

REVEGETATION AND RECLAMATION OF ASH LAGOON SURFACES
IN CENTRAL ALBERTA

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ABSTRACT

A number of experiments were initiated near Wabamun, Alberta to investigate methods of stabilizing ash lagoon surfaces, using revegetation and reclamation techniques, at coal-burning thermal power plants. The coal ash constitutes a poor plant growth medium since it is deficient in organic matter and many plant nutrients, contains potentially phytotoxic levels of boron, has a high pH, no ion exchange complex and is easily eroded when dry. A bulk ameliorant trial was established to determine revegetation success of a forage mixture seeded on an ash lagoon surface using several topsoil, minespoil and manure treatments. Results showed that all capped treatments produced a more dense plant cover than bare ash. Manure was the most effective amendment for improving forage yields. A mulch trial was initiated to determine the effects of surface straw mulch or cultivated straw mulch treatments on forage establishment and growth. Straw mulch treatments did not significantly increase plant cover and forage yields compared to the bare ash control and inhibited seedling development on surface straw mulch treatments. A legume trial was used to test the establishment, growth and nitrogen fixing capability of several legume species seeded on bare ash. Overall, the alfalfa, sweetclover (biennial) and birdsfoot trefoil legume species were easiest to establish, produced higher yields and fixed more nitrogen than cicer milkvetch and red clover.

INTRODUCTION

The Wabamun thermal power generating station is located approximately 65 km west of Edmonton in Central Alberta. After strip-mined coal is burned at the station, about 15% of the original material remains as silicious, non-carbon or non-combustible ash material. Fly ash is airborne particulate matter removed from the boiler flue gas emissions, while bottom ash is solid residual material accumulating in the bottom of the furnaces. At Wabamun, approximately 2 million tonnes of coal from the Whitewood Mine are burned annually, producing approximately 300,000 tonnes of ash material. Waste ash material is often removed from the plant by mixing it with water to form a slurry and pumping it through a pipeline to disposal lagoons in the vicinity of the station. The ash settles and water is removed until the lagoon is full, presenting a flat expanse of unstable, unaggregated, sand sized material. Unless steps are taken to stabilize the exposed ash surface, the material is highly susceptible to wind transport and dusting.

Revegetation is a common method of surface stabilization, but ash lagoons provide a hostile environment for plant growth. Desirable plant growth qualities are limited to factors such as the flat surface which reduces water erosion, the sandy loam texture which provides good drainage and easy root/shoot penetration, and a lack of salinity or sodium toxicity problems. Undesirable qualities include a strongly alkaline pH, phytotoxic levels of micronutrients such as boron, a lack of an organic fraction and micro-organisms, a very small cation exchange capacity and few plant nutrients (Burton *et al.*, 1982; Hodgson and Townsend, 1973; Monenco Limited, 1986; Ziemkiewicz *et al.*, 1981). Unless or until pozzuolanic cementation occurs, as a result of the cohesion of the carbonate coatings of the ash particles, the material is highly unstable, easily moved by wind and has low bearing strength. Experimental trials were initiated to investigate methods of dealing with undesirable ash characteristics.

BULK AMELIORANT TRIALS

The bulk ameliorant trials were initiated to determine the revegetation success of an agricultural forage mixture seeded on an ash surface using several topsoil, minespoil and manure capping treatments. A Gray Luvisol topsoil, non-sodic minespoil and barnyard manure were selected from locally available stockpiles. All three maintain some potential to improve fertility, lower pH, increase cation exchange capacity, reduce micronutrient phytotoxicity and increase microbial activity in an otherwise sterile ash growth medium.

Methods and Materials

Plots were established in 1977 when all possible combinations of topsoil (8 cm), minespoil (8 cm) and manure (8 cm) capping treatments were applied to an ash lagoon surface and cultivated to a depth of 15 cm. A fertilizer-only and unfertilized control were

included and all treatments were replicated twice. The experimental area was broadcast seeded with a forage mixture containing *Bromus inermis* (Smooth brome grass - 20 kg/ha), *Agropyron cristatum* (Crested wheatgrass - 12 kg/ha), *Festuca rubra* spp. *rubra* (Creeping red fescue - 4 kg/ha) and *Medicago sativa* (Common alfalfa - 4 kg/ha). Maintenance applications of fertilizer (N-P-K-S) were applied each year to all plots except the unfertilized control. The central portion (1m x 5m) of each sub-plot was used for experimental measurement of plant cover, forage yield and ash chemistry. Statistical analysis of data was completed using the Statistical Analysis System (S.A.S. Institute, 1985).

