IMPROVING REHABILITATION OPTIONS THROUGH RESEARCH[1]

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Abstract: The Ontario Aggregate Resources Corporation (TOARC), through the Management of Abandoned Aggregate Properties program (MAAP), rehabilitates former aggregate properties (deemed to be abandoned) in areas of Ontario that are designated under the Aggregate Resources Act and conducts research into pit and quarry rehabilitation techniques that will broadly benefit the aggregate industry in Ontario. The MAAP program is funded by a portion (1/2 cent per tonne) of the annual 11.5-cent/tonne licence fee paid by aggregate producers in Ontario.

To date, approximately $6.1 million has been spent to make over 520 hectares of land in Ontario safer, healthier and more productive at no cost to the landowner. Many of these properties exhibit severely degraded soils (lack of quantity and organics), steep and eroding slopes, difficult microclimates, unique species and are at various stages of naturalization. MAAP's research objectives are driven by the need to broaden the range of rehabilitation options given such constraints. Accordingly, research has focused upon such things as species selection to take best advantage of existing soil conditions, species that will expedite natural soil development, soil carbon amendment, bioengineering, mychorrhizal inoculation and unique habitat creation. These techniques lead to the expansion of habitat, the enhancement of biodiversity, an overall increase in ecological function and act as demonstration sites for others to replicate.

Key Words: pits, quarries, habitat restoration, aggregate, alvar, tallgrass prairie, fen, species at risk, reclamation.

Introduction

The Ontario Aggregate Resources Corporation (TOARC) through the Management of Abandoned Aggregate Properties (MAAP) program focuses on two important Aggregate Resource Trust purposes: (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.

When the Aggregate Resources Act (ARA) was put into effect, the aggregate industry represented by the now Ontario Sand Stone & Gravel Association (formerly the Aggregate Producers Association of Ontario) agreed that $0.005 per tonne of the licence fees payable would be dedicated to a program having the purpose of rehabilitating former pits and quarries "deemed abandoned". By definition, abandoned pits and quarries include those that have never

[1] Paper was presented at Mining and Environment V Conference, Sudbury, Ontario, Canada, June 25-30, 2011.

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been licenced following the establishment of the ARA in 1990. Based on recent levels of extraction in Ontario, approximately $600,000 to $700,000 is made available on an annual basis to fund the MAAP program. In addition to the rehabilitation of abandoned pits and quarries, monies from the funding also supports research into ways and means of undertaking new and creative approaches to rehabilitation in the often harsh environments created in post extraction sites.

Rehabilitation

At the onset of the ARA, the Ministry of Natural Resources (MNR) undertook an inventory of site disturbances that were thought to be the result of aggregate extraction. That investigation resulted in approximately 6600 files. The designation of additional parts of the province since 1990 has resulted in approximately 1300 new files being added to the inventory of sites qualifying under the program. However, it has also been discovered that many of the sites contained in the original inventory no longer need rehabilitation assistance through the MAAP program as many of these sites have now been developed, rehabilitated by the landowner, naturalized, or now hold an aggregate licence.

To manage the number of sites identified through the various inventories it has been necessary to establish certain priorities for organizing the MAAP work program. The site inventories provide a composite rating for each site based on a number of factors including site hazards, site size, aesthetics, accessibility, natural re-vegetation, and susceptibility to erosion. The composite rating is then used to rank sites 'high', 'medium' or 'low' priority. The appropriate course of rehabilitation is determined following a consultation with the landowners as well as an examination of the local conditions.

Historically, the majority of the sites have been rehabilitated to agricultural land (Figure 1(a)) or natural areas (Figure 1(b)). Some have been transformed into recreational areas, such as public parks, sports facilities and outdoor educational areas. However, the opportunity to reclaim the abandoned properties by creating, enhancing and connecting habitat, all while eliminating safety concerns, has been recognized by the MAAP program.

