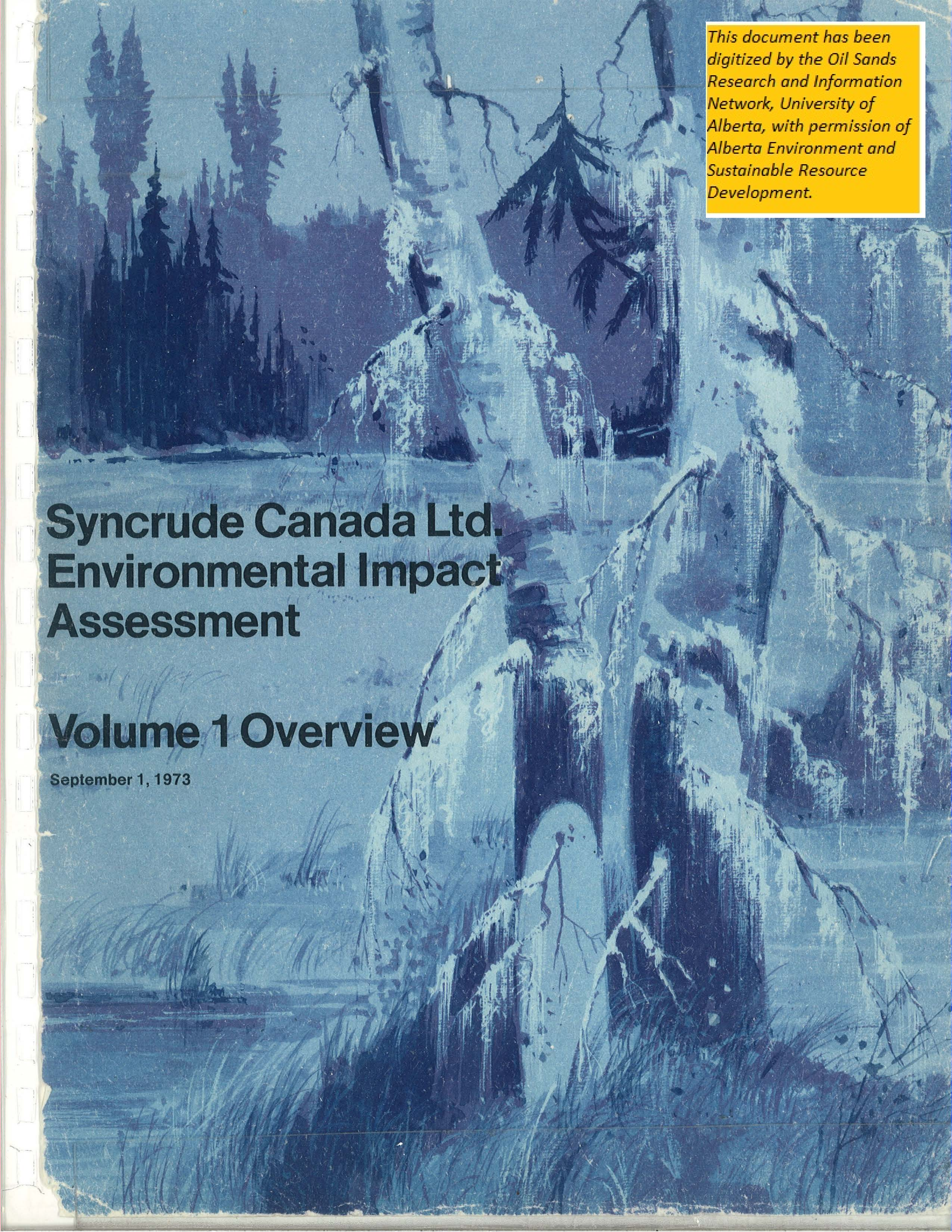

Syncrude Canada Ltd. Environmental Impact Assessment

Volume 1 Overview

September 1, 1973

SYNCRUDE CANADA LTD.
807 BAKER CENTRE — 10025 · 106 STREET, EDMONTON, ALBERTA, CANADA T5J 1G4
RESEARCH AND DEVELOPMENT OF THE ATHABASCA TAR SANDS

R. R. GOFORTH
Research & Environmental Affairs Manager

September 4, 1973

Honourable W. J. Yurko
Minister
Department of the Environment
207 Legislative Building
EDMONTON, Alberta

Dear Mr. Yurko:

I am pleased to submit herewith the Environmental Impact Assessment prepared during the planning stage of the proposed Syncrude commercial development of Athabasca Tar Sands - Lease 17.

Yours sincerely,

RRGoforth

This cover depicts MUSKEG which is an Ojibway term for a bog formed by the deposit of thick layers of decaying vegetable matter, mosses, sedges and rushes, in a depression or hollow in the earth's surface. Muskeg covers about 35% of Syncrude Lease 17.

SYNCRUDE CANADA LTD.

ENVIRONMENTAL POLICY STATEMENT

Syncrude Canada Ltd. works with the conviction that human use of the environment need not be destructive. With careful planning, based upon good information, man-altered and natural ecosystems can exist in harmony. In order to accomplish this planning, Syncrude considers resource development from a total-systems point of view. This comprehensive approach corrects the frequent tendency to attempt resolution of problems on a single purpose basis. The total-systems analysis approach leads to a plan of operations using the best practicable technology, both in resource development and in environmental protection. An ecosystem approach to resource development, an integral part of our approach, implies an understanding of and respect for the potential of natural systems and the use of the economy of nature, wherever possible.

Through a comprehensive program of surveillance of the effects of our technology and careful application of that technology, we aim to prevent accidental damage to the environment. Total effects will be examined by professional ecologists and study results provided to public representatives.

FORWARD

Syncrude Canada Limited and the Government of the Province of Alberta are currently negotiating the practicability of proceeding with a synthetic crude oil production project. During the course of analyzing the practicability of the project, the need for an environmental impact assessment was clearly revealed.

Three major time frames - during the planning stage, during construction, and during the commercial operation of the plant - have been accepted as appropriate for reporting environmental impact assessments.

This Environmental Impact Assessment has therefore been prepared by Syncrude Canada Limited, for submission to the Department of the Environment prior to the start of construction of its project.

ENVIRONMENTAL
IMPACT
ASSESSMENT

VOLUME I

OVERVIEW

SEPTEMBER 1, 1973

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PREFACE

Volume I of the Environmental Impact Assessment is an overview analyzing and interpreting various documents, studies, applications and reports prepared for or by Syncrude Canada Limited and encompassing a review of all pertinent environmental data.

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TERMS OF REFERENCE

SECTION 1

TERMS OF REFERENCE

As the extent and diversity of human demands upon the environment and its natural resources continue to mount, increasing concern is being expressed about the ability of that environment to continue to meet these demands. This concern is reflected in the trend toward a more complete evaluation of the short term and long term effects of human activities which alter or change conditions of the natural environment. The information needed for rational decision making can be expressed in a statement of impact on the ecological relationships and the environment which can be anticipated as a result of certain types of human activity.

This environmental impact statement will begin with a review of the environmental impact on the ecosystem of resource use and its relation to economic decision making. This will be followed by a review of alternatives for accomplishment of this purpose which were considered technologically feasible. From these alternatives one or more actions are proposed for meeting the specific objectives. This approach increases the certainty that all technological, economic and sociological constraints and opportunities have been considered.

This environmental impact statement contains an assessment of the ecosystem(s), encompassed by the project area and their structure and function under conditions unaffected by human action. This is called "baseline" information.

The impact statement will indicate which levels of biological organization are analyzed. It will also include the standards and the methods which were used for these measurements.

A predictive qualitative statement of benefits and losses to biophysical productivity is made. This is based on the time between disturbance and through the reclamation period until return to full productivity of renewable resources.

This environmental impact statement describes the program of monitoring to determine which changes are the result of natural processes and which are the result of disturbance.

A Statement of mitigation alternatives or recommended practices which will avoid economic or technologically irreversable depletion of renewable resources with "critical zones" completes the environmental impact statement.

This environmental impact statement will state the generalities of each category and then elucidate with specific examples for the Syncrude Canada Ltd. Mildred Lake Project Lease 17.

O V E R V I E W

SECTION 2.
INTRODUCTION

SECTION 2

INTRODUCTION

Resource Use: Its Environmental Impact on the Ecosystem and Its Relation to Economic Decision Making

Almost everyone is concerned about the environment as it is today, and as it will be when we pass it on to future generations. In Canada, we enjoy a generally high standard of living due to a great extent to the richness of our natural resources. However, we are now becoming aware that exploitation of our resources has been taking place at the expense of the quality of the environment.

The question of the moment is, consequently - how much of the quality of our environment are we entitled to trade away, to develop our natural resources, and to sustain the standard of living which we feel we should be enjoying?

We don't need to be told that this question is complex, and is often emotional. Industry tends to take the position which will produce the best profit and loss margins. Government tends to follow the current popular lines of thought in order to gain support at election time. Environmentalists have helped to confuse the issue by creating a new set of terms. We now have the "ecology", for example, for what we used to call the "balance of nature".

Governments try to create realistic environmental quality standards; and yet we have streams which, in their natural state, do not meet the legal requirements for chemical content. We have other watercourses which are so pure that they are almost sterile. The ability of these streams to support aquatic life would actually be improved by the addition of controlled amounts of organic wastes, although this is aesthetically undesireable or prohibited.

Our current problems with the quality of our environment have been created, for the most part, by man's efforts to gain access and to make use of the earth's natural resources. Does it follow then, that deterioration in the quality of the environment could be halted by an edict which would put an end to any further resource development? While this works in theory, we all know that it is not a really practical solution. It is like saying that the way to make our streets safe from the hazard of automobiles is to pass a law requiring everyone to leave his automobile at home.

We should appreciate, however, that if we want to talk in terms of practical solutions, in contrast to purely theoretical ones, we have to take the time to gain a somewhat better understanding of the problem. We have to know more than that deterioration in the quality of the environment has been caused by exploitation of natural resources.

One place we can start is with the resources themselves. There are actually three types.

First there are the renewable resources which are for the most part unaffected by human action. These are the resources on which we can draw in any amount, up to the limit of available technology and money, without fear of depleting them. These resources include the energy of the sun, winds, tides and gravity.

So far, development of this class of resources has not cost us much in quality of the environment. This being so we can neglect this class for the time being. As our proficiency in the use of these resources improves, however, the effect of their development on the environment should be reviewed.

Second, there are the non-renewable resources. We are using these resources with the full knowledge that the supply is limited, and that some day they will run out. In the meantime, we are gambling that developments in technology will find us new supplies of these resources or acceptable substitutes.

Finally, there are other renewable resources,[1] such as animal and

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[1]Most of the renewable resources with which we are concerned are resources which are affected by human action. Renewable resources in this class have "critical zones" of resource use. "Critical zone" means a more or less clearly defined range of rates below which a decrease in production

plant life, follow the standard life pattern. They are born, they mature, they reproduce, and they die. Other resources such as the air and soil, follow a continuing process of depletion and revitalization.

When we think about it, this thing we have come to call "the ecology" is a complex of renewing resources within a physical environment. Furthermore, what we have been calling a "deterioration in quality of the environment" is in reality the depletion of some or all of the renewable resources which together form the ecological complex in a particular area.

To save words, let's call the sum-total of all ecological activity, that is, energy exchange in a particular region an "ecosystem". While any ecosystem will be made up of a select group of renewable resources, this fact is not so important as the fact that the renewable resources are usually dependent on each other. If any resource which is a population of living things in the ecosystem is changed or depleted, this will change any other resources which depend on it. This in turn weakens relationships between other living resources which depend on them. Just what the various renewable resources within the ecosystem need to sustain them is consequently relevant.

The renewable resources which follow the life pattern include various communities of animal, plant, and microganism life. These communities have a common characteristic - the rate of production of the community is almost in direct proportion to the number of each species present and the available.

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[1] cannot be reversed economically under presently foreseeable conditions. Frequently, such irreversibility is not only economic but also technological.

Special emphasis should be given to this concept as it concerns intertemperal relations between rates of use of the same resource. The human actions which irreversibly decrease a production of a resource are primarily connected with the use of that same resource. However, one resource may be impaired irreversibly by using another resource. For example, in surface mining, a specific soil horizon(s) usable for the production of vegetation crops may be impaired irreversibly in order to obtain the underlying material. A method must be developed to reclaim the land which has been mined in order to return it to a predetermined beneficial use.

habitat. The ecosystem requires conditions which permit a population to replace those individuals which are consumed by other species, or which perish due to accident or old age. The number of individuals in an animal population present at any time must not be less than the number required to maintain the production rate.

For those renewable resources which follow the deplete-rebuild process, the time required for rebuilding is usually a function of the severity of depletion. Two things can consequently go wrong:

1. Depletion may be so severe that the time required to rebuild becomes infinitely long.
2. The depletion process recurs before adequate time for rebuilding has been allowed.

Before any resource is developed, we should study its place in the ecosystem for answers to these questions:

... What are the conditions necessary to maintain the production rate for the particular renewable resource within the ecosystem? If the resource is a life form what minimum number of individuals of the species must be maintained in order to sustain the ecosystem?

... How will the ecosystem change if the particular renewable resource is depleted?

So far, we have considered certain features of resources in order to understand their strengths and weaknesses. Where then does man's use of resources enter into the whole picture? At the present stage of the earth's history, two situations seem to predominate:

... Man may have his own need for a particular renewable resource. Accordingly, he feels free to harvest it. He may need, for example, salmon to eat, or trees to build houses.

... Man may have to disrupt or destroy a renewable resource in order to gain access to a non-renewable resource which he needs. Trees may have to be felled or streams diverted in order to lay pipelines which will bring natural gas or crude oil to the places where man can use them.

Our present dilemma is due in part to the fact that in the past we could not answer these questions if indeed we cared at all what the answers were. Harvesting of renewable resources is legitimate since nature tends to replenish these periodically. If only the surplus is harvested and the conditions which permitted growth to take place are unchanged, no harm is done to the ecosystem. If harvesting causes a great decrease in the number of individuals within the species, the number of species themselves, or in the habitat below the minimum requirement of the ecosystem, then the effect on the ecosystem has to be evaluated.

The effects are not necessarily all deterimental. One factor will be how heavily the ecosystem depends on the component in the first place. Another factor is whether or not nature will try to replace the depleted component with one which is equally acceptable to the ecosystem and which causes little change. This is a possibility, although experience indicates that where this has happened, nature's replacement is often less attractive to man than the original. For example, if the wolf and coyote are exterminated from a particular area, nature may very well replace them with skunks and foxes.

Another factor is the extent to which man is willing to intervene to redevelop or replace the depleted resources in order to preserve the ecosystem. Almost everyone agrees that this should be done as a matter of principle, but they feel that someone else should accept the responsibility. They would like to have the government do it (but not raise our taxes), or have industry do it (but not raise the price of its products).

Once again we are juggling theoretical solutions with practical ones. As before, developing practical solutions requires a better knowledge of the circumstances. Questions such as these become relevant:

... If our need for a particular resource or for access to a resource, will result in depleting the resource or another renewable resource, how much will it cost us to provide an acceptable alternative in time to maintain integrity of the ecosystem concerned?

... If this cost is too high, can we go part way at reasonable cost, to leave an ecosystem which is less attractive than the original, but still acceptable? (It is interesting to note that the aesthetic value which man places on an ecosystem seems to be directly related to the degree of ecological activity taking place within the ecosystem. This is highest in "climax" communities). (See Volume III, #1).

... Finally, remembering that an ecosystem has a broad geographic range, would the loss be too great if a portion of that particular ecosystem were to cease to exist or be radically changed? This presumes that the demise of a particular portion of the ecosystem would not bring about the demise of any neighbouring communities.

If we persist in the development of our resources, then we have to pay a price somehow: either in deterioration in the quality of the environment; or in money through higher taxes and prices; or both. The question is, "What is the combination which will produce the desired benefits at the lowest present and future cost?"

Obviously, the answer we are seeking is at neither of the extremes Blasting ahead with resource exploitation without concern for the ecological consequences is no longer acceptable. Neither is calling for unlimited amounts of money to restore the environment to its exact original condition in a relatively short period of time.

For governments the key questions seem clear. "Is the exploitation of a particular resource in the public interest, taking into account that some deterioration of the environment, at least on a temporary basis, is to be unavoidable?" There are very few resource development projects in which the value of the resources and the demand for them is so great that unlimited commitment to recreating the ecosystem can be made. Thus it is unrealistic to assume that industry will do the job at no cost to the environment or to the resource consumer. The emphasis, therefore, has to be on minimum damage to the environment.

As renewable resources produced by the ecosystem become available periodically or at intervals, conservation becomes concerned with the WHEN of the use. In the economic sense, resource conservation[2] is an attempt to maintain a dynamic balance between needs and supplies; it involves the future.

Renewable resources with "critical zones" are resources which give rise to serious social and economic problems when depleted. Renewable resources produced in the ecosystem are related to each other and to plant nutrients through highly complex biological processes. Although technology can affect these processes, such influences cannot be expected to be fast enough to lessen the economic and social significance of their depletion. On the other hand, use of these resources is rather sensitive to economic and social institutions - for example, those affecting land utilization. Concerning the difference between renewable resources with critical zones and non-renewable resources without critical zones S.V. Ciariacy-Wantrup states:

> "First, in stock resources, uncertainty concerning technological change is a much greater impediment to planning by individuals or by governments than in flow resources. Second, the confidence that technological progress will make social action in the interest in that distant future unnecessary appears justified for some important stock resources - for example, those used in the production of energy. Third, such confidence is only too often unwarranted complacency for flow (renewable) resources with critical zones;

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[2]Conservation (of the ecosystem) seeks to maximize the benefits of renewable and non-renewable resources through a process which strikes a long run succession of partial equilibria between short run demands for the various resources and short run supplies. The optimum state of conservation can be defined as that time-distribution of use rates that maximize the economic present value of flow of expected net revenues. Social and non assignable costs should be included in this calculation.

[3]S.V. Ciariacy-Wantrup, "Resource Conservation: Economics & Policies", University of California Press 1952

there is great danger that such confidence may be carried over from the field of stock (non-renewable) resources. Fourth, public conservation policy - that is, a change in the institutional framework - is equally promising as well as urgent for (proper conservation of) flow resources. Finally, recent important technological advances in the production of synthetics and in the transformation of energy do not obviate an inquiry into the economics of conservation. On the contrary, these advances underline the necessity for clear thinking about the meaning of (economic) conservation."

The natural processes of the ecosystem do not necessarily accommodate to the artificial boundaries and restrictions that economics and social institutions impose upon them. The stress of human demands upon the land tends to displace natural processes and to impair the capacity of the natural environment for self renewal. Under an economic philosophy which utilizes market price as an index to guide approaches to resource development, it is important that the true cost producing specific goods be illustrated. In any plan of economic conservation, all costs and revenues, including social costs and reclamation, must be taken into consideration whether or not they accrue directly to the resource developer. Ecological studies and environmental impact assessments may project the eventual outcome of a specific developmental approach. This projection of outcome may be expressed in terms of changes in the structure of the resource base and existing ecological arrangements. The outcome or changes in the quality of the resource base may also be expressed indirectly, utilizing various economic indices such as the cost of pacifying human discontent, lost licensing revenues and the cost of restoring the environment to some mutually acceptable standard.

This Environmental Impact Assessment contains information about the loss of potential productivity from a resource base as well as assessments of potential gain. The balance losses and gains resulting from the Syncrude project may be determined on the bases of the information presented here.

O V E R V I E W

SECTION 3.

RESOURCE DEVELOPMENT

SECTION 3

RESOURCE DEVELOPMENT

A. THE REQUIREMENT FOR THIS RESOURCE DEVELOPMENT

Syncrude prepared supply and demand estimates for crude oil and crude equivalent based on the historical growth rates of demand in Canada and in the United States, together with the supply position which has developed in these two countries. Other potential supply sources were considered in estimating the export potential for Canadian crude. This information was provided to the Energy Resources Conservation Board in August 1971.

