EFFECTS OF BORROW SITE PREPARATION AND FERTILIZATION ON NATURAL REVEGETATION

by

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January 1987

Prepared for:

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DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
DIVISION OF PLANNING AND PROGRAMMING
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IMPLEMENTATION STATEMENT

This study report describes the effects of experimental fertilization and surface conditioning of a gravel borrow site which lacked a topsoil covering.

Conditioning the surface by ripping or scarifying to create furrows was found to be most important for natural establishment of fireweed, the dominant vegetative covering.

Fertilization had a dramatic effect on fireweed growth, increasing the biomass by sevenfold. However, it had a very minor effect on the establishment and growth of woody plant species including willow, alder, birch, and poplar.

Spreading alder and willow seed artificially on the study sites increased their seedling densities by roughly a factor of four. Of the various woody plant species observed, grayleaf willow had the highest density while balsam poplar was the fastest growing. Alder also proved to be a species well adapted to growth on the test plots.

In summary, borrow site revegetation by fireweed may be greatly enhanced by scarifying and fertilization, while woody plant development and growth is enhanced by scarifying and seeding. Project designers should consider these facts when setting borrow site revegetation goals and specifying treatments.

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1.0 INTRODUCTION

In interior and northern Alaska, many borrow sites created for road construction have been slow to revegetate. Most of these sites have well-drained, coarse-textured soils derived from subsurface material which is low in nutrients. In addition, the soil surface is often compacted and smooth, which decreases infiltration, limits root growth, and provides few suitable microsites for seedling establishment. These sites are often planted with grass, which grows poorly and inhibits the establishment and growth of native herbs and woody plants. (Densmore 1982; Land Design North 1979; Native Plants 1980a, 1981; Neiland et al. 1981). It has also been suggested that native plant revegetation is limited by low levels of natural seed in-flow or "seed rain" on some disturbed sites (Johnson personal communication).

In Alaska, recent design criteria developed for proposed activities requiring surface disturbance have recommended stockpiling overburden, reducing compaction, replacing overburden, fertilization, and then reliance on natural revegetation, unless immediate erosion control is necessary (Alaska Power Authority 1984; Densmore 1982; Kubanis 1982, Native Plants 1980b, 1981). However, there are some difficulties with this approach. First, segregating and stockpiling overburden may not always be feasible or cost-effective. Many sites have little or no overburden prior to disturbance, and there are many existing sites where overburden was not segregated at the time of disturbance. On forested sites, removal of stumps and small trees from the overburden is difficult and expensive, and may leave little usable soil. A second problem is the relationship between harsh site conditions and seed rain, whose contribution to the slow rate of revegetation is not well understood.

The specific objectives of this study were 1) to assess the feasibility and effectiveness of site preparation and fertilization in promoting establishment and growth of native plants on a well-drained, rocky, compacted, smooth-surfaced site without available overburden, and 2) to evaluate the role of seed rain in limiting revegetation by native plants on this site.

2.0 STUDY SITE

The study site covered approximately four-fifths of an acre at a material site where the Jim River DOT camp is located. The main criteria for selecting this site were 1) the proximity of DOT equipment needed for site preparation, 2) freedom from conflicting uses during the study, and 3) poor revegetation prior to experimental treatment. The site had been repeatedly disturbed: it was originally a material site for construction of the Trans-Alaska Pipeline System, and was then mined again by DOT. It was used as a truckstop, then as a parking area for DOT personnel and private citizens. Undocumented contamination of the site (including a diesel spill) was unofficially reported by two independent sources.

Preliminary soil analyses indicated that the soil texture was Gravelly to Very Gravelly Loam. The study site was flat and, prior to experimental treatments, had a smooth, compacted surface. Vegetative cover was very sparse (<10%), consisting of planted grass which was barely surviving. Seedlings of native woody plants were virtually absent.

