BOLIN CREEK WATERSHED

Geomorphic Analysis and Potential Site Identification for Stormwater Structures and Retrofits

TOWN OF CARRBORO
NORTH CAROLINA

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Project Summary
Bolin Creek Geomorphic Analysis

Introduction

Earth Tech provided services to the Town of Carrboro during the spring and summer of 2007 to evaluate the stability of the entire Bolin Creek Watershed. This project was performed as the first step of the Towns of Carrboro and Chapel Hill as partners in the Bolin Creek Watershed Restoration Team (BCWRT) to rehabilitate the watershed and to one day have its biological integrity improved to the extent that Bolin Creek can be removed from the Federal (303d) list of impaired streams. The ultimate goal of this project is for the findings of this study to aid in the decision making process to evaluate, prioritize and fund the individual projects which are presented herein. The funds for the project were provided by Clean Water Management Trust Fund (CWMTF) stormwater mini- grant #S-003, with matching funds provided by the Towns of Carrboro and Chapel Hill.

Previous studies in the Bolin Creek watershed have included a Watershed Restoration Plan (WRP) and a Local Watershed Plan (LWP). This project continues the process initiated by these efforts and provides supplemental information focusing on geomorphology of the streams within the watershed, and solutions addressing specific areas of stream instability.

Methods

The field work consisted of professionals from Earth Tech and the BCWRT performing a qualitative survey of all perennial and intermittent streams within the watershed. Ephemeral systems were surveyed when a specific geomorphic instability indicated that further investigation of the ephemeral system was necessary to fully understand the cause and magnitude of the problem. The survey was conducted between May 7th, 2007 and June 21st, 2007. Weather during the survey was generally dry and sunny, and no streams were observed during or immediately following a storm event. GIS data was used to create a field map atlas of 35 pages, and the streams on each page were systematically walked by the survey crews. Walks using these field maps were completed from the upper watershed to the lower watershed, so that the walk ended at the confluence of Bolin Creek with Booker Creek. Each field crew carried a sub-foot accuracy global positioning system (GPS) unit, a digital camera, field assessment forms, a set of field maps showing 2-foot topography, roads and streams, and a set of maps with high resolution aerial photography.

When specific areas of instability were identified, they were semi-quantitatively surveyed in order to fill out a field assessment form. The parameters which are recorded by the form are used to understand the channel dimension, cause of the problem, and stability of the reach at each location. In addition, at each location a sub-foot GPS coordinate was recorded, a photograph was taken, and notes were recorded in a field book and on field maps for later reference. The “Raw Data” for each of these locations was compiled together and provided to the BCWRT for their use in future evaluations of the watershed’s condition. In the project site summaries contained in this report, each title page contains a “Raw Data Name” reference to a specific GPS point, and a reference to an Index Sheet, which were the 35 field maps used during the field evaluation. The index sheets and raw data maps showing the GPS points and notes for each observed stream reach, are contained in **Appendix D**.

After completion of the stream surveys, the sites was prioritized and approximately 50 sites were selected for consideration by Earth Tech and BCWRT as potential sites to be used as one of the final 30 project sites. To prioritize the sites, Earth Tech considered the input BCWRT members, along with professional judgment to give each site a qualitative score of 1 to 10. Because, at this point, pollutant loads and sediment export rates had not been calculated for any site, it was important to focus on the qualitative observations of geomorphic instability collected in the raw data. The most influential considerations in the ranking were the severity of the problem and the urgency of needing the problem fixed, as shown from the raw data, followed by ease of construction and opportunity for public involvement and education. Following the prioritization, 32 sites were selected for consideration by the Town of Carrboro and the Town of Chapel Hill as best management practice (BMP) installation or retrofit projects.

Each of these final sites were analyzed for feasibility, cost benefit, net reduction in loading of nutrients and suspended solids, anticipated reductions in runoff quantity and potential baseflow augmentation to the receiving channel. A second set of field visits were made to each of the 32 potential BMP sites, at which time additional notes, photographs and GPS data was collected. In particular, notes were made on constraints such as potential size restrictions, presence of existing utilities, and potential alternative treatments. A brief GIS analysis of each site was then undertaken, consisting of delineation of the site watersheds, analysis of land use in each watershed, and calculation of percent imperviousness. Areas of land use type were calculated using 1996 land cover data for Orange County available from the North Carolina Center for Geographic Information and Analysis. Because this data was out of date for several of the sites, the land use data was updated when necessary using 2005 aerial photography provided by the Towns of Carrboro and Chapel Hill. Percent imperviousness was calculated using GIS polygons representing roads, driveways, parking lots and other impervious features, which were provided by Carrboro and Chapel Hill. The inputs of drainage area, percent imperviousness, and land use type were used to estimate pollutant load rates for each watershed using the Simple Method (Schueler et. al., 2007). An annual rainfall depth of 46.2 inches was assumed for the calculation, based on Orange County rainfall data available from the National Oceanographic and Atmospheric Association.

For sites where sediment reduction through stabilization of streambanks was the primary focus, a modified BANCS model was used to estimate annual stream bank erosion rates (Rosgen, 2006). The BANCS model uses the combined inputs of Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) with a graph showing a relation between the two variables and stream bank erosion rates for a particular area. An estimate of BEHI was measured for each bank at each stream stabilization site for the length of the bank and then combined with a rough estimate of NBS to estimate stream bank erosion rates in tons per year using a North Carolina graph.

The results of this analysis, along with site descriptions and photos are found in the project specific reports that follow.

Construction costs were estimated using a combination of standard quantities and prices following North Carolina Department of Transportation (NCDOT) specifications, recent cost estimates for other projects calculated by professionals at Earth Tech, and equations that predict the cost of BMP construction as a function of potential storage volume (Schueler, et. al. 2007). Earth Tech first began by developing line item cost estimates using standard quanitites of materials for given areas and measurements. CADD software was relied upon to measure acreages and distances in order to calculate needed quantities of materials. These construction costs were then compared with equations that have been developed by several researchers to predict the cost of new and retrofit construction of different types of BMPs. In many cases, particularly with stormwater wetlands, the line item cost estimates were very similar to what research has shown as the actual cost of construction for a BMP. Where there was a discrepancy between the two, however, the equation-predicted figure was used. In addition, the contingency cost for each project was adjusted depending on site conditions. Sites that are harder to access or near utility right of ways were given a higher contingency cost.

Research has shown that maintenance costs for stormwater wetlands and wet detention ponds typically range from 3-5% of the base construction cost per year (Center for Watershed Protection, 2007). To err on the side of caution, the higher figure of 5% was used to estimate annual BMP maintenance costs for all the proposed BMP sites.

Data Summary

During the stream survey, a total of 115 GPS points were collected that specifically relate to an area of geomorphic instability, and are represented on a field form (See **Appendix C**). Other GPS points were taken that highlight notable features of concern or interest within the watershed, or that simply represent continuations of problem areas, but are not noted on a field form. **Table 1** provides a summary of the raw data recorded on the field form for each location, and shows the number of GPS points collected on Bolin Creek or its tributaries, the types of stream conditions present at each point and the observed type of problem at the point. Multiple indications of stream condition and multiple types of problems were observed at many of the points. Stream condition observations have been grouped into general stream observations (changes in stream dimension and stream profile), and observations of specific symptoms indicating stream change such as bed and bank scour, and bank failure.

Table 1. Summary of raw data collected during the stream survey

I. Location Within Watershed	
	# of GPS Points
Bolin Creek	14
Tributaries	101
II. Stream Condition Observations	
	# of GPS Points
Observations of Stream Dimension Change	
Aggrading	12
Downcutting	56
Widening	40
Total	108
Observations of Stream Profile Change	
Slope Failure	4
Headcutting	13
Total	17
Observations of Specific Symptoms of Instability	
Bed Scour	15
Bank Failure	35
Bank Scour	49
Sediment Depostion	6
Channelized	6
Total	111
III. Type of Problem	
	# of GPS Points
Pond Outfalls	25
Stream Crossings	29
Impacted Buffer	13
Utility impacts	23
Channel Modification	17
Confluence	4
Beaver Activity	1
Other	33

BMP Site Summary

A total of 32 potential BMP sites were identified during the course of this study. After evaluation of each site and its contributing watershed for pollutant loads, impervious surface and sediment contribution, and after completion of a conceptual-level cost estimate, the sites were prioritized according to a ranking system that is modeled on a similar system recommended by Schueler, et. al (2007). Four criteria were chosen to rank each site: “Cost per pollutant removed”, “Project Visibility”, “Construction Access”, and “Critical Nature of Project”.

The “Cost per pollutant removed” criterion was chosen out of a desire to compare the relative cost/benefit of each site, as the overarching goal of the Bolin Creek Watershed Restoration efforts is to reduce pollutants in the watershed, and thereby remove Bolin Creek from the 303(d) list. However, because of a lack of available information showing what specific pollutant is the primary cause of biological impairment in Bolin Creek, this criterion has been split into two separate criteria; cost per ton of sediment reduced, and cost per pound of nutrients reduced. Therefore, two separate prioritization tables have been produced: one for sites where the primary target is removal of nutrients and another for those sites where the primary target is sediment reduction through streambank stabilization. To compare the two different types of projects directly against one another was considered impractical without knowing the relative effects of the differing pollutants on the biological integrity of Bolin Creek.

The “project visibility” and “construction access” criteria were chosen because they were considered to be easy to judge based on site visits and available aerial photography and topographic GIS data. The final criterion of “Critical Nature of Project”, was chosen to account for the potential for future exacerbation of the observed problem at each site, if action is not immediately taken. While this criterion reflects more qualitative engineering judgment than quantitative analysis, it was felt that it was important to give a higher ranking to sites where problems are expected to increase steadily or even exponentially in the future. The justification for each site rank in this criterion is listed below in **Table 4.**

The BMP Ranking criteria and the points allocated to each criteria are represented in **Table 2**.

Table 3 presents a summary of each BMP site, with scoring of each criterion and total scores for each site.

Table 5 shows the prioritization of the sediment reduction projects, while **Table 6** presents the prioritization of the nutrient reduction projects.

Table 2. BMP Ranking Criteria and Point Allocation

BMP Ranking Criteria (20 Total Points Possible)		Possible Points
1	**Cost/Ton of Sediment Reduced**	**5**
	Less than $50	[5]
	Between $50 and $200	[4]
	Between $200 and $300	[3]
	Between $300 and $500	[2]
	Greater than $500	[1]
2	**Cost/ lb of Nutrients Removed**	**5**
	Less than $9,500	[5]
	Between $9,500 and $23,000	[4]
	Between $23,000 and $50,000	[3]
	Between $50,000 and $80,000	[2]
	Greater than $80,000	[1]
3	**Project Visibility**	**5**
	Poor (site cannot be seen from street)	[1]
	Good (site adjacent to a street)	[3]
	Excellent (site adjacent to a highly traveled street or public property)	[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]

Table 3. Summary of Final BMP Sites and Scoring

Final Site Name	Type of Project	Cost of Construction	Location	Cost/ton of sediment		Cost/ lb nutrients Removed		Project Visibility		Construction Access		Critical Nature of Project*		Total Score Nutrient Projects	Total Score Sediment Projects
					(pts)		(pts)		(pts)		(pts)		(pts)		
1	Dam Retrofit	$30,964	Outside	$21.46	5			Poor	1	Excellent	5	High	3		**14**
2	BMP- Retrofit	$43,879	Carrboro			$8,200.78	5	Excellent	5	Excellent	5	Low	1	**16**	
3	Stream Bank Stabilization	$31,734	Outside	$197.53	4			Poor	1	Good	3	Critical	5		**13**
4	BMP- Retrofit	$73,509	Carrboro			$98,769.50	1	Poor	1	Poor	1	Medium	2	**5**	
5	BMP- Retrofit	$22,660	Carrboro			$10,031.09	4	Good	3	Excellent	5	High	3	**15**	
6	BMP- Retrofit	$34,578	Carrboro			$15,307.01	4	Good	3	Excellent	5	High	3	**15**	
7	BMP- Retrofit	$100,619	Carrboro			$44,542.49	3	Good	3	Excellent	5	Very High	4	**15**	
8	BMP- Retrofit	$19,017	Carrboro			$3,504.29	5	Good	3	Excellent	5	Medium	2	**15**	
9	Stream Bank Stabilization	$18,215	Carrboro	$191.92	4			Good	3	Good	3	Medium	2		**12**
10	BMP-New Construction	$48,336	Carrboro			$9,121.72	5	Poor	1	Good	3	Medium	2	**11**	
11	BMP- New Construction	$30,323	Chapel Hill			$28,285.41	3	Excellent	5	Excellent	5	Medium	2	**15**	
12	BMP- New Construction	$69,358	Chapel Hill			$22,467.50	4	Poor	1	Good	3	Medium	2	**10**	
13	BMP- New Construction	$25,688	Chapel Hill			$2,353.10	5	Poor	1	Poor	1	Medium	2	**9**	
14	BMP- New Construction	$25,688	Chapel Hill			$6,416.48	5	Good	3	Excellent	5	Medium	2	**15**	
15	BMP- Retrofit	$27,266	Chapel Hill			$23,281.67	4	Poor	1	Good	3	Very High	4	**12**	
16	Stream Bank Stabilization	$56,479	Carrboro	$282.81	3			Excellent	5	Poor	1	Medium	2		**11**
17	Stream Bank Stabilization	$66,649	Carrboro	$1,098.79	1			Poor	1	Poor	1	Very High	3		**6**
18	BMP- New Construction	$17,416	Chapel Hill			$14,828.54	4	Good	3	Good	3	Very High	4	**14**	
19	Stream Bank Stabilization	$8,884	Carrboro	$319.81	2			Excellent	5	Excellent	5	Medium	2		**14**
20	Stream Bank Stabilization	$49,479	Chapel Hill	$26.04	5			Excellent	5	Good	3	Very High	4		**17**
21	Stream Bank Stabilization	$52,104	Chapel Hill	$74.33	4			Good	3	Poor	1	Critical	5		**13**
22	Stream Bank Stabilization	$72,526	Chapel Hill	$38.42	5			Excellent	5	Excellent	5	Very High	4		**19**
23	BMP- Retrofit	$32,030	Chapel Hill			$65,099.01	2	Poor	1	Poor	1	Low	1	**5**	
24	BMP- New Construction	$107,541	Chapel Hill	$285.11	3	$49,502.23	3	Good	3	Poor	1	Critical	5	**12**	
25	BMP- New Construction	$84,571	Chapel Hill			$52,133.47	2	Poor	1	Poor	1	Low	1	**5**	
26	BMP- New Construction	$69,375	Chapel Hill			$83,059.38	1	Poor	1	Poor	1	Low	1	**4**	
27	BMP- New Construction	$38,554	Chapel Hill			$213,283.40	1	Poor	1	Poor	1	Low	1	**4**	
28	BMP- New Construction	$36,660	Chapel Hill			$22,209.33	4	Poor	1	Poor	1	Low	1	**7**	
29	BMP- New Construction	$81,218	Chapel Hill	$144.51	4	$40,728.87	3	Poor	1	Poor	1	Very High	4	**9**	
30	BMP- Retrofit	$28,501	Chapel Hill			$3,625.74	5	Poor	1	Poor	1	High	3	**10**	
31	BMP- New Construction	$20,130	Chapel Hill	$38.91	5	$15,809.47	4	Poor	1	Good	3	High	3	**11**	
32	Stream Restoration	$207,000	Chapel Hill	$3,522.80	1			Excellent	3	Poor	1	Low	1		**6**

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Table 4. Justification of Critical Nature criterion for each site.

Justification of Critical Nature rankings for each site	
Site	**Reasoning**
1	The incised dam outfall is probably widening and the sediment problem will increase, but the extent of future impact upstream and downstream will be limited
2	The problem at this site is not worsening.
3	The headcut at this site will continue to work upstream, and incise a greater length of stream if not addressed.
4	Nothing imminent or critical at this site.
5	There is potential damage to adjacent streams from the current configuration of the BMP outlet.
6	There is potential damage to adjacent streams from the current configuration of the BMP outlet.
7	There is potential damage to adjacent streams from the current configuration of the BMP outlet.
8	Is presently stable, but there is some danger of damage to channel due to concentrated flows.
9	The extent of bank erosion is relatively small.
10	Due to headcut downstream of the site.
11	High nutrient contributions and potential for channel damage due to concentrated flows.
12	Some modest instability from discharges.
13	Some modest instability from discharges.
14	Some modest instability from discharges.
15	Active headcuts are present at this site.
16	The annual contribution is not expected to increase.
17	Bank wasting is likely increasing here.
18	The conditions at this site will likely get worse.
19	Sediment contribution is expected to be constant here.
20	Relatively high wasting banks, stream will continue to widen.
21	Stability of this hillside needs to happen.
22	Stability of this hillside needs to happen.
23	No expected increase in problem here.
24	Active increase in 3' headcut at this site.
25	No expected increase in problem here.
26	No expected increase in problem here.
27	No expected increase in problem here.
28	No expected increase in problem here.
29	At least three active headcuts on this channel will create an incised gulley over time, with expected increase in sediment contribution.
30	Hillside erosion is occuring here and will worsen, but extent of impact will likely be limited upstream and downstream.
31	Ditch in floodplain will continue to erode, but impact upstream and downstream will be limited.
32	Stream is channelized, but stable; no expected increase in sediment contributions.

Table 5. Prioritization of Sites Specifically Targeted at Nutrient Reduction

Final Site Name	Type of Project	Cost of Construction	Location	Total Score Nutrient Projects
2	BMP- Retrofit	$43,879	Carrboro	**16**
5	BMP- Retrofit	$22,660	Carrboro	**15**
6	BMP- Retrofit	$34,578	Carrboro	**15**
7	BMP- Retrofit	$100,619	Carrboro	**15**
8	BMP- Retrofit	$19,017	Carrboro	**15**
11	BMP- New Construction	$30,323	Chapel Hill	**15**
14	BMP- New Construction	$25,688	Chapel Hill	**15**
18	BMP- New Construction	$17,416	Chapel Hill	**14**
15	BMP- Retrofit	$27,266	Chapel Hill	**12**
24	BMP- New Construction	$107,541	Chapel Hill	**12**
10	BMP-New Construction	$48,336	Carrboro	**11**
31	BMP- New Construction	$20,130	Chapel Hill	**11**
12	BMP- New Construction	$69,358	Chapel Hill	**10**
30	BMP- Retrofit	$28,501	Chapel Hill	**10**
13	BMP- New Construction	$25,688	Chapel Hill	**9**
29	BMP- New Construction	$81,218	Chapel Hill	**9**
28	BMP- New Construction	$36,660	Chapel Hill	**7**
4	BMP- Retrofit	$73,509	Carrboro	**5**
23	BMP- Retrofit	$32,030	Chapel Hill	**5**
25	BMP- New Construction	$84,571	Chapel Hill	**5**
26	BMP- New Construction	$69,375	Chapel Hill	**4**
27	BMP- New Construction	$38,554	Chapel Hill	**4**

Table 6. Prioritization of Sites Specifically Targeted at Sediment Reduction

Final Site Name	Type of Project	Cost of Construction	Location	Total Score Sediment Projects
22	Stream Bank Stabilization	$72,526	Chapel Hill	**19**
20	Stream Bank Stabilization	$49,479	Chapel Hill	**17**
1	Dam Retrofit	$30,964	Outside	**14**
19	Stream Bank Stabilization	$8,884	Carrboro	**14**
3	Stream Bank Stabilization	$31,734	Outside	**13**
21	Stream Bank Stabilization	$52,104	Chapel Hill	**13**
9	Stream Bank Stabilization	$18,215	Carrboro	**12**
16	Stream Bank Stabilization	$56,479	Carrboro	**11**
17	Stream Bank Stabilization	$66,649	Carrboro	**6**
32	Stream Restoration	$207,000	Chapel Hill	**6**

Discussion of Specific Sources of Instability

The specific project sites address many of the water quality issues that Bolin Creek faces, however it is important to note that the projects in this report represent the types of projects that could be implemented throughout the watershed. A summary of key sources of instability and other observations made during the field investigation for the Bolin Creek Watershed follows:

1. Stream Channelization – Stream channelization is one of the most significant impacts that has occurred to the reaches in the Bolin Creek Watershed. Channelization was, at one time, a common means of dealing with a stream that was in the way, or that flooded neighboring properties. By deliberately lowering the stream elevation, overtopping of the banks would often be eliminated. The intentional carrying of higher flows within the channel is exactly opposite of natural processes where a stable stream will utilize access to a floodplain to dissipate the energy that is above the capacity of the stream channel. As a result, the higher flows which are now contained within the streambank are flows that greatly exceed the allowable shear stress of the channel. In the end, channelization results in steams that down cut to bedrock or saproilte and then begin to widen as exceedingly high shear stresses causes bank scour and thus a lateral movement of the streambank due to its erosion. The mass wasting of these banks is a significant cause of excess sediment in this watershed. Several of these selected projects are bank stabilization projects and the anticipated reductions in sediment loading indicate the magnitude of this problem.

   Another result of channelization is the loss of instream habitat and structure that can be found in the stable pool-riffle sequence of natural channel. Pools provide essential habitat and drought refuge areas for proper biological function. It should be noted that this is a problem on many reaches that are not a part of one of the proposed sites for stormwater BMPs included in this report.

2. Culverts and Channel Crossings - A significant amount of the instability in the Bolin Creek Watershed may have been started by the construction of stream crossings for roadways. The resulting channel contraction that occurs at most culverts may have caused the erosion on the downstream side that leads to a tail cut, and thus channel incision (no longer accessing the floodplain), a lowering of groundwater base, and continued instability that may exist for decades. Head-cuts can result from a depressed invert elevation, and work upstream until it hits some form of grade control. Overly wide crossings cause deposition of sediments when the wider channel becomes shallower in depth, thus reducing the shear stress needed to carry sediment. Backwater from floodplain encroachment of roadways

causes a loss of velocities, thus lowering shear stress, and a lack of sediment transport results.

It is difficult to have a road crossing and maintain a natural cross section, flood plain relief for proper sediment transport and flow capacity. Current DOT standards have improved with this regard and in the future, road crossings in this watershed should utilize floodplain culverts and main channel culverts that maintain a wider flow path with a base flow channel at the natural bed elevation.

3. Utility Impacts – The installation of sewer lines and other utilities within the floodplains of streams was the perceived cause of apparent channel relocations throughout the watershed. For the most part, these impacts occurred long ago and the remaining degradation is primarily in the form of channel instability from channelization, as mentioned in item #1. Current impacts were observed in several locations in the form of unstable channel crossings, culvert installations, and removal of woody riparian vegetation that is essential to channel stability. It will require a continued effort between the towns and the utility providers to minimize these future impacts, as well as to monitor them.

4. Bank Wasting – Streambank wasting is probably the largest cause of the degradation of the biological integrity of the streams within the Bolin Creek watershed, because of the large amount of sediment that is exported through bank wasting processes. There are very few streams in the watershed that do not possess mass wasting banks on outer meander bends and lower riffle sections. Any effort to manage stormwater in the future by reducing peak flow rates of runoff and total volume will aid in establishing stability in the watershed by reducing the shear stress experienced by these banks. Direct modification of all streams within the watershed is impractical, thus particular reaches that are identified as supplying the greatest amounts of sediment should be targeted and treated. While the Geormorphic Assessment identified the most unstable reaches within the watershed, an analysis of the estimated quantities of sediment produced by all unstable reaches within the watershed was beyond the scope of this effort. Notwithstanding this, many of the BMPs proposed in this report are targeted at treating what were observed to be the worst reaches.

5. Direct Discharges to the Channel – In many cases, a definite impact was observed at the location of stormwater outlets within, or very near the channel. This concentrated and sediment-starved stormwater causes channel instability in the form of mass wasting of banks and channel incision. Even when discharges occur onto the floodplain, but within 10-15 feet of the channel itself, mass wasting of downstream banks is present as well as a headcut through the stream bank up to the point of discharge.

The placement of BMP outlets in the floodplain, unfortunately, may also have the same effect. When possible, any discharge in a near-channel region should be diffused by use of level spreaders or substantial energy dissipation basins. Observations indicate that an "apron" at the outlet is grossly insufficient at energy dissipation and flow diffusion.

6. Railroads and Streams- The team observed multiple direct impacts from stormwater systems of railway lines. There is no treatment of the stormwater that is collected by the ditches associated with the fill and cut of the railway grade. This concentrated flow could be treated before discharging it to an ephemeral, intermittent, or perennial stream in a variety of ways, including retrofit of BMPs alongside the railway lines.

7. Recreation Impacts – Greenway trails, paved and unpaved, and recreational activities are causing a substantial impact to the reaches within the Bolin Creek watershed. Bolin Creek itself is suffering multiple locations of instability that are created simply by the foot traffic on the banks. Trails and greenways that are located close to the channel affect the vegetation along the streambank and cause mass wasting to occur. Paved greenways do not typically have stormwater treatment and therefore cause a concentration of flows from the impervious surface and associated grading. This concentration flow typically outfalls onto the floodplain or streambank at low points in the trail and causes instability. Paved greenways trails should be constructed in a manner that acknowledges the risk of placing an impervious surface in the riparian zone. Level spreaders, dissipater basins, etc. should be used to handle the stormwater that collects from these surfaces. It is recommended that any future greenway plans include strategies for education and outreach as part of the greenway development.

   Unpaved trails result in a compacted soil that behaves in a similar manner to an impervious surface except that the trail is normally a concaved depression. This depression and resistance to percolation results in concentration of flows down these paths and erosion of the trail. The sediment from the trails is often discharged directly into the channel at a low point.

   Individuals using these trails and riparian areas are normally there to enjoy the stream, not harm it. "Education and outreach" would dramatically improve many of the impacts that were observed. Stream crossings can be designated and stabilized, trails kept away from the streambank, etc. and the citizens of these communities would most likely be very receptive to the suggestions. Information kiosks at strategic locations could start this process at a relatively low cost.

8. Stormwater Runoff – As with any urban watershed, the development in the Bolin Creek watershed has caused an increase in the peak flow rates and total runoff volume that reaches the receiving channels. It is evident that increases and the concentration of runoff are the major problem in the watershed. However, specific observations, such as a headcut in an intermittent channel, are indicators that the instability created by stream crossings or direct alterations of the channel may be the more significant catalyst for channel instability in many cases. Increased stormwater flows that are "trapped" down inside a channel and not allowed to dissipate energy via a floodplain only serve to exacerbate the instability of an incised channel. Earth Tech strongly believes that our field experiences and completed restoration projects indicate that the increase in stormwater flows can be accommodated by reconnection with the floodplain and proper bank stabilization practices. Earth Tech encourages the use of these practices to stabilize problematic reaches where the sediment contributions are degrading the biological integrity of the system.

   In other cases, especially with ephemeral channels, increased stormwater flows are the perceived cause of instability in the form of channel scour. There are many ephemeral channels in the Bolin Creek watershed which are suffering from scour. These upper slope positions in less developed parts of the watershed can be observed to have no significant debris scour of significance, much less erosion of soil beneath the leaf litter. After investigating the cause of the scour in the ephemeral reaches, Earth Tech made the conclusion that concentration of storm flows from drainage networks were the prevailing cause of this instability. These ephemeral channels offer a location for dissipation of energy from the concentrated and increased flows from development. There are many opportunities in the Bolin Creek Watershed to reduce peak flows, nutrient contributions, and directly eliminate erosion by using BMPs within these reaches.

   Increases in nutrient export via stormwater runoff are also a likely cause of biological degradation of the streams in the watershed. Although the geomorphic assessment can not pinpoint the most severe cases of this problem within the watershed, direct pipe discharges and the observation that the majority of this watershed has development with no water quality treatment, indicates that a significant amount of nutrient loading is occurring in this watershed.

   Increases in water temperature are another expected cause of biological degradation within this watershed. Increases in impervious areas are usually associated with warmer stormwater runoff temperatures. This study has not addressed this issue. However, many of the BMPs that are outlined in this report are known to reduce this problem.

The BMPs outlined in the 32 conceptual projects address the various causes of instability that were observed. By using these projects as a guide, the BCWRT should be able to conceive and implement other projects to improve the biological integrity of Bolin Creek in the years to come.

Acknowledgements

The following persons contributed to this study through their efforts in assisting with field work, coordination, prioritizing of sites, report production and analysis:

Earth Tech

Russel Barbour- field work

Bryan Dick- project manager, field work leader, report writing and BMP conceptual designer, quality control

Ian Jewell- field work, GIS analysis, conceptual design production, report and map production, cost estimates

Ron Johnson- quality control

Kevin Lapp- GIS work, field map production

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Trish McGuire

Randy Dodd

Town of Chapel Hill

Trish D'Arconte

NC Division of Water Quality

Paul Clark

Steve Kroeger

Periann Russel

US Environmental Protection Agency

Tony Able

Table of Contents

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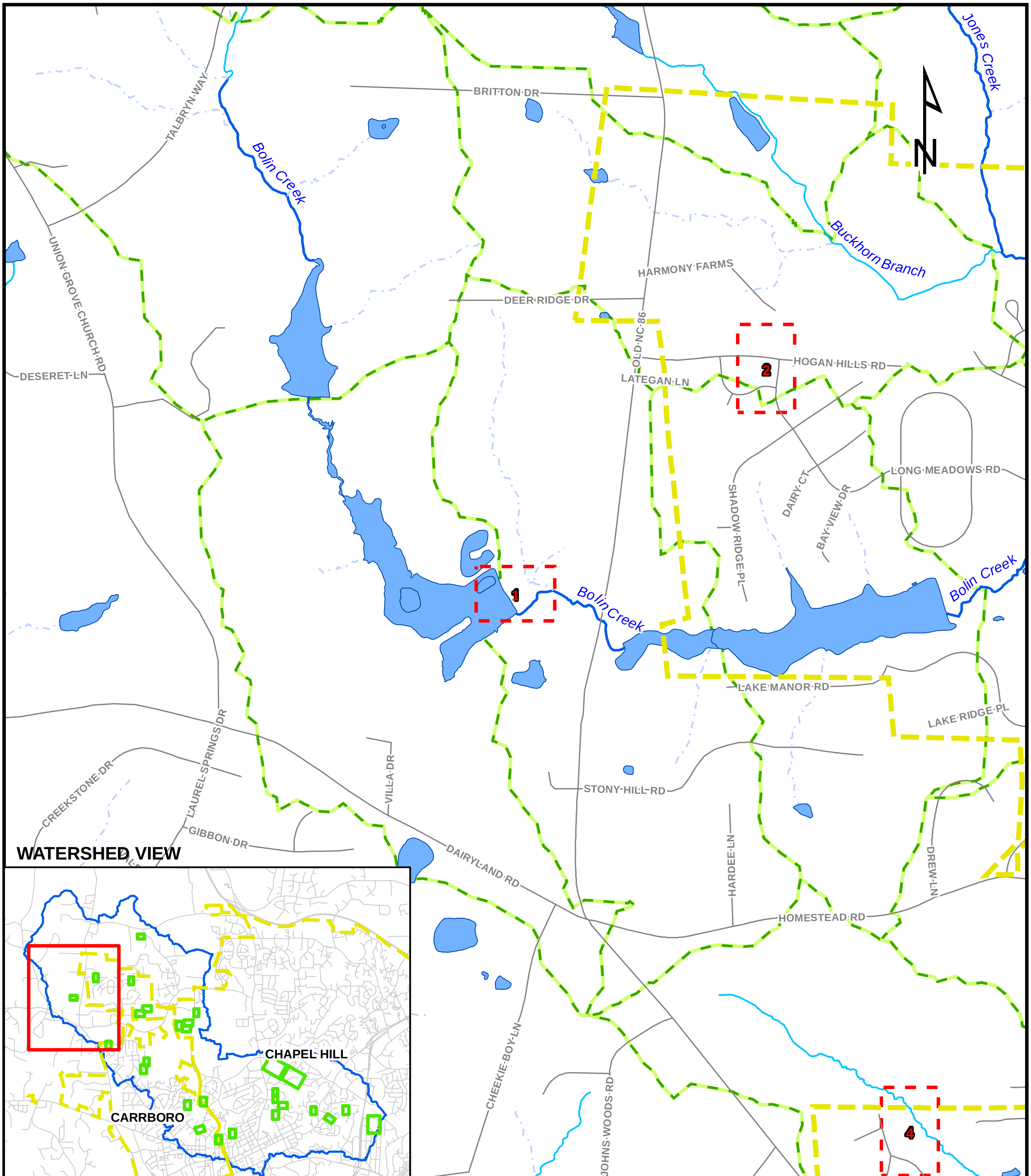
SITE 1

Dam Outfall Repair on Bolin Creek
Index Sheet No.: 4
Raw Data Name: IJ 04

Estimated Construction Cost: $31,000



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 1
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site1	553.9	20.5	3.7%

Location

Site 1 is located to the west of Old NC 86. To access Site 1, park along the shoulder of Old NC 86 just before it crosses Bolin Creek and follow Bolin Creek upstream until reaching a dam.

Problem Description

Site 1 consists of an actively eroding, deeply incised pond spillway outlet situated on Bolin Creek. The outlet channel is approximately 250 feet in length, and has dimensions of approximately 8 feet wide by 6 feet deep. This spillway is improperly constructed and serves as the only outlet for the relatively large lake on Bolin Creek. The slope of the spillway channel is approximately 4% which is too steep to serve as a constant flow channel of native soils with no hardening of the channel. The spillway invert has down-cut approximately 3 feet over the years and a beaver dam now sets the headwater elevation for the lake, which his approximately 2 feet above the invert

The chief problem with this site is the significant amount of sediment that is estimated to be exported by the site, due to the instability of the spillway channel. During site visits, Earth Tech consistently observed that the channel downstream of the lake was covered in a fine, red clay sediment. As the lake itself is a significant barrier to suspended sediment, the downstream siltation is an indicator of the massive sediment loading that is occurring to Bolin Creek due to this relatively short reach. Using a modified BANCS model for predicting streambank erosion rates (Rosgen, 2006), a total bank erosion rate of 1444.4 tons/year was estimated for this site, as shown in **Table 1.1**.

A secondary problem with this site is the observed loss of base flow due to the hydrologic disconnect created by the lake. In July of 2007, a slight base flow was observed in Bolin Creek at locations immediately upstream of the un-named lake that is in-line. The lake is presumed to have a higher rate of evaporation than it does incoming flow, as there was no baseflow discharge from the lake during the afore mentioned observation period. Also, the saturated hyporheic zone indicated a steady drawdown of water surface in the lake during the observation visit. Thus, indications are that the lake has terminated the baseflow in Bolin Creek during dry summer months. Active baseflow conditions were observed within a few hundred feet downstream of Old NC 86.

Table 1.1

Pre-Treatment	
Estimated Total Sediment Export	1444.4 tons/year
Erosion per length of Channel	5.8 tons/yr/ft
Pounds of Nitrogen	2888.9 lbs/year
Pounds of Phosphorus	1444.4 lbs/year
Post-Treatment	
Estimated Total Sediment Export	1.3 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	2.5 lbs/year
Pounds of Phosphorus	1.3 lbs/year

Proposed Solution

The solution to limiting erosion rates at this site is to construct new pond outlets consisting of a vertical riser in the pond and a properly designed overflow spillway, and to fill and vegetate the existing outfall channel (See Plan View). Filling the outfall channel should reduce erosion rates to nearly 0 tons/yr, as the chief source of sediment at this point is the outfall channel itself.

In addition to the benefits received by reducing sediment export rates, this project could potentially provide a location for base flow augmentation, which was observed to be a major water quality problem in this area. Creating an incremental, controlled discharge from the pond would provide a steady flow of water that could augment the missing baseflow. This would have a beneficial effect on the stream biota downstream.
In order to provide the controlled discharge of water from the pond, and in order to gain landowner cooperation, it will likely be necessary to raise the maximum water level of the pond, by raising the elevation of the top of the dam. This extra storage would provide the volume than can be used to restore baseflow downstream of the lake via a controlled release for an extended period of up to a few weeks. Specific design parameters of this site would dictate the actual time of delayed discharge and further Proposed Solution is necessary to accurately plan for this baseflow augmentation effort. The landowner most likely uses the pond for fishing and other recreation, and relies on the current water level for these activities. Installing a means of continuously discharging water would lower the water level, thereby impacting the landowner's use of the pond. By raising using a temporary storage volume above the existing permanent pool elevation, the goal of baseflow augmentation can be met while also meeting the needs of the landowner. The lake elevation will actually be higher on average than it is today, and the surface area and depth would increase, both of which are likely to be desirable to the landowner for fish pond management. As long as frequent rainfall occurs, the landowner will actually have a larger volume of water that is continually maintained in his lake.

With stability of the existing outlet in question, the landowner will also benefit from the assurance that his pond dam is less likely to be irreversibly damaged by a major rainfall event.

Constraints

The chief constraint at this site is landowner cooperation. The primary outlet will be somewhat limiting, as it will require the dewatering of the lake to complete. Dam safety considerations must be addressed and the proper agencies made aware of the retrofit to the outlet. In addition, vegetation removal will be required for some of the work to be completed.

Alternatives

No alternatives are anticipated at this site.

Cost-Estimate Breakdown

Table 1.2 shows a conceptual itemized cost estimate. These costs represent construction and maintenance costs only.

Table 1.2
SITE 1 Construction Costs

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Concrete Overflow Structure	1.0	Ea	3000	$3,000
Excavation	400.0	CY	15.00	$6,000
Site Preparation and Plantings	0.1	AC	7500.00	$750
Rip Rap Class B	5.0	Tons	45.00	$225
Filter Fabric	15.0	SY	5.00	$75
Silt Fence	300.0	FT	3.75	$1,125
Construction Safety Fence	500.0	LF	2.50	$1,250
Construction Entrance	1.0	Ea	2500.00	$2,500
Pond Outlet Structure	1.0	Ea	12000.00	$12,000
			Total	$26,925
Mobilization (5%)	1.0	LS		$1,346
Contingencies (10%)	1.0	LS		$2,693
	Total + Mobilization and Contingencies			**$30,964**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$1,548**

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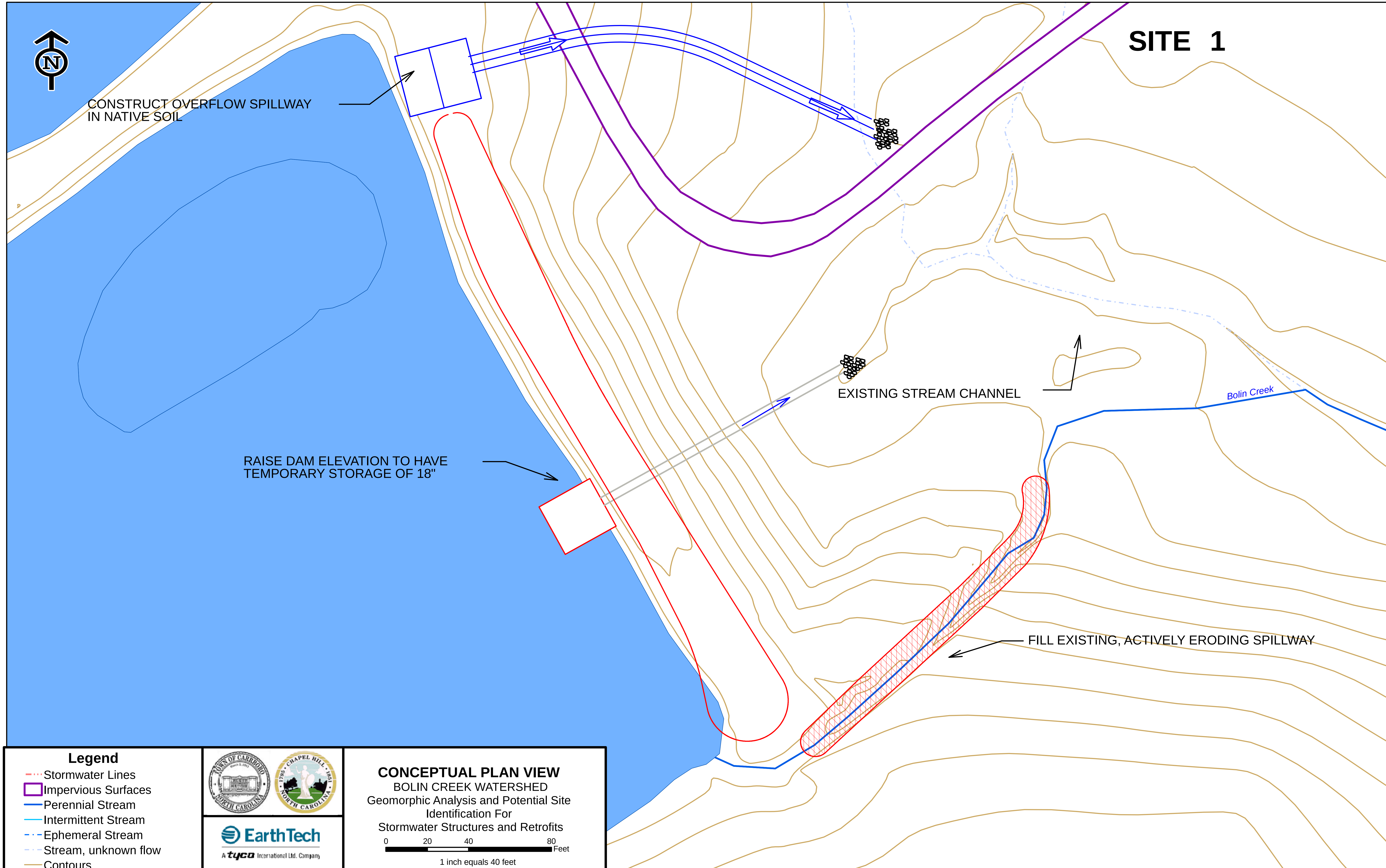

CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

0 20 40 80 Feet

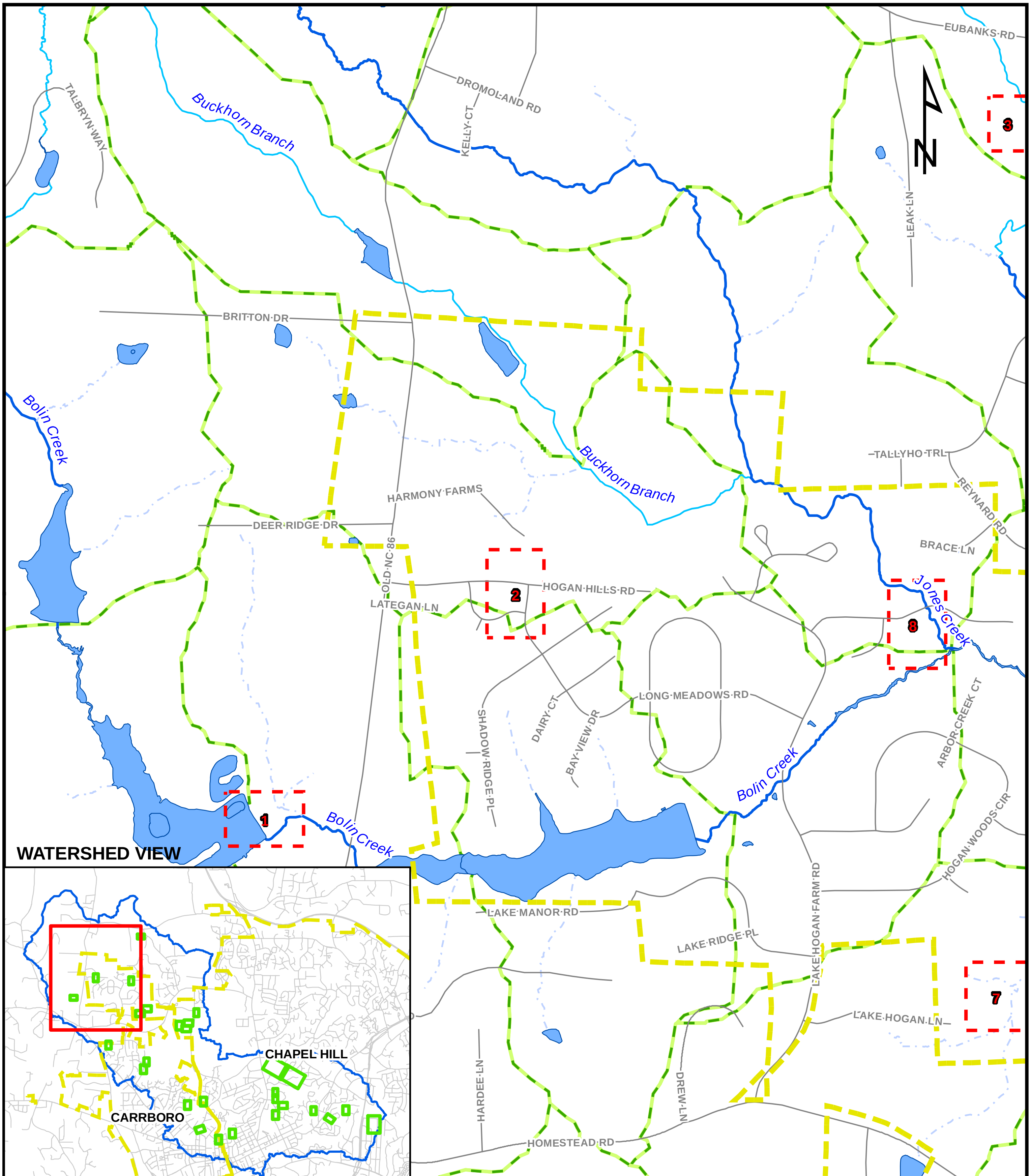
1 inch equals 40 feet

SITE 2

Retrofit of Existing Stormwater Pond

Index Sheet No.: 5
Raw Data Name: BD 100

Estimated Construction Cost: $44,000



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

SITE 2
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 2	5.0	2.3	45.2%

Location

Site 2 is located at the corner of Hogan Hills Rd and Long Meadows Rd in the subdivision of Lake Hogan Farms.

Problem Description

The continuing development of the Lake Hogan Farms subdivision was observed to be impacting the surrounding stream systems, including Jones Creek and Bolin Creek. A number of small sediment basins, which were likely built during construction of the subdivision, are still in existence in various parts of the subdivision. These provide an opportunity for stormwater BMP retrofits for water quality treatment and the attenuation of peak flows, which should help to alleviate the stress on the surrounding streams. It should be noted that the BMPs that are in place were predominantly designed for the control of water quantity, not quality.

Site 2 is an existing stormwater basin was designed under an old ordinance whereby the basin discharges all rainfall events at a 10 year flow rate. The basin is composed of a flat, shallow depression with sparse plantings of hardwood saplings scattered throughout. The basin currently collects the runoff of Hogan Hills Rd and surrounding rooftops. The basin inlet is a reinforced concrete pipe and the outlet is a concrete vertical riser structure with a 6 inch diameter orifice which has an invert that is even with the basin’s bottom elevation. This configuration creates a negative hydraulic effect, where a 1 year recurrence interval event is effectively discharged as a 10 year event. Also, with no permanent pool, soils that do not infiltrate, and no functional wetland system, this basin would not classify as any BMP that would be found in today’s NC BMP manual. If the orifice were smaller, it would function to reduce the peak flow rates leaving the sites, and nothing more. Both the inlet and the outlet structures are located on the same side of the basin, further making the basin ineffective by not allowing sediment to settle and not obtaining enough nutrient treatment due to the flow path being only a few feet in length.

Analysis

Proposed Solution

The existing basin of Site 2 is a prime candidate for a BMP retrofit in the form of a stormwater wetland to provide water quality treatment. To properly function as a wetland, this site should have a few permanent pools established and the soil amended so that plants will thrive. To accommodate the needed hydrology, the outlet structure should be modified to temporarily store approximately 6 inches of water depth and the outlet orifice would be sized to handle the excess, while reducing the runoff rate of the 10 year storm down to a 2 year storm. This can be accomplished by creating several orifices in increasing size as the stage increases in the pond. To allow the proper resonance time, the flow length must be increased by adding a berm and forcing the flow coming from the inlet pipe to be routed to the furthest point of the pond away from the outlet. Other pools and low marsh benches could be built to create the appropriate diversity of habitat for various aquatic and semi-aquatic plants, which will provide treatment of stormwater for nutrients. The site is a desirable one for a stormwater BMP in that the amount of earthwork will be minimal.

The current nutrient export rates, and potential benefit of a stormwater wetland here have been calculated based on land use, drainage area and percent imperviousness of the drainage area, and are displayed in **Table 2.1**:

Table 2.1

SITE 2	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	12.29	1.24	167.06
STORM WATER WETLAND TREATMENT REMOVAL %	40.00%	35.00%	85.00%
NET REDUCTION	4.92	0.43	142.00
FUTURE CONDITION	7.37	0.81	25.06

Constraints

The biggest constraint at this site could potentially be landowner cooperation and land acquisition. If the neighborhood does not want standing water near their home, then the outlet would have to be retrofitted to reduce peak flows and perhaps A landowner that lives adjacent to the site was spoken to during field visits and stated that the site was unsightly now that they had removed wetland vegetation and regarded it witching the past 2 years. If work is done to the make the existing basin into a stormwater wetland for water quality treatment, the design must be such as to satisfy the neighbors and perform better than the previous basin.

Alternatives

If the adjacent property owners do not want the wetland near their home, then the outlet would have to be retrofitted to reduce peak flows and possibly amend the retrofit the basin with a permeable soil layer, to allow some storage through infiltration. Cost would be similar to the wetland, but treatment would be significantly less. A compromise may be reached by allowing underground storage through a porous medium and a mantle of topsoil to support plant growth. This would achieve treatment of the stormwater, but the retrofit would begin to become much more expensive due to the amount of earthwork and required addition of porous medium.

Cost-Estimate Breakdown

Table 2.2 shows a conceptual itemized cost estimate. These costs represent construction and maintenance costs only. The cost for stormwater wetlands is derived from an equation developed by Brown and Schueler (1997).

Table 2.2
SITE 2 Construction Costs

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stormwater Wetland	27573.0	CF	Equation Derived	$38,156
			Total	$38,156
Mobilization (5%)	1.0	LS		$1,908
Contingencies (10%)	1.0	LS		$3,816
	Total + Mobilization and Contingencies			**$43,879**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$2,194**

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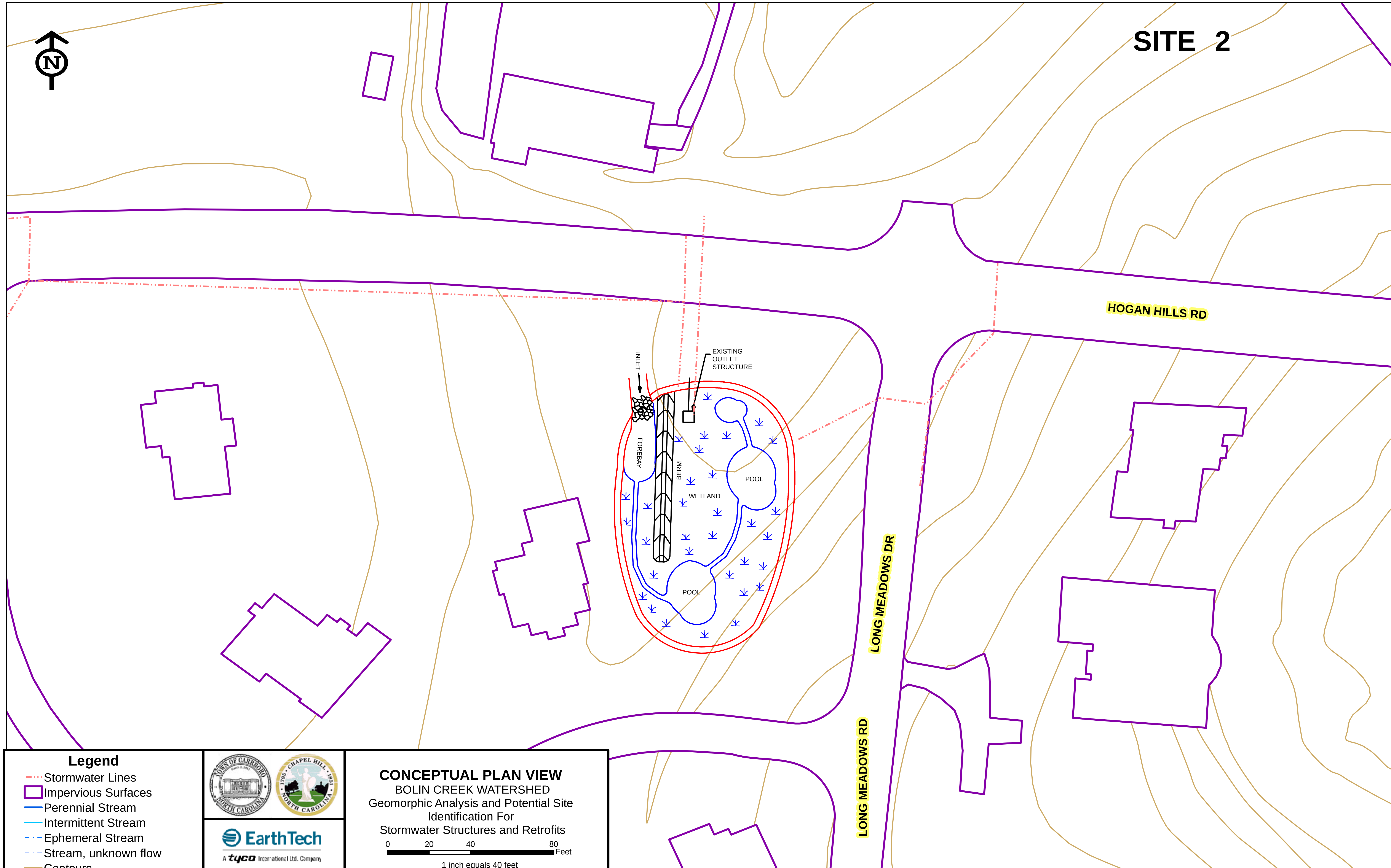

Legend

- Stormwater Lines
- Impervious Surfaces
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow
- Contours

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CONCEPTUAL PLAN VIEW

BOLIN CREEK WATERSHED

Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

0 20 40 80 Feet

1 inch equals 40 feet

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For
Stormwater Structures and Retrofits

0 20 40 80 Feet

1 inch equals 40 feet

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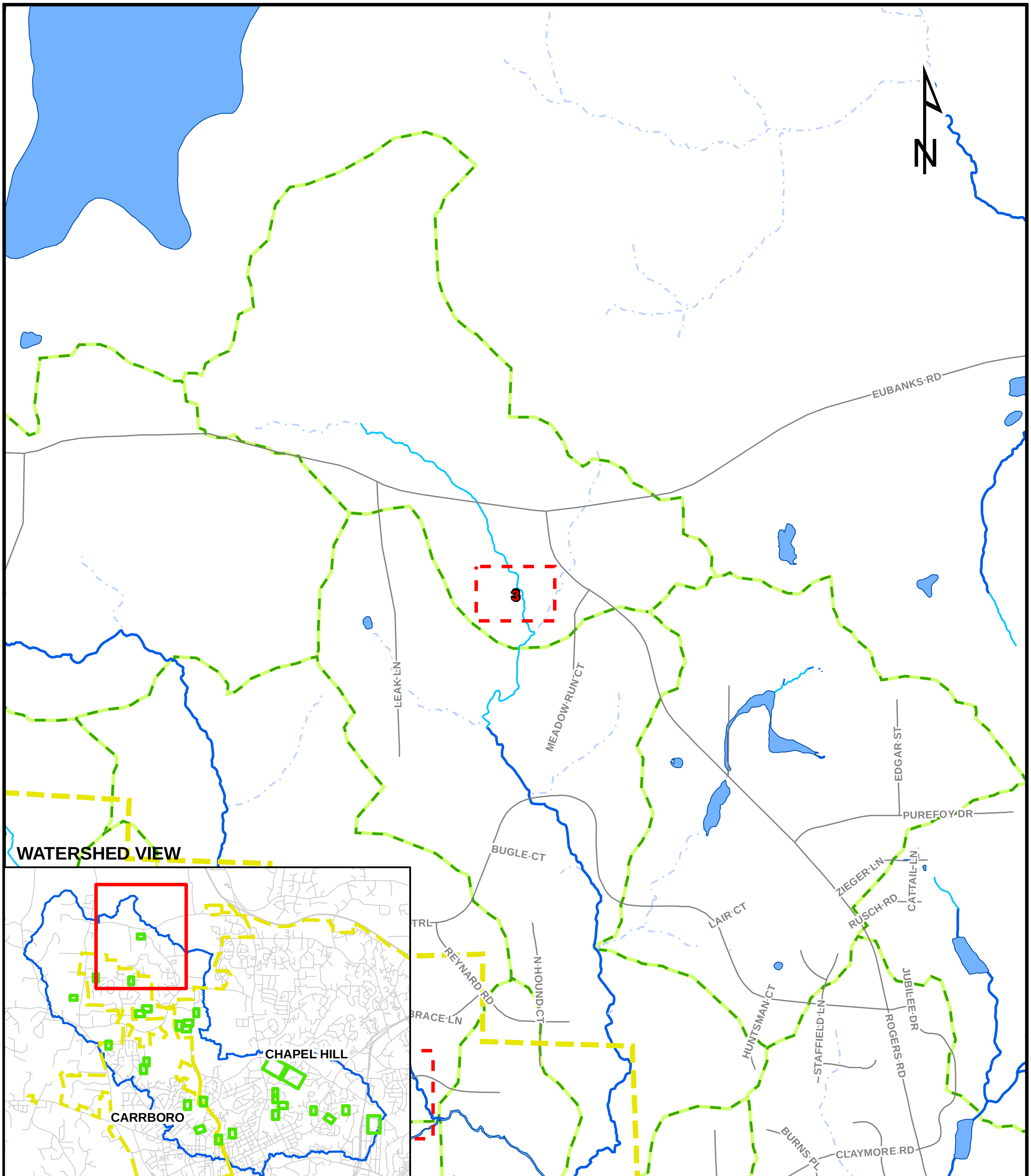
SITE 3

Stabilization of Headcut on Intermittent Channel

Index Sheet No.: 7
Raw Data Name: BD 27

Estimated Construction Cost: $19,200-$54,000



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO NORTH CAROLINA March 3, 1911

CHAPEL HILL 1793 1851 NORTH CAROLINA

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SITE 3
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 3	127.2	2.4	1.9%

Location

Site 3 is located to the southwest of the intersection of Rogers Rd and Eubanks Rd. Access to the site can be obtained by following a powerline easement west from Rogers Rd until it reaches a stream.

Problem Description

The primary problem at Site 3 is a headcut in a channel which was observed to be an intermittent stream channel. The stream has a headcut which is progressing upstream towards the powerline. The difference between the bed elevation upstream and downstream of the headcut is approximately 4 feet. Upstream of the headcut, the channel is relatively stable, shows very little incision, and still accesses its floodplain. Downstream of the headcut, the stream channel is incised for its entire length until it reaches a residential area and converges with a larger channel. Actively eroding banks along this reach are contributing sediment to the watershed, and as the headcut continues to work upstream, which will continue to add a significant amount of sediment to the system during this downcutting process. Once the channel can no longer access its floodplain, the shear stress will continue to increase, and continue to add massive sediment loads to receiving waters. The process of channel incision is much, much easier to stop than it is to repair. The typical stream restoration is a project of massive proportion and effort that is focused on restoring channel stability by providing a proper channel geometry and a shear stress reducing floodplain. The channel downstream is in trouble and would take an expensive project to repair. The channel upstream of the headcut is still in great shape and could be maintained by stopping the headcut.

Sediment export rates from bank erosion have been estimated and are shown in **Table 3.1**.

Table 3.1

Pre-Treatment	
Estimated Total Sediment Export	160.9 tons/year
Erosion per length of Channel	2.7 tons/yr/ft
Pounds of Nitrogen	321.9 lbs/year
Pounds of Phosphorus	160.9 lbs/year
Post-Treatment	
Estimated Total Sediment Export	0.3 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	0.5 lbs/year
Pounds of Phosphorus	0.3 lbs/year

Proposed Solution

To stop the advancing headcut, grade control structures should be used in the stream channel. Grade control structures are commonly employed in stream restoration practices, where a hard, immovable mass is needed to limit degradation of the bed of a channel. These structures are available in several different forms, the most common of which are the cross vane, log vane and grade control vane. These vanes are most often constructed from rock or logs to provide the needed mass, while also providing habitat and a natural appearance.

Several grade control vanes should be constructed at the upstream end of the advancing headcut. This will serve two functions by defining pools for energy dissipation and acting as a back-up for the downstream grade control. Three more should be constructed in sequence on the headcut itself and then backfilled, in order to create a "step-pool" feature. This will provide a more gradual transition between the two different streambed elevations, dissipate the confined energy and also aid in the prevention of any future degradation in the upstream channel. Along with this treatment, a bankfull bench should be built in the incised channel downstream for approximately 50 feet in order to lower near bank stresses on the banks that could potentially degrade and cut around the grade control structures.

There is a nearby powerline easement to this site which should provide easy construction access from nearby Rogers Rd.

Constraints

Implementation of the work at this site will require some removal of over-story hardwood trees. Period maintenance will be required if a stormwater wetland is built in the floodplain. Because the project is adjacent to a utility easement, memorandums of agreement (MOA) or memorandums of understanding (MOU) may be required to implement work.

Alternatives

Several alternatives are possible at this site:

Alternative 1: As mentioned above, build three grade control vanes structures in the area of the headcut to create a "step-pool", and place several more grade control structures upstream. Construct a bankfull bench downstream by sloping the streambank back.

Alternative 2: Implement the work mentioned in Alternative A, and also restore the downstream channel until its confluence with the next downstream tributary. Upstream, redefine the channel as it flows through the power line easement.

Construct a stormwater wetland in the adjacent floodplain of the stream. This wetland will serve to attenuate peak flows and thus help to alleviate stress on the downstream channel. Another benefit of side channel storage is it's potential to augment baseflow. A flow splitting device should be placed in the stream channel, which will allow a portion of the increased storm flows to be diverted into the wetland. The bottom elevation of the permanent pools of the wetland should not be lower than the bed of the stream channel, so that water stored in the wetland can properly infiltrate and recharge the stream channel. Though clay soils have low permeability, saturated soils can and do provide baseflow, as they do in a natural system. Micro-topographic features of the natural terrain retain small amounts of runoff, slowly infiltrate into piedmont soils and thus recharge aquifers and provide for baseflow in intermittent and perennial streams.

Alternative 3: Construct only the grade control upstream of the headcut. This would be the lowest cost option, but should provide the necessary grade control to stop the advance of the headcut.

Cost-Estimate Breakdown

Table 3.2, 3.3 and 3.4 show conceptual itemized cost estimates for the three alternatives. These costs represent construction and maintenance costs only. The cost for stormwater wetlands is derived from an equation developed by Brown and Schueler (1997). The contingency fee for this site has been increased due to the difficulty of access and proximity to a utility easement.

Table 3.2

SITE 3 ALTERNATIVE 1

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
Mobilization (5%)	1.0	LS		$1,269
Contingencies (20%)	1.0	LS		$5,078
	Total +	Mobilization and Contingencies		**$31,734**

Table 3.3

SITE 3 ALTERNATIVE 2

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	60.0	CY	15.00	$900
Stormwater Wetland	8375.0	CF	Equation Derived	$16,550
Site Preparation and Planting	0.1	AC	7500.00	$750
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	$42,538
Mobilization (5%)	1.0	LS		$2,127
Contingencies (20%)	1.0	LS		$8,508
	Total +	Mobilization and Contingencies		**$53,172**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$2,659**

Table 3.4

SITE 3 ALTERNATIVE 3

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	0.0	CY	15.00	$0
Site Preparation and Planting	0.0	AC	7500.00	$0
Rip Rap Class B	5.0	Tons	45.00	$225
Filter Fabric	15.0	SY	5.00	$75
Grade Control Vanes	4.0	EA	3000.00	$12,000
Silt Fence	100.0	FT	3.75	$375
Construction Safety Fence	100.0	LF	2.50	$250
Construction Entrance	1.0	Ea	2500.00	$2,500
			Total	$15,425
Mobilization (5%)	1.0	LS		$771
Contingencies (20%)	1.0	LS		$3,085
	Total +	Mobilization and Contingencies		**$19,281**

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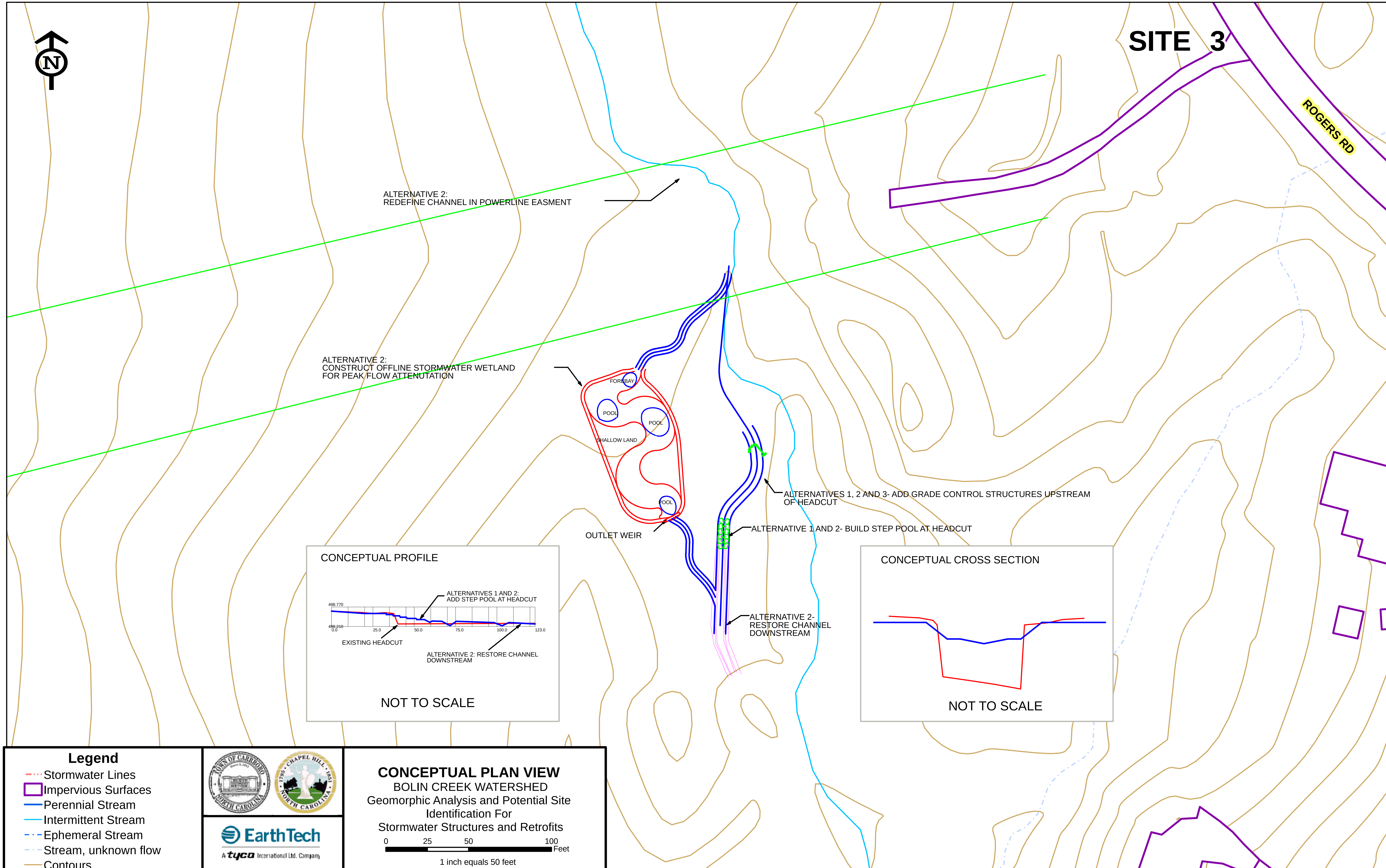
SITE 3
ROGERS RD
ALTERNATIVE 2:
REDEFINE CHANNEL IN POWERLINE EASMENT
ALTERNATIVE 2:
CONSTRUCT OFFLINE STORMWATER WETLAND
FOR PEAK FLOW ATTENUTATION
FOREBAY
POOL
POOL
SHALLOW LAND
POOL
OUTLET WEIR
ALTERNATIVES 1, 2 AND 3- ADD GRADE CONTROL STRUCTURES UPSTREAM
OF HEADCUT
ALTERNATIVE 1 AND 2- BUILD STEP POOL AT HEADCUT
ALTERNATIVE 2-
RESTORE CHANNEL
DOWNSTREAM
CONCEPTUAL PROFILE
ALTERNATIVES 1 AND 2:
ADD STEP POOL AT HEADCUT
498.770
498.210
0.0
25.0
50.0
75.0
100.0
123.0
EXISTING HEADCUT
ALTERNATIVE 2: RESTORE CHANNEL
DOWNSTREAM
NOT TO SCALE
CONCEPTUAL CROSS SECTION
NOT TO SCALE
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
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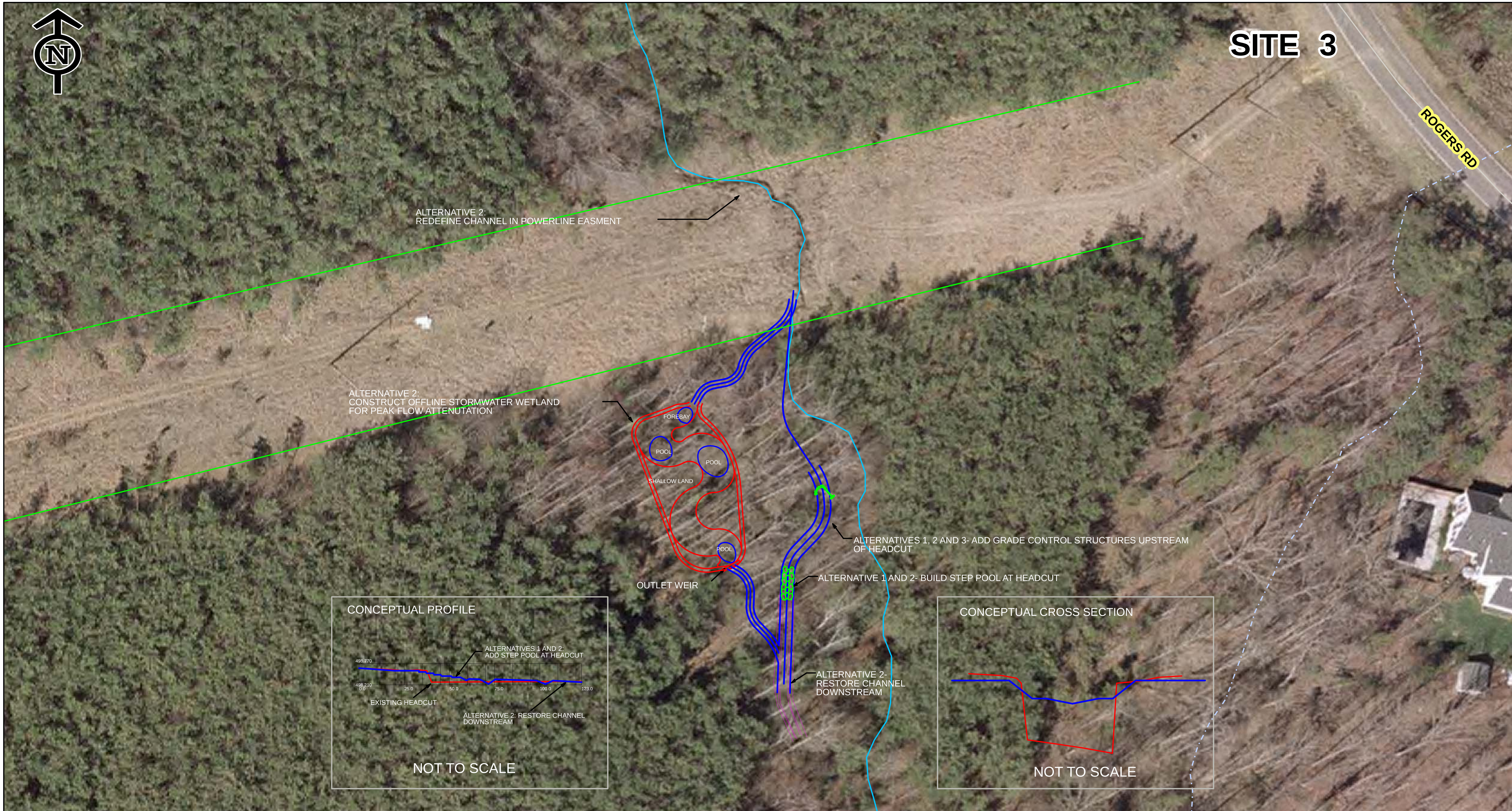
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0
25
50
100
Feet
1 inch equals 50 feet



Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO NORTH CAROLINA

CHAPEL HILL 1793 1851 NORTH CAROLINA

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

0 25 50 100 Feet

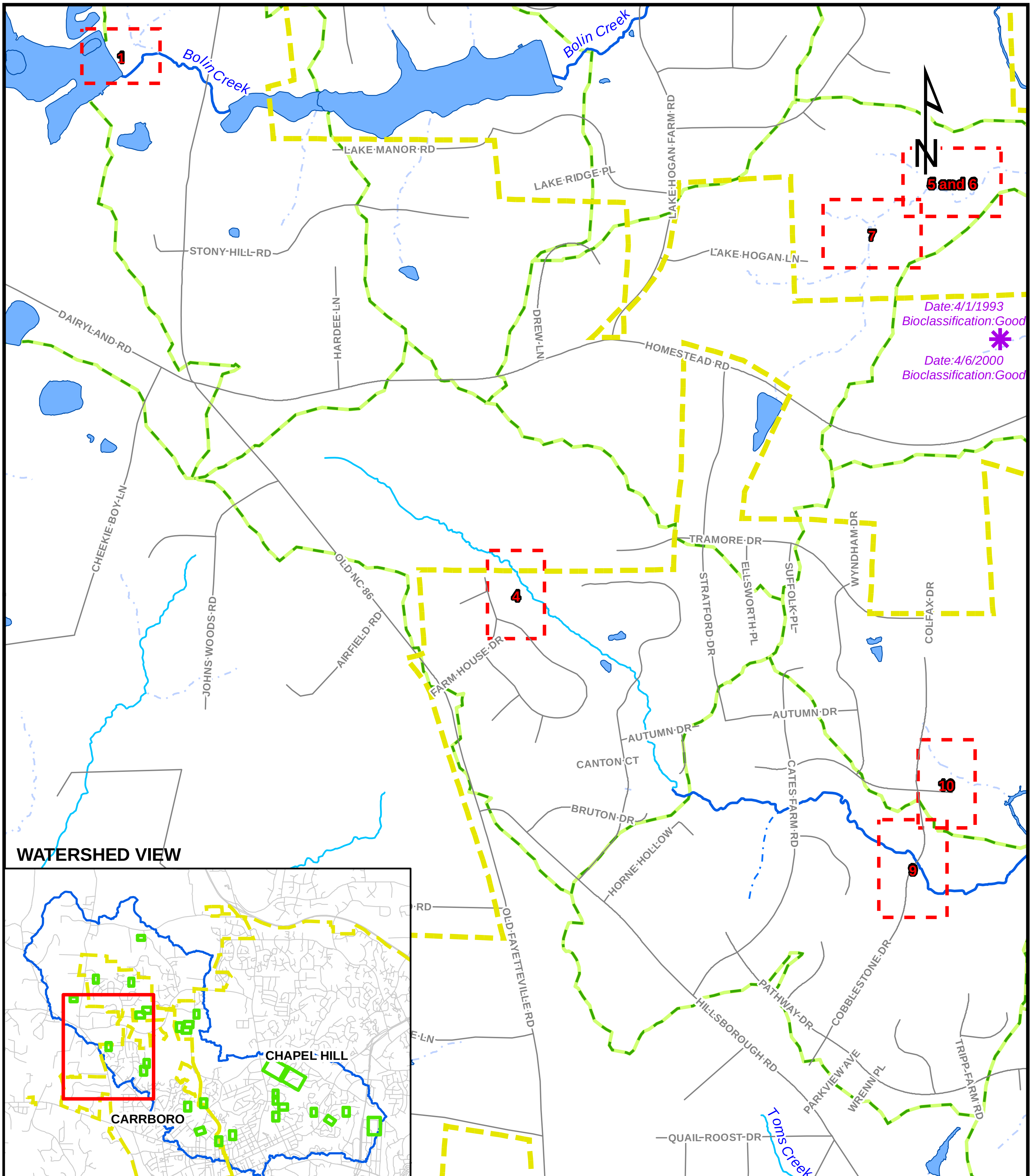
1 inch equals 50 feet

SITE 4

Retrofit of Stormwater Outfall at Subdivision

Index Sheet No.: 9
Raw Data Name: TA 3

Estimated Construction Cost: $73,500



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 4
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 4	11.8	2.6	22.2%

Location

Site 4 is located approximately 200 feet to the northeast of the intersection of Sunset Creek Circle and Farmhouse Dr., in a subdivision located southeast of the intersection of Old NC 86 and Homestead Rd.

Problem Description

Site 4 consists of an existing stormwater outfall structure located downhill from a subdivision, and uphill of a ditch leading into a stream. The structure is a square concrete box with two walls, which appears to collect stormwater and turn the flow 90 degrees into a ditch. Uphill of the structure is a stormwater pipe outlet and a steeply sloped, base ditch filled with rip-rap and lined with plastic sheeting leading into the structure. The drainage pipe appears to discharge the stormwater collected in the curb and gutter system of the subdivision. The ditch into which the structure turns flow is approximately 170 feet long, and leads into an incised stream channel. Bank erosion is evident where the ditch meets the stream, indicating that the velocity of the flow discharging into the stream is not sufficiently dissipated (see Appendix B-Photos).

There is no evidence that there is any water quality treatment being provided by the stormwater system at Site 4.

Proposed Solution

The existing conditions of Site 4 provide a challenge for implementing a “traditional” BMP. The ditch into which the concrete structure turns flow is narrow and deep, due to an earthen berm that was constructed parallel to the contour of the very steep hillside. Fitting a typical bio-retention area with sufficient volume to treat pollutants into this confined space would be impractical. Instead, a possible solution is to construct a “bio-grade step” within the narrow area of the existing ditch, and keep the existing structure, as it does effectively turn the flow from its path straight off the side of the slope. The “bio-grade step” consists of a series of small bio-retention cells filled with a filter media, such as a mixture of sand, fines and organic mater (see Appendix A-Details). Ideally, this media will have an infiltration rate of 1.0 to 2.0 inches per hour, to optimize pollution removal (Schueler, et. al., 2007). Each cell is connected to the next cell down-slope by a pervious drain layer of sand or other media, thus allowing stormwater to filter through each cell without the expense of an under-drain. Each cell is designed to overflow to the next after reaching the desired backwater elevation.

The surface areas of the "bio-grade step" should be planted with a mixture of woody and herbaceous native plants. The vegetation will provide filtration and stability.

Potential pollution removal rates using this method have been estimated and are shown in **Table 4.1**.

Table 4.1

SITE 4	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	4.20	0.37	73.80
BIORETENTION TREATMENT REMOVAL %	35.00%	45.00%	85.00%
NET REDUCTION	1.47	0.17	62.73
FUTURE CONDITION	2.73	0.21	11.07

Constraints

Construction access to the site could be limited by the narrow ditch and the very steep hillside. The removal of some trees to work around this ditch may be required. In addition, periodic maintenance of the bio-grade step will be required

Alternatives

No alternatives are proposed for this site.

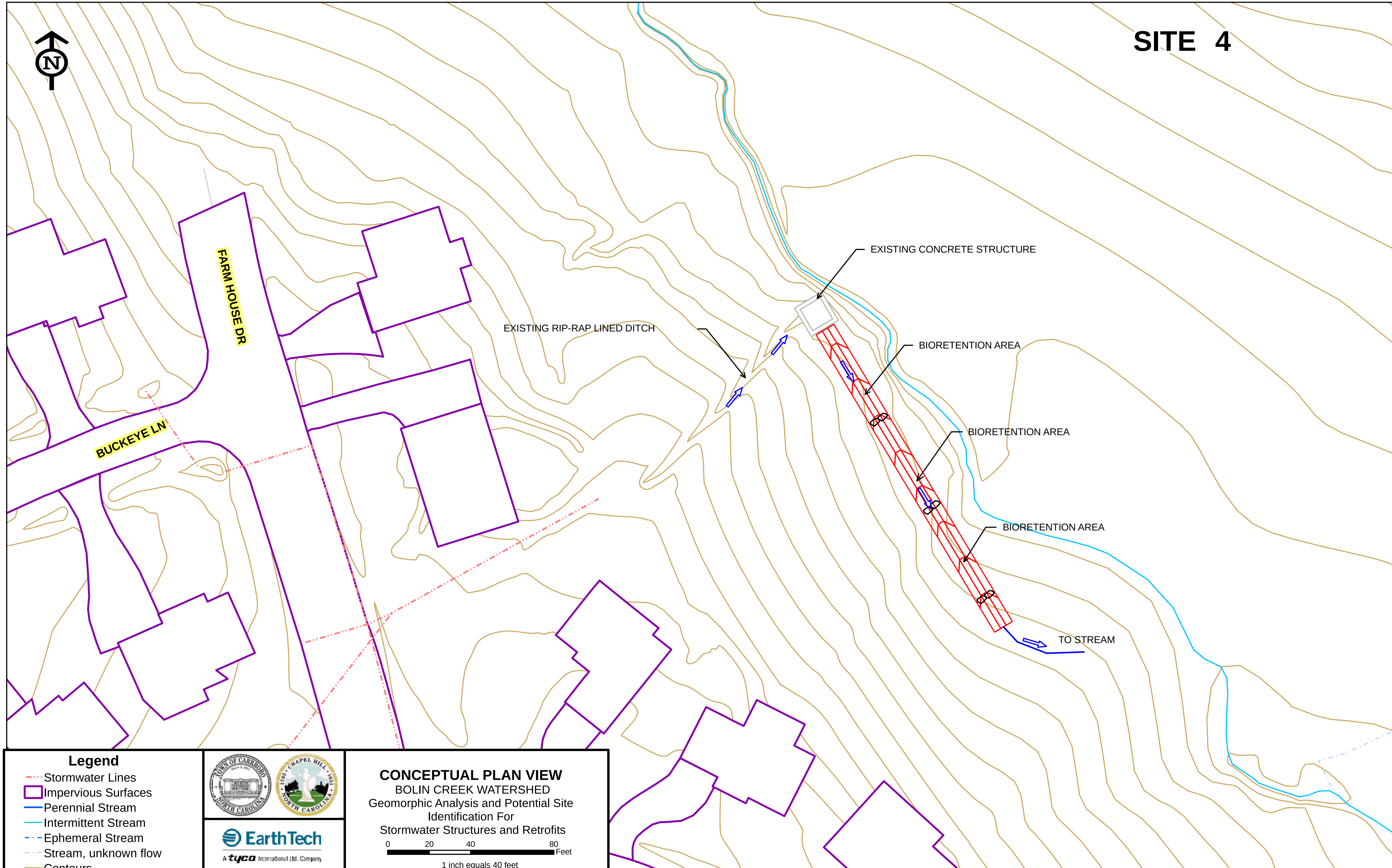
Cost-Estimate Breakdown

Table 4.2 shows a conceptual itemized cost estimate. These costs represent construction and maintenance costs only. The cost for the bio-grade step is derived from a cost per cubic foot treated for bioretention areas reported by Schueler, et. al. (2007). The contingency fee for this site has been increased due to the difficulty of access.

Table 4.2

Site 4 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Bio-grade Step	4854.0	CF	12.62	$61,257
			Total	$61,257
Mobilization (5%)	1.0	LS		$3,063
Contingencies (15%)	1.0	LS		$9,189
	Total + Mobilization and Contingencies			**$73,509**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$3,675**



Legend

- Stormwater Lines
- Impervious Surfaces
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow
- Contours

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CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

0 20 40 80 Feet

1 inch equals 40 feet

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

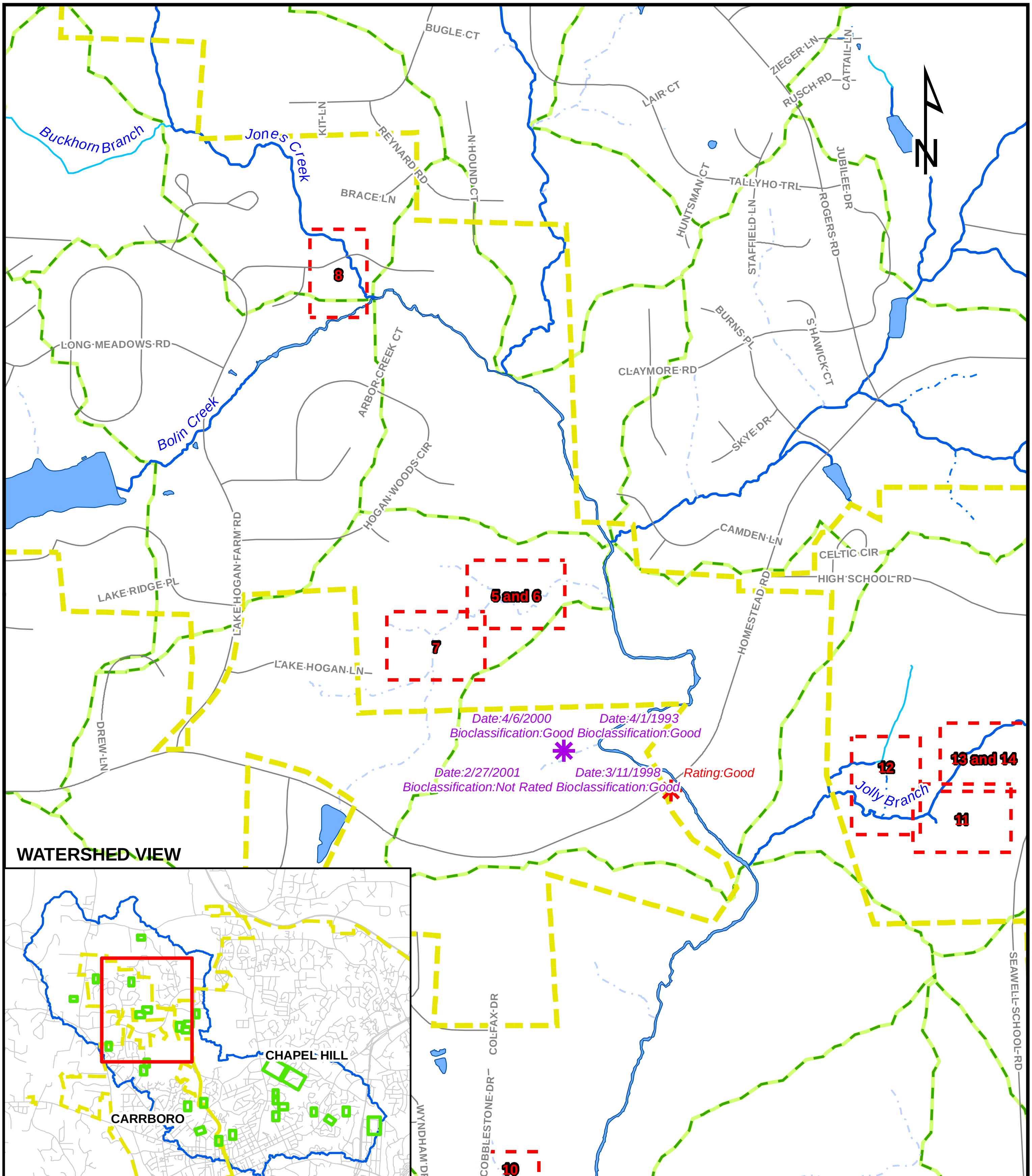
0 20 40 80 Feet

1 inch equals 40 feet

SITE 5

Index Sheet No.: 11
Raw Data Name: None

Estimated Construction Cost: $22,700



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO · March 3, 1911 · NORTH CAROLINA

CHAPEL HILL · 1795 · 1851 · NORTH CAROLINA

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SITE 5 and 6
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 5	3.2	1.0	29.6%

Location

Site 5 is located east of N. Cammelia Drive in the subdivision of Winmore, which is located off of Homestead Rd. At the time of this report, the subdivision was still under construction.

Problem Description

Site 5 is an existing stormwater BMP that was initially designed to act as a sediment basin during the construction of the subdivision Winmore, and which, according to the Winmore site plan, will be converted into a "pocket wetland" following construction. At the time of this report, the basin was still acting its capacity as a sediment basin. These BMP's are good examples of how the science of watershed management has progressed over the last few years. There are several features of the BMP that would be very different in order to meet the current BMP guidelines of the State. Earth Tech believes that the BMP's such as this one can benefit from retrofits that provide stability to the receiving channel and enhance water quality treatment.

The velocity dissipater of the basin outlet consists only of a rip-rap apron, with no pre-formed scour depression. During the field investigation, the aprons were observed to be showing indications of instability, "cut-arounds" and demonstrated a consistent problem of concentrated flows eroding the floodplain within the riparian zone. In most cases, the erosive forces of concentrated flows had yet to truly cause gullies, but the process has begun. There were headcuts beginning to form in the streambank where the concentrated flows joined the channel. These will most likely work their way through the floodplain from the channel, causing channel instability and contributing significant amounts of sediment to the stream.

The basin currently has no overflow spillway. Though this is not a requirement for North Carolina permits, many states require secondary spillways to be installed on stormwater structures in order to reduce the risk of the massive sediment inputs to a natural system when a structures berm is overtopped and fails. Earth Tech witnessed this effect on a site in north Raleigh in the spring of 2007 when a channel was completely denuded by clay silt after the failure of an upstream sediment basin.

The vegetated swale leading into the basin is relatively steep and showing definitive signs of eroding or incision. There are no check dams, or hydraulic structures that would serve to reduce channel velocities to a point lower than the critical shear stress velocity for the designed flexible lined channel.

Proposed Solution

Potential retrofits to this BMP include improving the swale leading into the wetland, construction of an overflow spillway, and using a pre-formed scour hole or energy dissipater basin (stilling basin) with a level spreader at the outlet discharge location. The swale may be retrofitted with grade control steps to flatten slopes incrementally or may be retrofitted to act as a "bio grade" steps as suggested in other sites within the Bolin Creek watershed. This will provide some storage of storm flow for base flow augmentation and reduce the erosive velocities that are present in the existing channel. The overflow spillway would provide some insurance from berm failure during high intensity rainfall events.

A pre-formed scour hole or other energy dissipater basin that is placed at the outlet pipe from the wetland will serve to adequately retain high energy flows and encourage energy dissipating turbulence at the desired location of the outlet. The existing aprons are not depressed and flows are apparently quickly flowing over or around the apron and onto native soils. A level spreader would provide for diffused flows verses the concentrated flows that exist with the current design. The stream bank should vegetated with appropriate plants to create a filter strip between the level spreader and the channel, which will assist with floodplain stability and nutrient treatment.

Table 5.1 shows an estimated decrease in pollutant load on this site as a result of the proposed treatment. Because the site is still under construction, the percent impervious surface used in this calculation is based off a projected percent impervious, based on typical percentages in subdivision areas.

Table 5.1

SITE 5	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	9.92	1.57	292.55
STORM WATER WETLAND TREATMENT	20.00%	17.50%	42.50%
NET REDUCTION	1.98	0.27	124.33
FUTURE CONDITION	7.94	1.29	168.21

Constraints

There are few constraints to this retrofit. Site access is very good, but working in the riparian zone will require permitting and sensitivity to the channel.

Alternatives

There are no proposed alternative for this project.

Cost-Estimate Breakdown

Table 5.2 shows a conceptual itemized cost estimate. These costs represent construction and maintenance costs only. The cost for stormwater wetlands is derived from an equation developed by Brown and Schueler (1997).

