# IMPLEMENTING INNOVATIVE HABITAT RESTORATION TECHNIQUES ON PITS & QUARRIES

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**Abstract:** The Management of Abandoned Aggregate Properties (MAAP) Program is dedicated to the rehabilitation and research of abandoned aggregate pits and quarries in areas of Ontario designated under the Aggregate Resources Act. To date, over $4.6 million has been spent rehabilitating over 216 sites to make over 416 hectares of land safer, healthier and more productive. The majority of these sites were rehabilitated to agricultural land or natural habitat.

The (MAAP) Program funds research to develop new techniques to apply to the rehabilitation of pits and quarries. Currently, there are several projects being undertaken where these experimental techniques are being implemented to restore habitats such as alvars, grasslands, and forests. These sites often exhibit severely degraded and dry soils, and require extensive planning and very particular species selection in order to expedite natural soil amendment and overall habitat enhancement. These projects will result in the expansion of rare habitats, the enhancement of biodiversity, the connection of fragmented habitat, an overall increase in ecological function, and act as demonstration sites for others to replicate.

**Key Words:** pits, quarries, seed, alvar, habitat restoration, forest, prairie, wildlife, reclamation.

## Introduction

Quarrying of rock represents one of the most ancient and important activities that supports human existence (Larson et al. 2004). Rock and surficial gravel deposits, (aggregate) have been extracted from the earth for use in building construction, tool manufacturing and road building for many thousands of years. As human population size increases, the rates of extraction have increased proportionately. Unfortunately, the extraction of aggregate from the ground removes the present terrestrial ecosystem. Unless the disturbed land is actively restored, the slow process of primary succession is the only mechanism by which another productive ecosystem can be established.

The Management of Abandoned Aggregate Properties (MAAP) Program has now successfully completed ten years of rehabilitating abandoned aggregate pits and quarries within the areas of Ontario designated under the *Aggregate Resources Act*. The MAAP Program has two focuses: (1) the ***rehabilitation*** of pits and quarries that were abandoned prior to January 1, 1990; and (2) performing ***research*** relating to aggregate resource management and rehabilitation. Both the rehabilitation and research portions of the Program are funded by the aggregate industry through a portion (1/2 cent) of the annual 11 ½ cent per tonne licence levy, as prescribed in the *Aggregate Resources Act* (Reg. 244/97 3(3)). The program, formerly administered by the Ministry of Natural Resources (MNR), was transferred to the Aggregate Resources Trust when it was created in 1997.

Each year the MAAP program selects sites for rehabilitation from different areas of the province. Site selection is based on a number of factors including on-site hazards, site size, aesthetics, ease of accessibility, and natural re-vegetation. MAAP attempts to rehabilitate higher priority sites, (those deemed to be the most severe in each area), before moving on to those that are considered lower priorities. Sites are rehabilitated by MAAP at no cost to the landowner. The appropriate course of rehabilitation is determined following a consultation with the landowners as well as an examination of local conditions. MAAP works to incorporate the landowners' ideas within the local context when designing a rehabilitation proposal.

Historically, the majority of sites have been rehabilitated to agricultural land or natural areas. Some have also been transformed into recreational areas, such as public parks, sports facilities and outdoor educational areas. To date, over $4.6 million has been spent on 216 projects that have rehabilitated 416 hectares of land at an average cost of $11,000 per hectare.

**Measuring the Success of a Rehabilitation Project**

The measurement of pit and quarry rehabilitation success should be based on safety, environmental, and aesthetic factors. The environmental rehabilitation component should be based on the achieved level of biomass, biodiversity, biofunction and biomimicry.

Biomass is the measurement of the production and preservation of organic matter in an ecosystem. Biomass is often lacking in pits and quarries due to the degradation of the topsoil that often occurs during the process of aggregate extraction. Rehabilitation efforts that include the regeneration of the organic soil layers are more likely to be successful. However, not all ecosystems require the same level of biomass to be considered important or productive (i.e. Alvar ecosystems).

Biodiversity is the measurement of the quantity of different species found in an ecosystem. There are frequently direct correlations between the level of biodiversity (i.e. flora) in an ecosystem and the variety of species (i.e. fauna) it can support, as well as the ecological functions that it may perform.

Biofunction in the context of habitats and ecosystems is the measurement of the biological function and ecological services that an ecosystem can provide. Biofunction may refer to ecological processes that are required for the ecological health of the ecosystem (such as erosion control), or may have beneficial impacts on habitats adjacent to the ecosystem (such as acting as a seed bank). Frequently, human health is also dependant on these functions (such as the recharge and purification of groundwater).

