ORNL Parking Structure Mitigation Report
Oak Ridge National Laboratory

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1.0 INTRODUCTION

Approximately 200 feet of an unnamed tributary to Fifth Creek and approximately 0.08 acres of wetland were impacted as a result of the construction of a new parking structure at Oak Ridge National Laboratory (ORNL) that was completed in Fiscal Year 2011. Compensatory mitigation, as per requirements set by the Tennessee Department of Environment and Conservation (TDEC), included the following:

- On-site expansion of an existing wetland (P2) by 0.04 acres adjacent to the new ORNL parking structure.
- On-site enhancement and preservation of approximately 800 feet of First Creek (between White Oak Avenue and West End Circle), 400 feet of White Oak Creek (at Building 4515, the High Temperature Materials Laboratory), and associated riparian zones.

Monitoring of restored or created mitigation sites for five years is a conventional requirement of TDEC's wetland-mitigation Aquatic Resource Alteration Permits (ARAPs) as required by Section 401 of the Clean Water Act (CWA) and is consistent with current science regarding the minimum length of time required for the stabilization of biological communities (Niemi, et al. 1990). The rates of recovery of wetland and stream restorations have been shown to be highly variable on the Oak Ridge Reservation (ORR); by monitoring the site, modifications can be made in a timely manner to best achieve restoration goals. For wetland mitigations, the restoration site must satisfy jurisdictional wetland requirements after five years.

This report summarizes the 2012 results of habitat assessments and vegetation surveys completed at the subject sites, representing the second year of study. The evaluation was based on data collected in the field directly associated with this task, as well as data collected as part of the ORNL Environmental Sciences Division (ESD) Biological Monitoring and Abatement Program (BMAP). BMAP data is a valuable resource in evaluating the success of stream restorations, when available.

2.0 METHODS

2.1 ORNL Parking Structure Wetland (P2)

Vegetation parameters were measured at the ORNL parking structure wetland (P2) in May-June 2012, approximately one year after mitigation. Parameters were measured in a series of ½ meter plots across the site. Percent cover by species was measured for each plot. Information was also taken on any fauna present on the site at the time of the survey.

2.2 First Creek and White Oak Creek

Stream habitat assessments were conducted at both First Creek (July 2012) and White Oak Creek (June 2012) reaches using Habitat Assessment Data Sheets found in the Tennessee Mitigation Guidelines. Metrics evaluated at both sites included epifaunal substrate, embeddedness (amount

of silt, etc, between rocks), velocity/depth regime, sediment deposition, channel flow, frequency of riffles, bank stability, and vegetative cover. These parameters were measured using rapid bioassessment protocols for use in wadeable streams and rivers (Barbour et al. 1999).

Quantitative habitat measurements recorded for both the First Creek site (July 2012) and the White Oak Creek site (June 2012) represent post-mitigation habitat conditions. Pre-mitigation conditions for First Creek are discussed qualitatively from information contained in previous reports (Ryon and Quarles 2008). The assessment of White Oak Creek pre-mitigation habitat conditions are discussed in detail in the ORNL Parking Structure Mitigation Report, Oak Ridge National Laboratory (Giffen, Ryon and Jett 2011).

Riparian zone vegetation surveys were conducted by establishing 10x5 meter plots approximately 10 meters apart (First Creek – east bank, White Oak Creek – north and south banks). A total of 11 plots were established at First Creek and 13 plots were established at White Oak Creek. For each plot the following parameters were measured; trees (≥ 3 inches diameter at breast height) - measured, shrub stems (< 3 inches diameter at breast height) - counted, percent groundcover, percent canopy cover, canopy height, vegetation overhang (cm) for each stream bank.

Fish and benthic community monitoring results were evaluated as an indicator of whether or not the stream sections are functioning as suitable habitat for in-stream organisms.

Benthic macroinvertebrate community data was gathered at First Creek (July 6, 2012) and White Oak Creek (July 6, 2012) using an EPA approved rapid qualitative assessment technique. At each site seven aquatic habitats were identified and sampled for aquatic macroinvertebrates; riffles , leaf packs, woody debris, rocks, root wads, aquatic vegetation, and in-stream sediment deposition. These habitats were located within 100 meters upstream and downstream of the sampling site established along each reach. When habitats were missing from the site they were not sampled. For each habitat a twelve inch rim D-Net with 500 micron nylon netting was used to collect samples. Each sample was sorted immediately at the site using forceps and a white sorting tray for 15 minutes. After 15 minutes of sorting all taxonomic identification was recorded on a data sheet and another habitat was sampled and sorted. After all habitats were sampled and recorded, the total number of families of insects was tallied to determine number of families represented by the orders Ephemeroptera, Plecoptera, and Trichoptera.

BMAP fish survey data used for evaluation of First Creek was from close proximity to the subject reach. The fish community data used for evaluation of the White Oak Creek site was from data taken during routine BMAP surveys within the subject reach. The fish communities within these reaches were monitored using a multiple pass removal estimate method (Ryon 2011). The sample sites were isolated by block-nets, multiple passes were made using backpack or barge electrofishers and all stunned fish were collected. Fish were identified to species, measured for length and weight, and returned to the site. Sample numbers were standardized to sample reach by using the surface area of the site and resulting data were analyzed using a computer program to estimate population densities and biomass. Similar monitoring is conducted at other sites and data are available for comparisons.

3.0 RESULTS

3.1 ORNL Parking Structure Wetland (P2)

This section contains vegetation sampling results and fauna recorded in the P2 wetland after mitigation.

Vegetation cover measurements were taken from ten ½ meter square plots for this wetland in May 2012. Groundcover averaged > 70% across all plots, significantly more than the < 28% average groundcover recorded in 2011 prior to mitigation. The vegetation in the plots consisted mostly of herbaceous wetland species, including softstem bulrush (*Schoenoplectus tabernaemontani*), soft rush (*Juncus effusus*) and Frank's sedge (*Carex frankii*). Small black willows (*Salix nigra)* and cattails (*Typha latifolia*) were noted growing in patches within the wetland.

A variety of fauna was observed on this site during the summer of 2012. During the plant survey in May, Cope's gray treefrog (*Hyla chrysoscelis*) eggs were discovered in a shallow pool in the wetland. Song sparrows (*Melospiza melodia*) were both seen and heard at the site, while barn swallows (*Hirundo rustica*) were noted foraging for insects over the wetland. Pond snails (*Physella sp*.) were found in abundance within the shallow pools at the western end of the wetland, along with a number of water beetles (*Agabetes sp*.) and dragonfly larvae (*Aeshna sp*.). Along the edges of the wetland, a small number of fragile forktails (*Ischnura posita*) were noted, as well as an eastern cottontail (*Sylvilagus floridanus*).

In an evening fauna survey in June, 2012, eastern narrow-mouthed toads (*Gastrophryne carolinensis*) were heard at the site, and several fireflies (Family Lampyridae) were present. A white-tailed deer (*Odocoileus virginianus*) was also recorded near the edge of the wetland.

Overall, a higher diversity of fauna was noted using the wetland in 2012 than in 2011.

Mitigation planting was completed in the wetland in June 2011. A list of species planted in the wetland is contained in Table 1. During an evaluation of known planted species during the 2012 survey, excellent coverage of soft rush was particularly noticeable. Only small patches of wool-grass (*Scirpus cyperinus*) were noted in the wetland. Square-sided spikerush (*Eleocharus quadrangulata*) was not recorded during the 2012 survey. However, chairmaker's bulrush (*Schoenoplectus americanus*) was found to be fairly prevalent in the planting zone. It is not clear if this species is a volunteer or may have come in with the mitigation plantings. In any case, this species is contributing to the excellent overall vegetation coverage on the site. Both cardinal flower (*Lobelia cardinalis*) and southern blueflag iris (*Iris virginica*) were noted growing along the wetland fringe. No dead plants were found during the survey.

Table 1. List of Species Planted at the P2 Wetland, June 2011.

Common Name	Scientific Name	Indicator Status[1]	Number of Plugs
Soft Rush	*Juncus effusus*	FACW	350
Wool-grass	*Scirpus cyperinus*	OBL	450
Square-sided Spikerush	*Eleocharis quadrangulata*	OBL	550
Cardinal flower	*Lobelia cardinalis*	FACW	200
Southern Blueflag Iris	*Iris virginica*	OBL	200
		Total	1750

[1]Obligate Wetland (OBL) = Occur almost always (estimated probability >99%) under natural conditions in wetlands. Facultative Wetland (FACW) = Usually occur in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.

Figure 1 shows photographs comparing the condition of the P2 wetland between 2011 (soon after mitigation) and 2012. The wetland continues to support good vegetation coverage.

Figure 1. Photographs of P2 Wetland in 2011 and 2012.

After Mitigation (September 12, 2011)

Current Appearance (June 12, 2012)

After Mitigation (September 12, 2011)

Current Appearance (June 12, 2012)

3.2 Habitat Assessments - First Creek and White Oak Creek Reaches

The streams were rated using the 10 main categories on the Habitat Assessment Data Sheet, with a grading scale ranging from 0 to 20. An example data sheet is contained in Appendix A. A brief description of the 10 habitat measurements and their significance is provided below (Barbour et al. 1999):

1. Epifaunal Substrate/Available Cover – This is a measurement of the relative quantity and variety of natural structures in the stream, such as cobble (riffles), large rocks, fallen trees, logs and branches, and undercut banks, available as refugia, feeding, or sites for spawning and nursery functions for aquatic macrofauna. A wide variety and/or abundance of submerged structures in the stream provides macroinvertebrates and fish with a large number of niches, thus increasing habitat diversity.

2. Embeddedness – This measurement refers to the extent to which rocks (gravel, cobble and boulders) and snags are covered and sunken into the silt, sand, or mud or the stream bottom. Generally as rocks become embedded the surface area available to macroinvertebrates and fish (shelter, spawning and egg incubation) is decreased. Embeddedness is the result of large-scale sediment movement and deposition, and is a parameter evaluated in the riffles and runs of high gradient streams.

3. Velocity/Depth Regime - Patterns of velocity and depth are included for high-gradient streams under this parameter as an important feature of habitat diversity. The occurrence of the 4 patterns (slow deep, slow-shallow, fast deep and fast-shallow) relates to the stream's ability to provide and maintain a stable aquatic environment.

4. Sediment Deposition - Sediment deposition may result in the formation of islands, bars or shoals, or result in the filling of runs and pools. High levels of sediment deposition is an indication of an unstable and continually changing environment that becomes unsuitable for many organisms.

5. Channel Flow Status - This is an important parameter because when water does not cover much of the streambed, the amount of suitable substrate for aquatic organisms is limited. In high-gradient streams, riffles and cobble substrate are exposed, thereby reducing the areas of good habitat.

6. Channel Alteration – This is a measure of the large scale changes in the shape of the stream channel, and degree of stream alteration as the result of diversion. These changes decrease the amount of natural habitats for fish, macroinvertebrates, and plants below that which would be expected for naturally meandering streams. Scouring is often associated with channel alteration.

7. Frequency of Riffles (or bends) - The frequency of riffles is a measure of heterogeneity in the stream. Riffles are a source of high quality habitat and diverse fauna and, therefore, an increased frequency of occurrence greatly enhances habitat diversity in the stream community. A high degree of sinuosity in a stream provides diverse habitat and fauna, and the stream is better able to handle surges when the stream fluctuates as a result of storm events. The absorption of this

energy by bends protects the stream from excessive erosion and flooding, and provides refugia for benthic invertebrates and fish during such storm events.

8. Bank Stability (conditions of banks) - Signs of erosion typically include crumbling, unvegetated banks, exposed tree roots and exposed soil. Eroded banks indicate a problem of sediment movement and deposition, and suggest a scarcity of cover and organic input to streams.

9. Vegetative Protection (banks) - This parameter provides information on the ability of the bank to resist erosion as well as some additional information on the uptake of nutrients by the plants, the control of stream scouring and stream shading. Banks that have full, natural growth provide better quality fish and macroinvertebrate habitat over those without vegetative protection, or those shored up with concrete or riprap.

10. Riparian Vegetative Zone Width - The riparian vegetative zone serves as a buffer to pollutants entering the stream from runoff, controls erosion and provides habitat and nutrient input into the stream. A relatively undisturbed riparian zone supports a robust stream system. Encroachment of roads and other disturbances can result in degradation of the riparian zone.

The ratings for each of the above parameters were tallied for both streams to come up with an overall score, which was used to determine whether or not they were considered to be impaired. This represents the second year of assessment for the mitigated reach of First Creek and the first year of assessment post-mitigation for the White Oak Creek reach. The 2011 assessment of the White Oak Creek reach was prior to mitigation. Results are summarized below.

3.2.1 First Creek Habitat Assessment

First Creek habitat attributes for 2012 were virtually the same as those recorded in 2011. The 2012 assessment is as follows:

1. Epifaunal Substrate/Available Cover – This reach of First Creek scored in the low optimal range for epifaunal substrate/available cover. It is estimated that approximately 70% of the substrate is favorable for epifaunal colonization and fish cover. This particular reach provides numerous riffles, undercut banks, cobble, larger rocks, falls and overhanging branches. The area is somewhat lacking in presence of logs and snags.

2. Embeddedness – This reach scored in the lower optimal range for embeddedness. This means that gravel, cobble and boulder particles are 0-25% surrounded by fine sediment. Gravel, cobble and boulder particles were <25% surrounded by fine sediment for most of the length of the First Creek reach. The reach contained a variety of rock and cobble sizes with some good layering and crevices for cover.

3. Velocity/Depth Regime - The First Creek reach scored in the mid-optimal range for velocity/depth regime. This means that all 4 velocity/depth regimes (slow deep, slow-shallow, fast deep and fast-shallow) were present.

4. Sediment Deposition - The First Creek reach scored in the mid-optimal range for sediment deposition. This means that there is little or no enlargement of islands or point bars and less than

5% of the bottom is affected by sediment deposition. The reach contained no islands or bars. There was some channeling in areas that contained mats of water-purslane (*Ludwigia palustris*).

5. Channel Flow Status **-** The First Creek reach scored in the mid-optimal range for channel flow. This means that the water reaches the base of both lower banks, and a minimal amount of channel substrate is exposed. Good bank to bank flow was noted in most all locations along the First Creek reach, with no noticeable locations where this wasn't the case.

