The University of Guelph Arboretum Gravel Pit Rehabilitation

40-Year Naturalization Review

Research Communication and Southwoods Hill Study

Final Report Submitted to The Ontario Aggregate Resources Corporation

February 12, 2024

The University of Guelph Arboretum Study Areas: Overview of the aggregate restoration sites contained within The University of Guelph Arboretum. In the middle is the Gravel Pit Restoration Collection (~.51 hectares), actively restored between 1977-1979, and then left to naturalize. On the right is the Southwoods Hill restoration area (~.75 hectares), where several reclamation experiments were conducted between 1977-1978.

Summary:

The Arboretum at the University of Guelph aims to connect people with nature and conserve biodiversity through the research, teaching, and outreach mandate of the University. Over more than 50 years, the 400 acres containing old growth forest, wetlands, former farmland and agricultural research fields, and decommissioned gravel pit and aggregate disturbed areas, have grown to become an internationally-accredited Arboretum and beloved, award-winning greenspace.

In the 1970s, following its inaugural master plan, The Arboretum research coordinator, Sarah Lowe, conducted rehabilitation in the abandoned gravel pit within The Arboretum grounds. This effort and the Gravel Pit Rehabilitation Collection became an innovative and award-winning aggregate reclamation research and demonstration site. Since 1978, the area was basically left to naturalize. Now more than 40 years later, with research support from The Ontario Aggregate Resources Corporation (TOARC), the Arboretum has undertaken a multi-year assessment of the original reclamation. The work aims to understand the success of the original restoration, the progression of plant and tree species (planted, naturalized, and introduced), the changes and context of restoration best practices and policy planning over the period. This review has been conducted in part to provide insight for future collection planning and research efforts in The Arboretum.

During 2021, the original "Gravel Pit Rehabilitation Collection" was surveyed and compared to nearby forest, and a novel geographic information system (GIS) was created to map the detailed vegetative survey results and signage was designed. In 2022-23, a follow up study was conducted to compare a second site called "Southwoods Hill", archival research materials were digitized and organized for future research access, interviews were conducted for a video produced about the history of the gravel pit rehabilitation in the Arboretum, and the communications and research results have been shared with the Arboretum communities and professional societies (American Public Gardens Association, OSSGA).

This report summarizes the project accomplishments under the TOARC funding from 2022-23. Three project objectives were: 1) Conduct a bioinventory of Southwoods Hill for comparison with the Gravel Pit Rehabilitation; 2) Designate the original Gravel Pit Restoration for new studies and treatments; and 3) Develop video and research communications to share the story of the Gravel Pit Rehabilitation in the University of Guelph Arboretum. This report summarizes project accomplishments in reverse order.

Objective: Gravel Pit Rehabilitation History and Research Communication

A core project objective was publication and communication of research results through educational components, including a video that tells the story of the Gravel Pit Rehabilitation project. Extensive archival photographs and materials were reviewed and digitized for both the documentation project and to support future studies in the Gravel Pit Rehabilitation Collection and Southwoods Hill. Interviews were recorded with Sarah Lowe (Arboretum Research Coordinator from 1976-1978 who conducted the original Gravel Pit Rehabilitation), Dr. Karen Landman (landscape architect and professor at the University of Guelph), Justine Richardson (Arboretum Director), and Ian Murphy (Graduate Research

Assistant, BSc Biodiversity and current student in the Master's of Landscape Architecture program). A public workshop on the Gravel Pit rehabilitation project focusing on methods for evaluating ecological restoration and focusing on future plans was held September 10, 2022 in conjunction with the Arboretum Expo and Society for Ecological Restoration. The research in the Gravel Pit Rehabilitation project was presented at the American Public Gardens Association annual meetings in June 2023. Two videos were completed. They can be found on the Arboretum's YouTube account via the links below, and embedded in the Arboretum Website and the TOARC website under "Naturalization".