United States

United States (Board Basis)* Demand for Petroleum Products in 1970 has grown to 14,479,000 BPD. This demand is expected to be 18,290,000 BPD by 1975 and 23,980,000 BPD by 1980. The following are details of the applicants' current forecast of United States Petroleum Products Demand:

United States Petroleum Products Demand
(Thousands of Barrels Per Day)

	1950	1960	1965	1970	1975	1980
United States						
Internal Demand	6,458	9,797	11,513	14,728	18,840	24,770
Districts I-IV	5,572	8,475	9,945	12,770	16,270	21,340
District V	886	1,322	1,568	1,958	2,570	3,430
Plus Exports	305	202	187	258	250	260
Less Bonded Imports	154	200	200	251	320	450
Less Processing Gains	49	145	220	359	480	600
Board Basis Demand*	6,560	9,654	11,280	14,479**	18,290	23,980

* Board Basis - U.S. Internal Demand + Exports - Bonded Imports - Processing Gains

**includes 103M BPD inventory increase

This increasing demand coupled with lagging indigenous supplies is creating a rapidly expanding energy gap in the United States. Long term weaknesses in the producing capabilities in the contiguous 48 states are becoming apparent. Trends in Texas and Louisiana, the major producing states, point up this weakness. Texas Railroad Commission producing well statistics from 1957 to the latest data available are shown in Figure 1. The steep decline in Texas' subject well allowables which began in 1967 demonstrates that additions to producing capabilities by exploration activity and all other industry activities are no longer replacing production. Figure 2 based on Louisiana Conservation Commission statistics, demonstrates cessation of growth in producing capability beginning in 1967 and confirms a declining trend beginning in 1970 for this area as well. It is expected that these states will be producing at capacity by 1973 and to decline thereafter. The Applicants' current estimate of U.S. production by area from 1970 to 1980 is as follows:

United States Production of Conventional Liquid Hydrocarbons
(Thousands of Barrels Per Day)

Year	Districts I-IV	District V ex North Slope	Total
1970	10,008	1,303	11,311
1971	10,150	1,250	11,400
1972	10,170	1,220	11,390
1973	10,430	1,200	11,630
1974	10,320	1,190	11,510
1975	9,990	1,150	11,140
1976	9,670	1,160	10,830
1977	9,440	1,190	10,630
1978	9,120	1,290	10,410
1979	8,810	1,390	10,200
1980	8,520	1,480	10,000

FIGURE 1

TEXAS ALLOWABLE BASE* Vs. TIME

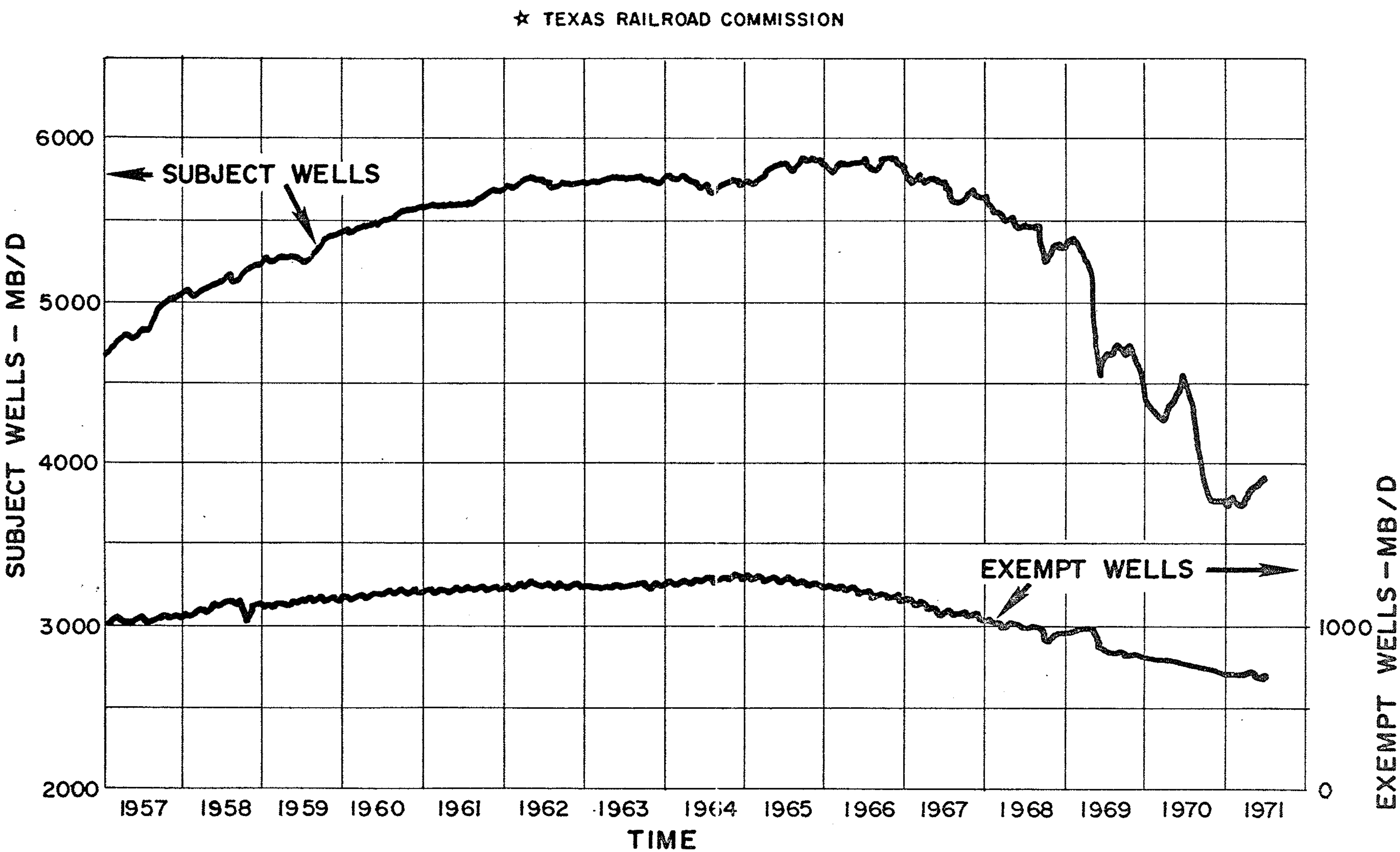
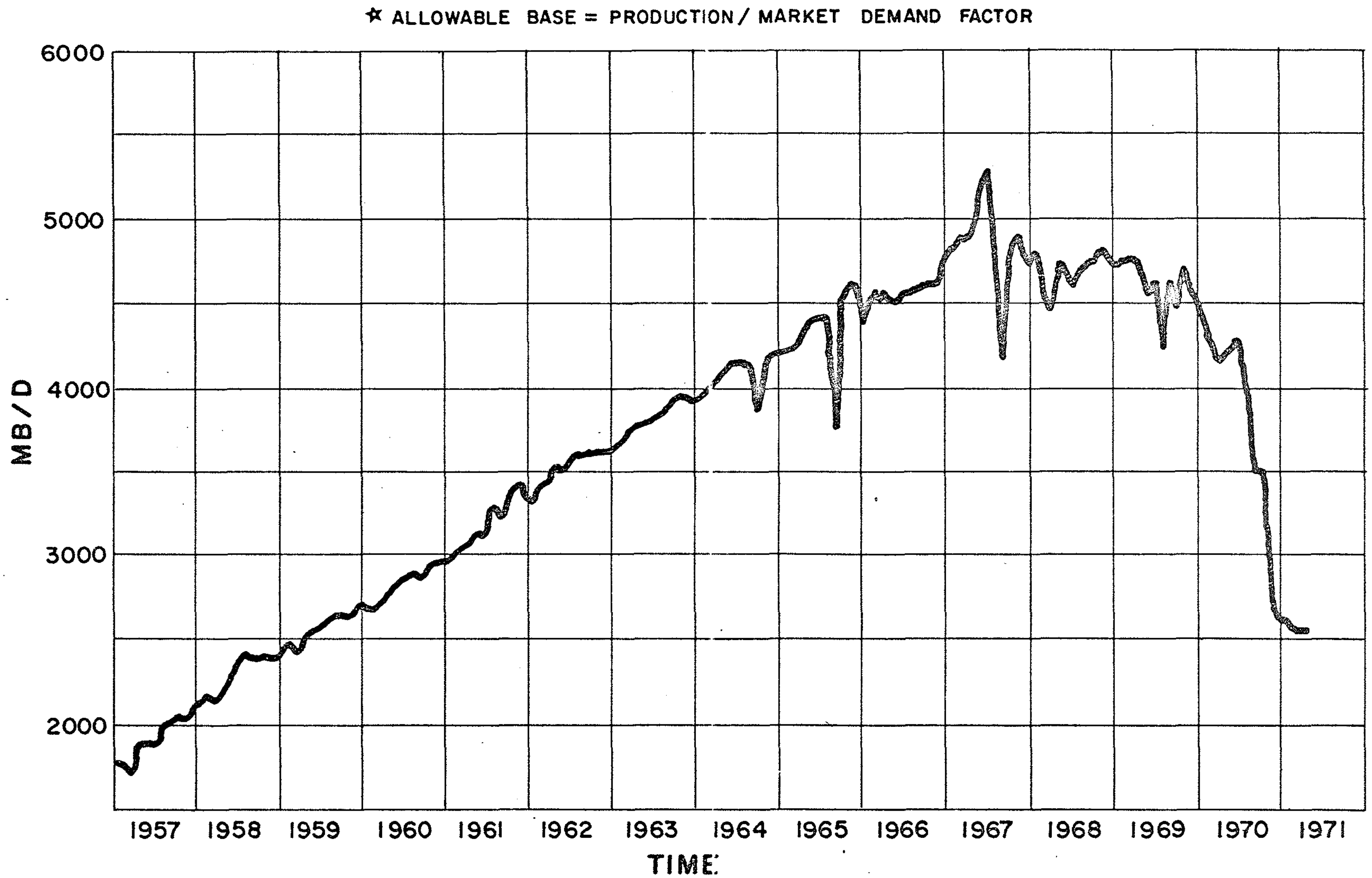


FIGURE 2

LOUISIANA ALLOWABLE BASE* Vs. TIME



U.S. PAD Districts I-IV are expected to peak in 1973 and decline thereafter reflecting a continued drop in production capability from this area. PAD District V (excluding North Slope) will hold about level assuming that new exploration areas are able to offset the decline expected in established California and Cook Inlet production. Due to competitive conditions the applicants will not offer internal estimates of North Slope potential but have agreed that the range of their current estimates is not seriously incompatible with the Board's High Alaska Case as shown in OGCB Report 69-C. Utilizing the applicants' estimates of conventional United States supply excluding North Slope and the Board's 1969 estimate of North Slope potential beginning in 1975, the deficiency of United States conventional crude increases from 3,168,000 BPD in 1970 to 6,150,000 BPD in 1975 and 11,180,000 BPD in 1980 as shown in the table on the next page.

United States Deficiency of Conventional Liquid Hydrocarbons
(Thousands of Barrels per Day)

Year	United States Demand	United States Conventional Production (ex North Slope)	Alaska North Slope (Board's High Alaska Case)	United States Deficiency of Conventional Production
1970	14,479	11,311	0	3,168
1971	15,080	11,400	0	3,680
1972	15,810	11,390	0	4,420
1973	16,500	11,630	0	4,870
1974	17,250	11,510	0	5,740
1975	18,290	11,140	1,000	6,150
1976	19,340	10,830	1,300	7,210
1977	20,180	10,630	1,600	7,950
1978	21,350	10,410	2,000	8,940
1979	22,610	10,200	2,400	10,010
1980	23,980	10,000	2,800	11,180

This widening gap increases the danger of reliance by the United States on insecure sources of petroleum supplies. In past years the United States has had a supply cushion which has been utilized on several occasions as disruptions of Eastern Hemisphere imports occurred. Any future overseas disruptions will be even more significant to the North American economy as United States demand increases and producing capability declines.

The foreseeable energy gap has become a matter of urgent concern to governmental officials of both the United States and Canada, particularly in light of total Western Hemisphere capability. Historically, Venezuela has been a major source of imported crude for both the United States and Canada but recent trends indicate that growing demand in South America will more than absorb any additional South American production that might be developed.

The following table shows the United States deficiency which must be filled by Canadian and Eastern Hemisphere imports to 1980.

United States Liquid Hydrocarbons Deficiency
(Thousands of Barrels per Day)

Year	Deficiency U.S. Conventional Supply Liquid Hydrocarbons	U.S. Synthetic Production	Assumed Imports of Western Hemisphere ex Canada Liquid Hydrocarbons	Gap for E. Hemisphere and Canadian
1970	3,168	0	1,915	1,253
1971	3,680	0	2,000	1,680
1972	4,420	0	2,000	2,420
1973	4,870	0	2,000	2,870
1974	5,740	0	2,000	3,740
1975	6,150	0	2,000	4,150
1976	7,210	0	2,000	5,210
1977	7,950	50	2,000	5,900
1978	8,940	50	2,000	6,890
1979	10,010	50	2,000	7,960
1980	11,180	100	2,000	9,080

In summary, the analysis of the U.S. Supply-Demand forecast indicates a rapidly increasing indigenous supply deficiency with a resulting need to develop secure supplies. The magnitude of the deficiency implies that there will be a market for any new North American supply that can be developed.

Demand for Canadian Crude

Following is the applicants' most recent projection of demand for Canadian crude, covering the period from 1970 to 1980:

Demand for Canadian Crude, Including Pentanes Plus
(West of the Ottawa Valley)

	1970	1975	1980
	(Thousands of Barrels per Day)		
Canadian Domestic Demand	712	855	1,050
Export Demand			
U.S. Districts I-IV	452	1,150	1,480
U.S. District V	218	150	150
Total Exports	670	1,300	1,630
TOTAL	1,382	2,155	2,680

The total export demand for 1975 and 1980 has been split between U.S. Districts I-IV and District V on the basis of the applicants' forecast. However, it is noted that the total forecast demand would not be affected by shifting of exports between districts.

Domestic demand is estimated to increase at a compound rate of 4.2% per annum from 1971 to 1980.

Export demand is forecast to increase by 125,000 BPD from 1971 to 1972 and 200,000 BPD annually for the following two years. This estimate is a conservative interpretation of cabinet-level discussions between the United States and Canada in November of 1970. In a joint statement released by the two governments, at the conclusion of this meeting, it was agreed that "arrangements should be worked out quickly to permit in subsequent years, full and unimpeded access to United States markets of Canadian crude oil and petroleum products, surplus to Canadian commercial and security requirements". President Nixon restated this objective in his energy message to Congress on June 4, 1971.

The levelling of export demand forecast for 1975 and 1976 reflects the estimated impact of commencement of deliveries of crude oil from the North Slope of Alaska. North Slope crude will displace at least a portion of the Canadian crude oil supplied to District V. Despite this, with the ever increasing supply/demand gap in the United States, demand for Canadian crude is expected to exceed its supply after 1976. Thereafter exports are expected to be limited by the available supply of Canadian crude and equivalent from sources west of the Ottawa Valley. The estimated available supply from Alberta was based on the maintenance of a minimum life index for pro-ratable crude oil reserves of 10.0 years.

The table following illustrates the heavy reliance which the United States will have to place on Eastern Hemisphere crude, after allowing for imports from Canada. Imports from Canada were about 40 percent more than those from the Eastern Hemisphere during 1970. This projection indicates that, by 1980, the requirement from the Eastern Hemisphere will be over four times the imports from Canada. This reliance on Eastern Hemisphere crude could be reduced by increasing volumes of synthetic crude production.

United States Liquid Hydrocarbons Imports from Eastern Hemisphere and Canada

(Thousands of Barrels per Day)

Year	Gap for E. Hemisphere and Canadian	Canadian Imports*	Gap for E. Hemisphere
1970	1,253	733	520
1971	1,680	860	820
1972	2,420	1,000	1,420
1973	2,870	1,220	1,650
1974	3,740	1,430	2,310
1975	4,150	1,430	2,720
1976	5,210	1,440	3,770
1977	5,900	1,580	4,320
1978	6,890	1,520	5,370
1979	7,960	1,650	6,310
1980	9,080	1,760	7,320

*From Canadian Production including LPG's and refined products but excluding liquid Ethane.

Supply of Canadian Crude

Alberta's share of the future market for Canadian crude was estimated by deducting the estimated amount that will be produced in all other areas west of the National Oil Policy Line from the total demand. It is now expected that oil from new areas, such as the northern segment of the Yukon and Northwest Territories, will enter the market in the late 1970's and increase in volume.

Supply of Canadian Crude and Pentanes Plus
(West of the Ottawa Valley)

	1970	1975	1980
	(Thousands of Barrels per Day)		
Area			
Alberta-Conventional	1,009	1,792	1,635
Alberta-Synthetic	33	65	300
Saskatchewan	246	185	130
Manitoba	16	15	12
British Columbia	72	75	75
Ontario	3	3	3
Yukon and N.W.T.	3	20	525
TOTAL	1,382	2,155	2,680

The synthetic crude estimate allows for the probable increased production at the Great Canadian plant, production from the proposed Syncrude plant and from other possible projects by 1980.

Production of crude oil from the East Coast offshore area is not expected to commence until the mid-1970's and from the Arctic Islands in the early 1980's. The applicants expect that this production will initially be refined in Canada in the area east of the National Oil Policy Line. If the production should grow to a volume greater than that required in this area, the applicants are of the opinion that the surplus could be exported to U.S. East Coast which is the most crude deficient area in that country.

Life Index

In Table IX-3 on page 84 of OGCB Report 69-C, the Conservation Board tabulated four life index calculations of Alberta's pro-ratable crude oil reserves based on varied combinations of the Board's low and medium reserves estimates and its new basic and high demand forecast. The lowest life index estimate, Case IV, based on the Board's low reserves estimate and high demand estimate, projected a life index of 26.6 years at the end of 1970, 15.4 years at the end of 1977 and 13.9 years at the end of 1978.

The Board noted that the application, as amended to March 24, 1969, would qualify under the life index criterion sometime between 1977 and 1978 if the trend illustrated in Case IV were to be realized.

Developments since the issuance of Report 69-C compel the conclusion that Alberta's life index will decline even more rapidly than that projected by the Board's Case IV.

The actual 1970 demand for Alberta pro-ratable crude oil exceeded the Board's Case IV estimate of 788,000 BPD by over 50,000 BPD. This variation was due principally to an increase in export demand. It is now apparent that the future demand for Alberta crude oil will substantially exceed even the most optimistic estimates submitted by the applicants or made by the Board with regard to the previous applications.

The Board's low reserves estimate which it utilized in Report 69-C estimated remaining reserves at December 31, 1970 of approximately 7,650 million barrels from pro-ratable pools, a figure 233 million barrels greater than the Board's current estimate of 7,417 million barrels (OGCB Report 71-18).

The last year in which initial proved reserves discovered in Alberta exceeded 1 billion barrels was in 1959, and 1965 was the only year since that time that the initial proved discoveries exceeded 500 million barrels. Alberta discoveries in 1969 and 1970 have continued the downward trend which started in 1965. After only a minor net reserves addition in 1969, there was a decline in Alberta net reserves in 1970.

In addition, lead indicators of future reserves discoveries offer no basis for optimism. The current level of exploration activity is down sharply. New field wildcat oil completions declined to 17 in 1969 and 5 in 1970 from a 5 year average of 43 over the years 1964-68. Also seismic activity in Alberta in 1970 was the lowest of the past decade.

In light of these trends, it is probable that future gross reserves additions will be less than those estimated in the Board's low reserves projection in Report 69-C.

On the basis of the Board's recently estimated reserves of 7,417 million barrels (OGCB Report 71-18) of pro-ratable crude oil and the actual average daily production of 840,000 BPD for 1970, the Alberta life index at the end of 1970 stood at 24.2 years instead of the 26.6 years projected in Case IV.

The table on the next page shows the applicants' estimate of the life index for Alberta's pro-ratable crude oil pools.

Production, Reserves and Life Index
of
Alberta's Pro-ratable Crude Oil Pools

	Production		Reserves			Life
	Daily	Annual	Additions	Initial	Remaining	Index
Year	(MBPD)	(MM Bbls)	(MM Bbls.)			Years
*1967	602	220	571	9,249	7,009	31.9
*1968	637	233	705	9,954	7,481	32.1
*1969	715	261	312	10,266	7,532	28.9
*1970	840	307	192	10,458	7,417	24.2
1971	935	341	402	10,860	7,478	21.9
1972	1,075	393	370	11,230	7,455	19.0
1973	1,315	480	340	11,570	7,315	15.2
1974	1,560	569	320	11,890	7,066	12.4
1975	1,570	575	300	12,190	6,793	11.9
1976	1,570	575	285	12,475	6,503	11.3
1977	1,690	617	270	12,745	6,156	10.0

*Source: OGCB Reports on Reserves of Crude Oil, Gas, Natural Gas Liquids and Sulpher - Province of Alberta

On the basis of the Board's comments relative to Table IX-3 of Report 69-C, the applicants' calculations indicate that the Alberta Life index will decline to the critical level sometime between 1973 and 1974. The startup date of 1977 for the Syncrude Project is in response to, and consistent with, the demand for crude oil and crude oil equivalents as outlined here.

SECTION 3

RESOURCE DEVELOPMENT

B. ALTERNATE SOURCES OF LIQUID AND GASEOUS HYDROCARBONS IN NORTH AMERICA*

Although North America is relatively well endowed with sources of energy, it is also a large consumer of energy. In the United States the steadily declining level of drilling and the ominous trend in proved crude and gas liquids reserve life index indicate a continually increasing gap between supply and demand. If, as all signs indicate, economical supplies of conventional crude oil and natural gas fall short of demand, the gap will be filled by imports and synthetic hydrocarbons. National security considerations and the balance-of-payments problem preclude complete reliance on imported offshore oil to supplement conventional domestic production with the result that the tar sands, oil shales and coal indigenous to the North American continent will become logical sources of synthetic hydrocarbons.

The trend of reduction in proved reserves life index may have been reversed temporarily by recent discoveries of large crude reserves on the Alaskan North Slope. However, in recent hearings before the Alberta Oil and Gas Conservation Board relative to an application by Syncrude Canada Ltd. for approval of a scheme to produce synthetic crude and specialty oils from the Athabasca tar sands, the Board agreed that even the most optimistic projection of Alaskan production would not fill completely the expected deficiency of production versus demand even when allowing for overland and overseas imports. Recognizing this fact, the Board granted approval for Syncrude Canada to implement their scheme with production to commence in July 1976.

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*From a Submission by Syncrude Canada Ltd. to House of Commons Standing Committee on Finance, Trade, and Economic Affairs with Respect to Proposals for Tax Reform, March, 1970.

At the present time, the technology of recovery of liquid hydrocarbons from the Athabasca tar sands is some years ahead of oil shale and coal conversion technology. However, delays in additional commercial development of the tar sands may well see this competitive advantage disappear. In the discussions which will follow it will become obvious that a number of companies are interested in at least two and in some cases all of the sources of synthetic liquid hydrocarbons. This would indicate that as yet no one of the sources has a clear-cut advantage. Those differences in the economic climates under which these resources will be developed may well determine which of the synthetic fuels develops at the fastest rate.

I. COLORADO, UTAH AND WYOMING OIL SHALES

The U.S. Geological Survey estimates that the Colorado, Utah, and Wyoming shale deposits contain reserves of approximately 2 trillion barrels of oil equivalent in shale richer than 10 gallons per ton, with 80 billion barrels considered recoverable by present technology.

Interest in the extraction of oil from the U.S. oil shale has been intense for a number of years. Several development projects have already been completed and new ones are now underway. As a point of interest, one of the participants in the Syncrude Canada Ltd. project has invested more money in the United States oil shales than it has in the Athabasca tar sands.

The United States Congress has recently recognized the need for and provided endorsement of added incentives for development of oil shale. The tax bill recently passed by both Houses of Congress, and signed into law by the President does not change the 15% rate of depletion on oil shale but places the point of allowed depletion at the retorted products rather than the mined oil shale. This essentially doubles the depletion allowance on oil extracted from shales and improves the economics of shale oil production relative to conventional petroleum (which suffered a reduction in depletion percentage) and other synthetic hydrocarbons.

Anvil Points Project

Private industry has attacked oil shale development problems through several separate projects. In the Anvil Points project, six companies co-operated in an extended research program into oil shale mining and retorting using facilities leased from the U.S. government. The Department of the Interior in May of 1964 leased its facilities at Anvil Points to Colorado School of Mines Research Foundation, Inc. This foundation performed research under contract to Mobil Oil, Humble Oil and Refining, Continental Oil, Pan American Petroleum, Phillips Petroleum and Sinclair Research.

Extensive test work on mining, crushing and retorting was carried out during Stage I of this project. By the time this stage had been completed in April 1966, the companies had spent $2.7 million. At this point, they agreed to increase the projected outlay for Stage II from $3 million to $4.5 million. Results obtained from the two small retorts utilized in Stage I led to modification of the government's 150 ton per day retort and runs at this facility began in November 1966. Retort operation ceased in August 1967 and the research work of Stage II was completed in early 1968. Results of this work are not yet available; however, a publication regarding the achievements of Stage I indicated that 80 - 85% of the organic values in crushed and sized oil shale could be recovered as oil and gas by the process investigated.

Colony Development Company Project

During the period 1964-1967 there was considerable activity on the part of the Colony Development Company, a corporation created by Standard Oil Company of Ohio, Cleveland Cliffs Iron Company, and The Oil Shale Corporation in April 1964 to act as their agent for development of mining and retorting systems for oil shale.

The Colony Development Company initially began operation of a room-and-pillar oil shale mine and a 1000 ton per day prototype TOSCO process retort in early 1965. TOSCO is the familiar name for The Oil Shale Corporation, a publicly held company which was founded in 1955. Its principal purpose was the development of a commercially feasible, above-ground retorting system for the economical recovery of oil and other products from the oil shales of the western United States. They developed a patented process utilizing heated ceramic balls for the retorting of shale oil. By November 30, 1964, TOSCO had expended $5,350,000 for operations and an additional $1,600,000 for acquisition of suitable oil shale reserves for a total of $6,950,000. At the same date it was committed to spend another $8,500,000 for reserve acquisitions and in furtherance of its production project.

In the initial stages of this program extreme difficulties were experienced with breakage of ceramic balls used in the process. However, after a period of experimentation with various formulations of ceramic balls, this problem was brought under control and TOSCO is now confident of the economic viability of the process.

