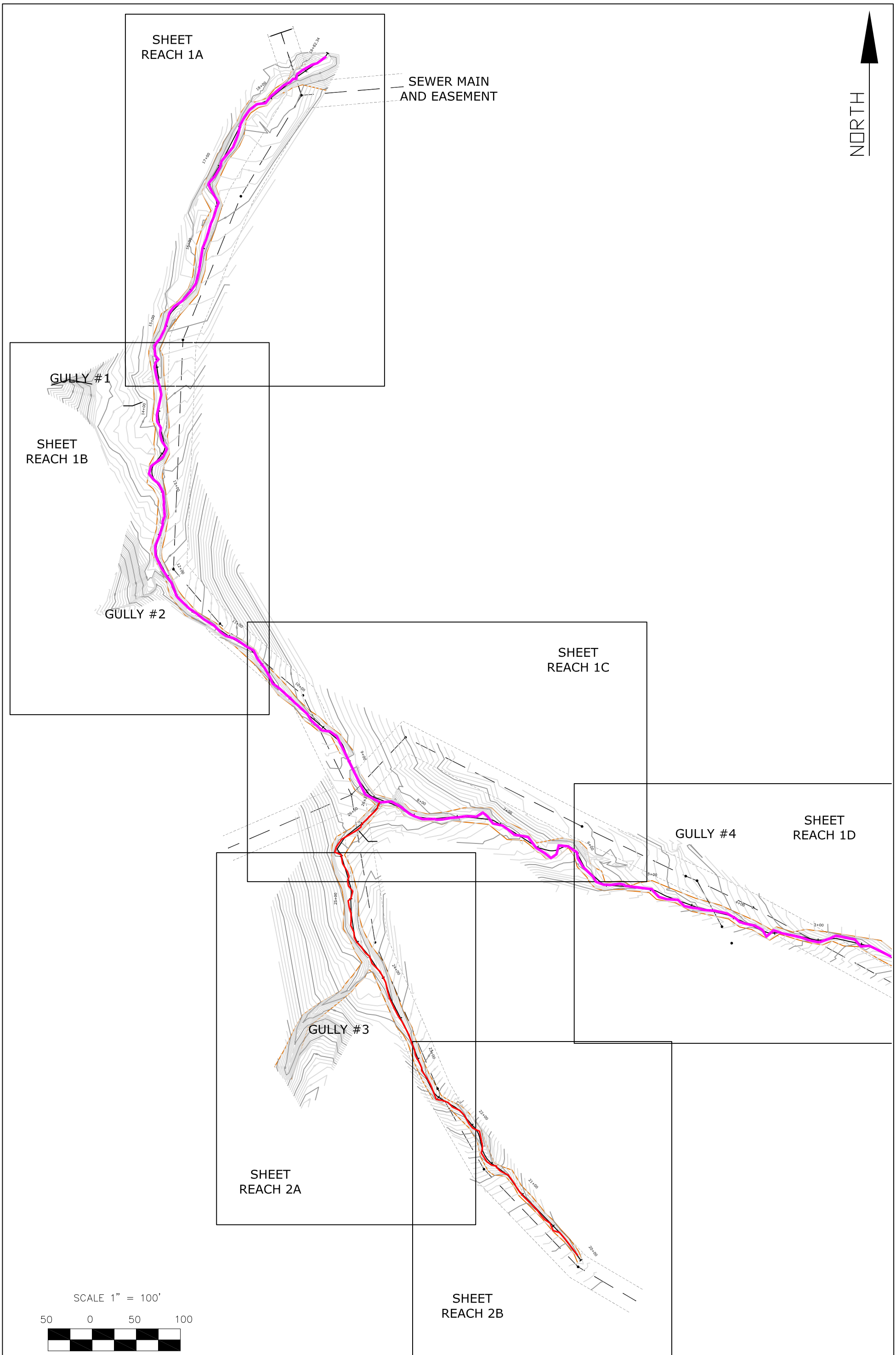
Weaver Labs Campus Box 7625
North Carolina State University
Raleigh, NC 27695

MILL RACE STREAM ENHANCEMENT AND EROSION CONTROL PROJECT CHAPEL HILL, NC

TITLE SHEET

DATE 06/30/2011
PROJECT NO.
FILENAME FILE.DWG
SHEET NO. PL – 1
DRAWING NO.



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SHEET NO.	PL – 1
FILENAME	FILE.DWG
PROJECT NO.	
DATE	06/30/2011

MILL RACE STREAM ENHANCEMENT
AND EROSION CONTROL PROJECT
CHAPEL HILL, NC

CONCEPTUAL PLAN
SITE OVERVIEW

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North Carolina State University
Raleigh, NC 27695

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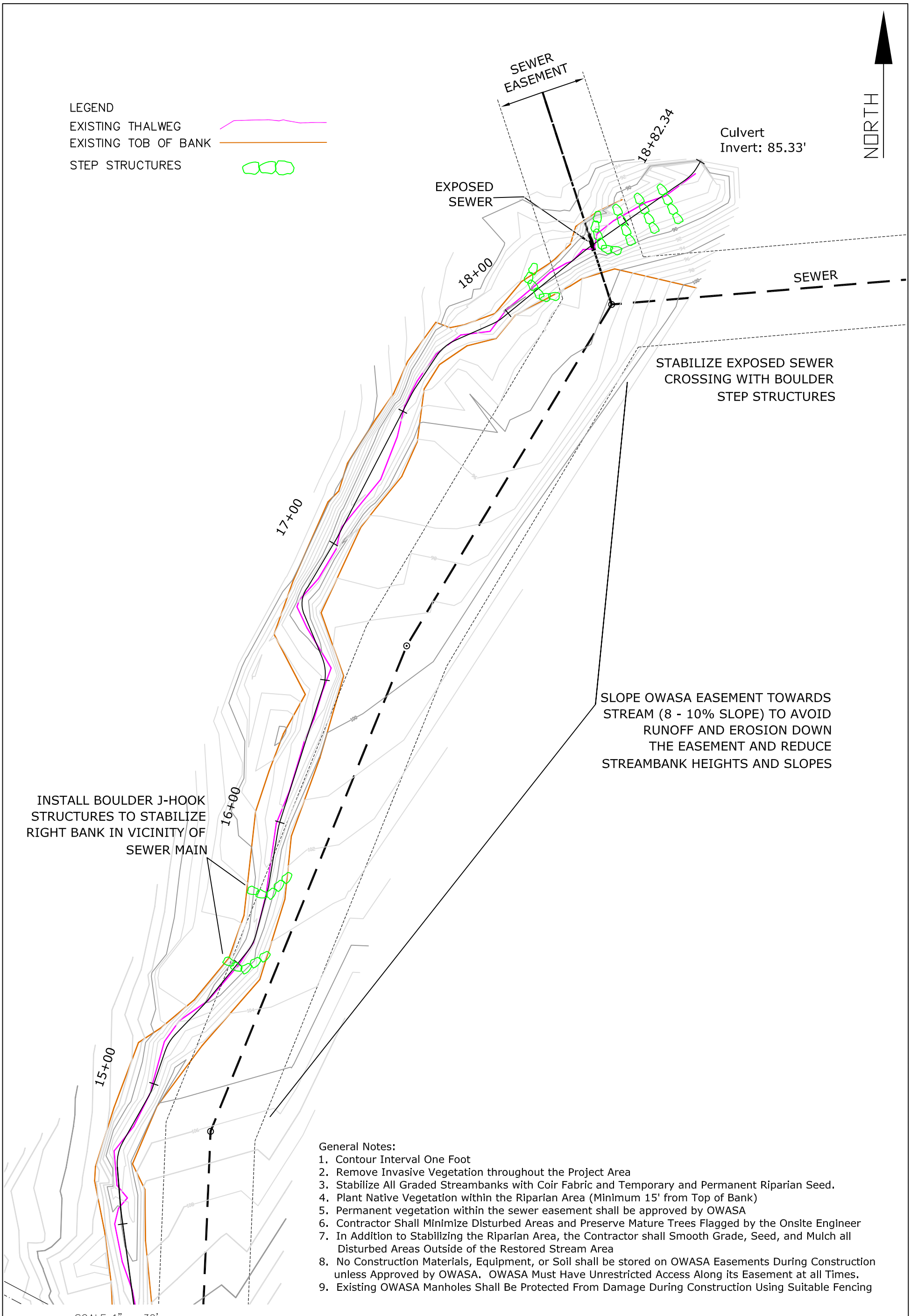
1	CONCEPTUAL DESIGN	ZP	GJ	06/30/11



General Notes:

1. Contour Interval One Foot
2. Remove Invasive Vegetation throughout the Project Area
3. Stabilize All Graded Streambanks with Coir Fabric and Temporary and Permanent Riparian Seed.
4. Plant Native Vegetation within the Riparian Area (Minimum 15' from Top of Bank)
5. Permanent vegetation within the sewer easement shall be approved by OWASA
6. Contractor Shall Minimize Disturbed Areas and Preserve Mature Trees Flagged by the Onsite Engineer
7. In Addition to Stabilizing the Riparian Area, the Contractor shall Smooth Grade, Seed, and Mulch all Disturbed Areas Outside of the Restored Stream Area
8. No Construction Materials, Equipment, or Soil shall be stored on OWASA Easements During Construction unless Approved by OWASA. OWASA Must Have Unrestricted Access Along its Easement at all Times.
9. Existing OWASA Manholes Shall Be Protected From Damage During Construction Using Suitable Fencing

DRAWING NO.			
SHEET NO.	PL – 1		
FILENAME	FILE.DWG		
PROJECT NO.			
DATE	06/30/2011		

MILL RACE STREAM ENHANCEMENT AND EROSION CONTROL PROJECT
CHAPEL HILL, NC

CONCEPTUAL PLAN SHEET
REACH 1A

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Weaver Labs Campus Box 7625
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Raleigh, NC 27695

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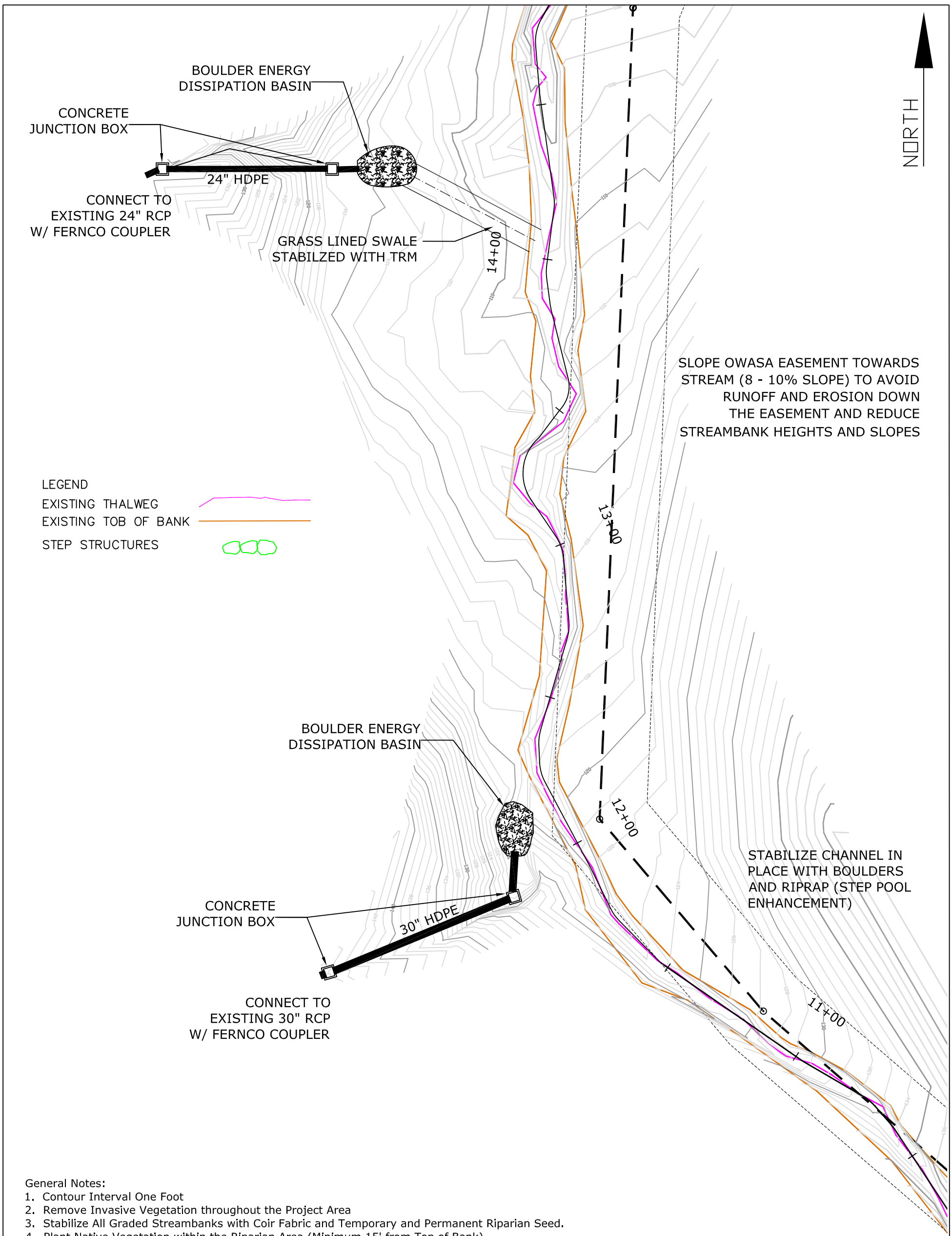

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SCALE 1" = 30'

15 0 15 30

DRAWING NO.	SHEET NO. PL – 1	FILENAME FILE.DWG	PROJECT NO.	DATE 06/30/2011	MILL RACE STREAM ENHANCEMENT AND EROSION CONTROL PROJECT CHAPEL HILL, NC CONCEPTUAL PLAN SHEET REACH 1B

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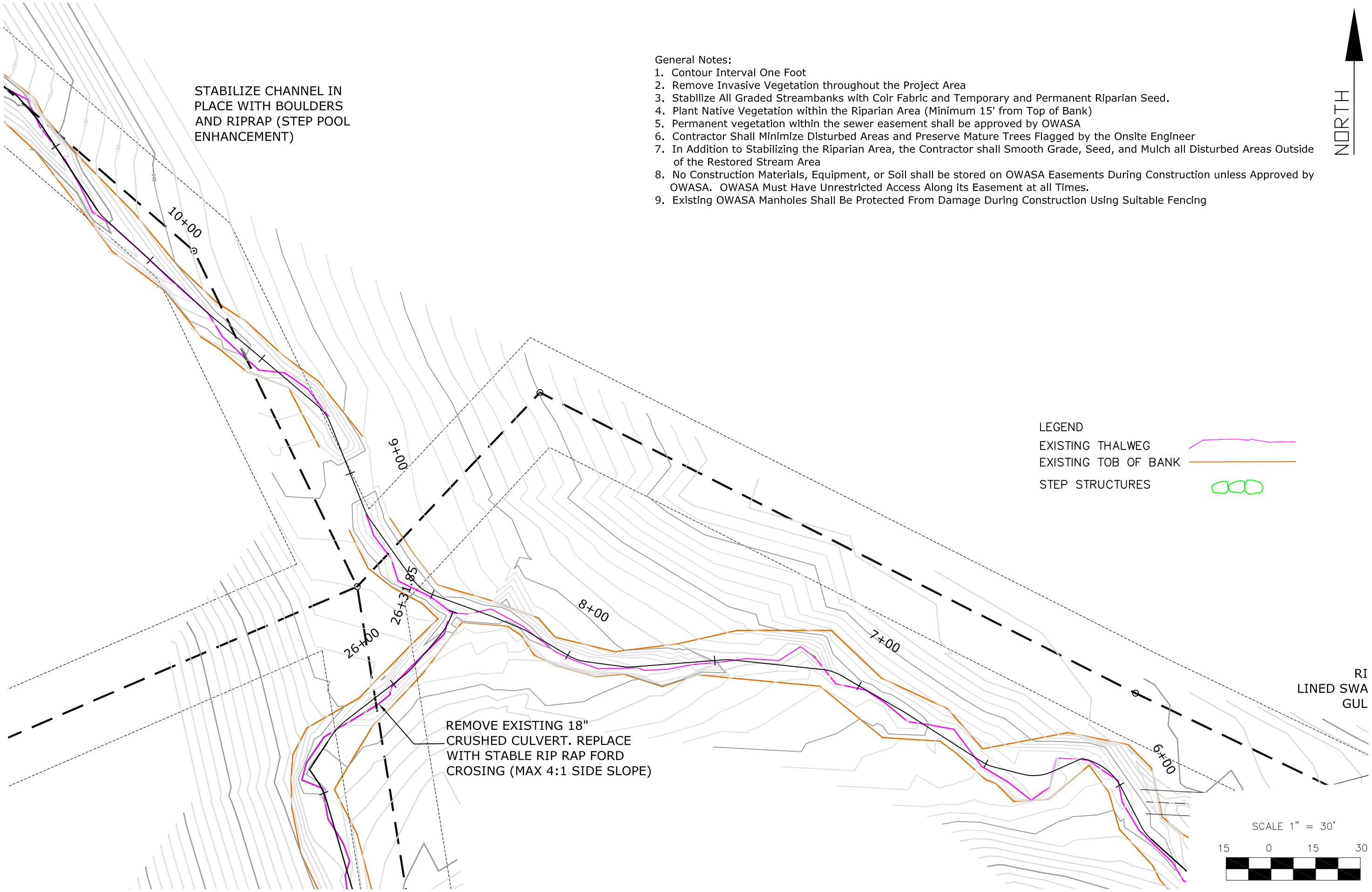
NORTH



NO	REVISIONS	DRN	CHK	DATE
1	CONCEPTUAL DESIGN	ZP	GJ	06/30/11

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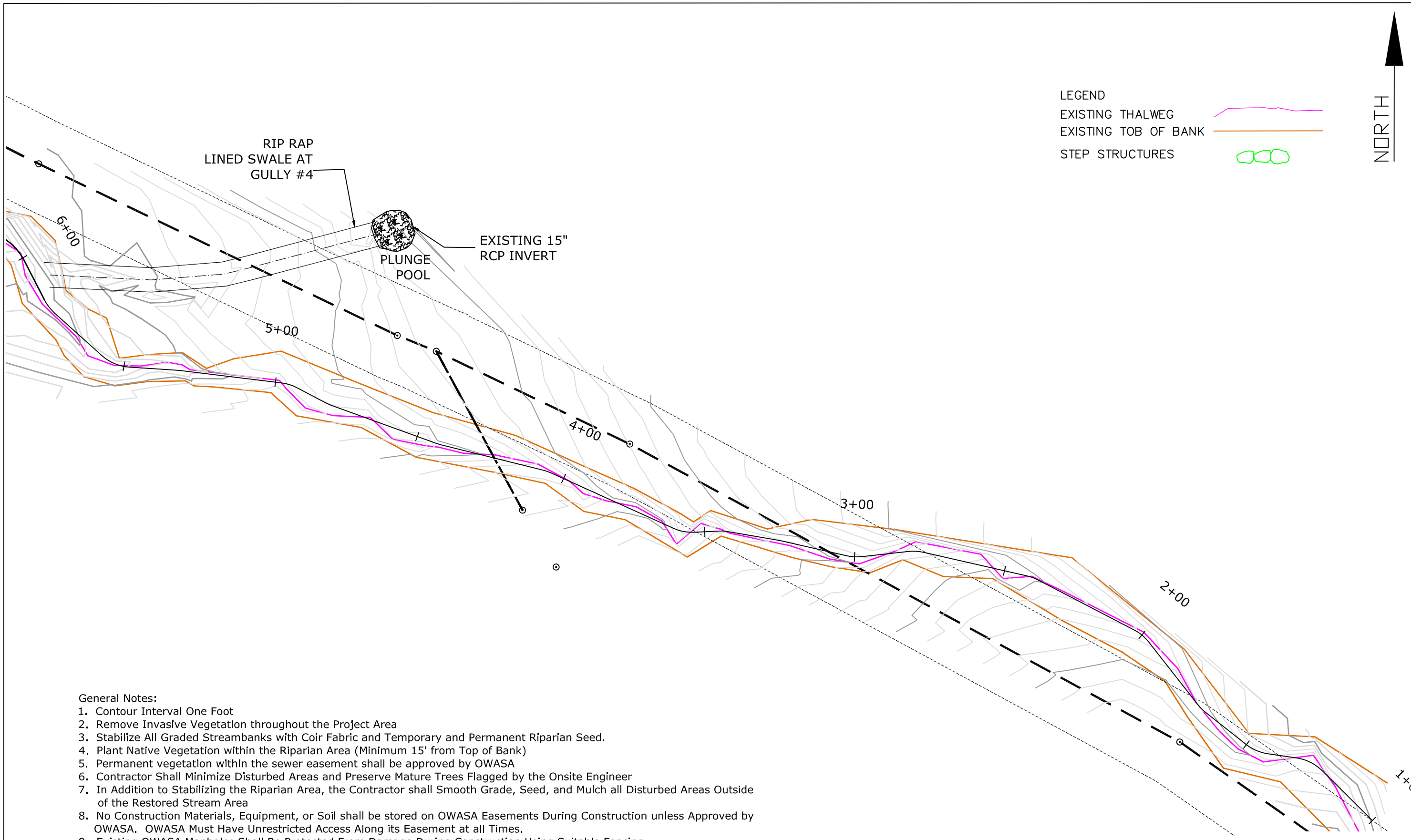
MILL RACE STREAM ENHANCEMENT AND EROSION CONTROL PROJECT
CHAPEL HILL, NC

CONCEPTUAL PLAN SHEET
REACH 1C

DATE	06/30/2011
PROJECT NO.	
FILENAME	FILE.DWG
SHEET NO.	PL – 1
DRAWING NO.	



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15 0 15 30

NO	REVISIONS	DRN	CHK	DATE
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MILL RACE STREAM ENHANCEMENT
AND EROSION CONTROL PROJECT
CHAPEL HILL, NC

CONCEPTUAL PLAN SHEET
REACH 1D

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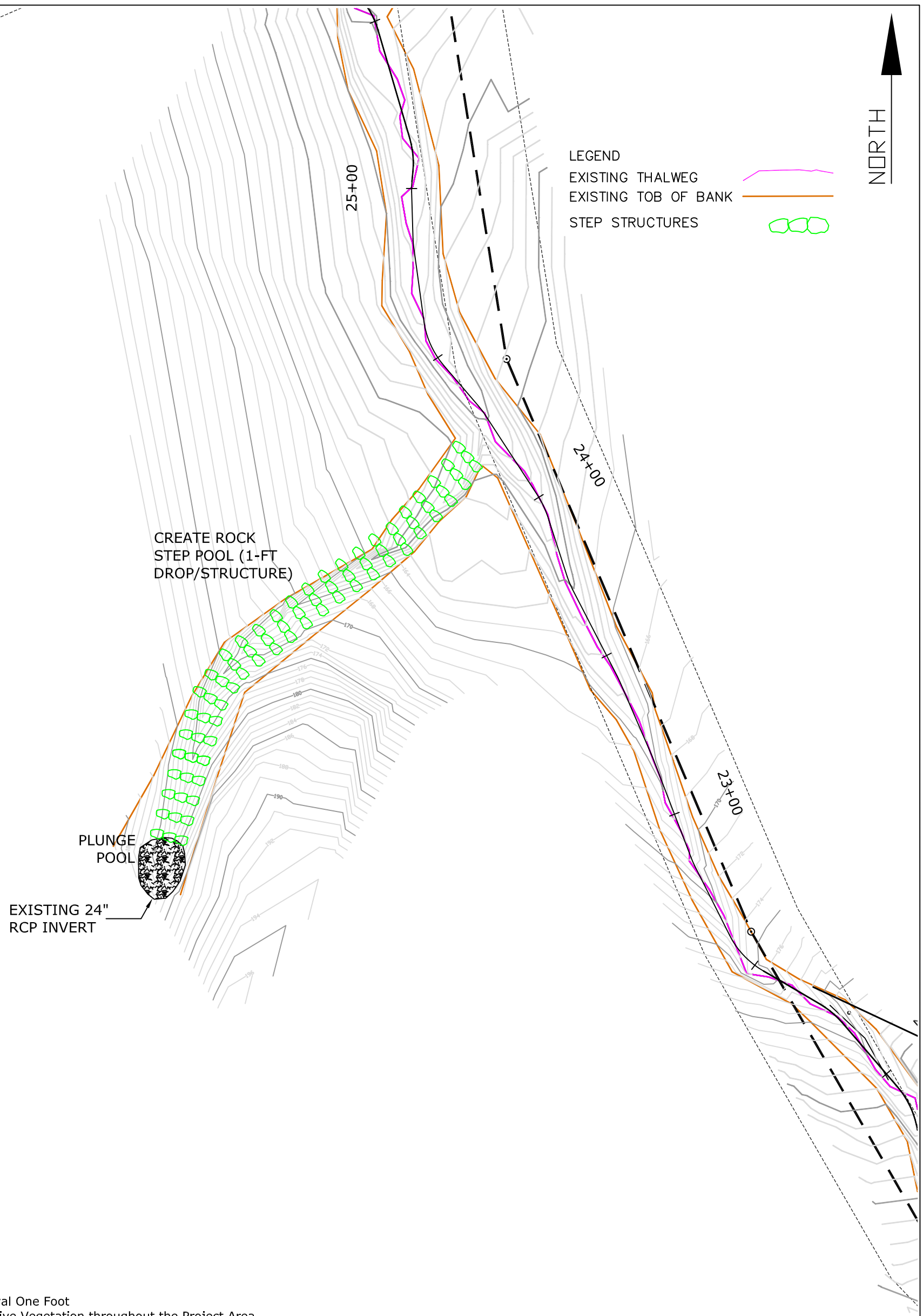
PROJECT NO.	
FILENAME	FILE.DWG
SHEET NO.	PL – 1
DRAWING NO.	



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15 0 15 30

DRAWING NO.

SHEET NO. PL – 1

FILENAME FILE.DWG

PROJECT NO.

DATE 06/30/2011

MILL RACE STREAM ENHANCEMENT
AND EROSION CONTROL PROJECT
CHAPEL HILL, NC

CONCEPTUAL PLAN SHEET
REACH 2A

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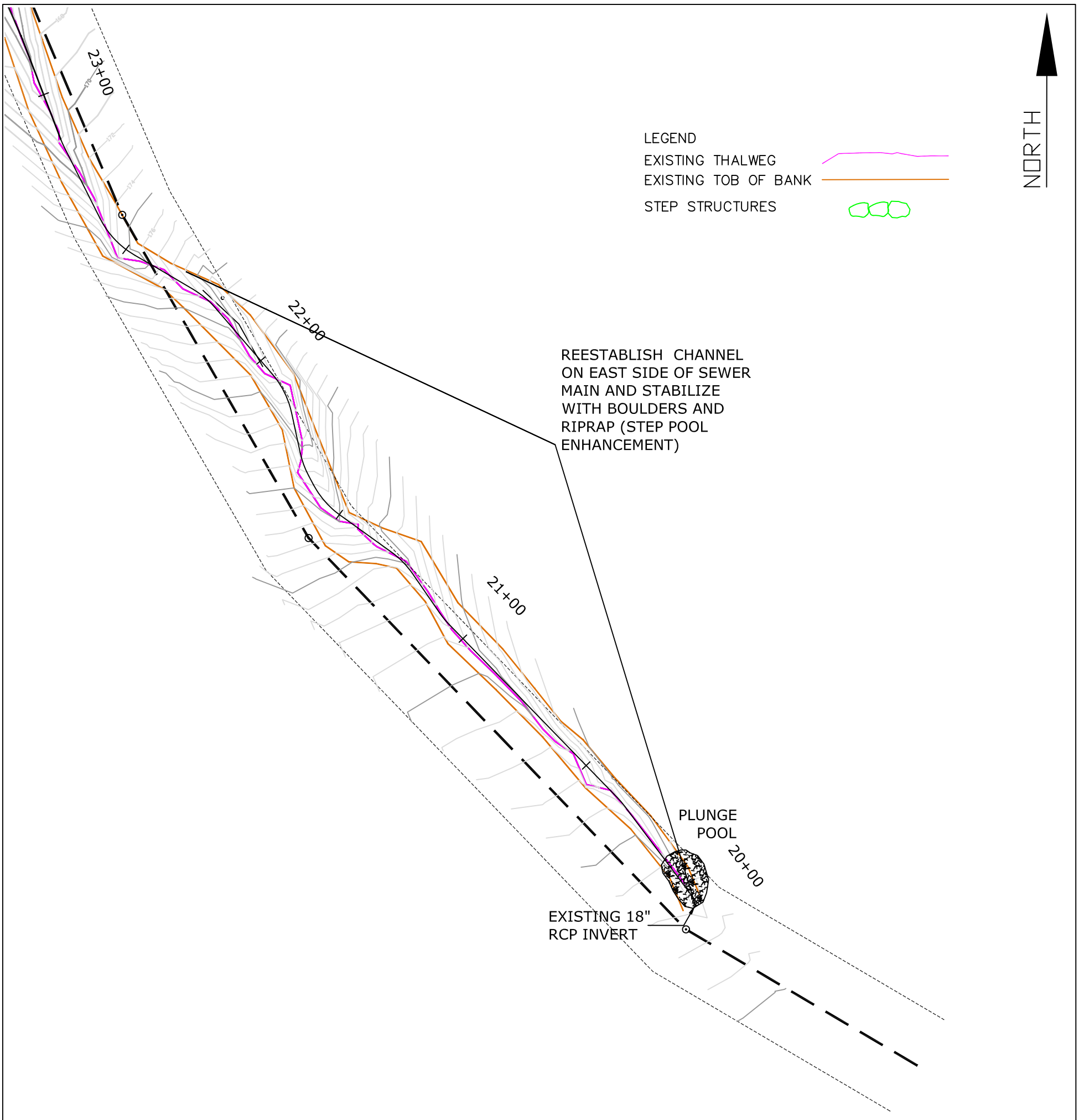
Raleigh, NC 27695

NO	REVISIONS	DRN	CHK	DATE
1	CONCEPTUAL DESIGN	ZP	GJ	06/30/11



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MILL RACE STREAM ENHANCEMENT AND EROSION CONTROL PROJECT
CHAPEL HILL, NC

CONCEPTUAL PLAN SHEET
REACH 2B

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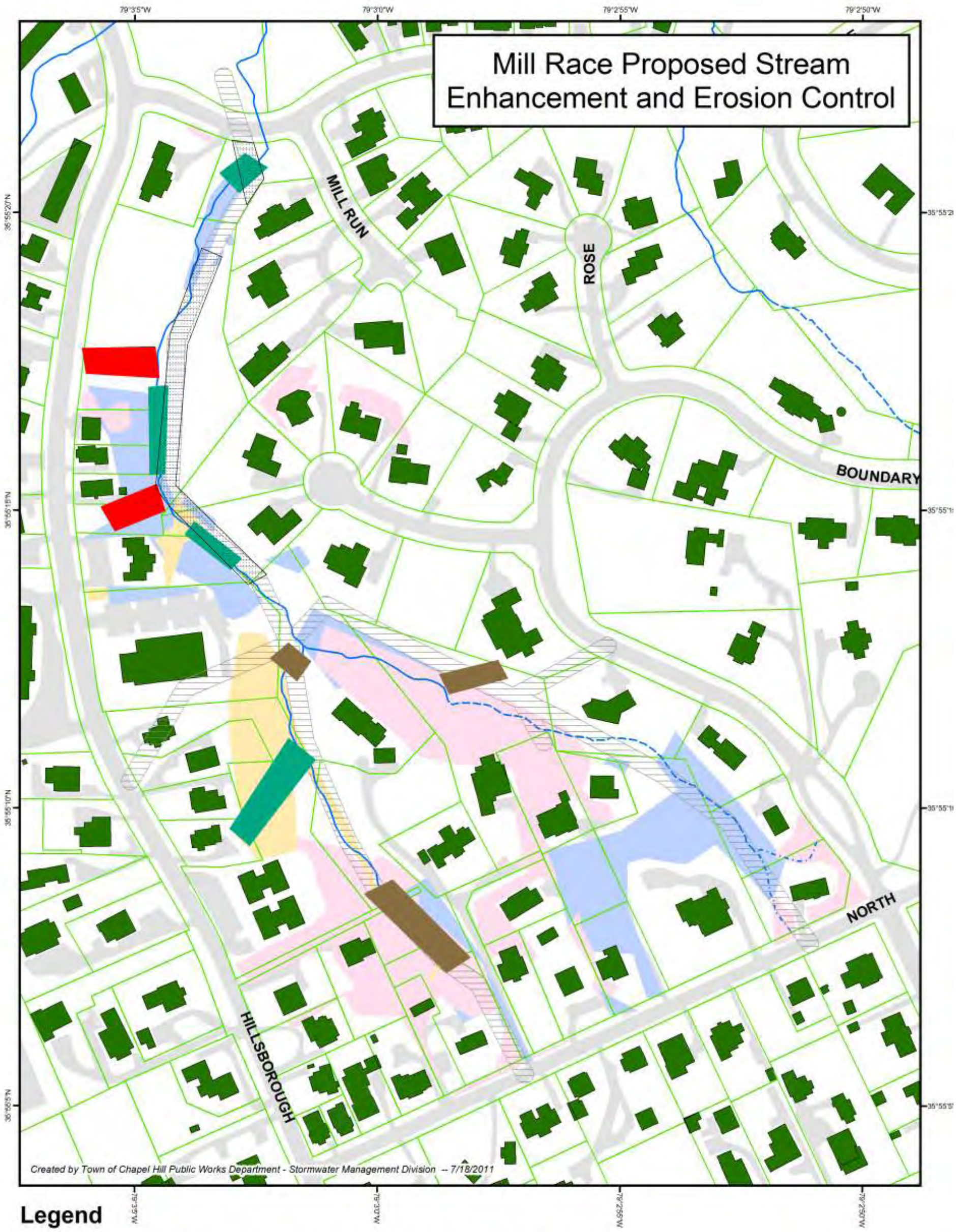
Raleigh, NC 27695

NO	REVISIONS	DRN	CHK	DATE
1	CONCEPTUAL DESIGN	ZP	GJ	06/30/11

Mill Race Proposed Stream Enhancement and Erosion Control



Legend

- Ephemeral Stream
- Intermittent Stream
- Perennial Stream
- Buildings
- Parcel Boundaries
- Streets and Driveways
- Pipes and Baffle Box
- Invasive Plants - Property Owner Guidance
- Invasive Plants - Cut and Paint
- Invasive Plants - Foliar Treatment
- OWASA Easement
- Grading in OWASA Easement
- Easement Stabilization
- Step-Pools

N W E S

0 150 300 600 Feet

Bolin Creek Watershed Restoration Project

Location: Mill Race Run, Chapel Hill

Project Description: Federal and State funding will pay for design, construction, materials, and native plants to stabilize the stream. This is one of two restoration projects underway in Chapel Hill to improve water quality in the Jordan Lake Watershed.

Estimated Completion: Spring 2012

EROSION is undermining sewer lines, stressing the lines and risking leaks.

In the site below, a series of in-stream “step-pools” and bank shaping is planned to reduce erosional stresses on the banks.

SEDIMENT smothers stream habitats and impairs water quality here and downstream in Bolin Creek. Sediment comes from erosion of sand sidewalks, OWASA easements, storm drain outfalls, and the stream channel itself.

INVASIVE PLANTS outcompete native trees and understory. Native plants and forest are critical to streams to reduce water temperature. Fallen tree leaves and microorganisms that colonize them form the basis of the stream food chain.

Replacement of invasive species with native trees, bushes, and undergrowth will provide slope stabilization and privacy for homeowners, while also providing shade

SEVERE GULLIES have formed below storm drain outfalls. Tons of sediment wash into streams and trees uproot as a result.

Repair includes extending storm drains down very steep slopes, installing energy-dissipating structures, and stabilizing banks of smaller gullies with step-pool structures.

APPENDIX 3: STORMWATER ALTERNATIVES ANALYSIS FOR TANYARD BRANCH

CHAPTER 5: INCREASING STREAM GEOMORPHIC STABILITY USING LOW-IMPACT DEVELOPMENT PRACTICES AND/OR WET PONDS IN A HEAVILY URBANIZED WATERSHED IN CHAPEL HILL, NORTH CAROLINA

This study used previously established unit critical discharges, annual allowable erosional hours and annual allowable volume of eroded bedload standards, to evaluate 2 types of stormwater control measures (SCMs): low-impact development (LID) practices and a large detention SCM (wet pond). Nine initial scenarios modeled in PCSWMM incorporated different combinations of wet ponds, green roofs, rainwater harvesting systems, permeable pavement, and rain gardens, to determine the best scenario for reducing stream erosion potential within a highly urbanized watershed in Chapel Hill, North Carolina and throughout Piedmont North Carolina. The best-case scenario to reduce annual erosional hours and eroded bedload within the stream consisted of an aggressive utilization of LID practices in combination with an undersized wet pond. While this scenario did not meet the annual erosional hour standard for rural reference streams, 0.33 h/ha/yr, it did reduce erosional hours and eroded bedload sediment by factors of 2.4 and 2.5 respectively, improving the existing condition. An alternative wet pond outlet, use of 2 drawdown orifices, was explored to determine if current wet pond design practices could be improved to include stream stability. The new configuration provided a modest improvement to erosional hours, factor of 1.3, while increasing volume of eroded bedload by a factor of 1.2 when compared to the “normal” wet pond. However, adding widespread LID practices to the alternative outlet design reduced erosional hours and bedload transport by factors of 1.8 and 1.2 respectively when compared to the “normal” wet pond. The failure to meet the erosional standards in all scenarios demonstrated the difficulty of requiring such urbanized watersheds (60% impervious) to meet such strict stream metrics.

5.1 Introduction

The negative effects of urbanization and increased imperviousness within watersheds have been explored and well documented (Leopold, 1968; Hammer, 1972; Leopold, 1973; Graf, 1977). As the percentage of impervious surfaces increases, less precipitation infiltrates through the soil to recharge the groundwater. Instead, rain flows over the impervious cover, increasing stormwater flow rates and volumes entering streams, leading to erosion and degradation in water quality (Hollis, 1975; Doyle et al., 2000; Bledsoe and Watson, 2001). An increase as small as 10% impervious surface can potentially cause stream geomorphic instability (Booth and Reinelt, 1993; Scheuler, 1995; Booth and Jackson, 1997).

To mitigate negative impacts of urban development, some state and local governments require post-construction hydrology to be restored to the pre-constructed state using stormwater control measures (SCMs). SCMs are designed to reduce peak flow rates, reduce stormwater runoff volumes, and/or improve water quality by providing additional storage for runoff. The North Carolina Department of Environment and Natural Resources (NCDENR), for example, requires post-urbanized peak flow rates not to surpass the pre-development peak flow rate for the 2-year and/or 10-year, 24-hour event in Piedmont North Carolina. SCMs are also required to capture runoff from the first inch of precipitation for water quality purposes (NCDENR, 2007a).

There are two general types of SCMs being designed in developing watersheds: (1) large structural SCMs such as wet ponds and stormwater wetlands, and (2) small, decentralized low-impact development (LID) practices such as green roofs, bioretention, rainwater harvesting, permeable pavement, and rain gardens. The larger SCMs require large plots of land and are placed in one location within the watershed (often near the outlet, discharging into streams). They are designed to temporarily store and slowly release surface runoff (USEPA, 2006). If placed along perennial streams, an alternative analysis using LID practices must be conducted to comply with 401/404 certification of the Clean Water Act (USEPA, 2002). Decentralized LID practices individually require less land and are placed in multiple locations (rooftops, yards, and underground) distributed throughout the watershed. They are designed to treat, infiltrate, and release surface runoff at the source. LID practices are commonly used in highly urbanized watersheds where space is limited and expensive (USEPA, 2010).

Recently, research has shown that while large structural SCMs are reducing peak flow rates and to some extent stormwater volumes (Lenhart and Hunt, 2011; EPA, 1999), they are not

reducing the frequency and duration of erosional events in streams. Every particle of sediment has a certain critical shear stress that, when exceeded, incipient motion, or erosion, of the particle will occur (Bledsoe, 2002). Urbanization causes site-specific critical shear stresses to be exceeded more frequently due to increase in peak flow rates and stormwater volumes. The result is uncontrolled erosion and geomorphic instability within stream channels (Robinson, 1976; Rhoads, 1991; May, 1998; Pizzuto et.al, 2000; Niezgoda and Johnson, 2005; Julien and Torres, 2006). Since larger SCMs capture and slowly release runoff, if the controlled sub-bankfull release rate exceeds the critical shear stress of the sediment, SCMs can extend the duration of erosional events beyond that of uncontrolled discharges *without an* SCM. Therefore, some SCMs are hurting geomorphic stability within streams by causing sub-bankfull erosive flows to remain within the channel longer (Bledsoe and Watson, 2001; Roesner et al., 2001; Bledsoe, 2002; Nehrke and Roesner, 2004; Navratil et al., 2006; Rohrer and Roesner, 2006; Pomeroy et al., 2008). These studies emphasize the importance of controlling sub-bankfull flows by altering discharge design standards to include stream stability.

Analyses conducted by Nehrke and Roesner (2004), Rohrer and Roesner (2006), and Pomeroy et al. (2008) demonstrated the need to incorporate: 1) volume controls to capture and control release 90% of all runoff producing events, 2) control the peak flow rate of the 1-year 24-hour storm event, and 3) a maximum unit discharge release rate, to limit the amount of erosion occurring within receiving streams. Tillinghast et al. (2011) used rural reference streams located in Piedmont North Carolina to establish a power regression relationship between sediment size (d_{65} (mm)) and unit critical discharge (Equation 5.1), an annual erosional hour standard (Equation 5.2), and annual volume of eroded bedload standard (Equation 5.3), to determine benchmarks to stabilize degrading streams of urbanized watersheds.

$$Q_c = 0.0035(d_{65})^{1.5048} \tag{5.1}$$

Where
Q_c = unit critical discharge (L/s/ha)
d_{65} = reach-wide d_{65} (mm) from pebble count

$$\text{Log (AAEH)} = -1.26\text{Log}(d_{65}) + 1.21 \tag{5.2}$$

Where
AAEH = allowable annual erosional hours (h/ha/yr)

d_{65} = reach-wide d_{65} (mm) from pebble count

$$\text{Log (AV)} = -0.64(Q_c) - 1.52 \tag{5.3}$$

Where
AV = allowable annual volume of eroded bedload sediment (m^3/m/ha/yr)
Q_c = unit critical discharge (L/s/ha)

The purpose of this study was to: 1) apply Equations 5.1, 5.2, and 5.3 developed by Tillinghast et al. (2011) and PCSWMM, to assess stability of a highly disturbed stream in Chapel Hill, NC using LID practices and a wet pond.

5.2 Site Description and Methods

5.2.1 Site Description

Tanyard Branch, an approximately 68 ha (168 acre) sub-watershed located in Chapel Hill, North Carolina (Figure 5.1), receives 1210 mm (48 in.) of rain annually. Loamy soils and sandy loam with moderate slopes ranging from 1.5 to 3.5% comprise the watershed (NRCS, 2011). Tanyard Branch is approximately 60% impervious and discharges from two 1.2 meter (4 feet) diameter concrete pipes into the receiving stream. No SCMs are present in this older urban watershed. Due to the excessive volumes and high flow rates of the stormwater runoff, the headwaters of Tanyard Branch are extremely unstable and experiencing substantial amounts of scour and erosion (Figure 5.2).

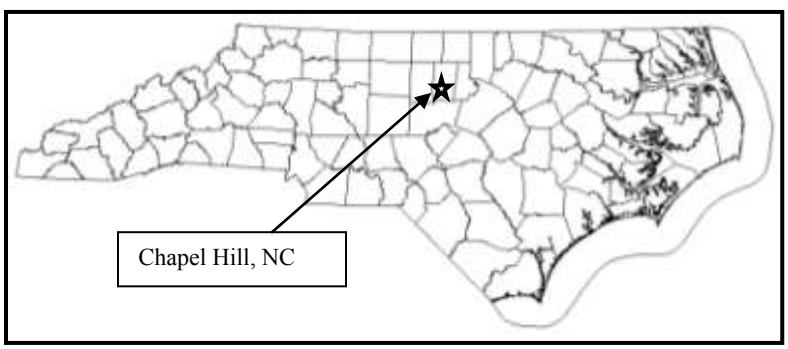


Figure 5.1: Location of Chapel Hill, NC (NCDOT, 2010)

Figure 5.2: Erosion and Incision of Tanyard Branch Banks

For this study, Tanyard Branch was split into 3 different land uses: residential, UNC campus, and downtown to generate multiple SCM treatment alternatives (Figure 5.3). The residential section of Tanyard Branch, approximately 24 ha (59 acres) and 44% impervious, consisting of single- and multi-family homes. The UNC campus portion of Tanyard Branch, approximately 12 ha (29 acres), consisted of campus buildings, parking lots, sidewalks, and houses. It was 46% impervious. The downtown section included a hotel, restaurants, commercial areas, parking lots, sidewalks, and roads. It was 32 ha (71 acres) and 77% impervious.

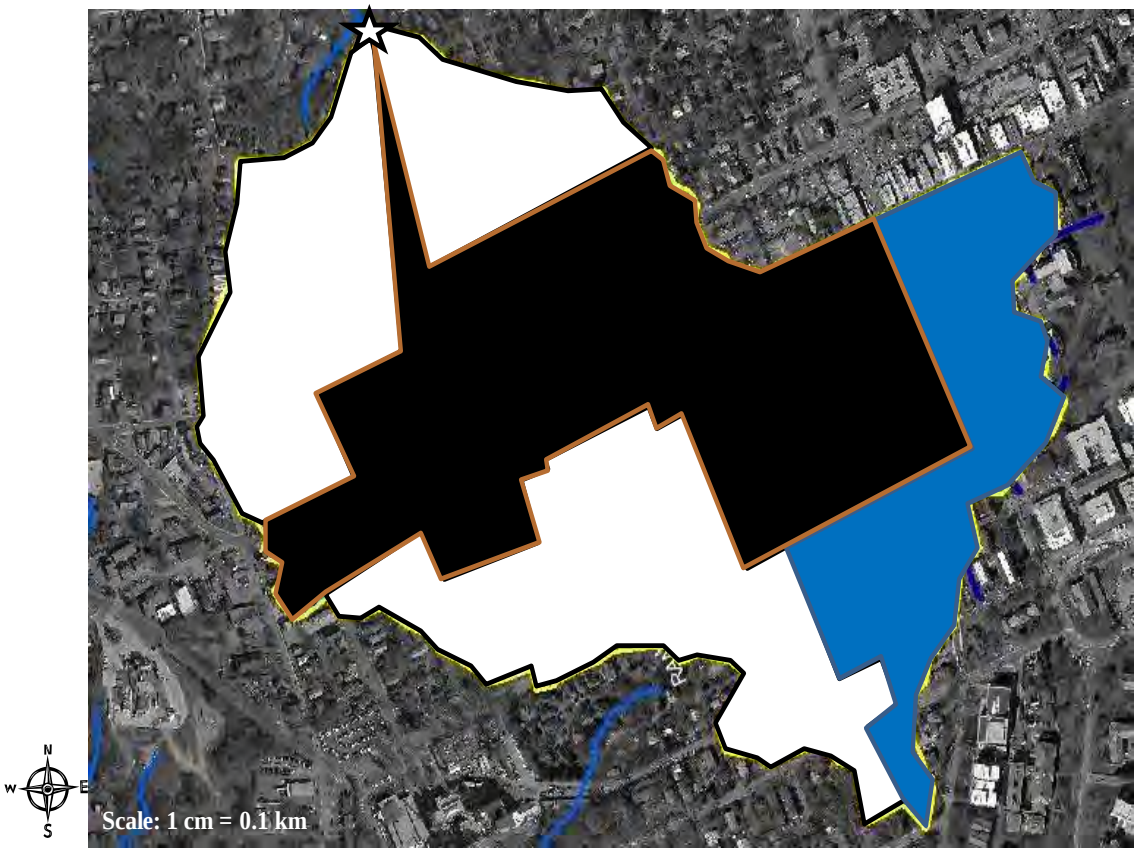


Figure 5.3: Location of Land Uses (Residential (White), Downtown (black), and UNC Campus (gray)) and Outfall (Star) of Tanyard Branch Used to Model 9 Scenarios in PCSWMM

5.2.2 Reach-Wide Pebble Counts and Tape-Down Cross-Sections

To determine the unit critical discharge of sediment found within Tanyard Branch, a Wolman reach-wide pebble count was conducted in a stable location within the stream (Leopold et. al, 1964). The measurer selected 100 pebbles by looking away from the bed of the channel and randomly putting their finger on the bed. Whichever particle was first touched, the length of the intermediate axis was recorded. A cumulative frequency plot of the particle size distribution was used to calculate the d_{65} (mm) of the sediment. The d_{65} was then the input to Equation 5.1 and 5.2 (Tillinghast et al., 2011), to determine the unit critical discharge and annual allowable erosional hours. The unit critical discharge calculated using Equation 5.1 was then the input to Equation 5.3 to calculate the annual allowable volume of eroded bedload the watershed treated by SCMs should not collectively exceed.

Three riffle tape-down cross-sections were conducted to determine the extent of incision within the stream (Harrelson et al., 1994). All three cross-sections were taken clear of culverts or pipes to prevent backwater effects. From the top of banks, a tape measure was placed perpendicular to flow at the height of the top of bank and the depth of the stream channel was

measured in 0.3 m (1 ft) increments. The bankfull width, maximum depth, bankfull area, entrenchment ratio, width-to-depth ratio, and bank height ratio (BHR) were calculated and compared to urban regional curves for Piedmont NC to determine the magnitude of channel incision (Doll et al., 2002).

5.2.3 Modeling Tanyard Branch Scenarios in Stormwater Management Model (PCSWMM)

Soil properties, land use characteristics, and slopes of Tanyard Branch were acquired via ArcGIS 9.3. This information was used as inputs for PCSWMM, a dynamic rainfall-runoff modeling program that uses non-linear reservoir routing to determine flow rates and pollutant loads in urbanized watersheds (CHI, 2009). PCSWMM, along with information from ArcGIS 9.3, were used to model 9 scenarios (Table 5.1).

Table 5.1: Description of 9 Scenarios Modeled in PCSWMM

Scenario	Areas Treated	Description
1	None	Existing condition
2	Entire watershed (68 ha) with additional 1.2 ha[1]	Undersized wet pond at outlet
3	Entire watershed (68 ha) with additional 2.4 ha[1] (Figure 6)	Full-size wet pond at outlet
4	Residential area only (24 ha)	41 cisterns and 56 rain gardens
5	Residential area + under-sized wet pond (25.2 ha)	48 cisterns, 63 rain gardens, under-sized wet pond from scenario 2
6	Residential + UNC campus (36 ha)	41 cisterns, 56 rain gardens, 4 green roofs (0.49 ha), and 7 permeable pavements (2.45 ha)
7	Residential + UNC campus + under-sized wet pond (37.2 ha)	48 cisterns, 63 rain gardens, 4 green roofs (0.49 ha), 7 permeable pavements (2.45 ha), and under-sized wet pond from scenario 2
8	Residential + UNC campus + downtown (68 ha)	41 cisterns, 56 rain gardens, 10 green roofs (1.01 ha), and 13 permeable pavements (6.5 ha)
9	Residential + UNC campus + downtown + under-sized wet pond (69.2 ha)	48 cisterns, 63 rain gardens, 10 green roofs (1.01 ha), 13 permeable pavements (6.5 ha), and under-sized wet pond from scenario 2

[1] Additional 1.2 and 2.4 ha added to drainage area due to partial construction of wet pond extending beyond initial drainage area.

PCSWMM uses a five-step aproach to model stormwater runoff: 1) continuous rainfall data or design storm precipitation is processed by SWMM Rain for use in SWMM Runoff, 2) SWMM Runoff uses topography, sub-catchment, land use characteristics, and precipitation to generate surface runoff, 3) SWMM Extran creates stage-discharge relationships from the surface runoff to be used in SWMM Transport, 4) SWMM Transport routes either continous or event-based flows through the sub-catchments to the outlet, where 5) SWMM Statistics Block performs necessary statistics (Rossman, 2009; Pomeroy et al., 2008).

5.2.3.1 Scenario 1: Existing Conditions Model

The existing condition scenario was modeled without LID practices or an in-line SCM. It represented the base model from which all other scenarios were built.

To determine the accuracy of the base model, field data were used for calibration. The monitoring equipment was installed at the end of a 3.7 meter (12.1 ft.) square, concrete culvert approximately 142 meters (465 ft) from the Tanyard Branch outfall. The automatic rain gage (Figure 5.4a) recorded the time of each bucket tip, equaling 0.25 mm (0.010 inches) of rainfall per tip. The ISCO 4230 (Figure 5.4b and 5.4c) used a bubbler to measure the level of flow within the culvert (ISCO, 1994). Manning's equation (Equation 5.3) was used to convert the depths to flowrates.

$$Q = \frac{1}{n} * A * R^{\frac{2}{3}} * S^{\frac{1}{2}} \tag{5.3}$$

Where:
Q = flowrate (m^3/s)
n = Manning's roughness coefficient (0.011)
A = cross-sectional area (m^2)
R = hydraulic radius (m)
S = slope of culvert (0.0004)

(a) (b) (c)

Figure 5.4: a) ISCO 674 Automatic Rain Gage b) ISCO 4230 Bubbler Flow Meter c) Bubbler Used to Measure Level

Eleven rainfall and flow rate storms were monitored from 10/14/2010 to 12/13/2010 to calibrate the model for Tanyard Branch. Scenarios were compared among each other without changing input parameters; therefore, exact calibration was not necessary, however, the calibration was used to verify the shape and peak flow rates of the modeled outflow hydrographs. Since the location of the monitoring equipment was 142 m away from the outfall, the additional contributing land area (2.4 ha) was also modeled (Figure 5.5). Once the model was calibrated,

the land area was removed for scenarios 1, 4, 6, and 8, half remained (1.2 ha) for scenarios 2, 5, 7, and 9, and fully remained for scenario 3.

Figure 5.5: Location of Added Drainage Area for Required Size Wet Pond

An 11-year continuous precipitation dataset from 1/1/1999 to 12/31/2009 from Chapel Hill-Williams Airport and daily potential evapotranspiration rates supplied by the North Carolina State Climate Office were used in all scenarios (NCSCO, 2003). The aiport was approximately 3.22 kilometers (2 miles) from the outfall.

5.2.3.2 Scenario 2-9: Modeling LID Practices and Wet Ponds of Tanyard Branch

The North Carolina BMP Manual (2007), BMP Modeling Concepts and Simulation (2006), along with multiple journal articles and factsheets developed by North Carolina State University were used to design the LID practices and wet ponds for scenarios 2-9 of Tanyard Branch (Table 5.2).

Table 5.2: Design of Multiple LID Practices and Wet Ponds Used In Tanyard Branch for Scenarios 2-9 and Modeled in PCSWMM

SCM	Design	References for Design

Under-Sized Wet Pond	• Drainage area: 69.2 ha
	• 3 Inlet stormwater pipes
	• Surface area: 0.29 ha
	• Vertical walls
	• Max. storage depth: 1.5 m
	• Storage volume: 4,441 m^3
	• Outlet structure:
	  o Draw-down orifice at stream elevation: 10.16 cm diameter
	  o 4 Rectangular weirs 1.5 m above orifice: 1.83 m by 0.457 m (one on each side of riser structure)
	  o Rectangular overflow weir : 1.83 m by 1.83 m
	  o Emergency Spillway (convey 10-yr, 24-hr storm): 9.14 m
	• Outflow through 1.83 diameter pipe to 3.66 m concrete culvert
	• Water quality volume released in 3.8 days
		NC DENR BMP Manual (2007)

Full-Sized Wet Pond	• Drainage area: 70.4 ha
	• 3 Inlet stormwater pipes
	• Surface area: 0.7 ha
	• Vertical Walls
	• Max. storage depth: 1.5 m
	• Storage volume: 10,553 m^3
	• Outlet structure
	  o Draw-down orifice at stream elevation: 20.32 cm diameter
	  o 4 Rectangular weirs 1.5 m above orifice: 1.52 m by 0.457 m
	  o Rectangular overflow weir: 1.52 m by 1.52 m
	  o Emergency Spillway (convey 50-yr, 24-hr storm) 6.1 m
	• Outflow through 1.83 diameter pipe to 3.66 m concrete culvert
	• Water quality volume released in 3.9 days
		NC DENR BMP Manual (2007)

Rain Garden	• Drainage area: 0.085 ha • Drainage area imperviousness: 27% • Drainage area slope: 0.5% • Depth: 15 cm • Surface area: 13 m^2 • Vertical Walls • Potential evapotranspiration factor: 1 • Infiltration parameters: Sandy loam or loam • 0.37 m diameter overflow pipe for larger storms	NC DENR BMP Manual (2007) Hunt and White, 2001 Huber et al., 2006
Cistern	• Template model from Geosyntec • Roof area: 91m^2 • 3785 liter cistern • Irrigation pump	Huber et al., 2006 Jones and Hunt, 2010

Table 5.2 (continued)

	• Car washing pump (1 hr at 757 liters per hr per month during April to Sept.) • Depth of rainfall on soil less than 3.81 cm, irrigation pump turned on; when depth of rainfall on soil greater than 5.08 cm, irrigation pump turned off.	Hunt and Spzir, 2006

Green Roof	• Roof : 100% impervious sub-catchment
	• Soil media storage device:
	  o Depth: 10 cm
	  o Porosity: 40%
	  o Evapotranspiration factor: 1
	  o Overflow pipe for larger storms
	  o Outlet to drainage layer storage
	• Drainage layer storage device:
	  o 4.06 cm depression pockets
	  o Storage capacity: 9.8L/m^2
		NC DENR BMP Manual (2007)
		
		Hathaway et al., 2008

Permeable Pavement	• 100% impervious sub-catchment
	• Initial abstraction: 0.03 cm
	• Permeable pavement storage device:
	  o Depth: 15 cm
	  o Hydraulic conductivity: 16 cm/hr
	  o Overflow pipe for larger storms
	  o Outlet to 57 stone gravel storage
	• 57 stone gravel storage device:
	  o Depth: 30.48 cm
	  o Hydraulic conductivity: 25 cm/sec
	  o Evapotranspiration factor: 0.25
	  o Porosity: 37%
	  o Internal water storage depth: 50.8 cm
	  o Outlet for infiltration
	  o Pipe for overflow back into conveyance system
		NC DENR BMP Manual (2007)
		
		Huber et al., 2006
		
		Bean et al., 2007
		
		NCSU BAE, 2008
		
		Das, 2006
		
		Brown and Hunt, 2009

5.3 Results and Discussion

5.3.1 Classifying Geomorphic Instability of Tanyard Branch

Rosgen's classification of natural streams and Piedmont NC hydraulic relationships for urban reference streams were used in conjunction with tape-down cross-sections to determine the current state of geomorphic instability within Tanyard Branch (Rosgen, 2006; Doll et al., 2002) (Table 5.3).

Table 5.3: Comparing Urban Reference Streams to Tanyard Branch Stream Characteristics to Determine Degradation and Incision (Doll et al., 2002)

	Urban Reference Stream	Tanyard Branch	Percent Difference Between Urban Stream Characteristic and Measured at Tanyard Branch
Bankfull Cross-Sectional Area (m^2)	2.19	8.1	-270
Bankfull Discharge (cms)	3.49	18.15	-420
Width (m)	4.61	7.62	-65
Depth (m)	0.46	1.28	-178

Due to urbanization and uncontrolled stormwater runoff, Tanyard Branch was incised and wider than stable, urban reference streams. The bankfull discharge was 420% greater, the bankfull width was 65% greater, and the bankfull depth was 178% greater than an urban reference stream with equivalent drainage area, demonstrating the high geomorphic instability for the curent state of Tanyard Branch.

Per the Rosgen classification of natural streams, Tanyard Branch does not neatly fall into one category, but mainly contains characteristics of a G4 stream (Table 5.4). A G4 stream is highly disturbed and typically classified as an "entrenched gully" with extreme sensitivity to disturbances, very poor recovery potential, very high sediment supply, and very high streambank erosion potential (Rosgen, 2006). The bank height ratio is a field measurement used to classify the extent of erosion within stream channels. Tanyard Branch had a BHR of 2.26, or 126% greater than the optimal stream restoration design goal of 1.

Table 5.4: Stream Characteristics of Tanyard Branch Calculated from Tape-Down Cross-Section

Stream Characteristic	Value
Entrenchment Ratio	1
Width-Depth Ratio	9.1
Bank Height Ratio	2.26
Sinuousity	1.2
d_{50} (mm)	14
Slope	0.013

5.3.2 Modeling Scenarios of Tanyard Branch in PCSWMM

The 9 scenarios involving LID practices and wet ponds were modeled in PCSWMM to determine the best combination of SCMs to meet the annual allowable erosional hour and volume of eroded bedload standards (Table 5.5) (Tillinghast et al., 2011). The unit critical discharges and annual allowable erosional hours were calculated using Equation 5.1, Equation 5.2, and a d_{65} of 21.2 mm. The unit critical discharges for all scenarios was 0.369 L/s/ha. An annual allowable erosional duration of 0.33 h/ha/yr was calculated as the threshold of natural erosion within stable streams (Equation 5.2) . The unit critical discharge, 0.369 L/s/ha, was then used to determine the allowable annual volume of eroded bedload of 0.02 m^3/m/ha/yr (Equation 5.3) (Tillinghast et al., 2011).

Table 5.5: Summary of Annual Erosional Hours, Annual Eroded Bedload, and Percent Volume Reduction Calculated from Modeling 9 Scenarios of Tanyard Branch in PCSWMM

Scenario	Average Annual Erosional Hours (hr/ha/yr)	Average Annual Eroded Bedload (m^3/m/ha/yr)	% Volume Reduction (Normalized by Drainage Area)
1) Existing Condition	8.33	0.15	0
2) Under-Sized Wet Pond	5.05	0.11	0
3) Full Sized Wet Pond	19.56	0.06	0
4) Residential	4.66	0.13	30
5) Residential+Under-Sized Wet Pond	4.66	0.08	30
6) UNC Campus	4.59	0.12	34
7) UNC Campus+Under-Sized Wet Pond	3.74	0.07	34
8) Downtown	4.44	0.10	41
9) Downtown+Under-Sized Wet Pond	3.53	0.06	41
Stability Thresholds	***0.33***	***0.02***	

All scenarios exceeded both the annual allowable erosional hour and allowable volume of eroded bedload standards (Tillinghast et al., 2011). The best scenarios to restrict volume of eroded bedload were both scenarios 3 and 9. In scenario 3, the full sized wet pond reduced peak

flow rates entering the stream due to the availability of storage for the stormwater runoff. In scenario 9, the LID practices reduced stormwater runoff volume through infiltration by 41%, and the under-sized wet pond reduced the flow rates before entering the stream. The full-sized pond reduced estimated volume of eroded bedload by a factor of 2.5, while a wet pond 42% of the storage capacity reduced volume of eroded bedload by a factor of 1.4 illustrating the importance of designing stormwater wet ponds with the correct storage volume.

The best scenario using the erosional hours metric was the Downtown+Under-Sized Wet Pond (reduced by factor of 2.4). The LID practices captured and infiltrated stormwater runoff at the location where the precipitation fell; therefore, reducing the volume annually traveling through stormwater conveyance system by 41%. The smaller runoff volumes led to a reduction in time that flow rates exceeded the unit critical discharge even though the wet pond was undersized (42% of required storage volume), indicating the importance of LID practices in a highly urbanized watershed. The under-sized wet pond had fewer expected erosional hours than a full sized wet pond due to more stormwater runoff leaving quickly through the overflow weir instead of the drawdown orifice, also indicated by the higher eroded bedload estimatation (incorporates magnitude of exceedance). The downtown + under-sized wet pond, scenario 9, still did not meet the annual erosional hour standard of 0.33 h/ha/yr, but clearly a combination of LID practices and a wet pond had the maximum reductions in annual erosional hours within the stream.

