TAR SANDS RECLAMATION RESEARCH

Task Force Report

Prepared for the

Conservation and Utilization Committee

February, 1973

TAR SANDS RECLAMATION RESEARCH TASK FORCE

Dr. F. D. Cook, Department of Soil Science, Faculty of Agriculture and Forestry, University of Alberta

Dr. H. M. Etter, Environmental Protection Service, Environment Canada

Mr. A. W. Goettel, Plant Products Division, Alberta Department of Agriculture

Dr. R. Green (Chairman), Earth Sciences Branch, Research Council of Alberta

Mr. D. G. Harrington, Interdepartmental Relations and Land Conservation Division, Alberta Department of the Environment

Dr. G. Lesko, Canadian Forestry Service, Environment Canada

Mr. J. D. Lindsay (Secretary), Soils Division, Research Council of Alberta

Dr. D. L. Mitchell, Product Research and Development Division, Research Council of Alberta

Dr. M. Paetz, Fish and Wildlife Division, Alberta Department of Lands and Forests

Mr. J. Selner, Forest Land Use Branch, Alberta Department of Lands and Forests

Dr. J. A. Toogood, Department of Soil Science, Faculty of Agriculture and Forestry, University of Alberta

Alternates.

Mr. D. McDonald, Fish and Wildlife Division, Alberta Department of Lands and Forests

Mr. J. J. Fitzpatrick and Mr. C. B. Berry, Great Canadian Oil Sands Limited, also attended one meeting, and outlined that company's reclamation program.

TERMS OF REFERENCE

Minute No. 5, Conservation and Utilization Committee One hundred and eleventh (111) Meeting, December 12, 1972.

"5. Tar Sands Reclamation Research - The Honourable Mr. Yurko has requested the Conservation and Utilization Committee to establish an interdepartmental task force or project team with additional membership from the Faculty of Agriculture and Forestry and others, if necessary, to define our applied research proposal which the government could propose to Great Canadian Oil Sands and possibly Syncrude for their joint participation. Mr. Yurko has expressed the desire to have the proposal adequately defined by the end of January.

Although the Committee was of the opinion that in most cases the onus should be on the developer for his own reclamation research program, the Committee also recognizes that it may be helpful to the developer to define what the content of the research project should be. The Committee was cautioned that reclamation is highly situational due to climatic and materials variations. The Committee has agreed to set up a project team to determine what a tar sands reclamation research project should entail, with membership from the Departments of Agriculture, Lands and Forests, and Environment as well as from the Agricultural and Forestry Faculties of the University of Alberta, the Federal Forestry Research Laboratory in Edmonton, and the Research Council of Alberta. It was suggested that the project team specifically take into consideration the fact that the primary onus for the research should be placed on the industry."

RESEARCH RECOMMENDATIONS

The research topics recommended are listed under main subject area headings. Where field aspects of certain research projects, such as on establishing life in tailings ponds, cannot yet be undertaken, estimated dates of fieldwork start are given. Most topics, if not already begun, can and should be initiated in 1973. G.C.O.S. has work under way in several research areas, and has data available on others, in categories 1, 2, 3, and 5.

More emphasis is placed on field programs than on greenhouse studies, because of the nature of the problems involved. However, some topics can only be studied by laboratory methods for several years, until field sites become available.

1. <u>Characteristics of tailings deposits</u>
   - (a) Chemical properties
     - i) identification and amount of toxic elements and compounds in tailings, leachates and seepage
     - ii) pH, cation exchange capacity, exchangeable cations, soluble salts, sodium adsorption ratio.
   - (b) Physical properties
     - i) particle-size distribution, texture, water holding capacity, bulk density, available moisture (1/3 and 15 atmos. pressures), etc.
   - (c) Mineralogical properties - distribution of bitumen on various mineral grains.
   - (d) Microbiological properties - populations of microorganisms.

2. <u>Amelioration (improvement) of tailings</u>
   - (a) Field studies
     - i) addition of topsoil and till for seedbed preparation

ii) leaching experiments - lysimeters

iii) use of synthetic plastics, manure (microbiological stimulation), peat, chemical treatment; etc.

