Continued Site Restoration at the Union Bay Natural Area at Ravenna Creek: Final Report for Autumn 2023 - Winter 2024 Project

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Background for UBNA and Restoration Projects

The Union Bay Natural Area (UBNA) is a wetland and wildlife habitat associated with the University of Washington and managed by the University of Washington Botanic Garden situated on Union Bay, part of Lake Washington, in Seattle, Washington, USA. Covering 74 acres and spanning 4 miles of shoreline, UBNA is the second largest natural area on Lake Washington (UW Botanic Garden, n.d.). With hundreds of plant species thriving in the area, UBNA offers distinct habitats, including open grassland, woodland, shrubland, wetland, shoreline, and riparian corridors, attracting a wide variety of life. In UBNA, more than 200 bird species have been seen over the years, where it is considered a paradise for bird watchers and has become one of the premier sites for birding in Seattle (Seattle - Union Bay Natural Area (Montlake Fill), n.d.). Apart from recreation, UBNA also serves as a living natural laboratory for students, researchers, and the community to study and appreciate native flora and fauna within this area. While it is one of the best places for urban residents to enjoy natural spaces, it was once the main landfill site for the City of Seattle for much of the last century.

[Figure 1 (Left). Aerial view, Montlake Dump (center), Union Bay marshland, Seattle, June 21, 1938 Photo by Pacific Aerial Surveys Inc. (Caldbick, 2013); Figure 2 (right). Montlake Landfill in the late 1950's, from Dr. Kern Ewing's slide about UBNA history (UW Botanic Garden, n.d.)]

From 1926 to 1966, UBNA was where things were dumped from all the sources - City-contracted waste haulers, commercial haulers, and ordinary residents - without limitation and any records, known as Montlake Dump back in the time. Sometimes, the place could store up to 60 percent of Seattle City's garbage (Caldbick, 2013). In 1956, Montlake Dump adopted the modern sanitary landfill technique, creating instead into Montlake Landfill. Today, some long-time residents still call this place Montlake Fill. By 1966, with the growing environmental awareness among residents and the city's recognition of the issue, the site was closed for any further dumps and capped with a layer of clay and soil from construction sites, and then graded and seeded with grasses (Caldbick, 2013). Soon after, the biotic processes and natural activities that had been absent for a long time started to take place. A vibrant grassland formed, dotted with trees and

shrubs, ponds made in low-lying soil, and marshes along the shoreline, UBNA quickly became home to a variety of flora and fauna.

However, as it was a heavily used, unregulated landfill for 40 years, safety issues and concerns about using this site in the long term emerged. Generally, a properly built and maintained cap can effectively keep and isolate the contaminated material, such as landfill trash, as long as it does not erode or form cracks or holes that allow water to reach the contaminants (EPA, 2021). However, as a riparian ecosystem adjacent to two of Seattle's urban watersheds - Ravenna and Yesler Creeks, Lake Washington- UBNA is at high risk of cap erosion and the release of toxins and pollutants into the City's water circulation system (Howell & Hough-Snee, n.d.). In addition to the contaminant leakage, another issue that makes the restoration of the UBNA site an arduous task is the thriving of invasive species. Although some native, early succession riparian species like red alder (*Alnus rubra*) and black cottonwood (*Populus trichocarpa*) started to settle on the site's wet edge and sunken depressions, the densely compacted clay cap above the landfill was not conducive for re-establishment of native plant species on a large scale. With the absence of native recruitment, invasive species, particularly the Himalayan blackberry (*Rubus armeniacus*) and Scotch broom (*Cystisus scoparius*), were quickly established and flourished over the site (Howell & Hough-Snee, n.d.). According to Huang and Moral (1988), though over 140 flowering plant species were recorded in the Montlake Wildlife Area, invasive species dominate and even form "shrub islands" at where today's UBNA is located.