Biomimicry is the study of and act of mimicking and replicating natural, biological processes. Typically, restoration designs and efforts that mimic local ecosystems as nature intended are more likely to be successful than projects using species and/or components not originally found in that ecosystem.

Frequently, there are processes or ecological components that could be categorized under many or all of these designations. Certainly biomass, biodiversity, biofunction, and biomimicry are all interconnected and dependent on each other for overall ecological health (though levels on various ecosystems may differ).

**Planning for a Successful Rehabilitation Project**

Soil degradation is frequently the primary issue with pit and quarry restoration, and therefore soil regeneration, (i.e. organic content) and/or species selection that can grow successfully in infertile soil should be a key step to the rehabilitation planning process.

If it is not known which species are best suitable for an ecosystem, it is best to apply the 'shotgun approach'. The 'shotgun approach' refers to the use of a greater quantity and variety of different species during the revegetation process, in order to improve the probability of some of the species' ability to revegetate the site. The MAAP program has been using the 'shotgun approach' to experiment with the use of native species seed mixes in order to determine which species can achieve various levels of success on a variety of types of soil and site conditions.

Forest or prairie ecosystems are the most common forms of upland habitat restoration on sand and gravel pits. In 2007, the MAAP program began experimenting with various alvar rehabilitation techniques on quarries with no topsoil. These ecosystems are primarily defined by species composition. Therefore, species composition must be a fundamental step of rehabilitation design.

The following is a list of recommendations regarding species selection that the MAAP program applies to their rehabilitation plans.

- Use species that are native (whenever possible)
- Species should be tailored to drainage, soil fertility, substrate, and geographic/climatic area
- Species/habitat type should be chosen based on long term desired effect (soil stabilization, soil regeneration, wildlife habitat, aesthetics)
- Habitat type should be compatible and conducive to surrounding habitats and landscape (connecting forest habitat)

- Sites requiring long term maintenance (>5 years) frequently fail because they do not mimic nature

**Issues With Non-Native Species**

Historically, non-native species mixes have been used to 'green up' rehabilitation sites. These mixes are often applied with fertilizers to encourage growth, and are generally bred to germinate immediately, or shortly, and do not require experiencing an Ontario winter before they germinate. This makes them useful for 'rehabilitating' sites quicker, as much of the non-native seed mix may be green in a matter of weeks, or even days. Unfortunately, there are several drawbacks to the use of non-native species.

Non-native rehabilitation seed mixes may include species such as alfalfa, red clover, white clover, birdsfoot trefoil, sweet clover, creeping red fescue, meadow fescue, spartan hard fescue, highland colonial bentgrass, entopper Kentucky bluegrass, and fiesta perennial ryegrass to name a few. This is in fact, a seed mix that the MAAP program has used in the past. This mix contains species that does not require cold moist stratification, because many of the species are from a climate warmer than that of Ontario, and do not require winter, or a simulation of winter (i.e. cold moist stratification) in order to germinate. This seed mix was hydro-seeded on many sites with fertilizer and various forms of mulch to ensure short term success. Many MAAP sites using this seed mix were found to be quite prolific in the following months. Unfortunately, our observations have shown that these non-native populations do not persist, and decline gradually each year. The fact that fertilizer was not reapplied, and many of the species aren't resilient to drought and Ontario winters may be factors in the decline. The result is that though the safety concerns were dealt with, the resulting non-native communities provided very little habitat value to wildlife, often contained an inferior rooting system (resulting in poor soil stabilization), and had the capacity to spread to and degrade neighbouring native plant communities (via aggressive competition).

Topsoil imported from agricultural fields commonly contains seed from invasive exotic species that has been accumulating in the soil. These species may outcompete many native species, and if not planned for, may negatively impact the success of rehabilitation efforts. Other invasives become more prolific when fertilization, cover crops and/or naturalization efforts occur.

**Restoring Sand and Gravel Pits to Prairies**

Though significant ongoing efforts have been made in Ontario to restore wetlands and replant significant forest habitat, often our prairie habitat gets overlooked. Results from the Ontario Breeding Bird Atlas research has shown us that many grassland birds are in serious decline (Birds Studies Canada 2007).

In 2006, the MAAP program began to experiment with native grass species mixes on 17 of our abandoned sand and gravel pits. The grass species that were selected for experimentation were chosen based on:

- their wildlife habitat value

- soil and drainage conditions (well drained sandy soil)
- their ability to tolerate infertile soils
- their ability to tolerate drought and Ontario winters
- their ability to stabilize soils and protect from erosion

When we compared our bioinventories of our 17 sites rehabilitated into grasslands to 24 abandoned pits that had yet to be rehabilitated, we found that the introduction of our native wild grass species had made the sites more favorable for many species of agricultural hay crop such as timothy and clover (which we did not plant), as well as a variety of other invasive species. However, after one year, the invasive species did not appear to be significantly out-competing our native grasses.