(b) Laboratory studies

i) laboratory (pilot plant) procedures simulating field work

ii) alteration in chemical and physical properties to meet environmental quality objectives.

3. <u>Revegetation</u>

(a) Field test plots[1]

i) suitable grass species

ii) tree and shrub plantings

iii) use of native species and habitat types

iv) seedbed preparation - smooth vs rough surface

v) fertilizer use - rates of application and type

vi) methods of seeding - hydro, broadcast

vii) irrigation potential.

(b) Growth chamber studies (to accelerate the program in winter).

(c) Determination of encroachment rates of native flora on reclaimed areas in relation to patterns of planting, vegetation and soil characteristics.

4. <u>Water quality and water bodies</u>

(a) possible effects of toxic water bodies on migratory birds

(b) possible effects of stream diversion upon fish populations

(c) thermal regime of lakes and streams as affected by discharge of tailings waters

(d) amelioration of tailings waters, seepage, or other surface and groundwater contamination (1978)

---

[1] see appendices for detail

(e) stimulation/colonization of aquatic life in tailings ponds (1978)

(f) use of bio-assays to identify problems such as tainting of fish by phenols, and both long-term and short-term toxicity effects of chemicals in effluents on fish and wildlife

(g) techniques for increasing potential of tailings ponds and other surface waters of the tar sands area for recreation, wildlife and fisheries production - nesting islands, etc. (1978).

5. Materials management

(a) Ideal size, arrangement and sequential development of tailings ponds from the reclamation viewpoint.

(b) Final configuration of land surface, with a topographic map of the post-mining area (landscaping surface).

(c) Tailings dyke design, with respect to:
  i) short- and long-term erodibility and failure potential
  ii) permeability
  iii) reclamation feasibility.

(d) Optimum scheduling of landscaping and revegetation, in relation to erodibility of materials and rates of strength increase of pond materials.

(e) Limitations respecting plant growth of
  i) non-commercial bituminous sands and clays (McMurray Formation)
  ii) non-bituminous overburden (Clearwater Formation)
  iii) bitumen-bearing and non-bituminous surficial (glacial) deposits.

(f) Limitations respecting plant growth of soil (i.e., A+B+C horizons - not the thick dark A horizon soils of the prairie regions).

(g) Organic peat and other vegetation debris, respecting:
  i) availability
  ii) storage feasibility and areas required

iii) fire hazard and internal degradation with time

iv) suitability for use as a soil mulch and mechanical stabilizer.

(h) Methods of recovering and stockpiling detritus and bottom sediments from water bodies to be drained for stockpiling and future use in reclamation programs.

(i) Methods of minimizing variation between topographic and vegetation patterns on adjacent areas mined by different companies and/or technological methods.

6. Natural ecosystems[1]

(a) Inventories of fish, waterfowl, ungulates, fur bearers and other wildlife than can be affected by these developments.

(b) Description of natural habitat components with a view to formation of productive wetlands during reclamation.

(c) Aquatic vegetative growth in lakes to define species useful for lake reclamation.

(d) Current utilization and dependence of wildlife species on specific vegetative types, as a guide to plants to be used in revegetation programs.

(e) Buffer strip requirements between water bodies and mining areas.

(f) Revegetation patterns and species mixtures desirable from a wildlife viewpoint - maximize edge effect, etc.

(g) Determination of critical wildlife areas such as spawning grounds which should be protected from physical disturbance during mining operations.

---

[1] Syncrude is believed to have undertaken some work in this category. The INTEG study includes regional wildlife and fish survey data.

(h) Biological monitoring of a pond, lake, stream and river system throughout the pre-development to post-reclamation period to serve as an indicator of aquatic environmental changes produced by tar sands mining.

(i) Impact of waste water from tailings ponds on bottom faunal populations of receiving streams.

GENERAL

In obtaining bitumen from the Athabasca Oil Sands, both Great Canadian Oil Sands Ltd. (G.C.O.S.) and Syncrude will use basically the same extraction method: surface mining of the oil sands, and separation of bitumen by a hot-water process. The basic steps in the operation are:

i) removal of the original vegetation,
ii) dewatering and removal of the overburden,
iii) mining of the bituminous sands,
iv) separation of bitumen from the sand, by hot-water methods,
v) disposal of sand and hot water, with minor clay bitumen and chemicals into tailings ponds,
vi) recycling of tailings pond water (proposed),
vii) reclamation of the mined areas.

