Proceedings of the 15th Annual British Columbia Mine Reclamation Symposium in Kamloops, BC, 1991.
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LAKE CREATION AND DEVELOPMENT AT AN ALBERTA FOOTHILLS COAL MINE

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Abstact

The creation of lakes for fisheries habitat and recreational opportunities can be a cost-effective method of reclaiming coal mine pits. In the Alberta foothills environment, the sustainable viability of such lakes is a key consideration in determining how appropriate this technique is.

In the past six years, two sets of lakes have been created in the final cuts of dragline pits at the Coal Valley Mine, in the Alberta foothills. These two lakes have been designed and constructed to meet recreational and fisheries habitat land uses. Data collected from these lakes since their creation, indicate that water quality characteristics are suitable for development of both end land uses. Results of recent biotic surveys indicate that benthic and aquatic macrophyte communities are establishing, and that a limited fish stocking program could now be supported.

This paper discusses the physical and biological characteristics of these two lakes in terms of their long-term viability and fulfillment of land use objectives.

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Création et développement de lacs dans une mine de charbon des contreforts albertains

par

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La réhabilitation des carrières de mine de charbon en lacs peut représenter une méthode efficace au niveau des coûts pour le développement des habitats de pêcheries ainsi que des secteurs à usage récréatif. Dans l'environnement des contreforts albertains, la viabilité soutenable de tels lacs constitue une considération importante pour déterminer la justesse de telle orientation d'aménagement.

Durant les cinq dernières années, deux ensembles de lacs ont été créés dans les coupes finales de la mine à ciel ouvert de Coal Valley, située au sud de Edson, dans les contreforts albertains. Ces deux lacs ont été conçus et construits pour répondre aux exigences d'une utilisation orientée vers les activités de pêche et de loisirs. Les données recueillies sur ces lacs, depuis leur création, montrent que les caractéristiques de qualité de l'eau sont adéquates pour le développement de ces deux types d'utilisation. Les résultats d'études limnologiques récentes montrent que les populations macrophytiques et benthigues s'installent bien et qu'un programme de peuplement limité de poissons pourrait maintenant être viable.

Cette communication discute des caractéristiques physiques et biologiques de ces deux lacs dans le contexte de leur viabilité à long terme et de la réalisation des objectifs initiaux d'utilisation.

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LAKE CREATION AND DEVELOPMENT AT AN ALBERTA FOOTHILLS COAL MINE

INTRODUCTION

Surface coal raining operations create final pit cuts which can be reclaimed to lakes or wetlands in the post-raining landscape. Depending on the type of mining/backfilling sequences used, and the degree and method of reclamation employed, such lakes have the potential for several important land uses, including fisheries and wildlife habitat, watershed protection, boating, resort development, and water supply.

Mining companies often favor lake development in the final cuts of their mine developments. Assuming the lake will achieve end land use objectives, it can be a more cost-effective reclamation method than the alternative of backfilling and upland reclamation. The land uses available through lake development also tend to be preferred by the public, thereby providing public relations benefits to the company.

At the Coal Valley Mine, two such lakes have been created in the past 6 years. These are the first mine-cut lakes designed and constructed specifically for fisheries/recreational land uses in the foothills. Limnological monitoring programs have been instituted since these two lakes were built, and it is now appropriate to make a preliminary assessment in terms of achievement of land use objectives and longterm sustainabi1ity.

This report provides a review of the history, design, and construction of these two lakes, and a summary of the past 5 years of limnological data collected. An assessment is made of the longterm fisheries viability of these lakes based on this data, as well as the potential for future lake developments at the Mine.

BACKGROUND

Mine Setting

The Coal Valley Mine, operated by Luscar Stereo (1977) Ltd., is located 80 km southwest of Edson, Alberta. Mining operations commenced in 1978, and current annual production is 1.8 million clean tonnes of thermal coal.

Coal Valley is a surface mining operation, employing open-pit (truck/shovel) and strip (dragline) methods to extract the coal resource. At present, three separate coal seams are being mined in four active mining areas. The coal is processed in a heavy media plant prior to being shipped to Great Lakes and West Coast terminals.