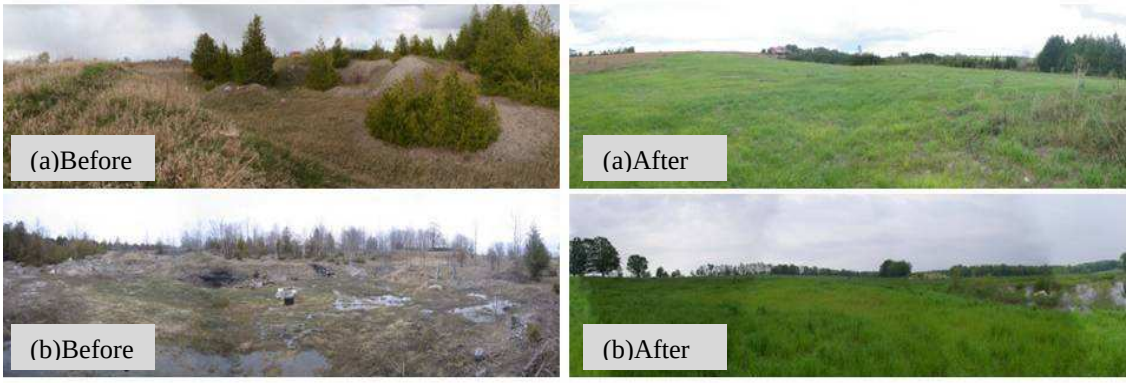

Figure 1: MAAP rehabilitation projects, (a) abandoned aggregate site prior and post rehabilitation to agriculture, 0.5 ha, Township of Mariposa, City of Kawartha Lakes; (b) abandoned aggregate site prior and post rehabilitation to natural area, Township of Keppel, Grey County, 3.0 ha.

Many unique habitats that were once extensive across Ontario have been diminished due to urbanization and agriculture and the adaptability of aggregate sites, both abandoned and active, provide an ideal canvas for reversing this trend.

To date, over $6.1 million has been spent on 322 projects that have rehabilitated over 520 hectares of land. However, many of these properties exhibit severely degraded soils (lack of quantity and organics (Figure 2(a)), unique species (Figure 2(b)), difficult microclimates, steep and eroding slopes (Figure 2(c)) and are at various stages of naturalization (Figure 2(d)).

Figure 2: MAAP research is driven by the need to broaden the range of rehabilitation options given such constraints as (a) lack of soils; (b) unique species; (c) steep eroding slopes; and (d) stages of naturalization.

Research

Soil degradation is frequently the primary issue with abandoned pit and quarry restoration, therefore soil regeneration (i.e. organic content) and/or species selection that can grow successfully in infertile and/or lack of soil has been a key focus of MAAP's research initiatives. As a result, in 2004, the MAAP program commissioned work by 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.

Alvar

Alvars are defined as "natural communities… centered around areas of glaciated horizontal limestone/dolomite bedrock pavement with a discontinuous thin soil mantle… distinctive flora and fauna with less than 60% tree cover" (Reschke et al., 1999) (Figure 3(a)). As many of Ontario's limestone quarry floors (Figure 3(b)) can similarly be described as this, the Quarry to Alvar Initiative was started.

This research studied the similarities between abandoned quarries and alvar communities. The work aimed to answer two specific questions:

(1) To what degree are abandoned limestone quarries similar to alvar in their ecological structure?
(2) What factors limit the ability of alvar species to colonize abandoned quarry floors?

Alvars are globally endangered ecosystems; hence answering these questions could have benefits both to the conservation of alvars and the restoration of both active and abandoned quarries.