The first six steps have implications concerning the seventh, and many of these implications have already been outlined by Pearson and Palmer (Page et al. 1972). It is clear that some comprehensive planning to include reclamation has been developed by G.C.O.S.; this reclamation planning relates mainly to tailings pond dykes; the major unknown or inadequately defined aspects are:

i) the type and quality of landscape left after mining, including land and water surfaces;
ii) the physical and chemical composition of the materials forming that landscape,
iii) the kinds of plant and animal life that could use these habitats,
iv) the timing and integration of reclamation requirements.

The following discussion is developed around these main topics, drawing freely on the Interim Report on the Athabasca Tar Sands (H.V. Page et al., for INTEG), and presumes that adequate baseline studies, detailing the present ecosystems, wildlife habitats, and hydrology will be completed before major reclamation is instituted.

CURRENT RESEARCH STATUS

Some basic geological and soils work has been carried out in the mining areas, sufficient to outline in broad terms the physical nature of the overburden materials, and the general nature of near-surface groundwater systems. Canada Land Inventory maps are being compiled, on a scale of 1:250,000, indicating capability for forests, recreation, fish, wildlife and waterfowl. Syncrude is understood to have made a biological inventory of its lease area. Regional wildlife and fish inventories have been carried out to supply baseline data for the INTEG study.

Partial physical and chemical data are available on the nature of G.C.O.S. and Syncrude process tailings.

Experimental revegetation work has been carried out on the Tar Island tailings pond dyke by G.C.O.S. in conjunction with the Alberta Department of Agriculture (Massey, 1973), after initial laboratory tests. Grasses, shrubs and tree seedlings were field-planted in 1970, 1971 and 1972. Additional test plots for 28 different plant species were established in 1971 by Environment Canada, also in the tailings dyke area. These trials indicate initial success of a number of plant species, and failure of some others. They also point out some problem areas, such as toxicity (e.g., bitumen, naphtha, alkalinity), erodibility, nutrient requirements, and moisture regime of the growth medium.

Note that these revegetation studies are still in their initial phases, and that several years of growth and observations are needed before definitive conclusions can be drawn.

G.C.O.S. has revegetation plans and time-schedules for its present tailings pond and adjacent waste dumps. These call for sequential plantings of vegetation on the dyke flanks as the dyke is built up each year; if the final elevation of the dyke is to be 1000 feet, then the pond will be filled and ready for seeding to grass in 1976; if the final elevation is 1100 feet, then seeding will not take place until 1980. Shrubs and trees would be planted two years later. Little, if any, of the current mining area will be ready for revegetating before at least 1980.

Alberta Department of Lands and Forests have some revegetation trial work scheduled for 1973.

G.C.O.S. has undertaken a substantial amount of research on the problem of removing suspended clay particles from the waste water, in order to improve quality of water for recycling, and so to reduce the volumes of clayey water to be stored in the tailings ponds.

WATER MANAGEMENT

The hot-water mining process requires, after removal of the bitumen, disposal of large volumes of tailings sand and water. Plans called for the slurry to be retained in ponds until the solids settle out and then for some water to be recycled. Recycling of about half of the process water was anticipated, but this has been found impracticable to date, because of the length of time required for the clay particles to settle, and because suspended clay is unacceptable in fresh process water. Any reduction in the physical magnitude of this disposal problem is desirable.

The reclamation implications are primarily that large areas of tailings ponds will be needed, for considerable periods of time, and that no revegetation can begin until these ponds have been drained and the tailings materials become sufficiently compacted to bear the weight of landscaping machinery. Obviously, if less total water should be required, less area would be needed for tailings ponds, and reclamation would be able to begin more quickly. As alternate methods are developed for recycling of water, careful consideration should be given not only to process implications, but also to any anticipated chemical or physical changes in tailings that may affect reclamation.

