AN EVOLUTION OF RECLAMATION APPROACHES THROUGH THE LIFE OF A SOUTHERN ONTARIO GRAVEL PIT[1]

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Abstract. Over the thirty-year life of the Lafarge Canada Inc. Uxbridge Pit, an evolution of regulatory constraints, social values, rehabilitation technologies and environmental imperatives has been documented. The pit is located northeast of Toronto in one of the largest re-forested regions in the Greater Toronto Area. Traditionally, after-use design of most pits in the area focused primarily on agricultural uses with uniform grades, soil applications and a stabilizing vegetative cover. However, progressive rehabilitation has evolved to reflect changing social and ecological conditions. Grading and soil management at the site are evolving to increase the diversity of topographic conditions, soil depth and density of ground cover. The establishment of tree cover on the site has included ornamental specimens, intensive but costly sapling plantings, widespread seedling plantings, application of forest plugs, nodal plantings, and natural regeneration. A comprehensive rehabilitation strategy has now been implemented to utilize local successional processes in the forest ecosystem surrounding the site. The strategy considers early successional invaders, predicted or targeted climax communities, local regeneration rates and factors that enhance or retard natural woodland expansion. We also introduce the concept of "cumulative rehabilitation" to deal with multiple aggregate sites in a regional context.

Additional Key Words: aggregate extraction, rehabilitation, ecology, forestry.

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Introduction

When high priority aggregate extraction areas are located in close proximity to relatively dense and growing populations, many conflicts arise between society's demand for material, the supply of new development land and the environment. These conflicts intensify in areas with increasing numbers of both gravel pits and people, and often become focused on the extent and types of rehabilitation in new and existing sites. With expanding extraction areas, gravel pit operators are often called upon to justify their reputations and "track records" relating to their site maintenance and rehabilitation.

Two concomitant events lead to a need for Lafarge to highlight advances in rehabilitation approaches and to integrate social values with reclamation (Prager, 1997). A license application for a proposed expansion of the pit was submitted during the same time period that restrictive new land use legislation was being drafted by the Ontario government for an area known as the Oak Ridges Moraine.

In addition, it has become evident that public perceptions are often tainted by the visible evidence of past rehabilitation and do not acknowledge advancements in rehabilitation technologies and approaches.

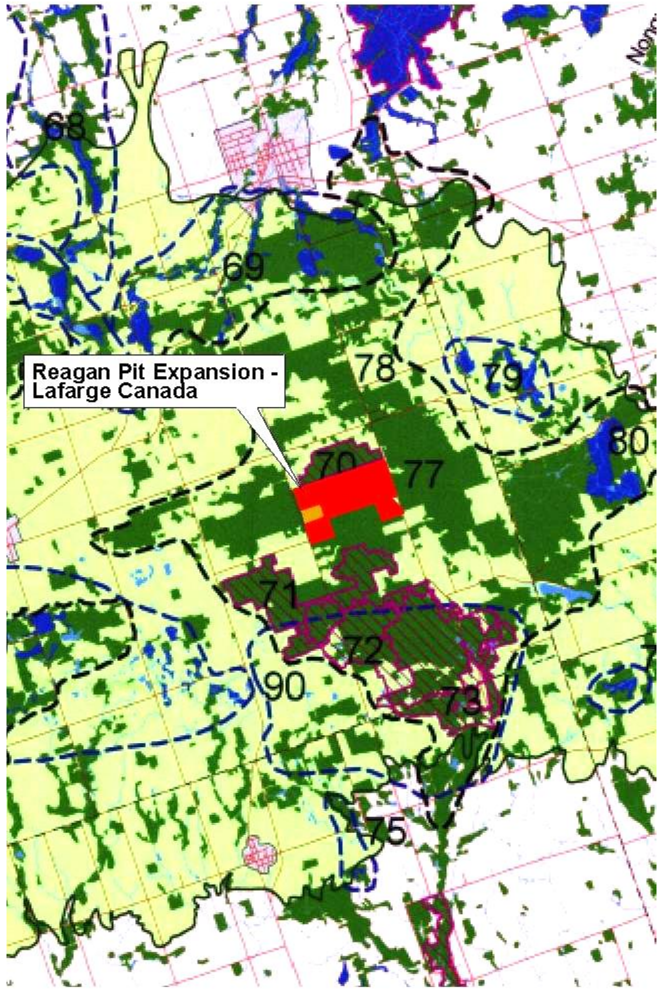
This paper summarizes a series of changes in both the local landscape setting as well as in the approaches to rehabilitation during the life of the pit. This evolution culminates with the application of "cumulative rehabilitation" (the integration of rehabilitation design across several licensed aggregate extraction areas) with succession-based ecosystem design. Presentation of these advancements to the public has become a key tool in the development of relationships between aggregate producers and communities.