Previous mining activities had occurred throughout the Lovett/Coal Valley area in the period from 1915 to 1955. Several surface and underground mines were operated during this period.

Environmental Setting

The Mine is located in the Rocky Mountain Foothills Region, Central Foothills Section (Pettapiece, 1986). The landscape is characterized by sub-parallel ridges which have local relief of 2Q 30 m. Elevations range from 1,320 to 1,460 m above sea level. The main drainage system is the Lovett River, which joins the Pembina River below the minesite.

Climate in the area is characterized by long, cold winters and mild summers. Climate can be extremely variable over short distances, given the elevation, high local relief, and wind conditions (including 'Chinooks'). The area falls within Class 5H agroclimatic area (very severe heat limitations), and climatic moisture index is positive (A.S.A.C., 1987). The area recieves an average of 630 mm of precipitation annually, of which 30% falls as snow.

Vegetation of the Coal Valley area is dominantly Upper Foothills Boreal Forest (Rowe, 1972). Stands consist primarily of fire-origin lodgepole pine *(Pinus contacta* var. *latifolia),* with smaller components of aspen *(Populus tremuloides)*, black spruce *(Picea mariana)*, white spruce *(P. glauca)*, and subalpine fir *(Abies lasiocarpa).* Wetlands (fens) have developed in the more poorly drained valleys and depressions.

Reclamation Objectives

The primary reclamation objective is to return the land disturbed during mining to a productive forest environment. Within this context, prescribed land uses include timber production, wildlife habitat, watershed management, and recreation. Lake development is a key component in achieving; the recreation, watershed, and wildlife habitat objectives.

Reclamation operations conducted to achieve these land use objectives involve backfilling, resloping, soil replacement, surface preparation, and revegetation. Resloping is accomplished using large tracked dozers, and slopes are returned to angles of between 4:1 and 2:1 in the post-reclamation landscape.

Soil is handled using scrapers, and is replaced at a minimum thickness of 30 cm on upland areas. Revegetation operations involve establishment of a grass-legume cover, fertilization, and subsequent planting of tree seedlings (lodgepole pine and white spruce). Lower densities of aspen, green alder *(Alnus crispa),* dwarf birch *(Betula glandulifera),* and willow *(Salixspp.)* are also planted.

Lake Planning

During initial mine planning stages, it was recognized that lake development could be a viable reclamation alternative at Coal Valley. However, at the time, mine-cut lake development in the Alberta foothills was still only a concept, so in 1981, the Mine retained a consultant to conduct a literature review and field study. The objective of the study was to develop procedures which could be used during mine-cut lake planning and reclamation to provide maximum potential for fisheries habitat (Hildebrand, et. al., 1982). In developing these procedures, the consultants collected data from surveys of natural lakes in the area, as well as from mine lakes created from pre-1950's operations (ie. prior to current reclamation standards).

It was recognized that there were physical limitations to the implementation of these procedures, and that even natural lakes in the area did not meet these optimum conditions» Therefore they were used as guidelines to aid planners in developing their operations. A brief summary of these guidelines is shown in Table 1. Both lakes were designed and reclaimed to these guidelines, where possible.

Table 1. Mine-Cut Lake Characteristics Which Tend To Create Optimum Fisheries Habitat In The Foothills

- Maximum lake depth - should be less than 15 m (areas of greater depth do not mix as well).
- Average depth - should be 2.6 - 3m.
- Lake surface area deeper than 12 m - should be less than 20% of total area.
- Littoral zone area (area less than 3 m deep) - should cover 40-60% of lake area.
- Deepest part of lake - should be at least 8 m (to allow over-wintering of fish).
- Water level fluctuations - fluctuations of up to 1 m are beneficial.
- Length of shoreline left as highwall - should be less than 25%, to maintain adequate littoral areas.
- Shoreline and lake bottom configuration - should be as irregular as possible, to minimize wave action, increase diversity, and improve microsite diversity.
- Exposure to winds - adequate exposure wi11 enhance deep mixing of water.
- Watershed - area draining; to lake should be stable.
- Inflow volumes - should equal twice the lake capacity.
- pH - water should be between 7.5 and 8.5.
- Turbidity - water should be at least moderately clear.