Colony Venture

At the end of 1968, Colony was restructured to include Atlantic Richfield Company as a participant in the reserves and technology formerly held by Colony Development Company. With Atlantic Richfield as operator, the Colony Venture participants are actively pursuing a new research program aimed at solving the remaining problems with the TOSCO process, gathering additional information on shale mining, and determining the true cost of building and operating a synthetic crude oil plant. In this effort, the mine and 1,000 ton per day retort at Parachute Creek, Colorado, will be utilized to determine projections for a commercial scale venture.

In Situ Methods

In situ retorting has the tremendous appeal and potential advantage that no material handling other than of raw shale oil would be necessary, and that there would be no problem of disposing of spent shale. In addition, an in situ process would be entitled to 22% depletion allowance instead of the 15% depletion allowance for mining-retorting projects.

In situ work done to date has involved fracturing the shale by electrical, chemical or hydraulic means prior to the application of heat, or operation in special horizons in the formation which possess adequate native permeability.

Sinclair Research used hydraulic fracturing to obtain inter-well communication and then employed downhole burners to initiate in situ combustion to heat the formation. In 1961 Mobil Oil conducted an in situ experiment along similar lines. Equity Oil Company is now field testing a process employing the injection of hot natural gas to retort the shale.

The most unorthodox proposal for in situ retorting is that contemplating the use of atomic explosives for fracturing. A joint feasibility study and contract negotiation effort involving the U.S. Bureau of Mines, the U.S. Atomic Energy Commission and twenty-four oil and mineral companies was carried out over a period of several months. Among them were: Atlantic Richfield Company, Cities Service Oil Company, Ashland Oil and Refining, Continental Oil Company, El Paso Natural Gas, Equity Oil, Getty Oil, Marathon Oil, Mobil Oil, Pan American Petroleum, Shell Oil, Sinclair Oil and Gas, Sohio Petroleum, Sun Oil, Tenneco Inc., Cleveland Cliffs Iron, Superior Oil, Union Pacific Railroad, Western Oil Shale, and Texaco, Inc. The concept envisions creation of huge underground chimneys of fractured shale as a result of buried atomic explosions. Heat would then be applied and the resulting crude oil pumped out.

The Atomic Energy Commission is extremely enthusiastic about this project and have stated that this method might recover 160 billion to 320 billion barrels of oil estimated to be locked up in the more deeply buried oil shales in the Piceance Basin of western Colorado. The technical feasibility and potential profitability of the method have been questioned severely and the effort is presently in limbo.

The United States Bureau of Mines has been active in research supporting the concept of nuclear fracturing of oil shales followed by retorting of the chimneys thus created. Toward this end, a 150-ton batch retort has been constructed to simulate the rubble created in a nuclear cavity. This facility is currently being operated to project operating conditions and expected yields from a fractured chimney of oil shale. These results will, no doubt, form the basis for future efforts to promote nuclear fracturing technique tests.

Another, more conventional, fracturing technique has been applied recently in shallow and comparatively thin oil shale beds in the Green River formation of Wyoming. The U.S. Bureau of Mines applied conventional explosive (nitroglycerine) to fracturing a thin bed of shale which had previously been drilled in a closely spaced pattern of development wells. Subsequent ignition of the formation around a central well confirmed communication had been created to certain peripheral wells and some shale oil was produced from the formation. The technique is still being evaluated for possible commercial significance.

Other Research Projects

The Denver Research Institute announced on November 10, 1965, the formation of the Centre for Fundamental Oil Shale Research. An initial program of three years duration was completed. Funds for the initial program were provided by the Shell Development Company, The Oil Shale Corporation, the Aquitaine Oil Corporation, Humble Oil and Refining Company and the University of Denver. A second three year program has been initiated under the sponsorship of Shell, the Oil Shale Corporation, Atlantic Richfield Company, Humble, and the University of Denver. The TOSCO and Atlantic Richfield sponsorships are on behalf of all the Colony Venture participants. Fundamental studies into the nature of kerogen and its transformation into useful products will be continued in this program.

Laboratory experiments have also demonstrated that several other processes such as the high temperature hydrogen processes, developed by Texaco, Inc. and Petrochemical Corporation, are feasible.

General

Oil shale has certain advantages over tar sands as a source of synthetic crude in that it is native to the country representing the market and is much closer to the market; also it has an advantage relative to coal in that much less hydrogen is required per barrel of product of comparable quality. The level of research activity on oil shale continues high and alternate possibilities for improved shale oil extraction are being explored.

II. PROCESSES FOR LIQUEFACTION OF COAL

An immense amount of work has been done on coal conversion to oil, particularly through the Office of Coal Research of the United States Department of the Interior. Liquefaction became an obvious goal of coal research many years ago since coal is energy in a most inconvenient form, despite its abundance and its low price in many locations. The extensive coal reserves in the United States and Canada and advances in technology for conversion of coal to liquid products may make coal a first choice in the search for a new source of liquid fuels if political obstacles continue to impede commercialization of both oil shales and tar sands.

With the development of economic hydrogenation processes, reductions in the cost of hydrogen, and the presence of a satisfactory differential between the price of coal and that of liquid fuels, it appears that commercial conversion of coal to liquid fuels will be in operation in the United States sometime between 1975 and 1985. Mr. Neal P. Cochran of the Office of Coal Research confirmed this thought when he stated on February 21, 1967 in a speech at the A.I.M.E. Annual Meeting in Los Angeles, that he felt both liquid fuels and pipeline gas from coal will be in commercial production by 1975, and at the same meeting Mr. Cochran and Mr. Walter R. Hibbard of the U.S. Bureau of Mines predicted that gasoline could be produced from coal in the 10 cent to 13 cent per gallon range. With this in mind, it is not too difficult to understand the reasons for the statement by Mr. J.K. Jamieson, Chairman of the Standard Oil Company of New Jersey, that "we will see commercial production from shale oil or coal within the next ten years".

Coal hydrogenation to manufacture synthetic liquid fuels was practiced during World War II in England and Germany. These processes were uneconomic under peacetime conditions. In recent years however, the economics of coal hydrogenation have been improved through development of improved catalysts' system which have reduced operating pressure, thereby reducing investment and operating costs. Other approaches to deriving liquids from coal by pyrolysis rather than hydrogenation have been demonstrated. These techniques have the advantage of reducing hydrogen requirements and thereby reducing the cost per barrel of product. However, these processes produce large amounts of solid, low-volatile char and must be used in conjunction with the need for fuel of this type, such as large steam electric plants. The U.S. Bureau of Mines has been testing the burning characteristics of coal char in a small unit and if by-product char possibilities are confirmed, the potential of producing competitively priced gasoline by coal pyrolysis will be enhanced.

Project Gasoline

The largest coal liquefaction project now under way is being performed under contract to the Office of Coal Research by the Consolidation Coal Company, a subsidiary of Continental Oil Company. Both companies had been working for a number of years on the basic development of a coal-to-gasoline process. During the course of the laboratory work, a new catalyst system was developed which promises to reduce the cost of gasoline below that originally predicted. Early in 1965, on the basis of an evaluation of all work to date by both the Office of Coal Research and by the Ralph M. Parsons Company, retained as a consultant and monitor of the project, a contract was executed between Consolidation Coal Company and the Office of Coal Research for construction of a $5.5 million pilot plant at Cresap, West Virginia. Efforts to bring the plant on stream have continued since May, 1967.

From the work to date it has been estimated that a 48,000 BPD gasoline plant could produce gasoline at a cost of 15.5 cents per gallon with a return on investment of 6.4%. The process has also been evaluated as a means of producing synthetic crude oil. The price of producing synthetic crude oil at a rate of 250,000 BPSD from western United States coal has been estimated at $3.25 per barrel, assuming a 6.4% return on investment. No value was assumed for the char produced but if a value based on 80% of the price of coal of equivalent heating value were assumed, the crude oil price would be reduced to $3.15 per barrel.

The pilot plant operations are continuing for further development of the process. Successful completion of the program will provide sufficient data to permit the process to be applied commercially in most of the major oil producing areas of the United States.

H-Coal Process

Hydrocarbon Research, Inc. has developed a process, trade-named the H-Coal Process, to convert coal to a light crude oil suitable for a gasoline feedstock. The development was furthered by a project, beginning in February 1965, sponsored by the Office of Coal Research. The Atlantic Richfield Company has been sponsoring continued development with HRI since March 1968. Bench-scale work, confirmed by operations at a pilot plant processing about 3 tons of coal per day, has produced higher yields than those originally predicted. Pilot plant operations have demonstrated the operability of the process through achieving many runs of several weeks duration.

Under contract to the Office of Coal Research, the American Oil Company in 1967 made an independent economic evaluation of the H-Coal Process in which the price of gasoline from a 100,000 BPSD gasoline refinery was estimated at 12¢ per gallon, assuming an 18% annual charge for capital before taxes.

In the H-Coal Process the coal is dried, pulverized and slurried with coal-derived oil for charging to a coal hydrogenation unit. The coal-oil slurry is charged continuously with hydrogen to a reactor containing an ebullating bed of catalyst.

The coal is hydrogenated catalytically and converted to liquid and gaseous products. Nearly 90 weight percent of the moisture and ash-free coal is converted. The synthetic crude oil produced in the H-Coal step requires additional processing to produce specification gasoline and furnace oil. More or less conventional refinery operations are suitable for these upgrading steps. The work to date indicates that a proposed refinery would yield 4 barrels of synthetic crude per ton of moisture and ash-free coal. This yield excludes propane and butane which, if recovered, would provide an additional 0.4 barrels per ton of dry coal.

Project Seacoke

A third method of conversion investigated was Project Seacoke, the work being performed by the Atlantic Richfield Company under contract to the Office of Coal Research. This process has possibilities in areas where large coal-fired electrical generating plants and oil refineries already exist in a local area, in that it has the potential of substantially increasing coal demand in existing markets without requiring new marketing channels or large accumulations of capital for new "grass roots" plants. The process would "top off" the coal in an adaption of the present oil refinery fluidized coking process. The topped off fractions of the coal are converted to gasoline and the char, still a large part of the original coal, continues to the power plant to serve as fuel. The process has been demonstrated to be technically feasible since coal has been topped and char produced in bench-scale fluidized cokers. The final report on this project will be issued soon by the Office of Coal Research.

Project COED

The fourth and oldest project undertaken by the Office of Coal Research for the liquefaction of coal is Project COED, carried out under contract by the FMC Corporation. The original objective of this project was to develop a process to produce a liquid product from coal which then could be mixed in with residual char and both transported to market by pipeline, but insufficient liquids were produced to slurry the char to a central plant. After investigating several alternatives, the project efforts evolved a multistage fluidized bed pyrolysis. (Pyrolysis is the heating of coal in the absence of air). A process development unit with a capacity of about 100 pounds of coal per hour was successfully operated throughout most of 1965 and 1966. Commercially feasible yields of oils, gases (both hydrogen and fuel gas) and char were obtained from various coals in this unit. An analysis based on these data indicates that a plant for producing a synthetic crude oil, fuel gas and solid char-fuel from coal using the COED process could be built to process 3.5 million tons of Utah coal per year, and would maintain a 13 to 25% return on investment before taxes. This estimate is based on the following prices: coal, $3.00 per ton; synthetic crude oil, $4.00 per barrel; and fuel char, 90% of coal value.

Further development of this approach is continuing with operation, beginning in May 1970, of a 25-ton per day pilot plant to prove the technical feasibility of the process on a large scale. This approach may be commercially feasible when the liquefaction plant is located adjacent to an electric utility stream plant.

General

Coal has distinct advantages over the tar sands or oil shales as a prime source of alternative fuel. First, large coal reserves are close to the consumption centers in the United States and will have a further advantage over tar sands in that they will not have to contend with import quotas in gaining access to United States markets. Second, coal provides a liquid yield of up to 3-1/2 barrels of synthetic crude oil per ton of ore, in comparison to indicated oil shale and tar sand yields of less than one barrel per ton of ore. Third, naphtha fractions derived from coal and subsequently reformed can produce 100 Research octane quality gasoline without requiring the addition of lead. Since lead-free gasolines may be mandatory in the future to meet air pollution restrictions, this factor may greatly enhance the attractiveness of coal liquefaction projects.

III. GASIFICATION OF COAL

Although synthetic gas from coal does not compete directly with synthetic oil from tar sands, oil shales and coal, the development effort centered toward commercialization of these processes is worthy of mention. The Institute of Gas Technology's Project Hydrogasification and the Consolidation Coal Company's CO_2 Acceptor Process are the two main processes now actively being developed in the United States. Since the cost associated with producing hydrogen represents a very large part of the overall cost of synthetic gas, major efforts are being made to lower the cost of hydrogen produced from solid fuel. All synthetic oil processes use considerable amounts of hydrogen; therefore, if these efforts are successful, they will, in turn, have a substantial impact on the economics of synthetic crude production.

SECTION 3

RESOURCE DEVELOPMENT

C. DESIGN CONSIDERATIONS FOR A TAR SANDS PROJECT

Introduction

As with most large industrial projects, an Athabasca tar sands plant requires careful integration of all design elements. Design criteria in one section of the plant can have major effects on other sections. This section deals with some of the major considerations entering into the design of a tar sands complex.

The mining type of tar sands project is composed of two markedly different major industrial operations - namely, open pit mining and petroleum processing - tied together by the keystone operation, the extraction-froth treatment process for separating the heavy oil from the tar sand.

The open pit mining is typical of an industry that must contend with the elements. Any particular day's operation can be affected by ground conditions, the vagaries of the weather, and the variability of the formation. Planning is important, but mainly in the intermediate and long term. The daily operation of the pit and the consequent production costs will frequently depend a great deal on the ability of the pit operator to foresee potential problems and to cope with the situation of the moment. The operation is, of necessity, subjective, with the result that operator judgement bears very heavily on mine planning and optimization. Rather than scheduling a major turnaround period, maintenance is usually done either on the run or in frequent short shutdowns.

By comparison, the bitumen upgrading units must aim for long onstream periods. The infrequent shutdowns are of a more lengthy duration and are planned on an annual or even biennial basis. Operating conditions are closely controlled through extensive automation because the units are very sensitive to upset. Optimization of the facilities, while much more complex, is considerably more amenable to systems analysis. Unlike the widely variable situation faced by the mining operation, bitumen upgrading, having a relatively uniform feedstock, can maintain steady state operation.

Extraction-froth treatment, as the key between these two major operations of basically different character, has some of the features of both, and its design must be such as to reconcile the operation differences between the other sections of the plant. Because it has this essential role and is unique to the Athabasca tar sands, the extraction-froth treatment operation has been the main area of research. By itself, it does not have a preponderant effect on the economics - but without it there can be no economics.

A tar sands operation necessitates extracting bitumen, a product that has a value in the order of half a cent a pound. To ensure the viability of a project, therefore, it is necessary that sufficient advantage of the economics of scale be realized. The optimum size for a tar sands project is in excess of 100,000 BPD.

Nature of Deposit

The proposed Syncrude commercial operation will be carried out on Lease 17, which lies 20 miles north of the town of Fort McMurray and borders on Lease 86, the site of the only existing tar sands operation. Lease 17 covers 49,788 acres and contains potentially mineable bitumen reserves of approximately 3.5 billion barrels.

The first problem facing the designer is the variability of the McMurray formation. The bitumen content, the fines distribution, and the chemical composition of any particular tar sand will greatly influence the design of the front end of the plant. Ensuring that a minimum of low grade material is incorporated in the plant feed and avoiding extreme variations in feed quality through blending or sequential mining techniques will contribute important downstream benefits. Some form of selective mining is highly desirable.

The quality of reserves on Lease 17 is illustrated from a mining standpoint in Figure 1. The shading on the figure indicates the amount of bitumen per cubic yard of total material mined by relating the grade and depth of tar sand in any given area to the thickness of overburden and reject material. An area of premium reserves, represented by the darkest coloring, lies in the region of Beaver Creek. Economic considerations make it very desirable to commence operations in a high grade section of the ore body; this was a primary factor in the selection of the plant location. It was necessary, of course, to establish that the plant proper will not cover valuable ore reserves.

For mine planning, Lease 17 has been divided into several areas. The site of the initial operation hereafter will be referred to as the initial mining area. It contains enough reserves to feed the proposed plant for approximately 14 years at its approved rate of 80,000 BPD of synthetic products. When the other reserves indicated in Figure 1 are included, the life of this portion of the deposit is about 70 years.

Figure 2 depicts the quality of the tar sand in the initial mining area. It will be noted that less than 1.0% of the total bitumen occurs in sections grading below 2 wt.% bitumen whereas 28.4% grades between 14% and 16%. The average bitumen content in the initial mining area is 8.8 wt.%. Figure 2 is somewhat arbitrary in construction inasmuch as the grade of any particular section can be raised or lowered by including richer or leaner adjacent sections.

Figure 3 is a further characterization of the deposit and shows the distribution of the total "fines" in association with the different grades of tar sand. "Fines" consist of silts and clays and are defined here as material passing through a 325 Tyler mesh screen. The shape of this bar graph is considerably different than that of Figure 2. Almost 40% of the fines occurs in barren clay bands and lean tar sand containing less than 2% bitumen.

The inverse relationship of fines to bitumen in the tar sand is illustrated in a somewhat different manner in Figure 4. It can be seen, for example, that tar sand from the initial mining area containing 12% bitumen would average approximately 11 wt.% fines. Fines are specified as a percent of the total solids rather than as a percent of the tar sand. The total solids in turn comprise approximately 84 wt.% of typical tar sand. The fines distribution, for a given bitumen content, shows a wide variation from core to core. Staying with our 12% illustration, the fines content of different samples may be anywhere from 4% to 28%. Tar sand of 12% bitumen content from the area to the south of the initial mining area averages about 14% fines and similar material from the area to the east averages 16.5%. As leaner material is charged to the unit, the percentage of fines increases drastically. For example, if tar sand containing 6% bitumen were being fed, we would expect the average fines content to be around 35 wt.%, but we could anticipate a variation of from 20% to 60%.

Also shown on Figure 4 is the relationship of connate water to bitumen. The water content of average quality tar sand from the initial mining area generally runs between 4 and 5 wt.%. Here, again, the amount can vary over a range. The sand grains, clay particles, and most of the silt occurring in the tar sand are water wet. This feature facilitates the separation of the bitumen from the solid material in the extraction step. The connate water would be considered fresh in the normal sense in that it is not high in dissolved minerals. However, there are significant trace amounts of various soluble ions present and these are important from the standpoint of recovery of bitumen. As discussed by Kaminsky and Nagy[1] and Bowman[2] polyvalent metal ions such as calcium, and ferrous iron, which are present in varying degrees in tar sands from different areas of the deposit, have a harmful effect on the separation characteristics. These cations tend to cause mutual flocculation of the clays and the bitumen particles.

Considering the inverse relationship of fines to bitumen, and the detrimental effects of fines on processing, it is most desirable to reject a certain amount of the lean, high-fines tar sand. Selection of the cut-off point for this rejection involves a balance of mining and processing costs in the front end of the plant.

Table I shows the effects of selective mining in the initial mining area on feed quality. Only that material containing less than the cut-off grade and occurring in beds of 5 ft. or more thickness is rejected (which results in somewhat different bitumen and fines distributions than those illustrated in Figure 2 and 3).

TABLE I

Effects of Selective Mining on Feed Quality

Bitumen Content of Reject, %	Average Bitumen Content of Feed, %	Average Fines Content of Feed, %
0	8.8	24
<2	10.3	18
<4	11.2	14
<6	11.8	11
<8	12.5	8
<10	13.5	5

With no rejection the bitumen content of the initial mining area averages 8.8 wt.% and the fines content comprises 24 wt.% of the solids fraction. If selective mining procedures were implemented and even the material containing less than 2 wt.% bitumen were rejected, the grade would be raised to 10.3% and the fines content lowered to 18%, a very significant improvement. Further increases in the cut-off point would result in additional improvements in feed quality, particularly with respect to the fines content.

In Table II, the effects of rejecting low grade material on the tonnages of material handled and on the conservation of the original in place bitumen can be examined. Conservation is defined here as the overall recovery of bitumen in the mining-extraction-froth treatment operations.

TABLE II

Effects of Selective Mining On Mining Rates and Bitumen Conservation

Bitumen Content of Reject, Wt.%	Total Mined Overburden plus Tar Sand plus Reject, M Tons/CD	Tar Sand Feed M Tons/CD	Conservation of Bitumen, %
0	239	207	87.9
<2	229	176	87.8
<4	221	158	87.0
<6	213	147	85.0
<8	215	137	80.2
<10	221	126	73.6

The amount of total material handled is minimized at a cut-off point of 6 wt.%. The quantity increases at lower cut-off points because a considerable amount of the low grade material occurs at the bottom of the ore body. The tar sand feed rate, of course, is reduced as the grade improves, which decreases the required size of the extraction facility.

If all material from the feed zone were charged, it is expected that 87.9% of the in-place bitumen would be recovered through the mining, extraction, and froth treatment stages. Tar sand of up to 6 wt.% bitumen can be rejected with only a relatively minor change in the overall conservation aspects. This is so because of the small amount of bitumen associated with the very lean material, and also because less of it is recovered in the subsequent extraction operation. With further increases in the cut-off point, the loss of bitumen is accelerated.

The decision with respect to the selective mining cut-off point is based on an evaluation of all penalties associated with the charging of high fines content feedstocks. These penalties are covered in more detail in the discussion of the extraction process and the tailings disposal requirements.

Mining Considerations

The nature of the deposit puts an obvious premium on selectivity in the mining operation. However, there are other factors of equal importance bearing on the design of the mining system and its relationship to the rest of the plant.

The mine is feeding a large, expensive processing sequence which must run essentially continuously for satisfactory operation. The bitumen upgrading section, especially, cannot tolerate frequent shutdowns. Reliability of feed, both summer and winter, takes on added importance because the daily quantities are so large as to rule out extended storage. Some compromise between cost and reliability is necessary - particularly in the early years of operation.

Various types of mining equipment have been proposed for the tar sands and most combine advantages and disadvantages. Among the types of equipment which have received serious consideration are bucket-wheel excavators, bucket ladder dredges, draglines and scrapers. The first three schemes are capital intensive whereas the scraper scheme is labour intensive.

The existing tar sands operation elected to install two large bucket wheel excavators for mining the tar sand. Where the feedstock is relatively uniform, the wheels offer the important advantage of providing a continuous flow of mined material, fairly well sized for conveying and feeding into the extraction process. It is understood that they have problems in mining hard layers of siltstone, which occur throughout the ore body, and reportedly, in contending with frozen material[3]. (Indeed, any tar sand mining scheme to be successful in the winter months has to mine at such a rate that the excavation is faster than the rate of frost penetration). These machines also have some difficulty in maneuvering. Because of the high cost of downtime associated with both scheduled and unscheduled maintenance, it is necessary in the case of a two wheel operation that each have essentially 100% capacity.

Dredges, to be practical, probably would have to contain a portable extraction facility. To the extent that the tar sand could be successfully extracted on the barge, and the tailings deposited behind in the mined out area, this scheme appears of interest. However, the dredges would be relatively unselective and might have trouble contending with the hard layers. Providing the high requirements of heat to a portable facility would be difficult, and steam arising from the pond surface could prove troublesome.