The Arboretum, University of Guelph – Gravel Pit Rehabilitation Project with Sarah Lowe
https://youtu.be/p41m8KT2LDI

The Arboretum, University of Guelph – Gravel Pit Rehabilitation Historical Summary (long version)
https://youtu.be/cCntBQg18Bo

Objective: Resources for New Research in the Gravel Pit Rehabilitation site

Our project aimed to designate and prepare one regional "lobe" of the Gravel Pit Rehabilitation site to serve as treatment and control areas for various studies, including invasive species control and lichen variability. All lobes of the original Gravel Pit Restoration Area were surveyed for Dr. Robert Hanner's lab by a graduate student. A series of moss species of potential use for restoration initiatives were identified. Removal of invasive species, specifically buckthorn, was identified as a significant and needed first step in preparing this site for further studies. Two group workdays were conducted for mechanical buckthorn removal in this site, and the Arboretum's Horticulture team has begun a trial with biological control agent Lalcide Chondro (containing *Chondrostereum purpureum*) to test its efficacy in reducing and eliminating buckthorn. This work is ongoing. In addition, all reviewed and digitized archival materials – including 1970s planting lists and plans, monitoring reports, photographs and publications – have been collected in a One Drive folder for researchers to access for future studies.

Finally, the Arboretum Master Plan will be updated as part of an overall Campus Master Plan process during 2024-25. This assessment of the Gravel Pit Rehabilitation and Southwoods Hill will be part of the overall Arboretum planning process.

Objective: Southwoods Hill Review and Comparison

In the 1970s, one section of the Arboretum became an innovative and award-winning aggregate reclamation research and demonstration project. Now 40 years later, with research support from TOARC, we are assessing two naturalized sites in The Arboretum that are associated with aggregate removal and deposition , to understand the success of the original restoration, the progression of plant and tree species (planted, naturalized, and introduced), the changes and context of restoration best practices and policy planning over the period. With the addition of the second restored site (Southwoods Hill, south of Stone Road in the Arboretum's "Nature Reserve" area)

we hope to gain a valuable comparison to the bioinventory and soil sampling conducted in the Gravel Pit Rehabilitation project during 2021.

In 1970, the former gravel pit, now known as Southwoods Hill, was filled in with material from an adjacent road construction, *with no intention of further restorative actions*. Indeed, no further restorative actions were conducted on site until 1976 when Dr. Bob Hilton, then Arboretum Director, and Sarah Lowe, the Research Coordinator, began to form the Arboretum's Rehabilitation Program. This program had at its disposal two severely disturbed sites including the Gravel Pit Rehabilitation Collection, and Southwoods Hill, presenting the Arboretum with an opportunity to explore various restoration strategies, at a time when little knowledge was available on best species and best practices, and the steps involved in creating a successful rehabilitation project.

Work towards the restoration project of Southwoods Hill began in 1976 with an initial survey to assess soil conditions and the state of vegetative development on the site. Following the vegetative survey, several experiments were designed, and various earthworks *procedures* were performed to improve site access and prepare the site for planting. Leaf litter and biosolids were collected and put to use in composting and fertilizer trials on site.

Several Arboretum employees mix sludge and leaf litter into exposed gravel and sand as a part of the Southwoods Hill reclamation experiments. Photo by Sarah Lowe, 1977.

The objective of the 1977-79 studies on Southwoods Hill was to assess the impact of herbaceous groundcovers on the growth and survival of woody trees and shrubs in disturbed soils. Preliminary research showed high mortality in original plantings on the Southwoods site.

In comparison to the Gravel Pit Rehabilitation collection, the 1970s era Southwoods Hill experiments were far more localized on individual sections of the site, and represented a less thorough restoration. The Southwoods Hill site was minimally accessed during the three years of experimentation and observation. After planting in Southwoods, individual plants were not watered or provided with any maintenance. This was likely in part due to limitations in water infrastructure, as well as the desire to replicate outcomes that might be experienced in the field in actual existing and future pits and quarries. In addition, on Southwoods Hill there was no replacement of dead or dying plants after various winter die-back occurred (This contrasts with the practice of replanting the Gravel Pit Rehabilitation Collection plantings annually over a three-year period after a winter dieback assessment). After the research

project finished in 1978, the area was left largely untouched by Arboretum staff and the public until this project to assess the status of the Southwoods Hill began in 2022, nearly 45 years later.

Over the course of several months in summer and fall of 2022 and 2023, this Southwoods Hill site underwent a bioinventory and comparative analysis. The methodology included a transect survey of plant species, and soil testing to assess the trajectory of the restoration that was performed with different intentions than the Gravel Pit Rehabilitation Collection. Forty-six (46) 1 x 1 m plots in 3 transects divided the site that had clear differences in the types and vegetation across its area. Soil samples were taken to assess textural and nutrient variations within and between sites around the Arboretum.