A key factor in determining how closely these guidelines could be followed is final lake elevation. A lot of reclamation work could be wasted if the waterline does not develop as planned. In the Coal Valley area, the pre-disturbance groundwater table generally lies within 15 m of surface, with strong aquifers located immediately on top of the coal seams. Reclamation plans were therefore based on the assumption that the lakes would fill to within 3 m of the pre-mine groundwater table (if topographic conditions permitted). This assumption has proven to be a safe one in Coal Valley's circumstances.

Lake History

Lovett Lake

Mining in the Mynheer B Zone began in 1981. The Page 752 dragline completed mining Pit 42 of this Zone in October of 1984, and lake development commenced as the dragline was leaving. While the pit was active, groundwater flows into the mine required continuous pumping to maintain operations, and when the dragline left and mine dewateririg finished, the water level began to rise quickly. Resloping operations had to be completed before the rising water level interfered, and some additional dewatering was required during reclamation to allow resloping to continue without interference.

Levelling operations were completed by January of 1985, and topsoil replacement in the area was completed in July. The water level reached its design level by August. An outflow channel has not been needed, because underground seepage out of the lake has been able to maintain the lake level.

Silkstone Lake

Mining in Pit 31E of the Silkstone Zone began in 1984 with the dragline. By August of 1985, coaling operations were complete, and as was the case in Lovett Lake, the pit immediately began filling with water. Resloping operations had progressed closely behind the dragline, and by December of 1985, the area surrounding proposed Silkstone Lake had been completed. Topsoil replacement was finished in most of the area by July of 1986, and an outflow channel to the Lovett River was completed in September. Within two weeks of this, the lake had reached its design elevation.

LAKE CHARACTERISTICS

Physical Characteristics

Table 2 summarizes physical and hydrological characteristics of the two existing lakes. These conditions have been stable since final lake elevations were achieved. Bathymétrie maps of the lakes are shown in Figure 1, and an aerial view of both lakes is provided in Plate 1 .

Water Quality Characteristics

Water quality monitoring in both lakes has been conducted once or twice yearly since the lakes reached final water line. Sampling sites, as shown in Figure 1, were chosen to provide information from the deepest part of each lake (ie. to provide the 'worst case' for those parameters measured).

Sampling/measurements were made in late summer and/or late winter, to coincide with those times of the season which would likely be most restrictive to fisheries. A natural lake in the area (Fairfax Lake) was also sampled in winter of 1991, to allow for further 'background' comparisons. Some of the physical characteristics of this lake are quite different from those of the two mine lakes, but some general comparisons can still be made.