Table 5.2
Site 5 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stormwater Wetland	10741.0	CF	Equation Derived	$19,704
			Total	$19,704
Mobilization (5%)	1.0	LS		$985
Contingencies (10%)	1.0	LS		$1,970
	Total + Mobilization and Contingencies			**$22,660**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$1,133**

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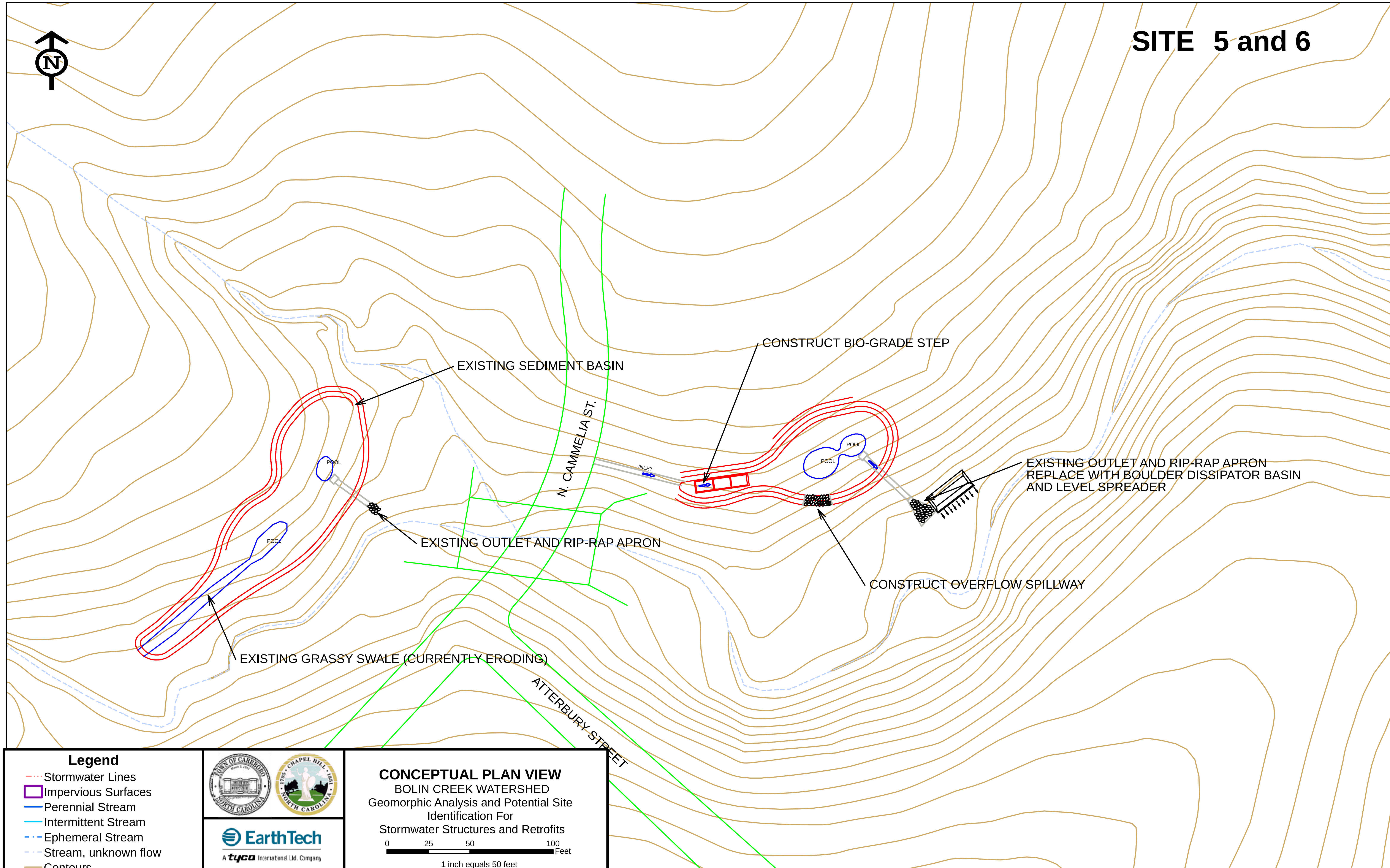
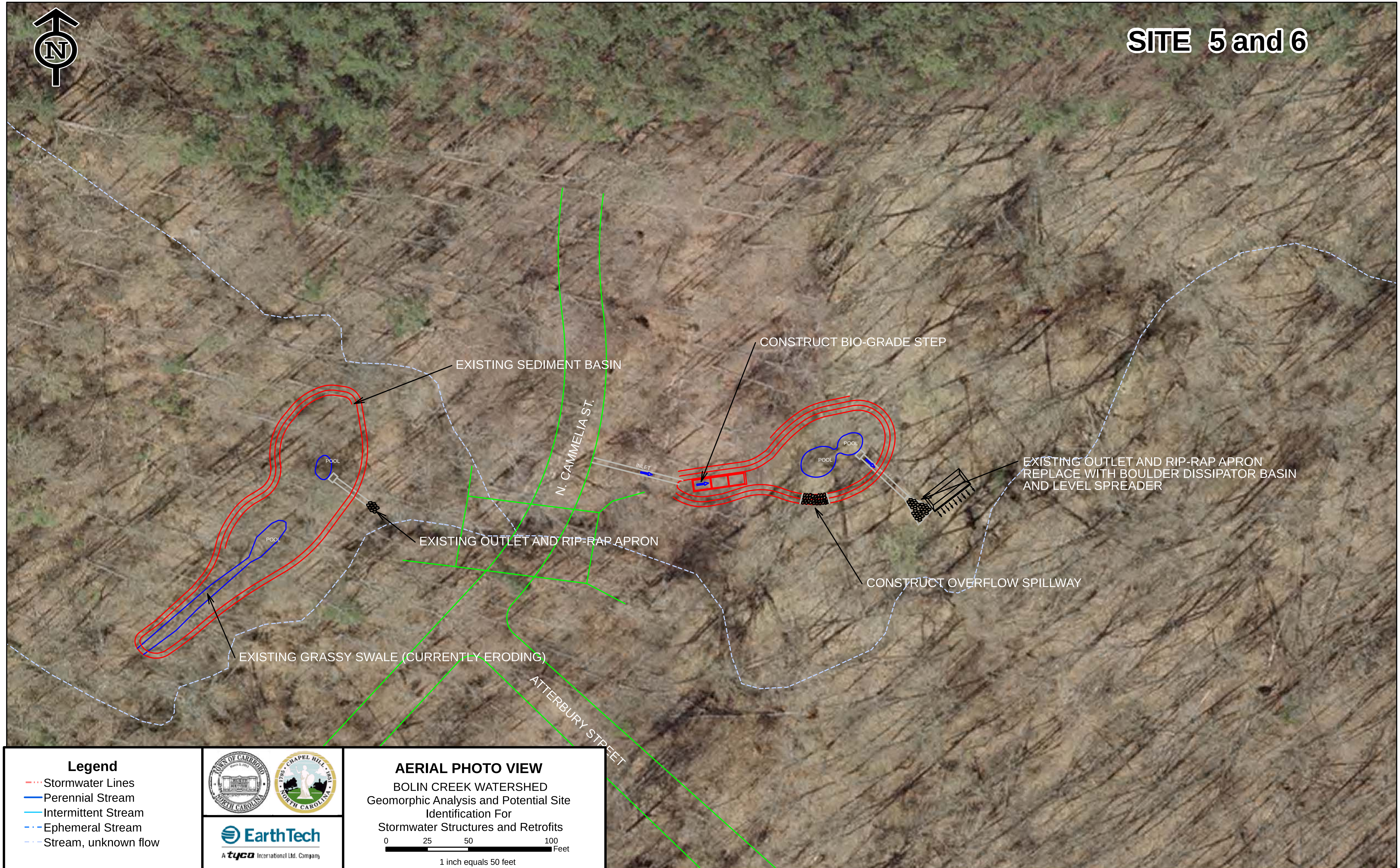


CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits


SITE 5 and 6
N
EXISTING SEDIMENT BASIN
CONSTRUCT BIO-GRADE STEP
N. CAMMELIA ST.
INLET
POOL
POOL
POOL
POOL
EXISTING OUTLET AND RIP-RAP APRON
REPLACE WITH BOULDER DISSIPATOR BASIN
AND LEVEL SPREADER
EXISTING OUTLET AND RIP-RAP APRON
CONSTRUCT OVERFLOW SPILLWAY
EXISTING GRASSY SWALE (CURRENTLY ERODING)
ATTERBURY STREET
Legend
Stormwater Lines
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
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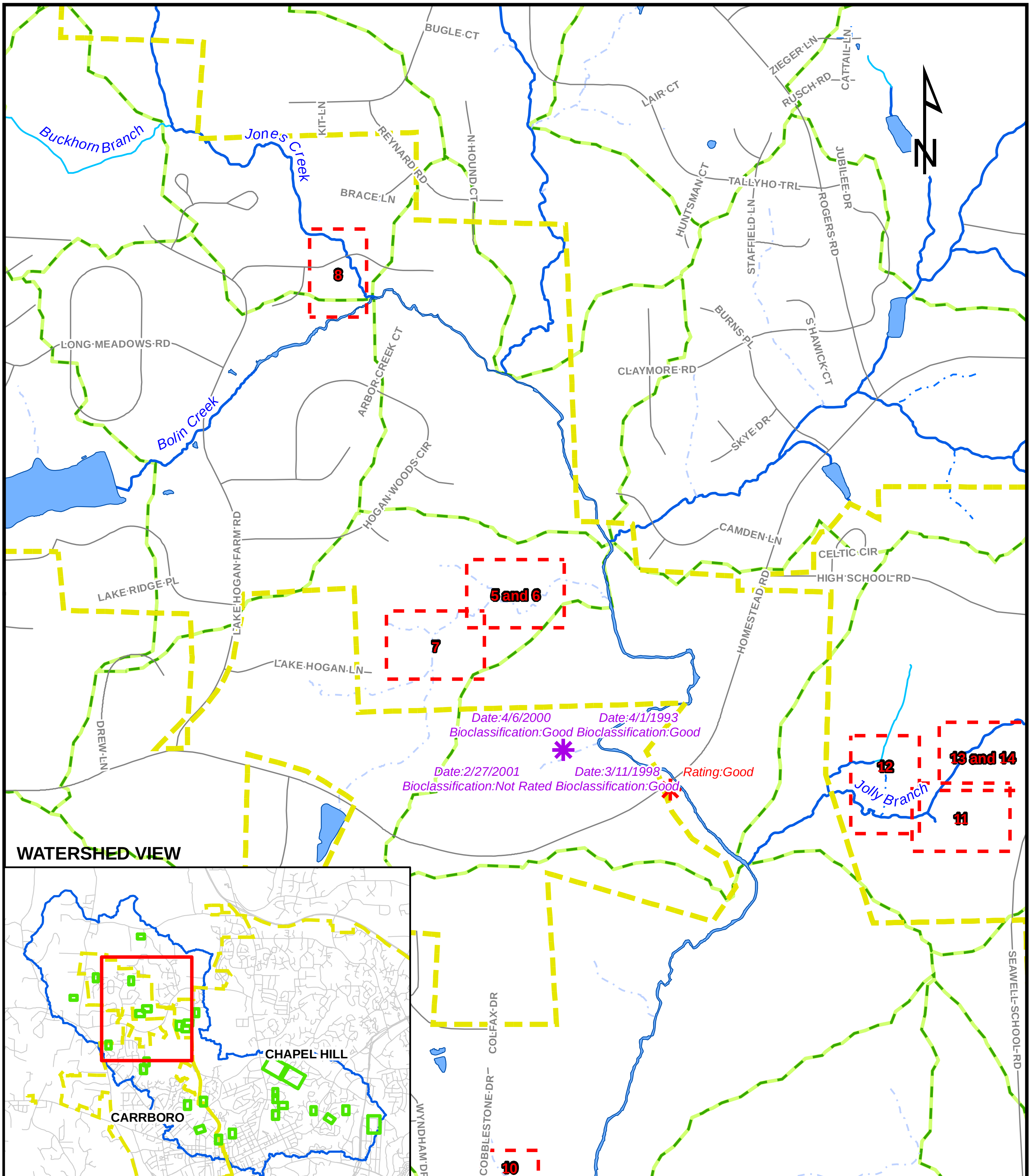
AERIAL PHOTO VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0
25
50
100
Feet
1 inch equals 50 feet

SITE 6

Index Sheet No.: 11
Raw Data Name: None

Estimated Construction Cost: $35,000



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO March 3, 1911 NORTH CAROLINA

CHAPEL HILL 1793 1851 NORTH CAROLINA

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SITE 5 and 6
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 6	4.5	1.3	30.0%

Location

Site 6 is located west of N. Cammelia Drive in the subdivision of Winmore, which is located off of Homestead Rd. At the time of this report, the subdivision was still under construction.

Problem Description

This basin is similar to the basin mentioned in Site 5. The problems and proposed solution here are the same as Site 5.

Proposed Solution

Refer to Site 5 solution.

Table 5.1 shows an estimated decrease in pollutant load on this site as a result of the proposed treatment. Because the site is still under construction, the percent impervious surface used in this calculation is based off a projected percent impervious, based on typical percentages in subdivision areas.

Table 6.1

SITE 6	Pollutant Load (lbs)		
	TN	**TP**	**TSS**
EXISTING CONDITION	9.92	1.57	292.55
STORM WATER WETLAND TREATMENT	20.00%	17.50%	42.50%
NET REDUCTION	1.98	0.27	124.33
FUTURE CONDITION	7.94	1.29	168.21

Constraints

Refer to Site 5 description.

Alternatives

No alternatives are proposed for this site.

Cost-Estimate Breakdown

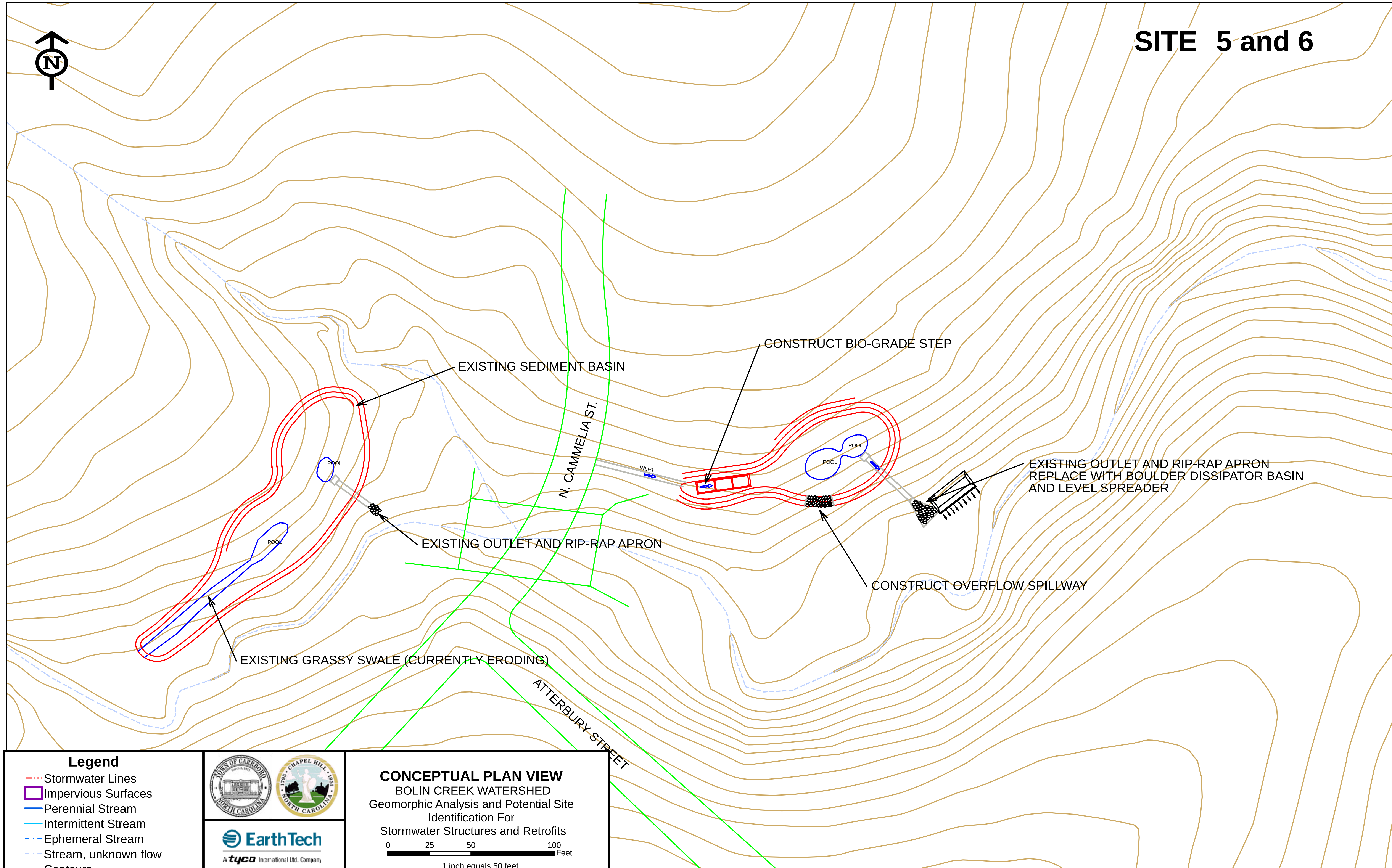
Table 5.2 shows a conceptual itemized cost estimate. These costs represent construction and maintenance costs only. The cost for stormwater wetlands is derived from an equation developed by Brown and Schueler (1997).

Table 6.2
Site 6 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stormwater Wetland	19628.0	CF	Equation Derived	$30,067
			Total	$30,067
Mobilization (5%)	1.00	LS		$1,503
Contingencies (10%)	1.00	LS		$3,007
			Total + Mobilization and Contingencies	**$34,578**

Maintenance Costs

Maintenance (5% of base construction cost)	1.0	Year		**$1,729**



Legend

- Stormwater Lines
- Impervious Surfaces
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow
- Contours

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CONCEPTUAL PLAN VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

0 25 50 100 Feet

1 inch equals 50 feet

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

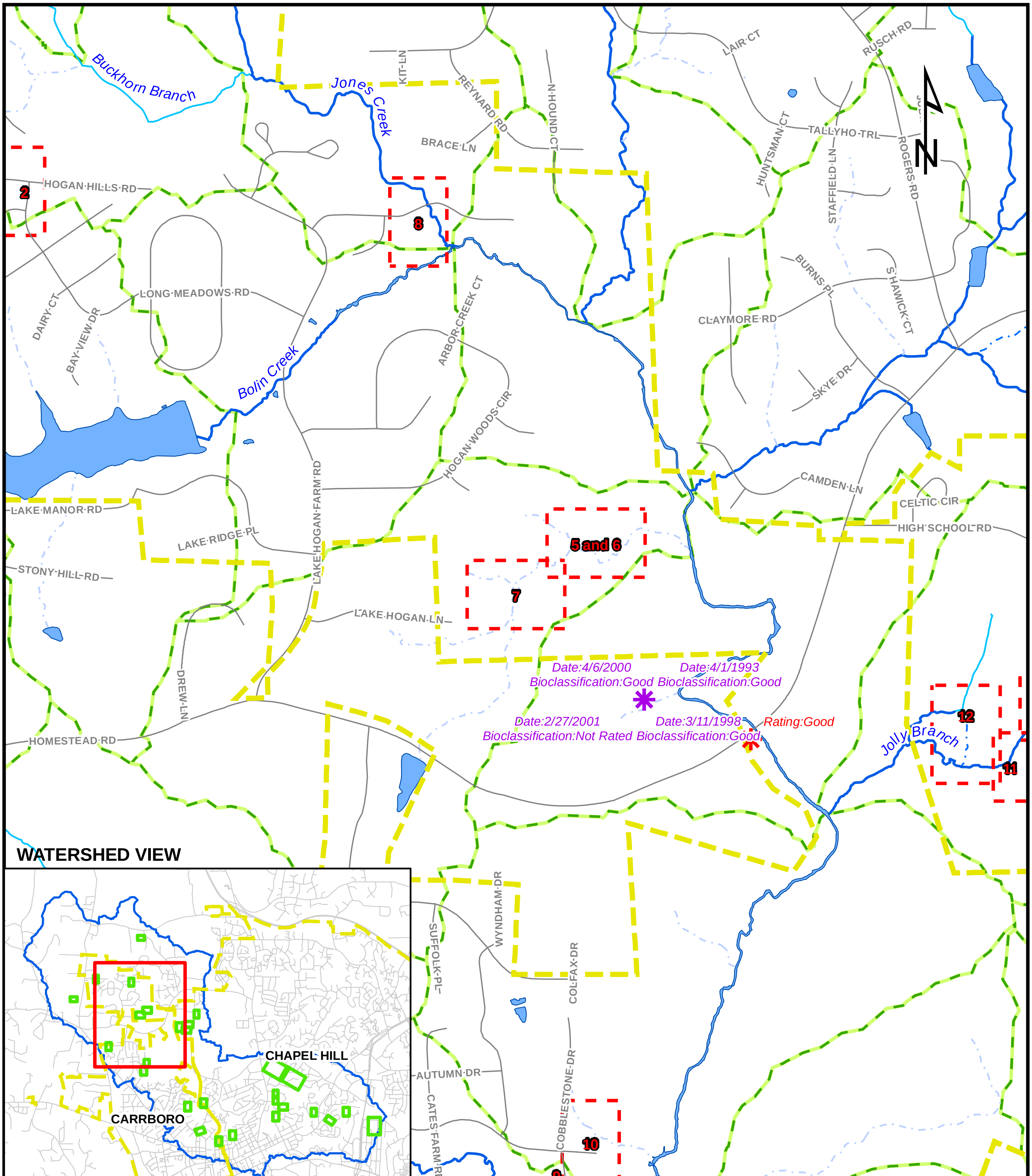
0 25 50 100 Feet

1 inch equals 50 feet

SITE 7

Index Sheet No.: 11
Raw Data Name: None

Estimated Construction Cost: $100,000



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO NORTH CAROLINA · CHAPEL HILL 1795 1851 NORTH CAROLINA

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SITE 7
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 7	2.4	0.7	29.6%

Location

Site 7 is located west of S. Cammelia Drive and private alley in the subdivision of Winmore, which is located off of Homestead Rd. At the time of this report, the subdivision was still under construction.

Problem Description

The stormwater system coming from several acres of the Winmore subdivision is discharged at a location that is very near an un-named perennial stream. The pipe system outlet had a small pre-formed scour type sediment basin and the plans call for a rip-rap apron at the completion of construction. During the site visit, Earth Tech observed the effects of concentrated flow on the perennial stream and the flood plain. Rill erosion has begun and a head cut up from the stream to the outlet will likely be the end result of the erosive forces of the concentrated flows. Also, from a water quality point of view, the approximately 10’ of distance between the BMP and the stream channel is not a sufficient filter strip. This BMP will very likely cause significant degradation to the water quality of the receiving waters due to the anticipated sediment inputs from future channel instability and direct inputs of nutrients.

Proposed Solution

The terrain of this site limits the options for retrofitting the existing BMP. A linear bio-retention area is proposed a solution to dissipative energy, reduce velocities by distributing flow over a significantly larger area, and utilizing a much larger area of biological treatment of nutrients by using the bioretention are itself and increased area of filter strip that results. This project would be a hybrid of a bioretention area with storage and a level spreader.

A secondary, although very significant benefit of this BMP retrofit would be the possibility of augmenting base flow via the stored stormwater volume. It may be desirable to add a series of “weeps” to the design which would be made of several collector pipes or seepage layer fill material with a vegetated geo-grid to prevent erosion due to the seep. An example of the later method would be the use of a pervious drain layer on a typical dam embankment design. The idea is to insure that you regain available storage volume in the BMP by allowing a delayed release of the volume over an extended period, up to 2 weeks, while intentionally adding base flow to the channel between rainfall events.

Table 7.1

SITE 7	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	9.92	1.57	292.55
STORM WATER WETLAND TREATMENT	20.00%	17.50%	42.50%
NET REDUCTION	1.98	0.27	124.33
FUTURE CONDITION	7.94	1.29	168.21

Constraints

The primary constraint of this site is the boundary of the roadway on one side and the stream on the other. Access to the site is excellent and the terrain is suitable for equipment. Due to the confinement of the site, there will be modifications to the floodplain of the small stream and this will create some environmental concerns that must be considered and managed. In addition, a utilities easement is adjacent to the site, and thus a MOU or MOA may be required to be executed with the utilities entity to implement the project.

Alternatives

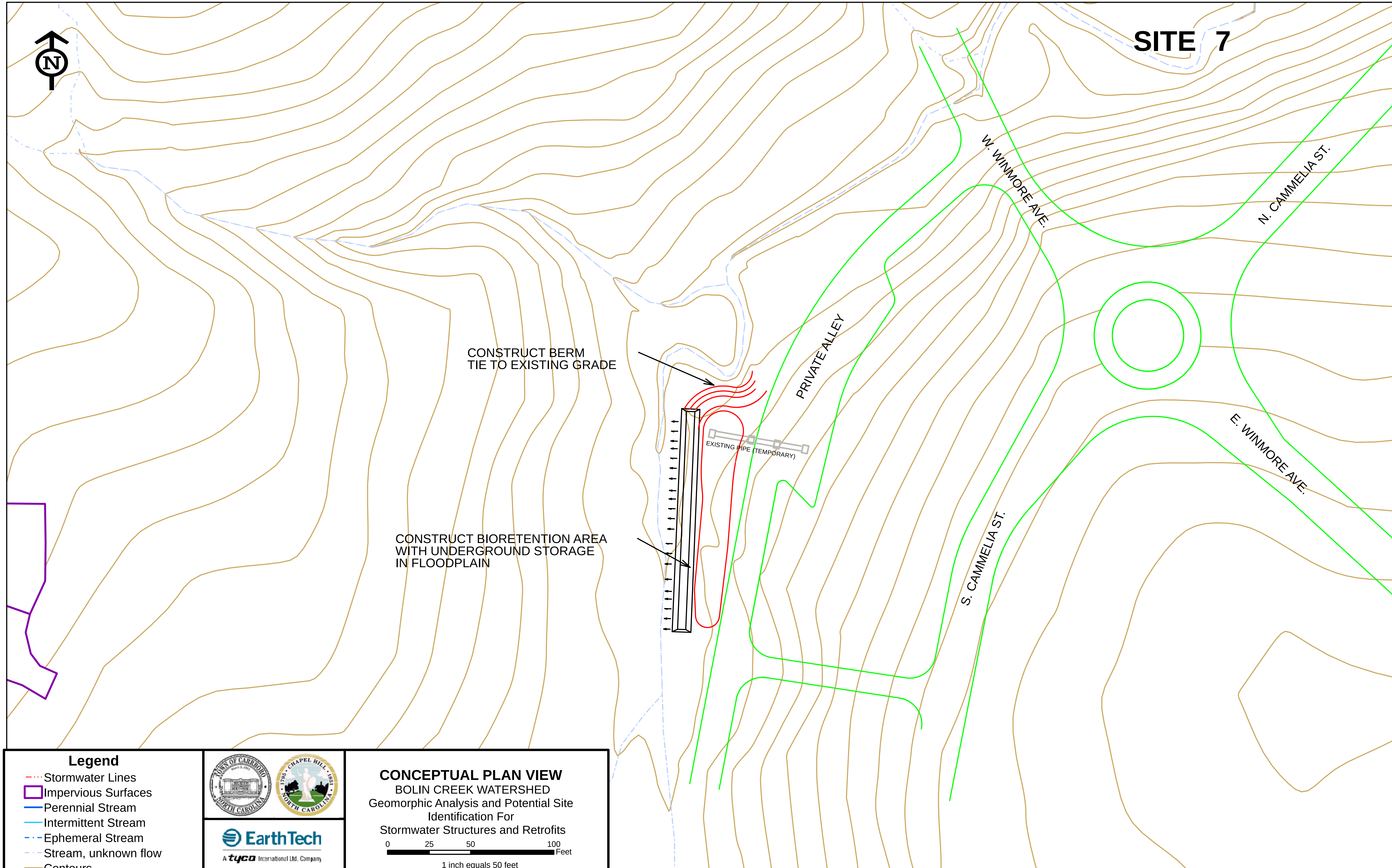
No alternatives are proposed for this site.

Cost-Estimate Breakdown

Table 7.2 shows a conceptual itemized cost estimate. These costs represent construction and maintenance costs only. The cost for the bioretention area is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007).

Table 7.2
Site 7 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Bioretention Area	6933.0	CF	12.62	$87,494
			Total	$87,494
Mobilization (5%)	1.00	LS		$4,375
Contingencies (10%)	1.00	LS		$8,749
	Total + Mobilization and Contingencies			**$100,619**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$5,031**



Legend

- Stormwater Lines
- Impervious Surfaces
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow
- Contours

CONCEPTUAL PLAN VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

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Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

0 25 50 100 Feet

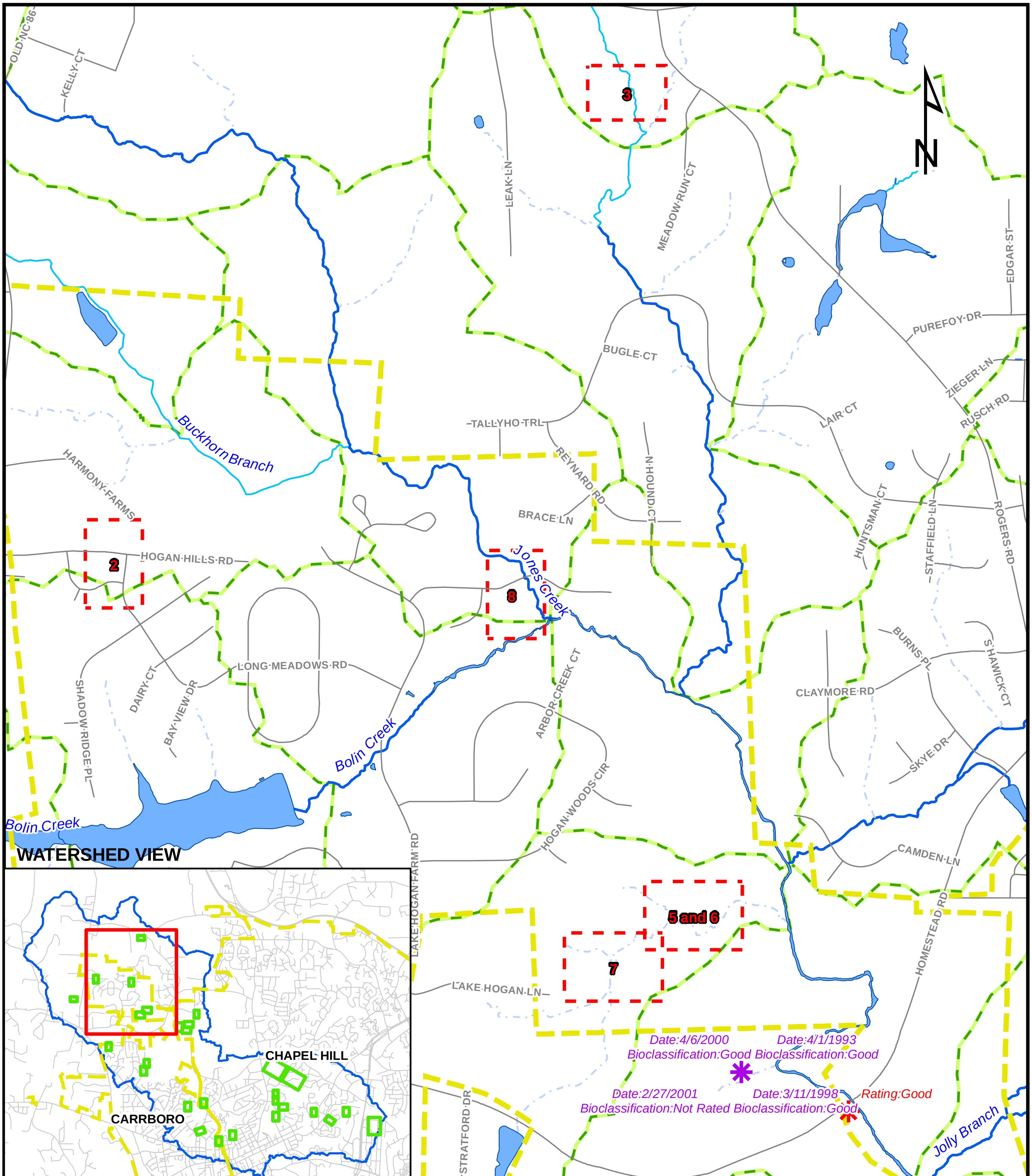
1 inch equals 50 feet

SITE 8

Index Sheet No.: 11
Raw Data Name: IJ 19

Retrofit of Existing Sediment Basin

Estimated Construction Cost: $19,000



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 8

VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs

Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 8	7.4	1.7	23.0%

Location

Site 8 is located near the intersection of Turtleback Crossing Drive and Painted Turtle Lane, in the Lake Hogan Farms subdivision.

Problem Description

The continuing development of the Lake Hogan Farms subdivision was observed to be impacting the surrounding stream systems, including Jones Creek and Bolin Creek. A number of small sediment basins, likely built during construction of the subdivision, are still in existence in various parts of the subdivision. These provide an opportunity for stormwater BMP retrofits for water quality treatment and the attenuation of peak flows, which should help to alleviate the stress on the surrounding streams.

At present, the BMP at Site 8 only serves as an energy dissipater with some water quantity management. The recessed boulder basin or energy dissipater is a good example of how a discharge outlet must typically be recessed to have an adequate effect of retaining the high velocity flows within a prescribed area. This BMP distributes its flow over a small area of about 20 feet, which then collects as a concentrated flow before entering the channel due to the natural terrain. Earth Tech observed signs of erosion due to this concentrated flow and further deterioration of the streambank of Jones Creek is expected to occur over time. No water quality treatment is presently achieved beyond what would occur due to some diffused flow through vegetation immediately after overflowing the crest of the basin.

Proposed Solution

The treatment at Site 8 should consist of retrofitting the existing basin into a stormwater wetland. This can be done by expanding the volume of the basin and digging out areas within the basin to serve as permanent pools. The wetland should have a constructed forebay to trap sediment and dissipate energy before reaching the remainder of the wetland. Areas of shallow land or low marsh benches can also be constructed to provide a diversity of habitat necessary for maximum pollutant removal. An outlet structure should be constructed consisting of an overflow weir that will discharge into a level spreader. The level spreader is important to ensure that flow spreads out diffusely into the surrounding floodplain, rather than concentrating into areas of scour. The entire site should be planted with native vegetation. A detailed site survey may reveal that the floodplain needs to be graded in order to maintain the diffused flow that will converge with Jones Creek. This project will also benefit from futhur water quality treatment by the use of the vegetated filter strip between the level spreader and Jones Creek, provided the site is adequate to maintain the shallow, diffused flow.

Potential pollution removal rates using this method have been estimated and are shown in **Table 8.1**.

Table 8.1

SITE 8	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	12.47	1.26	169.43
STORM WATER WETLAND TREATMENT REMOVAL %	40.00%	35.00%	85.00%
NET REDUCTION	4.99	0.44	144.02
FUTURE CONDITION	7.48	0.82	25.42

Constraints

An agreement may have to be worked out with the surrounding landowners to provide drainage and access easements, which are required for stormwater wetlands (NCDWQ, 2007). As with other projects, working in the riparian zone will require care and consideration of water quality effects of the construction project.

Alternatives

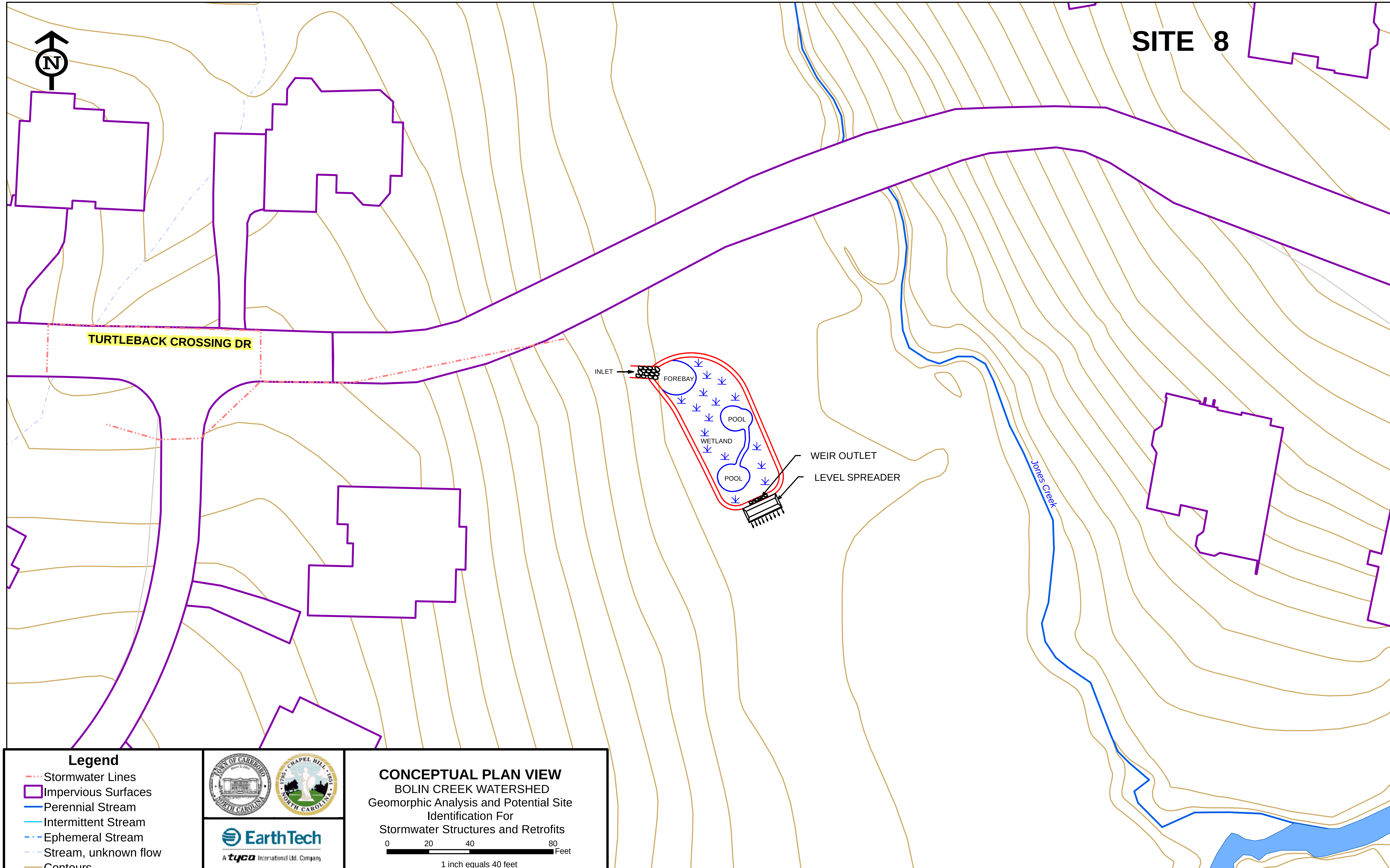
No alternatives are proposed for this site.

Cost-Estimate Breakdown

Table 8.2 shows a conceptual itemized cost estimate. These costs represent construction and maintenance costs only. The cost for stormwater wetlands is derived from an equation developed by Brown and Schueler (1997).

Table 8.2
Site 8 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stormwater Wetland	8365.0	CF	Equation Derived	$16,536
			Total	$16,536
Mobilization (5%)	1.0	LS		$827
Contingencies (10%)	1.0	LS		$1,654
	Total +	Mobilization and Contingencies		**$19,017**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$951**



Legend

- Stormwater Lines
- Impervious Surfaces
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow
- Contours

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CONCEPTUAL PLAN VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

0 20 40 80 Feet

1 inch equals 40 feet

SITE 8
N
TURTLEBACK CROSSING DR
PAINTED TURTLE LN
INLET
FOREBAY
POOL
WETLAND
POOL
WEIR OUTLET
LEVEL SPREADER
Jones Creek
Legend
Stormwater Lines
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
TOWN OF CARRBORO
NORTH CAROLINA
CHAPEL HILL
1793
1851
NORTH CAROLINA
EarthTech
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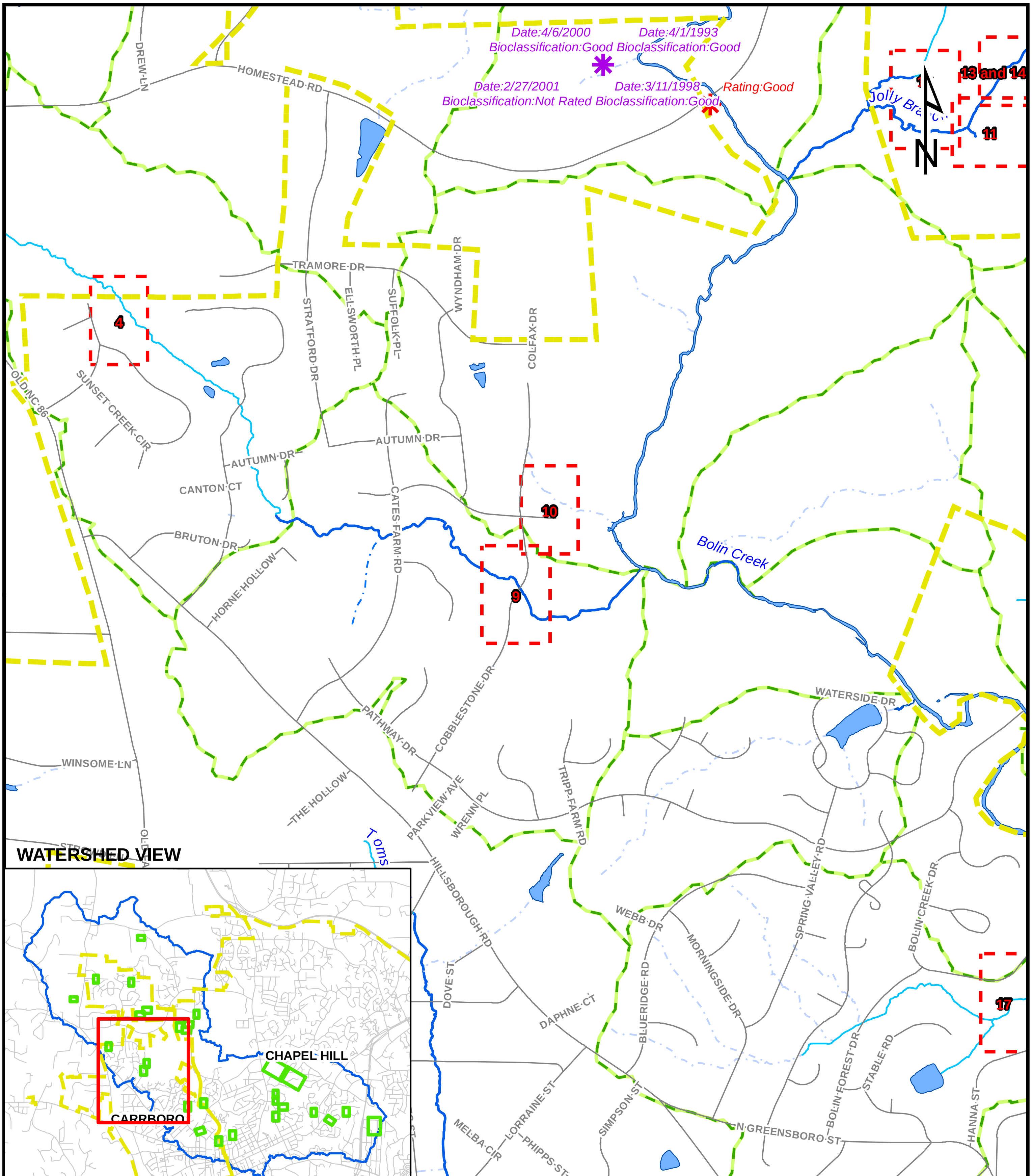
AERIAL PHOTO VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0
20
40
80
Feet
1 inch equals 40 feet

SITE 9

Bank Stabilization and Flow Attenuation

Index Sheet No.: 14
Raw Data Name: TA 5, TA 6 and TA 7

Estimated Construction Cost: $18,200



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO March 3, 1911 NORTH CAROLINA

CHAPEL HILL 1795 1851 NORTH CAROLINA

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SITE 9
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 9	290.8	42.8	14.7%

Location

Site 9 is located on the west and east sides of Cobblestone Drive where the road passes over a tributary to Bolin Creek.

Problem Description

Site 9 consists of an approximately 70 feet long stretch of an unnamed tributary to Bolin Creek which is experiencing extreme bank erosion on both banks as it approaches a road crossing. The erosion is likely due to combination of effects to channel stability that are created from the road crossing, a lack of a vegetated riparian buffer that would otherwise provide root stabilization on the banks, and increased peak flows from the high impervious surface of the contributing drainage area. Downstream of the road crossing, an additional area of extreme bank erosion is present on the outside of a meander bend.

The extreme bank erosion has been estimated to be contributing approximately 95 tons of sediment per year, or approximately 1.4 tons per year per foot of channel. Concomitant nutrient export has also been calculated and is listed in **Table 9.1**. In addition, the lateral movement of the stream cross section is causing adjacent landowners to lose more of their property every year. Therefore, the severity of the problem at this site warrants immediate action.

Proposed Solution

As with other bank stabilization/restoration projects, this site could benefit mainly from a change in the stream cross-section that provides the following:

- a bankfull bench that gives the stream access to a small floodplain which reduces the depth of flow near the bank and thus significantly reduces near bank stress during above-bankfull events
- reduced bank slopes, at a maximum of 2:1
- vegetated banks with woody plants that will provide stabilization through rooting mass

By modifying the cross-section of the stream in this way for the length of the extreme eroding banks, the sediment export rates of this site could potentially be reduced to 0.2 tons per year, with a corresponding reduction in nutrient export. Calculated sediment and nutrient reductions are shown in **Table 9.1**.

In addition to the change in cross-section of the stream, a wide, abandoned floodplain area adjacent to the stream on the downstream side of the road crossing provides a good location for an offline stormwater wetland or wet detention pond. A weir or other diversionary device could be placed in the stream upstream of the wetland, and allow for a certain percentage of stormflow to be diverted into the wetland while not interfering with the continual baseflow of the stream. The primary benefit of this would be reduction of peak flow during storm events, which could possibly reduce near bank stress on eroding banks downstream. A secondary benefit would be the possibility to augment baseflow by storing some of the runoff volume in the basin, which can be intentionally or passively discharged into the stream over longer periods of time.

Table 9.1

Pre-Treatment	
Estimated Total Sediment Export	95.1 tons/year
Erosion per length of Channe	1.4 tons/yr/ft
Pounds of Nitrogen	190.2 lbs/year
Pounds of Phosphorus	95.1 lbs/year
Post-Treatment	
Estimated Total Sediment Export	0.2 tons/year
Erosion per length of Channe	0 tons/yr/ft
Pounds of Nitrogen	0.4 lbs/year
Pounds of Phosphorus	0.2 lbs/year

Constraints

The primary constraint at this site is land acquisition and landowner cooperation, as it is located in a residential area with privately owned land on either side of the stream. Stormwater easements should be checked to see if work can be performed within the easements, primarily in laying back banks and revegetating the riparian area. In addition, a utilities easement is adjacent to the site, and thus a MOU or MOA may be required to be executed with the utilities entity to implement the project.

Alternatives

No alternatives are proposed for this site.

Cost-Estimate Breakdown

Table 9.2 shows a conceptual itemized cost estimate. These costs represent construction and maintenance costs only. The cost for stormwater wetlands is derived from an equation developed by Brown and Schueler (1997).

Table 9.2
Site 9 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	62.0	CY	15.00	$930
Stormwater Wetland	2534.0	CF	Equation Derived	$7,159
Site Preparation and Planting	0.1	AC	7500.00	$750
Rip Rap Class B	10.0	Tons	45.00	$450
Filter Fabric	30.0	SY	5.00	$150
Silt Fence	200.0	LF	3.75	$750
Construction Safety Fence	260.0	LF	2.50	$650
Construction Entrance	2.0	Ea	2500.00	$5,000
			Total	$15,839
Mobilization (5%)	1.0	LS		$792
Contingencies (10%)	1.0	LS		$1,584
	Total + Mobilization and Contingencies			**$18,215**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$911**

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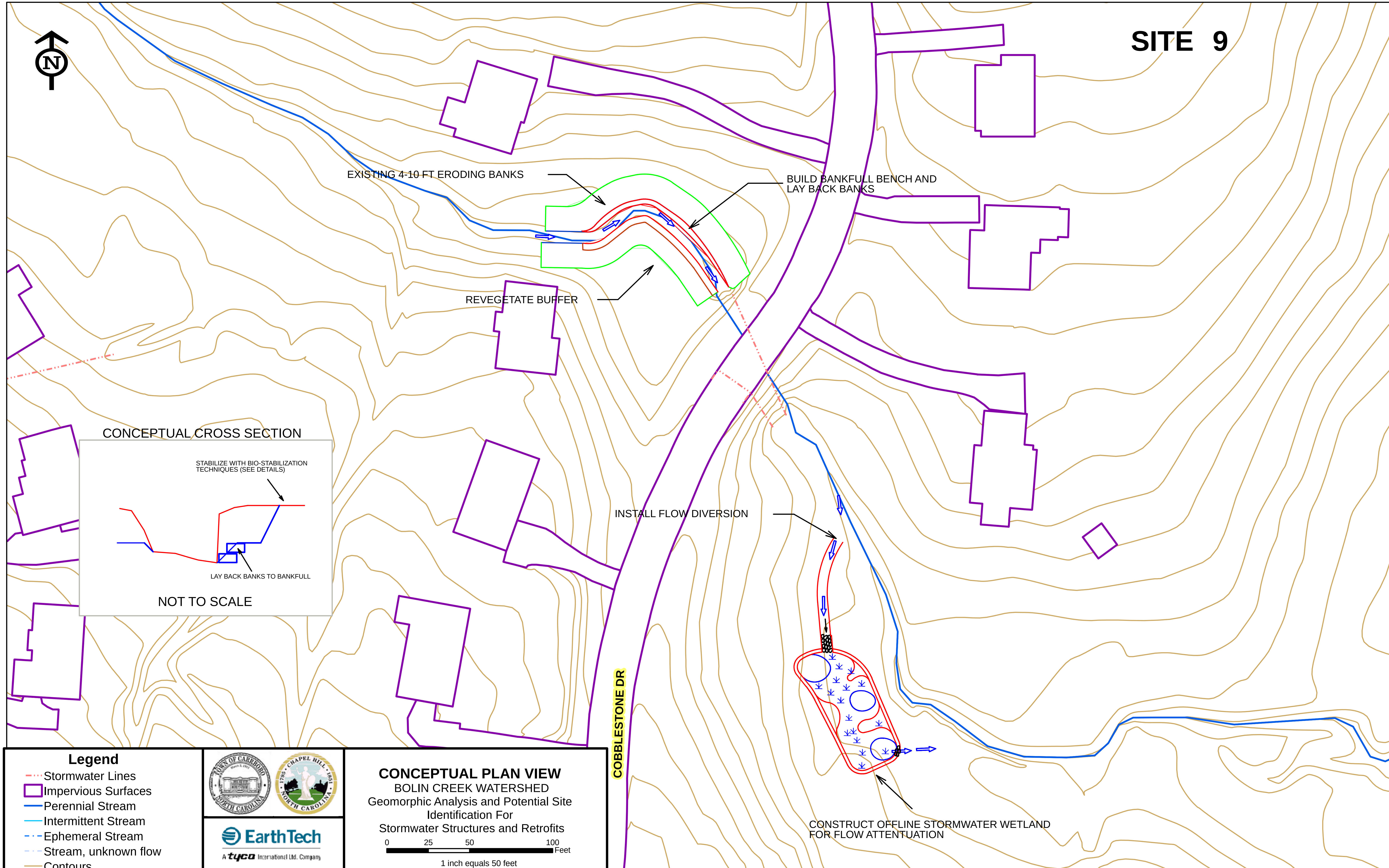
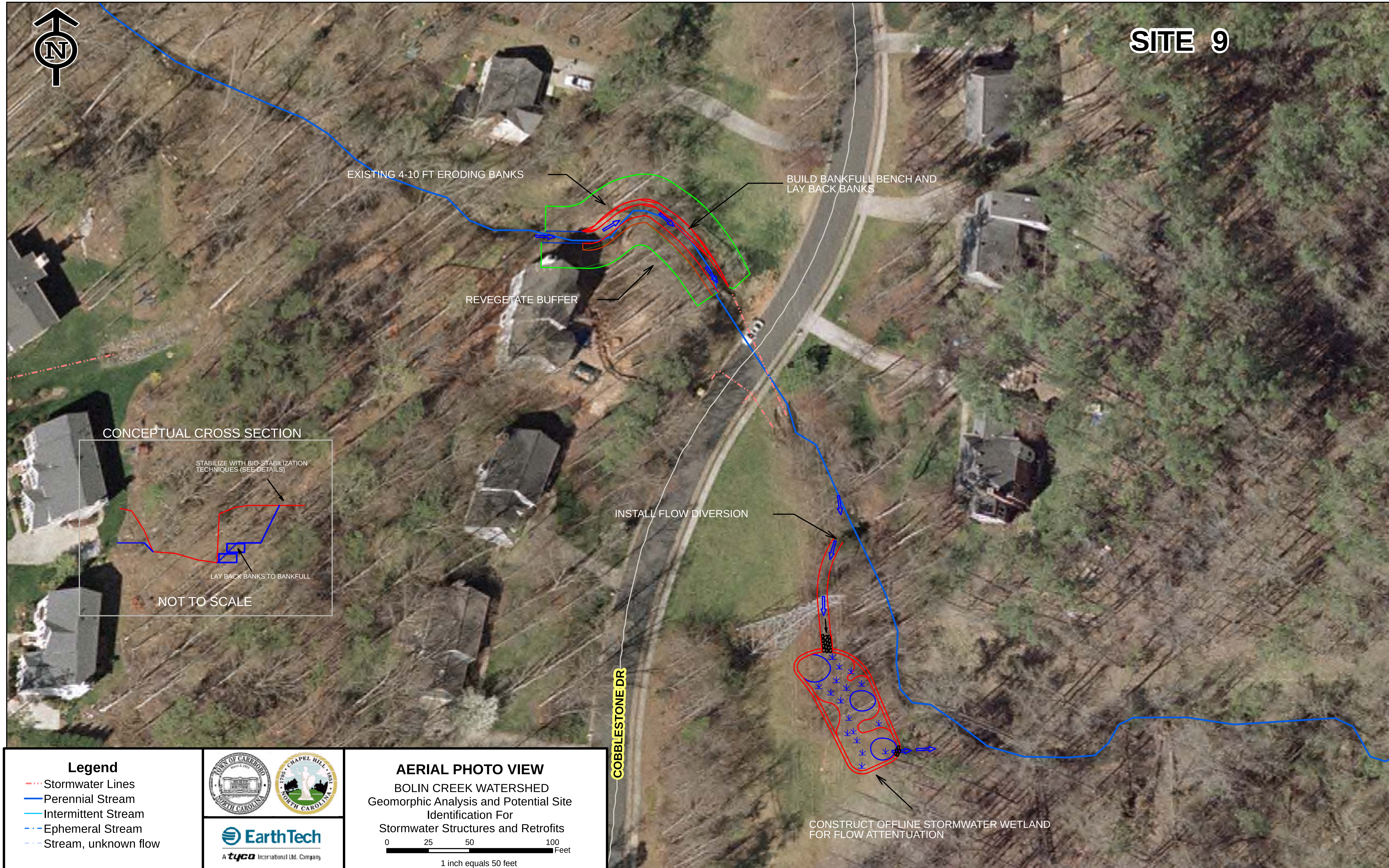


CONCEPTUAL PLAN VIEW

BOLIN CREEK WATERSHED

Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits


SITE 9
N
EXISTING 4-10 FT ERODING BANKS
BUILD BANKFULL BENCH AND
LAY BACK BANKS
REVEGETATE BUFFER
CONCEPTUAL CROSS SECTION
STABILIZE WITH BIO-STABILIZATION
TECHNIQUES (SEE DETAILS)
LAY BACK BANKS TO BANKFULL
NOT TO SCALE
INSTALL FLOW DIVERSION
COBBLESTONE DR
CONSTRUCT OFFLINE STORMWATER WETLAND
FOR FLOW ATTENTUATION
Legend
Stormwater Lines
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
EarthTech
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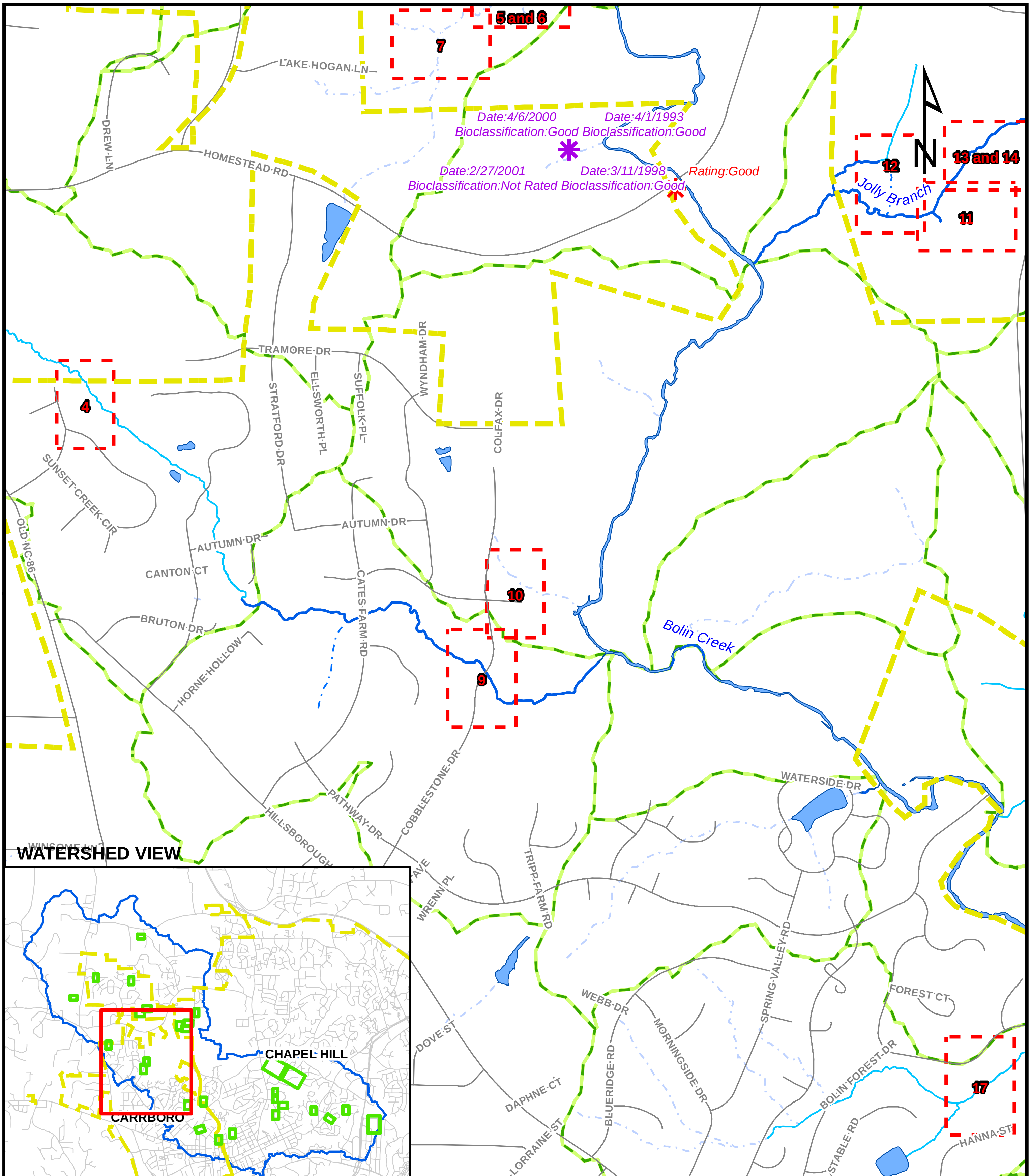
AERIAL PHOTO VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0 25 50 100
Feet
1 inch equals 50 feet

SITE 10

Construction of Stormwater Wetland on Ephemeral Channel

Index Sheet No.: 15
Raw Data Name: TA 12

Estimated Construction Cost: $48,300



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO · March 3, 1911 · NORTH CAROLINA

CHAPEL HILL · 1793 · 1851 · NORTH CAROLINA

EarthTech
A tyco International Ltd. Company

SITE 10
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 10	36.0	7.7	21.3%

Location

Site 10 is located to the east of Rockgarden Rd and Cobblestone Dr., behind several houses and adjacent to a sewer easement. To get to the site from downtown Carrboro, take Greensboro St. until it joins with Hillsborough Rd., and proceed north for a half mile before turning right on Cobbleston Dr. At the intersection with Rockgarden Rd. turn right into a dead end road. The site is downhill and to the north of the dead end.

Problem Description

Site 10 consists of an ephemeral stream (drainage area approximately 36 acres) that flows diffusely through a flat wooded area behind the yards of two houses, and then becomes concentrated where the slope of the valley begins to steepen. The stream flows directly into Bolin Creek after only a short distance downhill. Where the flow concentrates, a discernible head cut has formed, and is advancing upstream. The head cut is most likely caused by an increased amount of flow in the watershed due to the increase in impervious area, and the lowering of bed elevations of Bolin Creek, which is causing a corresponding drop in the bed of the tributary stream. Currently, the contributing drainage area of the stream has no water quality or water quantity treatment.

Proposed Solution

The topographically flat area present at Site 10 provides a good location to construct a stormwater wetland or bio-retention area at minimal cost. Due to the ephemeral nature of the drainage feature and large area available, a stormwater wetland is advised. A large enough area is present that the wetland could treat the calculated water quality treatment volume (WQv) for the contributing drainage area. A bio-retention area could be constructed, if a smaller surface area were used than what is proposed, otherwise the cost of the bioretention area, which is typically much higher than that of a comparably sized stormwater wetland, would be prohibitively expensive.

Potential pollution removal rates using this method have been estimated and are shown in **Table 10.1**.

Table 10.1

SITE 15-01	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	13.07	1.32	178.06
STORMWATER WETLAND TREATMENT REMOVAL %	37.00%	35.00%	85.00%
NET REDUCTION	4.84	0.46	151.35
FUTURE CONDITION	8.24	0.86	26.71

The stream that flows through Site 10 is labeled as "unknown flow" by both the Carrboro and Chapel Hill stream data, and therefore would need to be verified as ephemeral before construction of an in-line stormwater wetland. Earth Tech based our ephemeral classification purely on field experience and experience with DWQ stream classification forms.

The current nutrient export rates, and potential benefit of a stormwater wetland here have been calculated based on land use, drainage area and percent imperviousness of the drainage area, and are displayed in **Table 10.1**:

Constraints

The biggest constraint at this site could potentially be landowner cooperation and land acquisition. The access easement could be obtained to the current dead end of Rockgarden Rd, which is uphill of the project site. In addition, an existing sewer line runs parallel to the project site, indicating that a drainage easement may exist at the site. .

Alternatives

No alternatives are proposed for this site.

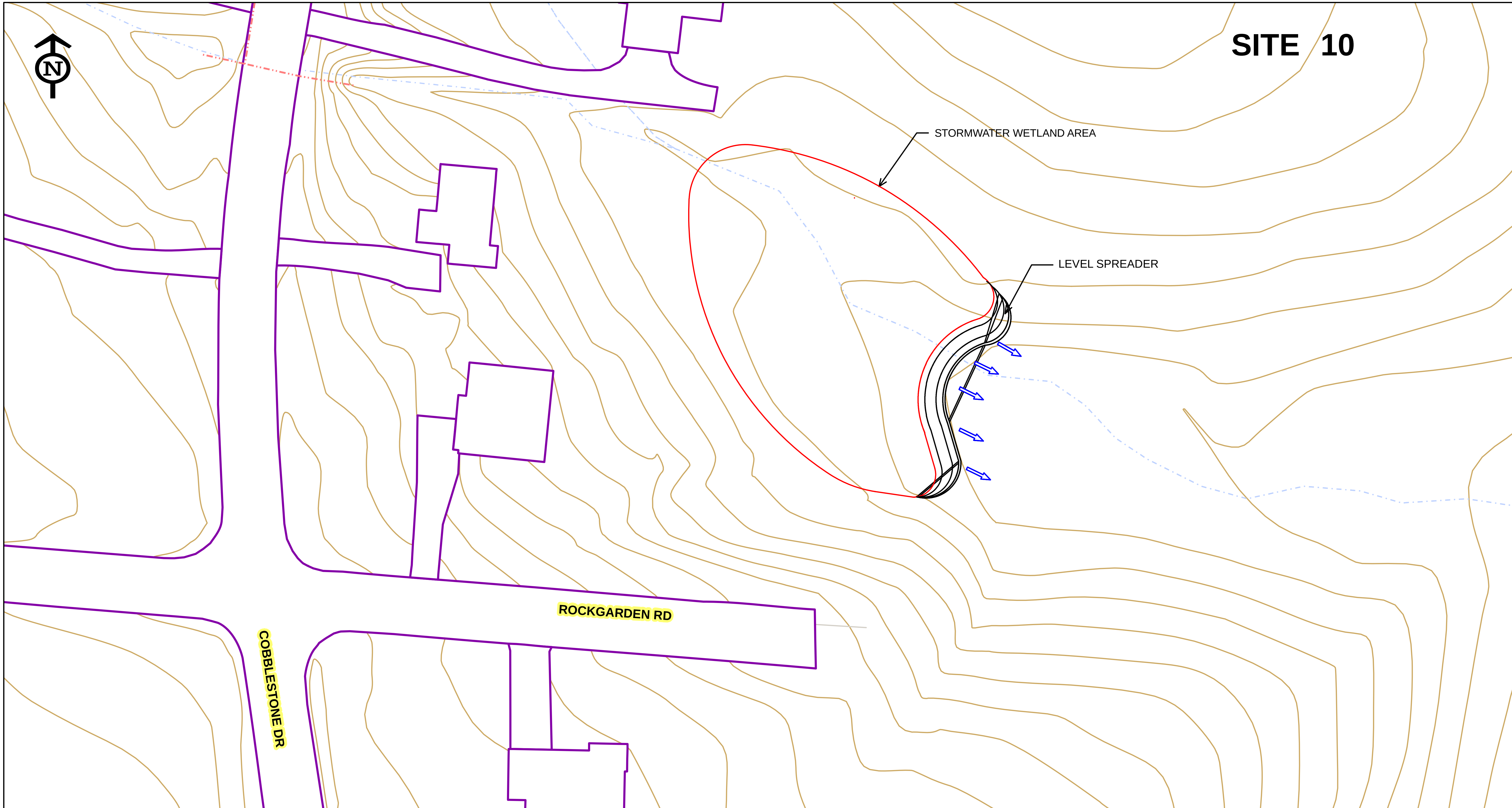
Cost-Estimate Breakdown

Table 10.2 shows a conceptual itemized cost estimate. These costs represent construction and maintenance costs only. The cost for stormwater wetlands is derived from an equation developed by Brown and Schueler (1997).

Table 10.2

SITE 10

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stormwater Wetland	31652.0	CF	Equation Derived	$42,031
			Total	$42,031
Mobilization (5%)	1.0	LS		$2,102
Contingencies (10%)	1.0	LS		$4,203
	Total	**+ Mobilization and Contingencies**		**$48,336**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$2,417**



Legend

- Stormwater Lines
- Impervious Surfaces
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow
- Contours

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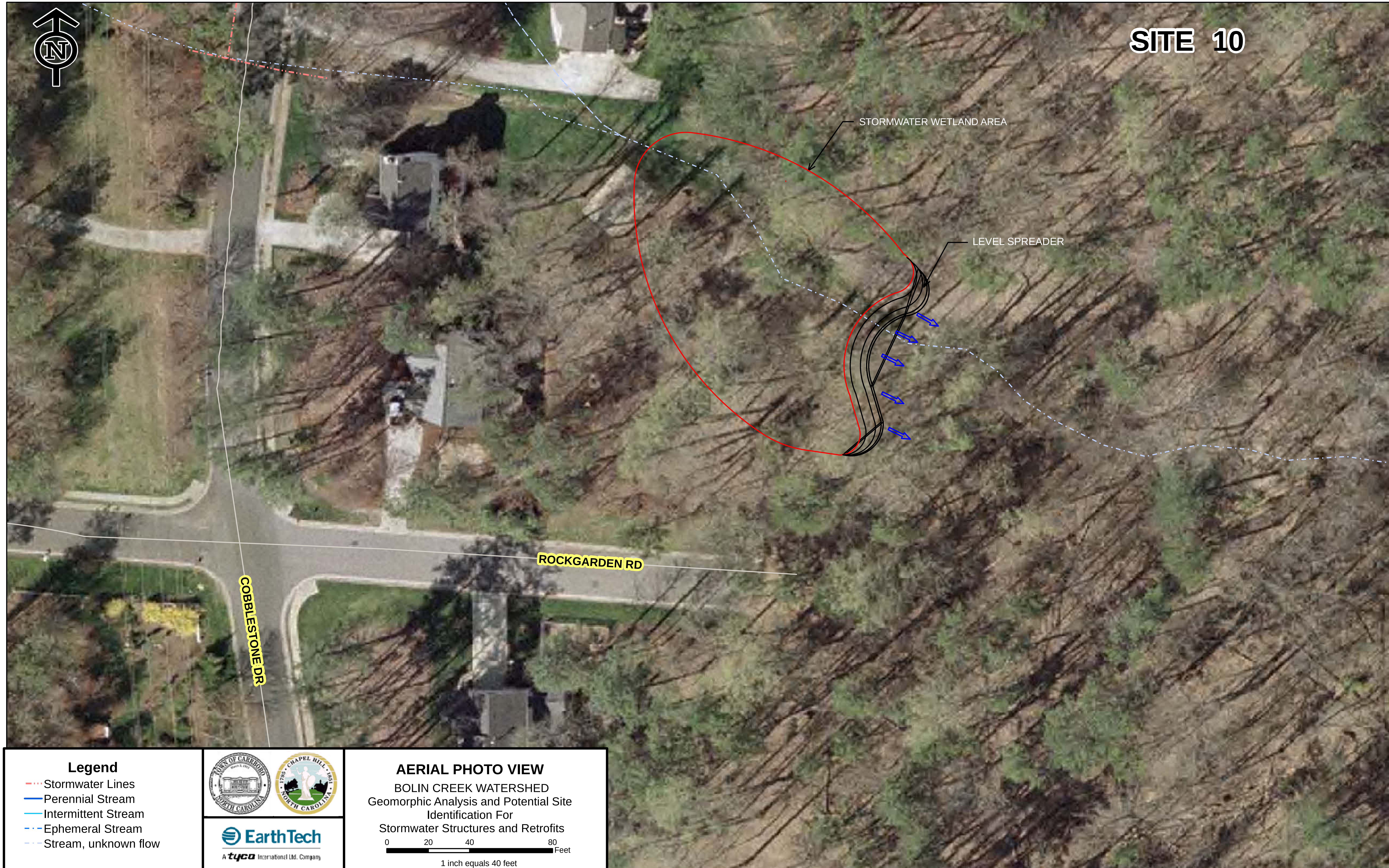
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

0 20 40 80 Feet

1 inch equals 40 feet



Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

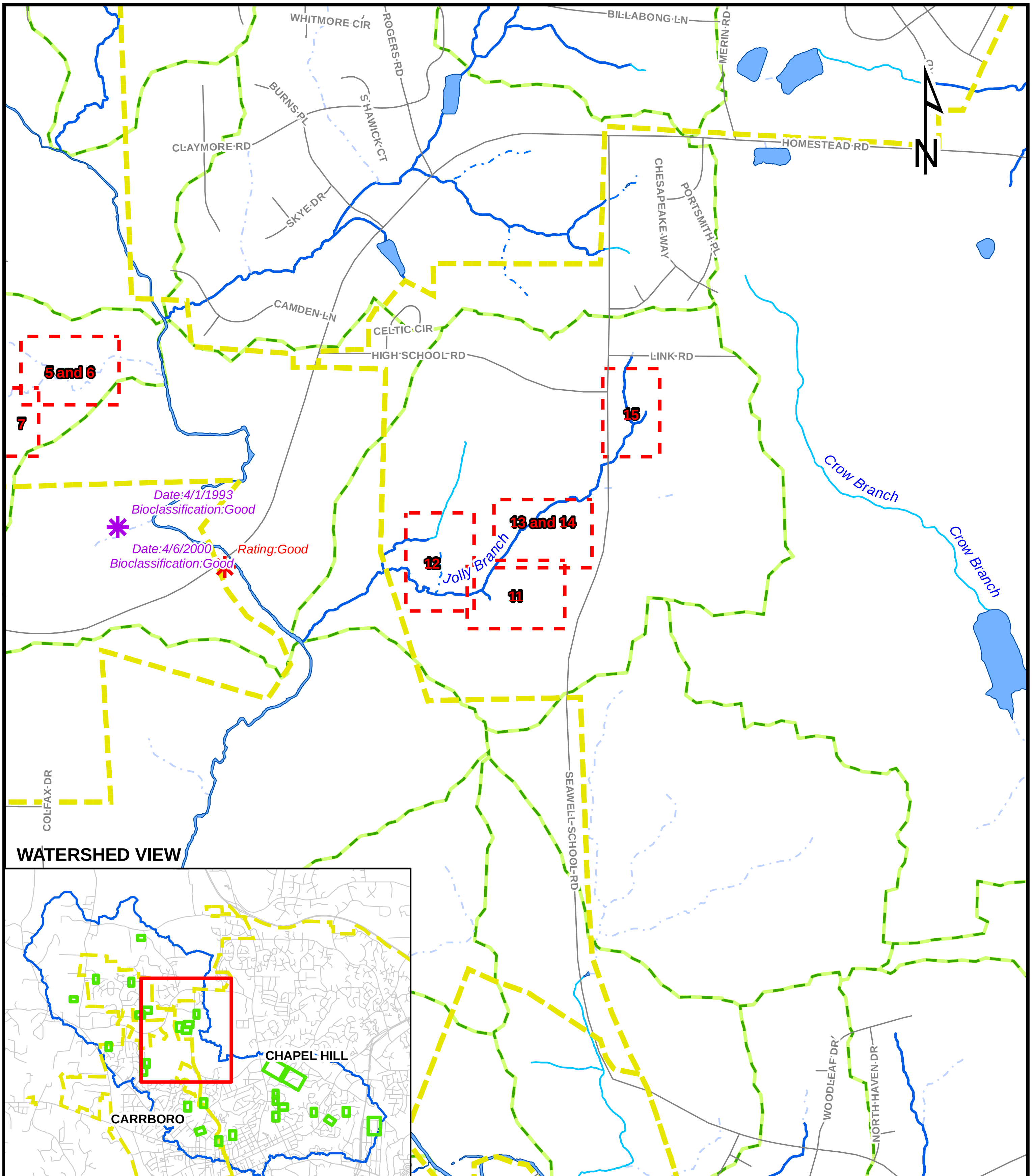
0 20 40 80 Feet

1 inch equals 40 feet

SITE 11
BMP retrofits at Smith Middle School

Index Sheet No.: 16
Raw Data Name: IJ 34

Estimated Construction Cost: $30,000-$110,000



Legend

Ambient Monitoring	Orange County Roads
Benthic Monitoring	Subwatersheds
Fish Sampling	Perennial Stream
Municipal Boundary	Intermittent Stream
	Ephemeral Stream
	Stream, unknown flow

EarthTech
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SITE 11
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 16-01	10.8	4.1	38.0%

Location

Site 11 is just north of the soccer field and track at Smith Middle School, which is located off Seawell School Road.

Problem Description

At Smith Middle School, it appears that most of the stormwater that collects on the schools rooftops and parking lots is routed to an outlet pipe at the northwestern corner of the school site. This outlet pipe, which is approximately 36" in diameter, currently has no water quality treatment in the form of retention or detention downstream of it. Instead, the pipe discharges stormwater into a pre-formed scour hole, then into a concentrated channel that flows into the nearby perennial stream, Jolly Branch. Thus, the pollutants collecting on-site flow into Jolly Branch with no treatment. Additionally, field observations indicate that the concentrated flows that leave the small pre-formed scour hole is causing erosion and will continue to degrade the floodplain and stream channel over time.

Sites 11 through 15 are in close proximity to each other, and could therefore be integrated amongst themselves as a single package. In addition, other similar opportunities for the work proposed here are present throughout the three surrounding campuses, as well as other parts of the Jolly Branch watershed.

Proposed Solution

Site 11 offers a good location for stormwater BMP retrofits, with the added benefit of public exposure and educational opportunities for students of the surrounding schools. The primary location for a Stormwater BMP is at the outlet pipe on the northwestern corner of the school property. Here, the pre-formed scour hole that was constructed can be expanded, and dug out to create a wet detention pond (wet pond). The wet detention pond will contain a permanent pool that will allow aquatic vegetation to thrive in the structure year-round. The floodplain has sufficient room to allow for this retrofit. The pond should have a boulder basin underneath the outlet pipe to provide energy dissipation.

The outlet structure of the wet detention pond should consist of a riser pipe, and then a level spreader just downhill of the pond. It is important that the level-spreader be used, so as to prevent flow from concentrating into an incised channel before reaching Jolly Branch. The floodplain along the channel provides ample room to install a level spreader parallel with the channel.

Any tree removal that is necessary can provide an opportunity to educate the students of neighboring schools about forest secession and how gap communities can dramatically increase diversity.

Pollutant reduction rates as a result of stormwater treatment are shown in **Table 11.1**.
Table 11.1

SITE 11	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	10.97	1.22	284.48
WET DETENTION TREATMENT	25.00%	40.00%	85.00%
NET REDUCTION	2.74	0.49	241.81
FUTURE CONDITION	8.23	0.73	42.67

Constraints

The recommended treatment may require removal of a few trees in order to excavate the necessary volume for the wet detention pond.

The site is located on public land, therefore and acquisition should not prove to be a constraint.

Alternatives

In addition the treatment mentioned above, several additional treatments could be implemented at this site to further capture and treat stormwater.

Alternative 1: consists of the treatment outlined above, with the construction of a wet detention pond with an energy dissipater basin and level spreader.

Alternative 2: consists of the treatment of Alternative 1, with the addition of the construction of an underground filtration area into which the stormwater system of the school is re-routed. This filtration area could be built beneath the existing soccer field, and would contain an aggregate material that would allow the stormwater to infiltrate into the surrounding soil. An overflow pipe would be built at a certain elevation within this area to allow any volume above the water quality treatment volume to discharge into the pipe outlet and wet detention pond constructed in Alternative 1. Construction of this system would also require a flow-splitting device to be placed before stormwater reaches the primary outlet.

Several drop inlets are located in the lawn areas around Smith Middle School, and each of these has the potential to harbor a small bio-retention area. In this way, the runoff of the rooftop would be treated immediately before entering the stormwater system of the school.

Cost-Estimate Breakdown

Tables 11.2 and 11.3 shows a conceptual itemized cost estimate for both alternatives at Site 11. These costs represent construction and maintenance costs only. The cost for the bioretention areas are derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007). In the same study, the cost of an underground infiltration area, similar to that proposed at this site, was stated to be similar to that of the cost of a bioretention area, therefore these two costs are the same. The cost for the wet detention pond is derived from an equation developed by Brown and Schueler (1997).

Table 11.2
SITE 11 Alternative 1

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Wet Detention Pond	3762.0	CF	Equation Derived	$26,368
			Total	$26,368
Mobilization (5%)	1.0	LS		$1,318
Contingencies (10%)	1.0	LS		$2,637
	Total + Mobilization and Contingencies			**$30,323**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$1,516**

Table 11.3
SITE 11 Alternative 2

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Wet Detention Pond	3762.0	CF	Equation Derived	$26,368
Bioretention Areas (x4)	3040.0	CF	12.62	$38,365
Underground Storage Area	2500.0	CF	12.62	$31,550
			Total	$96,283
Mobilization (5%)	1.0	LS		$4,814
Contingencies (10%)	1.0	LS		$9,628
	Total + Mobilization and Contingencies			**$110,725**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$5,536**

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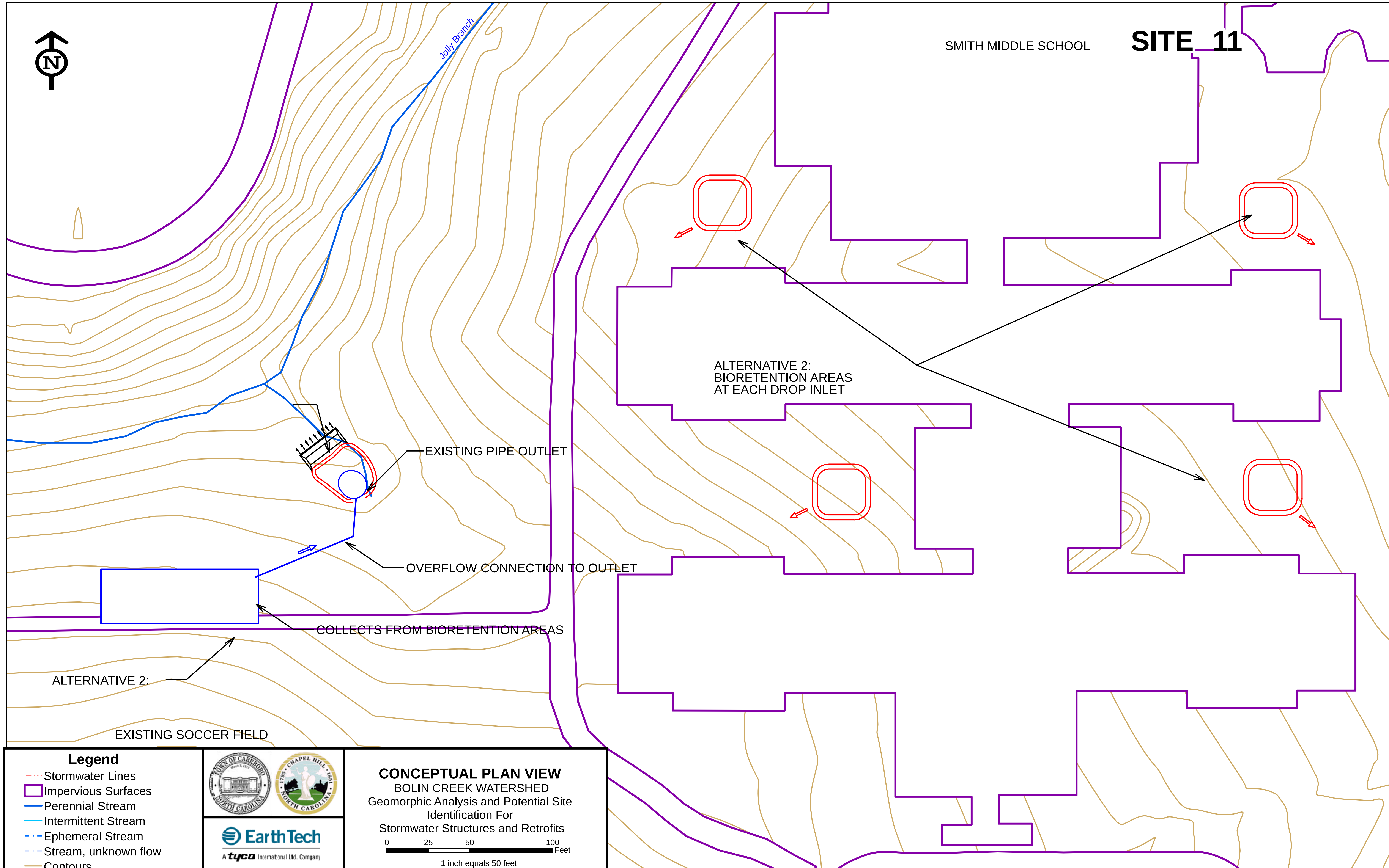

Legend

- Stormwater Lines
- Impervious Surfaces
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow
- Contours

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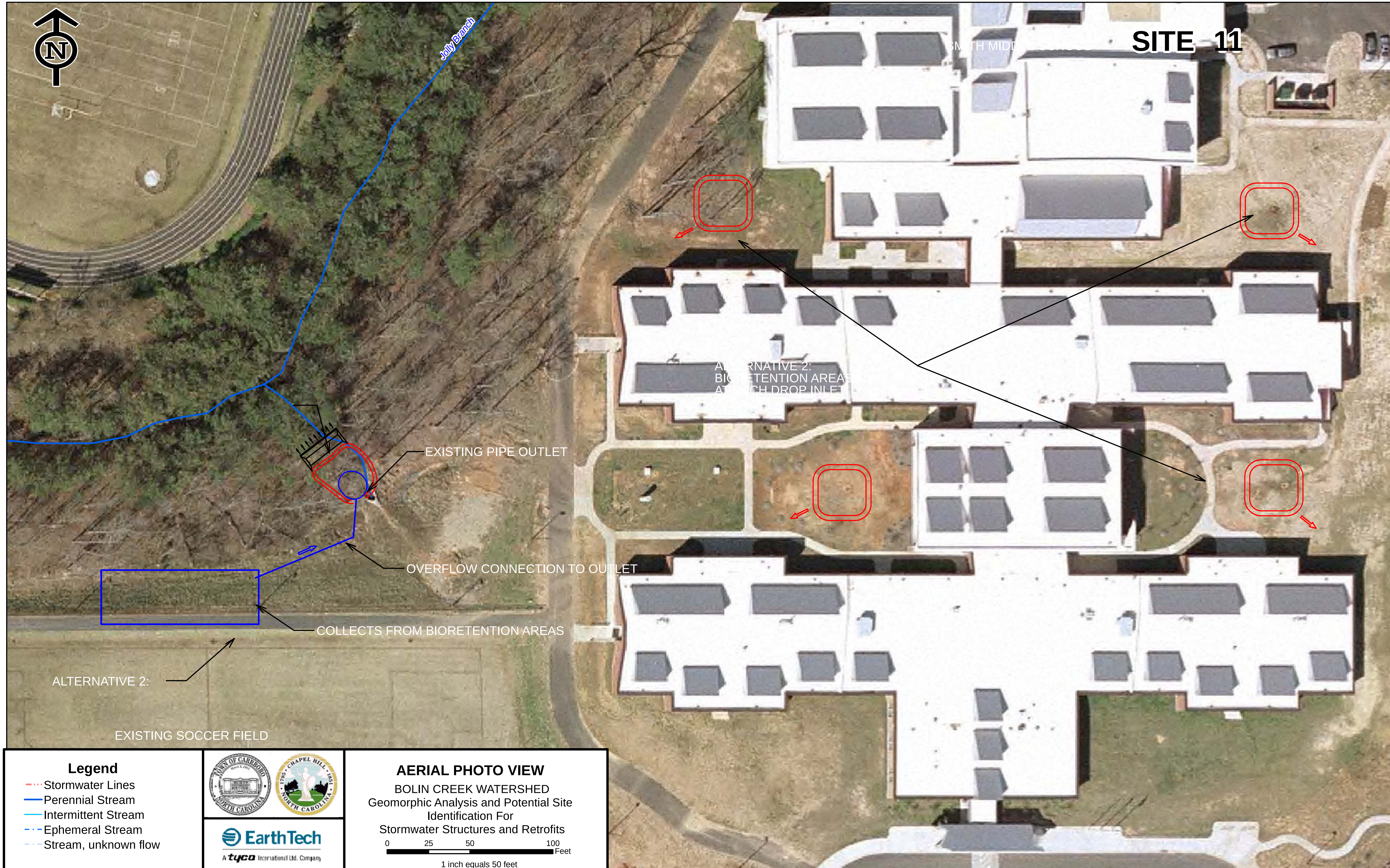
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

0 25 50 100 Feet
1 inch equals 50 feet



Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

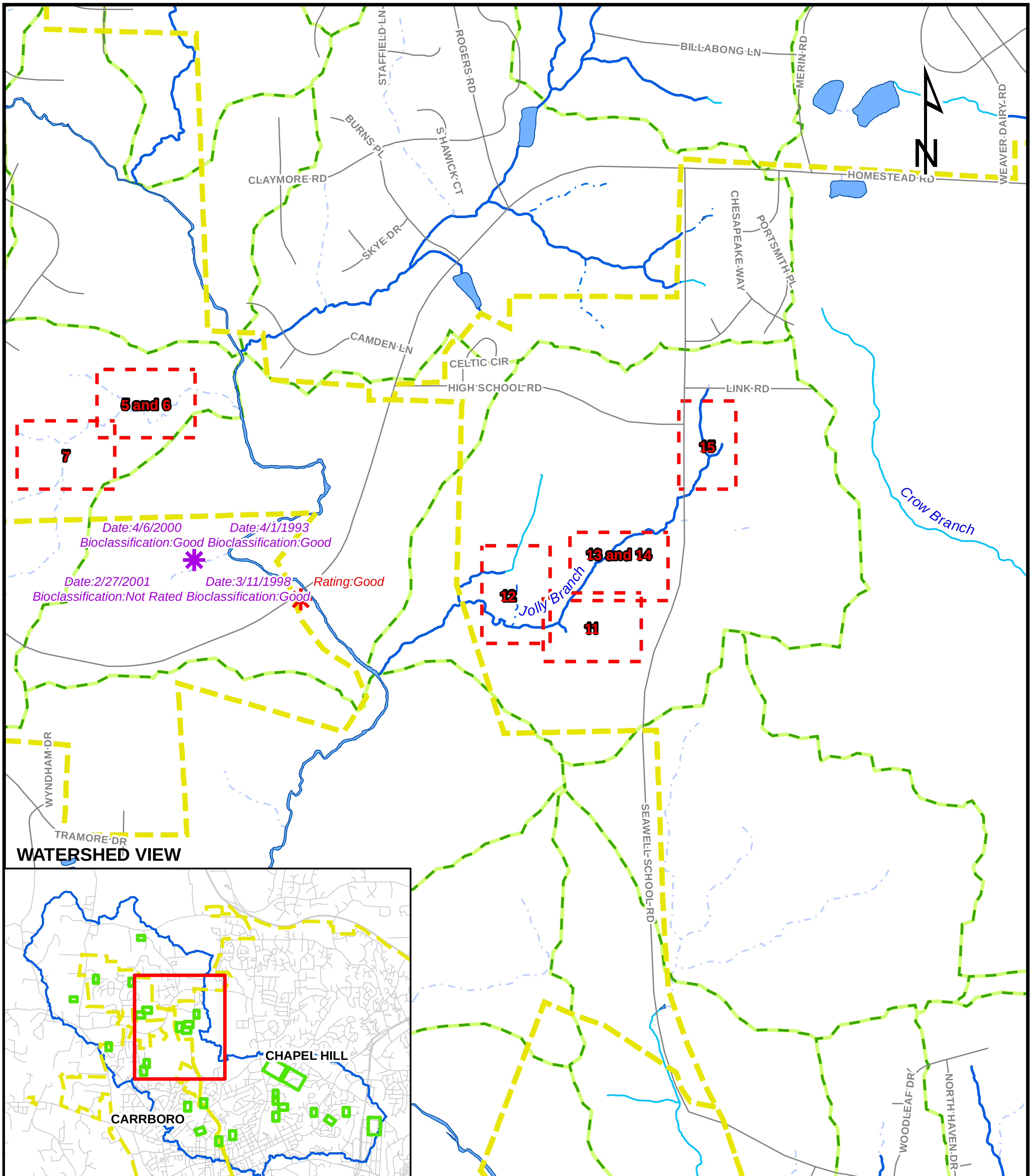
0 25 50 100 Feet

1 inch equals 50 feet

SITE 12

Index Sheet No.: 16
Raw Data Name: IJ 24

Estimated Construction Cost: $69,300



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 12

VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs

Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 12	10.8	4.1	38.0%

Location

Site 12 is located on the western side of the football stadium and track at Chapel Hill High School. Chapel Hill High School is located at the intersections of Seawell School Rd. and High School. Rd.