The following is a list of recommendations regarding seed acquisition and application that the MAAP program applies to their prairie rehabilitation plans.

- Use native species and buy local stock
- Grass species should be hydro-seeded (this includes the use of fibre mulch and fertilizer)
- Wildflower species may do better spread by hand
- Wildflower mixes should include a cover crop of oats or grass
- Plan for wildflowers to take 1-2 years to germinate
- Double or triple the seeding rate (amount of seed per hectare)

The following species of native grasses were successfully used by the MAAP program on 17 abandoned sand and gravel pit rehabilitation sites in 2006:

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| *Andropogon gerardii* | big bluestem |
| *Andropogon virginicus* | broom sedge |
| *Bouteloua curtipendula* | side oats grama |
| *Bromus kalmii* | prairie brome |
| *Elymus canadensis* | Canada wild rye |
| *Elymus trachycaulus* | slender wheatgrass |
| *Panicum virgatum* | switchgrass |
| *Schizachyrium scoparium* | little bluestem |
| *Sorghastrum nutans* | Indiangrass |
| *Sporobolus cryptandrus* | sanddrop |

Sixteen of the seventeen sites were hydro-seeded, and one was seeded by hand (at a significantly increased rate). The site that was seeded by hand had a considerably visible lower success rate than the hydro-seeded sites, to the extent that reseeding will be necessary. No other factor can currently be attributed to this failure.

Research and observation of natural colonization of the following species of prairie wildflowers will lead to more extensive experimentation with the following species of wildflowers:

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| *Heliopsis helianthoides* | sweet ox-eye |
| *Oenothera Biennis* | evening primrose |
| *Penstemon digitalis* | foxglove beardtongue |
| *Rudbeckia hirta* | black-eyed Susan |
| *Desmodium canadense* | snowy tick trefoil |
| *Symphyotrichum novae-angliae* | New England aster |
| *Liatris cylindracea* | dwarf blazing star |
| *Asclepias tuberosa* | butterfly milkweed |
| *Monarda fistulosa* | wild bergamot |

The seed should be obtained from established seed supply companies or native seed nurseries. If appropriate seed sources are not available, with adequate lead time, most seed distributors will collect appropriate seed sources as required for a given revegetation request. Once received, all seed and inoculants should be stored in a cool, dry location until use.

**Hydroseeding applications**

The hydro-seeding mix that MAAP uses is as follows:

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| • Native Grass Seed Mix | 50 kg/ha |
| • Verdyol Mulch (Natural plant fibre of 15-25 mm lengths) | 2000 kg/ha |
| • Fertilizer (based on site conditions and timing of seeding): | 250 kg/ha |
| • Water | min. 3800 L/ha |

**Restoring Sand and Gravel Pits to Forests**

Many efforts have been made to replant and transplant trees and shrubs on rehabilitation projects, with results that have been less than satisfactory. In every unsuccessful planting, there was at least one factor that led to the failure. Some factors leading to unsuccessful plantings include:

- Species used were unsuitable for site conditions
- Seedlings were planted too late in the season
- Trees and shrubs were not maintained adequately
- Stock may not have been planted properly, or stored properly prior to planting

**Recommendations**

- Use native species and buy local stock

- Seedlings should be planted early spring
- Transplanting should only be one component of a reforestation plan
- Species must be tolerant of full sun
- Species tolerant of low soil fertility do better
- Species should be drought resistant
- The use of tree and shrub seed may be more successful than seedlings
- Some deciduous trees and shrubs should be included in planting plans to aid in the regeneration of the organic soil layers
- Ensure that seedlings are kept in cold storage until planted
- Plan for watering (at least for the first year of root development)
- Plan for small mammals (mice, voles, and shrews)
- When in doubt, hire a forester or tree planting contractor

The MAAP program is currently experimenting with the following species of native trees and shrubs on Sand and Gravel pits:

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| *Quercus borealis* | red oak |
| *Acer saccharinum* | silver maple |
| *Betula papyrifera* | white birch |
| *Thuja occidentalis* | white cedar |
| *Picea glauca* | white spruce |
| *Acer rubrum* | red maple |
| *Fraxinus americana* | white ash |
| *Pinus strobus* | white pine |
| *Populus tremuloides* | trembling aspen |
| *Rhus typhina* | staghorn sumac |

**Restoring Quarries to Alvars**

Up until recently, the MAAP program has had little to do with abandoned quarries, due to a general lack of feasible rehabilitation techniques. Abandoned quarries are quite large, and are typically devoid of any available topsoil. Rehabilitating these abandoned quarries into agriculture, forests, or prairies, is a difficult undertaking. It would take approximately 1,000 $m^3$ of topsoil (approximately 50-70 truckloads) to spread just 10 cm (4") of topsoil over one hectare of quarry floor.