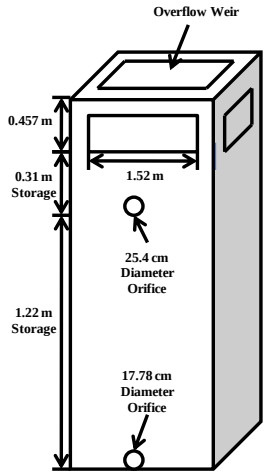
The infiltration of stormwater runoff from LID practices provde an additional benefit within urbanized watersheds: contribution of runoff to increase groundwater baseflow to the stream. This will help protect the stream within Tanyard Branch from drying up during periods of increased temperatures, evapotranspiration rates, and reduced precipitation.

The analysis conducted within Tanyard Branch does not determine the standard that is more indicative of geomorphic instability within streams. While the full sized wet pond had the highest reduction in estimated eroded bedload, a factor 2.5, it increased erosional hours by a factor of 2.4. This is due to the stored stormwater volume being slowly released at erosive flows. Since eroded bedload calculations incorporate both duration and magnitude of exceedance, the outlet structure of the full sized wet pond was explored to determine if an alternative outlet configuratation could reduce erosional hours and better protect stability of streams.

5.3.3 Altering Outlet Configuration of Wet Pond to Better Meet Erosional Standards

When the discharge from the pond orifice exceeds the critical discharge of the sediment, wet ponds extend the time of erosive flows leaving the system (full sized wet pond from Table 5.5). For this reason, an outlet structure with 2 orifices *specifically designed* to discharge outflow at rates less than the critical discharge of the sediment was modeled (Figure 5.6). This is not the current design convention used in North Carolina and most states (NCDENR, 2007a). The wet ponds used in the prior analysis were solely designed to meet current design requirement (for water quality) and therefore did not reflect this subtle change in outlet configuration. This new configuration released stored runoff volume in 4.2 days. By implementing this change to scenario 3 (only full sized wet pond), the average annual erosional hours noticeably decreased from 19.56 to 15.4 h/ha/yr and the volume of eroded bedload modestly increased from 0.06 to 0.07 m^3/m/ha/yr. The cause for volume of eroded bedload increase was the top 0.31 m of stored volume leaving the system at higher flow rates through the 25.4 cm orifice. The key to limiting allowable annual erosional hours through the new outlet configuration was to maximize the portion of stored water quality volume discharging through the smaller drawdown orifice (17.78 cm diameter) but still being released within 2-5 days time limit (NCDENR, 2007a).

The alternative wet pond outlet configuration was then applied to a full-sized wet pond (instead of under-sized) of scenario 9, to see if the annual erosional hour standard could be further reduced. The annual erosional hours decreased to 10.60 h/ha/yr and estimated volume of eroded bedload was 0.05 m^3/m/ha/yr. The erosional hours were reduced compared to the full sized wet pond with the alternative outlet configuration; however, the erosional hours still increased from the existing condition (from 8.33 to 10.60 h/ha/yr). The calculated eroded bedload was below any of the previous 9 scenarios conducted illustrating that the alternative outlet configuration has the potential to improve current wet pond design standards in regards to stream stability. While this optionstill did not meet the annual allowable volume of eroded bedload goal (by a factor of 2.5), this scenario did decrease estimated volume of eroded bedload by a factor of nearly 3 (0.15 to 0.05 m^3/m/ha/yr).



Description	Dimensions
Draw-Down Orifice at Stream Elevation	17.78 cm Diameter
Draw-Down Orifice 1.22 m above Stream Elevation Orifice	25.4 cm Diameter
4 Rectangular Weirs	1.52 m by 0.457 m
Overflow Weir	1.52 m by 1.52 m

Figure 5.6: Alternate Outlet Structure with 2 Draw-Down Orifices to Reduce Calculated Erosional Hours with the Full-Sized Wet Pond

The modeling of 9 initial scenarios in Tanyard Branch illustrated the importance of using LID practices in conjunction with a detention on SCM in highly urbanized watersheds to improve stream stability. The LID practices infiltrated and maximized storage of rainfall runoff, while the wet pond controlled the flow rate entering the stream, reducing erosional hours and volume of eroded bedload. Since calculation of eroded bedload incorporates both magnitude and duration of erosive flows, an alternative outlet structure designed to reduce flow rates even further than currently designed, was explored. The alternative outlet configuration, an additional draw-down orifice on the full-sized wet pond, reduced annual volume of eroded sediment by a factor of 2.1. When applied with LID practices, the volume of eroded bedload was reduced by a factor of 3, while the erosional hours increased by a factor of 1.3. This demonstrated that wet pond outlet structures can be altered from their current designs to increase stability within streams and reduce potential erosion; however, the annual erosional hour standard, 0.33 h/ha/yr, was not met, indicating the difficulty of requiring a 60% impervious watershed to meet robust stream erosion metrics.

5.4 Conclusion & Summary

Urbanization alters the geomorphic stability within streams through increased peak flow rates and stormwater runoff volumes. Tanyard Branch was classified as an “entrenched gully”, G4 stream, according to cross-sectional measurements and guidelines from Rosgen classification of natural streams (Rosgen, 2006). Due to the large runoff volumes and high peak flow rates, Tanyard Branch became incised and unstable. The bankfull flow rate was 420% greater, the

bankfull depth was 178% greater, and the bankfull width was 65% greater than stable, urban reference streams with equivalent drainage areas in Piedmont North Carolina. A large detention SCM (wet pond) and/or multiple LID practices (green roof, rain garden, cistern, and permeable concrete) were modeled in PCSWMM to determine their effectiveness in increasing stream stability and reducing in-stream erosion potential by meeting allowable annual erosional hour and volume of eroded bedload standards of rural reference streams (Tillinghast et al., 2011). From this study, it can be concluded that:

1. LID practices in conjunction with an under-sized wet pond maximized storage and infiltration within the watershed and had the largest reduction in modeled volume of eroded bedload and annual erosional hours.
2. By altering the outlet structure to include a second drawdown orifice, wet ponds can increase stream stability compared to their current design standards.
3. A highly impervious watershed, 60%, was incapable of meeting such strict stream erosion metrics using LID practices and wet ponds.

The analyses conducted in this study were extremely site specific depending on soil, topography, and land uses of Tanyard Branch. In this study, LID practices alone were not sufficient to reach a geomorphic stable stream in Tanyard Branch. An under-sized wet pond along with green roofs, permeable pavement, rainwater harvesting systems, and rain gardens were incapable of meeting the rural reference stream standards developed by Tillinghast et al. (2011), indicating the difficulty in requiring a 60% impervious watershed to meet such robust stream metrics. This scenario reduced both, volume of eroded bedload and erosional hours by factors of 2.5 and 2.4, respectively. This demonstrated that LID practices in conjunction with wet ponds provided the greatest reduction in erosion potential and increase in stream geomorphic stability.

Improvements to the outlet structure of wet ponds were explored to determine if alterations could better reduce erosional hours and volume of eroded bedload. When the new outlet configuration, and additional drawdown orifice, was compared to the current design requirements of wet ponds, the altered outlet structure reduced erosional hours by a factor of 1.3 and increased eroded bedload by a factor of 1.2. When LID practices were modeled in addition to 2 draw-down orifices in a full-sized wet pond, the LID practices did provide a substantial improvement. The LID practices plus the new configuration reduced erosional hours and

volume of eroded bedload even further (factors of 1.2 and 1.8 respectively when compared to a full sized wet pond without altered outlet structure). Similar applications of the altered wet pond outlet structure should be conducted before definitive conclusions can be made.

CHAPTER 6: COST-BENEFIT ANALYSIS OF TANYARD BRANCH

6.1 Introduction

As watersheds become urbanized, infiltration and recharge of groundwater decrease. Instead, stormwater runoff enters receiving surface waters at higher flow rates and volumes, impacting the geormorphic processes of streams. To mitigate the affect of urbanization on streams, most regulating authorities require post-constructed hyrdology to be returned to a pre-constructed state through the use of stormwater control measures (SCMs) for peak flow attenuation. Other design considerations include water quality volumes and reduction in stormwater runoff volumes (NCDENR, 2007a). There are two general types of SCMs being designed in developing watersheds: (1) large structural SCMs such as wet ponds and stormwater wetlands, and (2) small, decentralized low-impact development (LID) practices such as green roofs, bioretention, rainwater harvesting, permeable pavement, and rain gardens. The larger SCMs require large plots of land and are placed in one location within the watershed (often near the outlet, discharging into streams). They are designed to temporarily store and slowly release surface runoff (USEPA, 2006). Decentralized LID practices individually require less land and are placed in multiple locations (rooftops, yards, and underground) distributed throughout the watershed. They are designed to treat, infiltrate, and release surface runoff at the source. LID practices are commonly used in highly urbanized watersheds where space is limited and expensive (USEPA, 2010).

Recently, research has shown that while large structural SCMs are reducing peak flow rates and to some extent stormwater volumes (Lenhart and Hunt, 2011; EPA, 1999), they are not reducing the frequency and duration of erosional events in streams. Every particle of sediment has a certain critical shear stress that, when exceeded, incipient motion, or erosion, of the particle will occur (Bledsoe, 2002). Urbanization causes site-specific critical shear stresses to be exceeded more frequently due to increase in peak flow rates and stormwater volumes. The result is uncontrolled erosion and geomorphic instability within stream channels (Robinson, 1976; Rhoads, 1991; May, 1998; Pizzuto et.al, 2000; Niezgoda and Johnson, 2005; Julien and Torres, 2006). Since larger SCMs capture and slowly release runoff, if the controlled sub-bankfull release rate exceeds the critical shear stress of the sediment, SCMs can extend the duration of

erosional events beyond that of uncontrolled discharges *without an* SCM. Therefore, some SCMs are hurting geomorphic stability within streams by causing sub-bankfull erosive flows to remain within the channel longer (Bledsoe and Watson, 2001; Roesner et al., 2001; Bledsoe, 2002; Nehrke and Roesner, 2004; Navratil et al., 2006; Rohrer and Roesner, 2006; Pomeroy et al., 2008). These studies emphasize the importance of controlling sub-bankfull flows by altering discharge design standards to include stream stability.

Nine scenarios of Tanyard Branch (Table 6.1), consisting of combinations of green roofs, permeable pavement, wet ponds, rain gardens, and rainwater harvesting systems, were modeled in PCSWMM (a hydraulic-hydrologic modeling program for urbanized areas) to determine the best scenario to reduce erosion potential and to meet previously established stream stability thresholds (Chapter 4 and 5). The conducted cost-benefit analysis can aid the Town of Chapel Hill in determining the economic feasibilty of implementing the 9 scenarios in lieu of the benefits each scenario provided.

Table 6.1: SCMs and Drainage Areas Treated of 9 Scenarios Modeled of Tanyard Branch in PCSWMM

Scenario	Areas Treated	Description
1	None	Existing condition
2	Entire watershed (68 ha) with additional 1.2 ha	Undersized wet pond at outlet
3	Entire watershed (68 ha) with additional 2.4 ha (Figure 6)	Full-size wet pond at outlet
4	Residential area only (24 ha)	41 cisterns and 56 rain gardens
5	Residential area + under-sized wet pond (25.2 ha)	48 cisterns, 63 rain gardens, under-sized wet pond from scenario 2
6	Residential + UNC campus (36 ha)	41 cisterns, 56 rain gardens, 4 green roofs (0.49 ha), and 7 permeable pavements (2.45 ha)
7	Residential + UNC campus + under-sized wet pond (37.2 ha)	48 cisterns, 63 rain gardens, 4 green roofs (0.49 ha), 7 permeable pavements (2.45 ha), and under-sized wet pond from scenario 2
8	Residential + UNC campus + downtown (68 ha)	41 cisterns, 56 rain gardens, 10 green roofs (1.01 ha), and 13 permeable pavements (6.5 ha)
9	Residential + UNC campus + downtown + under-sized wet pond (69.2 ha)	48 cisterns, 63 rain gardens, 10 green roofs (1.01 ha), 13 permeable pavements (6.5 ha), and under-sized wet pond from scenario 2

6.2 Procedure

For the cost-benefit analysis, the capital costs of the SCMs from each scenario were computed based upon prices from previous projects within North Carolina. For constructing permeable pavements, rain gardens, and green roofs, an average value per square meter was used to determine the overall capital cost of the specific SCM (Table 6.2). For the cisterns, a local vendor, Rainwater Solutions, was contacted and an approximate cost of the residential rainwater

harvesting system; $1,500.00, was used. To determine the cost of the 2 wet ponds, prices were taken from the RSMEANS Building Construction Cost Data (Waier, 2006), as well as construction costs of previous local projects. Land acquisition and sewer line re-construction costs were based upon real estate estimates and information provided by Patricia D'Arconte, Town of Chapel Hill, and Orange Water and Sewer Authority (OWASA). The annual maintanence costs were calculated from Determining Inspection and Maintanence Costs for Structual BMPs in North Carolina (Hunt and Lord, 2007).

The benefits of the scenarios were determined based upon increased gemorphic stability (decrease in erosion) and decreased risk of flooding provided by PCSWMM (CHI, 2009), nutrient removal (NCDENR and NCState, 2011), and ecological enhancement (Costanza et al., 1997). The nutrient removal program, Jordan Lake Stormwater Load Accounting Tool (JLSLAT), models nitrogen and phosphrous loads and concentrations associated with specific land uses and the reductions attributed to specific SCMs. Each SCM (rain garden, cistern, permeable pavement, and green roof) and contributing drainage area were modeled individually and then applied to the entire watershed to determine the overall percent removal because JLSLAT is intended to model small sub-catchcments. This program was suited for very basic calculations given limited data of the watershed and therefore the reductions calculated should not be considered exact, but a crude estimate. This program estimated nitrogen and phosphorous removals to make relative comparisons among the scenarios. The data output by JLSLAT should not be considered exact. All benefits were not given a monetary value, but were instead compared to determine improvement upon the existing condition.

Table 6.2: Cost Per m^2 of LID Practices Used In Tanyard Branch

LID Practice	General Cost Per m^2 LID Practice Constructed	Reference
Permeable Pavement	$110	Hathaway and Hunt (2007)
Rain Garden	$35	Hathaway and Hunt (2007)
Green Roof	$135	Personal Correspondence (Ed Snodgrass) (01/2011)

6.3 Results

The costs and benefits of each scenario were calculated to determine the economic feasibility of implementing the LID practices and wet ponds vis-á-vis the benefits they provided (Tables 6.3). The costs consisted of: capital cost and installation, annual maintenance, land

purchase, sewer line removal and/or re-location, stream restoration, and stream compensatory mitigation. A price of $1150.00 per linear meter of stream was used for necessary stream restoration (vegetation, decrease bankfull depth/width, increase sinuosity, addition of riffles/pools, etc.) and to compensate for any length of stream that was taken for a wet pond (NC EEP, 2010). The maintenance costs were estimated based upon an average inflation rate, 2.46%, and a 30-year life span (USBLS, 2011).

The least expensive project was the existing scenario because no alteration to the watershed was made. The only cost consisted of restoring the stream (increase sinuosity, return back to respective bankfull depth and cross-sectional area based upon regional curves, vegetation along banks, etc); however, simply restoring the stream would be an immediate solution to stream erosion without addressing the factors (i.e. the developed watershed) causing the erosion. The stream would need to be maintained annually. The most expensive scenario was scenario 9 (the downtown + residential + UNC Campus LID retrofit, with an under-sized wet pond) due to construction of 6.5 ha of permeable pavement in downtown Chapel Hill.

Table 6.3: Estimated Costs of Implementing Wet Ponds and LID Practices of the 9 Scenarios Modeled of Tanyard Branch in PCSWMM (2010 Dollars)

Scenario	Total Capital Cost	Maintenance
1) Existing	179,000	447,800
2) Under-Sized Wet Pond	510,000	346,800
3) Required Wet Pond	1,840,000	114,200
4) Residential	265,000	1,756,100
5) Residential+ Under-Sized Wet Pond	610,000	2,282,900
6) Residential + UNC Campus	3,600,000	1,940,500
7) Residential + UNC Campus+Under-Sized Wet Pond	4,080,000	2,502,500
8) Residential + UNC + Downtown	13,800,000	2,063,500
9) Residential + UNC + Downtown+Under-Sized Wet Pond	14,300,000	2,634,200

The benefits consisted of 1) phosphorous and nitrogen reduction, 2) increased ecological habitat and water regulated services, 3) number of expectant flooding events, 4) the elimination

of some annual excavation of sediment within the stream that would have been due to erosion, and 5) risk of sewer line being exposed within 30 years (Tables 6.4-6.7).

To determine the benefit of restoring ecological functions within Tanyard Branch, the cost which people are willing to pay for equal services was explored. For example, if a river provided an additional $100.00 in fishing production, local fishermen should be willing to pay up to $100.00 to ensure the fish were able to survive. A study conducted by Costanza et al. (1997) determined that humans were willing to pay $8,498 per ha per year to ensure rivers and lakes provided the appropriate ecosystem services (water regulation, water supply, waste treatment, food production, and recreational functions). Based upon meeting the established erosional standards, each scenario was ranked from 1 (best) to 9 (worst) (Table 6.4 and Table 6.5) (Tillinghast et al., 2011). Scenario 9 best met both erosional standards, therefore is predicted to protect ecosystem services the best.

Table 6.4: Summary of Annual Erosional Hours, Annual Eroded Bedload, and Percent Volume Reduction Calculated from Modeling 9 Scenarios of Tanyard Branch in PCSWMM

Scenario	Average Annual Erosional Hours (hr/ha/yr)	Average Annual Eroded Bedload (m^3/m/ha/yr)	% Volume Reduction (Normalized by Drainage Area)
1) Existing Condition	8.33	0.15	0
2) Under-Sized Wet Pond	5.05	0.11	0
3) Full Sized Wet Pond	19.56	0.06	0
4) Residential	4.66	0.13	30
5) Residential+Under-Sized Wet Pond	4.66	0.08	30
6) UNC Campus	4.59	0.12	34
7) UNC Campus+Under-Sized Wet Pond	3.74	0.07	34
8) Downtown	4.44	0.10	41
9) Downtown+Under-Sized Wet Pond	3.53	0.06	41
Stability Thresholds	***0.33***	***0.02***	

Table 6.5: Subjective Ranking of Ecological Services, Reduction in Excavation of Sediment, and Protection of Existing Sewer Line Benefits of Implementing Wet Ponds and LID Practices in Tanyard Branch Based upon Meeting Erosional Standards

Scenario	Ecological Services[1]	Cost Needed to Excavate Eroded Sediment to Maintain Restored Stream[2]	Sewer Line Exposure (In 30 Years?)
1) Existing	9	9	Yes
2) Under-Sized Wet Pond	6	6	No
3) Required Wet Pond	2	2	Removed
4) Residential	8	8	No
5) Residential+ Under-Sized Wet Pond	4	4	No
6) Residential + UNC Campus	7	7	No
7) Residential + UNC Campus+Under-Sized Wet Pond	3	3	No
8) Residential + UNC + Downtown	5	5	No
9) Residential + UNC + Downtown+Under-Sized Wet Pond	1	1	No

[1]Ecological services were ranked from 1-9, 1 indicating stream and watershed provided best environment for ecological functions and 9 being the worst.
[2]Excavation of sediment were ranked from 1-9, 1 indicating smallest amount of transported sediment (but enough so stream not eroding itself) within the stream and 9 being the most.

Similar to ecological services, the erosion rate of Tanyard Branch's banks was ranked from 1 (best) to 9 (worst) based on incipient erosion analysis and meeting the annual erosional hour and volume of eroded bedload standards (Table 6.4 and Table 6.5). The decrease in predicted erosional hours and volume of eroded bedload, less erosion within the stream was expected, increasing geomorphic stability and decreasing eroding sediment. Less predicted eroded sediment meant less annual excavation was needed with the stream to maintain the restored bankfull depth, width, and cross-section. It was assumed that all scenarios provided enough suspended sediment to the channel to keep the stream from eroding itself. This assumption was applicable for Tanyard Branch because the main affect of erosion was incision due to high flow rates. Banks of Tanyard Branch remained stable. The higher the predicted annual erosional hour and volume of eroded sediment, the increase in incision, erosion, and instability with the stream, impacting nearby utility lines. The ability to meet the erosional standards affected whether a nearby sewer line would be exposed within 30 years (currently 0.91 meter below the stream). The only scenario expected to expose the sewer line was the existing condition. The sewer line would be removed to construct the full-sized wet pond. Due to the decrease in runoff volumes, the sewer line would not be expected to be exposed when LID practices were implemented. Due to the decrease in flow rates leaving the under-sized wet pond,

the sewer line was not expected to be exposed with the 30 years. Scenario 9 best met erosional standards, therefore is predicted to also provide the greatest stream stability and reduce annual excavation of eroded sediment and exposure of a nearby sewer line.

The reduction in nutrient loading was determined using JLSLAT (NCDENR and NCState, 2011). Officials in Chapel Hill are required to reduce nitrogen and phosphorous loads in Tanyard Branch to comply with the Jordan Lake Rules (NCDENR, 2007b). The Upper New Hope Creek portion of Jordan Lake (location of Chapel Hill) is required to have its total maximum daily load of nitrogen and phosphorous reduced by 35% and 5%, respectively (NCDENR, 2007b). For this reason alone, while the Existing scenario is the least expensive, it is not allowed. The only scenario complying with reduction goals was the required sized wet pond (Table 6.6). The full-sized wet pond allowed for enough contact time for the runoff to stay within the pond before being released. This allowed for sedimentation to occur, reducing nitrogen and phosphorous. Nitrogen was further removed through possible denitrification sites at the bottom of the pond. Nitrogen and phosphorous was not reduced substantially with the addition of green roofs and permeable pavement. Green roofs typically leach nitrogen and phosphorous due to the compost within the soil media (Hathaway et al., 2008). Due to aerobic conditions within permeable pavement, ammonia is nitrified to nitrate and not significantly reducing the amount of nitrogen in runoff when compared to untreated asphalt (Collins et al., 2010). The NC Ecosystem Enhancement Program (NC EEP) requires all entities to pay $20.59 per pound nitrogen and $142.02 per pound phosphorous exceeding the required limit (NC EEP, 2011).

Table 6.6: Reduction in Annual Nitrogen and Phosphorous Loads from Constructing LID Practices and/or Wet Ponds in Tanyard Branch (Potential Cost Paid by Town of Chapel Hill Due to Nitrogen and Phosphorous Exceedances in ())

Scenario	% Reduction Nitrogen	% Reduction Phosphorous
Existing	0 ($14,200)	0 ($2,100)
Under-Sized Wet Pond	11 ($9,700)	14
Required Wet Pond	39	52
Residential	4 ($12,500)	5
UNC Campus	4 ($12,500)	5
Downtown	4 ($12,500)	5
Residential+ Under-Sized Wet Pond	15 ($8,100)	19
UNC Campus+Under-Sized Wet Pond	15 ($8,100)	19
Downtown+Under-Sized Wet Pond	15 ($8,100)	19

The benefit of reduced flooding of nearby residential property was determined based upon the largest storm the SCMs (under-sized and full-sized wet ponds) and a restored stream could safely convey without over-topping the banks (Table 6.7). The depth of the restored stream, 0.46 m, was calculated from urban reference streams regime curves (Doll et al., 2002). The largest storm a restored Tanyard Branch without SCMs could safely convey was between the 1-year and 2-year, 24-hour event. This is consistent with the definition of bankfull, flow on the brink of overtopping banks and usually has a recurrent interval of 1.3- to 1.4-years (Doll et al., 2002, Navratil et al., 2006). The under-sized and required-size wet pond provided less risk to adjacent properties by safely conveying larger storms, 5- and 25-year, 24-hour storms, respectively.

Table 6.7: Risk of Flooding Residential Properties for Given Design Storm Events if the Exisiting Scenario, Under-Sized Wet Pond, or Full-Sized Wet Pond was Chosen to be Implemented in Tanyard Branch

Storm Event	As-Is Restored Channel	Under-Sized Wet Pond	Required Sized Wet Pond
100-year, 24-hour	Yes	Yes	Yes
50-year, 24-hour	Yes	Yes	Yes
25-year, 24-hour	Yes	Yes	No
10-year, 24-hour	Yes	Yes	No
5-year, 24-hour	Yes	No	No
2-year, 24-hour	Yes	No	No
1-year, 24-hour	No	No	No

This study demonstrated that while LID practices are commonly used in highly urbanized watersheds to reduce total available land dedicated to SCMs, the incremental cost of LID practices greatly surpassed those of wet ponds. When LID practices were used in conjunction with wet ponds, the greatest reduction in modeled erosional hours and volume of eroded bedload

were predicted (Table 6.4). But, the cost of the project increased by about $10 million. However, when LID practices were combined with the wet pond: 1) costs for future excavation of eroded sediment in the stream were reduced, 2) the need to replace a current sewer line crossing the stream was eliminated, 3) nitrogen and phosphorous compensations were less, and 4) the amount of compensation to nearby residents for property damage due to flooding was cut.

The residential scenario was the least costly of all retrofit options; however, it also provided the least benefit of stream geomorphic stability ($53,000/ha). Scenario 9 (LID in residential, UNC, downtown, and under-sized wet pond), provided the lowest risk of flooding and the highest potential for appropriate ecosystem services, reduction in nitrogen and phosphorous, and least amount of necessary excavation for eroded sediment, but had a cost of $14 million ($200,000/ha). Scenario 7, LID practices in residential and UNC campus with an under-sized wet pond, appears to be the optimal solution because it predicted the highest stability in terms of erosional processes while being cost effective ($60,000/ha).

6.4 Conclusion

Per this cost-benefit analysis, as higher geomorphic stability within a stream is achieved, so, too, do the costs of the project increase. Of 9 retrofit scenarios, scenario 9 (residential + UNC + downtown + under-sized wet pond) would mitigate the disturbances from the heavily impervious watershed the best at an estimated cost of $14 million ($200,000/ha), while scenario 7 (residential + UNC + under-sized wet pond) provided comparable stream stability at 29% of the cost.

Both the wet ponds, under-sized and full sized, decreased volume of eroded bedload; however, increased erosional hours from the existing scenario. When used solely, the under-sized wet pond provided minimal mitigation for 1) eroded sediment and 2) nitrogen and phosphorous reduction, negatively impacting ecological services when compared to the other scenarios. While the full sized wet pond had the highest reduction of estimated nitrogen and phosphorous, it also had the highest number of erosional hours, about 2.3 times larger than the existing condition. However, being such a large (68 ha) impervious (60%) watershed, LID practices alone did not provide sufficient benefits (4% and 5% reduction of nitrogen and phosphorous, respectively, and minimal ecological services) for their total appropriate capital costs. To obtain the most benefits in terms of the cost of the project, LID practices are needed with detention SCMs; however alternative methods to reduce nitrogen would be needed

regardless of scenario chosen (unless full sized wet pond) to meet current Jordan Lake introduction and phosphorous reduction goals.

D. 8 Plan View of Under-Sized Wet Pond

Figure D.7: Plan View of Under-Sized Wet Pond Designed for Outlet in Tanyard Branch

D.9 Plan View of Full Sized Wet Pond

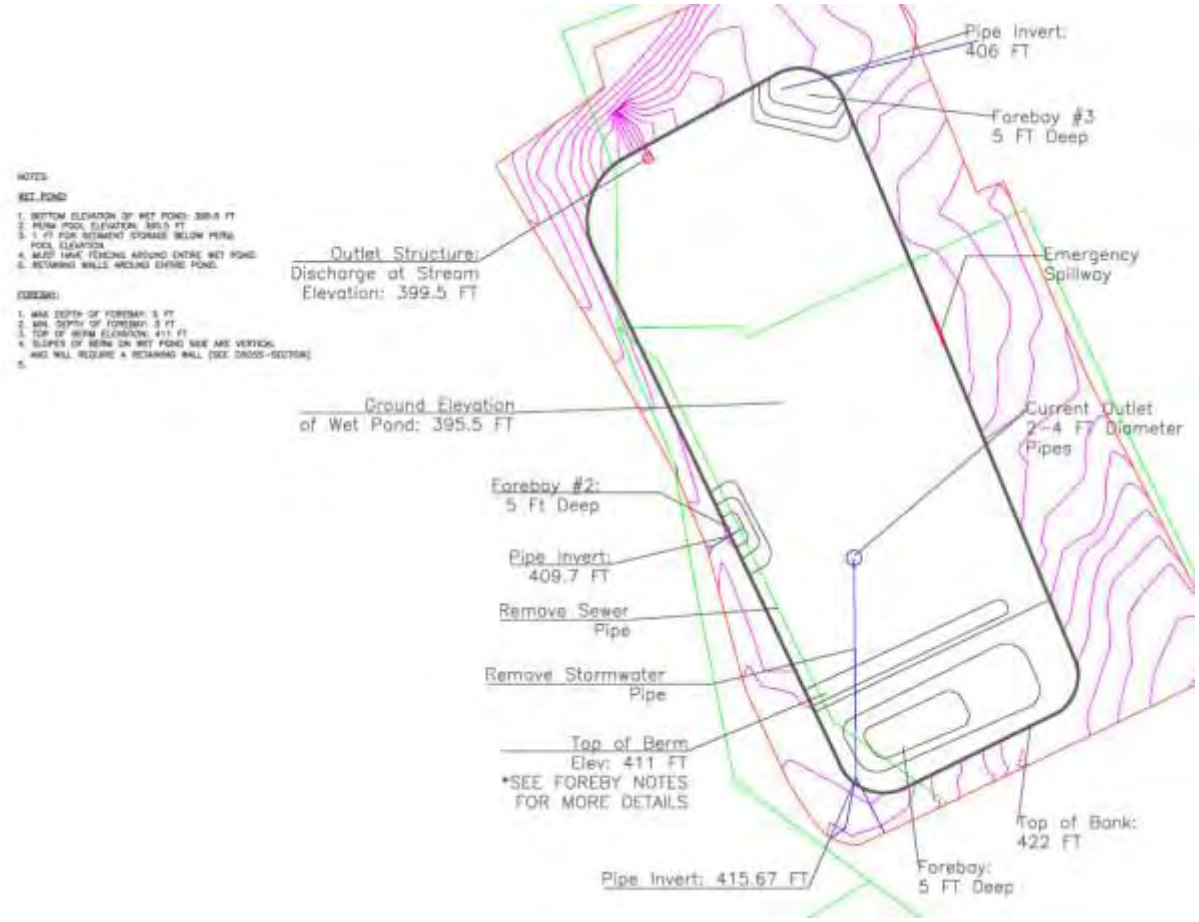


Figure D.8: Plan View of Full Sized Wet Pond Designed for Outlet in Tanyard Branch

D.10 Cross-Section of Under-Sized and Full Sized Wet Pond

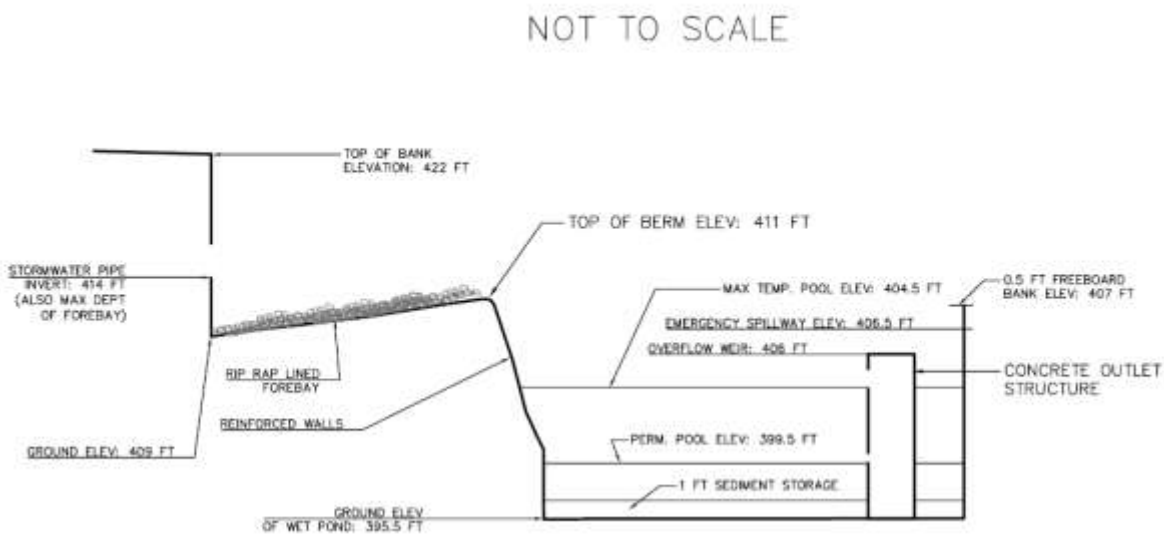


Figure D.9: Cross-Section of Full Sized and Under-Sized Wet Pond and Outlet Structure Designed for Outlet in Tanyard Branch

D.11 Added Drainage Area for Under-Sized Wet Pond

Figure D.10: Added Drainage Area (1.21 ha) Due to Construction of Under-Sized Wet Pond at Outlet of Tanyard Branch

D.12 Necessary Land for Full-Sized Wet Pond (Outlined in White)

Figure D.11: Necessary Land (1.05 ha) for Required Size Wet Pond Designed for the Outlet of Tanyard Branch

D.13 Sewer Line Removal for Full Sized Wet Pond

Figure D.12: Necessary Removal of Sewer Lines (Green Lines Crossed out by White Lines) and Re-location of Sewer Lines (Yellow Lines) for Required Size Wet Pond at Outlet of Tanyard Branch

APPENDIX E: COST-BENEFIT ANALYSIS

E.1 Wet Pond Costs

Under-Sized Wet Pond

Table E.1: Estimated Capital Cost for Under-Sized Wet Pond Designed for Tanyard Branch

Under-Sized Wet Pond Costs				
Description	Price		Estimated Days	Total
Excavator	2.37	per cubic yard		50071
Loading onto Trucks	0.15			1640
Dump Truck	10.35	per 20 cubic yards		10933
Mobilization and De-mobilization	305			305
Rip-Rap/Retaining Wall	172	per day	5	860
Fine Grading	1.23	per square yard	31363	38576
Removal Storm Pipes				140000
Plants				20000
Outlet Structure				2800
			TOTAL	**265186**

Full-Sized Wet Pond

Table E.2: Estimated Capital Cost for Full-Sized Wet Pond Designed for Tanyard Branch

Full-Sized Wet Pond Costs				
Description	Price		Estimated Days	Total
Excavator	2.37	per cubic yard		155256
Loading onto Trucks	0.15			5085
Dump Truck	10.35	per 20 cubic yards		33901
Mobilization and De-mobilization	305	per day	41	305
Rip-Rap/Retaining Wall	172	per day	10	1720
Fine Grading	1.23	per square yard		139305
Removal Storm Pipes				277500
Plants				34000
Outlet Structure				3350
			TOTAL	**650422**

E.2 Cost Analysis

Table E.3: Total Estimated Cost of 9 Scenarios of LID Practices and/or Wet Ponds Modeled in Tanyard Branch in PCSWMM

Scenario	Construction/ Installation Cost	Annual Maintenance	Land Acquisition	Sewer Removal/ Relocation	Stream Restoration	Stream Compensatory Mitigation	Total Cost
Existing	0	10240	0	NA	179200	0	**179200**
Under-Sized Wet Pond	190000	7860	0	140000	92750	86450	**509200**
Required Wet Pond	489000	2560	886664	277500	0	179200	**1832364**
Residential	92860	39200	0	0	179200	0	**272060**
UNC Campus	3362936	44200	0	0	179200	0	**3542136**
Downtown	13560664	46200	0	0	179200	0	**13739864**
Residential+ Under-Sized Wet Pond	293780	51960	0	140000	92750	86450	**612980**
UNC Campus+Under-Sized Wet Pond	3753856	56960	0	140000	92750	86450	**4073056**
Downtown+Under-Sized Wet Pond	13951584	58960	0	140000	92750	86450	**14270784**

E.3 Nutrient Removal of LID Practices

Residential Rain Garden

Physiographic/Geologic Region:	Piedmont
Soil Hydrologic Group	B
Precipitation location:	Carrboro

Total Development Area (ft²):	
Development Name:	
Model Prepared By:	

COLUMN 1 -- NON-RESIDENTIAL LAND USES

	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development (ft²)	Post-Development
COMMERCIAL				
Parking lot	1.44	0.16		
Roof	1.08	0.15		
Open/Landscaped	2.24	0.44		
INDUSTRIAL				
Parking lot	1.44	0.39		
Roof	1.08	0.15		
Open/Landscaped	2.24	0.44		
TRANSPORTATION				
High Density (interstate, main)	3.67	0.43		
Low Density (secondary, feeder)	1.4	0.52		
Rural	1.14	0.47		
Sidewalk	1.4	1.16		
PERVIOUS				
Managed pervious	3.06	0.59		
Unmanaged (pasture)	3.61	1.56		
Forest	1.47	0.25		
JURISDICTIONAL LANDS*				
Natural wetland	--	--		
Riparian buffer	--	--		
Open water	--	--		
LAND TAKEN UP BY BMPs	1.08	0.15		7,840

*Jurisdictional land uses are not included in nutrient/flow calculations.

Total post-development land use areas do not sum to equal entered development size!!!

COLUMN 2 -- RESIDENTIAL LAND USES

	Custom Lot Size (ac)	Age (yrs)	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development	Post-Development (ft²)
PART A						
¾-ac lots	--		--	--		
½-ac lots	--		--	--		
⅓-ac lots	--		--	--		
1-ac lots	--		--	--		
2-ac lots	--		--	--		
Multi-family	--		--	--		
Townhomes	--		--	--		
Custom Lot Size	0.15	Before 1995	2.0283	0.429	520,128	512,288
PART B						
Roadway		--	1.4	0.52		
Driveway		1.0	1.44	0.39		
Parking lot		--	1.44	0.39		
Roof		--	1.08	0.15		
Sidewalk/Patio		--	1.4	1.16		
Lawn		--	2.24	0.44		
Managed pervious		--	3.06	0.59		
Forest		--	1.47	0.25		
Natural wetland*		--	--	--		
Riparian buffer*		--	--	--		
Open water*		--	--	--		
LAND TAKEN UP BY BMPs		--	1.08	0.15		

LAND USE AREA CHECK	
Total Development Area Entered (ft²):	0
Total Pre-Development Calculated Area (ft²):	520,128
Total Post-Development Calculated Area (ft²):	520,128

Figure E.1: Input Parameters for Residential Rain Garden in Jordan Lake Stormwater Load Accounting Tool (NCSU, 2011)

REGION:	Piedmont
TOTAL DEVELOPMENT AREA (ft²):	520,128

	Pre-Development Conditions	Post-Development Conditions	Post-Development w/ BMPs
Percent Impervious (%)	28.5%	29.6%	1.5%
Annual Runoff Volume (c.f.)	615,805	635,304	413,932
Total Nitrogen EMC (mg/L)	2.03	1.99	1.15
Total Nitrogen Loading (lb/ac/yr)	6.53	6.60	2.49
Total Phosphorus EMC (mg/L)	0.43	0.42	0.17
Total Phosphorus Loading (lb/ac/yr)	1.39	1.39	0.36

Percent Difference Between:

	Pre-Dev. & Post-Dev. without BMPs	Pre-Development & Post-Development with	Post-Dev without BMPs & Post-Dev with BMPs
Percent Impervious (%)	1%	-27%	-28%
Annual Runoff Volume (c.f.)	3%	-33%	-35%
Total Nitrogen EMC (mg/L)	-2%	-43%	-42%
Total Nitrogen Loading (lb/ac/yr)	1%	-62%	-62%
Total Phosphorus EMC (mg/L)	-3%	-61%	-60%
Total Phosphorus Loading (lb/ac/yr)	0%	-74%	-74%

*Negative percent difference values indicate a decrease in runoff volume, pollutant concentration or pollutant loading. Positive values indicate an increase.

Figure E.2: Summary of Nitrogen and Phosphorous Removal of Residential Rain Garden (NCSU, 2011)

Residential Cistern

Physiographic/Geologic Region:	Piedmont
Soil Hydrologic Group	B
Precipitation location:	Carrboro

Total Development Area (ft²):	
Development Name:	
Model Prepared By:	

COLUMN 1 -- NON-RESIDENTIAL LAND USES

	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development (ft²)	Post-Development
COMMERCIAL				
Parking lot	1.44	0.16		
Roof	1.08	0.15		
Open/Landscaped	2.24	0.44		
INDUSTRIAL				
Parking lot	1.44	0.39		
Roof	1.08	0.15		
Open/Landscaped	2.24	0.44		
TRANSPORTATION				
High Density (interstate, main)	3.67	0.43		
Low Density (secondary, feeder)	1.4	0.52		
Rural	1.14	0.47		
Sidewalk	1.4	1.16		
PERVIOUS				
Managed pervious	3.06	0.59		
Unmanaged (pasture)	3.61	1.56		
Forest	1.47	0.25		
JURISDICTIONAL LANDS*				
Natural wetland	--	--		
Riparian buffer	--	--		
Open water	--	--		
LAND TAKEN UP BY BMPs	1.08	0.15		

*Jurisdictional land uses are not included in nutrient/flow calculations.

Total post-development land use areas do not sum to equal entered development size!!!

COLUMN 2 -- RESIDENTIAL LAND USES

	Custom Lot Size (ac)	Age (yrs)	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development	Post-Development (ft²)
PART A						
¾-ac lots	--		--	--		
¼-ac lots	--		--	--		
½-ac lots	--		--	--		
1-ac lots	--		--	--		
2-ac lots	--		--	--		
Multi-family	--		--	--		
Townhomes	--		--	--		
Custom Lot Size	0.15	Before 1995	2.0283	0.429	35,711	35,711
PART B						
Roadway		--	1.4	0.52		
Driveway		1.0	1.44	0.39		
Parking lot		--	1.44	0.39		
Roof		--	1.08	0.15		
Sidewalk/Patio		--	1.4	1.16		
Lawn		--	2.24	0.44		
Managed pervious		--	3.06	0.59		
Forest		--	1.47	0.25		
Natural wetland*		--	--	--		
Riparian buffer*		--	--	--		
Open water*		--	--	--		
LAND TAKEN UP BY BMPs		--	1.08	0.15		

LAND USE AREA CHECK	
Total Development Area Entered (ft²):	0
Total Pre-Development Calculated Area (ft²):	35,711
Total Post-Development Calculated Area (ft²):	35,711

Figure E.3: Input Parameters for Residential Cistern in Jordan Lake Stormwater Load Accounting Tool (NCSU, 2011)

REGION:	Piedmont
TOTAL DEVELOPMENT AREA (ft²):	35,711

	Pre-Development Conditions	Post-Development Conditions	Post-Development w/ BMPs
Percent Impervious (%)	28.5%	28.5%	0.0%
Annual Runoff Volume (c.f.)	42,280	42,280	38,052
Total Nitrogen EMC (mg/L)	2.03	2.03	2.03
Total Nitrogen Loading (lb/ac/yr)	6.53	6.53	5.88
Total Phosphorus EMC (mg/L)	0.43	0.43	0.43
Total Phosphorus Loading (lb/ac/yr)	1.38	1.38	1.24

Percent Difference Between:

	Pre-Dev. & Post-Dev. without BMPs	Pre-Development & Post-Development with	Post-Dev without BMPs & Post-Dev with BMPs
Percent Impervious (%)	0%	-28%	-28%
Annual Runoff Volume (c.f.)	0%	-10%	-10%
Total Nitrogen EMC (mg/L)	0%	0%	0%
Total Nitrogen Loading (lb/ac/yr)	0%	-10%	-10%
Total Phosphorus EMC (mg/L)	0%	0%	0%
Total Phosphorus Loading (lb/ac/yr)	0%	-10%	-10%

*Negative percent difference values indicate a decrease in runoff volume, pollutant concentration or pollutant loading. Positive values indicate an increase.

Figure E.4: Summary of Nitrogen and Phosphorous Removal of Residential Cistern (NCSU, 2011)

UNC Campus Scenario Permeable Pavement

Physiographic/Geologic Region:	Piedmont
Soil Hydrologic Group:	B
Precipitation location:	Carrboro

Total Development Area (ft²):	
Development Name:	
Model Prepared By:	

COLUMN 1 -- NON-RESIDENTIAL LAND USES

	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development (ft²)	Post-Development
COMMERCIAL				
Parking lot	1.44	0.16	263,538	263,538
Roof	1.08	0.15		
Open/Landscaped	2.24	0.44		
INDUSTRIAL				
Parking lot	1.44	0.39		
Roof	1.08	0.15		
Open/Landscaped	2.24	0.44		
TRANSPORTATION				
High Density (interstate, main)	3.67	0.43		
Low Density (secondary, feeder)	1.4	0.52		
Rural	1.14	0.47		
Sidewalk	1.4	1.16		
PERVIOUS				
Managed pervious	3.06	0.59		
Unmanaged (pasture)	3.61	1.56		
Forest	1.47	0.25		
JURISDICTIONAL LANDS*				
Natural wetland	--	--		
Riparian buffer	--	--		
Open water	--	--		
LAND TAKEN UP BY BMPs	1.08	0.15		

*Jurisdictional land uses are not included in nutrient/flow calculations.

Total post-development land use areas do not sum to equal entered development size!!!

COLUMN 2 -- RESIDENTIAL LAND USES

	Custom Lot Size (ac)	Age (yrs)	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development	Post-Development (ft²)
PART A						
⅓-ac lots	--		--	--		
¼-ac lots	--		--	--		
½-ac lots	--		--	--		
1-ac lots	--		--	--		
2-ac lots	--		--	--		
Multi-family	--		--	--		
Townhomes	--		--	--		
Custom Lot Size	0.15	Before 1995	2.0283	0.429		
PART B						
Roadway		--	1.4	0.52		
Driveway		1.0	1.44	0.39		
Parking lot		--	1.44	0.39		
Roof		--	1.08	0.15		
Sidewalk/Patio		--	1.4	1.16		
Lawn		--	2.24	0.44		
Managed pervious		--	3.06	0.59		
Forest		--	1.47	0.25		
Natural wetland*		--	--	--		
Riparian buffer*		--	--	--		
Open water*		--	--	--		
LAND TAKEN UP BY BMPs		--	1.08	0.15		

LAND USE AREA CHECK	
Total Development Area Entered (ft²):	0
Total Pre-Development Calculated Area (ft²):	263,538
Total Post-Development Calculated Area (ft²):	263,538

Figure E.5: Input Parameters for Permeable Pavement of UNC Campus Scenario in Jordan Lake Stormwater Load Accounting Tool (NCSU, 2011)

REGION:	Piedmont
TOTAL DEVELOPMENT AREA (ft²):	263,538

	Pre-Development Conditions	Post-Development Conditions	Post-Development w/ BMPs
Percent Impervious (%)	100.0%	100.0%	100.0%
Annual Runoff Volume (c.f.)	967,437	967,437	967,437
Total Nitrogen EMC (mg/L)	1.44	1.44	1.44
Total Nitrogen Loading (lb/ac/yr)	14.38	14.38	14.34
Total Phosphorus EMC (mg/L)	0.16	0.16	0.16
Total Phosphorus Loading (lb/ac/yr)	1.60	1.60	1.59

Percent Difference Between:

	Pre-Dev. & Post-Dev. without BMPs	Pre-Development & Post-Development with	Post-Dev without BMPs & Post-Dev with BMPs
Percent Impervious (%)	0%	0%	0%
Annual Runoff Volume (c.f.)	0%	0%	0%
Total Nitrogen EMC (mg/L)	0%	0%	0%
Total Nitrogen Loading (lb/ac/yr)	0%	0%	0%
Total Phosphorus EMC (mg/L)	0%	0%	0%
Total Phosphorus Loading (lb/ac/yr)	0%	0%	0%

*Negative percent difference values indicate a decrease in runoff volume, pollutant concentration or pollutant loading. Positive values indicate an increase.

Figure E.6: Summary of Nitrogen and Phosphorous Removal of UNC Campus Permeable Pavement (NCSU, 2011)

UNC Campus Scenario Green Roof

Physiographic/Geologic Region:	Piedmont
Soil Hydrologic Group	B
Precipitation location:	Carrboro

Total Development Area (ft²):	
Development Name:	
Model Prepared By:	

COLUMN 1 -- NON-RESIDENTIAL LAND USES

	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development (ft²)	Post-Development (ft²)
COMMERCIAL				
Parking lot	1.44	0.39		
Roof	1.08	0.15	52,743	52,743
Open/Landscaped	2.24	0.44		
INDUSTRIAL				
Parking lot	1.44	0.39		
Roof	1.08	0.15		
Open/Landscaped	2.24	0.44		
TRANSPORTATION				
High Density (interstate, main)	3.67	0.43		
Low Density (secondary, feeder)	1.4	0.52		
Rural	1.14	0.47		
Sidewalk	1.4	1.16		
PERVIOUS				
Managed pervious	3.06	0.59		
Unmanaged (pasture)	3.61	1.56		
Forest	1.47	0.25		
JURISDICTIONAL LANDS*				
Natural wetland	--	--		
Riparian buffer	--	--		
Open water	--	--		
LAND TAKEN UP BY BMPs	1.08	0.15		

*Jurisdictional land areas are not included in nutrient/flow calculations.

Total post-development land use areas do not sum to equal entered development size!!!

COLUMN 2 -- RESIDENTIAL LAND USES

	Custom Lot Size (ac)	Age (yrs)	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development (ft²)	Post-Development (ft²)
PART A						
¾-ac lots	--		--	--		
½-ac lots	--		--	--		
¼-ac lots	--		--	--		
1-ac lots	--		--	--		
2-ac lots	--		--	--		
Multi-family	--		--	--		
Townhomes	--		--	--		
Custom Lot Size	0.15	Before 1995	2.0283	0.429		
PART B						
Roadway	--		1.4	0.52		
Driveway	1.0		1.44	0.39		
Parking lot	--		1.44	0.39		
Roof	--		1.08	0.15		
Sidewalk/Patio	--		1.4	1.16		
Lawn	--		2.24	0.44		
Managed pervious	--		3.06	0.59		
Forest	--		1.47	0.25		
Natural wetland*	--		--	--		
Riparian buffer*	--		--	--		
Open water*	--		--	--		
LAND TAKEN UP BY BMPs	--		1.08	0.15		

LAND USE AREA CHECK

Total Development Area Entered (ft²):	0
Total Pre-Development Calculated Area (ft²):	52,743
Total Post-Development Calculated Area (ft²):	52,743

Figure E.7: Input Parameters for Green Roof of UNC Campus Scenario in Jordan Lake Stormwater Load Accounting Tool (NCSU, 2011)

REGION:	Piedmont
TOTAL DEVELOPMENT AREA (ft²):	52,743

	Pre-Development Conditions	Post-Development Conditions	Post-Development w/ BMPs
Percent Impervious (%)	100.0%	100.0%	100.0%
Annual Runoff Volume (c.f.)	193,617	193,617	96,809
Total Nitrogen EMC (mg/L)	1.08	1.08	1.08
Total Nitrogen Loading (lb/ac/yr)	10.75	10.75	5.38
Total Phosphorus EMC (mg/L)	0.15	0.15	0.15
Total Phosphorus Loading (lb/ac/yr)	1.50	1.50	0.75

Percent Difference Between:

	Pre-Dev. & Post-Dev. without BMPs	Pre-Development & Post-Development with	Post-Dev without BMPs & Post-Dev with BMPs
Percent Impervious (%)	0%	0%	0%
Annual Runoff Volume (c.f.)	0%	-50%	-50%
Total Nitrogen EMC (mg/L)	0%	0%	0%
Total Nitrogen Loading (lb/ac/yr)	0%	-50%	-50%
Total Phosphorus EMC (mg/L)	0%	0%	0%
Total Phosphorus Loading (lb/ac/yr)	0%	-50%	-50%

*Negative percent difference values indicate a decrease in runoff volume, pollutant concentration or pollutant loading. Positive values indicate an increase.

Figure E.8: Summary of Nitrogen and Phosphorous Removal of UNC Campus Green Roof (NCSU, 2011)

Downtown Scenario Permeable Pavement

Physiographic/Geologic Region:	Piedmont
Soil Hydrologic Group:	B
Precipitation location:	Carrboro

Total Development Area (ft²):	
Development Name:	
Model Prepared By:	

COLUMN 1 -- NON-RESIDENTIAL LAND USES

	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development (ft²)	Post-Development
COMMERCIAL				
Parking lot	1.44	0.16	699,476	699,476
Roof	1.08	0.15		
Open/Landscaped	2.24	0.44		
INDUSTRIAL				
Parking lot	1.44	0.39		
Roof	1.08	0.15		
Open/Landscaped	2.24	0.44		
TRANSPORTATION				
High Density (interstate, main)	3.67	0.43		
Low Density (secondary, feeder)	1.4	0.52		
Rural	1.14	0.47		
Sidewalk	1.4	1.16		
PERVIOUS				
Managed pervious	3.06	0.59		
Unmanaged (pasture)	3.61	1.56		
Forest	1.47	0.25		
JURISDICTIONAL LANDS*				
Natural wetland	--	--		
Riparian buffer	--	--		
Open water	--	--		
LAND TAKEN UP BY BMPs	1.08	0.15		

*Jurisdictional land uses are not included in nutrient/flow calculations.

Total post-development land use areas do not sum to equal entered development size!!!

COLUMN 2 -- RESIDENTIAL LAND USES

	Custom Lot Size (ac)	Age (yrs)	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development	Post-Development (ft²)
PART A						
¼-ac lots	--		--	--		
½-ac lots	--		--	--		
¾-ac lots	--		--	--		
1-ac lots	--		--	--		
2-ac lots	--		--	--		
Multi-family	--		--	--		
Townhomes	--		--	--		
Custom Lot Size	0.15	Before 1995	2.0283	0.429		
PART B						
Roadway		--	1.4	0.52		
Driveway		1.0	1.44	0.39		
Parking lot		--	1.44	0.39		
Roof		--	1.08	0.15		
Sidewalk/Patio		--	1.4	1.16		
Lawn		--	2.24	0.44		
Managed pervious		--	3.06	0.59		
Forest		--	1.47	0.25		
Natural wetland*		--	--	--		
Riparian buffer*		--	--	--		
Open water*		--	--	--		
LAND TAKEN UP BY BMPs		--	1.08	0.15		

LAND USE AREA CHECK	
Total Development Area Entered (ft²):	0
Total Pre-Development Calculated Area (ft²):	699,476
Total Post-Development Calculated Area (ft²):	699,476

Figure E.9: Input Parameters for Permeable Pavement of Downtown Scenario in Jordan Lake Stormwater Load Accounting Tool (NCSU, 2011)

REGION:	Piedmont
TOTAL DEVELOPMENT AREA (ft²):	699,476

	Pre-Development Conditions	Post-Development Conditions	Post-Development w/ BMPs
Percent Impervious (%)	100.0%	100.0%	100.0%
Annual Runoff Volume (c.f.)	2,567,747	2,567,747	2,567,747
Total Nitrogen EMC (mg/L)	1.44	1.44	1.44
Total Nitrogen Loading (lb/ac/yr)	14.38	14.38	14.34
Total Phosphorus EMC (mg/L)	0.16	0.16	0.16
Total Phosphorus Loading (lb/ac/yr)	1.60	1.60	1.58

Percent Difference Between:

	Pre-Dev. & Post-Dev. without BMPs	Pre-Development & Post-Development with	Post-Dev without BMPs & Post-Dev with BMPs
Percent Impervious (%)	0%	0%	0%
Annual Runoff Volume (c.f.)	0%	0%	0%
Total Nitrogen EMC (mg/L)	0%	0%	0%
Total Nitrogen Loading (lb/ac/yr)	0%	0%	0%
Total Phosphorus EMC (mg/L)	0%	0%	0%
Total Phosphorus Loading (lb/ac/yr)	0%	0%	0%

*Negative percent difference values indicate a decrease in runoff volume, pollutant concentration or pollutant loading. Positive values indicate an increase.

Figure E.10: Summary of Nitrogen and Phosphorous Removal of Downtown Permeable Pavement (NCSU, 2011)

Downtown Scenario Green Roof

Physiographic/Geologic Region:	Piedmont
Soil Hydrologic Group	B
Precipitation location:	Carrboro

Total Development Area (ft²):	
Development Name:	
Model Prepared By:	

COLUMN 1 -- NON-RESIDENTIAL LAND USES

	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development (ft²)	Post-Development
COMMERCIAL				
Parking lot	1.44	0.16		
Roof	1.08	0.15	539,272	539,272
Open/Landscaped	2.24	0.44		
INDUSTRIAL				
Parking lot	1.44	0.39		
Roof	1.08	0.15		
Open/Landscaped	2.24	0.44		
TRANSPORTATION				
High Density (interstate, main)	3.67	0.43		
Low Density (secondary, feeder)	1.4	0.52		
Rural	1.14	0.47		
Sidewalk	1.4	1.16		
PERVIOUS				
Managed pervious	3.06	0.59		
Unmanaged (pasture)	3.61	1.56		
Forest	1.47	0.25		
JURISDICTIONAL LANDS*				
Natural wetland	--	--		
Riparian buffer	--	--		
Open water	--	--		
LAND TAKEN UP BY BMPs	1.08	0.15		

*Jurisdictional land uses are not included in nutrient/flow calculations.

Total post-development land use areas do not sum to equal entered development size!!!

COLUMN 2 -- RESIDENTIAL LAND USES

	Custom Lot Size (ac)	Age (yrs)	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Development	Post-Development (ft²)
PART A						
⅛-ac lots	--		--	--		
¼-ac lots	--		--	--		
½-ac lots	--		--	--		
1-ac lots	--		--	--		
2-ac lots	--		--	--		
Multi-family	--		--	--		
Townhomes	--		--	--		
Custom Lot Size	0.15	Before 1995	2.0283	0.429		
PART B						
Roadway		--	1.4	0.52		
Driveway		1.0	1.44	0.39		
Parking lot		--	1.44	0.39		
Roof		--	1.08	0.15		
Sidewalk/Patio		--	1.4	1.16		
Lawn		--	2.24	0.44		
Managed pervious		--	3.06	0.59		
Forest		--	1.47	0.25		
Natural wetland*		--	--	--		
Riparian buffer*		--	--	--		
Open water*		--	--	--		
LAND TAKEN UP BY BMPs		--	1.08	0.15		

LAND USE AREA CHECK	
Total Development Area Entered (ft²):	0
Total Pre-Development Calculated Area (ft²):	539,272
Total Post-Development Calculated Area (ft²):	539,272

Figure E.11: Input Parameters for Green Roof of Downtown Scenario in Jordan Lake Stormwater Load Accounting Tool (NCSU, 2011)

REGION:	Piedmont
TOTAL DEVELOPMENT AREA (ft²):	539,272

	Pre-Development Conditions	Post-Development Conditions	Post-Development w/ BMPs
Percent Impervious (%)	100.0%	100.0%	100.0%
Annual Runoff Volume (c.f.)	1,979,645	1,979,645	989,823
Total Nitrogen EMC (mg/L)	1.08	1.08	1.08
Total Nitrogen Loading (lb/ac/yr)	10.78	10.78	5.38
Total Phosphorus EMC (mg/L)	0.15	0.15	0.15
Total Phosphorus Loading (lb/ac/yr)	1.50	1.50	0.75

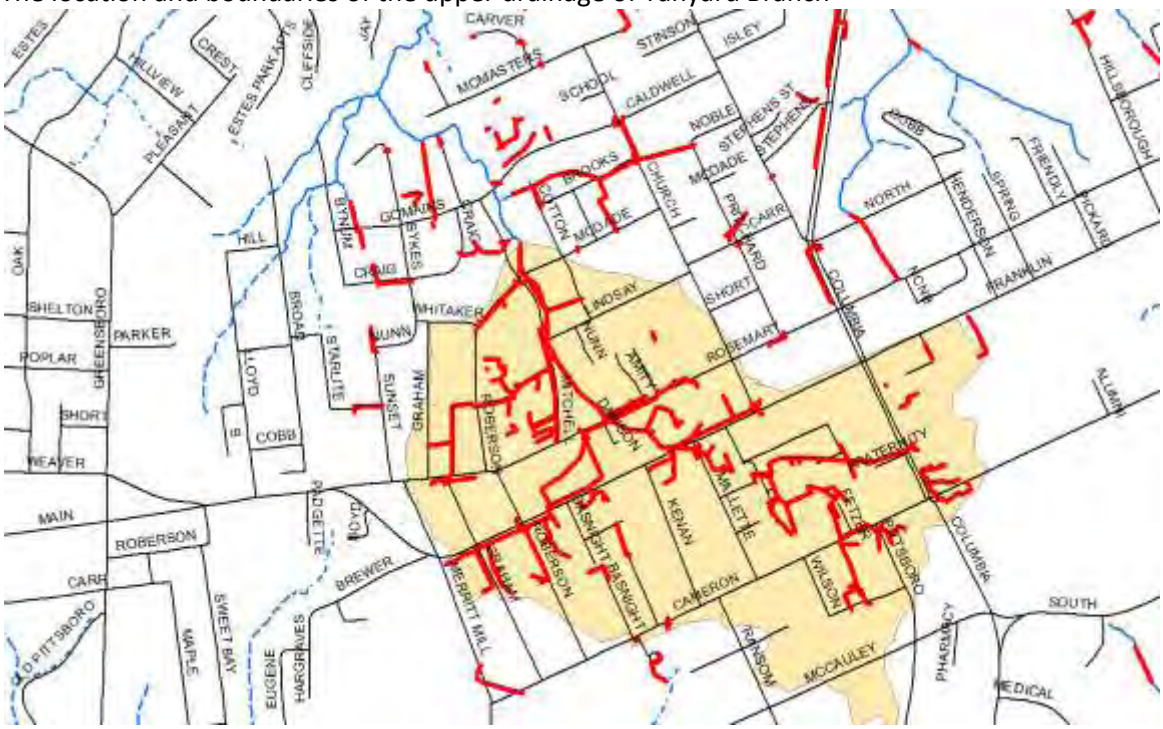
Percent Difference Between:

	Pre-Dev. & Post-Dev. without BMPs	Pre-Development & Post-Development with	Post-Dev without BMPs & Post-Dev with BMPs
Percent Impervious (%)	0%	0%	0%
Annual Runoff Volume (c.f.)	0%	-50%	-50%
Total Nitrogen EMC (mg/L)	0%	0%	0%
Total Nitrogen Loading (lb/ac/yr)	0%	-50%	-50%
Total Phosphorus EMC (mg/L)	0%	0%	0%
Total Phosphorus Loading (lb/ac/yr)	0%	-50%	-50%

*Negative percent difference values indicate a decrease in runoff volume, pollutant concentration or pollutant loading. Positive values indicate an increase.

