

Rehabilitation of Dufferin Aggregates' Milton Quarry

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Abstract

Progressive rehabilitation is a vital link between aggregate extraction and the development of a future conservation land use. Rehabilitation at Dufferin Aggregate's Milton Quarry, in the Region of Halton, provides an excellent opportunity to develop a working example of responsible stewardship of our natural resources.

This paper reviews rehabilitation objectives, practices and results at the Milton Quarry to evaluate current techniques and enhance future rehabilitation. Rehabilitation to date includes the preparation of cliff faces, shorelines, and islands and the establishment of vegetation for a future lake/wetland habitat. A demonstration area which will be allowed to fill with water will provide a valuable example of the long term land use and promote opportunities for research, monitoring and education.

Introduction

Dufferin Aggregates, a division of St. Lawrence Cement Inc., has operated a dolostone quarry on the Niagara Escarpment in the Region of Halton, in Southern Ontario, since 1962 (Figure 1). The quarry supplies 4-8 million tonnes per annum of high quality aggregates to the Greater Toronto Area. Progressive rehabilitation provides a vital link between the extraction of aggregate and the development of a valuable conservation land use. The proposed rehabilitation plan for the 467 ha quarry includes approximately 271 ha of lakes, over 13 km of cliff face and 14 km of shorelines.

Geology

The Escarpment brow and the adjacent land to the north which includes the quarry, consists of the Dolostone of the Middle Silurian Amabel formation (408-438 million

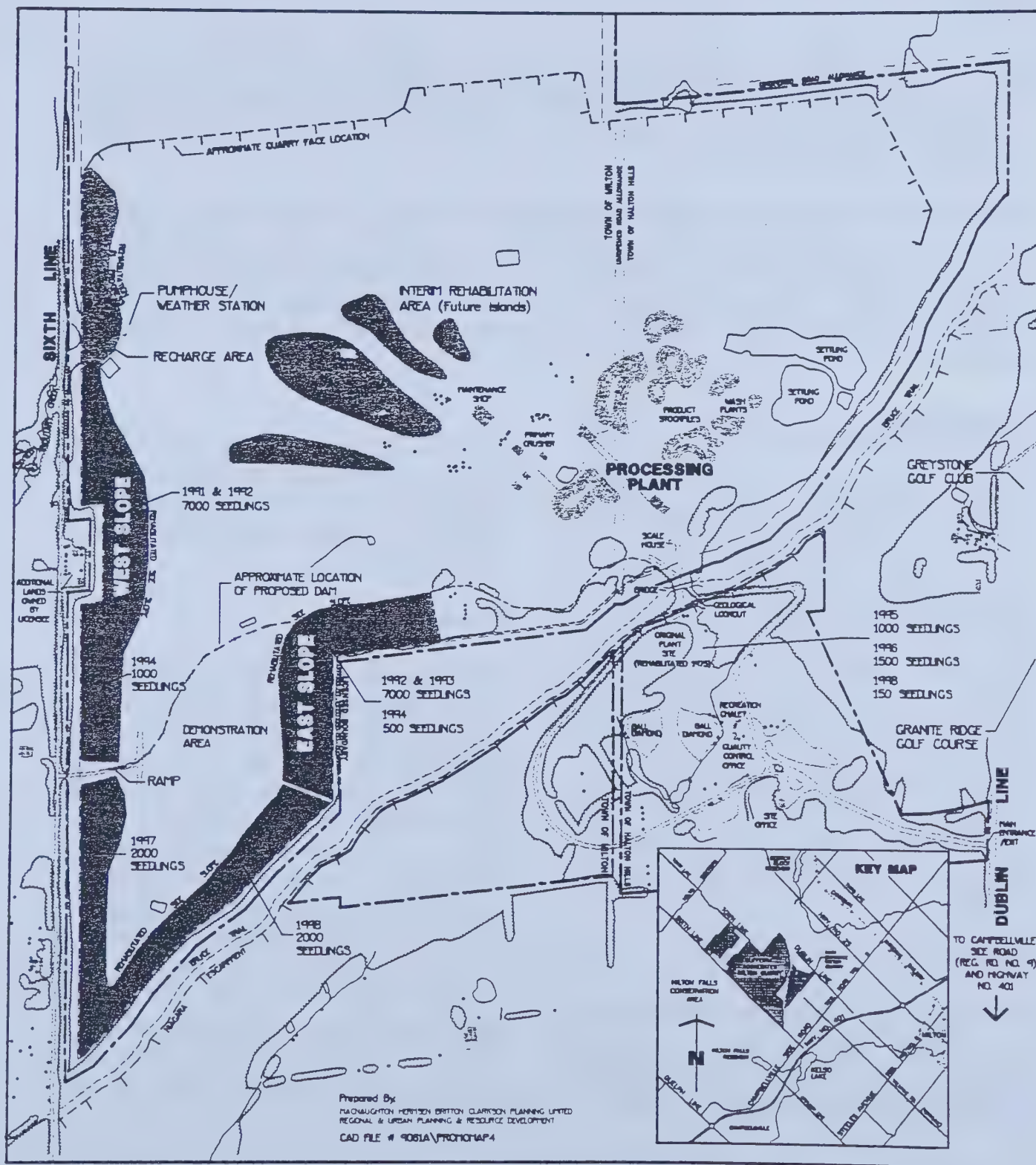
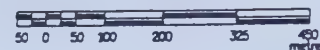
years old). 10 to 30 m of dolostone overlay the shaley dolostone of the Middle Silurian Reynales formation. The escarpment feature runs through Southern Ontario from Niagara Falls to Tobermory.