Problem Description

Site 12 consists of a corrugated metal pipe outlet and ditch draining part of the football stadium facility at Chapel Hill High School. The football field is likely fertilized on a regular basis. The ditch discharges the stormwater from this field into Jolly Branch, a perennial stream, without any water quality treatment. Several spots of geomorphic instability, in the form of eroding banks and scour lines in the floodplain, were noted in Jolly Branch where these stormwater inputs reach a confluence.

Sites 11 through 15 are in close proximity to each other, and could therefore be integrated amongst themselves as a single package. In addition, other similar opportunities for the work proposed here are present throughout the three surrounding campuses, as well as other parts of the Jolly Branch watershed.

Proposed Solution

Site 12 provides a good location for a bio-grade step (see Details). Constructing this BMP in this location would provide needed treatment of the stormwater produced by the contributing drainage area and reduce velocities of the flows reaching Jolly Branch. The bio-grade step allows for a linear shaped, grade-control BMP solution that will prevent future head cutting of the drainage ditch, while using minimum area.

The storage of some of the runoff volume will potentially augment baseflow to the stream and reduce the runoff volume that reaches the stream for the duration of the rain event. This attenuation of peak flows and chance to augment base flow is another tangible benefit of the linear bioretention.

Pollutant reduction rates as a result of stormwater treatment are shown in **Table 12.1**.

Table 12.1

SITE 12	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	7.35	0.82	190.56
BIORETENTION TREATMENT REMOVAL %	37.00%	45.00%	85.00%
NET REDUCTION	2.72	0.37	161.97
FUTURE CONDITION	4.63	0.45	28.58

Constraints

The primary constraints at Site 12 are the existing trees, that would need to be removed to provide room for construction of the bio-grade step. However, the bio-grade step uses minimum surface area, and could probably be constructed with the least impact to the surrounding forest in comparison to other BMP options.

Alternatives

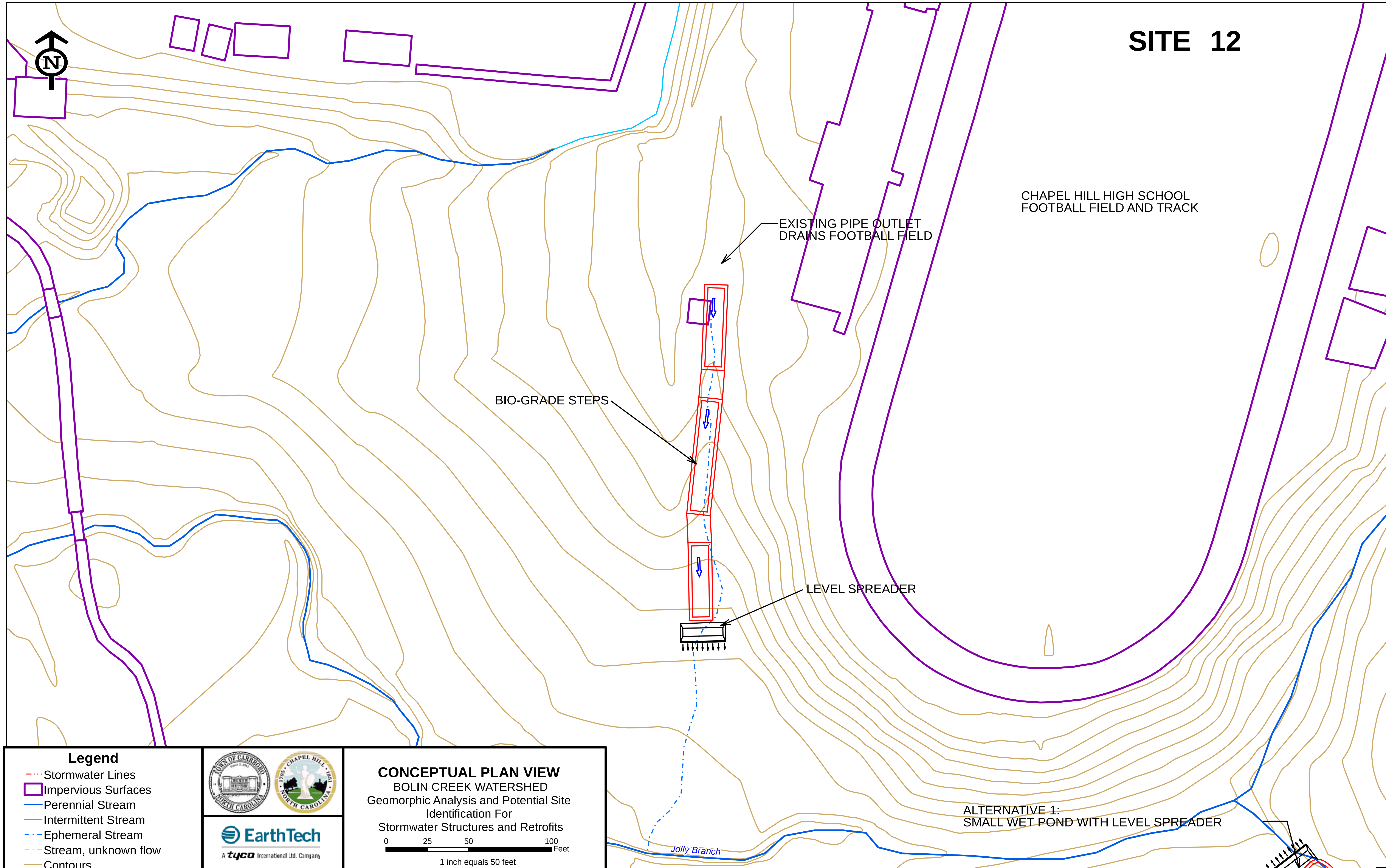
No alternatives are proposed for this site.

Cost-Estimate Breakdown

Tables 12.2 shows a conceptual itemized cost estimate for Site 12. These costs represent construction and maintenance costs only. The cost for the bio-grade step is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007).

Table 12.2
SITE 12

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Biograde Step	4779.0	CF	12.62	$60,311
			Total	$60,311
Mobilization (5%)	1.0	LS		$3,016
Contingencies (10%)	1.0	LS		$6,031
	Total + Mobilization and Contingencies			**$69,358**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$3,468**



N
SITE 12
CHAPEL HILL HIGH SCHOOL
FOOTBALL FIELD AND TRACK
EXISTING PIPE OUTLET
DRAINS FOOTBALL FIELD
BIO-GRADE STEPS
LEVEL SPREADER
ALTERNATIVE 1:
SMALL WET POND WITH LEVEL SPREADER
Jolly Branch
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
TOWN OF CARRBORO
NORTH CAROLINA
CHAPEL HILL
1795
1851
NORTH CAROLINA
EarthTech
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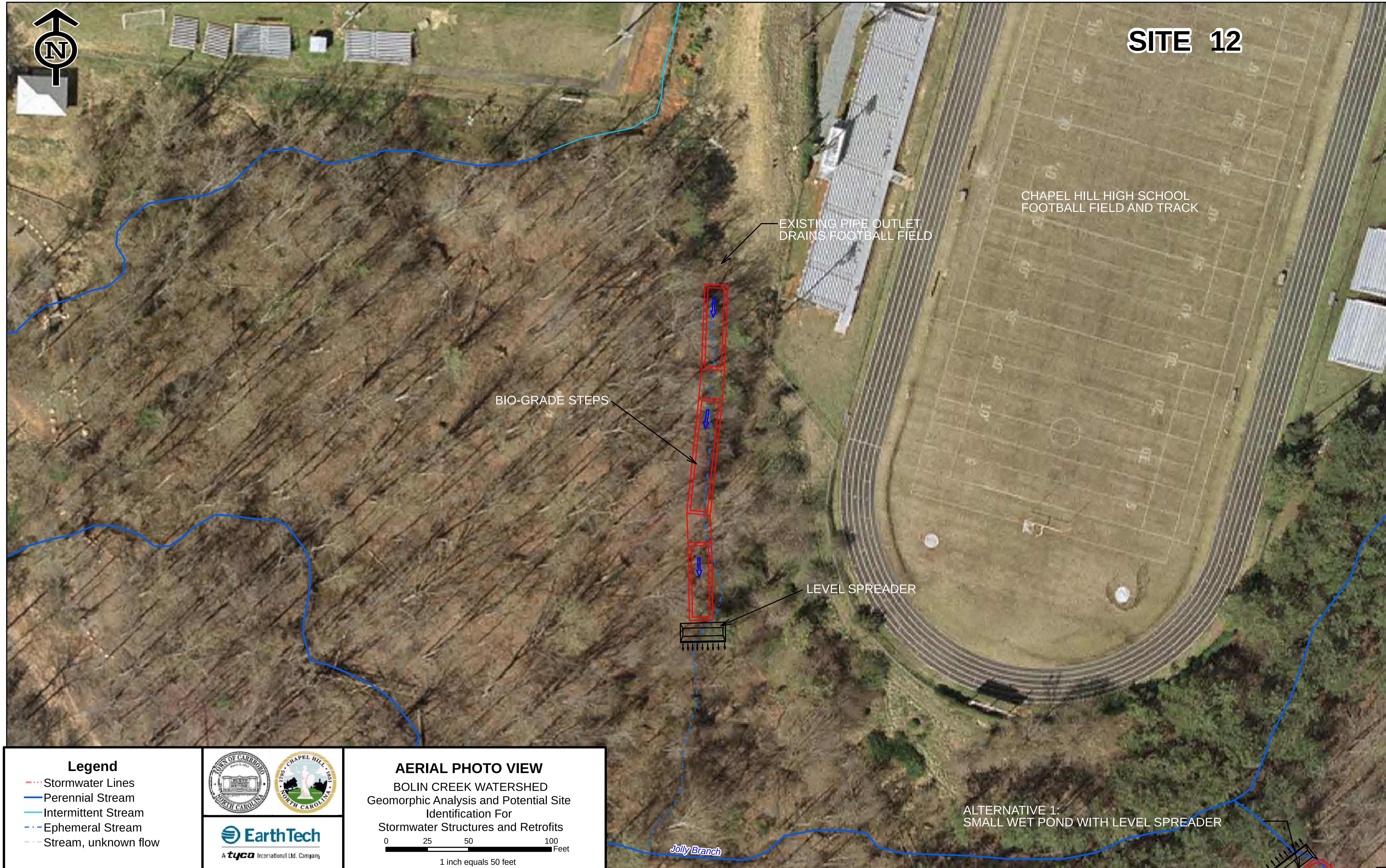
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0
25
50
100
Feet
1 inch equals 50 feet


SITE 12
N
CHAPEL HILL HIGH SCHOOL
FOOTBALL FIELD AND TRACK
EXISTING PIPE OUTLET
DRAINS FOOTBALL FIELD
BIO-GRADE STEPS
LEVEL SPREADER
ALTERNATIVE 1:
SMALL WET POND WITH LEVEL SPREADER
Jolly Branch
Legend
Stormwater Lines
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
EarthTech
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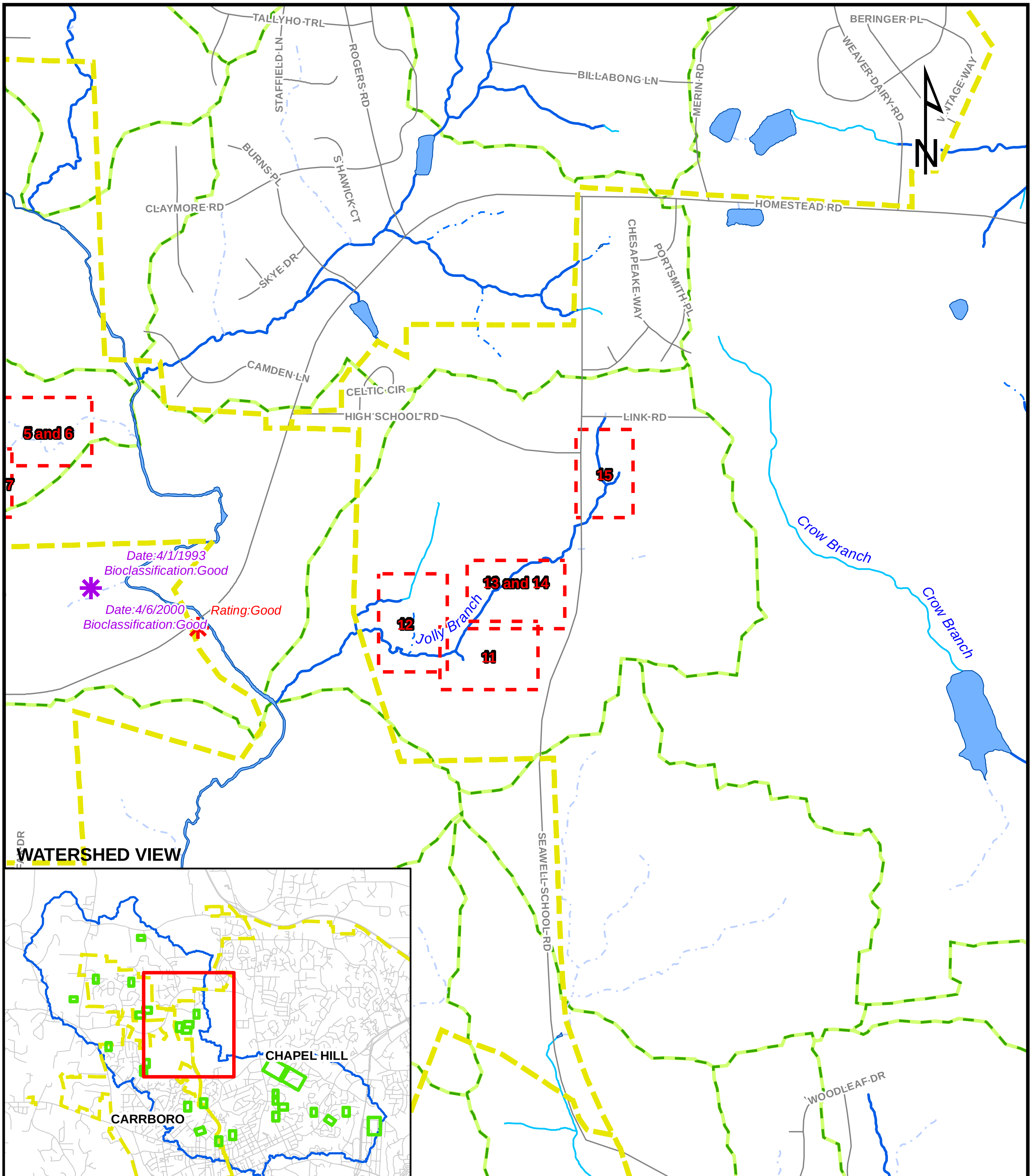
AERIAL PHOTO VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0 25 50 100
Feet
1 inch equals 50 feet

SITE 13

Index Sheet No.: 16
Raw Data Name: IJ 32

Estimated Construction Cost: $25,700



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 13 and 14
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 13	1.6	0.02	1.2%

Location

Project 16-03 is located just south of the practice football field at Chapel Hill High School, along a ditch that flows into the perennial stream Jolly Branch. A paved path crosses over the ditch just upstream of the site.

Problem Description

Project 16-03 consists of what was observed to be an ephemeral tributary to Jolly Branch that is currently incised and contains a headcut working upstream towards a paved path. The tributary has been channelized into a ditch, and has a concrete pipe outlet providing stormwater input. The contributing drainage area of this pipe appears to consist of part of the football field at Chapel Hill High School, part of the practice football field, and a portion of the student parking lot. These impervious surfaces are likely contributing pollutants, as well as the nutrients from the fertilization of the football fields, into the ephemeral tributary and into Jolly Branch. The confined ephemeral drainage feature does not have a floodplain or enough surface area to prevent erosion, so bank erosion will continue.

Sites 11 through 15 are in close proximity to each other, and could therefore be integrated amongst themselves as a single package. In addition, other similar opportunities for the work proposed here are present throughout the three surrounding campuses, as well as other parts of the Jolly Branch watershed.

Proposed Solution

Water quality treatment and quantity treatment at Site 13 could be provided by the construction of a small bio-retention area in-line with the tributary. A bio-retention area is preferred over another structural BMP here because of the lack of available space for construction, and the relatively small drainage area. The tributary on which the bio-retention area should be located was observed to be ephemeral, however further verification will be needed to ensure that an in-line BMP can be placed along it. Runoff volume will be stored in underground storage, reducing peak runoff rates and potentially augmenting baseflow.

An under-drain should be used with the bio-retention area, as the in-situ soils are most likely too impermeable to allow infiltration into the surrounding soils. This under drain or pervious drain layer will allow each successive cell to discharge to the next over extended periods of time.

Pollutant reduction rates as a result of stormwater treatment are shown in **Table 13.1**.

Table 13.1

SITE 13	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	27.44	1.70	673.47
BIO-RETENTION TREATMENT	37.00%	45.00%	85.00%
NET REDUCTION	10.15	0.76	572.45
FUTURE CONDITION	17.29	0.93	101.02

Constraints

Site 13 is located in a wooded area, and therefore tree removal will be required.

Alternatives

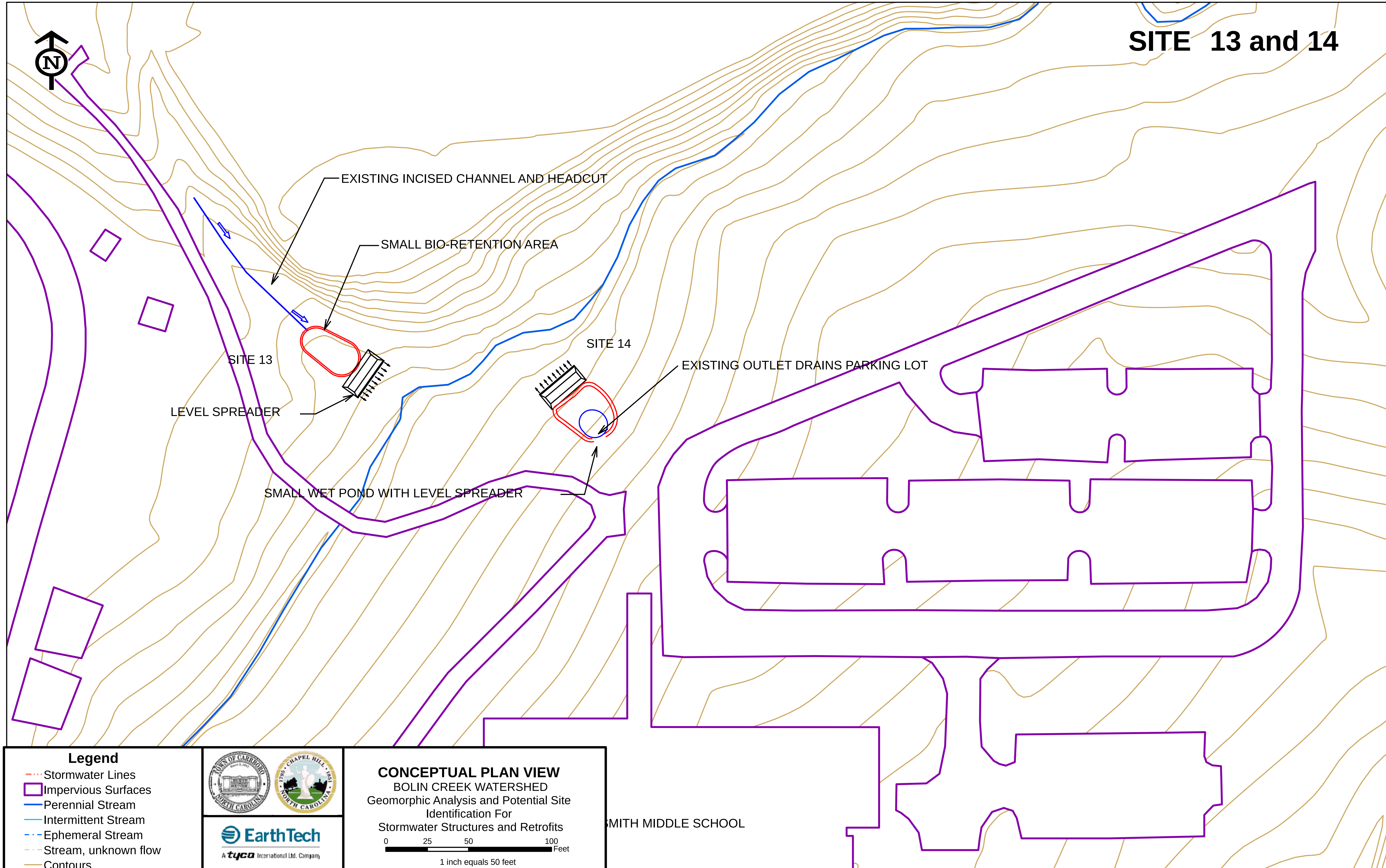
No alternatives are proposed for this site.

Cost-Estimate Breakdown

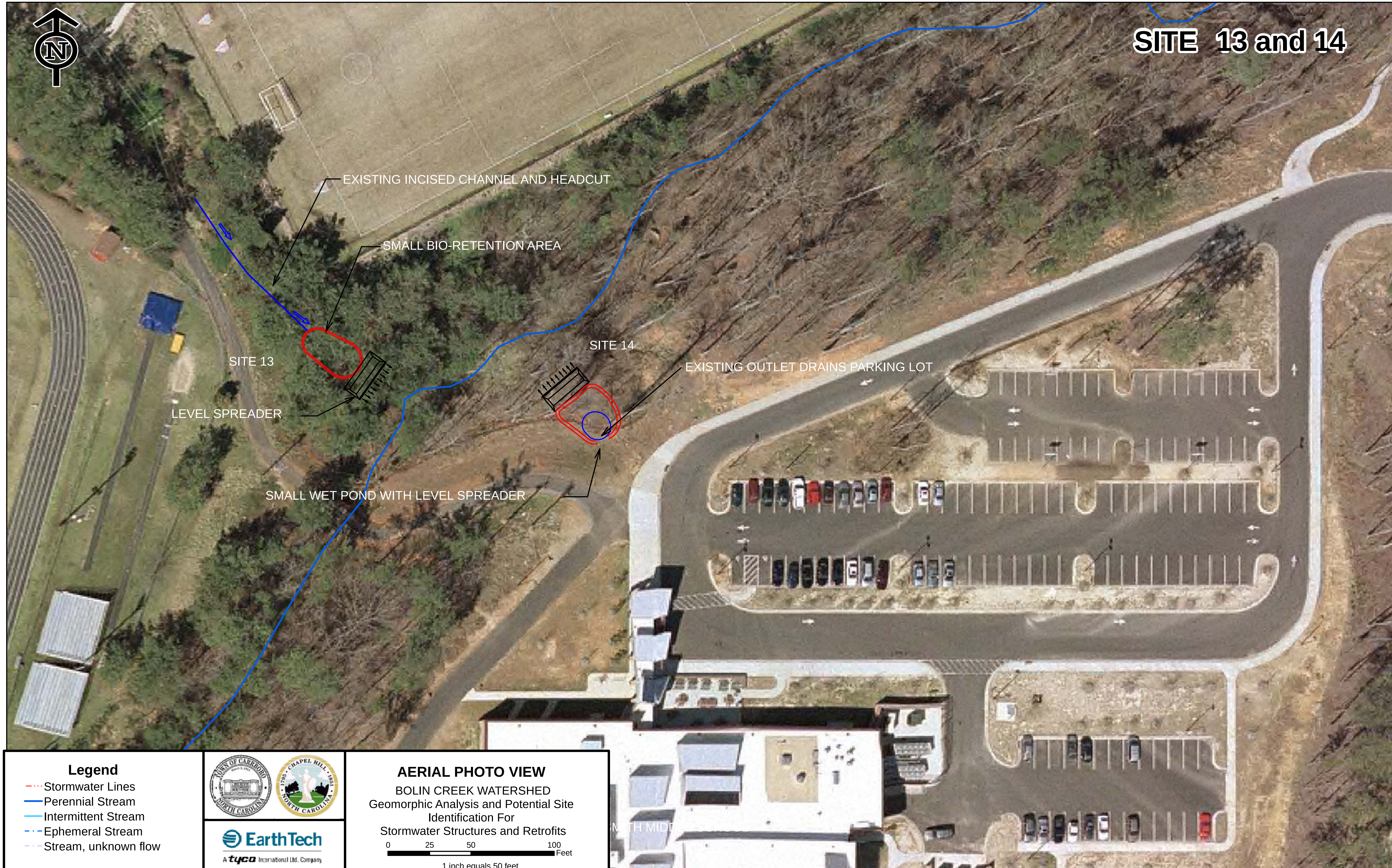
Table 13.2 shows a conceptual itemized cost estimate for Site 13. These costs represent construction and maintenance costs only. The cost for the bioretention area is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007).

Table 13.2
SITE 13

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Bio-Retention Area	1770.00	CF	12.62	$22,337
			Total	$22,337
Mobilization (5%)	1.0	LS		$1,117
Contingencies (10%)	1.0	LS		$2,234
	Total + Mobilization and Contingencies			**$25,688**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$1,284**



SITE 13 and 14
N
EXISTING INCISED CHANNEL AND HEADCUT
SMALL BIO-RETENTION AREA
SITE 13
LEVEL SPREADER
SITE 14
EXISTING OUTLET DRAINS PARKING LOT
SMALL WET POND WITH LEVEL SPREADER
SMITH MIDDLE SCHOOL
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
TOWN OF CARRBORO NORTH CAROLINA
CHAPEL HILL 1851 NORTH CAROLINA
EarthTech
A tyco International Ltd. Company
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0 25 50 100
Feet
1 inch equals 50 feet



Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

EarthTech
A tyco International Ltd. Company

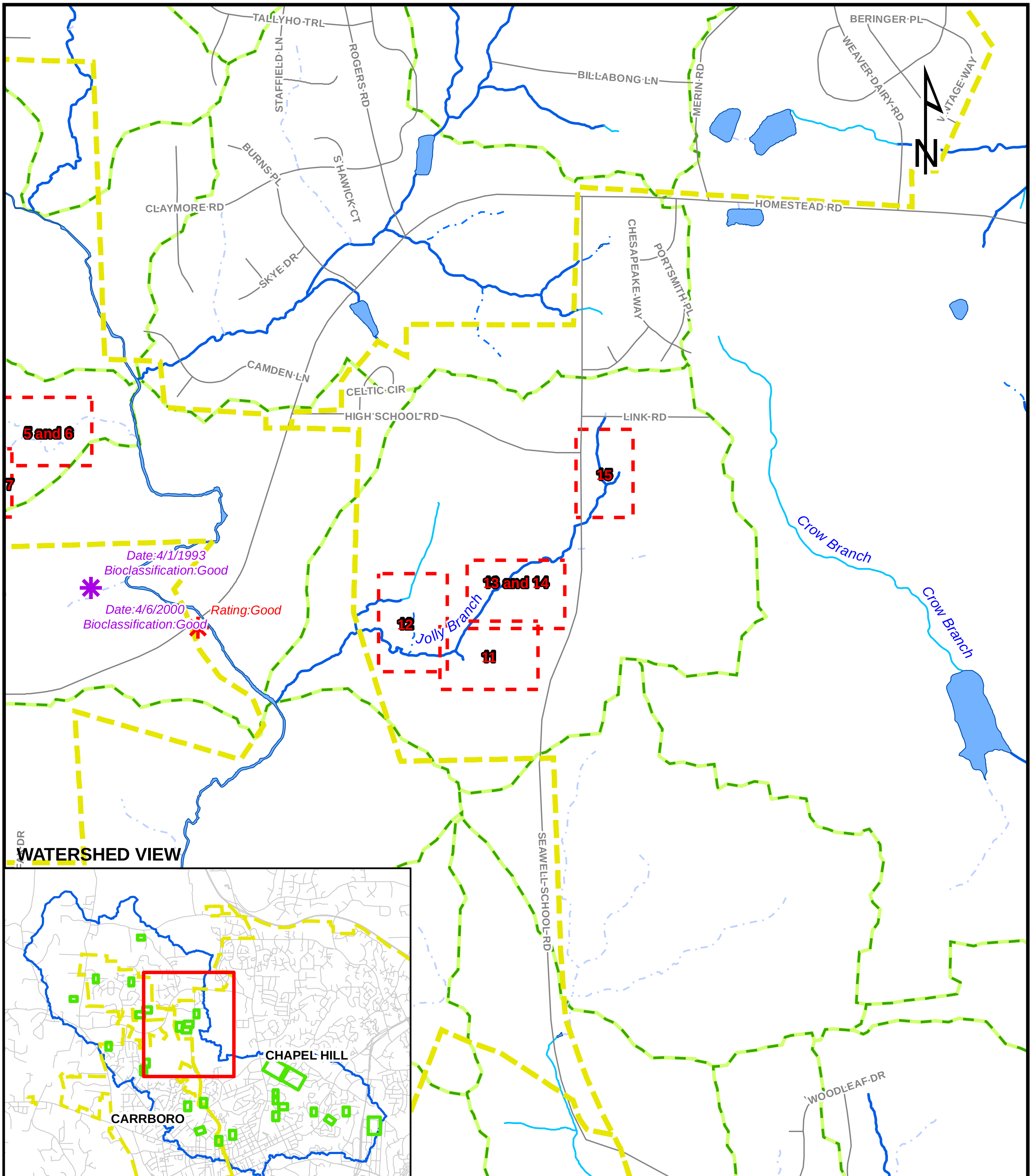
AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

SITE 14

Index Sheet No.: 16
Raw Data Name: None

Estimated Construction Cost: $25,600



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

EarthTech

A tyco International Ltd. Company

SITE 13 and 14
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs

Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 14	2.9	1.5	53.1%

Location

Site 14 is located north of a parking lot of Smith Middle School, off of Seawell School Rd.

Problem Description

Site 14 is situated at the outlet pipe that discharges the storm flow of one of the parking lots of Smith Middle School. Currently, no water quality treatment is provided for the parking lot runoff before it reaches the receiving stream, Jolly Branch. This direct discharge to the stream has caused channel incision and does not provide water quality or quantity treatment of any form. Channel instability will continue due to this direct discharge of stormwater into the receiving channel, Jolly Branch.

Sites 11 through 15 are in close proximity to each other, and could therefore be integrated amongst themselves as a single package. In addition, other similar opportunities for the work proposed here are present throughout the three surrounding campuses, as well as other parts of the Jolly Branch watershed.

Proposed Solution

The outlet pipe at Site 14 provides a good location to intercept the runoff produced by the parking lot and provide treatment for pollutants. Because of the small drainage area and limited space available for construction, a bio-retention area with underground storage is the preffered stormwater BMP here. The underground storage will serve to reduce the peak flows of the runoff from the impervious area and can be designed with a drain layer to augment baseflow to Jolly Branch while regaining needed storage volume for the next rain event. For this particular bio-retention area, the concept of providing a drain for the underground storage is an important one. Without intentional release of the stored rainfall, the BMP would loose some of its benefits during frequent rainfall events. It is suggested that this project be designed with a drain layer or under-drain that will drain the stored volume of rainfall within 3-5 days.

Table 14.1 shows a conceptual itemized cost estimate for both alternatives at Site 14.

Table 14.1

SITE 14	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	14.77	1.64	382.97
BIO-RETENTION TREATMENT	37.00%	45.00%	85.00%
NET REDUCTION	5.47	0.74	325.53
FUTURE CONDITION	9.31	0.90	57.45

Constraints

Some mature trees are present around the site, thus tree removal will be required.

Alternatives

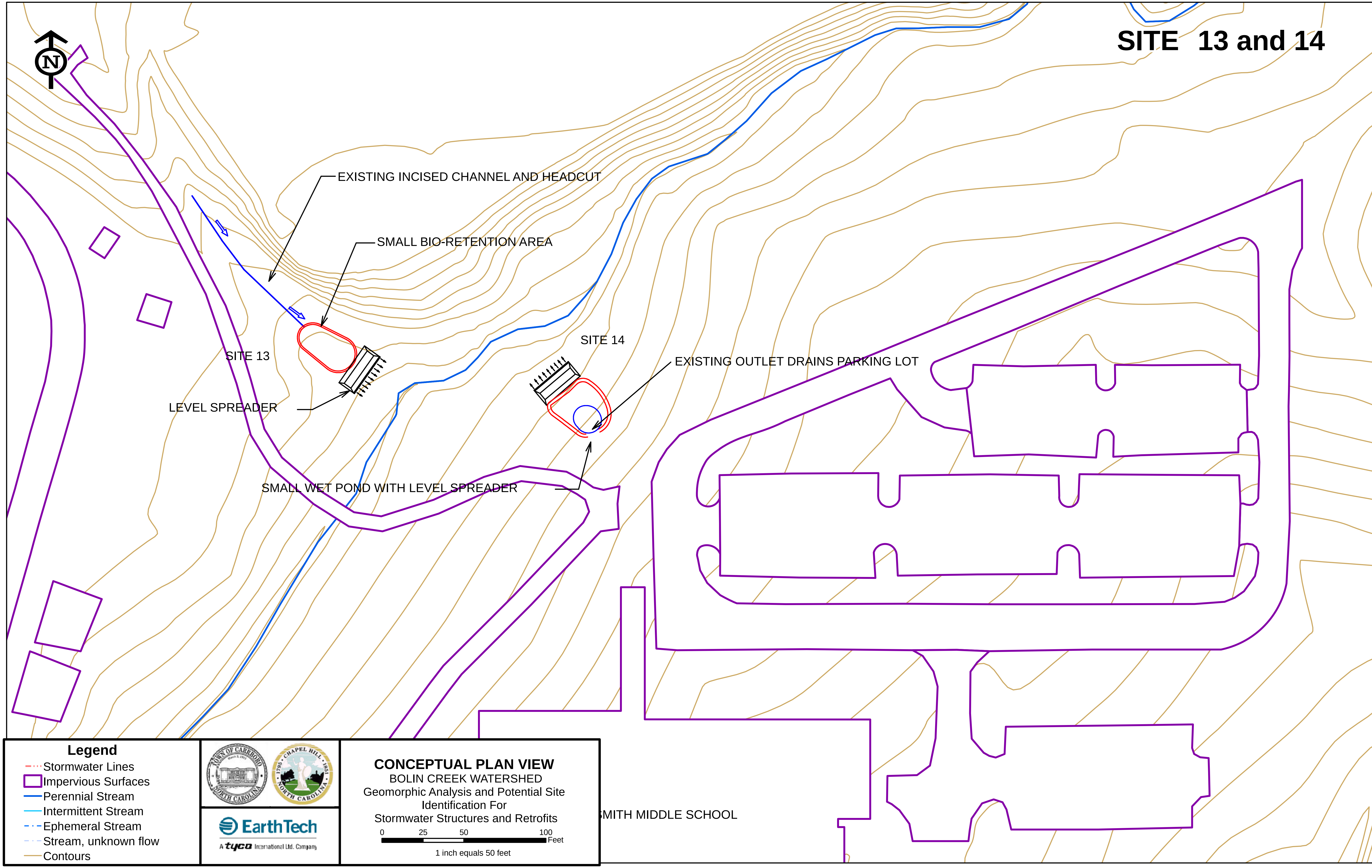
No alternatives are proposed for this site.

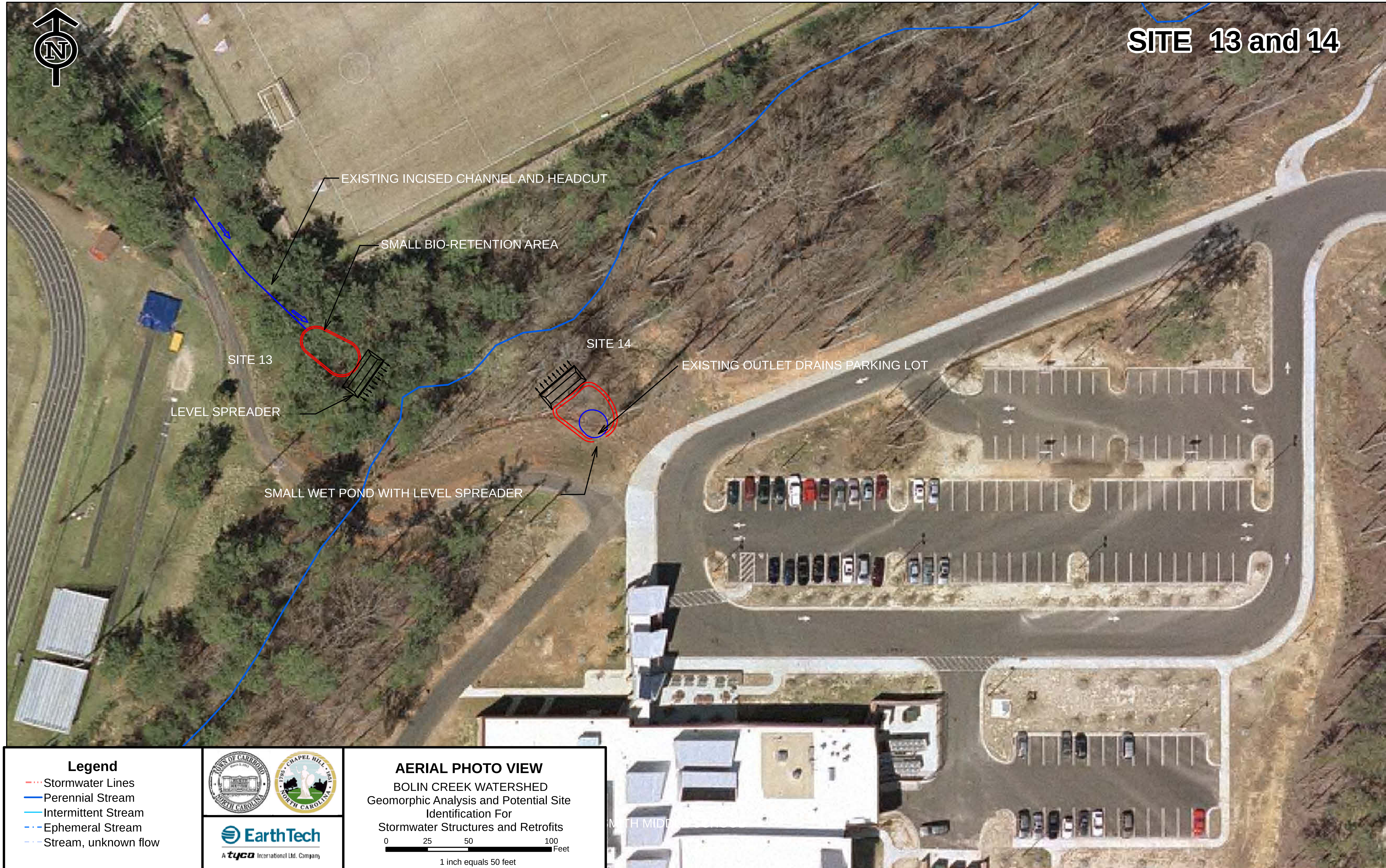
Cost-Estimate Breakdown

Table 14.2 shows a conceptual itemized cost estimate for Site 14. These costs represent construction and maintenance costs only. The cost for the bioretention area is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007).

Table 14.2
SITE 14 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Bio-Retention Area	1770.00	CF	12.62	$22,337
			Total	$22,337
Mobilization (5%)	1.0	LS		$1,117
Contingencies (10%)	1.0	LS		$2,234
	Total + Mobilization and Contingencies			**$25,688**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$1,284**


SITE 13 and 14
N
EXISTING INCISED CHANNEL AND HEADCUT
SMALL BIO-RETENTION AREA
SITE 13
LEVEL SPREADER
SITE 14
EXISTING OUTLET DRAINS PARKING LOT
SMALL WET POND WITH LEVEL SPREADER
SMITH MIDDLE SCHOOL
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
EarthTech
A tyco International Ltd. Company
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0 25 50 100
Feet
1 inch equals 50 feet



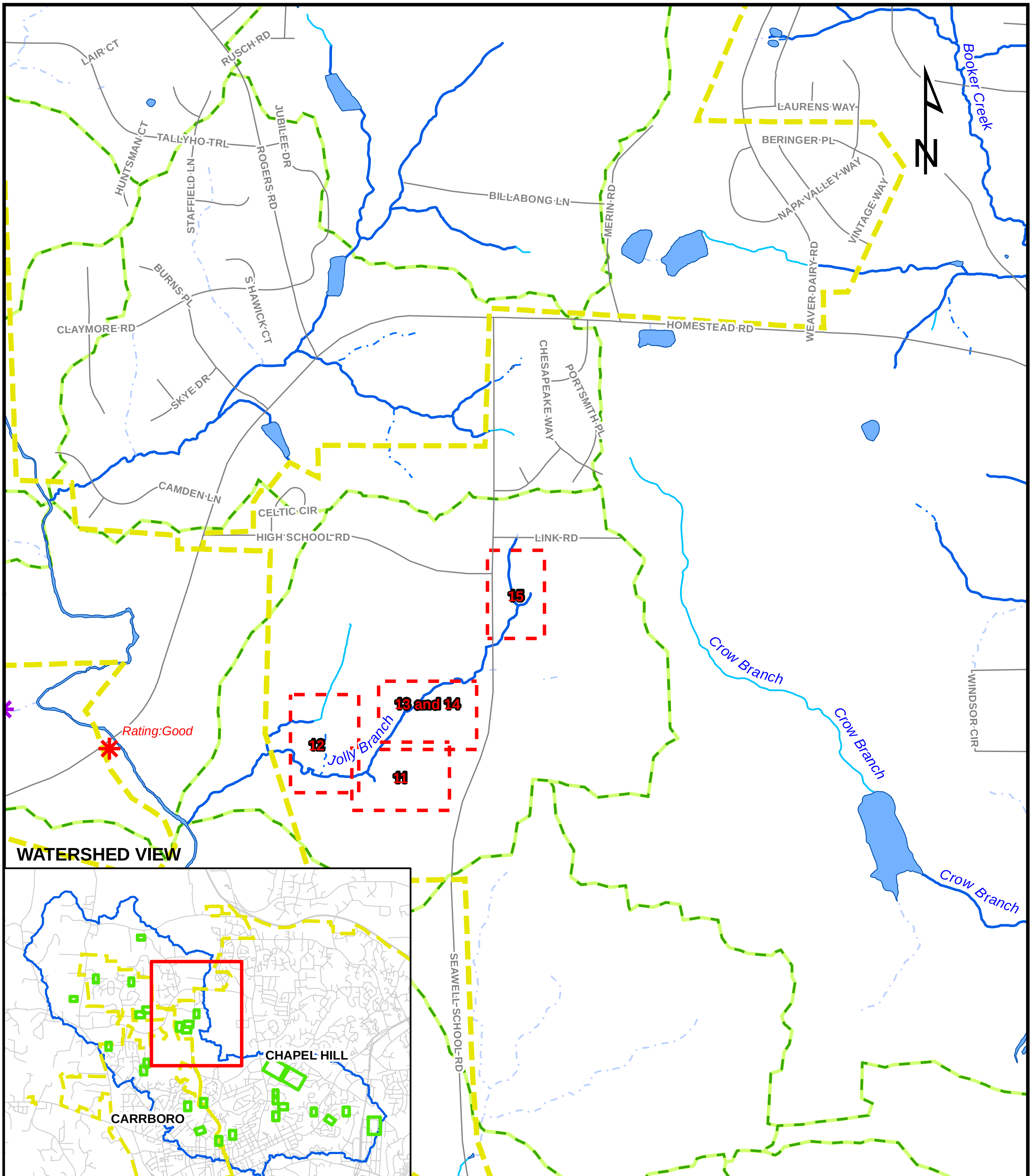
SITE 13 and 14
EXISTING INCISED CHANNEL AND HEADCUT
SMALL BIO-RETENTION AREA
SITE 13
SITE 14
EXISTING OUTLET DRAINS PARKING LOT
LEVEL SPREADER
SMALL WET POND WITH LEVEL SPREADER
Legend
Stormwater Lines
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
EarthTech
A tyco International Ltd. Company
AERIAL PHOTO VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0 25 50 100
Feet
1 inch equals 50 feet

SITE 15

Retrofit of Existing Sediment Basin

Index Sheet No.: 17
Raw Data Name: IJ 26

Estimated Consrtuction Cost: $27,300



Legend

Ambient Monitoring
Benthic Monitoring
Fish Sampling
Municipal Boundary
Orange County Roads
Subwatersheds
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow

TOWN OF CARRBORO NORTH CAROLINA

CHAPEL HILL 1793 1851 NORTH CAROLINA

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SITE 15
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 15	11.7	1.7	14.7%

Location

Site 15 is located south of a gravel driveway, at it's intersection with Seawell School Road. Chapel Hill High School and Smith Middle School are across the street from the site.

Problem Description

Site 15 consists of an existing sediment basin at the outlet of a culvert passing under a gravel driveway. The basin was likely constructed along with the driveway and the church to which the driveway leads to collect sediment from runoff during construction. The basin has filled in, and consists only of a remnant rip rap berm and a large flat area of silt and clay at an elevation equal to the berm. Stormwater from the culvert currently passes over the basin without any retention or detention, and then concentrates into a scoured drainage channel just downhill of the basin. The drainage channel deepens into a headcut just before reaching a perennial stream, Jolly Branch, approximately one hundred feet from the basin. Due to these existing conditions, there is no water quality treatment, sediment is exported from the actively eroding channel, and a headcut is advancing towards the basin, threatening to create an even deeper gulley.

Sites 11 through 15 are in close proximity to each other, and could therefore be integrated amongst themselves as a single package. In addition, other similar opportunities for the work proposed here are present throughout the three surrounding campuses, as well as other parts of the Jolly Branch watershed.

Proposed Solution

The existing basin of Site 15 is a prime candidate for a BMP retrofit in the form of a stormwater wetland to provide water quality treatment and peak flow attenuation. The retrofit could be facilitated by expanding the surface area of the current sediment basin, and digging out the accumulated sediment to create areas of shallow land, shallow water and deep pools. The site is a desirable one for a stormwater BMP retrofit in that the amount of earthwork will be minimal. In addition to the construction of a stormwater wetland, the existing erosive channel and headcut should also be stabilized. This can be done by creating a level spreader below the outlet of the wetland, which would cause stormwater to overflow diffusely through the floodplain and into the stream without concentrating the convergence at one location.

Benefits of the project would include the following:

- Attenuation of peak flows and relief of the main channel of Jolly Branch to keep it stable

- Water quality treatment of the contributing drainage area.
- Reduction of peak flow
- Possible baseflow augmentation from the water stored in the wetland

The current nutrient export rates, and potential benefit of a stormwater wetland here have been calculated based on land use, drainage area and percent imperviousness of the drainage area, and are displayed in **Table 15.1**:

Table 15.1

SITE 15	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	2.99	0.19	87.54
STORM WATER WETLAND TREATMENT REMOVAL %	37.00%	35.00%	85.00%
NET REDUCTION	1.11	0.07	74.41
FUTURE CONDITION	1.88	0.12	13.13

Constraints

Site 15 is heavily wooded, and care would therefore have to be taken to protect the larger trees on the site during construction. During field visits, it was observed that a large, dead maple is still standing just downhill of the sediment basin. This could be removed and provide a significant amount of the surface area for the expansion of the basin into a stormwater wetland.

Alternatives

No alternatives are proposed for this site.

Cost-Estimate Breakdown

Table 15.2 shows a conceptual itemized cost estimate. These costs represent construction and maintenance costs only. The cost for stormwater wetlands is derived from an equation developed by Brown and Schueler (1997).

Table 15.2

SITE 15 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stormwater Wetland	13986.0	CF	Equation Derived	$23,709
			Total	$23,709
Mobilization (5%)	1.0	LS		$1,185
Contingencies (10%)	1.0	LS		$2,371
	Total +	Mobilization and Contingencies		**$27,266**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$1,363**

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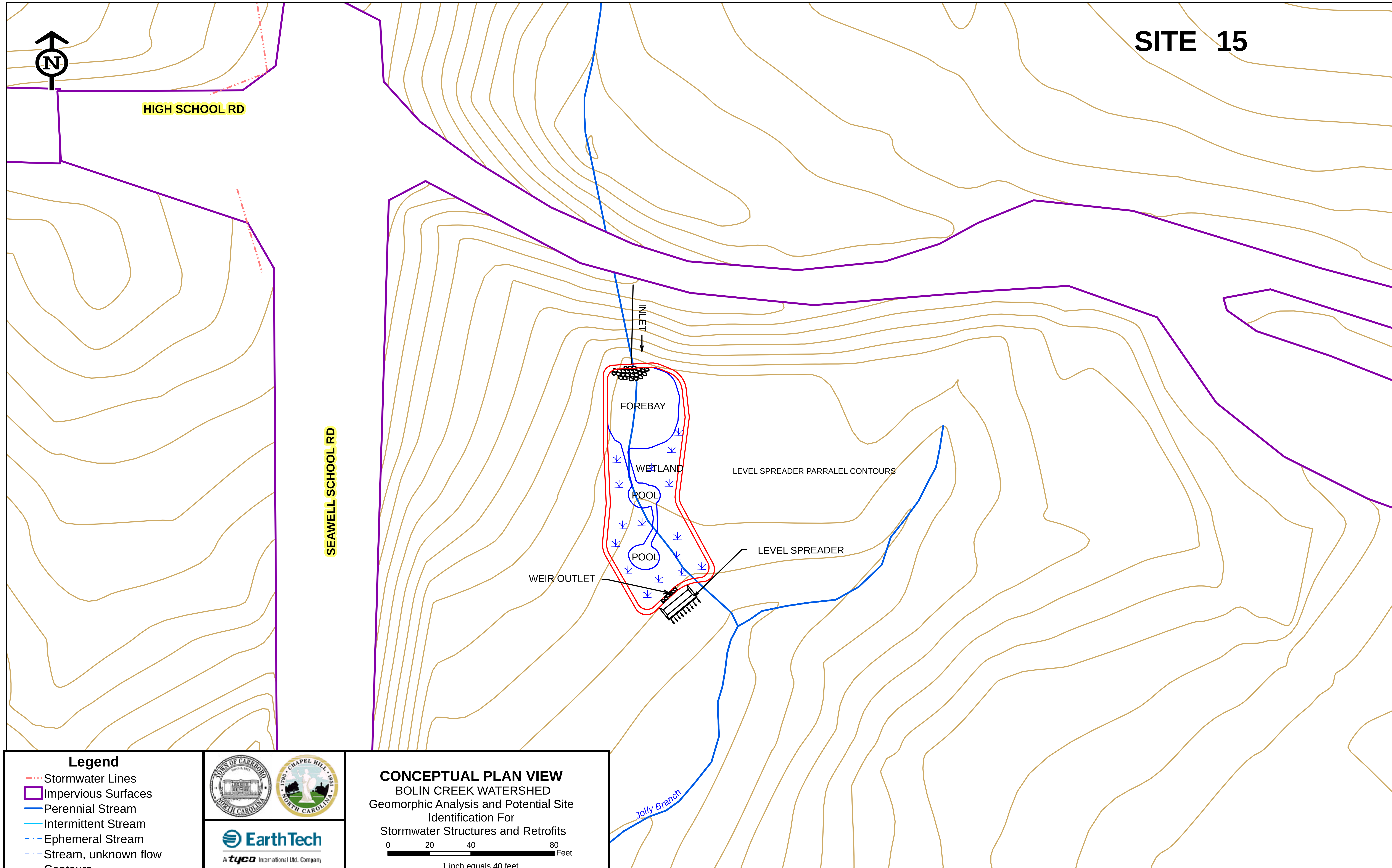
SITE 15



Legend

- Stormwater Lines
- Impervious Surfaces
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow
- Contours

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CONCEPTUAL PLAN VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

0 20 40 80 Feet

1 inch equals 40 feet

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

EarthTech
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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

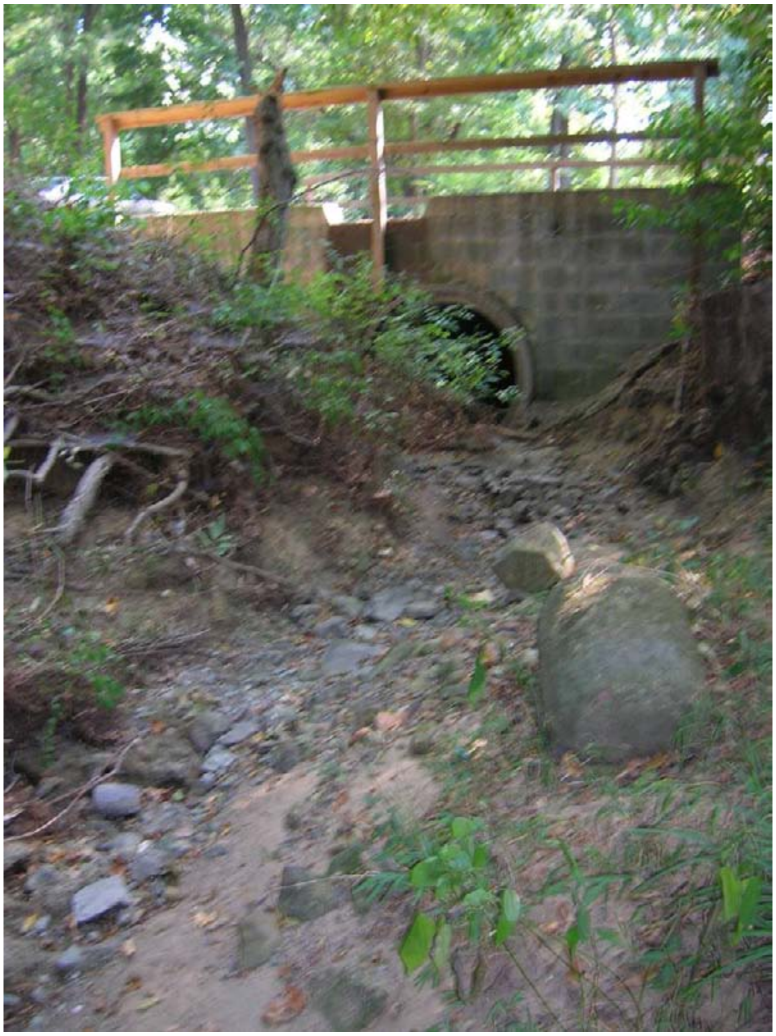
0 20 40 80 Feet

1 inch equals 40 feet

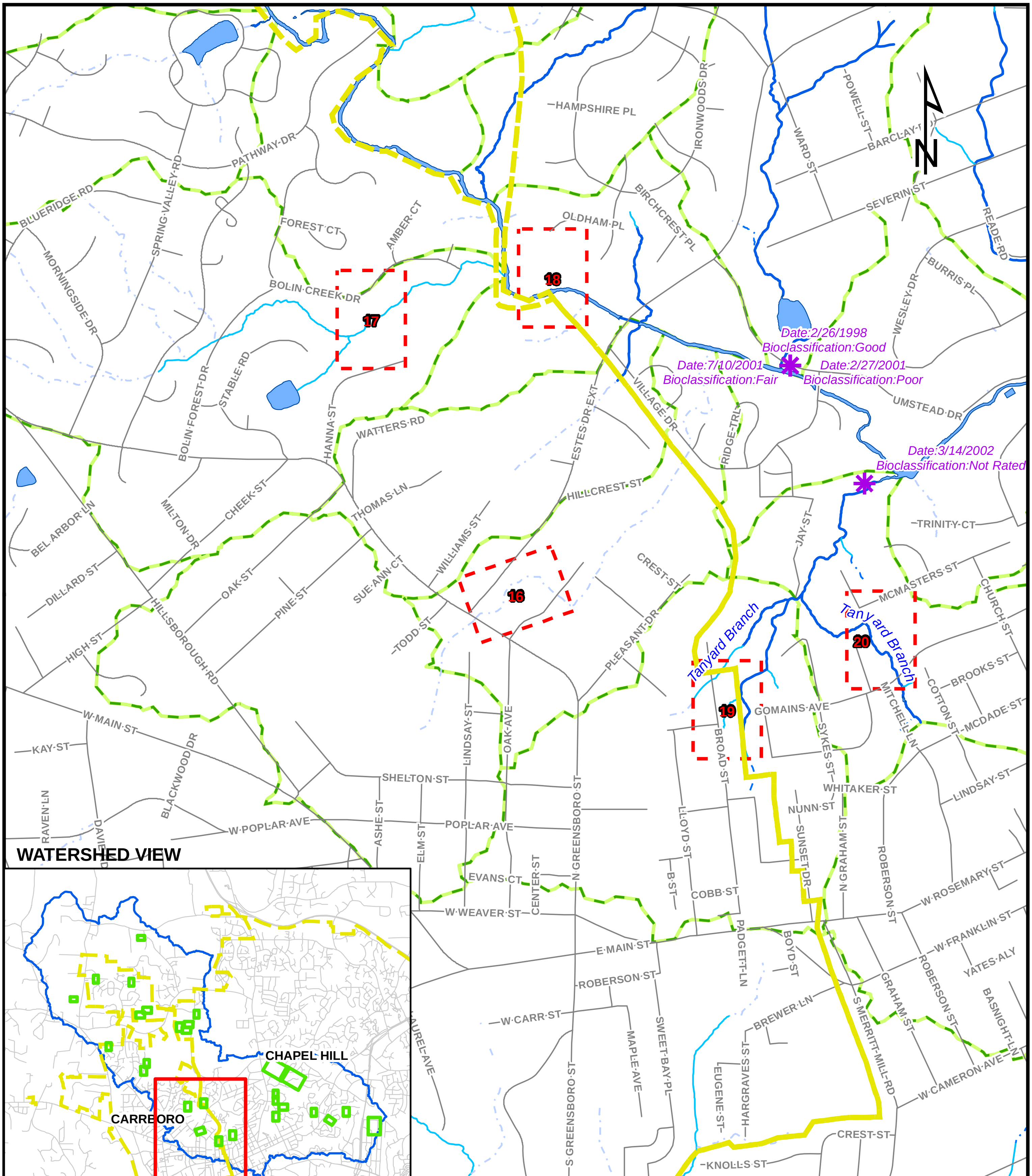
SITE 16

Stabilize Erosion at Apartment Complex and Provide Water Quality Treatment.

Index Sheet No.: 19
Raw Data Name: BD 47



Estimated Construction Cost: $56,500 - $86,300



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO, March 3, 1911, NORTH CAROLINA

CHAPEL HILL 1793 1851 NORTH CAROLINA

EarthTech

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SITE 16

VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs

Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 16	129.0	29.6	23.0%

Location

Site 16 is located just east of the intersection of Estes Drive Extension with N. Greensboro Street and is surrounded by an apartment complex.

Problem Description

Site 16 consists of approximately 500 feet of an incised, actively eroding stream, and small tributary that converges with the stream after passing through a culvert under Estes Drive Extension. Both the Carrboro and Chapel Hill stream datasets list the flow type as "Unknown". However, based on the drainage area of 0.2 square miles and the position in the landscape, the stream appears to be perennial, though further verification is needed. The stream is surrounded on both sides by the landscaping and hardscapes of an apartment complex. A wooden footbridge passes over the stream near the midpoint of the problematic reach.

The chief problems at site 16 are active mass wasting banks, and considerable sediment export from the eroding stream banks. Using the BANCS model, it is estimated that approximately 200 tons of sediment are being exported from the site each year. Concomitant nutrient export has also been calculated and is listed in **Table 16.1**.

Table 16.1

Pre-Treatment	
Estimated Total Sediment Export	200.4 tons/year
Erosion per length of Channel	13.4 tons/yr/ft
Pounds of Nitrogen	400.9 lbs/year
Pounds of Phosphorus	200.4 lbs/year
Post-Treatment	
Estimated Total Sediment Export	0.7 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	1.4 lbs/year
Pounds of Phosphorus	0.7 lbs/year

Proposed Solution

As with other bank stabilization/restoration projects, this site could benefit primarily from a change in the stream cross-section that provides the following:

- a bankfull bench that gives the stream a floodplain to access, thus significantly reducing shear stress and near bank velocities during above-bankfull events
- reduced slopes on the bank, at a maximum of 2:1, thus reducing potential for bank erosion
- vegetated banks with woody plants that will provide stabilization through rooting depth

By modifying the cross-section of the stream in this way for the length of the extreme eroding banks, the sediment export rates of this site could potentially be reduced to 0.7tons per year, with a corresponding reduction in nutrient export rates. Calculated sediment and nutrient reductions are shown in **Table 16.1**. The confinement of this site may force the designer to use relatively steep banks and no restored bankfull bench. However, laying back banks or using other alternative methods such as crib walls would be an improvement over the un-checked erosion that is occurring at present.

Constraints

Due to the highly urbanized location of this site, the chief constraint to this project would be the ability to acquire enough of a permanent drainage easement to implement the suggested treatment. Sloping back banks at a 2:1 ratio, yet keeping the existing depth of the stream at approximately 3.5 feet, would require moving back the banks laterally approximately 7 feet. In addition, landowners may not be amenable to construction equipment in close proximity to their apartment units.

Alternatives

Two alternative treatments could be implemented at this site, depending on size constraints and landowner cooperation.

In Alternative 1, the banks would be sloped back, a bankfull bench would be established and both would be vegetated. Brush matting on the banks will provide the necessary change in boundary conditions of the banks to resist the erosive force of peak flows. On the small tributary leading into the main stream channel, a step-pool should be built to stop the active headcut where the two channels meet.

In Alternative 2, the treatments recommended in Alternative 1 would be implemented, with the added water quality treatment of a bioretention area. The bioretention area should be constructed inline with the tributary and receive the flow of its contributing drainage area.

Cost-Estimate Breakdown

Tables 16.2 and 16.3 show a conceptual itemized cost estimate for both alternatives. These costs represent construction and maintenance costs only. The cost for the bioretention area is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007).

Table 16.2
SITE 16 ALTERNATIVE 1

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	1800.00	CY	15.00	$27,000
Bank stabilization with Brush Matting	630.00	SY	15.00	$9,450
Site Preparation and Planting	0.13	Ac	7500.00	$975
Silt Fence	750.00	LF	3.75	$2,813
Boulders	25.00	Tons	200.00	$5,000
Construction Safety Fence	550.00	LF	2.50	$1,375
Construction Entrance	1.00	Ea	2500.00	$2,500
			Total	$49,113
Mobilization (5%)	1.00	LS		$2,456
Contingencies (10%)	1.00	LS		$4,911
	Total + Mobilization and Contingencies			**$56,479**

Table 16.3
SITE 16 ALTERNATIVE 2

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	1800.00	CY	15.00	$27,000
Bank stabilization with Brush Matting	630.00	SY	15.00	$9,450
Site Preparation and Planting	0.13	Ac	7500.00	$975
Silt Fence	750.00	LF	3.75	$2,813
Boulders	25.00	Tons	200.00	$5,000
Construction Safety Fence	550.00	LF	2.50	$1,375
Construction Entrance	1.00	Ea	2500.00	$2,500
Bio-Retention Area with Underdrain	2061.00	CF	12.62	$26,010
			Total	$75,122
Mobilization (5%)	1.00	LS		$3,756
Contingencies (10%)	1.00	LS		$7,512
	Total + Mobilization and Contingencies			**$86,391**
Maintenance Costs				
Maintenance (5% of base construction cos of BMP)	1.0	Year		**$1,300**

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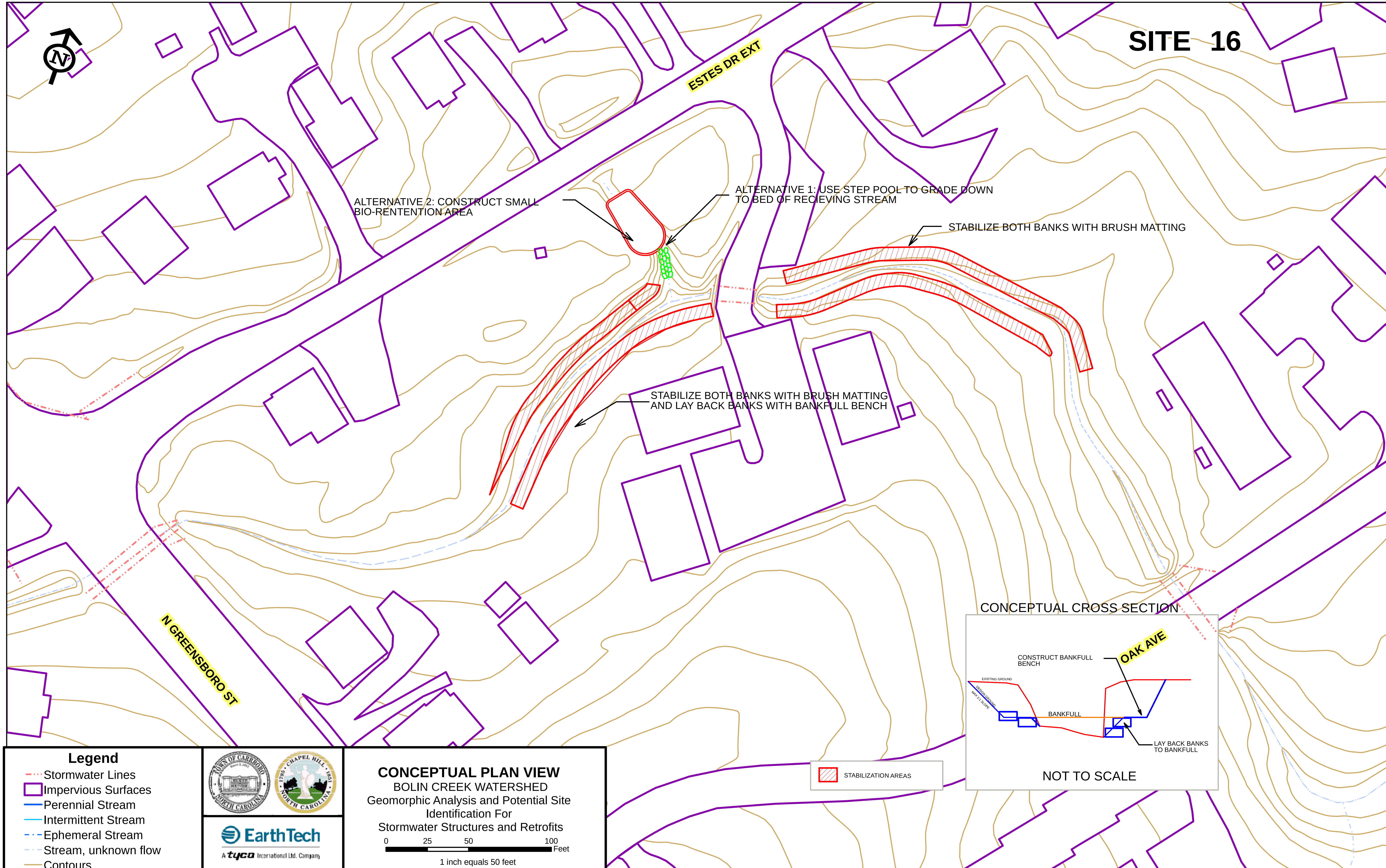

SITE 16
N
ESTES DR EXT
N GREENSBORO ST
OAK AVE
ALTERNATIVE 2: CONSTRUCT SMALL BIO-RENTENTION AREA
ALTERNATIVE 1: USE STEP POOL TO GRADE DOWN TO BED OF RECIEVING STREAM
STABILIZE BOTH BANKS WITH BRUSH MATTING
STABILIZE BOTH BANKS WITH BRUSH MATTING AND LAY BACK BANKS WITH BANKFULL BENCH
CONCEPTUAL CROSS SECTION
CONSTRUCT BANKFULL BENCH
EXISTING GROUND
BANKFULL
LAY BACK BANKS TO BANKFULL
NOT TO SCALE
STABILIZATION AREAS
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
EarthTech
A tyco International Ltd. Company
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits
0 25 50 100 Feet
1 inch equals 50 feet

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

EarthTech
A tyco International Ltd. Company

AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For
Stormwater Structures and Retrofits

0 25 50 100 Feet

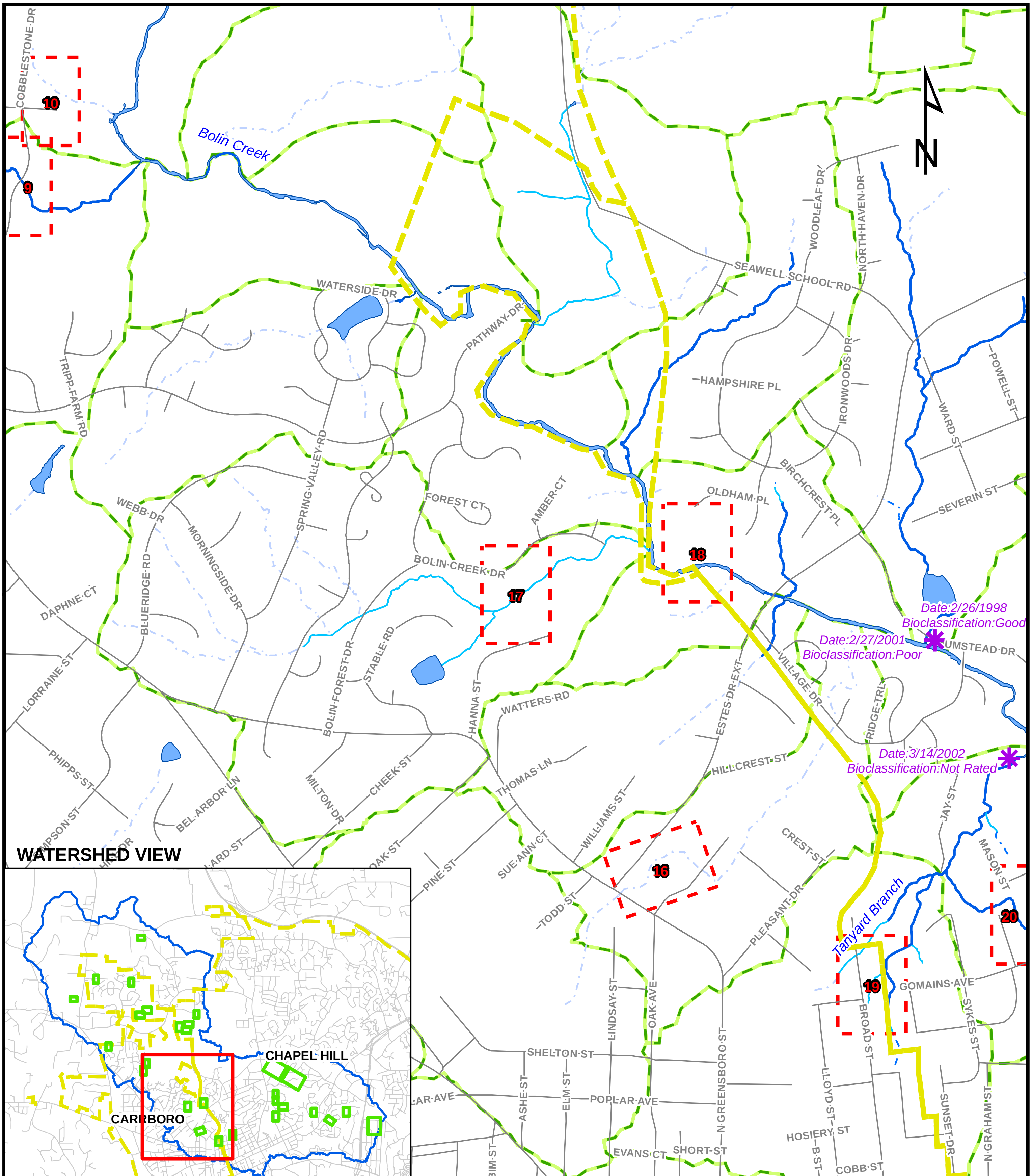
1 inch equals 50 feet

SITE 17

Offline Bioretention Area and Sediment Reduction Below New Development.

Index Sheet No.: 20
Raw Data Name: BD 11

Estimated Construction Cost: $66,700



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO NORTH CAROLINA

CHAPEL HILL 1793 1851 NORTH CAROLINA

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SITE 17
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 17	156.0	36.4	23.3%

Location

Site 17 is located downhill and to the south of Bolin Creek Drive, and downhill and to the north of Hannah Street. A sewer easement runs along the stream where treatment is proposed.

Problem Description

Site 17 consists of an incised channel and actively eroding bank, as well as a relatively flat area in the floodplain of the stream in which an offline bioretention area could be constructed. Water quality treatment is lacking in most of this watershed, thus a flat area such as that present at Site 17 affords an opportunity for diversion of flow and pollutant treatment.

An actively eroding bank at Site 17 is causing export of sediment and loss of bank. Using the BANCS model, it is estimated that approximately 60.8 tons of sediment are being exported from the site each year. Concomitant nutrient export has also been calculated and is listed in **Table 17.1**.

Table 17.1

Pre-Treatment	
Estimated Total Sediment Export	60.8 tons/year
Erosion per length of Channel	1 tons/yr/ft
Pounds of Nitrogen	121.6 lbs/year
Pounds of Phosphorus	60.8 lbs/year
Post-Treatment	
Estimated Total Sediment Export	0.2 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	0.3 lbs/year
Pounds of Phosphorus	0.2 lbs/year

Proposed Solution

As with other bank stabilization/restoration projects, this site could benefit primarily from a change in the stream cross-section that provides the following:

- a bankfull bench that gives the stream a floodplain to access, thus significantly reducing near bank stress during above-bankfull events

- reduced slopes on the bank, at a maximum of 2:1, thus reducing potential for bank erosion
- vegetated banks with woody plants that will provide stabilization through rooting depth

By modifying the cross-section of the stream in this way for the length of the extreme eroding banks, the sediment export rates of this site could potentially be reduced to 0.2 tons per year, with a corresponding reduction in nutrient export rates. Calculated sediment and nutrient reductions are shown in **Table 17.1**.

An offline bioretention area could also be built in the existing floodplain of the stream. A topographically flat area there could provide the needed surface area for providing pollutant removal for a percentage of the flow, with the added benefit of attenuation of peak flows and reduction of near bank stress against the outside meander that is currently eroding. Additionally, the storage of runoff volume in the bioretention area may supplement for some of the loss of baseflow that was observed in this channel. Side channel storage can generally be assumed to reduce channel stresses of the downstream system.

Constraints

Constraints consist of space needed for the construction of the bioretention area, and avoiding impacts to the existing sewer line.

Alternatives

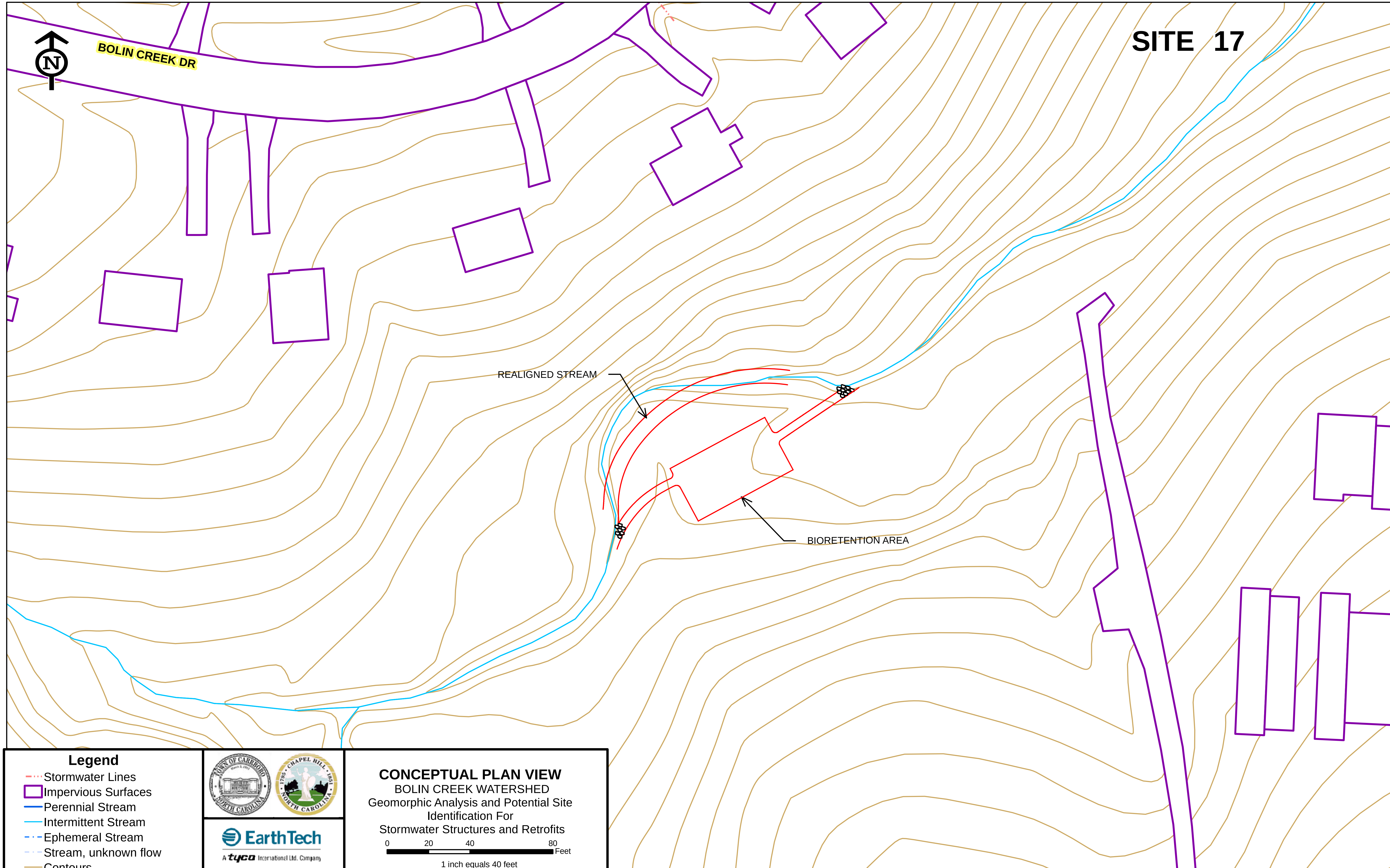
No alternatives are proposed for this site.

Cost-Estimate Breakdown

Table 17.2 shows a conceptual itemized cost estimate for Site 17. These costs represent construction and maintenance costs only. The cost for the bioretention area is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007). The contingency fee for this site has been increased due to the difficulty of access and proximity to a sewer easement.

Table 17.2
SITE 17 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Bio-Retention Area	4401.00	CY	12.62	$55,541
			Total	$55,541
Mobilization (5%)	1.00	LS		$2,777
Contingencies (15%)	1.00	LS		$8,331
	Total + Mobilization and Contingencies			**$66,649**
Maintenance Costs				
Maintenance (5% of base construction cost of BMP)	1.0	Year		**$2,777**



Legend

- Stormwater Lines
- Impervious Surfaces
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow
- Contours

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CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

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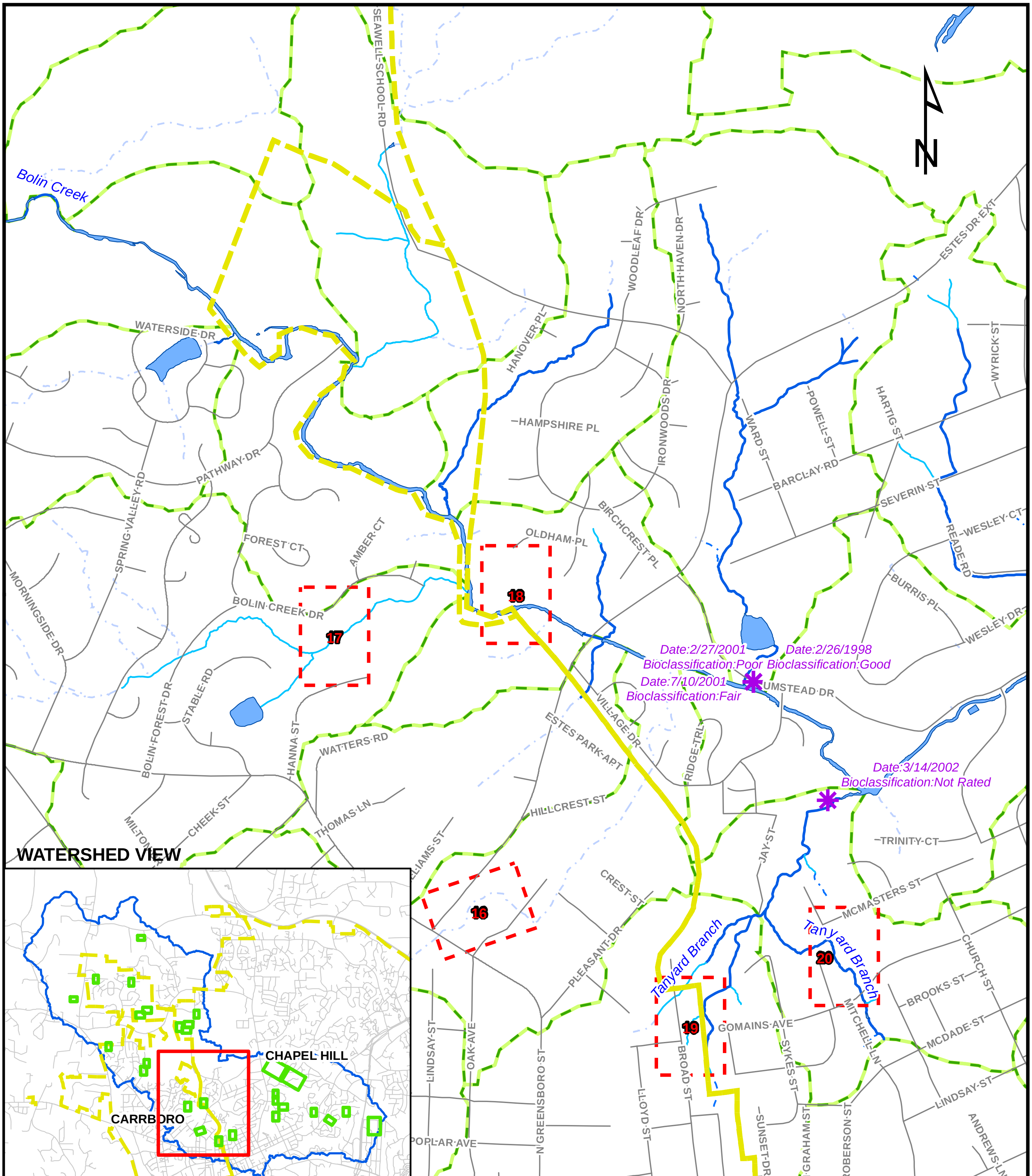
SITE 18

Restoration of Erosive Gulley Beneath Railroad Trestle, and Treatment of Pollutants From Subdivision

Index Sheet No.: 20
Raw Data Name: TA 19

Estimated Construction Cost: $17,400



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

SITE 18

VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 18	4.7	0.8	16.0%

Location

Site 18 is located beneath a railroad trestle approximately 500 feet to the west of Estes Drive Extension. The railroad trestle crosses over Bolin Creek, and the site is located on the left bank, looking downstream . Access to the site can be obtained by traveling along an existing sewer easement and footpath that follows the stream.

Problem Description

Site 18 consists of two actively eroding headcuts on an exposed hillslope adjacent to a railroad trestle. Upslope of the gulley is a subdivision and what appears to be an ephemeral stream discharging from the storm system of the neighborhood, which consists of a curb and gutter drainage system. The runoff that accumulates on the relatively high percentage of impervious surface concentrates in the gulley just before reaching Bolin Creek, causing severe scour and mass wasting, and contributing sediment to the watershed, as well as any pollutants that may be contained in the runoff from the subdivision. There is also an indication that impacts from recreational use of this site could be adding to the problem of the erosive banks by causing bank failure in between rainfall events.

Potential pollutant loads and reduction have been calculated based on impervious area and land use, and are shown in **Table 18.2**.

Proposed Solution

Site 18 poses a unique situation for stormwater treatment; a steep slope and limited space between the area of the headcuts, the footers of the railroad trestle and Bolin Creek. A solution for treatment at this site is to construct a "bio-grade step", which is a series of small bio-retention cells filled with a filter media, such as a mixture of sand, fines and organic mater (see Appendix A-Details). Ideally, this media will have a filtration rate of 1.0 to 2.0 inches per hour, to optimize pollution removal (Schueler, et. al., 2007). Each cell is connected to the other by the use of a drainage or seepage layer, thus allowing stormwater to filter through each cell without the expense of an underdrain. An underdrain is also an option if it is preferred. Each cell would have a given amount of volume to fill while infiltrating before cresting the berm and overflowing into the next cell downstream. Below the bio-grade step, a preformed scour hole (see Appendix A-Details), should be built to dissipate any overflow before reaching Bolin Creek. There is not enough room to dissipate energy via a level spreader.

This treatment option will provide a linear, grade-control solution to reduce erosive velocities of the stream, while also treating stormwater runoff for pollutants. A substantial amount of storage volume, with respect to drainage area, can help to reduce the total runoff that Bolin Creek receives. This may also augment baseflow to Bolin Creek by delaying the release of the stored runoff volume. It is important to note that this bio-grade step should drain completely over a period of 5-7 days in order to insure that there is available storage volume for runoff from the next rain event. Thus, the design of the weeps or drainage layers is an important factor for the continual success of this project.

The depth of each cell can vary depending on choice of planting materials. Trees, with a deeper rooting structure, will require deeper soils, while herbaceous plants and shrubs can have soil as shallow as 1.5 feet (Schuler et. al, 2007). Potential pollution removal rates using this method have been estimated and are shown in **Table 18.2**.

Table 18.2

SITE 18	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	8.24	0.81	121.55
BIORETENTION TREATMENT REMOVAL %	35.00%	45.00%	85.00%
NET REDUCTION	2.89	0.36	103.32
FUTURE CONDITION	5.36	0.45	18.23

Constraints

The nearest right of way to this site is Estes Drive Extension, nearly 500 feet downstream. What appears to be an existing sewer easement, as evidenced by manholes, runs parallel with Bolin Creek and a maintenance path runs from Estes Drive Extension to the site. Thus, a drainage easement and access easement may already exist.

Other constraints consist of the avoidance of the railroad trestle, gaining permission to do work around it, and the difficult terrain.

Alternatives

No alternatives are proposed for this site.

Cost-Estimate Breakdown

Table 18.3 shows a conceptual itemized cost estimate for Site 18. These costs represent construction and maintenance costs only. The cost for the bio-grade step is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007).

Table 18.3
Site 18 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Biograde Step	1200.0	CF	12.62	$15,144
			Total	$15,144
Mobilization (5%)	1.00	LS		$757
Contingencies (10%)	1.00	LS		$1,514
	Total + Mobilization and Contingencies			**$17,416**
Maintenance Costs				
Maintenance (5% of base construction cost)	1.0	Year		**$871**

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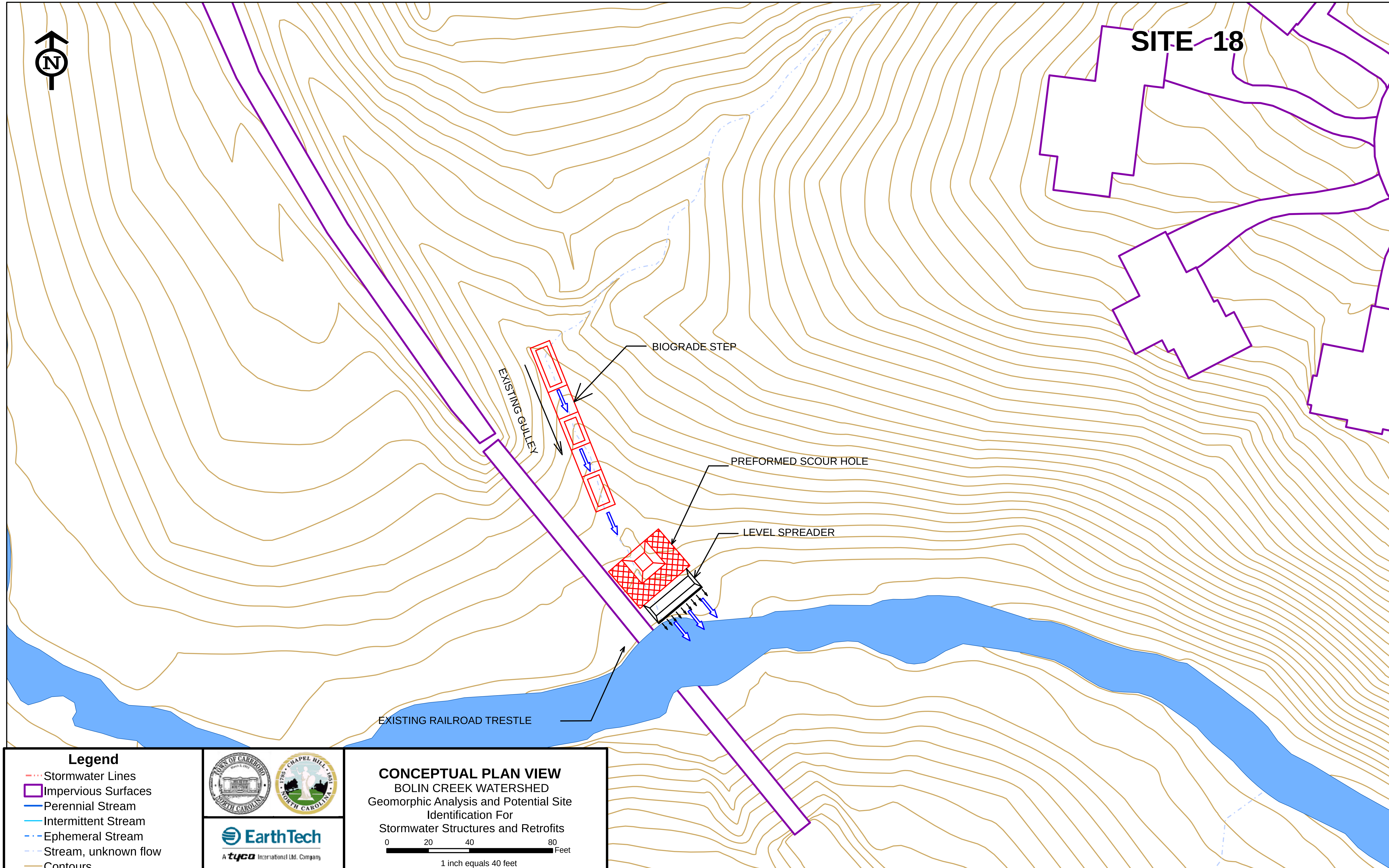


CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

AERIAL PHOTO VIEW

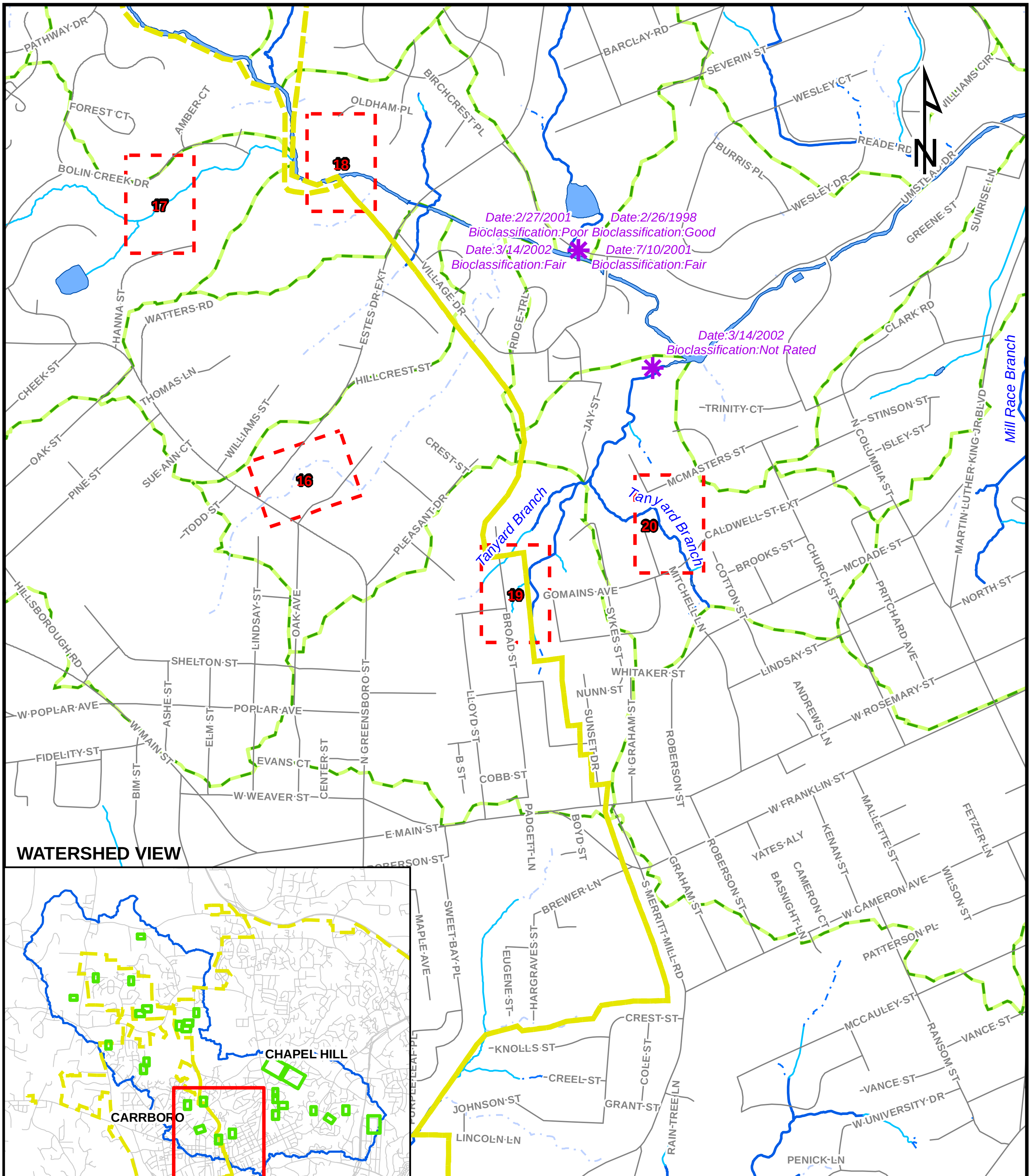
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

SITE 19

Stream Restoration/Bank Stabilization in Park

Index Sheet No.: 23
Raw Data Name: TA 29-31

Estimated Construction Cost: $10,300-$15,500



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 19

VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs

Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 19	149.5	31.5	21.0%

Location

Site 19 is located in a public park off of Broad Street and approximately 0.25 miles north of Rosemary Street/E. Main Street.