Analysis of archival records from the original 1977-79 efforts show that Southwoods Hill in the Arboretum Nature Reserve was not rehabilitated with the intention of the main Gravel Pit study area. Southwoods Hill is a slightly higher elevation, located just off the corner of two through roads – Victoria Road and Stone Road. The area is part of the Arboretum's Nature Reserve, and is not accessible to the general public. In contrast, the Gravel Pit Rehabilitation Collection is located in the central Arboretum, near the educational nature centre, Victoria Woods, and has a core trail, the Colonel John McCrae Trail, traversing the pit floor. Due to these locational differences, the Southwoods Hill area was used as an active experiment area, with particular amendments for ground cover and other studies that would be appropriate for a site not accessible to the general public.

Bioinventory Results:

One of the main goals of the bioinventory efforts completed over a period from May – August 2022 was to compile valuable information on the biodiversity, abundance, and relative state of rehabilitation in a largely unrehabilitated site, in order to compare the outcome to a site that received a more thorough restoration in order to able assess how different strategic interventions play out over an extended period of naturalization.

The plot sampling methodology for Southwoods Hill involved 46 1x1 m plots laid out along 5 transects. These plots were sampled for plant diversity along a changing environmental gradient in Southwoods Hill. Results of these plant diversity analysis show that several species remain from the series of the experiments between 1977-1979, however far more of the species currently found on site are those that have arrived through natural colonization from local sources. The specific species now found on site, as well as the origin of these species are presented at the end of this report. The 2022-23 plant diversity sampling results show that during the 45-year period since the restoration experiments were conducted in Southwoods Hill, 51 of the originally planted and surveyed plant species have disappeared from the site, with only 13 species remaining. In contrast, 45 species have arrived through natural process, indicated a *high rate of turnover* (the average of plant mortality and recruitment rates) on the site.

The most abundant plants are listed and compared at the end of this report. The most abundant plant found in Southwoods Hill is eastern white cedar (*Thuja occidentalis*), which had been planted as part of the rehabilitation trials, and was also found extant at the perimeter of the site in the 1970s. In contrast,

the Gravel Pit Rehabilitation Collection study in 2021 found that in that area common buckthorn (*Rhamnus cathartica*) was by far the most abundant species. The rank abundance curve presented at the end of this report demonstrates that (like the Gravel Pit Rehabilitation) a handful of species do outperform the majority in terms of abundance in plots.

In addition, on Southwoods Hill where significant surface gravel still exists visibly on the land surface 45 years later, the plant species that do survive there include significantly more herbaceous sedges, grasses and wildflowers, than the Gravel Pit Rehabilitation Collection. These are able to tolerate the stoney and highly alkaline conditions, and more readily spread from the exposed roadside aspect.

Soil Testing:

In this project's soil sampling, nine samples were taken from each of four locations around The Arboretum. This included Southwoods Hill and the Gravel Pit Rehabilitation Collection, and for comparison the old growth forest sections of Victoria Woods and Memorial Forest. Samples were taken from a minimum of 8 augured soil cores from randomly selected one square meter plots at each location. Soil cores were mixed together and excess soil over 300 g was discarded. Various nutrients and soil properties were analyzed by the Guelph Agri-food lab. Additional properties of these collected samples included sodium and calcium content and the overall proportions of sand, silt, gravel, and clay.

Comparing these soil properties sampled, there were few discernable patterns between any of the selected sites that could be indicative of differences in disturbance, or planting history. One notable difference between sites is that the two disturbed areas have a significantly higher pH and are thus quite alkaline compared to the control sites that are typically only slightly alkaline. These disturbed areas were found to have a higher calcium content, likely a result of crushing limestone cobbles and the overall extraction process. In addition, the rehabilitated sites were also found to have a lower magnesium and sodium content, and higher dry carbon content. Of all the sites, Southwoods Hill had the highest percentage of gravel and near the highest percentage of sand; visually displaying far more medium and large gravel and cobbles on the surface. Observing the vegetative community found in Southwoods, we see a higher diversity and abundance of grasses, sedges, rushes, and other communities that are more tolerant of the poor, dry soils. This is a distinct contrast to the relatively silt and clay rich soils of The Gravel Pit Rehabilitation Collection that host more annual and perennial dicots that prefer greater moisture levels. This difference reflects the limited earthwork efforts that were performed at Southwoods Hill to bring in removed topsoil and ameliorate this gravel and cobble as was performed in The Gravel Pit Rehabilitation Collection. No other variables provide a clear explanation.