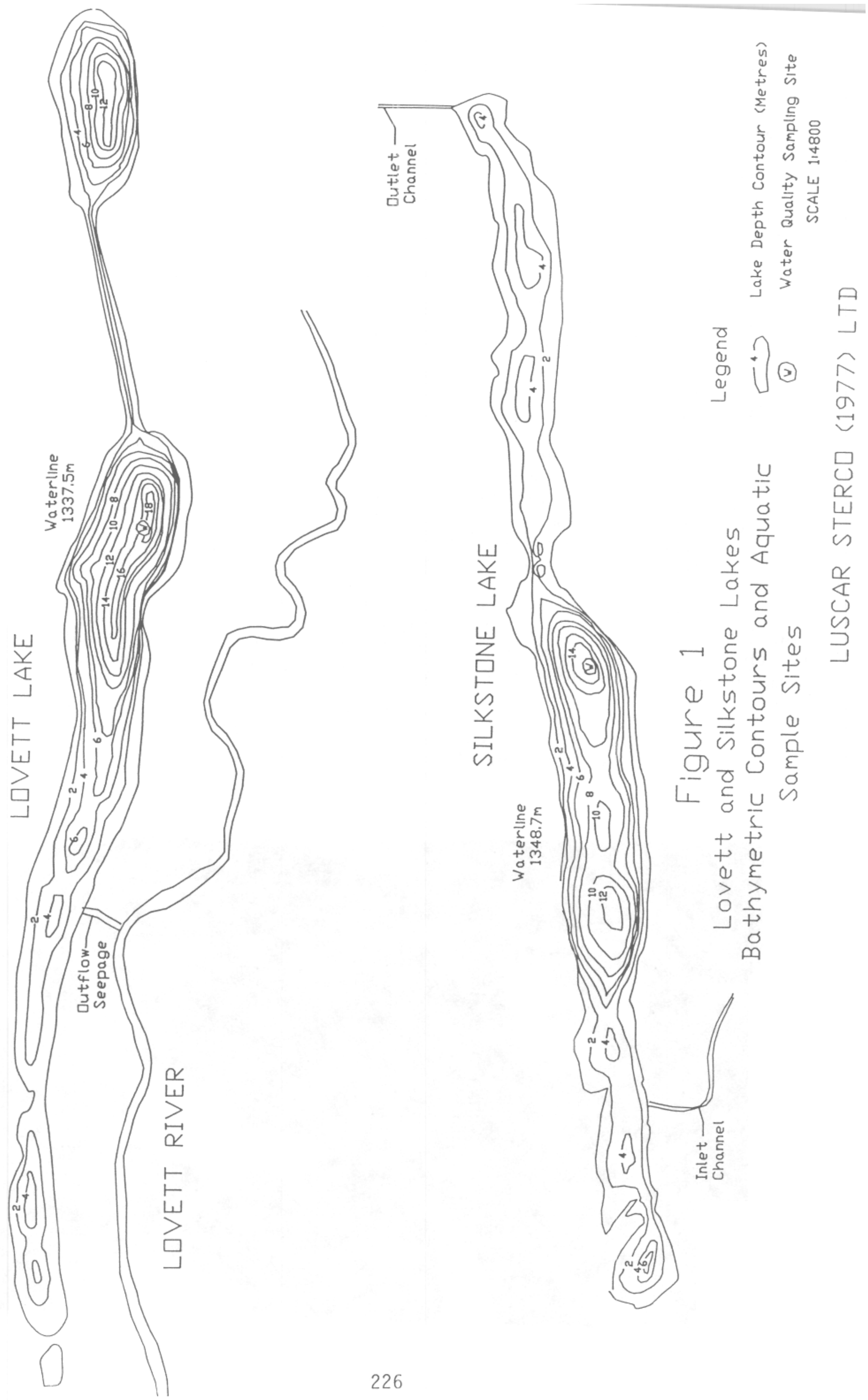

Figure 1
Lovett and Silkstone Lakes
Bathymetric Contours and Aquatic
Sample Sites

Table 2. Physical Characteristics of Lovett and Silkstone Lakes

Parameter	Lovett Lake	Silkstone Lake	Fairfax Lake
Lake surface area (ha)	6.0	6.4	28.4
Watershed area (ha)	161.6	146.2	153.7
Defined outflow channel	no	yes	yes
Maximum lake depth (m)	18.0	14.8	7.6
Average depth (m)	5.5	4.7	3.2
Lake surface area deeper than 12 m (%)	19	22	0
Littoral zone area (%)	32	37	63
Water level fluctuations (m)	1	0.3	0.3
Length of highwall only partly sloped (%)	8	16	0
Lake volume (x1000 cu. m.)	330.0	300.8	908.8
Annual inflow volume (compared to lake capacity)	1.2	1.3	no data
Max. inflow volume (CMS)*	1.5	1.4	no data
Max. outflow volume (CMS)*	0.03	0.94	no data

* Given 1:10 year 24-hour storm event of 86 mm.

Samples were collected from just, above lake bottom, and those requiring laboratory analysis were immediately preserved and sent Lo the lab. At each site, depth profiles of dissolved oxygen, temperature, and some other parameters were also developed.

Plate 1. Aerial view of Silkstone Lake (upper left) and Love 1.1 Lake (lower right), taken in 1989. The Lovett River valley lies between these two lakes.

A summary of data from the lake bottom sampling programs is shown in Table 3. Profiles of representative temperature and dissolved oxygen data are graphically summarized in Figures 2 & 3. Some trends are evident from these summaries.

