Restoration Plan

for the

Knight's Hollow Restoration Project

Wayne County, Wooster, Ohio
May 2012

KNIGHT'S HOLLOW IN THE NEWLY ACQUIRED GALPIN PARK

Prepared by The College of Wooster's Restoration Ecology Class

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Background:

Knight's Hollow (Galpin Park) is a 1.2-acre plot of land that is the focus of this restoration project. It is located on the Northwest end of campus, on the intersection of East Wayne Avenue and North Bever Street. It was first acquired by the College of Wooster in 1925, when William A. Galpin donated it to the college. Even then, there was some discussion about renovating the park for aesthetic purposes.

Now, Knight's Hollow is a catchment basin for runoff around the College of Wooster, and for 35 blocks upstream. This leads to sudden, unpredictable flooding, and likely carries with it much pollution. It is heavily impacted by invasive species (especially privet and garlic mustard) which have crowded out most of the native riparian vegetation. While removing invasives and creating a more stable hydrological regime are important, any changes made to the site must be consistent with its continued use as a stormwater catchment area.

Executive Summary:

This plan aims to restore the ecological value of Knight's Hollow by addressing various facets of the site. This plan will help restore the ecological, hydrological and cultural value of the park. This goal will be achieved by addressing various issues in the site, either by obtaining more information on a possible problem, or by directly altering the site. The site is periodically flooded and parts of the site are threatened by erosion. We aim to monitor the water flow patterns of the site and reduce erosion in areas affected by high velocity water with synthetic and biodegradable measures. It is likely that the site is impacted by pulses of pollution with the periodic flooding that this region receives. Pollutants may damage the biodiversity and ecological function of the area. We aim to reduce the pollution at the site through phytoremediation, possibly changed streamflow and community education. Knight's Hollow is dominated by invasive plants, and has poor biodiversity in general. The site contains many invasive species, including Japanese Knotweed, (*Polygonum cuspidatum*), privet (*Ligustrum sp.*), garlic mustard (*Alliaria petiolata*), ivy (*Hedera sp.*) and vinca (*Vinca minor*). We aim to increase native plant populations and reduce the number of targeted invasives by introduction and removal.

These facets of the site all interrelate with one another. Avoiding erosion allows plant life to take root; plant roots in turn hold soil together; reducing pollution will allow for better biodiversity; increased plants may help to remove pollution. Finally, all aspects of the project should appeal to the aesthetic ideals of the people who will access, maintain, and benefit from this site. For the long term success of this project, the community must be involved and engaged. People provide the creative energy and the effort to . Finally, even those not actively engaged in restoration benefit from increased education about the natural world.

Thus, our plan consists of four major goals. First, we must incorporate and address the needs of stakeholders. Second, erosion must be controlled and water velocity regulated. Third, levels of water pollutants must be reduced, and fourth, biodiversity in the region should be maximized with a strong focus on maintaining native species. The success of our plan is dependent on active management, informed by continuous long-term monitoring.

Section 1: Community Involvement and Aesthetic Enrichment

1.1 Executive Summary

In order to ensure the long-term sustainability of this project, we must incorporate a plan to address the needs of the stakeholders and the surrounding community. While maintaining a commitment to biophysical restoration, the project should appeal to the aesthetic ideals of the people who will be accessing, maintaining, and benefiting from this site. Ecological restoration and the creation of an educational space will increase the value of Knight's Hollow to the surrounding community, and actively engaging the community will increase the chances of long-term monitoring and use. We will accomplish this by constructing an outdoor classroom, improving trails, posting informational signs, and involving college students, professors, and community members.

1.2 Goal and Background

We aim to improve the ecological and cultural value of knight's hollow. By improving the aesthetic and community value of the site, we will improve the overall goal of ecological restoration at the site. By involving and drawing people to Knight's Hollow we may ensure the long term success of the project. In this section, we describe the stakeholders and break our goals into five main areas of concern: community, college, outdoor classroom, accessibility and aesthetics.

Stakeholders

The College of Wooster and the local community are both stakeholders of this site. Kurt Holmes, the Dean of Students at the College of Wooster, has expressed that the main goal of the College is to improve the site’s accessibility so that professors might bring their classes there. Professors, the students in their classes, and student groups are also stakeholders on the campus. For the community, the primary stakeholders would be those who live within walking distance of Knight’s Hollow and any outdoor education youth groups, such as the local Cub Scout and Boy Scout troops.

Local Community

Our goal is to involve the local community to ensure long-term commitment and the success of project, and to create an opportunity for environmental education and outreach by improving the accessibility and aesthetic qualities of the area. It is important to include the community (1) to improve community/college relations (2) to provide an accessible outdoor recreational and educational area, and (3) to provide a space for teaching the importance of land stewardship to younger generations. Specifically, Galpin Park is a prime location for teaching storm water management and local watershed education, and creating an open education program there would improve synergy between the College of Wooster and the surrounding community. The College of Wooster has an easement on the site for the purposes of storm water management, and one of the Environmental Protection Agency's mandates is that the holder provide education about stormwater best management practices.

College

The goal is to develop a relationship between Knight’s Hollow and the professors and students of the College so that future classes in various departments may use Knight's Hollow as a research and education resource and carry on restoration efforts and maintenance at this site. Currently, our restoration ecology class is the only group on campus involved in this restoration effort. Sustainable, ongoing support for this project will have to come from a school-sponsored source beyond the scope of this class. Gaining campus-community level support will provide Knight’s Hollow with a continuous source of manpower for any and all ongoing restoration projects. The overall goal is to fully establish Knight’s Hollow as a potential research site for students, a source of service hours for students, and an element in the curriculums of several classes. These various groups will also help with ongoing maintenance of the site as determined by our other goals.

Outdoor Classroom

Our goal is to create an outdoor classroom space within Knight's Hollow, as requested by Dean Holmes and the College of Wooster administration. This classroom space will be made of all or mostly natural materials, such as large rocks (available for no cost from the college) and wood. However, it will ideally have some amount of power and wireless internet for classes to use. While adding wireless would probably be fairly easy, installing and maintaining the hardware necessary for electrical power will be more difficult, and may not be worth the cost. This classroom could also potentially be used as an outdoor space by the neighborhood. Constructing a classroom as part of the restoration process will encourage students, professors, and community members to spend more time in the Hollow. Hopefully, the people who use this classroom will appreciate Knight's Hollow as a natural space to be preserved (and/or further restored) in the future. Right now, there is an ideal potential outdoor classroom space located near the bottom of the Hollow, but well above the water level. However, this location may be hard for people with limited mobility to reach, since the trail is on the other side of the stream bed. The classroom area could be reached either by building a better trail on the other side of the Hollow or constructing a bridge across the stream bed. The stream bed next to the classroom area has been cut out by runoff from storms flowing through Knight's Hollow. To make sure the classroom is not damaged, this stream bed will need to be monitored for erosion, and fortified if erosion is occurring. Otherwise the side of the stream bed may expand and encroach into the classroom area. Even with the bank fortified against erosion, constructing a classroom will require the clearing and leveling of a small area. However, the limited damage to the environment caused by the classroom will be worth it if the classroom gets college and community members involved and invested in the restoration and preservation Knight's Hollow.

Accessibility: Trails

Accessibility is important for both community value and visual appeal. Accessibility has many benefits in a small, urban site such as Knight’s Hollow. Access to Knight’s Hollow would facilitate a number of valuable activities. Access to a site allows for experiential education in restoration or broader sciences to be conducted, provides an aesthetically pleasing area for general education and recreation, and supports community bonds by providing a space for social activities like restoration, research and volunteer projects (SER Primer). Dean Holmes, a representative of the college, suggested a bridge and improved trails. This would support greater involvement of the College of Wooster community in the site. The College would benefit from educational opportunities. By extension, the neighborhood community would benefit by having greater access to a natural area. Both permanent residents and college students already live within an easy walk from the site. A sidewalk abuts the western edge of the site, allowing pedestrians to reach Knight’s Hollow. Currently, there is a trail running along the northern edge of the site. The trail is ungraded, mulch bedded and has 2” by 4” pieces of wood to designate its edges. The trail was installed by a Boy Scout troop some years ago, demonstrating that the local community has or had an interest in the site. The western end of the trail leads out onto the sidewalk on N. Bever St. and the southern end of the trail leads out in a grassy open area with no trail or sidewalk next to E. Wayne Ave. This southern end does not have any indication that it is a trailhead and there is no sidewalk on E. Wayne. Cultural goals and restoration goals can support each other. By improving access to this site, the community at the College and the possibly the neighborhood community will have a greater involvement in the site. The site can serve as a place for anyone to learn about native and invasive species, water control and ecology in general. Knight's Hollow can be a site for recreation and education.