Problem Description

Site 19 consists approximate 165 feet of an incised reach of Tanyard Branch, with actively eroding, vertical banks and lack of a riparian buffer. Upstream of the site, the stream is completely piped, and emerges from a culvert after passing under Broad Street, where it then flows through a town-owned park. The eroding streambanks are likely the result of what was observed to be repeated mowing up to the stream (mechanical stresses on the channel) and a lack of riparian buffer to resist the high shear stress coming from the concentrated flow discharge of the upstream pipe network. The eroding stream banks are causing export of sediment and associated nutrients. A preliminary investigation of streambank erosion potential using the BANCS model indicates that approximately 29 tons of sediment is being exported from the site each year. Concomitant nutrient export associated with the sediment has also been calculated and is listed in **Table 19.1**. .

Table 19.1

Pre-Treatment	
Estimated Total Sediment Export	28.3 tons/year
Erosion per length of Channel	2.4 tons/yr/ft
Pounds of Nitrogen	56.6 lbs/year
Pounds of Phosphorus	28.3 lbs/year
Post-Treatment	
Estimated Total Sediment Export	0.5 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	1 lbs/year
Pounds of Phosphorus	0.5 lbs/year

Proposed Solution

As with other bank stabilization/restoration projects, this site could benefit primarily from a change in the stream cross-section that provides the following:

- a bankfull bench that gives the stream a floodplain to access, thus significantly reducing near bank stress during above-bankfull events
- reduced slopes on the bank, at a maximum of 2:1, thus reducing potential for bank erosion
- vegetated banks with woody plants that will provide stabilization through rooting mass

In areas of fill soils, additional toe or bank protection using methods such as Bio-D or blocks or soil layering techniques may be necessary (see Appendix A- Details.)

Changes to the profile (riffle-pool sequence) could also be implemented at this site to restore in-stream habitat, but at a greater project cost (see Alternatives). The preferred alternative is one in which the banks are laid back and the streambank erosion reduced to the maximum extent possible. Calculated sediment and nutrient reductions as a result of this treatment are shown in **Table 19.1**.

In addition to the changes in stream cross-section, the banks of the stream should be planted with deep rooting plants that will provide banks stabilization through their rooting mass. As this site is located in an urban park, the needs of safety, aesthetics and functionality need to be met with a choice of plant species. While trees are preferred in the stabilization of stream banks, low-growing grasses and perennials may be more appropriate to a park setting. If low growing grasses pose a problem due to public concerns of thick brush, the select trees may provide stability with maintenance to the herb layer.

Constraints

Land acquisition is not a constraint here, as the stream travels through land owned by the Town of Chapel Hill.

Limited space available in the park may constrain the width of the buffer. Public relations and perception of re-vegetation may hinder the improvements to this site.

Alternatives

There are three alternatives at this site that could be implemented, based on available funds.

Alternative 1: Rather than laying back banks and incurring the expense of earthwork, brush matting (see Details) could be laid on all banks, providing a certain degree of resistance of erosive flows and reducing bank erosion. The riparian buffer area could then be re-vegetated with low-growing plants, as mentioned above.

Alternative 2: To reduce bank erosion rates to the greatest extent, lay back the stream banks at a maximum 2:1 slope and construct a bankfull bench. Then re-vegetate the riparian buffer with low-growing plants.

Alternative 3: In addition to the treatment of Alternative 2, modify the profile of the stream, constructing pools at each meander bend of the existing channel. This will lead to further dissipation of energy, while improving in-stream habitat.

Cost-Estimate Breakdown

Tables 19.2, 19.3 and 19.4 show a conceptual itemized cost estimate for all three alternatives. These costs represent construction costs only.

Table 19.2

SITE 18 ALTERNATIVE 1

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Construction Safety Fence	700.00	LF	2.50	$1,750
Site Preparation and Planting	0.13	Ac	7500.00	$975
Brush Matting	75.00	LF	50.00	$3,750
Construction Entrance	1.00	Ea	2500.00	$2,500
			Total	$8,975
Mobilization (5%)	1.00	LS		$449
Contingencies (10%)	1.00	LS		$898
	Total + Mobilization and Contingencies			**$10,321**

Table 19.3

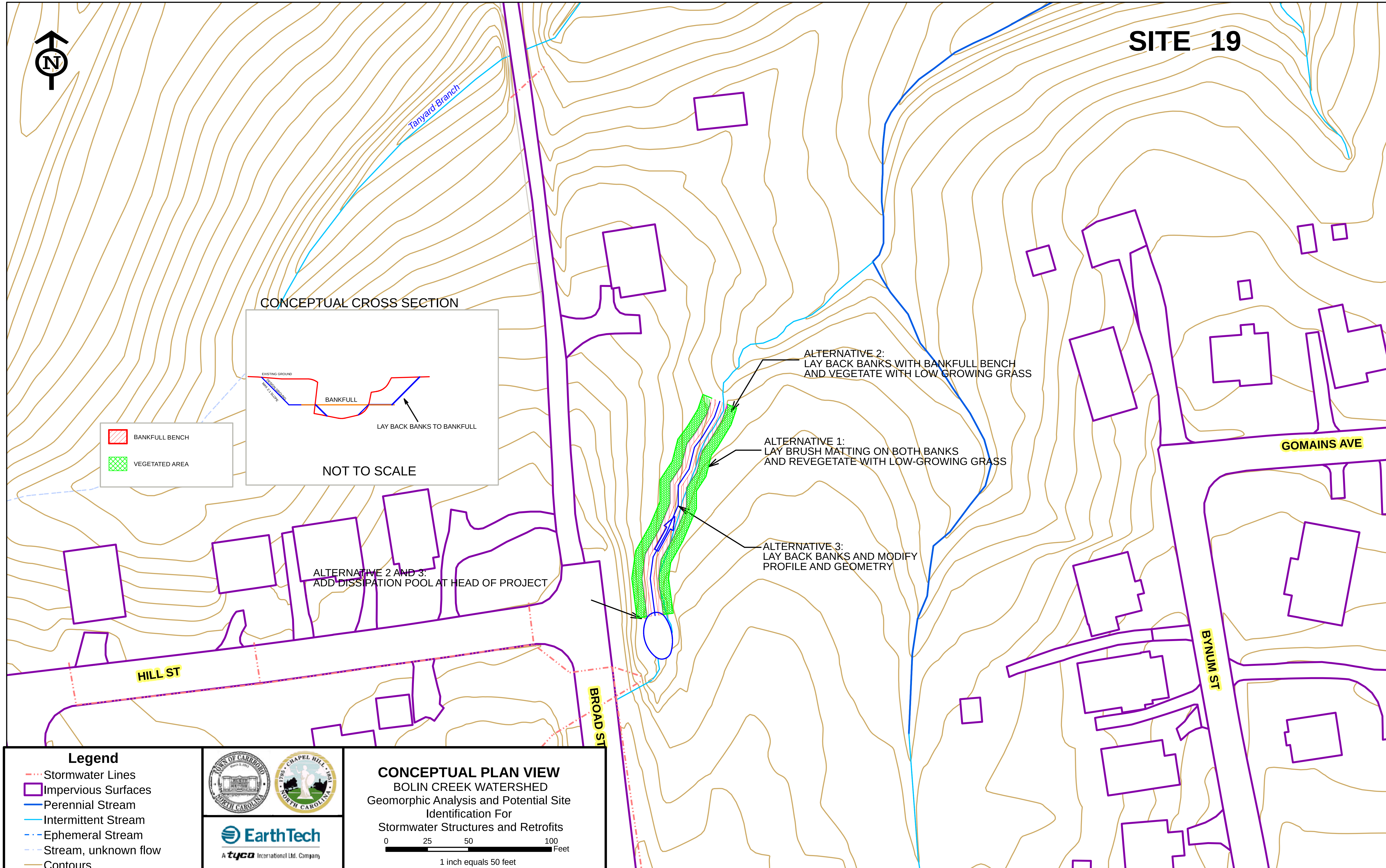
SITE 18 ALTERNATIVE 2

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	250.00	CY	15.00	$3,750
Site Preparation and Planting	0.13	Ac	7500.00	$975
Silt Fence	600.00	LF	3.75	$2,250
Bio -D Blocks for Bank Stabilization	75.00	LF	20.00	$1,500
Construction Safety Fence	700.00	LF	2.50	$1,750
Construction Entrance	1.00	Ea	2500.00	$2,500
			Total	$12,725
Mobilization (5%)	1.00	LS		$636
Contingencies (10%)	1.00	LS		$1,273
	Total + Mobilization and Contingencies			**$14,634**

Table 19.4

SITE 18 ALTERNATIVE 3

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	300.00	CY	15.00	$4,500
Site Preparation and Planting	0.13	Ac	7500.00	$975
Silt Fence	600.00	LF	3.75	$2,250
Bio -D Blocks for Bank Stabilization	75.00	LF	20.00	$1,500
Construction Safety Fence	700.00	LF	2.50	$1,750
Construction Entrance	1.00	Ea	2500.00	$2,500
			Total	$13,475
Mobilization (5%)	1.00	LS		$674
Contingencies (10%)	1.00	LS		$1,348
	Total + Mobilization and Contingencies			**$15,496**


SITE 19
N
Tanyard Branch
CONCEPTUAL CROSS SECTION
EXISTING GROUND
BANKFULL
LAY BACK BANKS TO BANKFULL
NOT TO SCALE
BANKFULL BENCH
VEGETATED AREA
ALTERNATIVE 2:
LAY BACK BANKS WITH BANKFULL BENCH
AND VEGETATE WITH LOW GROWING GRASS
ALTERNATIVE 1:
LAY BRUSH MATTING ON BOTH BANKS
AND REVEGETATE WITH LOW-GROWING GRASS
ALTERNATIVE 3:
LAY BACK BANKS AND MODIFY
PROFILE AND GEOMETRY
ALTERNATIVE 2 AND 3:
ADD DISSIPATION POOL AT HEAD OF PROJECT
GOMAINS AVE
BYNUM ST
HILL ST
BROAD ST
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
EarthTech
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CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0 25 50 100
Feet
1 inch equals 50 feet

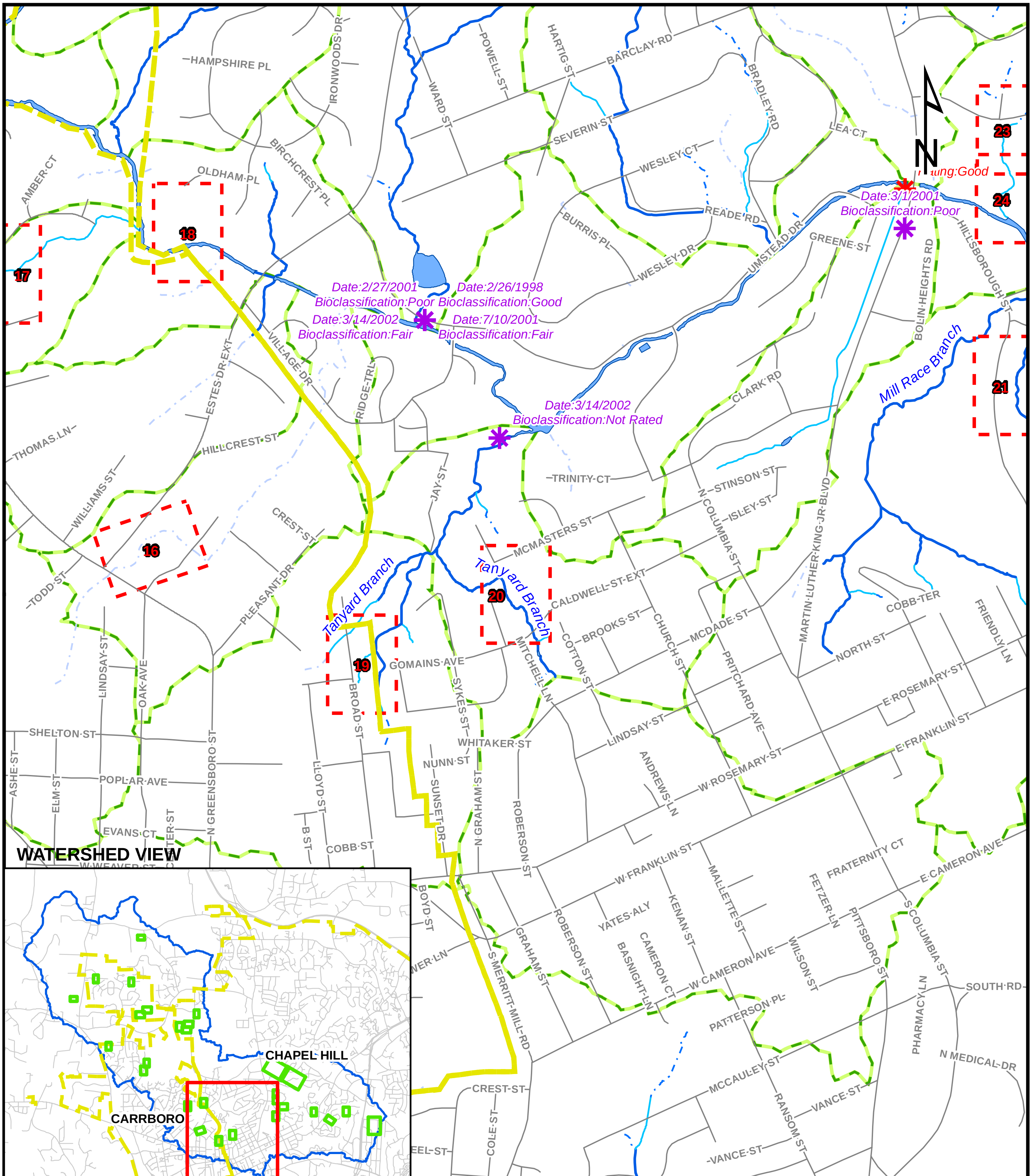
SITE 19
N
Tanyard Branch
BROAD ST
HILL ST
GOMAINS AVE
BYNUM ST
CONCEPTUAL CROSS SECTION
EXISTING GROUND
BANKFULL
LAY BACK BANKS TO BANKFULL
NOT TO SCALE
BANKFULL BENCH
VEGETATED AREA
ALTERNATIVE 2:
LAY BACK BANKS WITH BANKFULL BENCH
AND VEGETATE WITH LOW GROWING GRASS
ALTERNATIVE 1:
LAY BRUSH MATTING ON BOTH BANKS
AND REVEGETATE WITH LOW-GROWING GRASS
ALTERNATIVE 3:
LAY BACK BANKS AND MODIFY
PROFILE AND GEOMETRY
ALTERNATIVE 2 AND 3:
ADD DISSIPATION POOL AT HEAD OF PROJECT
Legend
Stormwater Lines
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
EarthTech
A tyco International Ltd. Company
AERIAL PHOTO VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0 25 50 100
Feet
1 inch equals 50 feet

SITE 20

Stream Restoration/Bank Stabilization on Incised Reach of Tanyard Branch

Index Sheet No.: 24
Raw Data Name: TA 24-01

Estimated Construction Cost: $49,500



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO · March 3, 1911 · NORTH CAROLINA

CHAPEL HILL · 1795 · 1851 · NORTH CAROLINA

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SITE 20

VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs

Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 20	205.9	102.9	50.0%

Location

Site 20 is located north of Caldwell Street Extension, approximately 0.5 miles north of Rosemary Street in downtown Chapel Hill.

Problem Description

Site 20 consists approximately 500 feet of an incised stream channel, Tanyard Branch, with actively eroding, vertical banks and lack of riparian buffer. The stream flows through an urban residential area, and a large culvert before reaching the project site. The eroding streambanks are likely the result of a combination of the upstream road crossing, increased peak flows due to the high percentage of impervious area in the contributing watershed, and lack or riparian vegetation to hold the banks. The mass wasting stream banks are causing export of sediment and associated nutrients. A preliminary investigation of streambank erosion potential using the BANCS model show that approximately 1902 tons of sediment are being exported from the site each year. Concomitant nutrient export associated with the sediment has also been calculated and is listed in **Table 20.1**.

Table 20.1

Pre-Treatment	
Estimated Total Sediment Export	1901.9 tons/year
Erosion per length of Channel	3.7 tons/yr/ft
Pounds of Nitrogen	3803.8 lbs/year
Pounds of Phosphorus	1901.9 lbs/year
Post-Treatment	
Estimated Total Sediment Export	2 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	3.9 lbs/year
Pounds of Phosphorus	2 lbs/year

Proposed Solution

Bank stabilization is the preferred solution to this problem with the addition of re-vegetation after construction is complete. This relatively short stretch of channel is not long enough to restore completely, but reducing near-bank stress could eliminate the majority of the sediment contributions from this reach. Laying back the banks as much as possible, establishing an interior floodplain or bankfull bench and possibly even placing a vane in this section would accomplish the goal of reducing stresses. Brush mattresses may be used to quickly stabilize the modified banks.

As this channel is overly wide, a bankfull bench would and modification to channel cross section geometry would promote channel stability. Revegetation is critical for this site.

Constraints

This site will require a certain degree of either site acquisition or agreement of adjacent landowners to implement the project. The sloping back of banks will place the current stream banks further from the stream channel than they are currently, requiring that a certain amount of land be appropriated for this use. According to Orange County Parcel data, one bank of the proposed reach is owned by the Town of Chapel Hill and Orange County. The other bank, however, is under private ownership, and the landowner would need to be contacted to provide permission for any work done.

Alternatives

There are no proposed alternatives at this site.

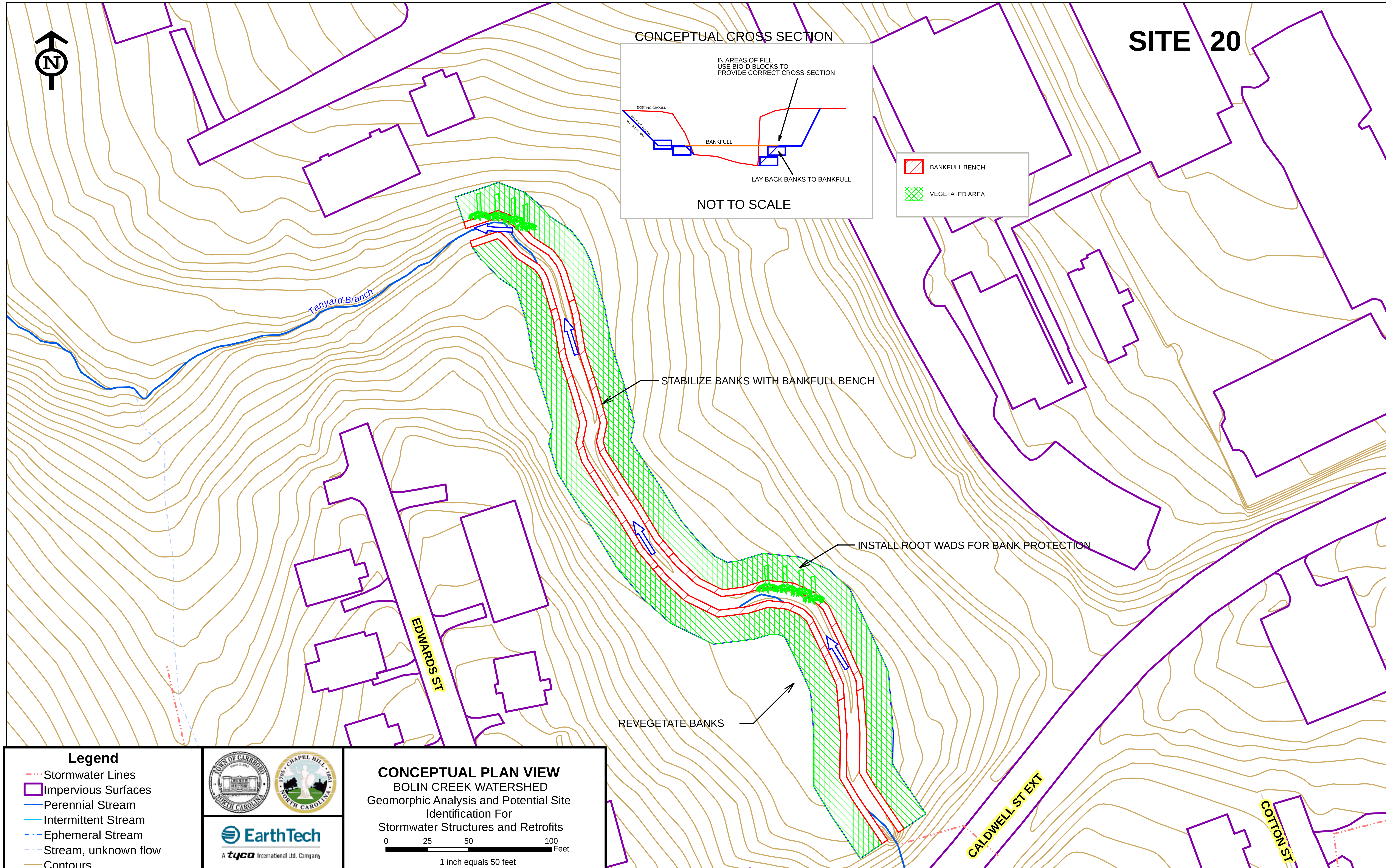
Cost-Estimate Breakdown

Table 20.2 shows a conceptual itemized cost estimate for Site 20. These costs represent construction costs only.

Table 20.2

SITE 20 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	1900.00	CY	15.00	$28,500
Site Preparation and Planting	0.47	AC	7500.00	$3,525
Bio-D Blocks for Bank Stabilization	100.00	LF	20.00	$2,000
Silt Fence	1000.00	LF	3.75	$3,750
Construction Safety Fence	1100.00	LF	2.50	$2,750
Construction Entrance	1.00	Ea	2500.00	$2,500
Root Wads	8.00	Ea	395.00	$3,160
			Total	$43,025
Mobilization (5%)	1.00	LS		$2,151
Contingencies (10%)	1.00	LS		$4,303
	Total + Mobilization and Contingencies			**$49,479**



SITE 20
N
CONCEPTUAL CROSS SECTION
IN AREAS OF FILL
USE BIO-D BLOCKS TO
PROVIDE CORRECT CROSS-SECTION
EXISTING GROUND
DESIGN GROUND
MAX 2:1 SLOPE
BANKFULL
LAY BACK BANKS TO BANKFULL
NOT TO SCALE
BANKFULL BENCH
VEGETATED AREA
Tanyard Branch
STABILIZE BANKS WITH BANKFULL BENCH
INSTALL ROOT WADS FOR BANK PROTECTION
REVEGETATE BANKS
EDWARDS ST
CALDWELL ST EXT
COTTON ST
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
EarthTech
A tyco International Ltd. Company
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0
25
50
100
Feet
1 inch equals 50 feet

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

EarthTech
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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For
Stormwater Structures and Retrofits

0 25 50 100 Feet

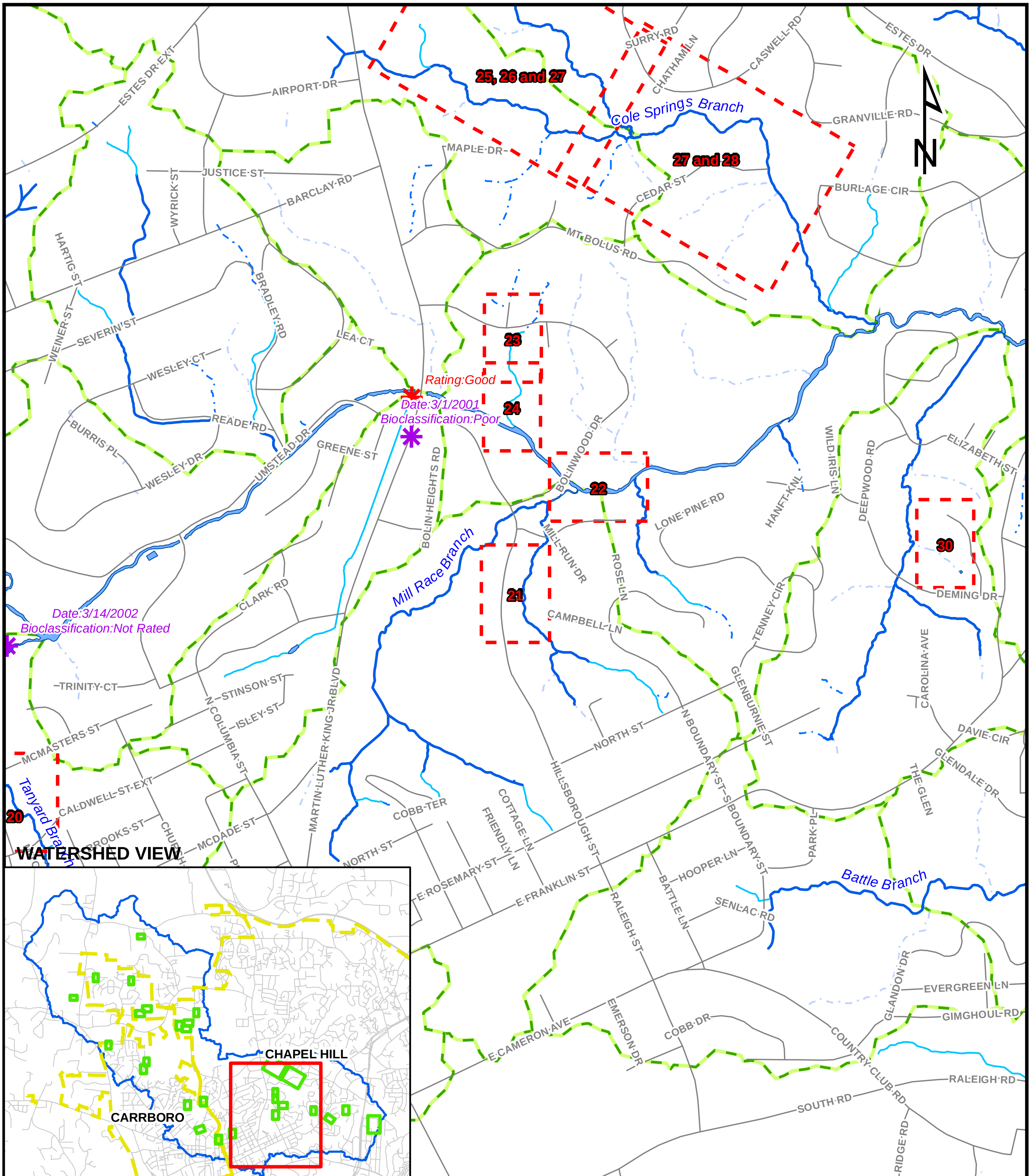
1 inch equals 50 feet

SITE 21

Restoration of Stormwater Outfall and Gulley off of Hillsborough St.

Index Sheet No.: 25
Raw Data Name: IJ 43

Estimated Construction Cost: $52,000



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 21

VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs

Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 21	3.4	1.9	54.8%

Location

Site 21 is located off of Hillsborough Street, approximately 0.3 miles north of the intersection of Hillsborough St. and Rosemary St.

Problem Description

Site 21 consists of a deep, actively eroding gulley on a hillside below a stormwater pipe outlet from Hillsborough Street.

Stormwater runoff from Hillsborough Street and surrounding houses collects into a curb and gutter system along the street, and then is discharged at several outlets as the street runs downhill from the downtown area of Chapel Hill towards Bolin Creek. One of these outlets discharges at the top of a steep hill, with a drop of approximately 30 feet over a distance of approximately 100 feet. At the base of the hill is a tributary to Bolin Creek. There is no energy dissipation structure at this outlet, and thus the stormwater has concentrated as it flows downhill towards the steam, forming a massive gulley that is approximately 8 feet deep. The sides of this gulley are actively eroding, and likely contributing a large amount of sediment to the watershed each year.

Using the BANCS model, it is estimated that approximately 700 tons of sediment are being exported from the site each year. Concomitant nutrient export associated with the sediment has also been calculated and is listed in **Table 21.1**. In addition, pollutant loads have been calculated based on impervious area and land use, and are shown in **Table 21.1**.

Table 21.1

Pre-Treatment	
Estimated Total Sediment Export	701 tons/year
Erosion per length of Channel	7.7 tons/yr/ft
Pounds of Nitrogen	1402.1 lbs/year
Pounds of Phosphorus	701 lbs/year
Post-Treatment	
Estimated Total Sediment Export	0.1 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	0.2 lbs/year
Pounds of Phosphorus	0.1 lbs/year

Proposed Solution

The target of treatment at this site is reduction of sediment caused by erosion, and thus the best solution is to restore the gulley into an "A" type-channel, which is stream type that would typically be found on a very steep slope (Rosgen, 1996). An "A" channel typically consists of large boulders and a run-pool sequence, with the direction and path of flow controlled by the location of rocks and boulders. These channels are typically very stable and are not a source of sediment export.

Constructing an "A" channel at this site would preclude the need to fill the existing gulley, as the channel could be constructed entirely within the gulley. At the bottom of the channel, a wet detention pond should be constructed with an energy dissipation pool. The water will potentially infiltrate through the bottom of the pond, providing base-flow augmentation to the perennial stream below, and overflow control will be provided by two level spreaders situated parallel to the stream channel. The level spreaders provide a distribution of flows that enter the stream. In addition to providing reduction in sediment export, the wet detention basin will serve to treat the pollutants in the stormwater runoff from Hillsborough St. An estimate of the reduction of sediment as a result of this practice has been calculated and is shown in **Table 21.2**. Pollutant reduction rates as a result of stormwater treatment are shown in **Table 21.2**.

Table 21.2

Site 21	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	16.82	2.66	357.95
WET DETENTION TREATMENT	25.00%	40.00%	85.00%
NET REDUCTION	4.21	1.06	304.26
FUTURE CONDITION	12.62	1.60	53.69

Constraints

The chief constraint of Site 21 is the difficulty of working in the existing gulley. Because of the steep side slopes and depth of the gulley, gaining access with equipment may be difficult.

Alternatives

Two alternatives are proposed for this site:

Alternative 1: Construct an "A" channel in the existing gulley, using large boulders and stone to define the channel. Construct a wet detention basin at the bottom of the hillslope, containing a permanent pool where the channel meets the basin, to provide energy dissipation. The depth of the basin should be higher in elevation than the bed of the stream, so that groundwater will discharge from the basin and recharge the stream. The bottom of the basin should consist of a porous soil media to allow infiltration through the soil. The overflow structure will be two level spreaders situated parallel to the stream.

Alternative 2: Construct a concrete-lined channel with friction blocks, rather than an "A" channel, and the wet detention basin and level spreaders described above.

Cost-Estimate Breakdown

Tables 21.3 and 21.4 show a conceptual itemized cost estimate for the two alternatives of Site 21. These costs represent construction costs only. The cost for the wet detention pond is derived from an equation developed by Brown and Schueler (1997). The contingency fee for this site has been increased due to the difficulty of access.

Table 21.3

SITE 21 Alternative 1

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	40.00	CY	15.00	$600
Wet Detention Pond	3518.0	CF	Equation Derived	$25,408
Site Preparation and Planting	0.10	Ac	7500.00	$750
Rip Rap Class B	5.00	Tons	45.00	$225
Filter Fabric	15.00	SY	5.00	$75
Boulders	25.00	Tons	200.00	$5,000
Silt Fence	100.00	LF	3.75	$375
Level Spreader	2.0	EA	3000.00	$6,000
Construction Safety Fence	300.00	LF	2.50	$750
Construction Entrance	1.00	Ea	2500.00	$2,500
			Total	$41,683
Mobilization (5%)	1.00	LS		$2,084
Contingencies (20%)	1.00	LS		$8,337
	Total +	Mobilization and Contingencies		**$52,104**
Maintenance Costs				
Maintenance (5% of base construction cost of BMP)	1.0	Year		**$1,270**

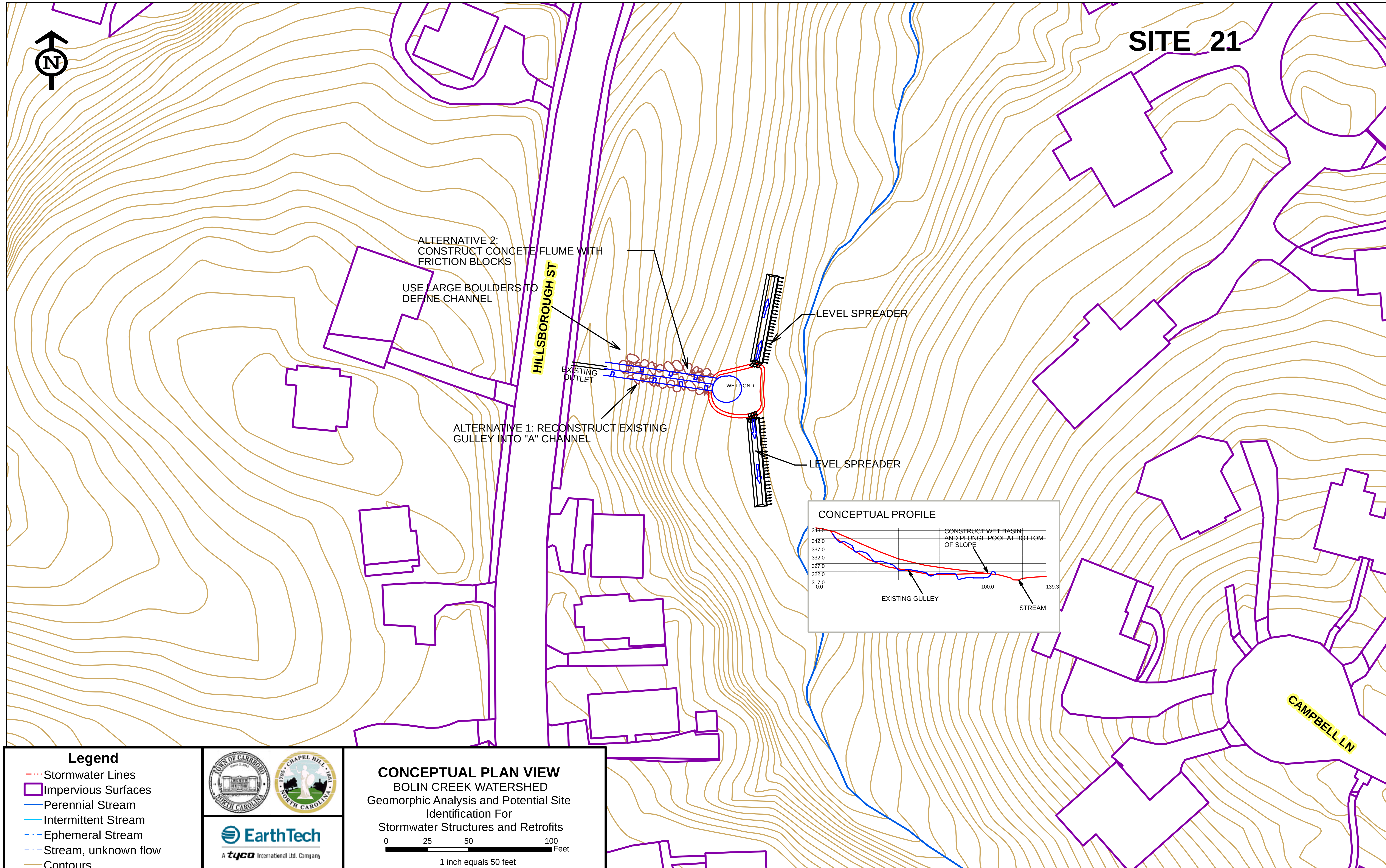
Table 21.4

SITE 21 Alternative 2

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	40.00	CY	15.00	$600
Wet Detention Pond	3518.0	CF	Equation Derived	$25,408
Site Preparation and Planting	0.10	Ac	7500.00	$750
Rip Rap Class B	5.00	Tons	45.00	$225
Filter Fabric	15.00	SY	5.00	$75
Silt Fence	100.00	LF	3.75	$375
Level Spreader	2.0	EA	3000.00	$6,000
Concrete Lined Channel with Friction Blocks	5.00	CY	500.00	$2,500
Construction Safety Fence	300.00	LF	2.50	$750
Construction Entrance	1.00	Ea	2500.00	$2,500
			Total	$39,183
Mobilization (5%)	1.00	LS		$1,959
Contingencies (20%)	1.00	LS		$7,837
	Total + Mobilization and Contingencies			**$48,979**

Maintenance Costs

Maintenance (5% of base construction cost of BMP)	1.0	Year		**$1,270**



CONCEPTUAL PLAN VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

0 25 50 100 Feet

1 inch equals 50 feet

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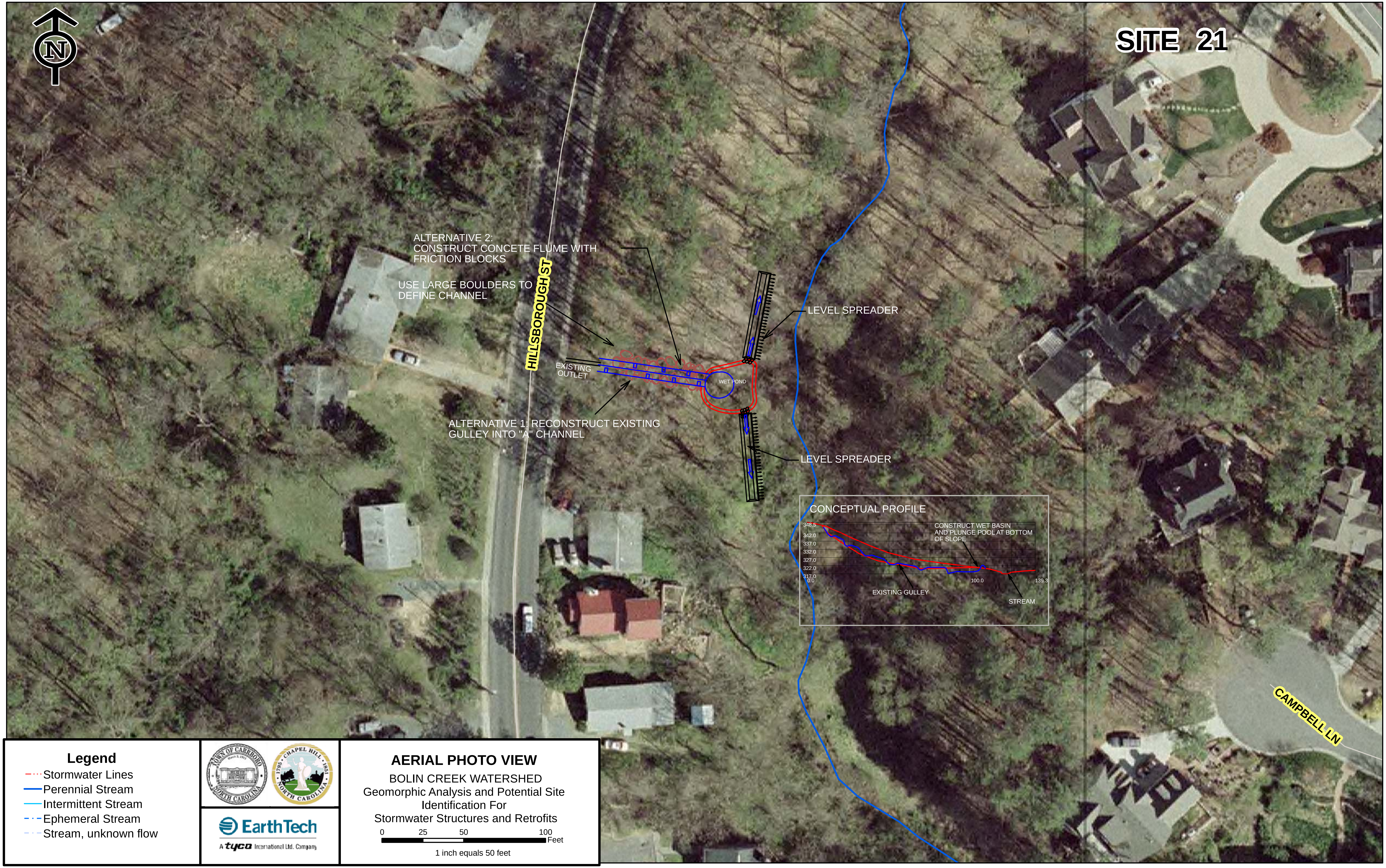

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO NORTH CAROLINA

CHAPEL HILL 1793 1851 NORTH CAROLINA

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

0 25 50 100 Feet

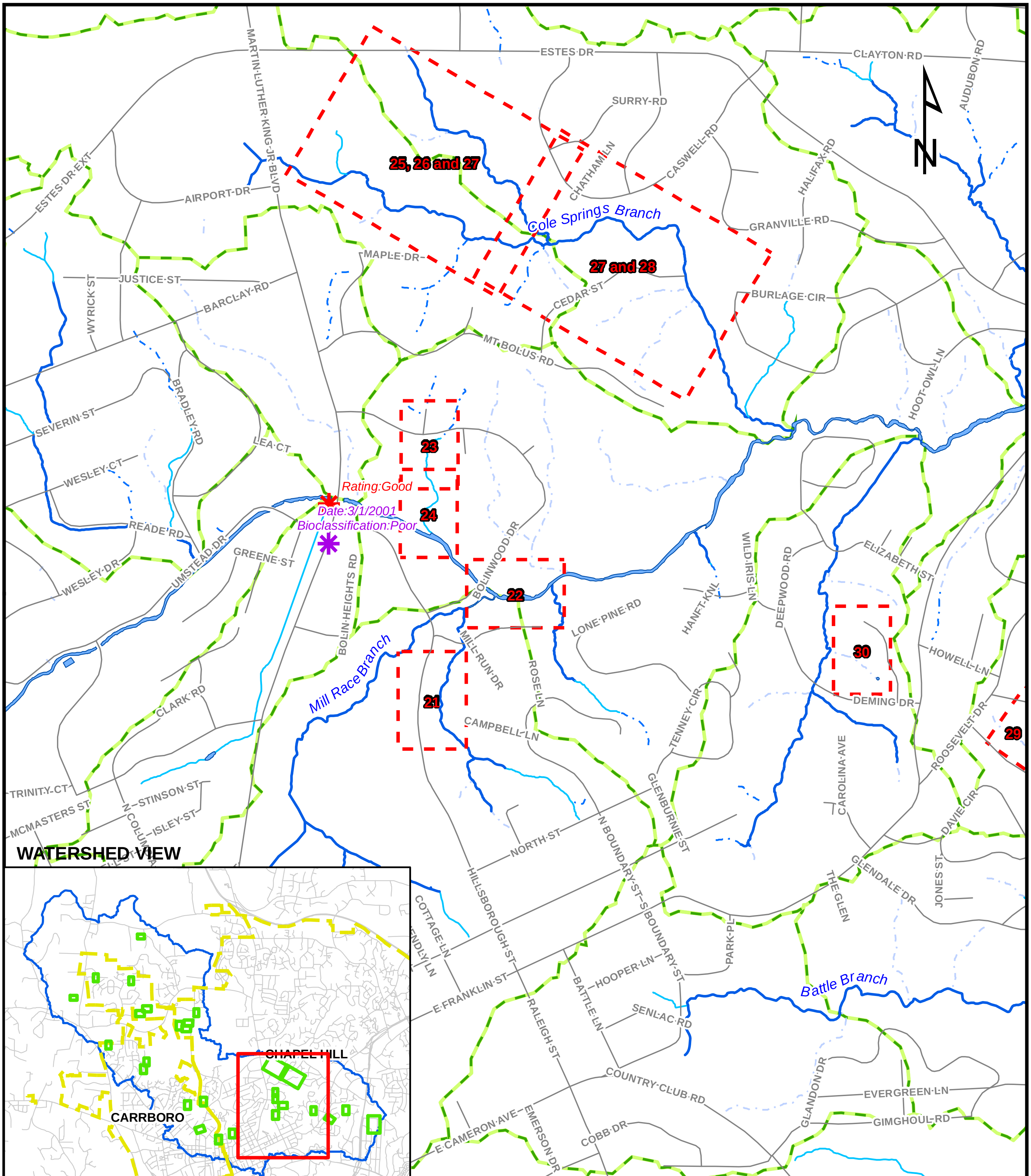
1 inch equals 50 feet

SITE 22

Stabilization of Bank Erosion on Bolin Creek

Index Sheet No.: 25
Raw Data Name: IJ 53

Estimated Construction Cost: $72,500



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

SITE 22
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

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Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 22	6050.0	780.5	12.9%

Location

Site 22 is located on Bolin Creek, just to the east of Bolinwood Drive. The site can be accessed by a greenway trail running parallel to Bolin Creek.

Problem Description

Site 22 consists of a massive, actively eroding bank along Bolin Creek. The bank is approximately 18 feet high at its highest point, and extends downstream for approximately 200 feet. The bank is the result of the stream flowing against the hillside at the edge of the streams valley, where it was probably moved during construction of the sewer line that runs parallel to Bolin Creek. Orange County tax parcel data shows that the properties which abut this bank have lost a significant amount their land to the erosion.

Using the BANCS model, it is estimated that approximately 1900 tons of sediment are being exported from the site each year. Concomitant nutrient export associated with the sediment has also been calculated and is listed in **Table 22.1**.

Table 22.1

Pre-Treatment	
Estimated Total Sediment Export	1889.3 tons/year
Erosion per length of Channel	8.7 tons/yr/ft
Pounds of Nitrogen	3778.7 lbs/year
Pounds of Phosphorus	1889.3 lbs/year
Post-Treatment	
Estimated Total Sediment Export	1.8 tons/year
Erosion per length of Channel	0.008 tons/yr/ft
Pounds of Nitrogen	3.7 lbs/year
Pounds of Phosphorus	1.8 lbs/year

Proposed Solution

Site 22 needs stabilization of the hillside that has been eroded by the flow of Bolin Creek. If the erosion continues, tons of sediment will continue to be exported each year, and the adjacent landowners will continue to lose more of their property. Stabilization of the hillside will require a fill slope to be placed against the existing eroded bank at a slope of 2:1 or less. Doing this will also require relocation of the existing stream channel (see

Plan View). The existing stream channel should then be filled, which will provide a floodplain for the new channel. The entire site should then be planted with native vegetation. Structures such as root wads and cross vanes can be used to temporarily protect the newly constructed banks while the vegetation becomes established. These types of projects have a very high rate of success when the constructed project has the proper bankfull height, thus providing flood plain access. This project is a very high priority and also has a high chance for success.

Constraints

While an existing drainage easement may exist at the site, as evidenced by the sewer line running parallel to the stream, Orange County Tax Parcel data shows the land surrounding Bolin Creek is privately owned. Thus permission may need to be obtained to perform the recommended treatment at the site. It is assumed the landowners will be cooperative with efforts to keep them from continuing to loose their property

The greenway and sewer lines run parallel to Bolin Creek at Site 22, therefore the relocation of the stream channel should be adjusted to maintain an adequate distance from these two features. Based on preliminary Proposed Solution, however, there is sufficient room to construct a fill slope and new channel without impacting the sewer line or greenway trail.

A floodway analysis and submission of a conditional letter of map revision (CLOMR) will likely be needed to determine if there will be any increase or decrease in flood elevations as a result of relocating Bolin Creek.

Alternatives

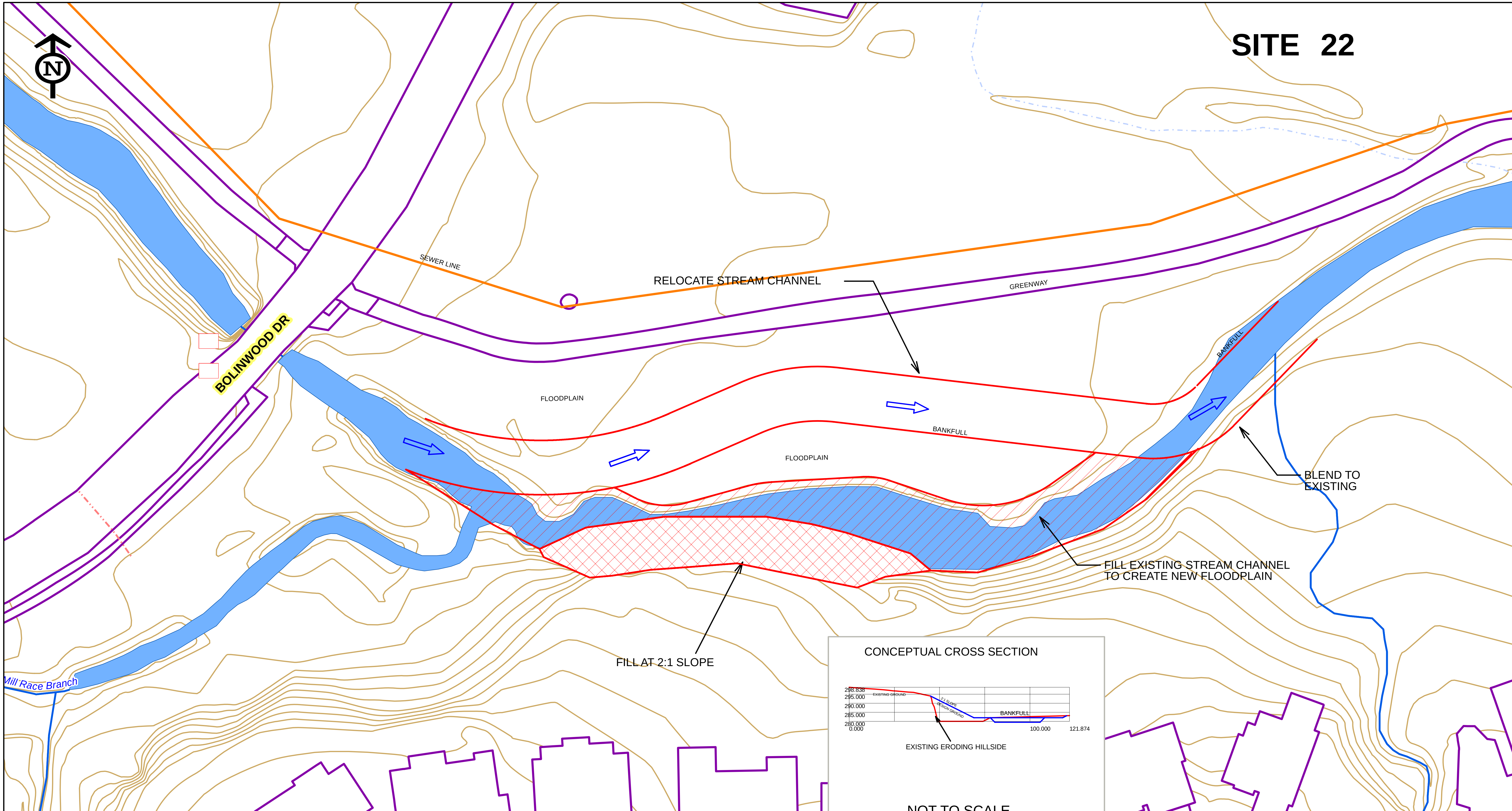
There are no alternatives proposed for this site.

Cost-Estimate Breakdown

Table 22.2 shows a conceptual itemized cost estimate for Site 22. These costs represent construction costs only.

Table 22.2

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	2500.00	CY	15.00	$37,500
Plantings	0.80	Ac	7500.00	$6,000
Root Wads	8.00	Ea	395.00	$3,160
Cross Vane	2.00	Ea	5000.00	$10,000
Silt Fence	575.00	LF	3.75	$2,156
Construction Safety Fence	700.00	LF	2.50	$1,750
Construction Entrance	1.00	Ea	2500.00	$2,500
			Total	$63,066
Mobilization (5%)	1.00	LS		$3,153
Contingencies (10%)	1.00	LS		$6,307
	Total + Mobilization and Contingencies			**$72,526**



Legend

- Stormwater Lines
- Impervious Surfaces
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow
- Contours

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CONCEPTUAL PLAN VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

0 25 50 100 Feet

1 inch equals 50 feet

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For
Stormwater Structures and Retrofits

0 25 50 100 Feet

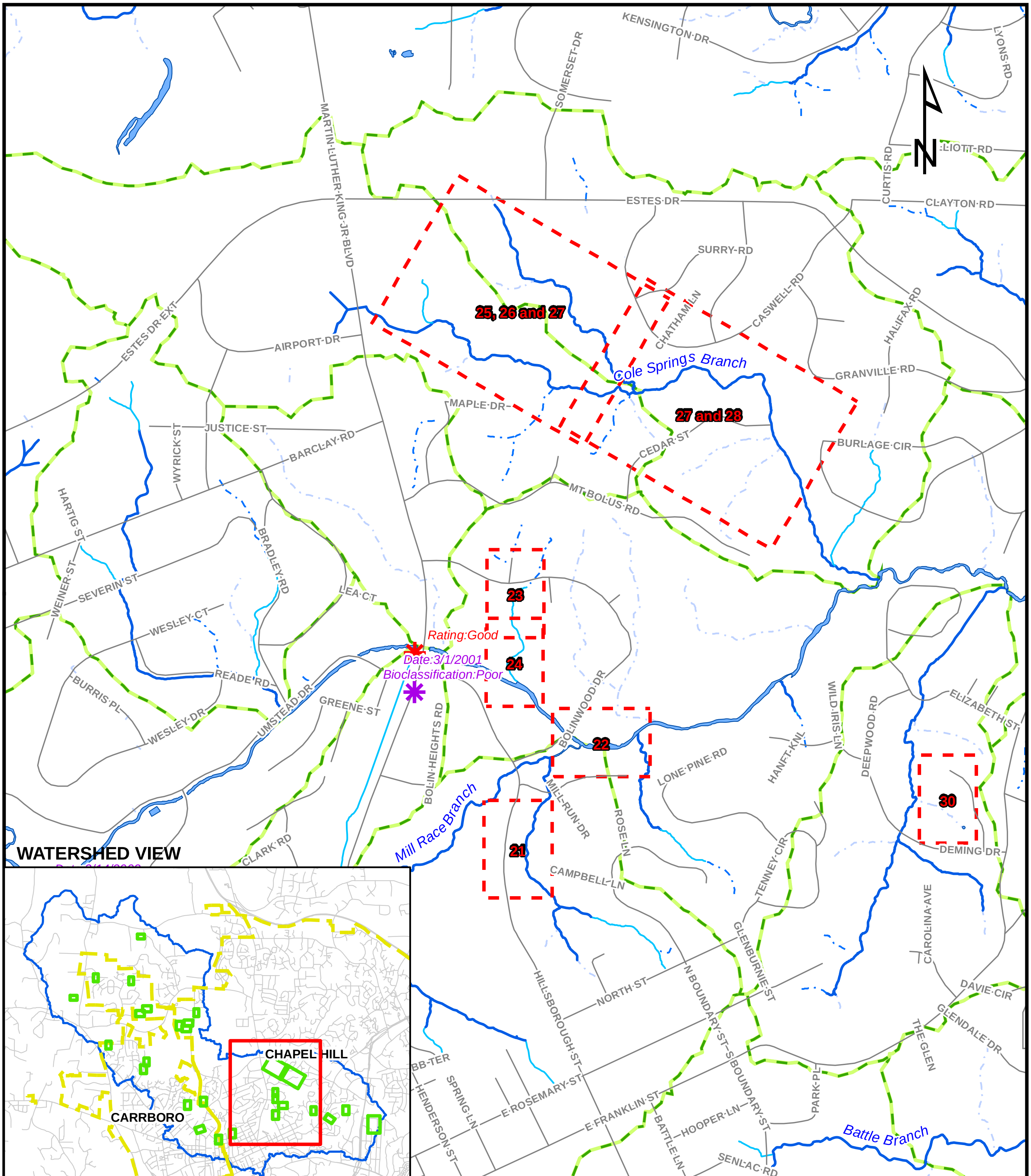
1 inch equals 50 feet

SITE 23

Retrofit of Existing Sediment Basin in Residential Area off Bolinwood Drive

Index Sheet No.: 25
Raw Data Name: BD 57

Estimated Construction Cost: $32,000



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 23

VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs

Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 23	14.5	2.6	18.1%

Location

Site 23 is located just south of Bolinwood Drive, near its intersection with Mullin Ct. The site is approximately 700 feet to the east of the intersection of Bolinwood Drive and Martin Luther King Jr .Blvd.

Problem Description

Site 23 consists of an existing sediment basin at a pipe outlet just south of Bolinwood Drive. The basin was likely built during construction of the surrounding neighborhood to collect sediment from runoff during construction. The basin has now filled in, and consists only of a rip rap berm and a long, flat area of silt and clay. Small trees have grown up in the basin over the intervening years, and the entire site is surrounded by a young forest. Stormwater from the culvert currently passes over the basin without any significant retention or detention, and then concentrates into a scoured channel just downhill of the basin. Due to these existing conditions, there is no water quality treatment of the runoff of the contributing drainage area, which consists of a residential area of large houses and driveways. The ephemeral drain downstream of the old basin is eroding and shows signs of hydraulic stress from concentrated flows. The downstream channel is incised and actively headcutting upstream. This headcut is addressed in Site 24.

Proposed Solution

The existing basin at Site 23 poses a good opportunity for a BMP retrofit in the form of a bioretention area. The existing basin is relatively long, which will provide an adequate flow path ratio of greater than 3:1, which is recommended for bioretention areas (DWQ, 2007). In addition, excavation will be limited to digging out the depth needed for adequate water quality storage volume. The storage volume in the bioretention area will reduce the runoff volume for the downstream reach, change the timing of peak flows and reduce peak flows leaving the site. This site would assist in the successful stabilization of the reach in site 24.

The current nutrient export rates, and potential benefit of a bioretention area here have been calculated based on land use, drainage area and percent imperviousness of the drainage area, and are displayed in **Table 23.1**:

Table 23.1

SITE 23	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	6.89	0.45	172.89
BIORETENTION TREATMENT REMOVAL %	35.00%	45.00%	85.00%
NET REDUCTION	2.41	0.20	146.95
FUTURE CONDITION	4.48	0.25	25.93

Constraints

Orange County tax parcel GIS data indicates that the property on which Site 23 is located is privately owned by a single landowner. The nearest right of way to this site is Bolinwood Drive. If Site 23 is constructed, it is advisable to implement these two designs simultaneously and access may be more feasible by selected pathway through the forest along the reach from the downstream site.

Alternatives

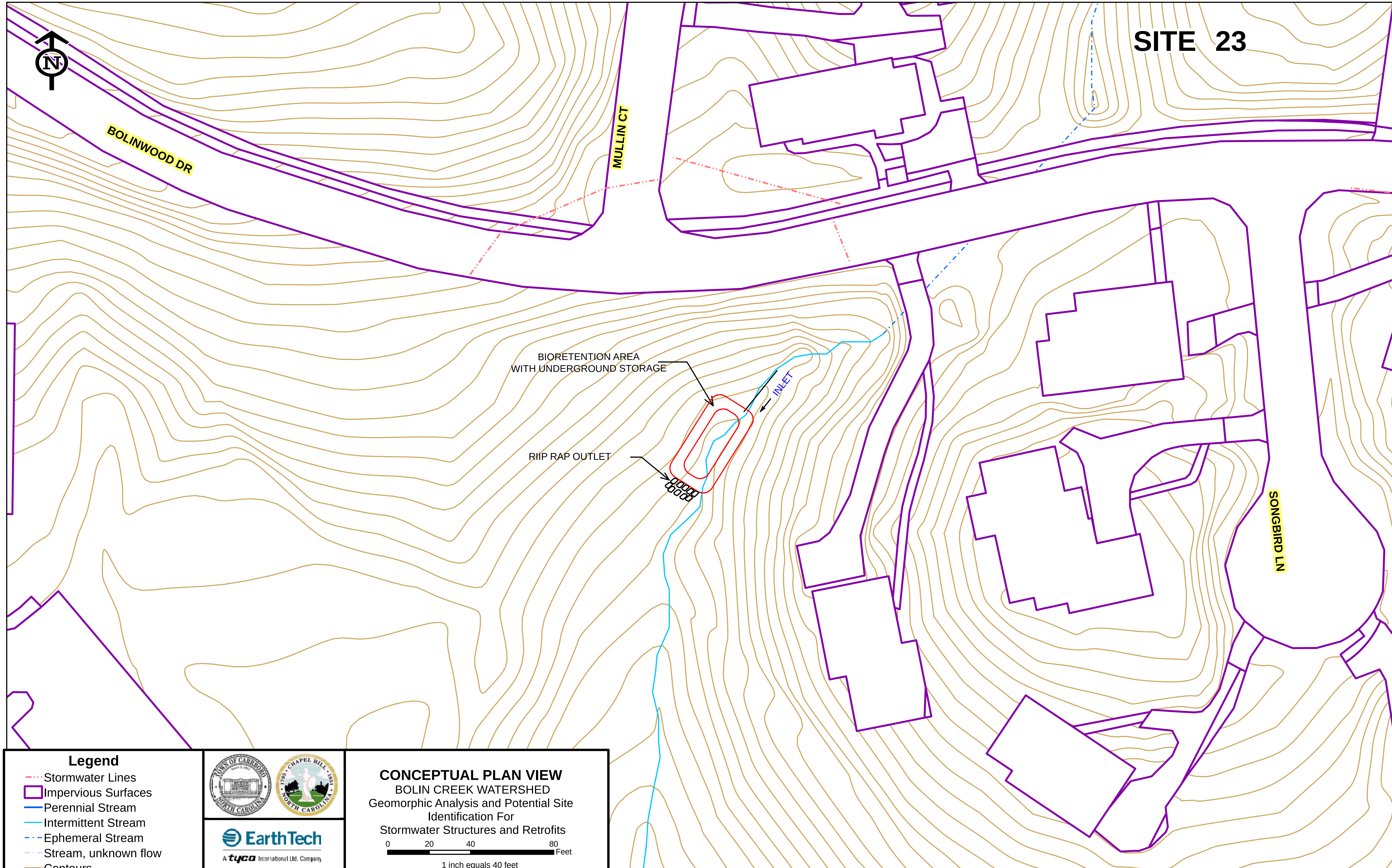
There are no alternatives proposed for this site.

Cost-Estimate Breakdown

Table 23.2 shows a conceptual itemized cost estimate for Site 23. These costs represent construction and maintenance costs only. The cost for the bio-grade step is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007). The contingency fee for this site has been increased due to the difficulty of access.

Table 23.2
SITE 23 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Bio-Retention Area	2115.00	CY	12.62	$26,691
			Total	$26,691
Mobilization (5%)	1.00	LS		$1,335
Contingencies (15%)	1.00	LS		$4,004
	Total + Mobilization and Contingencies			**$32,030**
Maintenance Costs				
Maintenance (5% of base construction cost of BMP)	1.0	Year		**$1,601**



Legend

- Stormwater Lines
- Impervious Surfaces
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow
- Contours

TOWN OF CARRBORO NORTH CAROLINA

CHAPEL HILL 1793 1851 NORTH CAROLINA

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CONCEPTUAL PLAN VIEW

BOLIN CREEK WATERSHED

Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

0 20 40 80 Feet

1 inch equals 40 feet

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO NORTH CAROLINA
CHAPEL HILL 1793 1851 NORTH CAROLINA

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

0 20 40 80 Feet

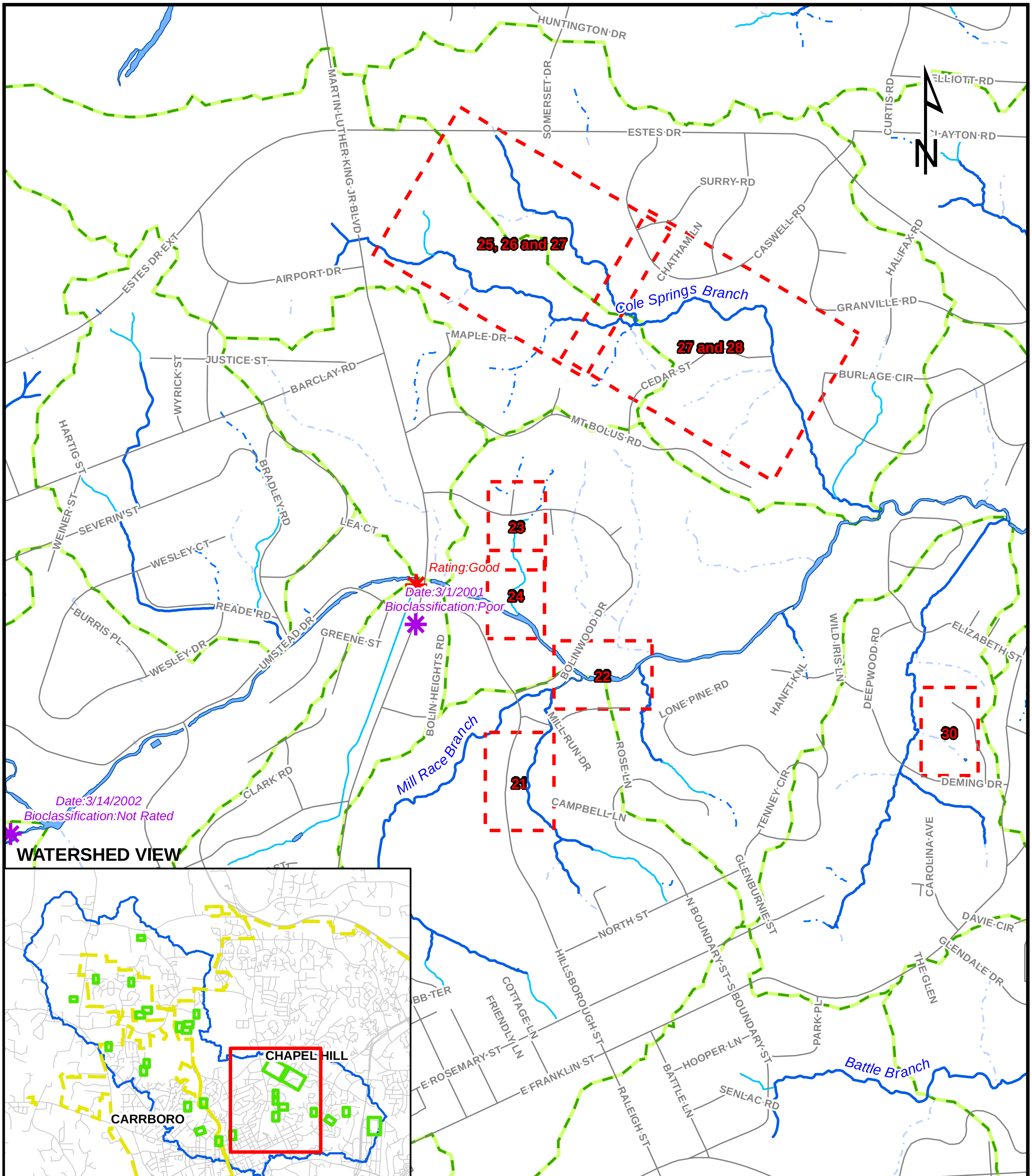
1 inch equals 40 feet

SITE 24

Construction of Bioretention Cells for Pollutant Removal at Apartment Complex

Index Sheet No.: 25
Raw Data Name: BD 55

Estimated Construction Cost: $107,500



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 24

VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 24	18.0	2.9	16.2%

Location

Site 24 is located on the western edge of an apartment complex adjacent to Bolinwood Drive, and to the north of the Bolin Creek Greenway.

Problem Description

Site24 consists of 140 feet of an incised, actively eroding stream (low bank height approximately 4 feet). A very prominent headcut (approximately 3' vertical in 1' horizontal) marks the top of this site (upstream). The head cut is active and undercut, demonstrating a high degree of mobility. A BEHI rating of "extreme" was found for the entire length of the channel. Likely causes of this incision are the increase in peak flows of the contributing drainage area due to development, headcut effects caused by the past construction of the greenway downstream, and possible stream modification during the construction of the adjacent apartment complex. The stream flows into Bolin Creek only 70 feet downstream of the site, after passing under the Bolin Creek Greenway.

Using a modified BANCS model, it is estimated that approximately 377.5 tons of sediment are being exported from the site each year. Concomitant nutrient export associated with the sediment has also been calculated and is listed in **Table 24.1**.

Table 24.1

Pre-Treatment	
Estimated Total Sediment Export	377.5 tons/year
Erosion per length of Channel	2.7 tons/yr/ft
Pounds of Nitrogen	755 lbs/year
Pounds of Phosphorus	377.5 lbs/year
Post-Treatment	
Estimated Total Sediment Export	0.3 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	0.6 lbs/year
Pounds of Phosphorus	0.3 lbs/year

Proposed Solution

The contributing drainage area of the stream at Site 24 is comprised of 16% impervious area, consisting of large homes, driveways, parking pads, apartment complexes and roads. Treatment of the runoff of this area is warranted especially by the fact that the stream flows directly into Bolin Creek after only a short distance, without any intervening storage or detention. However, space is limited within the site, which is composed of young pines and hardwoods, and a relatively narrow valley (man made). Thus, the preferred solution is the construction of a "bio-grade step", which is a series of small bio-retention cells filled with a filter media, such as a mixture of sand fines and organic mater (see Appendix A-Details). Ideally, this media will have a filtration rate of 1.0 to 2.0 inches per hour, to optimize pollution removal (Schueler, et. al., 2007). Each cell is connected to the other through a seepage or drain layer, thus allowing stormwater to filter through each cell and augment baseflow to the receiving channel. The combination of the underground storage volume that results from each cell can create a significant reduction in runoff volume to receiving waters and attenuates the peak flow rates. The individual cells must drain over time to regain the available storage volume for the next rain event. Below the bio-grade step, an energy dissipation, stilling/ boulder basin(see Appendix A-Details), should be built to dissipate any overflow before reaching the greenway and Bolin Creek.

Table 24.2

SITE 24	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	9.50	0.96	129.14
BIORETENTION TREATMENT REMOVAL %	35.00%	45.00%	85.00%
NET REDUCTION	3.33	0.43	109.77
FUTURE CONDITION	6.18	0.53	19.37

Constraints

The channel on which treatment is proposed is labeled as "intermittent" by Chapel Hill GIS stream data. This stream status was not verified during the course of this study. If this is the case, construction of an in-line bioretention area may not be allowed under NCDWQ rules. Earth Tech observations just upstream of this site indicate that this reach is likely to be ephemeral due to the lack of a clearly defined channel upstream of the head cut. Obviously, the scour channel downstream of the headcut gives the impression of a stream. It would require further analysis to determine the status of the channel.

The site is partially owned by the Town of Chapel Hill, and partially owned by a private landowner. If the proposed treatment is to be implemented, drainage and access easements must be acquired from the private landowner, as well as a maintenance agreement. Alternatively, a smaller length of channel could be treated using only the land owned by the Town of Chapel Hill.

Alternatives

If this reach classifies as intermittent, another approach would be warranted, such as bank stabilization and installation of grade control to limit the headcut. However, this is not treated as a formal alternative by this report.

Cost-Estimate Breakdown

Table 24.3 shows a conceptual itemized cost estimate for Site 24. These costs represent construction and maintenance costs only. The cost for the bio-grade step is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007).

Table 24.3
SITE 24 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Biograde Step	7410.0	CF	12.62	$93,514
			Total	$93,514
Mobilization (5%)	1.00	LS		$4,676
Contingencies (10%)	1.00	LS		$9,351
	Total + Mobilization and Contingencies			**$107,541**
Maintenance Costs				
Maintenance (5% of base construction cost of BMP)	1.0	Year		**$5,377**

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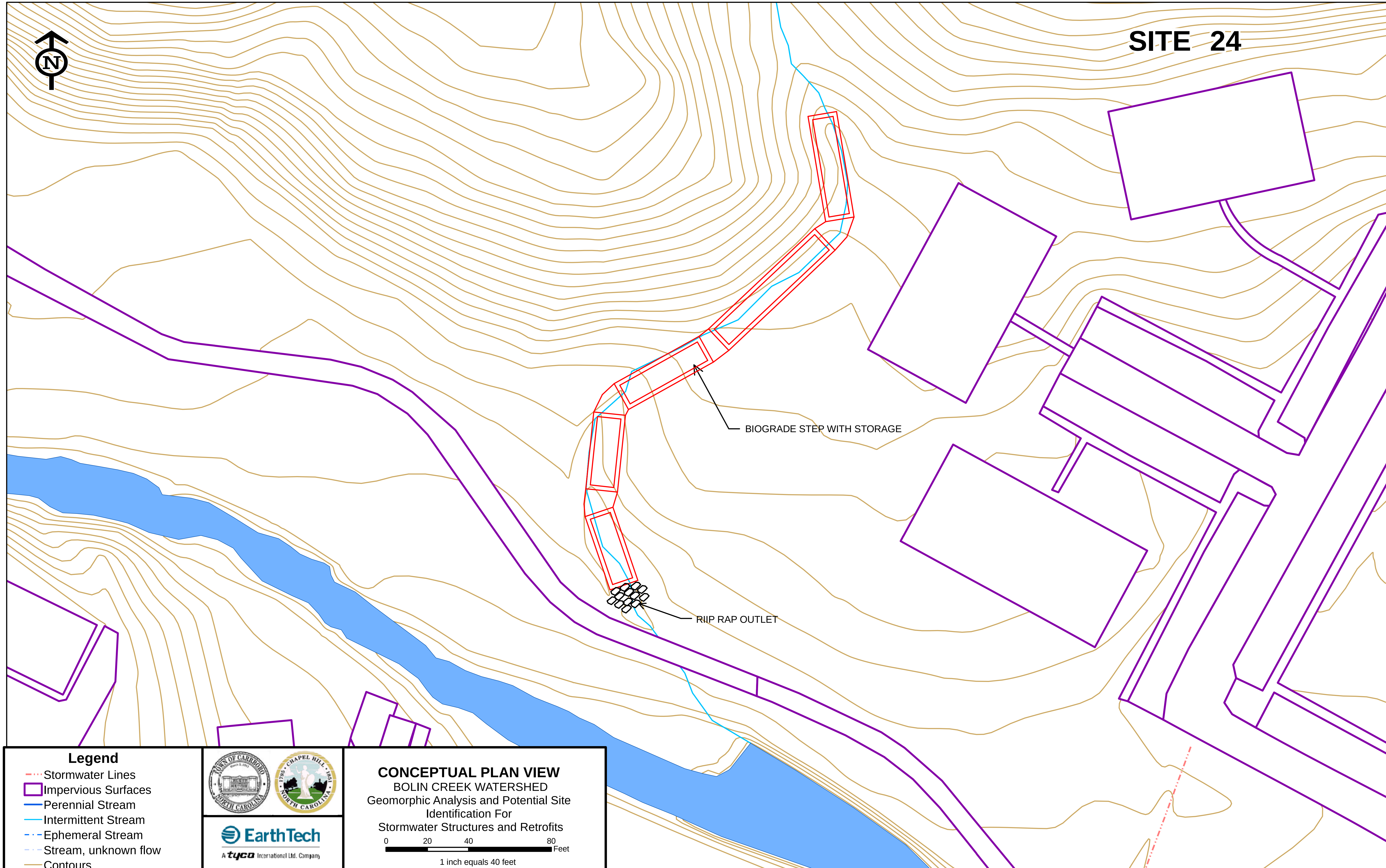

SITE 24
N
BIOGRADE STEP WITH STORAGE
RIIP RAP OUTLET
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
EarthTech
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CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0 20 40 80
Feet
1 inch equals 40 feet

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO NORTH CAROLINA

CHAPEL HILL 1793 1851 NORTH CAROLINA

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

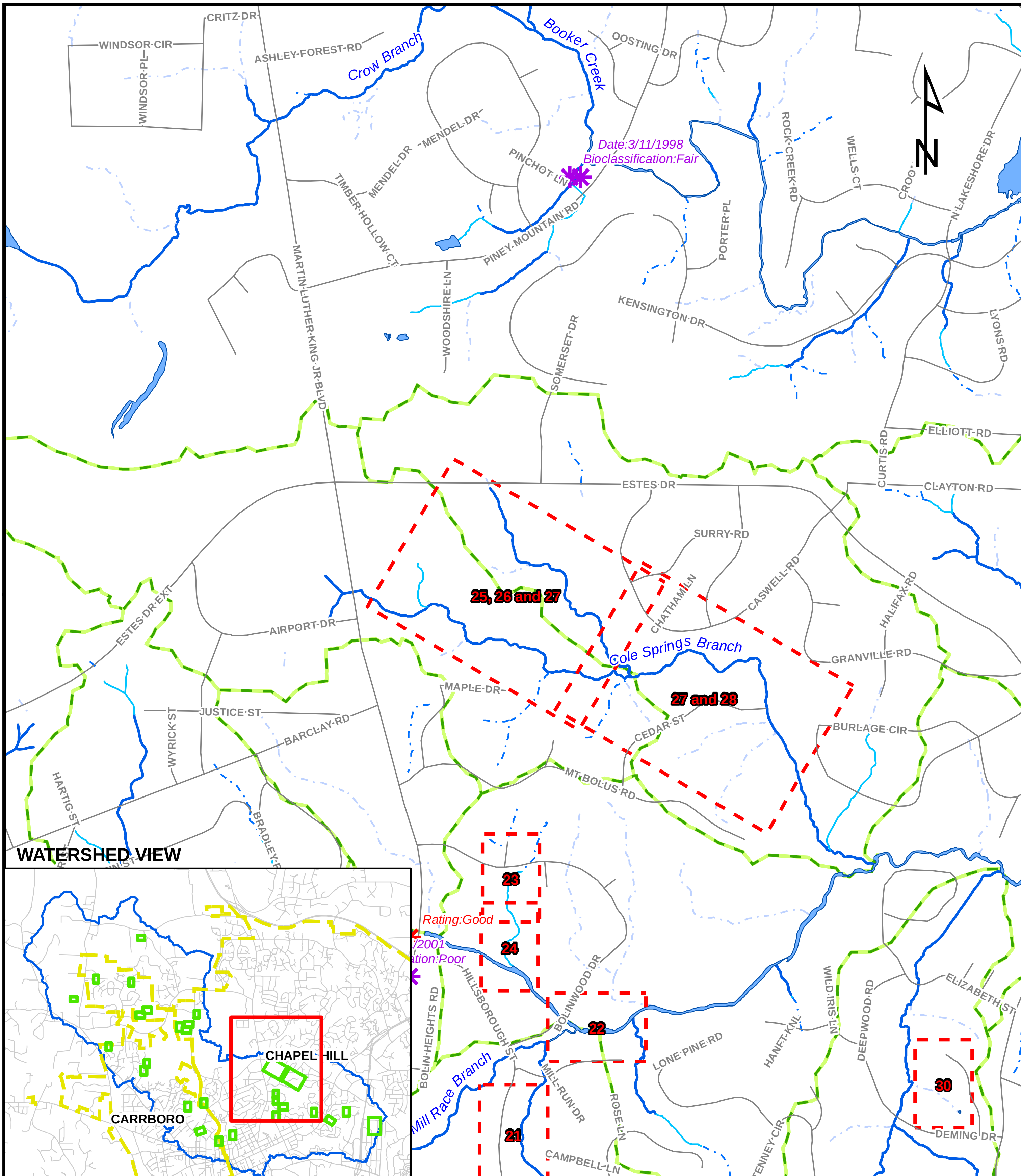
0 20 40 80 Feet

1 inch equals 40 feet

SITE 25

Index Sheet No.: 26
Raw Data Name: BD 58

Estimated Construction Cost: $84,500



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 25, 26 and 27
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

Cole Springs Branch

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 25	161.6	33.2	20.5%

Tributary

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 25	15.0	4.8	32.0%

Location

Site 25 is located approximately 800 feet southeast of the intersection of Martin Luther King Jr. Blvd. and Estes Dr. The site is south of a YMCA facility, on a tributary to a perennial stream, Cole Springs Branch.

Problem Description

The perennial stream along which Site 25 is located, Cole Springs Branch, exhibits severe incision and erosion for most of its course from it's headwaters to where it flows into Bolin Creek. The causes of this widespread degradation are apparent when examining the watershed of the stream, which consists of vast areas of impervious surface, including portions of Horace Williams Airport, the UNC facilities management complex, and high density residential developments. The crossing of Martin Luther King Jr. Blvd. also seems to have adversely affected the stream, as the accumulated and concentrated flow of most of the watersheds imperviousness is discharged after passing under that road.

While the riparian corridor of the stream after passing under Martin Luther King Jr. Blvd is largely intact, many small tributaries, most of which discharge from residential storm sewer systems, continue to flow into Cole Springs Branch before it meets Bolin Creek downstream. The combined problems of peak flow and pollutant input from all of these small drainages likely compounds the degradation already being caused by the accumulated flow and pollutants from upstream of Martin Luther King Jr. Blvd. The majority of the these ephemeral swales show signs of scour and debris packing that would not normally be associated with un-stressed ephemeral channels.

Site 25 is situated on one of these small drainages, and it's watershed consists of the impervious areas of a YMCA and office park facility, as well as residential areas.

Proposed Solution

Site 25 is located at the bottom of what was observed to be an ephemeral drainage, consisting of an incised channel. Two BMPs could possibly be constructed here. A bio-retention area could be placed in-line with the ephemeral channel just before it flows into Cole Springs Branch. Just downstream, a small stormwater wetland could be constructed as an off-line BMP where there is a flat, wide area in the valley of Cole Springs Branch. Off-line retention is needed throughout the watershed of Cole Springs Branch, both to attenuate peak flows and provide pollutant treatment. Base flow augmentation of the Cole Springs Branch could also result from this practice.

The bio-retention area is recommended as an in-line structure here, because of its ability to treat small drainage areas, the fact that it needs minimum area to construct it, and because it can function on steep slopes (NCDWQ, 2007). A bio-retention area would not likely be appropriate in the floodplain of Cole Springs Branch as an offline BMP, as it requires a minimum depth of 2 feet between the water table and the bottom of the retention area, which is a situation which is not often present in a floodplain (NCDWQ, 2007). Instead, a stormwater wetland would be more appropriate. Flow diversion into the wetland would be provided by a flow-splitting structure containing a a vane or weir, placed in Cole Springs Branch. This is a common way to "harvest" storm flows without impeding the base flows of the stream in any way. Such a structure would allow a designed volume of flow to enter into the wetland, while allowing any flow above that volume to continue downstream. If properly placed and designed, a grade control or cross vane can serve this same purpose while acting a grade control for the stream.

Pollutant loads of the contributing drainage area, as well as potential reductions, have been estimated and are displayed in **Table 25.1**.

Table 25.1

SITE 25	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	16.41	1.66	3344.86
BIORETENTION TREATMENT	35.00%	45.00%	85.00%
NET REDUCTION	5.74	0.75	2843.13
FUTURE CONDITION	10.66	0.91	501.73

Constraints

Most of the site consists of a mature hardwood forest, and therefore tree removal will be necessary at this site for both BMPs.

The site is located on two privately owned properties. Access to the site may be difficult due to the steep terrain and wooded condition of the site.

Alternatives

No alternatives are proposed for this site.

Cost-Estimate Breakdown

Table 25.2 shows a conceptual itemized cost estimate for Site 25. These costs represent construction and maintenance costs only. The cost for stormwater wetlands is derived from an equation developed by Brown and Schueler (1997). The cost for the bioretention area is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007).