6. Channel Alteration **–** The First Creek reach scored in the mid-suboptimal range for channel alteration. This means that there is some channelization present. Modification of banks probably occurred with past development in the area (e.g., landscaping, roads).

7. Frequency of Riffles (or bends) **-** The First Creek reach scored in the mid-optimal range for frequency of riffles. This means that the frequency of riffles is relatively frequent. Riffles were very frequent along this reach, with a ratio of distance between riffles divided by stream width measured at approximately 2:1. The reach displayed a variety of habitats with some small falls into pools, larger rocks, and natural rock obstructions.

8. Bank Stability (conditions of banks) **-** The First Creek reach scored in the lower optimal range for bank stability, for both banks. This means that banks are stable where evidence of erosion or bank failure is absent or minimal, with little potential for future problems. This reach showed little to no evidence of erosion or bank failure.

9. Vegetative Protection (banks) **-** The First Creek reach scored in the lower optimal range for vegetative protection along both the left and right banks. The optimal characterization means that more than 90% of the stream bank surfaces are covered by vegetation. The First Creek reach showed vegetation coverage along most of its length, with no real evidence of disruption on either side.

10. Riparian Vegetative Zone Width **-** The First Creek reach scored in the mid marginal and poor ranges for riparian vegetative zone width. The right bank riparian zone scored lower than the left bank. A poor rating is given when width of the riparian zone is less than 6 meters wide due to human disturbance. The right side riparian zone is narrower and contains some native vegetation mixed with some invasives [(e.g., Johnson grass (*Sorghum halepense*)]. Quality riparian zone is very narrow (average = 5.5 meters) on this side and is restricted by large areas of mowed turf, landscaped areas and parking lots. The left bank riparian zone (average = 11.5 meters) fell into the marginal range, which is given when width of the riparian zone is 6-12 meters with evidence of human disturbance. The reach of this riparian zone is restricted in width by the presence of curbing and a paved parking area. The left side represents the mitigated side of the creek riparian zone and contains a mixture of native plants, wood chips and some turf grass areas. Areas closer to the curb had a more groomed landscaped look and areas closer to the creek contained thicker growth, with a number of previously planted and volunteer species. Some invasive plants [e.g., winter creeper (*Euonymus fortunei*)] are also present on the left side of the creek. Riparian zone width values were similar to those found in 2011 (left= 10.9 m, right= 6.5 m). Figure 2 shows both left and right side riparian zones, with comparisons between 2011 and 2012. Additional vegetation growth and coverage was noticeable between 2011 and 2012 for the mitigated east/left side.

Table 2 shows individual ratings for each of the 10 main categories and the overall habitat assessment score for this First Creek reach. The overall rating given to this site places it well within the category of **non-impaired** for the 2012 evaluation, with the same score as that recorded in 2011. Figure 3 shows representative photos of certain habitat attributes along the First Creek reach.

Table 2. Habitat Assessment for First Creek Reach.

PARAMETERS	**07/16/2012**
Epifaunal Substrate/Available Cover	16
Embeddedness	17
Velocity/depth regime	18
Sediment deposition	18
Channel flow status	18
Channel alteration	13
Frequency of Riffles	18
Bank Stability – Left	9
Bank Stability – Right	9
Vegetative Protection – Left	9
Vegetative Protection – Right	9
Riparian Vegetative Zone Width – Left	5
Riparian Vegetative Zone Width – Right	2
Score (Goal ≥ 131)	**161**
Narrative Rating	**Non-Impaired**

Figure 2. First Creek Riparian Zones.

Left/East Site (2011)

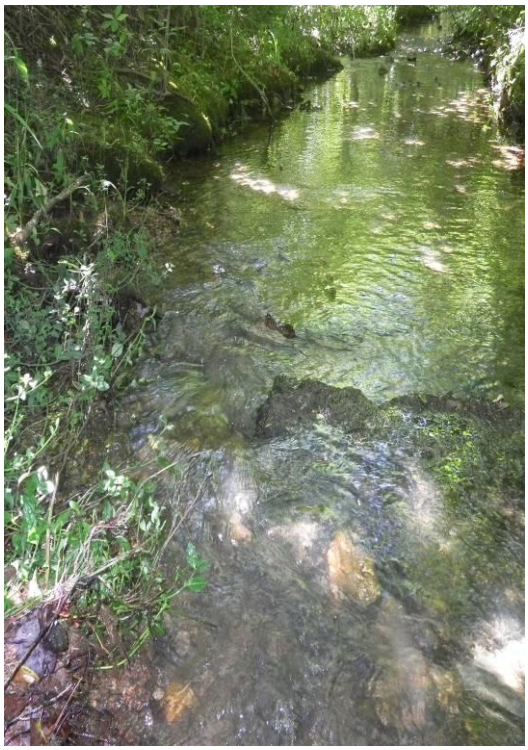
Left/East Side (2012)

Right/West Site (2011)

Right/West Side (2012)

Figure 3. Select Habitat Attributes of the First Creek Reach in 2012.

Epifaunal Substrate (favorable)



Velocity/Depth Regime (fast-deep)

Frequency of Riffles (very frequent)

Embeddedness (low sediment)

3.2.2 White Oak Creek Habitat Assessment

White Oak Creek habitat attributes for 2012 were virtually the same as those recorded in 2011, with the exception of noticeable improvements in the riparian vegetative zone width and quality. The 2012 assessment is as follows:

1. Epifaunal Substrate/Available Cover – This reach of White Oak Creek scored in the mid-suboptimal range for epifaunal substrate/available cover. It is estimated that approximately 55% of the substrate is favorable for epifaunal colonization and fish cover. This particular reach provides numerous riffles, some undercut banks, cobble, larger rocks (numerous), and overhanging branches. The area is lacking in presence of logs and snags.

2. Embeddedness – This reach scored in the mid-optimal range for embeddedness. This means that gravel, cobble and boulder particles are 0-25% surrounded by fine sediment. Gravel, cobble and boulder particles were approximately 15% surrounded by fine sediment for most of the length of the White Oak Creek reach.

3. Velocity/Depth Regime - The White Oak Creek reach scored in the high suboptimal range for velocity/depth regime. This means that 3 of the 4 velocity/depth regimes (slow deep, slow-shallow and fast-shallow) were present. The fast-deep velocity/depth regime was missing in this reach.

4. Sediment Deposition - The White Oak Creek reach scored in the lower optimal range for sediment deposition. This means that there is little or no enlargement of islands or point bars and less than 5% of the bottom is affected by sediment deposition. The reach contained sediment in certain areas, but it was very minimal.

5. Channel Flow Status - The White Oak Creek reach scored in the mid-optimal range for channel flow. This means that the water reaches the base of both lower banks, and a minimal amount of channel substrate is exposed. Good bank to bank flow was noted in most all locations along the White Oak Creek reach, with no noticeable locations where this wasn't the case.

6. Channel Alteration – The White Oak Creek reach scored in the high suboptimal range for channel alteration. This means that there is some channelization present. The White Oak Creek reach showed some channelization at bridge abutments where rip-rap was applied. Modification of banks probably occurred with development in the area (e.g., buildings, landscaping, roads).

7. Frequency of Riffles (or bends) - The White Oak Creek reach scored in the lower optimal range for frequency of riffles. This means that the frequency of riffles is relatively frequent. Riffles were frequent along this reach, with a ratio of distance between riffles divided by stream width measured at approximately 6:1.

8. Bank Stability (conditions of banks) - The White Oak Creek reach scored in the lower optimal range for bank stability, for both banks. This means that banks are stable where evidence of erosion or bank failure is absent or minimal, with little potential for future problems. This reach showed little to no evidence of erosion or bank failure.

9. Vegetative Protection (banks) - The White Oak Creek reach scored in the mid-suboptimal range for vegetative protection along both banks. The suboptimal characterization means that approximately 80% of the stream bank surfaces are covered by vegetation. The White Oak Creek reach showed vegetation coverage along its banks. Habitat quality had been compromised by the invasion of winter creeper, crown-vetch (*Coronilla varia*) and other invasive plants [e.g. Japanese honeysuckle (*Lonicera japonica*) and Johnson grass] prior to mitigation in 2011. The 2012 survey revealed significantly fewer invasive plants, largely attributed to the mitigation efforts undertaken in August 2011. There continues to be good tree and shrub growth, with green ash (*Fraxinus pennsylvanica*) and black willow present in several areas.

10. Riparian Vegetative Zone Width - The White Oak Creek reach scored in the mid marginal range for riparian vegetative zone width. A marginal rating is given when width of the riparian zone is 6-12 meters with evidence of human disturbance. Riparian zone widths were measured from creek banks to mowed areas. The left bank riparian zone averaged 9.3 meters in width and the right bank riparian zone averaged 10.3 meters in width along this reach, excluding managed turf zones. The zone width had drastically increased from what existed in 2011, where the left zone was 2.8 m and the right was 3.5 m. Riparian zones along this reach are no longer interrupted by extensive mowed areas, and the prevalence of invasive plants was significantly diminished with the mitigation planting efforts of August 2011. The left bank riparian zone is bordered by the High Temperature Materials Laboratory (Building 4515), while the right bank riparian zone is bordered by mowed turf grasses and Southside Avenue. Total potential riparian zone width is restricted by the presence of the building on the left side and by the road on the right side. Riparian zones are also interrupted by bridges (middle, east and west ends). Rip-rap zones at each bridge also interrupt riparian zones along the reach. The best quality riparian areas along this reach existed at creek-side where green ash and black willow shrubs and trees were present. Figure 4 shows both left and right side riparian zones, with comparisons between 2011 (pre-mitigation) and 2012.

Table 3 shows individual ratings for each of the 10 main categories and the overall habitat assessment score for this White Oak Creek reach. The rating given to this site places it well within the category of **non-impaired** for the 2012 evaluation, as it was rated in 2011. However, the overall score in 2012 (154) was higher than in 2011 (147). Figure 5 provides photographs of select habitat attributes at this reach for 2012.

Figure 4. White Oak Creek Riparian Zones (2011 [pre-mitigation] and 2012).

Left/South Side (pre-mitigation - 2011)

Left/South Side (post-mitigation - 2012)

Right/North Side (pre-mitigation - 2011)

Right/North Side (post-mitigation – 2012)

Table 3. Habitat Assessment for White Oak Creek Reach.

PARAMETERS	**06/13/2012**
Epifaunal Substrate/Available Cover	13
Embeddedness	18
Velocity/depth regime	15
Sediment deposition	17
Channel flow status	18
Channel alteration	15
Frequency of Riffles	17
Bank Stability – Left	9
Bank Stability – Right	9
Vegetative Protection – Left	7
Vegetative Protection – Right	7
Riparian Vegetative Zone Width – Left	5
Riparian Vegetative Zone Width – Right	4
Score (Goal ≥ 131)	**154**
Narrative Rating	**Non-Impaired**

Figure 5. Select Habitat Attributes of the White Oak Creek Reach in 2012.

Embeddedness
(rocks free from sediment)

Channel Flow Status
(bank to bank flow)

Frequency of Riffles
(relatively frequent)

Bank Stability (stable condition)

The total habitat score for the First Creek reach (161) compares favorably with habitat assessments conducted in other areas of the White Oak Creek watershed. The total score for the White Oak Creek reach (154) is lower than certain habitat assessments conducted in other areas of the White Oak Creek watershed, but is still in the middle range of scores found (Table 4).

Table 4. Habitat Assessment Results for BMAP Sampling Sites in White Oak Creek Watershed, 2012.

Habitat parameter	Sampling site/habitat score					
	FCK 0.1	**FFK 0.2**	**MEK 0.6**	**WCK 2.3**	**WCK 3.9**	**WCK 6.8**
1. Epifaunal substrate/available cover	13	13	18	15	11	20
2. Embeddedness	11	9	13	15	10	18
3. Velocity/depth regime	17	20	18	20	20	20
4. Sediment deposition	11	17	16	10	17	16
5. Channel flow	18	20	19	20	19	20
6. Channel alteration	15	15	18	20	15	20
7. Frequency of riffles	11	17	10	15	11	20
8. Bank stability						
Left	5	8	9	7	5	7
Right	5	8	7	7	2	6
9. Vegetative protection						
Left	7	6	9	8	9	5
Right	7	6	6	8	7	6
10. Riparian vegetative zone width						
Left	5	3	10	10	4	1
Right	3	2	7	10	1	10
Total score	**128**	**144**	**150**	**165**	**131**	**169**
Ecoregion 67f habitat goal (≥131)	**Fail**	**Pass**	**Pass**	**Pass**	**Fail**	**Pass**

FCK = First Creek kilometer; FFK = Fifth Creek kilometer (reference site); MEK = Melton Branch kilometer; WCK = White Oak Creek kilometer.

3.3 Riparian Zone Vegetation Survey Results

3.3.1 First Creek

Initial vegetation evaluations were conducted at the First Creek site in 2008 to gain a baseline for planned mitigation on the site. The existing riparian vegetation at that time was a mix of native trees and shrubs, with a strong component of invasive species such as Chinese privet (*Ligustrum sinensis*), thorny olive (*Elaeagnus pungens*), tree-of-heaven (*Ailanthus altissima*), Bradford pear (*Pyrus calleryana*), Japanese honeysuckle, and typical landscape species including crab apple (*Malus sp.*) and fescue (*Festuca sp.*). The northern 50 meters of riparian zone was planted with a mix of riparian trees and shrubs (Table 5), as part of the stream remediation in 1996. A large percentage of the original planted vegetation remained and had been supplemented by extensive expansion, creating a dense thicket of smaller trees and shrubs in certain areas. Existing trees and shrubs extended no more than 8 m on each side of the stream and the remainder of the buffer was a fescue-based turf grass.

Table 5. Trees and Shrubs Planted in Study Section of First Creek as Part of a Wetland Remediation in 1996.

Species	Number Planted	Still Present	Percent remaining
Silky dogwood	20	18	90
Gray dogwood	17	13	76
Spicebush	14	12	86
Winterberry holly	14	10	71
Buttonbush	7	5	71
Hazelnut	4	4	100
Flowering dogwood	6	4	66
American holly	4	1	25
Sugar maple	3	3	100
Black walnut	1	1	100
Mockernut hickory	1	1	100
Total	91	72	79

In 2008 plans were established for the mitigation of the eastern First Creek riparian buffer. An environmental landscape plan was developed that included native trees, shrubs and herbaceous species (Appendix B). Planting was completed in September 2009.