The Site

The Uxbridge Pit is located in the rural Township of Uxbridge in the Greater Toronto Area (GTA) (Fig. 1), within thirty minutes of Canada's fastest growing urban communities.

The site is 31 years old and is on a 200 ha (494 ac) property comprised primarily of licensed Lafarge lands. In addition to the licensed portion, there is a 20 ha (49.4 ac) unlicensed property and an adjacent 18 ha (44.5 ac) pit, which is owned by the Township and operated by Lafarge under agreement with the municipality.

The site is within the Great Lakes Forest Region. Sugar maple, American beech, basswood, white ash, white oak, bur oak, eastern hemlock and eastern white pine generally dominate natural upland forest cover in this region. The Regional Municipality of Durham has approximately 22% forest cover (Riley and Mohr, 1994). Approximately 15-30% of the Moraine remains in a natural condition (Lindsay, 1984).



Source: Map 1 Natural Heritage Features Oak Ridges Moraine Greater Toronto Area Portion. Ministry of Natural Resources, April, 2000.

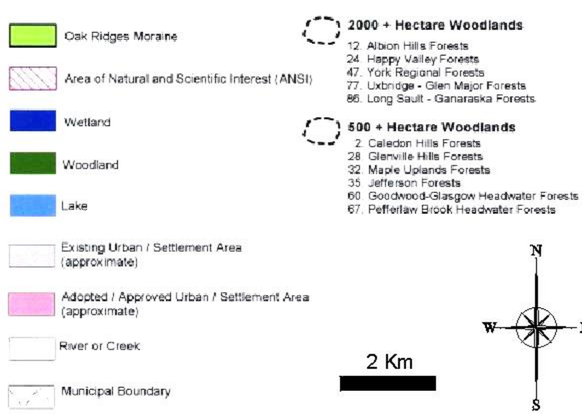


Figure 1. Site location in the context of the natural features and designated core areas of the Oak Ridges Moraine, approximately 50 km northeast of Toronto, Ontario, Canada.

A 20 ha (49.4 ac) parcel at the west end of the pit was not owned by the operator when the original license was approved. It was comprised of two individual residences and was surrounded on three sides by licensed extraction. Lafarge has since purchased these properties and is finalizing a new license, which will allow an extension of the existing pit into this parcel.

Socio-political History

The pit was originally approved through hearings during 1970 as Ontario's new Pits and Quarries Control Act was being put in place. Hearings were required again in the late 1970s, as additional lands were licensed, and additional modifications were made to license the site under the new Aggregate Resources Act (ARA), which replaced the Pits and Quarries Control Act in 1990. A recent change faced by the aggregate industry in Ontario was the shift toward self-regulation with respect to compliance monitoring and rehabilitation (Miller, 1997). Although this has fostered relationships between aggregate producers and government, it also places an increased onus on industry to overcome public perceptions that self-regulation may result in more lax environmental standards.

There are several areas, including Uxbridge Township, on the fringe of the GTA that supported a number of neighbouring and expanding aggregate extraction operations prior to the implementation of the new legislative acts, which require specific rehabilitation activities. During that earlier period, an increasing demand for aggregate close to growing market areas lead to large tracts of land that were stripped and/or mined without any progressive rehabilitation taking place. This visual record of past practices and lack of regulation has contributed to perceptions by the public that future aggregate operations will exacerbate impacts to rural communities. The areas that contain high quality aggregate reserves are the same as those, which are becoming target market areas for new developments that bring residents out of the core urban areas of Toronto to urbanizing rural communities. In some of these key areas, license application processes have become confrontational, seldom being resolved without hearings.