The material site and adjacent undisturbed vegetation are located on an old alluvial terrace of the Jim River. The material site is surrounded by open black spruce forest (Picea mariana) (Viereck and Little 1972) with scattered paper birch (Betula papyrifera) and Bebb willow (Salix bebbiana) and occasional littletree willow (S. arbusculoides). The shrub layer was dominated by Labrador tea (Ledum groenlandicum), diamondleaf willow (S. planifolia), and bog blueberry (Vaccinum uliginosum). The study site was approximately 1000 feet from the Jim River, which is bordered by white spruce (Picea glauca) and balsam poplar (Populus balsamifera) and by stands of feltleaf willow (S. alaxensis) with small numbers of halberd willow (S. hastata). Favorable microsites in part of the material site outside the study site had been colonized by fireweed (Epilobium angustifolium), feltleaf willow, and Bebb willow.

3.0 METHODS

3.1 Experimental Design

Experimental treatments included ripping for site preparation, fertilization, seeding with willow and alder, and control, producing the following treatment combinations:

- Ripped, fertilized, seeded
- Ripped, fertilized
- Ripped, seeded
- Ripped
- Fertilized, seeded
- Fertilized
- Seeded
- Control

Plot layout was controlled by the fact that ripping with heavy equipment required a large area and could not be done on small plots. Therefore, one-half of the study area was ripped and the other half was left unripped. The ripped and unripped sides of the study area were each divided into four replicate blocks. Each replicate block was then divided into 25 x 25 ft plots. Treatment combinations were randomized within replicate blocks.

3.2 Site Preparation

Because the study was intended to evaluate the feasibility of promoting natural revegetation by native plants as a substitute for planting grass, as much of the planted grass as possible was removed from the study site. A study site without planted grass would have been preferable, but no suitable sites without grass were available. Most of the grass was removed by scraping the surface with a motor grader, although some grass remaining in loose soil was raked up and removed by hand. Following grass removal, site preparation was conducted on one-half of the study site. The standard equipment used for reclamation of very compacted rocky disturbed sites--a bulldozer with several large rippers--was not available. The job was effectively but less efficiently done with the available equipment. The study site was first ripped to a depth of two feet with a bulldozer with one ripper. Afterwards, because a cat with one ripper flattened and compacted the ripped area when it moved over to do the next strip, the site was ripped a second time with the ripper mounted on a motor grader. The end result was friable soil with furrows 8 to 12 inches deep.

3.3 Fertilization

Plots were fertilized with commercial NPK (20-20-10) fertilizer at 600 lb per acre immediately after grass removal and site preparation were completed.

3.4 Seeding

Willow catkins and alder cones were collected when mature and beginning to open and disperse seed. Immediately after collection, twenty to forty catkins or cones of each species, along with seeds which had been released from catkins or cones into the collection bag, were uniformly distributed on each plot designated for seeding. Each catkin or cone contains a large number of seeds, which are readily wind-dispersed. Since the catkins were on the ground, some seeds remained near the catkins while others dispersed across the plot. A few seeds strayed into adjacent plots which had not been seeded.

At the time of initial site preparation and fertilization in June 1983, catkins of feltleaf willow collected along the Jim River near the study site were sown on plots. At the end of the 1983 growing season, catkins of grayleaf willow (*Salix glauca*), which disperses dormant seeds in the fall, and cones of alder (*Alnus crispa*) were collected several miles north of the study site and sown. On July 1, 1985, catkins of halberd willow and Bebb willow were collected several miles north of the study area and sown. A different seeding technique was tested with feltleaf willow, which was collected in Fairbanks early in June 1985. Seeds of this species were separated from catkins and hairs, and cleaned seeds were frozen until sown at a rate of approximately 300 seeds per plot on June 25.

3.5 Evaluation

The plots were evaluated in 1983, 1984, and 1985 during the last week of August and first week of September. For each plot, woody plant seedlings were identified to species where possible, and the height of each seedling was measured. Since small seedlings of Bebb willow and halberd willow could not readily be distinguished from each other, all seedlings of these two species were grouped as Salix spp. This category may also have included some diamondleaf willow seedlings. For each treatment, the mean (S.E.) number of woody plant seedlings per plot was calculated for total woody plants and for each of the six taxa which had ten or more seedlings on the entire study site. For balsam poplar and paper birch, which were not artificially seeded, seeded and unseeded plots were combined in the evaluation of other treatments.

Overall growth comparisons could not be made because relative numbers and age distributions of species varied among treatments, and there was interspecific variation in growth rate and age distribution. Treatment growth comparisons were made for two individual species, grayleaf willow and alder, where all seedlings were known to have established from one artificial seeding. Mean seedling height was calculated for each species on plots with ten or more seedlings. Clumped seedlings, usually around sown catkins or cones, were excluded. The mean (S.E.) of plot means was calculated for each treatment.