A riparian zone vegetation survey was conducted in June, 2012, to document the survivorship/success rate of the planted species. Eleven 10x5 meter plots were established on the east side of the creek where mitigation measures were taken. Plot locations were those established during the June 2011 survey. This included both plots directly adjacent to the creek and plots further upslope in the riparian zone. A total of 58 plant species were recorded on the site in 2012 (Appendix C – Table C1), an increase from the 51 plant species recorded in 2011. Of these 58 species, 14 species were originally part of the mitigation planting plan.

Overall, there was good survivorship of planted species. However, there were some areas that contained dead plant growth. Dead plant growth within survey plots included a few silky dogwoods (*Cornus amomum*), one spicebush (*Lindera benzoin*), and one gro-low sumac (*Rhus aromatica*). A brief survey was conducted along the entire eastern edge of First Creek to record any dead plants, the results of which are listed in Table 6. Although there is still good vegetation coverage in the riparian zone, there are plans to replace some of the dead plants to further improve coverage.

Table 6. Dead and Dying Plants Recorded in Riparian Zone Along First Creek Reach in July, 2012.

Species	Number of Individuals
Black-eyed Susan	18
Golden St. John's wort	1
Gro-low sumac	14
Little bluestem	4
Prairie coneflower	4
Prairie dropseed	4
Purple coneflower	5
River oats	6
Scaly blazing star	1
Total	57

Planted groundcover species thriving (>25% cover) on the site included gro-low sumac, and river oats (*Chasmanthium latifolium*). There were also areas where invasive winter creeper was prevalent. Dense growths of previously planted silky dogwood continued to flourish at the site (almost 152 stems counted in 11 plots), along with winterberry (*Ilex verticillata*). Black willow trees and shrubs were also prevalent along the creek in certain areas.

Groundcover at this site averaged approximately 45% across all plots. The relatively low percent groundcover is attributable to several things. Groundcover is shaded out by thick shrub growth in certain areas adjacent to the creek. In addition, there are relatively large areas of wood chips that were incorporated into the planting plan in some areas of the upper riparian zone. Rock incorporated into the rain gardens along the reach also accounted for lower vegetative groundcover in certain survey plots.

Canopy cover at the site averaged over 56% across all plots. However, this varied based on location of the survey plot. Canopy cover generally averaged about 76% adjacent to the creek where thick growths of trees and shrubs were common (N=6 plots). Areas further upslope from the stream banks generally averaged less than 22% canopy cover, where newly planted areas were dominated by smaller saplings and shrubs, and herbaceous species (N=5 plots).

Invasive plants were not found to be a major concern at the overall site, averaging less than 9% of the cover across the eleven plots. Invasive species recorded on the site included winter creeper, Nepal grass (*Microstegium vimineum*), crown vetch (*Securigera varia*), and Japanese honeysuckle. Winter creeper was by far the most common invasive species recorded at the site,

accounting for almost 57% (by cover) of invasive species records. This species could become a concern in the future. Ten thorny olive shrubs were also recorded on the site, an increase from the one shrub found in 2011.

Figure 6 provides a photographic comparison of site condition changes between 2008 and 2012.

Figure 6. First Creek Reach in 2011 and 2012.

Before Mitigation (2008)

After Mitigation (2011)

Current Appearance (2012)

Before Mitigation (2008)

After Mitigation (2011)

Current Appearance (2012)

3.3.2 White Oak Creek

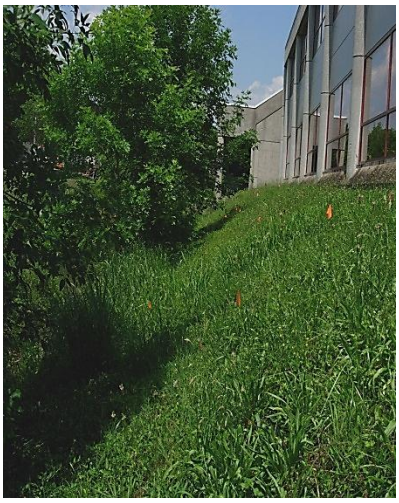
Mitigation planting was completed at this site in August 2011. A riparian zone vegetation survey was conducted in June, 2012. Thirteen 10x5 meter plots were established on alternating sides of the creek from a baseline plant assessment conducted in May-June, 2011, prior to mitigation. The survey range included both plots directly adjacent to the creek and plots further upslope, including areas adjacent to the road to the north and the building to the south of the creek. A total of 65 plant species were recorded on the site in 2012 (Appendix C – Table C2), a significant increase from the 34 species recorded on site before mitigation efforts in 2011. Green ash and black willow trees were prevalent in the lower riparian zone near the creek. Also prevalent in the lower riparian zone were green ash, eastern redbud (*Cercis canadensis*), black willow, and silky dogwood shrubs.

Groundcover at this site averaged almost 52% across all plots (N=13 plots). Percent groundcover was somewhat higher in plots adjacent to the creek (60.1%, N=7 plots), then in plots in the upper riparian zone (42.5%, N=6). Invasive plants were mostly found in the groundcover in the lower portion of the riparian zone adjacent to the creek, including winter creeper, Johnson grass and Nepal grass. However, invasive species accounted for an average of only 5% of the groundcover in this area (N=7 plots), a significant reduction from the 36% they made up along the creek prior to mitigation efforts. This decrease is likely due to mitigation planting efforts that involved removal of invasives and replacement with native plants. About 14% of the cover in the upper slope still consists of mowed turf grasses (N=6 plots), a reduction from the 50% that was present prior to mitigation. Wood chips constituted a relatively high percentage of the upslope sample plots (40%, N=6 plots). The wood chips and remaining turf grass areas on the site are those that were incorporated into the overall landscaping/mitigation plan along with the native plantings. Appendix D contains the mitigation planting scheme for the White Oak Creek reach. Only a limited number of dead plantings (N=8) were noted across the thirteen total survey plots. Although plant cover is very good along the reach, there are still plans to replace dead plantings to assure that good coverage is maintained.

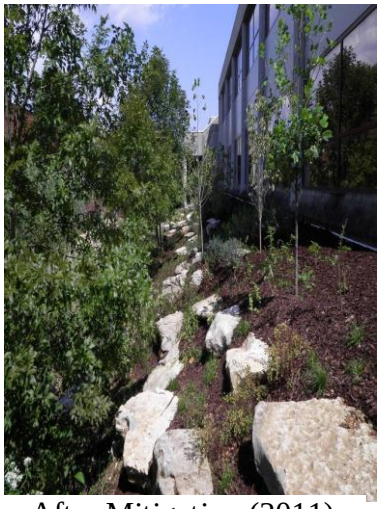
Canopy cover at the site averaged almost 57% across all plots. However, there was little canopy cover in the upper slope plots (21%, N=6 plots) where low herbaceous growth was dominant. Canopy cover averaged 87% in the lower riparian zone (N=7 plots) where shrubs and trees were present. The canopy species in this area were almost exclusively green ash and black willow in 2011, but now include a diverse mix of green ash, black willow, American sycamore (*Platanus occidentalis*), and other trees.

Figure 7 provides a photographic comparison of site condition changes between 2011 and 2012.

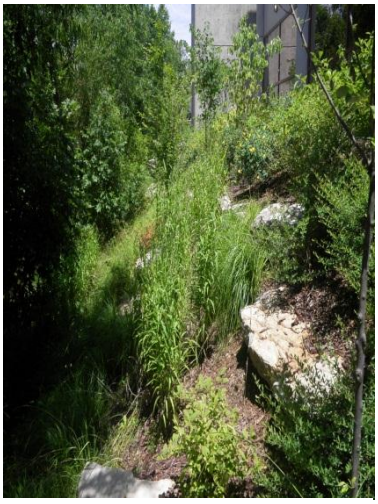
Figure 7. White Oak Creek Reach in 2011 and 2012.



Before Mitigation (2011)



After Mitigation (2011)



Current Appearance (2012)

Before Mitigation (2011)

After Mitigation (2011)

Current Appearance (2012)

3.4 Benthic Macroinvertebrate Communities

3.4.1 First Creek

A moderately diverse benthic macroinvertebrate population was recorded in this reach of First Creek in 2012, although somewhat lower than certain reference sites. This included some less tolerant taxa typically found in clear streams. In the U.S. Environmental Protection Agency's protocols for benthic macroinvertebrate sampling, a number of factors can be assessed to determine the health of a waterway. One such factor is the presence of Emphemeroptera/ Plecoptera/ Trichoptera (EPT) taxa. As the number of EPT macroinvertebrate taxa is expected to be lower in areas with greater perturbation occurring, the number of EPT taxa can help gauge the health of a site. A total of seven different families of EPT invertebrates were found in the First Creek Reach site, a slight increase over the six families of EPT invertebrates recorded in 2011. Four different types of more tolerant taxa were also found. Table 7 contains a comparison of 2011 and 2012 results. Habitats sampled included riffles, rocks, root wads and vegetation.

Table 7. Results of Benthic Community Sampling at the First Creek Reach, July 6, 2012.

	2011 (pre-mitigation)		2012 (post-mitigation)	
Taxa	**No. of Taxa**	**Density[1]**	**No. of Taxa**	**Density[1]**
EPHEMEROPTERA				
Baetidae			1	R
Heptageniidae	1	C	2	R
PLECOPTERA				
Leuctridae	1	C	1	R
Peltoperlidae	1	R	1	R
TRICHOPTERA				
Hydropsychidae	2	R	2	C
Leptoceridae	1	R	1	R
Limnephilidae	1	C	1	R
DIPTERA				
Ceratopogonidae			1	R
Culicidae			1	R
Tipulidae			1	R
ODONATA (Anisoptera)				
Aeshnidae	1	R		
ODONATA (Zygoptera)				
Coenagionidae	1	R		
COLEOPTERA				
Dryopidae			1	R
Elmidae	1	C	1	C

	2011 (pre-mitigation)		2012 (post-mitigation)	
Taxa	**No. of Taxa**	**Density[1]**	**No. of Taxa**	**Density[1]**
COLEOPTERA (cont'd)				
Psephenidae	1	C	1	C
HEMIPTERA				
Nephidae	1	R		
Gerridae	1	C	1	R
Notonectidae	1	R		
Veliidae	1	C		
TOLERANT TAXA				
OLIGOCHAETA	2	C	1	R
AMPHIPODA	1	R	1	A
ISOPODA	1	A		
CHIRONOMIDAE	1	R	1	R
SIMULIIDAE	1	C	1	R
PLANARIIDAE	1	R		
DECAPODA	1	R	1	C
GASTROPODA				
Pleuroceridae	2	A	3	A
HYDRACARINA	1	C	1	R

[1]R=RARE (<10), C=COMMON (10-100), A=ABUNDANT (>100)

When compared to the invertebrate survey taken in 2011, there was a slight decrease in the number of taxa recorded (2011=26, 2012=25). The density of taxa seen also decreased, with the majority of taxa falling into the rare category in 2012, whereas the majority of taxa were either common or abundant in 2011. However, such fluctuation is considered normal in annual surveys. The discrepancy in numbers does not necessarily stem from increased perturbation at the site, as a number of more sensitive species were found in the creek. The survey could have been affected by other factors, such as varying weather conditions.

3.4.2 White Oak Creek

A moderately diverse benthic macroinvertebrate population was recorded in this reach of White Oak Creek. This included four more tolerant taxa commonly found in ORR streams, as well as six different families of EPT macroinvertebrates. Table 8 contains a comparison of 2011 and 2012 results. Habitats sampled included riffles, wood, rocks and root wads.

Table 8. Results of Benthic Community Sampling at the White Oak Creek Reach, July 6, 2012.

	2011 (pre-mitigation)		2012 (post-mitigation)	
Taxa	**No. of Taxa**	**Density[1]**	**No. of Taxa**	**Density[1]**
EPHEMEROPTERA				
Baetidae	2	C	1	R
Heptageniidae	1	R	2	C
PLECOPTERA				
Leuctridae	1	R		
TRICHOPTERA				
Hydropsychidae	2	R	1	C
Hydroptilidae	1	C	1	C
Limnephilidae			1	R
Uenoidae	1	C	1	C
DIPTERA				
Ceratopogonidae			1	R
Culicidae			1	R
ODONATA (Anisoptera)				
Aeshnidae			1	R
Gomphidae	1	R	1	C
ODONATA (Zygoptera)				
Coenagrionidae	2	C	1	R
COLEOPTERA				
Dryopidae			1	R
Dytiscidae	1	R	1	R
Elmidae	1	C		
Psephenidae	1	C		
HEMIPTERA				
Gerridae	1	R	1	R
Veliidae	1	R	1	C
MEGALOPTERA				
Corydalidae	1	R	1	R
TOLERANT TAXA				
OLIGOCHAETA	2	R	2	C
ISOPODA	1	R		
CHIRONOMIDAE	3	C	2	C

	2011 (pre-mitigation)		2012 (post-mitigation)	
Taxa	**No. of Taxa**	**Density[1]**	**No. of Taxa**	**Density[1]**
SIMULIIDAE	1	A		
DECAPODA	1	C	1	C
GASTROPODA				
Pleuroceridae	3	C	2	A
BIVALVIA				
Corbiculidae	1	R	1	R
Sphaeriidae			1	R
HYDRACARINA	1	R	1	C

[1]R=RARE (<10), C=COMMON (10-100), A=ABUNDANT (>100)

There was an increase in the number of taxa present in White Oak Creek in 2012 (N=25), in comparison to 2011 (N=22). Overall, more of the taxa in 2012 fall under the category of abundant or common, so there is a greater abundance present for some of the taxa present in the creek. As with the survey results in First Creek Reach, such fluctuation is considered normal in annual surveys.

3.5 Fish Communities

Fish community sampling has been routinely conducted twice a year (spring and fall) in both First Creek and White Oak Creek as part of the BMAP program. The results presented here are post-mitigation for First Creek and White Oak Creek.

First Creek sampling has been conducted both downstream (FCK 0.1) and upstream (FCK 0.8) of the mitigated reach. In past sampling, the number of fish species downstream of the site tended to be similar or lower then reference streams. Results of recent sampling (March-May 2012) have shown the number of species to be lower downstream than in either reference stream. The number of fish species recorded upstream was also lower than reference streams, which has held true in the past as well. Fish densities for both downstream and upstream locations fell between those recorded for reference streams (Tables 9 and 10).