The Changing Landscape

Reforestation in the Region

A historic perspective on the landscape in the area was derived from air photos taken in c.1927 and 1948 as well as historic accounts of the region. During the 1920s, the landscape in which the Pit is now located was dominated by agricultural land uses. Most of the region was cleared with the exception of several isolated forest blocks and smaller isolated tree stands. Deforestation and clearing for agriculture in the sandy soils of this part of the Oak Ridges Moraine lead to extensive, wind generated, soil erosion.

After World War II, reforestation programs were initiated to stop the erosion and blow sand problems, as well as generating a source of immediate employment for returning veterans. Most of the Uxbridge lands were still clear in 1948, although some plantation blocks had already been planted in the general area.

When extraction began in the early 1970s, the Pit was almost completely surrounded by a combination of older, mature, mixed forests and contiguous plantation stands. Forests dominate this area as a result of low capability of lands for agriculture due to complex physiography and relatively poor surface soil conditions, as well as public acquisition of a number of sites (historical erosion sites or forest lands of public interest, more recently).

Environmental investigations of a proposed expansion of the Pit (ESG 2000) suggested that the surrounding plantations were comprised partially of larger contiguous stands of one or two species (always dominated by Red Pine) and partially of blocks with a number of smaller planting plots that may contain a higher coniferous species richness. The studies also suggested that these blocks are now succeeding with significant die-back in plots of Scots Pine and understory regeneration. In addition, these plantations are interspersed stands of older upland mixed forest dominated by maple-pine communities (sugar maple and white pine), as well as species such as beech, white ash, black cherry, red oak and white birch (Lindsay, 1984). Although lowland areas exist, much of the immediate surroundings are characterized by rolling sandy uplands with few surface water features.

Changing Rehabilitation Objectives and Approaches

Over the course of the thirty-year life history of the Uxbridge Pit, an evolution in rehabilitation practices has paralleled shifts in legislation, social values, the regional ecosystem and community relationships. The following examples of vegetation and soil replacement practices are discussed in relation to the changing environmental and cultural conditions in the area:

- Rehabilitation to agricultural uses;
- Increasing uses of trees, including ornamentals, forest "plugs", and experimental seedling plots;
- Consideration of a wildlife corridor;
- Extensive seedling plantings with traditional forestry principals; and,
- Utilization of successional processes and natural regeneration to develop large-scale rehabilitation plans.

Environmental considerations in earlier rehabilitation objectives across North America were overshadowed by concerns for slope stability, safety, land use and community perceptions (Morris, 1982). More recent approaches exemplify the need to place rehabilitation in the context of ecological and emerging social values (Trimble, 1997; Wade and Tritton, 1997).

Agriculture

Legislation in Ontario requires that aggregate extraction sites are to be returned to a condition suitable for the land use zoning that was in place prior to extraction. Therefore, agriculture has traditionally been a primary rehabilitation target for most aggregate extraction sites in southern Ontario.

Soils, sloping and vegetation establishment were all geared toward creation of relatively uniform landscapes that support pasture lands, forage crops such as corn, soy beans, hay and some grains, vegetable crops and tender fruit orchards (Fraser, 2001). In these conditions, demand and opportunities for naturalization have been relatively rare, even for rehabilitation of old, abandoned sites using the industry's Management of Abandoned Aggregate Properties (MAAP) fund. When alternative objectives and practices were employed, the focus was most often on traditional plantation development on lands graded for farming (i.e. relatively flat with uniform slopes at gradients of 3:1 or more).

The Uxbridge Pit is situated in an area with relatively low agricultural potential. The sandy soils and shallow topsoils have low fertility. Attempts at farming this area were abandoned in the 1920s either as a direct result of wind erosion damage or the need for re-forestation to arrest the erosion problem. As a result the site is now surrounded almost entirely by extensive forest lands under public ownership or the control of provincial and municipal tree-cutting legislation.

The Uxbridge Pit has been subjected to a number of re-vegetation schemes through its life history, but many of these were developed to stabilize mined out or re-graded areas toward the ultimate agricultural end use, and to foster good relations with the municipality and residents (Consedine, 1987).