Figure E.12: Summary of Nitrogen and Phosphorous Removal of Downtown Green Roof (NCSU, 2011)

The location and boundaries of the upper drainage of Tanyard Branch



The convoluted and dense stormdrain network is in red

The location of the proposed basin would be at the black triangle

The “double-barrel shotgun” outfall where it all daylights and erosion starts

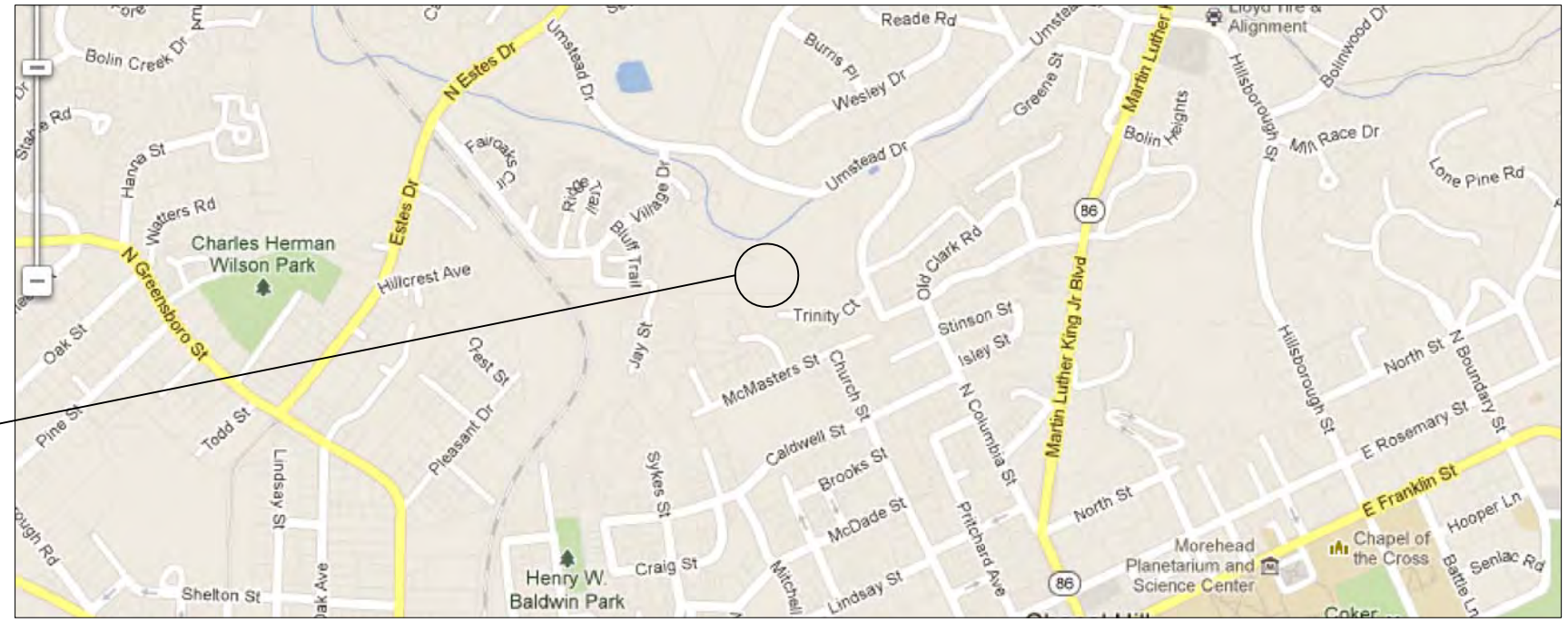
Erosion of the banks downstream

More downstream bank erosion

APPENDIX 4: TRINITY COURT STREAM RESTORATION PROJECT MATERIALS

Trinity Court
Stream Stabilization
Chapel Hill, NC
Orange County

SITE



Prepared for:
Town of Chapel Hill
Stormwater Management Division
208 N. Columbia Street
Chapel Hill, NC 27514

Prepared by:
North Carolina State University
Dept. of Biological and Agricultural Engineering
3100 Faucette Dr.
Raleigh, NC 27695

CHSWD Contact:
Patricia D'Arconte -
Project Manager
919-969-7202

NCSU Contact:
Zan Price - Design/Construction
828-712-9194

Sheet Index

Sheet 1: Cover & Sheet Index
Sheet 2: Existing Conditions - Plan View
Sheet 3: Design Plan View
Sheet 4: Design - Longitudinal Profile
Sheet 5: Design - Cross-sections
Sheet 6: Construction Details
Sheet 7: Construction Details

NO	REVISIONS	DRN	CHK	DATE
1	INITIAL DESIGN	ZP	GJ	01/16/12

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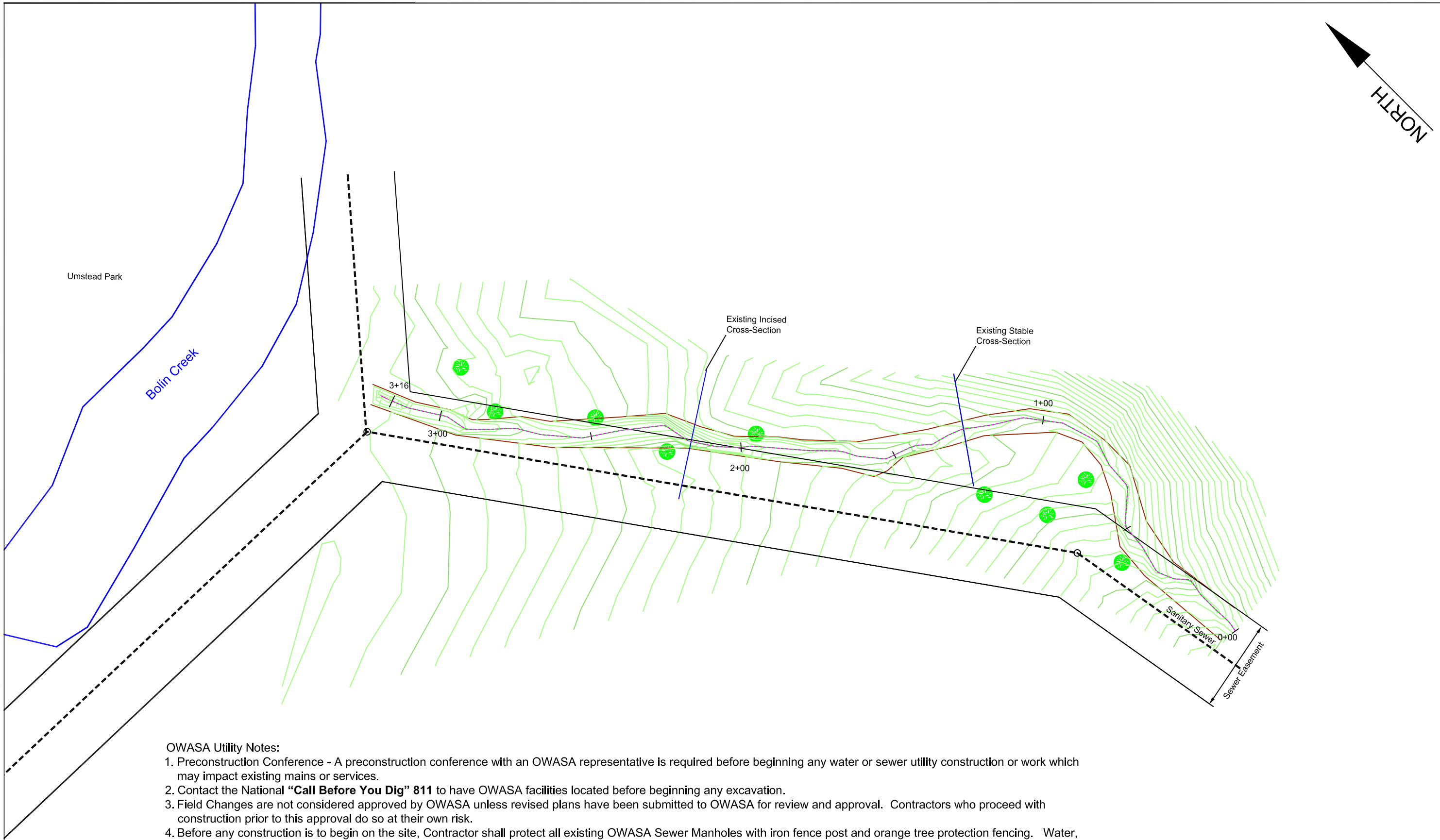
Weaver Labs Campus Box 7625
North Carolina State University
Raleigh, NC 27695

TRINITY COURT STREAM STABILIZATION
CHAPEL HILL, NC

COVER AND SHEET INDEX

DATE 1/16/12
PROJECT NO.
FILENAME FILE.DWG
SHEET NO. PL – 1
DRAWING NO.



OWASA Utility Notes:

1. Preconstruction Conference - A preconstruction conference with an OWASA representative is required before beginning any water or sewer utility construction or work which may impact existing mains or services.
2. Contact the National **"Call Before You Dig" 811** to have OWASA facilities located before beginning any excavation.
3. Field Changes are not considered approved by OWASA unless revised plans have been submitted to OWASA for review and approval. Contractors who proceed with construction prior to this approval do so at their own risk.
4. Before any construction is to begin on the site, Contractor shall protect all existing OWASA Sewer Manholes with iron fence post and orange tree protection fencing. Water, stone, dirt, or any other debris shall not be allowed to enter the OWASA Sanitary Sewer System during flushing operations or at any other time. Construction taking place in the vicinity of any existing OWASA sewer lines or manholes shall not cause any inflow of surface water or debris to enter the OWASA Sanitary Sewer System. Existing OWASA manholes located in construction sites are to be kept clear and accessible to OWASA personnel at all times. The Owner and/or Contractor shall be responsible for any damages incurred to the OWASA Sanitary Sewer System and any fines imposed by the State of North Carolina Division Of Water Quality due to sewer spills or overflows.
5. Existing water and/or sewer lines encountered during construction must be supported in a manner acceptable to the OWASA Construction Inspector. The OWASA Construction Inspector under the direction of the OWASA Engineering Manager may require existing pipes to be replaced with new ductile iron pipe.

SCALE 1" = 30'

15 0 15 30

NO	REVISIONS	DRN	CHK	DATE
1	INITIAL DESIGN	ZP	GJ	01/16/12

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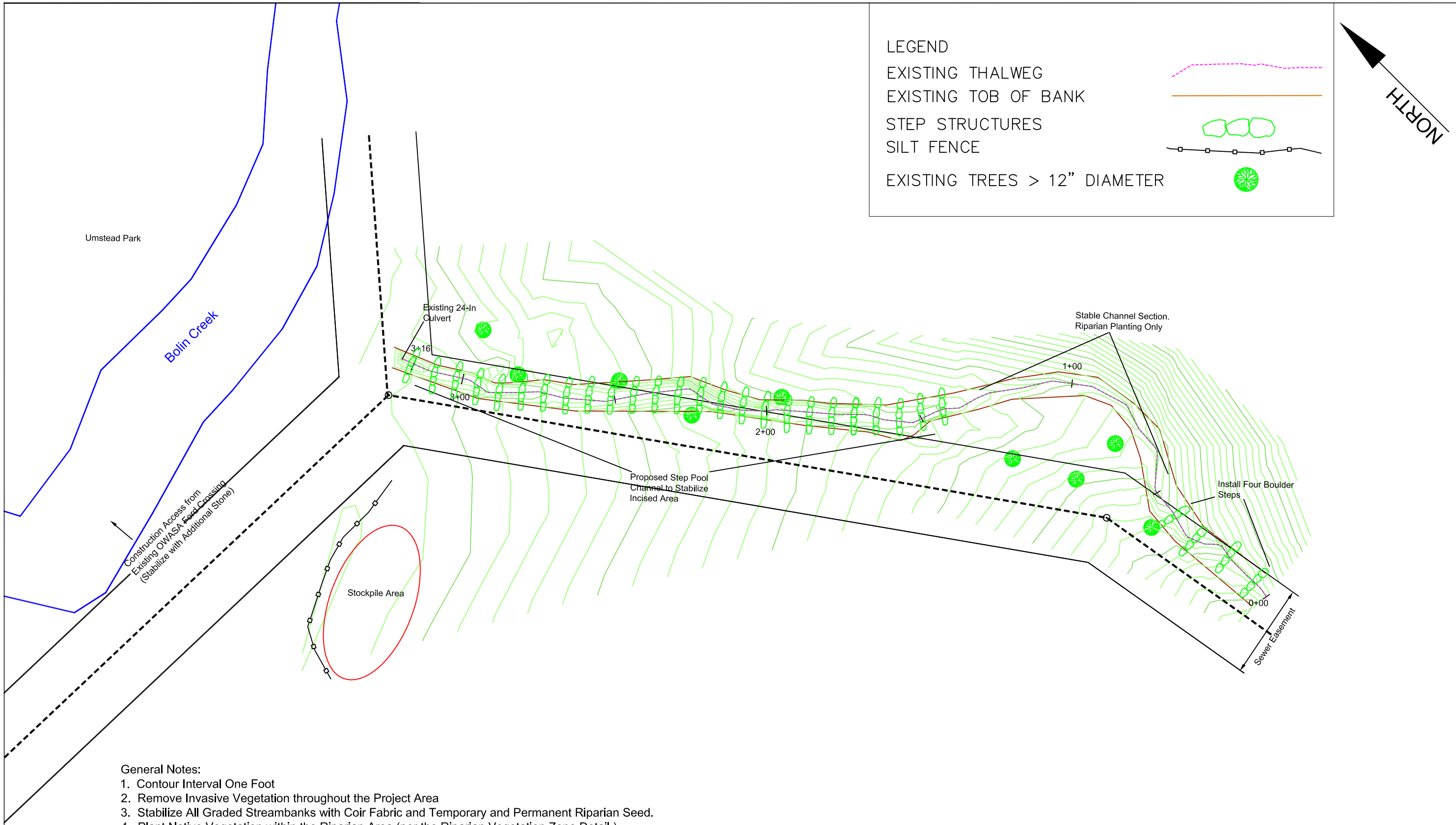
TRINITY COURT STREAM STABILIZATION
CHAPEL HILL, NC

EXISTING CONDITIONS PLAN VIEW

DATE 1/16/12
PROJECT NO.
FILENAME FILE.DWG
SHEET NO. 2
DRAWING NO.



General Notes:

1. Contour Interval One Foot
2. Remove Invasive Vegetation throughout the Project Area
3. Stabilize All Graded Streambanks with Coir Fabric and Temporary and Permanent Riparian Seed.
4. Plant Native Vegetation within the Riparian Area (per the Riparian Vegetation Zone Detail)
5. Permanent vegetation within the sewer easement shall be approved by OWASA
6. Proposed Step Locations Can Be Modified in the Field by the Onsite Engineer.
7. Contractor Shall Minimize Disturbed Areas and Preserve Mature Trees Flagged by the Onsite Engineer
8. In Addition to Stabilizing the Riparian Area, the Contractor shall Smooth Grade, Seed, and Mulch all Disturbed Areas Outside of the Restored Stream Area
9. No Construction Materials, Equipment, or Soil shall be stored on OWASA Easements During Construction unless Approved by OWASA. OWASA Must have Unrestricted Access Along the Easement at all Times.
10. Existing OWASA Manholes Shall be Protected From Damage During Construction Using Suitable Fencing.

SCALE 1" = 30'

15 0 15 30

NO	REVISIONS	DRN	CHK	DATE
1	INITIAL DESIGN	ZP	GJ	01/16/12

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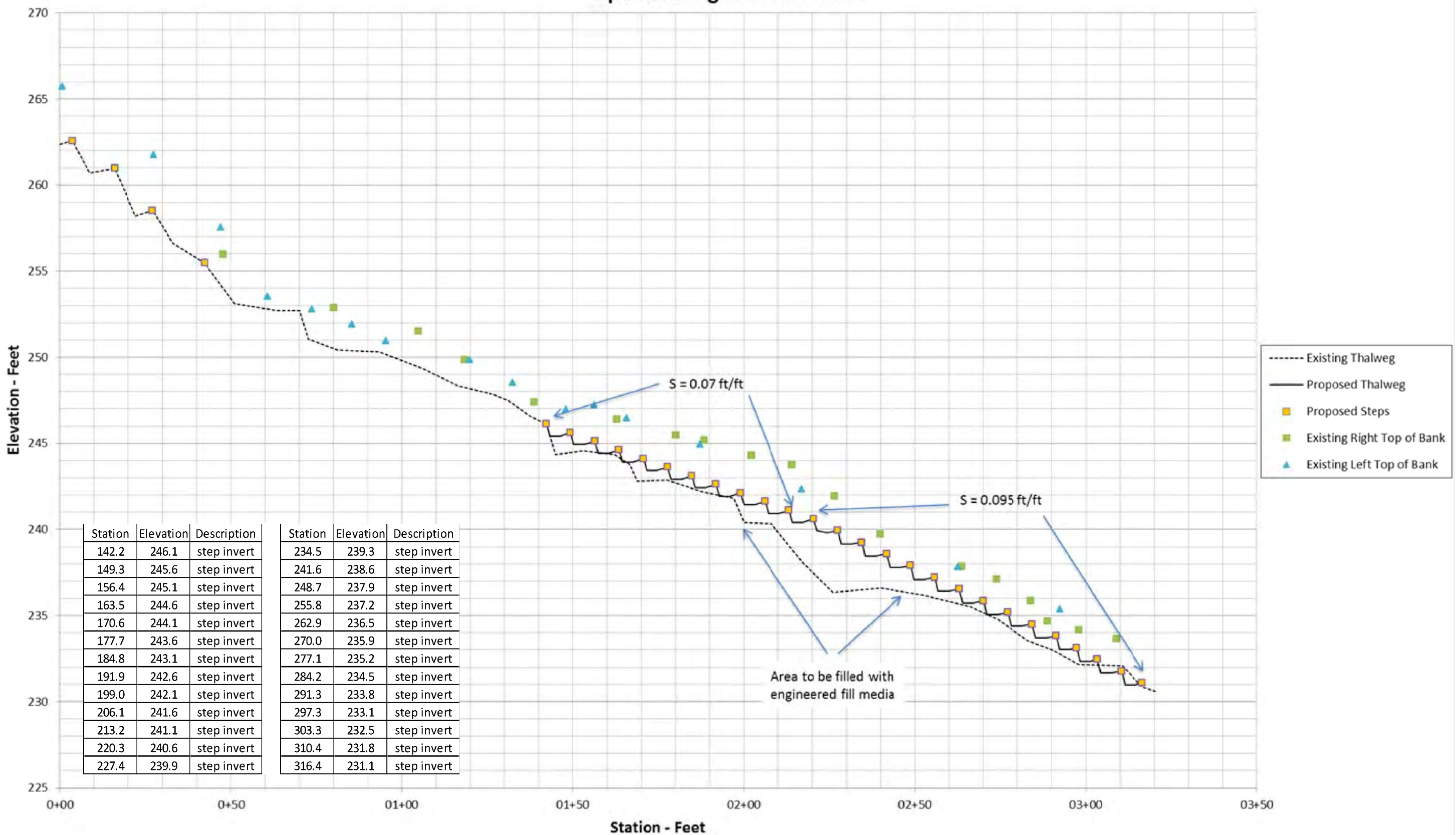
TRINITY COURT STREAM STABILIZATION
CHAPEL HILL, NC

DESIGN PLAN SHEET

DATE	1/16/12
PROJECT NO.	
FILENAME	FILE.DWG
SHEET NO.	3
DRAWING NO.	

Proposed Longitudinal Profile



Station	Elevation	Description
142.2	246.1	step invert
149.3	245.6	step invert
156.4	245.1	step invert
163.5	244.6	step invert
170.6	244.1	step invert
177.7	243.6	step invert
184.8	243.1	step invert
191.9	242.6	step invert
199.0	242.1	step invert
206.1	241.6	step invert
213.2	241.1	step invert
220.3	240.6	step invert
227.4	239.9	step invert

Station	Elevation	Description
234.5	239.3	step invert
241.6	238.6	step invert
248.7	237.9	step invert
255.8	237.2	step invert
262.9	236.5	step invert
270.0	235.9	step invert
277.1	235.2	step invert
284.2	234.5	step invert
291.3	233.8	step invert
297.3	233.1	step invert
303.3	232.5	step invert
310.4	231.8	step invert
316.4	231.1	step invert

NO	REVISIONS	DRN	CHK	DATE
1	INITIAL DESIGN	ZP	GJ	01/16/12

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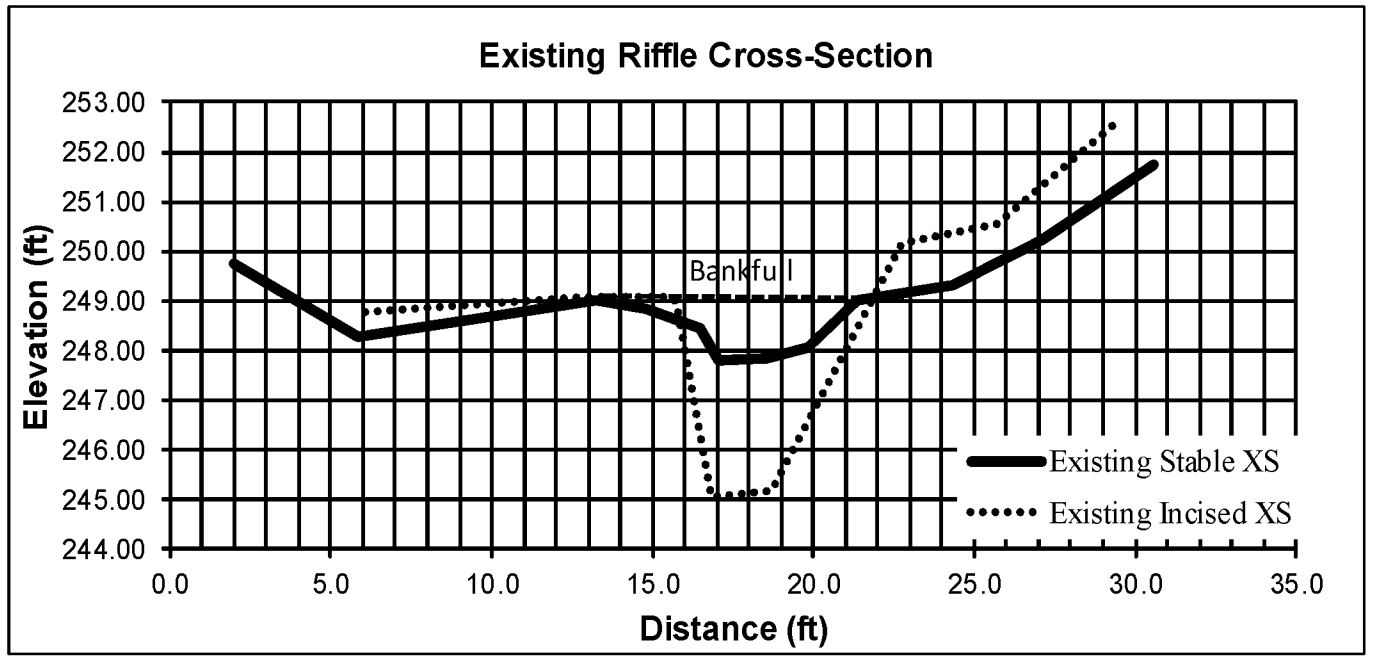
North Carolina State University
Raleigh, NC 27695

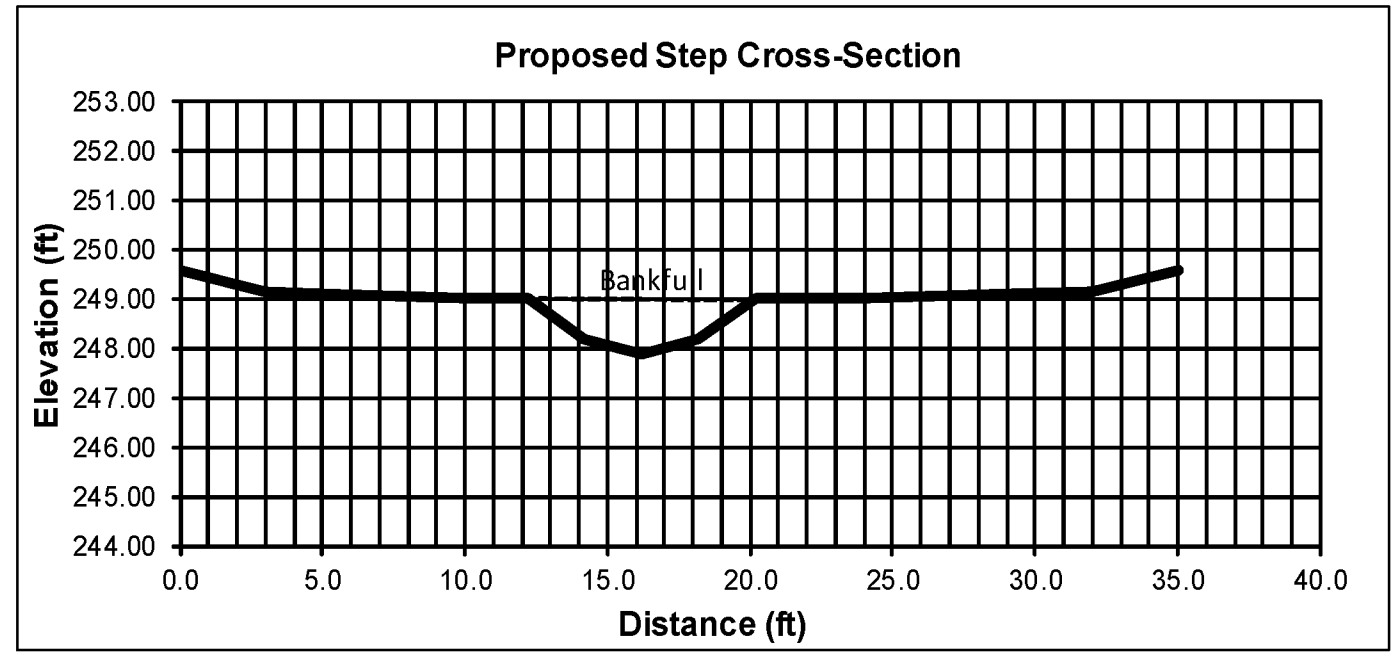
TRINITY COURT STREAM STABILIZATION
CHAPEL HILL, NC

DESIGN– PROFILE

DATE 1/16/12
PROJECT NO.
FILENAME FILE.DWG
SHEET NO. 4
DRAWING NO.

Trinity Court - Existing and Proposed Cross Section





Existing Condtions	Stable XS	Incised XS
Width flood-prone area, Wfpa (ft)	22	10.0
Bankfull Mannings n (estimate)	0.04	0.04
Average water surface slope, S (ft/ft)	0.089	0.089
Bankfull elevation (ft)	249	249
Riffle width, Wbkf (ft)	8.0	6.1
Entrenchment ratio, ER [Wfpa/Wbkf]	2.7	1.6
Riffle cross-section area, Abkf (sq ft)	5.0	15.4
Mean riffle depth, dbkf (ft)	0.6	2.5
Width-to-depth ratio, [Wbkf/dbkf]	12.9	2.4
Max riffle depth, dmbkf (ft)	1.2	4.0
Max riffle depth ratio, [dmbkf/dbkf]	1.9	1.6
Bankfull wetted perimeter, WP (ft)	9.3	11.1
Bankfull hydraulic radius, R (ft)	0.5	1.4
Mannings bankfull discharge, Qbkf (cfs)	36.9	211.5
Mannings bkf velocity, ubkf = Q/A (ft/s)	7.4	13.8
Bankfull shear stress, t (lb/ft2)	3.0	7.7

Proposed Condtions		
Width flood-prone area, Wfpa (ft)	35	(Flood prone width will vary depending on site conditions)
Bankfull Mannings n (estimate)	0.04	
Average water surface slope, S (ft/ft)	0.08	
Bankfull elevation (ft)	249	
Riffle width, Wbkf (ft)	8	
Entrenchment ratio, ER [Wfpa/Wbkf]	4.4	
Riffle cross-section area, Abkf (sq ft)	5.4	
Mean riffle depth, dbkf (ft)	0.7	
Width-to-depth ratio, [Wbkf/dbkf]	11.9	
Max riffle depth, dmbkf (ft)	1.1	
Max riffle depth ratio, [dmbkf/dbkf]	1.6	
Bankfull wetted perimeter, WP (ft)	9.4	
Bankfull hydraulic radius, R (ft)	0.6	
Mannings bankfull discharge, Qbkf (cfs)	39.4	
Mannings bkf velocity, ubkf = Q/A (ft/s)	7.3	
Bankfull shear stress, t (lb/ft2)	2.9	

Regional Curve Analysis

Site Drainage Area: 0.02 sq mi	XS Area (sq ft)	Discharge (cfs)	Bankfull Width (ft)	Mean Depth (ft)
NC Piedmont Urban	**4.7**	**26.1**	**6.7**	**0.7**
NC Piedmont Rural	1.6	5.7	3.5	0.5

Source: http://www.bae.ncsu.edu/programs/extension/wqg/srp/reg_curve_graph.html

Note: Existing regional curves do not have data points as low as 0.02 sq miles. This is an order of magnitude lower than the smallest drainage area on the published curves for the NC Piedmont. Therefore, it is not advised to use regional curve data for this site. A stable cross-section within the project reach was used to calculate the proposed cross-section dimensions.

NO	REVISIONS	DRN	CHK	DATE
1	INITIAL DESIGN	ZP	GJ	01/16/12

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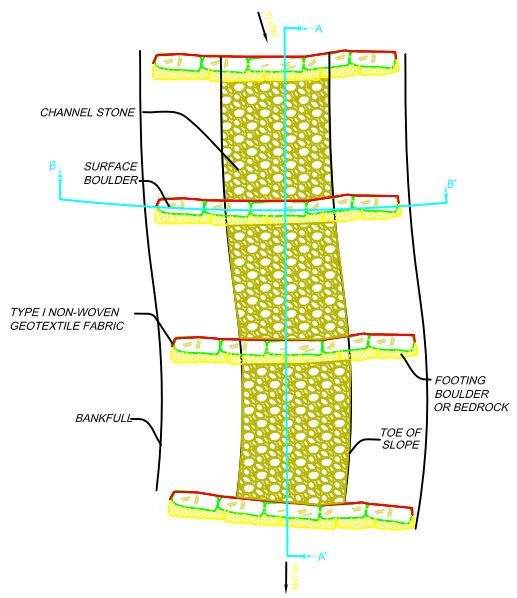
Raleigh, NC 27695

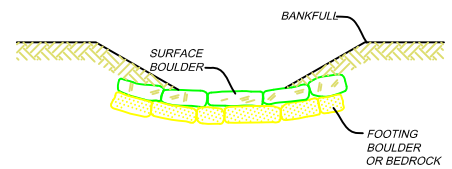
TRINITY COURT STREAM STABILIZATION
CHAPEL HILL, NC

DESIGN– CROSS SECTIONS

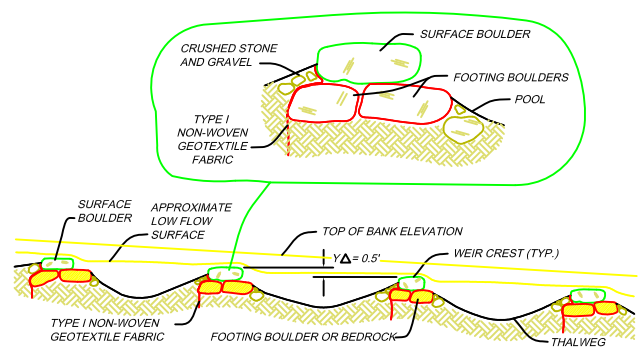
DATE 1/16/12
PROJECT NO.
FILENAME FILE.DWG
SHEET NO. 5
DRAWING NO.



STEP POOL PLAN VIEW



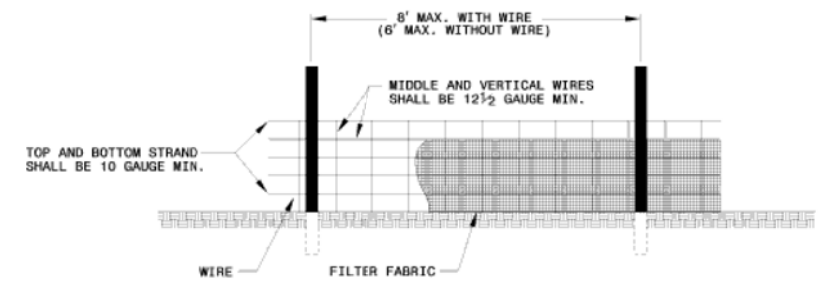
STEP POOL WEIR - SECTION B-B'
NOT TO SCALE



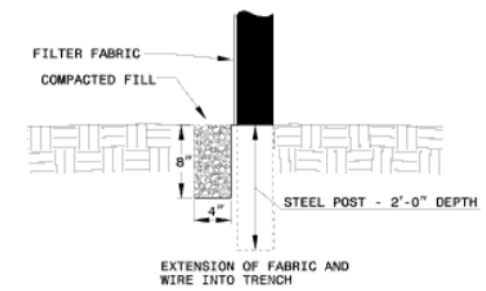
STEP POOL PROFILE - A-A'
NOT TO SCALE

STEP POOL CHANNEL
NTS

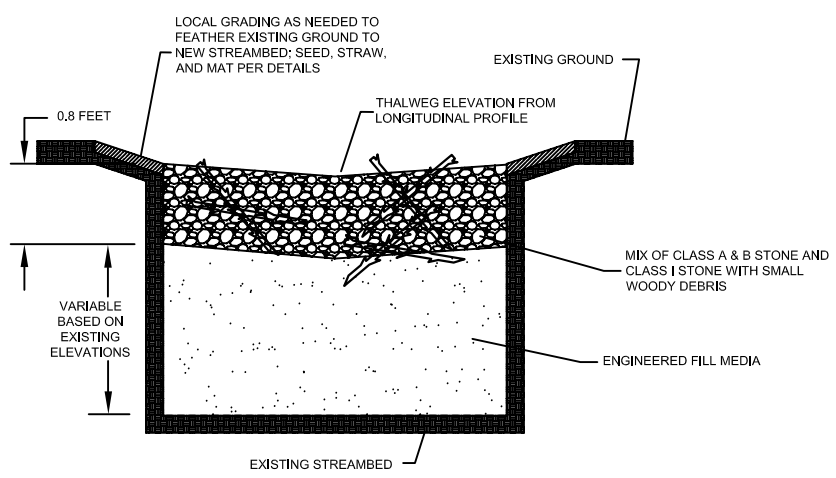
SILT FENCE DETAIL



NOTES
USE WIRE A MINIMUM OF 32" IN WIDTH AND WITH A MINIMUM OF 6 LINE WIRES WITH 12" STAY SPACING.
USE FILTER FABRIC A MINIMUM OF 36" IN WIDTH AND FASTEN ADEQUATELY TO THE WIRE AS DIRECTED BY THE ENGINEER.
PROVIDE 5'-0" STEEL POST OF THE SELF-FASTENER ANGLE STEEL TYPE. ANGLE STEEL TYPE.

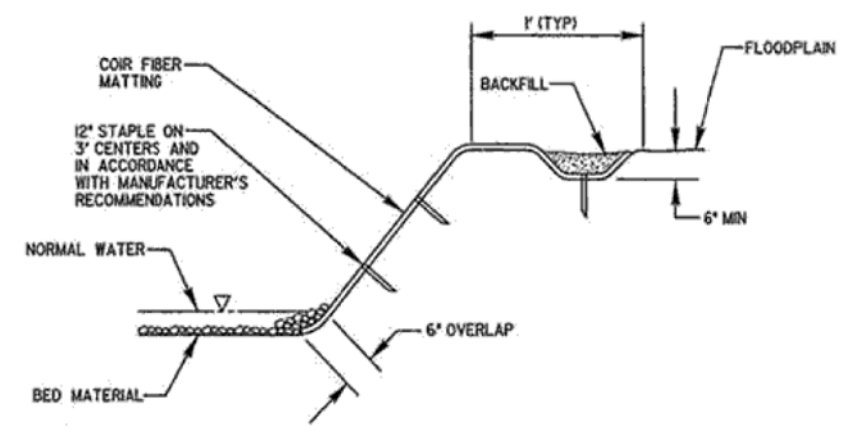


TYPICAL CROSS-SECTION TO RAISE CHANNEL BED



NOTES:
1. ENGINEERED FILL MEDIA SHALL CONSIST OF 80% SAND AND 20% FINE WOOD CHIPS, BY VOLUME..
2. SAND SHALL BE COARSE WASHED SAND, RIVER SAND, OR SIMILAR MATERIAL APPROVED BY ENGINEER.
3. SAND SHALL NOT ORIGINATE FROM A LOCATION LIKELY TO RESULT IN CONTAMINATION BY EXCESS NUTRIENTS, PETROLEUM PRODUCTS, OR OTHER CHEMICALS. SOIL TESTING AND/OR DOCUMENTATION OF ORIGINATION MAY BE REQUESTED AT THE DISCRETION OF THE ENGINEER.
4. MATERIAL AND SIZE OF FINE WOOD CHIPS TO BE APPROVED BY ENGINEER PRIOR TO PLACEMENT, AND MAY INCLUDE PINE BARK FINES.
5. FILL MEDIA SHALL BE WELL-MIXED PRIOR TO PLACEMENT IN STREAM.
6. SMALL WOODY DEBRIS SHALL BE DERIVED FROM ONSITE MATERIAL WITH DIAMETER <4".
8. SMALL WOODY DEBRIS SHALL NOT PROTRUDE ABOVE FINISHED STREAMBED BY >6".
9. NATIVE ON SITE BED MATERIAL CAN BE USED IF APPROVED BY ENGINEER PRIOR TO PLACEMENT
10. ALL DISTURBED STREAMBANKS SHALL BE REGRADED TO A 2:1 SLOPE OR FLATTER, UNLESS SUCH GRADING WOULD ADVERSELY AFFECT EXISTING STREAMSIDE VEGETATION.
11. SEE PROPOSED CROSS SECTION SHEET FOR CROSS SECTION DIMENSIONS.

MATTING DETAIL



COIR FIBER MATTING SECTION
NOT TO SCALE

NOTES:
1. All exposed stream banks shall be matted from toe of slope to top of bank.
2. Banks shall be matted the same day as final graded.
3. Wood stakes shall be used in place of wire staples.
4. 2-foot oak stakes shall be used at the toe and upstream edge of matting.
5. Use medium weight (700g/m^2) woven coir matting
6. No plastic netting shall be used on this project.

1	INITIAL DESIGN	ZP	GJ	01/16/12
NO	REVISIONS	DRN	CHK	DATE

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TRINITY COURT STREAM STABILIZATION
CHAPEL HILL, NC

DETAIL SHEET 1

DATE	1/16/12
PROJECT NO.	
FILENAME	FILE.DWG
SHEET NO.	6
DRAWING NO.	

SEEDING AND MULCHING NOTES

NOTES:
1. ALL DISTURBED AREAS SHALL BE SEEDED AND MULCHED AS PER NCDENR DLR LAND QUALITY REQUIREMENTS.
2. ALL DISTURBED AREAS SHALL BE PLANTED OR OTHERWISE PROVIDE PERMANENT GROUND COVER SUFFICIENT TO RESTRAIN EROSION WITH 15 WORKING DAYS OR 60 CALENDAR DAYS, WHICHEVER PERIOD IS SHORTER, FOLLOWING COMPLETION OF CONSTRUCTION.
3. ALL DISTURBED AREAS SHALL BE STABILIZED WITH VEGETATION OR OTHERWISE PROVIDED WITH GROUND COVER SUFFICIENT TO RESTRAIN EROSION WITHIN 21 CALENDAR DAYS OF COMPLETION OF ANY PHASE OF GRADING.
4. MULCH SHOULD BE APPLIED AT THE RATE OF 1 to 2 TONS PER ACRE AND TACKED WITH HYDRAULICALLY APPLIED MULCH WHEN INSTALLED.
5. TEMPORARY AND PERMANENT SEED SHALL BE APPLIED TOGETHER.
6. IRRIGATION MAY BE REQUIRED AT THE DESCRETION OF THE ENGINEER.
7. THE CONTRACTOR IS RESPONSIBLE TO FOLLOWING ALL RULES OF THE NCDENR DLR LAND QUALITY SECTION AS OUTLINED IN THE EROSION AND SEDIMENT CONTROL PLANNING AND DESIGN MANUAL.
8. ALL EROSION CONTROL DEVICES SHALL BE INSPECTED AT THE BEGINNING AND END OF EACH WORK DAY. THE CONTRACTOR AND DESIGNER SHALL CONDUCT THE INSPECTION JOINTLY.

TEMPORARY AND PERMANENT SEEDING SPECIFICATION

NON RIPARIAN AREAS

TEMPORARY AND PERMANENT SEED MIX

Rye Grain (Dec-Feb)	60 lbs/ ac
Red Clover *Trifolium pratense*	10 lbs / acre
Creeping Red Fescue *Festuca rubra*	20 lbs / acre

SOURCE: NC DIVISION OF WILDLIFE RESOURCES: SEED MIXES FOR REVEGETATING DISTURBED SITES

RIPARIAN AREAS

TEMPORARY SEED MIX

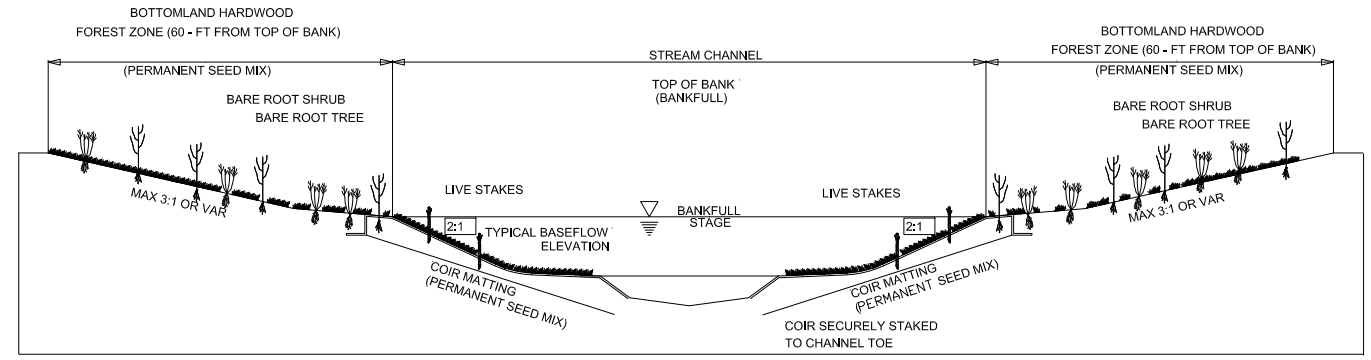
Rye Grain	30lbs/ acre
Wheet	30 lbs / acre

RIPARIAN AREAS
PERMANENT SEED MIX

AT LEAST 4 SPECIES FROM THE LIST BELOW, INCLUDING ONE SPECIES FROM EACH TYPE (WARM SEASON, COOL SEASON, WETLAND) AT A RATE OF 12-15 LBS/ACRE

Common Name	Type
Switchgrass	Warm Season
Indiangrass	Warm Season
Deertongue	Warm Season
Big Bluestem	Warm Season
Little Bluestem	Warm Season
Sweet Woodreed	Warm Season
Indian Woodoats	Cold Season
Viriginia Wildrye	Cold Season
Eastern Bottle-Brush Grass	Cold Season
Soft Rush	Wetland
Shallow Sedge	Wetland
Fox Sedge	Wetland

RIPARIAN VEGETATION ZONE DETAIL (OUTSIDE OF THE OWASA EASEMENT)
SCALE: NTS



BOTTOMLAND FOREST ZONE PLANTING
Plant Spacing: 8 ft
Bare Root Species List:

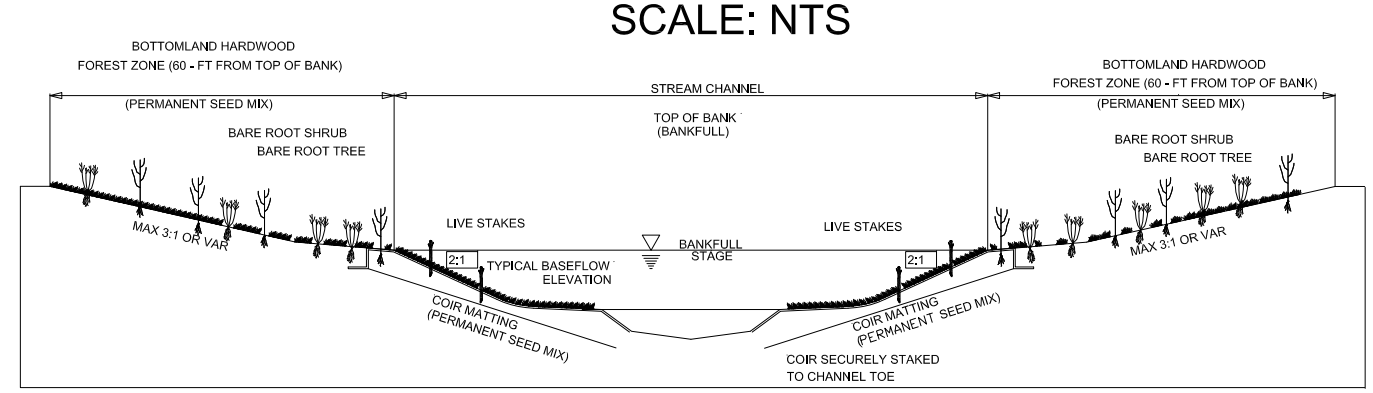
Cornus amomum (silky dogwood)
Physocarpus opulifolius (ninebark)
Sambucus Canadensis (American elderberry)
Hamamelis virginiana (witchhazel)
Lindera benzoin (spicebush)
Fraxinus pennsylvanica (green ash)
Betula nigra (river birch)
Aesculus sylvatica (painted buckeye) - transplants from on site

STREAM CHANNEL BANK ZONE PLANTING
Plant Spacing: 3 ft

Polystichum acrostichoides (christmas fern)

Live Stake Species List (potential for winter 2012/2013):
Cornus amomum (silky dogwood)
Physocarpus opulifolius (ninebark)

RIPARIAN VEGETATION ZONE DETAIL (WITHIN THE OF THE OWASA EASEMENT)
SCALE: NTS



NOTE: No trees or shrubs shall be planted within the main travel-way of the easement (approx 15-ft wide over the sewer main), only planted/replanted to the limit of where trees/shrubs are currently growing.

BOTTOMLAND FOREST ZONE PLANTING
Plant Spacing: 8 ft
Bare Root Species List:

Cornus amomum (silky dogwood)
Physocarpus opulifolius (ninebark)
Sambucus Canadensis (American elderberry)
Hamamelis virginiana (witchhazel)
Lindera benzoin (spicebush)
Aesculus sylvatica (painted buckeye) - transplants from on site

STREAM CHANNEL BANK ZONE PLANTING
Plant Spacing: 3 ft

Polystichum acrostichoides (christmas fern)

NO	REVISIONS	DRN	CHK	DATE
1	INITIAL DESIGN	ZP	GJ	01/16/12

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TRINITY COURT STREAM STABILIZATION
CHAPEL HILL, NC

DETAIL SHEET 2

DATE 1/16/12
PROJECT NO.
FILENAME FILE.DWG
SHEET NO. 7
DRAWING NO.

The stream at Trinity Court, showing the steep, eroded banks

More bank erosion, and one of three old bridges that were removed

A series of step-pools was installed

Close up of the large blocks arranged for the “step” in the step-pool structure

The area behind each step-pool is filled in with sand and wood chips over fabric, covered by heavier gravel and rocks

Looking down the 10% grade after the rocks are laid

Coir matting is laid for erosion control, the OWASA easement has new gravel to protect it from heavy foot and vehicle traffic, and flags are set out for plants

Further downstream after the ferns are planted

One of 100 Christmas ferns planted for bank erosion control

The bottom end of the reach near the confluence with Bolin Creek

A step-pool after grass has started growing

One of the witch-hazels planted along the stream

Bolin Creek Watershed Restoration Project
Trinity Court—Chapel Hill's Umstead Park

▲ (Before) **SEVERE CHANNEL EROSION** created large cuts in the streambed and bank, which would only get worse without stabilization. Sediment washed into Bolin Creek.

Location: South side of Chapel Hill's Umstead Park, between Trinity Court Public Housing and Bolin Creek

Project Description: Federal and State grant funding paid for restoration design, construction, materials, and plants in the 300' project to repair and stabilize an intermittent tributary to Bolin Creek.

Partner: NC State University Stream Restoration Program

Date of Completion: April 2012

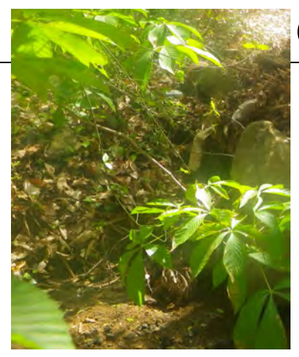
▲(After) **BANK RESHAPING AND STABILIZATION** angles the banks to allow floodwater to flow out of the channel and spread out, reducing water's destructive energy during high flows. This prevents further erosion of the banks. This bank has been reshaped, covered with fiber matting, and planted with shrubs and ferns.

▲ A finished "step" with "pools" above and below.

(After) **ROCK STEP-POOLS** absorb the energy of high flows and reduce erosion on the streambed and banks. Step-pools are comprised of large rock "steps" with small rock and gravel "pools" between them. Above are shown two of several steps installed along the stream's length. ►

▼In addition, the sewer easement was graded to drain more runoff into the floodplain area on its other side. A wider gravel path allows easy access for both the utility and park visitors.

NATIVE SHRUBS AND FERNS were planted to stabilize the streambank along the OWASA easement. To prevent sewage line leaks and breaks, OWASA prohibits trees and large shrubs to grow in their easements. This project used smaller shrubs and ferns to create a shallow network of roots to help stabilize stream banks and prevent erosion. Existing buckeye trees were rescued during construction and transplanted.



TRASH CLEANUPS beautified the area and prevented litter and household garbage from entering Bolin Creek. Anti-litter education will continue.

APPENDIX 5: MITCHELL LANE BIORETENTION PROJECT MATERIALS

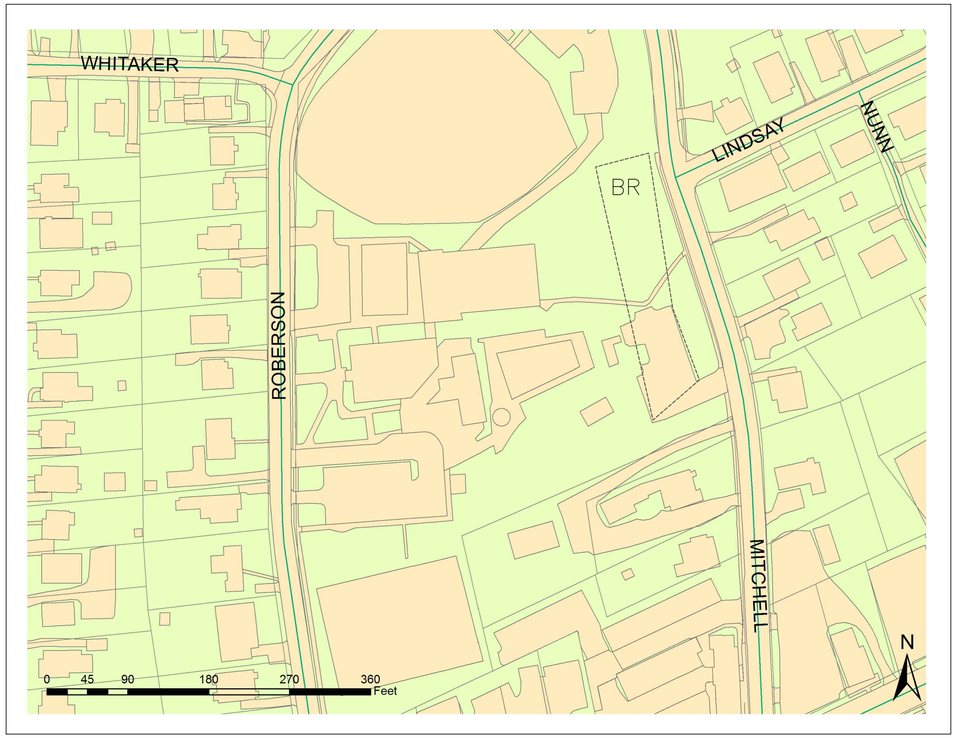
HARGRAVES COMMUNITY CENTER BIORETENTION RETROFIT

216 NORTH ROBERSON STREET
CHAPEL HILL, NORTH CAROLINA 27514
ORANGE COUNTY
CAPE FEAR RIVER BASIN

SCO NUMBER - _____

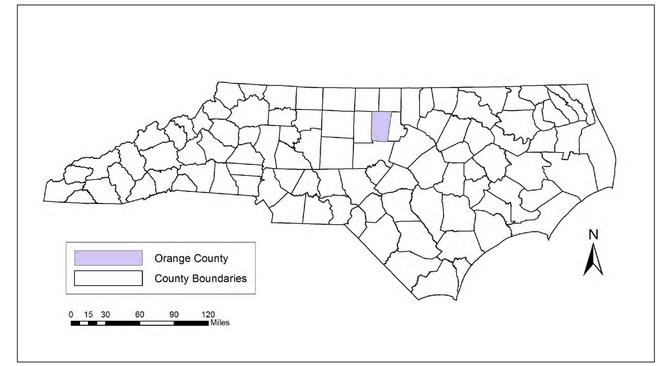
PREPARED FOR:
THE TOWN OF CHAPEL HILL
STORMWATER MANAGEMENT DIVISION
208 N. COLUMBIA STREET
CHAPEL HILL, NC 27514

PREPARED BY:
ANDREW R. ANDERSON, E.I.
North Carolina State University
Department of Biological and Agricultural Engineering
3100 FAUCETTE DR.
RALEIGH, NC 27695



VICINITY MAP

35.912617 deg lat
-79.063219 deg lon



BIORETENTION RETROFIT SITE - Mitchell Lane

TOWN OF CHAPEL HILL CONTACT:
PATRICIA D'ARCONTE - Project Manager
919-969-7202

NCSU CONTACTS:
ANDREW ANDERSON - DESIGN/CONSTRUCTION
919-515-8595

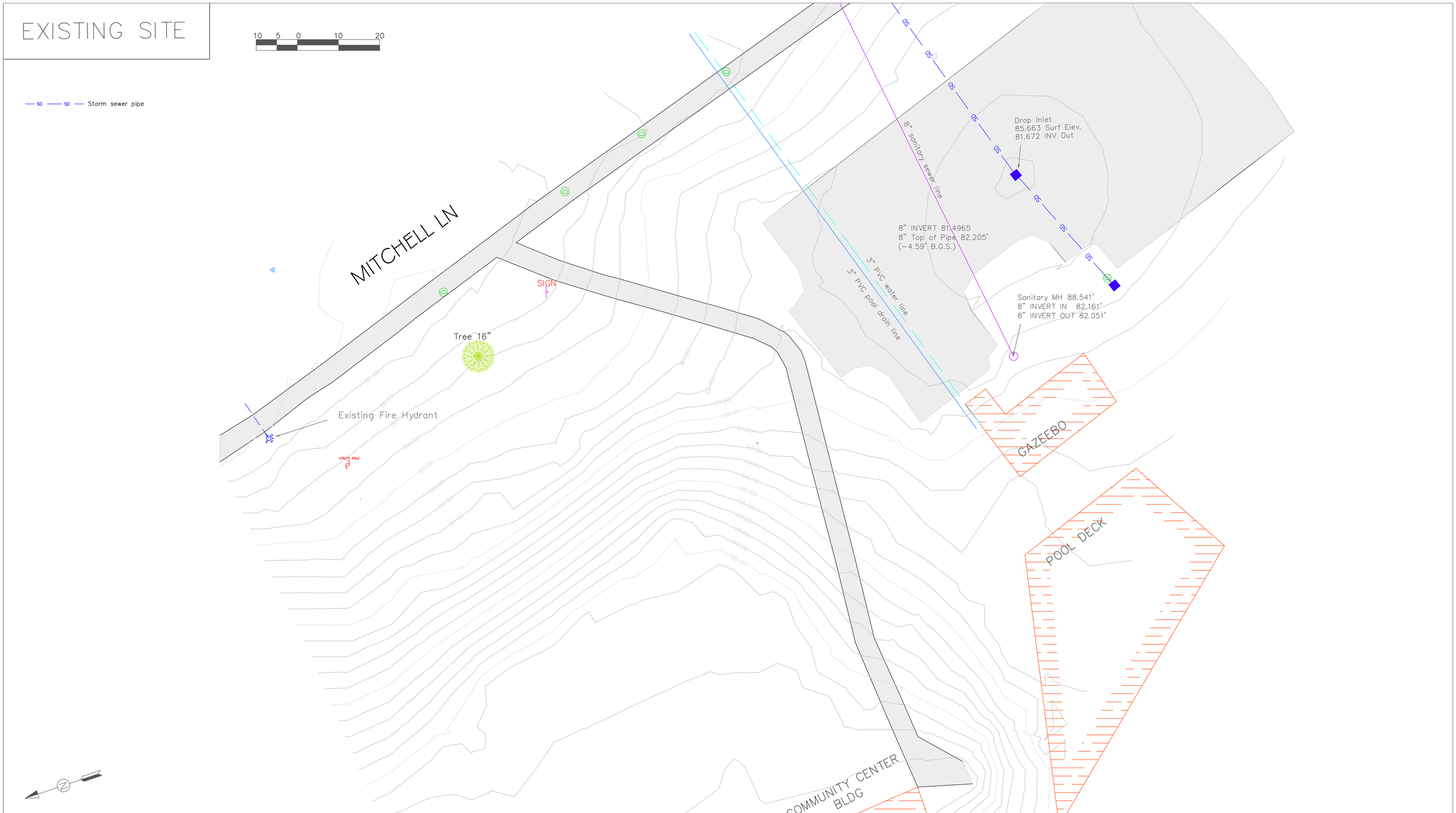
BILL HUNT - DESIGN
919-515-6751

INDEX OF SHEETS

1 COVER
2 EXISTING SITE
3 DRAINAGE AREA
4 PROPOSED PLAN
5 BIORETENTION DETAILS AND PROFILE
6 DETAILS

DATE PREPARED: 5-31-2012

EXISTING SITE



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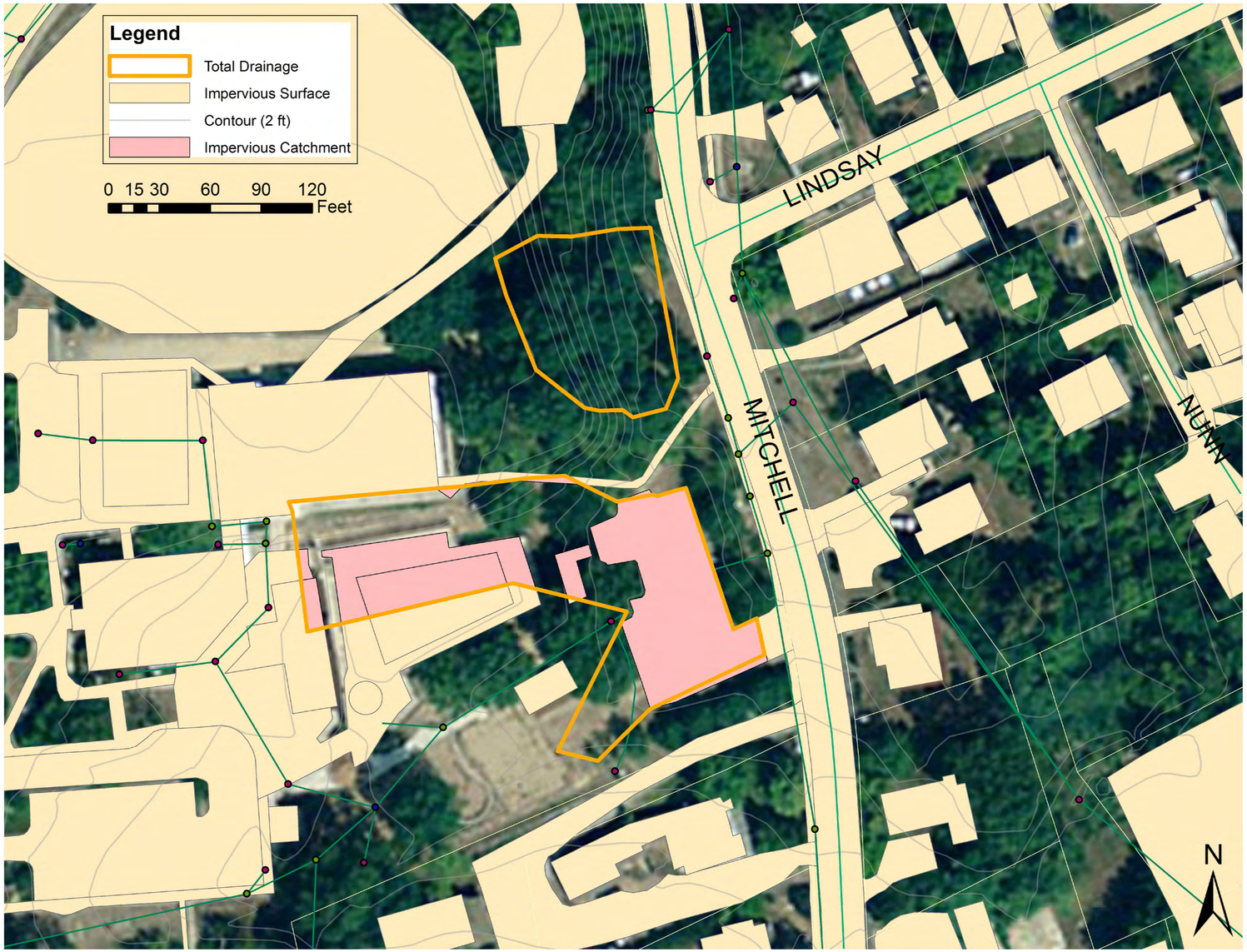
EXISTING SITE CONDITIONS

Designed By: ARA
Reviewed By: RJW, WFH

Date:
MAY 31, 2012

Scale
1" = 10 ft

Hargraves Community Center Bioretention Retrofit
216 N. Roberson St.
Chapel Hill, NC 27514



STORMWATER RUNOFF CALCULATIONS

Area (acre)	Area by Land Type (ac)			Design Storm (in.)	Runoff Vol (cu ft)
	CN = 69 ("Open", HSG B)	CN =79 ("Open", HSG C)	CN = 98 ("Paved", HSG D)		
0.98	0.0	0.65	0.33	1.0	1143

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DRAINAGE AREAS

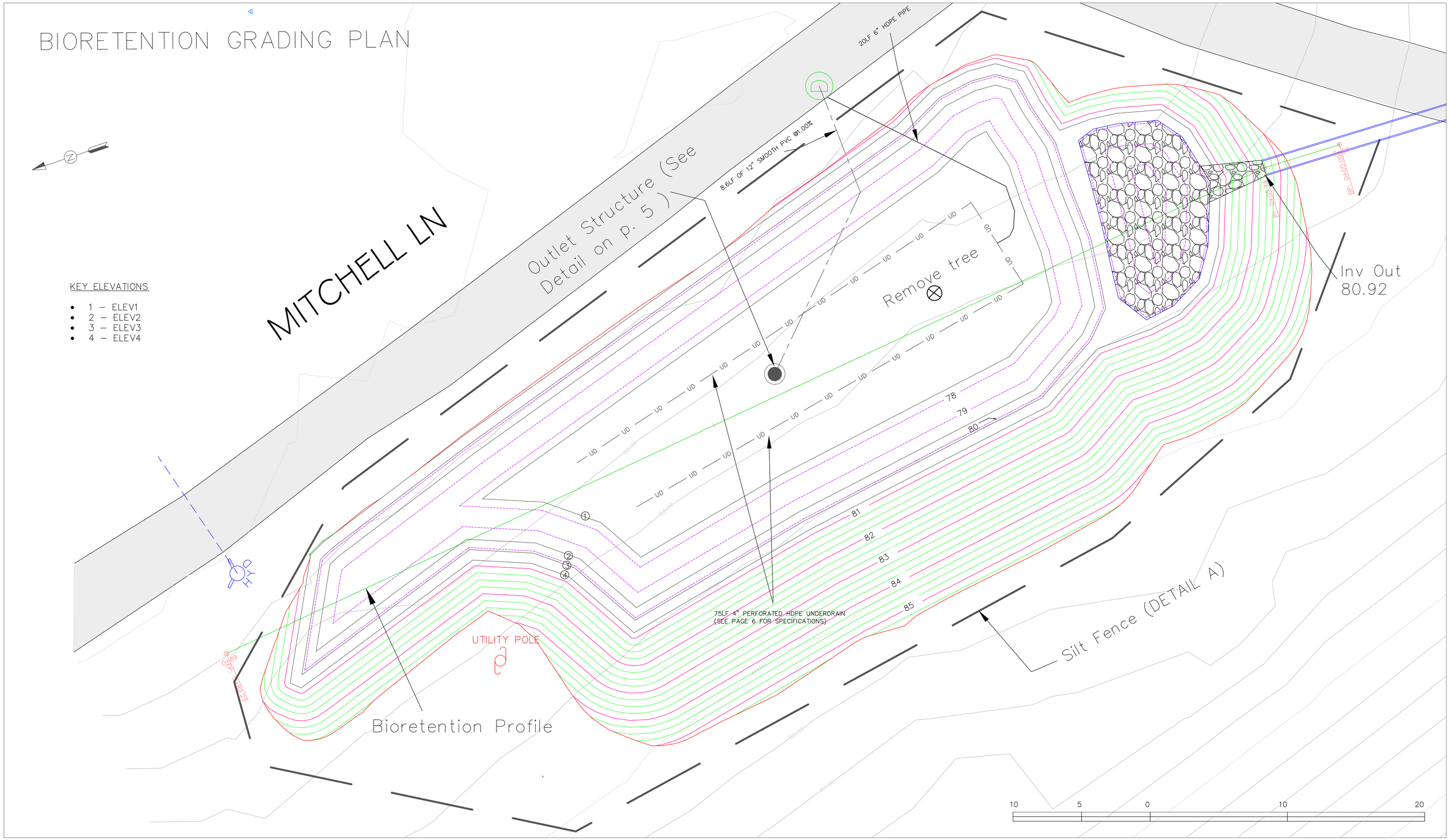
Designed By: ARA
Reviewed By: RJW, WFH

Date:
MAY 31, 2012

Scale:
As Noted

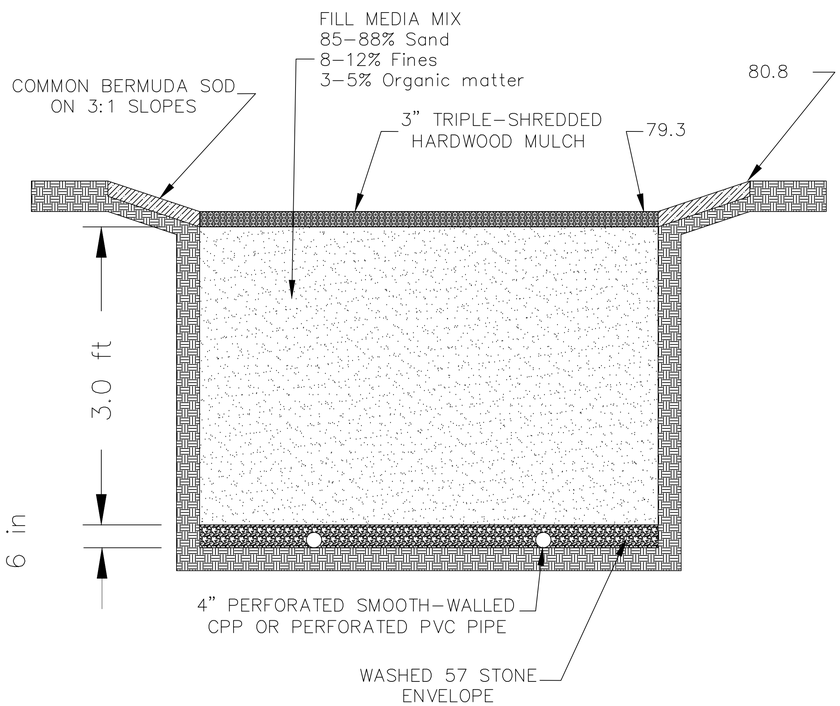
Hargraves Community Center Bioretention Retrofit
216 North Roberson St.
Chapel Hill, NC 27514

BIORETENTION GRADING PLAN

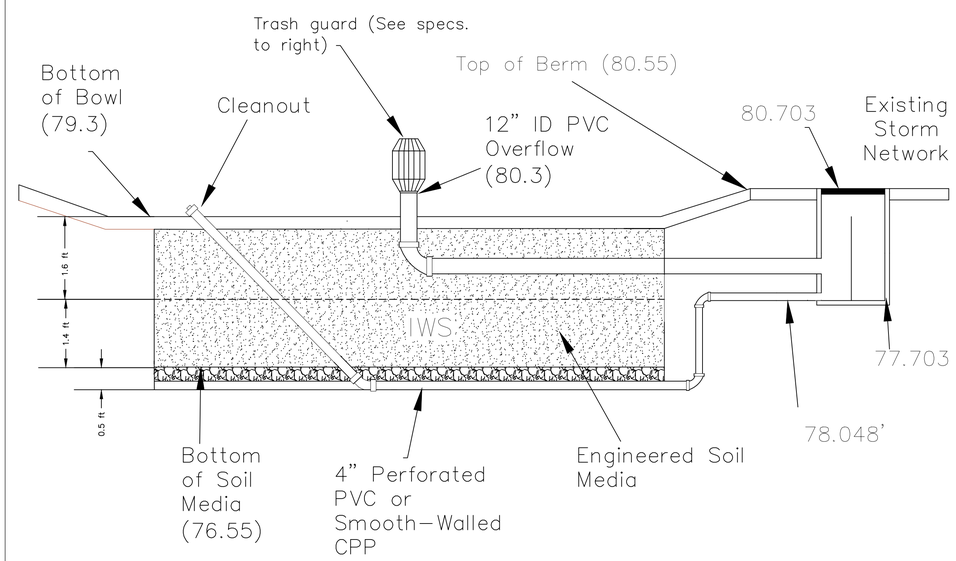


North Carolina State University Biological and Agricultural Engineering NCSU Box 7625 | Raleigh, N.C. 27695	PROPOSED CONSTRUCTION Designed By: ARA Reviewed By: RJW, WFH	Date: MAY 31, 2012	**Scale** 1" = 3 ft	Hargraves Community Center Bioretention Retrofit 216 N. Roberson St. Chapel Hill, NC 27514	Page Number 4 of 6

Bioretention Cross Section



Underdrain and Outlet Structure Detail



BIORETENTION FILL MEDIA SPECIFICATIONS

- 85–88% SAND
- 8–12% FINES (CLAY AND SILT)
- 3–5% ORGANIC MATTER
- P–INDEX FROM 10–30

THE SOIL MIX SHALL BE UNIFORM AND FREE OF STONES, STUMPS, ROOTS, OR OTHER AGGREGATE MATERIALS GREATER THAN 2 INCHES DIAMETER.