Results and Discussion

Analysis of plant cover data collected over 5 years showed that all capping treatments had significantly more total plant cover than the fertilized and unfertilized controls (Table 1). Capped treatments and controls consisted mostly of *Bromus inermis* (Smooth brome grass), *Festuca rubra* spp. *rubra* (Creeping red fescue) and lesser amounts of *Poa compressa* (Canada bluegrass) and *Agropyron repens* (Quackgrass). Creeping red fescue and Canada bluegrass are known for their tolerance to low fertility and drought, while smooth brome grass and quackgrass are very aggressive species, adaptable to a wide variety of growth conditions.

As was expected, harvest data showed that all cap treatments containing manure, including the manure-only (463 g/m²), manure + topsoil (443 g/m²), manure + minespoil (428 g/m²) and manure + topsoil + minespoil (477 g/m²) treatments, yielded significantly more plant biomass than all other treatments and controls. All remaining cap treatments, including the topsoil-only (297 g/m²), minespoil-only (298 g/m²) and topsoil + minespoil (291 g/m²) treatments, yielded more plant biomass than the fertilized and unfertilized controls. Although better plant growth was expected on topsoil than minespoil, no difference in yield measurements were observed. The fertilized (173 g/m²) and unfertilized (164 g/m²) controls yielded the significantly lowest amount of plant biomass, but were not significantly different from each other. Applications of fertilizer on seeded bare ash were not enough to significantly improve revegetation success, indicating that poor fertility is just one of many deficiencies in ash material.

Soil pH (0-15 cm) was significantly lower in all capped treatments than the fertilized and unfertilized controls. Levels of organic carbon (0-15 cm) were significantly lower in the fertilized and unfertilized controls than in all the capped treatments. Very low carbon levels demonstrate that bare ash is essentially sterile, contains no organic matter, few micro- and macro-organisms and has very low rates of carbon accumulation. The observed available boron levels in the ash (0-15 cm) range from 2.9-8.6 µg/g. Boron levels can be rated as slightly toxic to tolerant to plant species when ash levels range from 4-10 µg/g (Hodgson and Townsend, 1973). The manure + topsoil treatment had significantly higher available boron levels than all remaining capped treatments and controls, but were not directly attributable

TABLE 1

Bulk Ameliorant Trials
Relationship Between Single Treatments and Plant Biomass, Cover and
Ash Chemistry Over All Years (1978 - 1985)

Treatments	Manure Only	Topsoil Only	Minespoll Only	Manure plus Topsoil	Manure plus Minespoll	Topsoil plus Minespoll	Manure, Topsoil and Minespoll	Fertilizer Only	Untreated Control
<u>Biomass (g/m²)</u>									
Mean $\pm$ S.D.	463 $\pm$ 163	297 $\pm$ 192	298 $\pm$ 202	443 $\pm$ 111	428 $\pm$ 153	291 $\pm$ 148	477 $\pm$ 192	173 $\pm$ 88	164 $\pm$ 141
Grouping ^a	a	b	b	a	a	b	a	c	c
<u>Total Cover (%)</u>									
Mean $\pm$ S.D.	102 $\pm$ 10	110 $\pm$ 27	98 $\pm$ 13	115 $\pm$ 28	118 $\pm$ 29	120 $\pm$ 32	109 $\pm$ 27	68 $\pm$ 32	63 $\pm$ 32
Grouping ^a	bc	ab	c	a	a	a	abc	d	d
<u>pH (0-15 cm)</u>									
Mean $\pm$ S.D.	7.3 $\pm$ 0.3	7.5 $\pm$ 0.3	7.4 $\pm$ 0.2	7.0 $\pm$ 0.3	7.2 $\pm$ 0.3	7.2 $\pm$ 0.2	7.1 $\pm$ 0.2	7.8 $\pm$ 0.3	8.0 $\pm$ 0.4
Grouping ^a	bcd	b	bc	d	bcd	bcd	cd	a	a
<u>Total N (0-15 cm)</u>									
Mean $\pm$ S.D. (ug/g)	1933 $\pm$ 882	1155 $\pm$ 560	868 $\pm$ 284	2775 $\pm$ 223	1406 $\pm$ 249	952 $\pm$ 909	2810 $\pm$ 1373	286 $\pm$ 105	238 $\pm$ 25
Grouping ^a	b	bcd	cde	a	bc	cde	a	de	e
<u>Organic C (0-15 cm)</u>									
Mean $\pm$ S.D. (%)	2.5 $\pm$ 1.0	2.0 $\pm$ 1.0	2.2 $\pm$ 1.1	4.1 $\pm$ 0.3	2.8 $\pm$ 0.9	3.2 $\pm$ 0.4	3.9 $\pm$ 2.4	0.6 $\pm$ 0.1	0.7 $\pm$ 0.1
Grouping ^a	c	c	c	a	bc	abc	ab	d	d
<u>Available B (0-15 cm)</u>									
Mean $\pm$ S.D. (ug/g)	6.3 $\pm$ 5.5	3.9 $\pm$ 0.9	2.9 $\pm$ 0.9	8.6 $\pm$ 7.8	3.3 $\pm$ 1.1	5.2 $\pm$ 5.6	4.2 $\pm$ 2.0	3.2 $\pm$ 0.9	4.1 $\pm$ 3.4
Grouping ^a	b	de	e	a	de	bc	cd	de	d