Draglines are employed in a large number of strip mining operations in North America. They have a high degree of on-stream availability and would appear to have lower maintenance costs than other equipment. Progressively larger machines are becoming available; for example, a giant walking dragline carrying a 220 yard bucket is currently starting operation in Ohio. Provided the formation geometry is such that a freecasting stripping operation can be employed, the dragline offers many advantages in cost, selectivity and reliability. Its chief disadvantage in tar sand mining would be the difficulty in transferring material smoothly from the huge bucket to the transportation system. This problem can be resolved in practice, but it will be of considerable concern in a startup operation.

Scrapers would appear to be ruled out because of their higher labour requirements; however, they offer a number of attractive features, particularly in the initial critical start-up years[4]. The capital cost is relatively low, additional machines could be obtained on short notice, and because of the multiplicity of units required, an uninterrupted flow of feed material is more assured with this mining method than with any other considered.

In addition, there are two other key advantages. Machines could be digging from all depths of the formation simultaneously which would have an averaging effect on the feed quality and eliminate extreme variations in bitumen and fines content; this, in turn, would have beneficial process implications. Also very important is the ability of scrapers to selectively mine thin sections of poor quality material and reject this with the overburden. Scrapers and draglines were the most selective of the systems studied.

While there are advantages to utilizing the scrapers in both the overburden and tar sand since the scrapers from the overburden fleet could be used to supplement the mining fleet on short notice due to emergencies, or during the winter months when normal digging rate is slower, scrapers are not ideally suited for overburden removal. Some of the layers of the overburden are water laden, and scrapers are prone to get mired in this type of material. Also, some of the sandy material leads to traction difficulties and dead loading problems. Abrasive rocks contribute to high tire wear.

Extraction Considerations

Extraction and the subsequent froth cleanup units must provide an assured uniform feed to the upgrading units. As such, they have to absorb all the variability of the tar sand formation and the mining operation. This is accomplished partly by unit design and partly through the provision of intermediate storage capacity between extraction and bitumen upgrading.

Many schemes have been suggested for extracting bitumen from the tar sands. Because of the relative ease with which the coarser sand particles can be separated, a large number of basement inventors, as well as the major oil companies conducting tar sands research, have proposed processes to achieve this extraction. A number of the more promising approaches have been actively investigated by Syncrude, and while many will perform satisfactorily on good quality material, most break down when contending with some of the poorer quality, high fines content feedstocks. To the present time it appears that extraction schemes based on adaptations of the hot water process, pioneered by the late Dr. Karl A. Clark of the Alberta Research Council[6], offer the most assurance for near-term application.

Figure 5 shows the percent bitumen recovery normally obtained from tar sands of various qualities. Most rich sands process well but the leaner material gives a wide response. The variation occurs because of changes in the tar sand characteristics such as the fines content, the polyvalent metal ions content, the pH, the degree of oxidation, etc. And, of course, the type of separation equipment and the operating conditions employed are important. For any given tar sand, it is usually possible to raise the recovery through the choice of operating conditions, such as lowering the feed rate, through the addition of chemical re-agents, and through the addition of more flotation equipment, with its attendant froth cleanup units. Thus, the optimum conditions for processing tar sands of different grades vary, and it is necessary that the process as installed has enough flexibility to cope with the anticipated variations in feedstock quality.

Tar sands from the Beaver Creek area generally tend to process well, particularly in comparison with material from the east side of Lease 17 lying to the south of Mildred Lake, and identified on the graph as Mildred Lake trough material. Extracting tar sand from these two areas, using the same equipment under relatively similar operating conditions, produces results somewhat as illustrated by the two curves. The black dot on the Beaver Creek curve is the average recovery point on which Syncrude based its commercial application to the Conservation Board.

In our discussion of the nature of the deposit we referred to the fact that fines have a detrimental effect on the process, and we pointed out in Table I how the application of selective mining could improve the feed quality. The fresh water usage is dictated to a large extent by the concentration of fines in the feedstock. Some information on this subject was presented to the Seventh World Petroleum Congress by Innes and Fear[7].

As the feedstock quality is improved and the feedstock quantity is reduced by raising the selective mining cut-off point, not only is the amount of clarified water needed to satisfy the process lowered, but, equally significant, the amount of heat required to maintain the optimum temperature becomes less. Upgrading the tar sand feed can cut the extraction unit heat requirement to less than one half, as indicated in Figure 6. Since, for a project of this size, the BTU's are numbered in the billions per hour, this is an extremely important consideration.

Tailings Disposal Considerations

One of the unfortunate aspects of a water extraction process is that the fines in the plant effluent tend to settle very slowly and the resulting sludge does not compact to a very great degree, except over long periods of time. Therefore, the disposal of the tailings and middlings streams require serious consideration in the design and layout of any tar sand facility.

Table III relates the tailings pond requirements to the cut-off point of the feed. It is proposed to discharge the sand tailings hydraulically into this pond for the first four years of operation only -- after that time they would be returned to the mined out area. However, the pond would be used for sludge deposition and water clarification throughout the life of the project.

TABLE III

Tailings Pond Requirements VS Cut-off Point of Feed

Cut-off Point of Feed, % Bitumen	Relative Settling Area	Relative Retention Volume	Relative Dam Size
0	1.43	2.21	2.78
2	1.15	1.53	1.80
4	1.07	1.08	1.27
6	1.00	1.00	1.00
8	.91	.72	0.63
10	.84	.59	0.50

The settling area required to achieve clarification varies in proportion to the circulating water load, which in turn, is a function of the fines concentration and the feed rate. Over the range of cases studied the relative area requirements vary from .84 to 1.43. The volume requirements of the disposal basin are even more sensitive to changes in the cut-off point; here we have almost a four-fold difference. For any given mining site, the disposal problems will be unique to that area. The dam size referred to in this table assumes that it is necessary to contain the tailings by artificial means and that no natural settling basin exists. The size of the dam required is influenced by both settling area and sludge retention needs. When these are combined the effects of fines on disposal basin size are obtained.

Assessment of Feed Quality Effects

In the preceding sections, the penalties associated with the charging of low bitumen -- high fines content feedstocks have been discussed. Briefly restated, this poorer quality tar sand adversely affects the mining rate, the size of the extraction facilities, the heat requirements (which partially govern the size of the boiler plant and its fuel consumption), the process water and tailings pumping loads, the size of the disposal basins, and the size of tankage to provide surge between extraction and bitumen upgrading.

The effects of feed variability are shown in Figure 7. All capital costs, as well as the operating costs incurred by the various cases during the first 20 years of operation, were estimated, and then discounted by the use of an appropriate factor to a present worth basis. As shown, raising the feed cut-off point, through the application of selective mining, improves the economics over the entire range of cases studied. Syncrude based its request for a commercial permit on a 6% cut-off point. While not optimum from the economic standpoint, it **avoids** most of the penalties imposed by the inclusion of low grade material and, as shown in Table II, is still consistent with good conservation practice.

Froth Treatment Considerations

Bitumen is recovered from the hot extraction process in the form of a froth containing fairly high percentages of water and solids which range in particle size from sub-micron clay to 100 mesh sand grains. Before the bitumen can be upgraded to synthetic crude it is necessary to remove the bulk of the mineral contaminants from it. Kaminsky and Nagy presented a summary of the methods that have been proposed for beneficiating the froth stream[1].

The approach initially followed by most researchers is to dilute the froth with a light solvent, such as naphtha or kerosene, and settle the water and solids from the diluted mixture. While prolonged settling will generally produce a low solids, low water content diluted bitumen, for many grades of tar sands the losses of oil to the sludge stream through solids-stabilized emulsions are intollerably high. A large number of chemicals have been investigated in an attempt to improve this operation, and also electrostatic techniques have been applied. The results generally have been unsatisfactory.

One positive method of cleaning the diluted froth stream is by centrifugation and this was the route selected by the existing operation. Not only is the water content reduced but solids of quite small particle size can be removed without too excessive losses of oil to sludge. A solvent recovery unit is a necessary adjunct.

Another positive approach for removing water is to thermally distill it from the froth. With this approach it is necessary to insure that the variation in froth water content is not greater than the capability of the distillation equipment to remove it. An intriguing prospect with the dehydration route is the high degree of thermal efficiency which can be achieved. The water boiled off the froth in the form of steam can be utilized directly in the hot water extraction process, which has a large requirement for low level heat. To effect the distillation, the heat required can be imparted through direct fired furnaces or through heat exchange with exhaust steam from the power plant turbines.

While thermal dehydration removes the water, it does not in itself lower the solids content, and it is necessary therefore, with this approach to ensure that the froth is of a relatively low solids content, or that an additional solids reduction step is incorporated. The degree of solids reduction that is actually required is an important froth treatment consideration since this decision may affect process selection. Certain upgrading processes, such as fluid coking and H-Oil hydrocracking, use a fluidized or ebullating solids principle and are able to tolerate a somewhat higher percentage of fine solids in the bitumen feedstock than other upgrading processes.

Thermal dehydration of froth will require additional pilot scale development before it can be employed in a commercial operation.

Bitumen Upgrading Considerations

Bitumen, as it exists in the tar sands, is a black, asphaltic material, which is heavier than water. It contains almost 5% sulphur, more than 1% oxygen and about 0.4% nitrogen. In order to transport it to market it is necessary to convert the heavier ends to lighter fractions which are more readily pumpable. It is also desirable that the final products be relatively low in sulphur and other impurities and that any unstable compounds be saturated. Most of the upgrading sequences proposed for the tar sands include, therefore, a primary conversion step and a subsequent hydrotreating step, along with attendant processes such as vapour recovery, sulphur recovery, and hydrogen generation.

Figure 8 shows the gross yield of 1000^{o}F end point distillate which can be obtained from bitumen by various forms of processing; it also shows the amount of bitumen required to produce a barrel of distillate at the conversion levels achieved by the different processes. The figure ignores, for each of the processes considered, the amount of gas produced; gas has value as a process heater fuel and as feedstock for hydrogen manufacture. Nor has any allowance been made for any liquid fuel that may be consumed in the process or in producing hydrogen.

The initial boiling point of bitumen varies from slightly under 400^{o}F to about 500^{o}F. Only a portion of the virgin distillate -- representing about 20 vol.% of the bitumen -- can be recovered by atmospheric distillation; the bulk of it -- about 30% on bitumen -- consisting of heavy gas oil, requires the use of vacuum.

Thermal visbreaking is a relatively inexpensive conversion process. Because of the ease with which Athabasca bitumen can be thermally cracked, visbreaking can be employed to reduce the amount of residual fraction to about 30 wt.%; however, this still is considerably in excess of the amount required for plant fuel purposes. Therefore, visbreaking would be employed only if a good local market existed for the surplus fuel, or there were an application, such as in situ recovery of bitumen, where large quantities of steam were required to heat up the tar sand formation. Shell Oil, in their 1962 application for a commercial permit, proposed a thermal visbreaker as their primary conversion step; they estimated that 35 wt.% of the recovered bitumen, in the form of visbreaker pitch, would be consumed as fuel in the in situ recovery - thermal visbreaking operation[8].

The coking processes, delayed and fluid, can decrease the amount of residue produced, by converting it to coke -- a solid fuel. Under coking conditions the residual can be reduced to the order of 18-25 wt.% of the bitumen; about 78-80 vol.% of debutanized distillate is produced.

To lower further the residual yield it is necessary to resort to the addition of hydrogen. A somewhat unique H-Oil hydrovisbreaking process has been developed which can successfully reduce the amount of bottoms to as low as 6 wt.%. As described by Rapp and Van Driesen, the processing method requires less severity than most other H-Oil applications[9].

The hydrovisbreaking process consumes only a modest amount of hydrogen over most of the range studied, as can be seen in Figure 9. As would be expected, as the yield of bottoms is reduced, the quality of the unconverted hydrocarbon becomes poorer and the incremental hydrogen required to achieve additional conversion increases.

From economic calculations it appears to be feasible to decrease the bottoms yield to as low as 13-15 wt.%. Incentive to save heat, through integration of processing units, is thereby provided to that level of fuel production; simultaneously, lower capital investment and operating costs would be achieved through integration, and additional conservation of bitumen would result. Syncrude, therefore, believes that hydrovisbreaking is a preferred upgrading approach.

With widespread adoption throughout the petroleum industry of first, hydrotreating, and now hydrocracking, a great deal of effort is being put into search for ways to lower the cost of producing hydrogen. Any industry success in this area would be of benefit to the hydrovisbreaking approach.

Additional comparison of upgrading processes are made in the paper, Athabasca Bitumen High Conversion to Synthetic Crude (included in Volume II).

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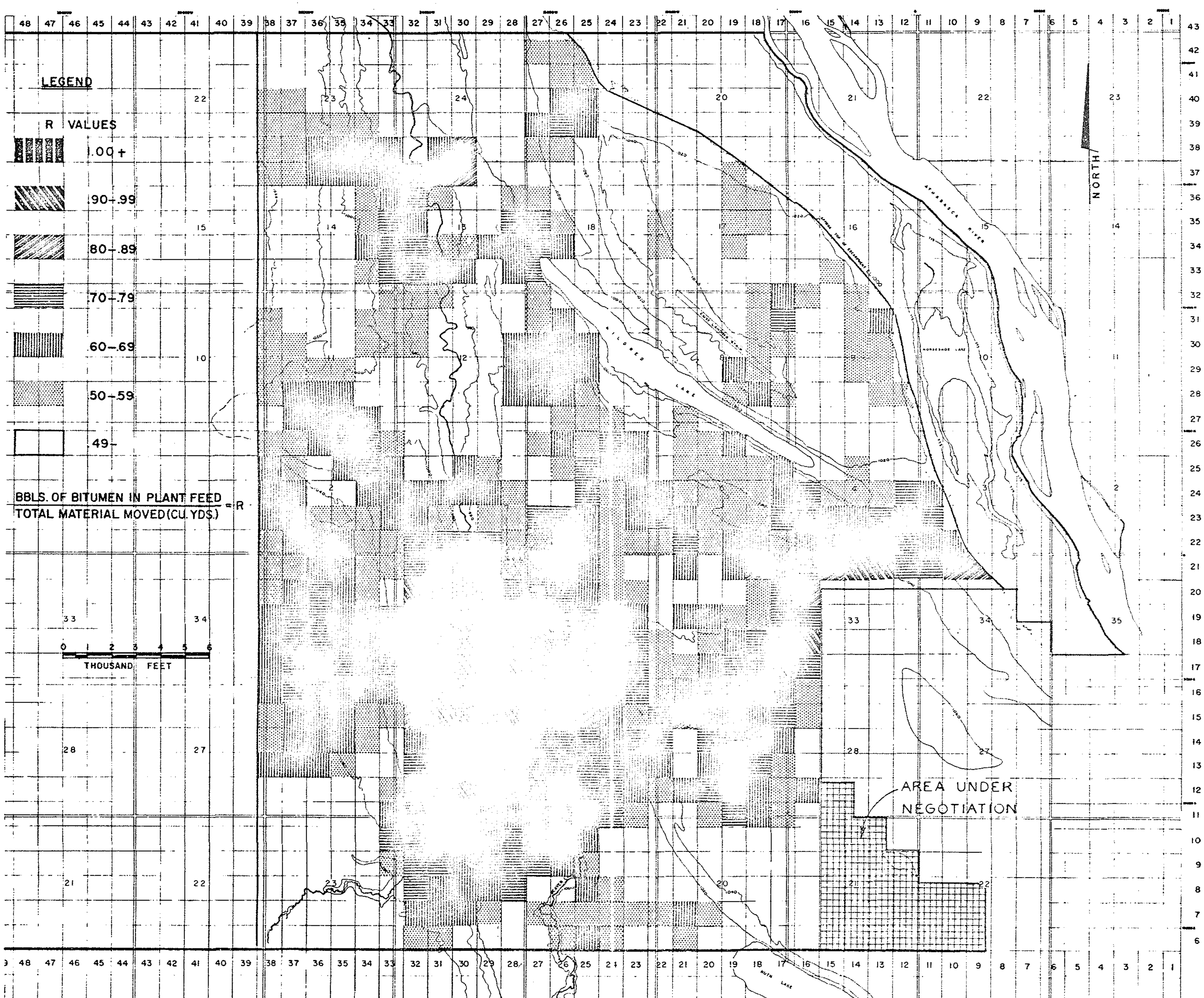