Herbaceous native plants were identified to species and counted in 1983 and 1984. In 1985, fireweed, which was the dominant herbaceous plant, was clipped from three randomly located 20 x 20 in subplots. The three samples from each plot were combined, dried, and weighed to estimate above-ground biomass. Introduced weeds were identified, and presence or absence of weed taxa was recorded for each plot.

4.0 RESULTS

4.1 Study Site Problems

The replicate blocks were designed to partition observed variation in soil texture and microtopography within the study site. Unfortunately, by the end of the 1985 growing season it was apparent that the main source of variability among plots was an unknown factor or combination of factors which caused large differences between the north and south sides of the study site, cutting across the replicate blocks on both the ripped and unripped sides of the study area. The number of plants for all species and treatments was significantly different between the two sides. For example, the mean (S.E.) number of woody plant seedlings was ninety-eight (23.6) per plot for the north half of the plots, and only nine (2.4) per plot for the south half of the plots.

Evaluation of the experimental results was delayed so that soil samples could be obtained from the study site during the 1986 growing season. The samples were to have been analyzed for contaminants and other factors which may have limited plant establishment during the study. Unfortunately, upon arrival it was discovered that almost all of the study site had recently been graded and buried under fill. Since the inhibiting effect of the unknown factor was so marked, and since the possibility of diesel contamination could not be eliminated by testing, plots in the south half of the study site were not included in the final data analyses. Data from plots on the north side of the study site were considered valid for evaluation of treatment effects, since plant establishment and growth on this side was similar to or better than that observed on other material sites with similar soils which were uncontaminated. Treatment combinations with less than three replicate plots were not evaluated.

4.2 Native Woody Plants

4.2.1 Overall Treatment Effects

Species Composition and Seed Rain. At the end of three growing seasons, seedlings of eleven woody plant species had been identified on the study site. There was little variation in woody plant species composition among treatments, with all treatments having eight to ten species. Seeding had no major effect on species composition because seeded species also established from natural seed rain and/or a few seeds dispersed from seeded plots into unseeded plots.

At least six species of woody plants established only from natural seed rain, including balsam poplar, paper birch, aspen (*Populus tremuloides*), buffaloberry (*Shepherdia canadensis*), littletree willow, and white spruce. The last four species were rare, with less than ten seedlings on the entire study site. Since diamondleaf willow was common around the study site, some unidentified seedlings may have been present, although this species rarely establishes on severely disturbed sites. Observations of seedling distribution and of species composition before artificial seeding indicated that feltleaf willow, Bebb willow, and halberd willow established from both natural seed rain and artificial seeding, but that all seedlings of grayleaf willow and alder originated from artificial seeding. Seedlings of these species in unseeded plots had apparently dispersed from adjacent seeded plots.

Density. In 1983, very few woody plant seedlings established in the study area. Woody plant seedlings were virtually absent on the ripped plots, and mean seedling density on the unripped plots was less than one seedling per plot.

There was no rain for most of the month of June and the plots were very dry, which prevented the establishment of feltleaf willow seeded on the plots and of any willow and poplar seeds naturally dispersed to the site.

In 1984, relatively large numbers of grayleaf willow and alder seedlings established on seeded plots, but unseeded plots had only a few woody plant seedlings. In 1985, many Bebb and halberd willow seedlings established from the spring seeding. At the end of the 1985 growing season, it was clear that both ripping and seeding had greatly increased the number of woody plant seedlings, but fertilization appeared to have no effect on density (Table 1). On ripped plots, woody plant seedlings established only in the furrows.

Considering that at least one-third of the seedlings on unseeded plots originated from seeds which strayed from seeded plots, the woody plant density produced by 3 years of natural seed rain was very low. Even on ripped plots, the number of seedlings present would have produced a very sparse stand.

Growth. Growth of all woody plant seedlings was very slow compared to the growth of these species on more favorable sites. The larger plants were several inches tall, with a few plants reaching 1 ft in height, but most seedlings were less than 1 inch tall. However, almost all of the plants had grown for only one or two seasons, since few established during the dry first growing season.