Natural Heritage

The Niagara Escarpment has been designated a world biosphere reserve (Francis, 1990). The quarry itself is situated in an area of rich natural heritage. The site is next to the Hilton Falls Complex, the largest designated Environmentally Sensitive Area (ESA) in the Region. The Complex is largely a mixed forest tract. The diversity of the forest communities are a reflection of the transition between the Eastern Deciduous and the St. Lawrence-Great lakes Forest Regions. The Complex consists of over 700 ha of mature sugar maple stands, numerous marshes, deciduous swamps, conifer plantations, tributaries of Sixteen Mile Creek, and cliff



Scale



face and talus slope communities (Braid, 1998).

Cultural Heritage

The quarry is close to numerous public parks, owned by the Halton Region Conservation Authority. These include: Hilton Falls Conservation Area which borders the western boundary of the site, Kelso Lake, Rattlesnake Point, Burns, and Crawford Lake Conservation Areas. The Bruce Trail travels along the southern boundary of the quarry, over the Dufferin foot bridge and through lands owned by Dufferin. Merged into the cultural and natural landscape of the Escarpment are numerous old lime kilns and quarries which were built in the 1870's and operated until the 1920's.

Education and Partnerships

Dufferin Aggregates considers itself a part of each community in which it operates and promotes an open communication approach. The Milton Quarry is already well visited for educational purposes. Approximately 40 guided tours a year include classes from elementary, secondary and university levels and public groups such as the Royal Ontario Museum.

Rehabilitation offers exciting opportunities for partnerships to benefit present practices and the future final use. Dufferin Aggregates has a long standing partnership with Scouts Canada. The Scouts are important to our tree planting program. The Company also works with the Bruce Trail Association, the Halton Region Conservation Authority and the local community to enhance nature trail access through the establishment of new hiking trails on Dufferin property and nearby lands.

Final Use

Through collaboration with the Halton Region Conservation Authority and the Ministry of Natural Resources, the Milton Quarry will be developed into an extensive naturalized area of lakes and islands, to enhance water availability within the Sixteen Mile Creek watershed. The proposed final use provides the private sector with the opportunity to develop a unique asset with the potential sharing of a valuable natural area for possible public access, conservation, education and recreation uses.

Rehabilitation Objectives

The rehabilitation process aims to create a final use that is ecologically productive and of value to future generations. The three major components of rehabilitation include designing new landforms, replacing soils and establishing vegetation and wildlife habitat.

The objective of rehabilitation practices at the quarry is to provide conditions that encourage diversity, natural succession and the development of wildlife habitat. Although originally a terrestrial environment of agricultural fields and mixed forest lands, the site will become an aquatic resource with islands, wetlands, cliffs, and shorelines.

Progressive Rehabilitation

The first stage of rehabilitation occurred when the plant was moved in the mid 1970's. For the past 13 years rehabilitation has occurred progressively (i.e. hand in hand with operations). The sequence includes:

1. stripping the topsoil, subsoil and overburden to expose the high quality dolostone

2. separation of the topsoil from the subsoil and overburden when possible
3. hauling and placement of pond fines from the processing plant
4. hauling and placement of the overburden, rubble and rock
5. grading to create the desired landforms.
6. vegetation establishment
7. natural succession of the slopes is accelerated by seed rain from the surrounding lands.

Soil Conditions

The predominant soil series is the moderately well drained Farmington Loam with pockets of poorly drained organic soil. The overburden is typically glacial till with abundant boulders and rubble of various sizes. Depths across the site range from little or no soil at the outcrops to isolated areas that can be up to 3 m deep. In the past, the shallow soils have had marginal value for grazing or other agricultural purposes.

The pH of the undisturbed Farmington Loam soils on the site is generally in the 7.5 to 8.0 range. Although limited in quantity, the organic soils in former lowland areas on site exhibit a pH of around 6.5. Phosphorus and Potassium levels are generally low with high levels of Magnesium.