Solutions to these problems should be sought in the area of flocculation technology and the related engineering processes dealing with clarification, recycling, chemical treatment, and dewatering, thickening and washing of solids to remove toxic constituents.

CHEMICAL AND PHYSICAL PROPERTIES OF THE WASTE PRODUCTS

The waste solids and liquids from the hot-water extraction process constitute the basic materials on which plant and animal life is to be established. A thorough knowledge of the chemical and physical properties of these materials is, therefore, necessary for an understanding of why plants and animals may or may not live in such an environment.

According to Creighton (Page et al., 1972) the main constituents of the tailings slurry are: sand, silt and clay (65 - 70%), water (30 - 35%), and unrecovered bitumen (0.5 - 1.2%). Small but significant amounts of caustic soda, phenols and naphtha are also present. The attached incomplete chemical analysis indicates the high pH of the waste water.

The sands and silts settle fairly rapidly, and are used for dyke construction by G.C.O.S. The clays and bitumen remain in suspension for a longer time, but will ultimately settle to the bottom, as may be seen in the old (9 years) Cities Service tailings pond in the same area. The chemical constituents will remain in solution; with time the alkali may be converted to sodium bicarbonate. The water will both evaporate (at up to 16 inches per year) and seep through the dyke, as is taking place through the Tar Island dyke. As the tailings pond water levels drop, the surface materials likely will be clayey and bitumen-enriched, and may (as postulated by Mitchell, 1972) also be saline -- a distinctly different medium to the coarser-grained, more permeable sands of the tailings dykes.

The chemical composition of the tailings materials appears to be incompletely known; the physical characteristics of the finer-grained tailings are not well defined. Research should be directed towards identifying the toxic substances - residual bitumen, excess sodium, alteration products of the bitumen, phenols, etc. It should not be assumed, however, that the tailings solids will be homogeneous (chemically and physically) throughout the lease areas and research should be carried out on tailings samples from a fairly large number of sites (if available) in the area. Such studies

Analysis of Tailings Pond Wastes
Great Canadian Oil Sands (mg/l)

	1968-69	1971-72
pH	8.4	9.3
TON	10,000	100,000 CH
BOD	145	
COD	3,557	560
ALK. P.P.	0	90
ALK. Total	315	460
Total Suspended	11,494	3,600
Total Ignition Loss	1,882	800
Non Filterable Residue	10,360	1,700
Non Filterable Ignition Loss	1,690	500
Oil and Grease	104	240
Phenols	150 ppb	970 ppb
Arsenic	0	
Chlorides		33
Nitrates		0.3
Sulphates		665
Iron		10.0

From Department of the Environment records

Trace Metals in G.C.O.S. Effluent
November 24/71
Analysis in mg/l

Arsenic	0.015	Manganese	0.050
Cadmium	0.002	Mercury	
Chromium	0.008	Nickel	0.037
Cobalt	0.004	Selenium	0.010
Copper	0.003	Tin	
Lead	0.124	Zinc	0.039

From Department of the Environment records would serve not only to identify the toxic substances but also to establish quantitatively the range in amount of the compounds that may be expected to occur in the tailings material. Neither the drainage and salinity characteristics of the tailings material nor the configuration of the final surfaces have been outlined.

If soluble salts ultimately are flushed from the tailings then, in some unknown time context, salinity problems may not be relevant. However, if final landscape plans include construction of undulating topography, it is likely that both saline and non-saline areas will be developed. The chemical properties of leachates from reclaimed areas must be known, with emphasis on minor elements and heavy metals.

MATERIALS MANAGEMENT

Materials management includes the removal, storage and/or processing, and disposal of all materials moved during the mining process. To obtain the best reclamation, the mining operations should have a materials management plan, including planning for and ultimate disposition of surface organic materials, soil, overburden, waste and tailings materials, as well as for surface water in and adjacent to the mining areas.

G.C.O.S. has plans for revegetation of its present tailings pond and adjacent waste dumps. It appears that the mining method is the primary overriding consideration in the landscape design. Discussion should therefore be held with G.C.O.S. and with any future operator, to determine the adequacy of this planning. To facilitate reclamation planning, knowledge is needed of the proposed and the desirable configuration of the landscape following mining, and of the suitability or limitations, respecting plant growth, of all of the overburden and waste materials. Such information would allow development of an optimum materials management plan, so that toxic materials could be buried, and the most suitable "soil" materials left of the surface.