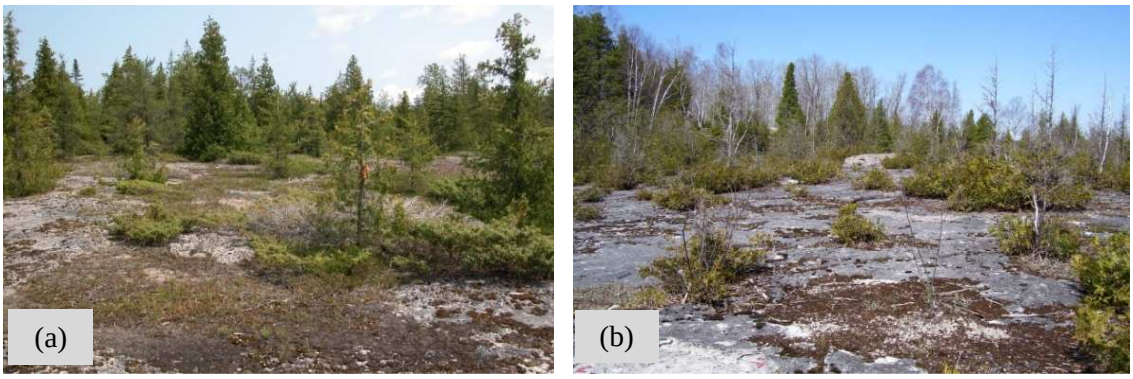

Figure 3: (a) Naturally occurring alvar; (b) Abandoned quarry floor; (photos courteously of Dr. P. Richardson).

The research included a bioinventory and comparison of vegetation and environmental factors between thirteen (13) abandoned quarries and seven (7) alvars. It was found that environmental, quarry floors were strikingly similar to alvars, and seventy- seven (77) of the two hundred forty six (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' (meaning they are found on more than half of the alvars in Ontario) of alvars. Strong evidence was found for seed limitation as the principle factor limiting the colonization of quarry floors by alvar species. The research, through manipulative work in four (4) abandoned quarry sites, determined that soil amendments had very minimal effects on establishment of alvar species in the abandoned quarry, though silica sand addition increased species establishment and nitrogen fertilization decreased establishment. It was found that a more rapid development of quarry floors into real alvars may require nothing more than seed and silica sand addition.

The Quarry to Alvar Initiative provided the MAAP program with a list of simple procedures to accomplish the restoration and management of abandoned limestone quarries to alvars including: (1) using alvar seeds, (2) leaving existing vegetation and soils, (3) increasing spatial heterogeneity, (4) decreasing disturbances and, (4) monitoring restoration results.

Dr. Doug Larson and his team established that quarries resembled alvars with respect to many environmental conditions and that a number of alvar herbs and forbs can successfully establish in quarries by seeding. However, natural alvars contain many mosses which aid in soil development. Consequently, the MAAP program commissioned Ms. Suzanne Campeau of Bryophyta Technologies Inc. to continue the Quarry to Alvar Initiative and determine if two alvar representative moss species (*Schistidium rivular* and *Tortella tortuosa*) can also be established in depleted limestone quarries with simple amendments including the addition of substrate (mulch, sand and gravel), changes in topography and nutrient addition.

Campeau found that addition of straw mulch to the plots with *S. rivular* and *T. tortuosa* yielded 44% and 73% higher establishments, respectively. In addition, when the mosses were grown on

a substrate composed of small particles (sand and gravel) in comparison to bare rock, and with the addition of topography, 'rock ridges', around the plots (Figure 4), higher establishment rates occurred. However, the addition of both sand and gravel substrate, and 'rock ridge' topography did not compensate for the absence of straw mulch. Work is currently ongoing to determine if a thin layer of silica sand and low nutrient doses will further increase moss establishment.

Figure 4: Spreading moss fragments on the central area of each plot, showing the surrounding 'rock ridges'.

Through the work of Dr. Larson and Campeau, the MAAP program has gained valuable tools to rehabilitate, and communicate how to rehabilitate, abandoned quarry floors to alvars. However, in the case of abandoned pits, many have had the topsoil stripped and removed leaving well drained sand and gravel. This makes these sites ideal for restoration to prairie due to the similarities of the sand pit substrates to that of tallgrass prairies, and also that it is relatively easier to rebuild the soil horizons of tallgrass prairies than some other habitat types (ex. forests). This has lead to work examining tallgrass prairies, including both species selection and soil amendments for these habitats.