In order to restore the land to what we see today, the University of Washington and associated communities have put in an enormous amount of effort. Starting in the late 1990s, a University of Washington professor, Dr. Kern Ewing, began to lead students in ecological restoration projects at UBNA (Backus, 2019a). Thereafter, numerous restoration projects were started to create native forest, wetland, and grassland ecotypes. These ecosystems are commonly used by students from one of the University of Washington's many restoration ecology courses and faculty within the School of Environmental & Forest Science (Howell & Hough-Snee, n.d.). While restoration ecology students and researchers are actively involved in the restoration projects at UBNA; visitors, volunteers, and non-restoration students are also highly welcome to join the restoration practices. In the Winter Quarter of 2019 alone, volunteers contributed many hours of removing a total of 600 pounds of invasive plant species and planting 452 native plants at one of the student-run nursery sites at UBNA (Backus, 2019b). In addition, considering adverse impacts of future city developments, state and city agencies also contributed to the restoration of the area. For example, in the planning of the construction of the SR 520 bridge replacement and HOV program, which crosses Lake Washington and connects Seattle and Bellevue, the Washington State Department of Transportation set up numerous mitigation projects mainly in Lake Washington to compensate for the construction influences. One of the projects started in 2016 was to enhance the University of Washington's UBNA management plan, focusing on establishing new wetlands, improving existing wetlands and riparian buffers, removing invasive species and installing native species (WSDOT, n.d.). Today, though

restoration efforts have been ongoing for more than thirty years, pollutants deep in the soil can still potentially threaten the local communities and surrounding environment. With the continuing efforts by the university and associated communities, many restoration projects have been established, most of which have been extended from earliest efforts, and more projects are planned for the future.

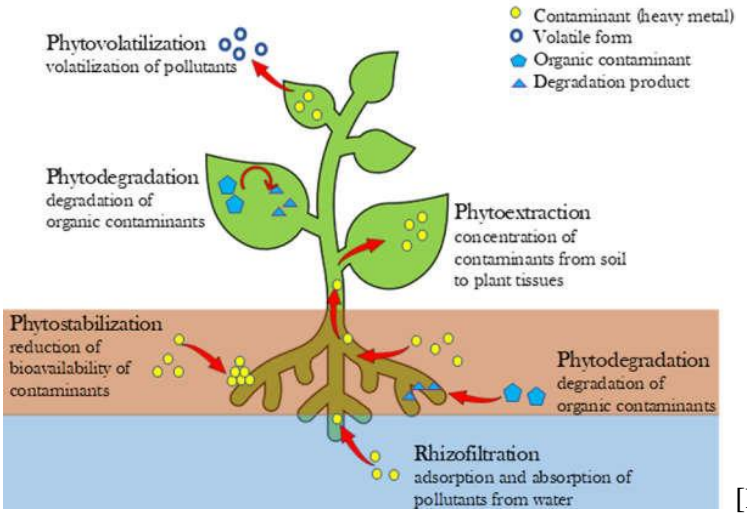
Applications of Phytoremediation and Riparian Buffers

Choosing the technique for the UBNA restoration project was difficult and crucial, as the area faced the dual challenges of highly concentrated underground pollutants and densely established invasive plant species. One possible solution for pollutant leakage was to continuously monitor the soil's chemical content and purify the polluted soil until the contaminant level stayed under the standard for safety. However, it can be very expensive in the long run. In addition, continuous digging and replacing site soil can cause further environmental disturbance, influence the local community, and even lead to secondary pollution (Reynolds, 2023). Therefore, an effective alternative remediation approach that was financially affordable and environmentally friendly was imperative. Fortunately, in the late 1980s, a new bioremediation method was introduced, using plants as the core mechanism for restoring contaminated sites: officially known as phytoremediation (Banca, 2020).

Phytoremediation is a technique that uses plants' innate abilities to remove contaminants from the environment. This process is powered by solar energy, making it self-sustaining and cost-effective (Yan et al., 2020). Plants can effectively extract water-soluble pollutants from the soil through their roots, functioning as pump-and-treat systems. These pollutants are then moved or translocated to other parts of the plant, where they can be metabolized, stored, or released into the air (Doty et al., 2007). Plants also foster the growth of microorganisms in the region around their roots, known as the rhizosphere, which actively accumulate and break down pollutants (Yan et al., 2020). Phytoremediation, in addition to rehabilitating toxic land soil, can also cleanse water and air through its roots and leaves, respectively, making it a widely applicable approach (Banca, 2020).