In 2004, the MAAP program funded Dr. Doug Larson of the Cliff Ecology Research Group from the University of Guelph to undertake research on the feasibility of restoring quarries to alvars. Alvars have been defined as…*"… natural communities… centred around areas of glaciated horizontal limestone/dolomite bedrock pavement with a discontinuous thin soil mantle. These communities are* *characterized by distinctive flora and fauna with less than 60% tree cover, that is maintained by associated geologic, hydrologic and other landscape processes".* (International Alvar Conservation Initiative 1995)

The research studied the similarities between abandoned quarries and alvar communities, experimented with a few alvar species under controlled circumstances to determine whether these alvar species could be introduced successfully, and determined what protocols would be best employed during the rehabilitation of a quarry into an alvar. Specifically, two questions were addressed: (1) To what degree are abandoned limestone quarries similar to alvars in their ecological structure; and (2) What factors limit the ability of alvar species to colonize abandoned quarry floors? The study included the bioinventory and comparison of vegetation on 13 abandoned quarries and 7 alvars. The results showed that seventy-seven of the 246 species of vascular plants, bryophytes, and lichens bioinventoried on quarry floors are also found on alvars, and 24 of the 200 vascular plant species, or 12%, are 'characteristic' of alvars (meaning they are found on more than half of the alvars in Ontario). This bioinventory was followed by experimenting with the germination and growth of 18 species of alvar plants on quarry floors under a series of different soil amendments and conditions.

The study came up with 18 different recommendations that could be contained in 4 different protocols. The protocols for the rehabilitation of a quarry into an alvar are as follows:

(1) Bring in alvar seeds.
(2) Do not remove existing vegetation or soil.
(3) Increase spatial heterogeneity and reduce disturbance.
(4) Monitor and report on your restoration results.

Since the controlled research experiments were successful, the MAAP program will be continuing to conduct field experiments using a wide variety of commercially available alvar seed species.
Some of the commercially available alvar species that we will be experimenting with are as follows:

Alvar Trees and Shrubs

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| *Betula papyrifera* | white birch | *Prunus virginiana* | choke cherry |
| *Thuja occidentalis* | white cedar | *Abies balsamea* | balsam fir |
| *Picea glauca* | white spruce | *Quercus macrocarpa* | bur oak |
| *Lonicera dioica* | mountain honeysuckle | *Juniperus horizontalis* | creeping juniper |
| *Amelanchier alnifolia* | Saskatoon service-berry | *Rhus aromatica* | fragrant sumac |
| *Pinus strobus* | white pine | *Juniperus communis* | ground juniper |
| *Populus tremuloides* | trembling aspen | *Cornus foemina ssp. Racemosa* | grey dogwood |
| *Rhus typhina* | staghorn sumac | | |

Alvar Herbaceous Plants

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| *Lilium philadelphicum* | wood lily |
| *Geum triflorum* | prairie smoke |
| *Hypericum kalmianum* | kalm’s St. John’s wort |
| *Coreopsis lanceolata* | lanceleaf coreopsis |
| *Allium cernuum* | nodding onion |
| *Aster pilosus* | heart-leaved aster |
| *Hedyotis longifolia* | longleaf bluets |
| *Liatris cylindracea* | dwarf blazing star |

…and numerous species of grasses and sedges

**Conclusion**

Pit and quarry rehabilitation projects frequently exhibit severely degraded and dry soils, that require extensive planning, and particular species selection in order to expedite natural soil amendment and overall habitat enhancement. Rehabilitation success should be based on the quantities and levels of biomass, biodiversity, biofunction, and biomimicry. The most important paradigm shift that is necessary for more successful rehabilitation is the replacement of non-native and potentially invasive species with native species that protect the soil better, provide better wildlife habitat, and are more stable over time. A great deal of attention needs to be given to the selection of the proper species to match site conditions, as well as other considerations including time variances and methodology of applications. Successful rehabilitation projects will result in the expansion of rare habitats, the enhancement of biodiversity, the connection of fragmented habitat, an overall increase in ecological function, and act as demonstration sites for others to replicate.