The replaced soils are characteristically fine with an altered soil structure as a result of the stripping and placement to create the desired landforms.

Pond fines, a by-product of processing from the wash plants, are used as a base for slope creation and to enhance future water retention within the quarry. Average particle size distribution of the silt loam textured material is approximately 27 % sand, 60 % silt and 13 % clay (Fraser, 1996).

The “Gap”

The plant was moved in the mid 1970's from the area at the foot of the escarpment below the “gap” to obscure the view of the operation. The site was rehabilitated to provide park facilities which Dufferin employees and public groups use for recreation and meetings. The disturbed slope was graded, covered with topsoil, seeded with grass and planted with 1,500 sumac seedlings. In the spring of 1995, 1996 and 1998, over 2,000 additional seedlings of native species were planted to accelerate the screening of the gap and to help restore the natural character of the slope.

Desired Landforms

Cliff faces resulting from extraction range from 10 m to over 30 m in height depending on the topography of the land and the depth of the Amabel formation. The exposed cliff faces and slope heights resulting from the backfilling process are quite variable throughout the rehabilitated areas.

Initially (1985-89), rehabilitation of the future lake edges within the quarry involved backfilling the entire quarry face from top to bottom at a 2:1 or 3:1 slope, seeding with a grass mix and planting seedlings. Since 1991, some of the quarry walls have been retained as cliffs. Many of the backfilled slopes are now limited to the bottom 1/3 to 1/2 of the faces to provide an edge for the future lakes.

A minimum elevation of 310 m.a.s.l. is required to ensure a land base above the predicted final water elevation of 307.8 m.a.s.l. This has resulted in cliff faces above the slopes that range from 2m in height along the most southern slope to almost 10m along the western boundary of the property. The

slopes created to date vary in grade and aspect. Slopes range from 2:1 to almost 10:1 in the most southern corner of the quarry and face southeast, northwest, north and south.

No mechanical compaction of the soils is practiced other than the compaction resulting from the placement and grading of material by the 60 Tonne trucks and D8 dozers. The slopes are ripped with a single shanked ripper and a D8 dozer prior to tree planting.

Demonstration Area

Previous rehabilitation practices focused on the edges and islands of the future lake. The next step includes the design and construction of a demonstration area that will be allowed to fill with water. The location of this area is illustrated in Figure 1.

A detailed design/plan (Figure 2) has been developed to guide the construction of this 20 ha demonstration area. The plan includes the construction of a berm up to 5 m in height to allow for an interim water level of up to 4 m in depth. This plan is currently on display in our employee chalet at the quarry.

The design incorporates sinuous edges, islands, an irregular topography on the quarry floor and a diversity of graded and ungraded slopes to provide variability in water depths and improve landscape diversity.

The top 2/3 of the slopes in the area have been covered with topsoil and planted with trees. The topdressing layer is a combination of topsoil, rubble and stumps placed to enhance landscape diversity and promote the development of micro-habitats.

The creation of shallows along the edges and throughout the pond area will enhance

wetland development. These areas will have a limited water depth of no more than 2 m to create littoral zones and fish habitat.

Pond fines placed on the quarry floor and against the walls from 1990 to 1995 enhance water retention and provide variable substrates within the flooded area. Placement of rock and brush piles will increase the variability in the substrate and enhance aquatic and shoreline habitat. The demonstration area will incorporate the existing exposed cliff faces and four mounds of fines/overburden that have been graded to form islands and mud flats. These features will enhance aesthetic and wildlife habitat value and provide refuge.

Predicted water levels on the slopes for both the interim and final levels have been identified to develop planting designs and ensure the planting of suitable species for shoreline and terrestrial habitats. The filling of the demonstration area will start after construction of the berm in late 1998/early 1999.

Vegetation Establishment

Rehabilitated areas have only been seeded where erosion was considered a problem. Tree and shrub nursery stock planting is an important component of the quarry rehabilitation. Most recent efforts have focused on planting a diversity of native species. Scouts Canada has maintained a very significant role in the planting of over 21,000 seedlings in the quarry over the last 8 years. Species planted throughout the rehabilitated areas are listed in table 1.