Phytoremediation can remove a variety of pollutants from the environment, including both organic and inorganic pollutants. Organic pollutants, such as pesticides and benzene, are carbon-based, bioavailable components that can be absorbed and degraded into stable and less hazardous forms within plant tissues or outside the plant by roots and facilitated soil microorganisms (Pilon-Smits, 2005; Amruta, 2023). On the other hand, Inorganic pollutants, including heavy metals, are not biodegradable, and can be very toxic for plants even at a low level. However, plants can minimize the impact of heavy metals on the environment by preventing their movement and limiting their availability to plants and other organisms (Yan et al., 2020). Some specific plant species, also known as hyperaccumulators, can safely extract inorganic compounds from a site. T (Yan et al., 2020). Plant tissues with high-valued metals can be harvested and recycled for metal production, which is called phytomining (Miller, 1996). In

addition, pollutants can also be removed from the soil and converted into less harmful forms by plants, which will then release the pollutants into the atmosphere through water leaving the plant's leaves(Yan et al., 2020). In polluted water bodies, plants can also remove contaminants and excess nutrients(Nedjimi, 2021).



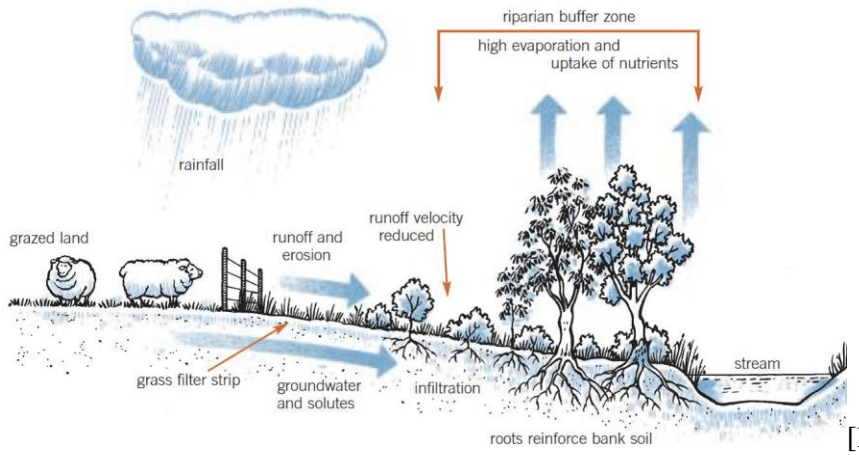
[Figure 3. Schematic representation of different phytoremediation approaches by plants under study. (Rigoletto et al., 2020)]

Phytoremediation can provide more benefits than restoring a polluted environment. By installing plants, a polluted site can be cleaned up in a more aesthetically acceptable and environmentally conscious way. This is appreciated by nearby residential communities (EPA, 2012). Plants can also control noise, purify air, stabilize soil, sequester carbon, and possibly produce timber and biofuel (Doty et al., 2007).

At UBNA, the plant species used for the phytoremediation method were carefully selected to deal with the issue of widespread coverage of non-native plant species. Poplar (*Populus spp.*) and willow (*Salix spp.*) are the two native species that were recorded as highly effective in taking up pollutants from the soil due to their rapid growth rate, high water uptake, and large biomass production (Doty et al., 2007). Poplar and willow are also easy to cultivate in nurseries and are highly adaptable to the site, as they can be planted and established simply by inserting a cut branch into the soil. In addition, as "pioneer" species with the ability to establish in sources-limited environments, poplar and willow are ideal for leading the recruitment of native plants. After the invasive species are removed, poplar and willow can quickly establish on the site and take up space in case invasive plants re-establish.