Aesthetics: Signs

Our goal is to open Knight's Hollow to the Wooster and campus community by creating a more welcoming space. Signs would acknowledge the existence of Knight's Hollow and increase community awareness of the area. Use of Knight's Hollow as a recreational area would increase, along with community values/connection to the area. This would also potentially increase the stakeholders/actors in our restoration project and prolong its lifespan and maintenance. Knight's Hollow was previously known as a part of Galpin Park, which was 8 acres of land donated by Mr. William A. Galpin in 1925. Historically, the area had a sign at one entrance, which said "Galpin Park" but it was damaged and never replaced. We would also like to make educational information accessible to the communities about the ecology and hydrology of the area and the species that live within it. This would increase community knowledge, interests, and use of the area. Historically, Knight's Hollow was a popular picnic site for Wooster students. Presently, it is hard to tell how many people within the campus and outer community know about and/or use Knight's Hollow. Talking to members of the class and some professors, it seems that not many people do know of its existence.

Education

Stakeholders of the site have education of the community as a goal for the site. ALl aspects of our plan should lead to that goal. Accessibility, aesthetics, signage and of course the outdoor classroom would all help to engage the community, give reason for people to enjoy and explore the site and help provide information to the community. The College, as an educational institute, of course has a goal of educating students. The site can assist in this goal, especially by providing a site for experiential education and exploration of topics in ecology, biology, geology and environmental sciences. The city has an interest in providing education on stormwater management: one of the Environmental Protection Agency's mandates is that the holder provide education about stormwater best management practices. Whether education comes in the form of continued restoration projects, courses that incorporate the site into their curriculum or simply people passing through Knight's Hollow and reading signs about the stream or the life in the area, education should be an outcome of our project.

1.3 Literature review:

Community

We would like to include the community (both from the College and the City of Wooster) in assessing the criteria for defining and assessing ecological restoration, as previous research (Palmer et. al, 2005; Hulse et. al, 2004; Mcdonald et. al, 2004) has found that utilizing the community leads to the best restoration outcomes in terms of meeting goals and overall community satisfaction. It is currently unclear how much is known about Knight's Hollow or how much it is used by the community, so a first step in increasing community awareness should be implementing a survey that can help answer these questions. Persuasive arguments have been shown to have little impact on respondent attitudes (Meadow et. al, 2005), so gauging community interest and figuring out where educational methods might be more useful would be a good technique in this situation. Knight's Hollow may not have any serious polarizing issues, it is always important to gauge community opinions and tread carefully around any sensitive issues that we may be unaware of or that might spring up.

Educational programs in both the broader town and the campus communities should be paramount to this project. Courses that utilize relevant and well-formulated experiential learning techniques, such as how Knight's Hollow has been used in this current Restoration Ecology course, have been found to have significant impacts on the learning achieved by students involved in those programs (Millenbah & Millspaugh, 2003; Domask, 2007). Some models, such as those produced by Geist and Galatowitsch (1999) and Donahue et. al (1998), suggest that community-based projects will be most successful when experts train the group in restoration decision making, when expertise and leadership are developed within the group, and when participants experience group cohesiveness and a sense of personal reward. This model also bridges the gap between environmental and human components of restoration and engages the concerns of diverse community members in multiple restoration approaches.
The primary concern we will have with developing these kinds of community and campus involvement initiatives will probably come from the location of the site. Many students and faculty on campus are unaware that Knight's Hollow even exists or that it is school property, and the area of people that contribute to the waste water that enters the site is much larger than the area of people that likely use the site. Surveys will help clarify exactly how Knight's Hollow is being used now, and which of these concerns are most founded. Determining how to continue site maintenance in all of its forms - from invasive species removal to community awareness programs - will definitely be a major factor as any restoration plans in Knight's Hollow move forward.

Outdoor Classroom

Outdoor classrooms have been successfully developed by many schools and universities across the country. The Fernbank Science Center in Stone Mountain, GA released a guide called "Developing an Outdoor Classroom to Provide Education Naturally" that explains basic procedures for establishing outdoor educational areas and their benefits. Many of these outdoor classrooms do not actually have constructed classroom facilities (including seating) like we plan to put in Knight's Hollow. However, outdoor educational areas are opportunities for younger students to learn about nature by interacting with it. Outdoor classroom areas that require restoration, such as Knight's Hollow, can provide educational experiences for older students through the restoration process. The Strawberry Creek urban riparian restoration project facilitated by the University of California, Berkley turned restoration process into an educational experience by recruiting local high school students to remove invasive plant species and plant natives under the guidance of UC graduate students (Purcell et al. 2007).

Accessibility: Trails

Accessibility to the site must balance the needs of the people entering the site and the needs of the ecological community. Walkways always damage a site by introducing a human element to a natural area. Ideally this damage is restricted only to the trail or any other walkways and is balanced by the benefits of community engagement and increasing people's awareness of restoration ecology.

Trails benefit a site in a number of ways. People benefit from the social experience of a public trail, from learning about history and ecology, and by being active on a trail (Wisconsin State Trails Network Plan, 2001). Urban trails can also give people access to nature who would typically not have that opportunity. A trail can help teach people about the environment and can make people appreciate their natural heritage (Ontario Ministry of Health Promotion, 2005).

All people should be allowed to benefit from getting out into nature. The American Disabilities Act requires pedestrian trails to accessible (American Trails, 2011). In Knight's Hollow the installation of a bridge would allow for equal access.

Finally, trails must minimize their potential damage to a site. Erosion, altered water flow and damage to plants are all possible. These can be avoided by good trail design and maintenance. Trails should be designed with awareness of the contour of the land and the flow of water as well as avoidance of trail widening, shortcuts and steep gradients (California State Parks and Rec). Trails should be sustainable, be made with awareness of the trail users, and have a maintenance plan (Tennessee Department of Environment and Conservation, 2007).

Aesthetics: Signs

The purpose of a sign according to the IDPR Sign Manual (2008) is "to communicate a specific message in a clear and concise manner to enhance the visitor's experience or protect a specific feature". Signs are used to "communicate, orient, direct, identify, inform, educate and protect" (IDPR Sign Manual). Also, signs raise public awareness (ECGA trail signage manual). Historically, Knight's Hollow had a sign at the entrance facing away from the campus and its supporting structure is still present. According to the NPS sign manual (1988), the entrance sign is noted as the most significant of all informational signs. This directs the visitor to the desired area. Signage is part an area's aesthetic and creates a more effective communication to the community (IDPR Sign Manual, 2008; ECGA trail signage manual). For our purpose, the entrance signs will indicate to both the campus and surrounding Wooster community that Knight's Hollow exists and is open for recreational use. The informational boards and species plaques would also increase the public's knowledge about the area. Presently, Knight's Hollow has accumulated lots of trash and debris due to dumping. A Protection and Regulation sign would serve as part of the regulation system to keep the area clean (NPS sign manual, 2008). Through this sign, forcible language is used and clearly stated to inform the public of how the area should be used.

1.4 Objectives and recommended plan:

Contributions of community involvement to other components of the restoration plan:

- Biodiversity – Both the local and campus community
    - Removal of invasives – short and long term
    - Planting seeds and seedlings for phytoremediation and increasing native population
- Hydrology – mostly the campus community (Geology department)
    - GIS and GPS
        - Monitoring stream path, flow velocity, suspended particulate content in water, water retention/expulsion rate
        - Monitoring erosion – general and outdoor classroom
- Pollution
    - Survey residents: chemical use
    - Educating the public about the harmful effects fertilizers/encouraging and incentivizing the use of fertilizers with lower nitrogen content.

STUDENT GROUPS OF INTEREST TO SITE:

- Greenhouse
- WOODS
- OneEarth
- Campus Sustainability Committee

PROFESSORS OF INTEREST TO THE SITE:

Department	Professor	Classes	Notes
Chemistry	Dr. Edmiston	CHEM 101: Chemistry and the World in Which We Live.	Interests: Advanced materials for water purification using swellable glass. Also founder of ABS, patent on Osorb.
Chemistry	Dr. Schultz	CHEM 101: Chemistry and the World in Which We Live. CHEM 216: Environmental Chemistry ENVS 200: Environmental Analysis and Action	Dr. Schultz said "I guess I would be interested." Probably best to contact her again at a later point when we have a more solid plan.
Biology	Dr. Strand	BIOL 200: Foundations of Biology BIOL 335: Microbiology	Willing to have students characterize microbes from Knight's Hollow for class next year (too late for this year)
Biology	Dr. Lehtinen	BIOL 311: Natural History of Vertebrates	Works with salamanders; says he has not worked in Knight's Hollow before
Env Studies	Dr. Mariola	ENVS 110: Science, Society, and Environment ENVS 205: Entrepreneurship and the Environment ENVS 230: Innovations in Agroecology Sociology of Agriculture	potentially interested in using the space for his classes, but thinks that restoration projects are probably more for the bio department
Geology	Dr. Wiles	GEOL 110: Environmental Geology Gemorphology and Environmental Hydrogeology	- has never used the space before, but would definitely consider doing so in the future with classes - expressed interest in putting a transducer and/or well point for data measurement - Dr. Wilson said there was some potential for fossils in the area and that the jointed

			sandstone outcrops could be helpful to a couple of his classes
Geology	Dr. Wilson	Sedimentology & Stratigraphy	
Religious Studies	Dr. Kammer	ENST 200: Environmental Analysis and Action	Very open to working with students, mostly interested in social justice.
Education	Dr. Broda	Environmental education	
English	Dr. Bourne	ENST 200: Environmental Analysis and Action Environmental writing	Interested in "creative nonfiction involving the environment" - teaches nature writing?
Psychology	Dr. Clayton	PSYC 225: Environmental Psychology	Major researcher in environmental & conservation psychology
Urban Studies	Dr. Burnell	Environmental and Natural Resource Economics Urban Revitalization and Sustainability	Not sure if he could really use our work, but another contact on the envs board
Sociology	Dr. Matsuzawa	SOCI 203: Environmental Sociology	
Philosophy	Dr. McBride	Environmental Ethics	
Political Science	Dr. Weaver		Currently on leave, but extremely interested and has previously researched watershed issues in Sugar Creek, and is also interested in how public perception impacts watershed project success
Biology	Dr. Sirot	BIOL 352: Behavioral Ecology (Animal Behavior), Natural History of Invertebrates	Willing to incorporate Knight's Hollow into her Inverts class.

Section 2. Hydrology

2.1 Executive Summary

The issue of hydrology is central to the restoration of the Knight's Hollow drainage basin area. The condition of the banks, the stream flow patterns, and groundwater movement will all affect the living environment of both current and new flora both above and within the drainage basin. Fast-moving, unpredictable stream patterns (which describe the current model) can cause irreversible damage to plants and soil. In order to keep the area both aesthetically pleasing and ecologically efficient, erosion must be carefully monitored and controlled, especially near the inlet and outlet drainage pipes. This will allow maintenance of an aesthetically pleasing environment where roots are not exposed, banks are stable and gently sloped and vegetated, and the stream travels relatively peacefully when it is present. It will also ensure the continued success of an outdoor space by preventing the substrate used by the public from eroding away. Previous work, while not abundant, is helpful in providing techniques for erosion control. For Knight's Hollow, a relatively small area, it makes the most sense to use a combination of synthetic materials where they already exist (e.g. at the inlet pipe) and biodegradable materials such as burlap for substrate support farther from the high velocity areas. Continuous monitoring for will be necessary until a pattern for filling and drainage has been established.

2.2 Goals and Background

Goal

The goals of this plan are to measure, define, and positively affect the hydrological regime through Knight's Hollow to create a fluvial pathway that does not erode away the natural stream banks, but which also does not have a greater potential of flooding the surrounding area above normal levels or arresting the natural flow in any way. This is important to preserve the area's natural attraction (prevent erosion and potential structural compromise), to protect the native flora growing on the banks, and to maintain the integrity of the surrounding terrain.

Impact

The achievement of our goal will mean better control on the flow parameters of the stream entering Knight's Hollow after substantial rainfall. It will also mean the preservation of important players in the biota (e.g. native plants) and more careful control of the storm water build up which, in turn, can cause breeding of mosquitoes and other undesirable organisms. This mitigation of erosion is essential to the continued survival and use of the park across multiple seasons. Thus anyone who uses the park, including the City of Wooster, the College of Wooster, and the general public, will benefit.

Current condition

The stream has clearly been undercutting the banks in a number of places. Roots and stratigraphy have been exposed in multiple cuts along the banks (figs. 1 and 2). The biggest point of issue is the channel leading down to the retention pond. Once in the pond, water appears to slow and deposit its suspended sediment load (fig. 3). In the stream, however, the water may be doing a substantial amount of damage to the surrounding terrain when it is at high enough volume after significant and/or long storms. Unfortunately, because this has been an exceptionally warm and dry winter, opportunities for data collection from the channel area have been extremely limited. We have had no chance to observe erosion from one event to another to measure speed and intensity with which this problem persists. Thus we can not make an effective guess as to what measures will need to be taken to control flow and consequent erosion.

Figure 1. Visible root and bank exposure beneath a fallen tree near the 4’ inlet pipe, with pencil for scale (photograph by Andrew Collins).

Figure 2. Undercutting of trees and substantial erosion appears to be a threatening issue in Knight’s Hollow, even far down the channel from the inlet pipe (photograph by Andrew Collins).

Figure 3. The bottom of the basin is a drop-zone for suspended particles as well as larger items such as tree branches, rocks, and litter (photograph by Andrew Collins).

Site history and erosion

This site has been used as a park, of sorts, since 1925. However, it became a drainage pond during the construction of the two north end dormitories (Bornhuetter Hall and Gault Manor). The catchment area is most of north campus and some are to the north of Wayne Avenue. In light of this function, there is a significant amount of pollution that enters the retention pond. Chemical testing will be in order to determine how much of a given pollutant enters, how much leaves, and where the pollutants that are lost are going (settling into the soil, evaporating, etc.). Because we don’t have any careful pictures from any time previous of this example, there is no way of telling how much time it has taken for hydrologic properties to erode the banks to their current state, and until it rains substantially again, there will be no way to tell. It is obvious that erosion is taking place, but it is not apparent at what rate or by what mechanism.

Restraints

We are limited by the engineering policies of the county and state. We can't change the general contours of the area, we can't dictate the flow direction of water in any way (e.g. via a permanent concrete bed), and we can't do anything that would disrupt the flow regime in a negative way (e.g. cause back-up flooding, sediment build-up or pollution downstream). Additionally, and perhaps most importantly, we are not allowed to change the volume in the basin at all. Any control of the flow must be done without disrupting the flow regime, or the way water generally travels from one side of the site to the other, and the basin's capacity. These laws are imposed at the town, county, state, and federal levels and are generally immovable. Thus we are limited in the amount of tinkering we can do to get the stream to act the way we want it to. Instead, we must learn not to control the stream, but to understand it.

2.3 Literature Review

In general, the connection between restoration ecology and geology (specifically hydrology and geomorphology) has been tenuous at best in terms of cohesive documented methodology. This is rooted in three principal problems: "The scientific basis for stream restoration is weak, the success of existing projects not well known, and the connection between research and practice is poorly developed" (Paola et al., 2006). There is still too much conflict over the various definitions, boundaries, limits, and capabilities of ecology and its associated facets. One such facet is the definition of an ecosystem. Post et al. (2007) explain that a common definition of ecosystem is necessary to further the working relationship between ecology and geology. The current gap, the authors propose, is the high variability of spatial resolution brought about when a geologist accustomed to working on a macroscopic scale is teamed with a microbiologist---channel behavior with nutrient processing. This issue is solvable in part by the establishment of definitive boundaries in space and time, but according to Post et al. (2007) it is never truly reconcilable.

Paola et al. (2006) acknowledge this complexity and connection, but propose a different solution to the various problems detrimental to restoration ecology's scientific validation. Wilcock (1997) notes a problem that is just applicable to us today as it was to researchers 15 years ago: each ecosystem (specifically streams) operates contingent on so many variables that it is highly unlikely that a true analog, or reference ecosystem, exists. Thus Paola et al. (2006) propose that "a testable, predictive framework linking cause and effect…based on a quantitative, transdisciplinary understanding of the physical, chemical, and biological dimensions of disturbance and recovery in streams, accounting for natural and human-induced variability" is needed to effectively establish a baseline for restoration research and documentation. This quandary and general lack of cohesive information still exists. However, while there is no perfect reference site, multiple reference sites can be observed to find common and comparable aspects. More generally, research in multiple fields related to specific aspects of restoration ecology can be synthesized into a more comprehensive discussion of the subject.

All of these authors argue that, regardless of their appearance (or lack thereof) in tandem on paper, ecology and geomorphology are by no means separable. Geomorphology can have a tremendous impact on ecology and vice versa. On a large scale, for example, geomorphology can put restraints not only on water transport (and plant life as a proxy), but also on fauna. For example, it can control the range of a predator and mediate predator-prey interactions (Hart and Finelli, 1999). On a smaller, though more effusive scale, it can have a tremendous effect on the distribution of carbon (Post et al., 2007). When considered in conjunction with human activity, geomorphology's impact is enhanced even further.

Roads, a human staple, are especially relevant to our study area. Jones et al. (2000) discuss the impact of roads on the geomorphology and hydrology of local ecosystems and their inherent, though not always considered, effects on the starting and stopping points of localized debris flows or unloading points of sediment-bearing stream. They thereby directly affect the rates and patterns of survival and recovery in disturbed patches within stream networks. This effect is not restricted to roads in the immediate vicinity---roads far from the area of interest also have the capability of affecting wetland behavior by controlling upstream tributaries or downstream release points. Our restoration site is conveniently located at the corner of two main thoroughfares of the city of Wooster, as well as responsible for draining much of the north end of campus including its parking lots. The impacts brought by the roads are of great relevance to the adequate restoration of our site.