A transplanting program was initiated in 1996 to 1998. Over 250 individual seedlings and young saplings as well as 72 plugs of forest floor soils were transplanted from

Table 1: Nursery Stock Species Planted in the Quarry

Species	No.	Year Planted
White Cedar	3,900	1991,93,95-98
White Pine	3,950	1991-95,97
White Spruce	4,750	1991-94
Tamarack	1,500	1992
Red osier Dogwood	1,300	1991,97-98
Highbush Cranberry	800	1991,98
Black Locust	650	1994, 97-98
Silver Maple	600	1994, 97-98
Autumn Olive	500	1991
Common Lilac	500	1991
Russian Olive	500	1991
Nannyberry	400	1997-98
White/Green Ash	400	1991,96-98
Choke Cherry	200	1997
Red Oak	200	1997-98
Red Pine	200	1995
Slender Willow	200	1998
white elm	200	1997-98
alternate leaved dogwood	150	1995,98
Bitternut Hickory	100	1998
Carolina Poplar	100	1998
Grey Dogwood	100	1998
Norway Spruce	100	1996
Pussy Willow	100	1998
Sandbar Willow	100	1998
European Larch	50	1991
21,550		

areas to be extracted on site (Table 2). Specimens and areas are identified and flagged in the field during the summer/spring months. In the fall, the plants are either transplanted individually by hand or in "plugs" (groups) using a 30 inch tree spade. The plants or plugs are wrapped in burlap, transported to the rehabilitated slopes and planted in both shaded areas under the thriving sumac and more exposed areas on the more recently created slopes.

Monitoring

The Company has started to monitor the success of the rehabilitation program. Plant growth and natural regeneration has been

monitored over the past 5 years (Monet, 1994; Monet, 1996a; Monet, 1996b; Monet, 1997; Monet, 1998) along with survival and growth of transplants (Morris, 1997). The annual qualitative plant inventories are used to document and assess the change in vegetation cover over time and to help determine future revegetation strategies.

Table 2: Saplings Transplanted on Site

Species	No.	Yr Planted
Alternate-leaved Dogwood	PI 6	1997
Balsam Poplar	I 12	1997
Basswood	I 1	1997
Bitternut Hickory	PI 32	1997,1998
Black Cherry	PI 8	1997,1998
Black Raspberry	P 1	1997
Bush-honeysuckle	P 1	1997
Butternut	P 1	1997
Choke Cherry	P 13	1997
Common Blackberry	P 5	1997
Eastern Hemlock	I 1	1997
Flowering Raspberry	P 6	1997
Green Ash	I 1	1997
Heart-leaved Willow	I 1	1997
Mountain Maple	I 4	1997
Pin Cherry	I 16	1997,1998
Red Oak	PI 12	1997
Red osier Dogwood	I 16	1997
Riverbank Grape	P 3	1997
Round leaved Dogwood	I 2	1997
Running Strawberry-bush	P 1	1997
Staghorn Sumac	I 4	1997
Sugar Maple	PI 52	1997,1998
Swamp Black Currant	P 1	1997
Trembling Aspen	PI 3	1997
Virgin's Bower	I 1	1997
White Birch	I 7	1997
Wild Red Raspberry	P 25	1997
White Ash	PI 59	1997,1998
White Cedar	I 28	1997
White Elm	PI 26	1997
White Spruce	I 2	1997,1998
White Spruce	I 1	1997
352		

Modified from Monet (1998)

P = planted in plugs

I = planted as individuals

The vegetation inventories are divided into two parts: an inventory of the rehabilitated slopes as a whole and an inventory of 14 transects set up from top to bottom along the slopes. The relative abundance, survival rates and height of species observed are described.

Ornithological Study

A bird study utilizing the British Trust of Ornithological Common Bird Census technique was initiated in the spring of 1998 to: determine the species currently inhabiting the rehabilitated areas of the quarry, establish any trends in numbers of these species over time and to document new species that colonize the site in the future (Sheppard, 1998).

The census involves a weekly walk along a pre-determined route throughout the breeding season to map the location and activity of every bird observed. At the end of the season, the data is transferred on a by-species basis and an assessment is made regarding the number of breeding pairs of each species. This quantitative approach will attempt to identify significant trends over time as the rehabilitated areas evolve.

Rehabilitation Results

Vegetation Establishment

Observations from the vegetation inventories and monitoring include:

- the survival rate of planted nursery stock is generally good with over 50 % survival. White Spruce, Tamarack, Silver Maple and Black Locust have had very good survival rates of 79 to 90 %. White Cedar and White Pine have had variable results ranging from 47 to 64 %.
- survival of nursery stock planted in 1997, following 2 growing seasons has been very good with a survival rate of over 80 %.
- Following one growing season, survival rates of woody species within the “plug” plantings are over 95 %.
- many herbaceous forest species are transplanted along with the woody species within the plugs.
- the surviving planted stock is generally growing well, especially White Spruce, Tamarack, Black Locust, and Red osier Dogwood. White Cedar, Red osier Dogwood and White Spruce have an average height of 1 to 1.5m. Tamarack can vary from 1.5 m to 3m in height while Black Locust are consistently 2.5 to 3 m tall.
- Growth rates appear to be better on the west slopes. Of the individuals examined, planted species can be 0.5 to 1m shorter on the east slope compared to the west. Stunted growth in some of the species, especially white pine has been observed on the northern section of the east slope.
- a high rate of recruitment by native trees, shrubs, with forest wildflowers in some areas.
- the rate of native herbaceous and woody volunteers is generally higher on the west slopes of the rehabilitated area than on the east slopes or the “gap”. Approximate average densities of woody vegetation vary from a high of 0.75/m² on the 1991-1992 west slopes to 0.60/m² on the 1994 west slopes to a low of 0.1/m² on sections of the east slope. Only one section of the east slopes has densities comparable to the 1991-1992 and 1994 slopes to the west.
- non planted woody species frequently observed on the slopes include: staghorn sumac, pin cherry, trembling aspen, white