In addition to cleaning up the soil, plants that grow on the top of bank regions can create riparian buffer zones, a strip of vegetation planted next to a stream or other water bodies (DEC, n.d.). Deep growing roots stabilize the soil, preventing erosion due to high stream flows washing away the bank of the stream(Drugge & Doty, 2019). Riparian buffers can also slow the rate of water flowing into a stream or river, preventing surface runoff and allowing water to percolate into the soil. This all leads to a decrease in flooding and recharging the groundwater. In addition,

established vegetative buffers provide habitat for wildlife and shade above water, decreasing the water temperature while holding more oxygen and creating a better living environment for aquatic organisms (Drugge & Doty, 2019). Most importantly, riparian buffers act as a physical barrier between developed land and the water body, which traps the pollutants from flowing into the water and decreases their harmful effects (Drugge & Doty, 2019).



[Figure 4. Riparian buffer in improving water quality and the surrounding environment. (AFDA, n.d.)]

Phytoremediation and riparian buffers are two technologies that have been proven to be successful at removing contaminants from the soil and waterways. They also provide a low cost way to improve the environment of a site without having to use harmful chemicals or large machinery. Both of these methods require knowledge about the site; from the contaminants present to what type of plants will grow there. The restoration project at Ravenna Creek in UBNA has many challenges, but using phytoremediation and by installing a riparian buffer, there is hope that it may return to a more ecologically sound state of being.

Introduction to our site

Our restoration project began in 2021 with some planting and became a project site in Autumn 2022 when Professor Sharon L. Doty from the School of Environmental & Forest Science (SEFS) acquired the right to use this land for her phytoremediation research at the University of Washington (Lowery et al., 2023). The restoration project is next to Ravenna Creek, as shown in Figure 5.

[Figure 5. The project site is delineated in yellow above. The screenshot was taken from Google Maps]

As the former landfill site is right on the Ravenna Creek's bank, which has remained unmanaged for decades, the site was heavily eroded due to the rain and the creek water, leaving only about one foot thick of soil above the landfill (Doty, n.d.). With the high risk of pollutant exposure, the surrounding environment and the creek water could be highly contaminated, threatening local organisms and residential communities. In addition to toxins leakage, the site was dominated by invasive species, including Himalayan blackberry (*Rubus armeniacus*), reed canary grass (*Phalaris arundinaceae*), and Scotch broom (*Cystisus scoparius*), which largely hindered the continuous restoration process (Doty, n.d.).

Work Completed Before Fall 2023

At the very beginning of the project, Doty and Autumn 2022 students decided first to remove invasive species from the land to clear more spaces for poplar and willow planting. In a few years, a site that was once cleared can be covered again by Himalayan blackberry. By spring 2022, the center of the site was cleared of invasive species and planted with willow cuttings. After willows were collected, the team, with the help of the Society for Ecological Restoration (SER-UW), expanded the area to the stream bank and started to build up a riparian buffer by planting poplar along Ravenna Creek (Lowery et al., 2023).

A new student team was introduced in Autumn 2022, which mainly focused on maintaining the site. To improve the growth of established willow and poplar, they spent a lot of effort with SER removing blackberries and competitive grasses and adopted a new technique of "sheet composting" that involves covering the base of young seedlings with wet cardboard and placing fertilizer on top. This method effectively enhanced tree growth because the slowly decomposed cardboard hindered fast-growing grasses from over-competing young trees while allowing nutrients to be still carried underground with water.. The same project team also carried out the first soil and water analysis of the site in Winter 2023, providing a better understanding of pollutant type and level in the area and a reference for future restoration teams (Lowery et al., 2023).

 [Figure 6. Spring 2023 Work Party to plant saplings. Taken by Grace Luo in May 11, 2023]

