Teaching How Water Works: Informal Science Education through Exhibit Design

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The mission of the Crosby Arboretum, Mississippi State University Extension (located in Picayune, Miss.), is to preserve, protect and display plants and their communities native to the Pearl River Drainage Basin. The Crosby Arboretum's nationally award-winning master plan has designated a portion of its facility for the creation of a small stream swamp forest educational exhibit. Small stream swamp forests are wetlands situated on bottomlands of small streams that are predominated in species type and frequency by black gum (*Nyssa biflora*) and sweet bay magnolia (*Magnolia virginiana*). As specified in Mississippi's Comprehensive Wildlife Conservation Strategy by the Mississippi Department of Wildlife and Fisheries (MDWF), small stream swamp forests are considered vulnerable in the state of Mississippi. The proposed swamp forest exhibit will address MDWF priorities through the construction and management of the habitat type, as well as providing a venue for public education and experience in this vulnerable forest.

The Crosby Arboretum Foundation was awarded a grant to create a small stream forest educational exhibit. Graduate students in the Department of Landscape Architecture at Mississippi State University utilized a semester-long class project in spring 2011 to research and design the proposed exhibit. Students conducted a literature search on small streams and related wetlands and visited several in situ small stream swamps in Mississippi. Students recorded environmental data at the natural wetlands to inform the restoration design. Students also conducted an environmental inventory and analysis at the proposed exhibit site that recorded the site's hydrology patterns, plant species, soils and other data. A design charrette, or a collaborative session to determine solution to the design problem, was conducted with wetland specialists and landscape architects to develop the preliminary design. This paper will discuss the method used to develop the exhibit design and will exhibit the drawings for the proposed stream and associated wetland types. Long-term vegetation monitoring will be initiated after construction.

INTRODUCTION

Ecological restoration is defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (Society for Ecological Restoration, 2013). Restoration ecology, or the study of the restorative process, was defined in the late 1980's at the University of Wisconsin-Madison (Jordan, Guilpin, Aber 1987). Ecological restoration strives to return a landscape as close as possible to its original undisturbed state, prior to human disturbance (NRC 1992). It incorporates advanced techniques of estimating abundance, estimating spatial patterns and dispersion, and experimental designs (Krebs 1998). The challenges to this goal include that the conditions of this pristine condition may not be known (Hobbs and Norton 1996), or that the original state may no longer be attainable due to recent environmental changes (Waal et. al 1998). Nassauer and Opdam (2007) note one other important challenge: That even though science has made great strides in understanding natural process for a variety of landscapes and their resulting patterns, there has been one obvious flaw: this increased understanding has made little inroads into the public decision-making process (Nassauer and Opdam 2007). Instead, they argue, that science must incorporate design to result in patterns that are valued by society. Cur-

rent ecological design methods are science-based and often center upon solving the hydrological functions in restoration projects. But in public landscapes, particularly in a today's pluralistic society, solving hydrological functions is often not enough. Eric Higgs noted in his 1997 article in Conservation Biology that ecological restoration "requires an expanded view that includes historical, social, cultural, political, aesthetic, and moral aspects." In 1994, a group of experts from the National Renewable Energy Laboratory developed the Sanborn Principles of Sustainability which adds one more important quality, that ecological design should be "beautiful." (Harwood et al 1994).

The landscape architecture firm of Andropogon Associates, located in Philadelphia, Pennsylvania, Ltd. is a noted firm for their merging of natural process and designed patterns. Founded in 1982 by a team of landscape architects, biologists, and engineers, the firm studied natural plant communities for their abstraction into designed landscapes for a variety of land use applications. In order to assess the spatial qualities of natural forested landscapes, the author tested a methodology in 1990 that combined the landscape determinants utilized by several landscape architects that were working on the Crosby Arboretum Master Plan, including Andropogon Associates, and Mississippi landscape architects Robert Poore, and Edward Blake, Jr. This method combines the understanding of the physical process of a landscape with the spatial patterns that occur (Brzuszek 1990).