Table 3: Colonizing Species Observed on the Rehabilitated Slopes

	Common Name	Scientific Name	Common Name	Scientific Name
	Trees, shrubs and woody vines			
Z	Manitoba Maple	Acer negundo	Tower-mustard	Arabis glabra
P	Red Maple	Acer rubrum	Jack-in-the-pulpit	Anisaema triphyllum
P	Silver Maple	Acer saccharinum	Swamp Milkweed	Asclepias incarnata
	Sugar Maple	Acer saccharum	Common Milkweed	Asclepias syriaca
T	Mountain Maple	Acer spicatum	Heart-leaved Aster	Aster cordifolius
	White Birch	Betula papyrifera	Heath Aster	Aster ericoides
	Bitternut Hickory	Carya cordiformis	Tall White Aster	Aster lanceolatus
	Virgin's Bower	Clematis virginiana	New England Aster	Aster nova-angiae
	Alternate-leaved Dogwood	Cornus alternifolia	Purple-stemmed Aster	Aster puniceus
	Gray Dogwood	Cornus cf. racemosa	Arrow-leaved Aster	Aster urophyllus
	Round-leaved Dogwood	Cornus rugosum	Yellow Rocket	Barbarea vulgaris
PC	Red-osier Dogwood	Cornus stolonifera	Nodding Beggarticks	Bidens cernua
	Hawthorn	Crataegus sp.	Devil's Beggarticks	Bidens frondosa
	Bush-honeysuckle	Diervilla lonicera	Beggarticks	Bidens sp.
*P	Russian Olive	Elaeagnus angustifolia	* Field Mustard	Brassica rapa
*P	Autumn Olive	Elaeagnus commutata	* Smooth Brome	Bromus inermis
	White Ash	Fraxinus americana	Shepherd's Purse	Capsella bursa-pastoris
	Ash	Fraxinus sp.	* Nodding Thistle	Carduus nutans
*P	Black Walnut	Juglans nigra	Sedge	Carex cf. albusina
*	Juniper	Juniperus sp.	Sedge	Carex deweyana
P	Tamarack	Larix laricina	Sedge	Carex hitchcockiana
*	Morrow's Honeysuckle	Lonicera morrowi	Sedge	Carex peckii
*	Tartarian Honeysuckle	Lonicera tatarica	Sedge	Carex cf. pennsylvanica
	Virginia Creeper	Parthenocissus quinquefolia	Sedge	Carex retrorsa
P	White Spruce	Picea glauca	Sedge	Carex sp.
P	White Pine	Pinus strobus	Sedge	Carex sparganioides
*	White Poplar	Populus alba	Sedge	Carex stipata
	Balsam Poplar	Populus balsamifera	Sedge	Carex tenera
	Large-toothed Aspen	Populus grandidentata	Sedge	Carex vulpinoidea
	Trembling Aspen	Populus x hybrid?	* Mouse-eared Chickweed	Cerastium fontanum
	Hybrid Poplar	Populus x hybrid?	* Lamb's-quarters	Chenopodium album
	Pin Cherry	Prunus pensylvanica	* Cichorium intybus	Chenopodium capitatum
T	Black Cherry	Prunus serotina	* Chicory	Cichorium intybus
	Choke Cherry	Prunus virginiana	* Enchanter's Nightshade	Circaea lutetiana
P	Red Oak	Quercus rubra	* Canada Thistle	Cirsium arvense
*	Common Buckthorn	Rhamnus cathartica	* Crown Vetch	Coronilla vana
*	Alder-buckthorn	Rhamnus frangula	* Bulblet Fern	Cystopteris bulbifera
PC	Staghorn Sumac	Rhus typhina	* Orchard Grass	Dactylis glomerata
	Wild Black Currant	Ribes americanum	* Queen Anne's Lace	Daucus carota
	Prickly Gooseberry	Ribes cynosbati	* Pink	Dianthus sp.
PC	Black Locust	Robinia pseudoacacia	* Teasel	Dipsacus fullonum
*	Dog Rose	Rosa canina	* Marginal Wood Fern	Dryopteris marginalis
	Wild Rose	Rosa blanda	* Barnyard Grass	Echinochloa crusgalli