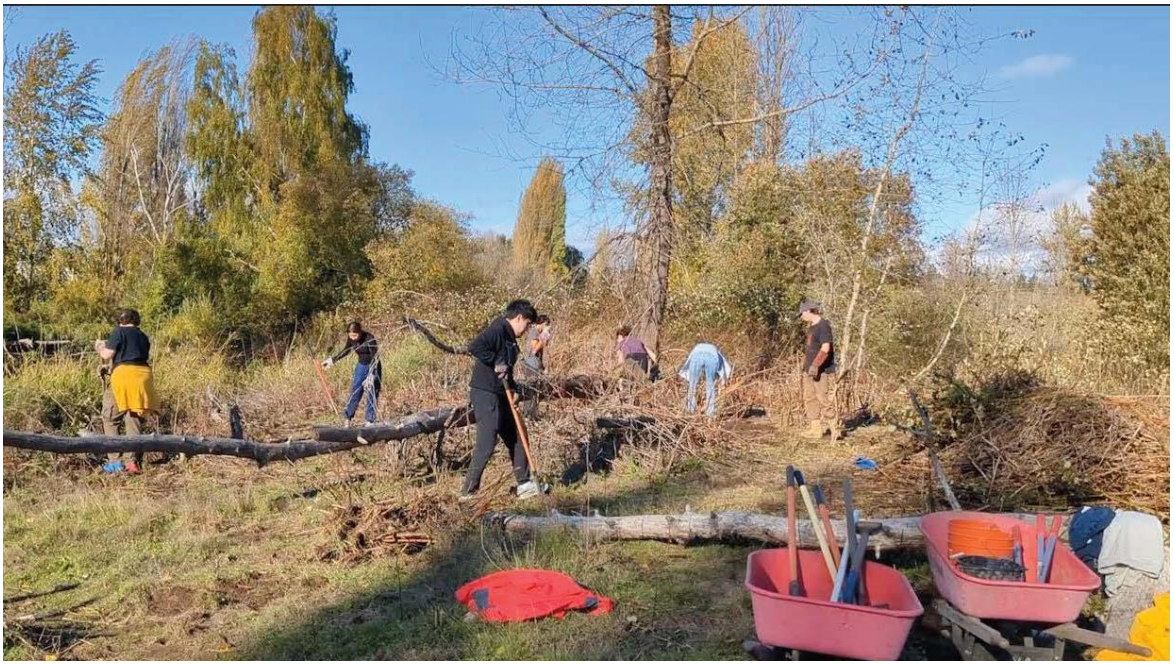
In Spring 2023, the third capstone project team undertook site management work. They continued removing blackberries and pushed the site north, planting new trees with the help of SER and volunteers from Doty's ESRM 201 class. Due to the severe damage caused to newly planted saplings by beavers, the team bought chicken-wire fencing and fenced each sapling at the following work parties. They also set up a GoFundMe page, with the goal of raising money to purchase equipment for better site management. By sharing the project details on social media and educational videos uploaded on TikTok, they acquired public attention and acquired a donation of nearly $1,500. With these donations and scholarships, they bought equipment, signs that linked to the project website to connect the site with visitors to UBNA, and two wildlife cameras that captured activities of the wildlife at the site. During the Summer of 2023, with heat waves threatening the plants' survival, the team shifted their focus to keep the plants alive in the high temperatures. They watered all the trees one to two times a week to prevent them from dying. In addition, to make watering work easier, and for team member's safety, they built two wooden platforms coated with waterproof paint to stand and keep their feet dry while collecting water (Lowery et al., 2023). This team's contribution was tremendous, as many of their ideas provided huge benefits and conveniences for the future team who would continue the maintenance of the site.

Methods

Applying phytoremediation and restoring the site to a more environmentally beneficial state required many steps and methods. At the start of the fall quarter of 2023 with the new capstone team, the goal was to remove as much blackberry as possible. Blackberry is difficult to remove as it grows into dense thickets and has stiff, hooked thorns that catch clothing and require thick gloves to handle safely (Washington State Noxious Weed Control Board. (n.d.)). Removing blackberries takes time, and then the blackberries have to be taken away to be composted off-site. Other invasive species are occasionally found at the site as well. English ivy

(*Hedera helix*) is a common weed around Western Washington and has grown on some of the mature tree at the site. Ivy can be a problem because it adds weight to the canopy of trees and can lead to them falling in wind, as well as shading out low-growing native species (Washington State Noxious Weed Control Board. (n.d. -b)). English ivy is less difficult to remove than Himalayan blackberry, but both weeds need to be removed for the restoration to continue. Scotch broom (*Cytisus scoparius*) is also an invasive species that has been found and removed from the site in the past. Scotch broom seeds can survive in the soil for at least 30 years, so even several years in the future they can still pose a problem for the site (Washington State Noxious Weed Control Boards. (n.d. -c)). All of these invasive species impact any site where they are present, so naturally the first method for restoring the site at Ravenna Creek was removing these plants.