In more recent years the aggregate industry in southern Ontario has advanced with respect to requirements and capabilities for separating soils during stripping and soil preparation during planting (APAO, 1999; Fraser, 2001). With this expanding knowledge base, it has become increasingly evident that the Uxbridge Pit is not well suited to agricultural after-uses, except those related to forestry. The topsoil layer is thin (less than 4 inches) and is not readily separated from the sandy sub-soils, especially in areas where existing trees are removed during stripping. Numerous socio-economic shifts have also reduced the emphasis on agriculture in the immediate area.

Increasing Use of Trees in Rehabilitation

Trees have been used sporadically on the site through its life history, and primarily for either ornamental reasons, or experimentally in areas that are not likely to be used for other agricultural purposes in the future.

Individual saplings of a number of species were periodically tree-spaded to various locations within the pit to add an aesthetic quality to access areas, site offices and rehabilitated areas of the pit floor.

Several small plots were planted with oak seedlings in 1994 to compare shelter treatments and weed controls on survival and growth (Browning, 1998). This small-scale project was an informal experiment run by the Ontario Ministry of Natural Resources in partnership with

Lafarge. After four years, specimens with greater protection of combinations of the treatments had demonstrated significantly better survival rates.

Experiments with transferred forest plugs were also conducted in the early 1990s on regraded slopes at the east end of the pit. Relative to standard groundcovers for agricultural after-uses, a less competitive seed mix (lower proportion of leguminous species) was used in a topsoil and overburden mixture. While the individual saplings in each forest plug generally survived, the secondary goal of promoting forest community establishment through seed production was not realized. This was likely due to the fact that the plugs should have been positioned to catch seed rain from the neighbouring forest and to provide habitat to encourage primary succession and expansion of forest edge species. A number of case studies in southern Ontario document the initial survival of forest floor species transplanted to pit slopes in plugs or soil applications, followed by immediate decline due to lack of forest subcanopy cover (ESG International, 2000b).

A Wildlife Corridor for the Oak Ridges Moraine

In recognition of the increasing forest cover in the region, the original rehabilitation plan included consideration of a narrow wildlife corridor across the site through an otherwise agricultural after-use landscape.

Shortly after the rehabilitation plans for the site were modified under the new Aggregate Resources Act (ARA), the progressive and final rehabilitation plans were further complicated by ongoing investigations into the importance and sensitivity of the Oak Ridges Moraine. In recognition of the many issues related to the moraine and its varied political implications, as well as an increasing emphasis on the forest cover in the region, detailed rehabilitation plans were developed for a 110m-forested wildlife corridor (Harrington and Hoyle Ltd. 1993). The species list included white pine, tamarack, red cedar, American elm, silver maple, basswood and black ash, as well as dogwood, sumac and alder. No specific soils or grading requirements were listed, and no reference was made to native species, the species composition of surrounding woodlands, or the likely invader species.

Re-forestation Practices

Emphasis on crop production or pasture as after-use targets continued to decline due to decreasing agricultural land uses in the area and increasing public interest in the forest resources around the site. A more extensive tree planting effort was undertaken in 2001 using traditional forestry practices. Given that extreme drought conditions persisted throughout the growing season, Lafarge was able to treat this planting program as an experiment as well as a demonstration of rehabilitation to forest.

Five separate planting blocks within the Uxbridge Pit were located on the floor of the pit on relatively flat ground, with surficial soils consisting of well-drained fine and silty sand. All blocks supported varying densities of groundcover vegetation, dominated by grasses and mixed herbs. Prior to planting, each area was prepared with light discing to expose mineral soil, reduce competition and remove cover for mice and voles.

A total of 20,040 seedlings were planted within the five blocks. Approximately 2/3 (13,440) of the seedlings where white pine and the balance, red pine. These species were selected based on site/soil conditions, prevalence in surrounding forests and stock availability. All planting stock consisted of healthy, vigorous three-year-old bare root seedlings averaging 25 to 35 cm in height. Trees were planted at 1.8 m spacing, typical of most reforestation operations in southern Ontario. A mixture of species was planted within each row. In total, approximately 6.7 ha (16.5 ac) were planted with an average seedling density of 2990/ha (1210/ac). Planting occurred on April 25, 26 and 27, 2001. All seedlings were transported and stored on-site by methods consistent with industry recommended practices. An audit of planting quality was completed during planting operations to ensure the seedlings were properly planted.