*	Multiflora Rose	Rosa multiflora	* Blueweed	Echium vulgare
	Common Blackberry	Rubus allegheniensis	* Bottlebrush Grass	Elymus hystrix
	Wild Red Raspberry	Rubus idaeus	* Field Horsetail	Equisetum arvense
	Black Raspberry	Rubus occidentalis	* Annual Fleabane	Erigeron annuus
	Flowering Raspberry	Rubus odoratus	* Philadelphia Fleabane	Erigeron philadelphicus
*	White Willow	Salix alba	* Dog Mustard	Erucastrum gallicum
	Peach-leaved Willow	Salix amygdaloides	* Wormseed Mustard	Erysimum cheiranthoides
	Bebb's Willow	Salix bebbiana	* Spotted Joe-Pye Weed	Eupatorium maculatum
	Heart-leaved Willow	Salix eriocephala	* Boneset	Eupatorium perfoliatum
	Shining Willow	Salix lucida	* White Snakeroot	Eupatorium rugosum
*	Slender Willow	Salix petiolaris	* Leafy Spurge	Euphorbia esula
	Basket Willow	Salix purpurea	* Grass-leaved Goldenrod	Euthamia graminifolia
	Common Elder	Sambucus canadensis	* Strawberry	Fragaria virginiana/vesca
	Red-berried Elder	Sambucus racemosa ssp. pubens	* Cleavers	Galium aparine
	Meadowsweet	Spiraea alba	* Herb Robert	Geranium robertianum
*	Common Lilac	Syringa vulgaris	* Yellow/White Avena	Geum aleppicum/canadense
PC	Eastern White Cedar	Thuja occidentalis	* Fowl Manna Grass	Glycena striata
	Basswood	Tilia americana	* Stickseed	Hackelia virginiana
	Poison Ivy	Toxicodendron radicans	* Woodland Sunflower	Helianthus divaricatus
P	White Elm	Ulmus americana	* Ox-eye	Heliopsis helianthoides
P	Nannyberry	Viburnum lentago	* Canada Waterleaf	Hydrophyllum canadense
P	Highbush-cranberry	Viburnum opulus/trilobum	* Virginia Waterleaf	Hydrophyllum virginianum
	Downy Arrow-wood	Viburnum rafinesquianum	* Prickly Lettuce	Lactuca seriola
	Riverbank Grape	Vitis riparia	* Tuberous Vetchling	Lathyrus cf. tuberosus
	Herbaceous plant species		* Motherwort	Leonurus cardiaca
*	Yarrow	Achillea millefolium	* Field Pepper-grass	Lepidium campestre
*	Agrimony	Agrimonia gryposepala	* Ox-eye Daisy	Leucanthemum vulgare
*	Quack Grass	Agropyron repens	* Butter-and-eggs	Linaria vulgaris
*	Redtop	Agrostis gigantea	* Indian Tobacco	Lobelia inflata
*	Creeping Bent Grass	Agrostis cf. stolonifera	* Bird-foot Trefoil	Lotus corniculatus
*	Garlic Mustard	Alliaria petiolata	* Water-horehound	Lycopus uniflorus
	Common Ragweed	Ambrosia artemisiifolia	* Wild-lily-of-the-valley	Maianthemum canadense
	Thimbleweed	Anemone virginiana	* False Solomon's-seal	Maianthemum racemosum
	Indian Hemp	Apocynum cannabinum	* Black Medic	Medicago lupulina
	Wild Columbine	Aquilegia canadensis	* Alfalfa	Medicago sativa
	Spikenard	Aralia racemosa	* White Sweet Clover	Melilotus alba
*	Great Burdock	Arctium lappa	* Yellow Sweet Clover	Melilotus officinalis
*	Common Burdock	Arctium minus	* Wild Bergamot	Monarda fistulosa
	Wild Ginger	Asarum canadense	* Muhly Grass	Muhlenbergia mexicana

Table 3: Colonizing Species Observed on the Rehabilitated Slopes (Continued)