QUALITY OF RESERVES Figure 1

FIGURE 2

DISTRIBUTION OF TOTAL BITUMEN IN FORMATION

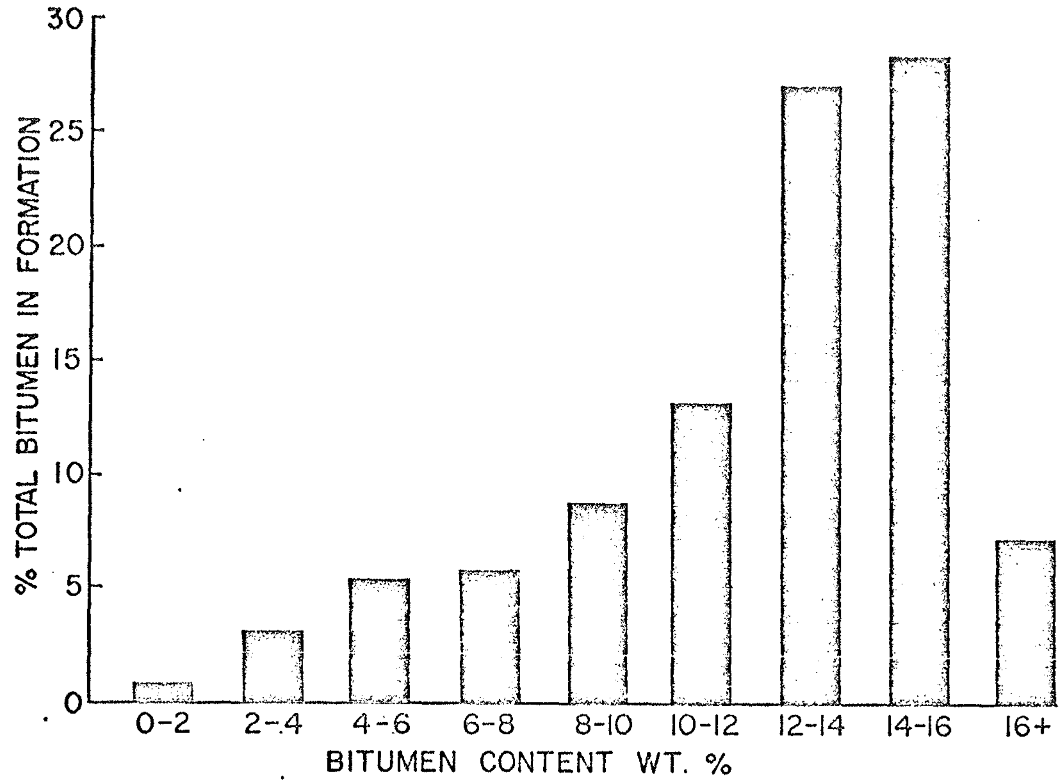


FIGURE 3

DISTRIBUTION OF TOTAL FINES IN FORMATION BY GRADE OF TAR SAND

INITIAL MINING AREA

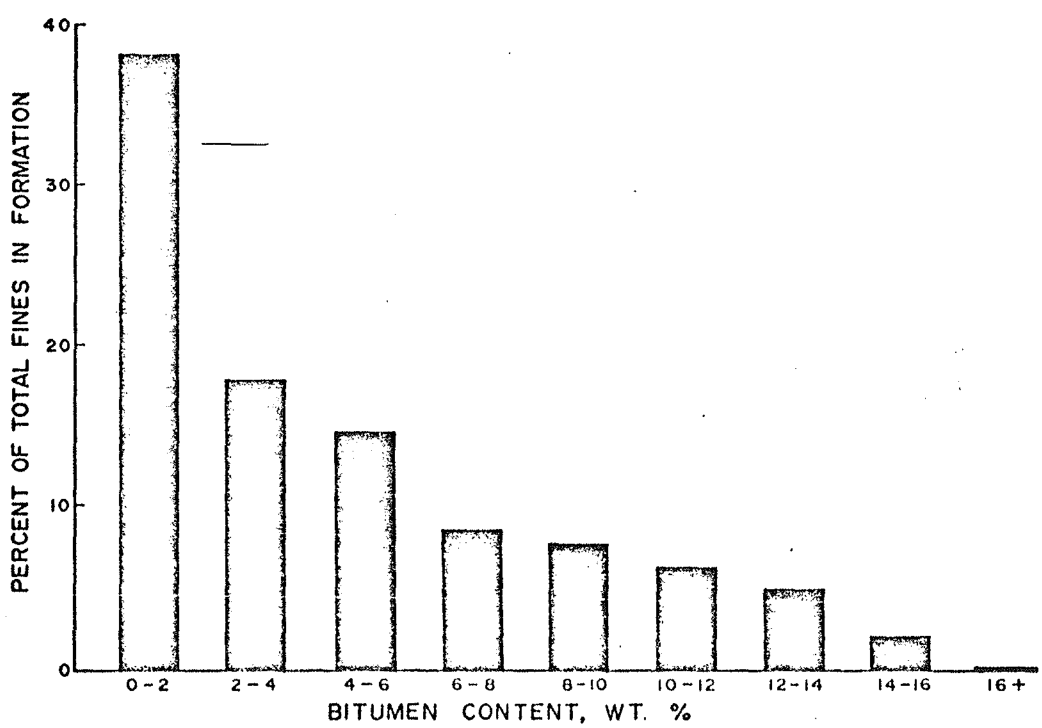


FIGURE 4

TAR SAND FINES AND WATER Vs % BITUMEN

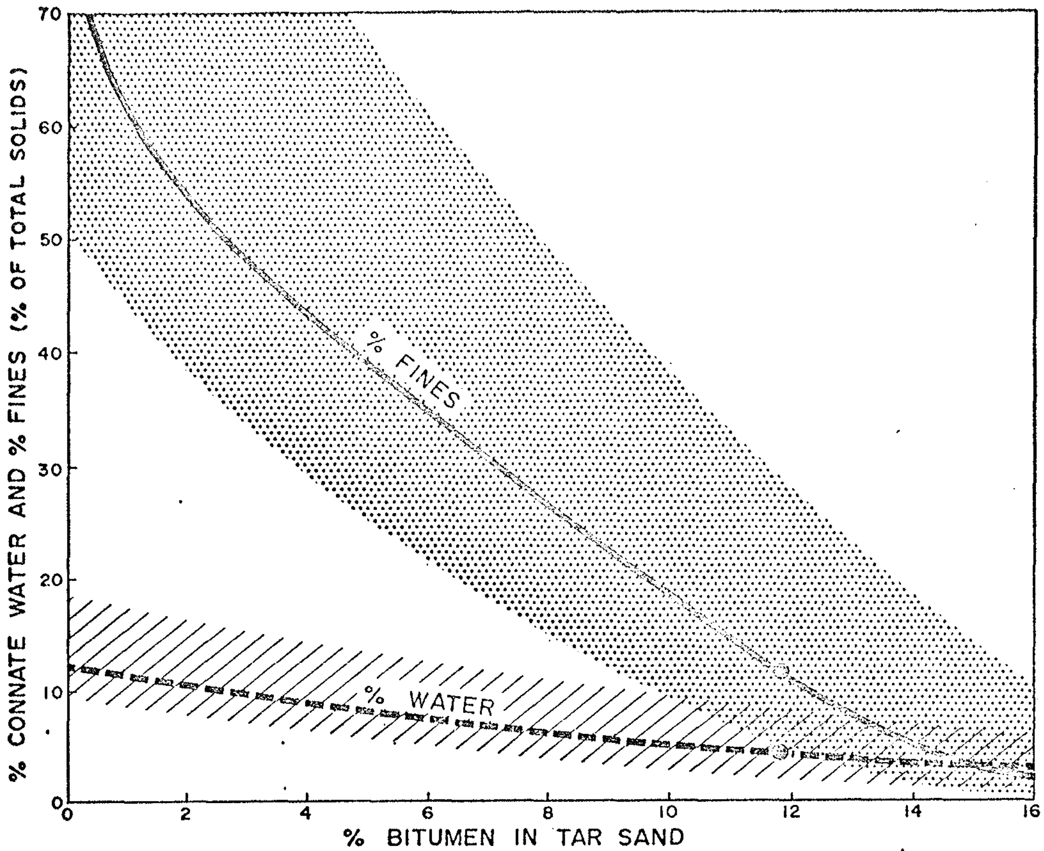


FIGURE 5

RECOVERY Vs BITUMEN CONTENT

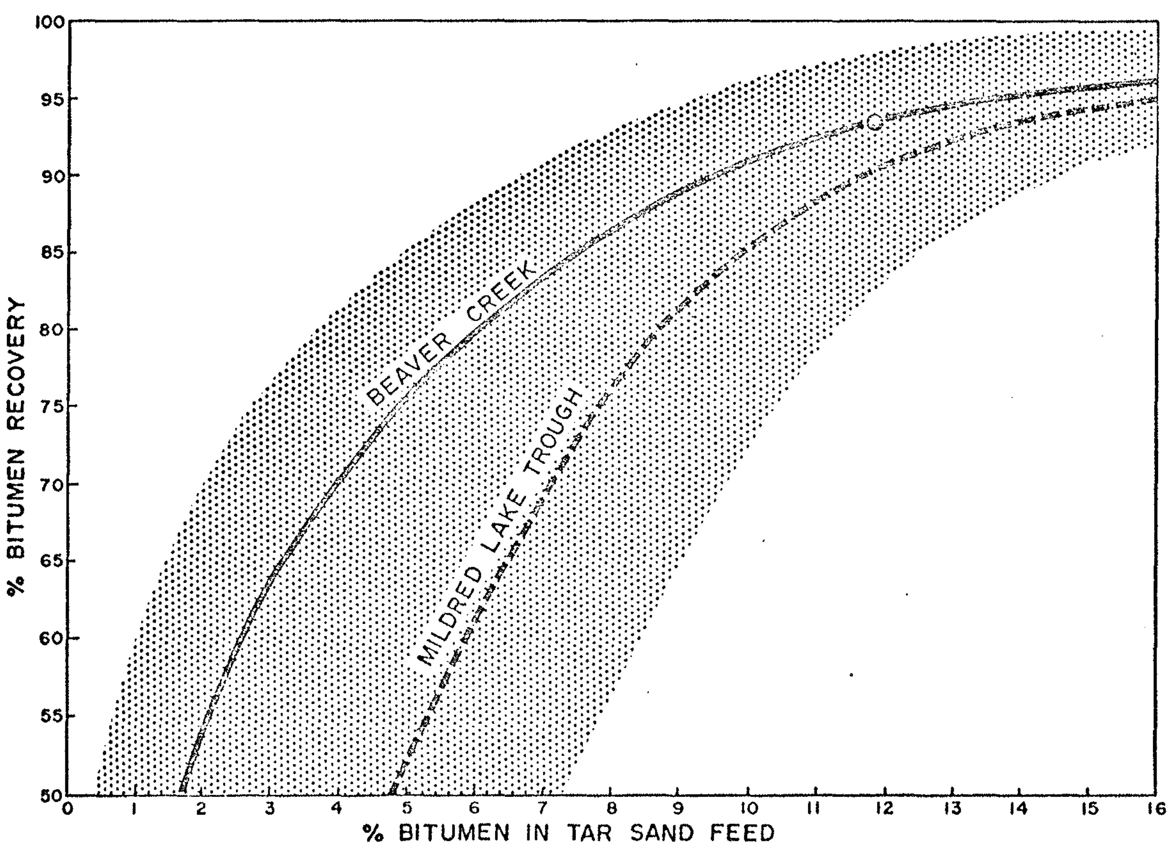


FIGURE 6

EFFECT OF SELECTIVE MINING ON EXTRACTION HEAT REQUIREMENTS

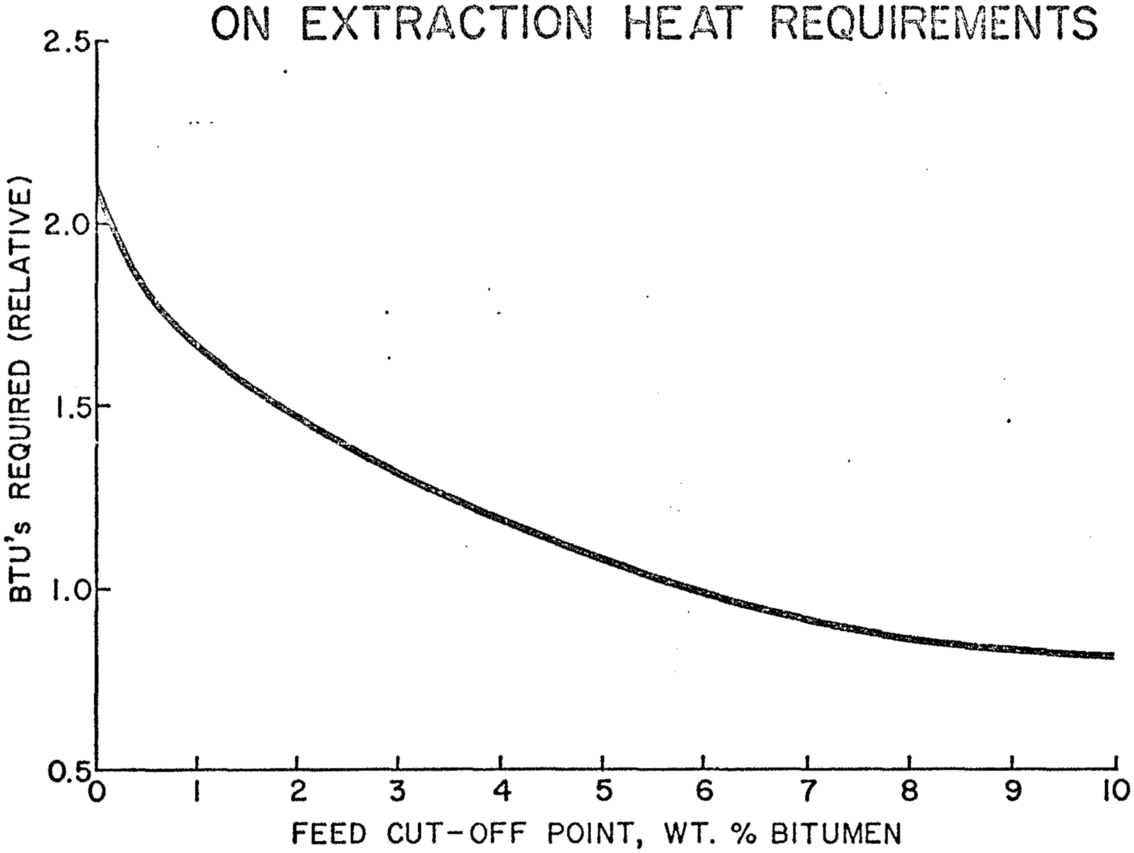
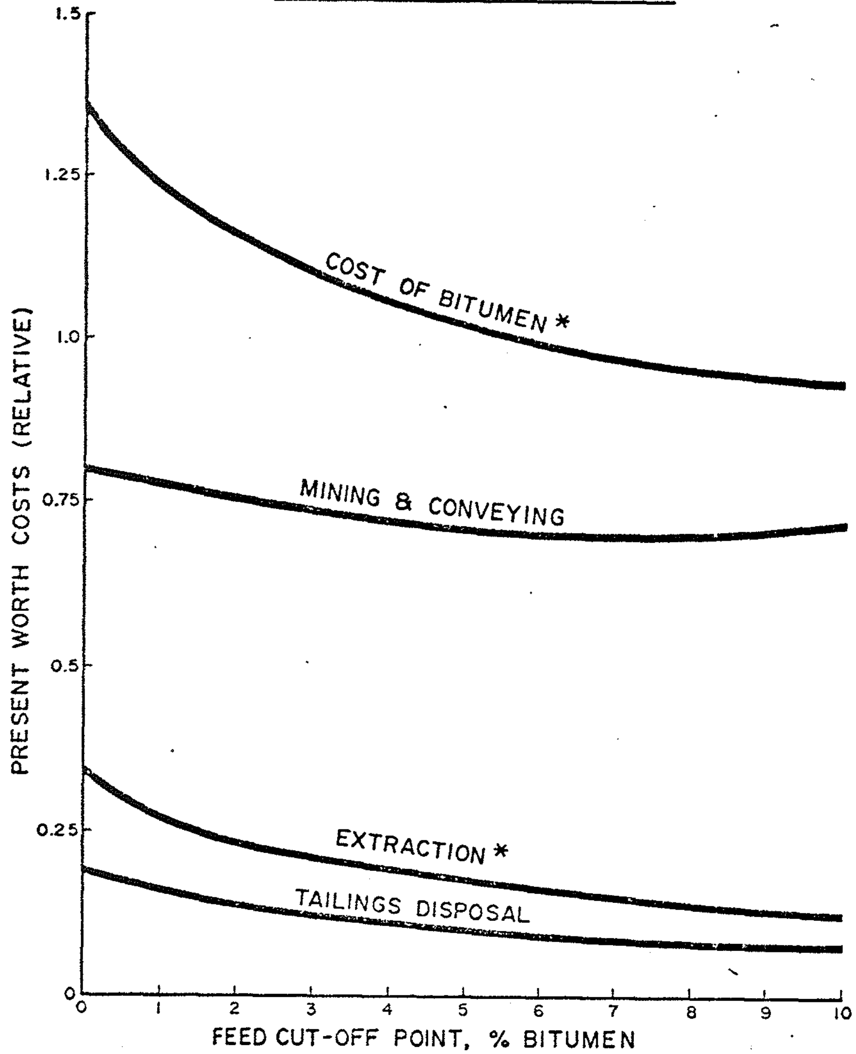


FIGURE 7

EFFECT OF SELECTIVE MINING ON PRESENT WORTH COSTS



* Excludes froth treatment costs

FIGURE 8

DISTILLATE YIELD Vs CONVERSION LEVEL

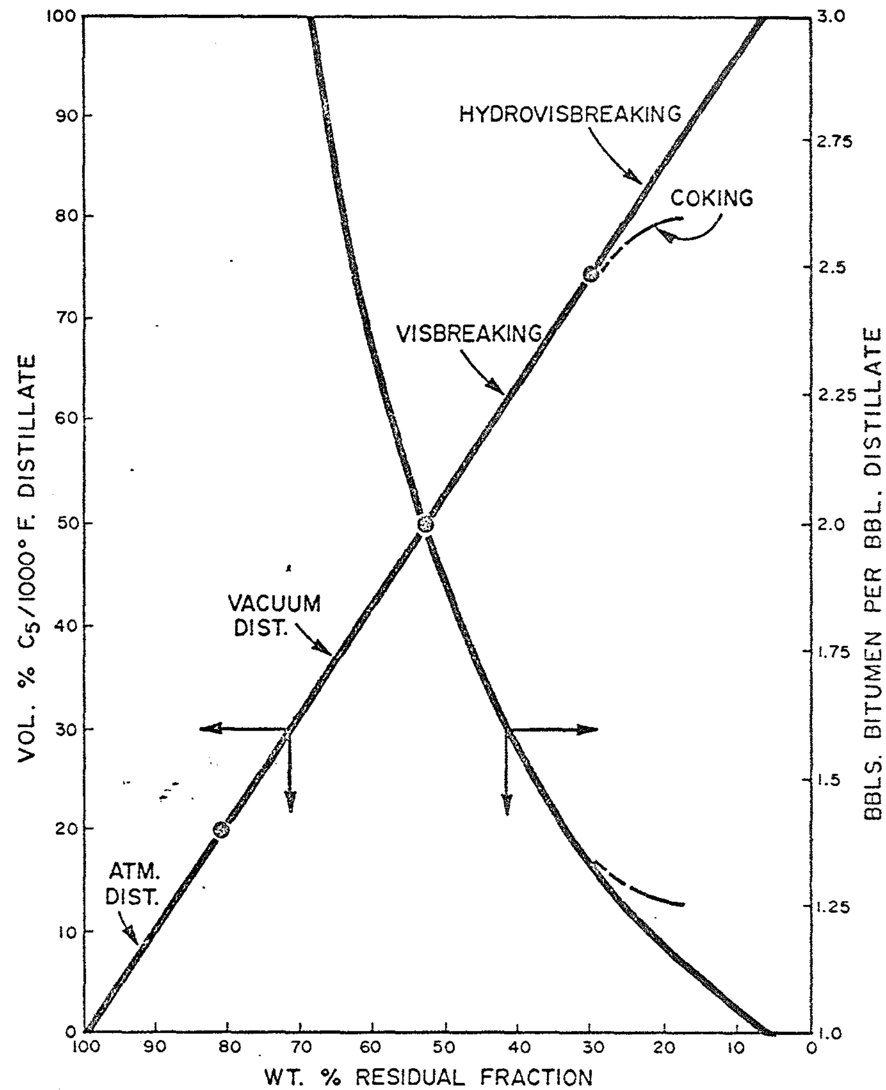
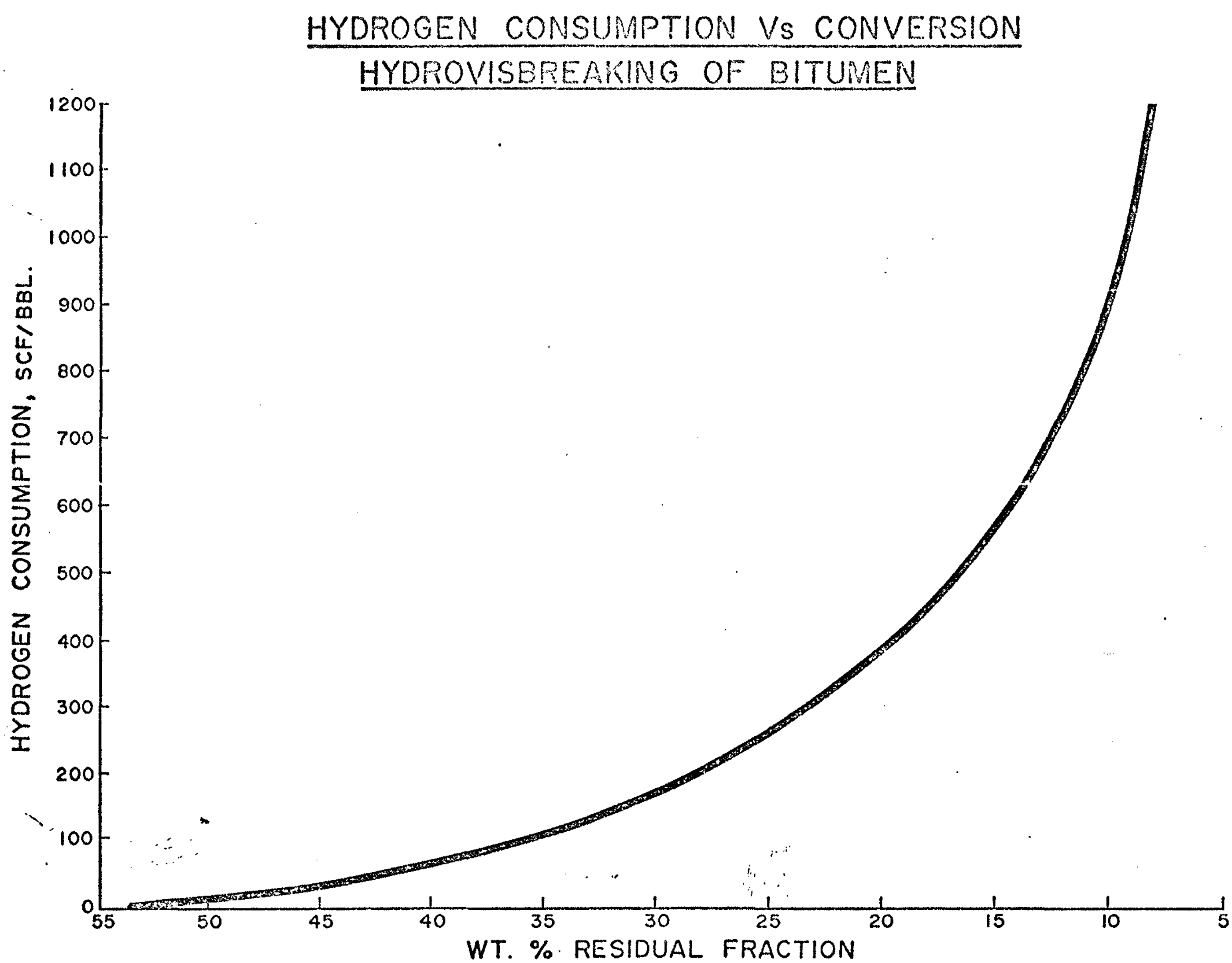


FIGURE 9



HYDROGEN CONSUMPTION Vs CONVERSION
HYDROVISBREAKING OF BITUMEN
HYDROGEN CONSUMPTION, SCF/BBL.
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
55
50
45
40
35
30
25
20
15
10
5
WT. % RESIDUAL FRACTION

SECTION 3

RESOURCE DEVELOPMENT

D. PLANT DESIGN AND EMISSION INFORMATION

Plant Area

The locations within the plant area are tied into a coordinate system. The coordinate system 0-0 point is the N.E. corner of Section 33, Township 92, Range 10, West of the Fourth Meridian. This point is on the Twenty-Fourth Base Line.

The location of the plant site, property boundaries and topography of the plant are is shown on Drawing IR-sk-A-101-D attached and labeled Figure 1. This drawing is preliminary and will be subject to minor revision during detailed engineering.

Buildings and Equipment used in Manufacturing

The exact location of buildings, equipment used in manufacture, water lines, etc., has not been determined at this time. This information will become available as detail design progresses. Figure 2, however, shows the plant layout as presently conceived. Tentative location of all buildings are shown except for the following building which will be located off the main plant site:

1. Mining area offices and maintenance shops.
2. Athabasca River water pumphouse.

All buildings except the central control house will be of steel frame construction with aluminum siding. All will be insulated and all will be steam heated with process steam, except for the office-warehouse-shop complex, which will have its own separate heating system.

The control house will be of reinforced concrete blast-resistent construction, will be pressurized, and air-conditioned.

Advantage has been taken of the existing topography in the area to insure that drainage from the plant and storage areas will be contained on the lease. It should be noted that from the plant site which is at 1,000 feet, the surface elevation rises to the east to 1,030 feet and to the west to 1,050 feet. The containment area will be bounded on the north by the low dam of the retention pond and on the south by the mining area dyke.

General Description of Plant and Processing

Description of Plant and Mine Site at Present

The plant and mine site straddles the Beaver Creek Valley. This valley is shallow and generally slopes gradually to the north and east toward the Athabasca River.

The plant and mine site itself consists of a series of low ridges. The ridges themselves are fairly dry and have some small spruce and poplar. The low spots between are covered with brush and muskeg. The muskeg depth varies from zero to as much as fifteen feet, with an average depth of three feet over the site.

The timber in the site area is not of marketable size.

The surface soils are basically of glacial origin; sand, clay, and gravel with some shale and sandstone lenses. This material overlays the tar sand orebody which in turn overlays limestone of Devonian age.

The overburden averages about 100 feet of surface material and lean tar sand. The tar sand is not uniform in quality throughout the section, with the variations in quality being bitumen content, and the ratio of sand to clay. The tar sand takes the form of a brown to a black sand-like material that is obviously bituminous in nature. The individual particles generally consist of a sand ore surrounded by films of water-clay and bitumen (tar).

Mining

The removal of the overburden and mining of the tar sands will be carried out by large excavators with the aid of auxiliary equipment. The overburden will be put into the mined-out area of the mining pit; and the plant feed tar sand will be put in piles on the opposite side of the pit.

The plant feed tar sand will be reclaimed from the piles with excavators with the aid of front-end loaders and bulldozers.

The reclaimed material will be conveyed to a dump pocket where the tar sand will be automatically dumped. The tar sand will be conveyed from the dump pocket to the separation plant.

Separation of Bitumen from Tar Sand

The bitumen will be separated from the tar sand by thoroughly mixing the sand with hot water and steam in a rotating drum. The resulting slurry will be screened to remove reject material, and the coarse sand and smaller particles will be settled out in two steps of settling; washing and froth flotation. The resulting froth will be a mixture of bitumen, water, and fine clays.

The froth is a very viscous material of about the same density as water and will be diluted with naphtha to reduce the viscosity and gravity for separation of water and fine solids.

The diluted froth will be fed to two stages of centrifuges where the water and solids will be taken off as one stream, and the diluted bitumen as another.

Tailings and Sludge Disposal

Tailings from the extraction plant will be transported hydraulically. Initial disposal will be to a settling pond where the tailings are deposited behind a retention dam. The downstream side of the tailings pile assumes the natural angle of repose. This procedure assures permanent stability of the tailings pile regardless of the percentage of fine material co-deposited.

The sand tailings will be disposed of in the retention pond for the first 3 years. After the mining has advanced sufficiently, the tailings will be deposited on top of the windrows of overburden. The water, containing fines, drained from the sand tailings deposited in the mined-out areas, will be pumped to the retention pond for clarification and recycle to the plant.

Eventually the waste material deposited in the area occupied by the retention pond will be excavated. The sludge, the initial sand tailings, and the overburden covering the tar sand will be deposited in a mined-out area.

Upgrading of Bitumen to a Saleable Product

Crude bitumen is a dense tarry substance that has practically no use except perhaps for road surfacing. As a fuel, it contains so much sulphur that it would present a substantial air pollution problem, and it cannot be converted into lighter materials such as household fuel oil or motor fuel without additional processing.

The additional processing of bitumen to upgrade it to a useful material will be done in two stages:

1. Cracking or breaking up the bitumen molecules to form lighter materials with the available hydrogen content of the bitumen, and converting the excess carbon from this operation into coke. This thermal cracking will be performed in fluid cokers. The term 'fluid' means that a gas (in this case steam) is added to a continuously circulating bed of fine coke particles in such a manner that the fine particles flow like a liquid.

2. Hydrotreating the distillate streams from the fluid coking operation to:

(a) Stabilize substances that do not have enough hydrogen and thus tend to combine with each other to form gums and other undesirable materials.