When the variable of urbanization is introduced, a stream system becomes completely different. One of the main factors at play is impervious surface cover (Paul &Meyer, 2001). This is area that does not allow water to soak into the ground. It is commonly caused by paved surfaces and buildings, or can be from highly compacted soils. The water from these areas is channeled into streams where it causes the flow regimes to become more sporadic and change quickly in response to rain events. These quick and short periods of high intensity flow can cause erosion of soils from the stream bank (Paul &Meyer, 2001). This process is very relevant to our site where the water enters.

In our case, with a storm water retention pond, a number of relevant suggestions have been made by previous authors. Gurnell et al. (2007) comments on the use of sustainable urban drainage systems (SUDS), which broadly aim “to slow down the rate of movement of stormwater towards the river network, to contribute to reinstating levels of infiltration and groundwater recharge that had existed prior to urban development and also to retain sediment and treat both sediment and water within local storage areas using natural bioremediation”. The Minnesota Stormwater Manual (2008) provides a number of suggestions for stormwater management via both rate and volume control. First and foremost, the manual proposes, emulate original hydrology and natural drainage. Contrary to the beliefs of only a few years ago, natural forms can handle increased flows and rapidly changing flow dynamics in a more stable manner than can man-made channels. Having this situation at the offset would be ideal, but retrofitting is also a possibility.

Failing this, structural management practices are widely available. For example, filtering out litter might merit a catch basin insert or hooded outlet pipe. Cross vanes, fish steps, curvilinear channel restoration, reinforced stream banks, and revetments are all potential solutions to the problem of channel instability. Vegetated buffers, grade breaks, riprap, rock check dams, and temporary seeding constitute different methods of controlling sediment transport and erosion in smaller systems. The manual also provides various relevant guidelines, including one that comments on grading within a storm retention pond. A larger surface area to volume ratio (i.e. a wider channel) is more effective in removing pollutants from the incoming source.

2.4 Objectives and Recommended Plan

- Reduce erosion at water inlet by:
    - Slowing water flow.
        - Create a pool feature below the inlet pipe. The slowed water allows suspended particulates to separate from the water, decreasing scouring farther downstream and burial deposition in the basin area. This can be done with a small dam made of natural materials, such as dead falls, found in out site that would need to be cleared out anyways.
        - Add diffuser grate to inlet. This will reduce initial water velocity, thereby lowering stress on surrounding soil and decreasing scouring farther downstream.
        - A concern that could apply to both of these options is the possibility of back flow. If the water cannot exit the pipe fast enough or the water level rises and flows back into the pipe, it could prevent the upland areas from draining properly. Continued monitoring would be required to asses maximum flow output and the necessary inlet pipe size for adequate water flow.
    - Reinforce bank (fig. 4)
        - Remove concrete blocks from inlet area
            - Move to brick yard next to golf course?
        - Line heavily eroded bank with large, native sandstone blocks. This will help absorb the blunt force of the velocity from high water flows.
        - Utilize bank-stabilizing plants. Plants will help stabilize soil and will also eliminate the less aesthetically pleasing bare banks.

        - Plants best suited for this would initially be grasses or reeds, followed by sedges.
    - Place burlap stream liner in the chute area between the inlet pipe and the basin area. This allows the stream to retain its natural appearance and reduces undercutting and bank erosion.
        - Also may be placed in the small drainage area around the outlet pipe.
        - Use of burlap allows groundwater travel and plant growth. Additionally, it biodegrades over time after the plant community has been more firmly established.
        - The implementation of the stream liner requires removal of large obstructions currently in place such as rocks, dead wood, and other course debris. This could displace biota in the immediate area on a short term scale, but over the long run will improve the bank stability and quality of the stream.

Figure 4. The current reinforcement around the inlet pipe in Knight's Hollow. Proposed changes would be more effective and more aesthetically pleasing (photograph by Andrew Collins).

- Monitor Erosion over time
    - Continue GIS-based photographic surveys.
        - Photographs will be stored with all metadata on the College of Wooster Digital Resource Commons at http://drc.wooster.edu/handle/2374.COLLW/11
    - Periodically measure of velocity and suspended particulate content in water entering and exiting Knights Hollow.

        - This can't be done on a regular basis because of the lack of regular flow into the area.
        - Until a pattern or effective model has been established, flow velocity and suspension load should be measured during and after storm events as often as possible.
        - After the establishment of typical behavior patterns, monitoring can become more sporadic.
            - Measurements and photographs should be taken at least four times per year, once per season.
- Monitor stream path
    - Continue photographic surveys of stream flow position during wet (both inundation and flow) and dry periods. This can be done in conjunction with velocity measurement.
- Monitor water retention/expulsion rate
    - Use multiple storm events to measure a relationship between maximum amount of stormwater in the pond and how long the water stays in catchments following a storm event.
        - This will involve taking depth measurements at various GPS-tagged sites in the chute and drainage areas.
        - It will also necessitate depth and velocity measurements at the inlet and outlet pipes.
- Budgeting and cost
    - The overall plan is designed to be low cost. The majority of the costs are from labor to complete the intended work. These labor costs can be brought down by incorporating the work needed into class projects, or as volunteer service opportunities for campus students and community members. Materials needing to be purchased would be Burlap to line the bank (roughly $100 for 450 square feet), a diffuser grate for the inlet pipe, and any plants we wanted to purchase for bank stabilization. Depending on the accessibility of sandstone blocks, those may also need to be purchased and/or moved over distance. These are low cost purchases that can fulfill the needs of our site.
- Timeline
    - Geologic change is slow. Therefore monitoring will be an ongoing (and consistently beneficial process).
    - Modification of the stream bank will need to take place in the following order:
        - The concrete blocks will need to be removed from their current position in the stream bed.
        - At this point, the pool below the inlet pipe should be excavated.
        - Burlap will be laid beneath the surface from below the inlet.
        - Resurfacing of the bed will take place. Sediment must be sufficiently packed so that water does not carry it all away.
        - Sandstone blocks will be placed in the stream bed.

Section 3. Pollution

3.1 Executive Summary

Knight's Hollow is a drainage basin used to collect excess water from surrounding regions on campus as well as from the nearby residential area, though it is in need of ecological restoration. Based on data gathered from similar sites in other locations, it seems likely that Knight's Hollow would face pulses of pollution with the periodic flooding that this region receives. These pollutants not only have an adverse effect on ecosystem health within Knight's Hollow, but also may have significant negative effects on the biotic community in Killbuck Creek, where water from Knight's Hollow is released without treatment. Methods by which water quality could be monitored include the use of bioindicator species, seed germination bioassays and periodic chemical testing of soil and water samples from the region. Water quality, and thus environmental integrity can be improved using simple strategies such as the construction of debris dams, planting of phytoremediative plants, or changing stream flow patterns to increase the dissolved oxygen content. Thus, using a few simple strategies, it may be possible to dramatically improve ecological conditions in this site. However, until a pattern of pollutant levels is established, regular monitoring of the site will be necessary.

3.2 Goals, Justifications, and Impacts

The primary goal our group will focus on is to enhance the water quality of the Killbuck watershed by pollution filtration and reduction at our site. Our site is part of the larger Killbuck area watershed, and should be managed as part of the larger project area to achieve maximum impact. Removing pollution from the water upstream at Knight's Hollow will remove and prevent further pollution from entering the Killbuck waterway, and potentially the communities' water. Knight's Hollow is used as a runoff basin for the College and approximately 35 residential blocks. The use of fertilizers is common throughout this entire area. From Knight's Hollow, the runoff water continues to the Killbuck. In the winter, salt as well as other chemicals from the surrounding areas are also drained into Knight's Hollow. These chemicals get carried into Knight's Hollow and can affect the flora and fauna that can inhabit the area. The increased pollution decreases the amount of biodiversity in the area and increases the amount of invasives that inhabit it because the invasives, such as the infamous garlic mustard, maintain a high tolerance for pollution. The management and removal of pollutants from the soil and water in the area will increase the amount of native species that can survive in the area. It will also reduce the amount of pollution and improve the ecosystems downstream to the Killbuck. In addition to having large-scale benefits, dealing with pollution in Knight's Hollow will directly benefit the immediate community.

Enhancing the water quality through the restoration of Knight's Hollow will help increase community values. Knight's Hollow will then serve as a recreation area and be aesthetically pleasing instead of an eye sore. This will also help increase the property values of the surrounding community as well as the College (Howard Hanna Realtors, personal communication; Purcell *et al*. 2002). By reducing the pollution that will pass through Knight's Hollow, the use of the area as a park will also be sustained. There is a large amount of trash and hazardous material that passes through Knight's Hollow as it is currently (glass, needles, tires, cups, etc). Through this restoration, the use of this site as a garbage dump will be eliminated. It will be a safer, more family friendly area for both the community and the college.