Methods of storing the topsoil and organic peat material for later use in seedbed preparation require study. Analyses of the material should be carried out to ensure that it does not contain toxic material that could prove detrimental to plant growth. In other words, "quality control" should be applied to those soil materials that will eventually be used in seedbed preparation.

Suitable overburden (till) should also be stored for later use. However, it has been indicated that some of the overburden can contain sufficient toxic material to be detrimental to plant growth. The precise nature of the toxic compounds (apparently bitumen) and the toxicity levels in the till should therefore be established, by field and growth chamber testing, in order that undesirable material can be rejected and buried. Reject tar sand material should be similarly evaluated, and if necessary, handled in such a manner to ensure that it is not left at the surface where it could inhibit revegetation.

Major study will likely be needed of tailings materials, since it is on these that vegetation will have to be established. The tailings are predominantly sandy materials, which are susceptible to wind erosion, and which when used to build dykes, show demonstrable water seepage on the lower slopes. This seepage is significant enough both to cause erosion and slumping along the dyke toes, and to inhibit growth of certain plants. The higher, more exposed parts, are droughty.

The surface stability of the tailings materials should be studied, in terms of susceptibility to wind and water erosion. G.C.O.S. has a continuing program on the engineering aspects of obtaining stability of their tailings dykes; the Government should, however, determine to its own satisfaction the adequacy of this program, as this will indicate the suitability or otherwise of these materials for use to form stream banks of reconstructed surface drainageways after mining in other lease areas.

SOIL RECLAMATION AND REVEGETATION

If the premise is accepted that the tailings materials contain some toxic compounds that may inhibit or prevent plant growth, then a high priority should be given to operational "tailings research."

At an early stage operational research should be initiated to provide an "antidote" or a means of ameliorating any apparent toxicity or deficiencies in the surfaces to be revegetated. This could follow a procedure of on-site and laboratory studies involving water leaching, chemical treatment, fertilizers, stimulation of microbiological activity by introduction of animal manures, and/or addition of till and peat. Addition of elemental sulphur as an amendment to lower pH values could be considered.

Revegetation of the G.C.O.S. tailings pond dyke has been initiated and this work should form the basis for further research. Since this work is of comparatively recent origin it should be closely followed with periodic observations by the investigators or those involved in the reclamation program.

Revegetation field trials should be expanded to include vegetation research (grasses, shrubs, trees) on the tailings deposits, tailings to which soil and peat have been added, tailings treated with, for example, synthetic plastic compounds, ammonified coal additives, etc.

The rates of application and types of fertilizers (nutrient levels) required and the use of irrigation should be investigated.

Other areas of revegetation research requiring attention include - seedbed preparation (smooth vs rough surface), vegetative succession, use of native species (re-establishment of various habitats), characteristics of peat material (muskeg), methods of seeding (hydroseeding, broadcast) and the establishment or preservation of shelter belts within each lease area.

Appendix A outlines as information plot design, seed mixtures, surface treatments and plant species of the Environment Canada 1971 plots on the G.C.O.S. tailings pond dyke. Appendix B offers suggestions for grass, shrub and tree planting in the reclamation areas.

WATER BODIES AND WILDLIFE BIOLOGY

The tailings ponds of the mining areas contain waters with chemicals and bitumen. Since the mining areas are located on a migratory bird flyway, research is required into the possible affect of poor water quality on aquatic birds. If existing lakes are used as tailings ponds, or if they are drained to mine underlying tar sands, their waterfowl value will be greatly decreased or lost (Schick and Ambrock, 1972).

Where existing lakes in the area are to be used for disposal of tailings waters, which are discharged from the processing plants at a temperature of 130°F, the thermal regime of such lakes and streams will be altered. The effects on fish populations, accumulation of weeds and water quality should be investigated. Again, the first requirement is an inventory of the biological communities in the immediate area of the development, and at downstream locations that could be effected.