A site inspection was completed on September 17, 2001 to assess planting success and determine the survival rates of the planted stock. Three of the five planting blocks (blocks 2, 3 and 5) experienced high mortality with only 10 to 15% of the seedlings surviving the summer. In another block (block 4) approximately 20 to 25% of the planted seedlings survived while the survival rate in the remaining block (block 1) was approximately 80%.

The high mortality, within blocks 2, 3, 4 and 5, is likely attributed to excessive drought conditions, coupled with the presence of a higher density of groundcover competition. It appears that small areas within these blocks, where lighter groundcover exists, support a higher rate of seedling survival. Survival rates within block 1 are estimated at 80%. Block 1 supports the least amount of competing vegetation and is situated at a slightly lower elevation than the rest of the planting blocks. This elevation difference may have been adequate to allow the roots of trees planted trees access to a depth in the soil profile containing higher moisture during extreme drought conditions. Overall, the most significant elements influencing the first year survival rates of the planted stock are the soil drainage conditions combined with the competitive effects of groundcovers during drought conditions. These results parrot those of Browning (1998) in red oak seedlings experiments at the site. Andrews and Kinsman (1990) recommended planting trees in subsoils to reduce the competitive effects of establishing groundcovers.

Advances in Soil Application and Grading

Topsoils in the vicinity of the Uxbridge Pit are thin, sandy and difficult to separate from subsoils. Therefore, mixtures have been applied in varying amounts to the rehabilitated areas of the pit, depending on the type of planting to be done.

Traditionally, grading was done with uniform slopes at maximum gradients of 3:1. The first attempts at innovative grading plans were associated with experimental transplants of forest plugs during the early 1990s and were only marginally successful. More recent grading in habitat creation areas has involved closer links between regional staff specialists and site managers and equipment operators. This has resulted in a number of examples of landform replication to re-create or blend with surrounding features and increase micro-habitat diversity.

A new rehabilitation design (discussed below) will mimic the hummocky topography that characterizes the Oak Ridges Moraine and variations in the thickness of soil applications in areas to be managed toward tree stands and planting nodes.

Cumulative Rehabilitation and Ecosystem Design

The initiation of an application to expand the extraction operation onto a 20 ha site at the west end of the Uxbridge Pit presented an opportunity utilize more advanced rehabilitation technologies.

In spite of the presence of two residences on the expansion site, with associated buildings and manicured areas, it is considered to be contiguous with provincially significant woodlands in the area because of the tree cover it supports. Both Provincial policy and the Aggregate

Resources Act allow encroachments or removal of significant woodlands only if the ecological functions of the woodland are maintained.

Recognizing that direct woodland impacts (from removal of 20 ha of designated forest), public interest in the Oak Ridges Moraine and approval complexities would necessitate an innovative solution, Lafarge allowed the rehabilitation design for the expansion area to incorporate a re-design of the rehabilitation plan for portions of the existing main pit, even though the existing licences included approved rehabilitation plans.

From an ecological perspective this cumulative approach to rehabilitation provided an opportunity to complete the establishment of a large contiguous woodland, the center of which had been occupied by the Uxbridge Pit (ESG International, 2001).

However, there has also been a general acknowledgement that reclamation design that is restricted to only portions of local ecosystem functions tend to be less cost effective or successful than holistic, systems level design (Andrews and Kinsman, 1990; Bradshaw, 1984; Trimble, 1997).

A revegetation project in Australia presents one example of ecosystem analysis with site-specific implications for reclamation (Ludwig and Tongway, 1996). The site-specific design was based on large-scale determinations of the composition, controlling processes and habitat distribution in a semi-arid grassland. This led to detailed design criteria including dimensions and juxtaposition of structures as well as soil and vegetation development.

The primary ecological goals for the rehabilitation strategy at the Uxbridge Pit include:

- Creation of mature forest community characteristics on the site typical of surrounding woodlands;
- Enhancement of the site's contribution to contiguous forest cover, connectivity, and ecological integrity (Noss, 1995) especially between designated Pine-Maple woodlands to the north and the regional forests to the south and west; and,
- Re-establishment of forest interior (home range) habitat across the site.