Knight's Hollow's history suggests that it could be used to fulfill both hydrological and recreational needs for the Wooster community. The site is a drainage basin and has been for a number of years. However, historical records indicate that it was once a public park. To restore it to its previous state as a park, the runoff basin will need to be incorporated into the plan. These dual purposes must be carefully balanced, which will require continuous monitoring and analysis of the site's pollutants. This would mean there must be some type of group or organization that needs to be instilled that can actively participate in the management of the site.

3.3 Condition, Pressures, and Constraints

Little data is available on Knight's Hollow: more in-site research and analysis must be conducted before comprehensive interventions can be proscribed. The pattern of nutrient and pollutant flow should be analyzed, and a plan on how best to address these issues should be established. Analysis will be done through water and soil testing. While more testing is necessary, initial observations and background research have yielded some insight into potential sources and types of pollution in Knight's Hollow.

Some insights into pollutant pressures in Knight's Hollow may be gleaned from its hydrological function, small size, and location. Due to its use as a runoff basin for a heavily fertilized area, we might expect the water in Knight's Hollow to contain high levels of arsenic, cadmium, lead, and nutrients, based on data gathered in similar situations. Furthermore, road and parking lot runoff may lead to higher levels of copper, zinc, and salt into the site (Schaffner 2012). Pollutants from both roads and fertilized lawns would primarily come through the main intake pipe. Finally, the site's accessibility and disuse has led to its use as a convenient receptacle for refuse, from discarded leaves to plastic bags and hypodermic needles. These pollutant loads are likely to vary over time based on certain factors that can be predicted, and others that cannot.

Some of Knight Hollow's pollutant inflows will likely vary seasonally. Lawn fertilizers, for example, are generally applied in the spring. Spring will also bring an annual thaw, which may facilitate the runoff of these fertilizers into Knight's Hollow. Therefore, we would expect to see peak levels of nutrients, cadmium, arsenic, and lead in the early spring. Road salt, on the other hand, will be a large pressure primarily during winter months. The runoff from a mid- or late-winter thaw would therefore likely bring the highest influx of salts into the project site (Polard *et al.* 2011). Interseasonal and interannual data needs to be collected in order to predict and understand the volatility of temporal pollutant fluctuations.

We will also have to follow the guidelines the city has set into place for this area. We cannot change the gradient or add volume to the catch basin. We also cannot alter anything below the second culvert. Our plan will need to take into account these aspects in order to successfully restore the area.

3.4 Literature Review

By definition, ecosystem services have value to nearby human communities: they provide a multiplicity of services that people either want, or need, ranging from cleaner air and water, to improved aesthetic or recreational value. However, few studies have been conducted on the benefits of urban green space in terms of ecosystem services (Pataki *et al.* 2011).
One of the primary objectives of restoring Knight's Hollow is to reduce levels of pollution released into Killbuck Creek, which adversely affects water quality and biota in the area. For instance, reducing levels of nitrogen in water is a high priority in several watersheds (Craig *et al.* 2008). While natural stream environments reduce levels of pollutants in water, these effects may be difficult to replicate in an urban, artificial habitat such as Knight's Hollow, as characteristics of the two habitats differ in significant ways. For instance, the height of the water table in such habitats may prevent an anaerobic zone from forming in the water, which would be essential for denitrification (Groffman and Boulware, 2002).

Several strategies have been employed with varying levels of success in order to reduce the nitrogen content (both nitrates and ammonia)of the water column. Some studies suggest that increasing biologically available levels of carbon, by the construction of structures such as debris dams or similar structures, is effective in achieving a reduction in NO3-/NH4+ wastes (Craig et al. 2008). This may also be one of the most cost effective strategies for pollution reduction. However, the nature of the hydrological regime in Knight's Hollow may make it difficult to make this a viable option. Other options include the creation of low-velocity environments within the floodplain, allowing microbes more time to degrade organic materials in the water, and the creation of riffles in the streambed, which increases the dissolved oxygen content (Craig et al. 2008).

Bioindicators

Bioindicators are organisms whose populations in an ecosystem that can be easily monitored and used to analyze the pressures and forces acting upon a habitat, in order to assess the habitat's health (Li *et al.* 2000). Bioindication is often more cost-effective than chemical or physical testing, as it focuses on biologically relevant information (avoiding the collection of unnecessary information) and can assess more factors with fewer tests as a single organism may be differentially affected by multiple toxins, or may reveal a history of otherwise untestable past conditions (van Straalen, 1998).

The strengths of bioindicators in pollution assessment varies due to the large array of available bioindicator systems. Bioindicator systems face tradeoffs between specificity - the ability to detect changes in specific factors – and generality – the ability to detect changes in multiple factors. Furthermore, they face tradeoffs in resolution: low resolution bioindicators are better at detecting serious effects, while high resolution bioindicators are better at detecting small changes. Ideally, multiple bioindicator systems will be used that can complement gaps in specificity and resolution (van Straalen 1998).

A heterogeneous bioindicator system is necessary to gain a full picture of the pressures on a habitat. Terekhova (2011), examining problems with bioassays, pointed out that homogeneous indicators often emphasize the wrong pressures. He further asserts that such focused bioassays do not yield much information on how the pressures work on a systems level. For a more comprehensive bioindicator system, Van Straalen (1998), focusing on arthropod communities, suggested using multivariate statistics to assess data collected from bioindicators across various ecological functional groups yields. Diverse functional groups can also be found in smaller taxa, enabling smaller grain size when analyzing pollution spatial distribution.

Assessing mid-sized microorganism communities may be the most effective approach to examining toxin levels. Li *et al.* (2000) note that analyzing trends in various populations of nematodes fulfills the requirements of having multiple functional groups, and can be analyzed using multivariate statistics. Various taxa of nematodes play very different functional roles in their communities, and are therefore affected by exposure to pollutants of various types, and at varying levels of specificity. However, at larger scales, spatially-restricted microorganisms would fail to provide a comprehensive indicator of the entire project range (Li *et al*. 2000).

Phytoremediation

Once pollutants are found within a habitat, project managers must work to remove them. A host of mechanical engineering options are available to well-funded projects in order to contain or remove pollutants from a habitat. However, these tend to be costly, focus on relatively few pollutants, and often involve intensive renovations with unexpected results on the habitat. Through phytoremediation, project managers can maintain the natural aesthetic of their habitat while reducing multiple forms of pollutants in a cost-effective way (Pilon-Smits and Freeman 2006).

Phytoremediation is the use of primary producers and associated microbes to remove, degrade, or sequester pollutants or excess nutrients from a habitat. An active management tool, phytoremediation requires the focused introduction of specific phytoremediative plants in large enough quantity to have an impact on the site (Pilon-Smits and Freeman 2006). The need for the extensive cultivation of a limited number of plant species raises concerns on phytoremediation effects on the biodiversity of the location.

Helfield and Diamond (1997) point out that addition of the extensive oligocultures used in constructed wetland phytoremediation can limit and potentially erode the biodiversity of the habitat, with limited benefits in on-site pollution reduction. Their case study focused on a heavily polluted river, with a constructed wetland built to take up pollution generated from a large urban area with multiple point-sources. They noted that the constructed wetland in their study damaged biodiversity by artificially redirecting nutrient flows and bioactivating certain pollutants that otherwise would have otherwise had fewer negative ecological effects. Furthermore, the “remediative” properties of their study’s constructed wetland were largely in pollution “storage”, not removal. In this way, pollution prevented from entering downstream habitats had the same, if not worse, negative effects at the project site itself. While they provide a cautionary illustration against overburdening phytoremediative efforts, more success has been found in projects with lighter responsibilities.

Phytoremediation projects should ideally be fitted to the pollution they address. Phytoremediation efforts must be appropriately sized for the pollutant load, and thought must be given to the fate of pollutants that are "stored" in plants. Marchiol *et al.* (2004) found phytoextractive benefits on relatively smaller plots with fewer contaminants than Helfield and Diamond's (1997). They found that canola and radish plants were able to survive while accumulating toxins in soil contaminated with multiple heavy metals. By using plant species cultivated for human use, they prevented the "storage" problem raised by Helfield and Diamond (1997), but failed to fully address issues with decreased biodiversity. Fitting phytoextractive species to a specific project is important not just for determining where pollutants end up, but also in reaching the pollutants in the first place.

The most effective phytoremediative plants are hand-in-glove matches to the site's pressures. In studying phytoextractive plants of various species across different soil and pollutant types, Keller *et al.* (2003) outlined three main requirements for phytoextractive plants: First, phytoextractive plants must be able to survive in the target site. The plants should be well suited to the soil type, and be able to withstand the high level of contaminants. Second, phytoextractive plants must have roots that fit the spatial distribution of the pollutants. Deep roots are necessary when the pollution is in a deep underground water table, wide and shallow roots are better when dealing with a shallow polluted stream, or when pollutants settle atop the sediment. Third, phytoextractive plants need to be efficient in their uptake of pollutants (Keller *et al.* 2003).