The ON soil survey of Wellington County shows that the Gravel Pit Collection and Southwoods Hill are found within the same historic soil class. This class is Parkhill loam, a dark grey gleysolic loam till, with poor drainage and slightly stoney. In contrast, Victoria Woods, one of the selected undisturbed sites, lies on Granby Sandy Loam soils, with medium sand and poor drainage, likely explaining why this site has the highest sand proportion of any of the tested soils. The final site, the Memorial Forest Collection, rests on gently sloping Guelph loam soil.

The parameters tested in this soil sampling effort do not represent overall soil health and fertility. To do this, additional metrics such as the level of potential chemical and physical contamination, and an assessment of soil biodiversity in terms of fungi, bacteria, and soil invertebrates would need to be

measured. These tests are both costly and require greater expertise, and out of the scope of this current stage of assessment. Therefore, conclusions about the development, and health of the disturbed and native soils tested are limited. However, the efforts here provide a clearer picture of both of these rehabilitated sites, as well as a steppingstone for future efforts and assessments. Next steps could include performing a soil bio-inventory and assessing for potential contaminants. Both of these studies could provide a clearer direction for future rehabilitation activities that could be undertaken to continue to improve the site to higher levels of ecological restoration.

							Soil Properties Tested						
Site	Texture	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Phosphorous (mg/L soil dry)	Magnesium (mg/L soil dry)	Potassium (mg/L soil dry)	Sodium (mg/L soil dry)	Calcium (mg/L soil dry)	pH	Carbon (% dry)	Nitrogen (% dry)
Gravel Pit Rehabilitation Collection (slopes)	Loam	7.1	45.5	41.3	13.2	11.45	200	115.0	16.5	3150	7.9	5.31	0.21
Memorial Forest	Silty Loam	1.5	30.9	54.5	14.7	7.45	600	92.5	20.5	2850	7.2	3.86	0.36
Southwoods Hill	Sandy Loam	10.7	53.9	36.9	9.2	2.13	133	47.3	18.0	3650	8.0	6.52	0.10
Victoria Woods	Sandy Loam	1.0	55.3	34.2	10.5	4.50	470	34.0	32.0	2200	7.3	3.03	0.19

Southwoods Study Conclusions

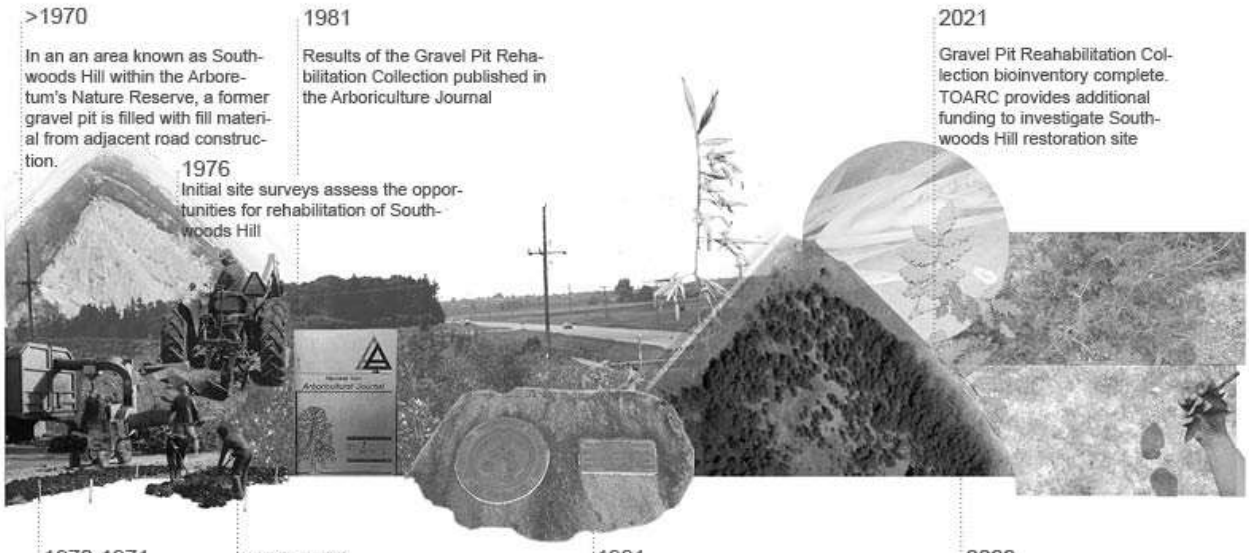
Overall, the Southwoods Hill survey, when compared to the Gravel Pit Rehabilitation Collection, demonstrates that increased soil amendments and repeated efforts over at least three years, does create a long-term effect of increasing plant species success in a restoration project. Indeed, in this era where Ecological Restoration is a globally identified aim, multiple year efforts to reverse the ecosystem effects of disruption, rehabilitate disturbed land, and ultimately restore ecosystems and functions should include multi-year goal setting, clear measurement frameworks, and follow-up monitoring mechanisms.