The process and patterns elements include:

1. Process. This assesses how the natural area may have been formed through physical, biological and cultural effects.
   a. The physical environment concerns the geology, soils, hydrology, and climate.
   b. The biological focuses on vegetative and faunal species present and stages of plant succession.
   c. Cultural effects concern the impact of the natural area by human disturbance including pollution, recreational activities, and ownership.
2. Spatial patterns. The study of spatial patterns determines the mass and void of the environment and the elements that occur within those spaces.
   a. The spaces are analyzed by determining the vertical layers of the forest (canopy, understory, shrubs and groundlayer), and the horizontal layout (degree of openness or enclosure along a transect).
   b. The elements refers to the design principles and elements that are typically experienced within the given plant community. Artistic design principles include balance, proportion, rhythm, emphasis, scale and unity. Design elements include point; line; form, shape and space; movement; color; pattern; and texture (Jirousek 1995).
   c. Personal interpretation is a subjective assessment that identifies the intuitive feelings that are experienced within a natural area.
   d. Edges or ecotones. The transition from one plant community to another (road edge, inner edges, etc.).

In this paper, I will discuss how we applied specific design principles and elements as part of a methodology that also integrates site physical and biological research. While this paper does not comprehensively assess all of the landscape and spatial processes as mentioned in the above mentioned method, it does make a place for accepted design criteria to be included alongside the research process. This paper will explore these concepts through a case study for the Forested Stream Exhibit at the Crosby Arboretum.

THE CROSBY ARBORETUM

The Crosby Arboretum, located in Picayune, Mississippi, began in 1980 with a mission of "preserving, protecting, and displaying the native plants and their communities of the Pearl River Drainage System" The Pearl River is a 444-mile long major wa-

tershed in western Mississippi that encompasses the lands of the Crosby Arboretum. The Crosby Arboretum was established as a living memorial to South Mississippi timber pioneer and philanthropist L.O. Crosby, Jr. In addition to its 64-acre public Interpretive site named Pinecote, the Crosby Arboretum would research and manage seven different natural areas comprised of approximately 700 acres. The natural areas fulfills the Arboretum's mission of preserving and protecting local plant communities and also served as inspiration in order to create Pinecote's plant community exhibits. These lands provide habitats for 300 native plant species and animals, some of which are endangered or threatened.

After being logged of its virgin timber sometime prior to 1930, Pinecote was a working strawberry farm that once encompassed one section of land (640 acres). A few years after being farmed, the land was replanted in pine trees and became one of the state's first reforestation efforts. The land was maintained as a pine plantation (which uses prescribed fire to control woody undergrowth) into the 1980s, until it was designated as Pinecote, the Crosby Arboretum Interpretive Center. In its early years the entire Arboretum site continued to be managed as a pine savanna landscape, with slash pine (*Pinus elliotti*), loblolly pine (*Pinus taeda*), and longleaf pine (*Pinus palustris*) as the dominant tree species, with an understory of grasses and wildflowers.

Andropogon Associates and Edward L. Blake, Jr. devised the conceptual designs that led to Pinecote's master plan, which received a national ASLA Honor Award in 1991 (ASLA 1991). The master plan for the Crosby Arboretum incorporates and improves the pre-existing savanna exhibit already occurring at the Interpretive Center site, but reduced the Savanna Exhibit acreage from 64 acres to 20 acres (Figure 1). Approximately 40 acres were dedicated to allow the savanna landscape to utilize natural vegetation succession to form the Woodland Exhibit, and approximately 4 acres to form the Aquatic Exhibits.

THE FORESTED STREAM EXHIBIT AT CROSBY ARBORETUM

The Crosby Arboretum Master Plan highlights water as an important educational feature to its visitors. The Master Plan identifies the construction of four main wetland exhibits that are based upon regional water features. These include a two-acre Beaver Pond Exhibit that abstracts the form and function of locally-occurring beaver ponds; a half-acre Slough Exhibit based upon local bayous; a one acre Gum Pond exhibit that features a Gulf Coast waterbody primarily composed of tupelo gum trees (*Nyssa sylvatica var. biflora*), and a 970' small stream corridor entitled the Forested Stream Exihibit (Figure 2). The Piney Woods Lake, Slough, and Gum Pond Exhibits have already been constructed prior to 2011, and this paper concerns the design and construction using ecological principles for the Forested Stream Exhibit (previously identified on the plan as the Wetland Edge).

Small forested streams are common wetland features in the Piney Woods landscape. These narrow first-order waterways collect water and distribute them to larger creeks and streams and play an important role in the health of local watersheds. Some of the associated features along small forested streams are important, such as the lowland depressions that occur adjacent to these creeks. Prior to being farmed in the 1930s, botanist Dr. McDaniel classified the exhibit area as a wet pine flatwood. Pine flatwoods range from Florida to Louisiana and are common landscape features along the Gulf Coast. More accurately known as the East Gulf Coastal Plain near-coast pine flatwood, these landscapes have low, flat land and poorly drained soils. The Forested Stream Exhibit is designed to occur within approximately four acres of a current wooded exhibit (approximately 30 years of successional growth), and will connect the Gum Pond Exhibit in the northern part of the site to the Slough and Beaver Pond to the south. This wetland exhibit will create habitat for fish, amphibians, reptiles, and birds that are indigenous to the Pearl River Drainage Basin, and will offer an opportunity to teach visitors about the importance of forested wetlands

by demonstrating the value of its functions.