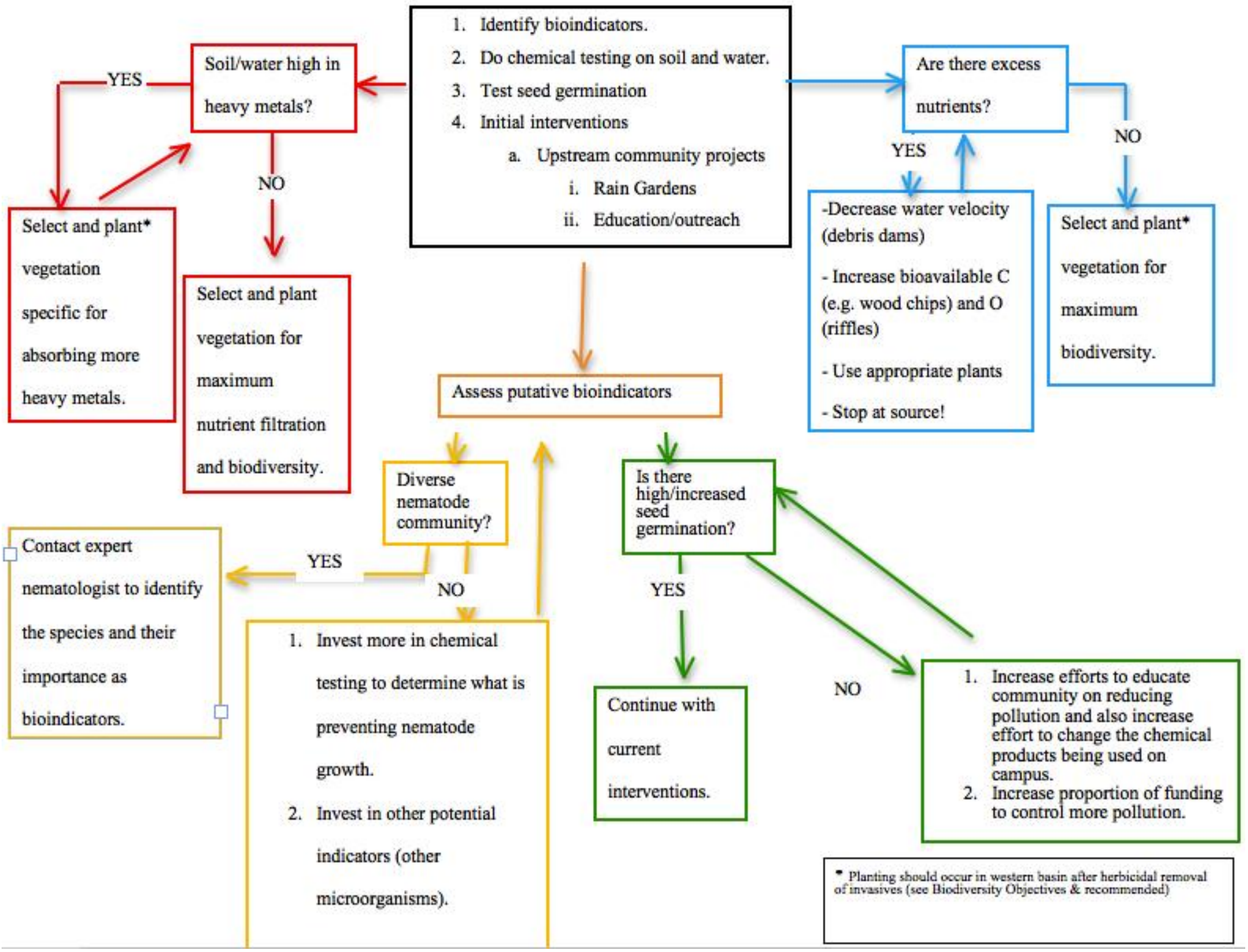
While phytoremediation efforts do have drawbacks, they remain among the most effective existing forms of pollution control. Compared with soil dredging, hydrological engineering, and negotiating reduction at pollution sources, they are likely to be easier for program managers to implement and maintain (Keller *et al*. 2003; Diamond 1997). They have some negative ecological effects locally, as they often store pollutants within the project site, but these effects are outweighed by their larger-scale benefits in redirecting massive pollution buildups. Programmatic restoration planners will turn to phytoremediation as a way to dilute, distribute, and redirect pollution.

3.5 Objectives and Plan

- Identify and quantify the pollutants acting on Knight's Hollow
    - Use soil and water tests to determine pollution
        - Take samples from multiple areas in Knight's Hollow
        - Analyze the soil samples at STAR Lab at the OARDC
            - Cost is $56.00 per sample
        - Samples should be taken multiple times throughout the year to create a seasonal pollutant profile
        - Once the results are obtained, we can better manage the site based upon the specific pollutants present
- Bioindicators
    - Use nematode sampling and seed germination rates to monitor soil and nutrient quality.

        - Seed germination is simply counting the seeds in a set volume of soil and how many of those seeds are germinating. This should be done periodically to track soil health and seed survival rates
        - Nemotode sampling needs to be sent away and done by an expert
- Involve community to reduce upstream pollutants
    - Determine what products they use on their lawns and homes that could be potentially harmful to Knight's Hollow
    - Applying for grants, such as the EPA Section 319 grants, to receive funding to implement the changes we want to see in the community to help reduce the amount of pollution that is entering Knight's Hallow
    - Encourage the community to install rain gardens, which would help reduce the pollutants in stormwater runoff
- Involve College of Wooster campus to reduce upstream pollutants
    - Identify where the COW grounds crew applies each of their fertilizer/pesticides.
    - Which of these pollutants are flowing into Knight's Hollow?
        - Encourage campus officials to switch to a less harmful pesticide/fertilizer to help reduce the harm done to Knight's Hollow
- Phytoremediation
    - Planting grasses, sedges, or other phytoremediative plants upstream along the runoff water will likely reduce nutrient flows to the entire project site
        - To avoid the potentially negative ecological side-effects of phytoextraction, interactions between introduced phytoremediative plants and existing microfauna must be closely monitored
- Community Outreach
    - Gather Volunteers
    - Educate and encourage the use of green fertilizers
    - Improve path
- Order of Action (Starting with most immediate steps)
    - Soil and water test to determine pollutants
    - Bioindicators
    - Engage campus/community to reduce upstream pollutatns
        - Rain gardens
    - Community Outreach
        - Surveys to determine what fertilizers and chemicals community members are using
        - Educate and encourage the use of green fertilizers
        - Gather volunteers
    - Phytoremediation

Contingency Plan



Section 4: Biodiversity

4.1 Executive Summary

Knight's Hollow, also known as Galpin Park, is a small plot of land located on the northwest corner of The College of Wooster's campus. It is a considerably riparian area consisting of a highland region and a lowland region, where water flows through a drainage pipe. The apparent dominance of invasives and poor biodiversity make this area appropriate for restoration. The goal is to restore biodiversity by minimizing the effects of invasives, while promoting the flourishing of native species. We hope that the shift is flora will increase the amount of invertebrate biodiversity as well. The plan includes removing invasives and planting native species in Knight's Hollow. This is a project that will have to be monitored in future years to ensure that the changes we make take effect.

4.2 Goals & Background

Our goal for Knight's Hollow is to restore flora and fauna to a healthier state by increasing native biodiversity of plants and animals while decreasing invasives. The health of an area increases when biodiversity increases for a variety of reasons. Biodiversity provides nutrient storage and recycling, pollution breakdown and absorption, maintenance of ecosystems, and recovery from unpredictable events. Primarily, there is a positive correlation between plant diversity and animal diversity, thus bolstering overall biodiversity (Haddad *et al.,* 2009). It has been shown that the expansion and relative dominance of invasive species in an area is a source of degradation, causing the health of a site to decline (Hobbs & Norton, 1996). Invasive plants tend to possess efficient seed production and dispersal patterns, which helps them to spread effectively in a damaged area. With these intrusive characteristics, invasives are able to outcompete natives and critically alter ecosystem functions, making it difficult for the ecosystem to return to its natural form (D'Antonio & Meyerson, 2002). By removing the primary detrimental invasives from the restoration site, including garlic mustard, Japanese knotweed, and privet, we hope to lessen their critical impact on the area. In addition, the gradual elimination of invasive plants from Knights Hollow will provide more area to plant natives, which will encourage native invertebrates to migrate to, and inhabit, this small plot of land.