Overall, the 2012 survey indicated a decrease in the number of species present in both sections of First Creek. The densities were similar to those recorded in 2011, and there was an increase in biomass found in both sections.

White Oak Creek sampling has been conducted in the eastern third (WCK 4.4) of the mitigated reach. Past surveys have shown the number of fish species in the reach have tended to be lower than for reference streams. The results of recent sampling (October-December 2011, March-May 2012), indicate that this trend remains the case. The fish density found in White Oak Creek was between those recorded for reference streams, and the biomass of fish was lower than the reference streams (Tables 9 and 10).

The 2012 survey indicated a slight increase in the number of species and fish density present in the sampling area in White Oak Creek from what was recorded in 2011, with a larger increase in biomass found in the creek.

Table 9. Fish species, density (fish/m^2), and biomass (g fish/m^2) in parenthesis, in First Creek, White Oak Creek, and reference sites, Mill Branch and Ish Creek, October-December 2011.

Species	Sites[a]				
	FCK 0.1	FCK 0.8	WCK 4.4	MBK 1.6	ISK 1.0
Largescale stoneroller (*Campostoma oligolepis*)	0.24 (0.19)	-	0.15 (0.28)	0.01 (0.13)	0.66 (2.38)
Spotfin shiner (*Cyprinella spiloptera*)	-	-	-	-	0.01 (0.05)
Striped shiner (*Luxilus chrysocephalus*)	0.24 (0.31)	-	-	0.03 (0.47)	2.69 (6.79)
Tennessee dace *(Chrosomus tennesseensis)*	-	-	-	<0.01 (0.01)	<0.01 (0.01)
Bluntnose minnow (*Pimephales notatus*)	1.83 (2.41)	1.19 (2.47)	-	-	3.54 (7.07)
Western blacknose dace *Rhinichthys obtusus*	-	-	0.69 (1.11)	0.22 (0.67)	0.04 (0.08)
Creek chub (*Semotilus atromaculatus*)	-	-	-	0.12 (1.08)	0.04 (0.45)
White sucker (*Catostomus commersonii*)	-	-	-	0.01 (0.18)	-
Northern hogsucker (*Hypentelium nigricans*)	-	-	-	<0.01 (0.16)	-
Western mosquitofish (*Gambusia affinis*)	0.18 (0.04)	-	-	-	-
Banded sculpin (*Cottus carolinae*)	0.02 (0.17)	0.17 (0.85)	-	-	0.03 (0.21)
Redbreast sunfish (*Lepomis auritus*)	-	-	0.03 (0.37)	-	0.25 (1.59)
Green sunfish (*Lepomis cyanellus*)	0.02 (0.33)	-	-	-	0.25 (1.53)
Warmouth (*Lepomis gulosus*)	-	-	-	0.02 (0.48)	-
Bluegill (*Lepomis macrochirus*)	0.02 (0.21)	-	0.01 (0.05)	0.22 (0.86)	0.07 (0.36)
Spotted bass (*Micropterus punctulatus.*)	-	-	-	<0.01 (0.01)	-
Stripetail darter (*Etheostoma kennicotti*)	-	-	-	0.05 (0.07)	-
Snubnose darter (*Etheostoma simoterum*)	-	-	-	-	0.19 (0.34)
Number of species (N)	7	2	4	11	12
Density	2.57	1.36	0.88	0.68	7.77
Biomass	(3.66)	(2.32)	(1.81)	(4.12)	(20.86)

[a] WCK = White Oak Creek kilometer; MBK = Mill Branch kilometer; ISK = Ish Creek kilometer, FCK = First Creek kilometer.

Table 10. Fish species, density (fish/m^2), and biomass (g fish/m^2) in parenthesis, in First Creek, White Oak Creek, and reference sites, Mill Branch and Ish Creek, March-May 2012.

Species	Sites[a]				
	FCK 0.1	**FCK 0.8**	**WCK 4.4**	**MBK 1.6**	**ISK 1.0**
Largescale stoneroller (*Campostoma oligolepis*)	0.15 (0.37)	-	0.56 (0.68)	0.01 (0.34)	0.21 (1.04)
Striped shiner (*Luxilus chrysocephalus*)	0.20 (0.82)	-	0.07 (0.65)	0.12 (1.45)	0.65 (2.56)
Tennessee dace *(Chrosomus tennesseensis)*	-	-	-	0.01 (<0.01)	0.01 (0.01)
Bluntnose minnow *(Pimephales notatus)*	-	-	-	-	0.03 (0.05)
Western blacknose dace *(Rhinichthys obtusus)*	1.77 (3.59)	1.42 (2.85)	0.60 (1.48)	0.19 (0.79)	0.05 (0.13)
Creek chub (*Semotilus atromaculatus*)	-	-	-	0.13 (1.10)	0.05 (0.42)
White sucker (*Catostomus commersonii*)	-	-	-	0.02 (0.96)	0.01 (0.13)
Northern hogsucker *(Hypentelium nigricans)*	-	-	-	0.01 (0.22)	-
Western mosquitofish *(Gambusia affinis)*	0.17 (0.09)	-	-	-	-
Banded sculpin (*Cottus carolinae*)	-	0.16 (0.52)	0.01 (0.05)	-	0.59 (3.46)
Redbreast sunfish *(Lepomis auritus)*	-	-	0.05 (0.76)	-	0.10 (0.59)
Green sunfish (*Lepomis cyanellus*)	-	-	-	-	0.31 (2.17)
Warmouth (*Lepomis gulosus*)	-	-	-	0.02 (0.23)	-
Bluegill (*Lepomis macrochirus*)	-	-	-	0.47 (0.83)	-
Largemouth bass (*Micropterus salmoides*)	-	-	-	0.01 (0.04)	-
Blackside snubnose darter *(Etheostoma duryi)*	-	-	-	-	0.01 (0.01)
Stripetail darter (*Etheostoma kennicotti*)	-	-	-	0.06 (0.10)	-
Snubnose darter (*Etheostoma simoterum*)	-	-	-	-	0.33 (0.55)
Number of species (N)	4	2	5	11	12
Density	2.29	1.58	1.29	1.05	2.35
Biomass	4.87	3.37	3.62	6.06	11.12

[a] WCK = White Oak Creek kilometer; MBK = Mill Branch kilometer; ISK = Ish Creek kilometer, FCK = First Creek kilometer.

4.0 CONCLUSIONS

4.1 ORNL Parking Structure Wetland (P2)

Baseline data obtained for the P2 wetland showed sparse vegetation with limited habitat prior to mitigation. Despite this, volunteer wetland plants had already become established on the site, providing a good initial start to the recovery of the wetland. The relatively marginal habitat present on the site was evident in the lack of fauna recorded during initial surveys. Supplemental planting conducted on the site with native wetland plants in June 2011 was expected to significantly improve the quality of these wetlands. The first year of post-mitigation monitoring for this site in 2012 suggests that there is indeed an improvement in habitat quality, as there is a diversity of wetland plants, and a significant increase in vegetation cover with little bare ground present in the wetland. The presence of a moderately diverse assemblage of fauna living in and around the wetland also indicates a more diverse habitat as a result of mitigation.

4.2 First Creek

The results of habitat measurements conducted in 2012 along this reach of First Creek showed that the creek provided good overall habitat and was in a non-impaired state. The relatively linear condition of the creek was evidence of past channelization with the development of the area. Relatively narrow riparian zones are a weakness of the site from the perspective of providing good quality habitat. However, riparian zones in this area are restricted by paved and landscaped areas being that the creek runs through a developed area. Mitigation plantings on the east side of the creek have improved habitat quality in that area over original habitat conditions that included large mowed turf grass areas and a high number of invasive plant species. The riparian zone on the west side is highly restricted due to the close proximity of landscaped and parking areas associated with a building complex. Cover is maintained to the maximum extent possible in this narrow zone. The presence of invasive plants in these zones, such as winter creeper and Johnson grass (growing on both sides) is a potential concern.

While there was some mortality of mitigation plantings found along the First Creek reach during the 2012 survey, overall survivorship of east side riparian plantings still appears to be very good. The cause of plant mortality is thought to be partially associated with the unusually high temperatures and short-term drought that occurred during the time of the survey. Replanting will occur in order to replace some of the plants lost, to assure that good vegetation cover is maintained. Dense growths of shrubs (e.g., silky dogwood, spicebush) previously existing on the site continue to provide significant cover along the creek banks, particularly along northern portions of the study area. Overall conditions at the site related to vegetation growth and success remain very good.

A moderately diverse benthic macroinvertebrate population was recorded at the site in 2012. This included taxa typically found in clear streams. Fish population (sampled upstream and downstream of the site) densities were similar to certain reference streams on the ORR. The number of fish species at both the downstream and upstream sampling locations was lower than reference streams.

The third year of post-mitigation monitoring for this site will be conducted in the summer of 2013.

4.3 White Oak Creek

The results of habitat measurements conducted along this reach of White Oak Creek in 2011 showed that the creek provided average overall habitat in the pre-mitigation condition and was in a non-impaired state, a rating that was maintained in 2012. Epifaunal substrate was somewhat lacking in the presence of logs and snags; however, the creek provided numerous riffles, some undercut banks, a variety of particle sizes and overhanging branches. One velocity/depth regime (fast-deep) was missing from the reach. Channel alteration from past development of the area was evident along some areas of the reach. Vegetative protection at the banks was compromised by the presence invasive plant species (i.e., winter creeper, Japanese honeysuckle, Nepal grass, and Johnson grass) in 2011. However, significant improvements were noted in 2012 due to removal of invasives and replacement with native plants during mitigation. Narrow riparian zones were a significant weakness on the site prior to mitigation, mainly due to the existence of adjacent areas that contained large areas of low turf grasses and weedy species. Although riparian zone width is restricted on the north side by an existing paved road and on the south side by a building, modifications made to the site with the mitigation planting has resulted in a significant increase in the width and quality of the vegetative riparian zone.

The site, pre-mitigation, displayed good vegetation cover. However, much of the area was covered by either managed/mowed turf areas or non-native invasive plant species. This year showed a decrease in the percentage of ground covered by invasive plants and turf grass, with an increase in diversity of native wetland plants. Overall survivorship of the plantings was good, with few unhealthy or dead plants found.

A moderately diverse benthic macroinvertebrate population was recorded at the site in 2012, with an increase in the number of taxa from 2011. This included some of the more tolerant taxa found in ORR streams. Fish population (sampled within the reach) densities were similar to certain reference streams on the ORR. The number of fish species recorded was lower than those found in the reference streams.

The second year of post-mitigation monitoring for this site will be conducted in the summer of 2013.

5.0 REFERENCES

Barbour, M. T., J. Gerritsen, B. D. Snyder and J. B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Bethic Macroinvertebrates, and Fish, Second Addition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Giffen, N.R., M.G. Ryon and R.T. Jett. 2011. ORNL Parking Structure Mitigation Report. Unpublished report.

Niemi, G. J., P. DeVore, N. Detenbeck, D. Taylor, A. Lima, J. Pastor, J. D. Yount, and R. J. Naiman. 1990. Overview of case studies on recovery of aquatic systems from disturbance. Environ. Manag. 15(5):571-588.

Ryon, M. G. 2011. Recovery of fish communities in a warm water stream following pollution abatement. Environ. Manag. 47(6):1096-1111.

Ryon, M .G. and H. D. Quarles. 2008. Considerations associated with landscaping of First Creek riparian buffer and installation of new pedestrian bridge. Unpublished report.

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APPENDIX A – HABITAT ASSESSMENT FORM

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME	LOCATION	
STATION #_____ RIVERMILE_____	STREAM CLASS	
LAT _____ LONG _____	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		
FORM COMPLETED BY	DATE _____ TIME _____ AM PM	REASON FOR SURVEY

Parameters to be evaluated in sampling reach	Habitat Parameter	Condition Category			
	1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Sow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% (50-80% for low-gradient) of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Habitat Parameter	Condition Category			
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

Total Score _____

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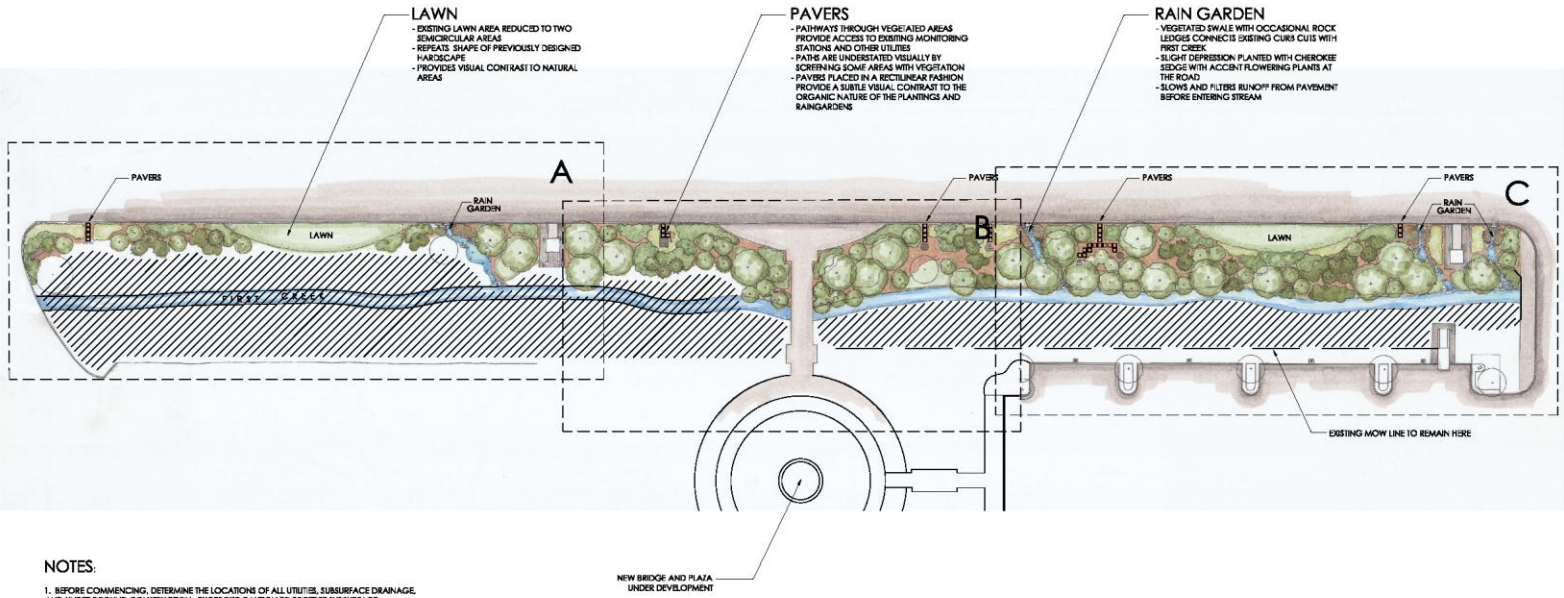
APPENDIX B – PLANTING PLAN FOR FIRST CREEK MITIGATION



NOTES:

1. BEFORE COMMENCING, DETERMINE THE LOCATIONS OF ALL UTILITIES, SUBSURFACE DRAINAGE, AND UNDERGROUND CONSTRUCTION. EXCERCISE CAUTION TO PROTECT SUBSURFACE IMPROVEMENTS.