The members of the Fall 2023 capstone team spent weeks removing the above ground stems of the blackberries (leaving some stems to indicate the base of the plant). Afterwards a work party was held to remove the underground roots, which grow wherever a stem touches the ground (Washington State Noxious Weed Control Boards. (n.d. -a)). Removing the roots is hard work, and requires a lot of skill with a shovel or pickaxe. The work party worked for several hours to remove the roots from the ground. This work party consisted of volunteers with members of the capstone group facilitating the event. Most of the visible blackberry was removed from the site, with only a few small patches left after the work party. Unfortunately, due to the nature of blackberries being able to regrow readily from roots left in the ground, the success of the work party will only be seen after the next year's growing season has started. Hopefully, most of the blackberries removed will not grow back.



[Figure 7. Photo taken from video at the first fall 2023 work party. Taken by Elizabeth Richmond on 11/02/2023]

After the invasive species were removed from the site, the next step in the process was to plant native species that would grow to form the riparian buffer next to the stream. In past

quarters, riparian buffer species like willow *(Salix ssp.*) were planted as live cuttings next to the stream. However, the site is frequented by beavers who proceeded to remove or cut most (if not all) of the cuttings planted by prior teams. The plan for fall 2023 was to take the strategy adopted by the team Spring 2023 and protect some of the plants with hardware cloth fences to keep the beavers away from the plants. A second work party was held to plant cuttings taken from nearby willow trees at UBNA. Cuttings are free and willow species have good root strength and grow quickly and easily (King County, Washington. (n.d.)). The volunteers at the second work party collected and planted the willow cuttings along the stream, where the prior years' plantings had been removed by beavers. Then a third work party was held in December to install fencing around some of the cuttings. Unfortunately there was not enough funding to protect all of the plants at the site, and the unprotected cuttings were again taken away or gnawed on by beavers. Currently, the protected plants at the site are still in place and several of them are starting to bud as spring approaches.

One limitation of our ability to restore the site is cost. Buying plants from a nursery is more expensive than taking cuttings, though it can be worth it to have a wider variety of more established plants. Fencing is also expensive, and there were not enough funds to secure fencing for all of the cuttings planted at the site in fall 2023. Part of the site's outreach is securing funds to aid the project. A GoFundMe was created by the previous team to raise funds for the project. Grants were also awarded to the project which were used for water analysis and buying plants from the Society for Ecological Restoration's nursery. These efforts increase the effectiveness of the methods applied at the site, from protecting plants to gathering information on what effect phytoremediation could have on the pollutants being released by the site into the surrounding waterways.

Another limitation of the site is the restriction on planting any native species that produces edible berries. Many native, riparian species like salmonberry (*Rubus spectabilis*) produce edible fruit that are tempting to humans and wildlife alike. Unfortunately, the site's prior history as a landfill means any number of toxic chemicals may be present in the soil and groundwater. This makes any fruit growing from the contaminated soil toxic. In order to protect the health of the surrounding wildlife and the visiting public, we are unable to plant fruiting species at the site.

An assessment of the pollution at the site is necessary to determine what effect the riparian buffer and phytoremediation are having on the pollutants entering the waterways from the contaminants at the site. The assessment of the site is currently ongoing. In Winter 2024, considering the available budget, it was decided to do a water analysis for organic pollutants, such as pesticides, benzene, and PAHs (polycyclic aromatic hydrocarbons). Samples were collected from Ravenna Creek and were taken from three different spots: one by the southeast corner of the restoration site, one to the north of the current plantation region, and one in between the two spots. All the samples were mixed into one 40 ml VOA sample and sent for analysis. The results of these tests will hopefully be used to inform future groups on the effectiveness of ecological restoration on waterway health.