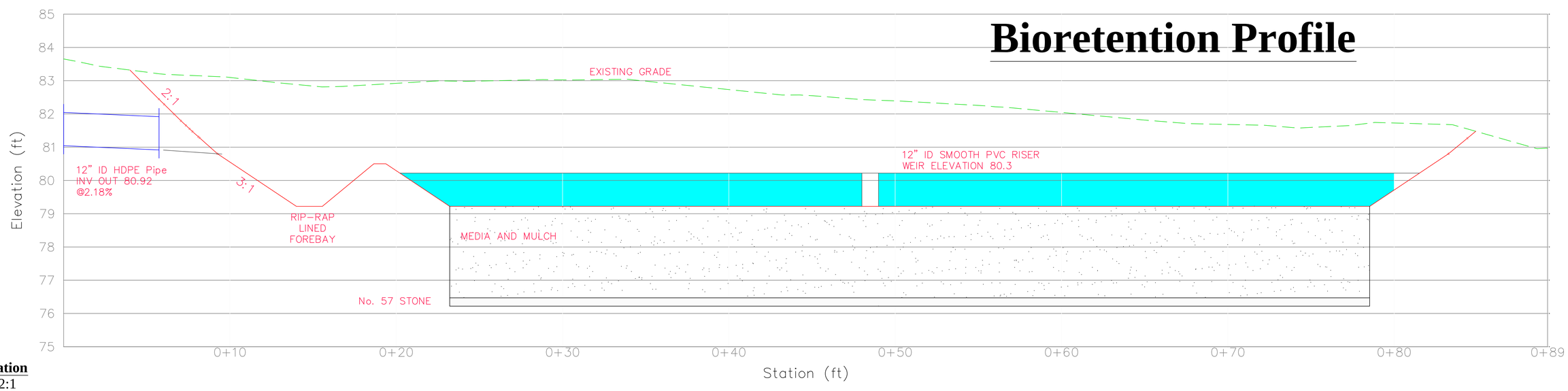
PROOF THAT THESE REQUIREMENTS HAVE BEEN MET MUST BE DOCUMENTED AND APPROVED BY PROJECT ENGINEER

OVERFLOW STRUCTURE SPECIFICATIONS

A 12" Bar Guard from Pond Dam Piping, Ltd. shall be used as a trash rack on the 12" PVC overflow pipe.

The invert of the 12" PVC overflow pipe shall be installed at 80.3' (1' above the mulch surface layer of the bioretention cell)

Bioretention Profile



Exaggeration
H:V = 2:1

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BIORETENTION DETAILS

Designed By: ARA
Reviewed By: RJW, WFH

Date: MAY 31, 2012

Scale: As Noted

Hargraves Community Center Bioretention Retrofit
216 N. Roberson St.
Chapel Hill, NC 27514

Underdrain Installation and Specifications

ALL UNDERDRAINS USED MUST BE CORRUGATED HDPE WITH A SMOOTH INNER WALL. THE DRAINS MUST BE INSTALLED AT THE SHOWN LOCATIONS AND GRADES. SOLID PIPE MUST BE USED IN THE SEGMENTS LEAVING THE BIORETENTION CELL. UNDERDRAIN PIPES SHOWN ARE 4 INCHES. AFTER THE TWO PARALLEL UNDERDRAIN LINES MEET, A TEE SHALL JOIN THEM, WITH A 6 INCH SOLID PIPE LEAVING TO TIE INTO THE JUNCTION BOX. SEWER CLEANOUTS MUST BE INSTLALED 45 DEGREE ANGLES AT THE UPSTREAM END OF EACH DRAIN (ONE PER UNDERDRAIN LINE, TOTALLING 2).

Planting Specifications

THREE TO SIX INCHES OF TOPSOIL MUST BE APPLIED TO ALL SITE DISTURBED AREAS, EXCEPT OVER THE BIORETENTION FILL MEDIA. DO NOT PLACE TOPSOIL OVER THE BIORETENTION FILL MEDIA.

Construction Sequencing

1. THE DRAINAGE AREA TO THE BASIN MUST BE STABILIZED BEFORE CONSTRUCTION BEGINS IN ORDER TO PREVENT CLOGGING OF THE BIORETENTION MEDIA.

2. INSTALL SEDIMENT FENCE AROUND AREA OUTLINED ON PROPOSED PLAN. INSTALL SEDIMENT FENCE ACCORDING TO DETAIL A. ALL SEDIMENT FENCE MUST BE INSTALLED BEFORE BEGINNING WORK. ALL SEDIMENT FENCE MUST BE INSTALLED WHEN WORK IS NOT TAKING PLACE.

3. THE CONTRACTOR SHALL CALL THE "CALL BEFORE YOU DIG" TOLL FREE NUMBER TO ENSURE THAT ALL UTILITES ARE LOCATED AND MARKED. THE CONTRACTOR SHALL BE RESPONSIBLE FOR ALL DAMAGES INCURRED DURING CONSTRUCTION. THE CONTRACTOR SHALL NOTIFY THE ENGINEER IMMEDIATELY IF UNEXPECTED FEATURES ARE DISCOVERD THAT WOULD NECESSITATE MODIFICATION TO THE ILLUSTRATED DESIGN.

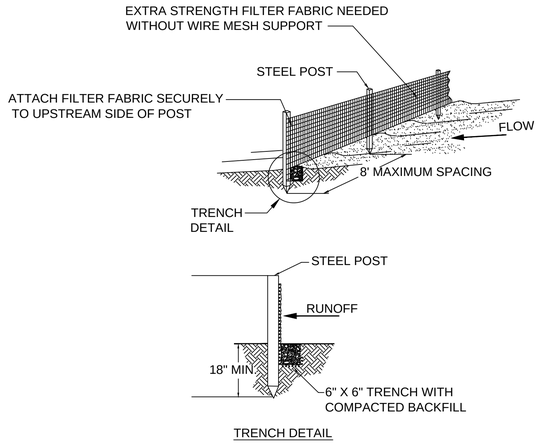
3. IT IS VERY IMPORTANT TO MINIMIZE COMPACTION OF IN-SITU SOIL AT THE BASE OF THE BIORETENTION CELL (BOTTOM OF THE EXCAVATION). USE EXCAVATION HOES TO REMOVE ORIGINAL SOIL. IF THE BIORETENTION AREAS ARE EXCAVATED USING A LOADER, THE CONTRACTOR SHOULD USE WIDE TRACK OR MARSH TRACK EQUIPMENT, OR LIGHT EQUIPMENT WITH TURF-TYPE TIRES. USE OF EQUIPMENT WITH NARROW TRACKS OR NARROW TIRES, RUBBER TIRES WITH LARGE LUGS, OR HIGH PRESSURE TIRES WILL CAUSE EXCESSIVE COMPACTION RESULTING IN REDUCED INFILTRATION RATES AND STORAGE VOLUMES, AND IS NOT ACCEPTABLE. COMPACTION WILL SIGNIFICANTLY CONTRIBUTE TO DESIGN FAILURE.

4. CONTRACTOR SHALL SCARIFY THE BOTTOM OF THE BIORETENTION EXCAVATION CUT WITH THE EXCAVATOR TEETH BEFORE THE ADDITION OF THE MEDIA.

3. ANY BIORETENTION FILL MEDIA INSTALLED MUST BE PROTECTED FROM FINE SEDIMENTS DURING CONSTRUCTION. AVOID COMPACTION BY ALLOWING TIME FOR NATURAL COMPACTION AND SETTLEMENT TO OCCUR. NO ADDITIONAL MANUAL COMPACTION OF SOIL IS NECESSARY. RAKE SOIL MATERIAL AS NEEDED TO LEVEL OUT. OVERFILL ABOVE PROPOSED SURFACE INVERT TO ACCOMMODATE NATURAL SETTLEMENT TO PROPER GRADE. DEPENDING UPON THE SOIL MATERIAL, UP TO 20% OF NATURAL COMPACTION MAY OCCUR.

Detail A

SEDIMENT FENCE DETAILS (N.T.S)



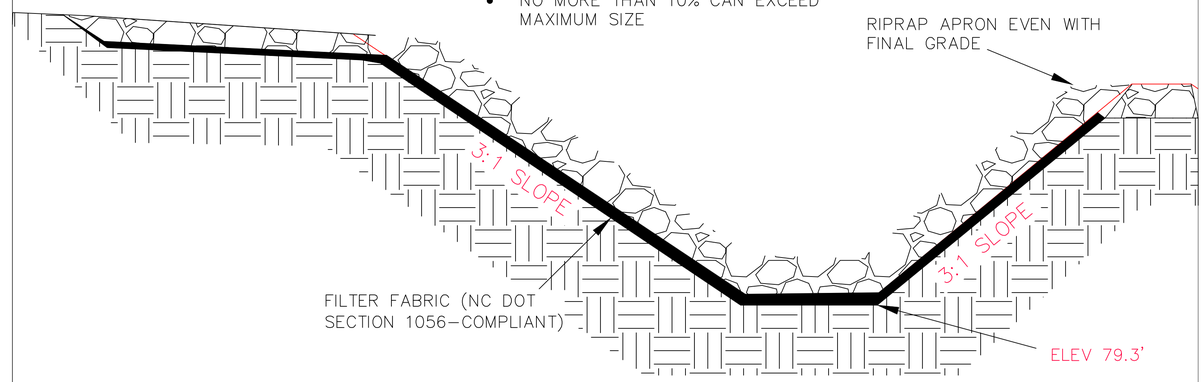
MAINTENANCE

INSPECT AND REPAIR FENCE EVERY 7 DAYS AND AFTER EACH STORM EVENT. REMOVE SEDIMENT WHEN NECESSARY, 6" MAXIMUM RECOMMENDED STORAGE HEIGHT.

Detail C

N.C. D.O.T. CLASS B RIPRAP SPECIFICATIONS

- MINIMUM 5" STONE DIAMETER
- D50 = 8"
- MAXIMUM 12" STONE DIAMETER
- NO MORE THAN 5% CAN BE LESS THAN MINIMUM SIZE
- NO MORE THAN 10% CAN EXCEED MAXIMUM SIZE



Detail B

CONSTRUCTION ENTRANCE (N.T.S)

I. CONSTRUCTION SPECIFICATIONS

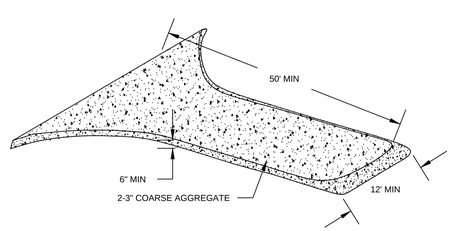
1. CLEAR THE AREA OF VEGETATION. REMOVE ALL ROOTS AND ORGANIC DEBRIS. GRADE ALONG THE INTENDED LENGTH OF THE ENTRANCE TO SMOOTH PROFILE. GRADE SUCH THAT WATER IS CARRIED TO DOWNSLOPE, BUT IS NOT CHANNELIZED.
2. PLACE THE GRAVEL TO THE DIMENSIONS AS SHOWN IN THE DETAIL.
* USE OF A GEOTEXTILE LAYER IS RECOMMENDED TO REDUCE MAINTENANCE AND IMPROVE THE PERFORMANCE OF THE ENTRANCE.

II. MAINTENANCE

1. PERIODIC TOP-DRESSING WITH TWO (2) INCH WASHED STONE MAY BE REQUIRED TO REDUCE THE TRANSPORT OF SEDIMENTS FROM THE CONSTRUCTION SITE.
2. AFTER EACH RAINFALL EVENT, INSPECT THE ROADWAY. IF STONE HAS BEEN DISPLACED OR A CHANNEL HAS BEEN FORMED, REPAIR IMMEDIATELY. DO NOT USE THE ENTRANCE FOR CONSTRUCTION TRAFFIC UNTIL THE ENTRANCE HAS BEEN REPAIRED.

III. REMOVAL

1. REMOVE THE CONSTRUCTION ENTRANCE AND SMOOTH THE DISTURBED AREA TO BLEND WITH THE SURROUNDING TOPOGRAPHY.



Forebay Installation Specifications

1. GRADE THE FOREBAY AS SHOWN ON THE PROPOSED SHEET

2. FILTER FABRIC CLOTH MUST BE PROPERLY PROTECTED FROM PUNCHING OR TEARING DURING INSTALLATION. REPAIR ANY DAMAGE BY REMOVING THE RIPRAP AND PLACING ANOTHER PIECE OF FILTER CLOTH OVER THE DAMAGED AREA. ALL OVERLAPPING SECTIONS SHOULD OVERLAP A MINIMUM OF 1 FOOT, WITH ANCHOR PINS SPACED EVERY 3 FEET ALONG OVERLAP. IF THE DAMAGE IS EXTENSIVE, REPLACE THE ENTIRE FILTER CLOTH.

3. GEOTEXTILE FABRIC MUST HAVE AN EOS NO LARGER THAN U.S. STANDARD SIEVE #70, A THICKNESS OF 20-60 MILS, A GRAB STRENGTH OF 90-120LB, AND MUST CONFORM TO ASTM D-1682 OR ASTM D-177.

4. SUBGRADE FOR GEOTEXTILE FABRIC SHOULD BE CLEARED AND GRUBBED TO REMOVE ALL ROOTS, VEGETATION, AND DEBRIS AND PREPARED TO THE LINES AND GRADES SHOWN ON THE PLAN.

5. EXCAVATE DEEP ENOUGH FOR BOTH FILTER AND RIPRAP.

6. ROCK AND/OR GRAVEL USED FOR RIPRAP SHALL CONFORM TO SPECIFIED GRADATION

7. VOIDS IN THE ROCK RIPRAP SHOULD BE FILLED WITH SPALLS AND SMALLER ROCKS.

North Carolina State University
Biological and Agricultural Engineering
NCSU Box 7625 | Raleigh, N.C. 27695

CITY OF CHAPEL HILL DETAILS

Designed By: ARA
Reviewed By: RJW, WFH

Date: MAY 31, 2012

Scale: Not Standard

Hargraves Community Center Bioretention Retrofit
216 N. Roberson St.
Chapel Hill, NC 27514

Along Mitchell Lane before construction

The parking lot, where we closed off the existing stormdrain and rerouted the runoff

Pre-construction view from the parking lot

The path for the pipe is laid out and underground utilities are measured to make sure we can clear them

The new stormdrain inlet is installed and a trench dug for the pipe to the bioretention

The parking lot was paved early so pool-users could park on the first day it opened

Excavation of the bioretention basin

Shaping the basin

Filling in the soil media

Laying the underdrains and the overflow drain

Filling in over the drains

Getting ready to put the mulch in

The forebay and stepp slope beside the bioretention basin

Ready for plants!

Planting day

Figuring out plant layout

Planting is done!

plants to add

(Ec) Eupatorium coelestinum (39)

(Ai) Asclepias incarnata (12)

(R) Rudbeckia fulgida (14)

Muhlenbergia capillaris (pink) (est 150) to fill in open areas of bioretention (1 to 1.5 ft apart) and to cover hillside

Already planted:

H Hamamelis virginiana (3)

J Juncus effusus

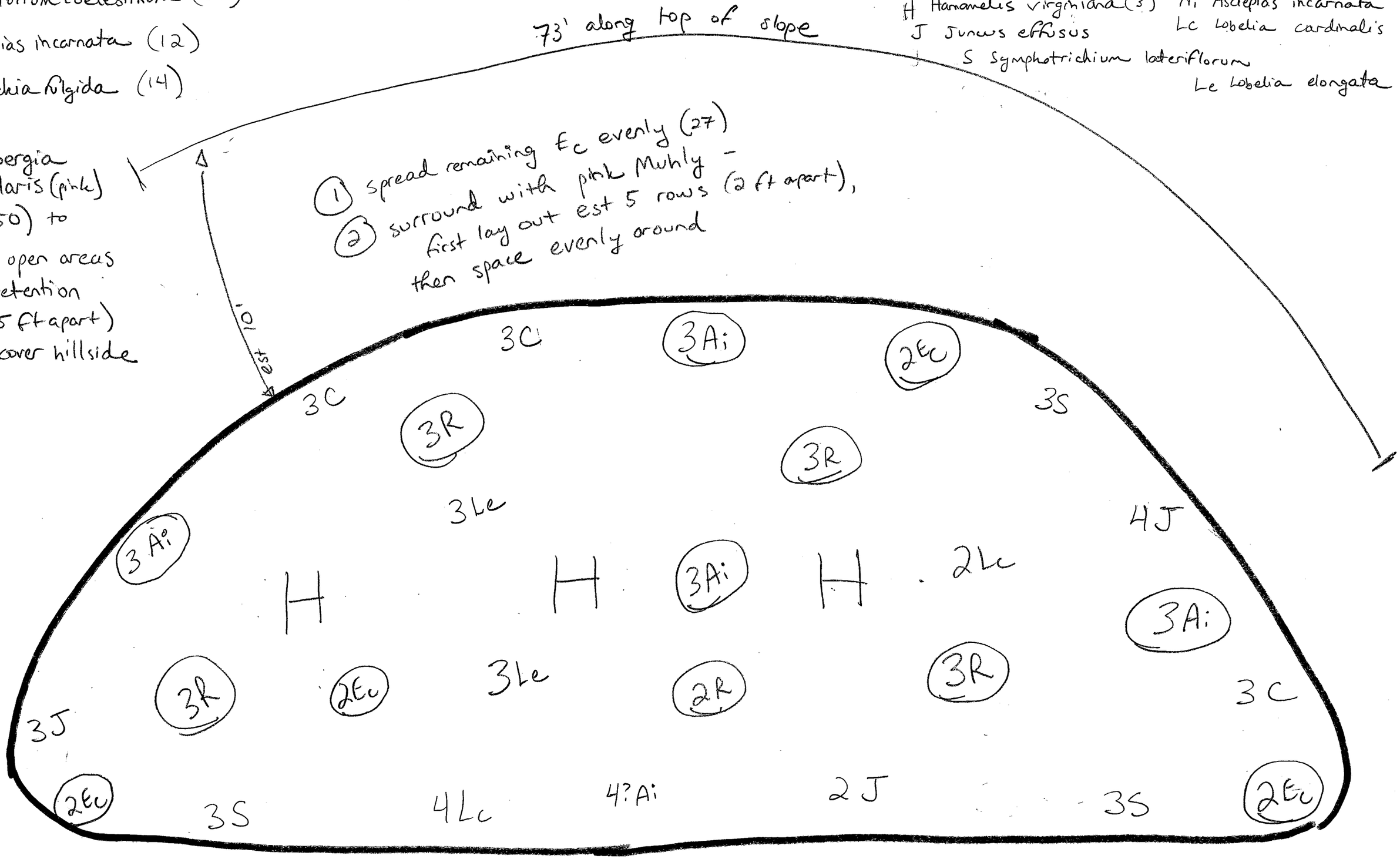
S Symphotrichium lateriflorum

C Chasmanthium latifolium

Ai Asclepias incarnata

Lc Lobelia cardinalis

Le Lobelia elongata

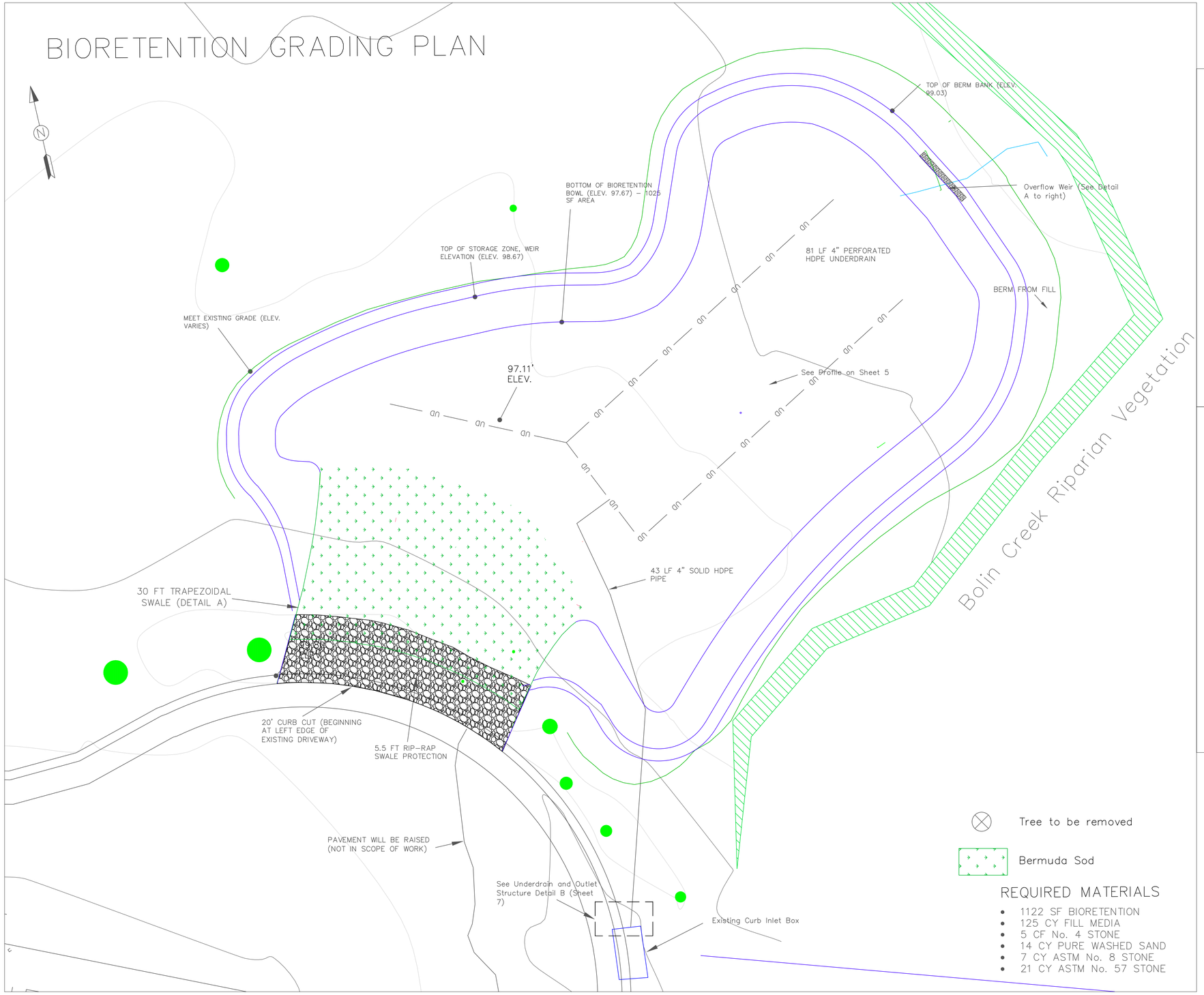


Project statistics on the Bolin Creek Chapel Hill EPA 319 Grant

Parameter	**Hargraves (Mitchell Ln.)**	**Dickerson Ct.**
Drainage area (acre)	0.98	0.55
BMP size (sf)	600	1195
WQ Storage depth (ft)	1.0	1.0
Media depth (ft)	3.0	3.0
IWS depth (ft)	1.4	2.0
Weir description	12” PVC stand pipe	Trapezoidal weir
Freeboard (ft)	0.25’	0.33’
TN load reduction (lb/yr)	1.88	4.42
TN post-BMP export (lb/yr)	3.48	8.19
TP load reduction (lb/yr)	0.25	0.60
TP post-BMP export (lb/yr)	0.31	0.74

APPENDIX 6: DICKERSON COURT BIORETENTION PROJECT MATERIALS

BIORETENTION GRADING PLAN

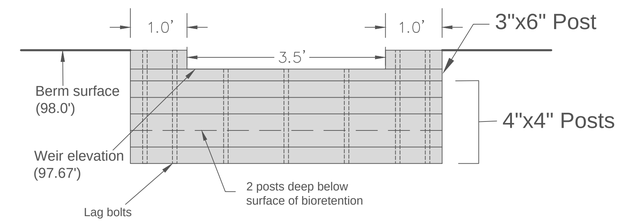


REQUIRED MATERIALS

- 1122 SF BIORETENTION
- 125 CY FILL MEDIA
- 5 CF No. 4 STONE
- 14 CY PURE WASHED SAND
- 7 CY ASTM No. 8 STONE
- 21 CY ASTM No. 57 STONE

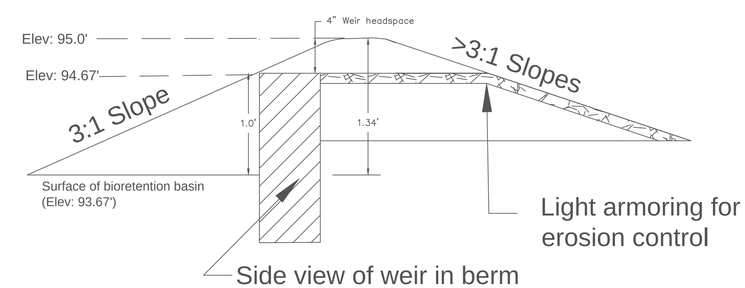
A. BIORETENTION OVERFLOW WEIR

VIEW PERPENDICULAR TO BERM AND FLOW PATH



Note: Screw 4x4 together with stainless steel screws

WEIR AND BERM SECTION VIEW



NOTES

1. The weir is constructed by stacking pressure treated lumber.
2. Weir structure shall be installed level on a 6" minimum compacted depth of coarse sand bedding. Backfill and grade adjacent areas.
3. Filter fabric shall be Mirafi 180N or equal.

North Carolina State University
Biological and Agricultural Engineering
NCSU Box 7625 | Raleigh, N.C. 27695

PROPOSED CONSTRUCTION

Designed By: ARA
Reviewed By: RJW, WFH

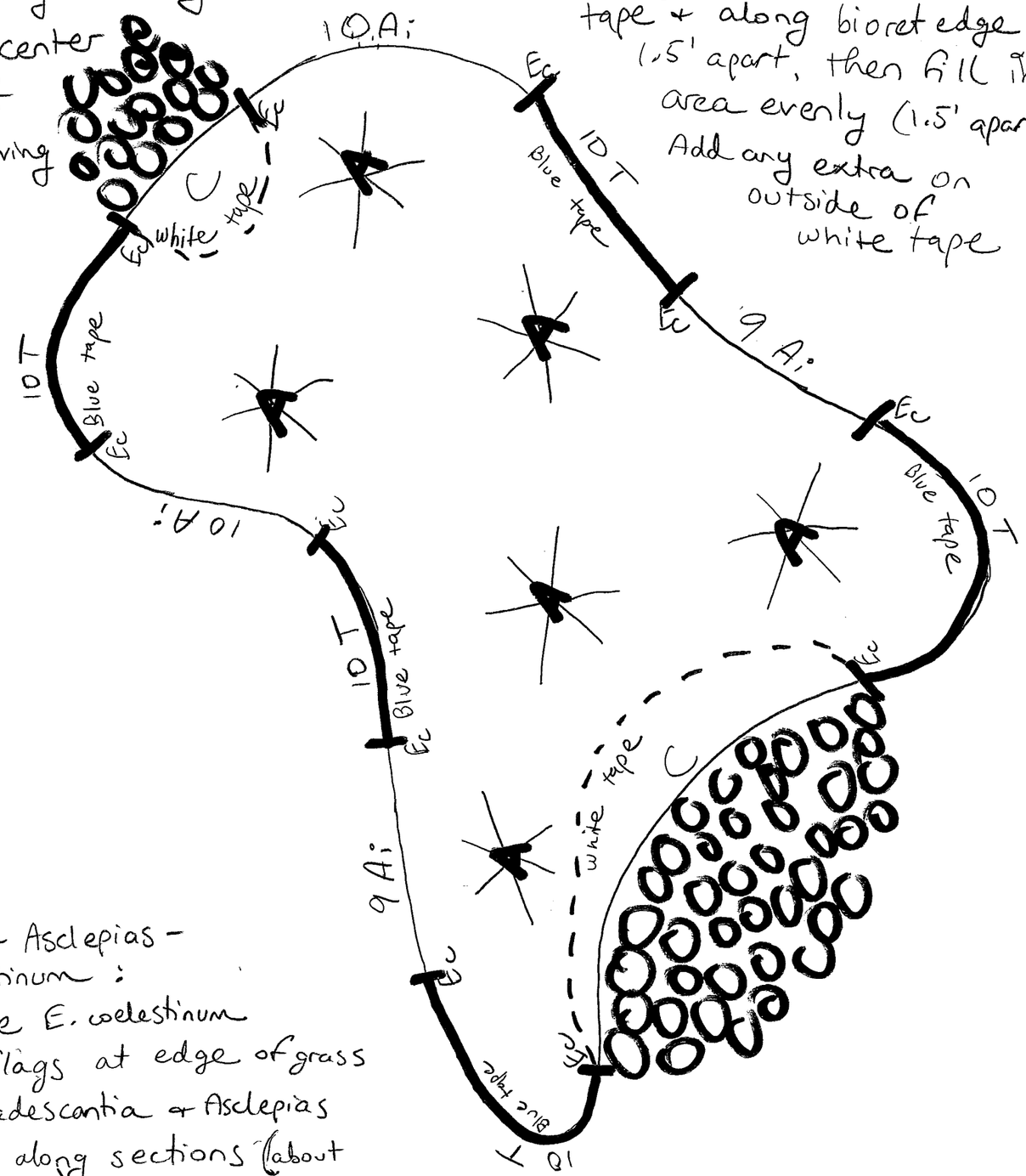
Date: JULY 11, 2012

Scale 1" = 4 ft

Dickerson Court Bioretention Retrofit
Dickerson Ct.
Chapel Hill, NC 27514

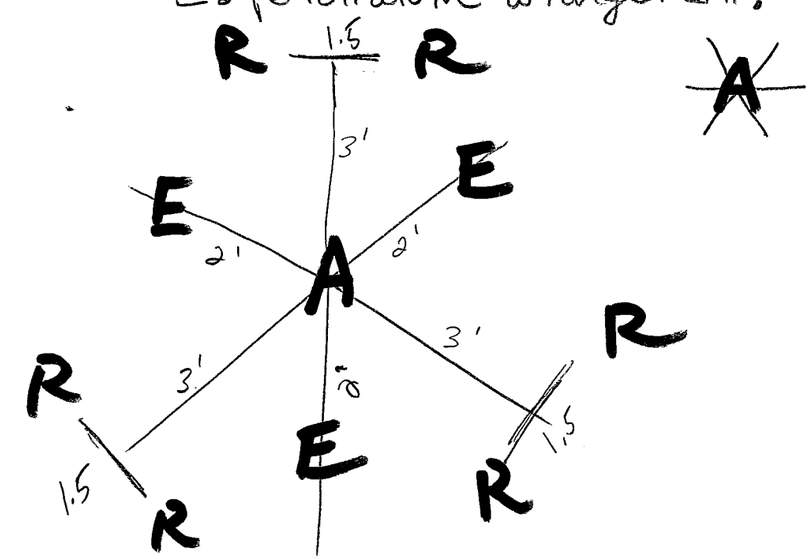
Fill in with pink muhly starting at the center 1 to 1.5 feet apart + moving outwards

Chasmanthium - start by laying out just inside white tape + along bioret edge 1.5' apart, then fill in area evenly (1.5' apart) Add any extra on outside of white tape



"A;" Asclepias incarnata (38)
"T" Tradescantia ohioensis (50)
"R" Rudbeckia fulgida (36)
"C" Chasmanthium latifolium (50)
"A" Andropogon gerardii (6)
"E" Eupatorium perfoliatum (18)
"Ec" Eupatorium coelestinum (11)
Muhlenbergia capillaris (pink) (est. 50)

Andropogon - Rudbeckia - E. perfoliatum arrangement:



Tradescantia - Asclepias - E. coelestinum:

① plant single E. coelestinum first at 11 flags at edge of grass

② space Tradescantia + Asclepias out evenly along sections (about every 1 to 1.5 ft) at edge of grass

Tradescantia along blue tape, Asclepias at other sections

The end of Dickerson Court before construction

Starting to excavate the bioretention basin

The basin is completely excavated

The shape of the basin

Laying the underdrains

Filling in with soil media

Ready for planting

Flags and tape are laid out to help the gardeners plant

The planting is finished

The driveway apron is cut flush and riprap laid at the entrance to the basin

Project statistics on the Bolin Creek Chapel Hill EPA 319 Grant

Parameter	**Hargraves (Mitchell Ln.)**	**Dickerson Ct.**
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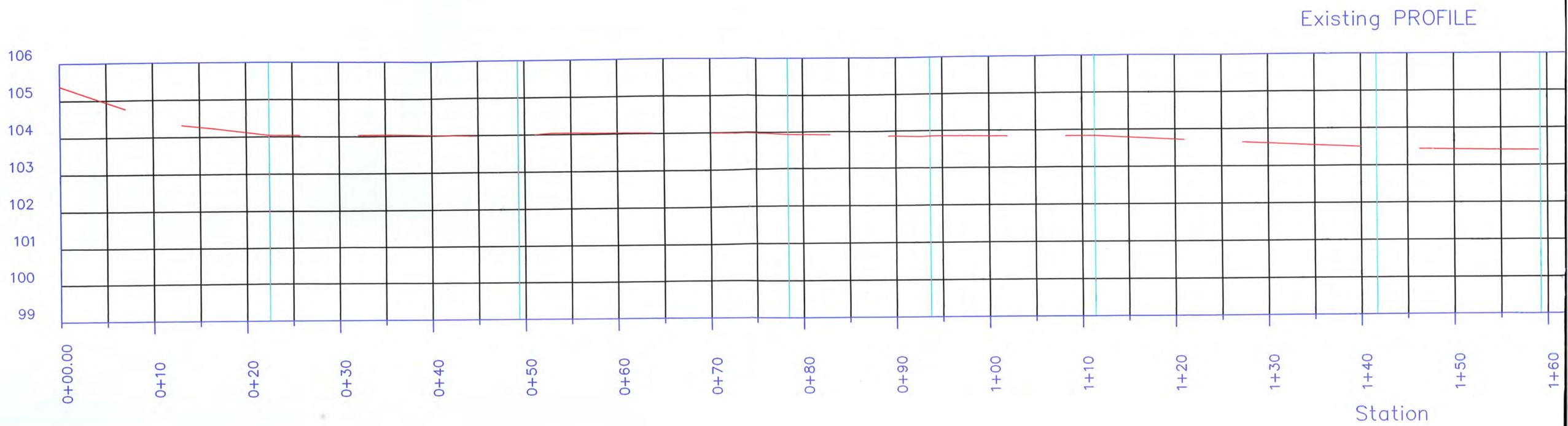
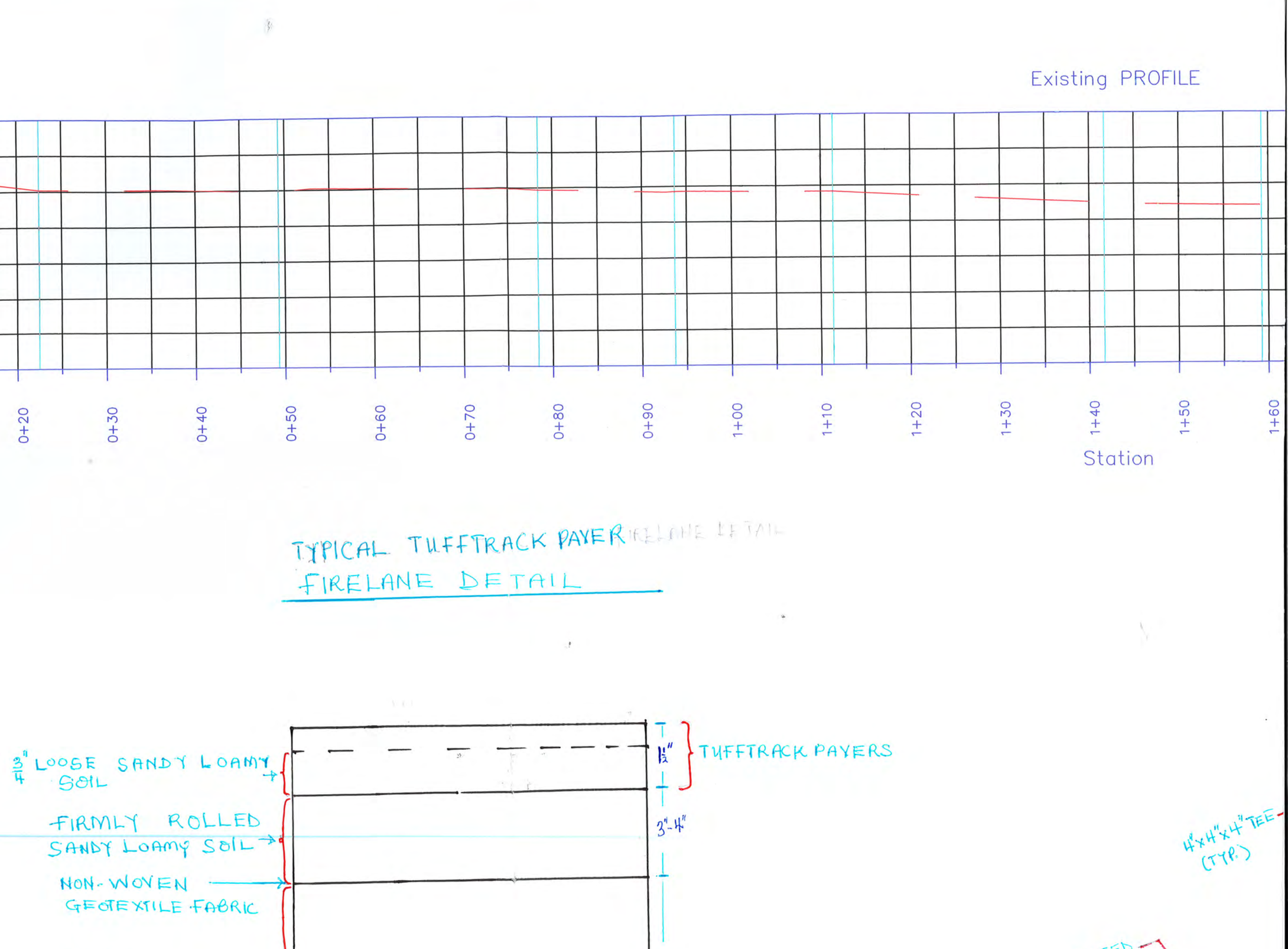
APPENDIX 7: HARGRAVES FIRE LANE PROJECT MATERIALS

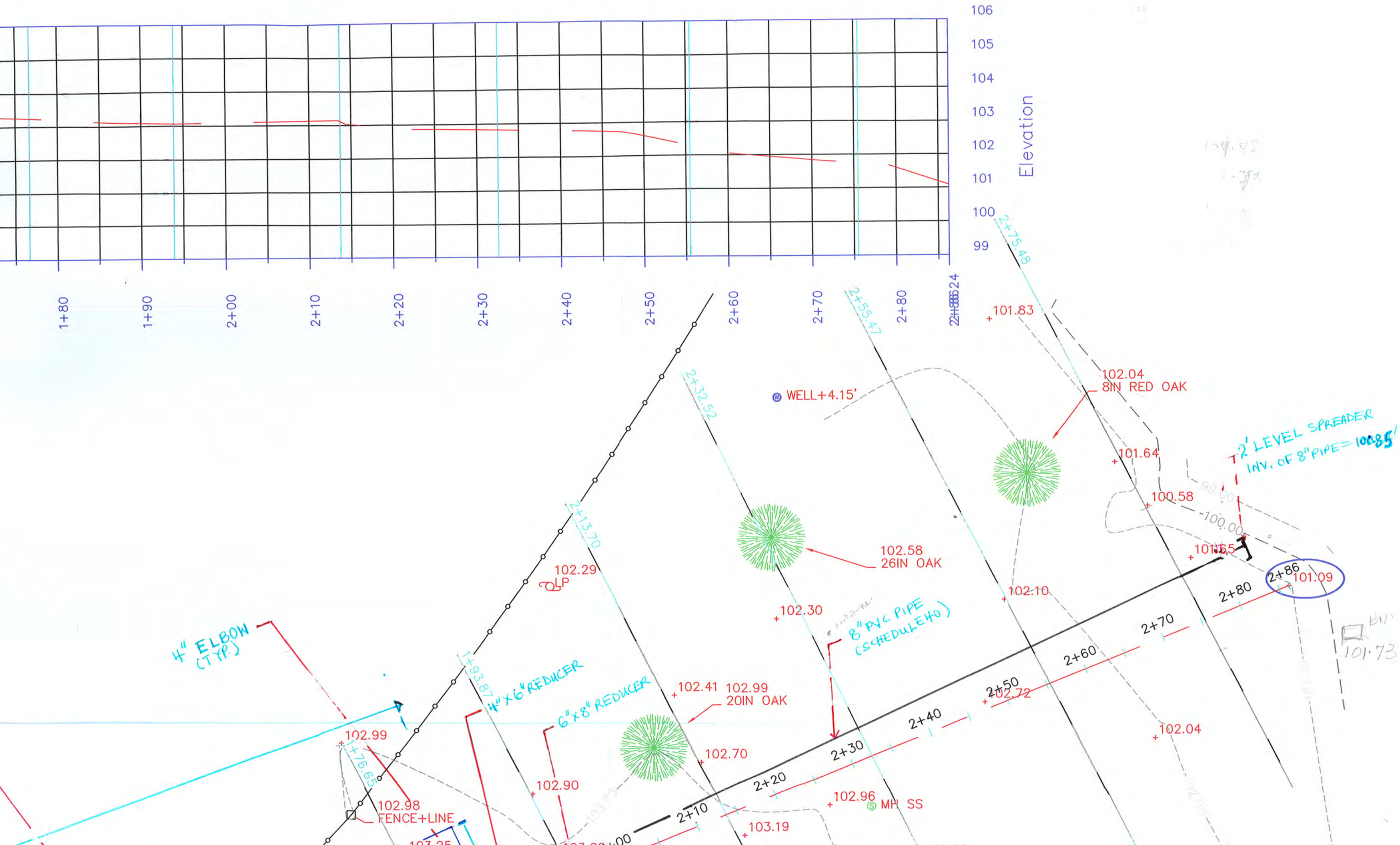


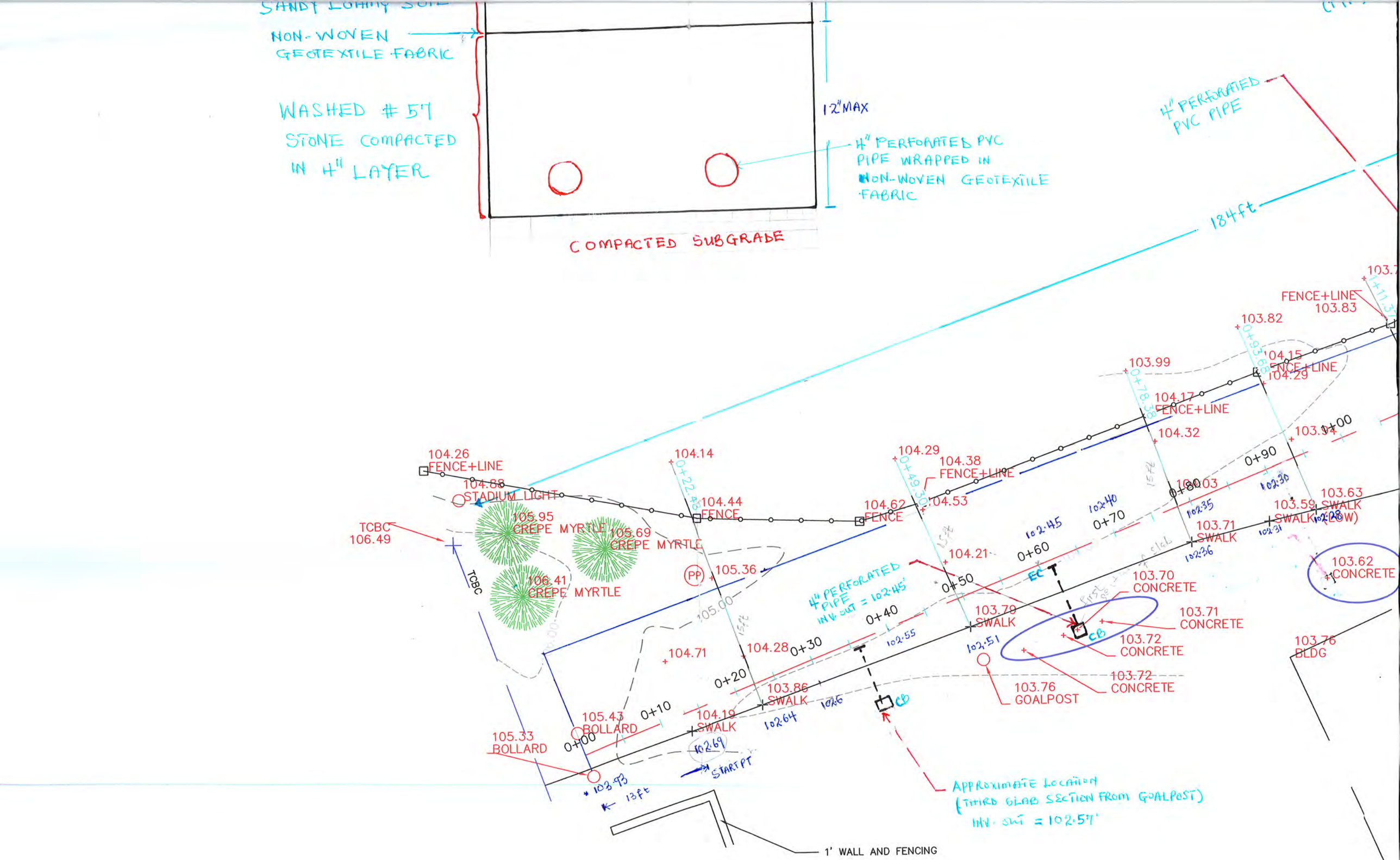
TYPICAL TUFFTRACK PAVER FIRELANE DETAIL

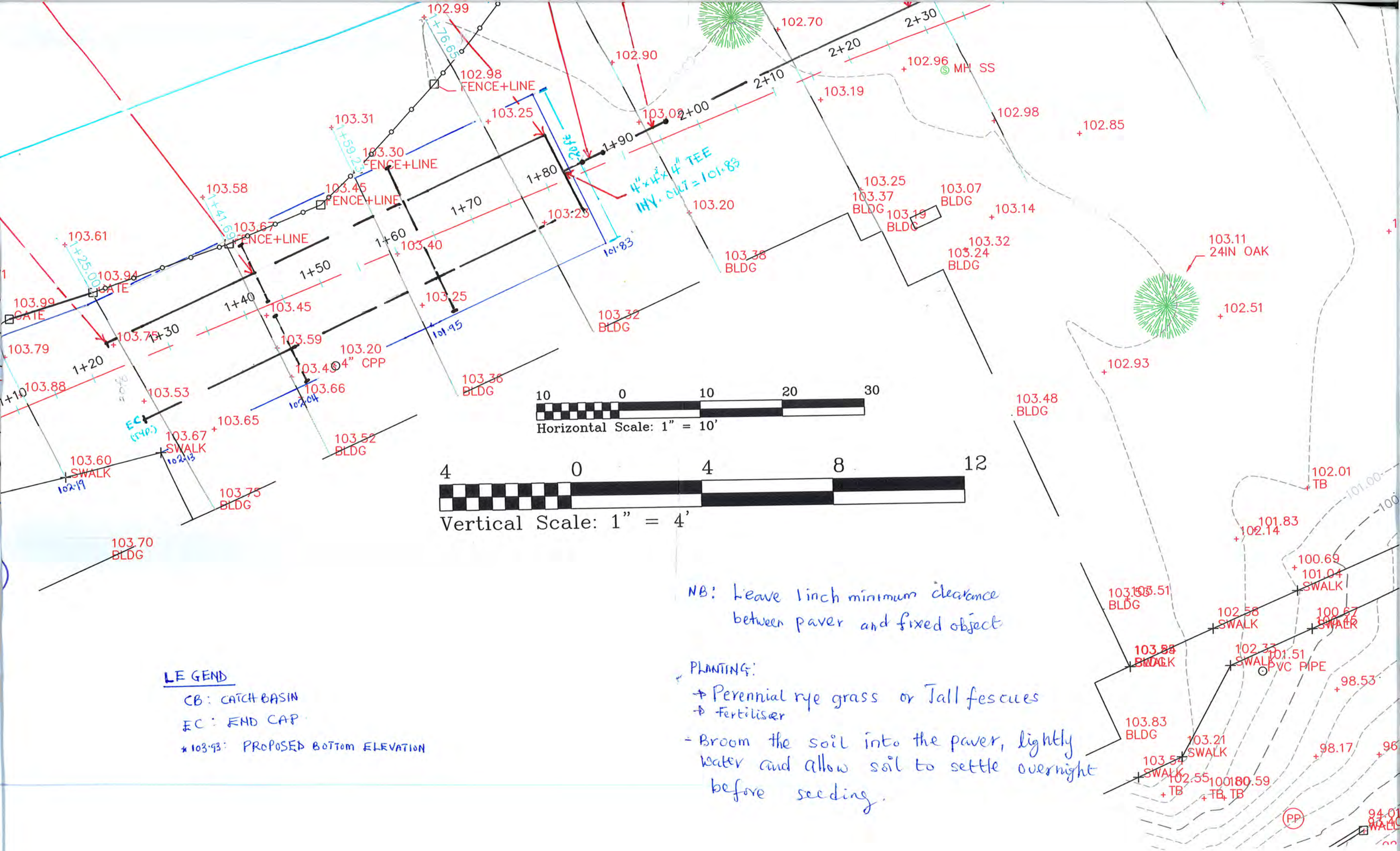
FIRELANE DETAIL



Convince Sue about Sodding.




SANDY LOAMY SOIL
NON-WOVEN GEOTEXTILE FABRIC
WASHED #57 STONE COMPACTED IN 4" LAYER
12" MAX
4" PERFORATED PVC PIPE WRAPPED IN NON-WOVEN GEOTEXTILE FABRIC
COMPACTED SUBGRADE
4" PERFORATED PVC PIPE
184ft
FENCE+LINE 103.83
103.82
104.15
FENCE+LINE
104.29
103.99
104.17
FENCE+LINE
104.32
103.94
0+00
0+90
0+80
103.03
104.26 FENCE+LINE
104.88 STADIUM LIGHT
104.14
104.44 FENCE
104.29
104.38 FENCE+LINE
104.62 FENCE
104.53
105.95 CREPE MYRTLE
105.69 CREPE MYRTLE
106.41 CREPE MYRTLE
TCBC 106.49
TCBC
PP
105.36
105.00
4" PERFORATED PIPE INV. OUT = 102.45'
104.21
0+60
0+70
0+50
0+40
0+30
0+20
0+10
0+00
104.71
104.28
103.86 SWALK
104.19 SWALK
105.43 BOLLARD
105.33 BOLLARD
103.93
13ft
START PT
102.69
102.64
102.26
102.55
102.51
102.45
102.40
102.35
102.36
102.30
102.31
102.28
103.79 SWALK
103.71 SWALK
103.59 SWALK (LOW)
103.63
103.62 CONCRETE
103.70 CONCRETE
103.71 CONCRETE
103.72 CONCRETE
103.72 CONCRETE
103.76 GOALPOST
CB
EC
103.76 BLDG
APPROXIMATE LOCATION (THIRD SLAB SECTION FROM GOALPOST) INV. OUT = 102.57'
1' WALL AND FENCING



NB: Leave 1inch minimum clearance between paver and fixed object

LEGEND

CB: CATCH BASIN

EC: END CAP

* 103.93: PROPOSED BOTTOM ELEVATION

PLANTING:

- Perennial rye grass or Tall fescues
- Fertiliser

- Broom the soil into the paver, lightly water and allow soil to settle overnight before seeding.

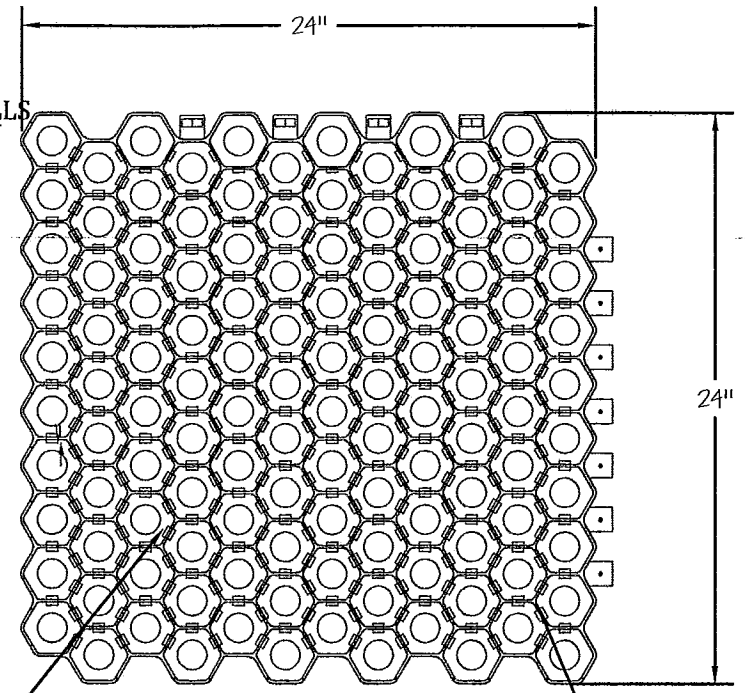
TUFFTRACK PRODUCT DESCRIPTION

PANEL SIZE - 24" x 24" x 1 1/2"

CELLS PER PANEL - (120) - 2-1/2" HEXAGONAL CELLS

NESTED HONEYCOMB CELL LAYOUT

COMPRESSIVE STRENGTH - 98,770 PSF
685 PSI
EXCEEDS H2O
LOADING



TONGUE & GROOVE LATCHING SYSTEM

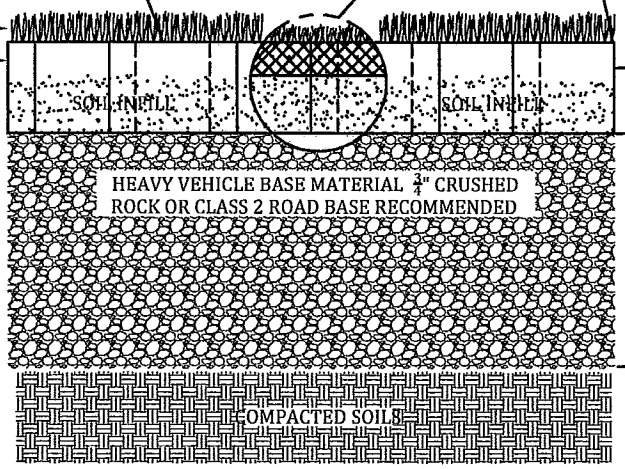
TUFFTRACK GRASS ROAD PAVER

"SOD" PLANTING LEVELS INSIDE CELLS

ADJOINING FINISH GRADE

ACTUAL FINISH GRADE

SOIL FILL LEVEL INSIDE PAVER GRIDWORK AFTER HEAVY WATER DOWN. THIS IS THE ACTUAL SOD PLANTING LEVEL.



NOTE:

EXISTING SOILS SHOULD BE EVALUATED TO ENSURE PROPER STRUCTURAL AND PERMEABILITY PROPERTIES.

NDS™

TECHNICAL SERVICES
1-888-825-4716
techservice@ndspro.com

TYPICAL TUFFTRACK PAVER FIRELANE DETAIL

HEAVY VEHICLE OR FIRE ACCESS ROAD

N. T. S.

Hargraves Fire Lane before construction

Hargraves Fire Lane before construction from other direction

Area for grass pavers is excavated and leveled

Underdrains are laid out

The gravel base is laid over the underdrains

Filter fabric and sandy loam is laid out

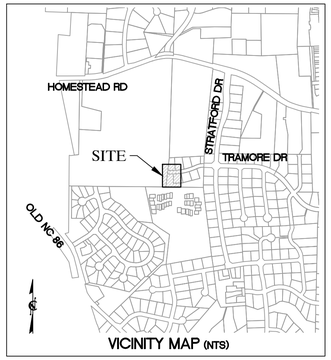
Here one of the pavers is laid along the edge of the sidewalk

Laying out the pavers

Raking sandy loam into the pavers

Pavers are covered in soil, waiting for grass seed, while driveway apron is poured

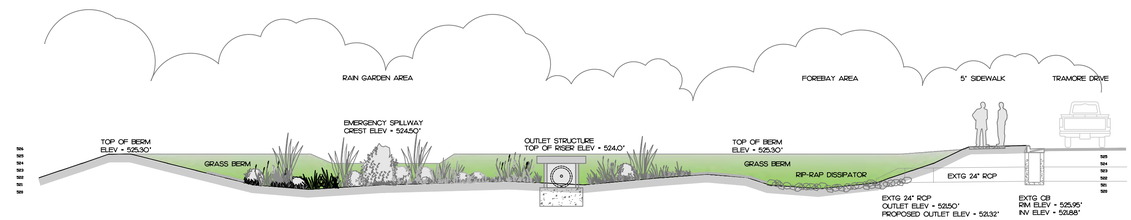
APPENDIX 8: CARRBORO RAIN GARDENS PROJECT MATERIALS



VICINITY MAP (NTS)

LEGEND: SYMBOLS FOR GRAPHICAL REPRESENTATION ONLY. SEE TABLES, SCHEDULES AND/OR DETAILS FOR SIZES/DIMENSIONS OF DEVICES/STRUCTURES.