This analysis of Southwoods Hill provides important historical background and current state data to inform the upcoming planning process for the Arboretum, which will include all collections and land masses. With this additional understanding of the site and soil conditions, the area will be available for research efforts by students and faculty across a range of disciplines. Southwoods Hill location in the Nature Reserve offers particular opportunities as access is restricted to research projects and personnel.

Acknowledgements:

Thanks to The Ontario Aggregate Resources Corporation for generously funidng this research and communication effort in The Arboretum at the University of Guelph. This report was drafted by Graduate Research Assistant Ian Murphy who conducted the scientific studies and produced the analysis, maps and graphics for this report. Arboretum Research Coordinator, Dr. Aron Fazekas, provided comments on the draft report. Arboretum Director, Justine Richardson completed the report.

Timeline of Activities in the Study Areas



>1970

In an an area known as Southwoods Hill within the Arboretum's Nature Reserve, a former gravel pit is filled with fill material from adjacent road construction.

1976

Initial site surveys assess the opportunities for rehabilitation of Southwoods Hill

1981

Results of the Gravel Pit Rehabilitation Collection published in the Arboriculture Journal

2021

Gravel Pit Reahabilitation Collection bioinventory complete. TOARC provides additional funding to investigate Southwoods Hill restoration site

1970-1971

The University of Guelph Arboretum is founded.

1977-1978

Major site ammendments begin in the spring of 1977 involving collection of leaves and biosolids for composting experiments.

Soil treatments are followed by a series of planting trials looking at the direct seeding of trees and shrubs, establishment of cuttings, and the effects of herbacious ground covers

Meauresments of plant height, spread and mortality were recorded until 1978, but no maitenance was provided following planting

1981

Gravel Pit Rehabilitation Collection recieves Bronze Plaque Award from The Aggregate Producers Association of Ontatio

2022

Transect survey in Southwoods Hill commences to provide comparison to Gravel Pit Collection.

Survey finds less establishment of trees and shrubs, and greater abundance of drought-tolerant herbacious species.

Soil Samples indicate poorer growing conditions for plants, reflected in exposed sand and aggregate in plots

Southwoods Hill Plot Sampling Map

Southwoods Hill Plant Species Table

Southwoods Hill Species Abundance Data

Species	Species Rank	Count
Thuja occidentalis	1	31
Frangula alnus	2	28
Rhamnus cathartica	3	23
Carex granularis var halaena	4	21
Danthonia spicata	5	18
Lotus corniculatus	6	17
Carex aurea	7	15
Poa compressa	8	15
Dicanthelium implicatum	9	14
Solidago canadensis	10	13
Centaurea X moncktonii	11	12
Plantago lanceolata	12	12
Daucus carota	13	10
Fragaria vesca	14	6
Prunella vulgaris	15	6
Carex spicata	16	5
Parthenocissus quinquefolia	17	5
Populus deltoides spp.	18	5
Sisyrinchium stricticum	19	5
Viburnum opulus	20	5
Carex eburnea	21	4
Fraxinus pennsylvanica	22	4
Populus balsamifera	23	4
Pyrus communis	24	4
Veronica officinalis	25	4
Vitis aestivalis	26	4
Cornus sericea	27	3
Eleagnus umbellata	28	3
Guem urbanum	29	3
Ligustrum vulgare	30	3
Cornus racemosa	31	2
Elymus repens	32	2
Equisetum arvense	33	2
Juncus dudleyi	34	2
Medicago lupulina	35	2
Potentilla recta	36	2
Syringa vulgaris	37	2
Vicia cracca L.	38	2
Vitis riparia	39	2
Dactylis glomerata	40	1
Erigeron strigosus	41	1