S.D. = Standard Deviation

^a = Results of Duncan's multiple range test. Means with the same letter are not significantly different ($P = 0.05$).

to either pH or organic matter content. Total nitrogen (0-15 cm) was significantly higher in the manure + topsoil and manure + topsoil + minespoil treatments than in all remaining treatments and controls, likely due to the presence of both manure and topsoil.

Conclusions

1. All capping treatments (manure, minespoil, topsoil), alone or in combination, produced more plant cover and forage biomass than the uncapped ash controls.
2. Applications of fertilizer alone did not significantly improve crop growth on seeded bare ash.
3. Manure appeared to be the most effective capping treatment for improving yields.
4. All capping treatments reduced pH levels from those observed on the bare ash.
5. All capping treatments were successful in improving organic carbon levels over the low levels found in bare ash. Untreated ash contains no organic matter, few (if any) micro/macro-organisms and has very low rates of carbon accumulation.
6. Available boron levels were rated as slightly phytotoxic to plant growth. The manure and topsoil treatment had the highest available boron levels but were not directly attributable to either pH or organic matter content.

STRAW MULCH TRIALS

The mulch trials were initiated to determine the effects of cultivated and uncultivated surface straw-mulch treatments on forage establishment and growth on an ash lagoon surface. Straw mulch was selected as an ash treatment due to its local availability and use as an agricultural soil amendment. Organic matter additions like straw, domestic sewage, peat, animal manure and other harvest wastes can help improve soil fertility, cation exchange capacity, soil aeration, water holding capacity, microbial activity and reduce phytotoxic concentrations of micronutrients.

Methods and Materials

Plots were established in 1979 when straw mulch₂ was applied to an ash lagoon surface at a rate of 1.7 kg/m². Cultivated treatments were rototilled to a depth of 15 cm while uncultivated treatments were covered with fish-netting to hold straw in place. A fertilizer-only control was included and all treatments were replicated three times.

All plots were seeded to a forage seed mix of *Agropyron trachycaulum* (Slender wheatgrass - 13 kg/ha), *Festuca rubra* spp. *rubra* (Creeping red fescue - 12 kg/ha), *Bromus inermis* (Smooth

bromegrass - 12 kg/ha), *Phleum pratense* (Timothy - 7 kg/ha), *Trifolium pratense* (Red clover - 2 kg/ha), *Trifolium hybridum* (Alsike clover - 2 kg/ha) and *Medicago sativa* (Common alfalfa - 2 kg/ha) using a hand broadcast applicator. Maintenance applications of fertilizer (N-P-K-S) were applied each year. The central portion (1m x 2m) of each sub-plot was used for experimental measurement of plant cover, forage yield and ash chemistry. Statistical analysis was carried out using the Statistical Analysis System (S.A.S. Institute, 1985).