4.2.2 Treatment Effects on Individual Taxa

Species differ in life history patterns and in their response to environmental variables. Therefore, to understand the overall treatment results and to apply them to other sites with different species compositions, it is valuable to examine the response of individual species to the experimental treatments.

Table 1. Effects of ripping, fertilization, and seeding after three growing seasons on the total number of woody plant seedlings and on the number of seedlings of four taxa which were artificially seeded. Data are mean (S.E.) number of seedlings per plot (625 sq ft). n = no. of plots.

Treatment	n	Alder	Grayleaf willow	Feltleaf willow	*Salix* spp.[a]	Total[b]
Ripped, fertilized, seeded	4	38(29.0)	130(37.6)	2(0.6)	53(13.8)	242(67.3)
Ripped, seeded	3	26(15.1)	112(33.0)	3(2.4)	62(33.2)	209(66.8)
Ripped	4	0 (0.0)	12 (8.8)	2(0.5)	19 (4.5)	42 (4.8)
Seeded	4	10 (4.3)	30(29.9)	7(2.6)	13 (6.0)	74(26.2)
Control	5	1 (0.4)	1 (0.5)	2(1.5)	5 (0.8)	17 (1.2)

[a] *Salix* spp. includes halberd willow and Bebb willow, which were seeded, and probably also includes some seedlings of unidentified willow species which established from natural seed rain.

[b] Total includes balsam poplar and alder seedlings (see Table 2), plus small numbers of littletree willow, aspen, white spruce, and buffaloberry seedlings, all of which established from natural seed rain.

Balsam Poplar. Balsam poplar, which established from natural seed rain, appeared to be adapted to the conditions of the study site. On the south half, which was eliminated from the study because very few plants established and contamination was suspected, balsam poplar was the only species found on many plots, and these plants were healthy. Although balsam poplar was the fastest growing and most vigorous species on the study site, the growth rate was slower than on more favorable sites. Healthy plants 2 to 3 years old averaged 5 in. in height, ranging from 2 to 12 in. Ripping had no effect on density, but fertilizer may have had a negative effect on unripped plots (Table 2). The density of this species appeared to be limited primarily by seed rain, since the seed source was not close to the plots.

Paper Birch. A few paper birch seedlings established from natural seed rain, and the combination of ripping and fertilization appeared to increase establishment (Table 2). It is very likely density was also limited by seed rain. There were few seed trees adjacent to the study site, and good seed crops do not occur every year (Zasada 1971). Most of the birch seedlings established in 1985 and were less than 1 in tall, and 2-year-old seedlings were 1 to 1.5 in tall. In contrast, paper birch seedlings on a good site in interior Alaska were 12 in tall at the end of the second growing season (Zasada et al. 1977). However, after many years of slow growth, paper birch stands have developed on many severely disturbed sites in interior Alaska, such as dredge tailings (Holmes 1981) and rock quarries (Densmore 1982).

Alder. Seed rain was the primary factor limiting alder, which only established from artificial seeding. There was a trend toward increased density on ripped and fertilized plots (Tables 1 and 3). Seedlings were small after 2 years of growth, but the few seedlings which survived the 1986 regrading of the study

Table 2. Effects of ripping and fertilization on establishment of balsam poplar and paper birch from natural seed rain. Data are mean (S.E.) number of seedlings per plot (625 sq ft). n = no. of plots.

Treatment	n	Balsam poplar	Paper birch
Ripped, fertilized	5	9(3.5)	5(1.6)
Ripped	7	8(1.7)	1(0.7)
Fertilized	3	1(0.4)	1(1.0)
Control	8	10(1.5)	0(0.0)

Table 3. Effects of ripping and fertilization on height of seeded grayleaf willow and alder after two growing seasons. Data are means (S.E.) of the plot averages, and the range of seedling heights within treatments. n = no. of plots, dash = no data.

	Grayleaf willow			Alder		
Treatment	n	height (in)	range	n	height (in)	range
Ripped, fertilized, seeded	4	0.6(0.12)	0.2-3.5	2	0.9(0.31)	0.2-4.9
Ripped, feeded	3	0.6(0.17)	0.2-2.8	2	0.6(0.18)	0.2-2.3
Seeded	-	-	-	2	0.3(0.05)	0.2-3.1

site had grown rapidly during their third year. Alder fixes nitrogen and not only grows well on harsh sites but increases soil nitrogen levels for other species. Along the route of TAPS, alder appears wherever alder plants are adjacent to the disturbance, even if site conditions are harsh (Densmore 1982, Native Plants 1980a).