A central premise of the rehabilitation strategy is to work with (in anticipation of) natural processes, promoting invasion and establishment of local, native species to accelerate early successional stages (Browning, 1998; Trimble, 1997). An understanding of successional trajectories from the species composition of mature forests in the region provided valuable information about the potential climax communities, primary succession processes and local invaders. The extent of active planting and selected species must not impede succession, or waste effort (i.e. on relatively risky secondary and tertiary successional species), or unnecessarily promote non-local species and genetic stock. Locally available and naturally seeded associations of native species will promote greater genetic conservation and resilience than importing stock from other areas (Darmer, 1992).

The rehabilitation goal will be achieved most efficiently and with the least risk if a balance of planting and adaptive management (monitoring) is employed. This will allow Lafarge to promote local species recruitment and early successional processes, to monitor the progress of rehabilitation, and to adjust or intensify planting efforts as needed. Rehabilitation technology in southern Ontario will be advanced through the preferred approach.

The successional pattern of forests in the area is characterized by early successional species such as poplar (*Populus* spp.) and white pine (*Pinus strobus*) followed by transition to white pine and hardwood forests with red oak (*Quercus rubra*), beech (*Fagus grandifolia*) and maples (*Acer rubrum, A. saccharum*.) (ESG International, Env Impact Study, 2000).

Since these lands are surrounded by woodlands that represent the target climax community, natural invasion of hardy native plant species onto the site will proceed through seed rain, wind and animal dispersal and vegetative propagation. Natural invaders [e.g. chokecherry (*Prunus virginiana*), large-toothed aspen (*Populus grandidentata*), white birch (*Betula papyrifera*), and white pine (*Pinus strobus*)] from surrounding forests will comprise locally adapted genotypes of the desired species and therefore will provide the best chance for high survival rates. The surrounding forests also harbor relatively few of the agricultural and weed species that would compete with target species.

The rehabilitation plan also considers the target wildlife species that will be indicators of the desired final habitat conditions on the site. Some of the species are management priorities. Examples of representative species include forest-dwelling, long distance migrant warblers and thrushes such as Cerulean Warbler. The Red-shouldered hawk requires mature deciduous or mixed woods forest with a closed canopy (Cadman *et al.*, 1987), and is representative of the species to be promoted in the area through rehabilitation at the site. While regional migration will generally not be affected by the proposed extraction for most wildlife species, corridor re-establishment would facilitate movement of smaller, less mobile organisms: forest-dwelling rodents and shrews and forest-interior plants.

Two distinct types of active re-vegetation will be employed, each on approximately half of the actively rehabilitated area:

- An ecologically based nodal planting concept to promote recruitment of species from surrounding forests; and,
- Extensive "solid forest plantings" in accordance with OMNR recommendations.

The nodal planting concept employs 'L' shaped planting blocks oriented to create micro-habitats and catch seed rain from the surrounding forests. The approach minimizes the need for extensive planting, while maximizing opportunities to promote the naturalized vegetation communities of the region to establish in the pit. This has facilitated cost savings that can be applied to ongoing adaptive rehabilitation experiments in the pit, while increasing the potential for achievement of regional ecosystem targets.

Summary

This paper has demonstrated two increasingly important practices in aggregate extraction operations:

1. The presentation of advancements in technologies for the education of agencies and public stakeholders; and,
2. The application of cumulative rehabilitation to achieve regional environmental goals by including numerous licensed operations in ecosystem based design.

Cumulative rehabilitation has been implemented at the Uxbridge Pit using succession-based ecosystem level design considerations. Design applied to more than a single site has increased the ability of pit operators to achieve large-scale environmental objectives (such as promotion of

locally adapted seed sources and establishment of targeted regional vegetation assemblages), along with potential gains in both cost-effectiveness and community relations.

Lafarge has also realized an increase in the level of community understanding of its rehabilitation advancements. Through site tours and open houses, agency staff and the public have become informed about the technological capabilities of the industry that are not visibly evident in the many older pit operations in urbanizing areas of southern Ontario.

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