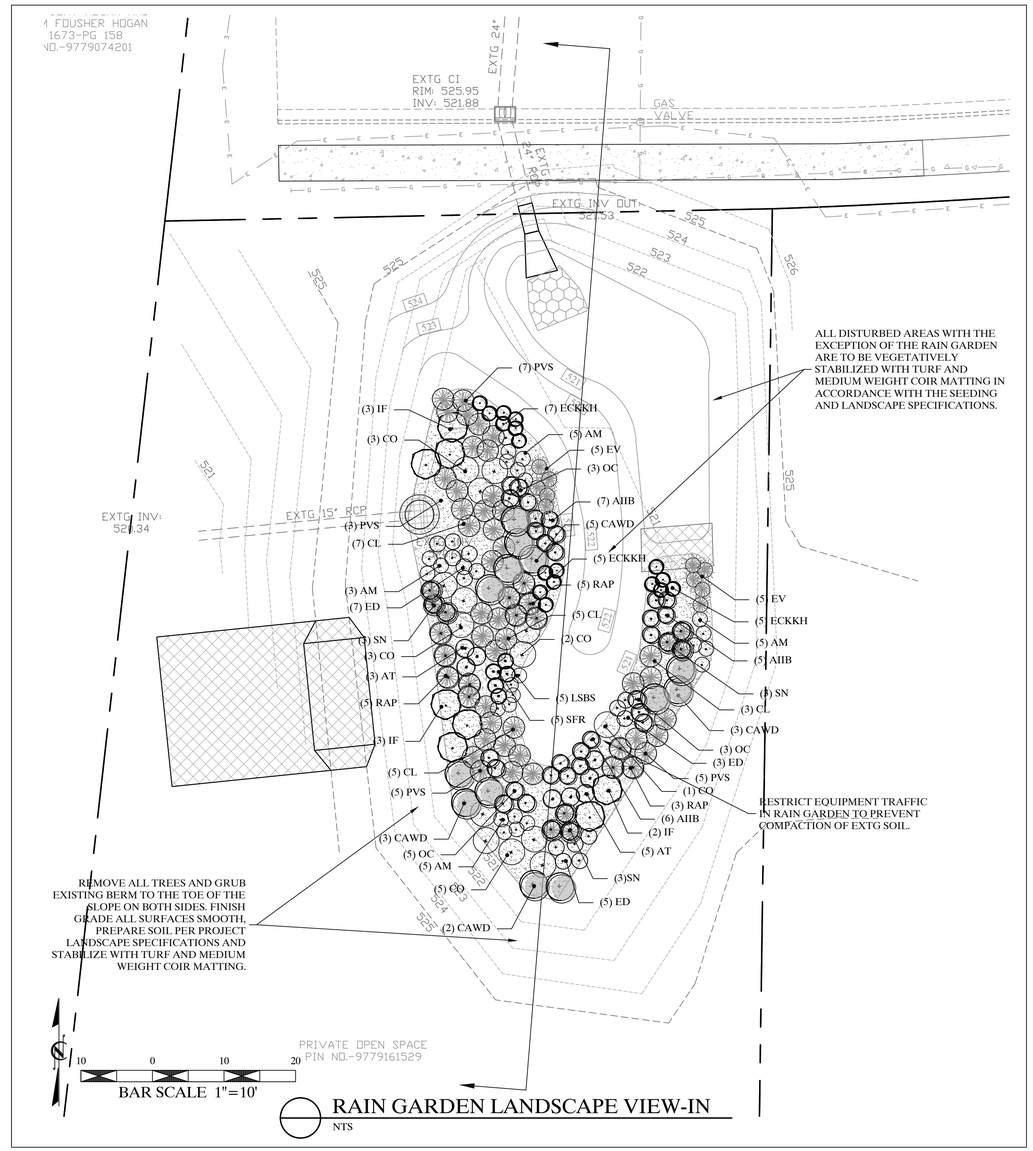
- EXISTING BACK OF CURB
- EXISTING EDGE OF PAVEMENT
- EXISTING EDGE OF CONCRETE
- 24"_RCP — EXISTING STORM DRAINAGE PIPE
- EXISTING CATCH BASIN
- EXISTING PROPERTY LINE/ RIGHT OF WAY LINE
- SL — EXISTING SEWER LINE
- W — EXISTING WATER LINE
- G — EXISTING GAS LINE
- E — EXISTING ELECTRIC LINE
- EXISTING WATER GATE VALVE
- EXISTING WATER METER
- GAS VALVE — EXISTING GAS LINE VALVE
- PP — EXISTING UTILITY POLE
- PROPOSED CONTOUR
- PERMANENT TURF REINFORCEMENT MATTING
- RAIN GARDEN



CONCEPTUAL SECTION VIEW OF TRAMORE WEST DETENTION RAIN GARDEN
NTS

DEER RESISTANT RAIN GARDEN PLANT LIST

BOTANICAL NAME	COMMON NAME	CALIPER	HEIGHT	REMARKS	QUANTITY	SYMBOLS	MATURE HT
SHRUBS							
CEPHALANTHUS OCCIDENTALIS	BUTTONBUSH	3 GAL			14	CO	3'-4'
CLETHRA ALNIFOLIA 'WHITE DOVE'	COMPACT SWEET PEPPERBUSH	3 GAL			13	CAWD	3'-4'
ILLICIUM FLORIDANUM	FLORIDA ANISE	3 GAL			8	IVLH	3'-5'
GRASSES							
CHASMANTHYRIUM LATIFOLIA	RIVER OATS	LINER			17	CL	3-4'
ELYMUS VIRGINICUS	VIRGINIA WILD RYE	LINER			10	EV	3-4'
PANICUM VIRGATUM 'SHENNADOAH'	SHENNADOAH SWITCH GRASS	LINER			20	PVS	3'
PHALARIS ARUNDINACEA 'PICTA'	RIBBON GRASS	LINER			13	RAP	3'
SORGHASTRUM NUTANS	INDIAN GRASS	LINER			9	SN	3-5'
PERENNIALS							
ACHILLEA MILLEFOLIUM	YARROW	1 QT			18	AM	1'-3'
ASCELEPIAS INCARNATA 'ICE BALLET'	ICE BALLET SWAMP MILKWEED	1 GAL			18	AIB	2'-4'
ASCELEPIAS TUBEROSA	BUTTERFLY WEED	1 GAL			8	AT	1'-3'
ECHINACEA PURPUREA 'KIM'S KNEE HIGH'	CONEFLOWER	1 QT			10	ECKKH	1'-3'
EUPATORIUM DUBIUM 'LITTLE JOE'	LITTLE JOE PYE WEED	1 QT			15	ED	1'-3'
LIATRIS SPICATA 'BLAZING STAR'	BLAZING STAR GAYFEATHERS	1 GAL			5	LSBS	2'-3'
OSMUNDA CINNAMOMERA	CINAMON FERN	1 GAL			8	OC	2'-3'
SOLIDAGO RUGOSA 'FIREWORKS'	FIREWORKS GOLDENROD	1 GAL			5	SRF	3'



RAIN GARDEN LANDSCAPE VIEW-IN
NTS

Rain Garden Construction Sequence

1. Rain garden area to be field staked by Contractor and approved by Project Landscape Architect before construction shall begin.
2. Begin installation by rough grading site and installing any necessary storm drainage structure and pipes as per plans and details.
3. If necessary, install silt fence or other approved erosion control measures to protect rain garden area during final grading, installation of planting soil & mulch and final landscape installation.
4. Finish excavating to the designed depth, size and bottom profile. The rain garden area should be over-excavated an additional 10"-12" to allow for the placement of planting soil, soil amendments and hardwood mulch.
5. The subsoils in the entire rain garden area must be thoroughly and deeply scarified 6" before the contractor places the soil amendments. Scarifying should be done with a "toothed" backhoe.
6. Proceed with backfilling with 6" of loamy sand topsoil. Spread 2" compost and till into topsoil.
7. Contractor should keep equipment off rain garden areas to avoid compaction of planting soil.
8. Install any woody landscape material as per Landscape Plan.
9. Mulch rain garden area with 3" double shredded hardwood mulch and install remaining perennial plant material per Landscape Plan.
10. Thoroughly water in all landscape material after initial installation.
11. Stabilize any remaining denuded areas with permanent cover specified.
12. Water every 7-10 days without adequate rainfall (1" per week) until plants become established.

RAIN GARDEN MAINTENANCE GUIDELINES AND SCHEDULE

Typical Inspection/Maintenance Frequencies for Rain Gardens

Frequency	Inspection Items	Maintenance Items
One time – After First Year	• Ensure that rain garden plants survive.	• Replant dead or missing rain garden vegetation per approved plans.
Monthly and After All Storms (>1" Rainfall)	• Inspect inlet and outlet structures and other pipes for clogging – Perform every visit. • Monitor sedimentation contamination in rain garden soil • Inspect principal and emergency spillway for blockage • Check for debris and undesirable vegetation. • Investigate embankment, dikes, berms and side slopes for erosion. • Monitor rain garden plant composition and health. • Look for graffiti, broken signs, and/or potentially public hazards. • Observe filtration performance • Inspect pretreatment areas for buildup of sediment • Monitor adjacent surrounding drainage area	• Unclog inlet/outlets structures • Immediate action required to prevent sediment from contaminating rain garden soil • Unblock spillways • Stabilize undercut, eroded and bare soil areas using appropriate erosion control measures • Remove trash and debris. • Repair mechanical/structural components if needed • Remove graffiti • Spot weeding • Corrective measures if filtration drawdown time becomes greater than designed drawdown time(ponding more than 48 hours after rain event) • Stabilize bare soil areas, remove excess silt/dirt and trash from pavement
Every six months	• Monitor rain garden plant composition and health. • Identify invasive plants.	• Trash and debris clean-up day. • Remove invasive plants • Remove dead or diseased vegetation • Repair mechanical/structural components if needed. • Remove vegetative growth from inlet structure, weir or principal spillway • Prune if necessary
Annually	• Monitor rain garden plant composition and health.	• Trash and debris clean-up day. • Remove dead or diseased vegetation and replace with appropriate plant material • Repair mechanical/structural components if needed. • Replenished mulch to maintain minimum mulch depth
Every 2 years	• All routine inspection items above. • Inspect inlet and outlet structures for damage. • Inspect all pipes. • Monitor sediment deposition in facility. • Conduct soil test	• Pipe repair as necessary. • Sediment removal and repair when needed. • Add lime as indicated on soil test – Do not fertilize
Every 3 years	• Monitor sediment deposition in facility. • Monitor water storage volume	• Sediment removal and repair when needed. • Remove old mulch accumulation if mulch depth exceeds 3 inches to accommodate initial water storage volume.
Every 5 years	• Sediment accumulation in rain garden area. • Monitor rain garden plant composition and health.	• Sediment removal from rain garden area. • Shrubs may need to be replaced or cut back to ground • Perennials and grasses may need to be divided

General Notes:
1. Do not fertilize rain garden area.
2. Prune rain garden vegetation to maintain sight lines, facilitate trash pick up, remove dead/disease vegetation and for public safety concerns.

PRELIMINARY DESIGN
NOT FOR CONSTRUCTION

SUNGATE DESIGN GROUP, P.A.
915 JONES FRANKLIN ROAD
RALEIGH, NORTH CAROLINA 27606
(919) 851-1912 FAX (919) 851-1918
ENG. FIRM LICENSE NO. C-893

NORTH CAROLINA REGISTERED LANDSCAPE ARCHITECT 935 WILLIAM B. HAMILTON

TRAMORE WEST BMP
CARRBORO, NC

LANDSCAPE PLAN

PROJECT # : 1029-10033
DRAWING NAME: TRAMRWEST11C103
DATE: 02-24-11
DRAWN BY: JRH
REVIEWED BY: CAM
REVISIONS: 10-8-10: ADDED SIDEWALK AND EXTEND EX. 24" RCP; REVISED PLANT LIST AND ADDED PLANTING PLAN

SHEET NO.
C1.03

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other techniques

The following are examples of other "best practices" that also help our creeks through the infiltration and retention of stormwater runoff:

- pervious pavement
- rain barrels and cisterns
- vegetated green roofs
- pocket/ backyard wetlands
- disconnecting down spouts
- converting lawns to naturally vegetated areas.

For additional information and to learn more about these techniques consult the resources!

resources

[additional information]

NCSU Stormwater Engineering Group
[www.bae.ncsu.edu/stormwater/research.htm]

NCSU backyard rain gardens
[www.bae.ncsu.edu/topic/raingarden/]

Center for Watershed Protection
[www.cwp.org/]

Low Impact Development Center
[www.lowimpactdevelopment.org/]

Low Impact Development Guidebook for NC
[www.ces.ncsu.edu/depts/agecon/WECO/lidguidebook/]

NC Department of Natural Resources
[www.ncstormwater.org/]

Town of Chapel Hill, stormwater management
[www.ci.chapel-hill.nc.us/index.aspx?page=381]

photo: NCSU Biological and Agricultural Engineering

town of carrboro, nc
301 w main street
carrboro, nc 27510

[www.townofcarrboro.org/pzi/Env/water.htm]

rain gardens

[helping our creeks, beautifying our backyards]

improve creek health and the urban environment, create a backyard rain garden TODAY!

[what is a rain garden?]

According to the Low Impact Development Guidebook of NC, a rain garden is a depressed landscape that filters and infiltrates stormwater runoff. Rain gardens usually contain an excavated basin, an underdrain, special soil and vegetation.

[how do rain gardens help creeks?]

One of the main problems our local creeks, and urban creeks in general, face is the rapid conveyance of rain water from roofs, pavement, and other surfaces that compromises the natural process of rain water soaking into the ground. Undisturbed, plants intercept the rain water, filter out pollutants and help infiltrate it into the soil profile. Increased urban development with the subsequent roofs and pavement (impervious surfaces) results in increased runoff, higher peak flows, lower groundwater recharge rates, lower stream flow during droughts, and limited capacity for natural pollutent filltration. Rain gardens are designed to address all of these challenges that threaten the health of our creeks, while simultaneously creating attractive landscape features.

Rain garden capturing and filtering runoff from a residential street.

[how to build a rain garden?]

Backyard rain gardens are easy to design and build with the right information. The main elements to consider when designing a rain garden are as follows: location in relation to the runoff source and the runoff destination, the soil type and drainage, the size of the garden based on drainage area and other site constraints, and the plants. Please refer to the resource provided in this brochure for more detailed information.

photo: NCSU Biological and Agricultural Engineering

[how much do rain gardens cost?]

Rain gardens are a cost effective tool for managing stormwater runoff and helping our creeks and average between $4.00 – 10.00 per square foot for residential projects. The cost will vary with each rain garden because of different site and design considerations. The factors that impact the cost of rain gardens are as follows: soil amendments, underdrain materials, mulch, plants, tools and labor.

[the town hall rain garden]

[before]

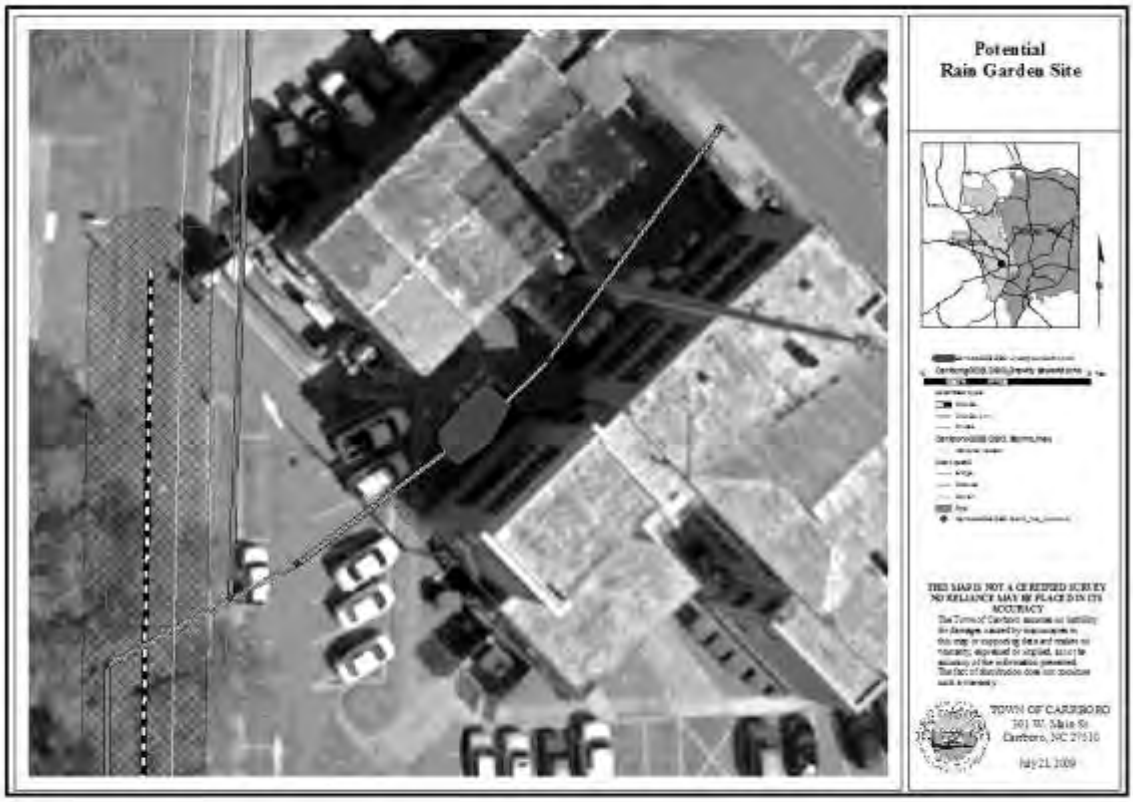
The rain garden by the Town Hall entrance off of Bim Street was installed in May 2010. It is designed to treat the runoff from the roof of the covered walkway and the small area between Town Hall and the Fire Station, out to the sidewalk. The site was chosen because of its visibility, applicability to many buildings in Carrboro, the opportunity to enhance the space, and the presence of the preexisting stormwater drain. The total cost of the materials (gravel, soil certified for rain garden use, fabric, pipe for underdrain and clean out, mulch, plants, rainbarrel, downspout) was about $600. Plants were selected based on adaptation to the unique soil conditions, ranging from very wet to very dry, western exposure, and for their aesthetic appeal and attraction of pollinators. More information is available by contacting Town Planning or Public Works staff.

[after]

Visit the Town Hall rain garden often and watch it change as the plants grow and mature!

CAUTION / CUIDADO
CAUTION
EXIT ONLY

CAUTION / CUIDADO
CAUTION / CUIDADO
CAUTION


Potential
Rain Garden Site
THIS MAP IS NOT A CERTIFIED SURVEY
NO RELIANCE MAY BE PLACED IN ITS
ACCURACY
TOWN OF CARRBORO
301 W. Main St
Carrboro, NC 27510
July 21, 2009

APPENDIX 9: GEODATABASE OF RESTORATION PROJECTS FEATURE CLASS ATTRIBUTES

APPENDIX 9: GEODATABASE OF PROJECTS - ATTRIBUTES AND DOCUMENTATION

Following are a list of attributes developed for describing and comparing proposed stormwater retrofit and stream restoration projects. Attributes are associated with a polygon project feature class in the geodatabase. Additional feature classes include drainage area to project and disturbed area of project. These are useful in determining the number and types of property owners that may be affected by a project.

PROJECTS GIS FEATURE CLASS:

Project ID: *(unique key)*

Project Type:

- *Bioretention w/IWS*
- *Bioretention w/o IWS*
- *Wet Detention Basin*
- *Sand Filter*
- *Stormwater Wetland*
- *Level Spreader + Filter Strip*
- *Dry Extended Detention Basin*
- *Grassed Swale*
- *Green Roof*
- *Permeable Pavement*
- *Rainwater Harvesting*
- *Infiltration devices/basins*
- *Floating Wetlands*
- *Mass Soil Amendment*
- *Offline Regional Treatment*
- *Proprietary Devices*
- *Underground/Other Storage/Retention*
- *Improvement of Existing BMP*
- *Priority 1 stream restoration – new stable channel connected to floodplain*
- *Priority 2 stream restoration – new floodplain and stable channel at present elevation*
- *Priority 3 stream restoration – widen floodplain, new bankfull bench, leave stream in place*
- *Priority 4 stream restoration – stabilize existing streambanks in place, no improved access to fp*
- *raising of stream bed and rebuild of hyporheos (stream restoration technique)*
- *instream grade control (to prevent downcutting or rebuild – includes step-pools, engineered riffles, and other instream structures for highly localized flow and grade control management)*
- *stream channel rerouting – restore natural pattern, move away from eroding areas or infrastructure*
- *rebuild instream structure and heterogeneity – riffle-pool structures, increased heterogeneity, hyporheos, emplaced large woody debris*
- *streambank erosion control and stabilization (includes streambank reshaping/new bankfull bench, accelerated streambank evolution, live stakes and other plantings, hard engineered surfaces, green-engineered combo methods)*

- *gully/erosion repair or prevention (includes all kinds of stormwater outfall energy dissipation)*
- *Stream daylighting and culvert removal*
- *Stream ford repair/improvement*
- *Culvert modification, enlargement, realignment, or other improvement*
- *Floodplain fill removal, legacy sediment removal*
- *Large dam removal*
- *Dam repair, replacement*
- *Targeted direct stormwater input removal (illicit discharges and cross-connections)*
- *High-density urban stormwater BMPs*
- *Floodplain restoration/vernal pools*
- *Groundwater remediation*
- *Street sweeping*
- *Leaf collection/management (gross solids control)*
- *Riparian buffer enhancement*
- *Riparian buffer reforestation*
- *Invasive species management and control*
- *Trash/debris cleanup*
- *Dump/trash excavation*
- *Septic system repair/replacement/retirement*
- *Stream fencing*
- *Vegetative erosion control*
- *Floodplain structure removal*
- *Soil restoration, amendment, ripping*
- *Small dam removal*
- *Residential rain garden (i.e. non-engineered bioretention/bioinfiltration)*
- *Upland reforestation/lawn replacement*
- *Conversion of impervious surface to pervious*
- *Illicit discharge enforcement*
- *aboveground storage tank removal, replacement, covering, ground covering, maintenance*
- *Industrial/Commercial Pollution Prevention – dumpsters, restaurant practices, etc.*

Project Description:

Location Description and Driving Directions:

Name of Receiving Water:

Receiving Water DWQ classification:

Receiving Water rating:

Town Subwatershed ID/Name:

Jordan Rules Creditable: *yes, pending, no, unknown*

Drainage Area to Project:

Property owner types in Drainage area and % (for assigning credits): *named jurisdiction, NCDOT, other federal/state (name), private*

Area available for Project:

Proposed Disturbed Area (ac/sqft?):

Disturbed Area current land cover (describe in detail):

Final Project Footprint Area:

Property Owners in Disturbed Area:

Property Owner Cooperation:

Property restrictions: *covenants, easements, regulated floodplain, regulated stream buffers, setbacks of all kinds, deed restrictions, etc. (or "unknown" or "partial listing")*

Construction Accessibility:

Est. Construction Costs:

Est. Utility Move Costs:

Other Implementation Costs:

Design complications: *like fully connected impervious (incl roofdrains), extensive/large network, deep existing network, low slope, limited daylighting opportunities, dedicated rainwater use/management*

Design analyses: *like flood studies, geotechnical testing, 401/404 alternatives analysis, other professional analyses, dedicated rainwater use/management*

Special Design notes: *such as for experimental university studies, improvement of existing underfunctioning BMP, reduce downstream erosion, or other changes to standard design to improve functionality, efficiency, resilience, reduce maintenance, etc.*

Maintenance Accessibility:

Maintenance Responsibility:

Maintenance Funding: *available? Guaranteed how?*

Est. Annual Maintenance costs:

Maintenance description:

Project Protection: *funds/restrictions in place to protect project?*

Drainage Area Average Slope:

Project Area Average Slope:

Soils in Drainage Area: (%?)

Soils in Project Area: *(hydrologic group or estimated or measured permeability)*

Estimated depth to groundwater table: (*some rough indication of whether it's on the order of 1-2 feet or >5 ft might be helpful for some types of BMPs, especially stormwater wetlands)*

Environmentally Sensitive Areas: *floodplain, stream buffers, E/I species habitat, wetlands, Natural Heritage, etc.*

Invasive Plant Species and Severity:

Utility conflicts: *"not investigated", "partial investigation - (list)", and full list*

Other Barriers to Implementation:

Est. Water Quality Volume:

Est. annual Drainage loading – N:

Est. annual Drainage loading – P:

Est. annual Drainage loading – other:

Potential N reduction:

Potential P reduction:

Potential other pollutant reduction:

Potential Runoff reduction:

Volume/rate control: *(List design storms used)*

Addressing Identified Problem: *(Problem IDs – for linkage to Problem ID table)*

Problem types addressed: *pollutants (list), sediment source, stream instability, instream erosion, poor aquatic habitat, poor terrestrial habitat, riparian forest, floodplain function, habitat heterogeneity, hyporheic exchange, connectivity/migration barrier, GW recharge, flashiness/hydrologic modification, low base flow, high water temp, low DO, BOD/COD, algae, drainage complaint, sanitary/septic*

Other Potential Benefits: *park space, pond amenity, support stream or watershed restoration, support another project, support plant community reconstruction, highway/road/public area beautification, wildlife habitat/food/cover, remove invasive plant seed source, address known drainage problem, public ed/involvement (like community garden, demonstration space), ongoing/planned/past academic study*

Feasibility Conclusions:

RETROFIT WQ CALCULATIONS ASSOCIATED TABLE:

Project ID: (parent key)

Land Use Type: *Roadway, Driveway, Parking Lot, Roof, Sidewalk/Patio, Lawn, Managed Pervious, Forest, Other*

Soil type

Drainage Landuse and Impervious types and %: *(do as a separate table or fields for each land use type)*

Soils in Drainage Area: (%'s by hydrologic soil groups)

Fields for each land use:

- TN EMC
- TP EMC
- Area
- Rv
- Annual #N
- Annual #P
- N Load per Ac
- N Reduction per Ac
- P Load per Ac
- P Reduction per Ac
- Total annual runoff for the watershed
- Projected retrofit volume capture
- Projected volume reduction

APPENDIX 10: BOLIN CREEK WATERSHED SITUATION ASSESSMENT

Bolin Creek Watershed Situation Assessment

February 8, 2012

Watershed Education for Communities and Officials
NC Cooperative Extension
North Carolina State University

www.ncsu.edu/weco

Patrick Beggs
Carolyn Buckner
Christy Perrin

Project funded by a US EPA Clean Water Act Section 319 grant

Executive Summary

The Bolin Creek watershed begins in rural Orange County, with its headwaters just north and west of Carrboro. Bolin Creek flows nine miles southeast through portions of downtown Carrboro and Chapel Hill, before joining Booker Creek to form Little Creek. Little Creek eventually flows to Jordan Lake in the Cape Fear River Basin. Since Bolin Creek flows to Jordan Lake, a major water supply source, its watershed is subject to the new Jordan Lake Rules. Bolin Creek is on the state's 303(d) list of impaired waters for not supporting the numbers or diversity of biological species that would be found in a comparable healthy stream. A 2003 NC Division of Water Quality (DWQ) report identified the following effects of urbanization as the primary factors stressing the Bolin Creek watershed: habitat degradation, riparian degradation, channel incision, low base flow (dry weather flows), and toxicity. The Towns of Carrboro and Chapel Hill , the NC DWQ and the US Environmental Protection Agency (EPA) formed the Bolin Creek Watershed Restoration Team (BCWRT) in 2006 to improve water quality such that Bolin Creek and its tributaries can support their designated uses and be removed from the 303(d) list. The BCWRT has received grants (NC Clean Water Management Trust Fund (CWMTF), and EPA) in partnership with North Carolina State University, the Friends of Bolin Creek and other local organizations to identify restoration projects, to develop a watershed plan required by the EPA, and to implement and monitor projects.

The BCWRT identified one of their main challenges to long-term restoration as difficulty in coordinating and leveraging efforts with the many active and interested citizens in the watershed. The BCWRT subcontracted part of a current EPA grant to Watershed Education for Communities and Officials (WECO), a NC Cooperative Extension program, to conduct a situation assessment in the Bolin Creek watershed. The purpose is to better understand the interests of watershed stakeholders and organizations, to identify opportunities to engage stakeholders in Bolin Creek restoration while meeting multiple interests, and to determine how stakeholders would like to participate in restoration efforts.

WECO staff conducted interviews and focus groups representing residents, businesses, non-profits, local and state government staff, and recreationists from a cross section of interests in the watershed. Most interviewees identify with Bolin Creek as a special and valuable community resource, and interact with it in many different ways. We were impressed with the community resources available and being used for a broad array of efforts to maintain and improve water quality, stream habitat, recreation, and educational opportunities. Agreement was not heard on the causes and sources of Bolin Creek's impairment, or on the preferred strategies for restoring the creek. While respondents overwhelmingly commented on the need for improving Bolin Creek, various efforts are underway that could provide more effective and sustainable restoration efforts if they were coordinated with each other. Many people cited differences in opinion about how to manage the riparian corridor through Carrboro and the Carolina North Forest- this has been a flashpoint of conflict for some segments of the watershed population.

A desire for comprehensive, collaborative visioning and goal-setting for the Bolin Creek watershed was clearly heard through the interviews. Stakeholders are ready and willing to participate in a coordinated effort to improve communication, share information, leverage resources, and improve restoration efforts. We recommend stakeholders focus on the

impressive number of positive attributes in the community and build on those as they move forward.

We recommend the BCWRT support this effort through the following recommendations which are more fully explained in Section V of this report.

A. Create a multi-organizational, collaborative watershed initiative to serve as the nexus for the watershed. This Bolin Creek Watershed Initiative can use the principles of inclusiveness, shared responsibility, neutral facilitation, consensus-based decision making, and can focus on leveraging the positive attributes of the community.

B. Enlist a neutral party to develop and actively manage an interactive online hub for the watershed community that enables interactive communication and houses links to all stakeholder organizations and relevant documents.

C. Examine how to more holistically plan and manage water resources across departments and jurisdictions

D. Increase community outreach and engagement on the Carolina North Forest Stewardship Plan.

E. Investigate how to raise revenue dedicated to water quality protection and restoration, such as a stormwater utility or other mechanism.

F. Continue to work together to address the landfill and groundwater contamination issues in the Roger-Eubanks community.

G. Convene a facilitated search for common understanding about ways to connect pedestrian and cyclist routes while also protecting and improving Bolin Creek's riparian corridor.

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I. Introduction

A. Purpose of the Situation Assessment

The Towns of Carrboro and Chapel Hill began meeting with the NC Division of Water Quality (DWQ) and the US Environmental Protection Agency (EPA) in April 2006. Together they formed the Bolin Creek Watershed Restoration Team (BCWRT) in an effort to restore Bolin Creek. The BCWRT's long term goal is to improve water quality such that Bolin Creek and its tributaries are able to support their designated uses and be removed from the 303(d) list. To date they have achieved the following successes:

In 2006, Bolin Creek was selected as one of only seven watersheds in the state to receive focused assistance from the NC Division of Water Quality (NCDWQ) and the US Environmental Protection Association's (USEPA's) Science and Ecosystem Support Division in preparing grant applications and leveraging other resources to remove it from the 303(d) list.

> What do we mean by collaboration?
>
> Collaboration is a process of shared decision-making in which all the parties with a stake in a problem constructively explore their differences and develop a joint strategy for action.
>
> - Scott London, Collaboration and Community

In 2007, the BCWRT received a Clean Water Management Trust Fund stormwater mini-grant used to conduct a detailed assessment of stream reaches to identify areas of erosion, instability, and other high risk locations. The final report identified and prioritized areas for future restoration projects (EarthTech, 2007).

In 2008 and 2009, the BCRWT in cooperation with NC State University, the Friends of Bolin Creek, and other local organizations received two 319 Grants funded by the USEPA through the NC DWQ Section 319 Nonpoint Source Grant Program. Section 319 refers to the US Clean Water Act. Nonpoint Source (NPS) refers to any pollution that does not have a discrete source, such as stormwater runoff. Through these grants the BCWRT is pursuing watershed assessment, monitoring, and specific restoration projects (Town of Carrboro).

There is great potential for achieving measurable improvements in the health of Bolin Creek, in large part due to the capacity for and strength of environmental initiatives from both local governments and local stakeholder groups. However, both town employee project coordinators have experienced unanticipated challenges in coordinating efforts with watershed stakeholders, including grant partners, given the complexity of the issues. In addition, watershed stakeholders hold strong and differing opinions on how to manage Bolin Creek's riparian areas.

The BCWRT has begun developing a watershed plan as required by the USEPA. Due to the previously mentioned difficulties, they have not yet been able to comprehensively engage watershed stakeholders in the watershed planning process required for the EPA grant . In addition, a major watershed organization is creating a separate conservation plan for a portion of the watershed. The BCWRT has identified one of their challenges to restoration

as difficulty in gaining support of property owners and recruiting participants. Engaging stakeholders through education and planning efforts is crucial to achieving support and active participation during implementation. Effectively coordinating with stakeholder efforts and leveraging resources is also crucial to achieving long term restoration of the Bolin Creek watershed.

For these reasons, the BCWRT requested assistance communicating and coordinating with, and engaging watershed stakeholders in Bolin Creek watershed management efforts. The Towns subcontracted a portion of their 319 Grant, *The Bolin Creek Watershed Initiative*, to Watershed Education for Communities and Officials (WECO), a NC Cooperative Extension program at NC State University (NCSU) to conduct this situation assessment. Effectively involving the public requires understanding their interests and how they want to be involved. This report intends to:

- identify organizations and individuals who can influence watershed decisions or are influenced by watershed decisions (stakeholders);
- identify issues of importance to the local community;
- seek to understand how stakeholders see these issues;
- identify conflicts and barriers to effective stakeholder involvement;
- identify opportunities to engage stakeholders and meet mutual interests; and
- determine how stakeholders would like to communicate and participate in restoration efforts.

This report does not intend to provide a quantitative, statistically accurate analysis of the issues, but rather a summary of the issues identified. The summary is followed by our interpretation of the stakeholder interests identified, and recommendations for the BCWRT and watershed stakeholders that may offer the most effective course for building the community's capacity for communication, networking, coordination, and leadership required for successful long-term watershed restoration. Although this report was written primarily for the BCWRT, recommendations are also provided for other organizations with responsibilities and interests in the watershed. The recommendations are intended to address a broad range of the diverse interests in the Bolin Creek watershed. Increased efforts to address these diverse interests can help to expand community involvement and support of watershed restoration activities. Whether or not these interests appear to be directly related to restoration activities, we include them because inviting multiple interests in community planning and management is necessary to find creative and long-lasting watershed restoration solutions.

B. About the Bolin Creek Watershed

The Bolin Creek watershed contains all of the land which drains into Bolin Creek. It is located completely within Orange County, NC. The headwaters begin on the southern side of Bald Mountain west of Old 86. Buckhorn Branch and Jones Creek join on the east side of Old 86, south of Eubanks Road and Twin Creeks Park, before flowing into the main stem of Bolin Creek. From its headwaters, Bolin Creek flows approximately nine miles southeast through portions of downtown Carrboro and Chapel Hill. Just south of Fordham Boulevard, Bolin Creek joins Booker Creek to form Little Creek which eventually flows to Jordan Lake,

in the Cape Fear River Basin (Bradley). A map of the Bolin Creek Watershed is found in Appendix 1.

Moving downstream, the Bolin Creek watershed transitions from rural to suburban to dense urban land uses. The headwaters are best characterized as rural with a mix of forested, agricultural, silvicultural, and low density residential land uses. Flowing south and east across Old 86 and Eubanks Road, the headwaters enter Orange County's future Twin Creeks Park and Educational Campus, and the Town of Carrboro's Northern Transition Area, a mix of forested, silvicultural, and mixed density residential land uses. Portions of this area are actively under development, with Morris Grove Elementary School and the Jones Creek greenway going in recently as well as a handful of recent and planned residential developments. Continuing south and east, across Homestead Road and Seawell School Road, Bolin Creek flows near the Chapel Hill High, Smith Middle and Seawell Elementary School campuses, the Carolina North Forest, and a mix of residential and commercial land uses as it passes downtown Carrboro and Chapel Hill. From MLK Jr. Blvd, the creek flows south past the University Mall area until it joins Booker Creek to form Little Creek. With the exception of the Carolina North Forest, the publicly owned and protected Adams Tract, and a privately owned tract of land, the Bolin Creek watershed south of Carrboro's Northern transition area is essentially "built out", transitioning between suburban and dense urban land uses as it flows downstream.

Bolin Creek is listed on the state's 303(d) list as biologically impaired. The State of North Carolina (NC) is required by the US Environmental Protection Agency (EPA) to put all water bodies that are not meeting their intended uses on this list. The 2005 NC Division of Water Quality (DWQ) Cape Fear Basinwide Plan indicates Bolin Creek is impaired for biological integrity (NC DWQ, 2005). This means it does not support the numbers or diversity of biological species that would be found in a comparable healthy stream. A list of studies conducted in Bolin Creek can be found in Appendix 2. The 2003 NC DWQ Little Creek Watershed Assessment Report identified the following effects of urbanization as the primary factors stressing the Bolin Creek watershed:

- habitat degradation;
- riparian degradation;
- channel incision;
- low base flow (dry weather flows); and
- toxicity.

Other potential stressors included:

- temperature ranges and extremes;
- high BOD/COD levels (biological and chemical oxygen demand, or measures of the amount of oxygen that bacteria will consume while decomposing organic matter);
- high nutrient levels; and
- cross-connections or leaks from sanitary sewer lines.

These problems were more prominent moving downstream in the watershed (NCDWQ WARP, 2003).

II. Methods

Stakeholders were identified through a snowball sampling method, which relies on referrals from initial subjects to generate additional subjects. Initial subjects included known stakeholders who have been actively involved with Bolin Creek issues. We interviewed thirty-eight (38) stakeholders including residents, businesses, non-profits, government staff, and recreationists representing a cross-section of interests. We also conducted a focus group with 6 members of the Friends of Bolin Creek, 3 of which were subsequently interviewed. All told, 41 stakeholders contributed and are referred to as interviewees or respondents throughout the report. The purpose was not to interview every person possible, but to reach a swath of stakeholder interests. For example, the team did not speak to every resident identified, but tried to interview people from throughout the watershed.

All interviews were conducted in person. Interviews lasted 40-60 minutes, with one team member taking notes while another conducted the interview. We used a set of questions (see Appendix 3) for guidance during the interviews. Interviewees were sent a copy of the questions ahead of time when possible.

Answers from the interviews were grouped by question and topic for review. We then summarized those answers in the "Results" section without attributing comments to specific people. Direct quotes from interviews are noted in quotation marks. The analysis is not intended to be a statistically quantitative report. Rather, we summarized the range of issues raised by people. If more than one person raised the issue, we reflected that in our report, but we typically did not quantify how many people raised the issue.

We responded to the information that we gathered with an analysis of the situation in the "Discussion" section, and then provided our "Recommendations" on how to best move forward. Our recommendations are based on our experience in collaborative watershed planning and consensus based decision making, informed by the resources in the "References" section.

The following table lists the interests represented in the interviews, and the number of interviewees who self-identified as representing that interest. The number of people interviewed from each interest group adds up to more than 38 since people interviewed often represented more than one interest group. For example, someone who is a resident of Bolin Creek watershed may also be a member of a certain community group and/or a resident of Carrboro or Chapel Hill. This is most likely a conservative account of residents (and other broad interest groups), because several people who worked in the watershed did not indicate if they lived in the watershed and/or Carrboro or Chapel Hill, etc.

In addition to the interests in the table below, many activities take place in the watershed including, hiking, running, biking on trails, biking on greenways, dog walking, bird watching, playing in the creek, exercise, walking meetings, non-motorized transportation, and mushroom harvesting, to name a few.

Interest Group Represented by Interviewee	# Interviewed
Business leadership organizations	2
Carrboro elected / appointed officials	4
Carrboro resident	3
Carrboro staff	3
Chapel Hill elected / appointed officials	4
Chapel Hill resident	6
Chapel Hill staff	5
Developers	2
Farmers	1
Friends of Bolin Creek	8
Haw River Assembly	1
Landowner along Bolin Creek	3
NC Department of Transportation	1
NC Division of Water Quality	1
NC Ecosystem Enhancement Program	3
Orange County Cooperative Extension	1
Orange County Soil and Water Conservation District	2
Orange County staff	3
OWASA	1
Private instruction	1
Professional Trailbuilding Association	1
Real estate agents	3
Recreational users	18
Resident in headwaters	3
Resident – other than headwaters	9
Rogers-Eubanks Coalition to End Environmental Racism	1
Save Bolin Creek	3
Sierra Club	1
Triangle Off Road Cyclists	2
University of NC- Chapel Hill	3

Given our time constraints we were not able to interview every interest we sought, including some that were identified by the interviewees. The following interest groups were contacted and asked to comment on a draft with specific attention paid to whether anything was missing from the report. The team worked to incorporate this feedback. A few interviewees noted the need to reach out to stakeholders who are not associated with an identified stakeholder group such as runners and cyclists not affiliated with clubs. The team was not able to contact those interest groups and hopes that stakeholders can present and distribute the final report as a method to reach those people.

Interests not interviewed that were contacted to comment on the final public draft report:

- UNC-Chapel Hill staff other than those interviewed
- Carrboro and Chapel Hill staff other than those interviewed
- County staff other than those interviewed
- NC Botanical Gardens
- OWASA staff other than those interviewed
- Chapel Hill Carrboro City Schools
- Trailheads running group
- Pacers running group
- Developers
- Land use consultants
- Board of Realtors
- Friends of Downtown
- Specifically named residents and/or landowners
- NAACP
- Neighbors for Responsible Growth
- Churches, communities of faith
- NC Wildlife Resources Commission

III. Results: What We Heard

This section of the report includes only data gathered from the respondents. WECO's comments are not included in this section.

A. How Do Respondents View Bolin Creek?

When asked to characterize or describe Bolin Creek, the interview team was surprised by the wide range of stakeholders who felt a connection to the creek. Of all the people interviewed, only a handful were either not very familiar with Bolin Creek and/or did not value it as a local resource. The rest felt it was a special and valuable resource. Several people commented on the scenic beauty it provides. Some mentioned it offers a feeling of being out of town. Others appreciated the wildlife drawn to the creek.

> "I used to play and swim in it as a child. It used to be deep enough to swing on a rope swing and jump into it."

Bolin Creek and its watershed were recognized by interview respondents as serving many purposes for the residents. Interviewees discussed agricultural uses and open space in the headwaters as well as urban uses downstream. Some see Bolin Creek as a natural connection of communities. Others said it provides open space and opportunities for recreation and non-vehicular transportation.

One recurring theme among interview respondents was the difficulty characterizing Bolin Creek. It varies significantly depending on location. Some commented on rock bluffs and scenic floodplains, especially in the areas upstream of Chapel Hill. It was noted that the watershed has two Significant Natural Heritage Areas, Bolin Creek Natural Area and Battle Park. Others mentioned sewer easements, urban encroachments and even piped segments. Most agreed that Bolin Creek is a struggling urban stream that exhibits progressive impairment as it moves downstream due to decades of development pressure and human activities.

> "It's very attractive. It's a nice scenic area, but it is polluted. The [living] things that used to be in there are not in there now in the numbers they used to be."

There was general consensus among those interviewed that Bolin Creek is impaired. Many people mentioned that Bolin Creek does not support the range of aquatic species that it used to. Some commented that they used to play, fish, or swim in Bolin Creek and now they would not or could not. One participant pointed out that development in the watershed dates back to the 18th century and that, in addition to current stressors, Bolin Creek is still dealing with a sediment problem from previous agricultural uses and old mill dams. Several interviewees commented on how low the water levels are compared to the past. One person attributed it to drought and another attributed it to upstream development.

B. Issues

In this section we summarize issues of concern and interest that were raised by people in response to the question "What issues concern or interest you or your organization regarding Bolin Creek and its tributaries?" This section is part of **'Results: What We Heard'** and does not contain input or opinions from WECO. The pronouns he and she are used indiscriminately. Direct quotes are marked with quotation marks. Issues are listed in no particular order.

Nature / Wildlife

Several interviewees said there used to be more plants and wildlife, such as mollusks, wildflowers, and different fish in the watershed. Others said there is currently a great abundance of wildlife, including great blue herons, snapping turtles, owls, song birds, and crayfish. It was reported that there is a historical record (from 1980) of a state special concern species, the four-toed salamander (Hemidactylium scutatum) in the Bolin Creek watershed. Invasive plant species were often mentioned as a problem. A few respondents mentioned the importance of having natural areas. Both the Chapel Hill greenway and Carolina North Forest were mentioned as suburban oases and a "way to commune with nature in what is actually a very developed place."

> "There is still a lot of life in the creek despite the problems and it gets people excited."

Development

A few interviewees stated the biggest threat to the watershed is from development. Several interviewees emphasized the need for sustainable development. One interviewee stated "I don't see development as a major risk to the Bolin Creek watershed." A few people cited the agricultural land in the upper headwaters as the only place development could occur on a large scale.

One respondent stated the problem everywhere is: "Some people want less regulation and more development and others want tighter regulations and more environmental restrictions." Another respondent stated that people blame others for the environmental degradation caused by development. ". . . In fact it is usually blamed on the new development that hasn't been built yet. No one ever seems to blame their own development where they live or that they helped build."

One land owner/developer stated, "Years ago I was concerned about the open space requirement for development but I now understand its value to the community and I support that requirement now."

A few interviewees stated that finding places for development and growth in a very built environment while also protecting the stream was a difficult challenge. One of these stated the need to meet all goals and requirements of the watershed including water quality and economic growth.

Local Policy

A few interviewees stated local policies were not strong enough to protect water quality. One respondent stated local policy on development issues was purposefully confusing. Another respondent said stormwater policy was too restrictive and didn't allow for creativity. A number of interviewees said local policy is touted as very pro-environment, when in fact they thought it was not as good as it could be. The Orange County erosion control program was mentioned as good for the county, but that it didn't work for Carrboro and Chapel Hill, and the University didn't have to follow it.

Two respondents stated the redevelopment rules are so restrictive that current non-conforming uses of land would remain because it is too costly to redevelop to a better use.

One respondent stated developers are unfairly singled out because even though current agricultural and residential development causes more problems overall, government can't force them to do anything.

Several interviewees stated that all costs should be considered when developing policy, including the long term environmental costs to the local economy both positive and negative.

Local Government

Some citizens said they would like to have more face time with local government staff regarding Bolin Creek, while local government staff expressed that it was getting more

difficult to spend large quantities of time on duties specific to Bolin Creek in the face of declining budgets and increasing stormwater management responsibilities attached to the new Jordan Lake Rules.

Some interviewees stated that municipal governments need to communicate and coordinate better, both internally and externally. Some citizens praised local government staff themselves for their expertise and ability, but found local government bureaucracy confusing.

One citizen stated that some issues are so sensitive the towns' staffs have trouble working on them because they become political issues, such as abandoned storage tanks, old dry cleaners sites, and old heating oil tanks. A couple citizens are worried that staff may be restricted from making innovative positive changes without support from above. Another citizen stated a reluctance of the towns to look at some issues.

It was noted that the management of Bolin Creek is different between Chapel Hill and Carrboro, which is the norm for many neighboring communities, but maybe it doesn't have to be. The Jordan lake rules will be an opportunity to shine or fail. One citizen said town staff is instrumental in protecting water quality because of the things they do, and congratulated them on working so diligently. Another citizen said stormwater issues need to be a part of everything the town does in the watershed.

Several interviewees noted that OWASA is a quasi-government agency that needs to both be involved in decision making and take responsibility for helping to meet community needs.

Greenway / Carolina North Forest /OWASA Corridor / Transportation

Some respondents worry that the OWASA sewer line and access road through the Carolina North Forest contributes to stream impairment; others feel the causes are from the headwaters upstream. One respondent said the OWASA easement is not a significant sediment source and paving the greenway is not a water quality issue. Another respondent stated the easement has negative side effects when located near a stream. Many voiced disagreement over paving a potential Bolin Creek greenway trail through the Carolina North Forest versus leaving it unpaved, as well as which of these options would be more damaging to the stream. Quotes about this issue included: "[It] is so polarizing it divided the community," "people lost friendships," and "it got ugly." One interviewee mentioned the need for discussing matters like "BMP retrofits - that may be more important to the creek" than whether the greenway is paved or not. A few interviewees offered that others don't prioritize supporting full accessibility by all, which would require meeting the Americans with Disability Act standards. A non-runner stated runners don't want the trail paved. A non-mountain biker stated the mountain bikers don't care if it is paved or not since they use other trails. One respondent noted that avoiding damage is good for everyone because damage requires remediation which could impact future use and access. One interviewee stated that people of other interests groups that he is not a part of are well intentioned but may not understand ecology.

Using the trail as a paved non-motorized transportation corridor was mentioned as a need by a number of respondents. Alternately, a number of respondents cited other roads and corridors that could be used for non-motorized transportation. Commuter safety is a

concern, as well as neighborhood connectivity. Some bicyclists interviewed feel strongly that the alternate routes offered are dangerous. A few respondents suggested that adjacent residents don't want to see changes in their own "backyard."

Some people expressed different aesthetic preferences for greenways. One respondent said the Chapel Hill Greenway is ugly, while another said it is beautiful.

Trails through Carolina North property which are not near the stream were also named as contributing to degradation, as well as dog waste, user defined trails, and trails crossing perennial and intermittent tributaries. A few respondents, including some mountain bikers, mentioned the need for a master plan or land management plan for Carolina North Forest.

We were told the Adams Tract, owned by Carrboro, was slated to hold a greenway connection. We were also told it has restrictions in place for bicycles, and another respondent said the restrictions are for paving and automobiles. Several respondents mentioned the importance of another privately owned undeveloped tract, as a key piece of land for connectivity of a trail along Bolin Creek.

The Carolina North development planned by UNC-Chapel Hill was mentioned by several interviewees. Some concern was expressed about the potential impacts on water quality. Many stated that only a small portion of the actual tract planned for development drains into the Bolin Creek watershed, though there were concerns about where infrastructure, such as utilities, would be allowed. Some mentioned they were pleased that a large portion of land would be set aside and left undeveloped and felt UNC could set a good example for how to develop and protect the creek.

Communication / Collaboration

One respondent stated certain "environmental interests groups have become alienated from the general public and they don't seem to care. Maybe since they've been beaten on for so long they don't know how else to function. They are just used to the uphill battle."

Another respondent said local "public involvement isn't always done so well, there isn't as much communication about how decisions will be or were made."

A number of interviewees stated their willingness to collaborate and work together to improve the creek.

A few respondents noted that the paving conflict (in the Carrboro section of the Carolina North Forest) has been the context for discussing anything to do with the creek for almost two years. Another stated, "people become so focused on the negative" and "when there is this conflict, it makes it hard to move positive things forward." One interviewee asked "how can we engage one another in a positive way", while another said we "want a happy community."

Landfill, Illegal dumpsites, and Groundwater Contamination

A few interviewees noted concern about groundwater contamination coming from the legal landfill, illegal dumpsites, and underground storage tanks (USTs). We were told a local

citizen group has located 42 illegal dumpsites within a ¾ mile radius of Rogers Road. In addition, the group conducted soil and water sampling on its own as well as with Orange County staff and presented the results to the Towns of Carrboro and Chapel Hill. We were told the health department found MTBE in the wells on Rogers Road, but there was some disagreement on the actual sources. Local government staff reported that DENR is currently monitoring two groundwater plumes of dry cleaner solvent and that town staff have also located many legal and illegal dumpsites in the Bolin Creek watershed, outside of the Rogers - Eubanks area.

Hydrology

Several respondents noted flooding in the lower watershed, mainly at businesses along the creek. One interviewee said cars get submerged about once a year and the force is enough to damage nearby condominiums. Another interviewee noted there was development in the floodplain, such as University Mall and a number of apartments. Flooding was blamed on upstream impervious surface, building in the floodplain, beaver activity, and vegetation in the stream corridor. One respondent told us some of this development is in the FEMA floodplain which is defined as an area with 1% or greater annual chance of flooding, as compared to the "natural floodplain" which extends much further and is rarely flooded.

Stormwater was mentioned as causing noticeable erosion problems, including undercutting tree roots. One respondent said it has been getting worse over time. Another said stormwater "shoot[s] like a water cannon out of the storm drain pipes into the buffer and creek." Local government staff notified us that changes in stormwater (amounts and timing) were identified by Earth Tech, 2003 DWQ report, and government staff as causing considerable changes in channel morphology (shape) including severe streambank and streambed erosion.

A few respondents noted the lack of water in the creek. One said that when it rains, the water is gone the next day. A few also mentioned that increased development was to blame for the lack of groundwater recharge and lower stream levels. One person mentioned how the lack of water affects everything living in the watershed: plants, people, animals, and insects. One interviewee said the upper watershed has creeks drying up but she doesn't know why.

Water Quality

One respondent said, "there has been no progress cleaning up the creek." Water quality issues mentioned include: sediment, erosion, fertilizer, pesticide, runoff, trash, sewage, nutrients, petroleum products, and chemicals used by households and businesses. One interviewee stated, "the tools we have to protect and improve water quality are not necessarily the best for the job, but they are what policy allows." Another respondent noted, "having clean water is a responsibility that society should provide." A mountain biker expressed concern about damage to the creek.

Interviewees provided many reasons for the cause of water quality problems. The following were listed by different respondents as causes of water quality degradation: the upper watershed, upstream construction and future runoff from development, OWASA water main breaks, house painters cleaning their paint brushes in the creek, development

channeling runoff into the creek, lawn fertilizing, and stormwater runoff, specifically from impervious surfaces.

Concerning human contact with the water, the following was noted from several interviewees: "Bolin Creek is dirty, filthy. I wouldn't let my kids play in it. I see kids in it all the time. It is pretty, so there is a perception of cleanliness, but I wouldn't drink from it. I wouldn't let my kids play in although now that I think about it, I do let them play in it - they turn over rocks and find crayfish."

C. Data Needs

When asked what information to collect to determine the health of Bolin Creek, respondents' answers ranged from general water monitoring to specific examples such as fecal coliform; biological data; regular monitoring of invertebrates and fish; an inventory of reptile, bird, and mammal species; stream flow and stormwater discharges; nitrogen; phosphorus; total solids; sediment; turbidity; pesticides; herbicides; fertilizers; hydrocarbons; caffeine (to detect sewage spills); population density; impervious surface density; and groundwater and soil testing to determine contamination from illegal dump sites.

Numerous participants mentioned the need for benthic or macro-invertebrate monitoring. Some people commented that this data is already collected by the Towns, the Haw River Assembly and the Friends of Bolin Creek. Several mentioned a need to increase the frequency of benthic monitoring and to expand monitoring to tributaries in addition to the main stem of Bolin Creek. We heard that increasing benthic monitoring in the same place more frequently than quarterly may damage the benthic population. One participant mentioned that the NC DWQ has fish monitoring sites on Bolin Creek. Another wanted to identify champion species throughout the Bolin Creek watershed, so people would know what they were preserving. One interviewee told us they heard creek monitoring had been temporarily halted.

Respondents use the following sources to get information about Bolin Creek. (Numbers in parentheses indicate how many interviewees cited that source.)

- local government employees (14)
- local newspapers (11) including Chapel Hill News, Herald Sun, Independent
- Bolin Creek itself (8)
- Friends of Bolin Creek (8)
- through work (7)
- local government websites (4)
- other websites (3)
- NCDENR/DWQ (4)
- existing studies (3)
- word of mouth (2)
- emails (2)
- neighborhood listserv (1)
- Haw River Assembly (1)
- monitoring results (1)
- NC State University (1)
- UNC Advisory Board (1)
- UNC Campus "Drains to Creek" signs (1)

Another recurring theme was the desire for stream flow data, or the amount of water flowing in Bolin Creek, the "missing piece" as one person put it. One respondent had checked into the feasibility of installing US Geological Survey water quality and stream flow monitoring stations, but found them to be cost prohibitive. Another commented that stream flow was easy to measure and they would love to see it happen. More than one respondent recommended developing a hydrograph for the Bolin Creek watershed, both as it exists and then using it to model stream flow by assuming development of the upper watershed. One interviewee wanted to see real time monitoring of several parameters and offered to build sensors for wireless pickup or data download. Town staff commented that they are limited by the requirement of standardized methods of data collection and very specific data quality requirements. People generally felt the need to determine the cause of the biological impairment and the location of pollutant sources. Specific suggestions included determining the source of sediment in Bolin Creek, identifying sources of erosion (from development, streambanks, or recreational trails), studying the impact of construction sites, identifying points of entry for private stormwater connections, identifying stream crossings that impede aquatic life, and identifying areas where pet waste is an issue.

> "This corridor has been studied six ways from Sunday. It's been multidisciplinary . . . They issue reports but there is not any one clearinghouse where you can go and look at everything. There is a lot to collect without reinventing the wheel, [before] commissioning a new study."

Several respondents said a lot was already being done to determine the health of Bolin Creek, but the information wasn't easy to access, such as the existing benthic monitoring by the Towns, the Haw River Assembly and the Friends of Bolin Creek. One participant said that every major tributary and the main stem of Bolin Creek were walked in 2007 and 2008 as part of a detailed assessment of stream reaches to identify areas of erosion, instability, and other high risk locations (Earth Tech, 2007). Several respondents did not know where to access information on Bolin Creek.

D. Participants' Ideas for Solutions

In answer to the question of what can and should be done regarding Bolin Creek, many respondents brought up the need for education and outreach to develop greater community awareness. One respondent pointed out that the majority of watershed residents are not adjacent to creeks and do not understand how individual behaviors contribute to the health of Bolin Creek. Other respondents suggested specific audiences and educational messages. Target audiences included homeowners, HOAs, urban property owners, recreationists, lawn and landscape management companies, construction professionals, developers, OWASA, and the public in general.

> "We, the whole group of involved people, have to examine this all in detail so it isn't causing the divisions that it is causing now".

Possible educational topics included watershed management, pollution prevention, ephemeral streams, wildlife and plants, stormwater and runoff management practices such as rain gardens, erosion and sediment control, landscaping practices, and dog waste management. Specific outreach activities suggested include a stream steward award program, regular emails and quarterly workshops to inform the community about progress, bike and trail maps, partnering with new library and with schools (particularly Seawell Elementary, Smith Middle, and Chapel Hill High). Other outreach ideas include events to get people out into the creek corridor, such as festivals, foot races, litter removal, invasive plant removal, and student and community service projects.

Summarizing outreach strategies that will effectively get more people on board, one citizen recommended positive approaches that make people happy rather than scare tactics, providing the positive example of helping to engage people outdoors with their children.

> "One of the great things I hope that comes out of this interview process is a way for us all to work together and take clear steps that we all know about".

Many respondents also recommended implementing stormwater best management practices (BMPs) in the Bolin Creek watershed. Since much of the watershed is already developed, retrofit projects such as rain gardens or cisterns that capture and hold excess stormwater on-site were suggested. One respondent noted the previously identified BMPs in the Earth Tech study and suggested the towns seek funds to construct these or determine a prioritization. Municipal employees suggested retrofitting and improving stormwater management on Town owned properties, and creating a regional stormwater pond for Tanyard Branch, which receives the stormwater runoff from downtown Chapel Hill. One respondent mentioned the need for highly visible stormwater management and stream restoration projects so people can see, touch, feel, and understand where their stormwater money is going. The benefit of visible projects was further validated by a person who recommended stream restorations "like the one the [Clean Water Management Trust Fund] is doing on the tributary I live on". Many commented that a few BMPs weren't going to restore the watershed, but using those projects to educate and recruit greater participation would help with long-term restoration. Two respondents from separate government agencies suggested dealing with limited resources by conducting hydrologic modeling to determine where stormwater management practices will have the most effect and using the results to prioritize the implementation list. Another said start with the headwaters and work downstream. Regarding the headwaters, fencing livestock out of the stream was suggested. Upstream health was noted as important to the success of downstream restoration and biological recolonization. This interviewee suggested protecting the creek from further degradation was a necessary step before beginning restoration.

A wide range of respondents had ideas on ways to improve stormwater management through policy and incentives. A couple respondents suggested giving grants for residential rain gardens. Other suggestions included stricter controls on future development than currently exist to ensure that Bolin Creek is protected; better land use planning; and better enforcement of existing environmental regulations. A resident in the upper watershed recommended placing restrictions on how the remaining undeveloped areas are managed. He gave the example of a hardwood forest near Jones Creek that was recently clear cut and wondered what the impact would be to Bolin Creek. Two respondents voiced a need for

assistance for businesses and small businesses without engaging the regulator (i.e. education and help creating stormwater management plans).

Several respondents mentioned the importance of preserving stream buffers. A municipal employee, a county employee and two residents advocated for land purchase and land conservation, particularly along stream corridors and other locations the community determines are most valuable to preserve. One respondent said we need to actively mitigate the effects of OWASA easements within the riparian zone, and thought the work OWASA was doing to move the sewer line away from Bolin Creek near Umstead Road was an excellent start. Several respondents suggested invasive species control and two suggested water quality monitoring. In addition, several respondents expressed the need to development a master plan on trails and a forest management/conservation plan for the Carolina North Forest and the Adams Tract.

> "Bolin Creek and [stormwater] runoff is not on anyone's radar, so an education program about what is wrong and why, would be good."

Respondents had a lot to say regarding the need for a common plan of action and increased communication and collaboration among stakeholders. A watershed restoration plan is being developed by the BCWRT as a requirement of existing 319 grants. At least one respondent expressed a wish for more communication and discussion surrounding the plan. In addition, there is a desire by stakeholders to work together and come up with a vision for improving the creek and a common action plan with clear steps that everyone can learn about. One respondent mentioned the need for a non-political resource center for Bolin Creek, as well as the possibility of a non-political website for Bolin Creek. At least two respondents recommended having a watershed coordinator that was independent of the towns. In general, there was a perceived need to "ramp up the stakeholder process". One suggestion was to hold a public meeting once this report was together to let people know about the problems and hopefully get more stakeholders involved. One interviewee noted the need to plan holistically across all the land tracts in question.

Interestingly, several respondents talked mostly of the controversy of constructing a paved greenway along the streamside sewer easement in the Carolina North Forest and the land entering Carrboro. No matter which side of the issue the stakeholders are on, there is consensus that it has been an extremely divisive issue in the watershed.

All interviewees responded with potential solutions except one who stated, "I don't know what the problems are".

What Can be Accomplished Together?

When asked this specifically, respondents created a large list of what they could potentially accomplish together. Two stakeholders envisioned Bolin Creek as a unifying feature of the community- one that could help energize and bring people together, while another suggested the community could enjoy features of the creek, together.

Possibilities include open communication among stakeholders and elected officials and improved coordination between them. The idea of developing common goals and objectives

between Carrboro, Chapel Hill, UNC and stakeholders was repeated. A few people suggested community planning for an open space plan, a Carolina North Forest Management plan, and greenway planning. One mentioned the benefit of increased funds for grant matching through collaboration, and increased likelihood of receiving grants. Greater oversight of development resulting in better enforcement of regulations such as sedimentation and erosion control was mentioned.

Many said that working together can accomplish the long term goals of improved water quality, healthy aquatic community, and biological diversity. Many saw possibilities for implementing projects to improve water quality and other valued services, similar to those mentioned in the previous section (i.e. reducing the impact of dog waste, riparian reforestation, stream restoration, open space conservation, Rogers Road residents removed from septic and wells, trails are improved through partnership, public access for non-motorized use, transportation corridors improved, and illicit discharges and trash in the creek eliminated).

E. Current Local Initiatives

There are an impressive number of initiatives already going on within the Bolin Creek watershed related to water resources. Respondents told us about the following. There are likely other initiatives occurring that were not captured through our interviews.

Towns of Carrboro and Chapel Hill

- Both participate on the Bolin Creek Watershed Restoration Team: help develop a watershed restoration plan; implement stream restoration and stormwater BMP retrofit projects; pursue grants and other resources; conduct stream monitoring with the end goal of restoring Bolin Creek's biological health.
- Both have Phase II NPDES Permits which steer stormwater management activities.
- Both are implementing the Jordan Lake Rules (i.e. updating land use ordinances, planning for retrofits of existing development, etc.).
- Both undertake many forms of municipal work that help protect water resources, land acquisition and management, trail maintenance and management, street sweeping and maintenance, stormwater system inspections and maintenance, stream restoration activities , stormwater management activities, environmental education to public and schools, community environmental organization such as Big Sweep clean ups, illicit discharges education, clean-up of spills in cooperation with OWASA.
- Both have citizen based Greenways Commissions, Environmental Advisory Boards, Planning Boards, etc. which make recommendations to elected officials.
- Chapel Hill created a Stormwater Management Utility in 2004 to fund stormwater BMP projects, stream restoration projects and environmental education.

Orange County

- Acquires land for parks, open space, farmland preservation, water quality protection, etc. through the Lands Legacy Program. Bolin Creek and land

conservation along Bolin Creek is in Orange County's Conservation Action Plan. Holds conservations easements, leverages funds with other organizations like the Triangle Land Conservancy (TLC).

- Operates and maintains the Jones Creek Greenway. Developing and operating a 193 acre park and educational campus in the upper watershed, 95 acres of future parkland and 96 acres of school sites. Pursuing environmentally friendly design.
- Conducts environmental education programming.
- Does stream restoration and pond restoration. Looking at downstream impacts of removing some of the farm ponds in the watershed.
- **Cooperative Extension Service** provides research based information to citizens through educational programs, publications and events.
- **Soil and Water Conservation District (SWCD)** assists rural landowners with erosion problems, streambank stabilization, and agricultural BMPs; has limited cost sharing resource for urban BMPs through the NC Community Conservation Assistance Program (NCCAP). Closes abandoned wells.
- **OWASA** (Orange County Water and Sewer Authority) maintains existing sewer lines and infrastructure. OWASA recently installed a new sewer line under Umstead Road between MLK Jr. Blvd. and Estes Road Extension to replace an undersized sewer line that ran along Bolin Creek.