Grayleaf Willow. Establishment of grayleaf willow was limited by seed rain and site conditions. Seedlings established only from artificial seeding, and density was higher on ripped plots than on unripped plots (Table 1). Fertilization did not affect seedling density and had little effect on growth (Table 3). Two-year-old seedlings were small, but the inherent growth rate of this species is slow relative to other willows. This willow has established on many well-drained disturbed areas in northern Alaska which are similar to the study site.

Feltleaf Willow. Site conditions on most of the study site did not favor establishment of feltleaf willow, and were not improved by ripping and fertilization (Table 1). This species requires a wet soil surface for establishment (Neiland et al. 1981, Moore 1983). Seed rain was not a problem; artificial seeding did not increase density, and wet microsites in the material site had many feltleaf willow plants. Most plants in the study site exhibited poor growth.

Bebb and Halberd Willow (Salix spp.). Density of Bebb and halberd willow was highest on ripped, seeded plots, but was not affected by fertilization (Table 1). Although small seedlings of these two species were very similar, enough larger specimens were present to determine that seedlings of both species established from the June 1985 sowing. 2- and 3-year-old Bebb willow seedlings which established from natural seed rain were vigorous and grew relatively rapidly, ranging up to 13 in in height.

4.3 Native Herbaceous Plants

Fireweed was the dominant native herbaceous plant (approximately 98% of the native herb cover). A few plants of dwarf fireweed (*E. latifolium*) were present, but these did not do well. Fireweed spreads vegetatively, and the treatments probably affected both establishment from seed and the subsequent vegetative production of new plants from rhizomes. Low numbers of fireweed were present in the unripped plots in 1983 but were absent from the ripped plots (Table 1). By 1984 fireweed was abundant on the study area.

Fertilization alone had little effect on the number of fireweed plants, but ripped plots had more than twice as many plants as control plots, and the combination of ripping and fertilization produced more plants than ripping alone (Table 4). On ripped plots all plants grew in the furrows.

Fertilization had dramatic effects on fireweed growth. Fireweed plants on unfertilized plots were reddish and remained in the flat rosette stage for all three growing seasons. Fertilized plants were green and vigorous, and produced tall flowering shoots during all three growing seasons. Above-ground biomass was seven times higher on fertilized ripped plots than on unfertilized ripped plots, with almost all of the difference attributable to an increase in the size of plants rather than the difference in the number of plants (Table 4). Quantitative data for fertilized unripped plots was not available, but qualitative observations indicated that its effect on these plots was similar. Ripping alone apparently increased the size of rosettes on unfertilized plots,

Table 4. Effects of ripping and fertilization on density of fireweed in 1983 and 1984 and on above-ground biomass in 1985. Data are mean (S.E.) number of ramets and dry weight (lb) per plot (625 sq ft). n = no. of plots, dash = no data.

	No. of Ramets			Biomass	
Treatment	n	1983	1984	n	1985
Ripped, fertilized	5	0(0.0)	790(191.6)	2	6.7(0.48)
Ripped	3	0(0.0)	475 (83.4)	3	0.9(0.34)
Fertilized	6	6(4.8)	230(138.8)	-	-
Control	6	20(8.8)	183 (69.4)	5	0.1(0.04)

but the biomass was still very low.

4.4 Planted Grass and Introduced Agricultural Weeds

Most planted grass was removed from the plots by grading, but a small portion remained. On unfertilized plots this grass was sparse and not vigorous, but on fertilized plots the remaining grass had become green and vigorous and had spread rapidly. However, since there was plenty of open soil between scattered grass clumps, the grass did not seriously interfere with the establishment of native plants.