Results and Discussion

The cultivated mulch treatment (94%) and untreated control (96%) both had significantly more plant cover of seeded species than the uncultivated mulch treatment (78%) (Table 2). Non-vegetated patches of surface straw on the uncultivated mulch treatment, as well as some volunteer species growth, accounted for this difference. The surface straw appeared to create an environment too cool and dark for successful seedling establishment. Vegetation on all plots consisted largely of *Medicago sativa* (Common alfalfa), *Bromus inermis* (Smooth bromegrass) and *Festuca rubra* spp. *rubra* (Creeping red fescue) as well as small amounts of *Phleum pratense* (Timothy).

Analysis of harvest data showed that forage yields from the cultivated surface straw mulch treatment (448 g/m²) and untreated control (431 g/m²) were not significantly different from each other, but were significantly higher than the yields from the uncultivated surface straw mulch treatment (305 g/m²).

The requirement for available nitrogen by forage crops grown on normal agricultural soil has been described as deficient from 0-10 µg/g, marginal from 10-25 µg/g and adequate from 25-38 + (Carsen, 1986). In comparison, levels of available nitrogen (0-15 cm) in the ash appear deficient across all treatments. Available nitrogen was significantly higher in the cultivated surface straw mulch treatment than in the uncultivated surface straw mulch treatment and fertilized control. This suggests a possible increase in ash available nitrogen due to decomposition of incorporated straw mulch.

The observed available boron levels in the ash (0-15 cm) ranged from 4.3 - 6.6 µg/g. Boron levels can be rated as slightly phytotoxic to tolerant to plant species when ash levels range from 4-10 µg/g (Hodgson and Townsend, 1973). Available boron was significantly lower in both straw mulch treatments compared to the fertilized control.

Conclusions

1. Straw mulch treatments did not improve plant cover and forage production compared to seeded bare ash. In fact, the uncultivated surface straw mulch treatment had less plant cover and forage biomass than the bare ash control. The surface mulch appears to create an environment too cool and dark for successful seedling establishment.

TABLE 2

Straw Mulch Trials
Relationship Between Single Treatments and Plant Biomass, Cover and
Ash Chemistry Over All Crop Years (1980 - 1985)

Variable	Treatment		
	Uncultivated Surface Straw Mulch	Cultivated Surface Straw Mulch	Fertilized Control
<u>Biomass (g/m²)</u>			
Mean $\pm$ S.D.	305 $\pm$ 165	448 $\pm$ 178	431 $\pm$ 184
Grouping ^a	b	a	a
<u>Seeded Cover (%)</u>			
Mean $\pm$ S.D.	78 $\pm$ 27	94 $\pm$ 16	96 $\pm$ 10
Grouping ^a	b	a	a
<u>Available N (0-15 cm)</u>			
Mean $\pm$ S.D. (ug/g)	3.7 $\pm$ 3.9	9.6 $\pm$ 9.4	5.6 $\pm$ 5.3
Grouping ^a	b	a	b
<u>Boron (0-15 cm)</u>			
Mean $\pm$ S.D. (ug/g)	4.3 $\pm$ 2.0	4.3 $\pm$ 1.6	6.6 $\pm$ 2.5
Grouping ^a	b	b	a

S.D. = Standard Deviation

a = Results of Duncan's multiple range test. Means with the same letter are not significantly different (P = 0.05).

2. Available plant nitrogen was deficient across all treatments, but was highest in the cultivated straw mulch treatment. Nutrient reserves appear to be depleting over time through plant uptake and leaching, while the limited number of ash micro-organisms appears to limit the rate of mulch decomposition.
3. Both straw mulch treatments had less available boron than the bare ash control, possibly due to an interaction between boron and the organic matter fraction.

LEGUME TRIALS

The legume trials were initiated to determine the establishment, growth and nitrogen fixing capabilities of several agricultural legume species grown on bare ash. Major plant nutrients, especially nitrogen, are vital for sustaining healthy plant growth. Legumes can provide their own organic source of nitrogen by fixing atmospheric nitrogen through a specialized bacterial symbiosis in legume root nodules. Since ash is deficient in major plant nutrients, the use of legumes in revegetation programs appears critical in obtaining long-term reclamation success.