APPROACH

In spring 2011, a graduate class in the department of landscape architecture at Mississippi State University, was assigned by the author the task of conducting the research and to develop the conceptual designs for the Forested Stream Exhibit. The semester-long project consisted of studying the research literature for small streams and stream restoration; site visits to small streams near the Arboretum site to measure and map their wetland configurations; study the plant species and spatial configurations of small stream corridors; to host a design charrette (which was facilitated by Duane Dietz and Karen Smith from Jones and Jones, Seattle, WA) to consider possible conceptual designs; and the resolution of conceptual ideas into a proposed exhibit design. To fund the exhibit construction, a federal grant was applied for and awarded through the National Fish and Wildlife Foundation's 5-Star Grant. The grant awarded $38,870 with a complementary match by the Crosby Arboretum and its partners, and the period required construction of the exhibit to be completed by June 2013.

RESULTS

Hydrology

The Forested Stream Exhibit area has traditionally served as a drainage corridor for the surrounding landscape. It is the valley between two sand ridges that occur to the east and west and has historically served as a first-order stream corridor. After the site was farmed in the 1930s, the land was ditched to allow the land to be more productive, and a small farm road was built through the exhibit site. Remnants of the old farm ditches are still present on the site and serve as the area's primary drainage channels. Students that visited the site after a rain event had noted the hydrological flow as: "After a significant rain event, it is observed the route of water flow on the site from the newly constructed gum-pond to the north to the beginning of the slough to the south" (Figure 3 Lackey and English 2011).

Design Spatial Patterns

Art elements and principles can be interpreted by designers near natural small streams. While there is some degree of presence of all design principles (balance, proportion, rhythm, emphasis, and unity) and elements (point, line, form, shape and space, movement, color, pattern, and texture) found within areas of small streams studied, the artistic elements such as line and rhythm were found to dominate the Small Forested Stream landscape type more strongly than others.

Line. Line is one of the more apparent design elements of a channelized water system. Most small streams have a clearly defined bank edge where the water travels, except in the occasional times when it overflows its edges (Figure 4). While the water level to a small stream varies widely in depth throughout the year, there is often an average water level. When a stream overflows its banks and begins to flood its surrounding area it is termed 'bankfull' (Dunne and Leopold 1978). An established stream has a defined bank edge that is apparent even when it is dry (Figure 5). Stream lines are horizontal features on the ground plane that contrast or complement other lines in the landscape. These include the strongly vertical lines of adjacent mature trees.

Local geology, topography, and the age of the stream can determine the form of the line. Steep mountain valleys feature streams and creeks with straight runs; while those in fairly flat floodplains meander through the landscape. The age of the stream can also determine the form of the waterway. Small water courses that recently formed can resemble a more channelized pattern, while those that are older have meanders and curves. Each of these line forms create a different emotional experience for the viewer, as straight streams provide a distant vanishing point and meandering streams create a sense of mystery as to what is around the next bend.

Rhythm. Rhythm is a design principle that reflects organized movement within a composition. Many

natural features create a sense of rhythm, including tree trunks in a dense forest. Tree trunks without shrub layers allow an open vista that reveals a repetitive element in a scene. These components can vary widely in material and form, and can include mass flowering and other vegetation, water, ant hills, and even rocks or snow patterns. Rhythm carries the eye across the landscape scene, and can help to unify a landscape of many diverse materials and forms. In a forested system, a creek becomes a contrast as it is a different material from the surrounding vegetation, rocks or soil. But it also serves importantly as a rhythmic item which literally flows from one part of the landscape scene to the next. Thus the eye winds along the channel and serves as the primary focal point to the surrounding matrix.