Table 25.2
Site 25 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Bio-Retention Area	4602.00	CF	12.62	$58,077
Stormwater Wetland	5547.0	CF	Equation Derived	$12,399
			Total	$70,476
Mobilization (5%)	1.00	LS		$3,524
Contingencies (15%)	1.00	LS		$10,571
	Total	**+ Mobilization and Contingencies**		**$84,571**
Maintenance Costs				
Maintenance (5% of base construction cost of BMP)	1.0	Year		**$4,229**

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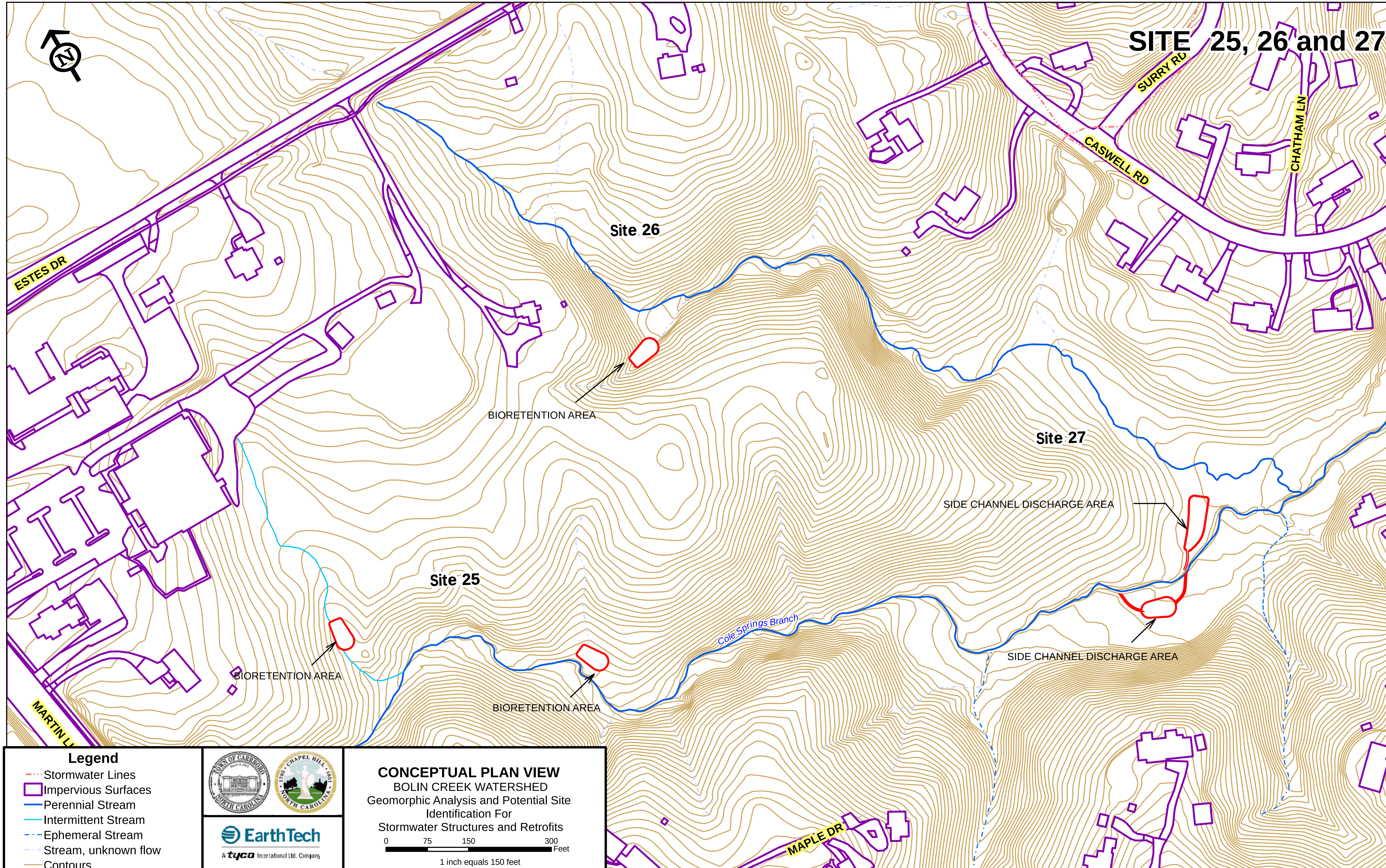
SITE 25, 26 and 27
N
ESTES DR
SURRY RD
CASWELL RD
CHATHAM LN
MARTIN L
MAPLE DR
Site 26
Site 25
Site 27
BIORETENTION AREA
BIORETENTION AREA
BIORETENTION AREA
SIDE CHANNEL DISCHARGE AREA
SIDE CHANNEL DISCHARGE AREA
Cole Springs Branch
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
TOWN OF CARRBORO
NORTH CAROLINA
CHAPEL HILL
1793
1851
NORTH CAROLINA
EarthTech
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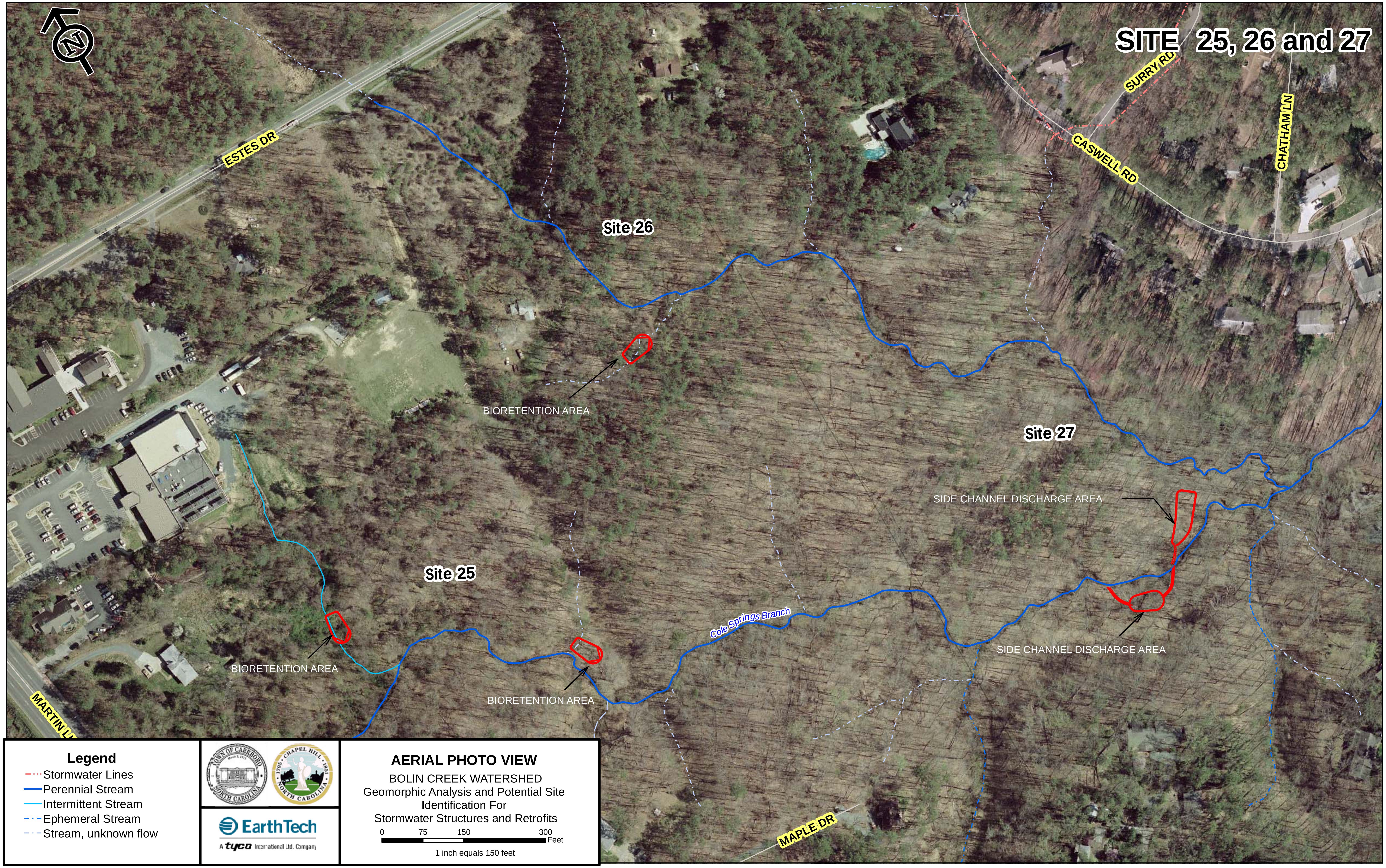
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0
75
150
300
Feet
1 inch equals 150 feet



Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For
Stormwater Structures and Retrofits

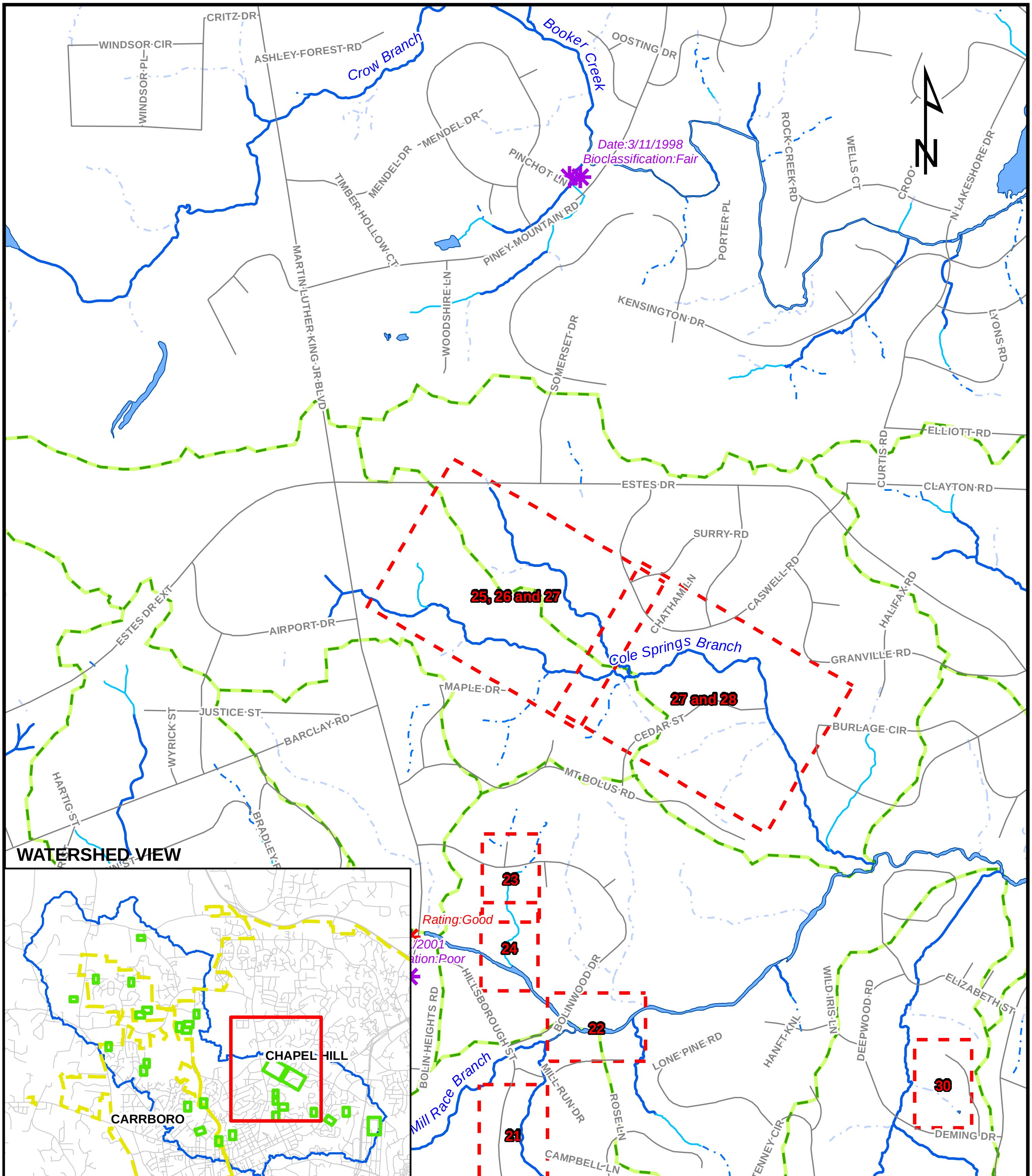
0 75 150 300 Feet

1 inch equals 150 feet

SITE 26

Index Sheet No.: 26
Raw Data Name: BD 71

Estimated Construction Cost: $69,400



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 25, 26 and 27

VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 26	29.0	3.0	10.3%

Location

Site 26 is located approximately 800 feet south of the intersection of Estes Dr. and Somerset Dr.

Problem Description

Site 26 is situated on a small tributary to Cole Springs Branch with active headcuts and bank erosion. The tributary was observed to be ephemeral, based on indicators such as position in the landscape, rooted plants in the channel and other factors. The headcut is actively cutting upstream, and needs immediate attention before it forms more of a gulley. **Table 26.1** shows a summary of calculated pollutant loads being produced by the contributing drainage area.

Proposed Solution

The ephemeral drain provides an ideal site for bio-retention when the drain meets the floodplain of Cole Springs Branch. The storage volume and reduced velocities will aid the stability of the Cole Springs Branch. Baseflow augmentation should result from this floodplain BMP. The outlet of the proposed bio-retention area should be a level spreader that runs parallel to Cole Springs Branch. This will alleviate the concentrated flow and scour that was observed on the site. Water quality and quantity management from the bio-retention area placed at the confluence of the steep ephemeral channel and Cole Springs Branch represents the type of project that should be implemented throughout this sub-watershed. Though a liner bio-retention, such as bio-grade step, would be applicable here, it is less expensive to manage these flows where the reach the lower slope of the perennial streams floodplain.

Pollutant loads of the contributing drainage, as well as potential reductions, have been estimated and are displayed in **Table 26.1**.

Table 26.1

SITE 26	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	3.74	0.38	50.80
BIORETENTION TREATMENT	35.00%	45.00%	85.00%
NET REDUCTION	1.31	0.17	43.18
FUTURE CONDITION	2.43	0.21	7.62

Constraints

Most of the site consists of a mature hardwood forest, and therefore tree removal will be necessary at this site for the BMP.

The site is located on a privately owned property.

Alternatives

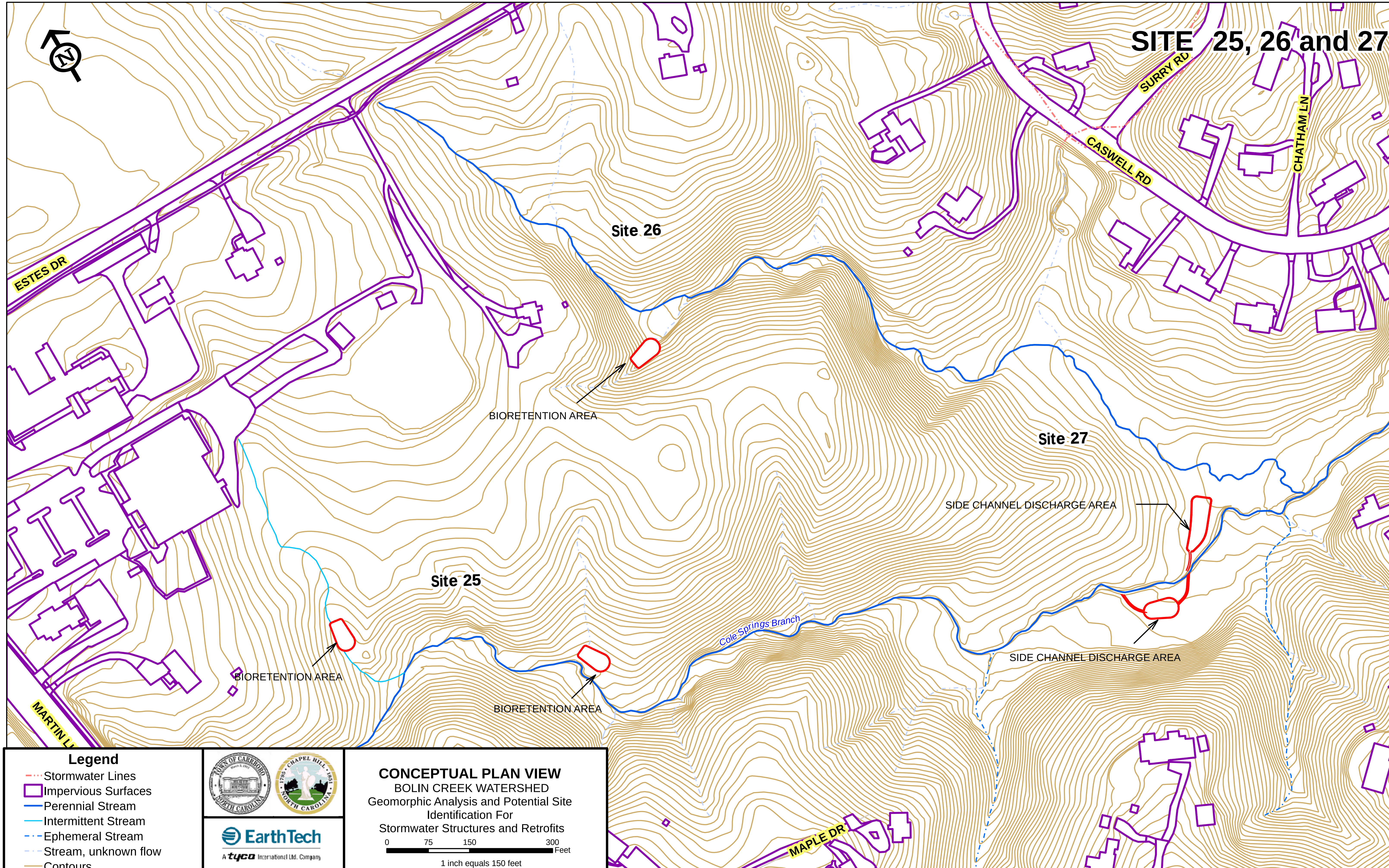
No alternatives are proposed for this site.

Cost-Estimate Breakdown

Table 26.2 shows a conceptual itemized cost estimate for Site 26. These costs represent construction and maintenance costs only. The cost for the bioretention area is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007). The contingency fee for this site has been increased due to the difficulty of access and proximity to a utility easement.

Table 26.2
SITE 26

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Bio-Retention Area	4581.00	CF	12.62	$57,812
			Total	$57,812
Mobilization (5%)	1.00	LS		$2,891
Contingencies (15%)	1.00	LS		$8,672
	Total +	Mobilization and Contingencies		**$69,375**
Maintenance Costs				
Maintenance (5% of base construction cost of BMP)	1.0	Year		**$3,469**


SITE 25, 26 and 27
N
ESTES DR
SURRY RD
CASWELL RD
CHATHAM LN
MARTIN L
MAPLE DR
Site 26
BIORETENTION AREA
Site 27
SIDE CHANNEL DISCHARGE AREA
SIDE CHANNEL DISCHARGE AREA
Site 25
BIORETENTION AREA
BIORETENTION AREA
Cole Springs Branch
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
TOWN OF CARRBORO
NORTH CAROLINA
CHAPEL HILL
1793
1851
NORTH CAROLINA
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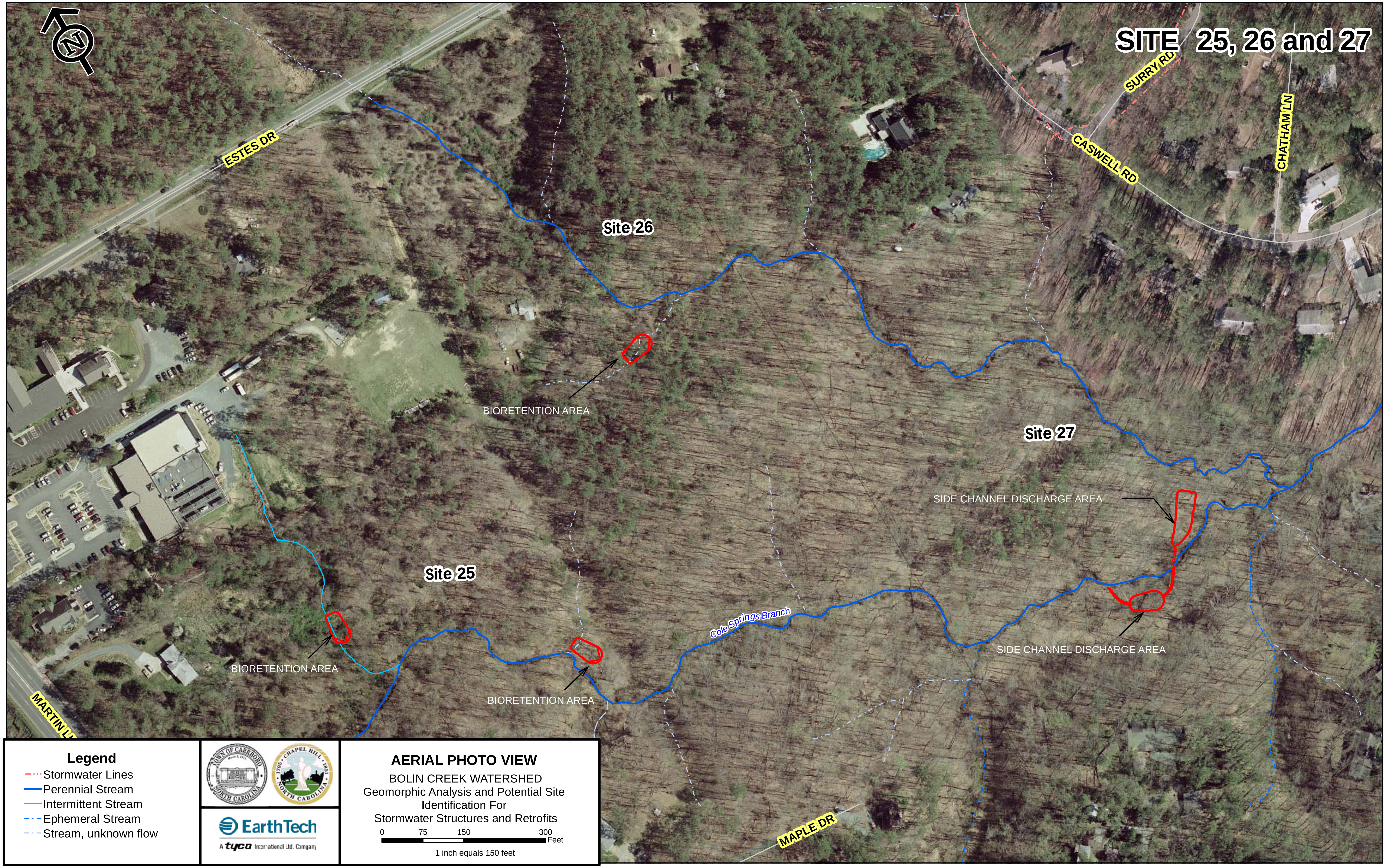
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0 75 150 300
Feet
1 inch equals 150 feet


SITE 25, 26 and 27
ESTES DR
SURRY RD
CASWELL RD
CHATHAM LN
Site 26
BIORETENTION AREA
Site 27
SIDE CHANNEL DISCHARGE AREA
Site 25
Cole Springs Branch
BIORETENTION AREA
BIORETENTION AREA
SIDE CHANNEL DISCHARGE AREA
MARTIN L
MAPLE DR
Legend
Stormwater Lines
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
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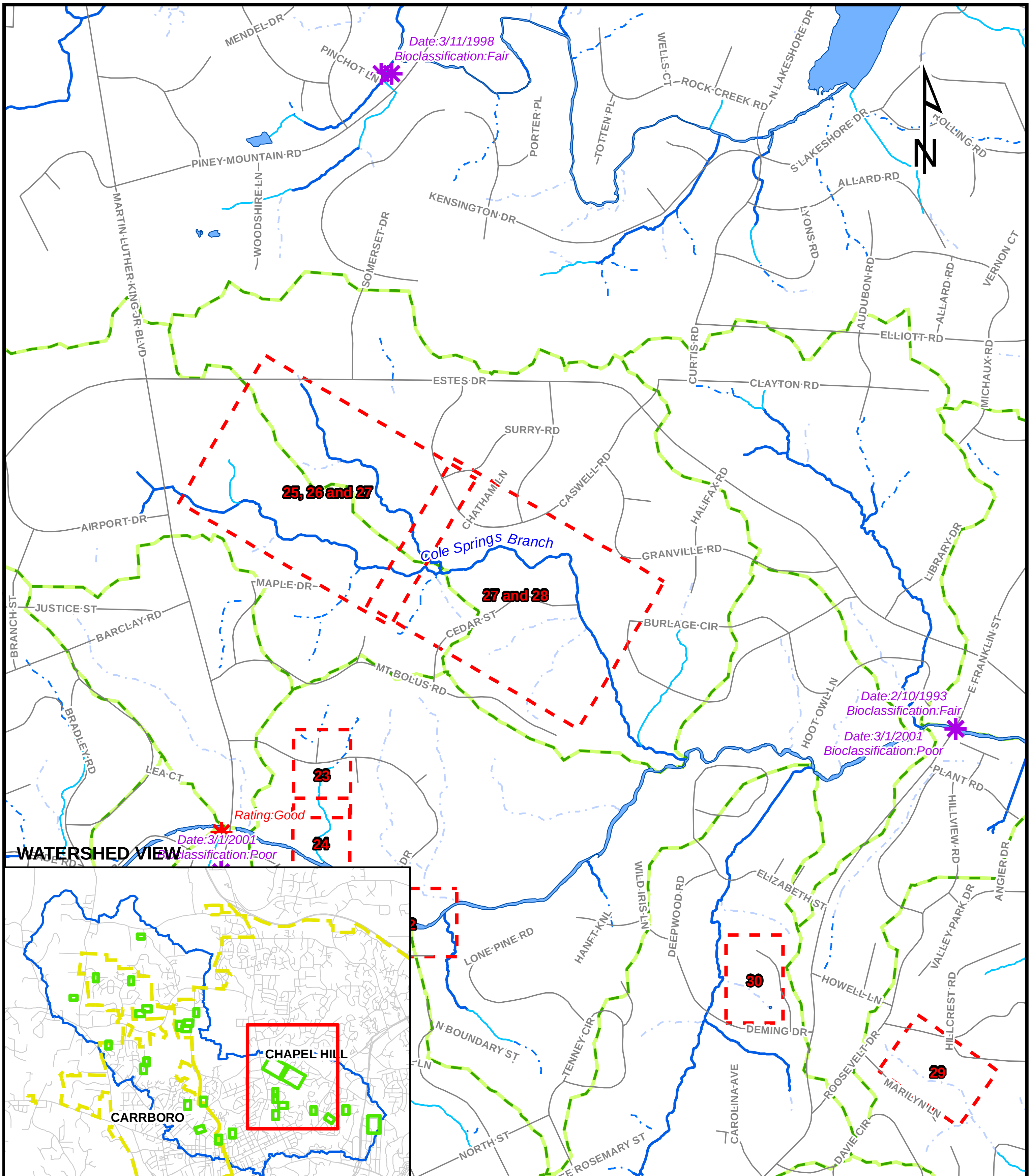
AERIAL PHOTO VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0 75 150 300 Feet
1 inch equals 150 feet

SITE 27

Construct Side-Channel Discharge Wetlands to Attenuate Peak Flows

Index Sheet No.: 26
Raw Data Name: BD 65

Estimated Construction Cost: $38,500



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 27 and 28
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

Cole Springs Branch

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 27	161.6	33.2	20.5%

Location

Site 27 is located approximately 900 feet to the southwest of the intersection of Caswell Rd. and Chatham Ln.

Problem Description

The perennial stream along which Site 27 is located, Cole Springs Branch, exhibits severe incision and erosion for most of its course from it's headwaters to where it flows into Bolin Creek. The causes of this widespread degradation are apparent when examining the watershed of the stream, which consists of vast areas of impervious surface, including portions of Horace Williams Airport, the UNC facilities management complex, and high density residential developments. The crossing of Martin Luther King Jr. Blvd. also seems to have adversely affected the stream, as the accumulated and concentrated flow of most of the watersheds impervious area is discharged from a culcert after passing under that road.

While the riparian corridor of the stream after passing under Martin Luther King Jr. Blvd is largely intact, many small tributaries, most of which discharge from residential storm sewer systems, continue to flow into Cole Springs Branch before it meets Bolin Creek downstream. The combined problems of peak flow and pollutant input from all of these small drainages likely compounds the degradation already being caused by the accumulated flow and pollutants from upstream of Martin Luther King Jr. Blvd.

Proposed Solution

Site 27 is situated in a wide, flat portion of the Cole Springs Branch floodplain, which provides a good location for the construction of off-line BMPs for peak flow attenuation, pollutant removal and baseflow augmentation.

At least two areas within this valley could be used for off-line stormwater wetlands. Stormwater wetlands are a preferred choice here, as the floodplain may not have the minimum depth required from the water table that is required for bio-retention areas. On the other hand, having a high water table is beneficial to a wetland as it allows for permanent pools (NCDWQ, 2007). These side channel wetlands capture a portion of the runoff volume which reduced the flow rate, velocities and changes the timing of peak flows to the downstream reach. The saturated condition of the wetland may be paralleled to a beaver pond in the expectation to augment baseflow via the saturated soils within the wetland.

Flow diversion into the wetland would be provided by a flow-splitting structure containing a a vane or weir, placed in Cole Springs Branch. This is a common way to "harvest" storm flows without impeding the base flows of the stream in any way. Such a structure would allow a designed volume of flow to enter into the wetland, while allowing any flow above that volume to continue downstream. If properly placed and designed, a grade control or cross vane can serve this same purpose while acting a grade control for the stream.

Constraints

Most of the site consists of a mature hardwood forest, and therefore tree removal will be necessary at this site for both BMPs.

The site is located on a privately owned property.

Access to the site for construction may be limited due to the wooded state of the surrounding area, and will have to be arranged with the landowners.

Alternatives

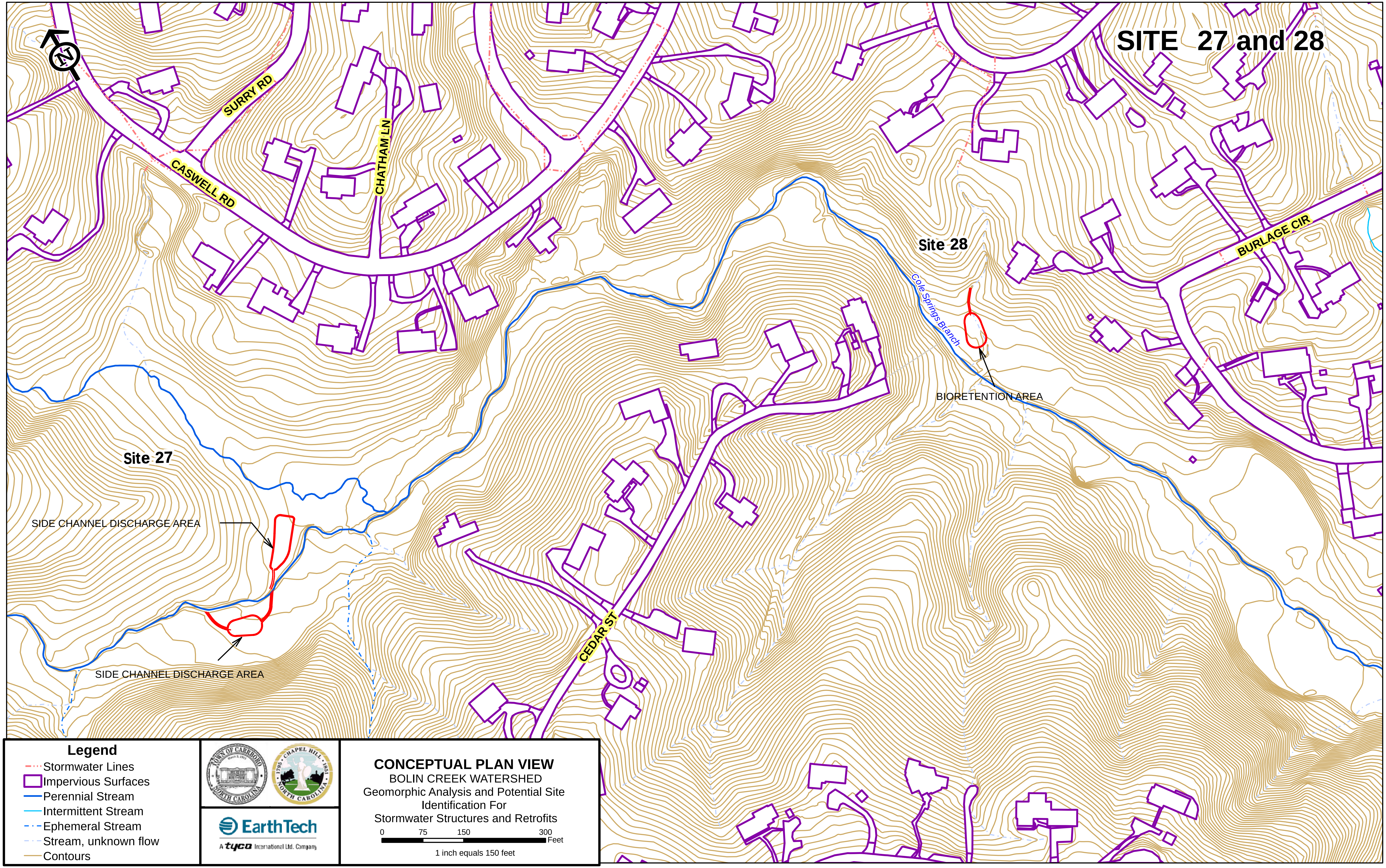
No alternatives are proposed for this site.

Cost-Estimate Breakdown

Table 27.1 shows a conceptual itemized cost estimate for Site 27. These costs represent construction and maintenance costs only. The cost for stormwater wetlands is derived from an equation developed by Brown and Schueler (1997).

Table 27.1
Site 27

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stormwater Wetland	6293.0	CF	Equation Derived	$13,545
Stormwater Wetland	9880.0	CF	Equation Derived	$18,583
			Total	$32,128
Mobilization (5%)	1.00	LS		$1,606
Contingencies (15%)	1.00	LS		$4,819
		Total + Mobilization and Contingencies		**$38,554**
Maintenance Costs				
Maintenance (5% of base construction cost of BMP)	1.0	Year		**$1,928**



SITE 27 and 28
N
SURRY RD
CASWELL RD
CHATHAM LN
BURLAGE CIR
Site 28
Cole Springs Branch
BIORETENTION AREA
Site 27
SIDE CHANNEL DISCHARGE AREA
SIDE CHANNEL DISCHARGE AREA
CEDAR ST
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
EarthTech
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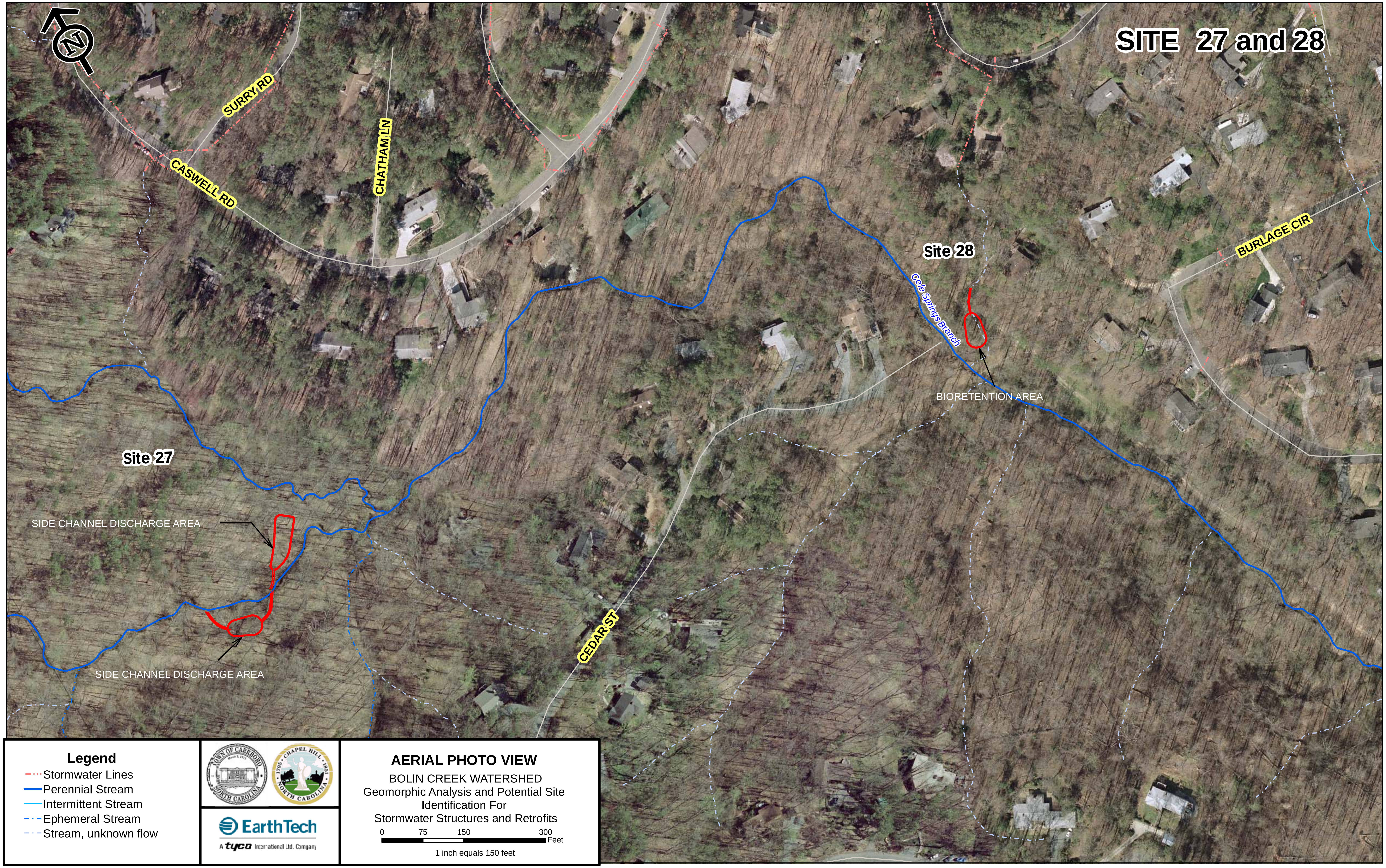
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0
75
150
300
Feet
1 inch equals 150 feet



Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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CHAPEL HILL · NORTH CAROLINA

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For
Stormwater Structures and Retrofits

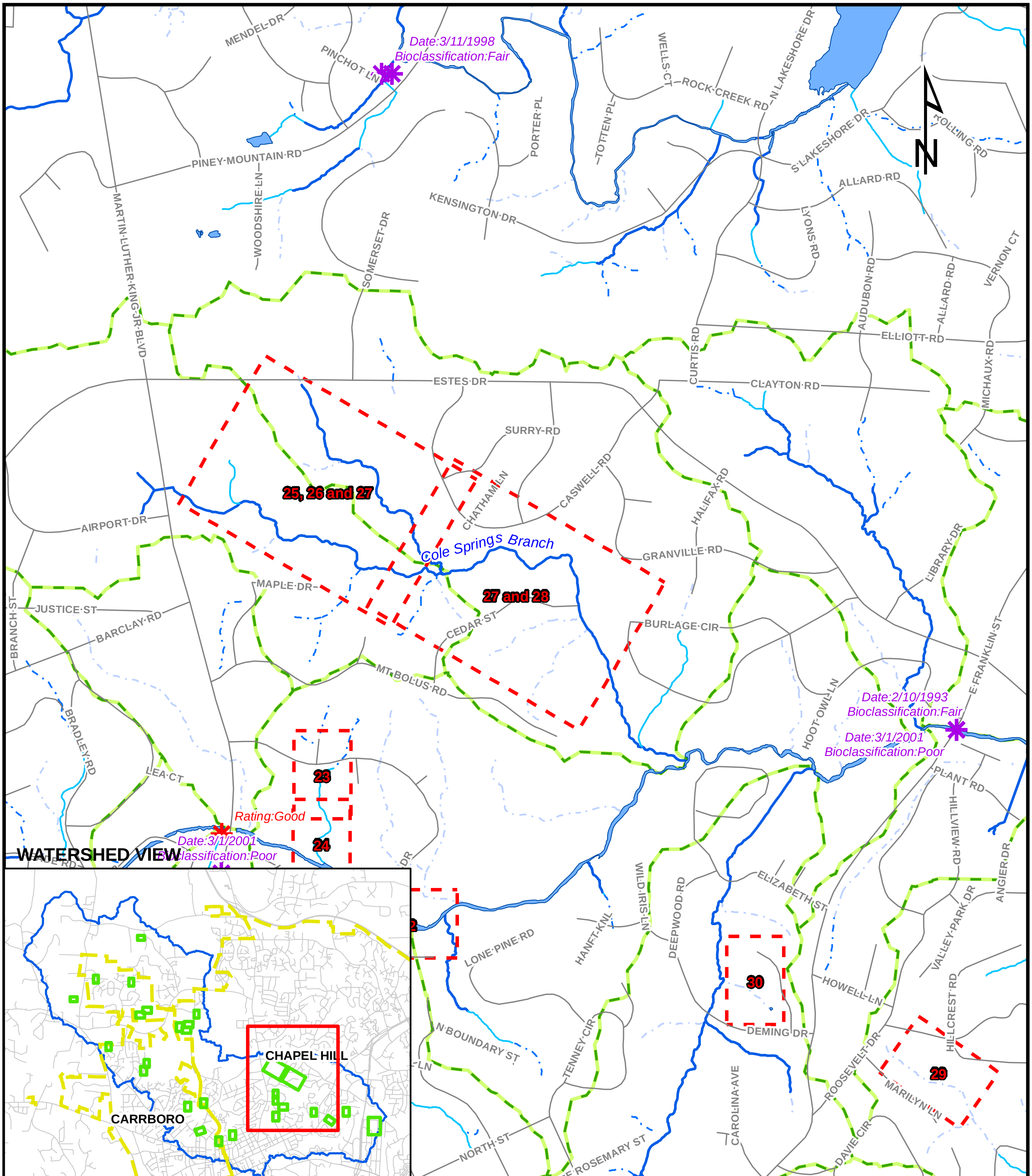
0 75 150 300 Feet

1 inch equals 150 feet

SITE 28

Index Sheet No.: 26
Raw Data Name: BD 75

Estimated Construction Cost: $36,660



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 27 and 28
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 28	16.0	4.0	25.0%

Location

Site 28 is located approximate 150 feet due east of the dead end road Cedar Street, along a small tributary to Cole Springs Branch.

Problem Description

The perennial stream along which Site 28 is located, Cole Springs Branch, exhibits severe incision and erosion for most of its course from it's headwaters to where it flows into Bolin Creek. The causes of this widespread degradation are apparent when examining the watershed of the stream, which consists of vast areas of impervious surface, including portions of Horace Williams Airport, the UNC facilities management complex, and high density residential developments. The crossing of Martin Luther King Jr. Blvd. also seems to have adversely affected the stream, as the accumulated and concentrated flow of most of the watersheds imperviousness is discharged after passing under that road.

While the riparian corridor of the stream after passing under Martin Luther King Jr. Blvd is largely intact, many small tributaries, most of which discharge from residential storm sewer systems, continue to flow into Cole Springs Branch before it meets Bolin Creek downstream. The combined problems of peak flow and pollutant input from all of these small drainages likely compounds the degradation already being caused by the accumulated flow and pollutants from upstream of Martin Luther King Jr. Blvd.

Site 28 is located just downstream of a utility crossing of Cole Springs Branch. The reach downstream of the crossing has suffered from the contraction and resulting incision from the utility crossing. Adding to the problem, and typical of this sub-watershed, just upstream of the crossing an ephemeral drain comes out of a residential area, down a steep valley, and carries high velocity flows that converge with Cole Springs Branch. The ephemeral drain is showing signs of incision and may become a head cut, creating a more significant sediment contribution in the future. The mass wasting banks that are downstream of the utility crossing are causing significant sediment contributions now.

Proposed Solution

This site was chosen as another site to use in this sub-watershed due to the blending of solutions that would be required to improve water quality. The ephemeral drain should be treated by the use of a stormwater wetland at the confluence with the floodplain of Cole Springs Branch. This wetland should be discharged via a level spreader, thereby reducing some of the destructive hydraulics that are impacting the immediate site. This would provide water quality treatment and quantity treatment for the runoff from the hill-top development. Immediately downstream of the wetland, the culvert at the utility crossing could be removed and the stream crossing can be accommodated by a stabilized ford. This will allow flood plain access and reduce the negative effects of contraction that are created by the culvert.

Downstream of the culvert, the already damaged stream banks need stabilization. The combination of these BMP's indicates the typical situation that will be required to restore stream stability in this troubled watershed.

Table 28.1

SITE 26-04		Pollutant Load (lbs)		
		TN	TP	TSS
EXISTING CONDITION		66.79	6.74	56.74
BIORETENTION TREATMENT	REMOVAL	35.00%	45.00%	85.00%
NET REDUCTION		23.38	3.03	48.23
FUTURE CONDITION		43.41	3.71	8.51

Constraints

Most of the site consists of a mature hardwood forest, and therefore tree removal will be necessary at this site for implementation of the BMPs.

The nearby utility line must be considered in all proposed final design plans.
MOUs or MOAs may be needed to be executed with the utility owners, as periodic vegetation removal likely occurs in the utility easement.

Alternatives

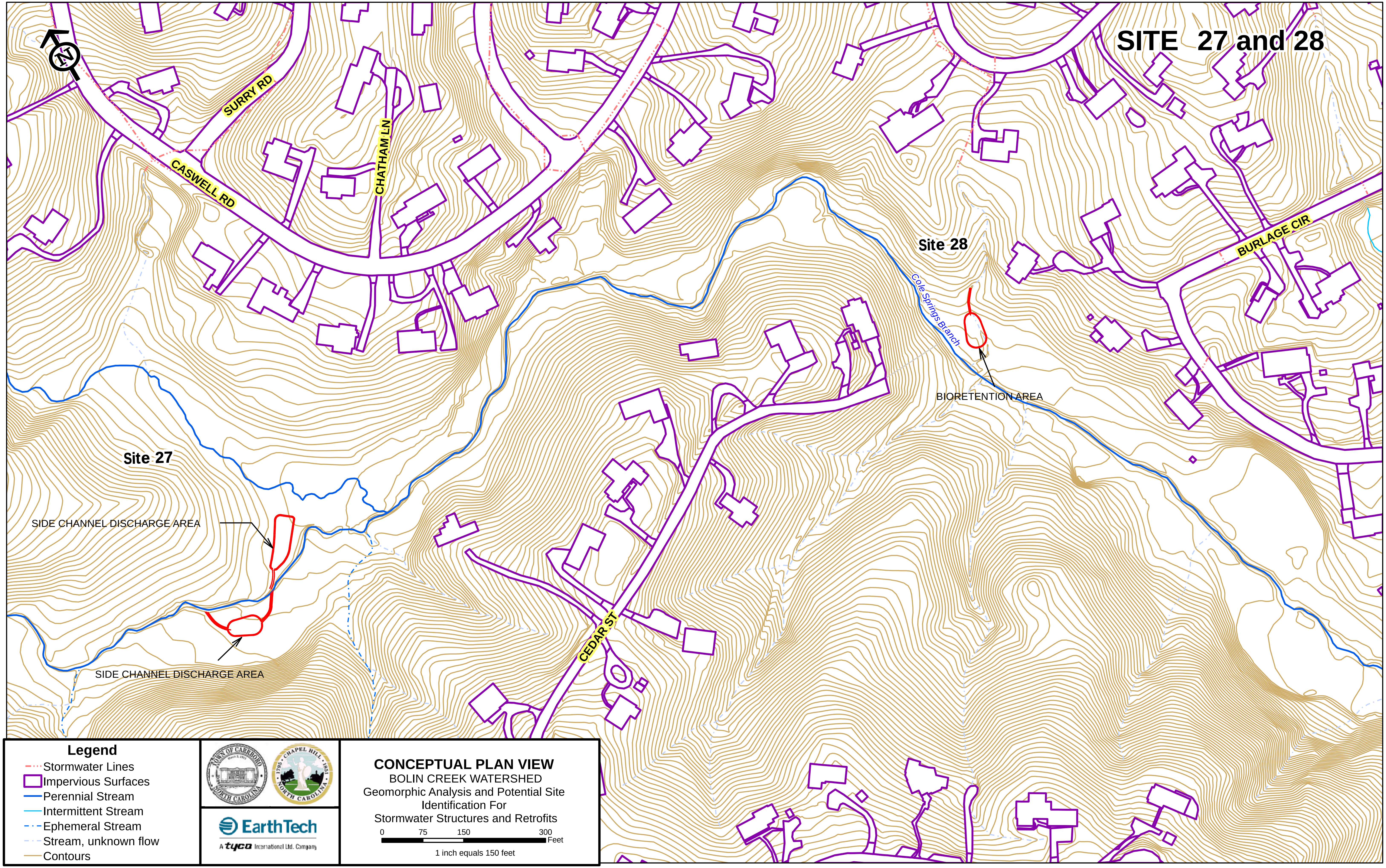
No alternatives are proposed for this site.

Cost-Estimate Breakdown

Table 28.2 shows a conceptual itemized cost estimate for Site 28. These costs represent construction and maintenance costs only. The cost for the bioretention area is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007).

Table 28.2
Site 28

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Bio-Retention Area	2526.00	CF	12.62	$31,878
			Total	$31,878
Mobilization (5%)	1.00	LS		$1,594
Contingencies (10%)	1.00	LS		$3,188
	Total + Mobilization and Contingencies			**$36,660**
Maintenance Costs				
Maintenance (5% of base construction cost of BMP)	1.0	Year		**$1,833**


SITE 27 and 28
N
SURRY RD
CASWELL RD
CHATHAM LN
BURLAGE CIR
CEDAR ST
Site 28
Cole Springs Branch
BIORETENTION AREA
Site 27
SIDE CHANNEL DISCHARGE AREA
SIDE CHANNEL DISCHARGE AREA
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
EarthTech
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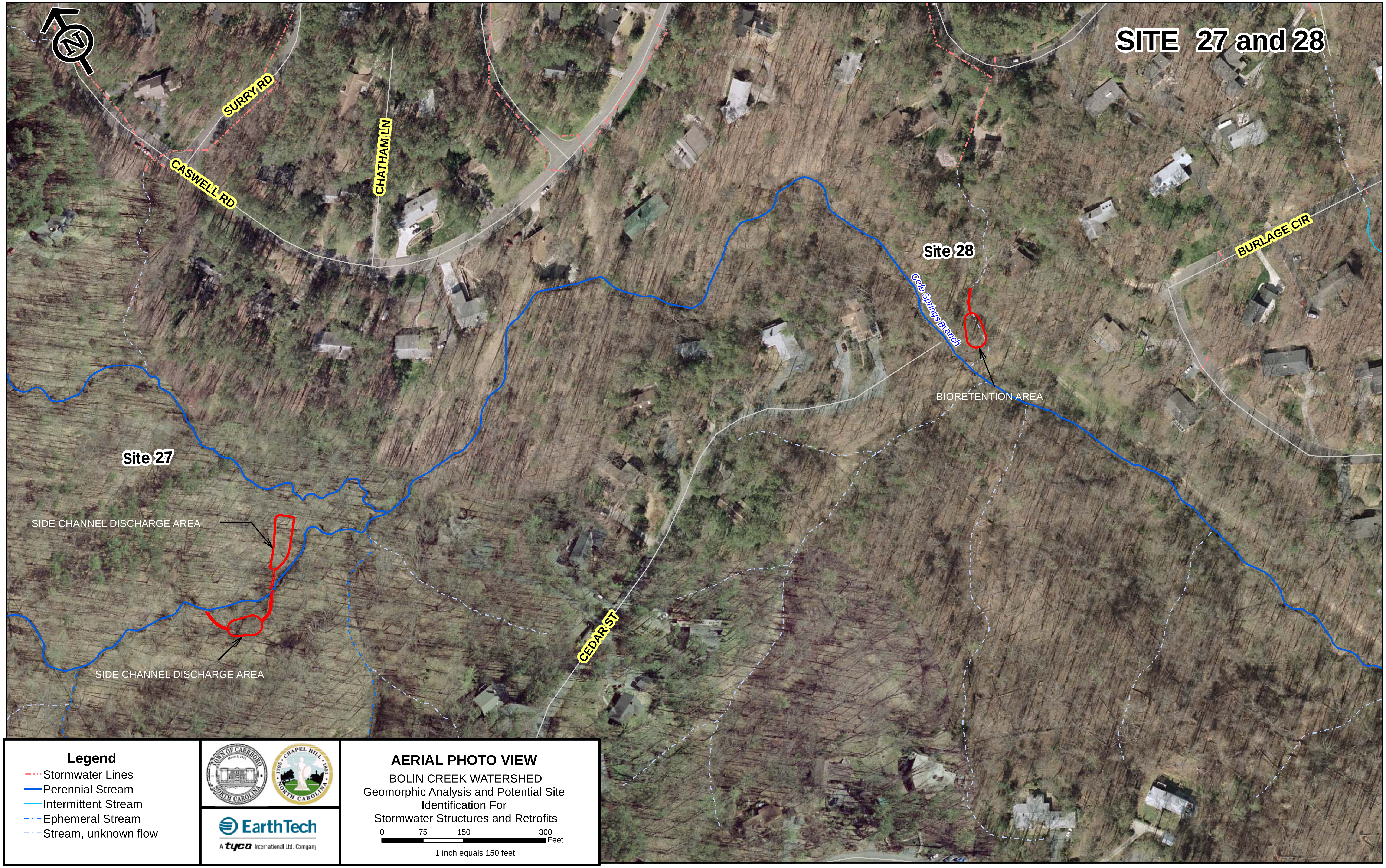
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0 75 150 300
Feet
1 inch equals 150 feet



Legend
- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

0 75 150 300 Feet

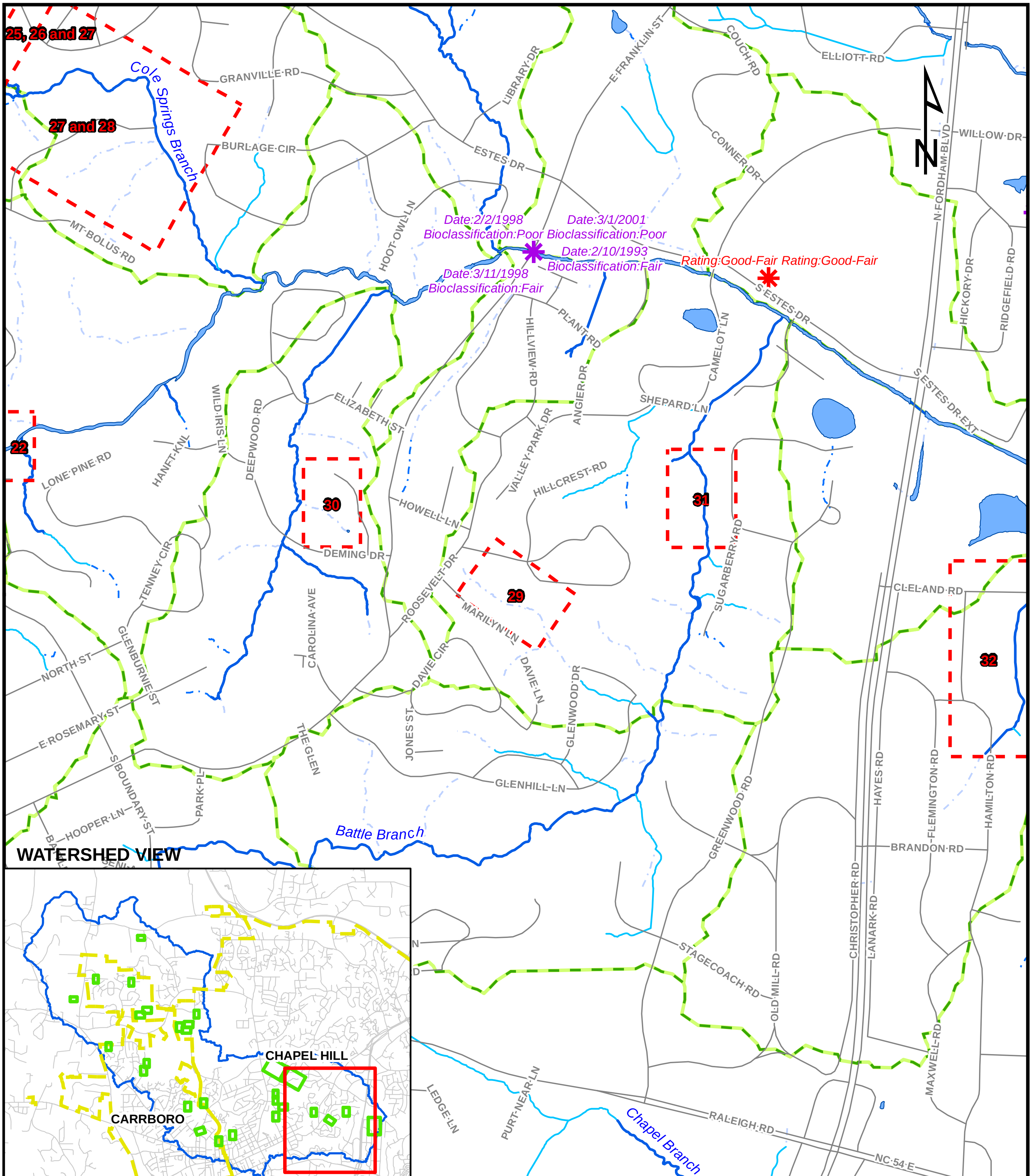
1 inch equals 150 feet

SITE 29

Stabilization of Headcuts on Steep Hillside Using Bioretention Cells

Index Sheet No.: 30
Raw Data Name: IJ 64

Estimated Construction Cost: $128,600



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 29
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 29	14.0	2.5	17.6%

Location

Site 29 is located east of the intersections of Roosevelt Drive, Hillcrest Rd and Maryilyn Ln, just to the east of downtown Chapel Hill. Access to the site can be gained by parking on Weaver Rd, which is southwest of the site, and walking northwest along an unpaved utility service road that parallels the stream.

Problem Description

Site 29 consists of a stream located on a steep hillside, on which the erosive velocities of peak stormflow have created at least three headcuts. The slope of the hillside, at approximately 10 %, along with the runoff produced by the 18% impervious surface of the contributing drainage area, has created high velocity flows that are eroding portions of the hillside. Given enough time, the headcuts will continue to erode uphill, releasing massive amounts of sediment and causing the stream to become a steep gulley. In addition to sediment, the relatively high imperviousness of the urbanized drainage area is contributing pollutants to the watershed, which should be treated before flowing into nearby Battle Branch, which is a major tributary to Bolin Creek.

Using the BANCS model, it is estimated that approximately 566 tons of sediment are being exported from the site each year. Concomitant nutrient export associated with the sediment has also been calculated and is listed in **Table 29.1**.

Table 29.1

Pre-Treatment	
Estimated Total Sediment Export	566.6 tons/year
Erosion per length of Channel	1.3 tons/yr/ft
Pounds of Nitrogen	1133.1 lbs/year
Pounds of Phosphorus	566.6 lbs/year
Post-Treatment	
Estimated Total Sediment Export	4.5 tons/year
Erosion per length of Channel	0.032 tons/yr/ft
Pounds of Nitrogen	9.1 lbs/year
Pounds of Phosphorus	4.5 lbs/year

Proposed Solution

Site 29 poses a difficult situation for traditional stormwater BMP treatment because of the lack of available space due to the steep slope and narrow valley of the stream. A solution for treatment at this site is to construct a "bio-grade step", which is a series of small bio-retention cells, each cell lower in elevation than the previous cell, filled with a filter media, such as a mixture of sand, fines and organic mater (see Appendix A-Details). Ideally, this media will have a filtration rate of 1.0 to 2.0 inches per hour, to optimize pollution removal (Schueler, et. al., 2007). Each cell is connected to the other through this same media, thus allowing stormwater to filter through each cell without the expense of an underdrain. Overflow of each cell would be provided by a "lip" constructed at the downstream end of each cell.

This treatment option will provide a linear, grade-control solution to reduce erosive velocities of the stream, thereby reducing sediment export, while also treating stormwater runoff for pollutants. The depth of each cell can vary depending on choice of planting materials. Trees, with a deeper rooting structure, will require deeper soils, while herbaceous plants and shrubs can have soils as shallow as 1.5 feet (Schuler et. al, 2007).

Below the proposed area of the bio-grade step, the slope of the hill flattens, and the stream flows diffusely through a sewer easement lined with rip-rap. This location affords a good opportunity for construction of a stormwater wetland, as a final means of pollutant removal and attenuation of peak flows before the stream concentrates once again into an incised channel downstream of the site.

Potential pollution removal rates using this treatment method have been estimated and are shown in **Table 29.2**.

Table 29.2

SITE 29	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	141.53	14.29	1923.76
BIORETENTION TREATMENT REMOVAL %	35.00%	45.00%	85.00%
STORM WATER WETLAND TREATMENT REMOVAL %	37.00%	35.00%	85.00%
NET REDUCTION	34.04	2.75	245.28
FUTURE CONDITION	107.49	11.54	1678.48

Constraints

Based on available GIS data, Site 29 appears to be located in a right of way owned by the Orange Water and Sewer Authority (OWASA), therefore land acquisition and access should not be a constraint to this project.

Alternatives

There are no alternatives proposed for this site.

Cost-Estimate Breakdown

Table 29.3 shows a conceptual itemized cost estimate for Site 29. These costs represent construction and maintenance costs only. The cost for stormwater wetlands is derived from an equation developed by Brown and Schueler (1997). The cost for the bio-grade step is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007).

Table 29.3
SITE 29 Construction Cost

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Biograde Step	7869.0	CF	12.62	$99,307
Stormwater Wetland	5642.0	CF	Equation Derived	$12,547
			Total	$111,854
Mobilization (5%)	1.00	LS		$5,593
Contingencies (10%)	1.00	LS		$11,185
	Total +	Mobilization and Contingencies		**$128,632**
Maintenance Costs				
Maintenance (5% of base construction cost of BMP)	1.0	Year		**$6,432**

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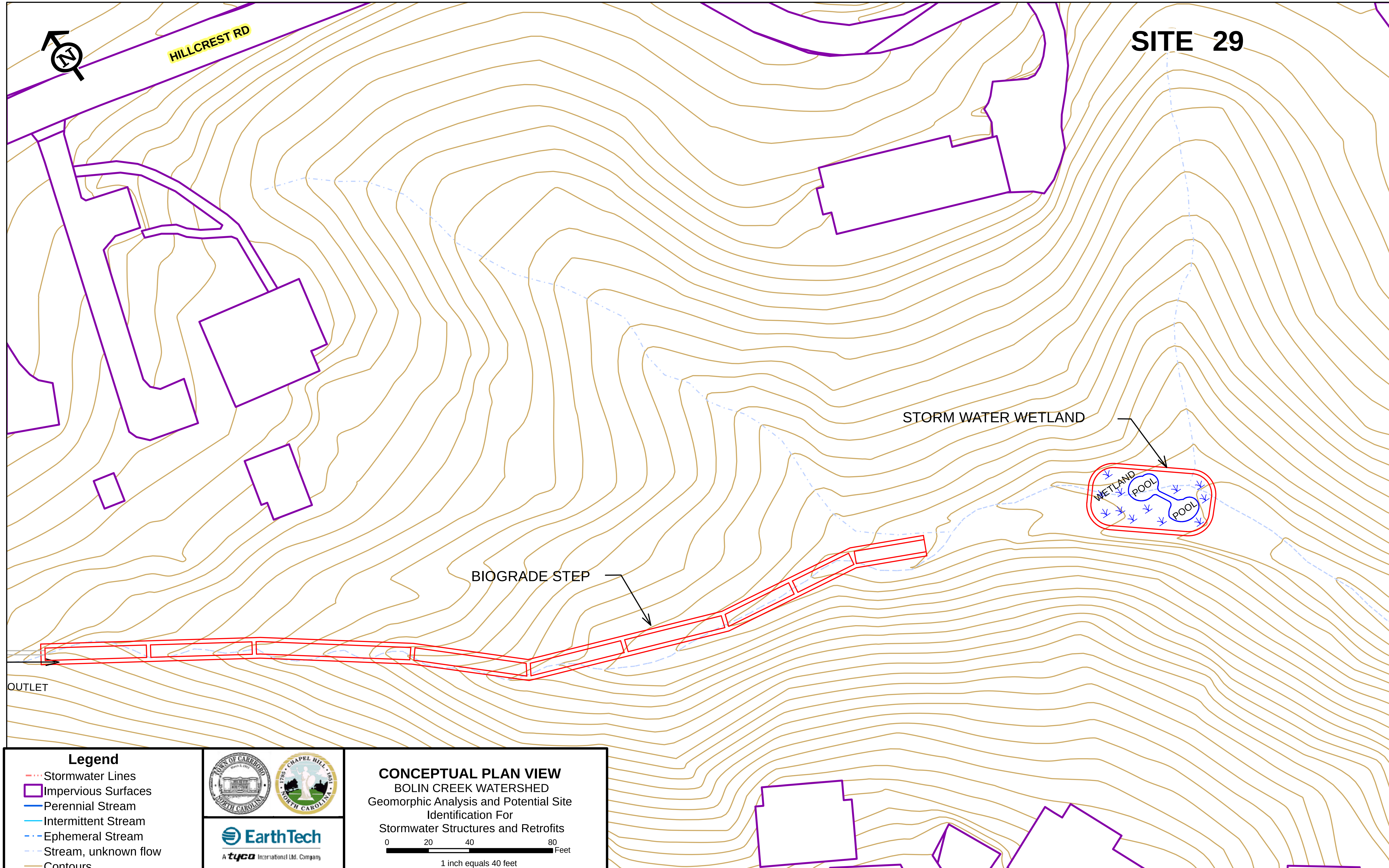

HILLCREST RD
N
SITE 29
STORM WATER WETLAND
WETLAND
POOL
POOL
BIOGRADE STEP
OUTLET
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
TOWN OF CARRBORO
NORTH CAROLINA
CHAPEL HILL
1793
1851
NORTH CAROLINA
EarthTech
A tyco International Ltd. Company
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0
20
40
80
Feet
1 inch equals 40 feet

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

EarthTech
A tyco International Ltd. Company

AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For
Stormwater Structures and Retrofits

0 20 40 80 Feet

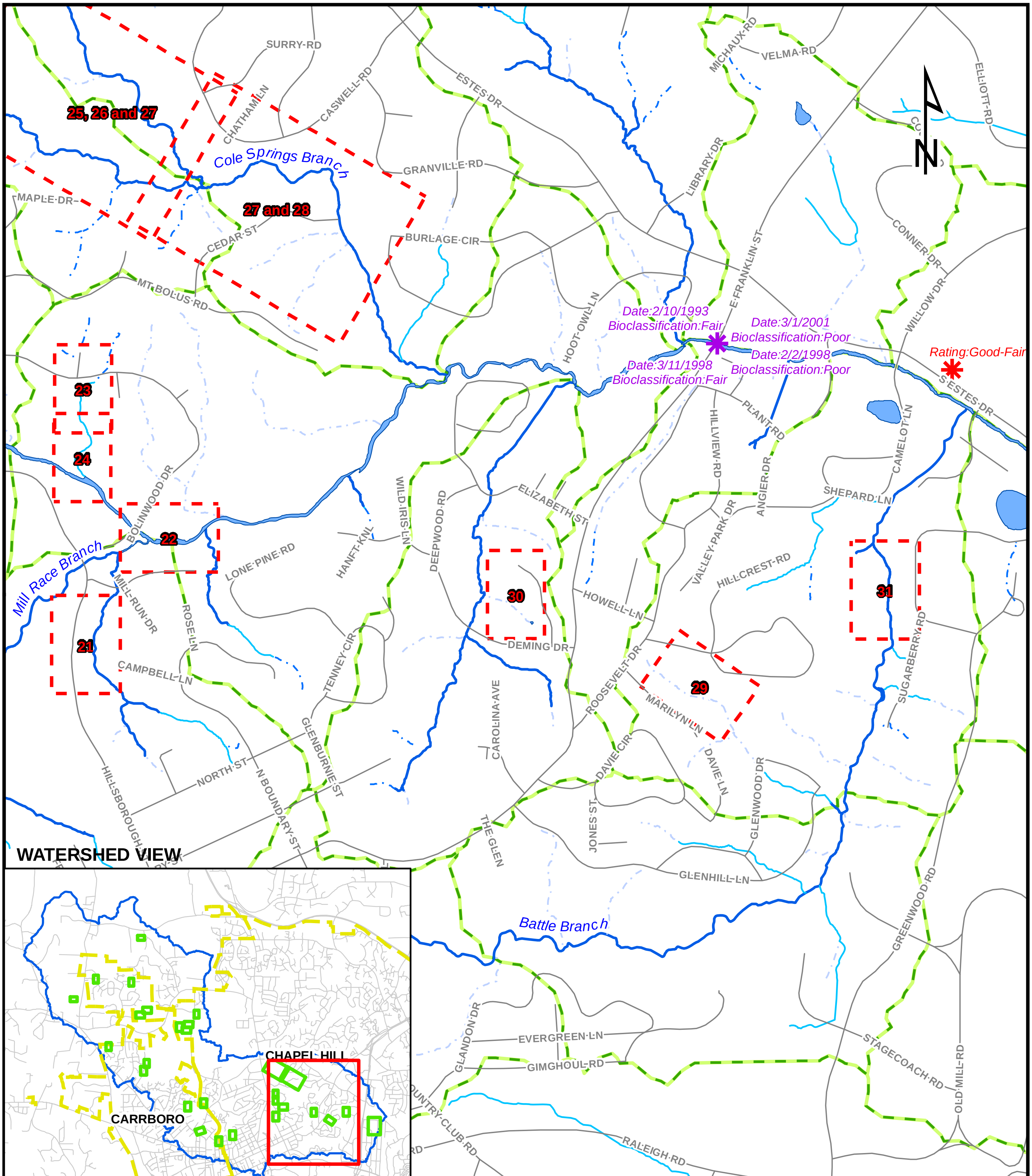
1 inch equals 40 feet

SITE 30

Retrofit of Existing Sediment Basin and Stabilization of Hillside erosion.

Index Sheet No.: 30
Raw Data Name: IJ 60

Estimated Construction Cost: $28,500



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO March 3, 1911 NORTH CAROLINA

CHAPEL HILL 1795 1851 NORTH CAROLINA

EarthTech
A tyco International Ltd. Company

SITE 30

VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 30	1.3	0.5	39.9%

Location

Site 30 is downhill and to the west of Hoteling Ct. The site can be reached from E. Franklin Street by turning onto Deming Drive,, taking the first right turn onto Hoteling Ct. and parking at the end of the cul-de-sac.

Problem Description

Site 30 consists of an existing sediment basin on a steep hillside, just below a residential development constructed on top of the hillside. The basin has filled in since the construction of the residential area, and is no longer storing the runoff produced from the street, rooftops and driveways. In addition, there is no evidence that the basin was ever intended for water quality treatment. Runoff flows over the rip-rap berm of the basin, into an apparently ephemeral drainage and then into a perennial stream at the bottom of the hill.

A concrete pipe outlet is located uphill of the existing basin, but has no stormwater control structure immediately below it. Because of this, the steep slope below the outlet has begun to erode. In the span of a month, between two visits to the site, the hillside below the outlet visibly increased in erosion. Evidence of the increased peak flows being produced by the drainage area can also be seen in the perennial stream located downhill from the site. Significant bank erosion is apparent where the ephemeral drainage joins with the stream, which is otherwise stable throughout most of its course.

Proposed Solution

The existing sediment basin at this site provides a good location for a stormwater retrofit. The solution at Site 30 is targeted at the treatment of pollutants from runoff, the stabilization of an actively eroding hillside to reduce sediment export and the attenuation of peak flows to prevent impacts to the perennial stream downhill from the site. This will be accomplished through the following:

- Retrofit the basin into a small, bioretention area with an overflow to a level spreader. An underdrain may be required to meet the required infiltration rate (NCDWQ, 2007).
- Stabilize the eroding hillside below the existing outlet by constructing a concrete lined “flume” with friction blocks. The friction blocks will provide a means of reducing the velocity of storm flow before entering the wet detention basin.
- Provide an energy dissipation basin where the flume meets the bio-retention area

These retrofits will reduce the velocities from the residential stormwater system before they flow reaches the receiving channel. A bioretention area will allow for treatment of the pollutants from the residential area and attenuate the peak flows of the site.

Based on the above treatment, pollutants are expected to be reduced in the amounts shown in **Table 30.1**.

Table 30.1

SITE 30	Pollutant Load (lbs)		
	TN	TP	TSS
EXISTING CONDITION	19.88	2.01	270.19
WET DETENTION TREATMENT REMOVAL %	25.00%	40.00%	85.00%
NET REDUCTION	4.97	0.80	229.67
FUTURE CONDITION	14.91	1.20	40.53

Constraints

Site access and construction will be difficult due to the steep terrain. This BMP is located on private property. Tree removal will be required.

Alternatives

There are no alternatives proposed for this site.

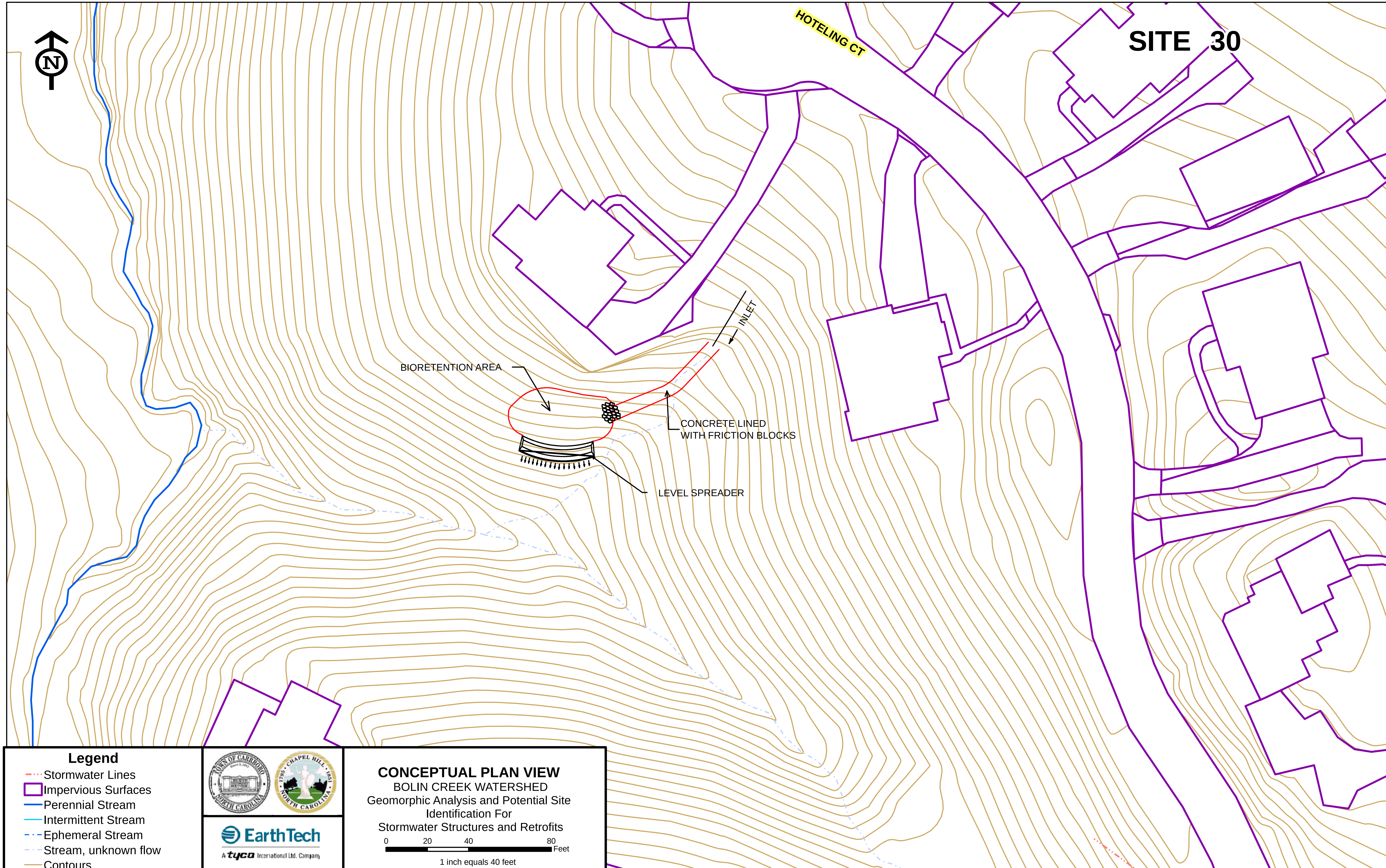
Cost-Estimate Breakdown

Table 30.2 shows a conceptual itemized cost estimate for Site 30. These costs represent construction and maintenance costs only. The cost for the bioretention area is derived from a cost per cubic foot treated for bioretention areas as reported by Schueler, et. al. (2007). The contingency fee for this site has been increased due to the difficulty of access and proximity to a utility easement.

Table 30.2

SITE 30

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Bio-Retention Area	1882.00	CF	12.62	$23,751
			Total	$23,751
Mobilization (5%)	1.00	LS		$1,188
Contingencies (15%)	1.00	LS		$3,563
	Total + Mobilization and Contingencies			**$28,501**
Maintenance Costs				
Maintenance (5% of base construction cost of BMP)	1.0	Year		**$1,425**



SITE 30
HOTELING CT
N
INLET
BIORETENTION AREA
CONCRETE LINED
WITH FRICTION BLOCKS
LEVEL SPREADER
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
EarthTech
A tyco International Ltd. Company
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0
20
40
80
Feet
1 inch equals 40 feet

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

EarthTech
A tyco International Ltd. Company

AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits

0 20 40 80 Feet

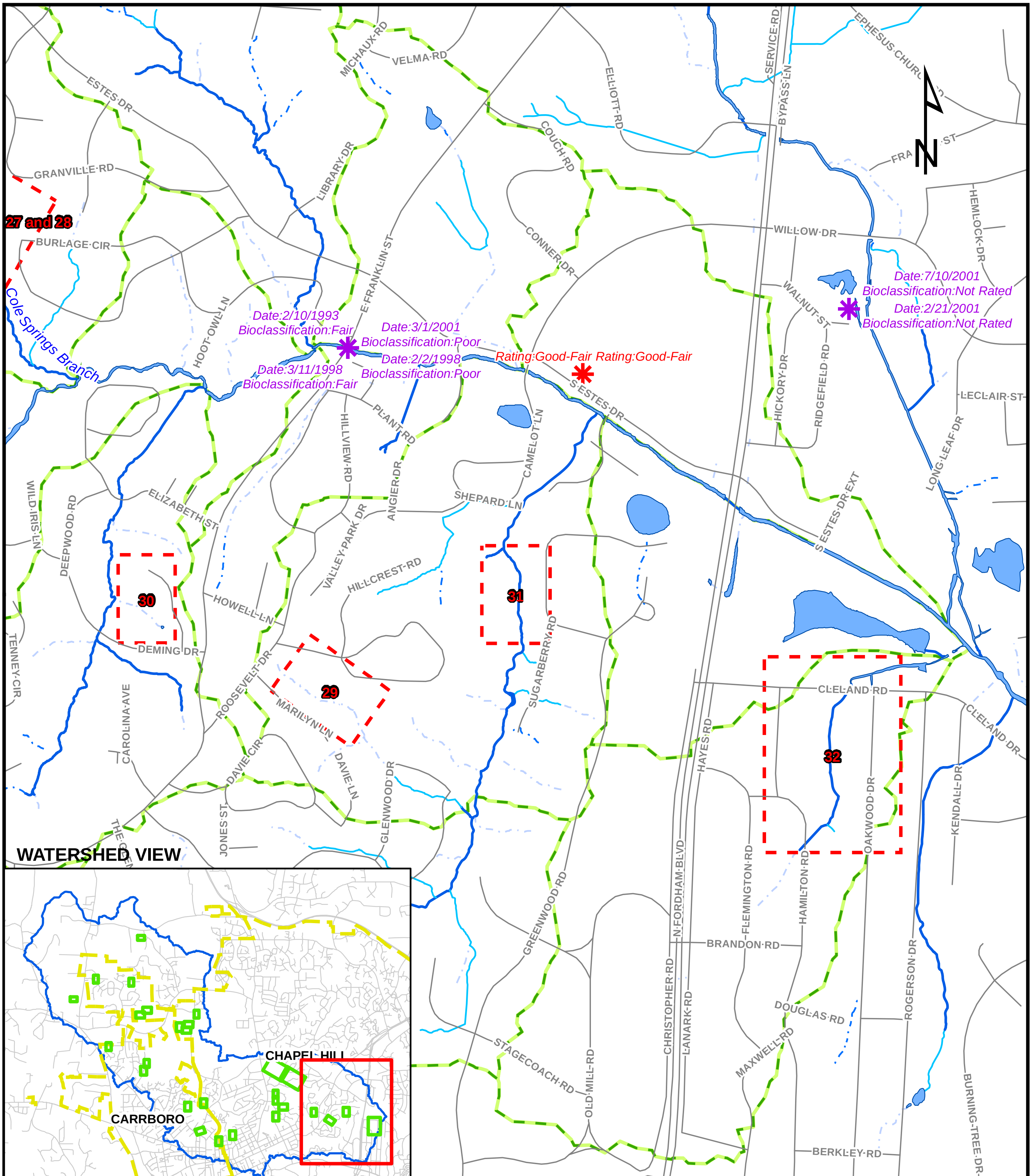
1 inch equals 40 feet

SITE 31

Apply Treatment to an Existing Ditch in the Floodplain of Battle Branch.

Index Sheet No.: 34
Raw Data Name: BD 88

Estimated Construction Cost: $10,000- $21,000



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO March 3, 1911 NORTH CAROLINA

CHAPEL HILL 1793 1851 NORTH CAROLINA

EarthTech

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SITE 31

VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs

Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 31	12.2	2.1	17.2%

Location

Site 31 is located to the west and downhill of Sugarberry Rd.

Problem Description

Site 31 consists of an actively eroding ditch in the floodplain of Battle Branch. The ditch is approximately 2.5 feet deep and 5 feet wide and approximately 317 feet long. It appears to have been constructed along with the sewer line that parallels Battle Branch. The ditch receives the flow from a stormwater collection system of a residential arra, and therefore is subject to increased peak flows due to impervious surfaces. The flows from the residential area have no apparent treatment of water quality and do not have treatment of water quantity.

Using the BANCS model, it is estimated that approximately 517 tons of sediment are being exported from the site each year. Concomitant nutrient export associated with the sediment has also been calculated and is listed in **Table 31.1**.

Table 31.1

Pre-Treatment	
Estimated Total Sediment Export	517.4 tons/year
Erosion per length of Channel	1.7 tons/yr/ft
Pounds of Nitrogen	1034.7 lbs/year
Pounds of Phosphorus	517.4 lbs/year
Post-Treatment	
Estimated Total Sediment Export	0 tons/year
Erosion per length of Channel	0 tons/yr/ft
Pounds of Nitrogen	0 lbs/year
Pounds of Phosphorus	0 lbs/year

Proposed Solution

Treatment of the runoff from the contributing drainage area of Site 31, as well as the reduction of sediment can be accomplished through construction of a stormwater wetland in the floodplain of Battle Branch, expanding on the area of the existing ditch. The outlet of this wetland will consist of an overflow structure with a level spreader situated parallel to Battle Branch.

The site should also be planted with native vegetation, which is currently lacking from much of the floodplain leading up to Battle Branch.

Constraints

The site is located on three privately owned properties.

Alternatives

Alternative 1:
Construct a stormwater wetland in the place of the existing ditch, as detailed above

Alternative 2:
An alternative to constructing a stormwater wetland at this site is to fill the existing ditch with a filtration media, consisting of a mix of sand, fines and silt, and allow it to function as a bioretention area. The length of the ditch will provide a sufficient flow path for infiltration and treatment of runoff from the contributing drainage area.

Cost-Estimate Breakdown

Table 31.2 shows a conceptual itemized cost estimate for the two alternatives at Site 31. These costs represent construction and maintenance costs only. The cost for stormwater wetlands is derived from an equation developed by Brown and Schueler (1997).

Table 31.2
SITE 31 ALTERNATIVE 1

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stormwater Wetland	9072.0	CF	Equation Derived	$17,504
			Total	$17,504
Mobilization (5%)	1.00	LS		$875
Contingencies (10%)	1.00	LS		$1,750
	Total + Mobilization and Contingencies			**$20,130**
Maintenance Costs				
Maintenance (5% of base construction cost of BMP)	1.0	Year		**$1,006**

Table 31.3

SITE 31 ALTERNATIVE 2

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Excavation	180.00	CY	15.00	$2,700
Site Preparation and Planting	0.10	Ac	7500.00	$750
Rip Rap Class B	5.00	Tons	45.00	$225
Filter Fabric	50.00	SY	5.00	$250
Silt Fence	350.00	LF	3.75	$1,313
Construction Safety Fence	400.00	LF	2.50	$1,000
Construction Entrance	1.00	Ea	2500.00	$2,500
			Total	$8,738
Mobilization (5%)	1.00	LS		$437
Contingencies (10%)	1.00	LS		$874
		Total + Mobilization and Contingencies		**$10,048**

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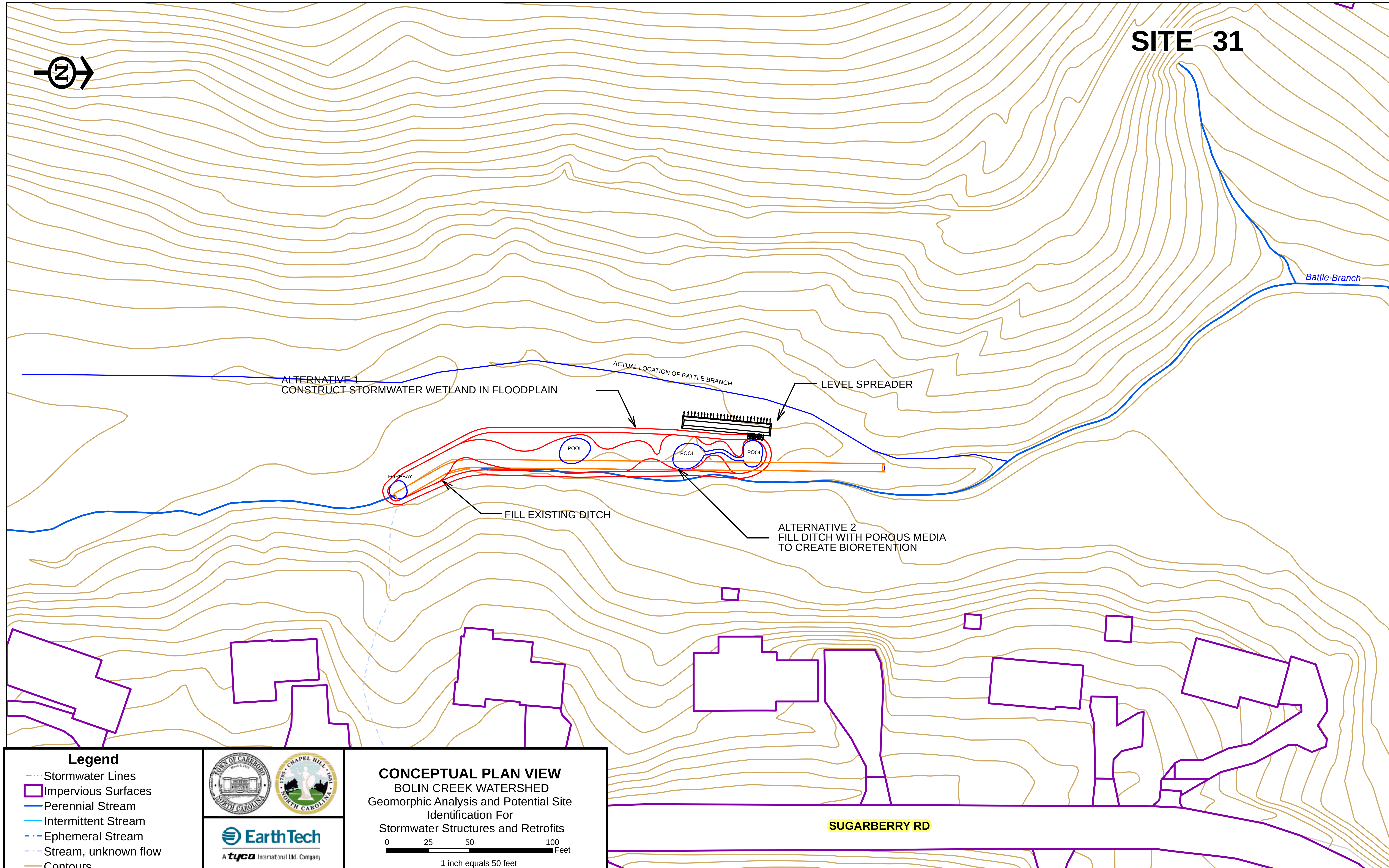
SITE 31
N
Battle Branch
ACTUAL LOCATION OF BATTLE BRANCH
ALTERNATIVE 1
CONSTRUCT STORMWATER WETLAND IN FLOODPLAIN
LEVEL SPREADER
POOL
POOL
POOL
FOREBAY
FILL EXISTING DITCH
ALTERNATIVE 2
FILL DITCH WITH POROUS MEDIA
TO CREATE BIORETENTION
SUGARBERRY RD
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
TOWN OF CARRBORO NORTH CAROLINA
CHAPEL HILL 1793 1851 NORTH CAROLINA
EarthTech
A tyco International Ltd. Company
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0 25 50 100
Feet
1 inch equals 50 feet

Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

EarthTech
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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For
Stormwater Structures and Retrofits

0 25 50 100 Feet

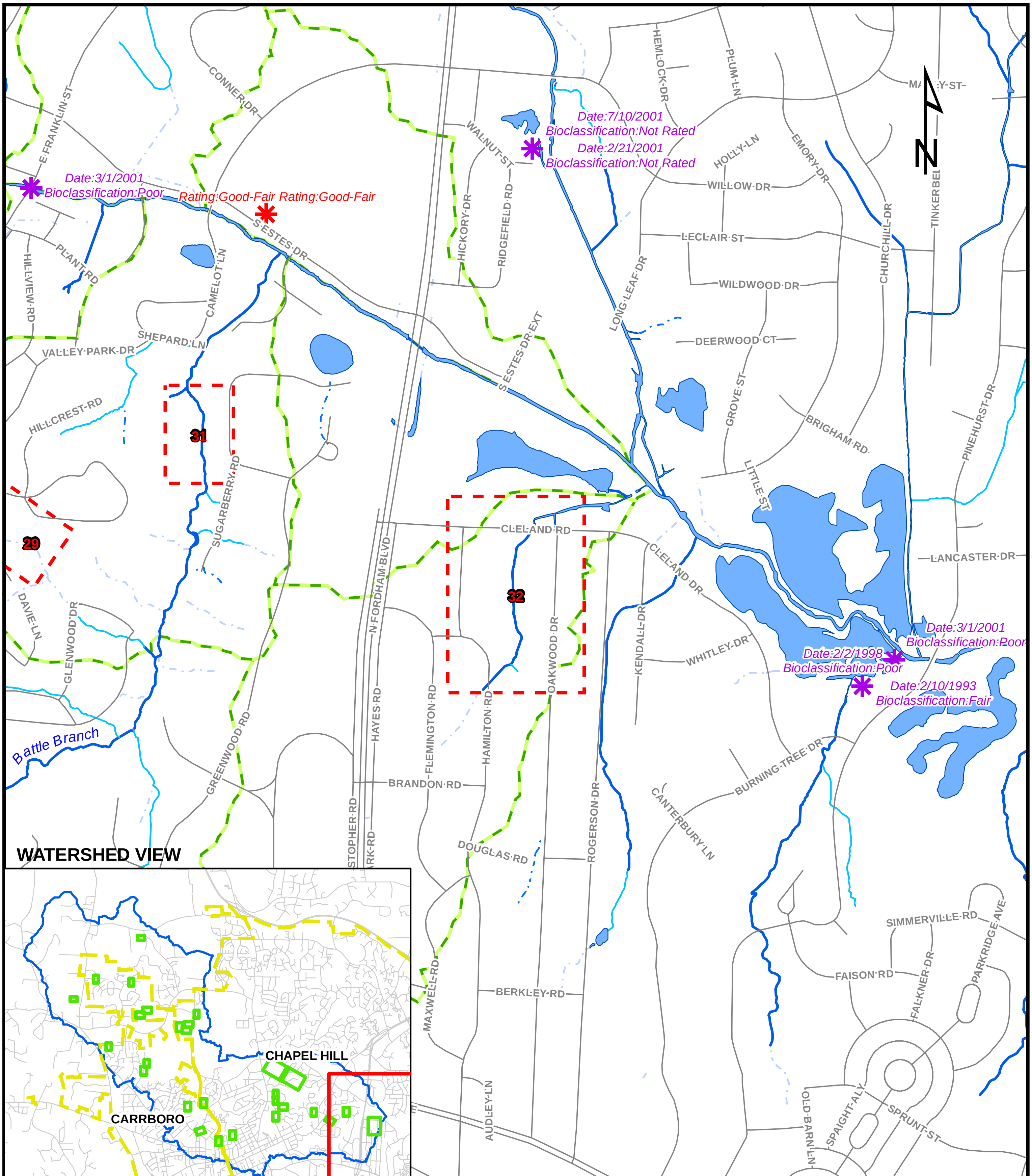
1 inch equals 50 feet

SITE 32

Restoration of Stream channel off Cleland Rd

Index Sheet No.: 34
Raw Data Name: BD 90

Estimated Construction Cost: $207,000



Legend

- Ambient Monitoring
- Benthic Monitoring
- Fish Sampling
- Municipal Boundary
- Orange County Roads
- Subwatersheds
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

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SITE 32
VICINITY MAP

Geomorphic Analysis and Identification of Potential Sites for Stormwater BMPs
Orange County, North Carolina

0 500 1,000 2,000 Feet

1 inch equals 1,000 feet

Project Description

	Drainage Area (acres)	Impervious Area (acres)	% Impervious
Site 32	149.6	38.0	25.4%

Location

Site 32 is located to the south of Cleland Rd, near the intersection of Cleland Rd and Oakwood Drive, and approximately 0.2 miles east of the intersection of US 15-501 and Cleland Rd. Several soccer fields are adjacent to the site.

Problem Description

Site 32 consists of a channelized, incised stream channel in the lower portion of the Bolin Creek Watershed. The stream appears to have been channelized and straightened at some point in the past, possibly during construction of the surrounding residential area and soccer fields. The resulting channel is incised and devoid of any natural stream habitat. The relic floodplain of the stream is filled with piles of spoil material, and heavily infested with exotic invasive species such as wisteria, multiflora rose, and privet. The contributing drainage area of the stream is comprised of medium to heavily developed residential areas, and a portion of US 15-501. Most of the stormwater in this drainage area is piped and discharges from an outlet at the southernmost edge of the Site 32. Bank erosion and BEHI ratings of "high" were observed along the entire reach.

Using the BANCS model, it is estimated that approximately 62 tons of sediment are being exported from the site each year. Concomitant nutrient export associated with the sediment has also been calculated and is listed in **Table 32.1**.

Table 32.1

Pre-Treatment	
Estimated Total Sediment Export	62.4 tons/year
Erosion per length of Channel	0.058 tons/yr/ft
Pounds of Nitrogen	124.8 lbs/year
Pounds of Phosphorus	62.4 lbs/year
Post-Treatment	
Estimated Total Sediment Export	3.6 tons/year
Erosion per length of Channel	0.003 tons/yr/ft
Pounds of Nitrogen	7.3 lbs/year
Pounds of Phosphorus	3.6 lbs/year

Proposed Solution

The stream channel that is the focus of treatment at this site is an ideal site for Priority I Restoration. Priority I restoration involves reconnecting the stream with the relic floodplain by raising the elevation of the bed, thereby restoring floodplain hydrology, reducing near bank stress and thus limiting the bank erosion problem. This site possesses ideal circumstances for this practice: a wide, intact relic floodplain and little need to meet elevations, other than the outlet pipe at the upstream end and the roadway culvert at the downstream end. Most of all, almost the entire floodplain is on state owned land, providing ample opportunity for changes in the planform and sinuosity of the stream. Besides the sediment reduction, stream restoration will provide the restoration of critical habitat for numerous aquatic species, as well as the hydrology needed to support riparian wetlands.

A conceptualized plan view of the site, based on average stream variables for the drainage area , is show in the the Plan View of Site 32 contained in this summary.

Constraints

Tree removal will be necessary if restoration is implemented at this site. The spoil piles will also need to removed, requiring additional earthwork.

Flooding issues may arise if the stream is reconnected to the relic floodplain, thus a flooding analysis and submission of a CLOMR will be required to determine if the project would affect the FEMA 100-year floodzone

Alternatives

No alternatives are proposed for this site.

Cost-Estimate Breakdown

Table 32.2 shows a conceptual itemized cost estimate for Site 32. The figure is based on an average stream restoration construction cost per linear foot, as of the time of this report.