(b) Reduce the sulphur and nitrogen content to the required level for blending into a synthetic crude.

The synthetic crude oil is a blend of the hydrotreated liquids. It requires further processing in a conventional oil refinery in order to make motor or household fuel. A pipeline will be built to Edmonton for transportation of the synthetic crude oil to conventional markets.

The gaseous streams (light hydrocarbons) from the fluid coking units and hydrotreating units will be processed to remove hydrogen sulphide. The concentrated H_2S stream, along with gas from sour water stripper, will be fed to a sulphur plant for sulphur recovery. The light hydrocarbon vapours leaving the H_2S removal unit are fed into the plant fuel gas system which will be supplemented as required with natural gas. Natural gas will also serve as feed to the hydrogen plant.

The fluid coker units also produce a low BTU gas which will be fired in special boilers commonly known as CO boilers. These boilers will supply part of the steam requirement in the processing areas.

Utility Plant

A central utility plant will supply the electric power, steam and boiler feed water for the overall complex using gas from the main plant fuel gas system. In order to maximize the fuel efficiency, the utility plant will employ a combined gas turbine-steam cycle. The exhaust from gas turbine generators will supply hot combustion air to the boilers. High-pressure steam from the boilers will be used to drive back pressure turbongenerators, and the low-pressure exhaust steam will be used for process heat requirements.

Flow Diagrams and Material Balances

Figures 3 and 4 show the flow diagrams and material balance for the processes involved in extracting bitumen from tar sand. Two cases are shown, one for the initial design and one for the ultimate design.

Overall bitumen and sulphur balances for initial and ultimate design are shown in Tables 1 and 2.

IDENTIFICATION OF TOXIC MATERIALS AND ODOROUS COMPOUNDS

The following materials contained, manufactured in, or emitted from the tar sands process are as follows:

1. Ammonia, recovered or incinerated.
2. Hydrogen sulphide, recovered or incinerated.
3. Mercaptans, converted to hydrogen sulphide.
4. Nitrogen oxides, emitted with stack gases.
5. Sulphur dioxide, emitted from main stack.
6. Phenols, disposed of with sour water which will be recirculated.

SIZE AND CAPACITY OF AIR POLLUTION CONTROL EQUIPMENT

Central Plant Stack

A single stack will be provided for the release of gaseous contaminants to the atmosphere during normal operation. The streams will include:

1. The flue gases from the utility plant boilers and gas turbines.
2. The sulphur recovery plant off-gases which are incinerated in the burner section of the CO boilers.
3. The effluent from the CO boilers subsequent to passing through the electrostatic precipitators for particulate removal.

Air quality studies, Volume IV, Section 4 have been based on these design concepts.

The stack will be 600 feet in height and will be of reinforced concrete construction with an independent steel liner.

The design stack gas exit velocity is under consideration at this time, but in no case will the velocity be less than 60 feet per second.

The gases will exit the stack at a temperature not less than 450°F. This temperature is based on a reasonable operating minimum for CO boiler exit gases at 500°F and utility plant gases at 450°F.

The stack height is based on an emergency operating condition: burning the feed to one sulphur plant in the CO or utility boilers. It can be seen from the stack gas calculations included in Appendix I, that this condition will result in a calculated SO_2 ground level concentration on the order of 0.1 ppm. Under normal operation, the calculated ground level concentration will be less than 0.04 ppm. Flaring of sulphur plant feed is not contemplated except for the period (estimated to be less than two hours) required to introduce this stream to the CO boilers and utility boilers. Stack monitoring instrumentation is listed in Appendix II.

Flare Stacks

Two flare stacks will be provided, both 235 feet in height. One stack will handle hydrocarbon streams, the other the low pressure hydrogen sulphide streams.

Both flare stacks will be equipped with automatic igniters, continuous pilots, bottom liquid knockout drums, carburetion gas and steam connections.

Flare knockout drum liquid will be returned to the coker feed or to the sour water stripper system.

Sour Water Strippers

Two sour water strippers will be provided, each having capacity to handle 150,000 lbs. per hour of sour water, approximately 2,800 lbs. per hour of hydrogen sulphide, and 1,200 lbs. per hour of ammonia.

The hydrogen sulphide will be fed to the sulphur recovery plants. Ammonia that is recovered will be sold or used for various plant purposes. Any unrecovered ammonia remaining in the hydrogen sulphide will be decomposed to nitrogen and water in the special sulphur recovery plants.

Sulphur Recovery Plants

The two sulphur recovery plants will be designed for a nominal capacity of 470 long tons per day each. They will be designed for the maximum recovery possible with three catalytic stages, using the most effective catalyst available at the time of start-up.

Service factor has been a problem in refinery-type sulphur recovery plants. We feel that this problem is primarily due to catalyst inactivation by ammonia. This problem will be alleviated by:

1. Removal of the bulk of the ammonia from the acid gas stream from the sour water stripper as mentioned above.
2. Water washing of the DEA acid gas stream to remove traces of ammonia.

The sulphur plant technology proposed is believed to be the best available at this time. A recovery efficiency of 95%, the maximum that we are confident of obtaining on a consistent basis, has been approved by The Department of the Environment. A discussion of receovery efficiency is given in Appendix III attached to this application.

CONTROL, TREATMENT, AND RELEASE OF AIR CONTAMINANTS

Gaseous wastes will be controlled as follows:

1. Safety valve and all gaseous vents that could contain hydrocarbon or noxious gases will be vented to the flare headers. Liquids from the flare knockout pots will be recycled to process. No continuous flaring of any substance is comtemplated.
2. Sulphur dioxide which results from catalyst regeneration will either be vented to the main plant stack or in the case of the hydrotreaters, will be absorbed in caustic.
3. All streams bearing hydrogen sulphide will be scrubbed to less than 10 grains per 100

SCF using DEA scrubbing.

4. Evaporation losses from tankage will be controlled by vapour recovery or by floating roof tanks as applicable, where the vapour pressure of the contents is more than 3 and less than 12 lbs. per square inch, absolute.
5. Any product having a vapour pressure of more than 12 lbs. per square inch absolute will be stored in pressure storage.
6. Flares will be equipped with automatic igniters, connections for carburetion gas, and steam injection for smokeless flaring. The steam injection will be manually operated.
7. In the event of the temporary loss of one of the two sulphur plants, the hydrogen sulphide will be diverted to the main plant stack after burning in the CO or utility boilers. This will be preceded by a brief period of flaring to adjust furnace loads.

VARIATIONS IN RATES OF RELEASE OF CONTAMINANTS IN NORMAL OPERATION

It would be anticipated that the rate of release of contaminants to the air would not vary widely in normal operation. The various operations modes and their anticipated effects follows:

*One train of upgrading down, mining and extraction operation: Sulphur dioxide release cut in half, concentration of sulphur dioxide in main stack reduced to approximately 1200 ppm and ground level concentrations of sulphur dioxide reduce accordingly.

*One-half of entire operation down: Concentrations remain constant, emissions cut in half, ground level concentrations substantially reduced.

It will be noted that all calculations are based on the ultimate capacity of all equipment.

The feed quality will not vary greatly in sulphur content, which is the source of the main contaminant. The precise distribution of sulphur between gaseous products, CO boiler effluent, and process gases is difficult to ascertain in advance of operation, but conservative approaches giving the highest concentrations in the gaseous effluents have been chosen.

POTENTIAL FOR ACCIDENTS AND EMERGENCIES

Flaring of Entire Plant Effluent and Contents

The flaring of all the contents and products of the upgrading section of the plant would occur only in the event of a catastrophic failure of a major vessel, or in the case of a complete power failure. A temperature runaway in one of the hydrotreaters could cause flaring of the input and contents on a temporary basis. This latter is unlikely because of precautions taken in the processing. The details of these precautions cannot be divulged because of contractual secrecy agreements with other parties.

Partial protection against total electric power failure will be provided as follows:

1. Standby boiler and generators.
2. Connection with the provincial power grid.
3. Load shedding in the event of large power demands.
4. Dual feeders in many critical services.

SHUTDOWN OF SULPHUR PLANT

Short shutdowns of the sulphur plants will be handled by burning the acid gas in either the CO boilers or power boilers, with the sulphur dioxide discharged to the main plant stack.

We anticipate that shutdowns of the sulphur plant between annual overhauls will be minimal following the initial shakedown period due to the high quality of rotating equipment; and to the installation of protective systems ahead of the plants to minimize catalyst deactivation. The plants will be highly automated and will require a minimum of operator attention for the attainment of high yields.

FAILURE OF THE CO BOILERS

In the event of failure of a CO boiler, it will be necessary to vent the coker burner gases to an atmospheric stack in order to allow an orderly coker shutdown. While the gases are released as hydrogen sulphide and carbon monoxide, the temperature of release is on the order of 1100^{o}F., and we anticipate that these gases will ignite upon reaching the atmosphere. It will be noted that the point of discharge is over 220 feet from grade level and the exit velocity is extremely high.

WATER SUPPLY, USAGE AND DISPOSAL

General

The main source of water supply will be the Athabasca River. Smaller quantities will be obtained from drainage systems within the plant and mine site. Surface water external to the plant and mine area will be diverted to existing watersheds. It is proposed that Beaver be diverted at the south-end of the mining area. A separate application has been made for the diversion of Beaver Creek.

With the plant and mine site located in the Beaver Creek Valley, all surface drainage or runoff due to rainfall in the plant or mine area will be contained within the lease and will initially go to the tailings pond. This water will ultimately become part of the extraction water via recycle from the tailings pond.

No process water, mine water or plant drainage water will be discharged to present watersheds under the existing plan of operations. Should discharge of any water become necessary or desirable, it would be treated to meet all environmental standards and monitored in accordance with the standards of the Clean Water Act.

Water Supply

The general arrangement of water supply is shown in Figure 1 and a brief technical description given in Appendix IV. It will be noted that it is proposed to use Mildred Lake as a reservoir for fresh water supply to the plant, and that it is proposed to raise the level of the lake by approximately 15 feet so that fresh water will flow by gravity to the plant site. It will be further noted that water from the Athabasca River will go through a sedimentation basin prior to pumping to Mildred Lake.

The main purpose in using Mildred Lake as a reservoir is to ensure water supply to the plant in the event of any problems with the river intake and pumping station. A second reason is to avoid pumping water from the Athabasca River during the period of extreme turbidity during spring runoff. Measurements of turbidity on the Athabasca River indicate that the period of extreme turbidity lasts for only a matter of days.

Raising the level of Mildred Lake and providing a circulation of fresh water could well result in an overall environmental improvement of the lake itself. Appendix V contains a summary of a survey of Mildred Lake conducted by Renewable Resourves Consulting Service Limited in June, 1972.

Water Usage and Disposal

Figure 5 shows the overall water balance and disposal system for the Mildred Lake Project. It will be noted that all effluent streams go to the tailings pond (sludge retention pond in Figure 1. Figure 5 shows the conditions after about 5 years of operation when the main tailings stream from the extraction plant are diverted to the mined out area.

It should be noted that the net water accumulation in the pond for these conditions is approximately 5200 M LB/calender hour. After the main tailings stream is diverted to the mined out area, approximately 3400 M LB/calender hour will remain with the course tailings in the mined out area and the net accumulation of water in the pond will only be that water associated with the fine minerals (sludge). The water associated with the sludge will be approximately 1800M LB/calender hour and the total volume of the sludge will be approximately 36 M ft^3/hr. or approximately 315 MM ft^3/yr. Total pond volume is approximately

12,200 MM ft^3.

VARIATIONS IN RATES OF RELEASE

Rates of water usage and release shown in Figure 5 are based on all processing units operating simultaneously (LBS/stream hour). During the various shutdown periods less water would be used and released, and the yearly average would be less than the rate with all units operating. The yearly average rates are also indicated in Figure 5 (MMCFY)

POTENTIAL FOR ACCIDENTS AND EMERGENCIES

Accidental release of oil to process sewers from the upgrading areas will be receovered in the API separators. Accidental or emergency release from the extraction and froth treating plants is provided for with special dump ponds where any bitumen or "froth" may be recovered.

ENVIRONMENTAL CONSIDERATIONS

The lease on which the Syncrude tar sands development is proposed covers an area of approximately seventy-five square miles adjacent to the west side of the Athabasca River. The MacKay River flows through the western part of the lease and Beaver Creed flows through the eastern portion. Two lakes, Mildred Lake and Horseshoe Lake, are also included in the area of the lease. Habitat Type maps show that the lease contains eleven terrestrial and acquatic community types in a broad mosaic over the lease.

Fisheries Considerations

The fisheries of the MacKay River will not be directly affected by any of the operations presently proposed by Syncrude.

Beaver Creek will be directly affected by the tar sands development in Mining Area "A". Since the initial mining area and retention pond will straddle Beaver Creek, the stream will be eliminated in these areas. Beaver Creek downstream of the south lease boundary will be effectively eliminated, since most of the water from the upper reaches will be diverted to impoundments and released through Ruth Lake and Poplar Creek to the Athabasca River via canal and the Poplar Creek channel; and/or steep spillway. Small drainages entering the Mining Area "A" will be diverted north into the lower Beaver Creek. The Renewable Resources Consulting Service study of Beaver Creek (1971) rates the stream "marginal for Arctic grayling due to habitat restrictions". A 1973 study by R.R.C.S., concludes that the spawning population of grayling is highly unstable and competition from rough fish is very high.

There is no question that alteration of Beaver Creek and the following surface mining will radically change this area from an ecological standpoint.

Two lake areas also evaluated and sampled for fish are Mildred and Horseshoe Lakes. Part of Mildred Lake will be included in the retention pond while the remainder will be used as a settling and raw water intake pond for plant operations. Horseshoe Lake will not be materially disturbed as it is recognized as a key waterfowl staging habitat. These developments will not affect fisheries since Horseshoe Lake (per se) will not be disturbed; and Mildred Lake contains only a few small rough fish (chubs, etc.) and is presently not suitable habitat for game fish due to climatic and limnologic factors.

Waterfowl

Aerial and ground reconnaissance of Mildred Lake indicated that it would not be a significant producer of waterfowl. particularly "dabbling" ducks, such as mallards, pintails, etc. Emergent vegetation was limited to a thin band of sedge and some cattail. Surveys (Fall 1971 & 1972) indicate that the lake is used as a staging area for waterfowl in the fall. Research has been carried out seasonally (spring and fall) to determine the use of Mildred Lake, Horseshoe Lake and Ruth Lake by waterfowl during migration period. Anticipated fluctuation caused by the addition of freshwater should not cause any deterioration as a staging area for waterfowl.

Use of these lakes by waterfowl as staging areas could have serious implications with regard to the condition of the surface of the tailings pond during migration periods. Substantial numbers of waterfowl presently stop over in existing lakes, and the nine-square mile retention pond will certainly be an additional attraction to migrating flocks. Data are available on numbers, migration chonology and species which may pass through and utilize the area.

Water

According to our present Application, no process water will move across Lease 17 and 22 boundaries or into any moving water systems. We feel this is an excellent safeguard, and we consider its implementation to be extremely important. We will give particular attention to minitoring points where leakage would result in process waters entering the Athabasca River. The channel of Beaver Creek downstream of the retention pond and Mildred Lake are examples.

The diversion of Beaver Creek presently proposed involves a dam that would back up water to the 1020' contour necessitating that the ditch be up to 25' in depth in certain areas. These canals will have adequate stabilzation material utilized in the design and construction to avoid the severe erosion and soil siltation which otherwise might result from this type of diversion. However, chemical changes in the water may result from diverted waters flowing through a recently-disturbed tar sand area into the Athabasca River. These waters are currently being monitored for baseline water quality data.

Two areas of concern related to the large retention pond. It is likely that at least some oil slicks will develop on the surface of this pond. In most cases this should be restricted to a froth around the tailings pile as oil-covered sand will sink due to its higher density than water. The implications of waterfowl using the pond have already been discussed and further evaluation toward mitigation of this problem will be carried out, both prior to the formation of the pond and following the onset of operations.

The concept of containment of process waters and the intensive nature of operations in a relatively small area for a long period of time are major factors limiting the adverse ecological implications of the proposed development.

TABLE 1

BITUMEN BALANCE

	INITIAL OUTPUT		ULTIMATE OUTPUT 125M BPCD Output Expected Within Ten Years from Start-up	
	BPCD	Mlbs/CD	BPCD	Mlbs/CD
Mining				
Tar Sand Mined	(78.04 MMTPY)	427,612	(93.30 MMTPY)	511,251
Bitumen in Tar Sand	139,976	49,560	167,347	59,254
Extraction (% Recovery)	93		93	
Bitumen in Froth	130,179	46,091	155,633	55,106
Bitumen in Tailings	9,797	3,469	11,714	4,148
Froth Treatment (% Recovery)	98		98	
Bitumen Feed	130,179	46,091	155,642	55,106
Naphtha Feed (261.1 #/B)	105,917	27,655	126,600	33,064
Bitumen Loss	2,604	922	3,112	1,102
Naphtha Loss	2,118	553	2,532	661
Bitumen Upgrading				
Bitumen Feed	127,575	45,169	152,529	54,004
H_2 Chem. Cons.		480		574
		45,649		54,578
Synthetic Crude	104,550	32,044	125,000	38,312
C_4 & Lighter Fuel		3,925		4,693
Coke		4,242		5,072
Sulphur		1,546		1,848
Release In Burner & CO Boiler		3,339		3,992
Makeup Naphtha	2,118	553	2,532	661
		45,649		54,578

TABLE 2

SULPHUR BALANCE

	DESIGN		ULTIMATE	
	M#/CD	LT/CD	M#/CD	LT/CD
Sulphur in Feed	2213	988	2646	1181
Sulphur in Syncrude	50	22	60	27
Sulphur in Coke	382	171	457	204
Released from Stack				
- from Coker Burner	154	69	184	82
- from Sulphur Plant Tail Gas	81	36	97	43
Product Sulphur	1546	690	1848	825
Total Sulphur Output	2213	988	2646	1181

SULPHUR TO ATMOSPHERE

	LT/SD*	LT/SD
Coker Burner	79.0	94.0
Sulphur Plant Tail Gas	41.0	49.0
Utility Plant Process Heaters	0.3	0.3
	120.3	143.3

* (LT/SD)(0.875)=(LT/CD)

ATMOSPHERIC CONDITION, HEAVY OVERCAST DAY OR NIGHT

STACK HEIGHT = 220.0 FT

WIND VELOCITY = 36.67 FPS
NEUTRAL STABILITY

SOURCE DIST.(FT)	DIFF.IN ELEV.(FT) (SURFACE)	EFF.STACK HEIGHT	CONCENTRATION (PPM) AT GROUND LEVEL
6500.0	.0	462.0	.0523
10000.0	.0	462.0	.0922
15000.0	.0	462.0	.0967
22000.0	.0	462.0	.0782
33000.0	.0	462.0	.0549
50000.0	.0	462.0	.0350
75000.0	.0	462.0	.0219
110000.0	.0	462.0	.0139
167000.0	.0	462.0	.0086
250000.0	.0	462.0	.0057

WIND VELOCITY = 29.33 FPS
NEUTRAL STABILITY

SOURCE DIST.(FT)	DIFF.IN ELEV.(FT) (SURFACE)	EFF.STACK HEIGHT	CONCENTRATION (PPM) AT GROUND LEVEL
6500.0	.0	564.0	.0148
10000.0	.0	564.0	.0484
15000.0	.0	564.0	.0713
22000.0	.0	564.0	.0689
33000.0	.0	564.0	.0547
50000.0	.0	564.0	.0380
75000.0	.0	564.0	.0249
110000.0	.0	564.0	.0163
167000.0	.0	564.0	.0103
250000.0	.0	564.0	.0070

WIND VELOCITY = 22.00 FPS
NEUTRAL STABILITY

SOURCE DIST.(FT)	DIFF.IN ELEV.(FT) (SURFACE)	EFF.STACK HEIGHT	CONCENTRATION (PPM) AT GROUND LEVEL
6500.0	.0	698.4	.0018
10000.0	.0	698.4	.0158
15000.0	.0	698.4	.0403
22000.0	.0	698.4	.0521
33000.0	.0	698.4	.0504
50000.0	.0	698.4	.0402
75000.0	.0	698.4	.0285
110000.0	.0	698.4	.0196
167000.0	.0	698.4	.0128
250000.0	.0	698.4	.0089

WIND VELOCITY = 14.67 FPS
NEUTRAL STABILITY

SOURCE DIST.(FT)	DIFF.IN ELEV.(FT) (SURFACE)	EFF.STACK HEIGHT	CONCENTRATION (PPM) AT GROUND LEVEL
6500.0	.0	1031.0	.0000
10000.0	.0	1031.0	.0002
15000.0	.0	1031.0	.0033
22000.0	.0	1031.0	.0114
33000.0	.0	1031.0	.0217
50000.0	.0	1031.0	.0275
75000.0	.0	1031.0	.0254
110000.0	.0	1031.0	.0206
167000.0	.0	1031.0	.0154
250000.0	.0	1031.0	.0115

WIND VELOCITY = 7.33 FPS
NEUTRAL STABILITY

SOURCE DIST.(FT)	DIFF.IN ELEV.(FT) (SURFACE)	EFF.STACK HEIGHT	CONCENTRATION (PPM) AT GROUND LEVEL
6500.0	.0	1524.9	.0000
10000.0	.0	1524.9	.0000
15000.0	.0	1524.9	.0000
22000.0	.0	1524.9	.0003
33000.0	.0	1524.9	.0028
50000.0	.0	1524.9	.0099
75000.0	.0	1524.9	.0162
110000.0	.0	1524.9	.0189
167000.0	.0	1524.9	.0187
250000.0	.0	1524.9	.0167

TOTAL GAS FLOW RATE = 3443.0 CFS EXIT GAS VEL. = 311.0 FPS
T2 = 1170.0 DEG F. T1 = 70.0 DEG F. Q = 12.30 CFS
[illegible]

[illegible]

ATMOSPHERIC CONDITION, HEAVY OVERCAST DAY OR NIGHT

STACK HEIGHT = 600.0 FT

SOURCE DIST.(FT)	DIFF.IN ELEV.(FT) (SURFACE)	EFF.STACK HEIGHT	CONCENTRATION (PPM) AT GROUND LEVEL
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WIND VELOCITY = 36.67 FPS
NEUTRAL STABILITY

1000.0	.0	1043.0	.0000
5000.0	.0	1043.0	.0000
10000.0	.0	1043.0	.0002
25000.0	.0	1043.0	.0199
45000.0	.0	1043.0	.0373
70000.0	.0	1043.0	.0365
100000.0	.0	1043.0	.0308
125000.0	.0	1043.0	.0268
200000.0	.0	1043.0	.0191

WIND VELOCITY = 29.33 FPS
NEUTRAL STABILITY

1000.0	.0	1251.7	.0000
5000.0	.0	1251.7	.0000
10000.0	.0	1251.7	.0000
25000.0	.0	1251.7	.0062
45000.0	.0	1251.7	.0225
70000.0	.0	1251.7	.0287
100000.0	.0	1251.7	.0278
125000.0	.0	1251.7	.0258
200000.0	.0	1251.7	.0204