Scale. The size of a landscape element in proportion to its surrounding features is an important principle of design. Small creek systems not only need to serve their hydrological role, but also serve their aesthetic parameters. The in situ small streams in south Mississippi that served as reference sites for the exhibit ranged from 3 feet in width of the stream channel to a maximum of 8 feet. Streams and creeks in excess of 8 feet wide often changed to a second-order stream type. Similarly, the most shallow stream depth encountered was 6 inches and a maximum of 3 feet. These stream sizes are determined by the volume of water handled (size of watershed and local precipitation amounts), and the maximal flow rates. Local geologic changes, erosion, or shifts in soil type can create changes in stream channel depth, and can widely vary along stream channels. Importantly, the size of the first-order stream channel should not dominate or overwhelm the landscape; but instead act as a smaller thread that is subordinate to the greater landscape features.

SUMMARY OF RESULTS

Steps in the traditional ecological restoration process were used in the design of this project, yet the additional study of spatial considerations and design elements and principles in natural small order streams was useful to result in better exhibit aesthetics. Line, rhythm and scale are by far the strongest design elements and principles encountered along natural stream channels in south Mississippi. Line, or the defined channel of the stream corridor, is a dominant landscape feature whether the channel is full or water or dry. The channel creates a topographic change in a relatively flat landscape that is in its own way—dramatic. The implementation of a line in the landscape creates a contrast to the surrounding matrix. Line creates a rhythmic element in the landscape, especially when it encompasses nearly 1,000 linear feet of exhibit area. Here the visitor will encounter the stream channel repeatedly throughout the space, and becomes one of the few consistent repetitive patterns in a very divergent vegetation type. The form of the lines studied in natural streams gives an overall idea of stream exhibit pattern. While the natural stream shapes will not be literally transcribed onto the Arboretum site, it does give a better definition to stream form. Similarly, understanding the scale parameters for the stream exhibit allows a better comprehension of stream size. Documenting the ranges of stream widths and depths gives the designer the latitudes in which to work to determine exhibit channel sizes for specific locations.

EXHIBIT LAYOUT AND CONSTRUCTION

With the conclusion of the class project in May 2011, which established the conceptual ideas for the Forested Stream Exhibit design, the author then further developed the site design details and construction documents. Since there already were mature trees located within the proposed stream corridor design, the centerline of the stream was studied and adjusted to minimize the removal of large pines and hardwoods. While the re-design still follows the general hydrological route of the major drainage corridor, it was then manipulated to weave around the large trees and other plant features. The proposed stream edges were then staked to mark their locations and then evaluated over a period of time for adjustments.

With the stream layout established, the next phase was to develop the widths and depths of the

corridor itself. These were determined by looking at depths and widths of similarly sized streams in nature and to integrate into the scale of the exhibit environment. The stream edge stakes were adjusted to reflect the final stream widths. The stream widths were also determined by the width of the construction equipment that will be used in constructing the stream exhibit. To minimize construction impacts to the surrounding environment the stream excavation and haul routes were required to stay within the stream corridor banks itself.

It is at this level of site design where the design elements and principles can be utilized by the designer. For example, small streams primarily utilize the design element of line. The construction of a stream creates a new horizontal line in the site. Placement of the line must work with other elements in the area, including the vertical lines of trees or vines (Figure 6). Design of the stream channel takes into account a multitude of attributes that affect the experience of the future visitor, including changes in canopy tree light levels, bringing the visitor to experience interesting trees and other existing natural phenomena, and pathway connections to other exhibits.

CONSTRUCTION

After a review of the project proposal by the U.S. Army Corps of Engineers, construction for the exhibit began in October 2012. The few small trees that required removal from the stream corridor were cut and stream excavation began. The majority of the stream channel was dug by mid-November (Figure 7). By November 15, substantial rains occurred at the exhibit site and prevented exhibit completion until Spring 2013 when the soils were once again conducive to excavation.

Future design work will include the layout and construction of exhibit trails, and the architectural elements of all bridges, pavilions, seating areas, interpretive signs, and gather spaces. Designs for these elements are scheduled to be completed in Spring 2013.

DISCUSSION

This paper describes an approach to wetland exhibit design at an established ecologically-designed arboretum in the southern United States. The methodology used to develop the exhibit combined ecological studies of natural reference sites to inform the design, but also allowed for a study and interpretation of design attributes. This combination of science and art can inform ecologically-designed landscapes to best function, hydrologically and for successful vegetative species placement, but also aesthetically to dramatically heighten the exhibit experience for the visitor. In this study, the design principles of rhythm and scale, and the design element of line were found to most dramatically impact the design and layout attributes of the Forested Stream Exhibit. By utilizing and applying these design tools, as inspired by natural landscapes, designers can bring heightened drama to constructed waterways and stream channels.