This goal is important because Knights Hollow has been damaged over many years and as a result many flora and fauna systems have been negatively impacted. Some of these negative influences include anthropogenic disturbances, frequent flooding, and lack of upkeep (Personal Communication, Gary Popotnik, Conservation Biologist). These anthropogenic interactions are a result of chemical compounds flowing through the system from drainage spouts in nearby neighborhoods, parking lots, and runoff from the softball field. Some of the chemicals that could potentially be carried into the restoration site by the drainage pipe include road salt, Melt-A-Way, Merit W-fertilizer, 4-4-5 iron, ProMax, Manicure, Spectator, Emerald, Razor Pro, Magellan, and Momentum (Personal Communication, Beau Mastrine, Grounds Manager). Littering has also been a significant detrimental factor to biodiversity in Knight's Hollow. In addition to the negative impacts from surrounding humans, natural pressures have caused damage to this area. The rapid flow of water into the area and sustained seasonal flooding has caused soil erosion, which could have enabled certain invasives to easily take over. Finally, there has not been enough public attention to Knights Hollow. We are currently unsure of the monitoring in the past, but the condition of the site may have worsened and directly, negatively impacted the biodiversity.

Our target goal would have a beneficial impact on the environment by increasing the number of native plant and animal species. As part of our goal, we are interested in only directly interacting with the current plant species in the park, along with the native varieties we plan on purchasing and introducing after all invasives have been removed. Our justification for doing this has to do with the “bottom-up” consequences of improving diversity. Haddad *et al.* (2009) explains that improving the diversity of primary producers causes improvements in the diversity of the herbivores that depend on these plants, including arthropods, birds, and small mammals. In this manner, we do not need to directly introduce other insects and small mammals into the park since the increased plant biodiversity will do this naturally. Thus, by eliminating the current invasive plant species and planting more native types in their stead, more animal species would eventually come to inhabit Knight's Hollow and improved biodiversity would be achieved.

Our preliminary observations are that the area contains many detrimental invasive plants such as garlic mustard, Japanese knotweed, and privet (Table 2). We also know that there are some native plant species existing in the area, including mixed varieties of oak, beech, sugar maple, elm, and ash, with maple, ash and oak dominating much of the canopy (Personal Communication, Gary Popotnik, Conservation Biologist). We have collected limited specific data on the types of vertebrate and invertebrate species currently inhabiting the site. We have also observed the geological qualities of Knight's Hollow. According to Bureau *et al.* (1984), the majority of the site appears to be Berks silt loam (BrF) with 25 to 75 percent slopes. It contains a V-shaped valley with steep slopes. The surface layer of soil is composed of two inches of dark gray, friable silt loam, with the subsurface layer being approximately four inches of pale brown friable silt loam. The strongly acidic subsoil is 22 inches deep, while brown sandstone can be found at a depth of 28 inches. This type of soil is best suited for trees. We can compare the contemporary community composition with historical information we have found from the Ohio Agricultural Experiment Station’s Department of Forestry. This data, collected in 1938, states that the white pine population in Galpin Park was being damaged by the rapid growth of pokeberry. In addition to pokeberry, the park also included copious amounts of poison ivy and dogwood, which were introduced to the area by birds. Soil tests also revealed high concentrations of nitrogen. Finally, we have already interacted with Joel Montgomery of the City of Wooster, Dean Holmes of the College of Wooster, and Land Stewardship director Gary Popotnik and received their recommendations on how to progress with the current project. Upon approval, this plan to restore and encourage biodiversity would be ready to begin immediately.

4.3 Literature Review

Invasive Removal

Invasive species are detrimental to most ecosystems because they cause species declines and native habitat degradation (D’Antonio & Meyerson, 2002). Several methods exist for removing invasive species ranging from manual removal, to chemical treatment, to controlled fires. In order to decide which method will be most effective against the invasive species in question it is important to have an understanding of the biology of the species as well as the various removal techniques available. Mechanical techniques are usually most effective for plants that are annual or simple as they are usually unable to regenerate from the roots, chemical means such as herbicide treatment may be needed for more aggressive plants (Clout & Williams, 2009), while fire use is effect but should be carefully considered as it can sometimes augment invasive species growth (Rice, 2004). Our site contains a number of invasive plant species that could be disrupting the ecosystem processes of our site. Three invasive species that have been identified and pose problems to our site are Japanese knotweed (*Fallopia japonica*), garlic mustard (*Alliaria petiolata*), and privet (*Ligustrum vulgare*). These plants are a priority for removal as they have detrimental effects on our site's ecosystem and they should be eradicated as soon as the resources to do so are available.

Japanese knotweed (*F. japonica*) infestation results in loss of wildlife habitat, decreased species diversity, and a reduction in the availability of water, which can impact the carrying capacity of rivers and streams (Weston, Barney, & DiTommaso, 2005). There are several feasible methods for removal of Japanese knotweed. First cutting back the plant with the goal of depleting the root reserves over time is possible as well as uprooting the plant, but these methods have been shown to work better in smaller areas than larger areas (Weston, Barney, & DiTammaso, 2005). Another option for removing Japanese knotweed is to treat it with an approved herbicide via either spraying, leaf wiping, or stem injection. The knotweed should be treated in late spring/early summer and then again in late August to September as the plant is already beginning to die back then and the herbicide will more effectively soak into its stem fragments (Chapin, McNamara, & Oppedahl, 2007). However a combination of both of these techniques is the best way to eradicate the knotweed from an environment and several years of treatment may be needed for well-established populations (Chapin, McNamara, & Oppedahl, 2007). Commercially available herbicides recommended for Japenese knotweed removal include Cornerstone and Round up Concentrate (Chapin, McNamara, & Oppedahl, 2007). It is important to note that herbicide treatment in riparian areas could have detrimental effects as the chemicals may make their way into the surrounding water (Weston, Barney, & DiTammaso, 2005). No matter what type of removal is chosen it is extremely important to properly dispose of the Japanese knotweed as the plant could easily spread to other unintended areas (Weston, Barney, & DiTammaso, 2005; Ecological Survey and Discussion, 2011). Proper disposal includes careful bagging of the pulled plants and placing them in an appropriate dumpsite. Monitoring and treatment of any re-growth should occur after removal (Ecological Survey and Discussion, 2011).

Garlic mustard (*A. petiolata*) infestation results in a reduction of the competitive abilities of native plants as the garlic mustard has been shown to interfere with their formation of mycorrhizal associations and root growth (Roberts & Anderson, 2001). Therefore garlic mustard has been shown to outcompete native plants and severely limit the diversity of plant life (Roberts & Anderson, 2001). The best method of removal for garlic mustard is to pull it from the ground so that no biomass from the plant can stay in the ground and alter soil composition (Barton & Cipollini, 2009). After removal it should be bagged so that it cannot reseed in another environment (Personal Communication, Gary Popotnik, Conservation Biologist). The site should be monitored for garlic mustard for 7 to 10 years after removal as the seed banks can remain viable for that length of time (Nuzzo 2000).

Privet (*L. vulgare*) is a problematic plant because it shades and out-competes native understory shrubs as well as because it produces berries that do not have the same protein values as native berries and is therefore an inferior food source for wildlife. Privet should be cut at ground level followed by an application of herbicide. One herbicide that would be effective would be Garlon 4 and the plants should be treated with a mixture of 3 parts penetrating oil to one part Garlon 4 (Personal Communication with Gary Popotnik).

Native Plants

An important aspect of this restoration plan is the emphasis on promoting native plant growth in Knight's Hollow. The accidental or intentional planting and spread of non-native, exotic plant species has had negative effects on not only on the plant community structure in an area, but also have negatively impacted mammal, avian, and insect biodiversity (Burghardt *et al.,* 2008). As result of the shift from native dominance to invasive, or non-native disruption in various areas, invertebrate community composition could have significantly changed, which would ultimately affect the surrounding food web that came to coevolve with these specific native plants and invertebrates (Burghardt *et al.*, 2008). These facts can be directly applied to Knight's Hollow. Based on our analysis of the current arrangement of plants and animals in this site, we can note that the area is lacking a plethora of biodiversity, with garlic mustard, Japanese knotweed, and privet occupying many sectors throughout the park.

However, one may question what the specific benefits of native species are when compared to non-natives. Isaacs *et al.* (2009) discuss that native plants can normally outperform non-natives when it comes to supporting permanent habitats for surrounding animals and supports native biodiversity to a greater degree. They do this by interacting with beneficial native arthropods, which serve larger functions to help support the rest of the community. Since specific native bees, predators, and parasitoids have evolved with certain native plants, they have come to support each other in a symbiotic manner. So, the use and promotion of native plant species will encourage the growth of biodiversity in an area. If we were to plant more native species in Knight's Hollow once we have removed the overly-competitive non-native invasives, then, ideally, the restoration site would experience a greater enhancement of overall biodiversity. Thanks to the assistance of conservation biologist Gary Popotnik, we have accumulated a list of potential native plants we could introduce into the site in order to accomplish our goal of promoting biodiversity. These plant species include wingstem (*Verbesina alternifolia*), spotted Joe-Pye weed (*Eupatorium maculatus*), giant goldenrod (*Solidago gigantea*), riverbank rye (*Elymus riparius*), virginia rye (*Elymus virginicus*), and silky dogwood (*Cornus amomum*) (Table 1). According to his advice, these species would be highly effective in the lower riparian zone of Knight's Hollow. These are all generally grasses and herbs, except for the silky dogwood tree, that thrive in areas of high moisture, which would be abundant in the valley of the riparian zone (Gregory *et al.,* 1991). Due to the high amounts of water flowing through the area, much of which is retained in the soil for a while following large rainfalls, these species could be introduced into the basin located on the western portion of the site. Here, the plants would also receive sufficient sunlight to grow. In addition, these species have been shown to attract various pollinators, including bees and butterflies. The attraction of these invertebrates would inevitably encourage more pollination, leading to more seed production, thus creating more native plant biomass to attract more invertebrates. In doing so, biodiversity is encouraged.