State Agencies

- **NCDOT** (NC Department of Transportation) oversees construction, operation, and maintenance of state maintained roads in the watershed.
- **NCDWQ** (NC Division of Water Quality)advises Towns on restoration efforts. Helps identify and meet needs. Helps identify and write grants for restoration activities.
- **NCEEP** (NC Ecosystem Enhancement Program) developed a local watershed plan for Morgan and Little Creeks, which included Bolin and Booker Creeks (TetraTech, 2004).
- **University of NC-Chapel Hill**
  - Developed a stormwater master plan in 2009. Has 6.5 people working in stormwater. Has a Phase II NPDES permit. Finds and fixes broken sewer lines through its illicit discharge program.
  - Plans to construct stormwater BMP retrofits when Carolina North is developed.
  - Is establishing conservation area in perpetuity in parts of the Carolina North property. Hired staff to help conserve, manage and protect the Carolina North Forest.
  - Is working on implementing the Jordan Lake Rules.
  - Helps towns with illicit discharge education and prevention.

Private Entities, Nonprofits, Community Groups

- **Business Leadership Organizations**: Help members understand stormwater regulations. Many area businesses use the Green Plus assessment tool, www.gogreenplus.org, which factors in water consumption and conservation as criteria. Help towns with illicit discharge education and prevention.
- **Friends of Bolin Creek (FOBC)**: Advocates to protect and improve the creeks within the Bolin Creek watershed. Works with the schools, community members, utilities and government to improve water quality in the watershed. Active

programs include a Healthy Watersheds Symposium, monitoring program, online library of scientific studies, and education through the schools, including McDougle Middle School Rain Garden.

- **Save Bolin Creek**: Advocates for not paving the trail along Bolin Creek north of Carrboro.
- **Advocates for Carrboro Greenways:** Adopted objectives include: protect and improve water quality along Bolin and Jones Creeks; protect, conserve wildlife habitat in the Bolin Creek watershed; connect surrounding land by providing a non-motorized mode of transportation; provide safe access to Bolin and Jones Creeks; enhance the quality of life by providing a recreational facility for all citizens of Carrboro, specifically including the elderly and disabled who are excluded by the current OWASA roadway.
- **Haw River Assembly (HRA)**: Conducts benthic monitoring in the watershed. Assists FOBC with outreach and education programs. Previously organized Muddy Water Watch program.
- **Orange/Chatham Sierra Club**: Has been removing invasive plants for nine years.
- **Triangle Off Road Cyclists (TORC)**: Holds Memorandum of Understanding (MOU) with UNC to help maintain and manage trails in the Carolina North Forest and beyond.
- **Landowners**: Entered into conservation easements in the headwaters and allow use of the land by permission. **The Lloyd-Andrews Historic Homestead** in the headwaters includes 121 acres (Triangle Land Conservancy conservation),
- **Farmers:** studying and implementing sustainable agricultural practices, including no-till and raising grass fed cattle.
- **The N.C. Wildlife Resources Commission**: provides the Green Growth Toolbox, a guide for counties, towns, and cities with tools for nature friendly growth. [http://www.ncwildlife.org/greengrowth] Also has a Wildlife Friendly Development certification program in coordination with the NC Wildlife Federation and the NC Chapter of the American Landscape Architects. [http://ncwildcertify.org/index.htm]
- **Colonial Heights Neighborhood:** on-going debate on whether to put up a conservation district for the neighborhood.
- **Pacifica Neighborhood: W**orks with NC State University to monitor runoff from their neighborhood and help evaluate low impact design practices.
- **Roger-Eubanks Neighborhood**: Located illegal dumpsites and organized a cleanup. Collected over 2,000 pounds of trash in their first cleanup. Working with Orange County to organize future cleanups. Hold workshops and tours at the Rogers-Eubanks Neighborhood Association's Center.
- **Talbryn Development:** has 135 acres protected by covenants.
- **Orange County Justice United in Community Effort (JUSTICE UNITED)**: A broad-based, multi-racial, multi-faith, multi-issue, strictly non-partisan citizens' power organization dedicated to making change on social justice issues provided support to the landfill and dumping issues in the Rogers Road Neighborhood.

F. Community Strengths

Progress in Bolin Creek

When asked what progress has been made in Bolin Creek, many respondents immediately thought about stream health and water quality, commenting that improvements have yet to be seen. When the interviewer explained that progress could mean anything, most respondents gave other examples.

Some responses focused on public awareness of Bolin Creek, education that is occurring, and the increase in relationships between stakeholders. A few discussed citizen involvement as a sign of progress, including stream litter clean-ups. A few responses pointed to studies that have been completed, including the local watershed plan developed by NC Ecosystem Enhancement Program.

Participants mentioned tangible projects as signs of progress including the opportunities created by Chapel Hill, Carrboro, and the Friends of Bolin Creek. It was mentioned that specific projects, including the Baldwin Park stream restoration and the McDougle School rain garden and cistern can be used for education and positive publicity. Other projects showing progress include invasive plant removal, the greenway constructed in Chapel Hill, increased recreational access, farmers moving to no till pasture instead of row crops in the headwaters, trail and road improvements and maintenance conducted by UNC-CH and Triangle Off-Road Cyclists (TORC) to reduce sediment in Carolina North forest, as well as sewer improvements on Umstead Road by OWASA.

Improvements in regulations were mentioned as signs of progress, with specific mention of stricter regulations in Carrboro (BMP requirements, stream buffers, open space, and stormwater ordinances), and Chapel Hill (stream buffers, stormwater, and erosion control). One mentioned that these helped to slow the decline in water quality.

Conservation of land was mentioned as progress, including the large conservation easements in the headwaters by Triangle Land Conservancy (TLC) and Orange County, Carrboro's purchase of the Adam's Tract, Chapel Hill's purchase of forested area adjacent to the creek UNC's preservation of land in the Carolina North Forest, and the protective covenants in the Talbryn development.

The issue of greenway paving was mentioned by one as an awareness-building event. One respondent noted that not adopting the paving plan was progress and gave credit to Save Bolin Creek. Setting aside this issue was mentioned as progress by another participant.

Community Resources

One of the most often heard responses to the question of what community factors have led to progress so far, was that Chapel Hill and Carrboro have an educated, motivated, environmentally aware community, evidenced by many people who actively participate in meetings for example. This response was provided by participants who represented a broad range of interests, including local government staff who appreciate active citizens' efforts in raising issues and ensuring the issues get attention. Some said that public use of

the Bolin Creek corridor and natural area increases awareness, while others mentioned educational programming has been helpful.

Some participants cited specific efforts, again the most praise went to Chapel Hill and Carrboro for providing leadership in environmental protection and initiating and implementing two EPA 319 Clean Water grants; many appreciated Friends of Bolin Creek for their role in recruiting volunteers, advocating and raising issues for consideration, and co-hosting educational demonstrations/events; Save Bolin Creek for its advocacy work; the Haw River Assembly's Muddy Water Watch for helping with erosion control enforcement; UNC-Chapel Hill for developing a Carolina North Forest trail management plan as part of a Forest Stewardship plan, hosting volunteer work days, and building a bridge over the creek that raised awareness; OWASA for trying hard to be a good environmental partner in the community; and NC Ecosystem Enhancement Program for sponsoring local watershed planning.

Some mentioned regulations and programs as factors for progress, including the Jordan Lake Rules, more stringent erosion-control measures, the Chapel Hill stormwater utility, and a general high level of environmental regulations in Chapel Hill and Carrboro. One commented that a positive aspect of the Town of Carrboro's greenway conceptual plan was that it focused people's attention on Bolin Creek.

A few people were unsure of what factors were leading to progress, as they either weren't sure of progress, or they weren't familiar enough with the watershed.

When asked what resources they or their organization could provide, almost all people interviewed stated that their organization could participate in a collaborative group. In addition, the following contributions and resources were offered by interviewees. There are likely other groups with resources to offer.

Organization	**Resources available for the Bolin Creek effort**
Advocates for Carrboro Greenways	Members who are biologist, botanists
Business leadership organizations	Staff time, outreach to members, helping people have a positive attitude about it, meeting space, information about economics & efficient stormwater management
Colonial Heights Neighborhood	Neighborhood listserv
Friends of Bolin Creek	Knowledge base of members and friends, coordinate and share technical inventory of watershed, advocate for the creek, create educational materials and conduct neighborhood education about rain gardens, host/conduct educational events
Haw River Assembly	Training for water quality monitoring, partner on grants, education and outreach to adults and children
NC Division of Water Quality	Technical assistance, sharing information between watershed partnerships in NC
NC Ecosystem Enhancement Program	Implement stream and wetland restoration projects that meet NCEEP criteria; possibly implement BMPs if state develops strategy to implement BMPs for mitigation credit.

Organization	Resources available for the Bolin Creek effort
NC Department of Transportation	For NC highway rights of ways- expertise in hydraulics, project development and analysis.
NC Wildlife Resources Commission	Green Growth Toolbox and Wildlife Friendly Certification Programs
Orange County	Staff who can evaluate biology of properties, maintain parks and greenway; funding for riparian land acquisition for stream restoration projects; ability to apply for grants that are available only to local governments.
Orange County Extension	Staff time and volunteers
Orange County Soil and Water Conservation District	Education and outreach; Potential funding for rural area BMPs to help developments over 3 years old with stormwater retrofits (CCAP program); apply for grants; share costs; experience; contacts, info.
Orange Water and Sewer Authority	Information about infrastructure, meeting space.
Professional Trailbuilders Association	Non-profit association of professional trail contractors, consultants, and designers
Roger Eubanks Neighborhood	Database of volunteers, professional partners (engineers, epidemiologists). Experience organizing stream clean-ups.
Sierra Club	Volunteer labor, invasive plant eradication program
Town of Carrboro	Education on websites and publications, targeted mailings, meeting space, help acquire grants, monitoring, implement Jordan Lake Rules, evaluate regulations
Town of Chapel Hill	Manage restoration projects, acquire and manage grants, provide education and outreach, purchase open space and easements , organize clean ups, provide recommendations on drainage and erosion problems, provide guidance on riparian improvement and protection
Triangle Off Road Cyclists	Sustainable trail design, construction, and maintenance; outreach to TORC members.
UNC-Chapel Hill	Provide technical support, access to professionals in various departments, kiosks in Carolina North Forest, organize community projects.

G. Collaborating on Solutions

Interviewees were asked to provide us with ideas about ways for people and organizations to work with each other. Several ideas emerged about collaborative partnerships, and the need for a coordinating organization. Specific suggestions included:

- Include small groups to undertake specific activities
- Create a structure for getting things done
- Set a mission and clear goals
- Identify shared motivation for success
- Include representation from the Towns, Orange County, and others
- Create a watershed group to bring organizations together

A few people suggested the use of online technology for helping work together, specifically suggesting raising funds over the web, and providing a clearinghouse for information on Bolin Creek. One stated that people are eager to use technology.

> "Give them a [way] to participate that is fun- people are really yearning for that type of stuff."

Some ways to work with people arose, including conducting community visioning for Bolin Creek, exhibiting transparency, and creative partnerships. A couple people mentioned this situation assessment as a way to help people work together. Some mentioned working through existing groups such as the Sierra Club, neighborhood associations, and Town commissions like the Greenways Commissions, possibly giving them something unique and interesting to add to their discussions. A few suggested FOBC working collaboratively with public and private entities, and expanding/bringing any divided factions back together.

Other ideas mentioned by interviewees:

- Activities initiated by Carrboro Recreation and Parks Department;
- Improve willpower for public access to creek (greenway);
- Communication and outreach concerning resource protection;
- Identify steady funding sources;
- Work together on projects to leverage resources - clean ups, stream monitoring, etc.;
- Approach private companies in return for advertising and marketing;
- Invite people to volunteer, by working in their backyards, helping with monitoring, giving them a way to help;
- Create educational forums to involve neighborhoods and HOAs;
- Bigger public meeting/forum for community;
- Festivals - use as community kick off events / hold at Umstead Park;
- Connect Chapel Hill and Carrboro Greenways, to break the artificial boundaries;
- Bolin Creek as Chapel Hill/Carrboro "Central Park";
- Build pride over Bolin Creek watershed (like historic districts do);
- Local government consortiums that meets occasionally;
- More collaboration between town departments;
- OWASA is good at getting information out in mailings;
- Carrboro should have a stormwater utility fee;
- Carrboro should make and implement plans for Jordan Lake rules;
- Engage municipal staffs to think bigger when it comes to the creek and floodplain;
- Continue with Chapel Hill's public comment/review process for plans and development review;
- Carrboro and Chapel Hill should each provide one staff member to work exclusively on Bolin Creek;
- Tighter controls are needed on design and construction of new developments to minimize pollution generation;
- Both towns need to enforce their standards and inspect for violations; and
- Friends of Bolin Creek is developing homeowner tool kits for water quality improvement, since the majority of the watershed is privately owned.

> "It is only constrained by the imagination."

A Coordinating Entity or a Collaborative Organization

Many participants suggested this option earlier in the interview without the prompting of Question 15, which asked: "How helpful would it be to have a coordinating entity or collaborative organization?"

Of 31 who answered the question, 28 said it would be helpful, with 11 qualifying that it would be very or always helpful, or extremely important, and 7 qualifying that it would only be helpful if certain conditions applied, including:

- it is not just another layer of bureaucracy;
- it is not a new entity, but one that already exists;
- the number of meetings are managed;
- somehow new people are informed as it goes;
- participating organizations are willing to give up some authority to the group;
- the goals and participants' roles are clear and agreed upon;
- a skilled mediator is involved;
- it needs to be a collaborative venue, with people willing to hear all sides;
- it has diverse representation and is not dominated by any one stakeholder group;
- it is well organized;
- if Chapel Hill, Carrboro, and Orange County would be willing to create a joint task force that meets separately from existing groups; and
- elected officials supported it.

Three of the 31 respondents answered no, stating that the pieces are already there but could be managed better by the Towns, and that the Chapel Hill Stormwater Department should already be doing this so no more taxpayers' funds should be used for it.

Additional suggestions for how a collaborative organization could work include:

> "[Bolin Creek] could be quite a unifying feature."

- an outside group with no stakeholder group affinity should coordinate;
- somebody needs to devote time to organizing it;
- the group should establish goals;
- outcomes do not bind the hands of property owners;
- existing organizational structures are explored, to prevent redundancies;
- a neutral organization creates and maintains a website to serve as a clearinghouse;
- the group includes residents beyond stakeholders adjacent to Bolin Creek and Carolina Forest;
- Friends of Bolin Creek may be able to coordinate this;
- it does not get bogged down by local politics; and
- make it fun.

IV. Discussion

In this section, the writers highlight and analyze the major issues that stakeholders raised, particularly focusing on the positive aspects of common ground on which the community can move forward.

Causes of Bolin Creek Impairment

Even among the actively involved stakeholders, we did not hear agreement nor complete understanding about the sources of Bolin Creek's impaired status. People may not have full access to available data and reports, or do have access to the information but are interpreting reports differently and independently. The technical reports completed by consultants for the NC Ecosystem Enhancement Program and the municipalities over the last nine years identify sources of impairment and potential restoration projects, stormwater retrofit projects, and policy actions for improving Bolin Creek. However, each stakeholder group has their own views of what should and should not be done to address the problems in the creek. A facilitated conversation to enable common understanding and goals among Bolin Creek watershed stakeholders would help to move the process forward. Several interview respondents suggested prioritizing restoration activities by determining "hot spot" areas of hydrologic changes and pollution. This would be a worthwhile effort, if results are shared with and reviewed by the broad range of stakeholder groups, and not just the Bolin Creek Watershed Restoration Team. The community needs to be engaged to provide feedback on the criteria used to select restoration activities.

Carolina North Forest

We heard consensus that the Carolina North Forest area is seen as an oasis by the community, though it is seen through different lenses. It is viewed as both degraded AND beautiful, and is highly used in multiple ways by the community. Many adjacent residents see it perfect as is, without need of improvement, while others see signs of degradation that can be improved upon. This latter group includes residents who live further away but actively use it for recreation. People hold various visions for this area, based on their use and interest. It would be an interesting exercise to allow users a forum to express their vision, and seek common ground. They may have more in common than they realize, as none of them want to see the area developed.

Town of Carrboro Greenway

We were told that the issue of extending Carrboro's greenway along the OWASA corridor through Carolina North Forest has diverted energy and resources from multiple groups and individuals. We did not ask people about the greenway issue; they brought it up. When the Town of Carrboro's greenway planning process raised the possibility of extending a paved greenway along the OWASA corridor through Carolina North Forest and on towards Chapel Hill, many concerns and opinions were expressed. During public meetings and online forums, the issue became framed in the community as "to pave" or "not to pave", resulting in opposing positions. Some feel that Carrboro's decision of 'not making a final decision' on the greenway through the Carolina North property is a positive result; others feel their interests regarding this issue are not being met. We heard a strong desire from the community to focus on positive issues and to heal wounds that arose from this divisive

issue. We believe this is possible through facilitated community discussion and collaborative decision making. Providing an opportunity for citizens to discuss the interests (the reasons why) behind the positions (to pave or not to pave) in a facilitated group process may help community members find creative long-term solutions to meet those interests. Interests we heard include improving the creek and the riparian corridor to better meet water quality and habitat needs; providing a natural recreational experience; providing safe and convenient pedestrian and cyclist connections; and providing citizens of all abilities with access to natural areas.

Development

The middle and lower portion of the watershed is developed and was constructed mainly before stormwater regulations were in effect. The upper portion of the watershed still has development potential. A previous regional agreement between local governments, the Orange County -Chapel Hill - Carrboro Joint Planning Agreement, channeled development to agricultural areas of the Bolin Creek headwaters in an effort to limit development in adjacent drinking water supply watersheds (Morgan Creek and University Lake). This trade-off from many years ago is seen by some as unwise now. The growing population's need for water may require OWASA to draw from Jordan Lake, which is downstream of Bolin Creek. A regional view of watershed management in outreach efforts could help the community understand the trade-offs made and discuss where they want development and open space conservation to occur. Nobody interviewed stated a desire to stop development, though many stated a desire for development that provides fewer impacts to water resources.

Many commented that development, stormwater and erosion and sediment control ordinances are much improved from the past, though a few commented that they could possibly be more stringent, and more commented that improved enforcement of existing regulations would be helpful.

We heard concerns that inflexible stormwater regulations may be limiting redevelopment in urban areas, and thus preventing the implementation of accompanying retrofits that may benefit the creek. Flexibility and predictability in stormwater regulations, as well as creative incentives for implementing retrofits, were mentioned as ways to help get stormwater runoff reduced in urban areas as redevelopment moves forward.

Education

Many interviewees stated that education was needed, necessary, and a solution to a lot of issues. There is a lot of experience and ability in the watershed, and many education initiatives taking place. There may be opportunities for collaboration and sharing of curricula between the many interest groups. Education is often an easy topic to agree upon if the outreach is science based and without value judgment.

Several people mentioned the need to educate residents and organizations about practices they could implement to improve water quality, and a few expressed frustration with the difficulty of reaching the diverse audiences. Convincing people to change their behaviors requires learning about the targeted audience, crafting an educational message or program that addresses their needs, and providing that audience access to the technical and/or

financial resources they need to enact the change. Increased successes may result from watershed stakeholders collaboratively identifying and prioritizing audiences for efforts in Bolin Creek, learning about the audiences, and working together to leverage resources in implementing educational outreach and engagement with the audiences. The County Cooperative Extension, Soil and Water Conservation District, Town of Chapel Hill, Chapel Hill-Carrboro City School system, Friends of Bolin Creek, and the Carolina Center for Educational Excellence are just some of the resources available for education outreach efforts.

Communication and Public Involvement

Many commented on the need for the local governments , OWASA and stakeholder groups to work together better, particularly including elected officials, and to collaborate on visioning and goal setting.

Most people interviewed do have the common goal of protecting Bolin Creek, but without a framework for communication and collaboration, and agreed upon common goals and objectives, one group's attempt at protecting the creek may be seen by another group as detrimental. One example is a restoration activity undertaken in the Carolina North Forest. UNC-Chapel Hill built a bridge over Bolin Creek to protect the stream from erosion, built large enough to withstand a large rain event without constricting its floodplain. Some people are happy about the bridge and how it keeps people out of the stream below, others think it is an eyesore and entirely too big. In addition, it limits access to the stream, which is "good from a conservation point of view, but bad if what you want to do is get close to the stream." Community discussion may have helped people to understand why it was so big, and that it was built to improve the stream's condition, or community input could have been solicited for the design. It is very possible that increased collaboration and agreement on common goals, and prioritized objectives to reach those goals could have resulted in a management action in the Carolina North Forest that was widely accepted as a successful step towards protecting Bolin Creek.

Many people suggested without being prompted that improved coordination by a non-biased third party was necessary for successful long-term watershed improvement. When we did ask interviewees if they thought a coordinating entity and collaborative organization would be helpful, they overwhelmingly responded "yes". A few people thought that coordination of all watershed activities should be the responsibility of the municipalities, particularly the Town of Chapel Hill since they have a stormwater utility. We heard that the broad responsibilities of addressing environmental issues, and the new responsibilities of implementing the Jordan Lake Rules, limit the time and resources that staff can contribute to comprehensive public involvement strategies that the public desires for Bolin Creek. This may be interpreted as a lack of interest, but in reality they are seeking ways to meet the needs and requirements of supervisors, elected officials, and citizens. Staff approved this situation assessment as a means for learning how to improve public involvement and outreach, and appear quite willing to find new ways to improve Bolin Creek efforts.

In addition, the towns are not seen by all stakeholders as neutral and non-biased in the watershed effort- the towns have their own goals and responsibilities that they must pursue, as do all of the stakeholder organizations who were interviewed.

Efforts and Resources Among Groups in the Bolin Creek Watershed

We were impressed by the number of activities groups are undertaking to improve watershed conditions, and the energy buzzing in the community. Many groups are working independently, some are partnering on projects. There are "unlimited" opportunities to communicate and leverage better, we were told, and most people interviewed expressed a desire to communicate and work together better. The resource table shows a broad array of resources that groups are ready and willing to contribute, and many are already contributing them. There are many other groups that likely have similar resources they may be willing to contribute. For example, we only interviewed residents from a handful of neighborhoods, representing a small portion of the watershed. Targeted efforts to reach other neighborhoods will unveil new networks of potential collaborators and other resources including listservs, project sites, and volunteers.

Most people interviewed acknowledged the positive roles and hard work of municipalities, the Friends of Bolin Creek, and other groups towards improving Bolin Creek. While improvements in the water quality, habitat and hydrology of the creek itself have not been seen, that is to be expected in an impaired urban watershed restoration project. The interim successes are visible - grant funds have been acquired, educational efforts have yielded segments of the population who are eager to participate in restoration activities, high-profile demonstration projects have been installed, and much data on Bolin Creek has been collected and analyzed. Current grants end soon, and the time is ripe for celebrating these successes and moving to the next, higher level of restoration activities together.

The pieces for a foundation of successful long-term watershed restoration are present in this engaged Bolin Creek watershed community. To leverage on the progress made by members of the community so far, we present our recommendations here for creating the final pieces of the foundation of long term success- the collaborative Bolin Creek watershed community.

Landfill and Groundwater Contamination in the Roger-Eubanks Community

While the landfill is outside of the Bolin Creek watershed, the Rogers-Eubanks Neighborhood is a stakeholder group largely within the watershed. At the time of the interviews, the perceived lack of action regarding previously promised remediation appeared to impede water quality restoration and outreach efforts in the Rogers Road area. Until this issue is addressed, the community's attention and energy may be required to resolve it, not allowing them to focus as much time on restoration activities. Since the interviews, the Orange County Board of Commissioners, Chapel Hill Town Council, Carrboro Board of Aldermen, and Hillsborough Town Board agreed to create a task force to decide how the Rogers -Eubanks neighborhoods will be compensated for living next to the Orange County landfill for the past 40 years. This agreement took place on January 26, 2012 at an Assembly of Governments meeting. The task force consists of two representatives from each municipality, two county commissioners, and two members of the Rogers-Eubanks Neighborhood Association (RENA). The task force will explore plans and costs for the community center and sewer lines requested by RENA, and present its finding to the governing boards at the end of the year.

V. Recommendations

Stakeholders pointed out a real opportunity to focus on Bolin Creek as a synergizing community feature. Many people experience and care about the creek and particularly, the Carolina North Forest and Adams Tract sections. With this in mind, we propose all activities focus on positive attributes within the community, further building on the strengths of Bolin Creek community network and successes. We make the following recommendations to build more networks, create more linkages, and design a lasting communication and coordination structure to steward long-term watershed restoration. The recommendations are for the Bolin Creek Watershed Restoration Team (BCWRT) and all organizations affected by or responsible for management decisions in the watershed, including all local governments and OWASA.

> What do we mean by collaboration?
>
> Collaboration is a process of shared decision-making in which all the parties with a stake in a problem constructively explore their differences and develop a joint strategy for action.
>
> - Scott London, Collaboration and Community

The recommendations do not spell out the action items needed to implement them because implementation can take many forms. A number of the recommendations require public involvement. We suggest following the Core Values for Public Involvement of the International Association of Public Participation. These values, also followed by the US EPA, set out a guideline or best management practice for involving the public. See Appendix 4.

The recommendations address a broad range of interests. Increased efforts to address these diverse interests will help expand community involvement and support of watershed restoration activities. Whether or not these interests appear to be directly related to water quality and restoration, they invite multiple interests in community planning and land management to find creative and long-lasting watershed restoration solutions.

A. Create a multi-organizational, collaborative watershed initiative to serve as the nexus for the watershed. This Bolin Creek Watershed Initiative can use the principles listed here.

- The Initiative is inclusive of all groups, governmental entities, and neighborhoods that are interested in participating.
- Responsibility for the Initiative is shared - no one group with a stake in the Bolin Creek watershed is “in charge”.
- To begin, BCWRT can engage an entity with no vested interest in the watershed to coordinate and facilitate the Group (WECO, TJCOG, Dispute Settlement Center of Orange County are organizations who regularly do this work).
- The Initiative uses consensus based decision making rather than voting. This allows all stakeholder groups to be heard, and enables finding creative solutions to meet multiple groups’ goals.

- The Initiative focuses on positive attributes in the community, on creative possibilities for the future, on success in the watershed.

Participants need to undertake the following activities:

- Learn consensus decision-making skills.

  (Natural Resource Leadership Institute, WECO, UNC-CH School of Government, and Dispute Settlement Center of Orange County are all qualified to teach these skills.)

- Share their visions and develop a commonly defined vision for Bolin Creek watershed. A public kick-off meeting would be ideal for this exercise.
- Review existing plans and reports for Bolin Creek watershed.

  (A watershed plan is required by the EPA and is currently being drafted by Carrboro and Chapel Hill. Watershed plans are dynamic documents that change as new information or new stakeholders are discovered.)

- Develop and agree upon a set of goals and objectives for the Initiative to support.

  (To prevent "meeting fatigue", after developing a vision and goals, the Initiative could meet annually or bi-annually, and split out into working committees to address specific topics.)

- Form workgroups to develop plans for the following topics:
  - education and outreach;
  - restoration/ stormwater retrofit planning and implementation;
  - monitoring, evaluation, and reporting;
  - watershed restoration finance

B. Enlist a neutral party to develop and actively manage an interactive online hub for the watershed community. This online hub needs to:

- house links to all stakeholder organization websites, reports, data, and relevant documents;
- have interactive features for online communication, such as a forum or other technology that allows discussion among the community;
- have the ability for stakeholders to post documents and for the watershed community to provide comments and feedback;
- allow and promote regular posting of upcoming events, including meetings and volunteer opportunities;
- provide a means for interaction between face to face meetings.

C. Examine how to more holistically plan and manage water resources across departments and jurisdictions.

Future sustainability of water calls for increased communication and coordination across local government departments, both internally (within) and externally (between). Issues of water supply, wastewater treatment, stormwater, watershed management, land use planning and zoning are all interconnected. Cooperative and collaborative relationships may require more energy and time upfront, but deliver a great return on the investment. This recommendation applies to all local governments and OWASA. Some ideas follow.

- Review policies and ordinances to assess how they can better protect water quality by using performance based standards, removing impediments to low impact design (LID), and providing incentives for LID. TJCOG conducted a policy review for member municipalities based on Center for Watershed Protection Better Site Design principles. This could be used as a basis for discussion .
- Share ideas for water resource management through interdepartmental meetings, a separately tasked committee, or by adding this topic to existing meeting agendas. The UNC Institute of Government or NC League of Municipalities may have additional resources for improving interdepartmental communication.
- An interdepartmental listserv can be used for sharing ideas and raising questions.
- Develop a regional approach to water resources management, while continuing to work together on utility infrastructure planning and maintenance.
- Hold a cross-jurisdiction discussion on the Jordan Lake Nutrient Strategy, to compare notes and determine if opportunities exist to work together.

D. Increase community outreach and engagement on the Carolina North Forest Stewardship Plan.

- Enlist UNC-Chapel Hill staff and the Carolina North Forest Advisory Committee to implement this recommendation.
- Provide opportunities for the broader community to offer input on management, conservation, restoration, trail usage, and maintenance to help increase buy-in for active personal stewardship.
- Additional educational outreach efforts, in partnership with others, could help raise awareness of the stewardship plan.

E. Investigate how to raise revenue dedicated to water quality protection and restoration, such as a stormwater utility or other mechanism.

- Enlist the Town of Carrboro to implement this recommendation.
- The investigation needs to include stakeholder feedback. The UNC Environmental Finance Center is a source for technical guidance.

F. Continue to work together to address the landfill and groundwater contamination issues in the Roger-Eubanks community.

- Enlist local governments and OWASA to implement this recommendation.
- The newly formed RENA Task Force is a positive step in moving this forward.
- All data, information, and updates on progress pertaining to the landfill remediation plans, illegal dumpsites, and contamination issues need to be available to the public in an easy to access website.
- Local governments and OWASA need to make efforts to address contamination throughout the watershed.

G. Convene a facilitated search for common understanding about ways to connect pedestrian and cyclist routes while also protecting and improving Bolin Creek's riparian corridor.

- Enlist Carrboro, Chapel Hill and UNC-CH to implement this recommendation.
- All stakeholder groups need to be represented to learn together and seek solutions to meet various interests.
- This needs to occur as a separate effort from the Watershed Initiative's efforts.
- This group needs to review existing greenway and bikeway plans, and other transportation plans, to determine any additional information needs.
- Ideally this will take place after Watershed Initiative participants have built trust and achieved some successes that they can use as examples of what can be accomplished together.

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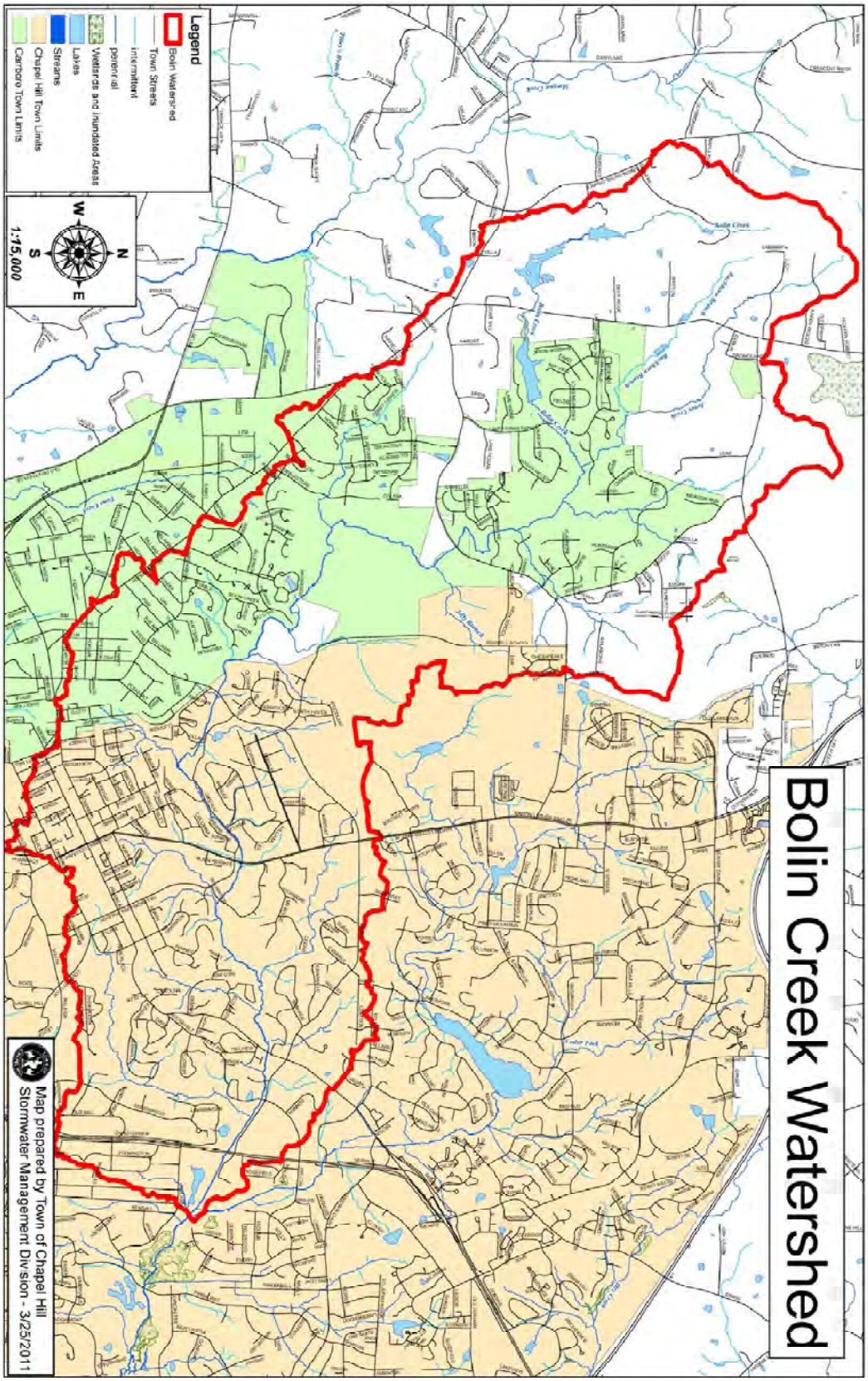
Appendix 1: Bolin Creek Watershed Map



Appendix 2: Studies conducted in the Bolin Creek watershed

[Listed in reverse chronological order.]

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Appendix 3: Bolin Creek Situation Assessment Interview Script

1. What groups or interests do you represent in the Bolin Creek watershed?
2. What activities do you participate in within the watershed?
3. What issues concern or interest you or your organization regarding Bolin Creek and its tributaries?
4. How would you characterize or describe Bolin Creek?
5. What information should be collected to determine the health/environmental quality of Bolin Creek?
6. What plans does your organization have within the Bolin Creek watershed? (recreation / growth/ development/ restoration/ education & other programs)
7. Are there any imminent changes to the watershed that you think might impact Bolin Creek, either positively or negatively?
8. What do you think can and should be done concerning Bolin Creek?
9. Where do you get information about Bolin Creek?
10. How interested would you (or your organization) be in learning about opportunities to improve Bolin Creek? Some examples: landscaping projects like rain gardens, streambank restoration, litter clean-ups, invasive vegetation removal.
11. What progress has been made in improving Bolin Creek?
12. What factors in the community have led to progress in efforts to improve Bolin Creek?
13. What could the community accomplish in the Bolin Creek Watershed if they worked together effectively?
14. What are possible ways for people and organizations to share information, leverage resources, plan and do projects together?
15. How helpful would it be to have a coordinating entity or collaborative organization?
16. What resources can you or your organization provide?
17. What about other watersheds/water bodies in the area?
18. How important is improving water quality of area creeks relative to other issues those local governments face?
19. Could we add you to our contact list for the listserv and mailings of updates?
20. Who else should we interview?
21. Before we leave, is there any other issue you want to talk about?

Appendix 4: Seven Core Values of Public Participation

As an international leader in public participation, IAP2 has developed the "IAP2 Core Values for Public Participation" for use in the development and implementation of public participation processes. These core values were developed over a two year period with broad international input to identify those aspects of public participation which cross national, cultural, and religious boundaries. The purpose of these core values is to help make better decisions which reflect the interests and concerns of potentially affected people and entities.

Core Values for the Practice of Public Participation

1. Public participation is based on the belief that those who are affected by a decision have a right to be involved in the decision-making process.
2. Public participation includes the promise that the public's contribution will influence the decision.
3. Public participation promotes sustainable decisions by recognizing and communicating the needs and interests of all participants, including decision makers.
4. Public participation seeks out and facilitates the involvement of those potentially affected by or interested in a decision.
5. Public participation seeks input from participants in designing how they participate.
6. Public participation provides participants with the information they need to participate in a meaningful way.
7. Public participation communicates to participants how their input affected the decision.

For more information, visit the IAP2 Web site at www.iap2.org.

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	comment	WECO response
1.	We do not have any records of listed fish or mussel species in Bolin Creek. However, there is a historical record (from 1980) for the state special concern four-toed salamander (Hemidactylium scutatum) in the Bolin Creek watershed. Also, there are two Significant Natural Heritage Areas in the watershed – Bolin Creek Natural Area and Battle Park.	Information was added to report.
2.	There are a couple of programs you may want to consider for the resource list. These include: The N.C. Wildlife Resources Commission's Green Growth Toolbox. The Green Growth Toolbox is a guide to provide North Carolina's counties, towns, and cities with tools for nature-friendly growth (http://216.27.39.101/greengrowth/Green_Dev_Review.htm). · The N.C. Wildlife Resources Commission, N.C. Wildlife Federation, and N.C. Chapter of the American Society of Landscape Architects' Wildlife Friendly Development Certification: This is a certification program that allows developments to be recognized as wildlife friendly after meeting sufficient criteria (http://ncwildcertify.org/index.htm).	Information was added to report.
3.	A request on page 22 to better edit the Friends of Bolin Creek description. We advocate to protect and improve the creeks within the Bolin Creek watershed. We work with the schools, community members, utilities and government to improve water quality in the watershed. Active programs include community events such as a healthy watersheds Symposium, monitoring program, on line scientific library of studies, and education through the schools, including McDougle Middle School Rain Garden.	This change was incorporated into SA report.

Recommendation A: Create a multi-organizational, collaborative watershed initiative to serve as the nexus for the watershed.

4. Re: Recommendation A

The Bolin Creek watershed has been much studied. Three major studies of water quality at Bolin Creek give us a clear idea of what the present and future threats to the creek are: stormwater runoff from existing developed areas in the watershed, which are sources of sediment, nutrients, petroleum products, and various chemicals used by households and businesses. The upper watershed is planned as an urban transition area, so the future threat is from new development and from stormwater runoff after development. The solutions are also clear: retrofit of the most serious problems in the existing developed area to reduce the flow of nutrients, sediment, and toxics into the creek. In developing areas, tight controls are needed on design and construction of new developments to minimize pollution generation. Both towns need to enforce their standards and inspect for violations. For both new and existing development, runoff peaks from impervious areas are damaging to stream stability and need to be controlled along with pollution sources. Given that much of the watershed is in private ownership, reducing non point pollution will depend partly on an education campaign to change practices of homeowners.

The stakeholders interviewed did not have a shared or commonly defined vision for the Bolin Creek watershed. Both towns reported an inability to implement several identified projects due to a lack of buy-in and cooperation from private landowners. While it is possible for an individual or a small group to come up with a scientifically sound watershed plan, it is not possible to implement it without the buy-in of stakeholders. When stakeholders and private landowners most impacted by watershed restoration plans are given a voice shaping the plan, it is much more likely to have long term participation and success. The long term benefits of this process outweigh the time and energy spent upfront.
We agree that involving homeowners through outreach will be needed. More specific feedback about engaging audiences was added under the subheading "Education" in the Discussion section.

Recommendation B: A neutral party should develop and actively manage an interactive website for the watershed community.

5. Re: Recommendation B

This goal could burn a lot of resources needlessly. It would be best for a non-profit watershed group such as Friends of Bolin Creek to take on this task. Their website already contains links to all the major studies that have been done. A product produced by a decade old non-profit group with an on-going presence in the community will be more effective than a short term product

The key is that the party be seen as neutral by fellow stakeholders. Current organizations may be able to meet the need. To ensure that a broad contingency of stakeholders will use the website, watershed stakeholders should decide together the best entity to

	produced by a contractor.	meet the need, and should have some input into what the website includes and how it is managed.

Recommendation C: Local governments should examine how to more holistically plan and manage water resources across departments and jurisdictions.

6.	Re: Recommendation C This is worthwhile goal and we fully support it. However we feel a mediated process is not the proper vehicle to bring this goal about. Local governments need to regulate or offer incentives for specific measures. For example, low impact design for new development is desirable and well known by professionals but has not been implemented in the private sector. It is unlikely in the current political climate such requirements would be put in place by local governments even if recommended. We applaud interdepartmental meetings but given local regulations don't cross municipal borders, what will ensure that joint planning goes on after a grant ends.	Intra- and inter-jurisdictional communication is key to managing water resources. Mediation was not recommended for this recommendation. Additional information in the form of a bullet was added to the recommendation. The additional bullet reads: "Local governments and OWASA could develop a regional approach to water resources management". We edited some of the explanations to make them clearer. Specific details can emerge in the implementation of this recommendation, as there are many models out there to consider, and many ways to implement it.

Recommendation D: UNC- Chapel Hill staff and the Carolina North Forest Advisory Committee should increase community outreach and engagement on the Carolina North Forest Stewardship Plan.

7.	Re: Recommendation D The UNC Forest and Trails Advisory Committee is a small one and not well known to the public. Their stated mission is to develop recreational opportunities in the Carolina North Forest and their work has focused on building new trails and making old ones more sustainable. We understand that a stewardship plan has been discussed. However, a plan has not been presented to the public nor does it appear as a public document. UNC has not developed a needed comprehensive	The term "conservation" was added in to the recommendation. It is not clear whether the stewardship plan includes this issue or not, and it is an interest we clearly heard from stakeholders. Since the Carolina North Forest Advisory Committee is helping develop the plan, our recommendation applies to them as well as UNC staff, even if it does

	Conservation Management Plan. In conjunction with the construction of the new campus, we recommend UNC develop a comprehensive Conservation Management Plan for the Carolina North Forest with lots of public input. The Carolina North Forest and Trails Advisory Committee has a narrow mandate and as such the committee doesn't have a broad enough charter or wide enough involvement to manage input from the community.	not fit under their current charter.
8.	Re: Recommendation D Carolina North Forest Advisory Committee has a narrow mandate that closely aligns with and is shaped by the University's land development plans. As such, that committee doesn't have a broad enough charter or wide enough involvement to manage a community-based outreach.	Providing opportunities for public input helps raise awareness and understanding of the Carolina North Forest Stewardship Plan and increases adherence to the plan. Since the Carolina North Forest Advisory Committee is helping develop the plan, our recommendation applies to them as well as UNC staff, even if it does not fit under their current charter.

Recommendation E: Investigate how to raise revenue dedicated to water quality protection and restoration, such as a stormwater utility or other mechanism.

Recommendation F: Continue to work together to address the landfill and groundwater contamination issues in the Roger-Eubanks community.

9.	Re: Recommendation F The landfill issues are already being addressed through a collaboration of local governments and RENA that somewhat lie outside the scope of protecting the community's watershed feeding Jordan Lake. Why not adopt a more broadly drawn charter? Suggestion, modify the language to: Local governments and OWASA would benefit from a regional approach by jointly creating a regulatory and management framework to work together to address common watershed concerns and improve the overall management of our community's watershed.	While the landfill is outside of the Bolin Creek watershed, the Rogers- Eubanks Neighborhood is a stakeholder group largely within the Bolin Creek watershed. At the time of the interviews, a perceived lack of action with regard to previously promised remediation actions appeared to impede water quality restoration and outreach efforts in the Rogers Road area. We are keeping the Roger-Eubanks Neighborhood specific

recommendations. We added a discussion section about this issue to provide updated information. We've separated into a separate bullet "Local governments and OWASA should also make efforts to address contamination throughout the watershed." We updated our recommendations and discussion in light of the newly formed RENA Task Force. Also, we are incorporating your suggestion for a broader charter (Local governments and OWASA would benefit …) into Recommendation C.

10. Re: Recommendation E and F

We fully support the creation of a Storm Water utility for the Town of Carrboro and addressing the groundwater contamination issues in the Rogers Road-Eubanks Community.

Note the landfill issues are already being addressed through a collaboration of local governments and RENA and lie outside the scope of protecting the community's watershed feeding Jordan Lake.

Suggestion, modify the language to: Local governments and OWASA would benefit from a regional approach by jointly creating a regulatory and management framework to work together to address common watershed concerns and improve the overall management of our community's watershed.

New information regarding the RENA Task Force was added to the report. A fuller response to this comment is included in item #9.

Recommendation G: Towns of Carrboro and Chapel Hill should convene a facilitated search for common understanding about how to connect Chapel Hill and Carrboro via pedestrian and cycling routes while also protecting Bolin Creek's riparian areas.

11.	Re: Recommendation G Strike "facilitated mediation on pedestrian and cycling routes while protecting riparian areas." as this is being covered elsewhere within our communities.	The controversy over the greenway issue was raised by many interviewees, with several mentioning that the current status was not meeting their interests. While there may be various plans for bicycle routes and pedestrian routes, they have not been looked at holistically or agreed upon by a broad range of stakeholders. Until stakeholders come to consensus and/or there is a final decision by the Towns on specific plans, this issue will continue to divide stakeholders, which prevents full leveraging of resources for restoration efforts in the Bolin Creek watershed.
12.	Re: Recommendation G. There is no doubt more coordination is needed between Chapel Hill and Carrboro on transit planning of all kinds but this sort of mediation may not be a top priority for water quality. The Carolina North Agreement brought significant additions to planned bike paths that will be built as part of the new campus. The Town of Carrboro had not been aware of those changes until recently as the contractual agreement was between Chapel Hill and UNC, a fact which brought about some confusion. Now both Towns are aware of the new transit routes that will be built and paid for by UNC. Transit planning always benefits from coordination. However no time need be devoted to the mediation of old controversies which have been tabled, i.e. putting pavement next to the creek in Northern Bolin Forest.	Response the same as for item #11.
13.	We prefer to see state and federal funds devoted toward programs such as education, instead of a mediated stakeholder process. Such a stake holder process cannot arrive at technical solutions because the controls, retrofits, and other measures have yet to be identified in a "restoration plan". Which actions will give us the most	The US EPA recommends a multi-stakeholder watershed approach, and often prioritizes funding those projects that use it above those that do not. The Center for Watershed Protection conducted

water quality improvement per unit cost? These controls and measures must be identified first before the community is engaged. Having a sincere interest in protecting the creek is valuable to support action, but the implementation steps of the plan needs to be identified first.

research that showed that implementation of a watershed plan has the greatest chance of success when stakeholders are brought into the process at the very beginning of the watershed planning effort. We've seen this in our experience, the earlier stakeholders are involved in identifying and prioritizing actions, the more inclined they are to help implement those actions. How this happens can be flexible. We agree that stakeholders often need help identifying technical solutions. For example, the more technical stakeholders could identify a range of opportunities, ask other stakeholders to review them and identify "what is missing?" We recommend involving stakeholders in collaboratively developing criteria to evaluate solutions, and helping prioritize solutions based on those criteria. Water quality improvement absolutely needs to be included in the criteria, and may carry stronger weight than other criteria. The criteria should be transparent for all to see.

For more information, see EPA "Handbook for Developing Watershed Plans to Restore and Protect Our Waters," March 2008. EPA 841-B-08-002. http://www.epa.gov/owow/nps/watershed_handbook.

14.	What is needed to move forward is more leadership by the towns, who have the authority and means to address the problems. The Earth Tech study has already identified 32 projects to resolve erosion problems and reduce sediment contributions to the creek. The towns should seek grant funds to speed up construction of these projects and to hire an engineering firm to define a list of the most important neighborhood stormwater retrofits that should be done in existing developed areas, including changes in how individual homeowners treat the stormwater on their lots. These two project lists will give the towns something specific to work toward. The need for facilitation might come at this point to help the towns work with landowners on how to implement these projects.	Response is the same as for item #13.
15.	Using facilitation to work out a consensus on an issue works well with small groups where everyone understands the issues, and where all participants are part of one organization or process that has respect and authority to motivate participation. The very dispersed, large scale, and complicated watershed and water quality issues do not lend themselves to this approach. Busy community leaders want to work with institutions that have the capability to make things happen and that they trust. Setting up yet another kind of meeting separated from the institutions with real authority (the towns) will discourage participation. Turning to a new "neutral" process without defining a plan will not result in a useful product.	The US EPA encourages collaborative, multi-stakeholder watershed management as a best practice for watershed management. Some states, such as Washington and Oregon, require it for receiving watershed funding. We recommend a facilitated process that engages people and groups in collaborative planning. The long term benefits outweigh the short term costs. We believe this can work well in Bolin Creek if all stakeholder groups agree to try it, and we heard broad willingness to do so.
16.	The towns are definitely understaffed. Each town needs at least one person to work on a plan for Bolin Creek without other responsibilities. This would be a good target for a grant application. Once the towns develop an action plan, public meetings can inform the public, identify needs to modify and improve the plans, and build support. Citizens and groups interested in water quality, such as Friends of Bolin Creek, can then support the plan and push for priority status for funding programs.	These things can occur alongside implementation of the SA recommendations, as they do not appear to be mutually exclusive.

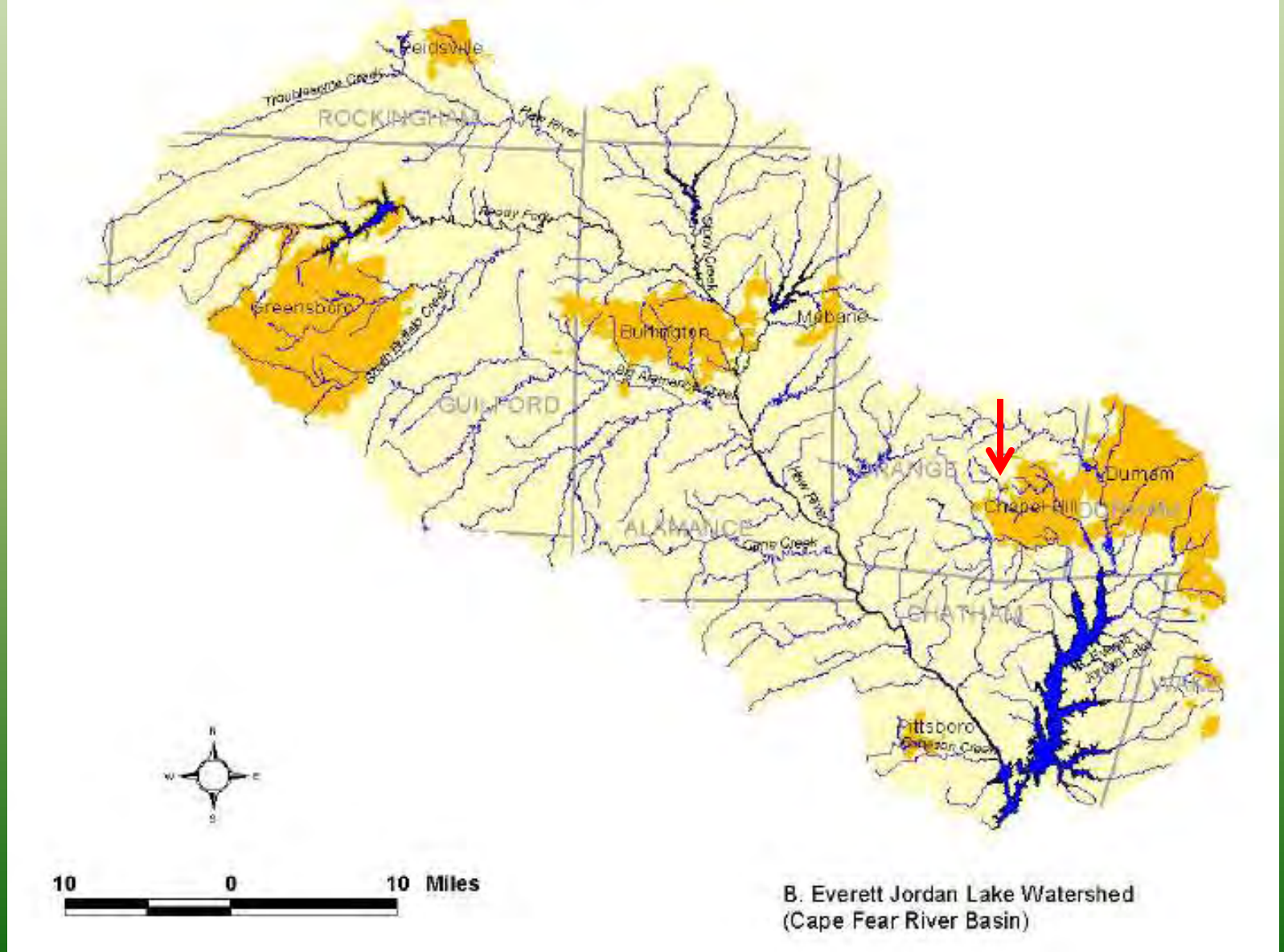
17.	We recommend planning for a transition in the event a new grant is funded to form a "new initiative". Should such an effort be funded, what are the plans to maintain gains after the few years of funding runs out?	Yes, planning for transition to a long-term collaborative effort makes sense, and should be a part of the collaborative group's charge. This could be part of the goal setting. Specific details can emerge in the implementation of the recommendations.

APPENDIX 11: "CAN WE HEAL OUR WATERWAYS?" SYMPOSIUM PRESENTATION

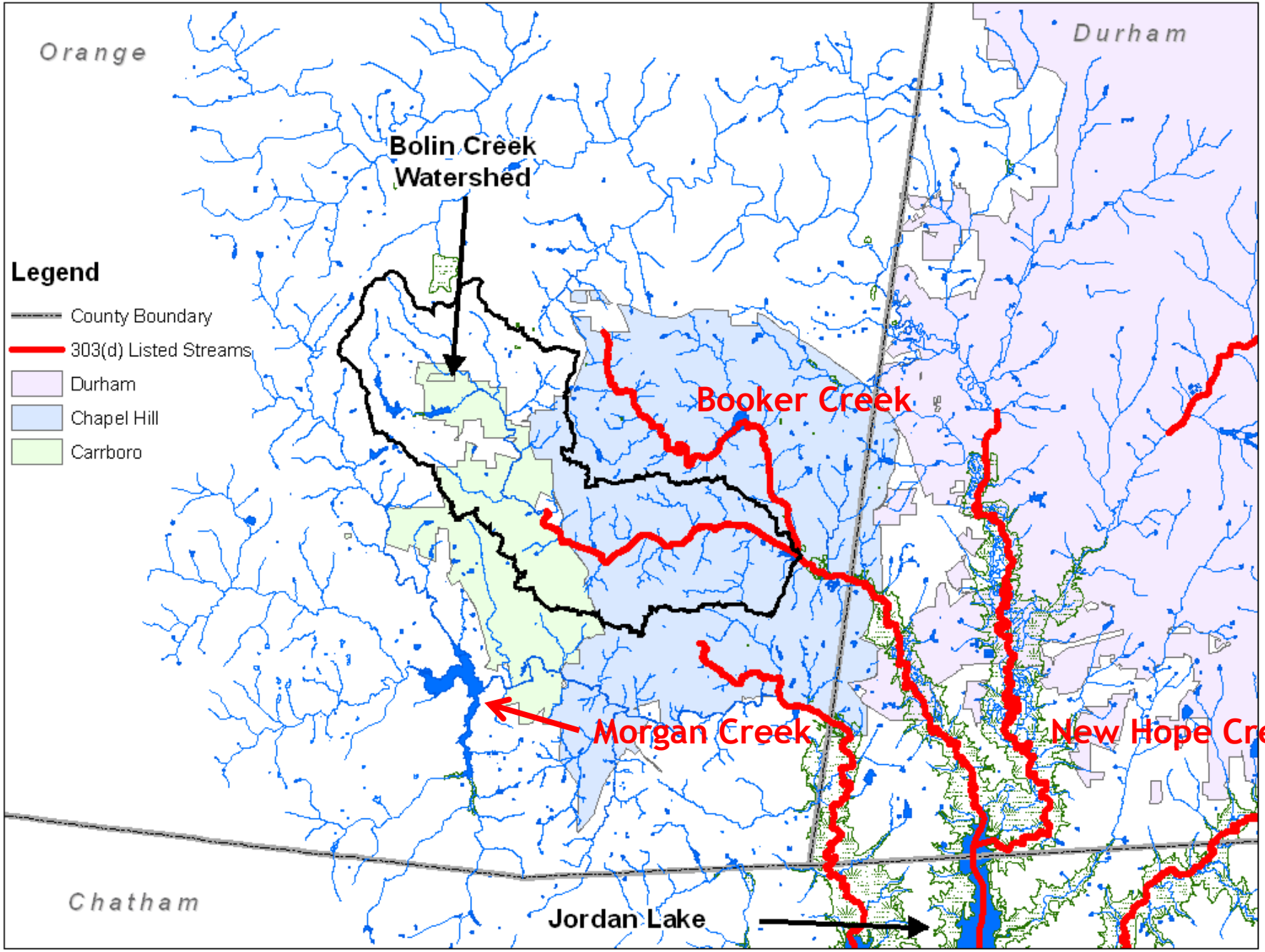
Restoring Bolin Creek

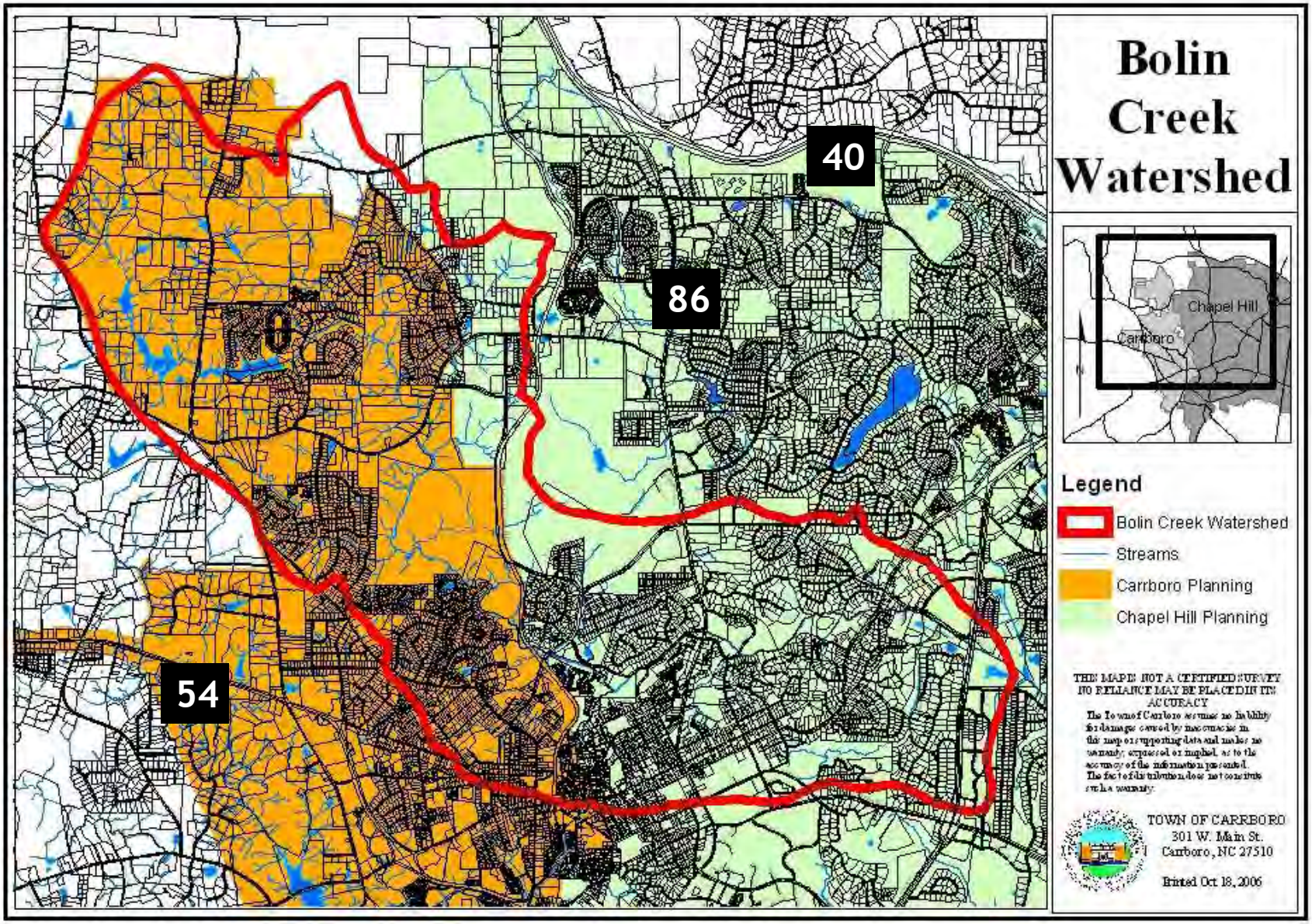
Randy Dodd, Town of Carrboro
Trish D'Arconte, Town of Chapel Hill

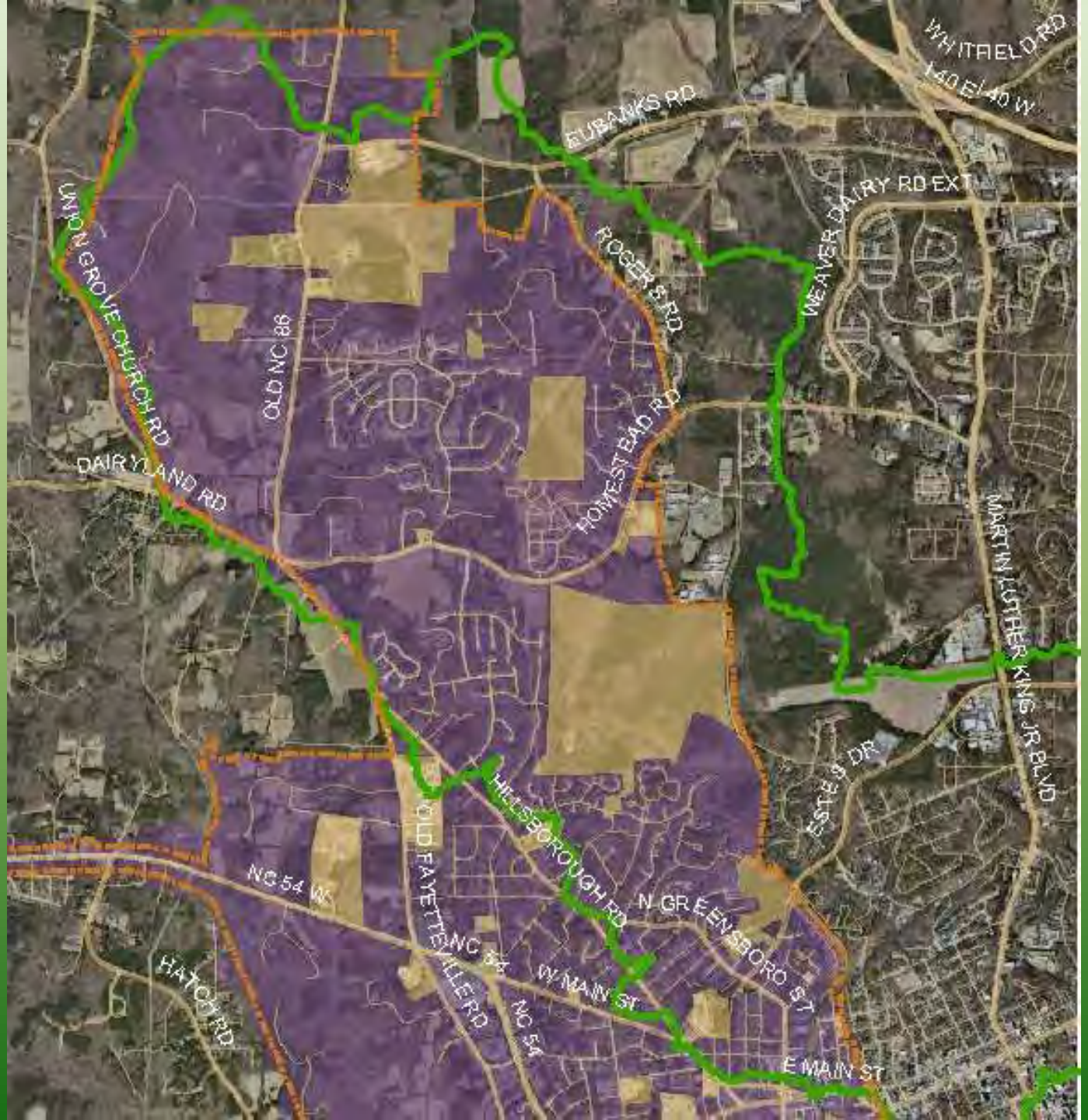
Where is Bolin Creek?