WIND VELOCITY = 22.00 FPS
NEUTRAL STABILITY

1000.0	.0	1508.2	.0000
5000.0	.0	1508.2	.0000
10000.0	.0	1508.2	.0000
25000.0	.0	1508.2	.0011
45000.0	.0	1508.2	.0102
70000.0	.0	1508.2	.0193
100000.0	.0	1508.2	.0228
125000.0	.0	1508.2	.0235
200000.0	.0	1508.2	.0216

WIND VELOCITY = 14.67 FPS
NEUTRAL STABILITY

1000.0	.0	2157.8	.0000
5000.0	.0	2157.8	.0000
10000.0	.0	2157.8	.0000
25000.0	.0	2157.8	.0000
45000.0	.0	2157.8	.0004
70000.0	.0	2157.8	.0029
100000.0	.0	2157.8	.0068
125000.0	.0	2157.8	.0098
200000.0	.0	2157.8	.0150

WIND VELOCITY = 7.33 FPS
NEUTRAL STABILITY

1000.0	.0	2910.1	.0000
5000.0	.0	2910.1	.0000
10000.0	.0	2910.1	.0000
25000.0	.0	2910.1	.0000
45000.0	.0	2910.1	.0000
70000.0	.0	2910.1	.0001
100000.0	.0	2910.1	.0010
125000.0	.0	2910.1	.0025
200000.0	.0	2910.1	.0037

TOTAL GAS FLOW RATE =23377.0 CFS   EXIT GAS VEL. = 60.0 FPS
T2 = 475.0 DEG F.   T1 = 70.0 DEG F.   Q = 44.00 CFS
END OF **OGPOL2
NOW AT END

15:42 RAN 0 MINS 1.02

CENTRAL STACK - 1 Sulphur Plant Down

ATMOSPHERIC CONDITION, HEAVY OVERCAST DAY OR NIGHT

STACK HEIGHT = 600.0 FT

SOURCE DIST.(FT)	DIFF.IN ELEV.(FT) (SURFACE)	EFF.STACK HEIGHT	CONCENTRATION (PPM) AT GROUND LEVEL
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WIND VELOCITY = 36.67 FPS
NEUTRAL STABILITY

1000.0	.0	1047.3	.0000
5000.0	.0	1047.3	.0000
10000.0	.0	1047.3	.0006
25000.0	.0	1047.3	.0560
45000.0	.0	1047.3	.1062
70000.0	.0	1047.3	.1043
100000.0	.0	1047.3	.0883
125000.0	.0	1047.3	.0769
200000.0	.0	1047.3	.0549

WIND VELOCITY = 29.33 FPS
NEUTRAL STABILITY

1000.0	.0	1246.0	.0000
5000.0	.0	1246.0	.0000
10000.0	.0	1246.0	.0000
25000.0	.0	1246.0	.0186
45000.0	.0	1246.0	.0663
70000.0	.0	1246.0	.0840
100000.0	.0	1246.0	.0809
125000.0	.0	1246.0	.0752
200000.0	.0	1246.0	.0592

WIND VELOCITY = 22.00 FPS
NEUTRAL STABILITY

1000.0	.0	1475.6	.0000
5000.0	.0	1475.6	.0000
10000.0	.0	1475.6	.0000
25000.0	.0	1475.6	.0040
45000.0	.0	1475.6	.0342
70000.0	.0	1475.6	.0612
100000.0	.0	1475.6	.0704
125000.0	.0	1475.6	.0715
200000.0	.0	1475.6	.0644

WIND VELOCITY = 14.67 FPS
NEUTRAL STABILITY

1000.0	.0	2041.0	.0000
5000.0	.0	2041.0	.0000
10000.0	.0	2041.0	.0000
25000.0	.0	2041.0	.0000
45000.0	.0	2041.0	.0025
70000.0	.0	2041.0	.0135
100000.0	.0	2041.0	.0272
125000.0	.0	2041.0	.0367
200000.0	.0	2041.0	.0507

WIND VELOCITY = 7.33 FPS
NEUTRAL STABILITY

1000.0	.0	2634.8	.0000
5000.0	.0	2634.8	.0000
10000.0	.0	2634.8	.0000
25000.0	.0	2634.8	.0000
45000.0	.0	2634.8	.0001
70000.0	.0	2634.8	.0018
100000.0	.0	2634.8	.0082
125000.0	.0	2634.8	.0164
200000.0	.0	2634.8	.0412

TOTAL GAS FLOW RATE =23377.0 CFS   EXIT GAS VEL. = 81.0 FPS
T2 = 475.0 DEG F.   T1 = 70.0 DEG F.   Q = 127.00 CFS
END OF **OGPOL2
NOW AT END

APPENDIX II

Stack Monitoring Instrumentation:

1. Four 12" x 12" ports at the midpoint for the admission of the pitot tube meters of the Department of Health or other government regulatory body;

2. Temperature-recording thermocouples at bottom, midpoint and exit of stack;

3. Annubar or pitot-flow velocity measuring device;

4. Heated sample line from the platform at midpoint;

5. Platform at midpoint and below the tip;

6. Stack gas analyzer (chromatograph);

7. Instrumentation for future installation of an integrator for calculation of total sulphur emission.

In order to balance stack gas emission, the duct work for each sulphur plant to its respective CO boiler will be equipped with:

1. Gas chromtograph for H_2S, SO_2, and N_2 or, alternately, a Dupont Ultra-violet analyzer;

2. Annubar, or other flow measurement device;

3. Temperature recorder;

4. Provision for integrator, as above.

APPENDIX III

Sulphur Recovery

A recovery efficiency of 95% has been used in calculating total emission. Study of sulphur plants processing acid gas containing ammonia shows 95% recovery to be realistic. This is based on the following factors:

1. Refinery acid gases contain varying amounts of ammonia, which generally ultimately go to the sour water treating plant and thence to the sulphur recovery plant.

2. The ammonia entering the sulphur plant must be preferentially oxidized to nitrogen and water vapour, or it rapidly de-activates the sulphur plant catalyst as ammonium sulphate (completely non-regenerable).

3. The conditions under which the ammonia must be destroyed are such as to redice the reaction furnace yield, as explained below.

4. The extra nitrogen and water vapour in the plant stream downstream of the reaction furnace depress yield.

5. Refinery gases contain considerable aromatic and cyclic gases, traces of which contaminate the acid gas.

While sulphur recovery at refineries is quite an old process, the on-stream time, catalyst life, and efficiency have been quite low -- particularly where hydrotreating of high nitrogen streams has been involved. Syncrude intends to approach this problem as follows:

The acid gas from the DEA regenerator reflux drum will be piped to an acid gas knockout drum for delivery to the sulphur recovery plant. Liquid from the knockout drum will be drained under level control to the sour water treating system.

A second knockout drum will be provided for the ammonia-contaminated acid gas stream from the sour water stripping facilities.

transmit signals to square root extractors which transform the square root signals to linear signals.

The linear flow signals are fed to an adding relay. The output of the adding relay goes to an air-gas ratio controller which sets the main process air flow control by also receiving an air flow signal from an orifice transmitter via a square root extracting relay.

The total amount of ammonia acid gas and DEA acid gas going to the special burner is measured by an orifice plate. The output from the orifice plate transmitter will be fed to a square root extractor, and then to a ratio controller which will control the total flow of gas to the special burner in accordance with the total air flow to the plant.

The signals from the adding relays in the ammonia acid gas circuits will go to their respective ratio controllers via bias relays so that adjustments can be made in accordance with changes in temperature, pressure, and composition. It is contemplated that these bias adjustments be made through a computerized feed-forward control system taking the following items into account:

1. Analysis of the ammonia acid gas stream for H_2S, NH_3 and hydrocarbon.

2. Analysis of the DEA acid gas stream for H_2S and hydrocarbon.

3. Temperature, pressure, and moisture content of acid gas and air streams.

A tail gas analyzer will be provided for each sulphur plant to analyze the tail gas stream for H_2S and SO_2. A computer control will be installed that will tend to return the total sulfur in the tail gas stream to a minimum, by adjustment of a trim air valve that by-passes process air around the main process air control valve.

An orifice-or pitot tube-type velocity meter will be installed in the tail gas line from each sulphur plant. This meter will provide for future integration with the tail

APPENDIX III

The ammonia acid gas will be introduced into the sulphur plant reaction furnaces through a special burner where it will be burned with all the air required for the normal sulphur reaction with the hydrogen sulphide content of both the ammonia and DEA acid gas. The following reactions will take place in this combustion zone:

1. $2NH_3 + 1\frac{1}{2}\ O_2 \qquad N_2 + 3H_2O$

2. $H_2S + 1\frac{1}{2}\ O_2 \qquad SO_2 + H_2O$

The conditions will be maintained in this combustion zone such that all ammonia will be decomposed, but that excess nitrogen oxides are suppressed and the minimum amount of SO_3 is formed. These conditions will be maintained by adding a controlled amount of DEA acid gas to the special burner along with the ammonia gas.

The balance of the DEA acid gas will be introduced into the furnace through secondary burners downstream of the special burner where it will react with the excess air remaining from the special burner, in approximate accordance with reaction (2) above and the following reaction:

$$H_2S + \tfrac{1}{2}O_2 \qquad S + H_2O$$

The balance of the plant will be a conventional three-converter sulphur plant. Indirect re-heat will be used on the gases to the last catalytic stage to maximize yield.

Following is the proposed form of instrumentation.

The sulphur recovery plants will be controlled from the central control house, but will be started up manually from local control panels before transferring control to the central system.

Basic control will be by controlling the ratio of air entering the plants to the amounts of gas entering the plants from two sources: DEA regenerator gas, and sour water system ammonia acid gas.

The flow of each sour gas stream is measured by oriface plates with flow transmitters. The flow transmitters gas chromatograph, for automatic computation of losses.

A number of ammonia-burning sulphur plants have been built by one major contractor, and one licensed by a major licensor. Success has been varied. Problems have been:

1. Catalyst fouling from ammonium sulphate;

2. Refractory damage caused by insufficient excess air in the ammonia oxidation zone;

3. Poor yield, due to poor thermal yield conditions.

The main innovation in design will be in the instrumentation proposed for control of the ammonia oxidation. This is considered to be experimental. If successful, the sulphur recovery plants will exceed 95% conversion efficiency. The plants will meet 95% efficiency with good manual operation of the ammonia oxidation.

APPENDIX IV

Technical Description of

Proposed Syncrude Water Supply System

Annual Withdrawal = 100,000 Acre-Feet
Maximum instantaneous withdrawal = 160 CFS
= 60,000 IGPM
= 72,000 USGPM

Proposed scheme consists of: river intake and pumping station, sedimentation basin, pipeline to Mildred Lake, storage capacity at Mildred Lake, gravity supply from Mildred Lake to Plant site.

River Intake and Pumping Station

- headwall type structure projecting from west shore into river channel.
- low lift pumping units to lift raw water to sedimentation basin.
- high lift pumping units to take water from sedimentation basin into main pipeline to Mildred Lake.
- intake located on outside of curve on limestone outcrop, channel about 10 feet deep below winter ice level - no indication of recent or impending channel movements.
- further study may indicate that an intake pier is necessary at this site.

Sedimentation Basin

- approximately 500,000 sq. ft. effective area.
- design depth 10 to 15 feet.
- between 50% and 75% of total suspended solids introduced will settle out in the basin.
- dykes to elevation 795 required around basin to protect against high river levels caused by ice jams.

Pipeline

- 12,000 l.ft. of 54" I.D. or 48" I.D. pipeline from high lift pumps to south end of Mildred Lake.

Mildred Lake Storage Reservoir

- provide approximately 7,000 Acre-Feet of live storage with a 15 foot increase in water level.
- outlet control structure required to release flow into open canal or buried pipe to plant site.
- gravity flow from lake to plant site.

APPENDIX V

MILDRED LAKE SURVEY

RENEWABLE RESOURCES CONSULTING SERVICE LTD

AQUATIC VEGETATION

Typha sp.) Present along entire shoreline - greatest percentage
Scirpus sp.) Present in water 1 - 2 ft. deep
Nuphar sp. - present in water up to 4 feet deep - not restricted to any particular area but heavy in north end.
Sagittaria sp. - up to 3 feet deep - just beginning to grow
Myriophyllum sp. - found in 2 feet of water
- just sprouting
Phragmites sp. - common in shallow regions
Potomogeton - found in 2 feet of water
Probable species of above genera (not keyed)
Typha latifolia - These are common species found in
Scirpus validus or acutus these lakes.
Nuphar variegatum
Sagittaria cuneata
Myriophyllum ?
Phragmites communis
Potamogeton gramineus or richardsonii

More aquatic plants will probably appear in July-August. Most probable will be appearance of common duckweed *(Lemna minor or triescula)*

Shoreline mainly black and white spruce *(Picea glauca and mariana)*

APPENDIX V

PHYSICAL DATA

Northern half of lake uniformly shallow. Deepest part near Station 1. Approximately 50-60% of lake 4 feet deep or less.

Ekman dredge samples revealed a uniform bottom type throughout the lake. Bottom type is mainly, finely decomposed organic matter with no evidence of sand or gravel. Marl was found in shallower areas of lake.

There was no visible evidence of phytoplankton growth or bloom at this time.

Aquatic invertebrates were abundant in shallow regions of lakes. Cursory examination revealed: Amphipods; damselfly and dragonfly nymphs; vast number of aquatic beetles *(Dytiscid-numerous)*; leeches.

Fish species found: flathead minnows known to exist: suckers *(Catostomus commersoni* - probably); stickle back (probably ninespine - *Pungitus pungitus)*.

Mildred Lake is a typical late eutrophic lake probably characterized by winter oxygen dificits, heavy summer plankton blooms, and large numbers of both emergent and submergent vegetation in summer.

Prevailing winds (N.W.) probably prevent stratification in summer.

APPENDIX V

CHEMICAL DATA

STATION NUMBERS

	1	2	3	4	5	6	
Depth (fl.)	8	0	4	0	3	0	
Dissolved Oxygen	9	7	8	10	8	7	ppm
Temperature	17	16	17	17	16	17	^{o}C
pH	7.8	7.8	8.0	8.2	7.8	8.0	
Alkalinity (Total)	115	150	170	170	125	150	ppm HCO_3
Calcium Hardness	125	130	120	90	125	130	ppm
Total Hardness	150	145	155	160	150	155	ppm $CaCO_3$
Turbidity	10	10	10	10	10	10	Jackson Turbidity Unit
Nitrate Nitrogen	14	11	14	12	12	12	ppm
Nitrite Nitrogen	0.05	0.0	0.05	0.05	0.05	0.0	ppm
Phosphates (ortho)	0.1	*4.5	0.7	*3.0	0.2	0.7	ppm

Surface Conductivity - 200 Micromhus/cm

Hach Kit used for all tests except:

pH - Hellige Comparator

Conductivity - Applicon Ltd.

Small number of stations due to uniformity of water depths throughout lake.

H_2S tests were negative at all sample sites. Smell of H_2S present in Ekman Dredge samples.

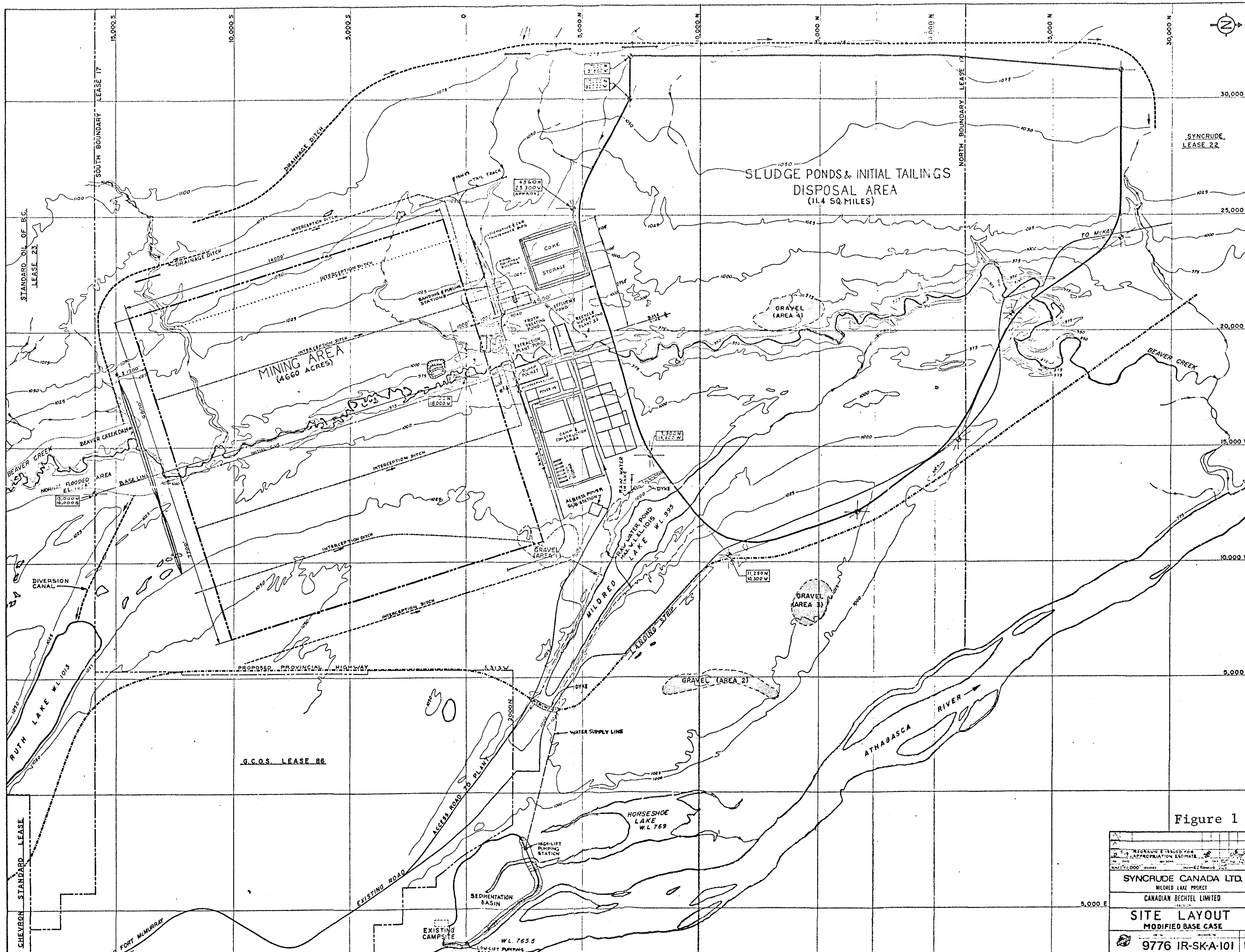

SLUDGE PONDS & INITIAL TAILINGS
DISPOSAL AREA
(11.4 SQ. MILES)
MINING AREA
(4660 ACRES)
COKE
STORAGE
CAMP & CONSTRUCTION AREA
ALBERTA POWER SUB STATION
RAW WATER POND
MILDRED LAKE W.L. 995
LANDING STRIP
GRAVEL (AREA 1)
GRAVEL (AREA 2)
GRAVEL (AREA 3)
GRAVEL (AREA 4)
BEAVER CREEK
BEAVER CREEK DAM
DIVERSION CANAL
RUTH LAKE W.L. 1013
PROPOSED PROVINCIAL HIGHWAY
G.C.O.S. LEASE 86
ACCESS ROAD TO PLANT
EXISTING ROAD
TO FORT McMURRAY
TO McKAY
WATER SUPPLY LINE
DYKE
HORSESHOE LAKE W.L. 769
HIGH-LIFT PUMPING STATION
SEDIMENTATION BASIN
EXISTING CAMPSITE
LOW-LIFT PUMPING STATION
ATHABASCA RIVER
STANDARD OIL OF B.C. LEASE 23
SOUTH BOUNDARY LEASE 17
NORTH BOUNDARY LEASE 17
SYNCRUDE LEASE 22
CHEVRON STANDARD LEASE
INTERCEPTION DITCH
DRAINAGE DITCH
SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT
CANADIAN BECHTEL LIMITED
SITE LAYOUT
MODIFIED BASE CASE
9776 IR-SK-A-101 D