The reclaimed mining areas likely will include some man-made lakes, and reconstituted streams may be expected to flow through parts of the area. Artificial lakes initially may be expected to contain sterile water, possibly with some toxic chemical components. Investigation is needed into methods of promoting life in this water and improving its quality. For example, addition of nitrogen and potassium may stimulate microbiological activity (based on animal manures), to utilize the 0.5 to 0.75 per cent of bitumen in the tailings. Microbiological activity may also aid emulsification of the clay particles. Both processes would aid development of a suitable medium for aquatic life; the nutrients added would also be available to stimulate plant growth.

Colonization of new water bodies by animal life is in part effected by organisms carried on the feet or in the digestive tracts of migratory waterfowl. Thus the development of water bodies that will be used by waterfowl is an important initial step in the regeneration of aquatic communities. If wetlands attractive to waterfowl are produced, one can expect heavy utilization by waterfowl in this area. These wetlands could be managed for hunting and observation of waterfowl as an important recreational opportunity. On the other hand, if these proved to contain toxic minor elements in water and vegetation, they could be responsible for the death or contamination of thousands of migrating birds annually.

Where reconstituted streams are expected to flow through the reclaimed land, evaluation is necessary of the nature of the stream banks and beds, particularly concerning their erodibility and sediment loads. Also, the nature of seepages from the banks into the streams, and the anticipated duration, should be considered. Long-term alkaline or toxic "groundwater" discharges into such streams will inhibit recolonization by aquatic life.

RESEARCH COORDINATION

The universities, and provincial and federal agencies all have competence and expressed interest in tar sands reclamation research work. As more studies are initiated, the problem of duplication of effort and expense will become more significant. Coordination of work on these complex problems is necessary.

It is suggested that a primary coordinator of reclamation research in the Bituminous Sands area be designated. A similar recommendation is presented in the INTEG report prepared by Intercontinental Engineering of Alberta Ltd.

Coordination of any federal involvement on environmental matters should take place through the Prairie and Northern Regional Directors' Board of DOE, Canada.

REFERENCES CITED

Massey, D. L. (1973): Tailings sand to trees; a report on tailings sand re-vegetation at Fort McMurray, Alberta; Agricultural Soil and Feed Testing Laboratory, Alberta Department of Agriculture, 8 pages.

Mitchell, D. L. (1972): Revegetation of tailings-disposal areas; internal report, Product Research and Development Division, Research Council of Alberta, 9 pages.

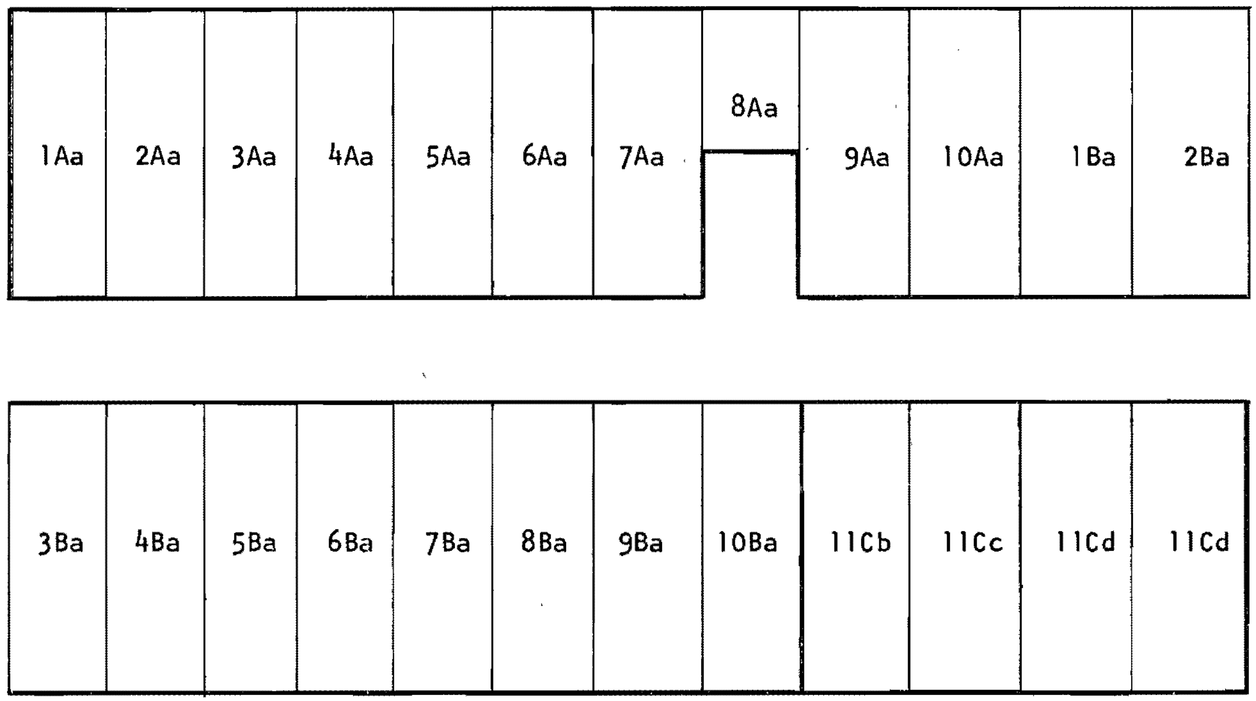
Page, H. V. and others (1972): Interim report on environmental constraints and research priorities for mining/hot water extraction technology; prepared for Alberta Department of the Environment by Intercontinental Engineering of Alberta Limited, 335 pages.