Table 3. Summary of Lake Bottom Water Quality Characteristics - Average (and Range) of Summer and Winter Data, 1986-91

Parameter (ppm)	Lovett Lake	Silkstone Lake	Fairfax Lake
Aluminum	0.838(.063-1.7)	0.205(.018-.506)	0.022
Arsenic	0.0052(.0007-.0099)	0.0025(.0005-.0084)	0.0006
Barium	0.269(.267-.27)	0.091(.0006-.181)	0.063
Boron	0.118(.082-.133)	0.078(.073-.088)	no data
Iron	0.99(.228-1.96)	0.719(.088-1.54)	no data
Manganese	0.2160(.011-.701)	0.088(.011-.245)	0.845
Molybdenum	0.008	0.006	<0.004
Zinc	0.1694(.008-.591)	0.008(.005-.014)	0.01
pH	8.2(7.4-8.6)	8.1(7.3-8.6)	7.6(7.4-7.7)
Total phos.	0.19(.08-.37)	0.07(.02-.08)	0.08
Ortho phos.	0.04	0.03	0.05
Tot. organic carbon	3.4	2.8	6.9
TDS	580(464-673)	616(400-1047)	198
Conductivity (uMHO/cm)	604(352-845)	704(539-820)	145
Clarity	high	high	no data
NH4-nitrogen	0.59(.06-1.86)	0.13(<.05-.3)	0.21
NO3-nitrogen	4.80(.55-16.6)	7.00(2.43-10.5)	no data
Total K. nitrogen	<0.01	<0.01	0.2
Sodium	143(116-214)	161(125-198)	9.2
Potassium	2.0(1.6-2.7)	4.5	1.0
Calcium	21.6(11.2-23.6)	42.4(30.8-65.1)	25.0
Magnesium	5.1(2.5-8.6)	14.4(7.2-24.5)	9.3
Sulphate	71.6(38-107)	294.5	28.8
Chloride	2.5(1.8-4.3)	1.6(1.4-1.8)	1.2
Bicarbonate	397(261-549)	381(334-478)	123.2
Hardness	78.9(38.3-164)	128(80.5-263.5)	100.7

For the following parameters, values were close to or below detectable limits at the time samples were taken: total kjeldahl nitrogen, beryllium, cadmium, chromium, cobalt, copper, lead, molybdenum, selenium, and vanadium.

Temperature data indicate that both mine lakes undergo thermal stratification in summer and to a lesser extent in winter. Summer-time water temperatures range from 11-18° C. at surface, and 7-14.5 C. at the bottom. The thermocline in these basins occurs at a depth of 5-7 m. Winter water temperatures are 1-3° C. at surface and 2-4.5°C. at bottom.

In summer, dissolved oxygen levels in the two mine lakes were at 5-14 ppm above the thermocline, and 1.5-6 ppm below. Reduced oxygen levels below the thermocline indicate that the waterbodies