Common Name	Scientific Name	Common Name	Scientific Name
Herbaceous plant species			
* Catnip	Nepeta cataria	* Nightflowering Catchfly	Silene noctiflora
* Evening-primrose	Oenothera cf. biennis	* Bladder Campion	Silene vulgaris
* Marjoram	Origanum vulgare	* Blue-eyed Grass	Sisyrinchium montanum
* Wood-sorrel	Oxalis stricta	* Carrion-flower	Smilax herbacea
* Witch Grass	Panicum capillare	* Bittersweet	Solanum dulcamara
* Wild Parsnip	Pastinacea sativa	* Tall Canada Goldenrod	Solidago altissima/ canadensis
* Reed Canary Grass	Phalaris arundinacea	* Blue-stem Goldenrod	Solidago caesia
* Timothy	Phleum pratense	* Zig-zag Goldenrod	Solidago flexicaulis
* Common Reed	Phragmites australis	* Early Goldenrod	Solidago juncea
* English Plantain	Plantago lanceolata	* Gray Goldenrod	Solidago nemoralis
* Broad-leaved Plantain	Plantago major	* Rough Goldenrod	Solidago rugosa
* Canada Blue Grass	Poa compressa	* Sow-thistle	Sonchus sp.
* Fowl Manna Grass	Poa palustris	* Slender Wedge Grass	Sphenopholis intermedia
* Kentucky Blue Grass	Poa pratensis	* Dandelion	Taraxacum officinale
* Rough Cinquefoil	Potentilla norvegica	* Early Meadow Rue	Thalictrum dioicum
* Rough-fruited Cinquefoil	Potentilla recta	* Tall Meadow Rue	Thalictrum pubescens
* Common Cinquefoil	Potentilla simplex/ canadensis	* Penny Grass	Thlaspi arvense
* White Lettuce	Prenanthes alba	* Red Clover	Trifolium pratense
* Heal-all	Prunella vulgaris	* White Clover	Trifolium repens
* Bracken	Pteridium aquilinum	* White Trillium	Trillium grandiflorum
* Small-flowered Buttercup	Ranunculus abortivus	* Coltsfoot	Tussilago farfara
* Tall Buttercup	Ranunculus acris	* Common Cattail	Typha latifolia
* Black-eyed Susan	Rudbeckia hirta	* Stinging Nettle	Urtica dioica
* Sheep Sorrel	Rumex acetosella	* Common Mullein	Verbascum thapsus
* Curled Dock	Rumex crispus	* Common Speedwell	Veronica officinalis
* Bitter Dock	Rumex obtusifolius	* Bird Vetch	Vicia cracca
* Black Snakeroot	Sanicula marilandica	* Marsh Violet	Viola affinis
* Dogmint	Satureja vulgaris	* Canada Violet	Viola canadensis
* Black Bulrush	Scirpus atrovirens	* Long-spurred Violet	Viola rostrata
* Yellow Foxtail	Setaria glauca	* Common Blue Violet	Viola cf. sororia
* Green Foxtail	Setaria viridis	* Violet	Viola sp.

* = Exotic to the Regional Municipality of Halton

P = Planted from nursery stock

C = Colonizing

Z = Naturalized in the Regional Municipality of Halton

Modified from Monet, 1998

- birch, red osier dogwood, and virgin's bower.
- violets, trilliums, bellwort, wild ginger, etc. have been found on the forest soils of the west slopes.
- although similar numbers of trees have been planted on both the east and west slopes, nursery stock plantings represent a larger proportion of the relative abundance of woody vegetation on the east slopes when compared to the west slopes. Planted species such as Tamarack (18 %), White Cedar (12 %) and White Spruce (9 %) are as dominant as Sumac (18 %) on the eastern slopes. In contrast, volunteer species such as sumac (up to 74 %), pin cherries (up to 21 %), red osier dogwood (6%), and elderberry (4%) dominant woody vegetation cover on the western slopes. Planted species such as White Cedar (3%), White Spruce (4%), Tamarack (3%) and Silver Maple

(1%) account for much less of the woody vegetation.

- average height of the volunteer pin cherries is greater than 2 m after five years.
- although, the first to arrive and most abundant volunteer woody species is staghorn sumac, species such as pin cherry, balsam poplar and elderberry are now as tall or taller than the sumacs (Morris, 1997)
- The majority of the sumac appears to spread from the top of the slopes downwards towards the quarry floor.
- Of the 214 species identified over 9 general rehabilitated areas within the quarry in 1998, 132 of the species (61.7 %) were native. Thirty nine native woody species, not including planted stock and 93 native herbaceous species have been identified.

- exotic herbaceous species are most dominant on the seeded slopes with less desirable soil conditions. Colonization of exotic woody species is low across the site with only 13 species identified.
- to date, 20 woody species and 32 herbaceous species for a total of 177 individuals have been planted in 72 plugs
- further monitoring will continue to substantiate results and determine reasons for variation
- Colonizing species observed on the rehabilitated slopes are listed in Table 3.