Schick, C. D. and K. R. Ambrock (1972): Waterfowl evaluation of the Athabasca Tar Sands area; Canadian Wildlife Service, Edmonton.

Appendix A.

Summary of plot design, seed mixtures, surface treatments and plant species:
Environmental Canada experimental plots (1971)
on the G.C.O.S. tailings pond dyke.

H. M. Etter
Environment Canada



G.C.O.S. Mine Experimental Area

1 - 11 are seed mixes
A, B, & C are surface treatments
a - d are slurry mixtures
Scale: 1" = 40'

DOE, Canada; H.M. Etter

Seed Mixtures for G.C.O.S. Mine Experiment, September, 1971

Mix 1 Agropyron cristatum Amelanchier alnifolia Aster conspicuus	Mix 2 Agropyron latiglume Prunus virginiana Lonicera tatarica	Mix 3 Agropyron riparium Poa pratensis Rosa woodsii	Mix 4 Pinus contorta var. latifolia Agropyron trichophorum Caragana arborescens
Mix 5 Agrostis alba Medicago sativa	Mix 6 Bromus inermis Melilotus alba	Mix 7 Dactylis glomerata Vicia americana Cornus stolonifera	Mix 8 Picea engelmannii Elymus junceus Elaeagnus commutata
Mix 9 Festuca rubra Phleum pratense Epilobium angustifolium	Mix 10 Koleria cristata Phacelia sericea Lunaria dalmatica	Mix 11 Picea glauca Agropyron cristatum Phleum pratense Caragana arborescens Epilobium angustifolium Lunaria dalmatica	Pinus contorta var. latifolia Bromus inermis Rosa woodsii Medicago sativa Phacelia sericea

Surface Treatments for G.C.O.S. Mine Experiment

Surface Treatment A

Contour trenches about 3" high and 6" between ridges.

Surface Treatment B

Packing in seed with a crawler tractor after hydroseeding and before hydromulching.

Surface Treatment C

No treatment after grading.

Hydroseeding Slurry Mixes for G.C.O.S. Mine Experiment

Ingredients	Slurry a	Slurry b	Slurry c	Slurry d
Water (liters/sq. meter)[a]	3.5	3.5	3.5	3.5
Wood Fiber Mulch (grams/sq. meter)[b]	206 to 245	206 to 245	206 to 245	-
Fertilizer (grams/sq. meter)[b]				
10-30-10	32.5	32.5	32.5	-
Organic	32.5	32.5	32.5	-
46-0-0	15.0	15.0	15.0	-
Adhesive, Curasol AH (liters/sq. meter)[a]	0.06	0.06	-	-

a. gal./acre = liters/sq. meter mult. by 890.21

b. lbs./acre = grams/sq. meter mult. by 8.92

Seeding rates and potential germinants per sq. meter of species seeded at Cardinal River and G.C.O.S. Mine