Methods and Materials

Plots were established in 1980 and 1983 when several common agricultural legume species were broadcast seeded and packed onto an ash lagoon surface. Pre-inoculated seed treatments included *Medicago sativa* (Common alfalfa - 20 kg/ha), *Melilotus alba* (White sweetclover - 40 kg/ha), *Astragalus cicer* (Cicer milkvetch - 60 kg/ha), *Lotus corniculatus* (Birdsfoot trefoil - 20 kg/ha) and *Trifolium pratense* (Red clover - 40 kg/ha), as well as a *Festuca rubra* spp. *rubra* grass control (Creeping red fescue - 40 kg/ha), and an unseeded control. All treatments were replicated four times in a randomized block. Maintenance applications of fertilizer (P-K-S) were applied each year. The central portion (1m x 2m) of each sub-plot was used for experimental measurement of plant cover, forage yield and ash chemistry. Statistical analysis was carried out using the Statistical Analysis System (S.A.S. Institute, 1985).

Results and Discussion

The sweet clover (71%), alfalfa (70%) and creeping red fescue (63%) had significantly more plant cover of seeded species than the other legumes and controls (Table 3). Cicer milkvetch (38%) and birdsfoot trefoil (31%) had significantly more seeded plant cover than the red clover (17%). The birdsfoot trefoil, cicer milkvetch, red clover and unseeded control contained notably more volunteer species than the alfalfa, sweet clover and creeping red fescue. The alfalfa had very few weeds, once established, and the unseeded control had a considerable amount of volunteer legume growth from adjacent plots.

Harvest data from each three year program showed alfalfa (508 g/m²) yielding significantly more plant biomass than all other

TABLE 3

Legume Trials
Relationship Between Single Treatments and Plant Biomass, Cover and
Ash Chemistry Over All Established Crop Years

Treatment	Alfalfa	Birdsfoot Trefoll	Clcer Milk Vetch	Red Clover	Sweetclover	Grass Control	Unseeded Control
<u>Biomass (g/m²)</u>							
Mean $\pm$ S.D.	508 $\pm$ 136	286 $\pm$ 127	234 $\pm$ 134	171 $\pm$ 128	313 $\pm$ 213	46 $\pm$ 59	123 $\pm$ 105
Grouping ^a	a	b	bc	cd	b	a	de
<u>Seeded Cover (%)</u>							
Mean $\pm$ S.D.	70 $\pm$ 21	31 $\pm$ 22	38 $\pm$ 17	17 $\pm$ 25	71 $\pm$ 18	63 $\pm$ 32	0
Grouping ^a	a	b	b	c	a	a	d
<u>Available N (0-15 cm)</u>							
Mean $\pm$ S.D. (ug/g)	7.2 $\pm$ 3.9	4.6 $\pm$ 2.1	4.4 $\pm$ 2.4	6.4 $\pm$ 7.5	9.9 $\pm$ 6.2	2.6 $\pm$ 1.3	4.9 $\pm$ 3.7
Grouping ^a	ab	bc	bc	b	a	c	bc
<u>Total N (0-15 cm)</u>							
Mean $\pm$ S.D. (ug/g)	370 $\pm$ 116	403 $\pm$ 88	327 $\pm$ 43	317 $\pm$ 56	440 $\pm$ 85	294 $\pm$ 76	282 $\pm$ 78
Grouping ^a	bc	ab	cd	cd	a	d	d

S.D. = Standard Deviation

^a = Results of Duncan's multiple range test. Means with the same letter are not significantly different (P = 0.05).

seeded legumes and controls. Alfalfa is well adapted to a wide range of conditions, is relatively drought tolerant due to a deep root system and is moderately tolerant to alkaline soils. As a result, this adaptable legume was reasonably easy to establish. Biennial sweetclover was the easiest legume to establish and was very productive during the first year, but has to be reseeded every two years to maintain a continuous stand and did not always yield two cuts² per season. Sweetclover (313 g/m^2) and birdsfoot trefoil (286 g/m^2) yields were not significantly different, but were significantly more productive than all remaining legumes and controls except cicer milkvetch (234 g/m^2). Sweetclover is well adapted to a variety of growth conditions, has good drought tolerance and moderate tolerance to alkalinity. Birdsfoot trefoil has high tolerance to alkalinity, is fairly drought resistant and moderately tolerant of poor fertility. The birdsfoot trefoil was not as easy to establish as the alfalfa or sweetclover and provided patchy growth on some plots. Cicer milkvetch was more difficult to establish and contained numerous volunteer (weed) species. It has some tolerance to drought² and alkalinity, but is poorly competitive. Red clover (171 g/m^2) was very difficult to establish, so yields were not significantly different from the unseeded control (123 g/m^2). Red clover is adapted to a wide range of soil conditions, but has poor drought tolerance. The grass control (46 g/m^2) yielded significantly less plant biomass than all legumes and the unseeded control, but had no volunteer (weed) growth. Creeping red fescue is known for its tolerance to drought and poor fertility.