In 1983, most of the plant cover on the study site was composed of introduced agricultural weeds, including lambsquarters (*Chenopodium album*), chickweed (*Stellaria media*), *Amsinckia* spp., knotweed (*Polygonum aviculare*), shepherd's purse (*Capsella bursa-pastoris*), common plantain (*Plantago major*), and several other weed taxa familiar to Alaskan farmers and gardeners. These weeds were introduced in grass seed and straw mulch during the TAPS revegetation program (Kubanis 1982). The seeds had apparently been lying dormant in the soil for several years, broke dormancy when exposed to light by the grading and ripping, and germinated following July rains. The weeds barely survived on the unfertilized plots, but were large and vigorous on the fertilized plots. In 1984 the number of weeds was reduced, and in 1985 they were virtually gone.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The combination of ripping and fertilization produced an attractive vegetative cover by the second growing season following treatment. It consisted primarily of a vigorous, dense stand of flowering fireweed, interspersed with scattered clumps of grass, all of which grew in furrows produced by ripping. Similar results have been reported for a section of the TAPS workpad which was fertilized but not seeded with grass, and for parts of other well-drained, rocky TAPS material sites which were fertilized but accidentally not seeded with grass (Native Plants 1980a, Densmore 1982). These communities of fireweed and other native herbaceous plants were still growing vigorously 5 years after fertilization.

Soil treatments did not completely solve problems with woody plant revegetation. Ripping doubled the number of woody plants, which grew only in the furrows, but had no effect on growth. Fertilization had very little effect on density or growth. Similar results have been reported for other TAPS material sites north of this study site, where repeated application of fertilizer had no long-term effects on growth of willows (Densmore et al. in press). Even with ripping, woody plant density was relatively low (plants would have been 4 ft. apart, if evenly spaced) and growth was very slow compared to better sites, with plants only a few inches tall after two or three growing seasons.

Plant density and species composition were limited by a lack of sufficient natural seed rain. Artificial seeding increased the density of woody plant species already present and added two species which were well-adapted to the site: alder and grayleaf willow. Seed rain was controlled by adjacent vegetation. While the dominant species of the adjacent mature black spruce forest are not adapted to well-drained, rocky disturbed sites, the species which did colonize the site came from scattered decadent plants in the black spruce forest or from younger successional stands further way from the site, thus limiting the quantity of seed dispersed to the site.

There was a relationship between seed rain and soil conditions. For the same level of seed rain, ripped plots had more seedlings than unripped plots, and moist, silty spots within adjacent disturbed areas had more seedlings than any part of the study site. As the density of suitable microsites for seedling establishment decreases, a higher seed rain is required to ensure that some seeds land on suitable sites.

Compared to the study site, woody plant growth was much faster on gravel in moist depressions and on well-drained silty soils in adjacent disturbed areas, indicating that the moisture retention capacity of rocky soils was a major factor limiting plant growth. Judging by the wet condition of the lower end of the material site in which the study site is located, it is possible that the woody plants in the study site may grow rapidly when the roots reach subsurface water. If this does not occur, a woody plant community may require 15 to 20 years to develop (Native Plants 1980a).

Fertilization greatly increased the growth of grass on the study site, but there was sufficient distance between clumps of grass; thus these clumps did not significantly affect the establishment and growth of native herbs and woody plants.

Large numbers of agricultural weeds germinated from dormant buried seeds when the study site was redisturbed by grading and ripping. Many of these weeds produced seeds before disappearing after two growing seasons. Since buried agricultural weed seeds may remain viable for hundreds of years, the weeds may be considered a long-term component of the plant community on this site and on adjacent undisturbed areas to which they may have dispersed. These weeds are likely to reappear after a future disturbance, but will not persist when native plants re-establish. Therefore, these species are not likely to pose a problem unless agriculture is developed in the area.

In conclusion, ripping and fertilization are recommended for well-drained, rocky disturbed sites. Soil should be ripped to a minimum depth of 12 in, leaving furrows or hollows with a minimum depth of 6 in. On many sites this can be accomplished with a motor grader. Areas too steep to rip may be left with a rough surface during construction or mining. These techniques are likely to produce a vegetative cover of native forbs which can be augmented with a light seeding of grass at a rate of 5 to 10 lb per acre without detriment to native plants. Although ripping will increase the density of native woody plants, growth will be very slow unless the overburden is replaced or fines are added by other means. In addition, natural revegetation contains few or no plants of the species adapted for colonization of the disturbed site. The level of seed rain and the species composition can be predicted by evaluating the adjacent vegetation.

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