Tallgrass Prairie

In 2010, TOARC commissioned work by Dr. Klionomos and Brain Ohsowski (PhD student) from the University of British Columbia (UBC-O) that would examine ways to attain the highest quality tallgrass prairie restoration with simple and practical land management tools on abandoned sand and gravel pits where soils were denuded. The work is aimed to answer the practical questions:

> (1) Can we better assure the success of native plant establishment with the use of mycorrhizal inoculants, thereby adding value (through successful establishment) to the overall restoration scheme?
> (2) can the addition of soil supplements in various proportions significantly and cost effectively accelerate soil restoration thus managing soil erosion?

Tallgrass prairies have particularly diverse vegetation communities that can thrive in different microclimates and have a high annual plant biomass accumulation in soils that are rich in organic matter. Due to the high organic soils, this once expansive habitat has now been diminished for cattle grazing and agriculture.

Aggregate sites offer significant opportunities to restore tallgrass prairies because of their already 'open' nature and adaptability to management scenarios. The research is testing the restoration strategies that promote the establishment of native prairie plants in former sand and

gravel pits. The biotechnological land management tools utilized in this project will include the application of commercially available arbuscular mycorrhizal fungus (AMF), *Glomus intrardices* and carbon amendment addition (municipal compost and biochar) (Figure 5(a)). The soil carbon amendment aspect of this project attempts to more closely mimic abiotic conditions of remnant prairie soils as many abandoned sand and gravel pits are highly mineral with a diminished organic carbon fraction. Native plant species including Snowy Tick- trefoil (*Desmodium canadense*) and Switchgrass (*Pancicum virgatum*) will be planted as plugs (Figure 5(b)) in stage one of the research, AMF inoculum will be pre-mixed into the plant plug soil and used to grow 50% of the native plant species. In stage two of the research, native seeds will be planted to determine a more economic approach to tallgrass prairie rehabilitation.

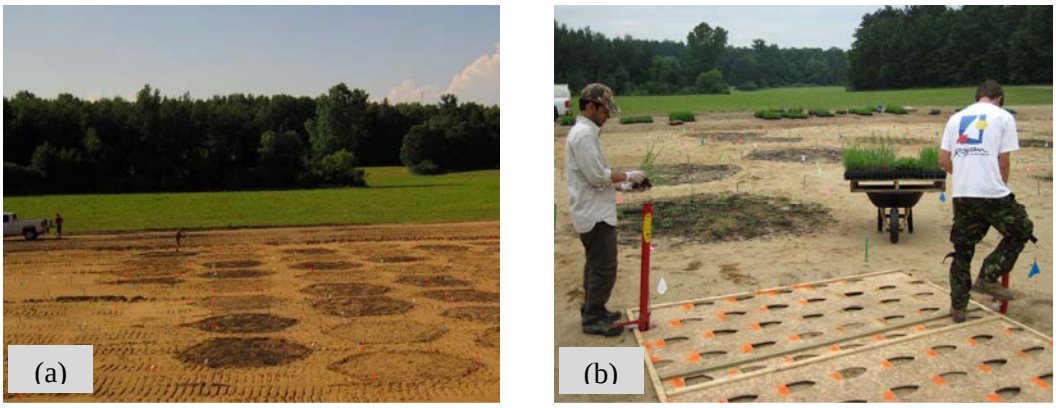

Figure 5: (a) Hexagonal plots with different soil amendments including biochar, compost & biochar and no amendment are ready for planting; (b) Field technicians plant native prairie plugs into the experimental plot.

The proposed treatments are anticipated to drastically alter: (1) microbe – driven biogeochemical cycles; (2) soil building processed; and (3) plant- mycorrizal symbiosis, resulting in the regeneration of ecosystem- level feedbacks that facilitate native plant and soil microbe production in tallgrass prairies.

Fen

As many of Ontario's pits and quarries are influenced by groundwater seepage, aided by funding assistance through the MAAP program, Dr. Waddington and PhD student Tim Duval of McMaster University examined the feasibility of rehabilitating former quarries into fen ecosystems. Fens are one of the rarest forms of wetlands in Ontario. They are exclusively groundwater fed and are found overlaying areas of limestone and dolomite rock. This results in waters that are rich in calcium and magnesium and a distinctive flora of rare, calciphillic species. The objective of the research was to understand the ecohydrological conditions required for the establishment of a wetland type that would readily establish in shallow quarries and along deep quarry shorelines dominated by groundwater seepage.