These are not the only native plant species that we could introduce into Knight's Hollow. We could also plant native phytoremediation grasses to the basin. According to Nedunuri *et al.* (2010), five types of grasses that are considered native to Ohio and serve to remove contaminants from the soil are the sideoats grama (*Bouteloua curtipendula*), the arctic brome (*Bromus kalmii*), switchgrass (*Panicum virgatum*), Indian woodoats (*Chasmanthium latifolium*), and Indian grass (*Sorghastrum nutans*). These grasses would serve two major functions for our restoration site. First, they would serve to filter out the detrimental chemicals that are entering the site that could be damaging the quality of the soil, thus affecting the growth of natural plants. Second, they could serve as sources of food to attract other animal wildlife. Switchgrass serves as a moderate source of food for terrestrial and water birds, along with being a form of cover for small mammals, while Indian woodoats serves as a minor source of food for terrestrial birds and large animals (USDA, 2012). By planting these grasses in the basin of Knight's Hollow, potentially more vertebrate species would naturally migrate into the area, thus increasing biodiversity without the direct influence of human intervention.

Invertebrates and Vertebrates

After personal observations, we discovered that the invertebrates in Knight’s Hollow include a variety of unidentified species of earthworms, caterpillars, slugs, yellow jackets, bees, ants (white, red, and black), spiders (white, brown), pill bugs, and mites. The micro invertebrates that inhabit our site are unknown at the present. In riparian zones, woody debris is an important factor for invertebrate habitats. Wood can also be consumed directly by some aquatic insects and a good source of organic matter for other bottom feeders (Hutchens & Wallace, 2002). In Knight’s Hollow, we are focusing on the introduction of native plants and vegetation rather than the introduction of invertebrates because we speculate that more species of invertebrates will find their way there after our restoration goals have been accomplished.

In addition to invertebrates, we have noticed the presence of some vertebrate species. On a recent general scan of the site, we noticed the presence of chipmunks (*Tamias striatus*), gray squirrels (*Sciurus carolinensis*), and different types of birds, which have not been classified by our group. We can say with some degree of certainty that at least the chipmunks reside in the site, locating multiple burrows. As far as the squirrels and birds are concerned, we have no current knowledge if they actually inhabit Knight’s Hollow.

Overall, the emphasis on removing detrimental invasive plant species and introducing beneficial natural species will ideally encourage a natural growth in biodiversity in Knight's Hollow. We acknowledge that this entire process will be lengthy, considering the expansive amount of time invasives, like garlic mustard, persist in an area. However, once we have eradicated Knight's Hollow of these target harmful invasives and planted more native species to foster further biodiversity, the quality and health of the entire park will improve significantly.

4.4 Objectives & Recommended Plan

Our objectives will be broken down into short-term goals, lasting five years, and long-term goals, lasting up to 20 years. The short-term goals will be primarily focused on the large-scale removal of the target invasive species. In the process, we will also begin planting native species immediately. This is to prevent the soil from being degraded because of increased exposure to the sun and other elements. Ideally, the growth of the phytoremediation grasses will absorb any of the remaining chemical compounds persisting in the soil from the herbicide applications. The area will be monitored monthly for the entire short-term period, with special attention allotted during the growing seasons in the late spring/ early fall. The long-term goals will emphasize the continued planting of native species and elimination of any remaining invasive plants. The key facet of the long-term goals is ensuring that native plants begin to flourish and inhabit Knight's Hollow. In addition, we will also be monitoring the growth of native invertebrates and vertebrates.

Short-term Objectives

- We will primarily be concentrated on the removal of garlic mustard, Japanese knotweed, and privet.
- These invasives will be removed in the direction of the water flow so that seeds are not dispersed and spread to an area that has already been treated.
- Removal of garlic mustard:
  - The process has already begun and can occur at any time.
  - We will be pulling this species by hand.
  - During the pulling of garlic mustard, it is important to completely uproot it. If any remnants of this species remain in the soil, it could easily begin infesting the area again.
  - Once the plant has been uprooted, carefully place in a garbage bag. This bag should be tied once full and disposed of properly.
- Removal of Japanese knotweed:
  - Treatment of Japanese knotweed should occur twice a year: once in the late spring/ early summer, and then again in the late summer/ early fall.
  - First, Japanese knotweed should be cut back and uprooted if possible. The plant parts removed should be bagged, tied, and disposed of appropriately.
  - Whatever is left of the plant should be treated with Cornerstone or Round-Up herbicide by means of stem injection, leaf wiping, or spraying.
  - Lastly, the plants treated with herbicides should be removed from the area, bagged, and disposed of properly.
- Removal of privet:
  - Privet should first be cut at ground level. The cut pieces should be bagged and disposed of properly.
  - The remaining parts of privet should be treated with Garlon 4 herbicide. When applying, the solution should be three parts penetrating oil and one part Garlon 4.
  - Dead remnants of privet should be removed with care, bagged, and disposed of properly.
- Planting native species:
  - We will be planting both the phytoremediation grasses and other native species in seed or seedling form. These plantings will occur during the removal periods for the invasive species.

- The phytoremediation grasses we will plant include sideoats grama (*B. curtipendula*), arctic brome (*B. kalmii*), switchgrass (*P. virgatum*), Indian woodoats (*C. latifolium*), and Indian grass (*S. nutans*).
- The other native species include wingstem (*V. alternifolia*), spotted Joe-Pye weed (*E. maculatus*), giant goldenrod (*S. gigantea*), riverbank rye (*E. riparius*), virginia rye (*E. virginicus*), and silky dogwood (*C. amomum*).
    - Silky dogwood can be purchased from Wayne SWCD (428 W. Liberty Street, Wooster, OH 44691). The price is $9.00 for a pack of ten.
    - The Wilderness Center sells Indian grass, spotted Joe-Pye weed.
- The phytoremediation grasses will be planted in the lower basin, located on the west side of the site.
- The other native species will be planted in the areas where the invasives were removed and also in the basin. It would be best to purchase silky dogwood as well developed seedlings while the other species can be planted from seeds.

- Monitoring regime:
    - Garlic mustard must be monitored monthly for at least seven to ten years. This means that its monitoring must continue into the long-term period.
    - Japanese knotweed and privet will be monitored monthly for five years.
    - The native plants should be monitored monthly for five years.
    - During these monitoring periods, any visible invasive species, especially garlic mustard, should be removed and discarded.
    - If there is a natural disturbance in the site, such as flooding, natives can be replanted to ensure that some survive and grow.

Long-term Objectives

- The long-term objectives will focus on encouraging the thriving of native plant and animal species.
- Persisting invasive species will continue to be treated and removed from the area, but more emphasis will be placed on planting more native plants.
- Natives will be planted at the beginning of every growing season. We will monitor their growth less frequently than in the short-term objectives (twice a year).
- We will also be monitoring the growth of invertebrate and vertebrate populations in Knight's Hollow. A simple observational sampling method will be used to acquire a rough estimate of the amount of animal species are in the site. This will happen twice a year at the same times the monitoring of native plants occurs.

One challenge that the complete restoration of this site will encounter is the persistent guidance and interest in Knight's Hollow. One solution is to appoint someone to be responsible for this site in the coming years. The progress should be recorded following the frequent monitoring. It is crucial to this project that the results are reported, not only for the completion of this restoration plan, but also for the benefit of future restorations on small riparian areas. The cost of this portion of the plan is minimum. If herbicides can be used, the price and materials for that will have to be factored in. Otherwise, the main costs include the seeds and seedlings of native plants.

4.5 Tables

Table 1. Native plant species and the animals they feed.

Species	Food source for..
Wingstem	Deer, rabbits, bees, caterpillars, moths
Spotted Joe-pye Weed	Bees and butterflies
Calico aster	Bees and main source for monarch butterfly caterpillars
Zig zag aster	Butterflies
Giant goldenrod	Bees, leaf beetles, caterpillars, rabbit, deer, vole, muskrat, birds
Silky dogwood	Birds and deer

Table 2. Invasive plant species characteristics.

Species	Rank	Impact	Extent	Management Difficulty
Japanese Knotweed	1	High	Low	High
Garlic Mustard	2	High	High	High
European Privet	3	Low	Low	Low

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