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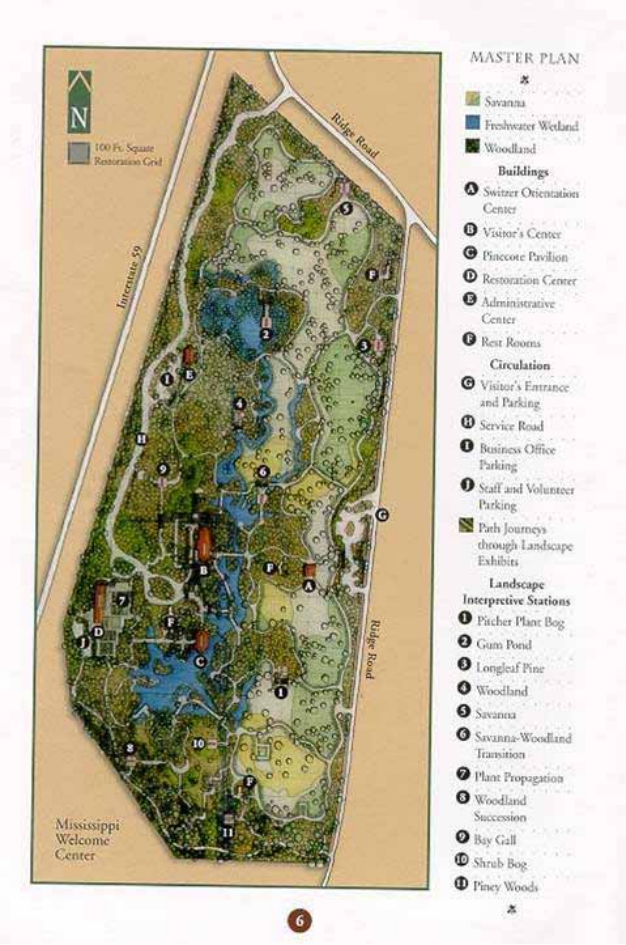

Figure 1: The Crosby Arboretum Master Plan (1994) shows the Arboretum's created plant community exhibits for savannas (20 acres), woodland (40 acres), and wetlands (4 acres).

Figure 2: The new Forested Stream Exhibit area incorporates a 970 linear feet constructed ephemeral stream.