Fragaria virginiana	42	1
Hypericum perforatum	43	1
Lonicera morrowii	44	1
Lonicera tatarica	45	1
Parthenocisis vitacea	46	1
Phleum pratensis	47	1
Picea abies	48	1
Picea glauca	49	1
Pilosella aurantiaca	50	1
Prunus americana	51	1
Rubus strigosus	52	1
Sorbus aucuparia	53	1
Tafaxacum officinale	54	1
Ulmus americana	55	1

Southwoods Hill Species Abundance

Southwoods Hill Species Abundance

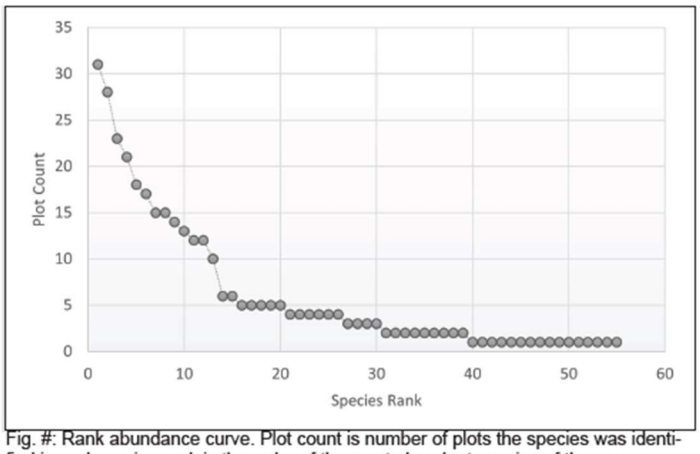


Fig. #: Rank abundance curve. Plot count is number of plots the species was identified in and species rank is the order of the most abundant species of the survey

Fig. #: The 10 most abundant species based on species occurence in plots

1.

Eastern White Cedar
Thuja occidentalis

2.

Glossy Buckthorn
Frangula alnus

3.

Common Buckthorn
Rhamnus cathartica

4.

Limestone Meadow Sedge
Carex granularis var. haleana

5.

Poverty Oat Grass
Danthonia spicata

6.

Birdsfoot Trefoil
Lotus corniculatus

7.

Golden-fruited Sedge
Carex aurea

8.

Canada Blue Grass
Poa compressa

9.