SUMMER OXYGEN AND TEMPERATURE PROFILES
LOVETT AND SILKSTONE LAKES

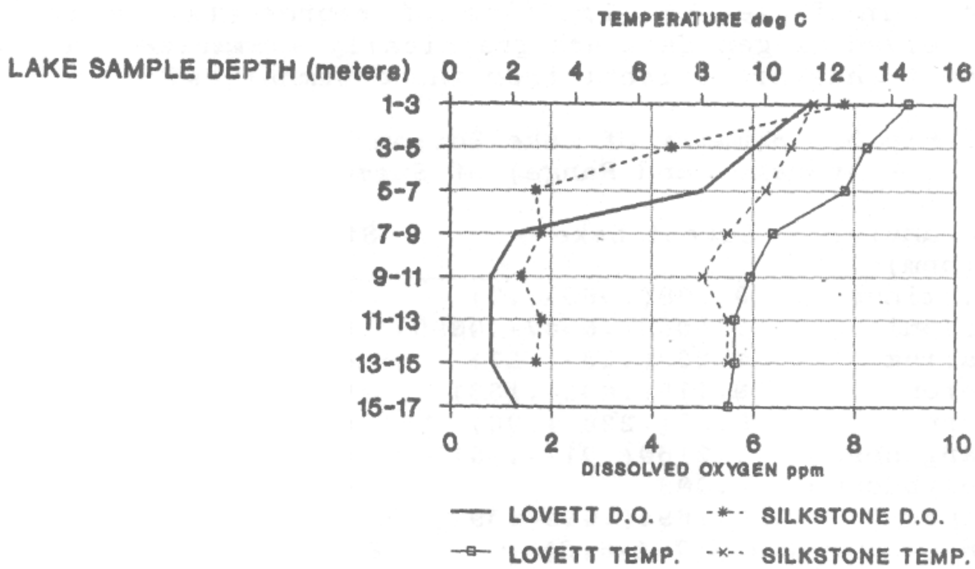

FIGURE 2

WINTER OXYGEN AND TEMPERATURE PROFILES
LOVETT, SILKSTONE, AND FAIRFAX LAKES

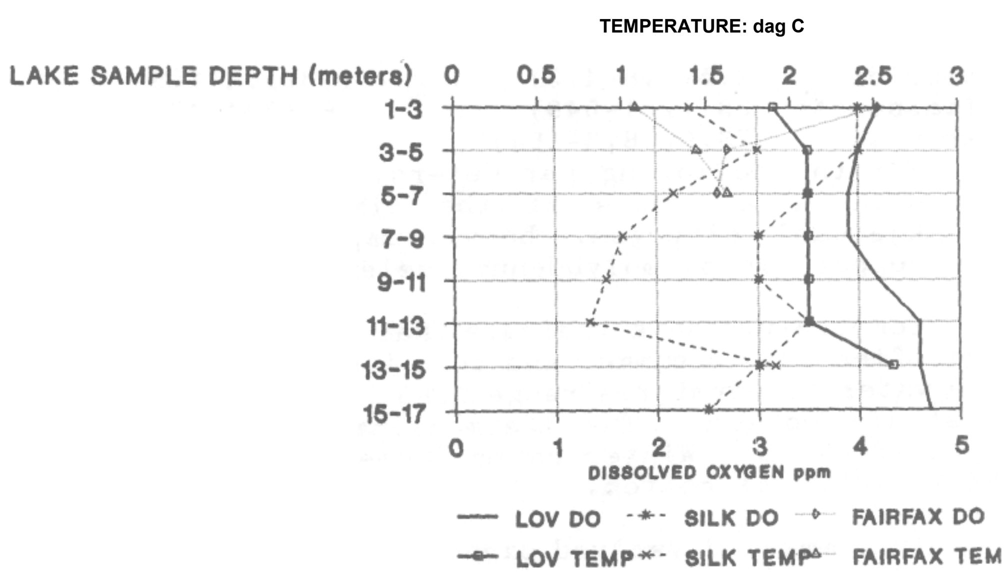

FIGURE 3

may be meromictic (ie. not undergoing defined spring turn-over). A similar situation appears to occur in other natural lakes in the area (R.L.&L., 1989), although no data are available from Fairfax Lake. In winter, dissolved oxygen in the mine lakes ranges from 3.5-7.4 ppm at surface, to 1-3 ppm at bottom. The one set of winter measurements at Fairfax Lake were similar.

Most of the other parameters measured are similar between the two mine lakes. Values of several parameters are higher than would be expected in natural lakes in the area, but direct comparisons can not be made with data from other lakes because the mine lake samples were collected from lake bottom. Other lake sampling programs generally concentrate on the epilimnion (ie. shallower areas), where most fish activities occur.

No consistant trends are evident in terms of changes over time. However, limited surface sampling indicates that the higher concentrations of nutrients, conductivity, dissolved solids, and metals are found at lake bottom. This is consistant with findings reported by Hildebrandt, et. al., 1982.

Results of the limited winter sampling exercise in Fairfax Lake are difficult to compare with the mine lake data, because Fairfax was only sampled once. Most values fall within the range determined for ten mine lakes, with the exceptions of total dissolved solids, sodium, sulphates, and bicarbonates.

Aquatic Biota

Biotic characteristics of the two mine lakes were investigated in July of 1989. Investigations included benthic invertebrates (5 samples per lake), zooplankton, phytoplankton (chlorophyll 'a'), and observations of aquatic macrophyte development. Comparison with Fairfax Lake could not be made, because of the absence of data. A summary of results is provided in Table 4.