B. Everett Jordan Lake Watershed
(Cape Fear River Basin)


Orange
Durham
Bolin Creek
Watershed
Legend
County Boundary
303(d) Listed Streams
Durham
Chapel Hill
Carrboro
Booker Creek
Morgan Creek
New Hope Creek
Chatham
Jordan Lake


Bolin Creek Watershed
40
86
54
Chapel Hill
Carrboro
Legend
Bolin Creek Watershed
Streams
Carrboro Planning
Chapel Hill Planning
THIS MAPE NOT A CERTIFIED SURVEY
NO RELIANCE MAY BE PLACED IN ITS ACCURACY
TOWN OF CARRBORO
301 W. Main St.
Carrboro, NC 27510
Printed Oct 18, 2006



Private Land

Public Land

Private Land

Public Land

Town Land

Local Streets

How is Bolin Creek Doing?

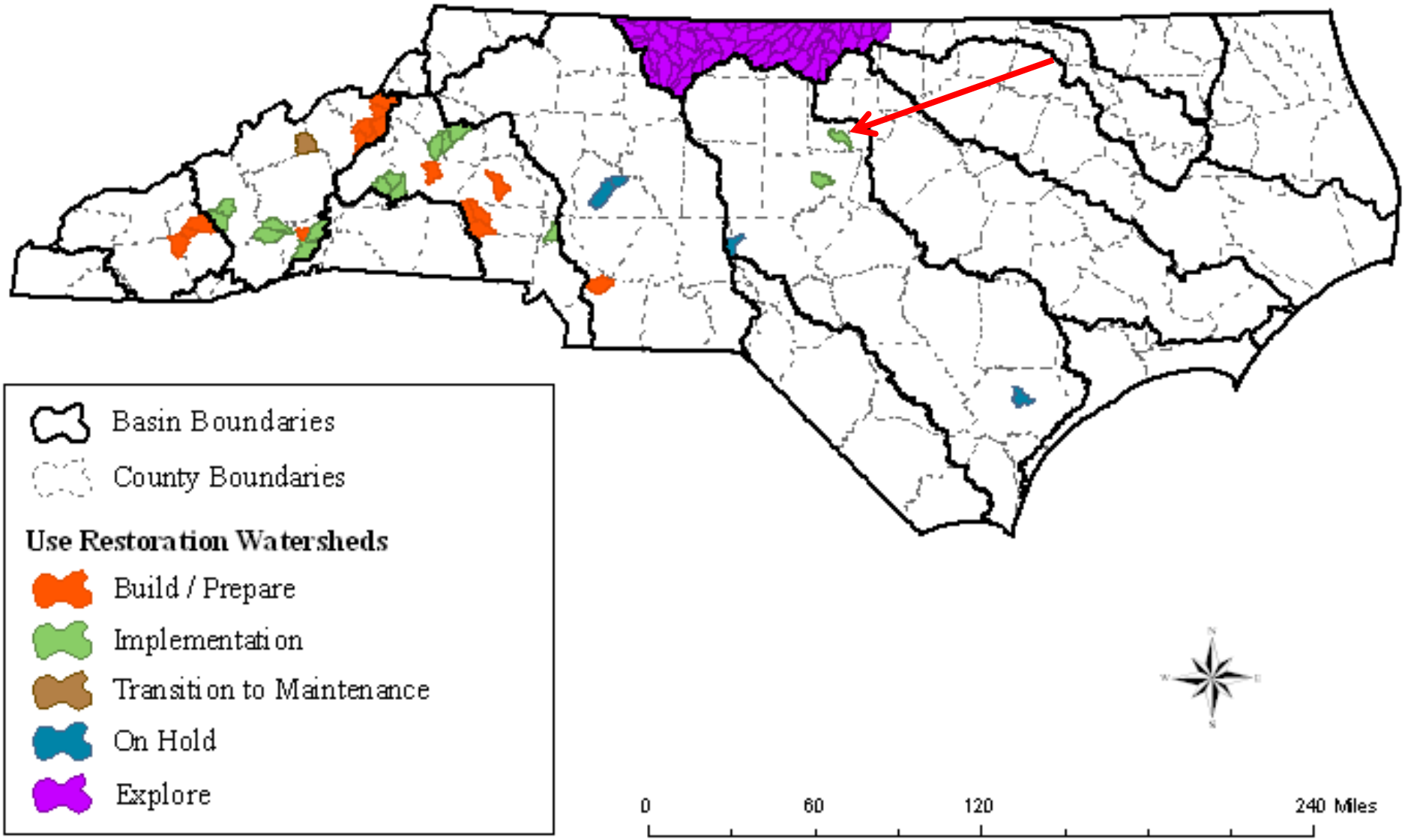
One of more studied streams in central NC

- NC DWQ – every 5 years
- Intensive WARP study - 2003
- Chapel Hill monthly physical and chemical data: 1994-2008
- Aquatic Insects:
  - Carrboro - 2000-2011
  - Chapel Hill – 2011
- Miscellaneous studies
- Volunteer monitoring

Bolin Creek Watershed Restoration

- Bolin Creek Watershed Restoration Team formed: 2005
  - Local, State, Federal collaboration
- Goal: **Improve the aquatic health of Bolin Creek and its tributaries**
- Objectives:
  - Restore stream hydrology
    - Storm flow
    - Base flow
  - Restore habitat
  - Address pollutant (sediment, toxic, nutrient) inputs
  - Stabilize streambanks
  - Improve riparian conditions

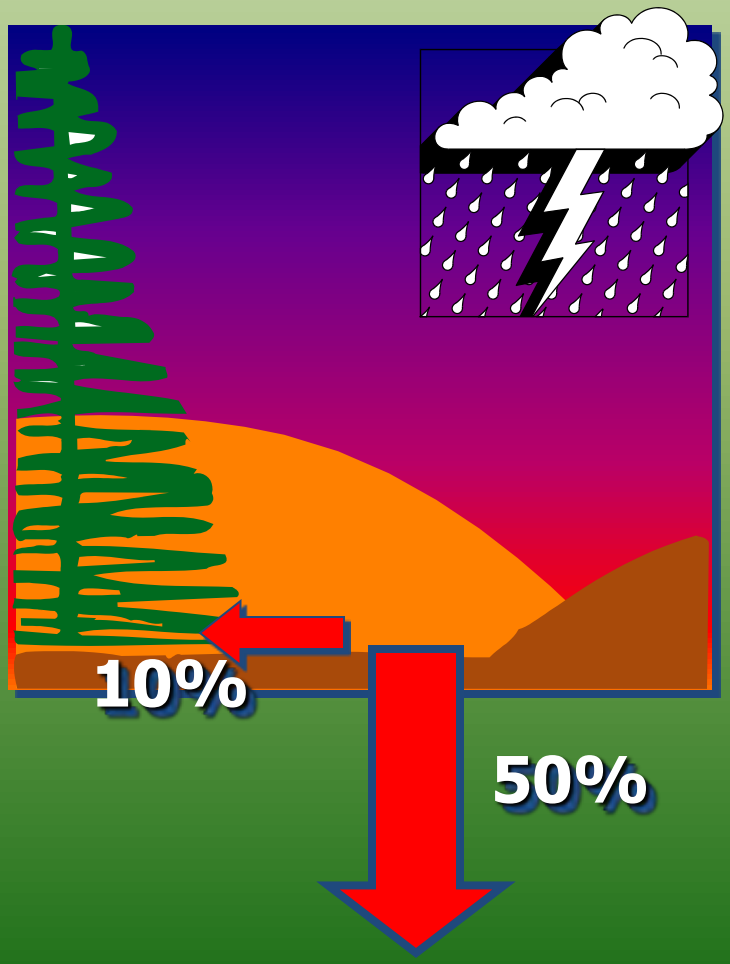
Restoration Watersheds in North Carolina
October 2010

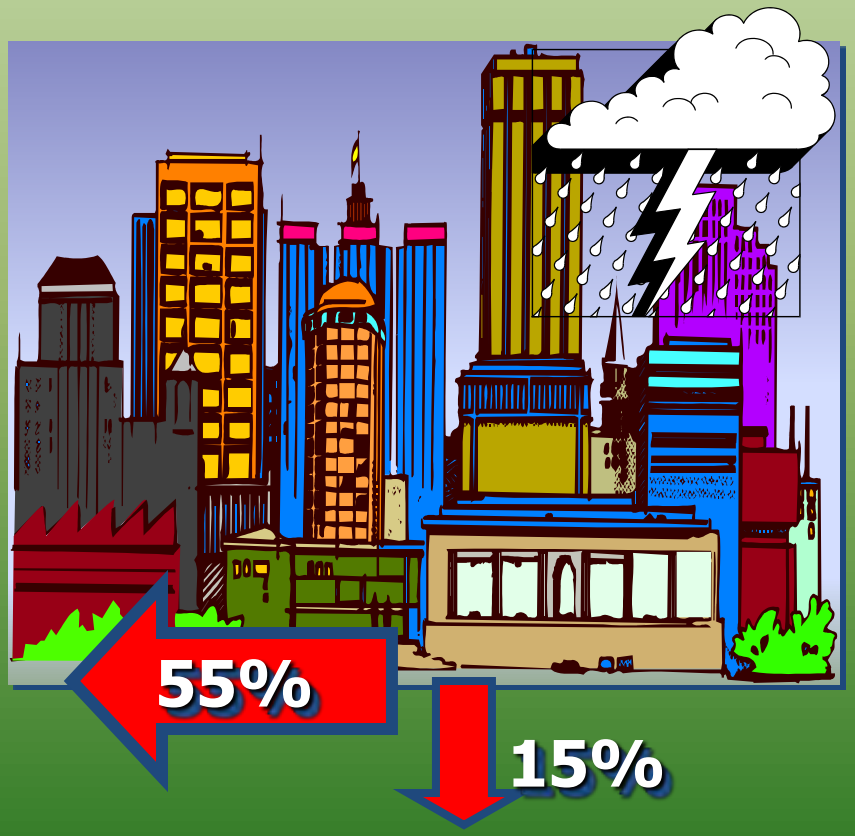


Use Restoration Waters Program

- Bolin Creek selected because of confidence in local community
- Alternative to more stringent federal/state regulation
- Partnership to restore impaired waters
- Emphasis on “measurable results”
- Federal/State financial and technical assistance
- Required Watershed Restoration Plan
- Two EPA/DENR grants received to date.
  - 2008-2012
  - Total value: $986k

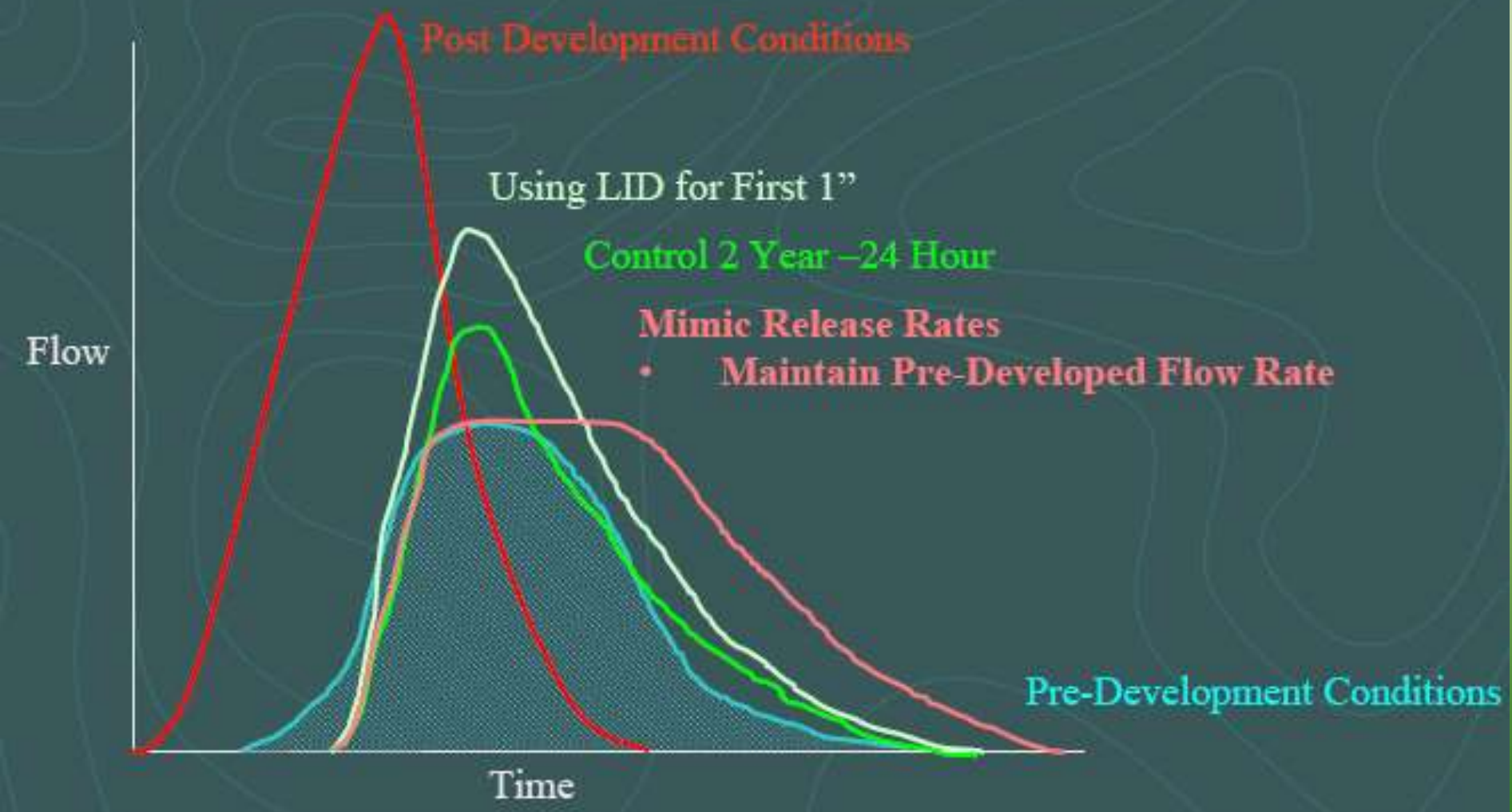
Development Impacts on the Water Cycle





Credit: NCSU

Hydrograph



Credit: Huntersville

Bolin Creek WRT Initial Project

- Mini-grant from Clean Water Management Trust Fund (2007)
  - Contracted with Earth Tech:
    - Identify/prioritize areas of instability
    - Identify/prioritize restoration opportunities

BOLIN CREEK WATERSHED

Geomorphic Analysis and Potential Site Identification for Stormwater Structures and Retrofits

TOWN OF CARRBORO
NORTH CAROLINA

Prepared By:
EarthTech
A tyco International Ltd. Company
Earth Tech of North Carolina, Inc.
701 Corporate Center Drive, Suite 475
Raleigh, NC 27607

Earth Tech Study

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	60.0	CY	15.00	$900
Site Preparation and Planting	0.0	AC	7500.00	$150
Rip Rap Class B	5.0	Tons	45.00	$225
Filter Fabric	15.0	SY	5.00	$75
Grade Control Vanes	6.0	EA	3000.00	$18,000
Silt Fence	500.0	FT	3.75	$1,875
Construction Safety Fence	665.0	LF	2.50	$1,663
Construction Entrance	1.0	Ea	2500.00	$2,500
			Total	$25,388

iteria and Point Allocation

	ia (20 Total Points ble)	Possible Points
	t Reduced	5
		[5]
	00	[4]
	300	[3]
	500	[2]
		[1]
	Removed	5
		[5]
	$23,000	[4]
	d $50,000	[3]
	d $80,000	[2]
	)	[1]
		5
	seen from street)	[1]
	o a street)	[3]
	ent to a highly traveled y)	[5]
4	Construction Access	5
	Poor	[1]
	Good	[3]
	Excellent	[5]
5	Critical Nature of Project	5
	Critical (exponential increase of problem is expected if project is delayed; i.e. headcut causes channel incision which causes decades of channel instability and is order of magnitudes higher if you wait to repair)	[5]
	Very High (problem will increase in future at a steady rate)	[4]
	High (problem will increase, but range of future impact is limited)	[3]
	Medium (problem is severe but not expected to increase significantly)	[2]
	Low (problem is present, but stable, no expected increase)	[1]

Earth Tech Project Recommendations

- **<u>Streambank stabilization; 8 projects</u>**
- Stormwater projects (retrofits and new); 22 projects
- Stream restoration; 1 project
- Dam retrofit; 1 project
- Conceptual designs

BCWRT Follow Up/ Current Work

- Follow up on EEP, ET, other studies
- 2 319 grants received
- Restoration projects (pilot/demonstration)
  - 4 on the ground projects
- Low Impact Development site monitoring study
- Intensive subwatershed analysis
- Watershed restoration plan

319 Restoration Grants

- 2008 Chapel Hill lead
- 2009 Carrboro lead
- 60/40 federal/local funding
- Partnering with NCSU, Chapel Hill Carrboro City Schools, Friends of Bolin Creek

To Bolin Creek
To Morgan Creek
To Tom's Creek
McDougle Site Runoff
Stormwater Pipe
Streams
TYPE
Intermittent
Permanent

McDougle Project

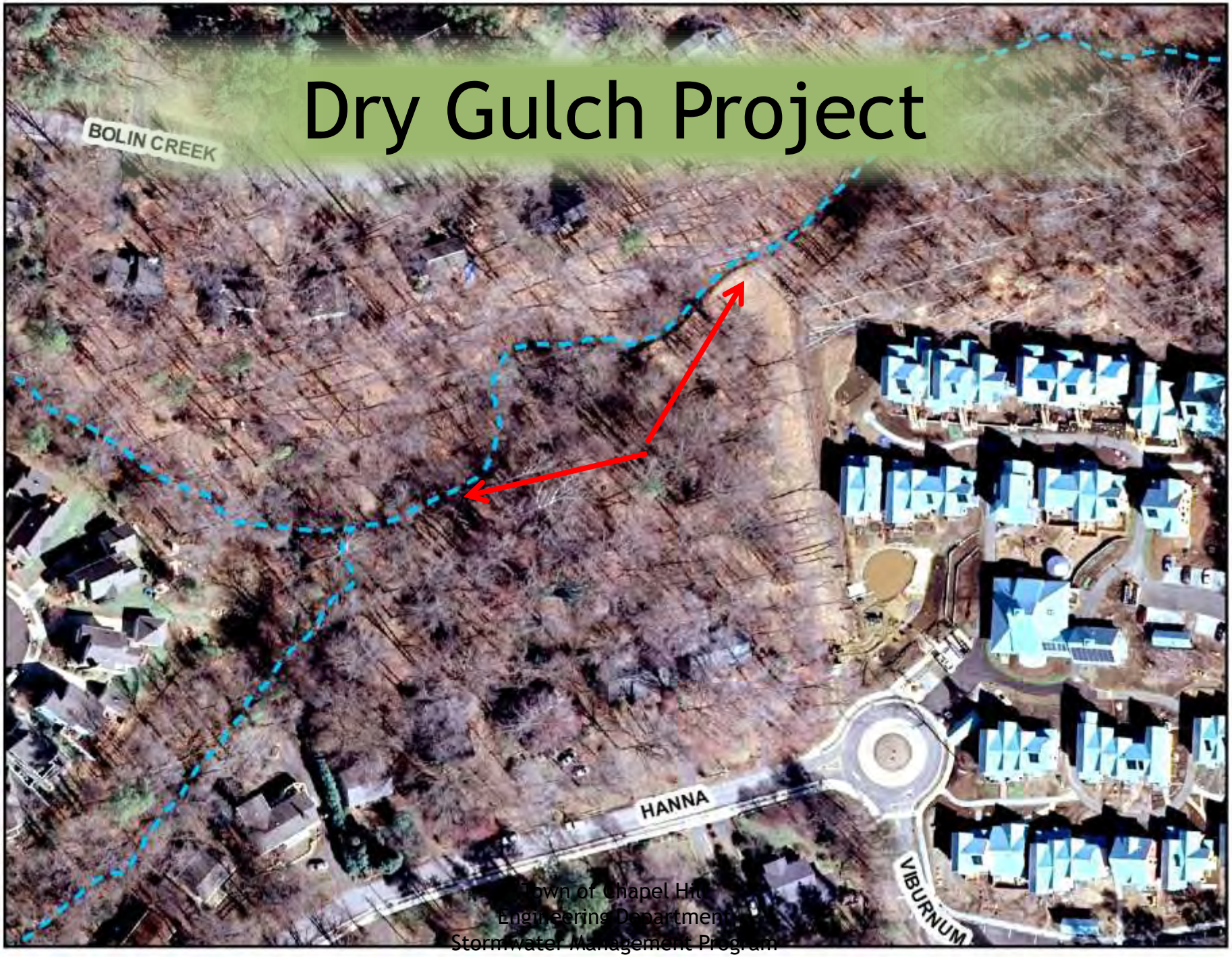
Rain garden

CAT

23

Credit: Dave Otto

Dry Gulch Project



Town of Chapel Hill
Engineering Department
Stormwater Management Program

- *Scope: channel stabilization*
- *Project construction planned: March, 2012*

Pacifica Runoff Monitoring

- Evaluate effectiveness of Low Impact Development, stormwater management
- 2 year continuation
  - Predevelopment and construction runoff monitoring complete

Baldwin Park Stream Restoration

SITE 19

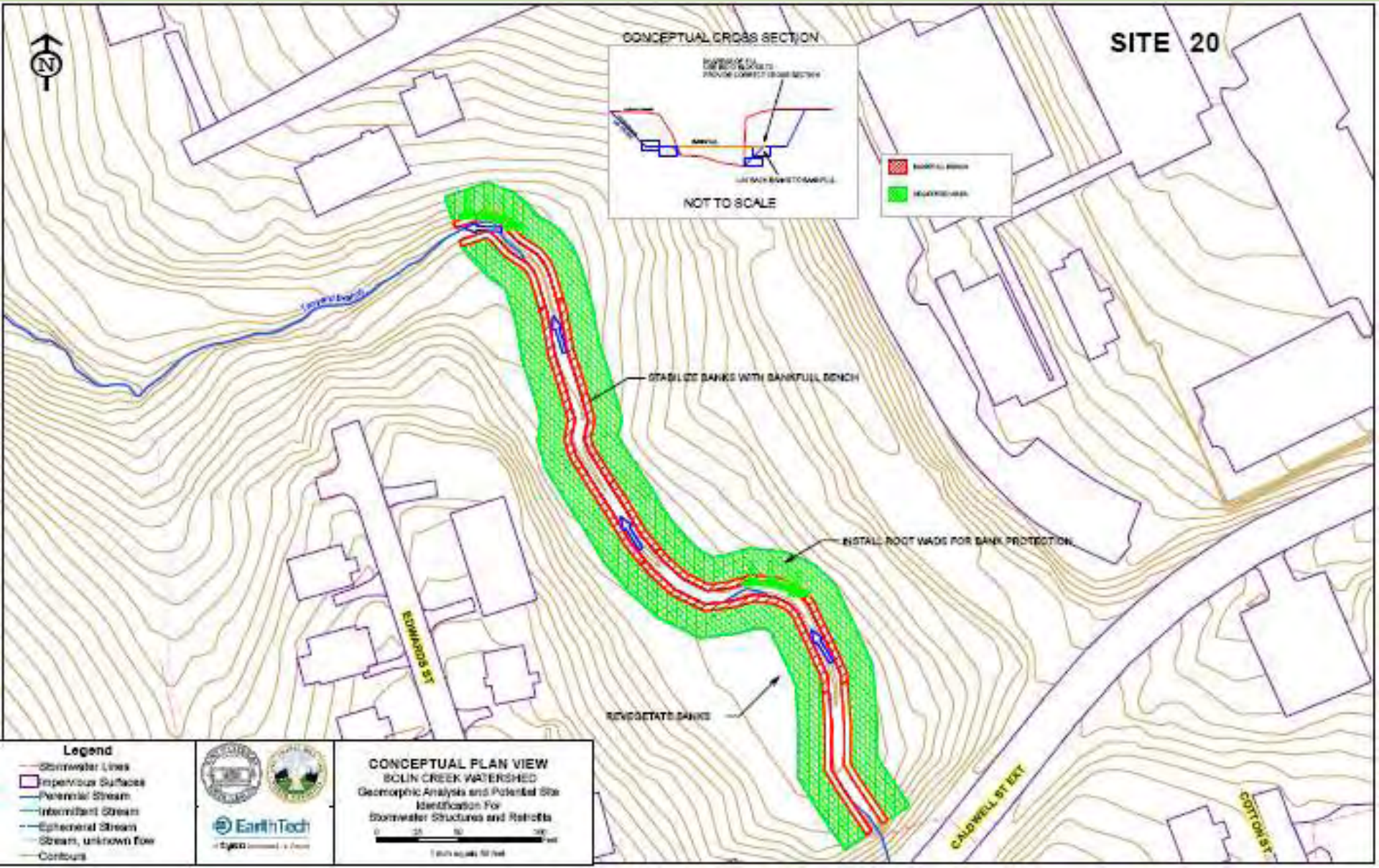
Problems Observed

Construction

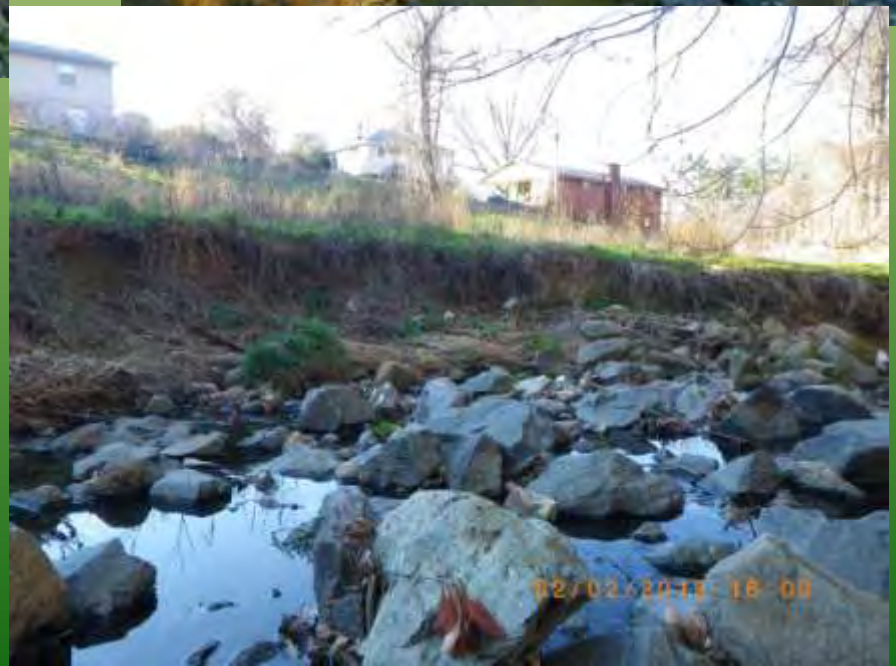
After Construction

After construction

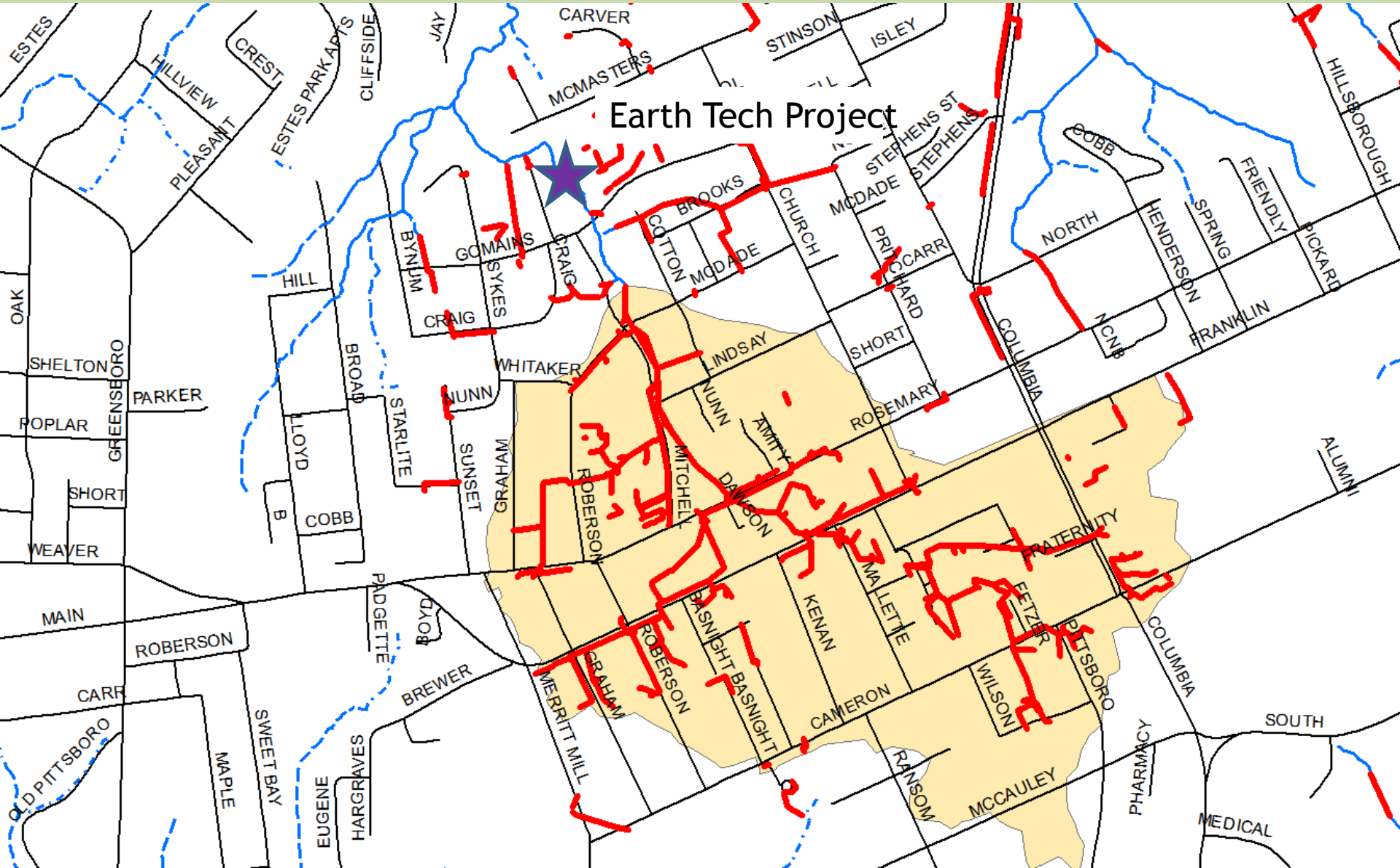
Proposed Tanyard Branch Stream Restoration



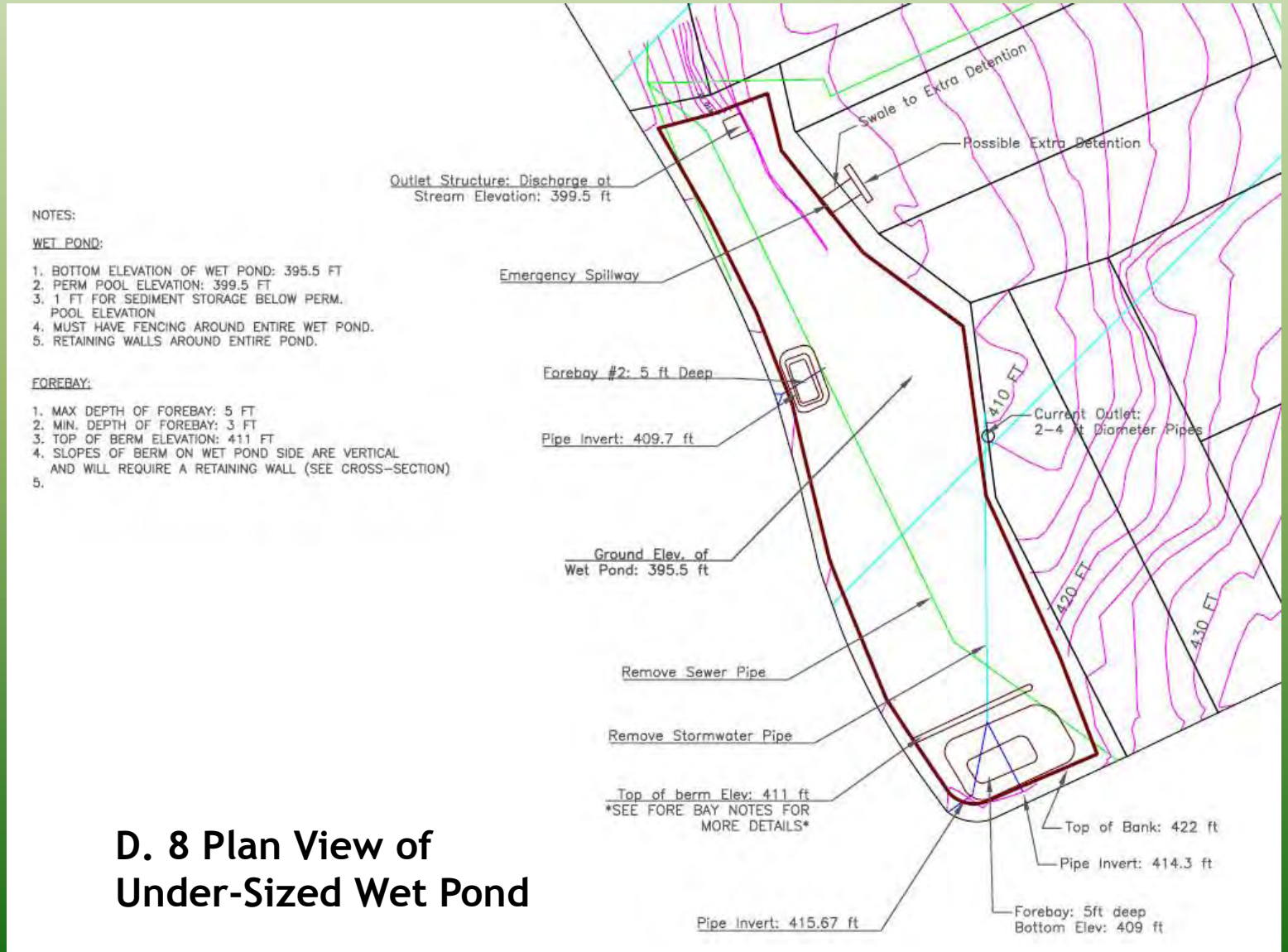
Tanyard Branch erosion



Tanyard Branch Drainage Network

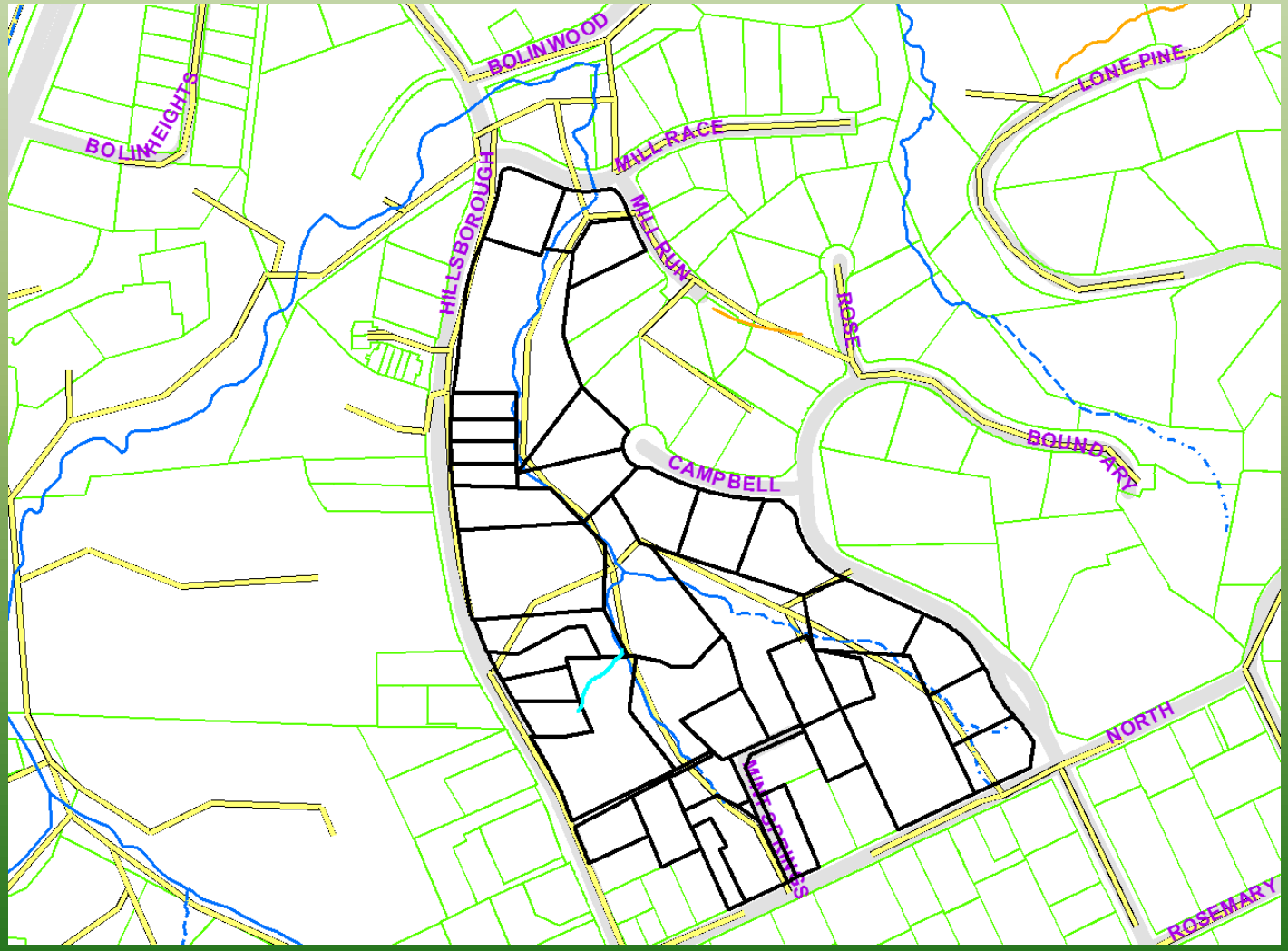


Tanyard Branch Alternatives Analysis

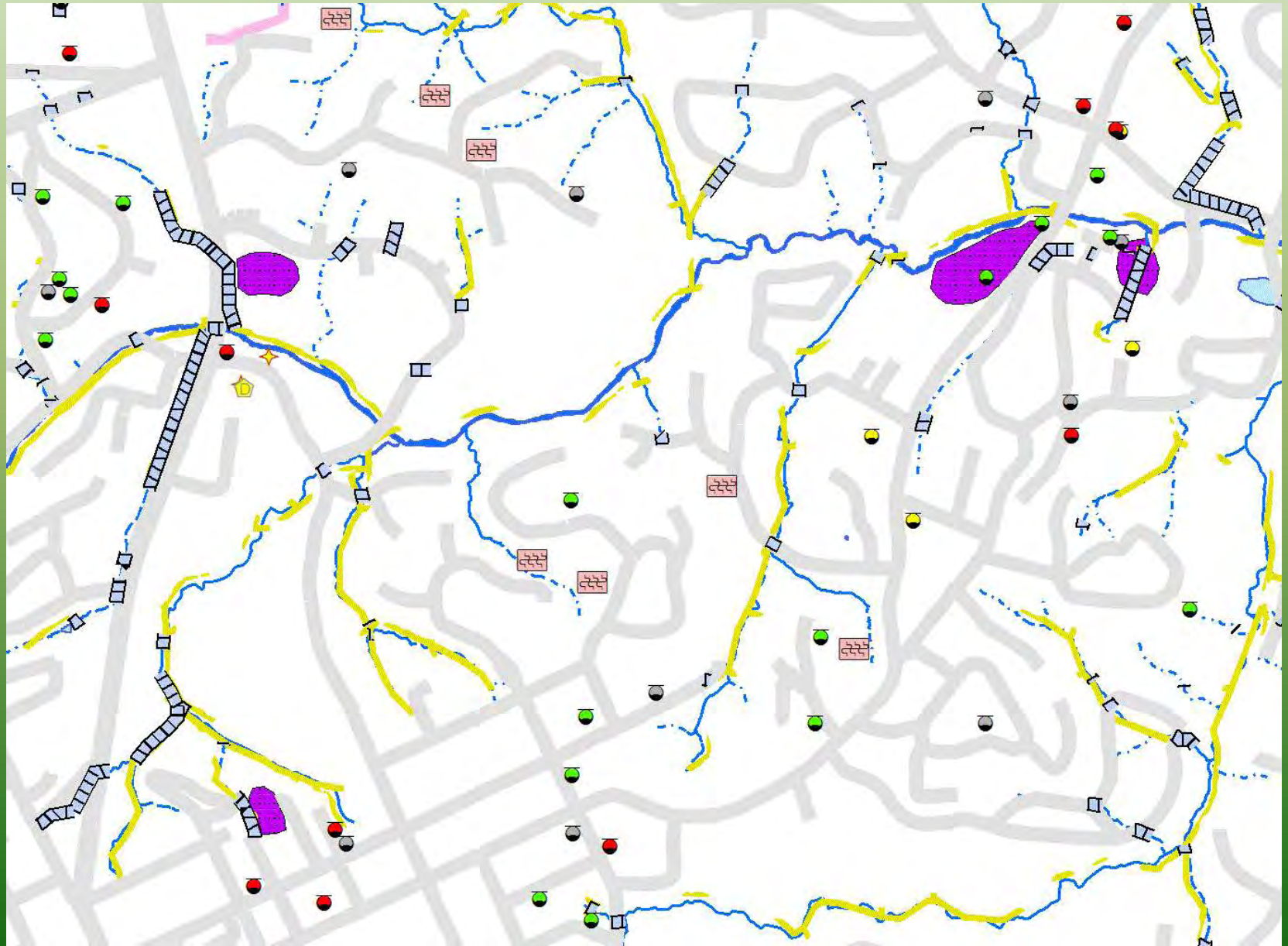


D. 8 Plan View of Under-Sized Wet Pond

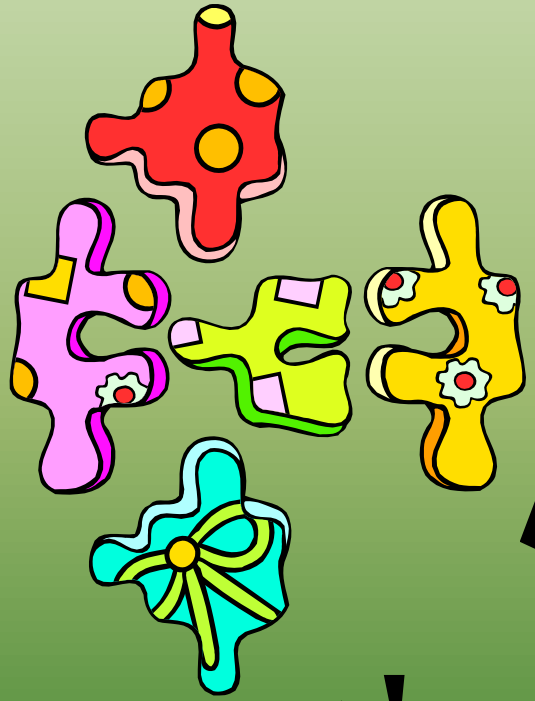
Watershed Restoration Challenges

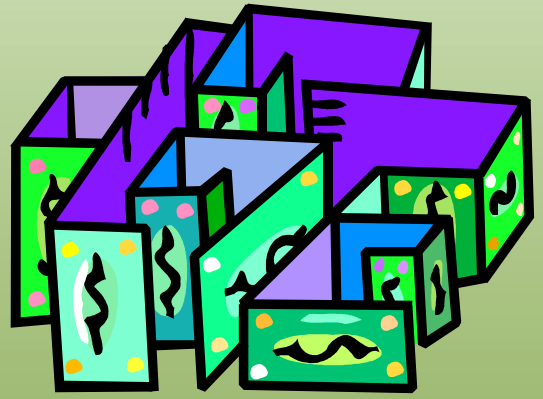


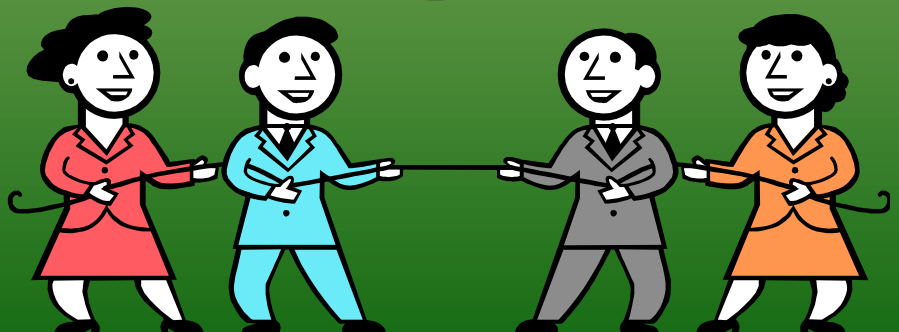
Watershed Restoration Challenges



Watershed Restoration Challenges







Watershed Situation Assessment

- Conducted by Watershed Education for Communities and Officials (WECO) – affiliated with NCSU
- Study goal: understand full spread of interests related to Bolin Creek and watershed restoration
- Help Towns determine how to better engage stakeholders

WECO Situation Assessment Recommendations

- Create new collaborative watershed group
- Neutral party for watershed facilitation
- Online commons
- Local government internal review
- More Carolina N Forest outreach
- Carrboro revenue ideas
- Utility infrastructure planning and maintenance
- Facilitated, holistic discussion of environmental management and transportation

Watershed Restoration Planning

- Meet requirement for 9-element EPA plan
- This version: focus on technical aspects
  - Stressors and sources – rate by severity
  - Projects – rate by technical feasibility
- Identify challenges and barriers
- Estimate costs, identify funding sources
- Monitoring plan
- Process for regular evaluation and revision
- Incorporate stakeholder concerns from Situation Assessment

Watershed Plan Life Cycle

Umbrella Organization
(as recommended by WECO)

- Inclusive, broad range of stakeholders
- Shared responsibility
- Consensus decision making
- Visioning, collaborative goal development
- Will likely need a facilitator to help get things going

WANTED: CAT HERDER

(AKA Watershed Facilitator)

Next Steps for the Towns

- Complete draft Watershed Plan for technical review by State/EPA
- Evaluate funding and staffing needs
- NPDES and Jordan Lake Rules activities:
  - Education and outreach
  - Eliminate discharges and dumping
  - New Development stormwater requirements
  - ID stormwater retrofit projects

Next Steps For Everyone

- Follow up on WECO recommendations
  - Set up “umbrella organization” or expand existing restoration team
  - Watershed Facilitator
  - Create online commons
- Seek commitment for resources from stakeholders
- Share with your neighbors
- Communicate priorities to elected officials
- Every little bit counts

For More Information

- Chapel Hill Stormwater Management Division *www.townofchapelhill.org/stormwater*
- Town of Carrboro Surface Water *www.townofcarrboro.org/pzi/Env/water.htm*
- NCSU Watershed Education for Communities and Officials *www.ncsu.edu/weco*
- EPA 9-element watershed plans *water.epa.gov/polwaste/nps/handbook_index.cfm*
- DWQ Use Restoration Watershed Program *portal.ncdenr.org/web/wq/ps/bpu/urw*
- EPA - Impaired Waters and Total Maximum Daily Load *water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/intro.cfm*

APPENDIX 12: APPROVED MONITORING QUALITY ASSURANCE PROGRAM PLAN

Quality Assurance Project Plan

Required for certain US EPA funded grants and contracts that are awarded by the Division of Water Quality, NCDENR

NCDENR- DWQ QUALITY ASSURANCE PROJECT PLAN CHECKLIST

To first assess whether a Quality Assurance Project Plan is necessary, please answer the following four questions:	
1. Is Federal money from the US EPA being spent on this activity? (*If the answer is "No" then a QAPP is not necessary; proceed to answer section A1 only. If "Yes" then proceed to # 2).*	❑ **Yes** ❑ **No**
2. Will work require acquisition of environmental data generated from direct measurements activities (i.e., water quality sampling), collected from other sources, or compiled from computerized databases? *(If the answer is "No", then a QAPP is not necessary; proceed to answer section A1 only. If "Yes" then proceed to # 3).*	❑ **Yes** ❑ **No**
3. *Will all instream water quality samples be analyzed by a Laboratory certified by the State of North Carolina? Proceed to # 4.*	❑ **Yes** ❑ **No**
4. Has a QAPP already been approved for your activity*? (If the answer is "No" then please complete Sections A-D on the following pages. If "Yes", then please answer section A1 and attach a copy of the approved QAPP, or provide a reference (including Agency, Telephone number, and Web Address, if available) for the complete approved QAPP, and return this form with attachments to your DWQ EPA Funds Manager*).	❑ **Yes** ❑ **No**
5. Do you intend for your data to be considered for Use Support decisions, e.g., 303(d)	❑ **Yes** ❑ **No**

Quality Assurance Project Plan Form

Adopted from the US EPA by the Division of Water Quality, NCDENR

A1. Project Title and Approval Sheet

Bolin Creek Watershed Restoration Initiative

(Project Name)

Town of Chapel Hill, Division of Stormwater Management

(Responsible Agency)

September 10, 2009

(Date)

1666

(NC DENR Contract #)

Project Manager Signature _____

(Name/Date)

Project QA Officer Signature _____

(Name/Date)

DWQ EPA Funds Manager

Signature of Receipt (Name/Date)_____

Quality Assurance Project Plan Details and Explanation

All environmental projects that are funded, directly or indirectly, by the US Environmental Protection Agency (EPA) and which generate data from direct measurement activities, collect data from other sources or compile data from computerized data bases and information systems must have a Quality Assurance Project Plan (QAPP) approved prior to the collection of project data. QAPPs are required under Code of Federal Regulations 48CRF46, and 40CFR 30, 31 and 35. The QAPP documents the planning, implementation and assessment procedures of the project's data needs. Specifically, it describes and documents the collection methods, and type and quality of data to be gathered. These criteria will vary from project to project depending on the scope of the work, expectations for the end result and perhaps overall cost of the project. Some project QAPPs must follow the national consensus standard, (ANSI/ASQC E4-1994, Specifications and Guidelines for Environmental Data Collection and Environmental Technology Programs*) in order to be acceptable for their end use. Whereas other projects may use non-standardized or simplified data collection approaches because the end result, or use of the data, may not need to conform to existing data quality or may not be as critical for decision making .The overall purpose of the QAPP is to assure that appropriate methods of data collection are used and that documentation of the quality assurance approach is available for users of the data.*

EPA has established requirements for an acceptable QAPP. Details and explanations of these requirements can be found on EPA's web site at ***http://www.epa.gov/quality1/qapps.html.*** *Many of the required elements may already be found in your DWQ approved study proposals (e.g., Scope of Work). If so, please copy the appropriate information from your workplan to the attached DWQ/EPA QAPP form. The completed QAPP MUST be submitted to the DWQ BEFORE data collection activities begin.*

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Appendix A: Location and Site Maps

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A3. Distribution List

Names and telephone numbers of those receiving copies of this QAPP. Attach additional page, if necessary. (Name, Organization, Telephone)

Name	Organization	Phone	Email	Mailing Address
Kim Nimmer	NC DWQ	919-807-6438	kimberly.nimmer@ncdenr.gov	NPS Planning Unit, NCDWQ, 1617 Mail Service Center, Raleigh, NC 27699-1617
Sue Burke	Town of Chapel Hill, Stormwater Management	919-969-7233	sburke@townofchapelhill.org	405 Martin Luther King Jr., Blvd., Chapel Hill, NC 27514
Randy Dodd	Town of Carrboro	919-918-7326	rdodd@townofcarrboro.org	301 W. Main Street, Carrboro, NC 27510
Paul Clark	NC DWQ	919-807-6443	paul.clark@ncdenr.gov, paul.clark@ncmail.net	NPS Planning Unit, NCDWQ, 1617 Mail Service Center, Raleigh, NC 27699-1617
Greg Jennings	NCSU, Biological and Agricultural Engineering	919-600-4790	jennings@ncsu.edu, Greg_Jennings@ncsu.edu	North Carolina State University Campus Box 7625 Raleigh, NC 27695-7625
Bill Hunt	NCSU, Biological and Agricultural Engineering		bill_hunt@ncsu.edu, wfhunt@ncsu.edu	North Carolina State University Campus Box 7625 Raleigh, NC 27695-7625
Michael Herrmann	NC Ecosystem Enhancement Program	919-715-5458	Michael.Herrmann@ncmail.net, michael.herrmann@ncdenr.gov	NC Ecosystem Enhancement Program, 1652 Mail Service Center, Raleigh, NC 27699-1652
Michael Shaffer	NCSU, Biological and Agricultural Engineering	336-312-8786	mike_shaffer@ncsu.edu, mbshaffe@ncsu.edu	North Carolina State University Campus Box 7625 Raleigh, NC 27695-7625
Patricia D'Arconte	Town of Chapel Hill, Stormwater Management	919-969-7202	pdarconte@townofchapelhill.org	405 Martin Luther King Jr., Blvd., Chapel Hill, NC 27514
Zan Price	NCSU, Biological and Agricultural Engineering	828-712-9194	gaprice@ncsu.edu	North Carolina State University Campus Box 7625 Raleigh, NC 27695-7625
Karen Hall	NCSU Water Quality Group	919-515-8242	karen_hall@ncsu.edu	NC Cooperative Extension, Campus Box 7637, Raleigh, NC 27695-7637
Rachel Huie	NCSU, Biological and Agricultural Engineering	919-515-6766	huie@eos.ncsu.edu	North Carolina State University Campus Box 7625 Raleigh, NC 27695-7625

A4. Project/Task Organization

Key project personnel and their corresponding responsibilities are listed below. Organization chart is Figure 1.

Name, Position	Project Title/Responsibility
Patricia D'Arconte	Project Manager
Dr. Greg Jennings	QA Officer
Michael Shaffer, Patricia D'Arconte	Field/Sampling Leaders
David Almond, Randy Dodd	Field Assistants
NCSU BAE Lab (Rachel Huie)	Laboratory Manager/Leader
Zan Price, Michael Shaffer	Project Engineer, Surveying
NCSU BAE Lab, Dave Lenat	Subcontractors (if applicable)
Town of Chapel Hill, Town of Carrboro, NC Division of Water Quality	Data users (list organizations/agencies that will use data)

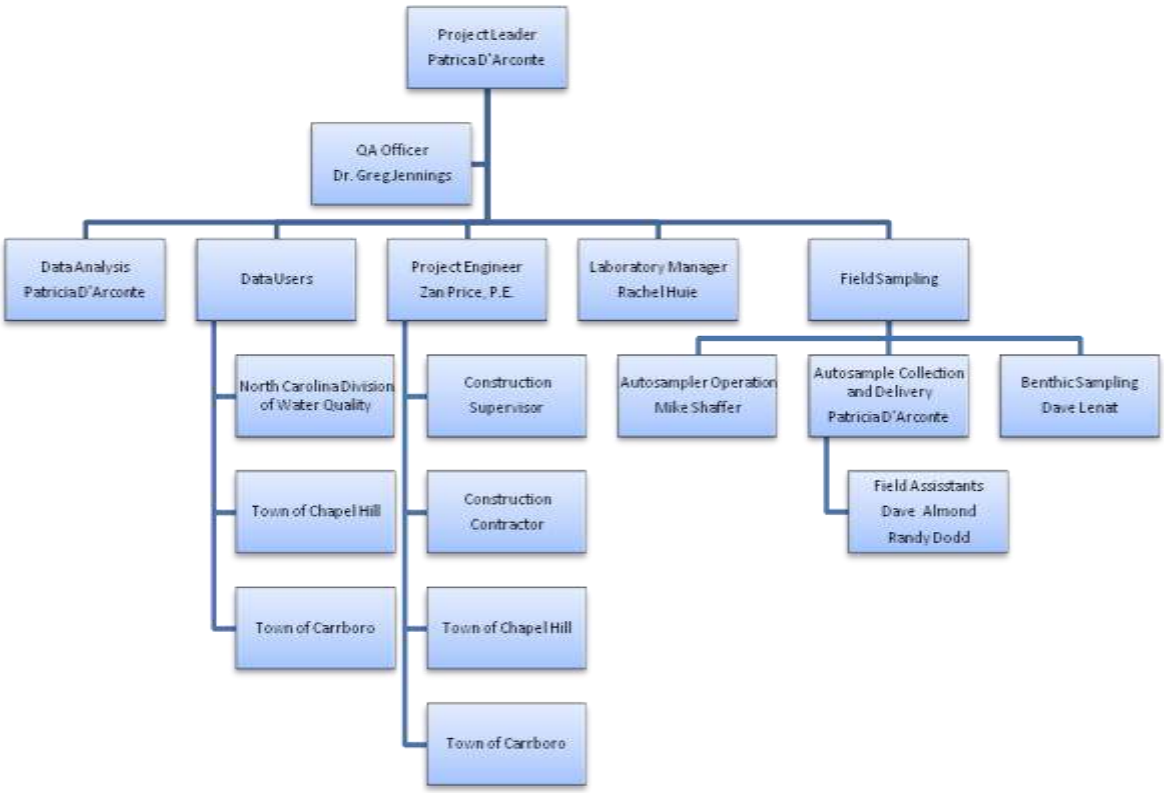


Figure 1. Organization Chart

A5. Problem Definition/Background

Problem Statement - Explain the background of the project and the reasons for initiating the project Also include uses and/or designated uses and impairment of the water resource, if applicable.)

The Bolin Creek Watershed Restoration Initiative is a joint project between the Towns of Carrboro and Chapel Hill, the Ecosystem Enhancement Program, US EPA and NC DWQ to improve the health and functioning of the Bolin Creek Watershed, with a goal of removing all listed segments of Bolin Creek from the State's 303(d) List of Impaired Waters. Watershed restoration is being approached on a subwatershed basis since sources of impairment are well-distributed throughout the watershed.

Two project subwatersheds within the larger Bolin Creek watershed have been chosen as pilot projects to restore a more natural hydrology and reduce nutrient export. These projects call for the installation of stormwater BMPs and stream enhancement, restoration, and riparian reforestation in order to decrease stormwater runoff velocities and volumes, increase infiltration and groundwater recharge, reduce erosion and export of sediment and nutrients, and improve stream habitats and biological conditions.

The monitoring described in this QAPP is specifically for evaluation of effectiveness of these two projects, comparing water chemistry, flow, and morphology before construction to conditions after construction.

Intended Usage of Data - State the usage and outcomes expected from the information to be collected (e.g., remove from impaired list, show that the BMP is effective, watershed characterization or background data, environmental education, etc.). Describe type of data to be collected (e.g., screening, definitive, characterization, baseline/background). If applicable, cite technical or regulatory standards or criteria to which data will be compared.

The purpose of this monitoring is to determine effectiveness of combined installed stormwater BMPs and stream channel enhancement, restoration, and reforestation for two project watersheds. In specific, we expect a decrease in suspended sediment, nitrogen, and phosphorus loads, moderation of a "flashy" urban hydrograph, reduction in bank/bed erosion rates, and increased channel stability.

Certain outcomes may take longer periods of time to detect changes, such as increased base flow, reduced temperatures (both base flow and stormwater), denser canopy cover/vegetative community, more diverse benthic habitats and stream geomorphology, and an improved Index of Biotic Integrity using benthic macroinvertebrates. These subsystems take longer to respond to changes in hydrology and chemical fluxes. Taking measurements of these subsystems right before and after construction gives us a baseline to compare to in five to ten years, should monitoring resources become available then.

A6. Project/Task Description

General Overview of Project - Summarize the work to be performed. Define geographic, spatial, and/or temporal boundaries. Briefly describe the monitoring/experimental design and how monitoring data will assist in achieving project monitoring objectives. Note, details on sample locations and monitoring design should be provided in Section B1 below. Discuss resource and time constraints, as appropriate.

Chemical, hydrological, biological, and morphological conditions before construction will be compared to conditions after construction. The primary aims of monitoring are to detect reductions in export of nitrogen, phosphorus, and suspended sediment and a reduced flood peak (i.e. reduced flashiness). While we would like to observe an improved biological community as a result of changes in morphology, hydrology, and chemistry, sampling of benthic macroinvertebrates for one or two years after construction is probably insufficient to detect changes in the community, as it can take well over 5 years for the community to respond to changes in chemistry, flow, or habitat. However, samples taken as part of this project can be compared to samples taken in 5 years or more to detect changes in the macroinvertebrate community.

Some conditions are being monitored for purposes of pre-construction analysis and engineering design (i.e. rainfall, flow). Some conditions are being monitored for changes that might require additional maintenance or care (i.e. stability of modified channel sections and longitudinal profile, erosion, survivorship of riparian plantings, resprouting of invasive species, photos). Other conditions are being monitored in support of benthic macroinvertebrate monitoring, where additional information may help us better understand factors that may help or hinder improvement in the macroinvertebrate community (stream habitat, bed sediment, temperature).

Primary monitoring locations will be below areas of construction and riparian plant management in the two project subwatersheds (Baldwin Park and a tributary to Mill Race). Monitoring will begin prior to construction in fall of 2009, continue through construction, and conclude in fall of 2011. Construction will be staggered, with work done in summer 2010 for Baldwin Park, and work done in winter 2010/2011 for the tributary to Mill Race.