2. SPECIAL ATTENTION, APPROVAL, AND COORDINATION SHALL BE REQUIRED PRIOR TO AND DURING DISTURBANCE OF ANY AREAS KNOWN OR SUSPECTED TO CONTAIN HAZARDOUS OR RADIOACTIVE SEDIMENTS.

3. COORDINATE PLANTING LAYOUT AND INSTALLATION WITH THE LANDSCAPE ARCHITECT.

4. TAKE PRECAUTIONS TO AVOID DAMAGE TO EXISTING WALKS, PAVING, FENCES, LIGHTING, AND OTHER SITE IMPROVEMENTS.

5. SIZE, QUALITY, ROOT BALL PREPARATIONS, AND GRADING STANDARDS SHALL CONFORM TO THE AMERICAN ASSOCIATION OF NURSERYMEN, INC., AS PUBLISHED IN "THE AMERICAN STANDARD FOR NURSERY STOCK."

6. PLANTS SHALL BE NURSERY GROWN AND HAVE A HABIT OF GROWTH THAT IS NORMAL FOR THE SPECIES. THEY SHALL BE SOUND, HEALTHY, VIGOROUS AND FREE FROM INSECTS, PLANT DISEASES, AND INJURIES. ROOTS SHALL BE PROTECTED DRYING SUN AND WINDS UNTIL PLANTED.

7. SITE PREPARATION, PLANTING, AND MAINTENANCE GUIDELINES FOR LAWNS WILL BE PROVIDED BY THE LANDSCAPE ARCHITECT.

8. RAIN GARDEN SWALES WILL INITIALLY BE LINED WITH EROSION FABRIC (NORTH AMERICAN GREEN C125BN OR APPROVED EQUAL)BEFORE PLANTING WITH SEDGE PLUGS.

9. LEDGE ROCK FOR RAIN GARDENS SHALL BE INDIGENOUSTO THE LOCALE AND FROM SITES COORDINATED AND APPROVED BY THE LANDSCAPE ARCHITECT. PREFERENCE WILL BE GIVEN TO AREAS PREVIOUSLY DISTURBED BY CONSTRUCTION ACTIVITIES OR SITES PENDING DEVELOPMENT.

S.T.E.M. ZONE (Selective Thinning and Exotics Management)

IN ADDITION TO THE REMOVAL OF INVASIVE EXOTIC PLANT SPECIES, SOME NATIVE SPECIES WILL ALSO BE FLAGGED FOR REMOVAL BY THE LANDSCAPE ARCHITECT. THE PURPOSE FOR SELECTIVE THINNING IS TO MAXIMIZE THE AESTHETIC QUALITY OF THE CREEK AND THE ARCHITECTURAL SETTING, WITHOUT COMPROMISING THE ECOLOGICAL INTEGRITY OF THE RIPARIAN ZONE.

EXISTING INVASIVE EXOTIC SPECIES TO BE REMOVED:

Ailanthus altissima	Tree of Heaven
Cynodon dactylon	Bermudagrass
Elaeagnus angnsta	Thorny Olive
Euonymus fortunei	Creeping Eunonymus
Hedera helix	English Ivy
Lespedeza cuneata	Sericea Lespedeza
Ligustrum sinense	Chinese Privet
Lonicera japonica	Japanese Honeysuckle
Pyrus calleryana 'Bradford'	Bradford Pear
Vicia sp.	Vetch

First Creek Riparian Buffer - ORNL

Environmental Landscape Plan

Conceptual Master Plan

Environmental Landscape Design Associates (ELDA)

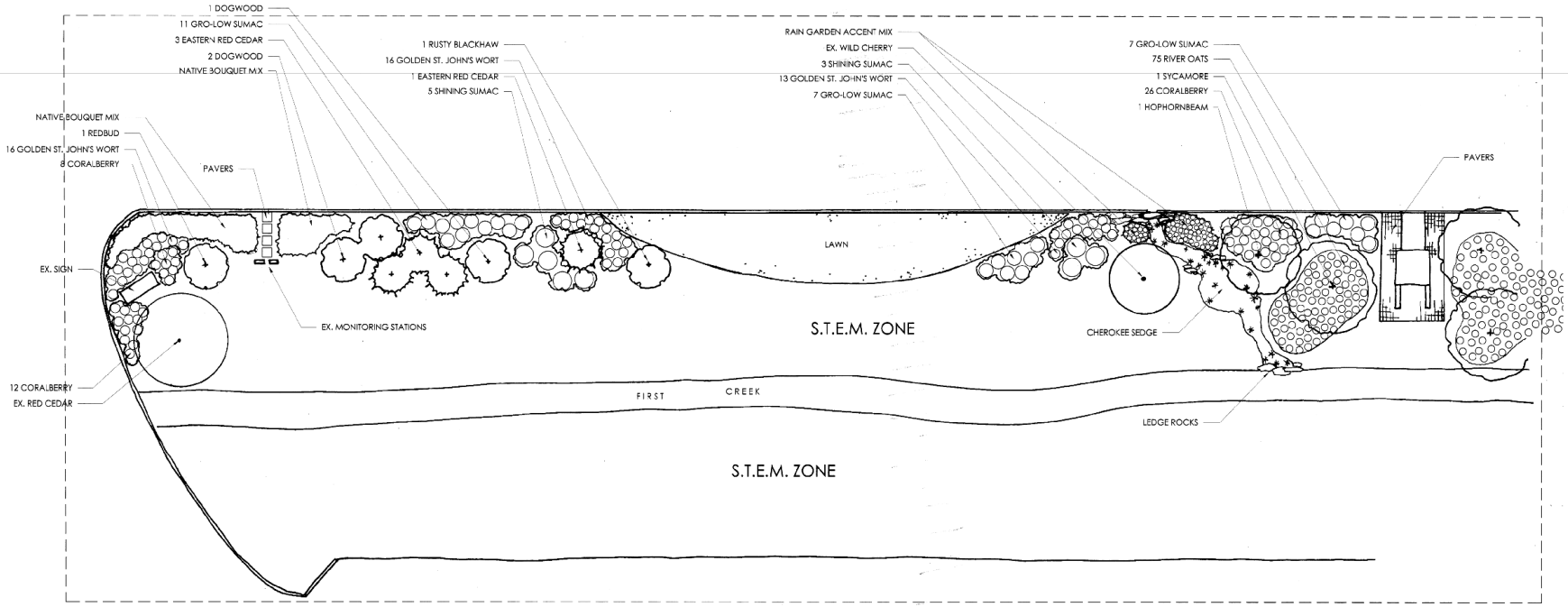
Prepared by:
Sam Rogers, ASLA, RLA
Leah Gardner, MLA

SAMUEL M. ROGERS REGISTERED LANDSCAPE ARCHITECT

Prepared 09/2008

Illustration not to scale

Sheet 1 of 4



PLANT LIST

SCIENTIFIC NAME	COMMON NAME	QUANTITY	SIZE
TREES			
Cercis canadensis	EASTERN REDBUD (CLUMP)	1	4-5' BB
Cornus florida	DOGWOOD	3	4-5' BB
Juniperus virginiana	EASTERN RED CEDAR	4	5-6' BB
Ostrya virginiana	HOPHORNBEAM	1	4-5' BB
Platanus occidentalis	SYCAMORE	2	6-8' BB
Viburnum rufidulum	RUSTY BLACKHAW	1	3-4' BB
SHRUBS			
Hypericum frondosum	GOLDEN ST. JOHN'S WORT	45	2 GAL
Rhus aromatica 'Gro-low	GRO-LOW SUMAC	25	2 GAL
Rhus copallina	SHINING SUMAC	8	2-3' BB
Symphoricarpos orbiculatus	CORALBERRY	46	1 GAL
HERBACEOUS LAYER			
Chasmanthium latifolium	RIVER OATS	75	1 GAL
NATIVE BOUQUET MIX			
Asclepias tuberosa	BUTTERFLY WEED	35	PLUG
Coreopsis lanceolata	LANCELEAF COREOPSIS	35	PLUG
Echinacea purpurea	PURPLE CONEFLOWER	35	PLUG
Liatris spicata	DENSE BLAZINGSTAR	35	PLUG
Liatris squarrosa	SCALY BLAZINGSTAR	35	PLUG
Penstemon digitalis	FOXGLOVE BEARDTONGUE	35	PLUG
Ratibida pinnata	PRAIRIE CONEFLOWER	35	PLUG
Rudbeckia fulgida	BLACK-EYED SUSAN	35	PLUG
Schyzachirium scoparium	LITTLE BLUESTEM	35	PLUG

SCIENTIFIC NAME	COMMON NAME	QUANTITY	SIZE
RAIN GARDEN ACCENT MIX			
Carex cherokeensis	CHEROKEE SEDGE	200	PLUG
Asclepias incarnata	SWAMP MILKWEED	10	1 GAL
Conoclinium coelestinum	WILD AGERATUM	10	1 GAL
Eupatorium fistulosum	DWARF JOE-PYE WEED	10	1 GAL
Iris versicolor	BLUE FLAG IRIS	10	1 GAL
Lobelia cardinalis	CARDINAL FLOWER	10	1 GAL
Rudbeckia triloba	BROWN-EYED SUSAN	10	1 GAL

First Creek Riparian Buffer - ORNL

Environmental Landscape Plan

Planting Plan - Window A

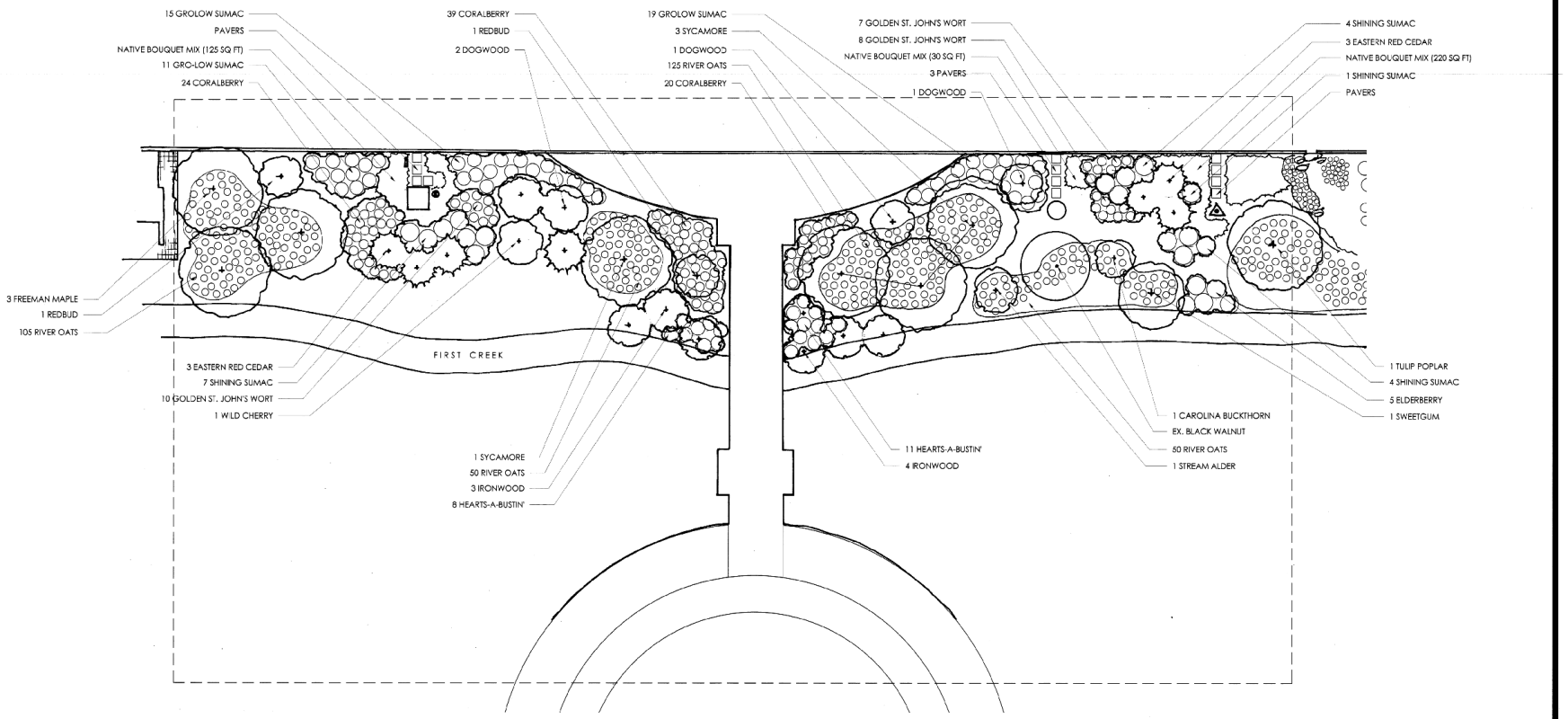
Environmental Landscape Design Associates (ELDA)

Prepared by:
Sam Rogers, ASLA, RLA
Leah Gardner, MLA

Prepared 093008

0' 10' 20'