Table 32.2

SITE 32

Pay Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Stream Restoration	1,200.00	LF	150.00	$180,000
			Total	$180,000
Mobilization (5%)	1.00	LS		$9,000
Contingencies (10%)	1.00	LS		$18,000
			Total + Mobilization and Contingencies	**$207,000**

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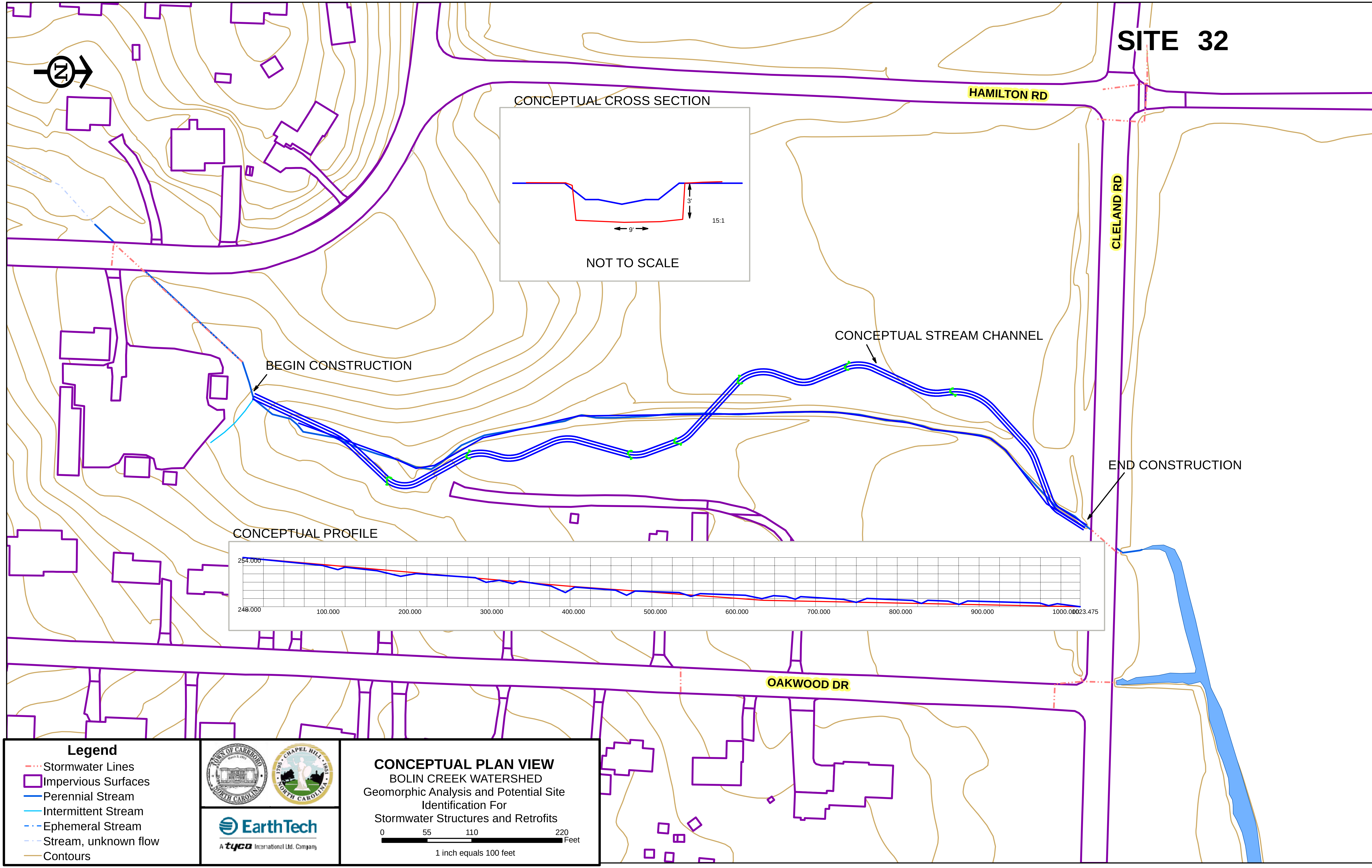
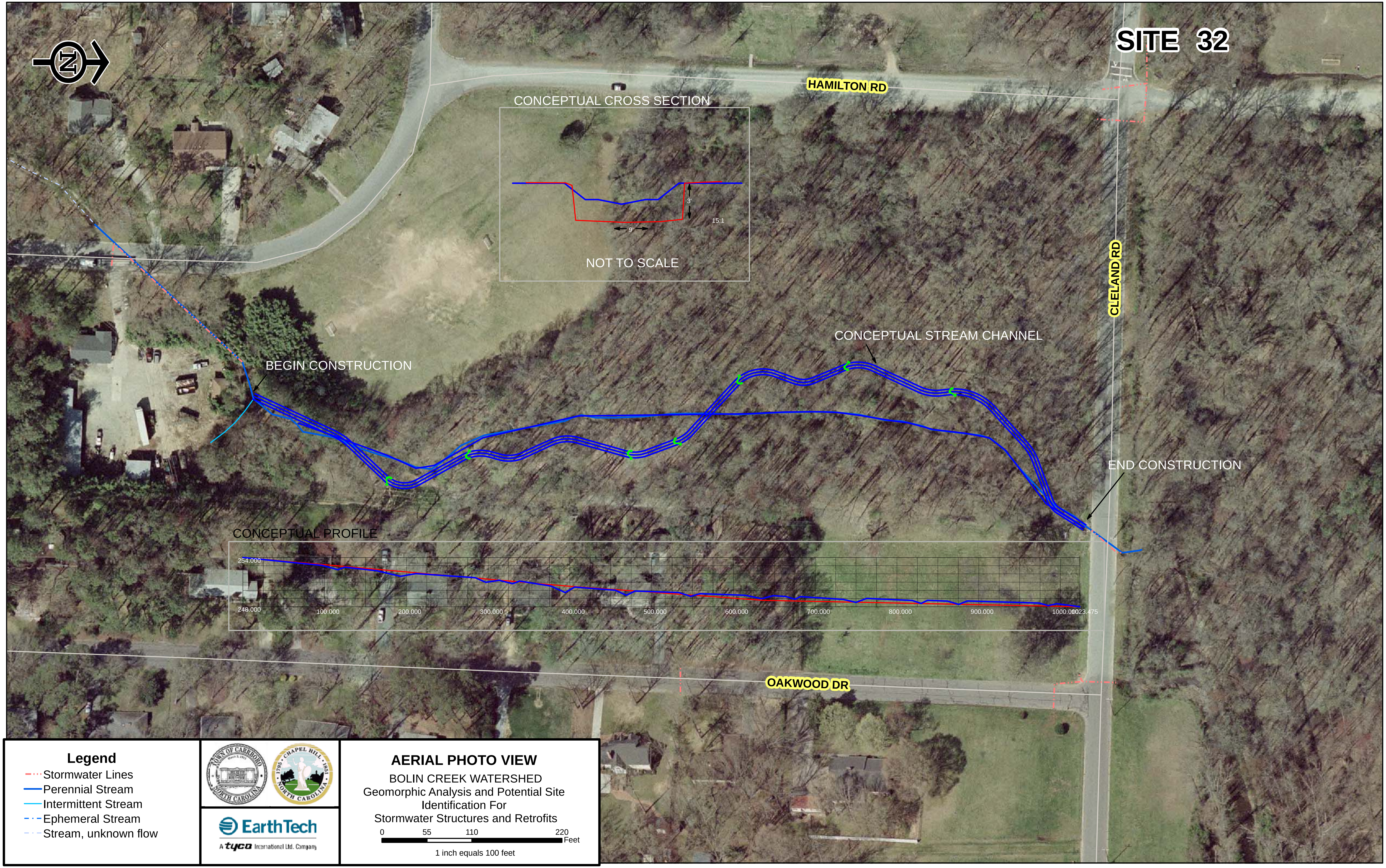


SITE 32
HAMILTON RD
CLELAND RD
OAKWOOD DR
CONCEPTUAL CROSS SECTION
3'
15:1
9'
NOT TO SCALE
CONCEPTUAL STREAM CHANNEL
BEGIN CONSTRUCTION
END CONSTRUCTION
CONCEPTUAL PROFILE
254.000
248.000
100.000
200.000
300.000
400.000
500.000
600.000
700.000
800.000
900.000
1000.000
1023.475
Legend
Stormwater Lines
Impervious Surfaces
Perennial Stream
Intermittent Stream
Ephemeral Stream
Stream, unknown flow
Contours
EarthTech
A tyco International Ltd. Company
CONCEPTUAL PLAN VIEW
BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site
Identification For
Stormwater Structures and Retrofits
0
55
110
220
Feet
1 inch equals 100 feet



Legend

- Stormwater Lines
- Perennial Stream
- Intermittent Stream
- Ephemeral Stream
- Stream, unknown flow

TOWN OF CARRBORO NORTH CAROLINA

CHAPEL HILL 1793 NORTH CAROLINA

EarthTech

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AERIAL PHOTO VIEW

BOLIN CREEK WATERSHED
Geomorphic Analysis and Potential Site Identification For Stormwater Structures and Retrofits

0 55 110 220 Feet

1 inch equals 100 feet

References

Center for Watershed Protection. October 30th, 2007. *Stormwater Management Fact Sheet: Stormwater Wetland.* Accessed online at [http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Wetland/Wetland.htm]..

North Carolina Department of the Environment and Natural Resources. July, 2, 2007 *Stormwater BMP Manual.* Division of Water Quality. Raleigh, NC.

Rosgen. D. 2006. *Watershed Assessment of River Stability and Sediment Supply*. Wildland Hydrology. Fort Collins, Colorado.

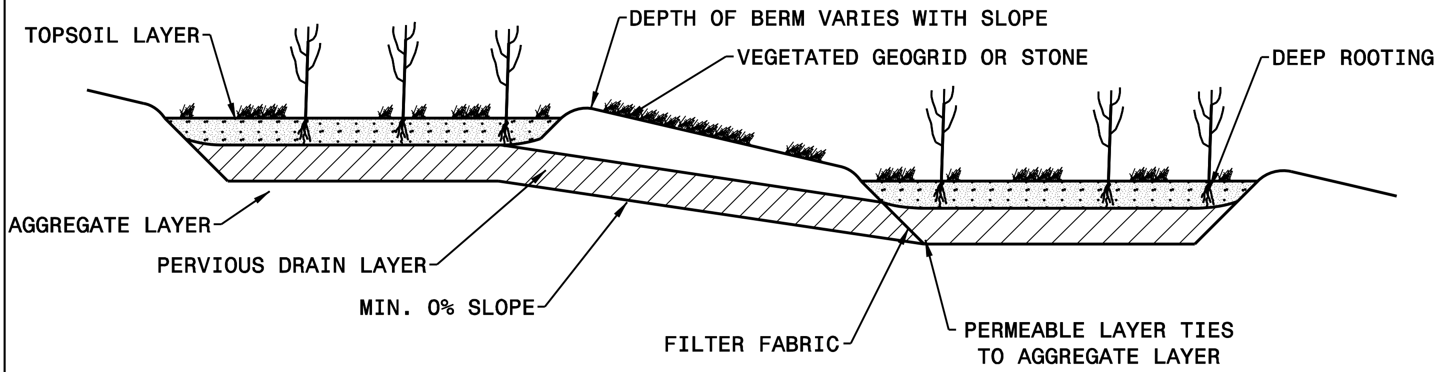
Rosgen. D. 1996. *Applied River Morphology*. Wildland Hydrology. Pagosa Springs, Colorado.

Schueler, Hirschman, Novotney and Zielinski. 2007. *Urban Stormwater Retrofit Practices Version 1.0*. Center for Watershed Protection. Ellicott City, MD.

APPENDIX A

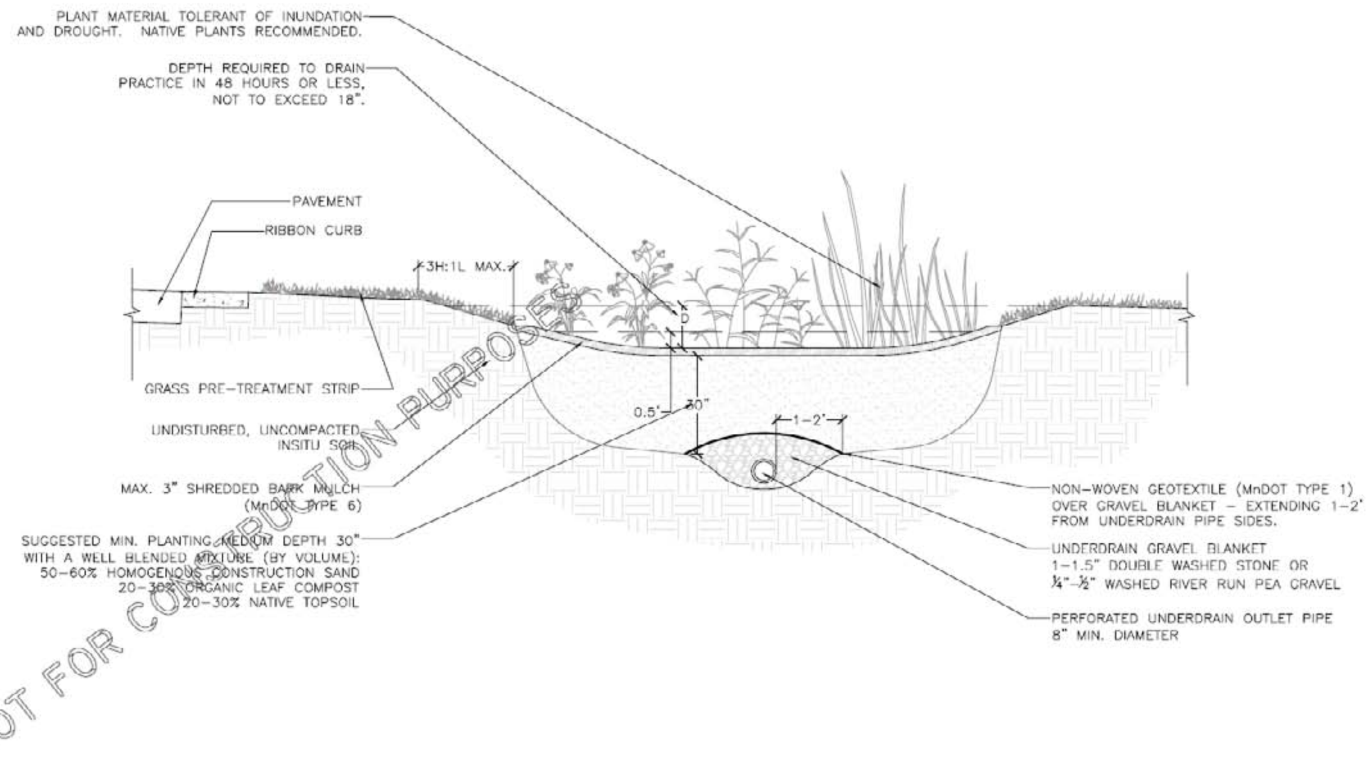
Details

STORMWATER BMP DETAILS



BIO-GRADE STEP

SCALE: NTS



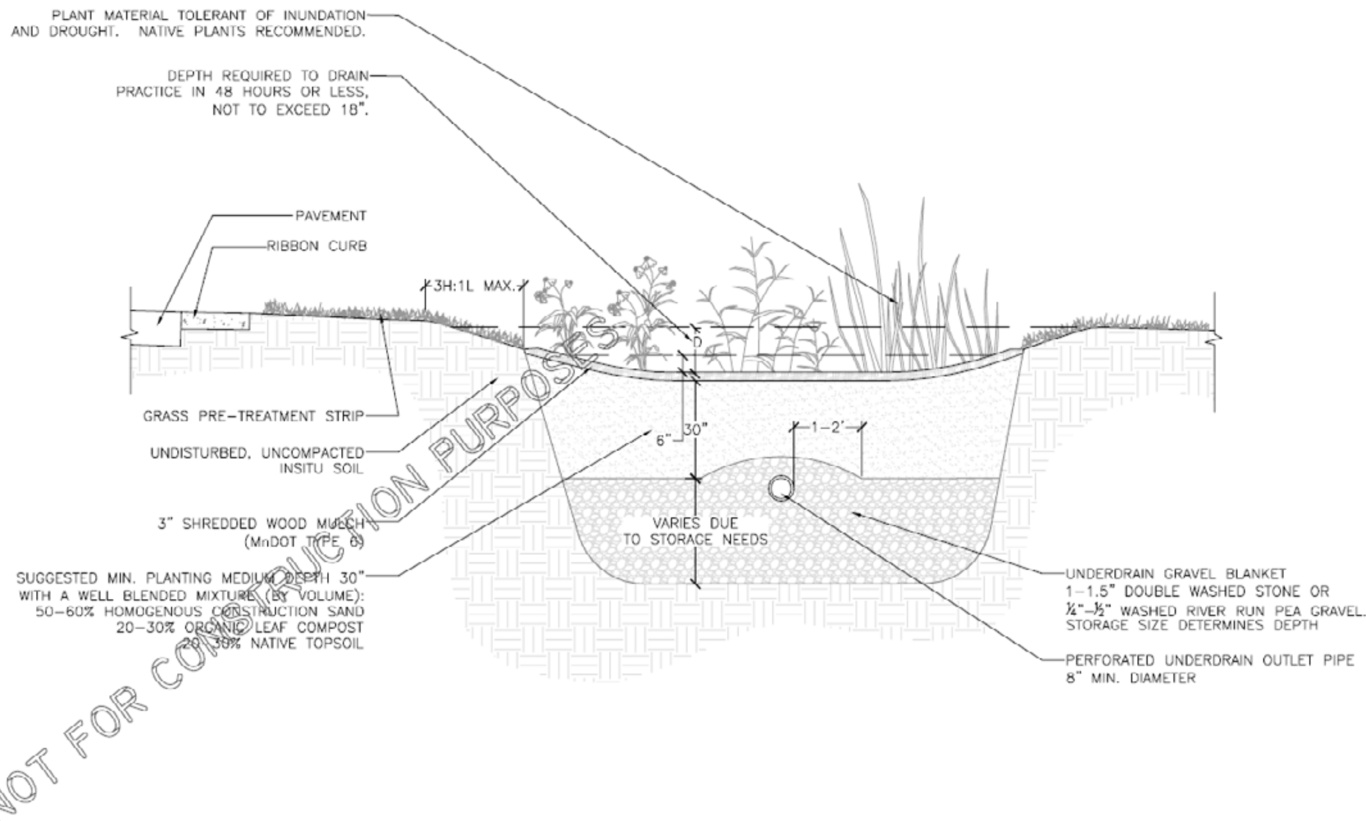
NOTE: NORTH CAROLINA SPECIFICATIONS MAY VARY

BIORETENTION AREA- FILTRATION AND PARTIAL RECHARGE

SCALE: NTS

Source: Minnesota Stormwater Manual. Version 1.1
Minnesota Pollution Control Agency

STORMWATER BMP DETAILS



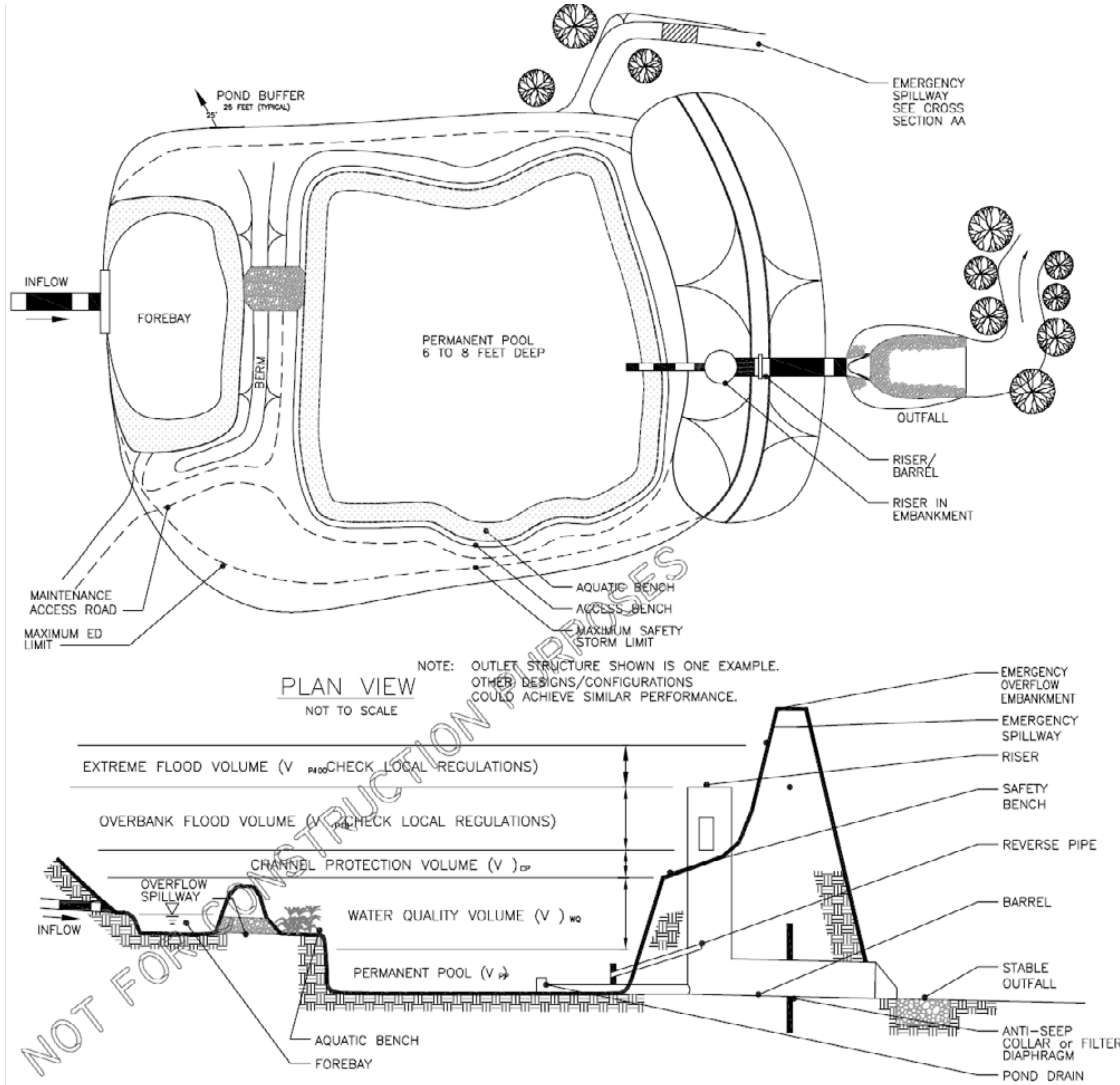
NOTE: NORTH CAROLINA SPECIFICATIONS MAY VARY

BIORETENTION AREA- FILTRATION/INFILTRATION/RECHARGE

SCALE: NTS

Source: Minnesota Stormwater Manual. Version 1.1
Minnesota Pollution Control Agency

STORMWATER BMP DETAILS

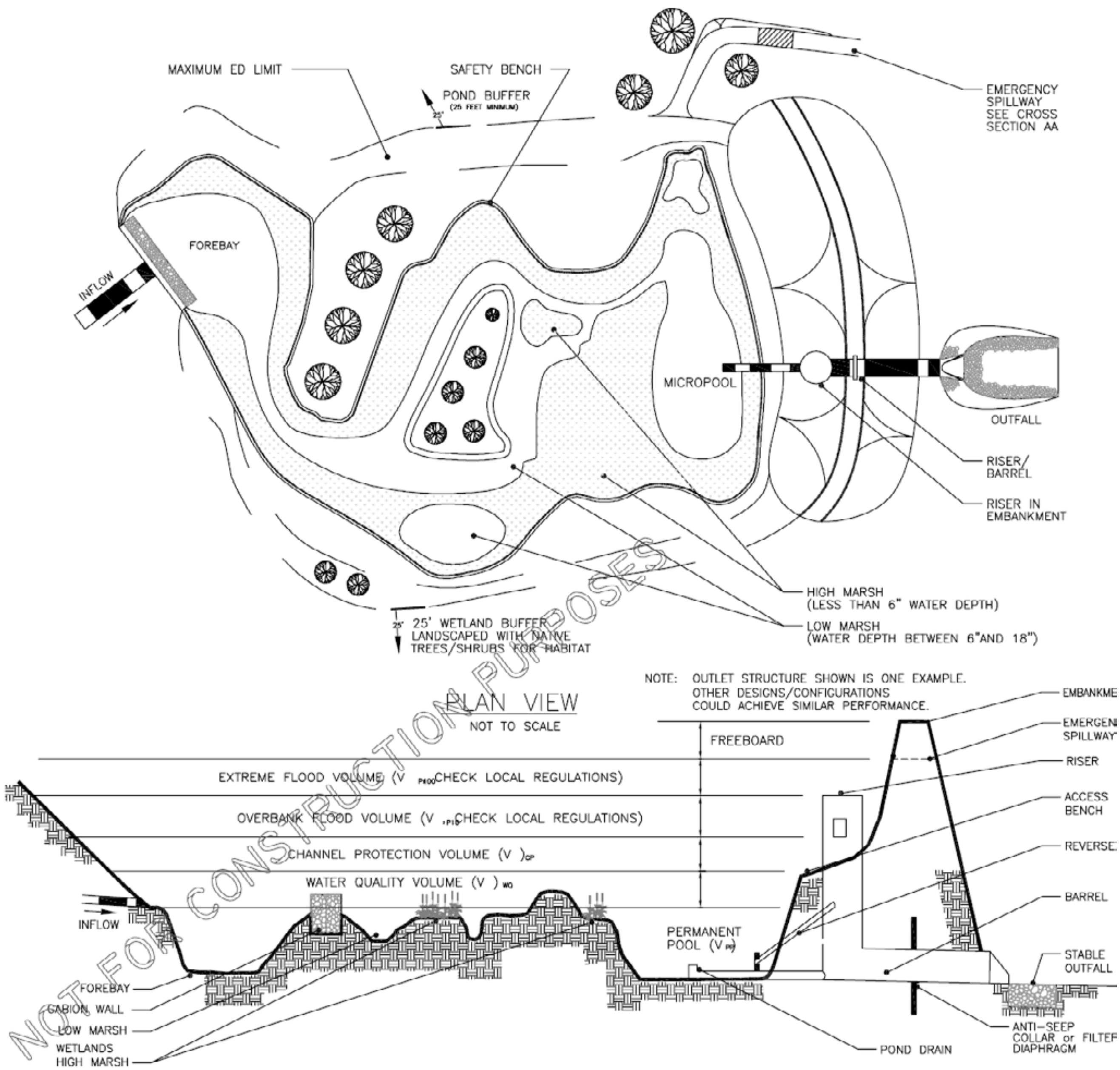


EXAMPLE WET DETENTION POND

SCALE: NTS

Source: Minnesota Stormwater Manual, Version 1.1
Minnesota Pollution Control Agency

STORMWATER BMP DETAILS

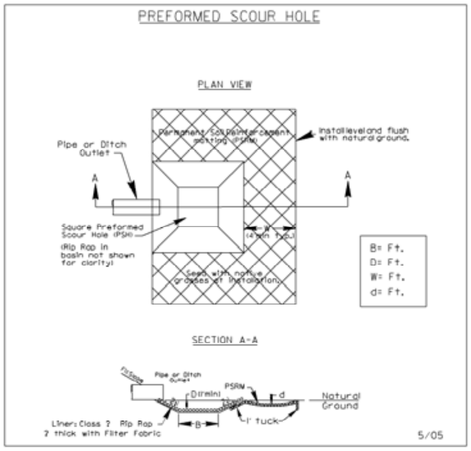


EXAMPLE STORMWATER WETLAND

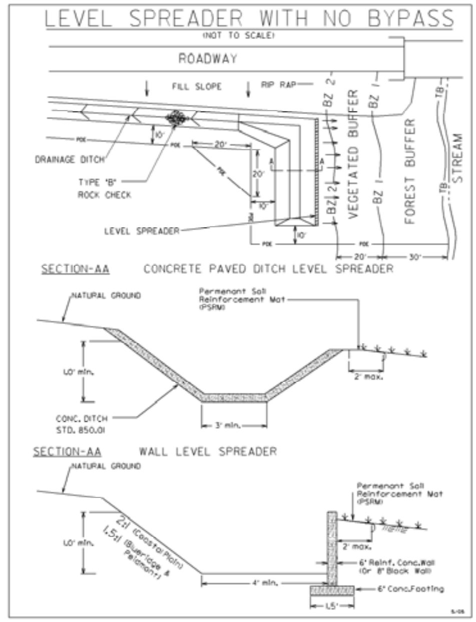
SCALE: NTS

Source: Minnesota Stormwater Manual, Version 1.1
Minnesota Pollution Control Agency

BMP COMPONENT DETAILS



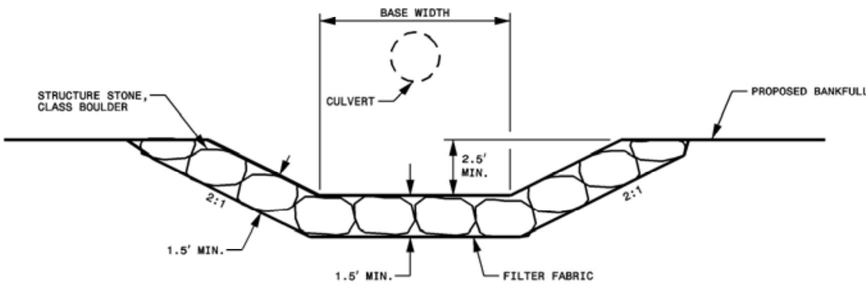
STA.



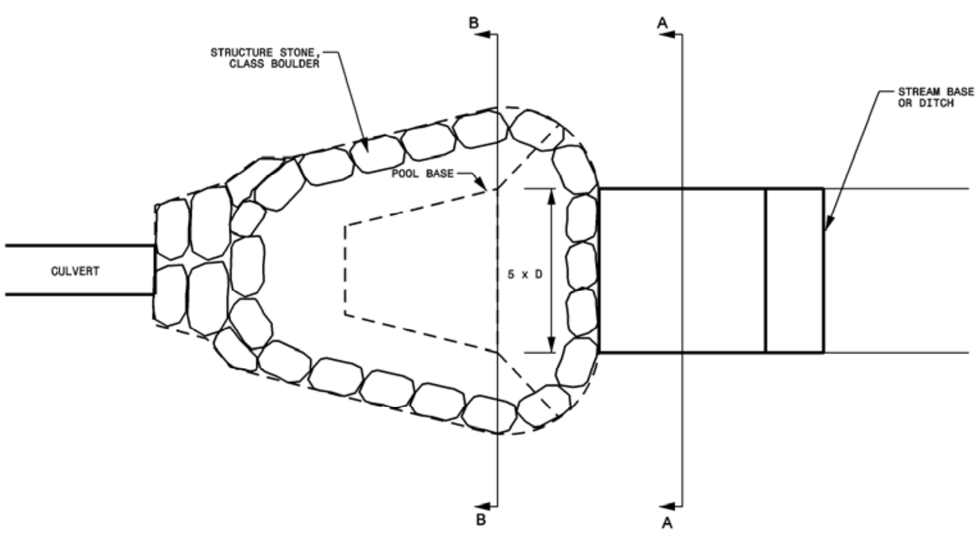
FROM STA. TO STA.

Note: Use concrete berm crest on all level spreaders.

Source: North Carolina Department of Transportation



SECTION B-B



NOTE:

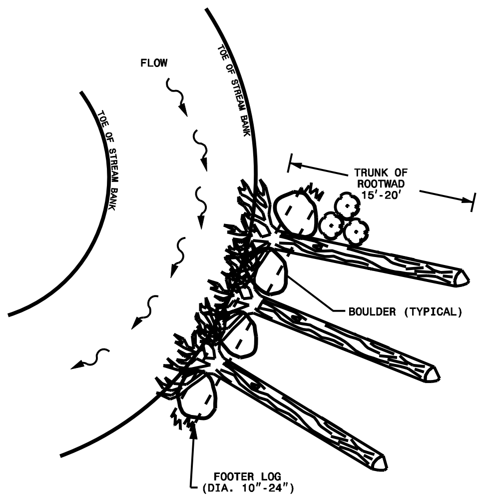
BASIN BOULDERS NOT SHOWN FOR CLARITY.
INCIDENTIAL RIP RAP AND FILL MATERIAL MAY BE REQUIRED AROUND FOOTER ROCKS FOR PROPER EMBEDMENT.

PLAN

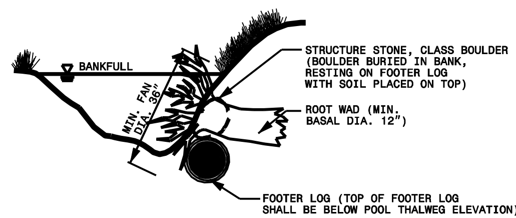
BOULDER DISSIPATOR BASIN

SCALE: NTS

STREAM RESTORATION DETAILS



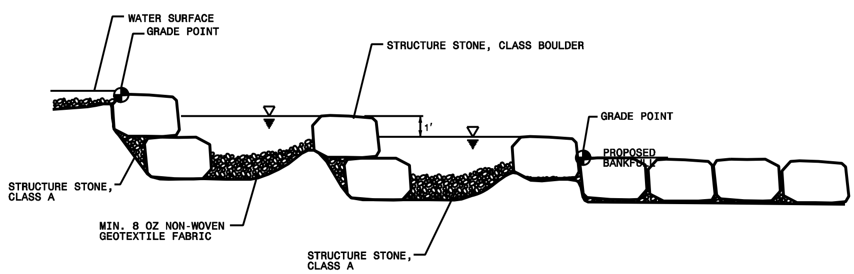
PLAN



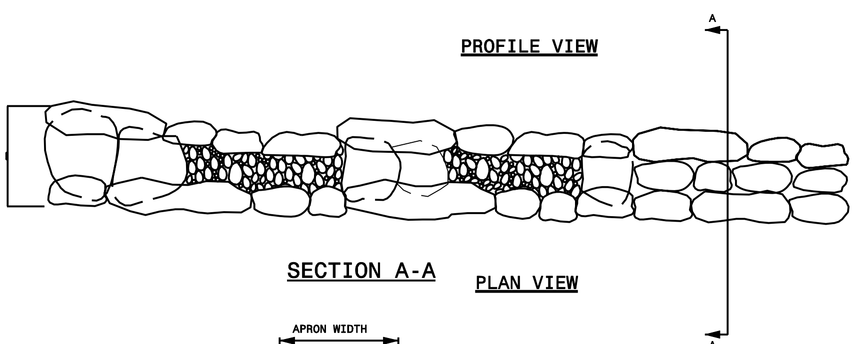
CROSS-SECTION

ROOT WAD

SCALE: NTS

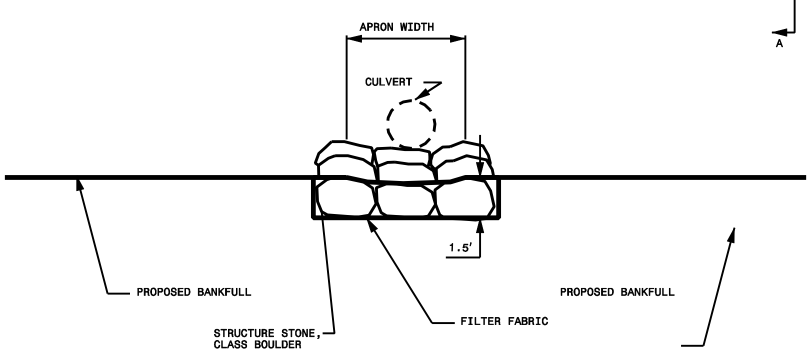


PROFILE VIEW



SECTION A-A

PLAN VIEW



STEP-POOL OUTFALL W/APRON

SCALE: NTS

BANK STABILIZATION DETAILS

Figure 1

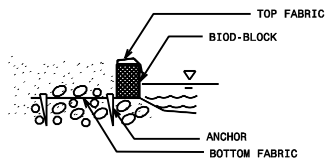


Figure 2

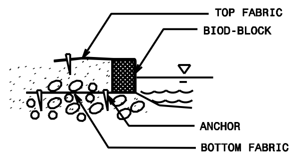


Figure 2a

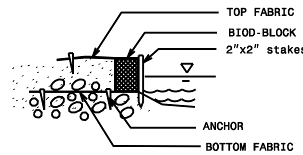


Figure 3

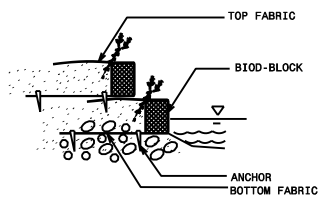
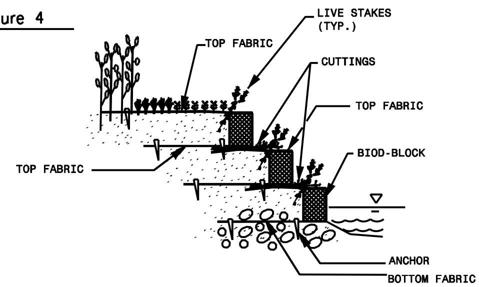
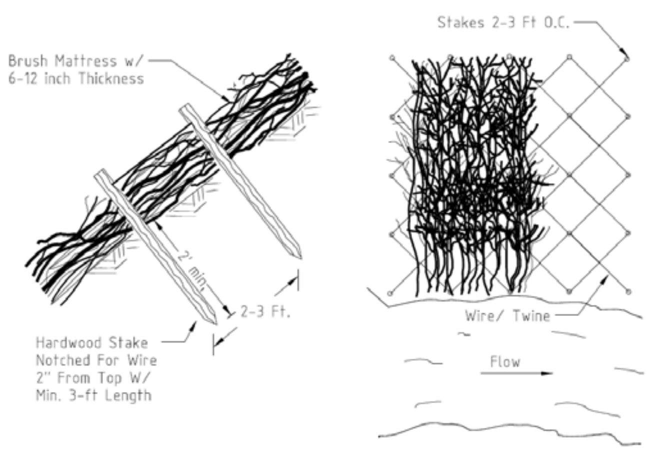


Figure 4

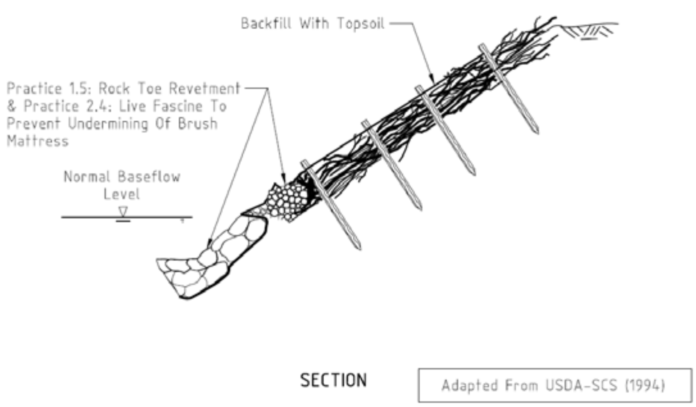


MUTILAYER BioD-BLOCK COIR BLOCK SYSTEM INSTALLATION GUIDE (vertically placed blocks)



DETAIL

PLAN



SECTION

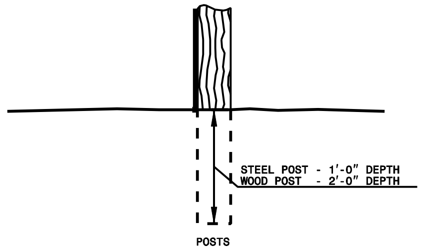
Adapted From USDA-SCS (1994)

BRUSH MATRESS

SCALE: NTS

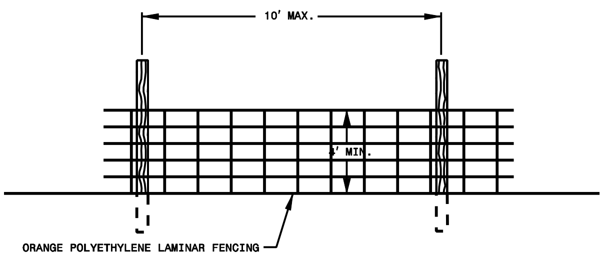
Source: Virginia Stream Restoration & Stabilization Best Management Practices Guide, 2004
Virginia Department of Conservation and Recreation

SITE PREPARATION DETAILS



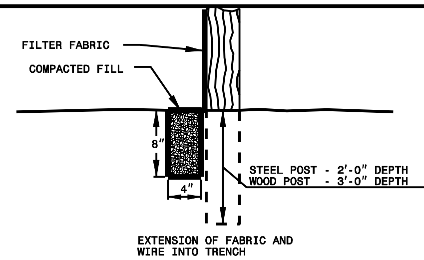
NOTES:

1. STEEL POSTS SHALL BE 5'-0" IN HEIGHT AND BE OF THE SELF-FASTENER ANGLE STEEL TYPE.
2. WOOD POST SHALL BE 6'-0" IN HEIGHT AND 3" MINIMUM IN DIAMETER.



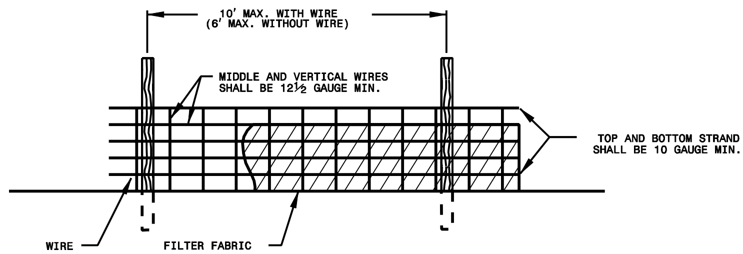
SAFETY FENCE/TREE PROTECTION FENCE

SCALE: NTS



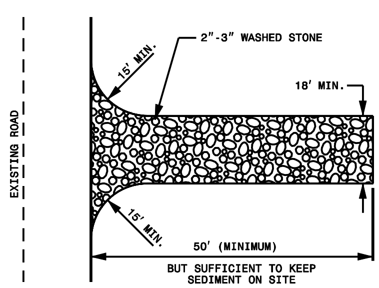
NOTES:

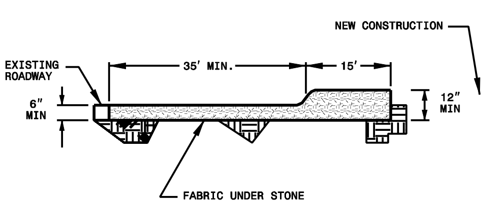
1. WIRE SHALL BE A MINIMUM OF 32" IN WIDTH AND SHALL HAVE A MINIMUM OF 6 LINE WIRES WITH 12" STAY SPACING.
2. FILTER FABRIC SHALL BE A MINIMUM OF 36" IN WIDTH AND SHALL BE FASTENED ADEQUATELY TO THE WIRE AS DIRECTED BY THE DESIGNER.
3. STEEL POSTS SHALL BE 5'-0" IN HEIGHT AND BE OF THE SELF-FASTENER ANGLE STEEL TYPE.
4. WOOD POST SHALL BE 6'-0" IN HEIGHT AND 3" MINIMUM IN DIAMETER.



TEMPORARY SILT FENCE

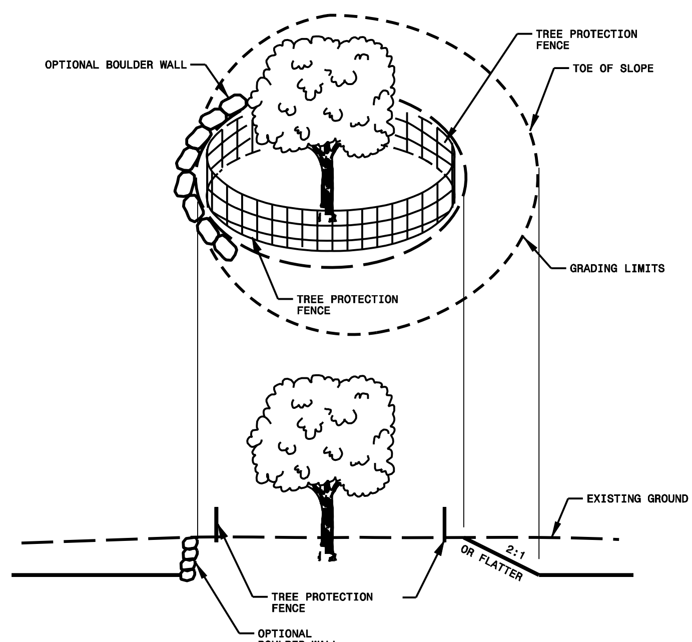
SCALE: NTS





TEMPORARY CONSTRUCTION ENTRANCE

SCALE: NTS



TREE ISLAND

SCALE: NTS

APPENDIX B

Photo Log

Site 1

A degraded and eroding spillway on Bolin Creek just below the pond dam. Facing upstream towards the dam.

Downstream of the spillway, sediment has accumulated in the bed of Bolin Creek. Facing downstream.

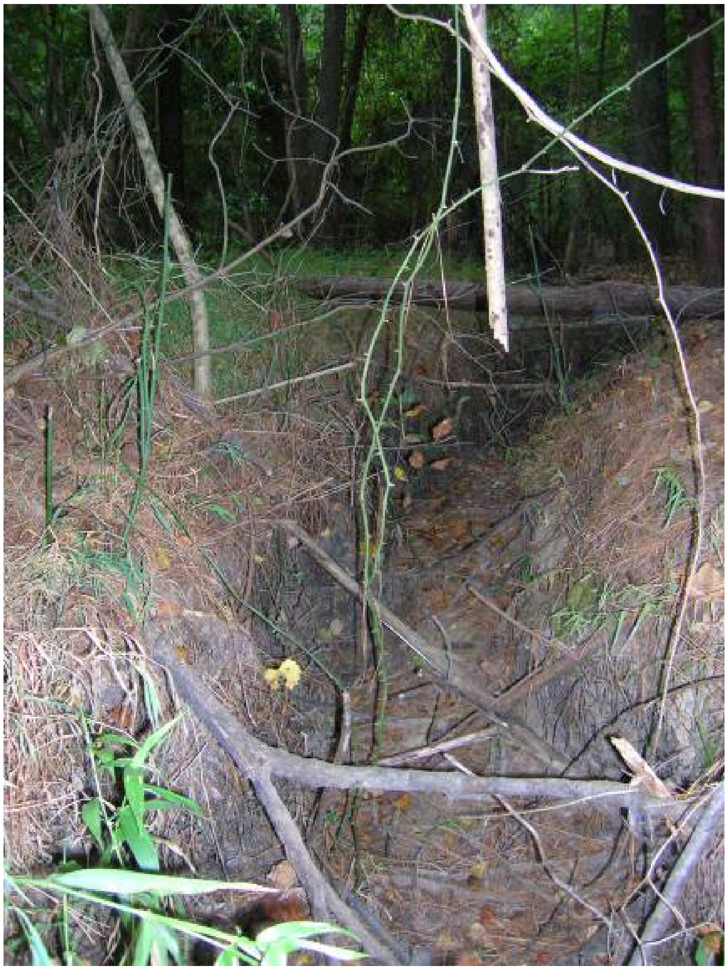
Site 2

The existing stormwater basin. Note the lack of vegetation and the close proximity of the inlet pipe to the outlet structure.

Site 3

Upstream of the headcut at Site 3. Facing downstream.

Downstream of the headcut, the channel is much more incised. Facing downstream.



Downstream of the headcut. Facing upstream.

The actively eroding headcut. Note the difference in elevation of the stream bed upstream and downstream. Facing upstream.

Site 4

Facing uphill towards the outlet pipe that discharges into a rip-rap lined ditch.

The stream into which the ditch at Site 4 leads. The ditch is on the left side of the photo. Facing upstream.

The concrete flow dissipation structure at Site 4.

Facing downsream where the ditch from the dissipating structure meets the stream. Note the eroding, partially caused by the flow discharging from the ditch.

Looking upstream at the ditch.

Sites 5 through 7

Site 5. The sediment basin outlet structure, facing northwest.

Another sediment basin at Site 6. Note the eroding grassy swale leading into the basin. Facing east.


An eroding grassy swale, facing west.


The stormwater outfall of the sediment basin at Site 5.   Facing south.

The second sediment basin at Site 6. The pipe outfall is only feet away from the stream, which is located at the bottom of the photo. Facing North.

The private alley at Site 7. The potential area for bioretention is on the left side of the photo. Facing north.

Facing south from the same location as above.

The current pipe and outlet at Site 7. Facing east.

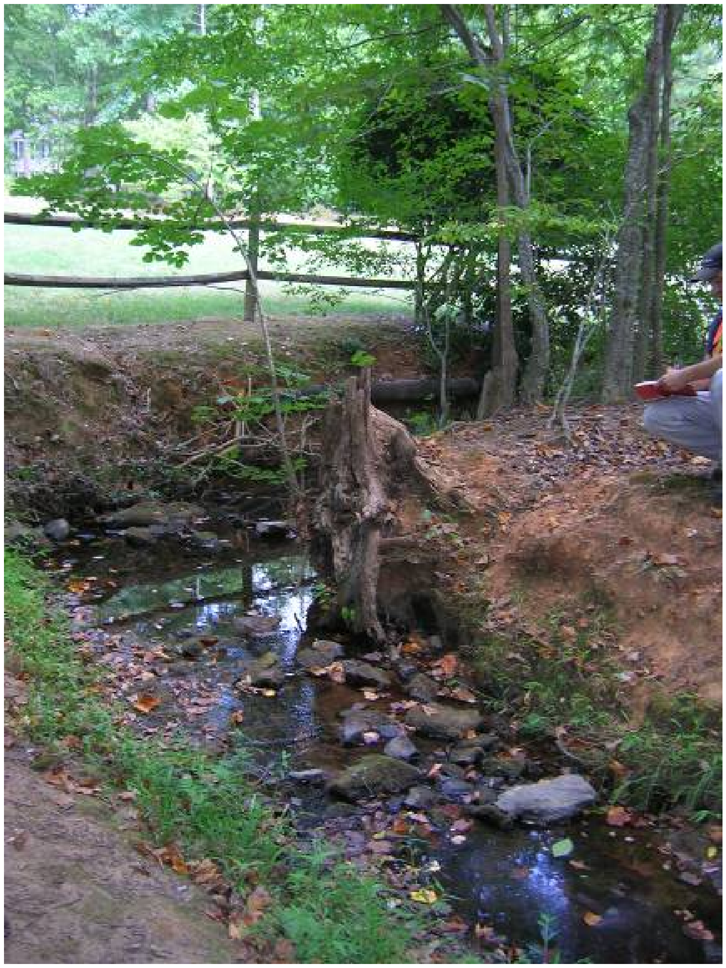

An eroding bank at Site 6. Facing north.

Site 8

An existing stormwater basin at Site 8. Facing northeast.

The stormwater basin one month later. The berm has been removed and the site re-seeded with grass.

Site 9



Eroding stream banks upstream of the Cobblestone Drive crossing. Facing downstream.

A utility line runs parallel with the streambank, just upstream of Cobblestone Drive crossing.

Eroding streambanks downstream of the road crossing. Facing towards right bank.

Site 10

Scour areas are present across from a utility easement, behind the backyard of several houses. Facing west towards the houses.

Where the flow has concentrated, an eroding channel and headcut has formed. Facing downstream.

Sites 11 through 14

A drop inlet at the middle school. Each of these could be converted into a bioretention area.

The pipe outlet discharging stormwater from the middle school. Facing south towards the middle school.

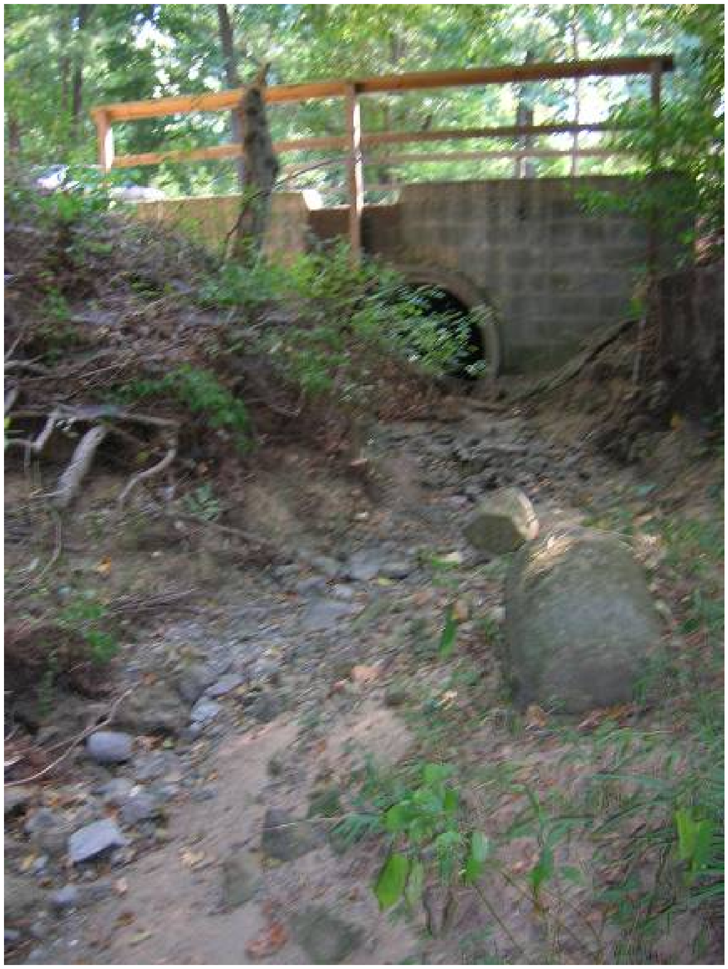
Site 15

An existing sediment basin below a gravel driveway and culvert. Facing north towards the driveway.

A view of the rip-rap berm around the basin. An eroding channel has formed below the basin. Facing north.

An eroding channel and headcut have formed in the floodplain of Jolly Branch.

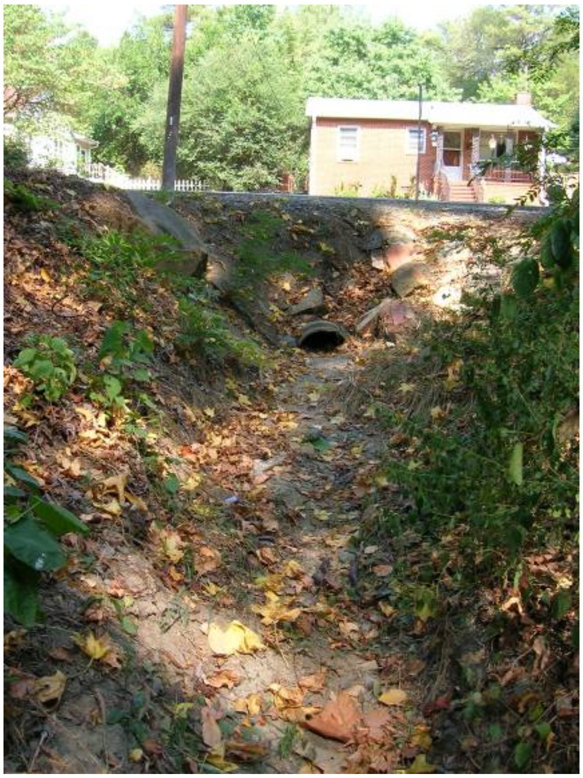
Site 16



A driveway to an apartment complex crosses the stream. Facing downstream.

The stream is severely incised, and has degraded below the roots of several large trees. Facing upstream.


What was observed to be an ephemeral stream joins the main channel after flowing under Estes Drive Ext. Facing downstream.


The ephemeral tributary facing upstream towards Estes Drive Ext.

Site 17

An eroding hillside at Site 17. Facing upstream.

Site 18

A view of the erosion occurring adjacent to a railroad trestle. Facing north.

The erosion consists of two headcuts eroding uphill. Facing north.


Stormwater flows past the railroad trestle footers and directly into Bolin Creek. Facing south.

Site 19

A view of the stream and surrounding park. Note the lack of riparian vegetation. Facing downstream.

Mass wasting is occurring along this reach. Facing upstream.

Facing downstream.

Site 20

Severe bank erosion is occurring along this reach. Facing upstream.

Another view of the incised channel and bank erosion. Kudzu dominates the floodplain of the stream. Facing downstream.

Site 21

The gulley at Site 21. Facing west towards Hillsborough Street.

A view from the top of the gulley looking downhill. Facing east.


The stormwater outfall pipe from Hillsborough Street is almost completely buried. Facing northwest.

Site 22

An eroding hillside along Bolin Creek is the primary feature at Site 22. The bank is approximately 18 feet high.

Site 23

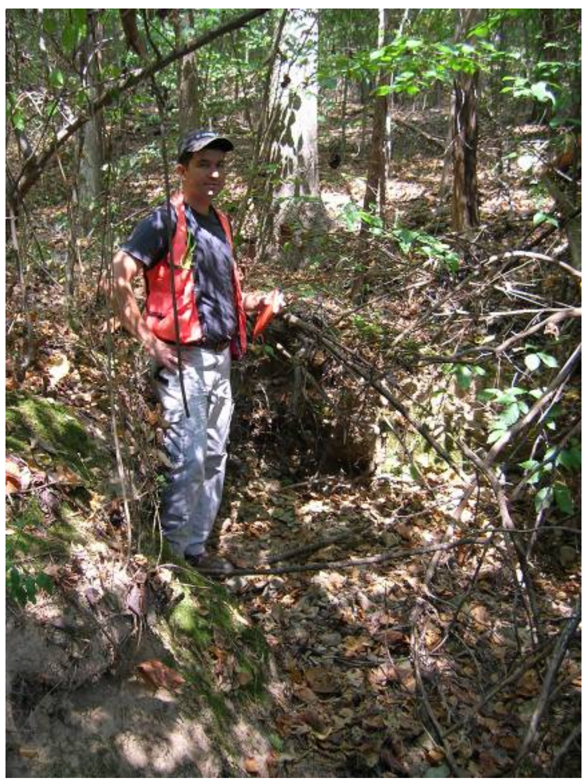
An existing sediment basin in-line with what was observed to be an ephemeral channel. The basin has filled with sediment and trees have become established. Facing south and downstream.


The stormwater outfall at Site 23, which flows into the existing basin. Facing north and upstream.


The basin provides a good location for a stormwater BMP retrofit. Facing northeast.

Site 24

The stream channel at site 24 is incised as it flows towards Bolin Creek and the Bolin Creek Greenway. Facing downstream.



A headcut along the channel. Facing upstream.

Sites 25 through 28

Cole Springs Branch is incised with undercut banks near Site 25. Facing downstream.

An eroding bank on Cole Springs Branch near Site 25. Facing downstream.


Fill has been placed in an ephemeral channel near Site 26.


An old spring-head improvement near Site 26.

A relic stream channel in the floodplain near Site 27. This floodplain area provides a good location for side-channel BMPs.

The stream channel near Site 27.


What was observed to be an ephemeral stream at Site 28. This could serve as the location for a bio-retention area.


A utility crossing near Site 28 has caused mass wasting on the stream banks.

Site 29

One of the headcuts present at Site 29. Looking upstream.

Another headcut area. Looking downstream

After flowing downhill, the stream flows across a utility easement road. Facing upstream and west.

Site 30

A view of Hotelling Ct, which comprises part of the drainage area of the basin at Site 30. The existing BMP is downhill and to the left of the photo. Facing northwest.

The stormwater outfall pipe below Hotelling Ct. Facing northeast.


Flow from the stormwater outfall is causing hill erosion before flowing into the existing BMP. Facing northeast.


The existing BMP has filled in since its construction. Facing southeast.

Site 31

A ditch was dug in the floodplain of Battle Branch. On the right side of the photo is a residential backyard. The left side of the photo is the floodplain and utility easement along Battle Branch. Facing downstream.

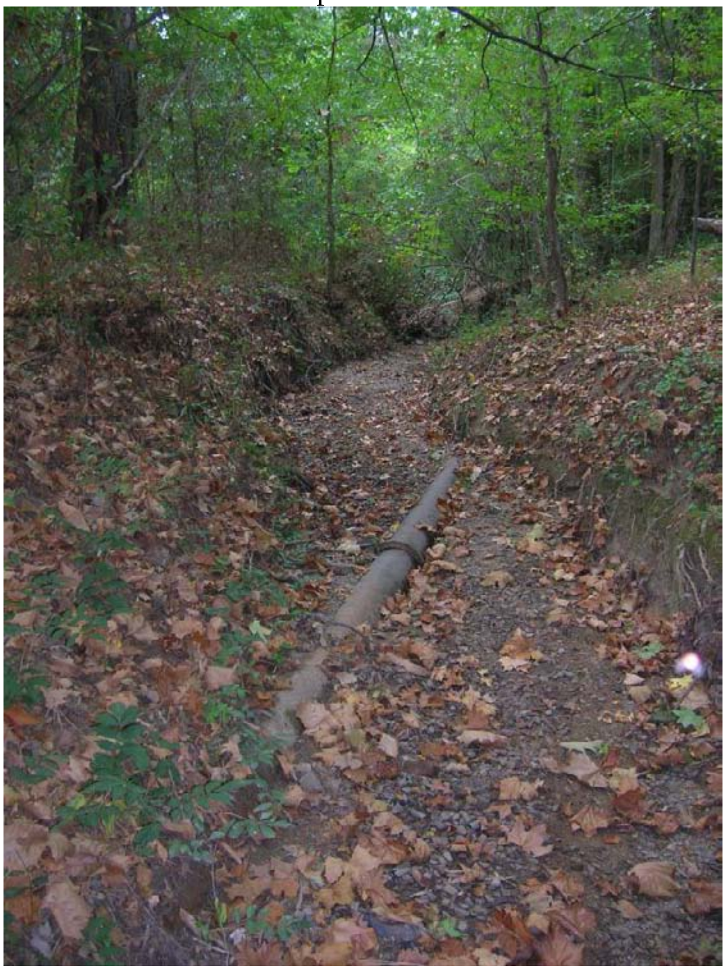
A view of a stormwater scour area flowing from the paved roads of a residential area into the floodplain ditch.


The confluence of the floodplain ditch with Battle Branch. Facing upstream.


The upstream end of the floodplain ditch, where it is met by stormwater flowing from the nearby road.

Site 32

The upstream end of a channelized stream, where a stormwater outfall discharges into a large pool. Facing upstream.



A utility line crosses the bed of the stream. Facing downstream.


The stream has been straightened for most of its course. Spoil piles are present in the floodpain. Facing upstream.


Eroding banks along the stream. Facing downstream.

APPENDIX C

Raw Data Forms for Final Sites

STREAM NAME: BOLIN CREEK	**DATE: 5/30/07**	**MAP SHEET #: 4**
PHOTO NUMBERS:	**LANDMARK: LAKE WEST OF OLD NC 86**	**SKETCH ON BACK**

GPS ID START: IJ04 **DESCRIPTION:**	**GPS ID END: IJ04** **DESCRIPTION:**
RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain X None ☐ Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

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

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

DOMINANT SUBSTRATE X 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 ___5____(ft) **Width**: Bottom ___3_____(ft) Top ____3____(ft) Water Surface ____0.5____(ft) **Depth:** Max BKF ________(ft) **B:H Ratio:** Low bank/Max BKF=_______	**OBSERVED IMPACTS** ☒ Outfall ☐ Confluence ☐ Impacted buffer ☐ Stream crossing ☐ Channel mod ☐ Utility impacts ☐ Beaver ☐ Other
CHANNEL DYNAMICS ☒ Downcutting ☐ Widening ☒ Headcutting ☐ Aggrading ☐ Bed scour ☒ Bank failure ☒ Bank scour ☐ Sed. deposition ☐ Slope failure ☐ Channelized ☐ Unknown		**NOTES** -HAVE POND OUTFALL- LARGE AMOUNTS OF BANK EROSION OCCURING AND DEEPLY INCISED- COULD DO POSSIBLE OUTFALL REPAIR

QUALITATIVE IMPAIRMENT RATING: ☐ Low ☐ Moderate X Severe	**CHANNEL EVOLUTIUON STAGE:** ☐ **I** ☐ **II** ☐ **III** ☐ **IV** ☐ **V** ☐ **VI** (*Simon et. al., 2003*)

STREAM NAME: UT	**DATE:** 5/31/07	**MAP SHEET #:** 7
PHOTO NUMBERS: 1118-1122	**LANDMARK:** ROGERS AND EUBANKS	**SKETCH ON BACK**

GPS ID START: BD 27 **DESCRIPTION:**	**GPS ID END:** BD 28 **DESCRIPTION:**
RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain X None ☐ Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

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

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

DOMINANT SUBSTRATE X 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 __4.1______(ft) **Width**: Bottom __6______(ft) Top __6.5______(ft) Water Surface ___0.1____(ft) **Depth:** Max BKF ____NA_(ft) **B:H Ratio:** Low bank/Max BKF=_______	**OBSERVED IMPACTS** ☐ Outfall ☐ Confluence HEAD CUTS ☐ Impacted buffer ☐ Stream crossing ☐ Channel mod ☐ Utility impacts ☐ Beaver ☐ Other

CHANNEL DYNAMICS ☐ Downcutting ☐ Bed scour ☐ Slope failure ☐ Widening ☐ Bank failure ☐ Channelized ☒ Headcutting ☐ Bank scour ☐ Unknown ☐ Aggrading ☐ Sed. deposition	**NOTES** **SOME FLOW FROM YARDS MAY BE CAUSING HEADCUTS ALSO SIGNS OF RILLS**
QUALITATIVE IMPAIRMENT RATING: ☐ Low X Moderate ☐ Severe	**CHANNEL EVOLUTIUON STAGE:** ☐ I ☐ II ☐ III ☐ IV ☐ V ☐ VI (*Simon et. al., 2003*)

STREAM NAME: UT	**DATE: 6/5/07**	**MAP SHEET #: 9**
PHOTO NUMBERS: 1087	**LANDMARK: UP STRM CIRCADIAN WAY**	**SKETCH ON BACK**

GPS ID START: TA 1 **DESCRIPTION: BRIDGE OVER CIRCADIAN WAY**	**GPS ID END: TA 4** **DESCRIPTION: FOOT BRIDGE**
RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain X None ☐ Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

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

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

DOMINANT SUBSTRATE ☐ Silt/clay (fine or slick) 1 Sand (gritty) 2 Gravel (0.1-2.5") ☐ Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**CHANNEL DIMENSIONS AT RIFFLE** **Height**: Low bank 3.5________(ft) **Width**: Bottom 4.5 ________(ft) Top 10.0________(ft) Water Surface 3.5________(ft) **Depth:** Max BKF 1.0________(ft) **B:H Ratio:** Low bank/Max BKF=_______	**OBSERVED IMPACTS** ☒ Outfall ☐ Confluence ☐ Impacted buffer ☐ Stream crossing ☒ Channel mod ☐ Utility impacts ☐ Beaver ☐ Other - Incision

CHANNEL DYNAMICS ☒ Downcutting ☐ Bed scour ☐ Slope failure ☒ Widening ☐ Bank failure ☐ Channelized ☒ Headcutting ☒ Bank scour ☐ Unknown ☐ Aggrading ☐ Sed. deposition	**NOTES** **TA 2 - TA 4 INCISED CHANNEL** **TA 3- STORMWATER DRAINAGE DITCH**
QUALITATIVE IMPAIRMENT RATING: ☐ Low X Moderate ☐ Severe	**CHANNEL EVOLUTIUON STAGE:** ☐ I ☐ II X III X IV ☐ V ☐ VI (*Simon et. al., 2003*)

Stream Name: UT below Gates Farm Rd	**Date:** 6/5/07	**Map Sheet #:** 14
Photo Numbers: 1093-1095	**Landmark:** Gates Farm Rd	**Sketch on back**

GPS ID START: TA-5 **Description:** Near Gates Farm Rd	**GPS ID END:** **Description:**
Rain in last 24 hours ☐ Heavy rain ☐ Steady rain X None ☐ Intermittent ☐ Trace	**Present conditions** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

Surrounding land use: ☐ Industrial ☐ Commercial ☐ Urban/Residential X Suburban/Res ☐ Forested ☐ Institutional ☐ Golf course ☐ Park ☐ Crop ☐ Pasture ☐ Other:

Base Flow width as % Channel Width ☐ 0-25% ☐ 25-50 % ☐ 50%-75% X 75-100%	**Water Clarity** X Clear X Turbid *(suspended matter)* ☐ Stained *(clear, naturally colored)* ☐ Opaque *(milky)* ☐ Other (chemicals, dyes)

Dominant Substrate	**Channel Dimensions at riffle**	**Observed Impacts**
☐ Silt/clay (fine or slick) 1 Sand (gritty) ☐ Gravel (0.1-2.5") 2 Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**Height**: Low bank 3.5________(ft) **Width**: Bottom 7.0________(ft) Top 11.0________(ft) Water Surface 7.0________(ft) **Depth:** Max BKF 1.1________(ft) **B:H Ratio:** Low bank/Max BKF=_______	☒ Outfall ☐ Confluence ☒ Impacted buffer – **Cat litter dump site** ☐ Stream crossing ☐ Channel mod ☒ Utility impacts ☐ Beaver ☒ Other- scour from increased SW

Channel Dynamics	**Notes**
☐ Downcutting ☒ Widening ☐ Headcutting ☐ Aggrading ☐ Bed scour ☐ Bank failure ☒ Bank scour ☐ Sed. deposition ☐ Slope failure ☐ Channelized ☐ Unknown	

Qualitative Impairment Rating: X Low X Moderate ☐ Severe	**Channel evolutiuon Stage:** ☐ I ☐ II ☐ III X IV ☐ V ☐ VI (*Simon et. al., 2003*)

STREAM NAME: UT	**DATE: 6/6/07**	**MAP SHEET #: 15**
PHOTO NUMBERS: 1098-1099	**LANDMARK: COBBLESTONE DR**	**SKETCH ON BACK**

GPS ID START: TA 12 **DESCRIPTION:**	**GPS ID END: TA 13** **DESCRIPTION:**
RAIN IN LAST 24 HOURS ☐ Heavy rain X Steady rain ☐ None ☐ Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

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

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

DOMINANT SUBSTRATE	**CHANNEL DIMENSIONS AT RIFFLE**	**OBSERVED IMPACTS**
X Silt/clay (fine or slick) ☐ Sand (gritty) ☐ Gravel (0.1-2.5") ☐ Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**Height**: Low bank 0.3________(ft) **Width**: Bottom 1.0________(ft) Top 1.0________(ft) Water Surface 0.0________(ft) **Depth:** Max BKF 0.3________(ft) **B:H Ratio:** Low bank/Max BKF=_______	☐ Outfall ☐ Confluence ☐ Impacted buffer ☐ Stream crossing ☐ Channel mod ☐ Utility impacts ☐ Beaver ☒ Other- R/O from Cobblestone Dr

CHANNEL DYNAMICS			**NOTES**
☒ Downcutting ☐ Widening ☐ Headcutting ☐ Aggrading	☒ Bed scour ☐ Bank failure ☐ Bank scour ☐ Sed. deposition	☐ Slope failure ☐ Channelized ☐ Unknown	**POTENTIAL FOR SWALE OR RAIN GARDEN**

QUALITATIVE IMPAIRMENT RATING: ☐ Low X Moderate ☐ Severe	**CHANNEL EVOLUTIUON STAGE:** ☐ I ☐ II X III ☐ IV ☐ V ☐ VI (*Simon et. al., 2003)*

<table>
<tr><td colspan="2">STREAM NAME: UT TO JOLLY BRANCH</td><td>DATE: 6/5/07</td><td>MAP SHEET #: 16</td></tr>
<tr><td colspan="2">PHOTO NUMBERS: 0418</td><td>LANDMARK: SMITH MIDDLE SCHOOL</td><td>SKETCH ON BACK</td></tr>
<tr><td colspan="2">GPS ID START: IJ 34
DESCRIPTION:</td><td colspan="2">GPS ID END: IJ 34
DESCRIPTION:</td></tr>
<tr><td colspan="2">RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain
X None ☐ Intermittent ☐ Trace</td><td colspan="2">PRESENT CONDITIONS ☐ Heavy rain ☐ Steady rain ☐ Intermittent
☐ Clear ☐ Trace ☐ Overcast X Partly cloudy</td></tr>
<tr><td colspan="4">SURROUNDING LAND USE: ☐ Industrial ☐ Commercial X Urban/Residential X Suburban/Res X Forested ☐ Institutional
☐ Golf course ☐ Park ☐ Crop ☐ Pasture ☐ Other:</td></tr>
<tr><td colspan="2">BASE FLOW WIDTH AS % CHANNEL WIDTH
☐ 0-25%
☐ 25-50 %
X 50%-75%
☐ 75-100%</td><td colspan="2">WATER CLARITY ☐ Clear XTurbid (suspended matter) ☐ Stained (clear, naturally colored) ☐ Opaque (milky)
☐ Other (chemicals, dyes)</td></tr>
<tr><td>DOMINANT SUBSTRATE
X Silt/clay (fine or slick)
X Sand (gritty)
☐ Gravel (0.1-2.5")
☐ Cobble (2.5 –10")
☐ Boulder (>10")
☐ Bed rock</td><td>CHANNEL DIMENSIONS AT RIFFLE
Height: Low bank 2________(ft)
Width: Bottom 2.5________(ft)
Top 2.75________(ft)
Water Surface 2.1________(ft)
Depth: Max BKF 0.5________(ft)
B:H Ratio: Low bank/Max BKF=_______</td><td colspan="2">OBSERVED IMPACTS
☒ Outfall
☐ Confluence
☐ Impacted buffer
☐ Stream crossing
☐ Channel mod
☐ Utility impacts
☐ Beaver
☒ Other – Pipe outlet</td></tr>
<tr><td colspan="2">CHANNEL DYNAMICS
☒ Downcutting ☒ Bed scour ☐ Slope failure
☐ Widening ☐ Bank failure ☐ Channelized
☒ Headcutting ☒ Bank scour ☐ Unknown
☐ Aggrading ☐ Sed. deposition</td><td colspan="2">NOTES
RCP AT MIDDLE SCHOOL NEEDS ENERGY DISSIPATION BEING UNDERCUT BY FLOW
GOOD BMP POTENTIAL</td></tr>
<tr><td colspan="2">QUALITATIVE IMPAIRMENT RATING: ☐ Low X Moderate ☐ Severe</td><td colspan="2">CHANNEL EVOLUTIUON STAGE: ☐ I ☐ II X III X IV ☐ V ☐ VI (Simon et. al., 2003)</td></tr>
</table>

STREAM NAME: JOLLY BRANCH | **DATE: 6/5/07** | **MAP SHEET #: 16**

PHOTO NUMBERS: NO PHOTO | **LANDMARK: HIGH SCHOOL TRACK** | **SKETCH ON BACK**

GPS ID START: IJ 24
DESCRIPTION:

GPS ID END:
DESCRIPTION:

RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain X None ☐ Intermittent ☐ Trace

PRESENT CONDITIONS ☐ Heavy rain ☐ Steady rain ☐ Intermittent ☐ Clear ☐ Trace ☐ Overcast X Partly cloudy

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

BASE FLOW WIDTH AS % CHANNEL WIDTH
X 0-25%
☐ 25-50 %
☐ 50%-75%
☐ 75-100%

WATER CLARITY ☐ Clear ☐Turbid *(suspended matter)* ☐ Stained *(clear, naturally colored)* ☐ Opaque *(milky)* ☐ Other (chemicals, dyes) **NA-NO FLOW**

DOMINANT SUBSTRATE
X 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 3________(ft)
Width: Bottom 1.5________(ft)
Top 4________(ft)
Water Surface NA________(ft)
Depth: Max BKF NA________(ft)
B:H Ratio: Low bank/Max BKF=_______

OBSERVED IMPACTS
☒ Outfall
☐ Confluence
☐ Impacted buffer
☐ Stream crossing
☐ Channel mod
☐ Utility impacts
☐ Beaver
☒ Other – CULVERT OUTLETS

CHANNEL DYNAMICS
☒ Downcutting
☒ Widening
☐ Headcutting
☐ Aggrading
☒ Bed scour
☐ Bank failure
☒ Bank scour
☐ Sed. deposition
☐ Slope failure
☒ Channelized
☐ Unknown

NOTES
CULVERT OUTLETS FROM TRACK FLOWING INTO STREAM – JOLLY BRANCH- COULD HAVE STORMWATER BMPs HERE

QUALITATIVE IMPAIRMENT RATING: ☐ Low ☐ Moderate ☐ Severe

CHANNEL EVOLUTIUON STAGE: ☐ **I** ☐ **II** X **III** X **IV** ☐ **V** ☐ **VI** (*Simon et. al., 2003)*

STREAM NAME: UT JOLLY BRANCH	**DATE: 6/5/07**	**MAP SHEET #: 17**
PHOTO NUMBERS: 396-398	**LANDMARK:**	**SKETCH ON BACK**
GPS ID START: IJ 26 **DESCRIPTION:**	**GPS ID END:** **DESCRIPTION:**	
RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain X None ☐ Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent ☐ Clear ☐ Trace ☐ Overcast X Partly cloudy	
SURROUNDING LAND USE: ☐ Industrial ☐ Commercial X Urban/Residential ☐ Suburban/Res X Forested ☐ Institutional ☐ Golf course ☐ Park ☐ Crop ☐ Pasture ☐ Other:		
BASE FLOW WIDTH AS % CHANNEL WIDTH ☐ 0-25% ☐ 25-50 % X 50%-75% ☐ 75-100%	**WATER CLARITY** ☐ Clear X Turbid *(suspended matter)* ☐ Stained *(clear, naturally colored)* ☐ Opaque *(milky)* ☐ Other (chemicals, dyes)	
DOMINANT SUBSTRATE X 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 3________(ft) **Width**: Bottom 3________(ft) Top 3________(ft) Water Surface NA________(ft) **Depth:** Max BKF NA________(ft) **B:H Ratio:** Low bank/Max BKF=_______	**OBSERVED IMPACTS** ☒ Outfall ☐ Confluence ☐ Impacted buffer ☒ Stream crossing ☐ Channel mod ☐ Utility impacts ☐ Beaver ☐ Other
CHANNEL DYNAMICS ☒ Downcutting ☒ Bed scour ☐ Slope failure ☒ Widening ☐ Bank failure ☐ Channelized ☐ Headcutting ☒ Bank scour ☐ Unknown ☒ Aggrading ☒ Sed. deposition	**NOTES** OUTLET OF CULVERT IS CAUSING OVERLAND EROSION AND SEDIMENT DEPOSITION INCISION OF STREAM OLD BMP IS FAILING	
QUALITATIVE IMPAIRMENT RATING: ☐ Low ☐ Moderate ☐ Severe	**CHANNEL EVOLUTIUON STAGE:** ☐ I ☐ II ☐ III ☐ IV ☐ V ☐ VI (*Simon et. al., 2003)*	

STREAM NAME: UT	**DATE: 6/6/07**	**MAP SHEET #: 20**
PHOTO NUMBERS: 1111- 1112 (TONY)	**LANDMARK: ESTES**	**SKETCH ON BACK**

GPS ID START: BD 44 **DESCRIPTION:**	**GPS ID END: BD 47** **DESCRIPTION:**
RAIN IN LAST 24 HOURS ☐ Heavy rain X Steady rain ☐ None ☐ Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

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

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

DOMINANT SUBSTRATE X Silt/clay (fine or slick) ☐ Sand (gritty) X Gravel (0.1-2.5") ☐ Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**CHANNEL DIMENSIONS AT RIFFLE** **Height**: Low bank 4.2________(ft) **Width**: Bottom 6________(ft) Top 10 ________(ft) Water Surface 2________(ft) **Depth:** Max BKF 1.0 ________(ft) **B:H Ratio:** Low bank/Max BKF=_______	**OBSERVED IMPACTS** ☐ Outfall ☐ Confluence ☒ Impacted buffer- YARD WORK ☐ Stream crossing ☐ Channel mod ☐ Utility impacts ☐ Beaver ☐ Other
CHANNEL DYNAMICS ☐ Downcutting ☒ Widening ☐ Headcutting ☐ Aggrading ☐ Bed scour ☐ Bank failure ☐ Bank scour ☐ Sed. deposition ☐ Slope failure ☐ Channelized ☐ Unknown		**NOTES** **MASS BANK FAILURE**

QUALITATIVE IMPAIRMENT RATING: ☐ Low ☐ Moderate ☐ Severe

CHANNEL EVOLUTIUON STAGE: ☐ I ☐ II ☐ III ☐ IV ☐ V ☐ VI (*Simon et. al., 2003*)

Stream Name: UT Bolin	**Date: 5/8/07**	**Map Sheet #: 20**
Photo Numbers: 23	**Landmark:**	**Sketch on back**

GPS ID START: BD 11 **Description:**	**GPS ID END:** **Description:**
Rain in last 24 hours ☐ Heavy rain ☐ Steady rain ☐ None ☐ Intermittent X Trace	**Present conditions** ☐ Heavy rain ☐ Steady rain ☐ Intermittent ☐ Clear ☐ Trace X Overcast ☐ Partly cloudy

Surrounding land use: ☐ Industrial ☐ Commercial ☐ Urban/Residential X Suburban/Res X Forested ☐ Institutional ☐ Golf course ☐ Park ☐ Crop ☐ Pasture ☐ Other:

Base Flow width as % Channel Width X 0-25% ☐ 25-50 % ☐ 50%-75% ☐ 75-100%	**Water Clarity** X Clear ☐Turbid *(suspended matter)* ☐ Stained *(clear, naturally colored)* ☐ Opaque *(milky)* ☐ Other (chemicals, dyes)

Dominant Substrate	**Channel Dimensions at riffle**	**Observed Impacts**
☐ Silt/clay (fine or slick) ☐ Sand (gritty) ☐ Gravel (0.1-2.5") X Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**Height**: Low bank ___3.2_____(ft) **Width**: Bottom ___13_____(ft) Top ___17_____(ft) Water Surface ___1.4_____(ft) **Depth:** Max BKF ____0.6____(ft) **B:H Ratio:** Low bank/Max BKF=_______	☐ Outfall ☐ Confluence ☐ Impacted buffer ☐ Stream crossing ☐ Channel mod ☒ Utility impacts ☐ Beaver ☐ Other

Channel Dynamics ☐ Downcutting ☐ Widening ☐ Headcutting ☐ Aggrading ☐ Bed scour ☒ Bank failure ☒ Bank scour ☐ Sed. deposition ☐ Slope failure ☐ Channelized ☐ Unknown	**Notes**
Qualitative Impairment Rating: ☐ Low X Moderate ☐ Severe	**Channel evolutiuon Stage:** ☐ I ☐ II ☐ III ☐ IV ☐ V ☐ VI (*Simon et. al., 2003*)

STREAM NAME: UT	DATE:	MAP SHEET #: 20
PHOTO NUMBERS: 1105	LANDMARK: OFF CARDIFF PL	SKETCH ON BACK

GPS ID START: TA 19 **DESCRIPTION: SCOUR OF RR FILL**	**GPS ID END:** **DESCRIPTION:**
RAIN IN LAST 24 HOURS ☐ Heavy rain X Steady rain ☐ None ☐ Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

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

BASE FLOW WIDTH AS % CHANNEL WIDTH X 0-25% ☐ 25-50 % ☐ 50%-75% ☐ 75-100%	**WATER CLARITY** ☐ Clear ☐Turbid *(suspended matter)* ☐ Stained *(clear, naturally colored)* ☐ Opaque *(milky)* ☐ Other (chemicals, dyes) NA-NO FLOW

DOMINANT SUBSTRATE	CHANNEL DIMENSIONS AT RIFFLE	OBSERVED IMPACTS
1 Silt/clay (fine or slick) ☐ Sand (gritty) 2 Gravel (0.1-2.5") ☐ Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**Height**: Low bank ________(ft) **Width**: Bottom ________(ft) Top ________(ft) Water Surface ________(ft) **Depth:** Max BKF ________(ft) **B:H Ratio:** Low bank/Max BKF=_______	☐ Outfall ☐ Confluence ☐ Impacted buffer ☐ Stream crossing ☐ Channel mod ☐ Utility impacts ☐ Beaver ☒ Other- SW r/o

CHANNEL DYNAMICS	NOTES
☒ Downcutting ☒ Widening ☒ Headcutting ☐ Aggrading ☒ Bed scour ☐ Bank failure ☒ Bank scour ☐ Sed. deposition ☐ Slope failure ☐ Channelized ☐ Unknown	SIGNIFICANT SCOUR OF RR FILL SITE FOR POTENTIAL RETENTION SEWER SMELL

QUALITATIVE IMPAIRMENT RATING: ☐ Low X Moderate ☐ Severe	**CHANNEL EVOLUTIUON STAGE:** ☐ I ☐ II X III ☐ IV ☐ V ☐ VI (*Simon et. al., 2003*)

STREAM NAME: UT	**DATE: 6/7/07**	**MAP SHEET #: 23**
PHOTO NUMBERS: 1117- PIPED CH 1118-11120 DEGRADED	**LANDMARK: BROAD ST.**	**SKETCH ON BACK**

GPS ID START: TA 29 **DESCRIPTION: PIPED ST** **NO GPS**	**GPS ID END: TA 30** **DESCRIPTION: DEGRADED STR** **NO GPS**
RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain X None ☐ Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

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

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

DOMINANT SUBSTRATE ☐ Silt/clay (fine or slick) 2 Sand (gritty) 1 Gravel (0.1-2.5") 3 Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**CHANNEL DIMENSIONS AT RIFFLE** **Height**: Low bank 1.3 (ft) **Width**: Bottom 4.0 (ft) Top 5.0 (ft) Water Surface 3.0 (ft) **Depth:** Max BKF 1.3 (ft) **B:H Ratio:** Low bank/Max BKF=_______	**OBSERVED IMPACTS** ☒ Outfall ☐ Confluence ☐ Impacted buffer ☐ Stream crossing ☐ Channel mod ☐ Utility impacts ☐ Beaver ☐ Other

CHANNEL DYNAMICS ☒ Downcutting ☐ Bed scour ☐ Slope failure ☒ Widening ☐ Bank failure ☐ Channelized ☐ Headcutting ☒ Bank scour ☐ Unknown ☐ Aggrading ☐ Sed. deposition	**NOTES- UPSTREAM OF BROAD ST STREAM IS PIPED AND COULD BE DAYLIGHTED TA 29** **- DOWN STR OF BROAD ST STREAM IS DEGRADED AND COULD USE RESTORATION**
QUALITATIVE IMPAIRMENT RATING: ☐ Low X Moderate ☐ Severe	**CHANNEL EVOLUTIUON STAGE:** ☐ I ☐ II ☐ III X IV ☐ V ☐ VI (*Simon et. al., 2003*)

Stream Name: UT	**Date: 6/7/07**	**Map Sheet #: 24**
Photo Numbers:1124-1125	**Landmark:**	**Sketch on back**

GPS ID START: TA 33 **Description:**	**GPS ID END: TA 34** **Description:**
Rain in last 24 hours ☐ Heavy rain ☐ Steady rain X None ☐ Intermittent ☐ Trace	**Present conditions** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

Surrounding land use: ☐ Industrial ☐ Commercial X Urban/Residential ☐ Suburban/Res ☐ Forested ☐ Institutional ☐ Golf course ☐ Park ☐ Crop ☐ Pasture ☐ Other:

Base Flow width as % Channel Width ☐ 0-25% ☐ 25-50 % X 50%-75% ☐ 75-100%	**Water Clarity** X Clear ☐Turbid *(suspended matter)* ☐ Stained *(clear, naturally colored)* ☐ Opaque *(milky)* ☐ Other (chemicals, dyes)

Dominant Substrate	**Channel Dimensions at riffle**	**Observed Impacts**
☐ Silt/clay (fine or slick) 3 Sand (gritty) 1 Gravel (0.1-2.5") ☐ Cobble (2.5 –10") ☐ Boulder (>10") 2 Bed rock	**Height**: Low bank 10.0 (ft) **Width**: Bottom 10.0 (ft) Top 20.0 (ft) Water Surface 8.0 (ft) **Depth:** Max BKF 1.4 (ft) **B:H Ratio:** Low bank/Max BKF=_______	☒ Outfall ☐ Confluence ☐ Impacted buffer ☐ Stream crossing ☐ Channel mod ☒ Utility impacts ☐ Beaver ☒ Other- SCOUR from SW

Channel Dynamics			**Notes**
☒ Downcutting ☒ Widening ☐ Headcutting ☐ Aggrading	☐ Bed scour ☒ Bank failure ☒ Bank scour ☐ Sed. deposition	☐ Slope failure ☐ Channelized ☐ Unknown	**Entire reach has approx 5 to 6 ft.eroding vertical bank from SW downcutiing**

Qualitative Impairment Rating: ☐ Low X Moderate ☐ Severe

Channel evolutiuon Stage: ☐ I ☐ II ☐ III X IV ☐ V ☐ VI (*Simon et. al., 2003*)

STREAM NAME: UT MILL RACE	**DATE: 5/21/07**	**MAP SHEET #: 25-24**
PHOTO NUMBERS: 2976-2979	**LANDMARK: HILLSBOROUGH ST**	**SKETCH ON BACK**

GPS ID START: IJ 43
DESCRIPTION:

GPS ID END: IJ 43
DESCRIPTION:

RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain ☐ None X Intermittent ☐ Trace

PRESENT CONDITIONS ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

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

BASE FLOW WIDTH AS % CHANNEL WIDTH ☐ 0-25% X 25-50 % ☐ 50%-75% ☐ 75-100%

WATER CLARITY ☐ Clear X Turbid *(suspended matter)* ☐ Stained *(clear, naturally colored)* ☐ Opaque *(milky)* ☐ Other (chemicals, dyes)

DOMINANT SUBSTRATE

X 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 ___3-10___(ft)
Width: Bottom ___3-6____(ft)
Top ___3-6____(ft)
Water Surface ___0.5____(ft)
Depth: Max BKF ___0.2____(ft)

B:H Ratio: Low bank/Max BKF=_______

OBSERVED IMPACTS

☒ Outfall
☐ Confluence
☐ Impacted buffer
☐ Stream crossing
☐ Channel mod
☐ Utility impacts
☐ Beaver
☐ Other

CHANNEL DYNAMICS

☐ Downcutting ☐ Widening ☐ Headcutting ☐ Aggrading
☐ Bed scour ☐ Bank failure ☐ Bank scour ☐ Sed. deposition
☐ Slope failure ☐ Channelized ☐ Unknown

NOTES: BURIED PIP IS CAUSING MASSIVE EROSION ON HILLSIDE
DEEP GULLY FORMED
POSSIBLE STEP-POOL OR ENERGY DISSIPATION
EVEN CULVERT REPLACEMENT

QUALITATIVE IMPAIRMENT RATING: ☐ Low ☐ Moderate X Severe

CHANNEL EVOLUTIUON STAGE: ☐ **I** ☐ **II** X **III** ☐ **IV** ☐ **V** ☐ **VI** (*Simon et. al., 2003)*

STREAM NAME: BOLIN CREEK	**DATE: 2/21/07**	**MAP SHEET #: 25**
PHOTO NUMBERS: 3015-3016	**LANDMARK: BOLINWOOD DR**	**SKETCH ON BACK**

GPS ID START: IJ53 **DESCRIPTION:**	**GPS ID END: IJ53** **DESCRIPTION:**
RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain ☐ None X Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

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

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

DOMINANT SUBSTRATE X Silt/clay (fine or slick) X Sand (gritty) X Gravel (0.1-2.5") ☐ Cobble (2.5 –10") ☐ Boulder (>10") X Bed rock	**CHANNEL DIMENSIONS AT RIFFLE** **Height**: Low bank ___5-20_(ft) **Width**: Bottom ____20__(ft) Top ____20__(ft) Water Surface ____20__(ft) **Depth:** Max BKF ____2.5__(ft) **B:H Ratio:** Low bank/Max BKF=_______	**OBSERVED IMPACTS** ☐ Outfall ☐ Confluence ☒ Impacted buffer ☐ Stream crossing ☐ Channel mod ☐ Utility impacts ☐ Beaver ☐ Other

CHANNEL DYNAMICS ☐ Downcutting ☐ Bed scour ☐ Slope failure ☐ Widening ☒ Bank failure ☐ Channelized ☐ Headcutting ☐ Bank scour ☐ Unknown ☐ Aggrading ☐ Sed. deposition	**NOTES** **MAJOR BANK FAILURE ON BOLIN CREEK** **POSSIBLE BANK STABILIZATION**
QUALITATIVE IMPAIRMENT RATING: ☐ Low ☐ Moderate ☐ Severe	**CHANNEL EVOLUTIUON STAGE:** ☐ I ☐ II ☐ III ☐ IV ☐ V ☐ VI (*Simon et. al., 2003)*

STREAM NAME: UT	DATE: 6/21/07	MAP SHEET #: 26
PHOTO NUMBERS: 1162-1165	LANDMARK: YMCA	SKETCH ON BACK

GPS ID START: BD 58 DESCRIPTION:	GPS ID END: BD 59 DESCRIPTION:
RAIN IN LAST 24 HOURS ☐ Heavy rain X Steady rain ☐ None ☐ Intermittent ☐ Trace	PRESENT CONDITIONS ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

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

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

DOMINANT SUBSTRATE	CHANNEL DIMENSIONS AT RIFFLE	OBSERVED IMPACTS
☐ Silt/clay (fine or slick) X Sand (gritty) ☐ Gravel (0.1-2.5") X Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**Height**: Low bank __2.1___(ft) **Width**: Bottom __7.1___(ft) Top __9_____(ft) Water Surface __2_____(ft) **Depth:** Max BKF __0.5____(ft) **B:H Ratio:** Low bank/Max BKF=_______	☐ Outfall ☐ Confluence ☐ Impacted buffer ☐ Stream crossing ☐ Channel mod ☐ Utility impacts ☐ Beaver ☐ Other NA- development=high flow

CHANNEL DYNAMICS	NOTES
☒ Downcutting ☐ Widening ☐ Headcutting ☐ Aggrading ☐ Bed scour ☐ Bank failure ☒ Bank scour ☐ Sed. deposition ☐ Slope failure ☐ Channelized ☐ Unknown	THIS NEEDS HELP. ACTIVE, GETS WORSE DS. SEE BD 59-60.