Project Timetable - Work schedule indicating critical project points

Activity	Start Date	Known or Anticipated Date of Completion
Install automated samplers, rain gauge	June 2009	September 2009
Collect water samples, discharge, water level, temperature, precipitation	October 2009	September 2011
Longitudinal and cross-sectional surveys, bed and bank erosion, bed sediment	December 2008, February 2009 (pre-design); March 2010, March 2011 (post-design)	December 2008, February 2009 (pre-design); March 2010, March 2011 (post-design)
Photo documentation	Fall 2009, Spring 2010, Fall 2010, Spring 2011	Fall 2009, Spring 2010, Fall 2010, Spring 2011
Collect benthic macroinvertebrates and habitat	Summer 2009, Summer 2010, Summer 2011	Summer 2009, Summer 2010, Summer 2011
Vegetation survivorship	Fall 2010, Spring 2011, August 2011	Fall 2010, Spring 2011, August 2011
Quarterly Reports (to include a summary of data from each quarter)	End of each quarter, starting October 2009	October 2011
Data Analysis & synthesis	July 2011	October 2011
Complete Project Final Report	July 2011	October 2011

A7. Quality Objectives and Criteria Identify performance/measurement criteria for all information to be collected; and acceptance criteria, including project action limits and laboratory detection limits, and range of anticipated concentrations of each parameter of interest (includes field and lab, if applicable)

Data Precision, Accuracy, Measurement Range

Express the degree to which sample results are repeatable. State decision error limits, if applicable
Note: Projects which are based on authoritative rather than statistical sampling designs will not have quantitative decision error limits

Matrix	Parameter	Measurement Range	Accuracy	Precision
Water	Nitrate + nitrite	0.0-2.0 mg N/L, MDL 0.011 mg N/L	0.0024 mg N/L	0.0035 mg N/L
Water	Ammonia/ammonium	0.0-2.0 mg N/L, MDL 0.015 mg N/L	0.0003 mg N/L	0.0017 mg N/L
Water	Orthophosphate	0.00-0.80 mg P/L, MDL 0.008 mg P/L	0.0006 mg P/L	0.003 mg P/L
Water	Total Phosphorus	0.0- 4.0 mg P/L, MDL 0.014 mg P/L	0.0143 mg P/L	0.0045 mg P/L
Water	Total Kjeldahl Nitrogen	0.0-6.0 mg N/L, MDL 0.038 mg N/L	0.023 mg N/L	0.011 mg N/L
Water	Total suspended solids	1 mg/L	Not available at this time	Not available at this time
Water	Temperature	-20° to 50° C (HOBO) -5.00 to 55.00° C (Hanna)	0.2° C (HOBO) 0.15° C (Hanna)	0.02° C (HOBO) 0.01° C (Hanna)
Water	pH	0.00 to 14.00	600.0 mV	0.01
Water	Specific conductivity	0.001 to 9.999 mS/cm	0.001 mS/cm	0.001mS/cm
Water	Dissolved oxygen	0.00 to 30.00 mg/L	0.10mg/L	0.01mg/L
Water	Level	0 – 3 feet	0.001 feet	0.01 feet
Water	Velocity	0.001 m/s to 4.5 m/s	0.001 m/s	0.001 m/s
Benthic habitats	Benthic macroinvertebrates	N/A	ID to lowest possible taxonomic level	N/A
Precipitation	Volume/rate	0 – 50 inches	0.01 inches	0.01 inches
Stream channel	Bank erosion	± 2 feet	0.1 feet	0.25 feet
Stream channel	Bed erosion	± 2 feet	0.1 feet	0.25 feet
Stream channel	Bed substrate	N/A	N/A	N/A
Stream channel	Cross-section profiles	N/A	Depends on local benchmark data quality	0.01 foot vertical, 0.1 feet horizontal
Stream channel	Longitudinal profiles	N/A	Depends on local benchmark data quality	0.01 foot vertical, 0.1 feet horizontal
Riparian area	Vegetation survivorship plots	N/A	N/A	N/A
Riparian area	Photos	N/A	N/A	N/A

Data Representativeness

Express the degree to which the data accurately represents the population or the environmental condition at the sampling location (i.e. explain how well the monitoring characterizes the physical conditions)

Water sampling locations (chemistry, flow, temperature) are selected on a judgemental basis (not random/statistical) and located below construction and riparian management areas. Water sampling locations at the end of each watershed (instead of scattered throughout) are expected to be sufficiently representative of stream chemistry conditions at those points only, but may give an adequate understanding of nutrient and sediment export to lower reaches. They are not expected to represent conditions throughout each watershed. The specific locations for water sampling are somewhat biased due to the difficulty of siting autosamplers in high-density urban areas (i.e. there may be better locations to site them if it weren't for the surrounding land uses and constraints).

Locations for biological samples are taken as far down in the watershed as possible, but must also avoid being too close to culverts, construction areas, and water sampling areas to reduce effects on organisms. Biological sampling locations are thus limited by the high density of land use and may not well represent biological conditions through most of each watershed.

Locations for channel measurements (surveys, sediment, erosion) are necessarily biased towards areas undergoing purposeful channel adjustment (i.e. construction) or accidental channel adjustment (areas observed to appear to have high erosion).

It is assumed the area will maintain fairly normal climatic conditions through the length of the study. Any severe climatic deviations (such as the exceptional drought of 2007-08) will be carefully considered in data analysis should they occur.

Data Comparability

Express the degree of confidence that one data set can be compared to another at the sample location or to a sample taken at another location

To ensure within-project data comparability, established standard operating procedures will be used, and sampling locations will not change throughout the length of the study. We intend to maintain similar or comparable procedures for subsequent projects of a similar nature in the Bolin Creek watershed.

Channel surveys, bed sediment, and measurement of erosion use standard methods used for many other projects familiar to many of the project participants.

Biological samples are being collected using DWQ's Qual4 method, and being identified by a retired DWQ employee who conducted such sampling while employed by the agency. This ensures that our biological data are more readily comparable to other streams, collections made by other teams, as well as to collections at the two project areas made several years from now.

Data Completeness

Measure of the amount of valid data needed to develop conclusions (i.e., estimate how many measurements are needed to meet each monitoring objective(s))

Parameter	No. Valid Samples	Minimum No.	Monitoring

	Anticipated	Valid Samples needed	Objective
Base flow chemistry	24 per watershed	12	Detect differences between pre- and post-construction
Storm flow chemistry	24 per watershed	6	Detect differences between pre- and post-construction
Benthic macroinvertebrates	3	2	Get a community baseline

A8. Special Training/Certification - General description of training requirements and needs. Describes special personnel or equipment requirements, if applicable.

Training Logistical Arrangements

Training Topic(s)	Personnel Trained	Training/Certification Frequency
Macroinvertebrate collection methods	D'Arconte, Almond, Dodd	once
Plant ID	D'Arconte, Almond, Dodd	As needed (at least once)
Autosampler care and maintenance	D'Arconte, Almond, Dodd	At least once

Description of Training and Trainer Qualifications

Training Topic(s)	Training Description	Trainer Qualifications
Macroinvertebrate collection methods	DWQ methods	Dave Lenat, retired DWQ
Plant ID	Based on target invasive species for management, selected planted species	Karen Hall, NCSU Extension Biologist
Autosampler care and maintenance	Installation, programming, maintenance and data manipulation	Michael Shaffer, NCSU Extension Associate

A9. Documents and Records - Identify all data reporting information and list all project documents, reports, and electronic files that will be produced. Include QA records and reports, List information and records to be included in data reports (e.g., lab/field raw data, field logs, lab records, results of QC checks, problems encountered).

Information/Data Type	Recording Medium & Retention Duration	Responsible Party
Field notes	Field book using checklist (copy attached) and permanent storage of field books	Field Sampling Leader
Field data	See section B-10	Field Sampling Leader
Lab analysis reports	Excel, two separately stored permanent electronic copies of results	Lab supervisor and Project Leader

Photos	Two separately stored permanent electronic copies of each photograph	Field Sampling Leader and Project Leader
Survey data	Excel, two separately stored permanent electronic copies of results	Project Engineer and Project Leader

B1. Monitoring Experimental Design - Describe and justify the experimental monitoring design strategy, indicating size of the area, volume, or time period to be represented by the monitoring (detail the type and total number of sample types/matrix or test runs/trials expected and needed). Also include monitoring of covariates such as rainfall and discharge.

Rationale or Criteria for Selection of Sampling Sites- Describe and justify the experimental monitoring design strategy, indicating size of the watershed area, discharge volume, or time period to be represented by the monitoring. Describe appropriate validation study information for nonstandard sampling situations (if applicable).

Two small project watersheds: "Baldwin Park" (approximately 2776 acres) and "Trib to Mill Race" (approximately 2363 acres). Monitoring is taking a "before-after construction" approach for each project location rather than a paired watershed approach. This is due to the difficulty of finding well-matched watersheds of similar size and land use type and history for comparison in our urban areas.

Due to the restrictive timeline of EPA funding (3 years), and the need to stagger construction (i.e. construction in one watershed summer 2010) and the other winter 2010/2011), the two watersheds will have different amounts of pre-construction and post-construction monitoring. At a minimum, we will have 4 months of sampling before construction, and 6 months of sampling after planting.

See section A7 for a description of possible biases due to sampling location.

Project Monitoring Locations and Watershed Boundaries - Show map that delineates watershed boundaries or drainage area being monitored. Provide maps or tables that show/state geographic locations of sample locations (include GPS data coordinates). If other data sources are to be obtained and compiled, list these sources as well.

Each project includes a combination of multiple stormwater BMPs, riparian vegetation management, stream enhancement and stream restoration along the stream lengths. Water flow, chemistry, and temperature sites are located below all areas of disturbance. See Appendix A, Map 1 for the location of the Bolin Creek Watershed relative to other sections of the Upper Cape Fear Basin. See Appendix A, Map 2 for locations of project watersheds within Bolin Creek Watershed.

The "Baldwin Park" water flow/chemistry/temperature site is located just below the confluence of two tributaries (both with project activity on them), on Town of Chapel Hill-owned property. It is accessed via a cleared OWASA easement. See Appendix A, Map 3 for approximate locations of surveys and monitoring in the "Baldwin Park" watershed. A rain gauge is located in Baldwin Park in an open area.

The "Tributary to Mill Race" water flow/chemistry/temperature site is located just above a concrete-encased OWASA line crossing that is acting as grade control. It is on property owned by the local Homeowner's Association and accessed via a cleared OWASA easement. See Appendix A, Map 4 for approximate locations of surveys and monitoring in the "Trib to Mill Race" watershed.

Benthic macroinvertebrate collection areas are approximately 100 feet along the channel, upstream from the water flow/chemistry locations, not in areas to undergo channel modification.

Post-construction vegetation survivorship surveys will be multiple 1m x 5m plots representative of different treatments (i.e. kudzu control with riparian reforestation, privet/ivy control with riparian reforestation, bank stabilization with non-woody plants, riparian understory enhancement, and park/ornamental riparian plantings).

Longitudinal and cross-sectional profiles will be collected along the length of the channel for engineering design purposes prior to construction. A post-construction as-built survey will be conducted and permanent markers placed for locations of longitudinal and cross-sectional profiles. Cross-sections, photos, and bed sediment monitoring will be conducted where the stream channel has been modified or moved, to be determined during engineering design. Bank/bed erosion rate monitoring will be conducted at identified areas of probable high erosion observed prior to construction.

Sample Design Logistics - Sample numbers and frequency. Also include monitoring of covariates such as rainfall and discharge. State if parameter is for informational purposes only and not critical.

Type of Sample/ Parameter (i.e. storm/grab, water/sediment, etc.)	Number of Samples	Sampling Frequency and Period	Importance
Baseflow water chemistry – "grab" using autosampler	24 per watershed	Monthly	Critical
Stormflow water chemistry – flow-proportional storm composite	24 per watershed	Depending on precipitation events	Critical
Water level	Continuous - bubbler module 24 – staff gage	(bubbler measures every 5 minutes), staff gauge height noted at each maintenance visit	Critical
Water field parameters	48 per watershed	At each baseflow and stormflow sample time	Supporting
Discharge	Irregular	Sufficient measurements at different flow levels to develop rating curve	Critical
Precipitation	Continuous	measures every 0.01 inches of precipitation	Supporting
Benthic Macroinvertebrates and habitat	3 per watershed	One every summer	Critical
Water Temperature	Continuous	measures every 5 minutes	Supporting
Longitudinal Profiles	3 per watershed	One before construction, one as-built, at least one after	Supporting
Cross-section Profiles	3 per cross-section	One set before construction, one as-built, at least one set after	Supporting
Bed Sediment Survey	Once per year pebble count (2 total) at each permanent cross section	Annually (at least twice) before and after construction	Supporting
Bank/Bed Erosion	From annual cross sections and scour chains	Annually (at least twice) before and after construction	Supporting
Planted vegetation survivorship	3 per watershed	Once each spring after construction	Supporting
Photo documentation	3 sets per watershed	Before during and after construction at fixed photo points	Supporting

B2. Sampling Methods

Identify Sampling Equipment, Collection Methods and SOPs

Parameter	Sampling Equipment	Sampling Method	Sample Container, Size, Preservative, Max Holding Time
Water chemistry – nitrogen and phosphorus	Teledyne ISCO 6712 Portable Sampler	Baseflow – grab Stormflow – flow proportional	500 mL, Polyethylene bottle, acidified to pH<2 (w/ H_2SO_4), refrigerate at 4 degrees C, 48 hours
Water chemistry – total suspended solids	Teledyne ISCO 6712 Portable Sampler	Baseflow – grab Stormflow – flow proportional	500 mL, Polyethylene bottle, refrigerate at 4 degrees C, 7days
Water level	Teledyne ISCO 730 Bubbler Module, Staff gage	recorded	N/A
Water chemistry – field parameters (pH, DO, cond.)	Hanna multiparameter meter	recorded	N/A
Water temperature	Onset HOBO U22 Water Temperature Pro 2 logger (with Solar Radiation Shield)	recorded	N/A
	Hanna multiparameter meter		
Water discharge	Sontek FlowTracker	Equal width increment	N/A
Precipitation	Davis Rain Collector II	Tipping rain gauge – recorded	N/A
Benthic macroinvertebrates, habitat	Screens/nets with 0.5mm mesh	DWQ Qual 4	Glass vials, 95% ethanol
Bed sediment survey	Ruler (mm)	Wolman pebble count	N/A
Longitudinal and cross-section profiles	Topcon 320-D Total Station	3-D survey	N/A
Bank/Bed erosion	Bank pins (rebar) and scour chains	Annual measurement	N/A
Vegetation survivorship	N/A	N/A	N/A
Photo documentation	Digital camera, minimum 3.0 megapixel	Defined photo points, annually	N/A

Field Sampling Methods. Describe procedures for collection of monitoring samples. Describes sample preservation methods. Describe process for preparation and decontamination of sampling equipment. Describe or reference selection and preparation of sample containers and sample volumes. (Please do not simply reference another document, but summarize the procedures to be used here and include reference for details! Identify individuals responsible for corrective action

Cross-sections used for measuring discharge will set using painted rebar, and tape stretched between these for each manual discharge measurement. A series of discharge measurements through the duration of at least one storm for each site will be used to develop a stage-discharge rating curve. A new stage and discharge measurement will be made at each sample collection time.

Water level is recorded every 5 minutes by the autosampler using a bubbler module. The recorded level will be referenced back to a stage measurement on a stage gauge at each site visit. The elevation of a stage gauge will be referenced back to a known benchmark using standard survey methods. A measurement of pH, temperature, dissolved oxygen, and specific conductivity will be made using the multiparameter meter at the time of sample collection.

Precipitation will be recorded at Baldwin Park only using a tipping bucket rain gauge that records each 0.01 inch of rainfall. Data will be downloaded every 2 months by the field crew.

Water temperature is measured every 5 minutes by the logger, and downloaded every 2 months by the field crew. The logger should be covered by a temperature shield or cover of some kind to prevent heating of the logger by sunlight.

Lab bottle sets will be labeled with the site name (Mill Race or Baldwin Park) the date the sample bottle was filled and the date the autosampler collected the sample. They will be placed directly into a cooler with ice and transported to NCSU's lab within 48 hours of collection. Chain-of-custody forms are filled out at the time of collection. Stormflow samples will be retrieved from the autosampler no later than 40 hours after the beginning of the storm so that they may be delivered to the lab with in the holding time of 48 hours.

Bottle sets for each site will include one 500mL sample bottle for nitrogen and phosphorus analyses, and one 500mL bottle for total suspended solids analysis. Nutrient samples will be acidified to a pH below 2 using 0.5mL H2SO4 added after collection and before transport. Acidified bottles will be labeled with a "+".

3 sets of QA samples will be taken; one in fall 2009, one in fall 2010, and one in fall 2011. Each set will include a blank and a replicate for each site. Blanks will be supplied by the lab.

Baseflow samples will be collected monthly, at least 48 hours after rainfall or 72 after snow/ice using the autosampler's "grab" function to ensure comparability to the storm samples (rather than grabbing "by hand").

Autosamplers will be programmed to start sampling stormflow after 0.02" rise in water level, depending on results from the developed discharge rating curve. Each autosampler will be programmed for one rinse prior to collecting flow-proportional samples. The developed stage-discharge rating curve will be used to program the sampler for flow-proportional sampling, including the trigger water level rise, termination of the autosampler program, the flow increment for each sample, and the sample size taken at each flow increment.

Compositing the storm flow samples will utilize a dedicated incremented 4 liter polyethylene wide-mouth bottle using all the samples from the storm event. All stormflow samples will be agitated and an equal volume of each poured into the compositing bottle. The volume required from each sample will be determined by the volume of sample required and the volume available in sample bottles. The composited sample will be agitated again before filling each of the lab bottles.

Compositing bottles will be rinsed with deionized water, dried, and stored covered/capped between sample collections.

Macroinvertebrates are collected in sets of 4 types – one kick-net, one sweep-net, one leaf-pack, and one visual collection. Samples are rinsed through 0.6mm mesh and hand-picked in the field. All organisms are collected and stored in 95% ethanol for ID in the laboratory. Habitat characterization takes place at the time of organism collection using DWQ's habitat form.

Bed sediment is characterized using Wolman pebble counts unless the majority of the sediments are sand or finer, in which case sieves are to be used. Pebble counts include collection of 100 samples divided proportionally between riffles and pools.

Bank erosion is measured by the installation of rebar into banks, and the amount of rebar exposed recorded once per year. Bed erosion is measured by the installation of scour chains into the bed, and the amount of chain exposed (or buried) also measured once per year.

Longitudinal surveys – Starting at a permanently-marked point, and continuing downstream for a length of more than 2 times the meander wavelength. Elevation points of the thalweg, water surface, bankfull height, and top of bank height on both banks will be recorded at each station, to a precision of hundredths of an foot. Stations are located 10 feet apart, or at each change in bed form, whichever is the shorter distance. Standard survey procedures should be used to reference the elevation back to a known benchmark, and to make turning-points as necessary.

Cross-sectional surveys – a tape is stretched taut across the cross-section from a permanently-marked starting point to an ending point located above top of bank. Elevation measurements are taken at a minimum at every break in slope, or every foot (whichever is the shorter distance), to a precision of hundredths of a foot. Standard survey procedures should be used to reference the elevation back to a known benchmark.

Photos are to be taken at marked photo points, facing the same direction for each set of shots. An object of a standard size should be placed in the field of view to provide a replicable visual comparison from shot to shot.

Vegetation survivorship plots should have at least one corner permanently marked; which corner is recorded in field notes, as well as the plot size and dimensions. Numbers of surviving planted individuals, as well as "volunteers" should be counted, recorded by species. Presence of any invasive species should be noted and an estimate of percent area covered made.

Sources and References used as Guidance for Typical Data Collection (e.g., USGS field collection methods, data needs for watershed models, monitoring design guidance documents)

Water sample collection, water level (using bubbler) – 6712 Portable Samplers: Installation and Operation Guide. 730 Bubbler Module: Installation and Operation Guide. FlowLink software manual. Teledyne ISCO.

Water level (using staff gage) – Buchanan, T.J. and Somers, W.P. 1982. Stage Measurement at Gaging Stations. Techniques of Water-Resources Investigations of the US Geological Survey. Book 3, Chapter A7.

Water temperature – HOBOWare Pro Manual and related HOBO manuals. Onset Corp.

Discharge measurement – Nolan, Michael K. and Shields, Ronald R. 2000. Measurement of Stream Discharge by Wading. Water Resources Investigations Report 00-4036, version 1.1. US Geological Survey. (MPEG format on CD), also Sontek FlowTracker Manuals (v2.6)

Precipitation – Rain Collector II manual, Davis Instruments.

Stage-discharge rating curve development – Kennedy, E.J. 1984. Discharge Ratings at Gaging Stations. Techniques of Water-Resources Investigations of the US Geological Survey. Book 3, Chapter A10.

Benthic Macroinvertebrates and Habitat – Standard Operating Procedures for Benthic Macroinvertebrates. 2003. Biological Assessment Unit, NC Department of Environment and Natural Resources.

Photo documentation – Hall, Frederick C. 2002. Photo Point Monitoring Handbook. US Forest Service General Technical Report PNW-GTR-526. US Department of Agriculture.

Safe Field Techniques – Yobbi, D.K, Yorke, T.H., and Mycyk, R.T. 1996. A Guide to Safe Field Operations. Open-File Report 95-777. US Geological Survey.

B3. Sample Handling and Custody - Identify how the samples will be physically handled, transported, and received; and describe the documentation of sample information handling and chain-of-custody. Include maximum allowed holding times from collection to analysis and lab preservation procedures.

See Standard Methods for the Examination of Water and Wastewater 20th Edition. Section 1060 on Collection and Preservation of Samples with an emphasis on filling the sample container full, take care not to overfill the bottle if it already contains a preservative. Sample bottles can be submitted to the BAE/EAL between the hours of 7:30 am and 4:00 pm. Sample Bottles will be clearly labeled (with a permanent label and marker) with Sample Site/Date/ID Code/ if the sample has been acidified indicate with "+". A separate "non-acidified" sample is taken for the analysis of suspended solids. A chain-of-custody form will be submitted with each batch of samples and include: sample code, name of collector, date of collection, date samples submitted to the lab, sample type, preservation measures taken. Samples will be placed on ice at collection and remain on ice until the lab receives them. Deliver samples to the EAL as soon as practicable after collection. The EAL follows the recommendations for "Special Sampling and Handling Requirements" listed in Standard Methods. Samples are refrigerated at 4 degrees C until analysis. NO3/NO2 and O-PO4-P analysis are done 48-72 hours upon arrival to the lab. Completed samples are held in storage at 4 degrees C for 1 month.

EAL=Environmental Analysis Laboratory.
See Appendix B for the Chain of Custody form.

B4. Analytical Methods

Identify laboratory(ies) to conduct testing and indicated if they are State certified. Identify all analytical SOPs including field and laboratory procedures (include method for every parameter being monitored). Specify needed laboratory turnaround time. Identify individuals responsible for corrective action.

Nitrate + Nitrite (NO_3^- and NO_2^- as N). Copper Cadmium Reduction Method. EPA 353.2 and SM 4500-NO3 F (Colorimetric, Automated).Nitrate is reduced to nitrite be a copper cadmium column. The nitite ion then reacts with sulfanilamide under acidic conditions to form a diazo compound. This compound couples with N-1 naphthylethylenediamine dihydrochoride to form a reddish purple azo dye. Colorimetric procedure is read at 520 nm using Seal Analytical Autoanalyzer II system

Ammonia/Ammonium (NH_3/NH_4^+ as N). EPA 351.2 Automated procedure is based on a colorimetric procedure in which an emerald green color is formed by the reaction of ammonia, sodium salicylate, sodium nitroprusside and sodium hypochorite in a buffered alkaline medium at a pH of 12.8-13. The ammonia salicylate complex is read at 660 nm using Seal Analytical Autoanalyzer III system.

Ortho-phosphate (O-PO4-P). EPA 365.1 Automated Ascorbic Acid Method in which orthophosphate reacts with ammonium molybdate and antimony potassium tartrate in an acid medium and then is reduced with ascorbic acid to form a phosphomoybdenum complex. Complex is read at 660 nm using a Seal Analytical Autoanalyzer III system.

Total Kjeldhal Nitrogen (TKN) – Digestion: EPA 351.2 (Colorimetric, semi-automated block digestor AAII), Standard Methods 420A Macro Kjeldahl Method. Automated Analysis: see Ammonia/Ammonium. Digestion converts free ammonia and most organic nitrogen compounds to (NH4)2SO4. TKN includes ammonia and organic nitrogen, but does not include nitrate nitrogen. The ammonia-salicylate complex is read at 660 nm using automated

Seal Analytical Autoanalyzer III system

Total Phosphorus (TP) Digestion: EPA 365.4 (Colorimetric, semi-automated block digestor AAII), Standard Methods 424 C Preliminary Digestion Steps for Total Phosphorus III. Automated Analysis: Automated ascorbic acid method, see Ortho-phosphate.

Total Suspended Solds: Filtration method. Reference: Standard Methods for the Examination of Water and Wastewater, American Public Health Association, American Water Works Association, and Water Pollution and Control Federation, Total Suspended Solids Dried at 103°-105° C, Washington, D.C., American Public Health Association, Method 2540D.

All nutrients are analyzed by the NCSU Biological and Agricultural Engineering Departments Environmental Analysis Laboratory using Seal Analytical Autoanalyzer III systems. Nutrient samples are submitted to the Laboratory within 48 hours of storm events. Total Suspended Solid analysis is performed in the laboratory within 24 hours. Bring samples to room temperature before analysis. Max holding time 7 days.

B5. Quality Control - Identify QC activities which will be used for each type of sampling, analysis, or measurement technique; for example, blanks, spikes, duplicates, etc., and at what frequency (also include what criteria will be used to determine if a corrective action is needed and what that corrective action will be).

Field QC Checks

The following table outlines QC procedures

Activity	QC Procedure	Purpose
Water chemistry replicates	3 replicate samples for each site – fall 2009, fall 2010, fall 2011	Check for replicability of field sampling. Assess field precision in sampling
Water chemistry field blanks	3 field blanks for each site – fall 2009, fall 2010, fall 2011	Check for field sources of sample contamination
Data downloads from autosamplers, temperature logger, rain gauge, multiparameter meter	Data downloads are observed to ensure recording instrument doesn't run out of memory or have another kind of error	Retrieve all electronic records with minimal errors
Field data recording	Paper forms and labels are checked for competeness before leaving the site	Reduce missing data

Laboratory QC Checks - Describe Laboratory QC procedures

The BAE-EAL QA/QC protocol is as follows:

- Initial Calibration Curves are performed for each analysis run (7-9 points)
- QC- check standards (mid level calibration standard). QC check standards are run at least 5 % of the samples in the batch.
- Laboratory Certified Samples (run once a week or when changes are made to the system – such as new reagents or instrument maintenance). Standards are purchased from an outside source, diluted to fit the range and analyzed using a 95% confidence interval.
- Duplicate Analysis – Duplicates are run every 10 samples.
- Sample Spikes – Spikes are run every 15 samples.
- % Recoveries must be between 85% and 115% to be considered acceptable.
- Duplicates must fall within 25% of each other.
- All duplicates and % Recovery results are recorded in the labs record books. Charts for each QC per parameter are also recorded and updated monthly.

See Appendix B for the lab's QA/QC pamphlet.

Data Analysis QC Checks- Describe data analysis QC procedures. Include what criteria will be used to determine if a corrective action is needed and what that corrective action will be. Provide or reference QC statistics used to determine precision and bias, if applicable.

Sample results will be reviewed and summarized every quarter as part of the quarterly report. Part of the summary process will be to look for outliers and other probable bad values, look for missing data, look for unusual/unexpected trends. The summary process should compare the current quarter's results to those of previous quarters to best identify outliers and other errors.

For outliers, the QA Officer or Sampling Leader should review field notes and lab results from the affected dates and discuss these with staff that collected/analyzed the data to determine likely sources of error and appropriate corrective actions to take (i.e. such as special cleaning, clarifying sampling procedures, etc.). The QA Officer or Sampling Leader should follow similar actions in the case of unusual or unexpected trends in data.

For missing data, the QA officer or Sampling Leader should review the field notes with staff that collected the affected samples to determine why data are not being collected, and institute new procedures to minimize more such events.

B6. Instrument/Equipment Testing, Inspection, and Maintenance - Identify field and laboratory equipment needing periodic maintenance, and the required inspection schedule. Describe preventative and corrective maintenance activities.

Equipment Type	Inspection Frequency	Responsible Party	Type of Inspection / Preventative / Corrective Action
Automated Sampler	Biweekly	D'Arconte / Almond / Shaffer / Dodd	Check functioning prior to installation; Clean enclosure; clear away weeds/vines (unless used for camouflage); check tubing connections/lengths for clogs/kinks, jammed distributor, pump (for fine gravel/sand), animal nests/damage, sampling report/errors/warnings, vandalism; change dessicant; download data
Bubbler Module	Biweekly	D'Arconte / Almond / Shaffer / Dodd	Check functioning prior to installation; Check for algae on end of tube, obstructions, kinks, make sure it's buried/secure; adjust water level/stage; download data
Sontek Flow meter	Biweekly	D'Arconte / Almond	Check battery level
Hanna multiparameter meter	Biweekly	D'Arconte / Almond	Check functioning, order new cable and/or probes if any difficulties, check battery level
Water	Biweekly	D'Arconte /	Check functioning prior to installation; Check

temperature logger and solar radiation shield		Almond / Shaffer / Dodd	anchoring of logger and shield; clear debris; download data
Rain gauge	Each storm event	D'Arconte / Almond / Dodd	Check functioning prior to installation; Check for obstruction, debris; download data
Bank pins/scour chains	After every storm event	D'Arconte / Almond / Shaffer / Dodd	Measure exposed section; check for looseness – replace and resurvey if necessary
Reference points, photo points, vegetation plots, cross-section markers	Annual	D'Arconte / Almond / Shaffer / Dodd	Check markers annually to make sure they can be found, replace/remark if necessary
Staff gage	Biweekly	D'Arconte / Almond / Shaffer / Dodd	Clean; check for looseness
Solar array/power	Biweekly	D'Arconte / Almond / Shaffer / Dodd	Charge batteries prior to installation; Clean solar panel; check connections, battery power; exchange battery with new charged one if insufficient solar

B7. Instrument/Equipment Calibration and Frequency - Identify equipment, tools, and instruments that should be calibrated, and the frequency and method for this calibration (include summary of method for calibrating laboratory equipment unless a state certified lab is used; also include calibration of field equipment such as stage recorders and flow meters). Note how calibration records will be kept and traceable to equipment.

Equipment Type	Calibration Frequency	Responsible Party	Standard or Calibration Instrument Used	Recordkeeping
Bubbler Module	At installation and monthly baseflow sampling	D'Arconte / Almond / Shaffer / Dodd	Installed nearby staff gage	Note in site visit field notes
Flowmeter	Annual	D'Arconte / Almond	Check/update firmware	Note in quarterly report when conducted
Rain gauge	None required	D'Arconte / Almond / Shaffer / Dodd	N/A	Clean and note condition in field notes
Multiparameter meter	Monthly	D'Arconte / Almond	Hanna Quick Calibration Solution (HI 9828-25)	Calibration records stored in meter and downloaded with data
Staff gage	Survey elevation at installation and at annual survey time	D'Arconte / Almond / Shaffer / Dodd	N/A	Clean and note condition in field notes

B8. Inspection/Acceptance of Supplies and Consumables

Identify critical supplies and consumables for field and laboratory, and acceptance criteria. Note responsible individual(s).

Equipment / Supply	Inspection / Maintenance Activity	Responsible Party	Vendor / Source
Sample bottles	Properly labeled, pre-preserved (if appropriate), proper number and size for sampling	D'Arconte / Almond	NCSU lab
Automated sampler bottles	Check for cleanliness, damage	D'Arconte / Almond	Johnson Controls (local ISCO distributor)
Automated sampler tubing	Check for cracks, holes, obstructions	D'Arconte / Almond	Johnson Controls (local ISCO distributor)
Calibration solutions for multiparameter meter	Check remaining left, order new solution if necessary	D'Arconte / Almond	various

B9. Non-Direct Measurements - Identify data sources, for example, computer databases or literature files, or models that will be accessed and used, data recording methods, and references for this information.

Non-direct Measurements.

Identify data sources, for example, computer databases or literature files, or models that will be accessed and used. Describe limitations of the secondary data. Document rationale for original collection of data and its relevance to this project.

GIS data layers – parcels, impervious surfaces, hydrology, 2-foot contours, street centerlines, others as available from the Towns of Chapel Hill and Carrboro

These data layers are used primarily for cartography and other presentations, rather than for specific analysis purposes. Data have been collected and processed at a non-survey-grade and are not meant for scientific analysis except at full watershed scales.

Data Recording Methods for Non-Direct Measurements

Data Element/Measurement	Minimum Data Recording Method
GIS data	N/A

B10. Data Management

Describe data management scheme from field to final use and storage, and describe the process for data archival and retrieval. Include a summary of data analysis procedures, data transformations, and statistical analyses, if applicable.

Data Type and Data Management/Storage

Data Type	Format/Medium	Archival Duration	Responsible Party
Water level	raw ISCO file (FlowLink v.5.10)	6 years	Chapel Hill Stormwater Management Program

Water velocity, discharge	FlowTracker file	6 years	Chapel Hill Stormwater Management Program
Water velocity QA data	FlowTracker file	6 years	Chapel Hill Stormwater Management Program
Water temperature	Raw data file (HOBOWare)	6 years	Chapel Hill Stormwater Management Program
Precipitation	Raw data file	6 years	Chapel Hill Stormwater Management Program
Water field parameters	Raw data file	6 yaers	Chapel Hill Stormwater Management Program
Chain-of-custody forms	Paper forms	6 years	NCSU Soil Science Lab
Lab analysis results (includes field QA samples)	Excel spreadsheets	6 years	NCSU Soil Science Lab
Lab QA records	Excel spreadsheets	6 years	NCSU Soil Science Lab
Field Notes, maintenance/inspection notes, bank/bed erosion measurements	Paper field notes	6 years	Chapel Hill Stormwater Management Program
Macroinvertebrate ID data	Excel spreadsheets	6 years	Dave Lenat
Macroinvertebrate, habitat collection field notes/data	Paper forms	6 years	Dave Lenat
Macroinvertebrate voucher specimens	Preserved organisms	6 years	Dave Lenat
Macroinvertebrate Report	MS Word Document	6 years	Dave Lenat
Longitudinal, cross-sectional, bed sediment, vegetation surveys	AutoCAD, Paper field notes	6 years	Chapel Hill Stormwater Management Program
Photos	Digital (JPG)	6 years	Chapel Hill Stormwater Management Program
GIS data	ArcGIS shapefiles and geodatabase	6 years	Chapel Hill Stormwater Management Program

Data Management and Analysis. Describe data management scheme from field to final use, data compiling and data storage. Describe the process for data archival and retrieval. Include summary of data analysis procedures, data transformations, and statistical analyses, if applicable. Include project-specific calculations or algorithms, if applicable.

Digital data files will be saved to the Town of Chapel Hill's Stormwater server, copies may be made to the Town of Carrboro and others as requested.

Hardcopy data, such as field sheets or faxed laboratory data (if not available electronically), will be scanned into PDF file format and given descriptive file names. Where such data would be best used for graphing, GIS, or other electronic analysis or display, the data values themselves should be entered into a specially-prepared Excel spreadsheet or MS-Access database. This provides another QA check.

At the end of the project, after the Final Report has been prepared, all data and documents will be collected together into a single directory with subdirectories on Chapel Hill's server, and backed up digitally to a CD or DVD. The QA Officer, Sampling Leader, and Project Manager will review the collected information to ensure all raw and processed data, reports, presentations, and associated project documents (including the original 319 grant application and budget) have been included. This includes data that will be formally archived by others (e.g. NCSU Soil Science Lab and Dave Lenat) in order to maintain a "full-picture" collection of data for this project. Copies would be made for the Town of Chapel Hill, the Town of Carrboro, NCSU, DWQ, and any other interested members of the project. Records will be maintained in accordance with the NC Records Retention and Deposition

Schedule for Municipalities by the Town of Chapel Hill's Stormwater Management Program (6 years for Engineering Project Records). Data requests should be made to the Town of Chapel Hill's Stormwater Management Program.

C1. Assessments and Response Actions - List the number, frequency, and type of assessment activities that should be conducted. Specific response actions for the situations listed below will generally apply. Also list who is responsible for each action.

Situation	Response Action	Responsible Person/Organization
Autosampler malfunction	Rent replacement from ISCO while original is repaired	Shaffer
Quarterly review of field notes (including maintenance notes)	Resolution of problems with field staff	D'Arconte
Review of lab reports	Discuss problems with lab contact	D'Arconte

C2. Reports to Management - Identify what project QA status reports are needed and how frequently they will be prepared

Report	Frequency	Who Prepares Report	Who Receives Report
Project Status	Quarterly	D'Arconte	Nimmer, Jennings, Dodd
Results of performance evaluation and audits (if applicable)	Quarterly	D'Arconte	Nimmer, Jennings, Dodd
Results of periodic data quality assessments (if applicable)	Quarterly	D'Arconte	Nimmer, Jennings, Dodd
Any significant QA problems	Quarterly	D'Arconte	Nimmer, Jennings, Dodd

D1. Data Review, Verification and Validation - Describe the criteria that will be used for accepting, rejecting, or qualifying project data. (include criteria for determining anomalies or outliers, what portion of data will be reviewed, who will do it, and what happens if data deemed 'bad')

Criteria for Accepting, Rejecting, or Qualifying Project Data.

Include criteria for determining anomalies or outliers, what portion of data will be reviewed, who will do it, and what happens if data deemed 'bad'

Water chemistry data generated by the laboratory will undergo internal lab QA/QC checks to identify data outside of the Data Quality Objectives. While Project staff will receive and archive these data, they will be excluded from analysis.

Continuous-measurement devices (such as the bubbler module, the flowmeter, precipitation, and temperature logger) record large numbers of data points and it is not uncommon for there to be a few isolated outlier data points. When these instruments are malfunctioning they tend to record a single value, multiple extreme values, or no value. These are easily detected by plotting out newly-retrieved data and discarding suspect points. If the review indicates a potential equipment failure, field staff will repair or replace the equipment as soon as possible. These devices may also experience some measurement drift over time, but a two-week recalibration cycle should be sufficient to avoid these errors as they tend to occur during long deployments.

Cross-section and longitudinal-profile surveying involves the measurement of the elevation of a known benchmark at the beginning and ending of data collection for each location of the tripod. When these measurements don't match, that round of surveying must be redone. For this reason, data quality checks are first done in the field. A secondary check using the plotted data will detect outliers to be corrected (if correct data can be interpreted from field notes) or discarded. Biases and offsets can also be detected from plotted data. If a correction can be determined from field notes, then the full set of data will be corrected.

Field leaders and assistants will confirm data have been entered and reviewed properly, checking for errors or omissions. Throughout the course of the project, Project staff will review data and modify protocols where there are problems with them or they generate considerable errors.

Decision Rule or "if/then" Statement. Provide if applicable.
Note: Some projects, especially research or preliminary investigations, may not require a specific "if/then" statement. This is also applicable for decisions regarding data "outliers."

N/A

D2. Verification and Validation Methods -

Describe the process for data verification and validation, providing SOPs and indicate what data validation software will be used. State the percentage of the data to be reviewed. List the responsible individual/organization.

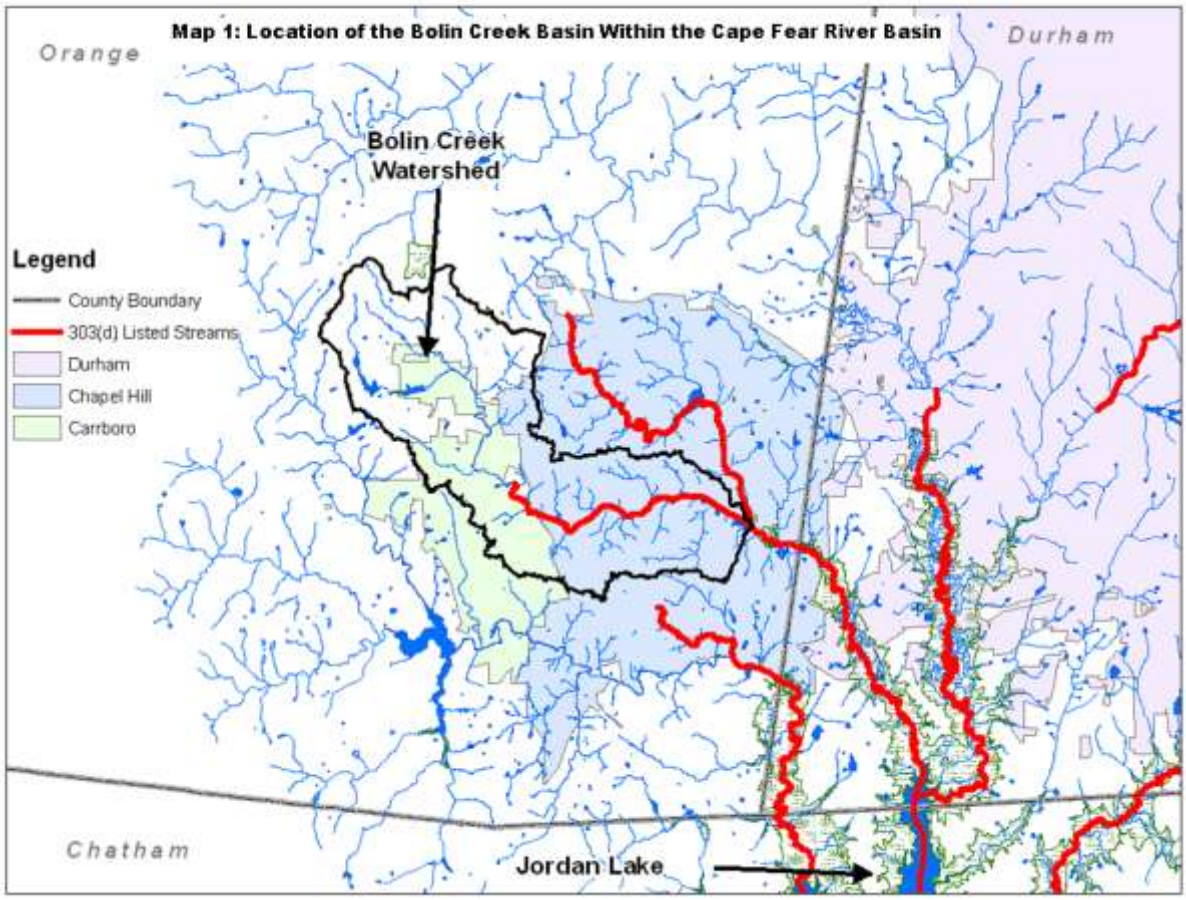
Data Element	Typical Validation and Verification Methods
Water velocity/discharge	Use recommended signal-to-noise cutoff values, use recommended QA methods in FlowTracker software to check for equipment errors, data quality problems, etc.
Water level	Check for outliers, continuous single value measurements
Water temperature	Check for outliers, continuous single value measurements
Nutrients	(see Lab QA procedures)
Total Suspended Solids	(see Lab QA procedures)
Precipitation	Check for outliers, continuous single value measurements
Macroinvertebrates	Voucher samples retained

D3. Reconciliation with User Requirements and Data Quality Objectives

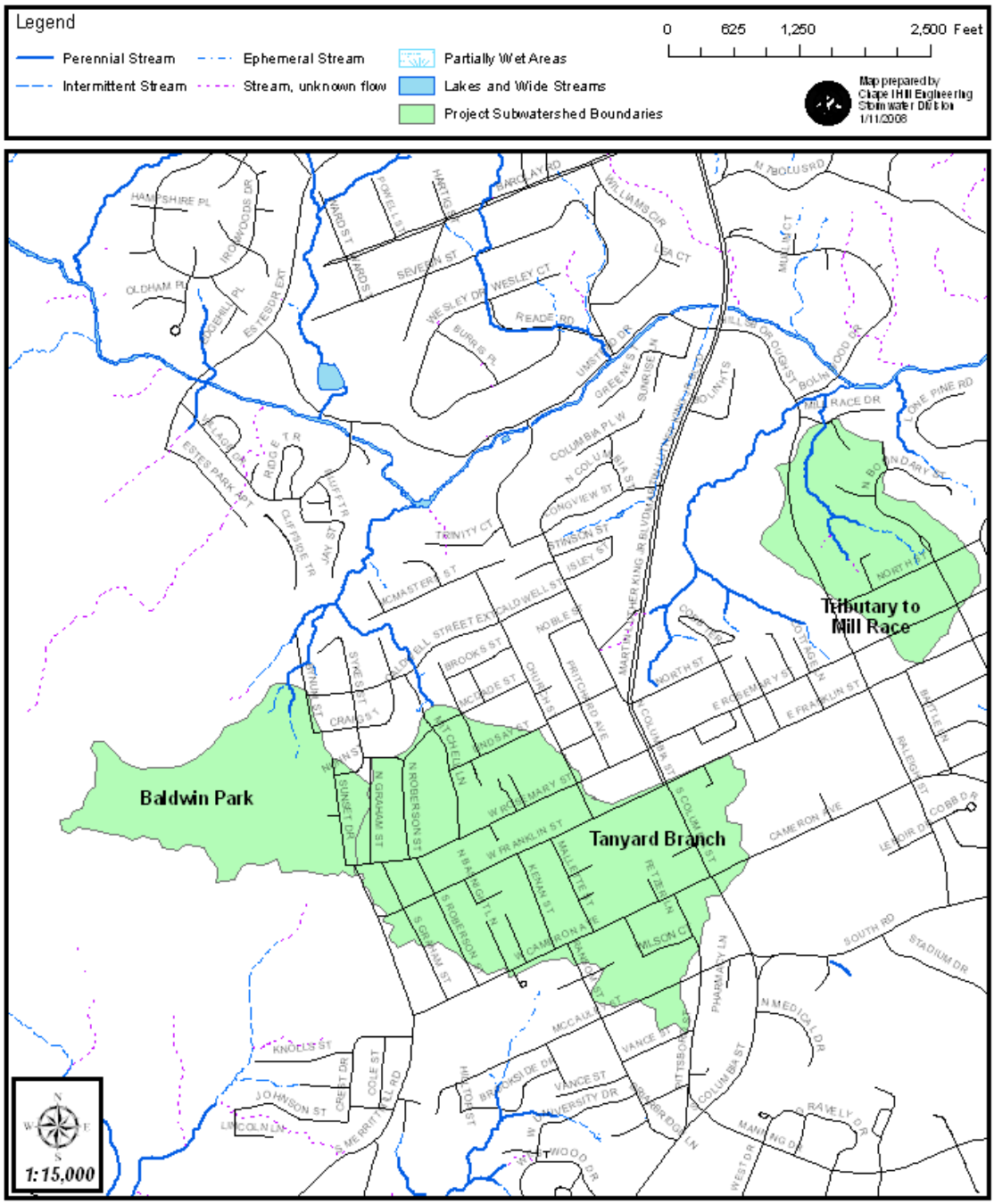
Also include how the data will be summarized to be able to report results to decision makers. Describe process for reconciling project results with data quality objectives (DQOs) and reporting limitations on use of data. Identify issue resolution procedure(s) and responsible individuals

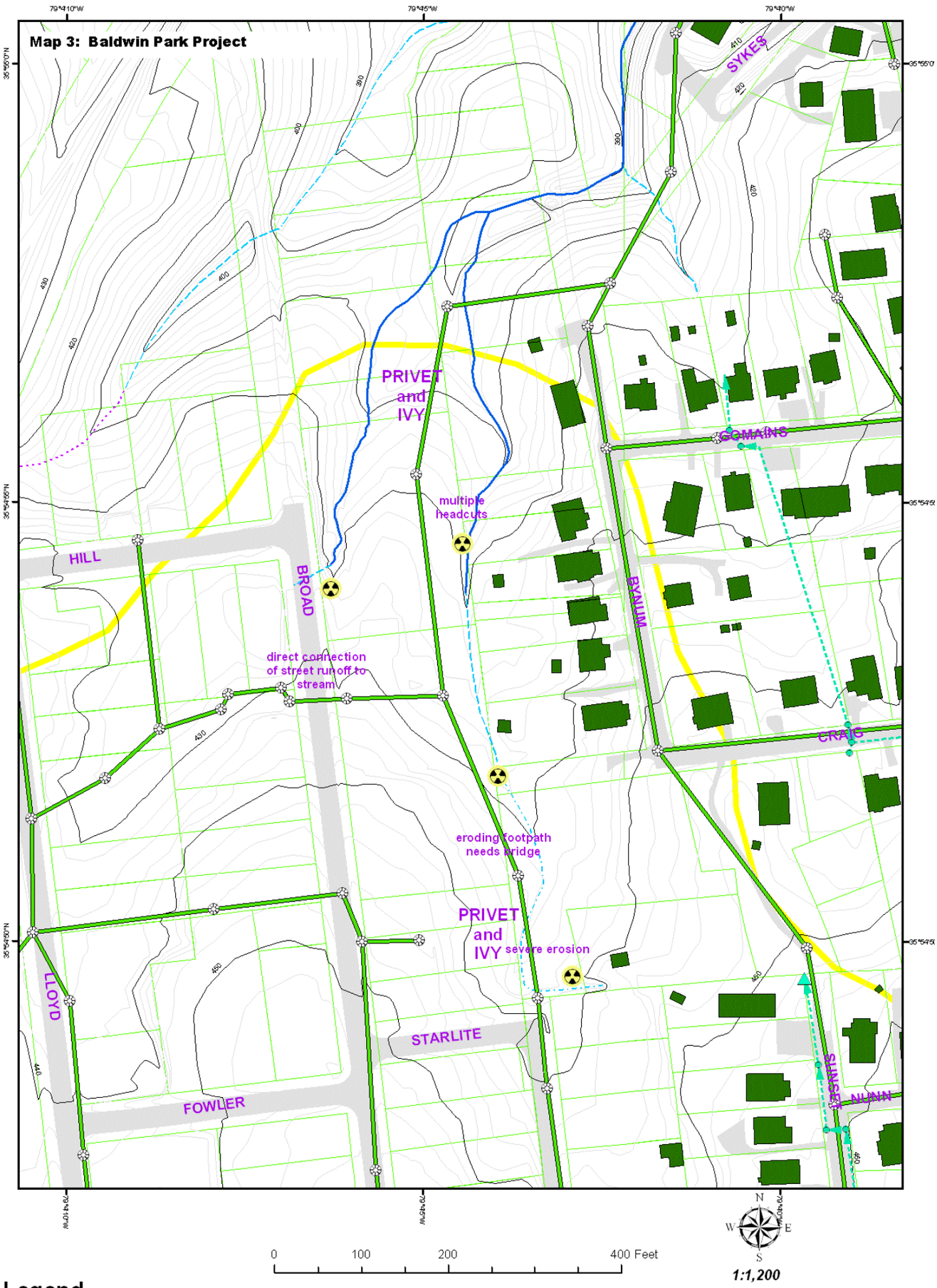
Quarterly data reports summarizing the data will be prepared by Chapel Hill staff and distributed to team members from Chapel Hill, Carrboro, NCSU, and EEP. Others will receive copies as requested. Insufficient acceptable base flow or storm flow samples will push back the construction schedule for either site, as additional sampling can go on beyond the 3 year period if needed.

Appendix A: Location and Site Maps


Map 1: Location of the Bolin Creek Basin Within the Cape Fear River Basin
Orange
Durham
Bolin Creek Watershed
Legend
County Boundary
303(d) Listed Streams
Durham
Chapel Hill
Carrboro
Chatham
Jordan Lake

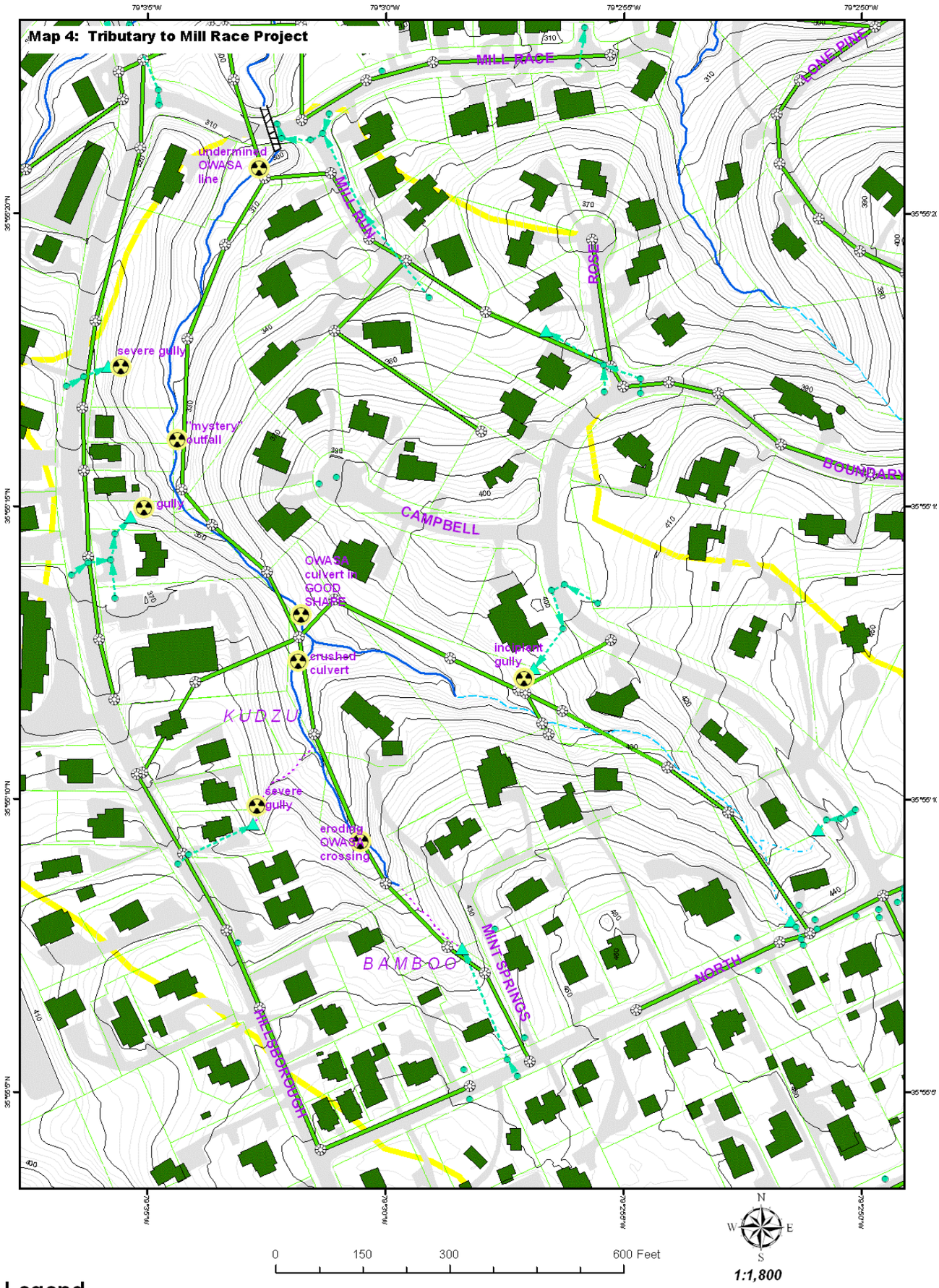
Map 2: Bolin Creek Watershed Restoration Project Locations





Legend

Inlets	Stormwater Lines	Perennial Stream	Buildings
Stormwater Outfall	OWASA Sewer Mains	Intermittent Stream	Parcel Boundaries
OWASA Manholes	10-foot Contours	Ephemeral Stream	Streets and Driveways
Problem Area	2 ft Contours	Stream, unknown flow	Subwatershed Boundaries



Legend

Inlets	Stormwater Lines	Perennial Stream	Buildings
Stormwater Outfall	OWASA Sewer Mains	Intermittent Stream	Parcel Boundaries
OWASA Manholes	10-foot Contours	Ephemeral Stream	Streets and Driveways
Problem Area	2 ft Contours	Stream, unknown flow	Subwatershed Boundaries

APPENDIX 13: BUDGETED AND ACTUAL EXPENDITURES

Appendix 13: Budgeted and Actual Expenditures

CONTRACT#: 1666
SPONSOR: Town of Chapel Hill
PRINCIPLE INVESTIGATOR: Trish D'Arconte
PROJECT: Boil Creek WS
CONTRACT DATES: 10/1/2008-9/30/2012

Federal Expenditures	QTR 1	QTR 2	QTR 3	QTR 4
Date Received:	**12/31/2008**	**3/31/2009**	**7/10/2009**	**10/9/2009**
Activity Period:	**Oct-Dec 08**	**Jan-Mar 09**	**Apr-Jun 09**	**Jul-Sep 09**
Salary + Benefits	0.00	0.00	0.00	0.00
Travel	0.00	0.00	0.00	0.00
Equipment	0.00	0.00	13,009.52	0.00
Supplies	0.00	0.00	0.00	0.00
Education	0.00	0.00	0.00	0.00
Construction	0.00	0.00	0.00	0.00
Contracted Services	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.00
Total Request	**$ -**	**$ -**	**$ 13,009.52**	**$ -**

Federal Expenditures	QTR 5	QTR 6	QTR 7	QTR 8
Date Received:	**4/7/2010**	**4/9/2010**	**7/12/2010**	**10/8/2011**
Activity Period:	**Oct-Dec 09**	**Jan-Mar 10**	**Apr-Jun 10**	**Jul-Sep 10**
Salary + Benefits	0.00	0.00	0.00	0.00
Travel	0.00	0.00	0.00	0.00
Equipment	1,990.48	0.00	0.00	0.00
Supplies	0.00	0.00	0.00	0.00
Education	0.00	0.00	0.00	0.00
Construction	0.00	0.00	0.00	0.00
Contracted Services	37,750.00	19,750.00	122,932.00	0.00
Other	0.00	0.00	0.00	0.00
Total Request	**$ 39,740.48**	**$ 19,750.00**	**$ 122,932.00**	**$ -**

Appendix 13: Budgeted and Actual Expenditures

CONTRACT#:	1666
SPONSOR:	Town of Chapel Hill
PRINCIPLE INVESTIGATOR:	Trish D'Arconte
PROJECT:	Boil Creek WS
CONTRACT DATES:	10/1/2008-9/30/2012

Federal Expenditures				
	QTR 9	**QTR 10**	**QTR 11**	**QTR 12**
Date Received:	**1/10/2011**	**4/13/2011**	**7/11/2011**	**10/10/2011**
Activity Period:	**Oct-Dec 10**	**Jan-Mar 11**	**Apr-Jun 11**	**Jul-Sep 11**
Salary + Benefits	0.00	0.00	0.00	0.00
Travel	0.00	0.00	0.00	0.00
Equipment	0.00	0.00	0.00	0.00
Supplies	0.00	0.00	0.00	0.00
Education	0.00	0.00	0.00	0.00
Construction	0.00	0.00	0.00	0.00
Contracted Services	23,086.00	19,750.00	50,630.00	0.00
Other	0.00	0.00	0.00	0.00
Total Request	**$ 23,086.00**	**$ 19,750.00**	**$ 50,630.00**	**$ -**

Federal Expenditures				
	QTR 13	**QTR 14**	**QTR 15**	**QTR 16**
Date Received:	**1/11/2012**	**4/16/2012**	**9/29/2012**	**11/15/2012**
Activity Period:	**Oct-Dec 11**	**Jan-Mar 12**	**Apr-Jun 12**	**Jul-Sep 12**
Salary + Benefits	0.00	0.00	0.00	0.00
Travel	0.00	0.00	0.00	0.00
Equipment	0.00	0.00	0.00	0.00
Supplies	0.00	0.00	0.00	0.00
Education	0.00	0.00	0.00	0.00
Construction	0.00	0.00	0.00	0.00
Contracted Services	18,894.00	15,096.00	13,000.00	23,075.00
Other	0.00	0.00	0.00	0.00
Total Request	**$ 18,894.00**	**$ 15,096.00**	**$ 13,000.00**	**$ 23,075.00**

Appendix 13: Budgeted and Actual Expenditures

CONTRACT#:	1666
SPONSOR:	Town of Chapel Hill
PRINCIPLE INVESTIGATOR:	Trish D'Arconte
PROJECT:	Boil Creek WS
CONTRACT DATES:	10/1/2008-9/30/2012

Match Expenditures	QTR 1	QTR 2	QTR 3	QTR 4
Date Received:	**12/31/2008**	**3/31/2009**	**7/10/2009**	**10/9/2009**
Activity Period:	**Oct-Dec 08**	**Jan-Mar 09**	**Apr-Jun 09**	**Jul-Sep 09**
Salary + Benefits	7,237.30	4,686.62	7,179.56	19,538.17
Travel	0.00	0.00	0.00	0.00
Equipment	0.00	0.00	0.00	0.00
Supplies	0.00	0.00	1,310.68	14.49
Education	10.80	43.68	0.43	0.00
Construction	0.00	0.00	0.00	0.00
Contracted Services	0.00	0.00	0.00	0.00
Other	1,153.00	8,891.00	869.00	5,524.00
Total Spent	**$ 8,401.10**	**$ 13,621.30**	**$ 9,359.67**	**$ 25,076.66**

Match Expenditures	QTR 5	QTR 6	QTR 7	QTR 8
Date Received:	**4/7/2010**	**4/9/2010**	**7/12/2010**	**10/8/2011**
Activity Period:	**Oct-Dec 09**	**Jan-Mar 10**	**Apr-Jun 10**	**Jul-Sep 10**
Salary + Benefits	10,270.47	12,426.90	27,273.91	12,884.87
Travel	0.00	39.38	114.50	73.00
Equipment	1,018.47	119.98	0.00	0.00
Supplies	0.00	41.83	3.90	1.99
Education	0.00	0.00	106.02	5.00
Construction	0.00	0.00	727.00	241.00
Contracted Services	0.00	0.00	0.00	0.00
Other	0.00	544.50	3,920.00	0.00
Total Spent	**$ 11,288.94**	**$ 13,172.59**	**$ 32,145.33**	**$ 13,205.86**

Appendix 13: Budgeted and Actual Expenditures

CONTRACT#:	1666
SPONSOR:	Town of Chapel Hill
PRINCIPLE INVESTIGATOR:	Trish D'Arconte
PROJECT:	Boil Creek WS
CONTRACT DATES:	10/1/2008-9/30/2012

Match Expenditures				
	QTR 9	**QTR 10**	**QTR 11**	**QTR 12**
Date Received:	**1/10/2011**	**4/13/2011**	**7/11/2011**	**10/10/2011**
Activity Period:	**Oct-Dec 10**	**Jan-Mar 11**	**Apr-Jun 11**	**Jul-Sep 11**
Salary + Benefits	14,539.27	18,712.12	19,337.35	20,736.65
Travel	73.00	73.00	136.00	94.00
Equipment	0.00	0.00	0.00	0.00
Supplies	0.00	330.17	6.97	0.00
Education	5.00	100.00	497.15	304.75
Construction	0.00	0.00	0.00	0.00
Contracted Services	0.00	0.00	0.00	0.00
Other	0.00	0.00	10,040.00	0.00
Total Spent	**$ 14,617.27**	**$ 19,215.29**	**$ 30,017.47**	**$ 21,135.40**

Match Expenditures				
	QTR 13	**QTR 14**	**QTR 15**	**QTR 16**
Date Received:	**1/11/2012**	**4/16/2012**	**9/29/2012**	**11/15/2012**
Activity Period:	**Oct-Dec 11**	**Jan-Mar 12**	**Apr-Jun 12**	**Jul-Sep 12**
Salary + Benefits	17,654.89	22,060.87	31,198.21	42,608.54
Travel	94.00	94.00	94.00	94.00
Equipment	0.00	0.00	0.00	0.00
Supplies	14.34	0.00	377.80	21,784.30
Education	187.24	8.01	253.86	0.00
Construction	0.00	0.00	0.00	0.00
Contracted Services	0.00	0.00	0.00	0.00
Other	0.00	0.00	5,082.95	26,000.00
Total Spent	**$ 17,950.47**	**$ 22,162.88**	**$ 37,006.82**	**$ 90,486.84**

Appendix 13: Budgeted and Actual Expenditures

CONTRACT#:	1666
SPONSOR:	Town of Chapel Hill
PRINCIPLE INVESTIGATOR:	Trish D'Arconte
PROJECT:	Boil Creek WS
CONTRACT DATES:	10/1/2008-9/30/2012

	Federal Funds Expenditures			Non-Federal Expenditures	
	Contract Totals	**Approved Budget**	**Funds Remain**	**Actual Totals**	**Approved Budget***
Salary + Benefits	-	-	-	288,345.70	132,150.00
Travel	-	-	-	978.88	3,000.00
Equipment	15,000.00	15,000.00	-	1,138.45	-
Supplies	-	-	-	23,886.47	6,000.00
Education	-	-	-	1,521.94	-
Construction	-	-	-	968.00	-
Contracted Services	343,963.00	354,792.00	10,829.00	-	55,928.00
Other	-	-	-	62,024.45	65,450.00
Total Spent	**$ 358,963.00**	**$ 369,792.00**	**$ 10,829.00**	**$ 378,863.89**	**$ 262,528.00**

Partner Matches:	**Actual**		**Actual**	**Budgeted****	
Chapel Hill Match	*$207,268.56*	**Total**	*$378,863.89*	*$262,528.00*	
Carrboro Match	*$84,585.33*	**Cash**	*$87,049.37*	*$77,328.00*	
NCSU Match	*$60,000.00*	**In-kind**	*$291,814.52*	*$185,200.00*	
EEP Match	*$26,000.00*				**Project**
Volunteer Match	*$1,010.00*		**Federal**	**Non-federal**	**Total**
Total Match	*$378,863.89*	**project %**	48.65%	51.35%	$ 737,826.89

* approved budget numbers are summed from the Non-federal match amounts in Table 14 (pg 6) of the grant contract dated 10/16/2008

** approved match amounts are from Table 16 of the grant contract revision dated 4/29/2009