The requirement for available nitrogen by forage crops grown on normal agricultural soil has been described as deficient from $0-10 \text{ } \mu\text{g/g}$, marginal from $10-25 \text{ } \mu\text{g/g}$ and adequate from $25-38 +$ (Carson, 1986). In comparison, available nitrogen from the ash surface appears to be deficient in all legume treatments and controls. Available nitrogen ($0-15 \text{ cm}$) was significantly higher under sweetclover than under all other legumes and controls, except alfalfa. Total nitrogen ($0-15 \text{ cm}$) was also significantly higher under sweetclover than under all remaining legumes and controls, except birdsfoot trefoil. Total nitrogen was not significantly different under alfalfa and birdsfoot trefoil, but was significantly lower under cicer milkvetch, red clover and both controls. Cicer milkvetch and red clover did not have significantly different total nitrogen levels in the ash than both controls.

Conclusions

1. Sweetclover, alfalfa and creeping red fescue had better seeded species plant cover than the remaining seeded legumes. All three were relatively easy to establish. Once established, the alfalfa and creeping red fescue had very few weeds. The less easily established legumes, including birdsfoot trefoil, cicer milkvetch and red clover had higher occurrences of volunteer (weed) species.
2. Alfalfa produced more plant biomass than the other legume species and controls. Sweetclover was a vigorous, productive species, but has to be reseeded every two years (biennial) to

maintain a continuous stand. Birdsfoot trefoil produced well, but was a little more difficult to establish. Cicer milkvetch and red clover were both difficult to establish and had low yields.

3. Levels of available plant nitrogen in the ash were deficient across all treatments, however, sweetclover had more available nitrogen than all other seeded legumes. Total nitrogen was also highest under the sweetclover, while alfalfa and birdsfoot trefoil were higher than cicer milkvetch, red clover and both controls. Sweetclover appears to be fixing more nitrogen and improving soil fertility better than the other seeded legumes.

ACKNOWLEDGEMENTS

The author wishes to thank TransAlta Utilities Corporation for funding this project and allowing use and access to land and facilities. The author would also like to acknowledge John Railton and Holly Quan of TransAlta Utilities for project supervision.

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ELEVENTH ANNUAL MEETING

LAND REHABILITATION: Policy, Planning Systems and Operational Programs

June 3 - 6, 1986

University of British Columbia
Vancouver, B.C.



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ISSN 0705-5927

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FOREWORD

The British Columbia Chapter of the Canadian Land Reclamation Association was formed in 1985 to provide a local public forum for the exchange of information and experience in land rehabilitation. Comprised of professionals from a wide range of backgrounds and interests, this organization pulled together quickly to host the 1986 Annual Meeting. The diverse membership in the B.C. Chapter was realized in a program that expanded the scope of the conference to include many fields that have not been represented in past programs. The quality of presentations and range of topics kept audience participation at a spirited level. It is our hope that we have initiated a trend to widen the scope of the annual meetings so as to not focus on traditional mining or energy development issues.

I wish to thank all speakers and attendees for making this first formal function of the B.C. Chapter a success. The enthusiastic support of chapter members in the planning and administration of the conference demonstrated a strong desire for a quality meeting. This drive bodes well for the future of our chapter.

A great deal of effort went into the publication of the proceedings of the 1986 Annual Meeting. Care was taken to accurately reproduce all papers, however minor errors may have escaped the review process. We hope that this will not detract from the information presented by the authors.

May the CLRA and all local chapters continue to grow and function as a focal point for land rehabilitation.