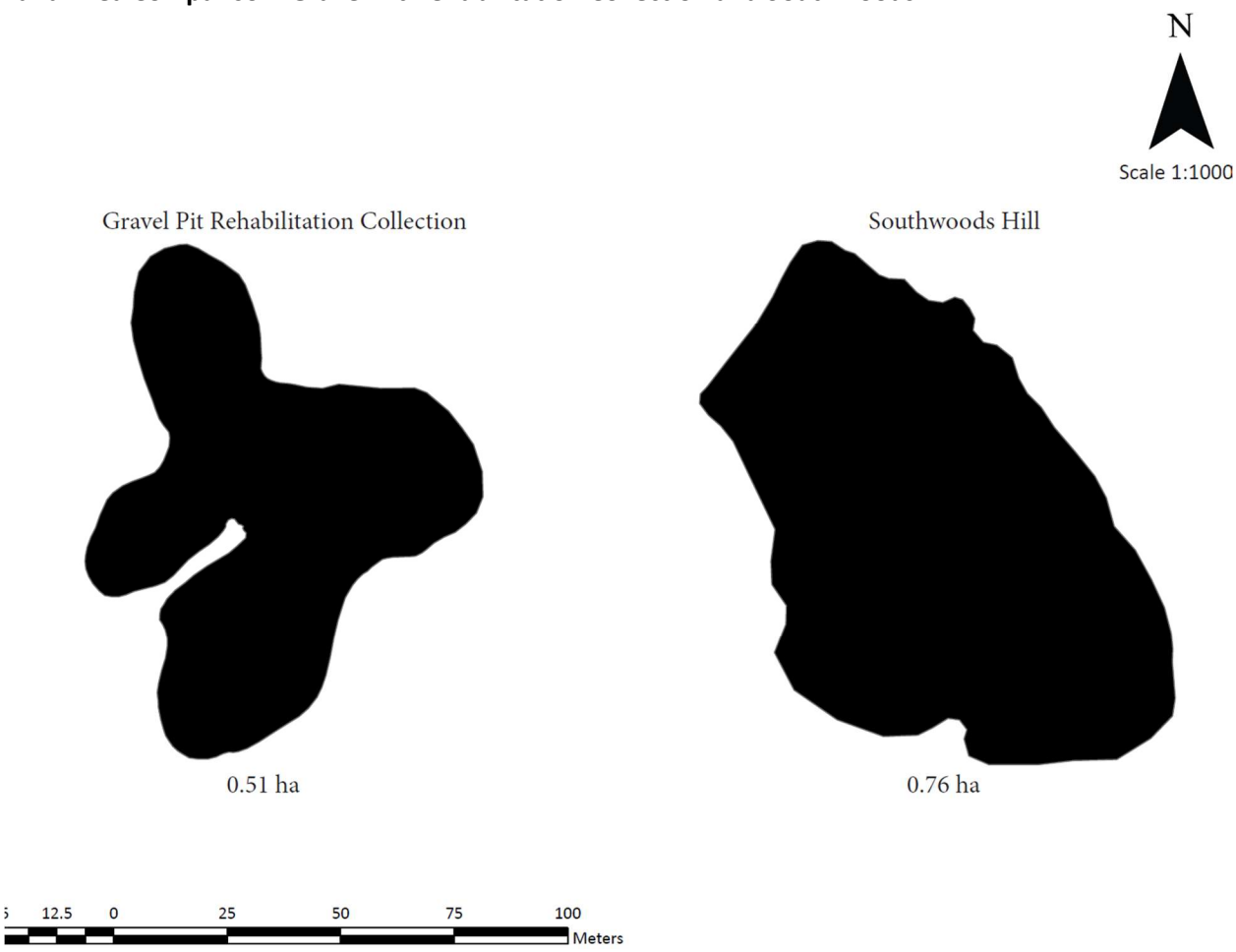
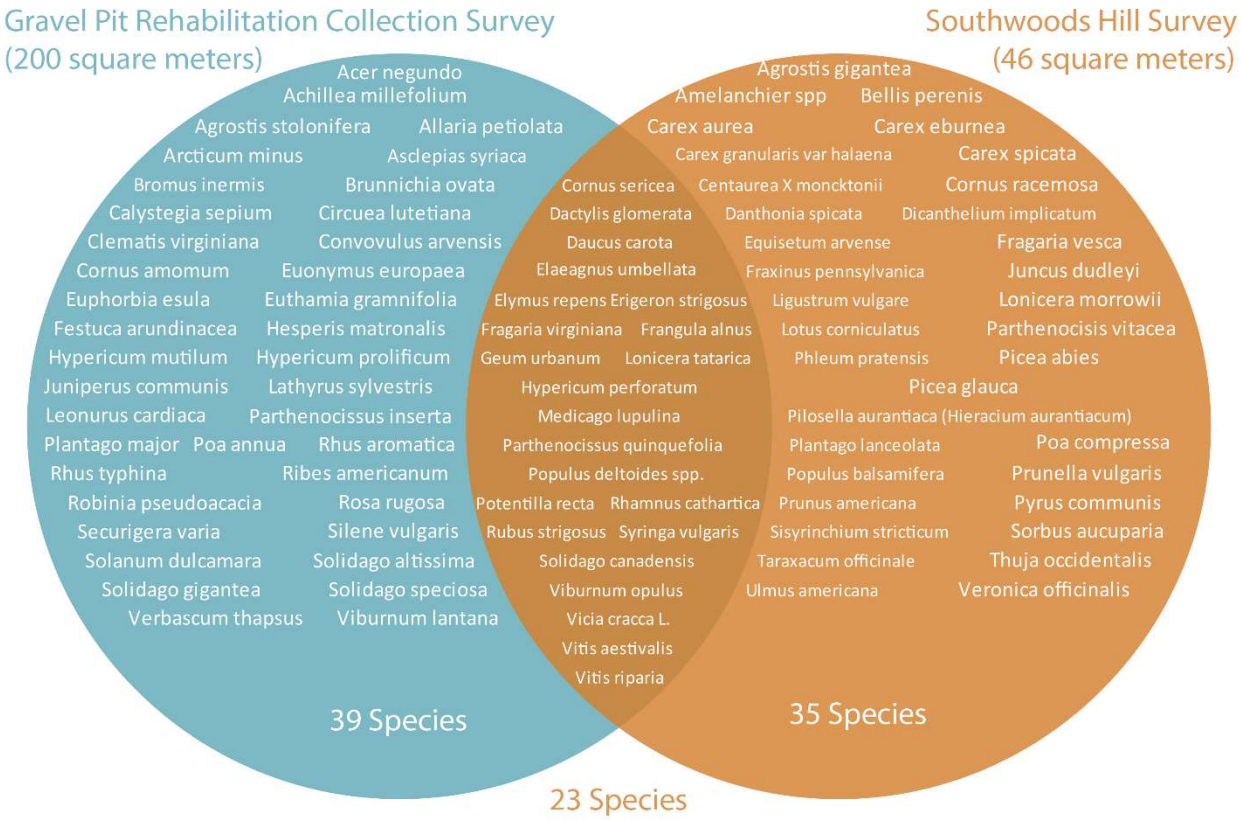
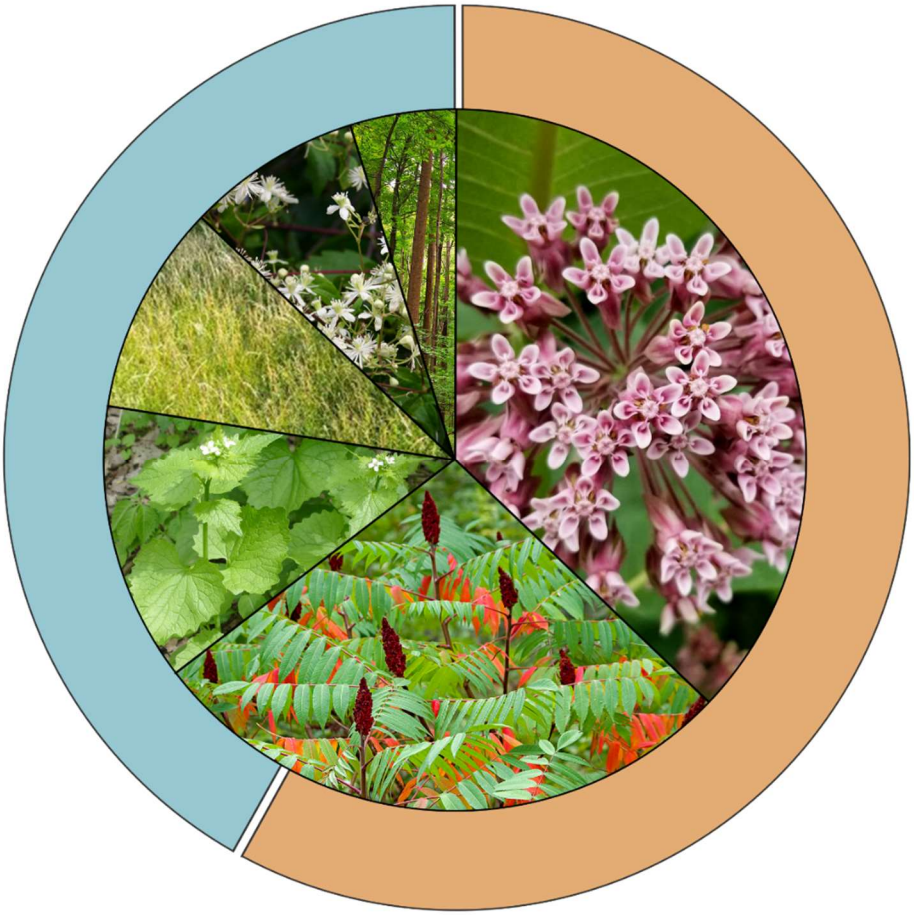
Old Field Panic Grass
Dichanthelium implicatum

10.

Canada Goldenrod
Solidago canadensis

Southwoods Hill Species 1977 to 2022-23 Comparison

Land Area Comparison: Gravel Pit Rehabilitation Collection and Southwoods Hill



Species Comparison: Gravel Pit Rehabilitation Collection and Southwoods Hill