Table 4: Bird Species Observed in the Milton Quarry

(Common Loon)	Blue Jay
Great Blue Heron	American Crow
Canada Goose *	Black-capped Chickadee
Wood Duck	House Wren *
Mallard *	American Robin *
Turkey Vulture *	Gray Catbird *
(Coopers Hawk)	American Pipit
(Red-tailed Hawk)	Cedar Waxwing *
Killdeer *	European Starling *
Spotted Sandpiper *	Red-eyed Vireo
Least Sandpiper	Nashville Warbler
Ring-billed Gull	Yellow Warbler *
Rock Dove *	Common Yellowthroat *
Mourning Dove	Rose-breasted Grosbeak
American Goldfinch	Indigo Bunting *
Belted Kingfisher	Chipping Sparrow *
Northern Flicker	Field Sparrow
Willow Flycatcher	Savannah Sparrow *
Great Crested Flycatcher	Song Sparrow *
Eastern Kingbird *	Slate-colored Junco
Horned Lark *	Bobolink
(Purple Martin)	Red-winged Blackbird *
Tree Swallow	Eastern Meadowlark *
Northern Rough-winged Swallow *	Ruby-throated Hummingbird *
Bank Swallow *	Baltimore Oriole
Cliff Swallow *	(Pine Siskin)
Barn Swallow	Eastern Phoebe
	Flycatcher
	Common Grackle

Modified from Sheppard (1998)

() observed flying over the quarry

* confirmed or suspected breeders.

Ornithological Study

To date, 52 species of birds have been observed within the quarry and 4 more flying over head. Of the 53 species, are thought to be breeding within the rehabilitated areas. The first year of study provides baseline data to assess future trends as the rehabilitated slopes and demonstration area continue to evolve. Birds observed throughout the first spring/summer season of study are listed in Table 4. The most interesting result is 52 pairs of nesting cliff swallows on the faces next to the demonstration area.

Discussion

The more recent approach of retaining some of the quarry walls as cliff faces has enhanced the rehabilitation of the quarry. As a result, the landscape now includes cliff faces and a variety of slopes that are more diverse, attractive and a better fit with the surrounding landscape including the escarpment face. The exposed faces provide cliff habitat and already have 52 pairs of cliff swallows nesting (Sheppard, 1998).

In the original rehabilitation of the "gap", plant growth and natural colonization has not been as vigorous as anticipated. The thick mat of grass and compaction from grading have impeded natural succession and the growth rate of the seedlings. Future rehabilitation will include additional treatment to accelerate woody growth on this slope and help close the gap.

Survival and growth of trees and shrubs on the future pond slopes is generally satisfactory. Significant natural colonization by native species is very encouraging. The favorable natural colonization results achieved on the west slopes are thought to be largely the result of superior soil

conditions. The soils were primarily forest floor soils rather than the agricultural soils used to backfill the east slopes.

Some soil amelioration and amendments in the future may be required to enhance the growth and survival of vegetation along sections of the east slope.

The accelerated rate of colonization and higher diversity of species on the west slopes also appears to have been aided by a change in seeding practices. Prior to 1991, all slopes were seeded with a grass mixture to quickly "green up" the slopes and control erosion prior to tree planting. The more recent approach utilizes the seed bank, rich and diverse natural vegetation surrounding the site and dispersion of seeds through wind, wildlife and birds to naturally colonize the slopes. The thick mat of grass species resulting from seeding on the east slopes appear to have impeded natural succession of woody species.

Monitoring natural colonization of the slopes provides an opportunity to evaluate current practices and may lead to new practices regarding species selection and timing of transplanting in relation to the developing vegetation cover. For example, will the shade provided by the early successional woody species such as sumac restrict the growth of planted species or enhance the growth of others? How successful is a diverse landform in producing habitat and species diversity.

The vigorous rehabilitation efforts continue to receive industry recognition for excellence. The quarry has received progressive rehabilitation awards from the Aggregate Producers Association of Ontario each of the last 3 years. The quarry has also received the prestigious "About Face

Award" from the National Stone Association recognizing our achievements in rehabilitation throughout North America.

Future Work

The studies currently undertaken to monitor and assess previous rehabilitation strategies will continue to provide useful information to help guide future efforts. As the demonstration area continues to develop, it will provide a valuable example of the future land use anticipated for the remainder of the quarry. Additional lessons can be applied to future rehabilitation throughout the quarry.

Dufferin Aggregates will continue to foster partnerships with universities and colleges to study and improve rehabilitation techniques and monitor results. The Company was a recent partner in a NSERC Scholarship with a University of Guelph Masters student who studied the successful use of pond fines in rehabilitation. Dufferin will also continue to explore the potential for developing new partnerships in the future with agencies interested in applied research to enhance the knowledge, practices and success of rehabilitation, habitat enhancement, fisheries establishment, and natural succession, seed rain, biodiversity and biosphere monitoring.

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