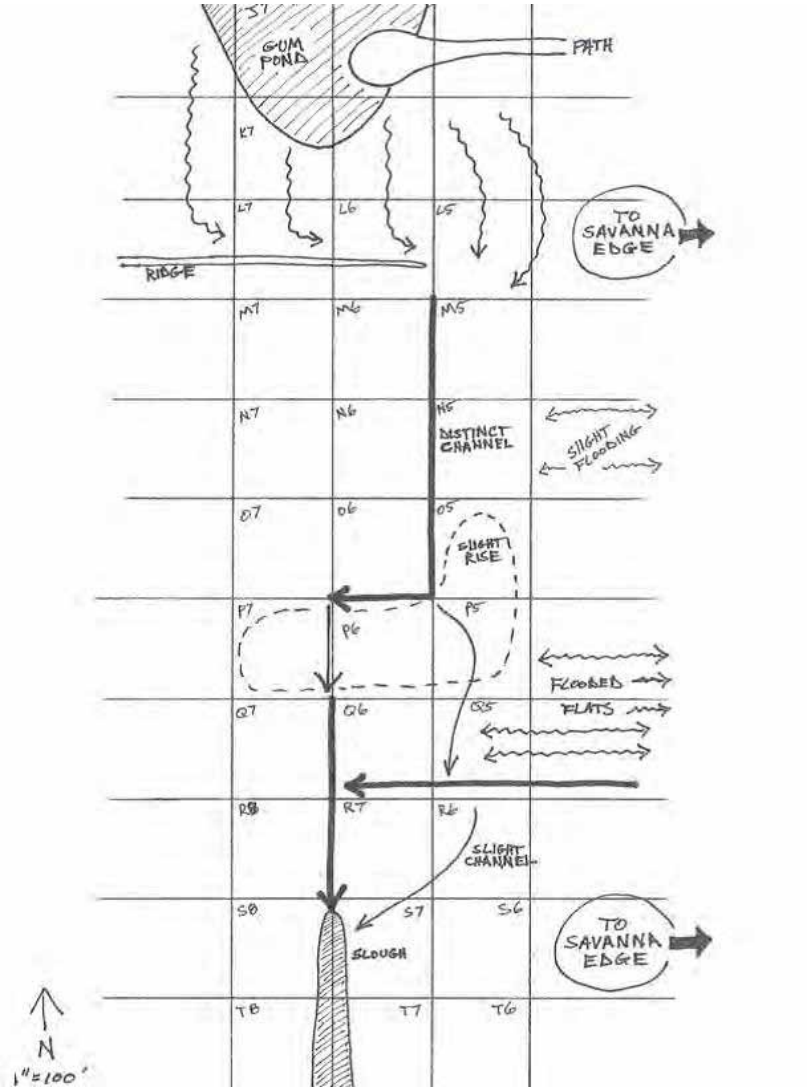

Figure 3: Students mapped the existing drainage patterns for the exhibit site.

Figure 4 (right). Studies of nearby streams provided the design elements inherent in natural waterbodies, such as the strong linear channels of bank edges.

Figure 5 (below). Stream bank widths and depths of small natural first-order channels informed the design of the exhibit.

Figure 6. This sketch by the author shows how the stream channel placement maximized the design composition and aesthetic potential for the constructed stream.

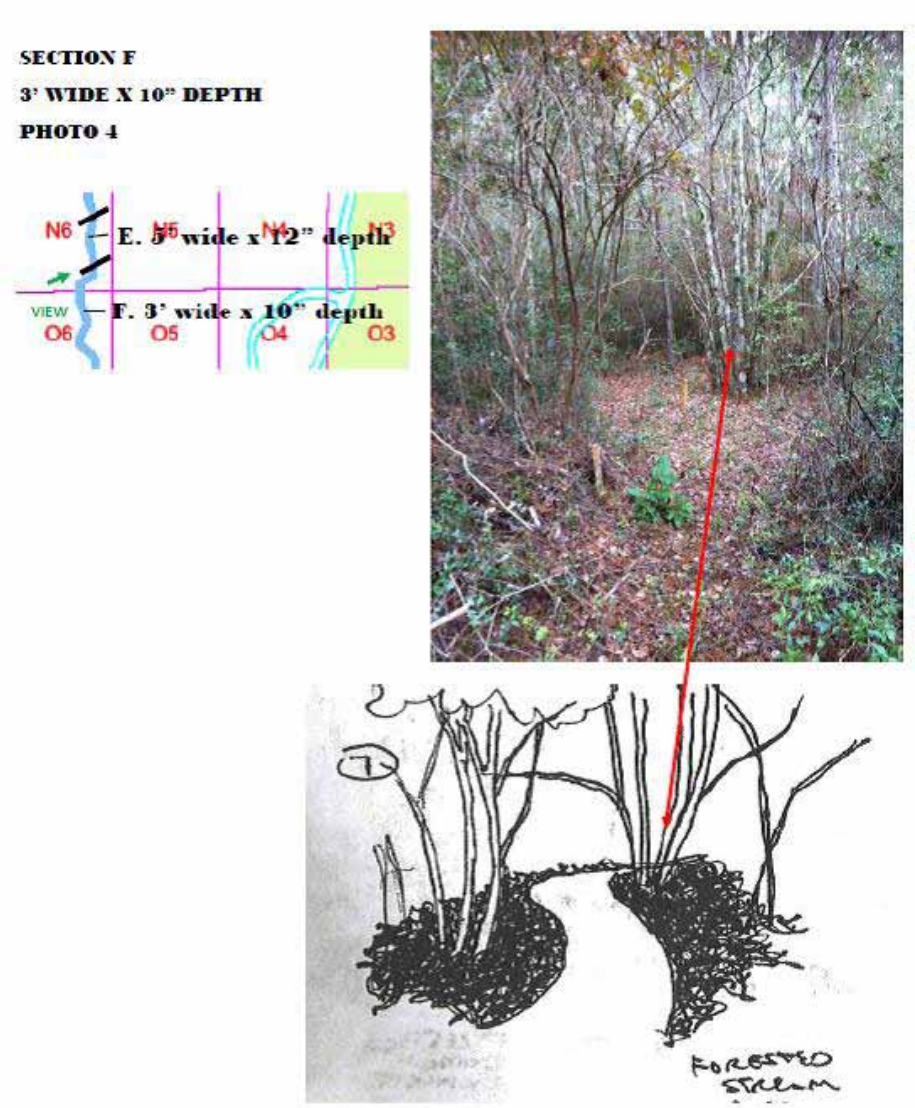

Figure 7. The first rain following channel construction displays the sinuous nature of the constructed stream exhibit.