Research was conducted at the Fletcher Creek Preserve, Puslinch ON. The site contains both naturally occurring calcareous fens, and an abandoned wet quarry site. For the research site, the rock walls of the abandoned quarry were lowered and resultant materials were used to reshape the quarry to appropriate fen depths (Figure 6).

Figure 6: Abandoned wet quarry site prior to and after earthwork was completed, Fletcher Creek Ecological Preserve, Puslinch Township.

The study included a bioinventory and water chemistry of the naturally occurring fens. Plugs were transplanted into the abandoned modified quarry at various depths with different medium treatments (fines, top soil, and 'peat ball'). Waddington and his team determined a list of recommendations for establishing fen species in quarry rehabilitation projects that can be summed up in five steps: (1) the quarry should be covered in a thin layer of cobbles; (2) a small amount of top soil should be added; (3) the quarry floor needs to be saturated for a minimum of eight weeks prior to growing season; (4) the water table should not drop more than 50 cm below the quarry floor, and should not be higher than 40 cm above quarry floor for majority of season; and (5) primary species for rehabilitation should include water and yellow sedge.

Species at Risk

For the approximate 7,900 abandoned pits and quarries, 3,700 licences and 3,400 permits across the province, there are significant opportunities for the MAAP program and aggregate operators to avoid, minimize, and/or mitigate adverse effects on the natural environment and to maximize positive ones. With Ontario's new *Endangered Species Act* (2007) encouraging the consideration of Species at Risk (SAR), The Ontario Aggregate Resources Corporation completed a '*Best Practice Guidelines for Aggregate Rehabilitation Projects- extracting the benefits for species at risk and rare habitat'* manual. The Guidelines address important topics including:

- Threats to SAR;
- Rehabilitation approaches to benefit SAR;
- Candidate habitats suitable for restoration to benefit SAR; and
- Recommended monitoring and reporting approaches.

The Guideline uses a variety of tools and information (e.g., checklists of planning considerations, detailed matrices of SAR reliance upon various biophysical conditions, species range maps and mapping which overlays SAR occurrences with pit and quarry locations) to communicate and encourage rehabilitation that incorporates SAR. While the Guidelines provide substantial detail regarding species requirements, the focus is upon the creation of suitable host habitats (e.g., alvar, cliff/crack/crevice/cave, talus, swamp, fen marsh and shallow open water, woodland, savannah and prairie). The Guideline can then be paired with research that has been conducted by the MAAP program to complete a successful rehabilitation project.

Bioengineering

Abandoned and active aggregate properties provide the opportunity to enhance, increase and connect habitat or create unique habitats. However, in many abandoned aggregate sites, the MAAP program is faced with situations where there are varying degrees of naturalization, where access to the site is limited, or where a landowner would prefer to not have earthwork completed, notwithstanding the presence of steep dangerous slopes. Recently, the MAAP program has been implementing various bioengineering techniques to aid in these situations. For example, native shrubs and grasses such as staghorn sumac, grey dogwood, virginia creeper, etc., can be planted to stabilize soil and reduce slumping with help from deep forming roots which retain the soil. For steeper slopes live staking with willow species and installation of fascines will shield soil from rain due to foliage and root systems will hold soil in place. MAAP is currently working closely with foresters and seed producers to determine the best practices for various seed mixtures and trees to rehabilitate abandoned sites under a range of conditions.

Conclusion

The MAAP program has successfully completed over 10 years of rehabilitating abandoned aggregate pits and quarries within the areas of Ontario designated under the Aggregate Resources Act. These projects frequently exhibit severely degraded soils (lack of quantity and organics), steep and eroding slopes, difficult microclimates, unique species and are at various stages of naturalization. These sites require extensive planning and particular species selection in order to expedite natural soil amendment and overall habitat enhancement. There are significant opportunities for the MAAP program and aggregate operators to expand and connect habitat. However, 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 which MAAP program is aiming to provide guidance to with its research. 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.

References

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