Sheet 2 of 4



PLANT LIST

SCIENTIFIC NAME	COMMON NAME	QUANTITY	SIZE
TREES			
Acer freemanii	FREEMAN MAPLE	3	6-8' BB
Alnus serrulata	STREAM ALDER	1	4-5' BB
Carpinus caroliniana	IRONWOOD	7	4-5' BB
Cercis canadensis	EASTERN REDBUD (CLUMP)	2	5-6' BB
Cornus florida	DOGWOOD	4	4-5' BB
Juniperus virginiana	EASTERN RED CEDAR	6	5-6' BB
Liquidambar styraciflua	SWEETGUM	1	6-8' BB
Liriodendron tulipifera	TULIP POPLAR	1	6-8' BB
Platanus occidentalis	SYCAMORE	4	6-8' BB
Prunus serotina	WILD BLACK CHERRY	1	6-8' BB
Rhamnus carolniana	CAROLINA BUCKTHORN	1	4-5' BB
SHRUBS			
Euonymus americanus	HEARTS-A-BUSTIN'	19	3-4'
Hypericum frondosum	GOLDEN ST. JOHN'S WORT	25	2 GAL
Rhus aromatica 'Gro-low	GRO-LOW SUMAC	45	2 GAL
Rhus copalina	SHINING SUMAC	16	2-3' BB
Sambucus canadensis	ELDERBERRY	5	2-3' BB
Symphoricarpos orbiculatus	CORALBERRY	83	1 GAL

SCIENTIFIC NAME	COMMON NAME	QUANTITY	SIZE
HERBACEOUS LAYER			
Chasmanthium latifolium	RIVER OATS	330	1 GAL
NATIVE BOUQUET MIX			
Asclepias tuberosa	BUTTERFLY WEED	40	PLUG
Coreopsis lanceolata	LANCELEAF COREOPSIS	40	PLUG
Echinacea purpurea	PURPLE CONEFLOWER	40	PLUG
Liatris spicata	DENSE BLAZINGSTAR	40	PLUG
Liatris squarrosa	SCALY BLAZINGSTAR	40	PLUG
Penstemon digitalis	FOXGLOVE BEARDTONGUE	40	PLUG
Ratibida pinnata	PRAIRIE CONEFLOWER	40	PLUG
Rudbeckia fulgida	BLACK-EYED SUSAN	40	PLUG
Schyzachirium scoparium	LITTLE BLUESTEM	40	PLUG

First Creek Riparian Buffer - ORNL

Environmental Landscape Plan

Planting Plan - Window B

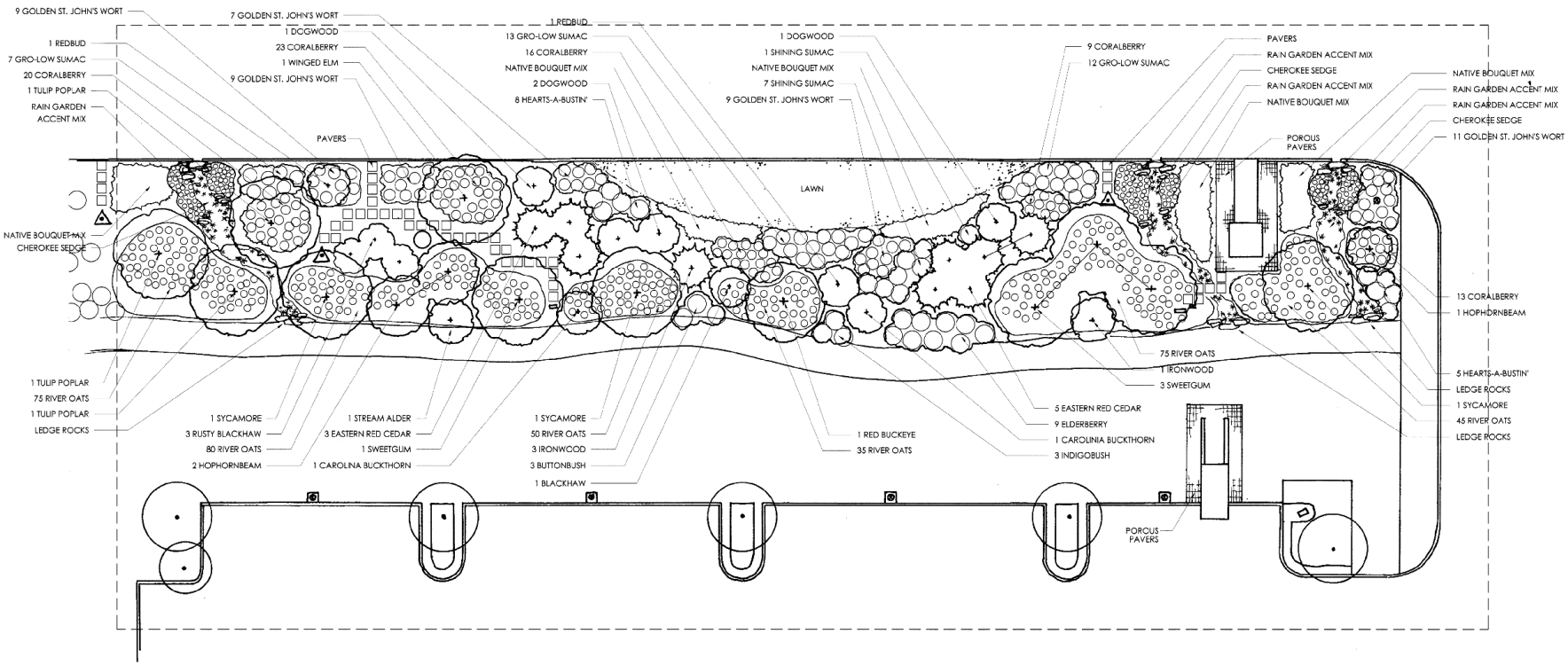
Environmental Landscape Design Associates (ELDA)

Prepared by:
Sam Rogers, ASLA, RLA
Leah Gardner, MLA

Prepared 093008

0' 10' 20'

Sheet 3 of 4



PLANT LIST

SCIENTIFIC NAME	COMMON NAME	QUANTITY	SIZE
TREES			
Aesculus pavia	RED BUCKEYE	1	5-6' BB
Carpinus caroliniana	IRONWOOD	4	5-6 BB
Cercis canadensis	EASTERN REDBUD (CLUMP)	2	5-6 BB
Cornus florida	DOGWOOD	4	4-5 BB
Juniperus virginiana	EASTERN RED CEDAR	8	5-6 BB
Liquidambar styraciflua	SWEETGUM	4	6-8 BB
Liriodendron tulipifera	TULIP POPLAR	3	6-8 BB
Ostrya virginiana	HOPHORNBEAM	3	4-5 BB
Platanus occidentalis	SYCAMORE	3	6-8 BB
Rhamnus caroliniana	CAROLINA BUCKTHORN	2	4-5 BB
Ulmus alata	WINGED ELM	1	5-6 BB
Viburnum prunifolium	BLACKHAW	1	4-5 BB
Viburnum rufidulum	RUSTY BLACKHAW	3	4-5 BB
SHRUBS			
Amorpha fruticosa	INDIGOBUSH	3	2-3
Cephalanthus occidentalis	BUTTONBUSH	3	2-3
Euonymus americanus	HEARTS-A-BUSTIN'	5	2-3
Hypericum frondosum	GOLDEN ST. JOHN'S WORT	45	2 GAL
Rhus aromatica 'Gro-low'	GRO-LOW SUMAC	32	2 GAL
Rhus copallina	SHINING SUMAC	13	2-3 BB
Sambucus canadensis	ELDERBERRY	9	2-3 BB
Symphoricarpos orbiculatus	CORALBERRY	81	1 GAL

SCIENTIFIC NAME	COMMON NAME	QUANTITY	SIZE
HERBACEOUS LAYER			
Chasmanthium latifolium	RIVER OATS	360	1 GAL
NATIVE BOUQUET MIX			
Asclepias tuberosa	BUTTERFLY WEED	60	PLUG
Coreopsis lanceolata	LANCELEAF COREOPSIS	60	PLUG
Echinacea purpurea	PURPLE CONEFLOWER	60	PLUG
Liatris spicata	DENSE BLAZINGSTAR	60	PLUG
Liatris squarrosa	SCALY BLAZINGSTAR	60	PLUG
Penstemon digitalis	FOXGLOVE BEARDTONGUE	60	PLUG
Ratibida pinnata	PRAIRIE CONEFLOWER	60	PLUG
Rudbeckia fulgida	BLACK-EYED SUSAN	60	PLUG
Schyzachirium scoparium	LITTLE BLUESTEM	60	PLUG
RAIN GARDEN ACCENT MIX			
Carex cherokeensis	CHEROKEE SEDGE	360	PLUG
Asclepias incarnata	SWAMP MILKWEED	25	1 GAL
Conoclinium coelestinum	WILD AGERATUM	25	1 GAL
Eupatorium fistulosum	DWARF JOE-PYE WEED	25	1 GAL
Iris versicolor	BLUE FLAG IRIS	25	1 GAL
Lobelia cardinalis	CARDINAL FLOWER	25	1 GAL
Rudbeckia triloba	BROWN-EYED SUSAN	25	1 GAL

First Creek Riparian Buffer - ORNL

Environmental Landscape Plan

Planting Plan - Window C

Environmental Landscape Design Associates (ELDA)

Prepared by:
Sam Rogers, ASLA, RLA
Leah Gardner, MLA

Prepared 093008

0 10' 20'

Sheet 4 of 4

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APPENDIX C – PLANT SPECIES LISTS FOR THE FIRST CREEK AND WHITE OAK CREEK REACHES

Table C1. Plant Species List for the First Creek Reach (July 2012).

#	Scientific Name	Common Name
1	*Acer rubrum*	Red maple
2	*Acer saccharinum*	Silver maple
3	*Aster sp.*	Aster
4	*Allium canadense*	Wild Garlic
5	*Boehmeria cylindrical*	False nettle
6	*Campsis radicans*	Trumpet-creeper
7	*Carex cherokeensis*	Cherokee sedge
8	*Carex frankii*	Frank's sedge
9	*Carpinus caroliniana*	Ironwood*
10	*Chasmanthium latifolium*	River oats*
11	*Cirsium sp.*	Thistle
12	*Coreopsis lanceolata*	Lanceleaf coreopsis*
13	*Cornus florida*	Flowering dogwood*
14	*Crataegus sp.*	Hawthorne
15	*Cynodon dactylon*	Bermuda grass
16	*Digitaria sp.*	Crabgrass
17	*Dioscorea bulbifera*	Air potato**
18	*Diospyros virginiana*	Persimmon
19	*Echinacea purpurea*	Eastern purple cornflower*
20	*Elaeagnus pungens*	Thorny olive**
21	*Euonymus sp.*	Winter creeper**
22	*Festuca sp.*	Fescue
23	*Fraxinus pennsylvanica*	Green ash
24	*Galium sp.*	Bedstraw
25	*Hypericum densiflorum*	Bushy St. John's wort
26	*Hypericum frondosum*	Golden St. John's wort*
27	*Ilex verticillata*	Winterberry
28	*Impatiens sp.*	Jewelweed
29	*Juglans nigra*	Black walnut
30	*Juncus coriaceus*	Leathery rush
31	*Juncus effusus*	Soft rush
32	*Juncus tenuis*	Path rush
33	*Juniperus virginiana*	Eastern red cedar*
34	*Ligustrum sinensis*	Chinese privet**
35	*Lindera benzoin*	Common spicebush
36	*Liriodendron tulipifera*	Tulip poplar*
37	*Ludwigia palustris*	Evening primrose
38	*Lonicera japonica*	Japanese honeysuckle**
39	*Mentha sp.*	Mint
40	*Microstegium vimineum*	Nepal grass**
41	*Parthenocissus quinquefolia*	Virginia creeper
42	*Potentilla indica*	Mock Strawberry**

43	*Prunus serotina*	Black cherry*
44	*Ratibida pinnata*	Prairie coneflower*
45	*Rhus aromatica*	Gro-low sumac*
46	*Rhus copallina*	Winged sumac
47	*Rubus argutus*	Blackberry
48	*Rumex crispus*	Curled dock
49	*Schizachyrium scoparium*	Little bluestem*
50	*Securigera varia*	Crown vetch**
51	*Sorghum halepense*	Johnson grass**
52	*Solidago sp.*	Goldenrod
53	*Sporobolus heterolepis*	Prairie Dropseed
54	*Symphoricarpos orbiculatus*	Coralberry*
55	*Toxicodendron radicans*	Poison ivy
56	*Vernonia gigantea*	Tall ironweed
57	*Viburnum sp.*	Blackhaw*
58	*Vitis sp.*	Grape

*Species on the mitigation planting list
**Exotic invasive species

Table C2. Plant Species List for the White Oak Creek Reach (June 2012).