Observations from the past two quarters

Many species of birds gather in and around the site (Seattle - Union Bay Natural Area (Montlake Fill), n.d). Providing habitat for bird species is very important to the restoration of the site. Many species of birds have been seen at the site, like great blue herons (*Ardea herodias*). Beavers are also present at the site, while they are a sign of a healthy aquatic ecosystem, they do eat trees and make restoration of the site more difficult. Deer, snakes and many types of insects have also been found at the site. With the biological diversity comes visitors who are attracted to the wildlife at the site. Many people pass by the site on any given day. The site is next to one of the main entrances to UBNA; the bridge over Ravenna Creek. When working at the site, members of the restoration team have been asked "what are you doing?" and many variations on that question. A goal of our site is to connect the community to the site; from having a website (Doty, S. L. (n.d.)), to making videos, and the hope to one day have signage describing what is happening at the site. The community benefits from and contributes to the restoration of the site. Paths have been made at the site to facilitate visitors and protect the fragile plants.

During the fall 2023 and winter 2024 quarters, four work parties were held at the site. Most of the participants were volunteers. Volunteers are needed to work at the site, from blackberry removal (an endless task) to planting and watering in the dry months. Many of the volunteers at the site come from the UW, mainly from the Society for Ecological Restoration (SER) and Professor Doty's classes in the Environmental Science and Resource Management (ESRM) major. Volunteers are a vital part of this project, and with their help, major changes have happened at the site this year. From the clearing of most of the blackberry (above and below ground segments) to the planting of native willows, dogwoods and roses at the site. Installing the fences around the plants to protect from beavers was also a task tackled during one of the work parties held this year. The project would not have been possible without volunteers from the surrounding community. This project is only possible because of the connections beyond the site, and hopes to impact ecological systems beyond the site's boundaries.

Future plans

For the future of this project, steps need to be taken to prevent the resurgence of blackberry, further continue to connect to the wider community through outreach, and continue the planting (and maintenance) of native species at the site. Blackberry is difficult to control, even with constant vigilance and experienced crews. It is highly invasive in Western Washington and is carried far and wide by birds who eat the delicious berries and drop them in their feces. For future teams, removing any regrowth and watching for new plants will be an unending task.

Continuing and expanding outreach into the community in and around UBNA and the University of Washington is essential to the long term success of this project. This quarter videos have been created to demonstrate the changes and work done at the site. Documentation is important for use by future project teams and for demonstrating the impact this year has had on the site. Videos and pictures are also useful for outreach as they are more engaging and straightforward for people to learn about our project. Other forms of outreach should also be

explored; including more of the non-UW community around UBNA and engaging with tourists. Signage is a future goal, and this would not only explain what the project is, but expand the community of people invested and involved with the project.

Once the willows and other native species are established, they will need less watering and maintenance throughout the year. Last summer, watering was a large consideration and took up a lot of time for the capstone team. Hopefully a more mindful planting technique will lead to less watering in the dry months for future teams. More plants should be added in the future as well, due to the lack of fencing, there are fewer willow cuttings taking root than expected. If more fencing can be acquired in the future, more cuttings should be planted. Native plants that are resistant to beaver predation can also be planted (nootka rose (*Rosa nutkana*) is one example), which also will increase biodiversity at the site. These measures will ensure that future teams and visitors will see the results of this capstone team's efforts.

This project will also be an example of how a site can be restored and contaminants in the soil mitigated. By implementing phytoremediation, it is anticipated that the polluted land and nearby water systems will have decreased levels of soil and water contaminants. The site will need work and maintenance, and several more capstone teams and work parties of volunteers in the future to become a success. Though the timeline is uncertain, all the restoration efforts are making good progress, and a promised future of a fully restored natural area is already being seen at the site.

Discussion

The history and location of this site have created a need for ecological restoration to improve the health of nearby waterways and the soil at the site. Phytoremediation is the ideal method at this site for removing contaminants from the soil and water. Our focus was primarily on removing the invasive species from the site and introducing plant species that are native to the site and effectively absorb toxins from the soil. This required many hours of work from the capstone teams, as well as several work parties and volunteers. More work needs to be done at the site to continue the maintenance of the current plantings and to introduce more plants to the site. Invasive species will continue to be a problem, but the hope is after this season the number of invasive plants will have been severely reduced. All of this work produces an environment that is healthier for people as well as wildlife that frequents the site and surrounding areas. All of these aspects lead the site closer to the end goal of remediation: a site that has a healthy ecological function and connection to the world around it.

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