While this project was not intensive enough to provide a full description of these characteristics, some general conclusions can be drawn (as extrapolated from R.L.&L., 1989). First, both lakes exhibit poorly developed benthic invertebrate and aquatic macrophytic communities, compared to natural waterbodies in the area (such as Mary Gregg Lake). This finding is representative of recent Iy formed waterbodies. Second, phytoplanktort chlorophyl1 'a' values were about half of those for natural lakes in the area, due in part to differences in sampling time (the mine lakes were sampled earlier in the growing season).

It was also noted that much of the littoral area in these two lakes was deficient in organic substrate content. Natural lakes in the area tend to be characterized by ooze and detritus bottoms, whereas the mine lakes were characterized by soft inorganic substrate. Further, no suitable spawning sites were found in either lake (for trout species), and neither lake had permanent streams entering them to provide alternate spawning habitat.

Table 4. Summary of Biotic Characteristics in Silkstone and Lovett Lakes

Organisms/Parameter	Lovett Lake	Silkstone
Benthic Invertebrates		
Mean #/sample	49.8	45.8
Total #/sq.m.	2165	1991
Total # of Taxa	11	10
Chironomidae larva contributed 81-91% to the total number of organisms collected		
Zooplankton		
Total #/liter	58.9	78.4
Total # of Species	12	12
Diaptomus denticornis (a Copepod) made up 66-78% of the total number collected.		
Standing Crop Phytoplankton		
Epilimnion mg/cu.m.	1.07	0.41
Hypolimnion mg/cu.m.	0.84	0.52
Aquatic Macrophytes		
Limited patches of several species of submergent macrophytes were identified in the two lakes, including the following: *Potamogeton aquatilis*, *Potamogeton nedosus*, *Potamogeton natans*, *Hippuris vulgaris*		

ASSESSMENT OF LONG-TERM VIABILITY

Fisheries Potential

Following review of water quality results, limnological data, and physical characteristics of the two mine lakes, there are no major limiting factors evident which would preclude the development of a fishery. However, due to the relatively small and underdeveloped populations of benthics, plankton, and macrophytes determined in 1989, growth rates of fish populations would be very low. Also, because of the apparent lack of suitable trout spawning habitat, fish stocks would probably have to be replenished by annual stocking programs.

At the level of productivity measured in 1989, the lakes would not support standard trout stocking rates (ie. those used in most natural waterbodies) . Further evaluations would be needed to define the appropriate stocking rates. As the lakes age (for a period of a few more years), productivity and fisheries growth potential would be expected to increase. Colonization invertebrates and macrophytes, and resulting productivity, could be accelerated through nutrient enrichment and/or further artificial introduction of selected species.

Achievement of End Land Use Objectives

Recreation and wildlife/fisheries habitat are the key end land uses designated for these lake areas. Physical and water quality characteristics identified for these lakes thus far meet the requirements of these uses. Some characteristics discussed above tend to limit fisheries capability on a short-term basis, and this would also impact recreational uses. On the long term, the limitations to fisheries productivity are expected to diminish, with corresponding improvements in land use capability.

The Alberta Fish and Wildlife Division has suggested that recreational lake fishery opportunities in the Coal Branch area are limited by the lack of suitable lakes (Alberta Forestry, Lands, and Wildlife, 1990). Based on the data available to date, the two mine lakes at Coal Valley will provide important additional recreational opportunities in the area. These lakes are also unique in that their form is long and narrow, thus offering good shoreline access to most areas of the lake.

Long-term Research and Lake Development Plans

The potential exists in Coal Valley's operations to develop several more lakes in the final cuts of dragline pits. Reclamation plans incorporating three such lakes have been approved, and four more are in various stages of the planning/approvals process. The mine would realize significant economic benefits through development of these lake projects, and recreational/fisheries habitat qualities of the region would also be enhanced.

While available data support the development of these lakes to meet their designated end uses, further work is needed to define longterm productivity expectations, and to 'fine-tune' reclamation practises to enhance or accelerate productivity. To this end, a study is being developed by Luscar Stereo and Cardinal River Coals Ltd., a sister mine in the area, to further evaluate lake characteristics and refine lake development guidelines. An important part of this study will be to have one of Coal Valley's two mine lakes stocked with trout early in the study, and include these fish in subsequent productivity measurements. This research work will provide significant information on mine-cut lake development in the Foothills.

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