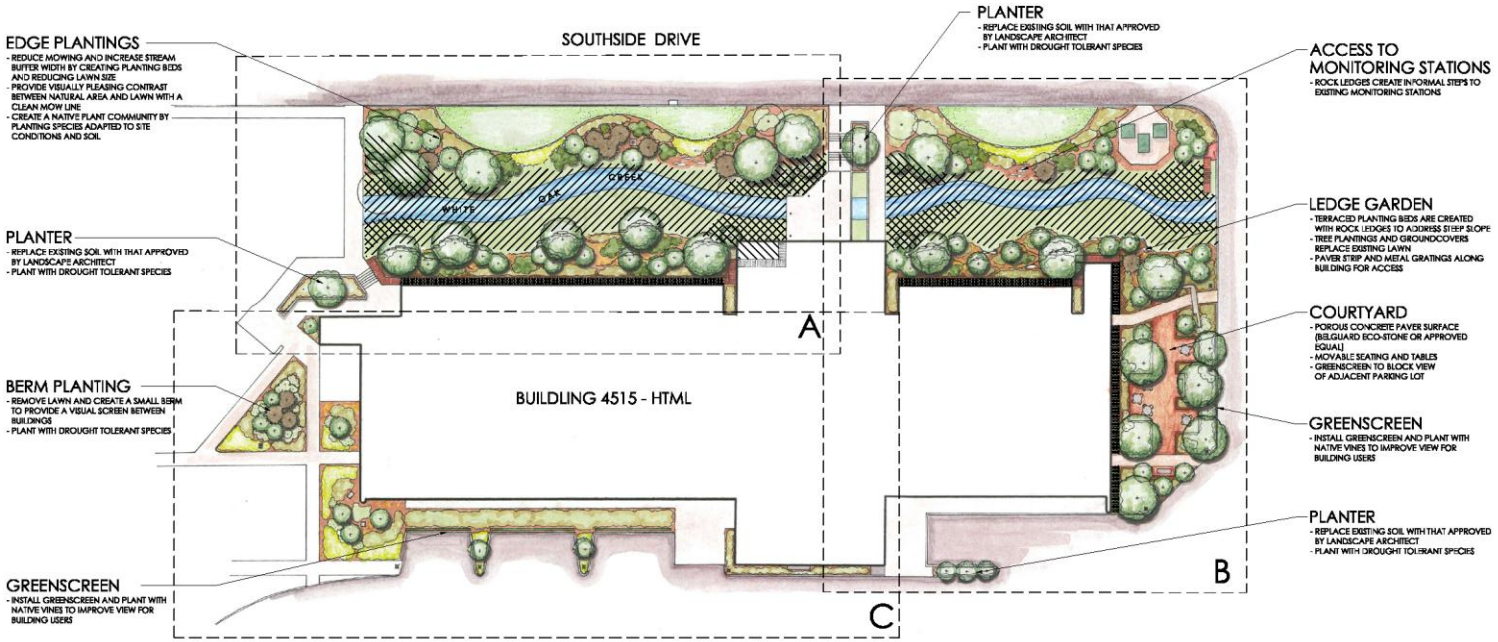
#	Scientific Name	Common Name
1	*Acer negundo*	Box elder
2	*Allium canadense*	Wild garlic
3	*Asclepias tuberosa*	Butterfly weed*
4	*Barbarea verna*	Early winter-cress
5	*Brassica rapa*	Rape mustard
6	*Callicarpa americana*	American beautyberry*
7	*Campsis radicans*	Trumpet-creeper
8	*Carex cherokeensis*	Cherokee sedge*
9	*Cephalanthus occidentalis*	Buttonbush
10	*Cercis canadensis*	Eastern redbud*
11	*Chasmanthium latifolium*	River oats*
12	*Cirsium sp.*	Thistle
13	*Cladrastis kentukea*	American yellowwood*
14	*Coreopsis sp.*	Tick-seed
15	*Cornus amomum*	Silky dogwood
16	*Cornus florida*	Flowering dogwood*
17	*Cynodon dactylon*	Bermuda grass
18	*Dioscorea bulbifera*	Air Potato**
19	*Diospyros virginiana*	Persimmon
20	*Equisetum sp.*	Horsetail
21	*Euonymus sp.*	Winter creeper**
22	*Festuca sp.*	Fescue
23	*Fraxinus pennsylvanica*	Green ash*
24	*Galium sp.*	Bedstraw
25	*Halesia sp.*	Silver bell
26	*Hamamelis virginiana*	Witch-hazel
27	*Hydrangea quercifolia*	Oakleaf hydrangea*
28	*Hypericum frondosum*	Golden St. Johnswort*
29	*Hypericum hypericoides*	St. Andrew's cross*
30	*Impatiens sp.*	Jewelweed
31	*Juglans nigra*	Black walnut
32	*Juniperus virginiana*	Eastern red cedar*
33	*Liatris squarrosa*	Scaly blazing star*
34	*Liquidambar styraciflua*	Sweetgum*
35	*Liriodendron tulipifera*	Tulip poplar*
36	*Lonicera japonica*	Japanese honeysuckle**

37	*Medicago lupulina*	Black medick
38	*Microstegium vimineum*	Nepal grass**
39	*Panicum virgatum*	Swtichgrass
40	*Parthenocissus quinquefolia*	Virginia creeper*
41	*Penstemon digitalis*	Fox-glove beard-tongue*
42	*Phytolacca americana*	Pokeweed
43	*Platanus occidentalis*	American sycamore*
44	*Polygonum cespitosum*	Smartweed
45	*Polygonum hydropiperoides*	Water smartweed
46	*Potentilla indica*	Mock strawberry**
47	*Prunus serotina*	Black cherry
48	*Rhus aromatica*	Gro-low sumac*
49	*Rhus copallina*	Winged sumac*
50	*Rhus glabra*	Smooth sumac
51	*Rubus argutus*	Blackberry
52	*Rudbeckia hirta*	Black-eyed susan*
53	*Rudbeckia pinnata*	Prairie coneflower*
54	*Rumex crispus*	Curled dock
55	*Salix nigra*	Black willow
56	*Schizachyrium scoparium*	Little bluestem*
57	*Sorghum halepense*	Johnson grass**
58	*Sporobolus heterolepis*	Prairie dropseed*
59	*Symphoricarpos orbiculatus*	Coralberry*
60	*Toxicodendron radicans*	Poison ivy
61	*Ulmus alata*	Winged elm
62	*Verbesina alternifolia*	Wingstem
63	*Vernonia gigantean*	Tall ironweed
64	*Viburnum sp.*	Rusty blackhaw*
65	*Vitis sp.*	Grape

*Species on the mitigation planting list

**Exotic invasive species

APPENDIX D – PLANTING PLAN FOR WHITE OAK CREEK MITIGATION



NOTES:

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2. COORDINATE PLANTING LAYOUT AND INSTALLATION WITH THE LANDSCAPE ARCHITECT.

3. TAKE PRECAUTIONS TO AVOID DAMAGE TO EXISTING WALKS, PAVING, FENCES, LIGHTING, AND OTHER SITE IMPROVEMENTS.

4. SIZE, QUALITY, ROOT BALL PREPARATIONS, AND GRADING STANDARDS SHALL CONFORM TO THE AMERICAN ASSOCIATION OF NURSERYMEN, INC., AS PUBLISHED IN "THE AMERICAN STANDARD FOR NURSERY STOCK."

5. PLANTS SHALL BE NURSERY GROWN AND HAVE A HABIT OF GROWTH THAT IS NORMAL FOR THE SPECIES. THEY SHALL BE SOUND, HEALTHY, VIGOROUS AND FREE FROM INSECTS, PLANT DISEASES, AND INJURIES. ROOTS SHALL BE PROTECTED DRYING SUN AND WINDS UNTIL PLANTED.

6. SITE PREPARATION, PLANTING, AND MAINTENANCE GUIDELINES FOR PLANTINGS WILL BE PROVIDED BY THE LANDSCAPE ARCHITECT.

7. ROCK FOR LEDGE GARDENS SHALL BE INDIGENOUS TO THE LOCALE AND FROM SITES COORDINATED AND APPROVED BY THE LANDSCAPE ARCHITECT. PREFERENCE WILL BE GIVEN TO AREAS PREVIOUSLY DISTURBED BY CONSTRUCTION ACTIVITIES OR SITES PENDING DEVELOPMENT.

S.T.E.M. ZONE (Selective Thinning and Exotics Management)

IN ADDITION TO THE REMOVAL OF INVASIVE EXOTIC PLANT SPECIES, SOME NATIVE SPECIES WILL ALSO BE FLAGGED FOR REMOVAL BY THE LANDSCAPE ARCHITECT. THE PURPOSE FOR SELECTIVE THINNING IS TO MAXIMIZE THE AESTHETIC QUALITY OF THE CREEK AND THE ARCHITECTURAL SETTING, WITHOUT COMPROMISING THE ECOLOGICAL INTEGRITY OF THE RIPARIAN ZONE.

EXISTING INVASIVE EXOTIC SPECIES TO BE REMOVED:

Cynodon dactylon	Bermudagrass
Euonymus fortunei	Creeping Euonymus
Hedera helix	English Ivy
Lespedeza cuneata	Sericea Lespedeza
Ligustrum sinensis	Chinese Privet
Lonicera japonica	Japanese Honeysuckle
Pyrus calleryana 'Bradford'	Bradford Pear
Vicia sp.	Vetch

AESTHETIC IMPROVEMENT OF EX.RIPRAP

RIPRAP WILL REMAIN IN PLACE EXCEPT FOR IN AREAS DESIGNATED BY THE LANDSCAPE ARCHITERCT. PLANTING PITS WILL BE CREATED BY REMOVING SMALL AREAS OFRIPRAP AND FILLING WITH APPROVED SOIL. THE UNDISTURBED RIPRAP WILL BE COVERED WITH A BLANKET OF APPROVED SOIL, THEN PLANTED WITH NATIVE VINES THAT WILL EVENTUALLY HIDE THE ROCK.

HTML Building Riparian Restoration - ORNL

Environmental Landscape Plan

Conceptual Master Plan

Environmental Landscape Design Associates (ELDA)

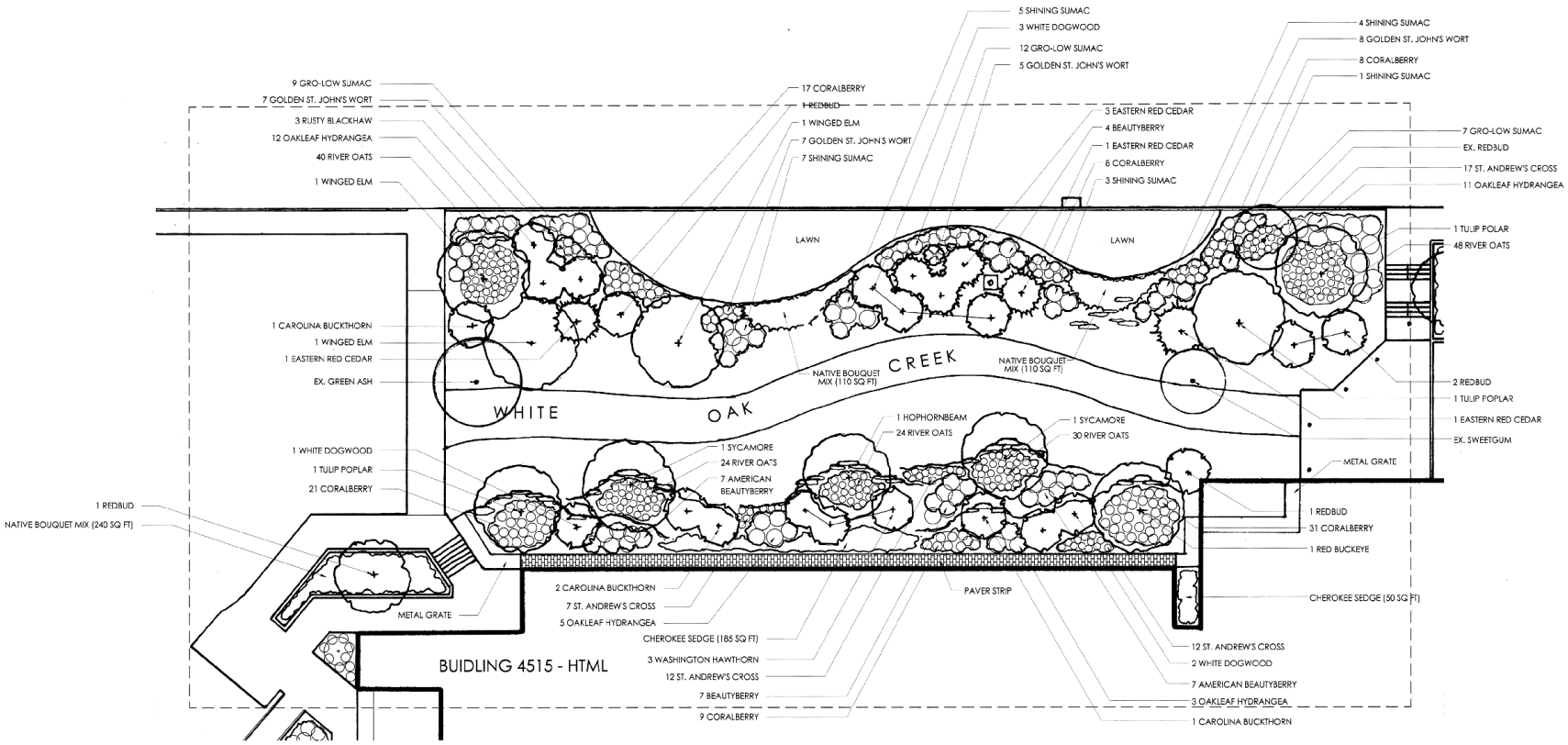
Prepared by:
Sam Rogers, ASLA, RLA
Leah Gardner, MLA

SAMUEL M. ROGERS
REGISTERED
TENNESSEE, U.S.A.
LANDSCAPE ARCHITECT

Prepared 09/30/08

0' 20' 40'

Sheet 1 of 4



PLANT LIST

SCIENTIFIC NAME	COMMON NAME	QUANTITY	SIZE
TREES			
Aesculus pavia	RED BUCKEYE	1	3-4' BB
Cercis canadensis	EASTERN REDBUD (CLUMP)	5	4-5' BB
Cornus florida	WHITE DOGWOOD	6	4-5' BB
Crataegus phaenopyrum	WASHINGTON HAWTHORN	3	4-5' BB
Juniperus virginiana	EASTERN RED CEDAR	6	5-6' BB
Liriodendron tulipifera	TULIP POPLAR	3	6-8' BB
Ostrya virginiana	HOPHORNBEAM	1	5-6' BB
Platanus occidentalis	SYCAMORE	2	6-8' BB
Rhamnus caroliniana	CAROLINA BUCKTHORN	4	4-5' BB
Ulmus alata	WINGED ELM	3	4-5' BB
Viburnum rufidulum	RUSTY BLACKHAW	3	3-4' BB
SHRUBS			
Callicarpa americana	AMERICAN BEAUTYBERRY	25	2-3' BB
Hydrangea quercifolia	OAKLEAF HYDRANGEA	41	3 GAL
Hypericum frondosum	GOLDEN ST. JOHN'S WORT	27	2 GAL
Rhus aromatica 'Gro-low'	GRO-LOW SUMAC	28	2 GAL
Rhus copallina	SHINING SUMAC	20	3-4' BB
Symphoricarpos orbiculatus	CORALBERRY	94	1 GAL