Botanical name	Seeding rates (grams/ 110 sq. meters)[a]	Seeds per gram[b]	Seeds per sq. meter	Percentage germination	Max. potential germinants/ sq. meter
Picea engelmanii	11.9	503	55	75	41
Picea glauca	11.9	503	55	57	31
Pinus contorta var. latifolia	19.9	302	55	87	48
Agropyron cristatum	155.5***	386	545	83	452
Agropyron latiglume	177.9	337	545	24	131
Agropyron riparium	195.4	307	545	94	512
Agropyron trichophorum	419.0	143	545	96	523
Agrostis alba	5.4	11,009	545	76	414
Bromus inermis	200.1***	300	545	96	523
Dactylis glomerata	78.5	734	545	90	491
Elymus junceus	155.5	386	545	94	512
Festuca rubra	44.2	1,356	545	89	485
Koleria cristata	13.9	4,323	545	31	169
Phleum pratense	22.1	2,711	545	97	529
Poa pratensis	12.5	4,800	545	53	289
Amelanchier alnifolia	19.9	301	55		
Prunus virginiana	485.5	12	55		
Rosa woodsii	666.7	9	55		
Caragana arborescens	156.5	38	55	63	35
Medicago sativa	27.2***	441	109	86	94
Melilotus alba	20.9	573	109	96	105
Lupinus sp. (Russel lupine)*	100.0	35	32	39	12
Vicia americana	151.2	79	109	18	20
Elaeagnus commutata	644.5	9	55	43	24
Epilobium angustifolium	0.07	171,428	109	57	62
Cornus stolonifera	360.0	17	55		
Phacelia sericea	3.8	3,141	109	32	35
Lunaria dalmatica	2.1	5,581	109	18	20
Lonicera tatarica	121.3	49	109	81	88
Aster alpinus*	15.5	528	74	25	19
Aster conspicuus**	22.9	528	109	12	13

* seeded only at Cardinal River Mine.

** seeded only at G.C.O.S. Mine.

*** Seeding rates reduced by one-half for mix 11.

Appendix B.

Suggested grass, shrub and tree species to be used in reclamation studies in the Fort McMurray area.

J. Selner
Alberta Forest Service

The following tree and shrub species should be tested on the Athabasca Tar Sands:

Balsam poplar - Populus balsamifera L.
Trembling aspen - Populus tremuloides Michx.
Local native willows - Salix sp.
Mountain alder - Alnus tenuifolia Nutt.
White birch - Betula papyrifera Marsh.
Western white birch - Betula papyrifera Marsh. var. commutata (Regel) Fern.
Water birch - Betula occidentalis Hook.
White spruce - Picea glauca (Moench) Voss.
Jack pine - Pinus banksiana Lamb.
Balsam fir - Abies balsamea (L.) Mill.
Pin cherry - Prunus pensylvanica L.f.
Choke cherry - Prunus virginiana L.

Locally obtained seeds and cuttings are preferable. Container planting and bare-root seedlings should both be used.

The following grass and legume species should be tested.

Nordan crested wheat grass
Intermediate wheat grass
Pubescent wheat grass
Tall wheat grass
Sport timothy
Timothy evergreen
Ithasca timothy
Toro timothy
S-5-D timothy
Tardus 11. Orchard grass
Chinook orchard grass
Barenza perennial grass
Canada bluegrass compressa
Nugget Kentucky bluegrass
Tall fescue

Reptans creeping red fescue
Rough fescue
Erica creeping red fescue
Sheep fescue (Festuca ovina var. duriusculla)
Arctared creeping red fescue
Magna brome
Baylor brome
Polar brome
Rise reed canary grass
Russian wild rye
Tall oatgrass
Krasnodar sanfoin
Cicer milkvetch
Roamer alfalfa
Rambler alfalfa
Sweet clover white
Sweet clover yellow
Alsike clover
White clover
Birdsfoot trefoil
Sanfoin
Lupin (Lupinus sp.)