QUALITATIVE IMPAIRMENT RATING: ☐ Low X Moderate ☐ Severe	CHANNEL EVOLUTIUON STAGE: ☐ I X II ☐ III ☐ IV ☐ V ☐ VI (*Simon et. al., 2003*)

STREAM NAME: COLE SPRINGS BR.	**DATE: 6/21/07**	**MAP SHEET #: 26**
PHOTO NUMBERS: 1231,1232	**LANDMARK:**	**SKETCH ON BACK**

GPS ID START: BD 75 **DESCRIPTION:**	**GPS ID END:** **DESCRIPTION:**
RAIN IN LAST 24 HOURS ☐ Heavy rain X Steady rain ☐ None ☐ Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

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

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

DOMINANT SUBSTRATE	**CHANNEL DIMENSIONS AT RIFFLE**	**OBSERVED IMPACTS**
☐ Silt/clay (fine or slick) ☐ Sand (gritty) ☐ Gravel (0.1-2.5") ☐ Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**Height**: Low bank 4________(ft) **Width**: Bottom 4________(ft) Top 14________(ft) Water Surface 2________(ft) **Depth:** Max BKF 1.8________(ft) **B:H Ratio:** Low bank/Max BKF=_______	☐ Outfall ☐ Confluence ☐ Impacted buffer ☐ Stream crossing ☐ Channel mod ☐ Utility impacts ☐ Beaver ☐ Other

CHANNEL DYNAMICS			**NOTES**
☒ Downcutting ☒ Widening ☐ Headcutting ☐ Aggrading	☐ Bed scour ☒ Bank failure ☒ Bank scour ☐ Sed. deposition	☐ Slope failure ☐ Channelized ☐ Unknown	**CULVERT FOR UTILITY ROADWAY ALONG SS LINE CAUSES CONTRACTION**

QUALITATIVE IMPAIRMENT RATING: ☐ Low X Moderate ☐ Severe	**CHANNEL EVOLUTIUON STAGE:** ☐ I ☐ II X III ☐ IV ☐ V ☐ VI (*Simon et. al., 2003)*

STREAM NAME: UT BATTLE BRANCH	**DATE: 6/22/07**	**MAP SHEET #: 30**
PHOTO NUMBERS:NO PHOTO	**LANDMARK:**	**SKETCH ON BACK**

GPS ID START: IJ 64 **DESCRIPTION:**	**GPS ID END: IJ 64** **DESCRIPTION:**
RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain ☐ None X Intermittent ☐ Trace	**PRESENT CONDITIONS** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

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

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

DOMINANT SUBSTRATE X 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 ___3-4_____(ft) **Width**: Bottom ___3_____(ft) Top __5______(ft) Water Surface ___NA_____(ft) **Depth:** Max BKF _____NA___(ft) **B:H Ratio:** Low bank/Max BKF=____NA___	**OBSERVED IMPACTS** ☐ Outfall ☐ Confluence ☐ Impacted buffer ☐ Stream crossing ☐ Channel mod ☐ Utility impacts ☐ Beaver ☒ Other

CHANNEL DYNAMICS ☒ Downcutting ☒ Bed scour ☐ Slope failure ☐ Widening ☒ Bank failure ☐ Channelized ☒ Headcutting ☐ Bank scour ☐ Unknown ☐ Aggrading ☐ Sed. deposition	**NOTES** SERIES OF HEADCUTS PROGRESSING UP STEEP CHANNEL LOTS OF SILT AND SEDIMENT FROM BANK FAILTURE ORIGINATES AT PARTIALLY BURIED PIPE UPSTREAM
QUALITATIVE IMPAIRMENT RATING: ☐ Low ☐ Moderate X Severe	**CHANNEL EVOLUTIUON STAGE:** ☐ I ☐ II ☐ III ☐ IV ☐ V ☐ VI (*Simon et. al., 2003*)

Stream Name: UT to Bolin Cr	**Date: 6/21/07**	**Map Sheet #: 30**
Photo Numbers: 3032-3034	**Landmark: steep hillside**	**Sketch on back**

GPS ID START: IJ 60 **Description:**	**GPS ID END: IJ 60** **Description:**
Rain in last 24 hours ☐ Heavy rain ☐ Steady rain ☐ None X Intermittent ☐ Trace	**Present conditions** ☐ Heavy rain ☐ Steady rain ☐ Intermittent X Clear ☐ Trace ☐ Overcast ☐ Partly cloudy

Surrounding land use: ☐ Industrial ☐ Commercial ☐ Urban/Residential X Suburban/Res X Forested ☐ Institutional ☐ Golf course ☐ Park ☐ Crop ☐ Pasture ☐ Other:

Base Flow width as % Channel Width ☐ 0-25% NA-hillside ☐ 25-50 % ☐ 50%-75% ☐ 75-100%	**Water Clarity** ☐ Clear ☐Turbid *(suspended matter)* ☐ Stained *(clear, naturally colored)* ☐ Opaque *(milky)* ☐ Other (chemicals, dyes) NA

Dominant Substrate	**Channel Dimensions at riffle**	**Observed Impacts**
2 Silt/clay (fine or slick) 1 Sand (gritty) ☐ Gravel (0.1-2.5") ☐ Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**Height**: Low bank ________(ft) **Width**: Bottom ________(ft) Top ________(ft) Water Surface ________(ft) **Depth:** Max BKF ________(ft) **B:H Ratio:** Low bank/Max BKF=_______	☒ Outfall ☐ Confluence ☐ Impacted buffer ☐ Stream crossing ☐ Channel mod ☐ Utility impacts ☐ Beaver ☒ Other- old BMP

Channel Dynamics			**Notes**
☐ Downcutting ☐ Widening ☐ Headcutting ☒ Aggrading	☐ Bed scour ☐ Bank failure ☐ Bank scour ☐ Sed. deposition	☒ Slope failure ☐ Channelized ☐ Unknown	**Old BMP – maybe level spreader ;could easily retrofit** **Gully formation above** **rock check dams below**

Qualitative Impairment Rating: ☐ Low X Moderate ☐ Severe	**Channel evolutiuon Stage:** ☐ **I** ☐ **II** ☐ **III** ☐ **IV** ☐ **V** ☐ **VI** (*Simon et. al., 2003*)

STREAM NAME: BATTLE BR	**DATE: 6/22/07**	**MAP SHEET #: 34**
PHOTO NUMBERS: 1271-1279	**LANDMARK:**	**SKETCH ON BACK**

GPS ID START: BD 87 **DESCRIPTION:**	**GPS ID END: BD 88** **DESCRIPTION:**
RAIN IN LAST 24 HOURS ☐ Heavy rain ☐ Steady rain X 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% X 25-50 % ☐ 50%-75% ☐ 75-100%	**WATER CLARITY** X Clear ☐Turbid *(suspended matter)* ☐ Stained *(clear, naturally colored)* ☐ Opaque *(milky)* ☐ Other (chemicals, dyes)

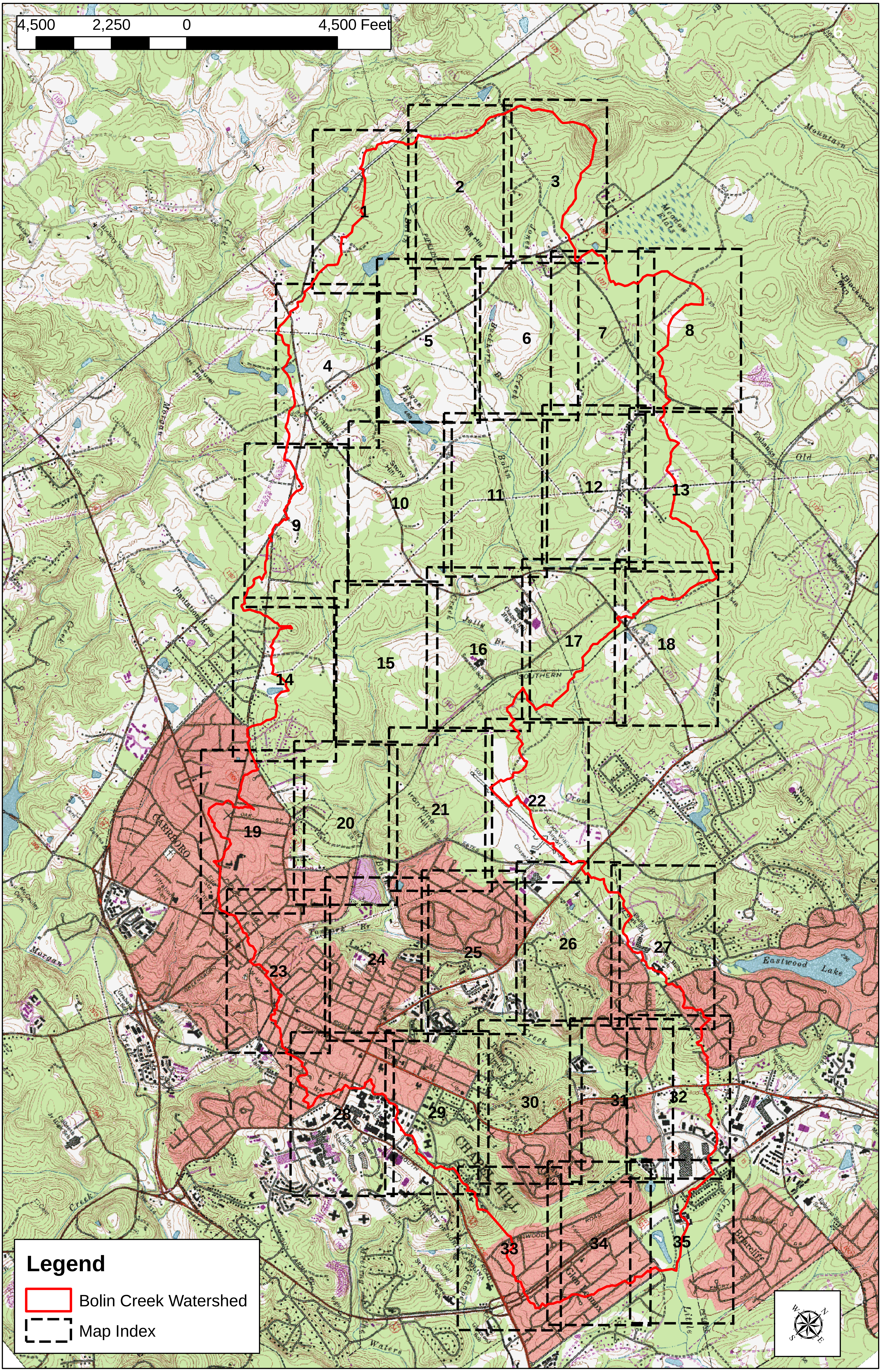
DOMINANT SUBSTRATE	**CHANNEL DIMENSIONS AT RIFFLE**	**OBSERVED IMPACTS**
☐ Silt/clay (fine or slick) ☐ Sand (gritty) ☐ Gravel (0.1-2.5") ☐ Cobble (2.5 –10") ☐ Boulder (>10") ☐ Bed rock	**Height**: Low bank ________(ft) **Width**: Bottom ________(ft) Top ________(ft) Water Surface ________(ft) **Depth:**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

CHANNEL DYNAMICS			**NOTES**
☐ Downcutting ☐ Widening ☐ Headcutting ☐ Aggrading	☐ Bed scour ☒ Bank failure ☒ Bank scour ☐ Sed. deposition	☐ Slope failure ☐ Channelized ☐ Unknown	**SEE PHOTOS** **DITCH BUILT BY SS LINE**

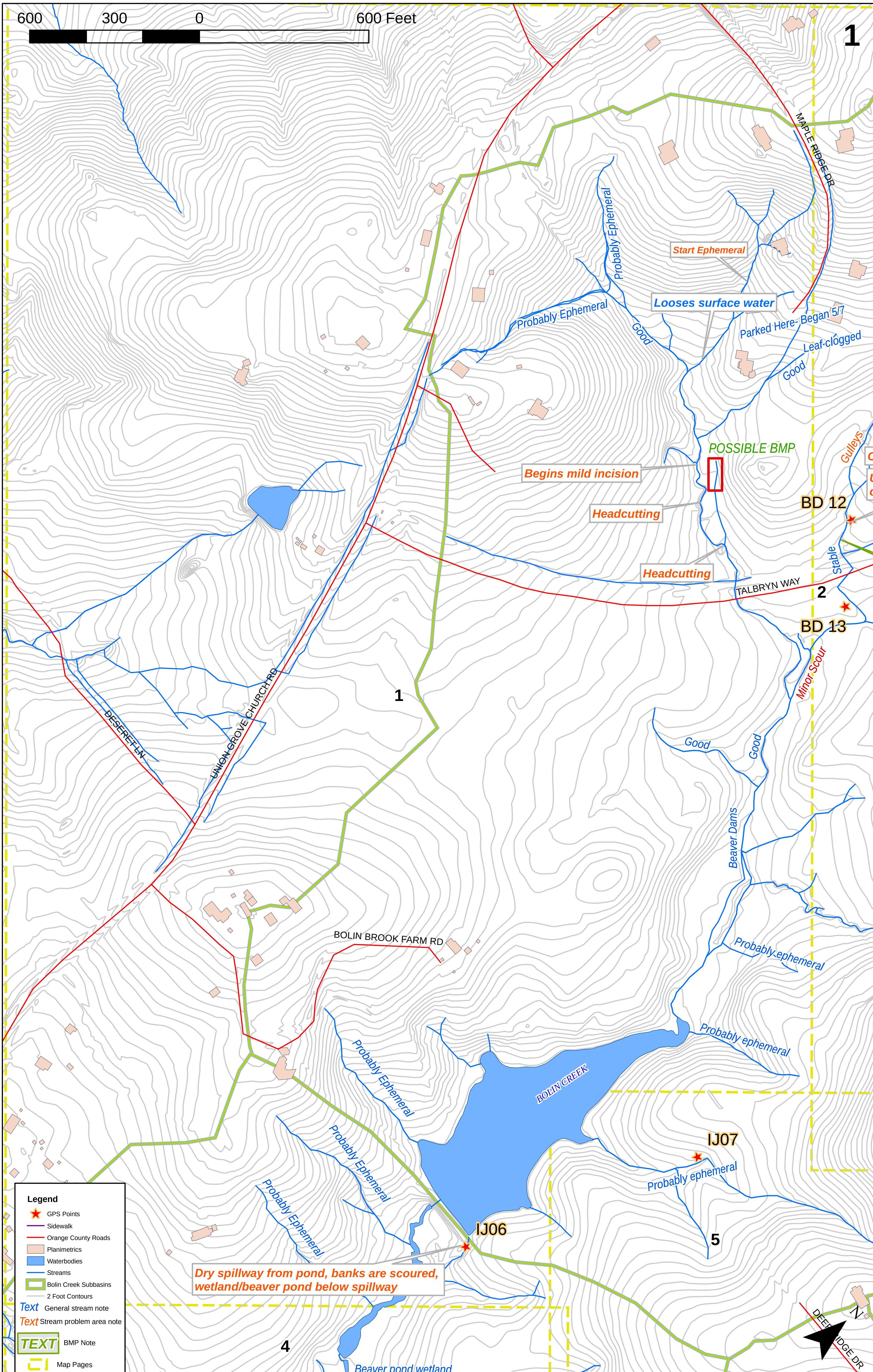
QUALITATIVE IMPAIRMENT RATING: ☐ Low ☐ Moderate X Severe	**CHANNEL EVOLUTIUON STAGE:** ☐ **I** ☐ **II** ☐ **III** ☐ **IV** ☐ **V** ☐ **VI** (*Simon et. al., 2003)*

APPENDIX D

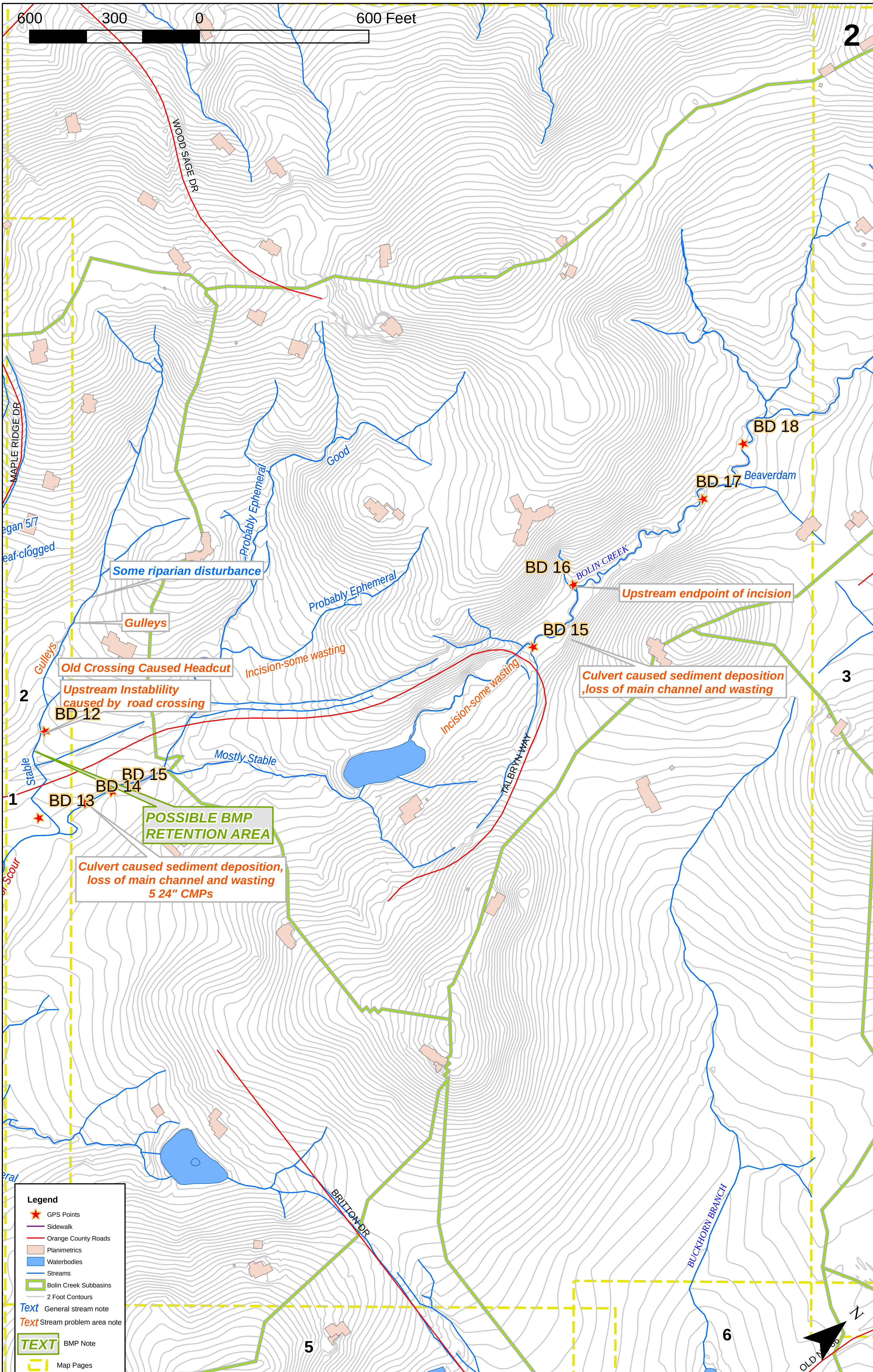
Raw Data Maps

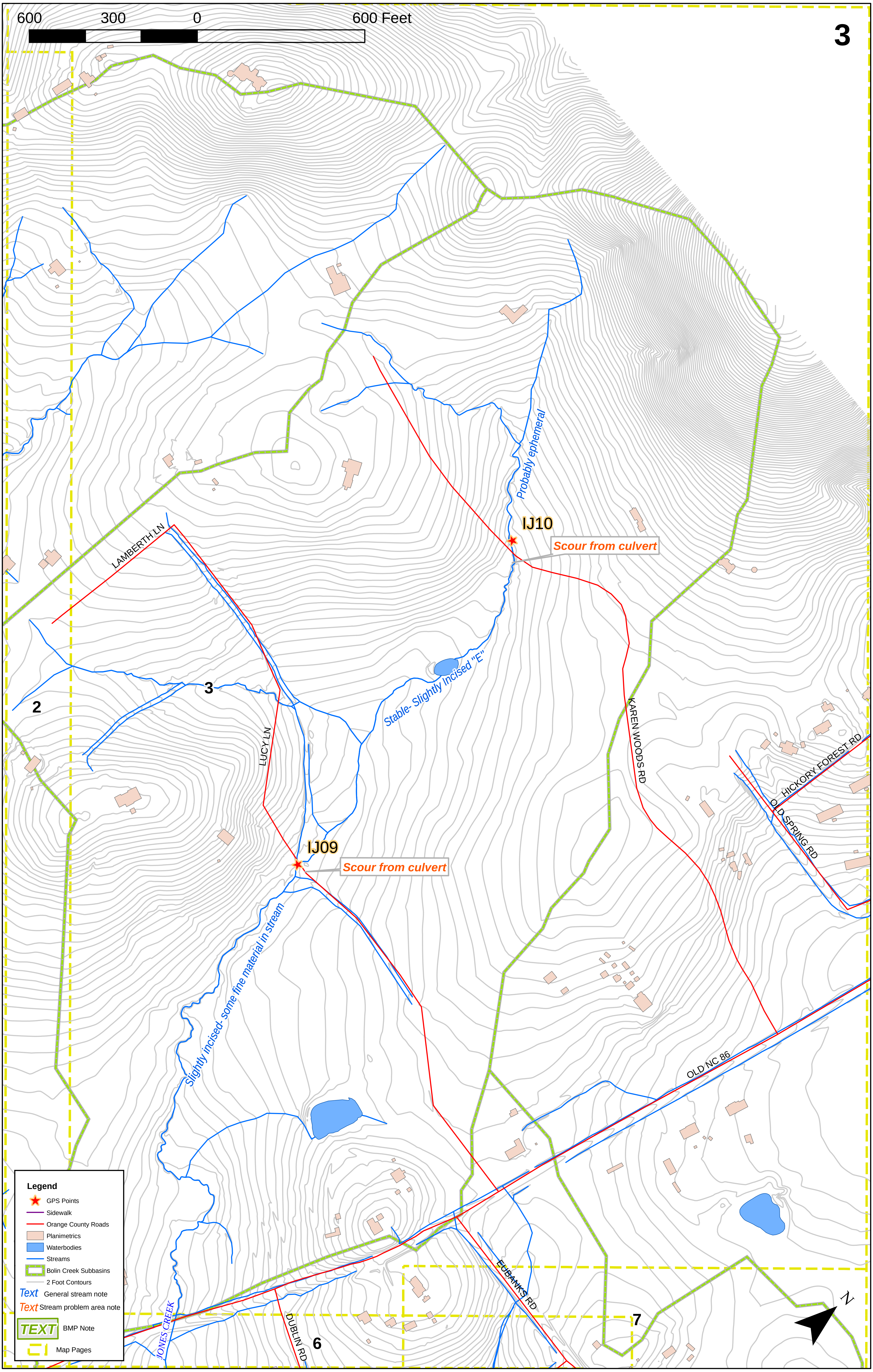


4,500 2,250 0 4,500 Feet
Legend
Bolin Creek Watershed
Map Index
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35

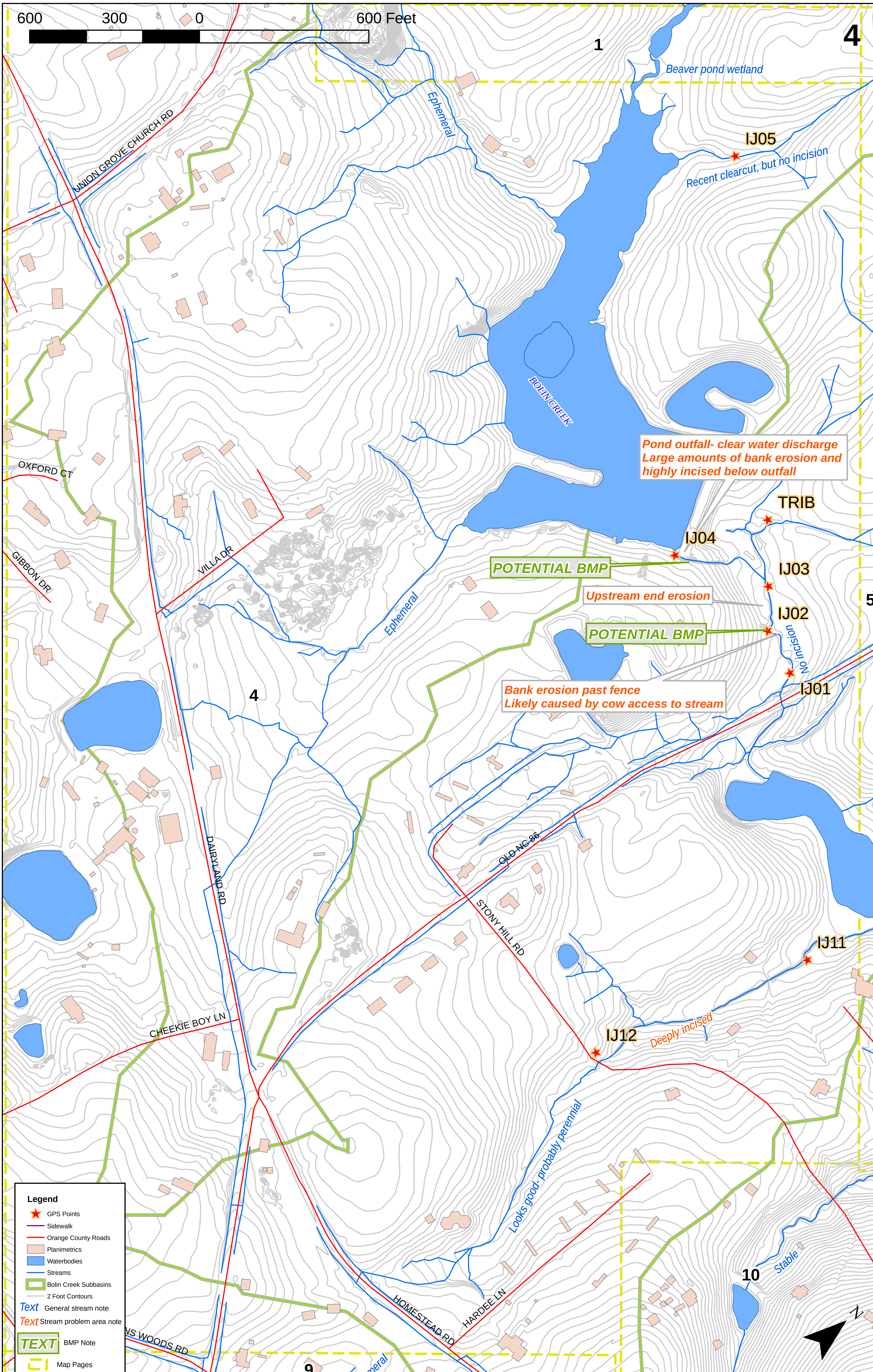


600 300 0 600 Feet
1
MAPLE RIDGE DR
Probably Ephemeral
Start Ephemeral
Looses surface water
Probably Ephemeral
Good
Parked Here- Began 5/7
Leaf-clogged
Good
POSSIBLE BMP
Gulleys
Begins mild incision
Headcutting
BD 12
Headcutting
Stable
TALBRYN WAY
2
BD 13
Minor Scour
1
DESERET LN
UNION GROVE CHURCH RD
Good
Good
Beaver Dams
Probably ephemeral
BOLIN BROOK FARM RD
Probably ephemeral
Probably Ephemeral
BOLIN CREEK
Probably Ephemeral
IJ07
Probably ephemeral
Probably Ephemeral
IJ06
5
Dry spillway from pond, banks are scoured, wetland/beaver pond below spillway
4
Beaver pond wetland
N
DEER RIDGE DR
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages

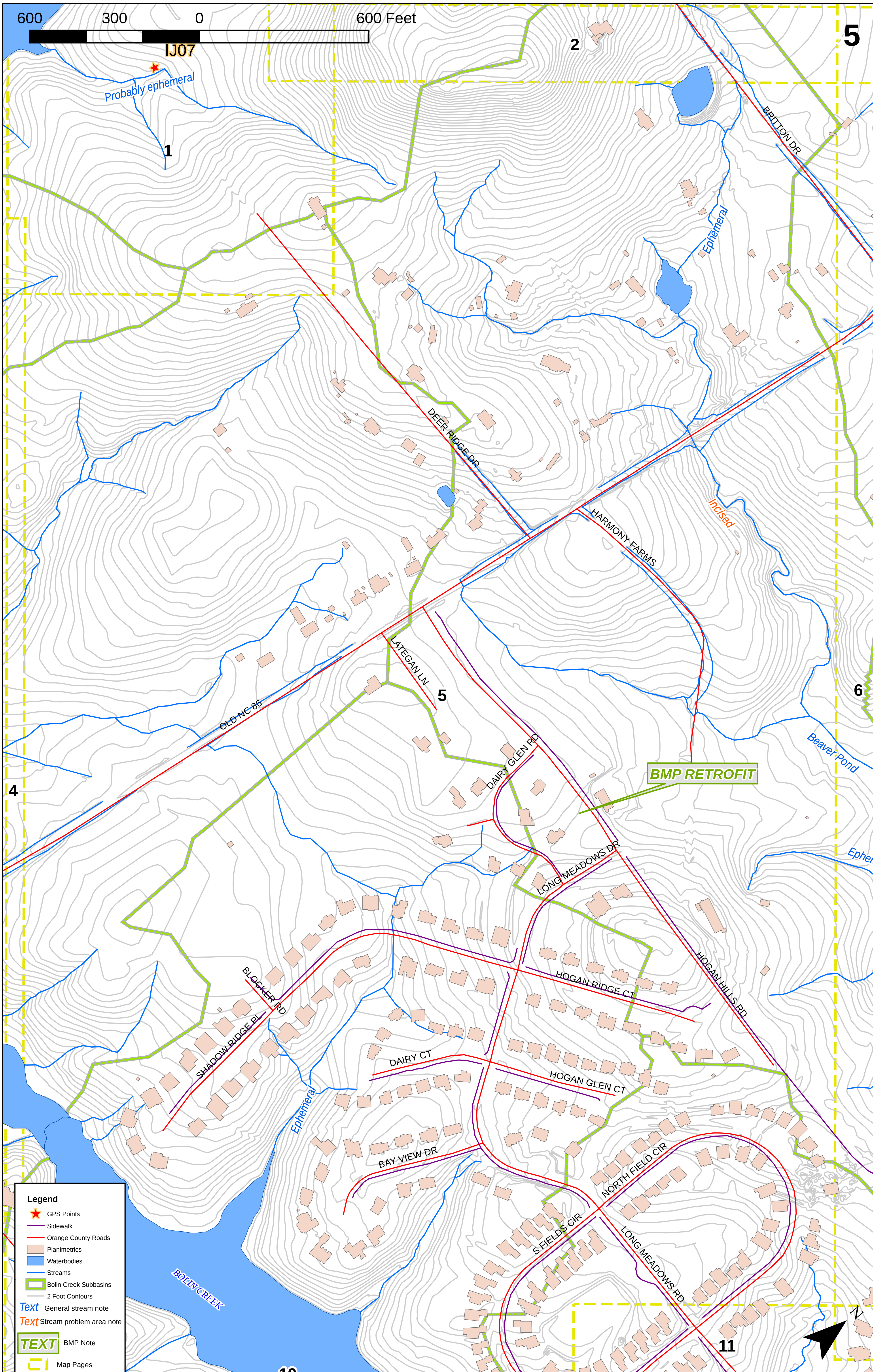

600
300
0
600 Feet
2
WOOD SAGE DR
MAPLE RIDGE DR
Good
Probably Ephemeral
Probably Ephemeral
Some riparian disturbance
Gulleys
Gulleys
Old Crossing Caused Headcut
Upstream Instablility
caused by road crossing
Incision-some wasting
Incision-some wasting
BD 12
Stable
Mostly Stable
BD 15
BD 14
BD 13
1
2
POSSIBLE BMP
RETENTION AREA
Culvert caused sediment deposition,
loss of main channel and wasting
5 24" CMPs
TALBRYN WAY
BD 18
BD 17
Beaverdam
BD 16
BOLIN CREEK
Upstream endpoint of incision
BD 15
Culvert caused sediment deposition
,loss of main channel and wasting
3
BRITTON DR
BUCKHORN BRANCH
5
6
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages



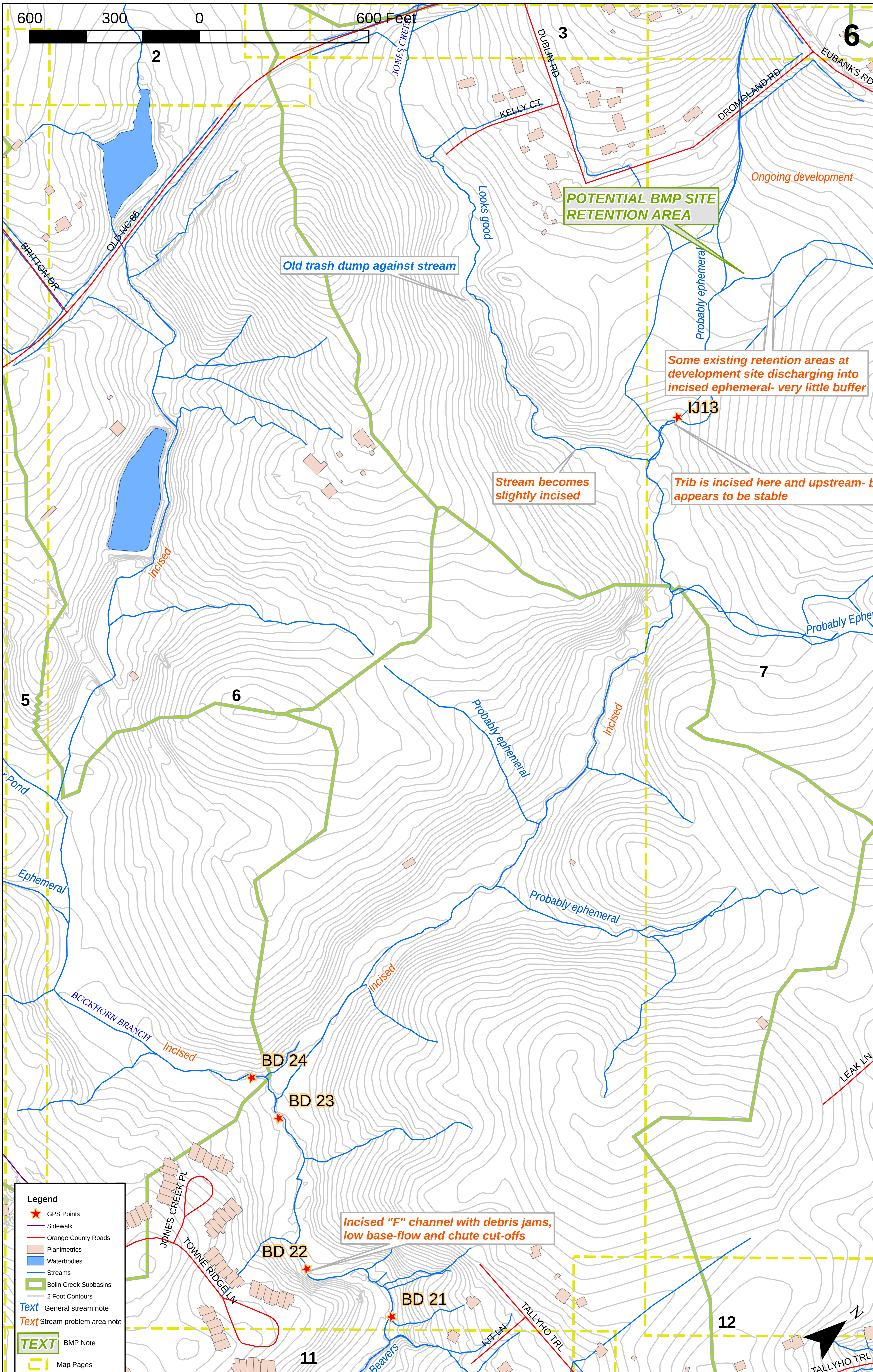
600 300 0 600 Feet
3
Probably ephemeral
IJ10
Scour from culvert
LAMBERTH LN
3
2
LUCY LN
Stable- Slightly Incised "E"
KAREN WOODS RD
HICKORY FOREST RD
OLD SPRING RD
IJ09
Scour from culvert
Slightly incised- some fine material in stream
OLD NC 86
EUBANKS RD
DUBLIN RD
JONES CREEK
6
7
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages
N



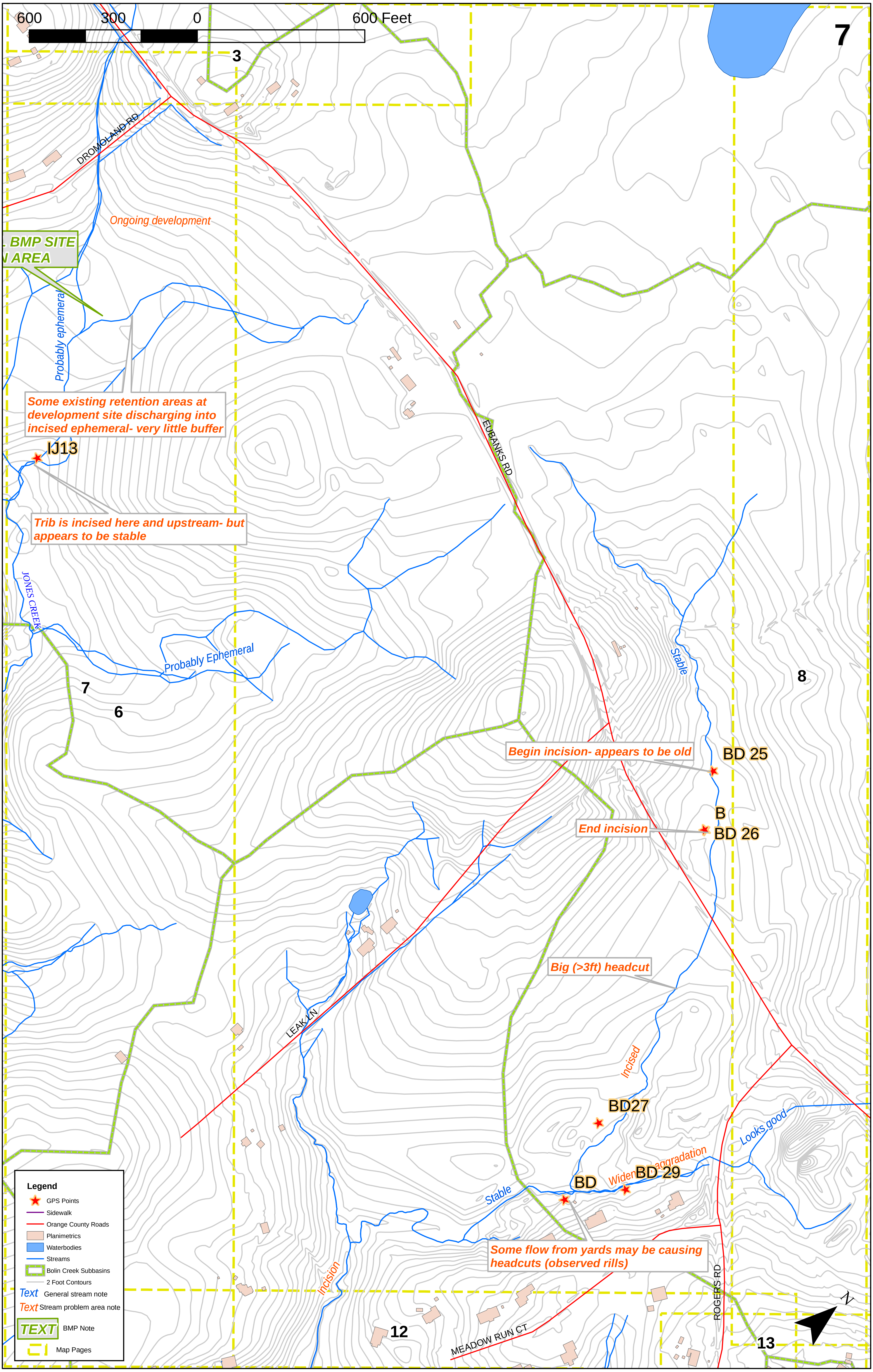
600 300 0 600 Feet
4
1
Beaver pond wetland
Ephemeral
IJ05
Recent clearcut, but no incision
UNION GROVE CHURCH RD
BOLIN CREEK
Pond outfall- clear water discharge
Large amounts of bank erosion and
highly incised below outfall
OXFORD CT
TRIB
IJ04
GIBBON DR
VILLA DR
POTENTIAL BMP
IJ03
Upstream end erosion
5
IJ02
Ephemeral
POTENTIAL BMP
No incision
Bank erosion past fence
Likely caused by cow access to stream
IJ01
4
OLD NC 86
DAIRYLAND RD
STONY HILL RD
IJ11
CHEEKIE BOY LN
IJ12
Deeply incised
Looks good- probably perennial
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages
10
Stable
HARDEE LN
HOMESTEAD RD
NS WOODS RD
9
Ephemeral
N



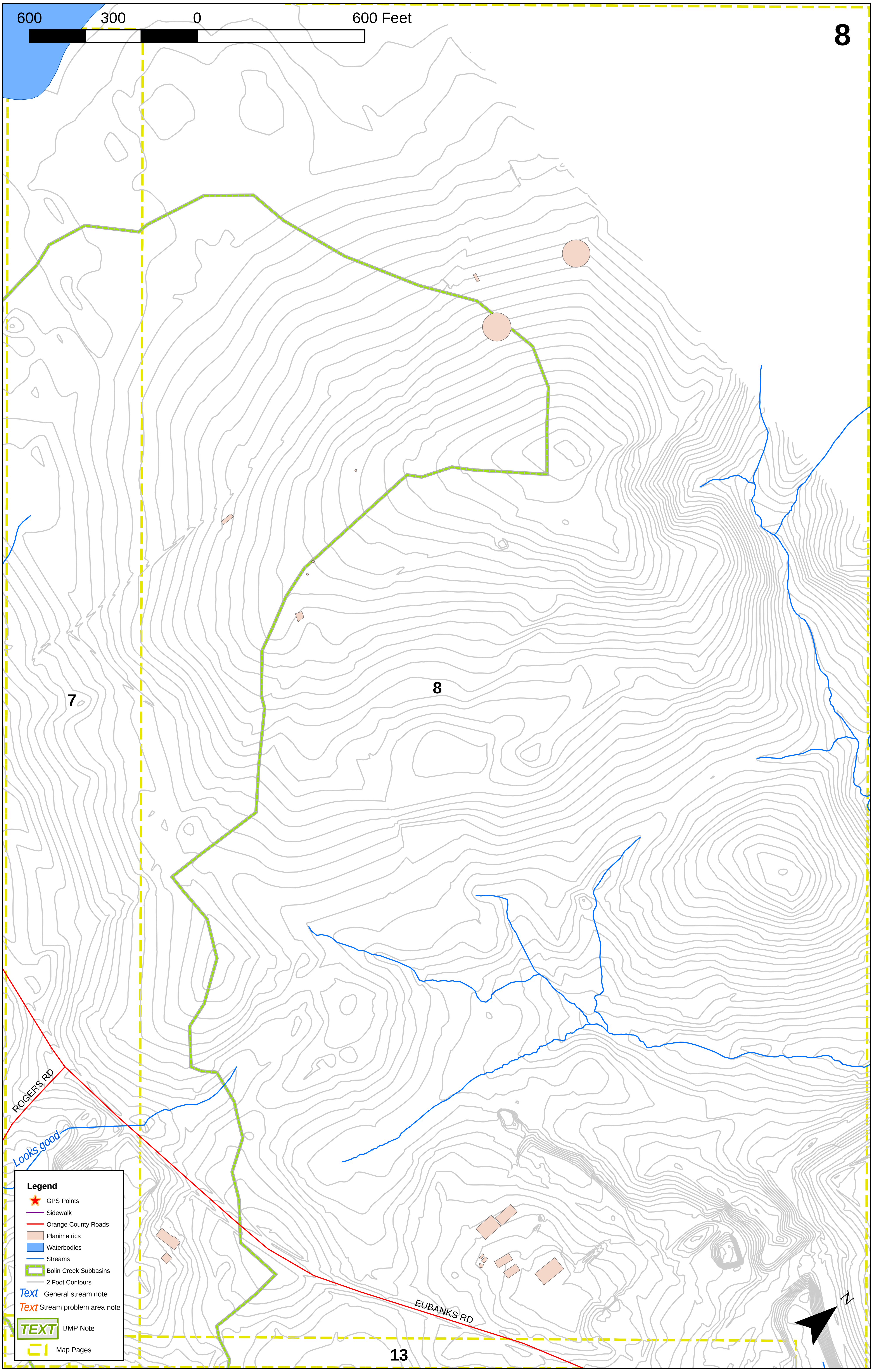
600 300 0 600 Feet
IJ07
Probably ephemeral
1
2
5
BRITTON DR
Ephemeral
DEER RIDGE DR
HARMONY FARMS
Incised
LATEGAN LN
OLD NC 86
5
6
Beaver Pond
DAIRY GLEN RD
BMP RETROFIT
4
LONG MEADOWS DR
Ephemeral
HOGAN HILLS RD
HOGAN RIDGE CT
BLOCKER RD
SHADOW RIDGE PL
DAIRY CT
HOGAN GLEN CT
Ephemeral
BAY VIEW DR
NORTH FIELD CIR
S FIELDS CIR
LONG MEADOWS RD
BOLIN CREEK
11
10
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages



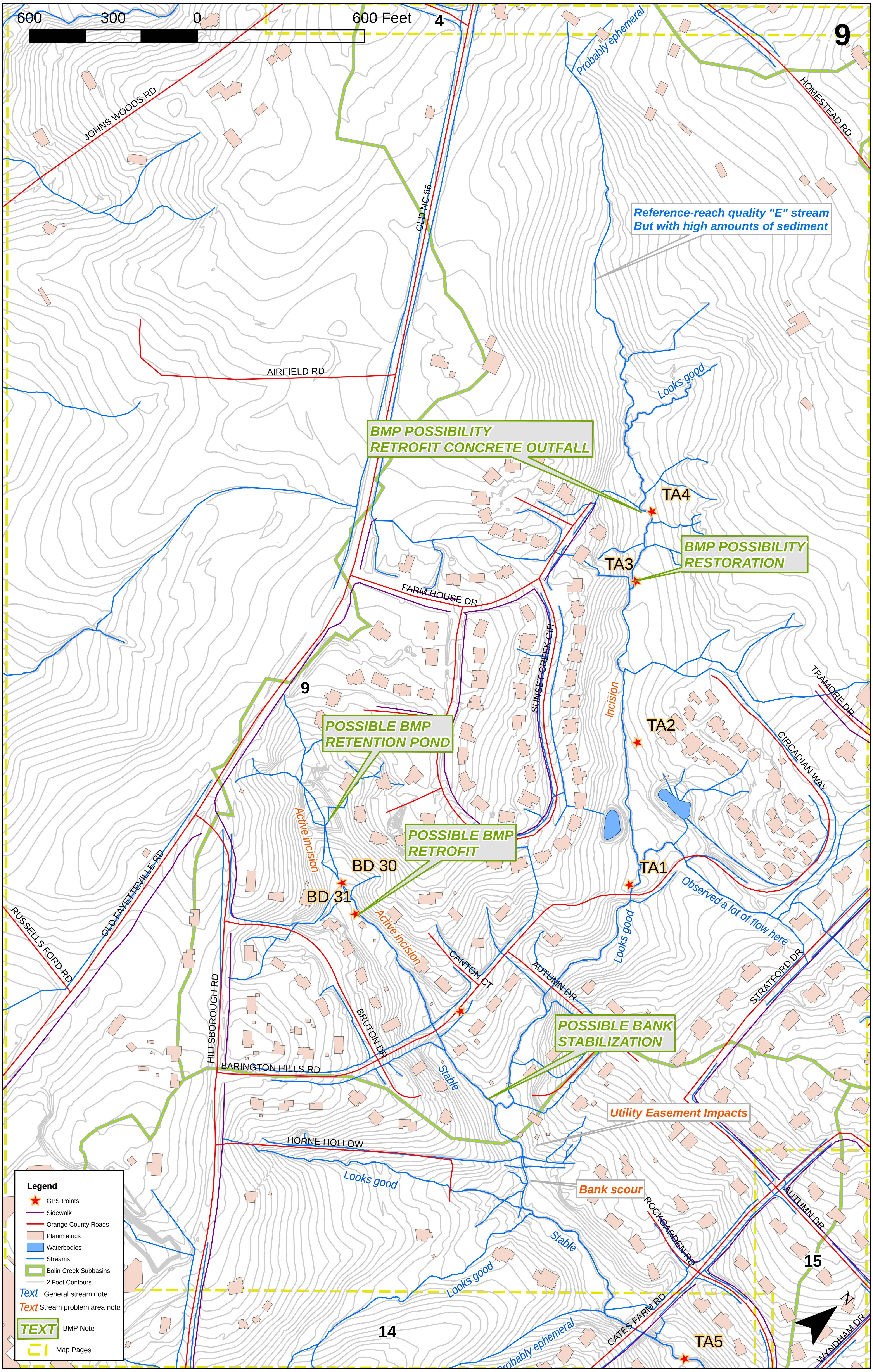
600
300
0
600 Feet
6
2
3
5
7
11
12
JONES CREEK
DUBLIN RD
KELLY CT
EUBANKS RD
DROMOLAND RD
OLD NC 86
BRITTON DR
Ongoing development
POTENTIAL BMP SITE
RETENTION AREA
Looks good
Old trash dump against stream
Probably ephemeral
Some existing retention areas at
development site discharging into
incised ephemeral- very little buffer
IJ13
Stream becomes
slightly incised
Trib is incised here and upstream- bu
appears to be stable
Incised
Probably Ephem
Probably ephemeral
Incised
Pond
Ephemeral
Probably ephemeral
Incised
BUCKHORN BRANCH
Incised
BD 24
BD 23
LEAK LN
JONES CREEK PL
TOWNE RIDGE LN
Incised "F" channel with debris jams,
low base-flow and chute cut-offs
BD 22
BD 21
TALLYHO TRL
KIT LN
Beavers
N
TALLYHO TRL
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages



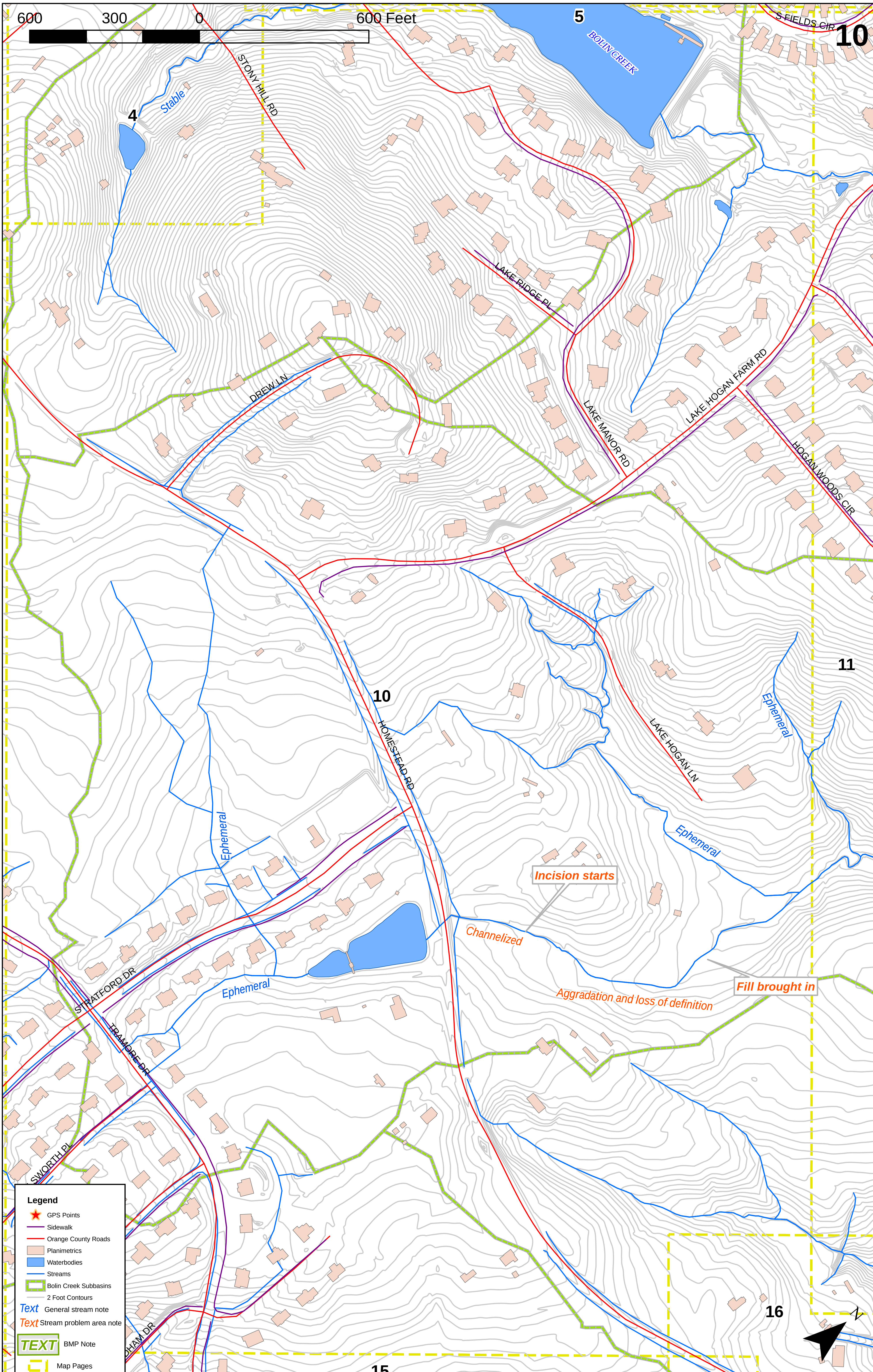
600
300
0
600 Feet
3
7
DROMOLAND RD
Ongoing development
BMP SITE
N AREA
Probably ephemeral
Some existing retention areas at development site discharging into incised ephemeral- very little buffer
IJ13
Trib is incised here and upstream- but appears to be stable
EUBANKS RD
JONES CREEK
Probably Ephemeral
7
6
Stable
8
Begin incision- appears to be old
BD 25
B
BD 26
End incision
Big (>3ft) headcut
LEAK LN
Incised
BD27
Looks good
Widen
aggradation
BD 29
BD
Stable
Some flow from yards may be causing headcuts (observed rills)
Incision
ROGERS RD
MEADOW RUN CT
12
13
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages

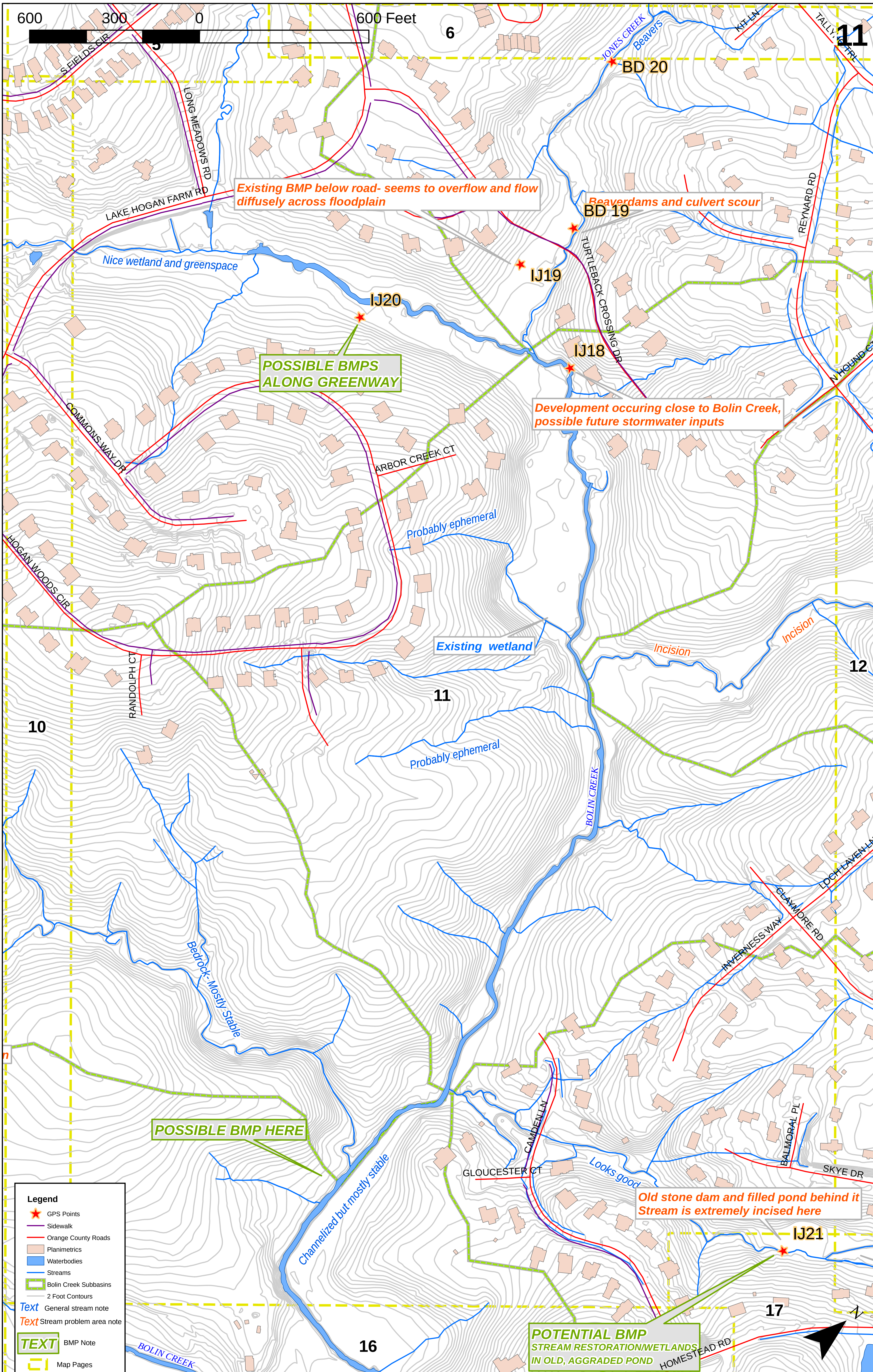


600 300 0 600 Feet
8
7
8
13
ROGERS RD
EUBANKS RD
Looks good
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages

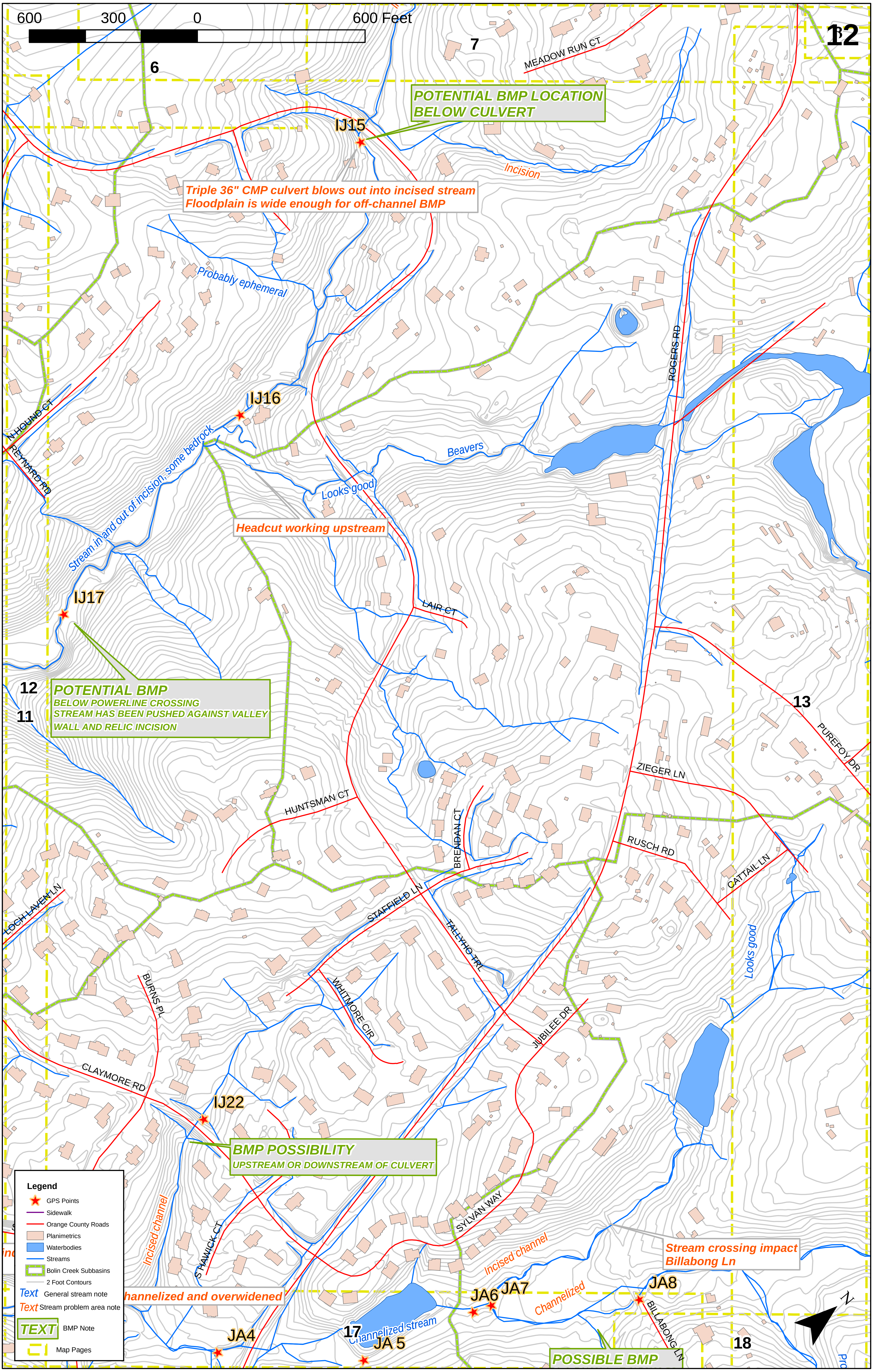


600 300 0 600 Feet
4
9
JOHNS WOODS RD
OLD NC 86
Probably ephemeral
HOMESTEAD RD
Reference-reach quality "E" stream
But with high amounts of sediment
AIRFIELD RD
Looks good
BMP POSSIBILITY
RETROFIT CONCRETE OUTFALL
TA4
TA3
BMP POSSIBILITY
RESTORATION
FARM HOUSE DR
SUNSET CREEK CIR
Incision
TA2
TRAMORE DR
CIRCADIAN WAY
POSSIBLE BMP
RETENTION POND
Active incision
POSSIBLE BMP
RETROFIT
BD 30
BD 31
TA1
Observed a lot of flow here
Looks good
OLD FAYETTEVILLE RD
RUSSELLS FORD RD
Active incision
CANTON CT
AUTUMN DR
STRATFORD DR
HILLSBOROUGH RD
BRUTON DR
POSSIBLE BANK
STABILIZATION
BARINGTON HILLS RD
Stable
Utility Easement Impacts
HORNE HOLLOW
Looks good
Bank scour
ROCKGARDEN RD
AUTUMN DR
Stable
15
Looks good
CATES FARM RD
14
Probably ephemeral
TA5
WYNDHAM DR
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages

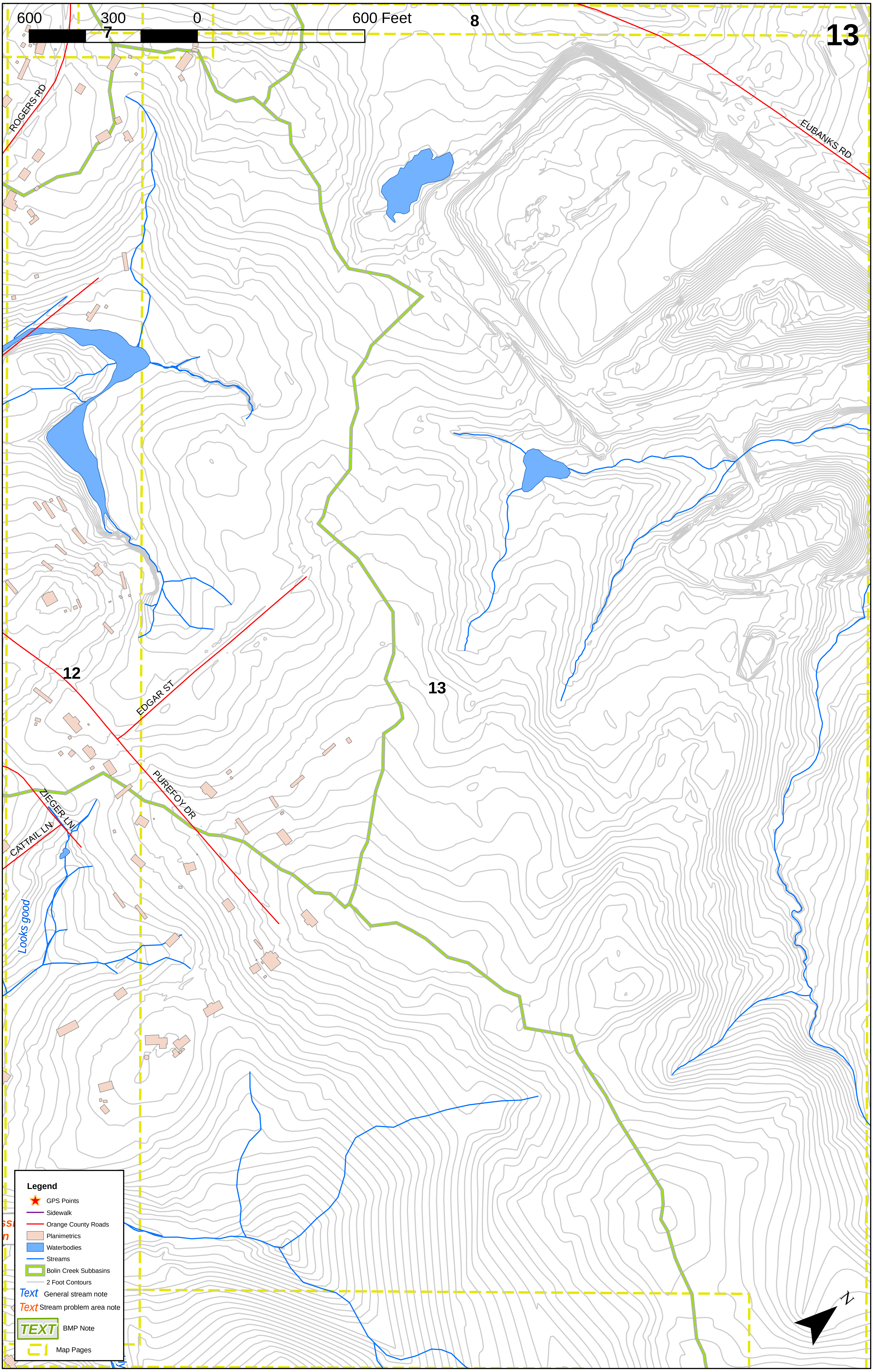

600 300 0 600 Feet
10
5
4
11
15
16
BOLIN CREEK
Stable
S FIELDS CIR
STONY HILL RD
LAKE RIDGE PL
DREW LN
LAKE MANOR RD
LAKE HOGAN FARM RD
HOGAN WOODS CIR
HOMESTEAD RD
LAKE HOGAN LN
Ephemeral
Incision starts
Channelized
Fill brought in
Aggradation and loss of definition
STRATFORD DR
TRAMORE DR
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages



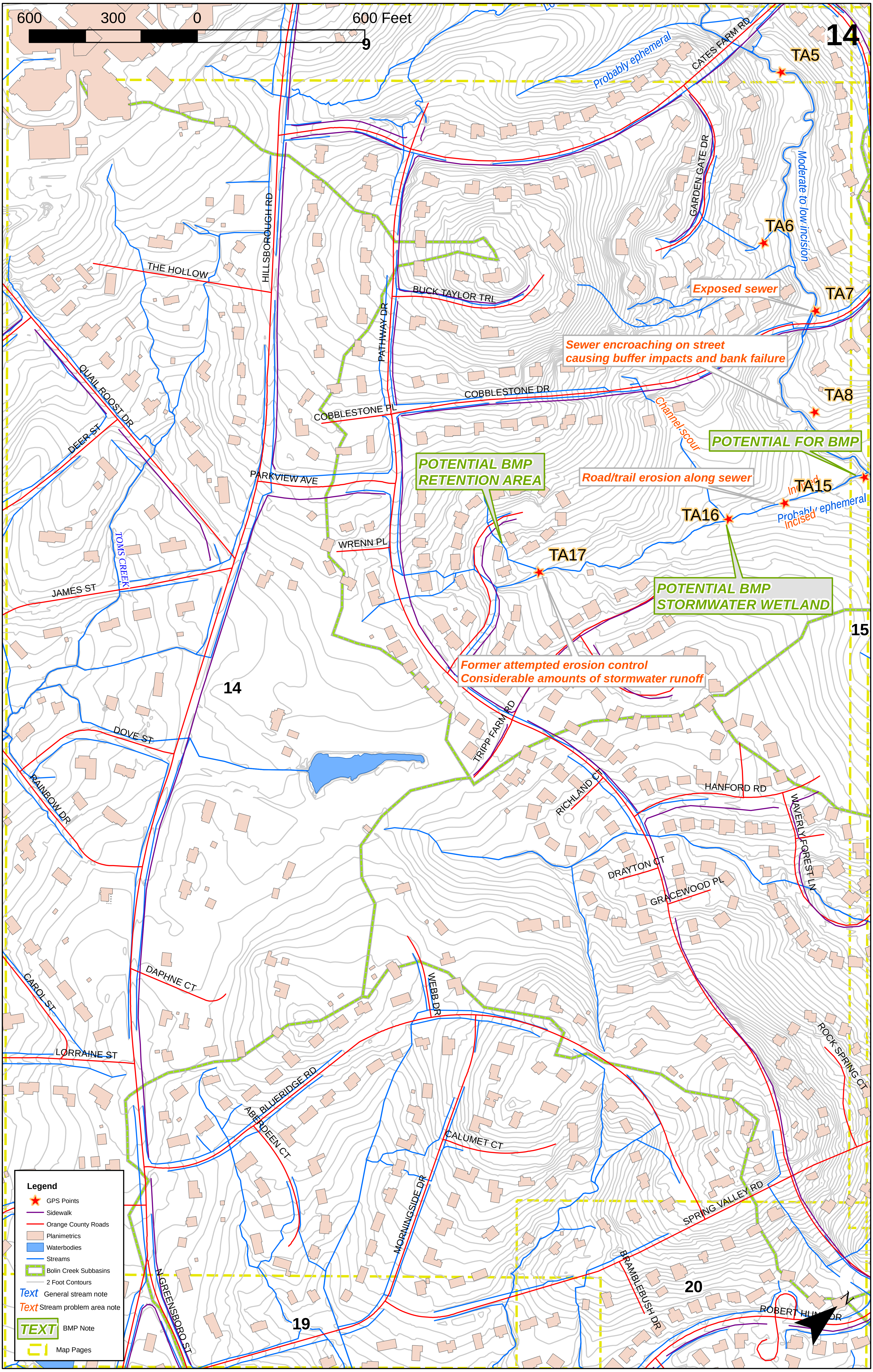
11
600 300 0 600 Feet
Existing BMP below road- seems to overflow and flow diffusely across floodplain
Beaverdams and culvert scour
BD 19
BD 20
Beavers
JONES CREEK
IJ19
IJ20
IJ18
Nice wetland and greenspace
POSSIBLE BMPS ALONG GREENWAY
Development occuring close to Bolin Creek, possible future stormwater inputs
Probably ephemeral
Existing wetland
Incision
Probably ephemeral
BOLIN CREEK
Bedrock- Mostly Stable
POSSIBLE BMP HERE
Channelized but mostly stable
Looks good
Old stone dam and filled pond behind it
Stream is extremely incised here
IJ21
POTENTIAL BMP
STREAM RESTORATION/WETLANDS IN OLD, AGGRADED POND
LAKE HOGAN FARM RD
LONG MEADOWS RD
S FIELDS CIR
COMMONS WAY DR
HOGAN WOODS CIR
RANDOLPH CT
ARBOR CREEK CT
TURTLEBACK CROSSING DR
REYNARD RD
KIT LN
TALLYHO TRL
N HOUND CT
LOCH LAVEN LN
CLAYMORE RD
INVERNESS WAY
BALMORAL PL
SKYE DR
CAMDEN LN
GLOUCESTER CT
HOMESTEAD RD
5
6
10
11
12
16
17
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages



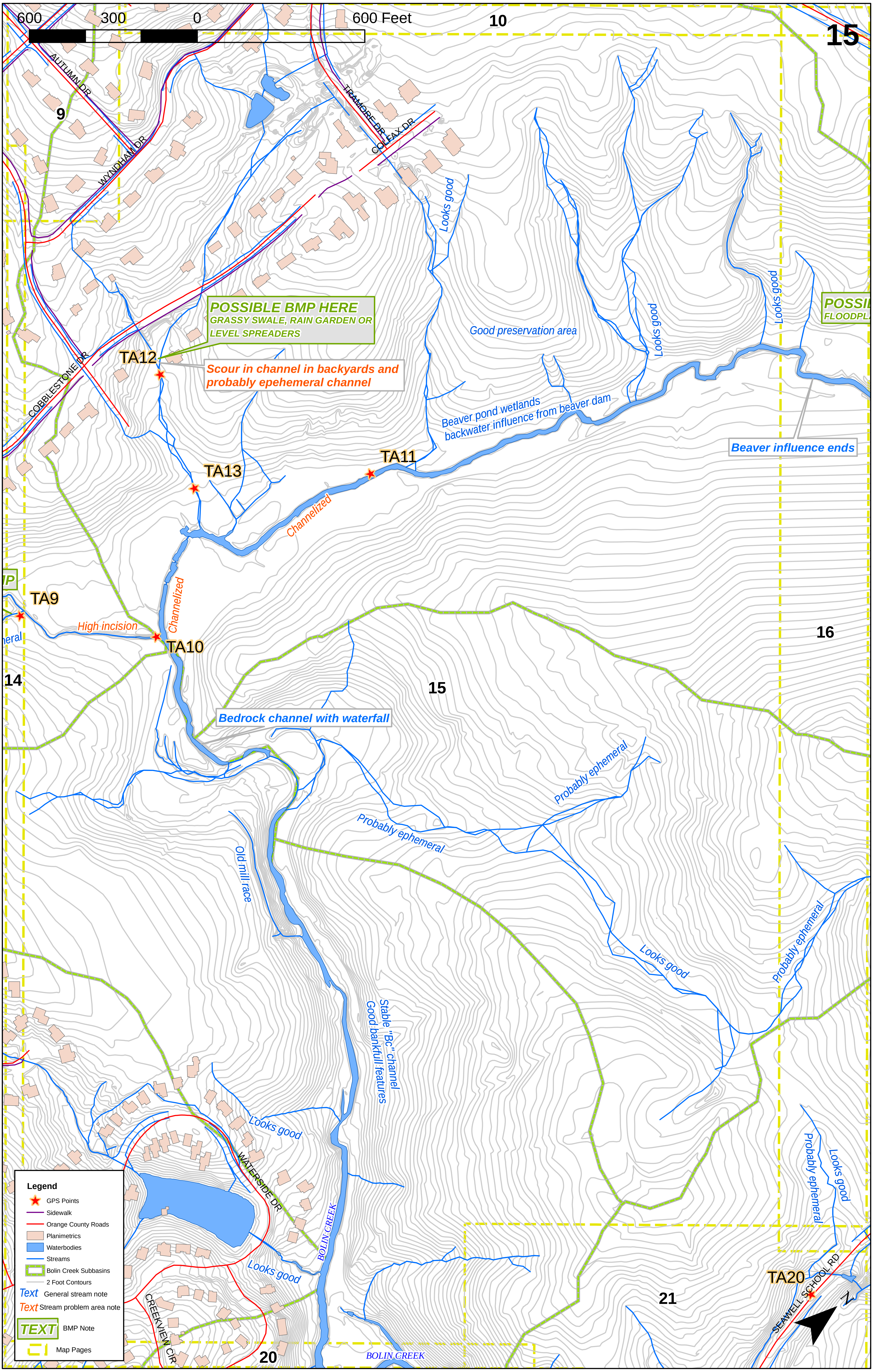
600 300 0 600 Feet
12
6
7
MEADOW RUN CT
POTENTIAL BMP LOCATION BELOW CULVERT
IJ15
Incision
Triple 36" CMP culvert blows out into incised stream
Floodplain is wide enough for off-channel BMP
Probably ephemeral
ROGERS RD
IJ16
N HOUND CT
REYNARD RD
Stream in and out of incision, some bedrock
Beavers
Looks good
Headcut working upstream
IJ17
LAIR CT
POTENTIAL BMP
BELOW POWERLINE CROSSING
STREAM HAS BEEN PUSHED AGAINST VALLEY WALL AND RELIC INCISION
12
11
13
PUREFOY DR
ZIEGER LN
HUNTSMAN CT
BRENDAN CT
RUSCH RD
CATTAIL LN
LOCH LAVEN LN
STAFFIELD LN
TALLYHO TRL
Looks good
BURNS PL
WHITMORE CIR
JUBILEE DR
CLAYMORE RD
IJ22
BMP POSSIBILITY
UPSTREAM OR DOWNSTREAM OF CULVERT
Incised channel
S HAWICK CT
SYLVAN WAY
Stream crossing impact Billabong Ln
Incised channel
Channelized and overwidened
JA6
JA7
JA8
Channelized
BILLABONG LN
JA4
17
Channelized stream
JA 5
18
POSSIBLE BMP
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages



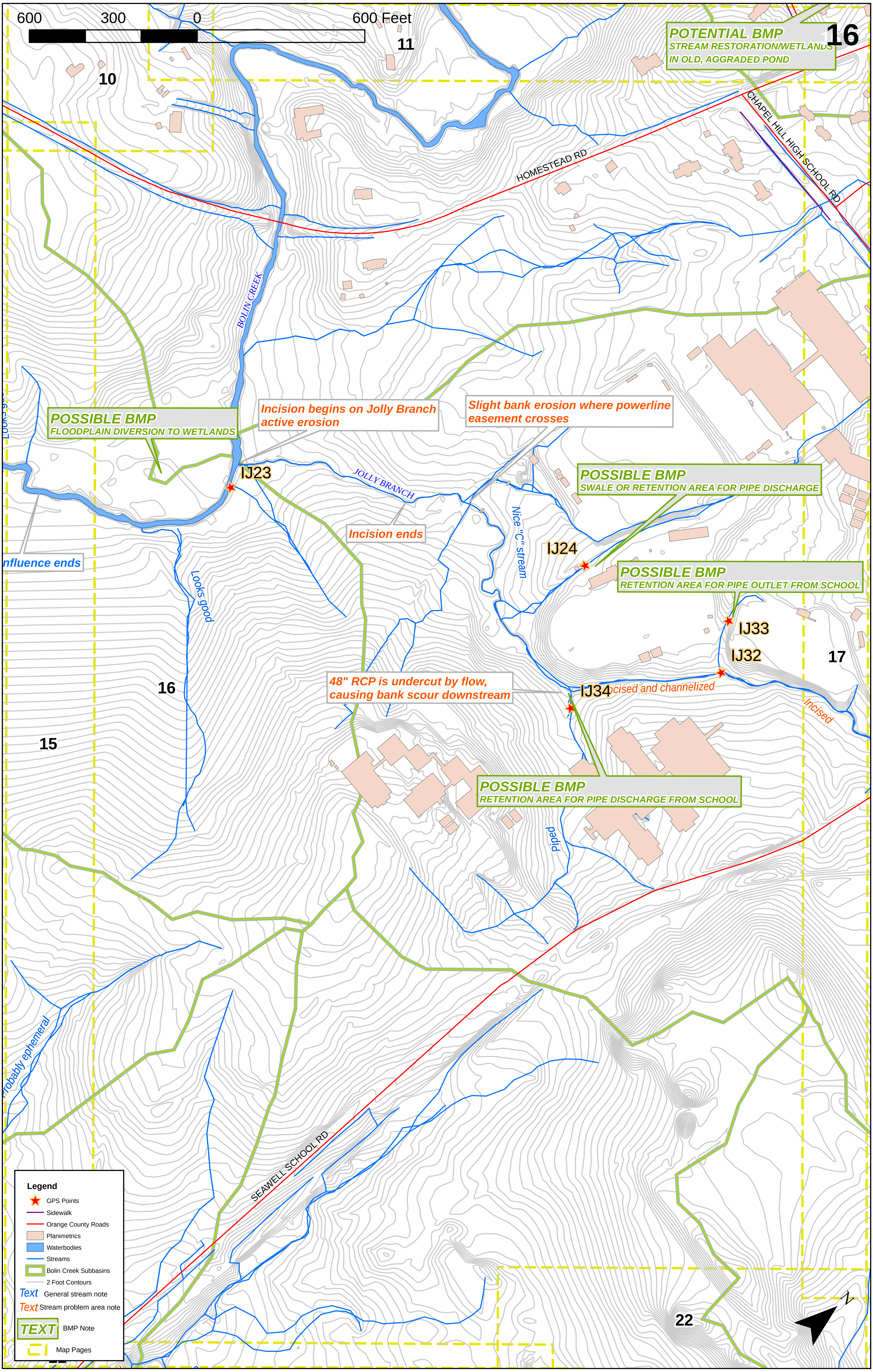
600
300
0
600 Feet
7
8
13
ROGERS RD
EUBANKS RD
12
EDGAR ST
13
PUREFOY DR
ZIEGER LN
CATTAIL LN
Looks good
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages
N



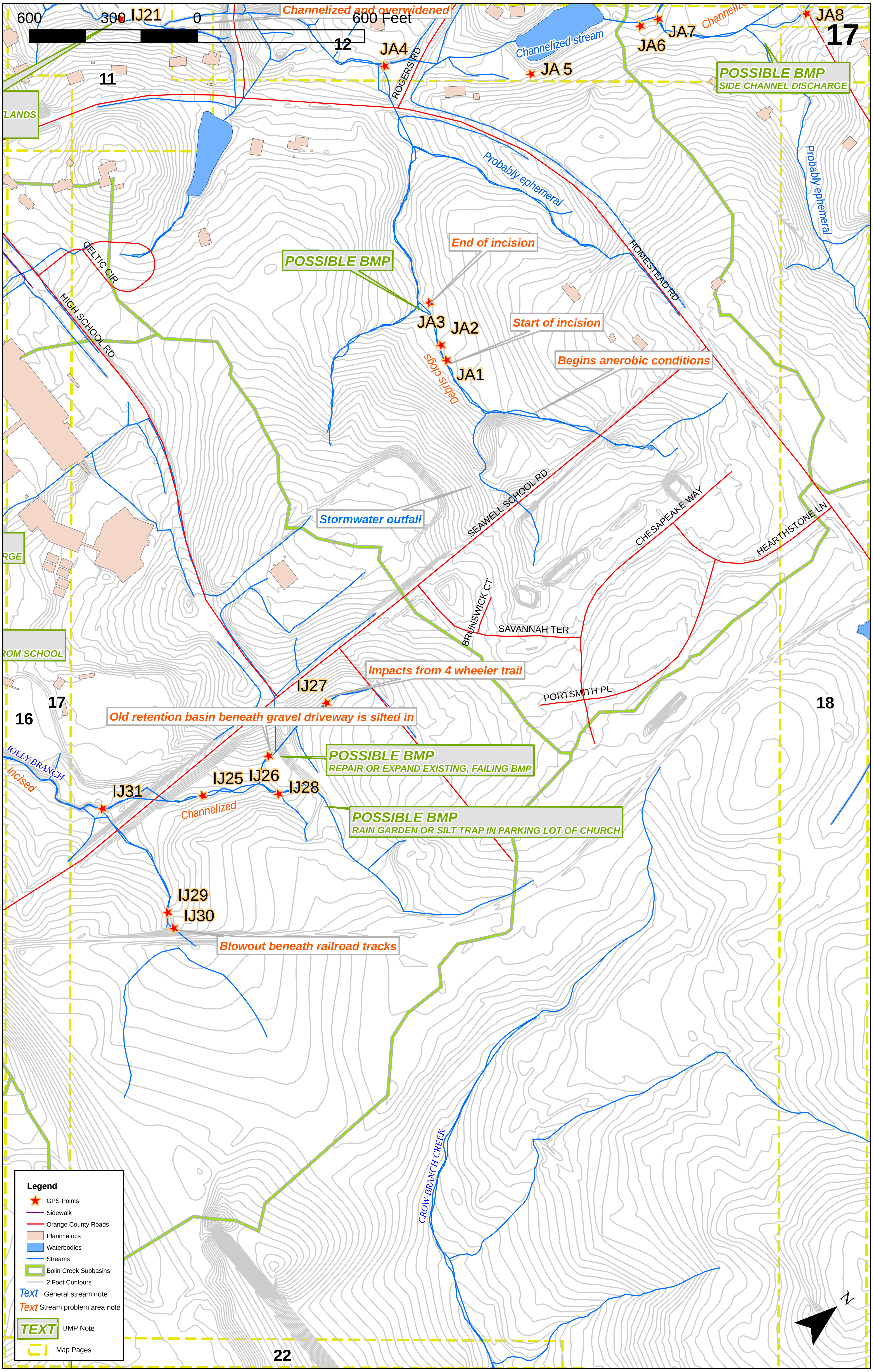
600 300 0 600 Feet
9
14
TA5
TA6
TA7
TA8
TA15
TA16
TA17
Probably ephemeral
Moderate to low incision
Exposed sewer
Sewer encroaching on street causing buffer impacts and bank failure
Channel scour
POTENTIAL FOR BMP
POTENTIAL BMP RETENTION AREA
Road/trail erosion along sewer
Incised
Probably ephemeral
POTENTIAL BMP STORMWATER WETLAND
Former attempted erosion control
Considerable amounts of stormwater runoff
15
20
19
CATES FARM RD
GARDEN GATE DR
HILLSBOROUGH RD
THE HOLLOW
BUCK TAYLOR TRL
PATHWAY DR
COBBLESTONE DR
COBBLESTONE PL
QUAIL ROOST DR
DEER ST
PARKVIEW AVE
WRENN PL
TOMS CREEK
JAMES ST
DOVE ST
RAINBOW DR
TRIPP FARM RD
RICHLAND CT
HANFORD RD
WAVERLY FOREST LN
DRAYTON CT
GRACEWOOD PL
CAROL ST
DAPHNE CT
WEBB DR
LORRAINE ST
ROCK SPRING CT
BLUERIDGE RD
ABERDEEN CT
CALUMET CT
MORNINGSIDE DR
SPRING VALLEY RD
BRAMBLEBUSH DR
N GREENSBORO ST
ROBERT HUNT DR
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages



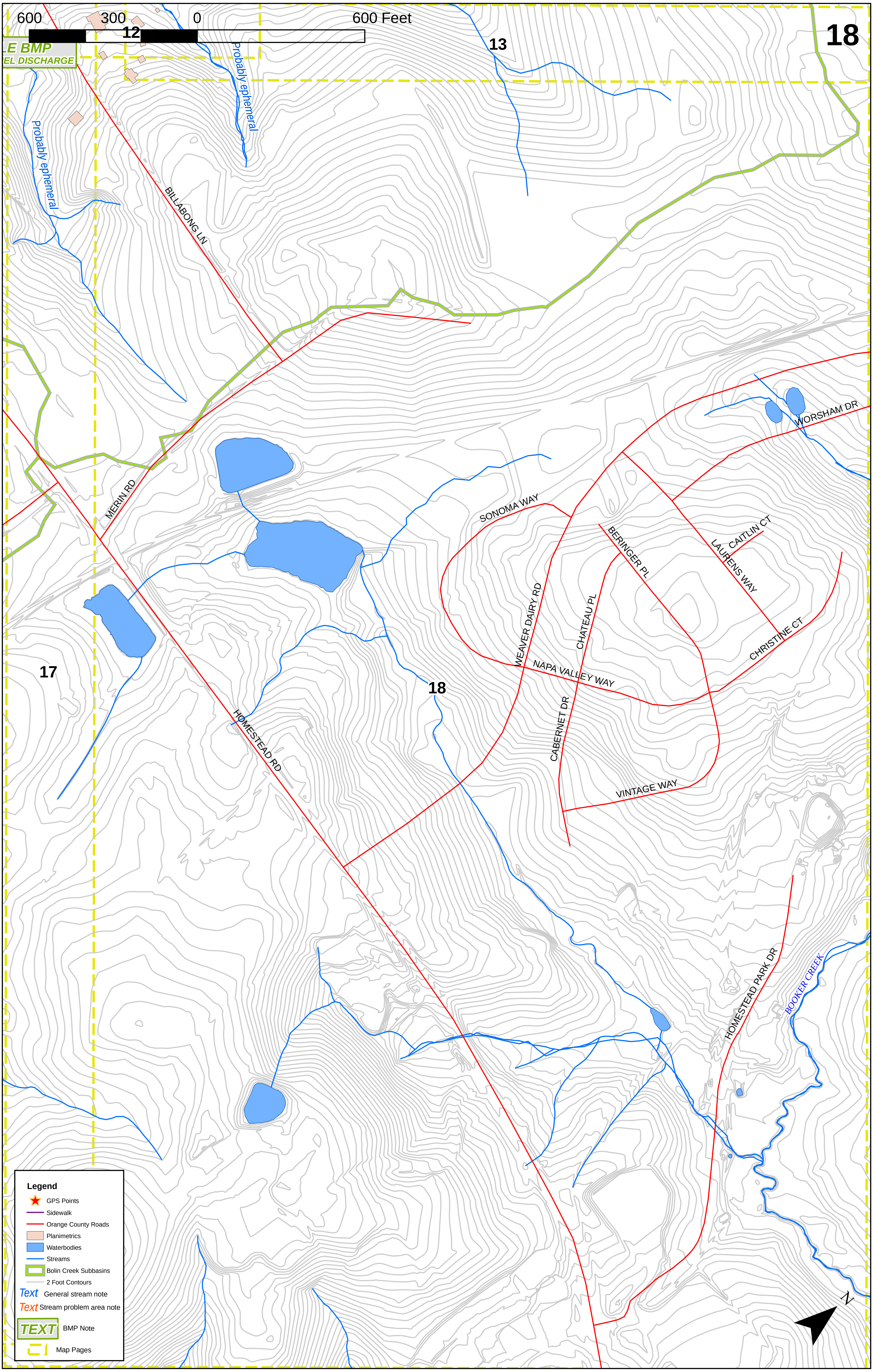
600
300
0
600 Feet
10
15
9
AUTUMN DR
WYNDHAM DR
TRAMORE DR
COLFAX DR
COBBLESTONE DR
Looks good
POSSIBLE BMP HERE
GRASSY SWALE, RAIN GARDEN OR LEVEL SPREADERS
TA12
Scour in channel in backyards and probably epehemeral channel
Good preservation area
Looks good
Looks good
POSSI
FLOODPL
Beaver pond wetlands
backwater influence from beaver dam
Beaver influence ends
TA11
TA13
Channelized
Channelized
TA9
High incision
TA10
14
16
15
Bedrock channel with waterfall
Probably ephemeral
Probably ephemeral
Old mill race
Looks good
Probably ephemeral
Stable "Bc" channel
Good bankfull features
Looks good
Looks good
WATERSIDE DR
BOLIN CREEK
Probably ephemeral
Looks good
TA20
SEAWELL SCHOOL RD
21
N
CREEKVIEW CIR
20
BOLIN CREEK
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages

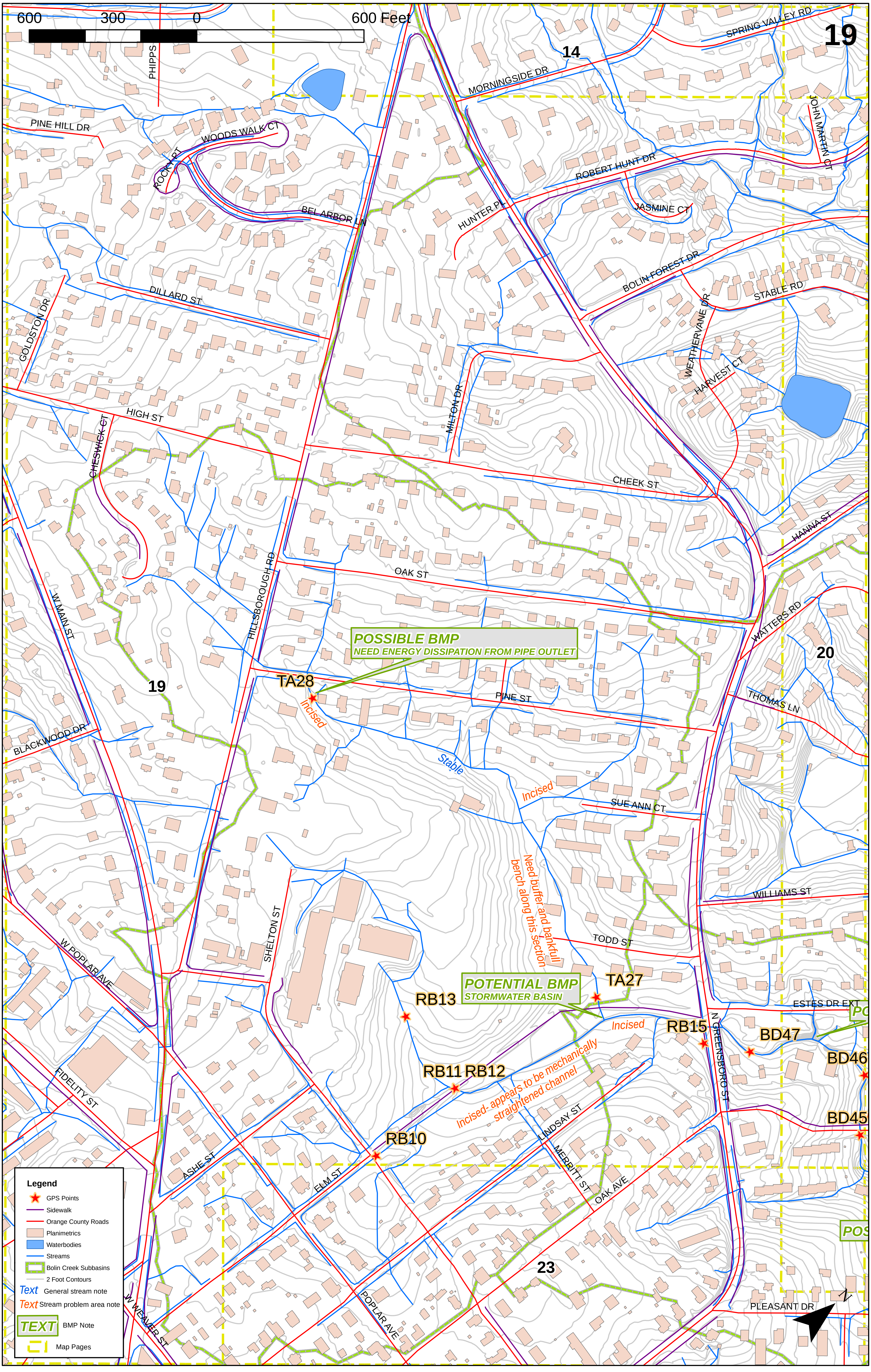


600 300 0 600 Feet
16
POTENTIAL BMP
STREAM RESTORATION/WETLANDS IN OLD, AGGRADED POND
10
11
HOMESTEAD RD
CHAPEL HILL HIGH SCHOOL RD
BOLIN CREEK
POSSIBLE BMP
FLOODPLAIN DIVERSION TO WETLANDS
Incision begins on Jolly Branch active erosion
Slight bank erosion where powerline easement crosses
IJ23
JOLLY BRANCH
POSSIBLE BMP
SWALE OR RETENTION AREA FOR PIPE DISCHARGE
Incision ends
IJ24
Nice "C" stream
nfluence ends
POSSIBLE BMP
RETENTION AREA FOR PIPE OUTLET FROM SCHOOL
Looks good
IJ33
IJ32
17
48" RCP is undercut by flow, causing bank scour downstream
IJ34
ncised and channelized
Incised
16
15
POSSIBLE BMP
RETENTION AREA FOR PIPE DISCHARGE FROM SCHOOL
Probably ephemeral
SEAWELL SCHOOL RD
22
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages

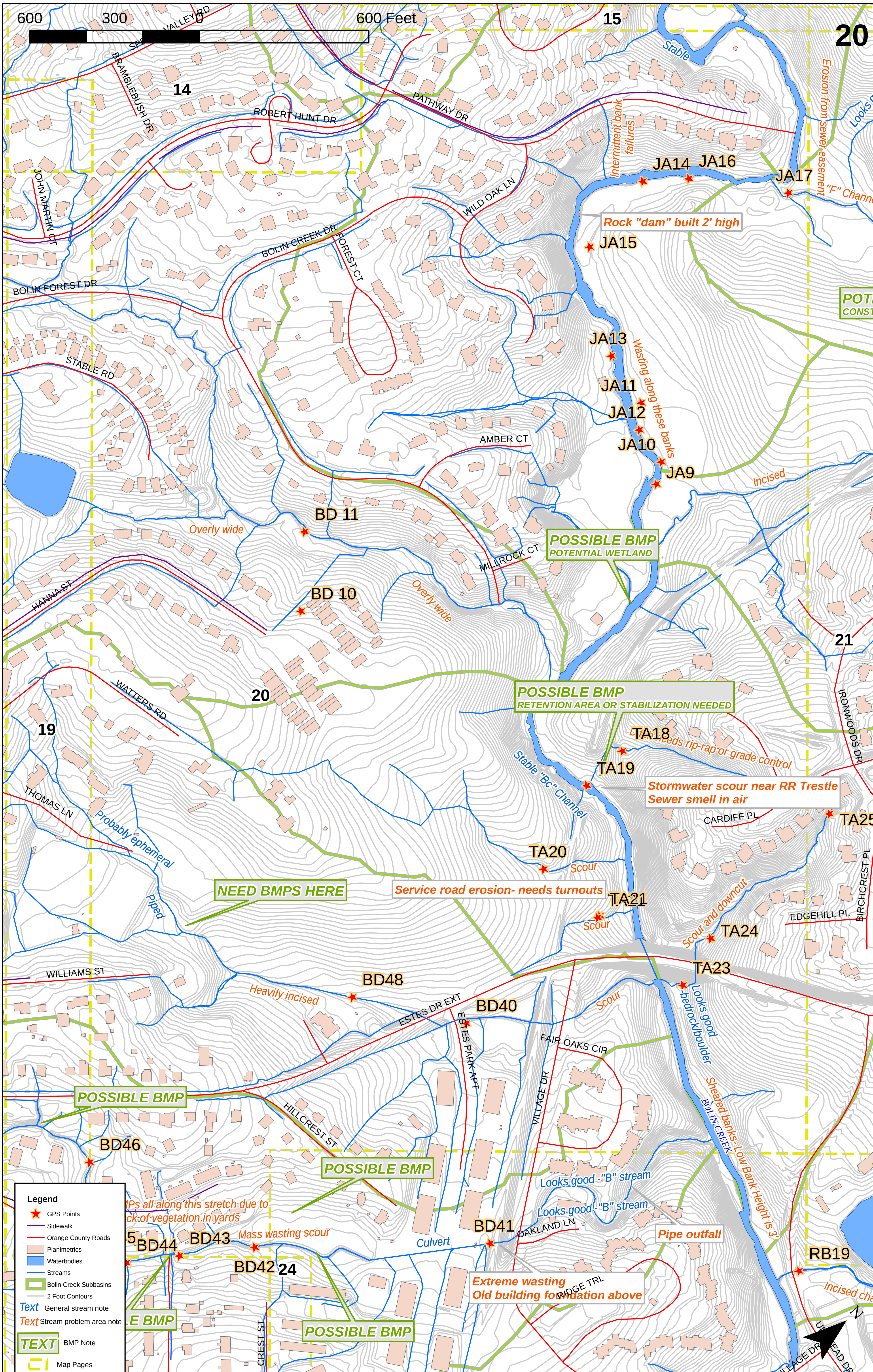


600
300
0
600 Feet
Channelized and overwidened
JA4
ROGERS RD
Channelized stream
JA 5
JA6
JA7
JA8
17
POSSIBLE BMP
SIDE CHANNEL DISCHARGE
IJ21
11
12
Probably ephemeral
End of incision
POSSIBLE BMP
JA3
JA2
Start of incision
Begins anerobic conditions
Debris clogs
JA1
CELTIC CIR
HIGH SCHOOL RD
HOMESTEAD RD
Stormwater outfall
SEAWELL SCHOOL RD
CHESAPEAKE WAY
HEARTHSTONE LN
BRUNSWICK CT
SAVANNAH TER
PORTSMITH PL
Impacts from 4 wheeler trail
IJ27
Old retention basin beneath gravel driveway is silted in
17
16
18
JOLLY BRANCH
Incised
POSSIBLE BMP
REPAIR OR EXPAND EXISTING, FAILING BMP
IJ31
IJ25
IJ26
IJ28
Channelized
POSSIBLE BMP
RAIN GARDEN OR SILT TRAP IN PARKING LOT OF CHURCH
IJ29
IJ30
Blowout beneath railroad tracks
CROW BRANCH CREEK
22
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages
N

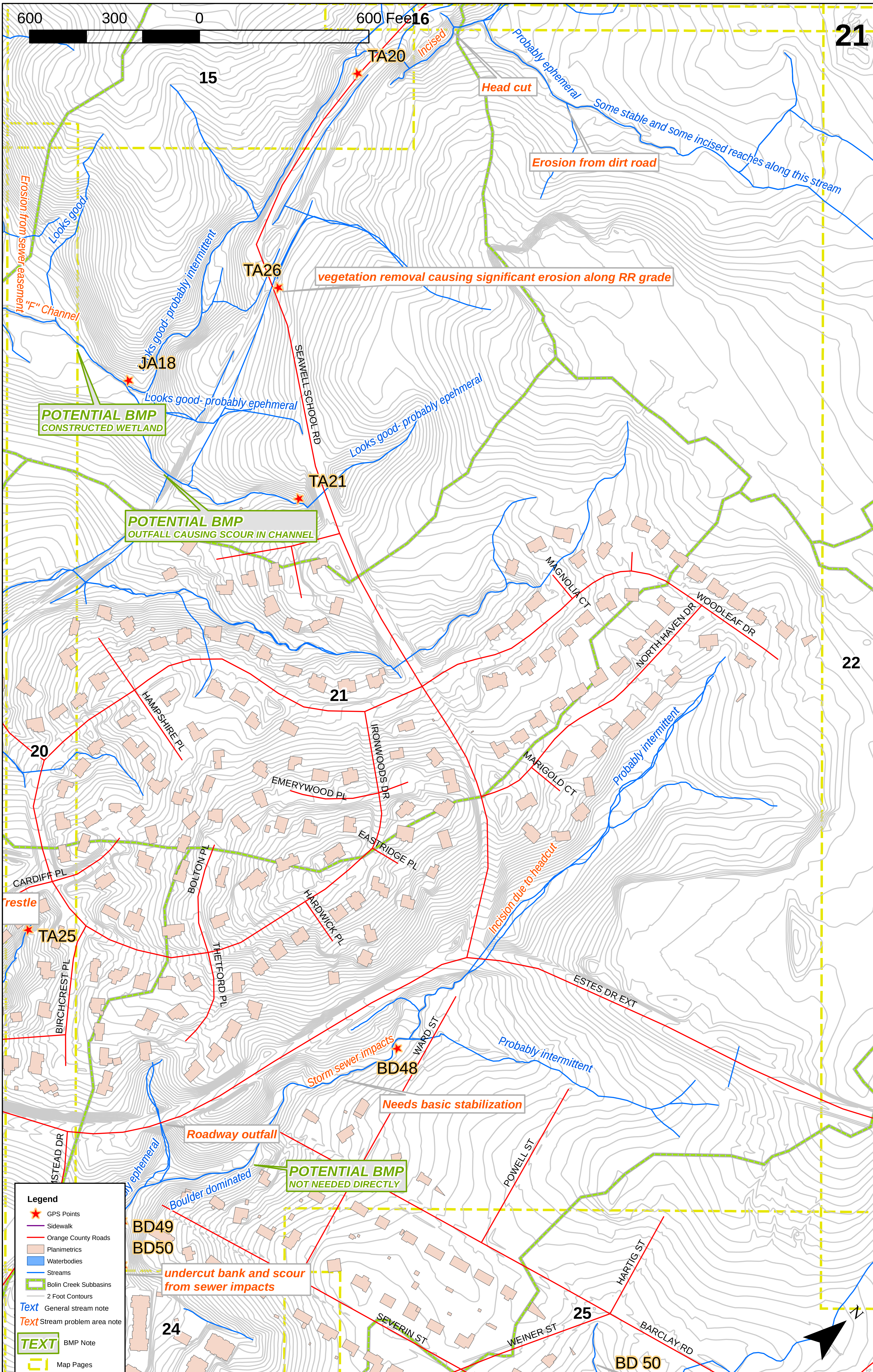

600
300
0
600 Feet
18
12
13
17
18
LE BMP
EL DISCHARGE
Probably ephemeral
Probably ephemeral
BILLABONG LN
MERIN RD
HOMESTEAD RD
SONOMA WAY
WEAVER DAIRY RD
CHATEAU PL
BERINGER PL
LAURENS WAY
CAITLIN CT
WORSHAM DR
CHRISTINE CT
NAPA VALLEY WAY
CABERNET DR
VINTAGE WAY
HOMESTEAD PARK DR
BOOKER CREEK
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages



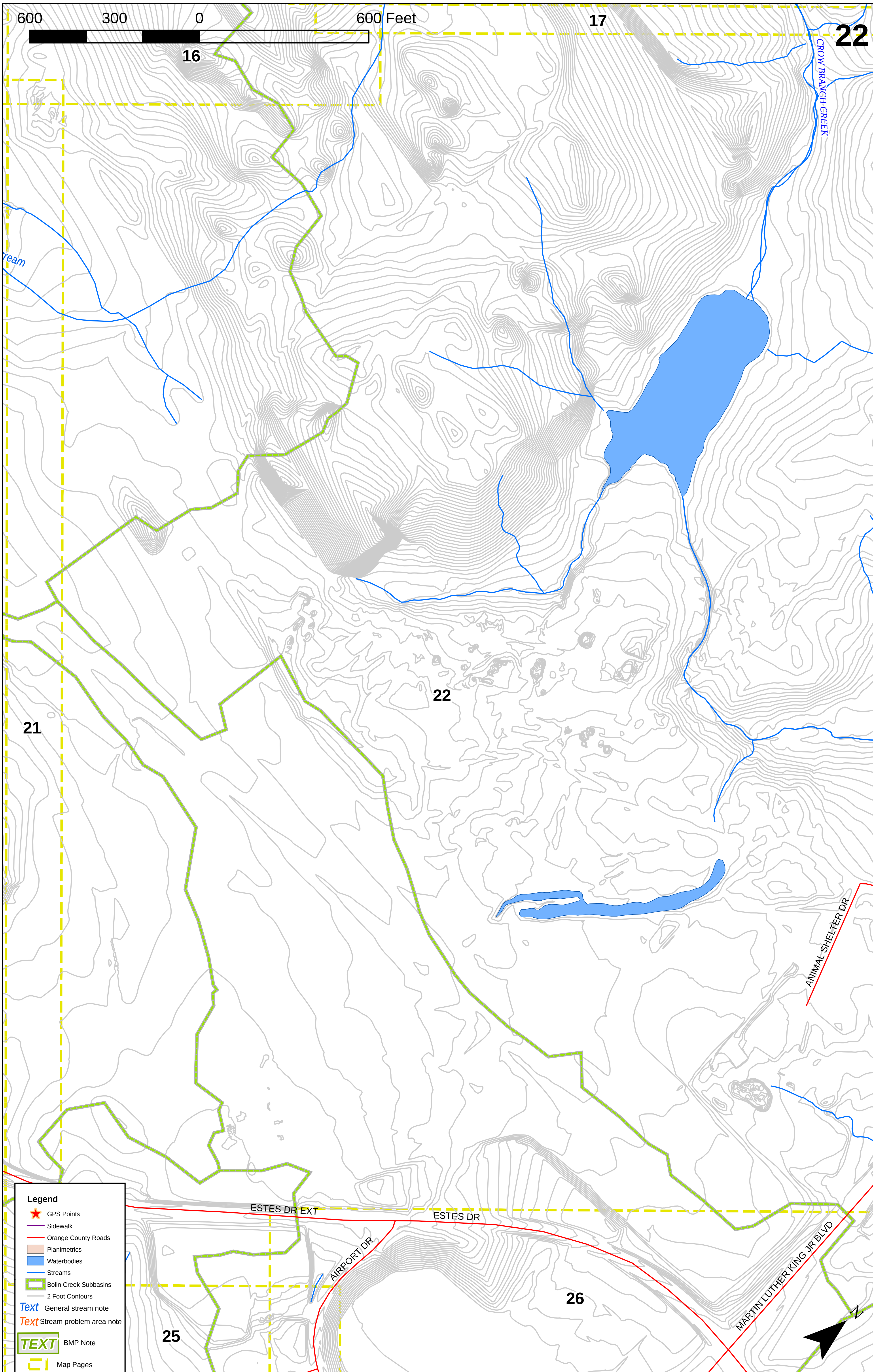
19
600 300 0 600 Feet
14
20
23
SPRING VALLEY RD
MORNINGSIDE DR
JOHN MARTIN CT
PHIPPS
PINE HILL DR
WOODS WALK CT
ROCKY PT
BEL ARBOR LN
HUNTER PL
ROBERT HUNT DR
JASMINE CT
BOLIN FOREST DR
STABLE RD
WEATHERVANE DR
HARVEST CT
DILLARD ST
GOLDSTON DR
HIGH ST
CHESWICK CT
MILTON DR
CHEEK ST
HANNA ST
OAK ST
HILLSBOROUGH RD
W MAIN ST
WATTERS RD
POSSIBLE BMP
NEED ENERGY DISSIPATION FROM PIPE OUTLET
TA28
Incised
PINE ST
THOMAS LN
BLACKWOOD DR
Stable
Incised
SUE ANN CT
Need buffer and bankfull bench along this section
WILLIAMS ST
SHELTON ST
TODD ST
W POPLAR AVE
POTENTIAL BMP
STORMWATER BASIN
TA27
RB13
ESTES DR EXT
Incised
RB15
BD47
N GREENSBORO ST
BD46
RB11 RB12
Incised- appears to be mechanically straightened channel
FIDELITY ST
LINDSAY ST
BD45
RB10
ASHE ST
ELM ST
MERRITT ST
OAK AVE
POPLAR AVE
W WEAVER ST
PLEASANT DR
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages

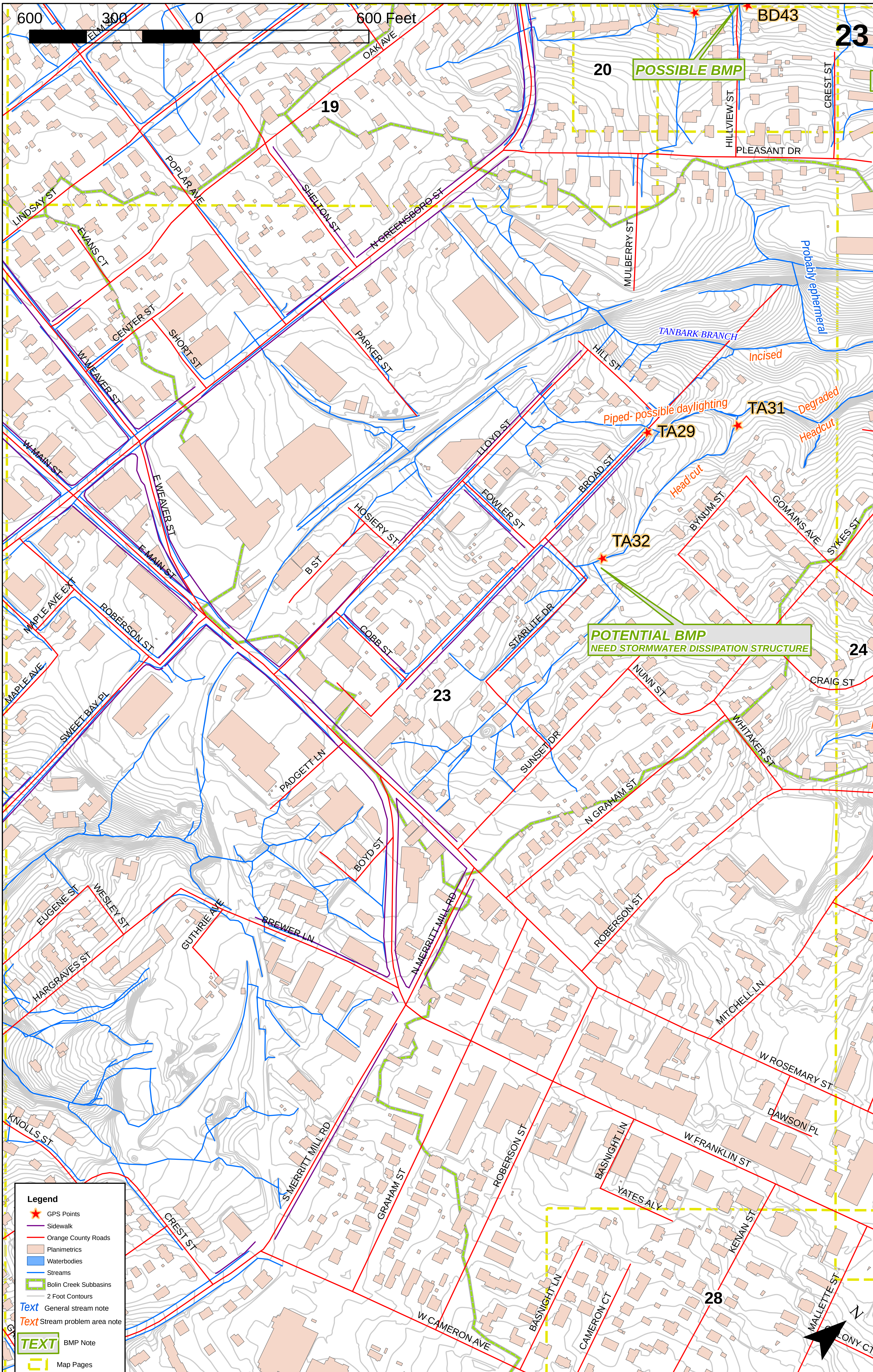


20
600 300 0 600 Feet
15
14
21
19
24
Stable
Erosion from sewer easement
Looks good
"F" Channel
Intermittent bank failures
JA14
JA16
JA17
Rock "dam" built 2' high
JA15
JA13
JA11
JA12
JA10
JA9
Wasting along these banks
Incised
POSSIBLE BMP
POTENTIAL WETLAND
BD 11
BD 10
Overly wide
Overly wide
POSSIBLE BMP
RETENTION AREA OR STABILIZATION NEEDED
TA18
Needs rip-rap or grade control
TA19
Stormwater scour near RR Trestle
Sewer smell in air
Stable "Bc" Channel
TA25
TA20
Scour
Service road erosion- needs turnouts
NEED BMPS HERE
TA21
Scour
Scour and downcut
TA24
TA23
Probably ephemeral
Piped
BD48
Heavily incised
BD40
Scour
Looks good -bedrock/boulder
Sheared banks-Low Bank Height is 3'
BOLIN CREEK
POSSIBLE BMP
BD46
POSSIBLE BMP
Looks good -"B" stream
Looks good -"B" stream
Pipe outfall
BMPs all along this stretch due to lack of vegetation in yards
Mass wasting scour
BD44
BD43
BD42
BD41
Culvert
Extreme wasting
Old building foundation above
RB19
Incised channel
POSSIBLE BMP
POSSIBLE BMP
POTENTIAL CONSTR
N
VALLEY RD
BRAMBLEBUSH DR
ROBERT HUNT DR
PATHWAY DR
JOHN MARTIN CT
WILD OAK LN
BOLIN CREEK DR
FOREST CT
BOLIN FOREST DR
STABLE RD
AMBER CT
MILLROCK CT
HANNA ST
WATTERS RD
THOMAS LN
IRONWOODS DR
CARDIFF PL
BIRCHCREST PL
EDGEHILL PL
WILLIAMS ST
ESTES DR EXT
ESTES PARK APT
FAIR OAKS CIR
VILLAGE DR
HILLCREST ST
OAKLAND LN
RIDGE TRL
CREST ST
VILLAGE DR
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages

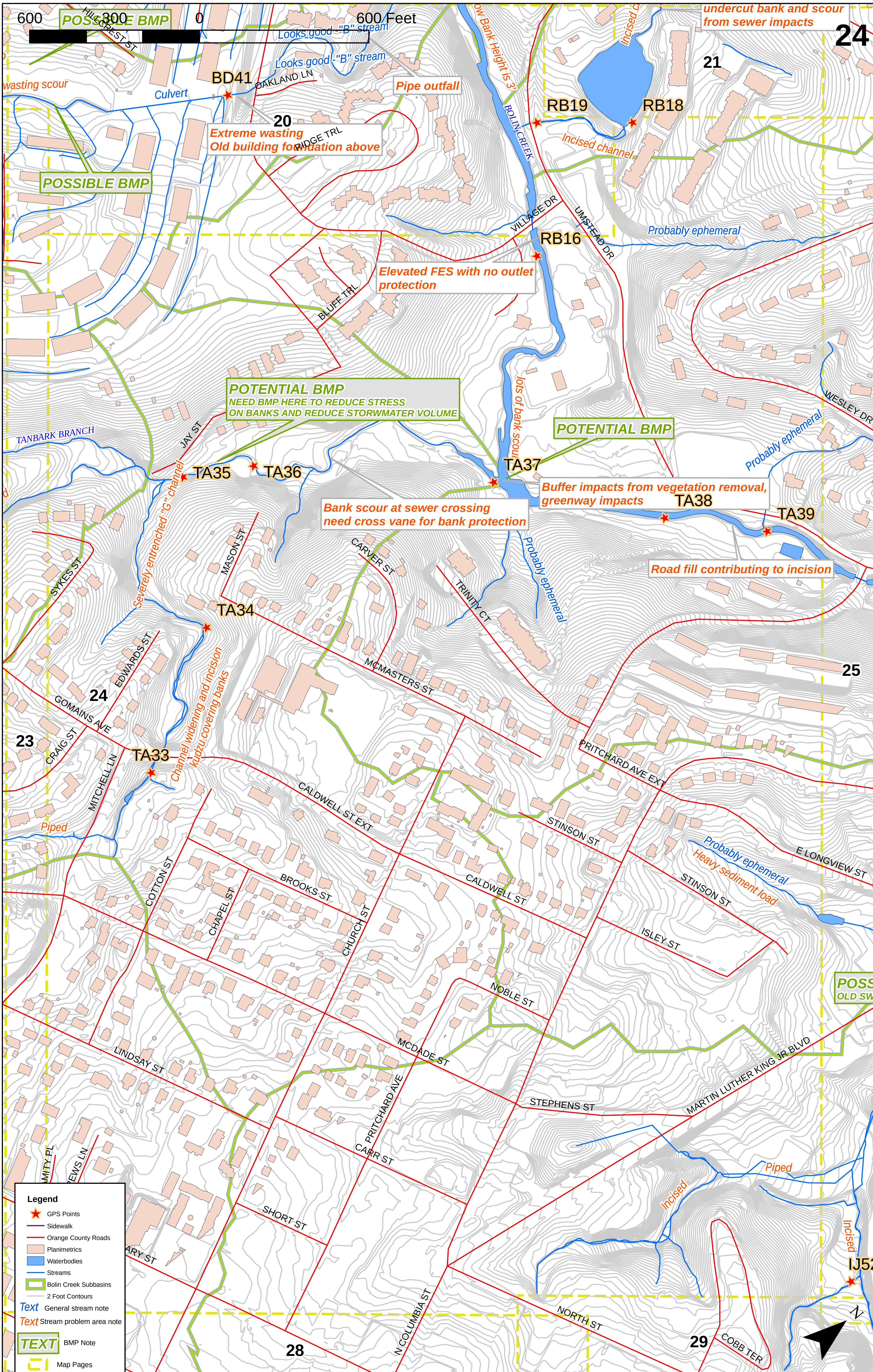


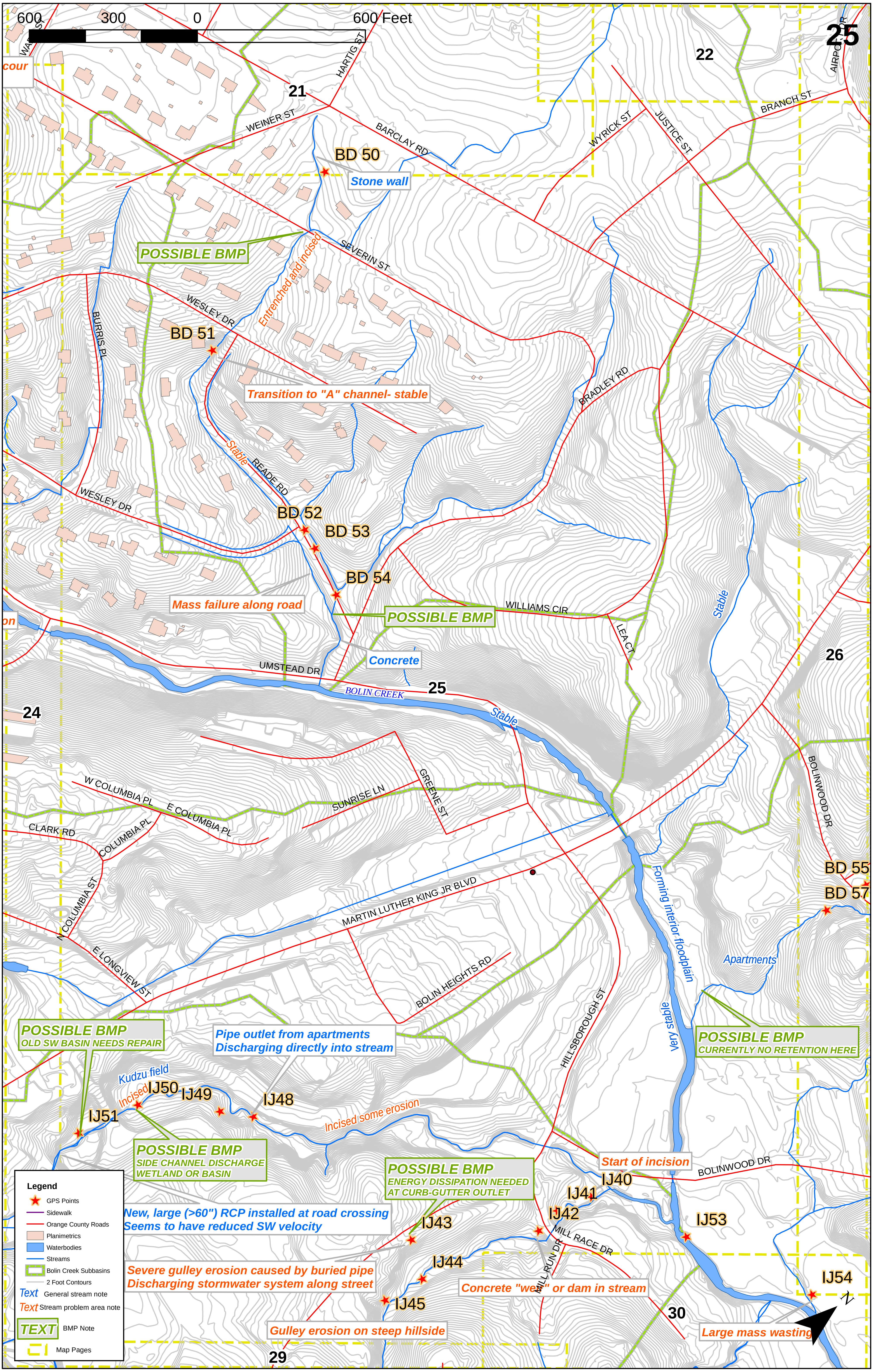
600 300 0 600 Feet
16
21
15
22
20
24
25
Incised
TA20
Head cut
Probably ephemeral
Some stable and some incised reaches along this stream
Erosion from dirt road
Erosion from sewer easement
Looks good
Looks good- probably intermittent
"F" Channel
TA26
vegetation removal causing significant erosion along RR grade
SEAWELL SCHOOL RD
JA18
Looks good- probably ephemeral
POTENTIAL BMP
CONSTRUCTED WETLAND
Looks good- probably ephemeral
TA21
POTENTIAL BMP
OUTFALL CAUSING SCOUR IN CHANNEL
MAGNOLIA CT
WOODLEAF DR
NORTH HAVEN DR
HAMPSHIRE PL
IRONWOODS DR
EMERYWOOD PL
MARIGOLD CT
Probably intermittent
EASTRIDGE PL
CARDIFF PL
BOLTON PL
HARDWICK PL
Incision due to headcut
Trestle
TA25
BIRCHCREST PL
THETFORD PL
ESTES DR EXT
WARD ST
Storm sewer impacts
BD48
Probably intermittent
Needs basic stabilization
Roadway outfall
POTENTIAL BMP
NOT NEEDED DIRECTLY
Boulder dominated
POWELL ST
BD49
BD50
undercut bank and scour from sewer impacts
HARTIG ST
SEVERIN ST
WEINER ST
BARCLAY RD
BD 50
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages


600
300
0
600 Feet
16
17
22
CROW BRANCH CREEK
22
21
ANIMAL SHELTER DR
ESTES DR EXT
ESTES DR
AIRPORT DR
MARTIN LUTHER KING JR BLVD
26
25
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages

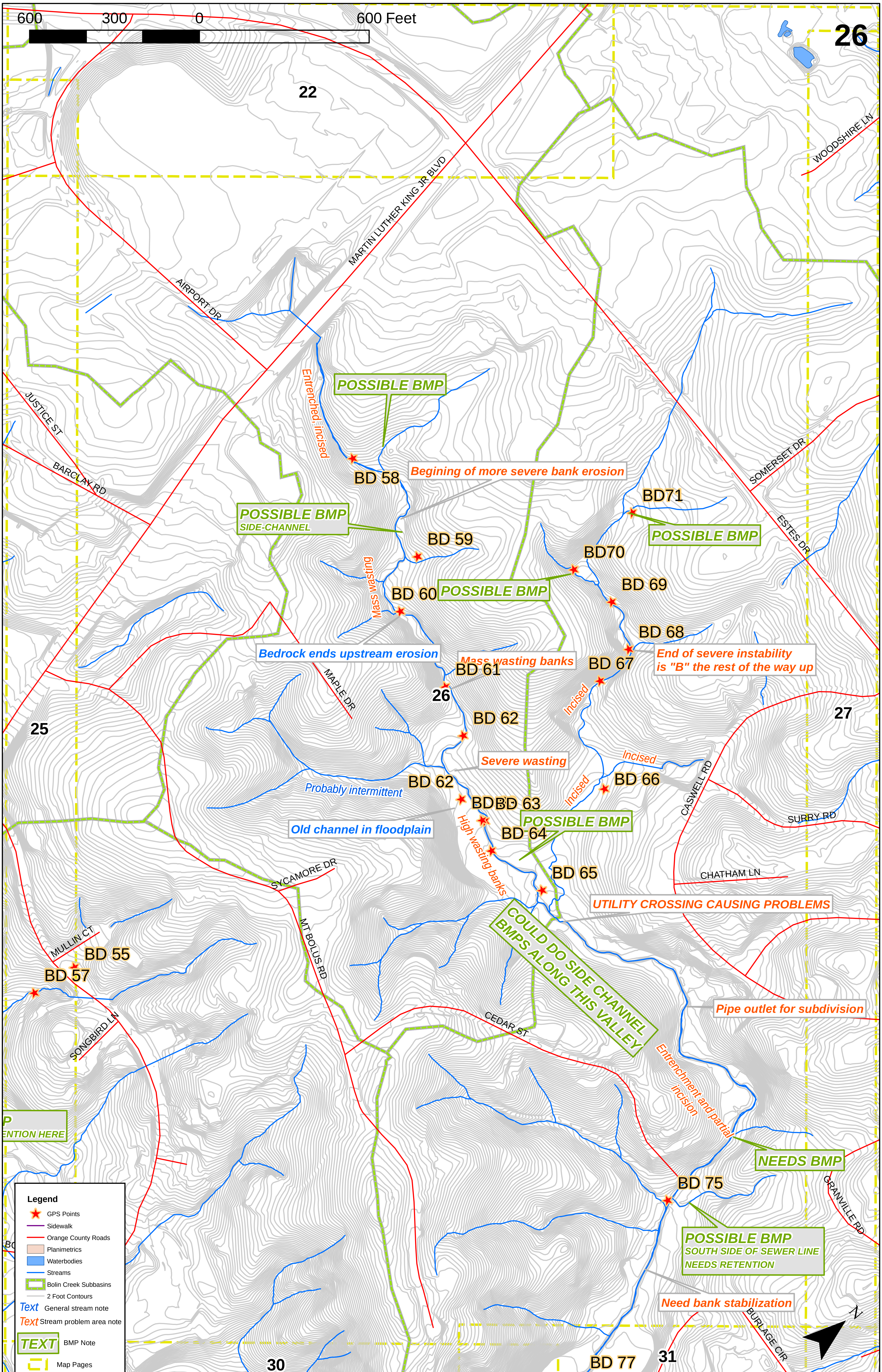


600 300 0 600 Feet
23
20
19
24
28
BD43
POSSIBLE BMP
TA29
TA31
TA32
POTENTIAL BMP
NEED STORMWATER DISSIPATION STRUCTURE
TANBARK BRANCH
Probably ephermeral
Incised
Piped- possible daylighting
Degraded
Headcut
Head cut
ELM ST
OAK AVE
CREST ST
HILLVIEW ST
PLEASANT DR
LINDSAY ST
POPLAR AVE
SHELTON ST
N GREENSBORO ST
MULBERRY ST
EVANS CT
CENTER ST
SHORT ST
PARKER ST
HILL ST
W WEAVER ST
W MAIN ST
LLOYD ST
BROAD ST
E WEAVER ST
HOSIERY ST
FOWLER ST
BYNUM ST
GOMAINS AVE
SYKES ST
E MAIN ST
B ST
MAPLE AVE EXT
ROBERSON ST
COBB ST
STARLITE DR
NUNN ST
CRAIG ST
MAPLE AVE
SWEET BAY PL
PADGETT LN
SUNSET DR
WHITAKER ST
N GRAHAM ST
BOYD ST
EUGENE ST
WESLEY ST
GUTHRIE AVE
BREWER LN
N MERRITT MILL RD
HARGRAVES ST
MITCHELL LN
W ROSEMARY ST
DAWSON PL
KNOLLS ST
S MERRITT MILL RD
GRAHAM ST
ROBERSON ST
BASNIGHT LN
W FRANKLIN ST
YATES ALY
KENAN ST
CREST ST
CAMERON CT
MALLETTE ST
W CAMERON AVE
COLONY CT
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages

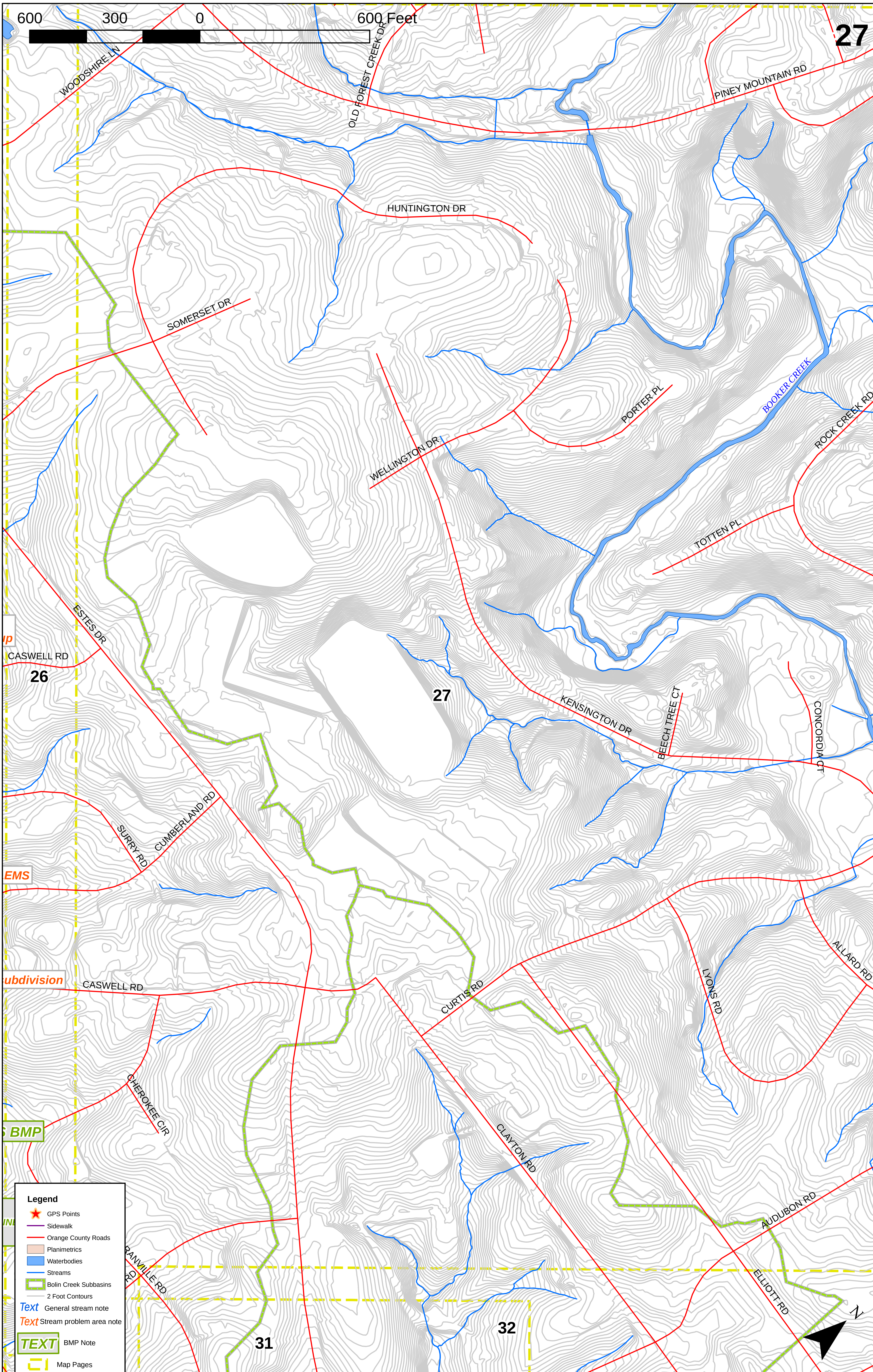

600 300 0 600 Feet
POSSIBLE BMP
Looks good -"B" stream
Looks good -"B" stream
Pipe outfall
BD41
Culvert
wasting scour
20
Extreme wasting
Old building foundation above
POSSIBLE BMP
undercut bank and scour
from sewer impacts
21
RB19
RB18
Incised channel
Bank Height is 3'
BOLIN CREEK
RB16
Elevated FES with no outlet
protection
Probably ephemeral
POTENTIAL BMP
NEED BMP HERE TO REDUCE STRESS
ON BANKS AND REDUCE STORWMATER VOLUME
TANBARK BRANCH
lots of bank scour
POTENTIAL BMP
TA35
TA36
TA37
Buffer impacts from vegetation removal,
greenway impacts
TA38
TA39
Bank scour at sewer crossing
need cross vane for bank protection
Probably ephemeral
Road fill contributing to incision
Severely entrenched "G" channel
TA34
Channel widening and incision
kudzu covering banks
24
23
TA33
25
Piped
Probably ephemeral
Heavy sediment load
POSSI
OLD SW
Piped
Incised
Incised
IJ52
28
29
HILLCREST ST
OAKLAND LN
RIDGE TRL
VILLAGE DR
UMSTEAD DR
BLUFF TRL
JAY ST
WESLEY DR
MASON ST
CARVER ST
TRINITY CT
SYKES ST
EDWARDS ST
GOMAINS AVE
CRAIG ST
MITCHELL LN
MCMASTERS ST
PRITCHARD AVE EXT
CALDWELL ST EXT
STINSON ST
E LONGVIEW ST
COTTON ST
CHAPEL ST
BROOKS ST
CHURCH ST
CALDWELL ST
STINSON ST
ISLEY ST
NOBLE ST
MCDADE ST
LINDSAY ST
STEPHENS ST
MARTIN LUTHER KING JR BLVD
PRITCHARD AVE
CARR ST
SHORT ST
N COLUMBIA ST
NORTH ST
COBB TER
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages
N

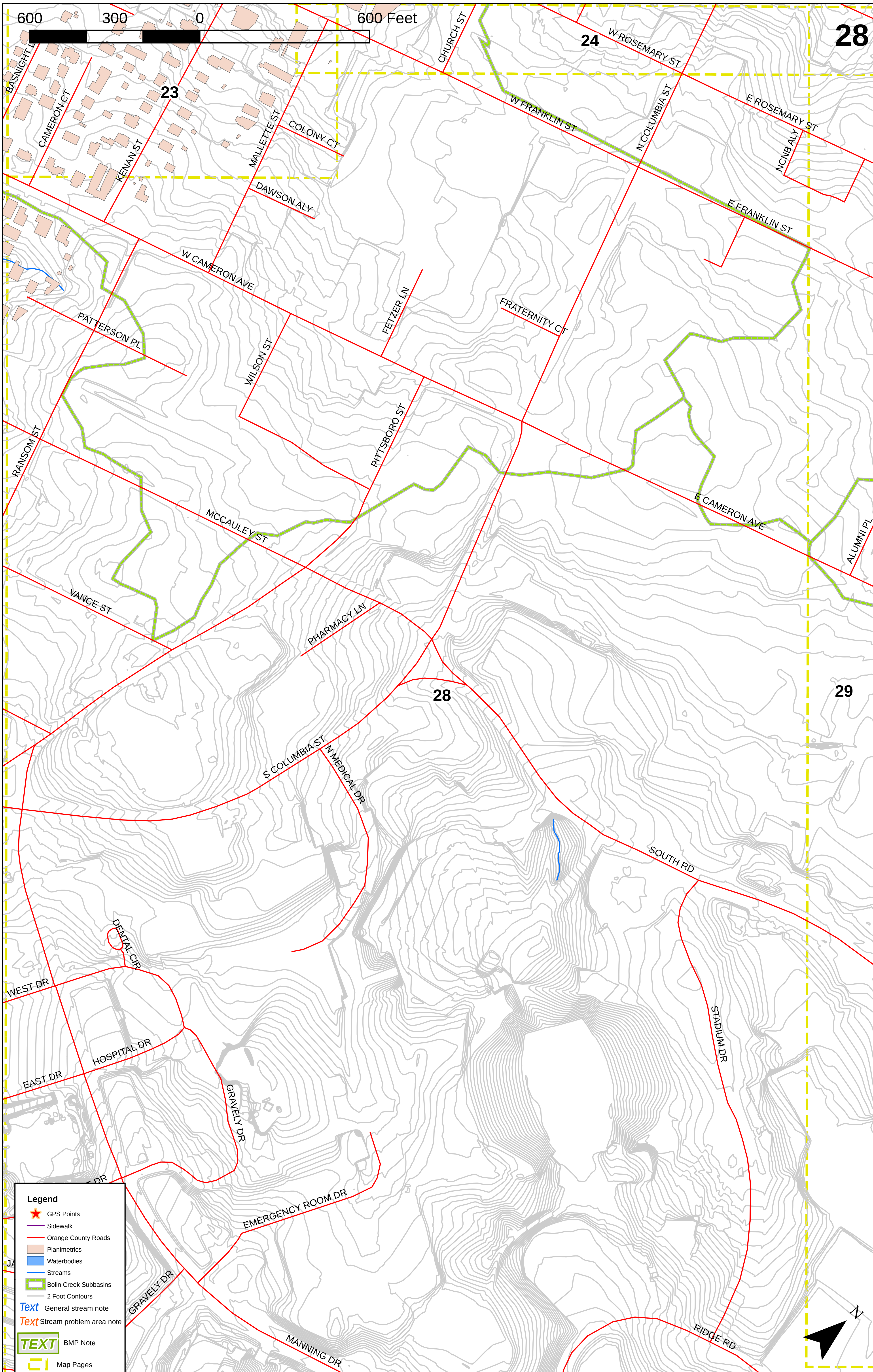


600 300 0 600 Feet
25
21
22
24
26
29
30
BD 50
Stone wall
POSSIBLE BMP
Entrenched and incised
BD 51
Transition to "A" channel- stable
Stable
BD 52
BD 53
BD 54
Mass failure along road
POSSIBLE BMP
Concrete
BOLIN CREEK
Stable
Stable
Forming interior floodplain
Very stable
Apartments
BD 55
BD 57
POSSIBLE BMP
CURRENTLY NO RETENTION HERE
POSSIBLE BMP
OLD SW BASIN NEEDS REPAIR
Pipe outlet from apartments
Discharging directly into stream
Kudzu field
Incised
IJ50
IJ49
IJ48
IJ51
Incised some erosion
POSSIBLE BMP
SIDE CHANNEL DISCHARGE
WETLAND OR BASIN
POSSIBLE BMP
ENERGY DISSIPATION NEEDED
AT CURB-GUTTER OUTLET
Start of incision
IJ40
IJ41
IJ42
IJ43
IJ44
IJ45
IJ53
IJ54
New, large (>60") RCP installed at road crossing
Seems to have reduced SW velocity
Severe gulley erosion caused by buried pipe
Discharging stormwater system along street
Concrete "weir" or dam in stream
Gulley erosion on steep hillside
Large mass wasting
WEINER ST
HARTIG ST
BARCLAY RD
WYRICK ST
JUSTICE ST
BRANCH ST
SEVERIN ST
WESLEY DR
BURRIS PL
READE RD
BRADLEY RD
WILLIAMS CIR
LEA CT
UMSTEAD DR
W COLUMBIA PL
E COLUMBIA PL
SUNRISE LN
GREENE ST
CLARK RD
COLUMBIA PL
N COLUMBIA ST
E LONGVIEW ST
MARTIN LUTHER KING JR BLVD
BOLIN HEIGHTS RD
HILLSBOROUGH ST
BOLINWOOD DR
MILL RACE DR
MILL RUN DR
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages
N

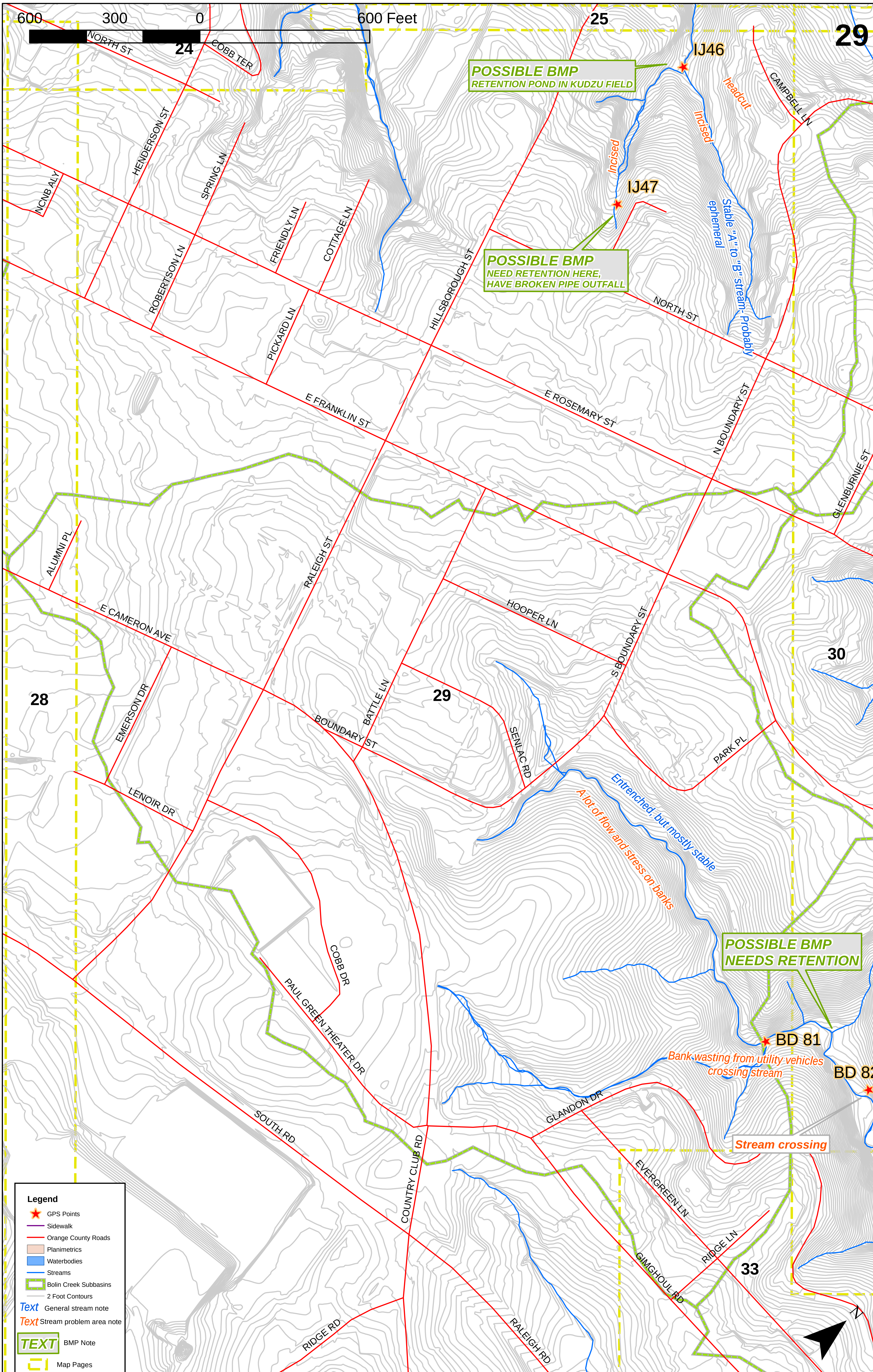


600 300 0 600 Feet
26
22
25
27
30
31
MARTIN LUTHER KING JR BLVD
AIRPORT DR
JUSTICE ST
BARCLAY RD
MAPLE DR
SYCAMORE DR
MT BOLUS RD
MULLIN CT
SONGBIRD LN
CEDAR ST
WOODSHIRE LN
SOMERSET DR
ESTES DR
CASWELL RD
SURRY RD
CHATHAM LN
GRANVILLE RD
BURLAGE CIR
Entrenched incised
POSSIBLE BMP
BD 58
Begining of more severe bank erosion
POSSIBLE BMP
SIDE-CHANNEL
BD 59
Mass wasting
BD 60
POSSIBLE BMP
BD71
POSSIBLE BMP
BD70
BD 69
BD 68
Bedrock ends upstream erosion
Mass wasting banks
BD 61
End of severe instability
is "B" the rest of the way up
BD 67
Incised
BD 62
Severe wasting
Incised
Probably intermittent
BD 62
Incised
BD 66
BD BD 63
Old channel in floodplain
POSSIBLE BMP
BD 64
High wasting banks
BD 65
UTILITY CROSSING CAUSING PROBLEMS
COULD DO SIDE CHANNEL
BMPS ALONG THIS VALLEY
BD 55
BD 57
Pipe outlet for subdivision
Entrenchment and partial
incision
P
ENTION HERE
NEEDS BMP
BD 75
POSSIBLE BMP
SOUTH SIDE OF SEWER LINE
NEEDS RETENTION
Need bank stabilization
BD 77
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages

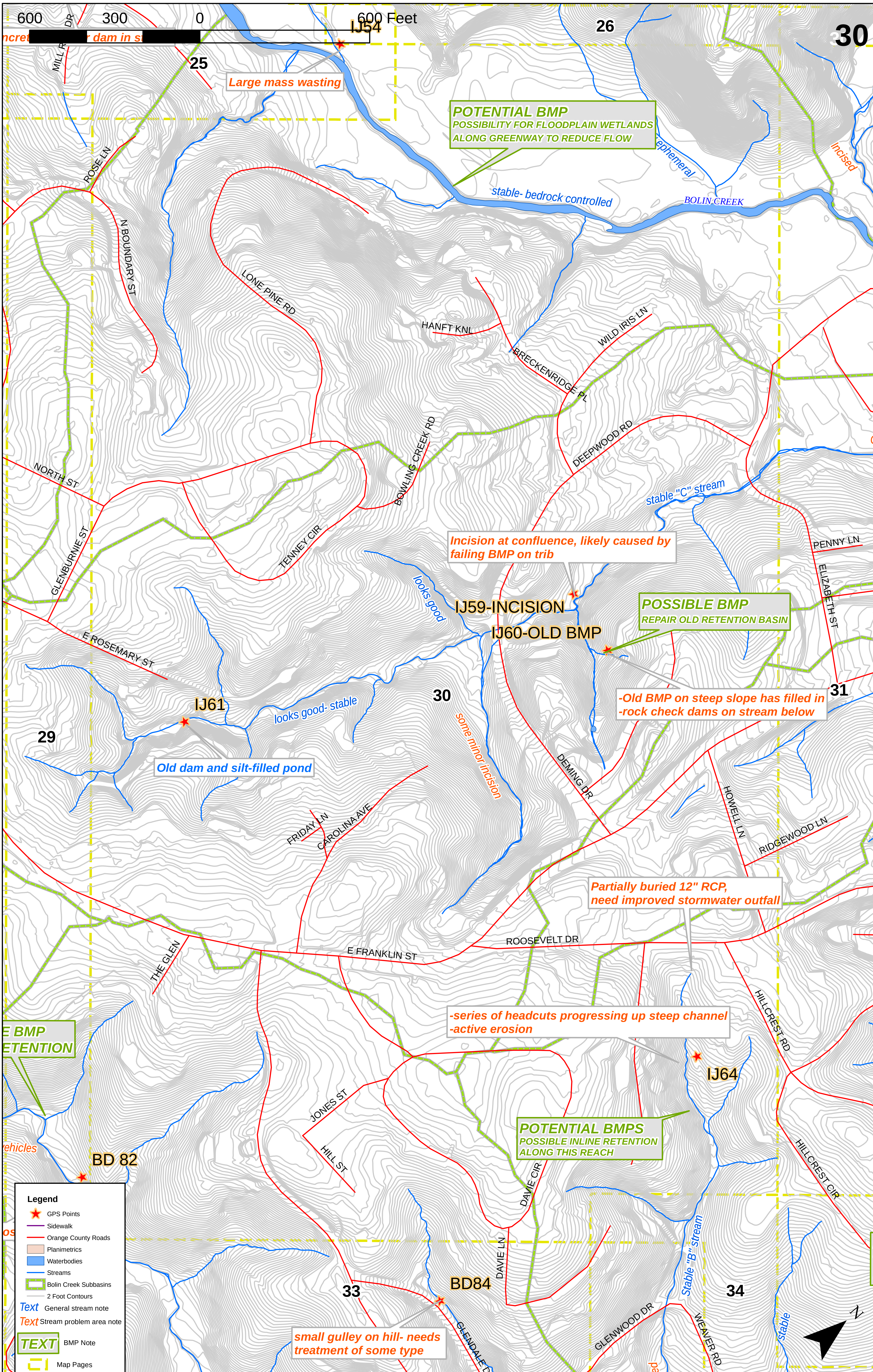

600
300
0
600 Feet
27
WOODSHIRE LN
OLD FOREST CREEK DR
PINEY MOUNTAIN RD
HUNTINGTON DR
SOMERSET DR
PORTER PL
BOOKER CREEK
ROCK CREEK RD
WELLINGTON DR
TOTTEN PL
ESTES DR
CASWELL RD
26
27
KENSINGTON DR
BEECH TREE CT
CONCORDIA CT
CUMBERLAND RD
SURRY RD
EMS
ubdivision
CASWELL RD
CURTIS RD
LYONS RD
ALLARD RD
CHEROKEE CIR
CLAYTON RD
AUDUBON RD
ELLIOTT RD
S BMP
RANVILLE RD
31
32
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages



600
300
0
600 Feet
28
24
23
29
BASNIGHT L
CAMERON CT
KENAN ST
MALLETTE ST
COLONY CT
CHURCH ST
W ROSEMARY ST
E ROSEMARY ST
NCNB ALY
W FRANKLIN ST
N COLUMBIA ST
E FRANKLIN ST
DAWSON ALY
W CAMERON AVE
PATTERSON PL
FETZER LN
FRATERNITY CT
WILSON ST
PITTSBORO ST
RANSOM ST
MCCAULEY ST
E CAMERON AVE
ALUMNI PL
VANCE ST
PHARMACY LN
S COLUMBIA ST
N MEDICAL DR
SOUTH RD
DENTAL CIR
WEST DR
HOSPITAL DR
EAST DR
GRAVELY DR
STADIUM DR
EMERGENCY ROOM DR
MANNING DR
RIDGE RD
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages



600 300 0 600 Feet
29
24
25
28
30
33
IJ46
IJ47
BD 81
BD 82
POSSIBLE BMP
RETENTION POND IN KUDZU FIELD
POSSIBLE BMP
NEED RETENTION HERE, HAVE BROKEN PIPE OUTFALL
POSSIBLE BMP
NEEDS RETENTION
headcut
Incised
Incised
Stable "A" to "B" stream; Probably ephemeral
Entrenched, but mostly stable
A lot of flow and stress on banks
Bank wasting from utility vehicles crossing stream
Stream crossing
NORTH ST
COBB TER
HENDERSON ST
SPRING LN
NCNB ALY
ROBERTSON LN
FRIENDLY LN
COTTAGE LN
PICKARD LN
HILLSBOROUGH ST
CAMPBELL LN
E FRANKLIN ST
E ROSEMARY ST
N BOUNDARY ST
GLENBURNIE ST
ALUMNI PL
RALEIGH ST
HOOPER LN
S BOUNDARY ST
E CAMERON AVE
EMERSON DR
BATTLE LN
BOUNDARY ST
SENLAC RD
PARK PL
LENOIR DR
COBB DR
PAUL GREEN THEATER DR
SOUTH RD
GLANDON DR
COUNTRY CLUB RD
EVERGREEN LN
RIDGE LN
GIMGHOUL RD
RIDGE RD
RALEIGH RD
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages


600 300 0 600 Feet
30
25
26
29
30
31
33
34
IJ54
Large mass wasting
POTENTIAL BMP
POSSIBILITY FOR FLOODPLAIN WETLANDS
ALONG GREENWAY TO REDUCE FLOW
ephemeral
Incised
stable- bedrock controlled
BOLIN CREEK
MILL R
ROSE LN
N BOUNDARY ST
LONE PINE RD
HANFT KNL
BRECKENRIDGE PL
WILD IRIS LN
DEEPWOOD RD
BOWLING CREEK RD
NORTH ST
GLENBURNIE ST
TENNEY CIR
stable "C" stream
PENNY LN
ELIZABETH ST
Incision at confluence, likely caused by
failing BMP on trib
looks good
IJ59-INCISION
IJ60-OLD BMP
POSSIBLE BMP
REPAIR OLD RETENTION BASIN
-Old BMP on steep slope has filled in
-rock check dams on stream below
E ROSEMARY ST
IJ61
looks good- stable
Old dam and silt-filled pond
some minor incision
DEMING DR
HOWELL LN
RIDGEWOOD LN
FRIDAY LN
CAROLINA AVE
Partially buried 12" RCP,
need improved stormwater outfall
THE GLEN
E FRANKLIN ST
ROOSEVELT DR
HILLCREST RD
-series of headcuts progressing up steep channel
-active erosion
IJ64
E BMP
ETENTION
ehicles
BD 82
JONES ST
HILL ST
POTENTIAL BMPS
POSSIBLE INLINE RETENTION
ALONG THIS REACH
DAVIE CIR
HILLCREST CIR
DAVIE LN
BD84
Stable "B" stream
Stable
GLENDALE DR
GLENWOOD DR
WEAVER RD
small gulley on hill- needs
treatment of some type
Legend
GPS Points
Sidewalk
Orange County Roads
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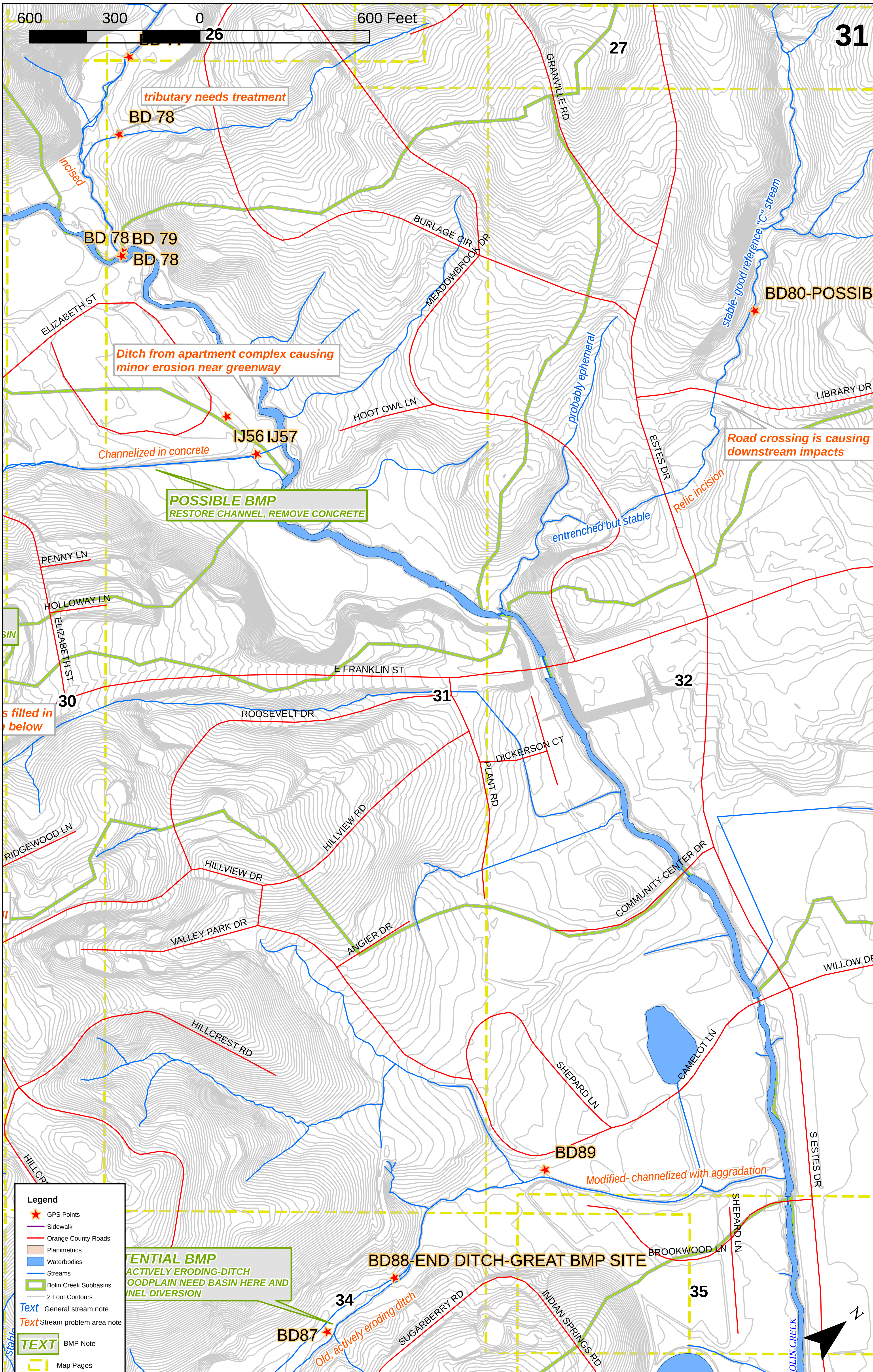
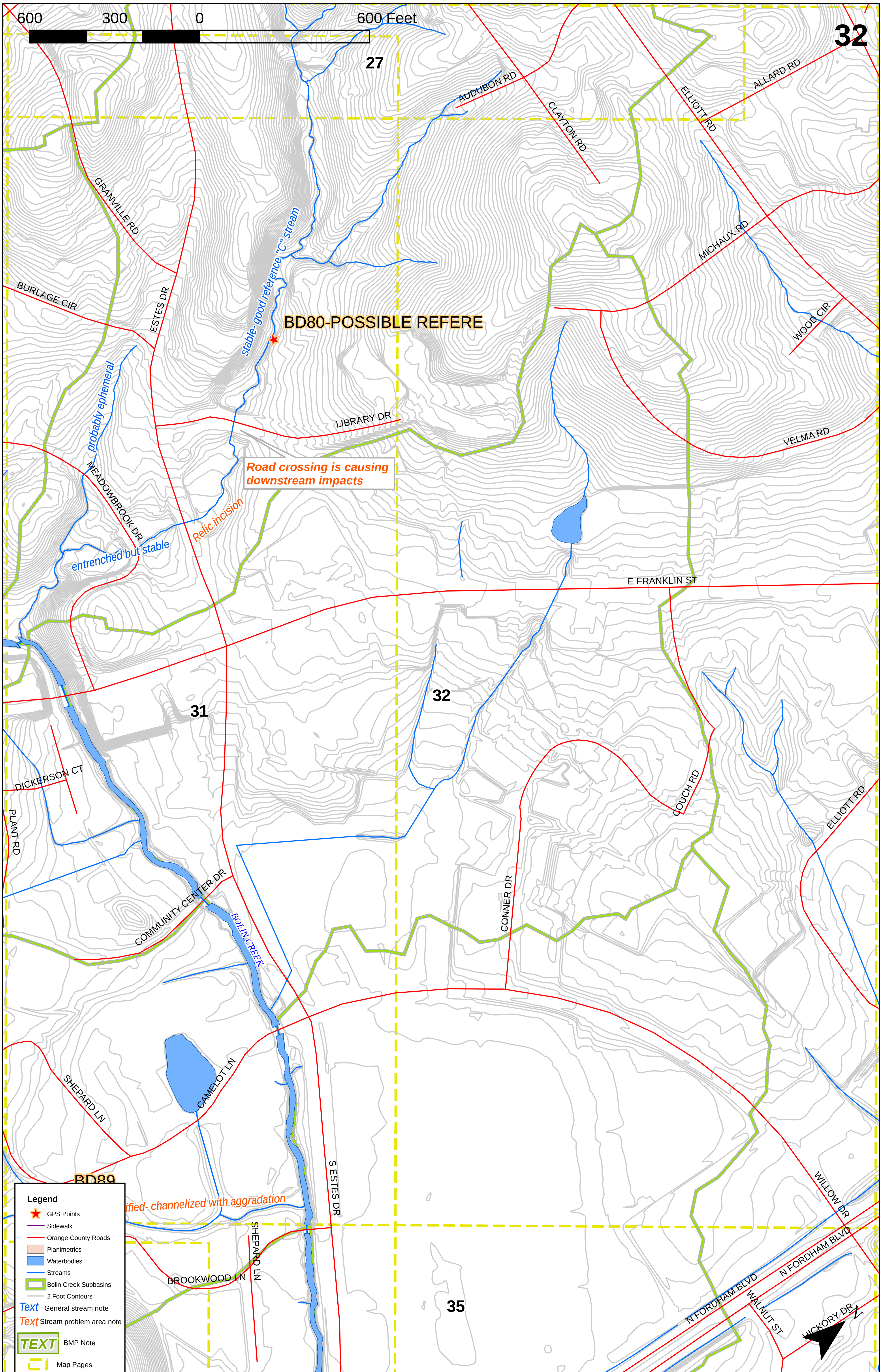
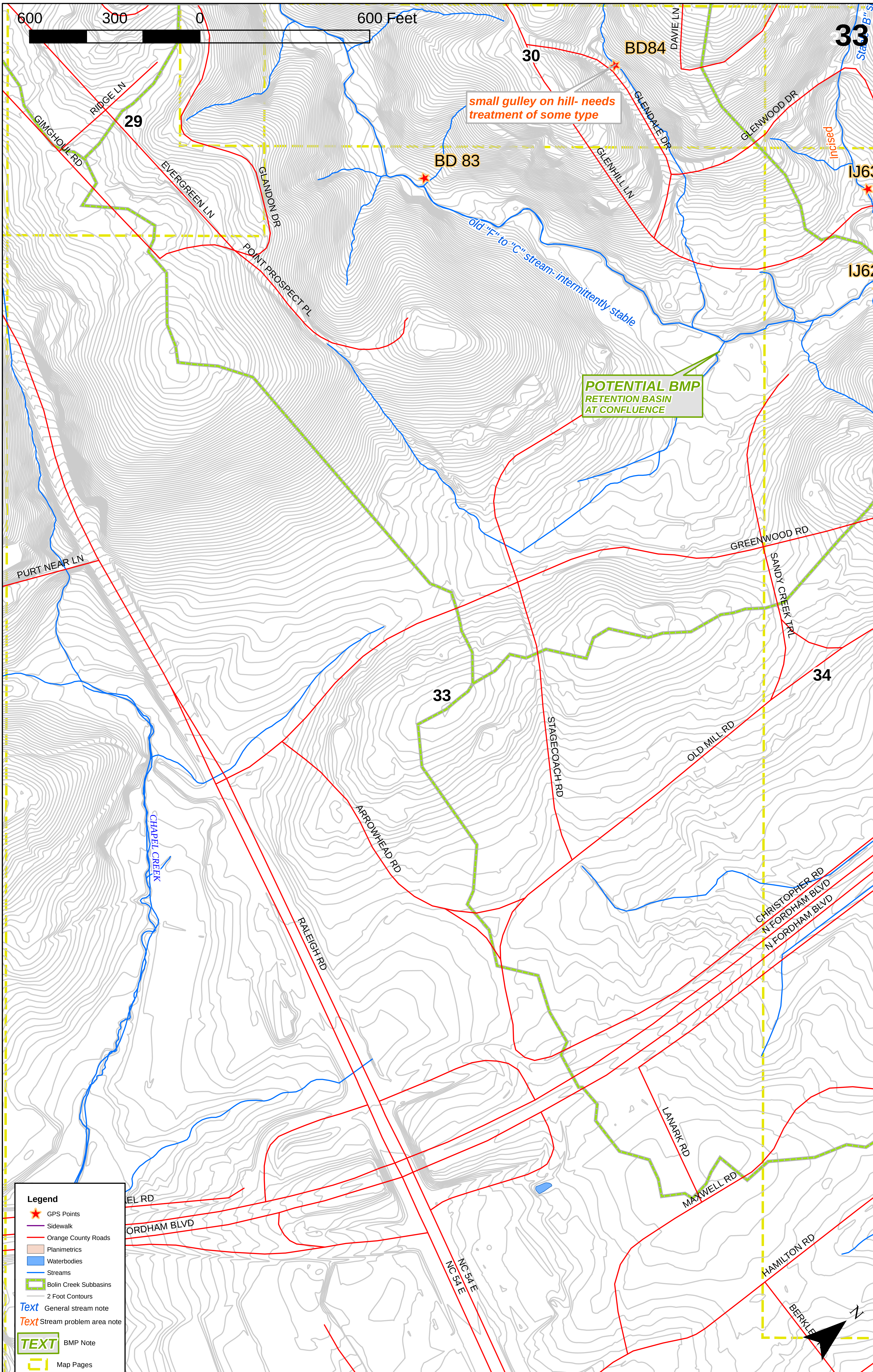
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages
N



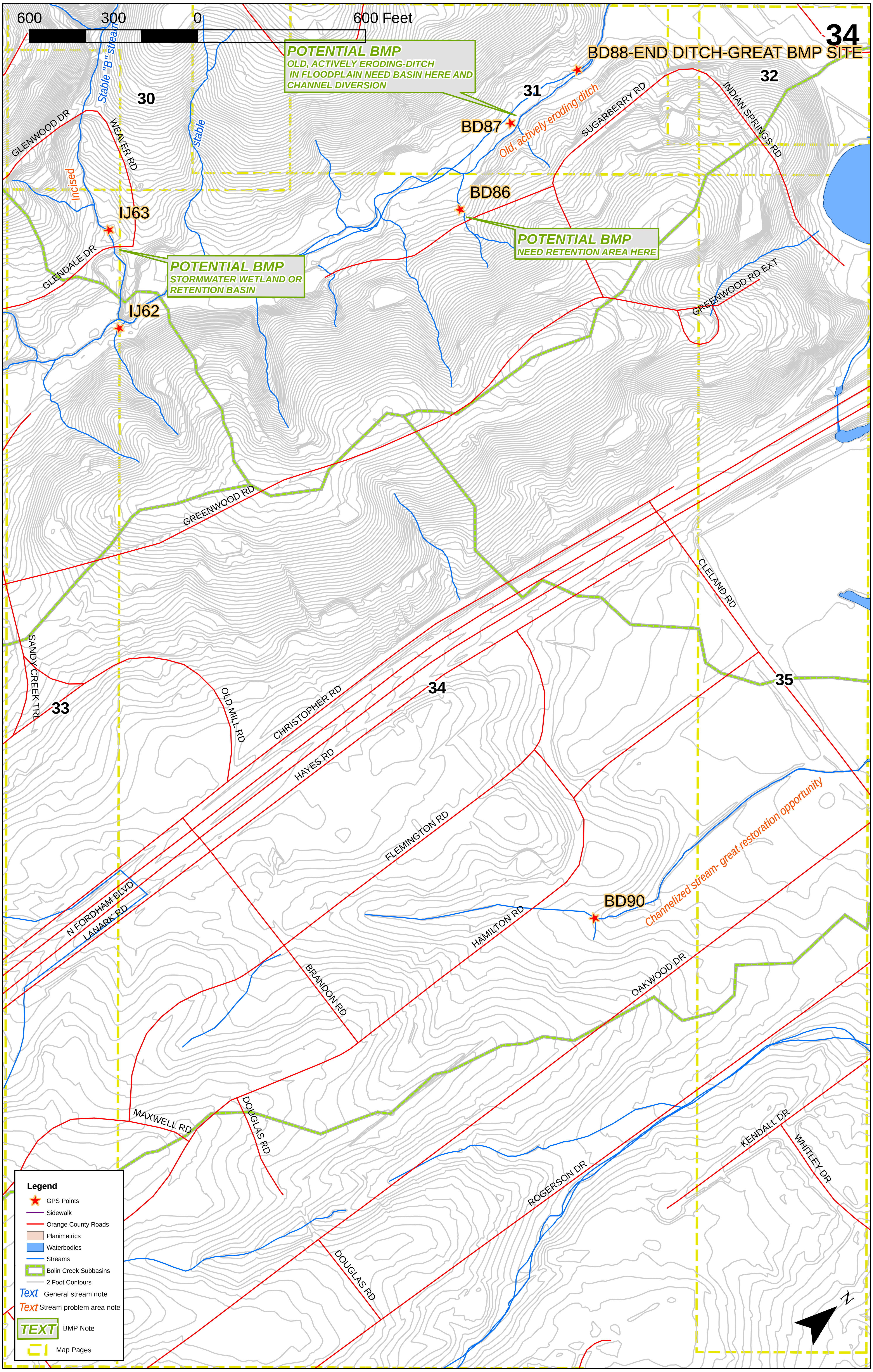
600
300
0
600 Feet
26
27
31
tributary needs treatment
BD 78
Incised
GRANVILLE RD
BD 78
BD 79
BD 78
BURLAGE CIR
MEADOWBROOK DR
BD80-POSSIBL
stable- good reference "C" stream
ELIZABETH ST
Ditch from apartment complex causing
minor erosion near greenway
probably ephemeral
LIBRARY DR
HOOT OWL LN
IJ56
IJ57
ESTES DR
Road crossing is causing
downstream impacts
Channelized in concrete
Relic incision
POSSIBLE BMP
RESTORE CHANNEL, REMOVE CONCRETE
entrenched but stable
PENNY LN
HOLLOWAY LN
ELIZABETH ST
E FRANKLIN ST
32
30
31
ROOSEVELT DR
DICKERSON CT
PLANT RD
HILLVIEW RD
RIDGEWOOD LN
HILLVIEW DR
COMMUNITY CENTER DR
VALLEY PARK DR
ANGIER DR
WILLOW DR
HILLCREST RD
CAMELOT LN
SHEPARD LN
S ESTES DR
BD89
Modified- channelized with aggradation
SHEPARD LN
BROOKWOOD LN
BD88-END DITCH-GREAT BMP SITE
TENTIAL BMP
ACTIVELY ERODING-DITCH
OODPLAIN NEED BASIN HERE AND
NEL DIVERSION
34
35
SUGARBERRY RD
INDIAN SPRINGS RD
BD87
Old, actively eroding ditch
BOLIN CREEK
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages



600 300 0 600 Feet
32
27
AUDUBON RD
CLAYTON RD
ELLIOTT RD
ALLARD RD
GRANVILLE RD
stable- good reference "C" stream
MICHAUX RD
BURLAGE CIR
ESTES DR
BD80-POSSIBLE REFERE
WOOD CIR
probably ephemeral
LIBRARY DR
VELMA RD
MEADOWBROOK DR
Road crossing is causing downstream impacts
Relic incision
entrenched but stable
E FRANKLIN ST
31
32
DICKERSON CT
PLANT RD
COUCH RD
ELLIOTT RD
COMMUNITY CENTER DR
BOLIN CREEK
CONNER DR
SHEPARD LN
CAMELOT LN
BD89
ified- channelized with aggradation
S ESTES DR
SHEPARD LN
BROOKWOOD LN
WILLOW DR
N FORDHAM BLVD
N FORDHAM BLVD
WALNUT ST
HICKORY DR
N
35
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages



600
300
0
600 Feet
33
30
29
34
BD84
BD 83
IJ63
IJ62
small gulley on hill- needs treatment of some type
Incised
old "F" to "C" stream- intermittently stable
POTENTIAL BMP
RETENTION BASIN AT CONFLUENCE
CHAPEL CREEK
DAVIE LN
GLENDALE DR
GLENHILL LN
GLENWOOD DR
RIDGE LN
GIMGHOUL RD
EVERGREEN LN
GLANDON DR
POINT PROSPECT PL
PURT NEAR LN
GREENWOOD RD
SANDY CREEK TRL
STAGECOACH RD
OLD MILL RD
ARROWHEAD RD
RALEIGH RD
CHRISTOPHER RD
N FORDHAM BLVD
N FORDHAM BLVD
LANARK RD
MAXWELL RD
HAMILTON RD
NC 54 E
NC 54 E
ORDHAM BLVD
N
Legend
GPS Points
Sidewalk
Orange County Roads
Planimetrics
Waterbodies
Streams
Bolin Creek Subbasins
2 Foot Contours
Text General stream note
Text Stream problem area note
TEXT BMP Note
Map Pages


600 300 0 600 Feet
34
BD88-END DITCH-GREAT BMP SITE
POTENTIAL BMP
OLD, ACTIVELY ERODING-DITCH
IN FLOODPLAIN NEED BASIN HERE AND
CHANNEL DIVERSION
Old, actively eroding ditch
BD87
BD86
POTENTIAL BMP
NEED RETENTION AREA HERE
IJ63
IJ62
POTENTIAL BMP
STORMWATER WETLAND OR
RETENTION BASIN
Incised
Stable "B" stream
Stable
30
31
32
33
34
35
GLENWOOD DR
WEAVER RD
GLENDALE DR
SUGARBERRY RD
INDIAN SPRINGS RD
GREENWOOD RD EXT
GREENWOOD RD
SANDY CREEK TRL
OLD MILL RD
CHRISTOPHER RD
HAYES RD
CLELAND RD
FLEMINGTON RD
N FORDHAM BLVD
LANARK RD
HAMILTON RD
BD90
Channelized stream- great restoration opportunity
BRANDON RD
OAKWOOD DR
MAXWELL RD
DOUGLAS RD
ROGERSON DR
KENDALL DR
WHITLEY DR
DOUGLAS RD
N
Legend
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Sidewalk
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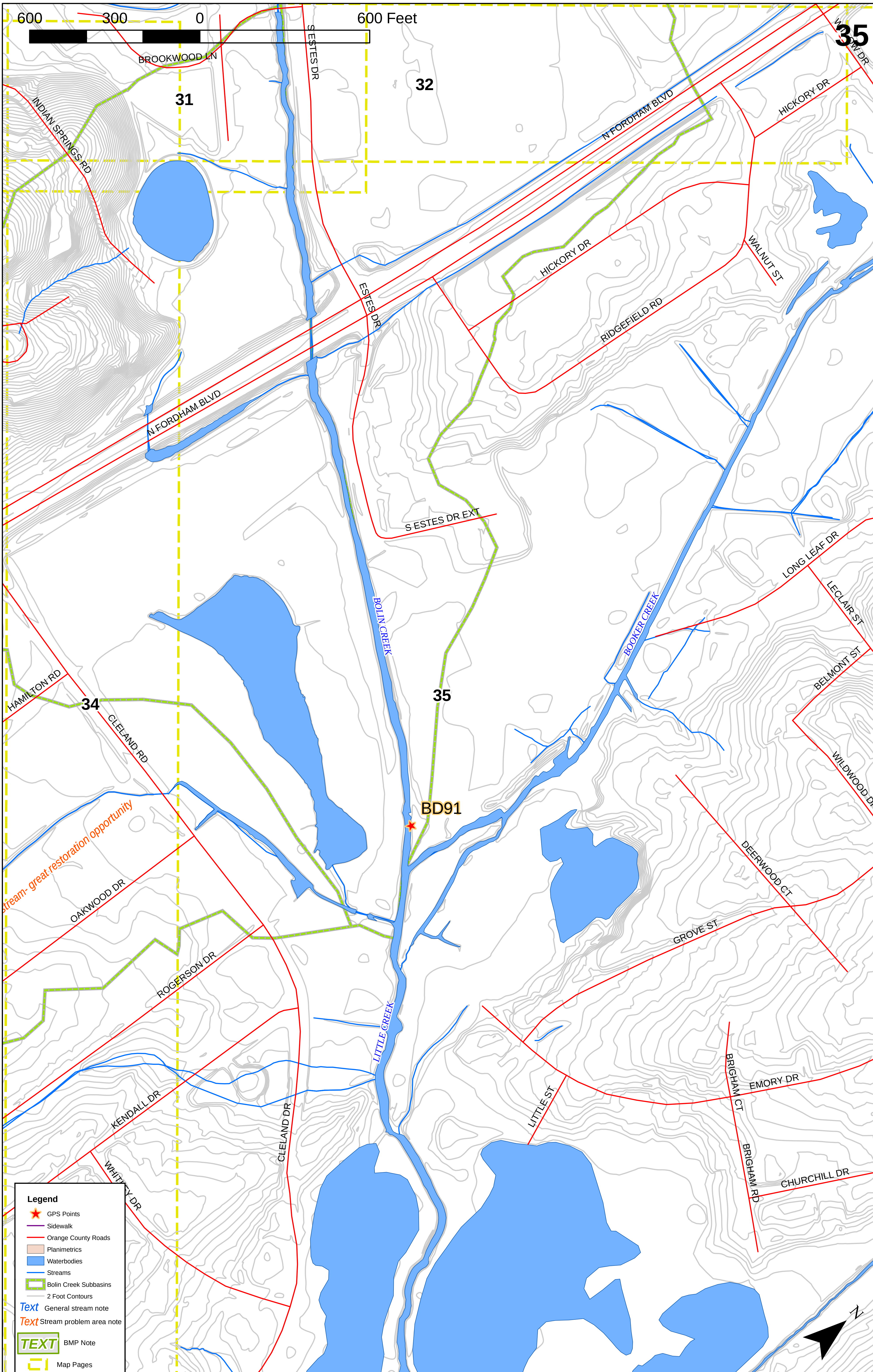

600
300
0
600 Feet
35
BROOKWOOD LN
S ESTES DR
31
32
INDIAN SPRINGS RD
N FORDHAM BLVD
HICKORY DR
WALNUT ST
ESTES DR
HICKORY DR
RIDGEFIELD RD
N FORDHAM BLVD
S ESTES DR EXT
LONG LEAF DR
LECLAIR ST
BOLIN CREEK
BOOKER CREEK
BELMONT ST
HAMILTON RD
34
CLELAND RD
35
WILDWOOD DR
BD91
stream- great restoration opportunity
OAKWOOD DR
DEERWOOD CT
GROVE ST
ROGERSON DR
LITTLE CREEK
EMORY DR
BRIGHAM CT
LITTLE ST
KENDALL DR
CLELAND DR
BRIGHAM RD
CHURCHILL DR
N
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Planimetrics
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Text Stream problem area note
TEXT BMP Note
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