SCIENTIFIC NAME	COMMON NAME	QUANTITY	SIZE
HERBACEOUS LAYER			
Carex cherokeensis	CHEROKEE SEDGE	235	PLUG
Chasmanthium latifolium	RIVER OATS	166	1 GAL
Hypericum hypericoides	ST. ANDREW'S CROSS	48	1 GAL
NATIVE BOUQUET MIX			
Asclepias tuberosa	BUTTERFLY WEED	50	PLUG
Coreopsis lanceolata	LANCELEAF COREOPSIS	50	PLUG
Echinacea purpurea	PURPLE CONEFLOWER	50	PLUG
Liatris spicata	DENSE BLAZINGSTAR	50	PLUG
Liatris squarrosa	SCALY BLAZINGSTAR	50	PLUG
Penstemon digitalis	FOXGLOVE BEARDTONGUE	50	PLUG
Ratibida pinnata	PRAIRIE CONEFLOWER	50	PLUG
Rudbeckia fulgida	BLACK-EYED SUSAN	50	PLUG
Schyzachirium scoparium	LITTLE BLUESTEM	50	PLUG
NATIVE VINES			
Bignonia capreolata	CROSSVINE	1	1 GAL
Lonicera sempervirens	CORAL HONEYSUCKLE	1	1 GAL
Parthenicissus quinquefolia	VIRGINIA CREEPER	1	1 GAL

* NATIVE VINE PLANTING LOCATIONS DESIGNATED IN THE FIELD BY LANDSCAPE ARCHITECT

HTML Building Riparian Restoration - ORNL

Environmental Landscape Plan

Planting Plan - Window A

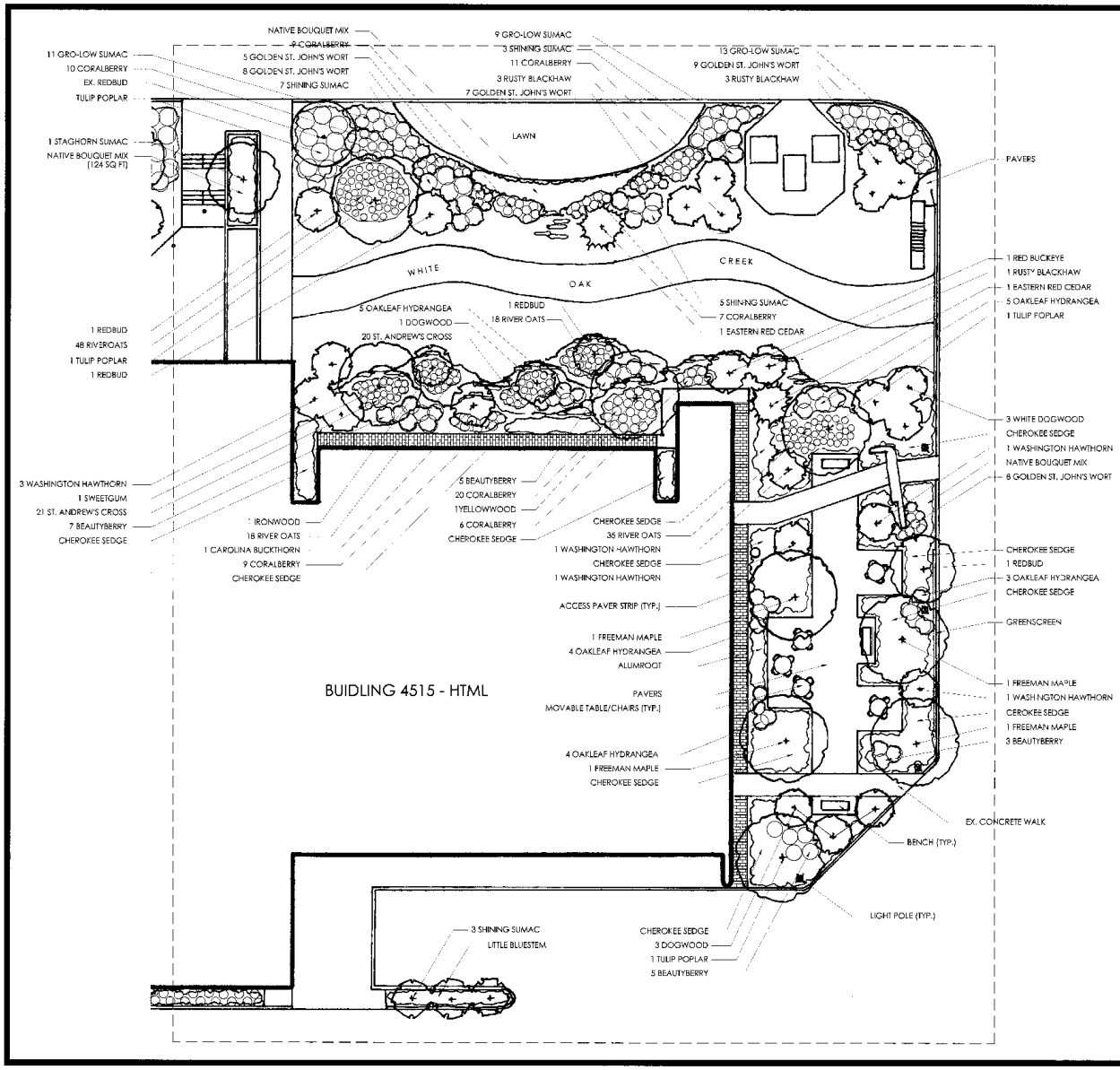
Environmental Landscape Design Associates (ELDA)

Prepared by:
Sam Rogers, ASLA, RLA
Leah Gardner, MLA

Prepared 090308

0' 10' 20'

Sheet **2** of **4**



PLANT LIST

SCIENTIFIC NAME	COMMON NAME	QUANTITY	SIZE
TREES			
Acer freemanii	FREEMAN MAPLE	4	6-8' BB
Aesculus pavia	RED BUCKEYE	1	3-4' BB
Carpinus caroliniana	IRONWOOD	1	5-6' BB
Cercis canadensis	EASTERN REDBUD (CLUMP)	4	4-5' BB
Cladrastis lutea	YELLOWWOOD	1	5-6' BB
Cornus florida	WHITE DOGWOOD	7	4-5' BB
Crataegus phaenopyrum	WASHINGTON HAWTHORN	7	4-5' BB
Juniperus virginiana	EASTERN RED CEDAR	2	5-6' BB
Liquidambar styraciflua	SWEETGUM	1	6-8' BB
Liriodendron tulipifera	TULIP POPLAR	4	6-8' BB
Rhamnus caroliniana	CAROLINA BUCKTHORN	1	3-4' BB
Viburnum rufidulum	RUSTY BLACKHAW	7	3-4' BB
SHRUBS			
Callicarpa americana	AMERICAN BEAUTYBERRY	20	2-3' BB
Hydrangea quercifolia	OAKLEAF HYDRANGEA	21	2-3' BB
Hypericum frandosum	GOLDEN ST. JOHN'S WORT	37	2 GAL
Rhus aromatica 'Gro-low'	GRO-LOW SUMAC	33	2 GAL
Rhus copallina	SHINING SUMAC	20	3-4' BB
Rhus typhina	STAGHORN SUMAC	1	5-6' BB
Symphoricarpos orbiculatus	CORALBERRY	82	1 GAL
HERBACEOUS LAYER			
Carex cherokeensis	CHEROKEE SEDGE	82	PLUG
Chasmanthium latifolium	RIVER OATS	71	1 GAL
Hypericum hypericoides	ST. ANDREW'S CROSS	41	1 GAL
NATIVE BOUQUET MIX			
Asclepias tuberosa	BUTTERFLY WEED		PLUG
Coreopsis lanceolata	BUTTERFLY WEED		PLUG
Echinacea purpurea	PURPLE CONEFLOWER		PLUG
Liatris spicata	DENSE BLAZINGSTAR		PLUG
Liatris squarrosa	SCALY BLAZINGSTAR		PLUG
Penstemon digitalis	FOGLOVE BEARDTONGUE		PLUG
Ratibida pinnata	PRAIRIE CONEFLOWER		PLUG
Rudbeckia fulgida	BLACK-EYED SUSAN		PLUG
Schyzachirium scoparium	LITTLE BLUESTEM		PLUG
VINES			
Bignonia capreolata	CROSSVINE		1 GAL
Lonicera sempervirens	CORAL HONEYSUCKLE		1 GAL
Parthenicissus quinquefolia	VIRGINIA CREEPER		1 GAL

* NATIVE VINE PLANTING LOCATIONS DESIGNATED IN THE FIELD BY LANDSCAPE ARCHITECT

HTML Building Riparian Restoration - ORNL

Environmental Landscape Plan

Planting Plan - Window B

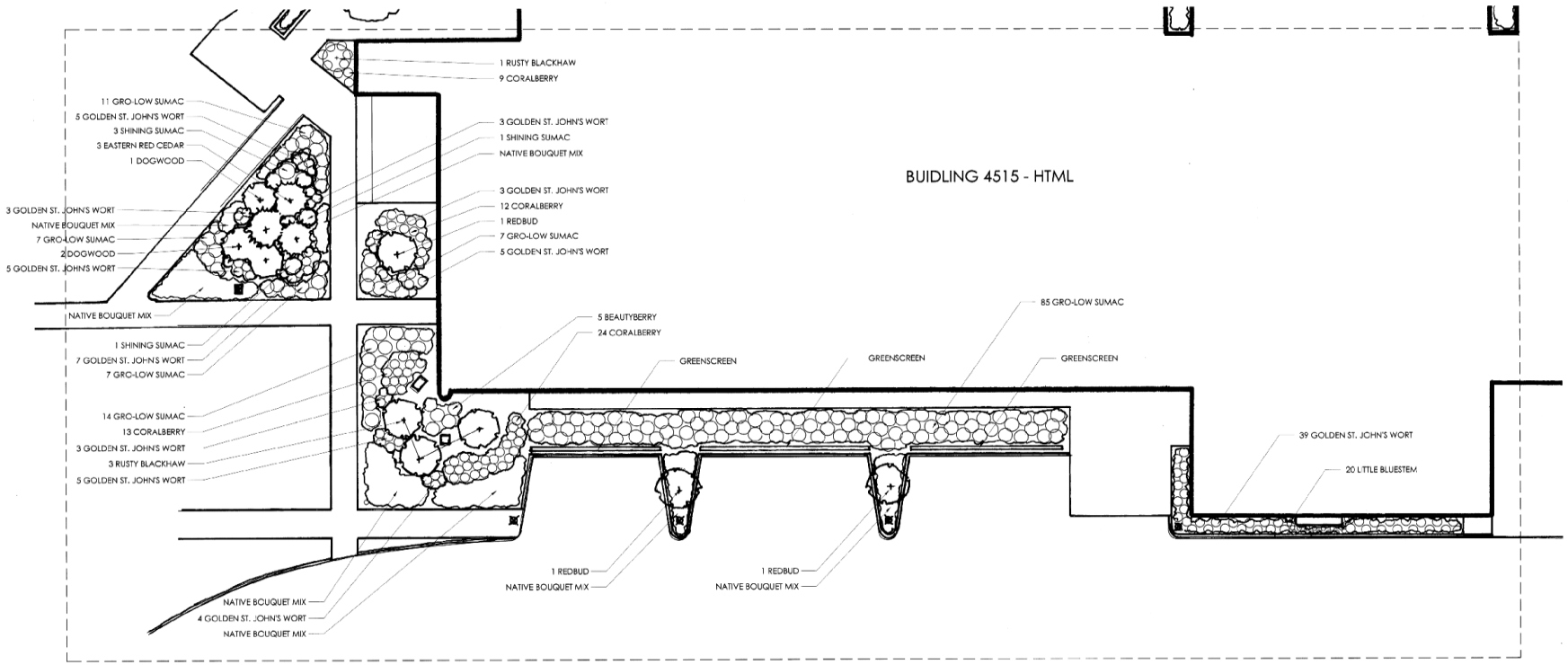
Environmental Landscape Design Associates (ELDA)

Prepared by:
Sam Rogers, ASLA, RLA
Leah Gardner, MLA

Prepared 093008

0' 10' 20'

Sheet 3 of 4



PLANT LIST

SCIENTIFIC NAME	COMMON NAME	QUANTITY	SIZE
TREES			
Cercis canadensis	EASTERN REDBUD (CLUMP)	3	4-5' BB
Cornus florida	WHITE DOGWOOD	3	4-5' BB
Juniperus virginiana	EASTERN RED CEDAR	3	5-6' BB
Viburnum rufidulum	RUSTY BLACKHAW	4	3-4' BB
SHRUBS			
Callicarpa americana	AMERICAN BEAUTYBERRY	5	2-3' BB
Hypericum frondosum	GOLDEN ST. JOHN'S WORT	82	2 GAL
Rhus aromatica 'Gro-low'	GRO-LOW SUMAC	131	2 GAL
Rhus copallina	SHINING SUMAC	5	3-4' BB
Symphoricarpos orbiculatus	CORALBERRY	58	1 GAL

* NATIVE VINE PLANTING LOCATIONS DESIGNATED IN THE FIELD BY LANDSCAPE ARCHITECT

SCIENTIFIC NAME	COMMON NAME	QUANTITY	SIZE
NATIVE BOUQUET MIX			
Asclepias tuberosa	BUTTERFLY WEED	70	PLUG
Coreopsis lanceolata	BUTTERFLY WEED	70	PLUG
Echinacea purpurea	PURPLE CONEFLOWER	70	PLUG
Liatris spicata	DENSE BLAZINGSTAR	70	PLUG
Liatris squarrosa	SCALY BLAZINGSTAR	70	PLUG
Penstemon digitalis	FOGLOVE BEARDTONGUE	70	PLUG
Ratibida pinnata	PRAIRIE CONEFLOWER	70	PLUG
Rudbeckia fulgida	BLACK-EYED SUSAN	70	PLUG
Schyzachirium scoparium	LITTLE BLUESTEM	70	PLUG
	LITTLE BLUESTEM	20	1 GAL
VINES			
Bignonia capreolata	CROSSVINE		1 GAL
Lonicera sempervirens	CORAL HONEYSUCKLE		1 GAL
Parthenocissus quinquefolia	VIRGINIA CREEPER		1 GAL

HTML Building Riparian Restoration - ORNL

Environmental Landscape Plan

Planting Plan - Window C

Environmental Landscape Design Associates (ELDA)

Prepared by:
Sam Rogers, ASLA, RLA
Leah Gardner, MLA

Prepared 093008

0' 10' 20'

Sheet **4** of **4**