Figure 1

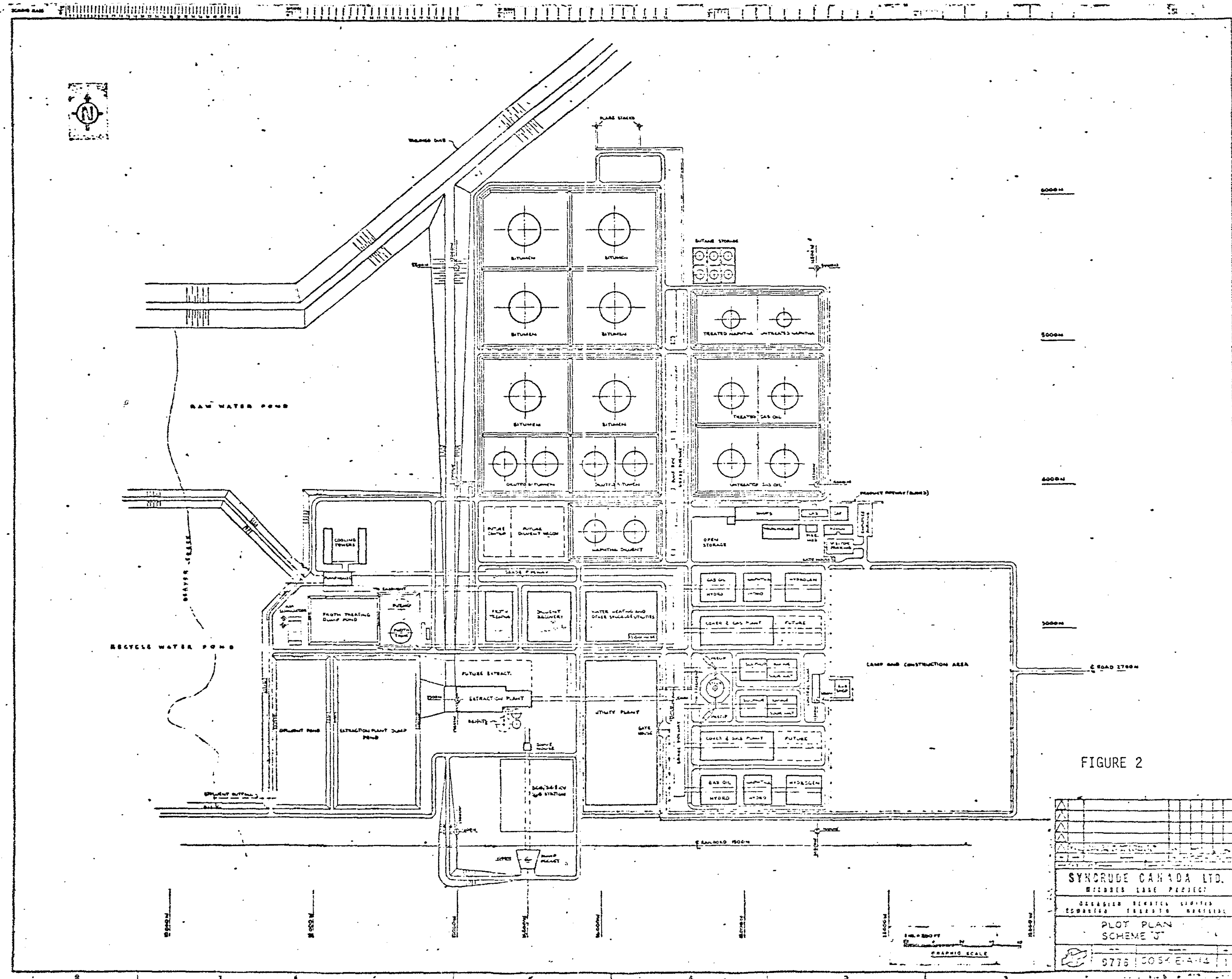
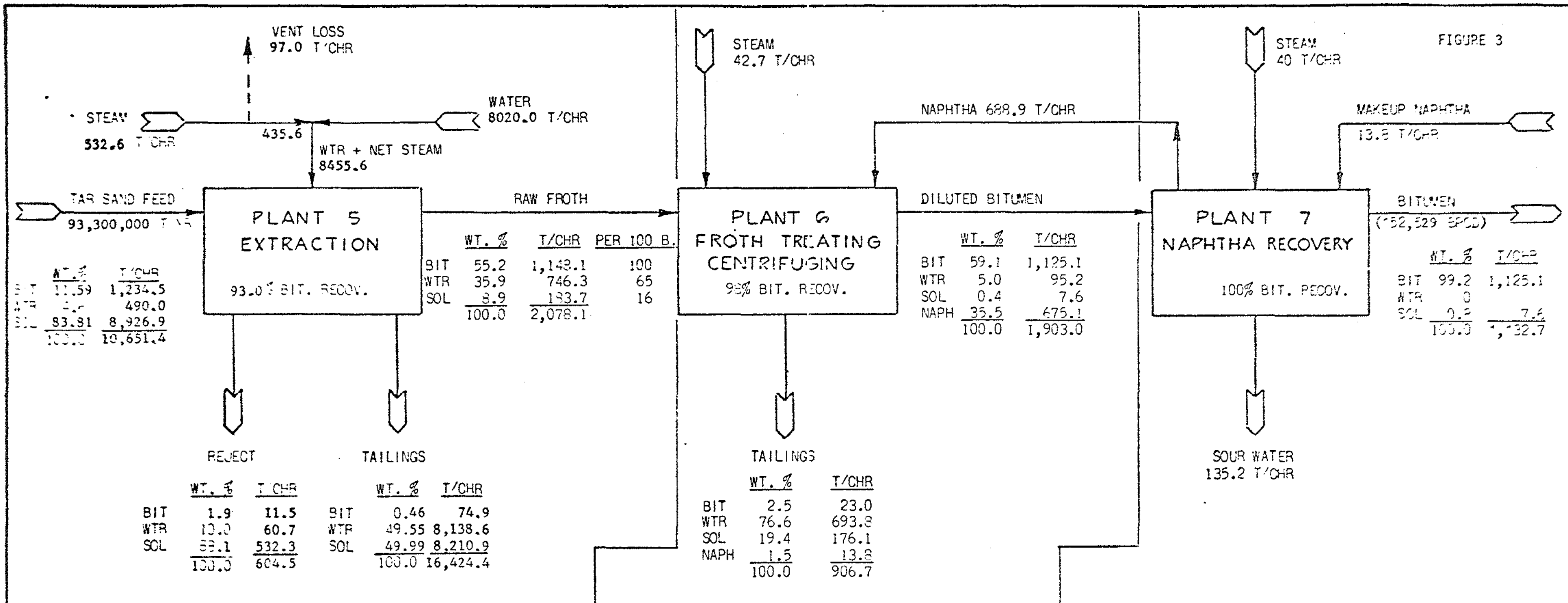


FIGURE 2

SYNCRUDE CANADA LTD.
MILDRED LAKE PROJECT

PLOT PLAN
SCHEME "J"

FIGURE 3



MATERIAL BALANCE EXTRACTION

	TAR SAND	STM WTR	TOTAL IN	FROTH	TAILINGS	REJ	TOTAL OUT
BIT	1,234.5		1,234.5	1,148.1	74.9	11.5	1,234.5
WTR	490.0	8,455.6	8,445.6	746.3	8,138.6	60.7	8,995.6
SOL	8,926.9		8,926.9	183.7	8,210.9	532.3	9,144.9
NAPH							
TOT	10,651.4	8,455.6	19,107.0	2,078.1	16,424.4	604.5	19,375.0

MATERIAL BALANCE FROTH TREATING

	FROTH	NAPH	STM	TOTAL IN	DIL BIT	TAILINGS	TOTAL OUT
BIT	1,148.1			1,148.1	1,125.1	23.0	1,148.1
WTR	746.3		42.7	789.0	95.2	693.8	789.0
SOL	183.7			183.7	7.6	176.1	183.7
NAPH		688.9		688.9	675.1	13.8	688.9
TOT	2,078.7	688.9	42.7	2,809.7	1,903.0	906.7	2,809.7

MATERIAL BALANCE NAPHTHA RECOVERY

	DIL BIT	STM	MAKE UP NAPH.	TOTAL IN	BIT	NAPH	SOUR WTR	TOTAL OUT
BIT	1,125.1			1,125.1	1,125.1			1,125.1
WTR	95.2	40		135.2			135.2	135.2
SOL	7.6			7.6	7.6			7.6
NAPH	675.1		13.8	688.9		688.9		688.9
TOT	1,903.0	40	13.8	1,956.8	1,132.7	688.9	135.2	1,956.8

NOTE: ALL UNITS - SHORT TONS/CALENDAR HOUR

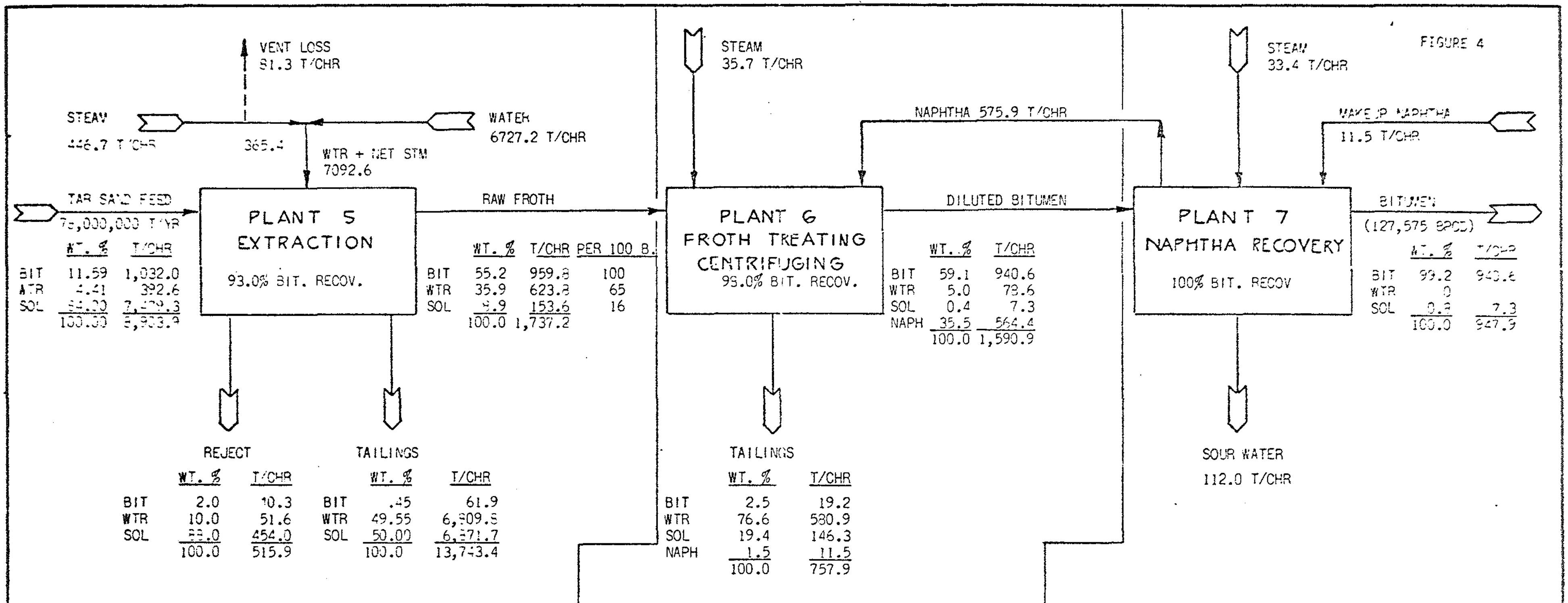
REFERENCE	NO.	DATE	REVISED	BY	APP.
	1	JAN 16 73	REVISED REDRAWN	WR	

SYNCRUDE CANADA LTD.

EXTRACTION, FROTH TREATING AND NAPHTHA RECOVERY BLOCK FLOW DIAGRAM 125,000 BPCD SYNCRUDE

DRAWN W.R. DATE JAN 16/73
CHECKED DATE
DESIGNED DATE
APPROVED DATE
SCALE NIL
DRAWING No. B-8-100-79-1 REV. 1

FIGURE 4



MATERIAL BALANCE EXTRACTION

	TAR SAND	STM WTR	TOTAL IN	FROTH	TAILINGS	REJ	TOTAL OUT
BIT	1,032.0		1,032.0	959.8	61.9	10.3	1,032.0
WTR	392.6	7,092.6	7,485.2	623.8	6,809.8	51.6	7,485.2
SOL	7,479.3		7,479.3	153.6	6,871.7	454.0	7,479.3
NAPH							
TOT	8,903.9	7,092.6	15,996.5	1,737.2	13,743.4	515.9	15,996.5

MATERIAL BALANCE FROTH TREATING

	FROTH	NAPH	STM	TOTAL IN	DIL BIT	TAILINGS	TOTAL OUT
BIT	959.8			959.8	940.6	19.2	959.8
WTR	623.8		35.7	659.5	78.6	580.9	659.5
SOL	153.6			153.6	7.3	146.3	153.6
NAPH		575.9		575.9	564.4	11.5	575.9
TOT	1,737.2	575.9	35.7	2,348.8	1,590.9	757.9	2,348.8

MATERIAL BALANCE NAPHTHA RECOVERY

	DIL BIT	STM	MAKE UP NAPH	TOTAL IN	BIT	NAPH	SOUR WTR	TOTAL OUT
BIT	940.6			940.6	940.6			940.6
WTR	78.6	33.4		112.0			112.0	112.0
SOL	7.3			7.3	7.3			7.3
NAPH	564.4		11.5	575.9		575.9		575.9
TOT	1,590.9	33.4	11.5	1,635.8	947.9	575.9	112.0	1,635.8

NOTE: ALL UNITS - SHORT TONS/ CALENDAR HOUR

REFERENCE	No.	DATE	REVISED	BY	APP.

SYNCRUDE CANADA LTD.

EXTRACTION, FROTH TREATING AND NAPHTHA RECOVERY
BLOCK FLOW DIAGRAM
104,550 B PCD SYNCRUDE

DRAWN W.R.	DATE JAN 17/75
CHECKED	DATE
DESIGNED	DATE
APPROVED	DATE
SCALE NIL	
DRAWING No. B-8-100-79-2	REV.

SIMPLIFIED WATER BALANCE

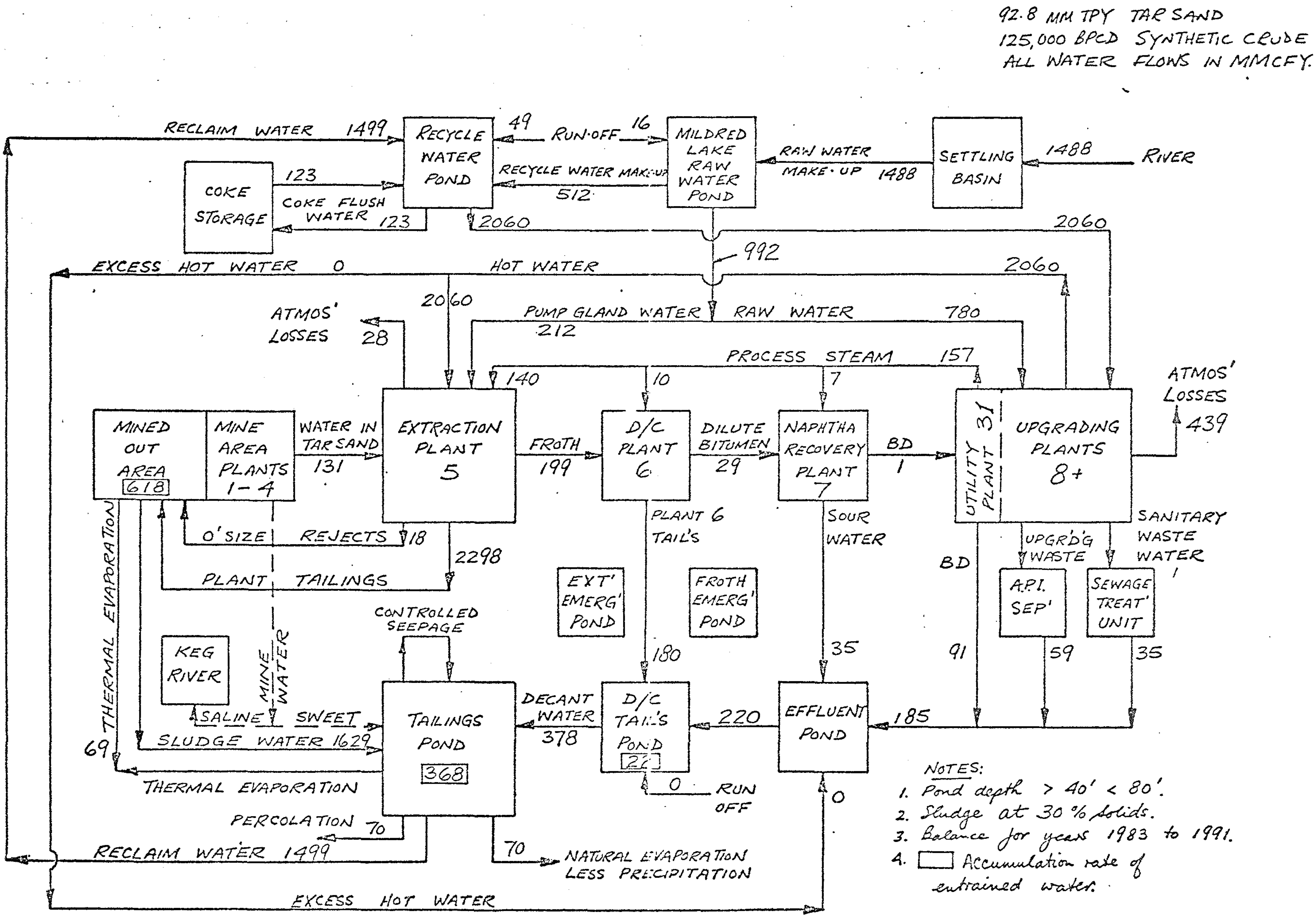


FIGURE 5

OVERVIEW

SECTION 4.

ECOSYSTEM STRUCTURE

SECTION 4

ECOSYSTEM STRUCTURE

A. GENERAL

Ecology is the study of the interrelationship between living organisms and their physical environment. It includes studies of the interrelationship between organisms, as well as the environment these organisms create for other living things.

Ecological impact occurs when natural interrelationships are changed or altered. This alteration can be either the result of human activity, natural evolutionary processes or natural catastrophies. In attempting to define what constitutes an ecological impact and its significance, we feel that it is essential to analyze information in these five categories:

1) A knowledge of ecosystem structure. } "baseline data"
2) Principles of ecosystem function. }
3) Criteria for assessing impact.
4) Comparison of types of impact with extant undisturbed system.
5) Monitoring of impact to maintain constant record of change.

The ecosystem is defined as an interacting, interrelating, energy driven complex of plants, animals, and humans, and the physical environment in which they live. An understanding of the workings of an ecosystem is essential to the practise of environmental conservation. Modern man in a highly technological society may not directly feel his dependence upon the workings of a natural ecosystem inasmuch as this very technology has estranged him from the prime sources of his energy. In reality, man is still dependent upon the green plants and the animals that consume them for a large portion of his energy.

Knowledge of this interdependence has been recognized historically by a number of sources. The Bible contains the quotation "all flesh is grass" (Isaiah 40:6 and I Peter 1:24). From another culture, Brings-Down-the-Sun, a Blackfoot Indian, stated to an anthropologist (Lodge, 1913), "I was born in the moon when the grass was green. Grass as you know is the head chief of everything. Without grass the animals could not live, and without the animals our children would starve." The interdependence of consumer organisms on producer organisms in intricate food chains and webs is more apparent to people living close to the land.

It is upon these individuals that impacts have their most immediate effect. This does not mean that dangers which result from ecosystem degeneration and loss of productivity do not just as seriously affect modern urbanized man, but only that these dangers may not be as readily apparent.

Energy exchange occurs both within and between ecosystems; these ecosystems may be of any size. The ecosystem for small organisms that have a very specific range and discrete niche (occupation) may be limited, as within a jar of pond water in a laboratory window. The ecosystem may be represented as one or more forest communities, such as Cypress Hills in southern Alberta, which is surrounded by short grass prairie. It may include the entire bio-geographic and climatologic region such as the forest of the Canadian Taiga. However, the basic principles which control functions of ecosystems apply universally. Only the degrees to which they influence the interrelationships vary.

A practical level at which an "ecosystem" unit can be defined is the plant-animal-soil complex persisting under a certain climatic regime. An example is the Boreal (or northern) Mixedwood Forest ecosystem. The soil types, animal component and vegetation are generally uniform under the same environmental influences. Complexity of the system becomes more apparent at lower levels of resolution.

Energy circulates in an ecosystem through the organisms which comprise it. What ever the size, the ecosystem operates as a unit because its physical and biological parts are so enmeshed in their function. It is difficult to describe ecosystems in neat, simple categories. Indeed, all of the organisms play at least two roles: as part of the living core of the system and as parts of the environment for other organisms themselves. Therefore, in order to understand the ecosystem, the structure and function of its various components must be analysed.

An ecosystem is comprised of two major components, the physical environment and the biological community. The physical environment provides the energy and living space that the biological community requires for existence and which it uses for growth and maintenance.

Energy in the form of light energy and chemical energy is circulated through the organisms in the system and through portions of the physical environment.

Odum (1959) states that from a functional standpoint an ecosystem has two components: an autotrophic or "self nourishing" component in which fixation of light energy, use of simple inorganic substances, and build-up of complex substances predominate; and a heterotrophic component which is "other-nourishing." In the latter, utilization and rearrangement and decomposition of complex materials are predominant. It is convenient to recognize four constituents as comprising an ecosystem:

1. Abiotic substances. - basic inorganic and organic compounds of the environment.

2. Producers. - autotrophic organisms, largely green plants which are able to manufacture food from simple inorganic substances.

3. Consumers. - heterotrophic organisms, chiefly animals which ingest other organisms or particulate organic matter;

4. Decomposers. - heterotrophic organisms chiefly bacteria and fungi, which break down the complex of compounds of dead protoplasm, absorb some of

the decomposition products and release simple substances usable by the producers. (Odum, 1959).

These trophic levels or constituents of the ecosystem simply show transfers of energy and energy flow.

As in the case of all energy transfers, as explained by the Second Law of Thermodynamics, no transfer of energy is ever one hundred percent efficient. Not all energy is utilizable-some energy is dissipated. In energy transfers at the herbivore trophic level, much of the energy is dissipated as heat energy. All food chains end as the waste products of living things, dead plant parts, or dead organisms themselves which are consumed by fungi and bacteria. The decomposers utilize the last remnants of energy left in the waste materials (detritus) and return the basic chemical components into the air, soil, or water. These components may then be used again as the green plant renews the endless cycle.

The concept of levels of biological organization may give some insight into what constitutes impact on an ecosystem. Beginning at the smallest unit and continuing through to the largest unit the sequence follows:

1. Molecule
2. Organelle
3. Cell
4. Tissue
5. Organ
6. Organism or individual
7. Population of individuals
8. Community or association
9. Ecosystem
10. Biome
11. Biosphere

Impacts upon one organism or individual may not significantly affect the structure and function of the population or community. The level of disturbance or impact must be based on an evaluation of the effect on energy flow through the ecosystem. Therefore, when assessing impact, it is essential to note at what levels of biological organization this impact is taking place.

Plants and animals tend to group together in different kinds of communities. Climate is very important in the determination of community structure and composition. Climatic factors include temperature and precipitation regime, photoperiodicity and its variation, wind pressure, and the effect of solar radiation. The climate is also a controlling factor on the development of soil upon which the plants depend. Parent materials of soils also greatly influence plant communities since climate and vegetation operating on various parent materials produce soil types of varying characteristics. The plant community in turn provides an environment suitable for certain kinds of animals. Climatic regions may encompass many ecosystems which, when grouped together, constitute a biome.

Since climate plays such a great part in the establishment of the physical environment, it is well to note the Bioclimatic Law as described by Hopkins (1917).

> "Other conditions being equal (that is, slope, aspect, etc.) variation in the time of occurrence of a given periodical biological event in the life activity in temperate North America is given at a general average rate of four days for each degree of latitude, five degrees of longitude, and four hundred feet elevation, later northward, eastward, and upward in the spring and early summer and the reverse in late summer and autumn."

The following are known to be biologically effective physical and chemical factors of the atmospheric environment which effect man and other organisms:

1. Temperature
2. Moisture (humidity, rainfall, snowfall, etc.)
3. Air motion
4. Natural radiation (gamma, ultraviolet, visible, infrared).
5. Air composition (dust, smoke, vapors, gases)
6. Ionizing wave and particle radiation including fallout.
7. Atmospheric pressure

Most of these factors have received little attention in the past. This does not mean that significant effects on organisms will not interact and change the organisms' operational patterns. Recognition of limiting factors in the atmospheric physical environment has not always occurred. For example, the inference that long days during the growing season make up for the short growing season is not always correct as other factors relating to energy flux (intensity, light wave length, duration and albedo) have their effects. This applies especially to the northern latitudes. Photoperiodicity has definite regulatory effects on man and his activities because it affects plant and animal communities as well as his own behavior. The more northerly the latitude, the greater the effect. It is especially important to recognize that the effect of increasing latitude on plants and animals is not linear but expotential. An understanding of weather cycles and background knowledge of long term climatic patterns can increase the understanding of the natural forces which effect the energy flux in ecosystems.

SECTION 4

ECOSYSTEM STRUCTURE

B. ECOSYSTEM STRUCTURE SPECIFIC TO LEASE 17

In order to learn how these principles were applicable to Lease 17, the management of Syncrude Canada Limited engaged Renewable Resources Consulting Services to carry out assessments of potential environmental impacts on the lease area. As a result, a preliminary investigation of environmental and ecological relationships was undertaken in July, 1971. An attempt was made to identify potential areas of concern during the preliminary investigation which might occur as a result of the development. Assessments of potential conflicts between resources extraction operations and the functioning of ecological relationships on the lease area were initiated. These preliminary investigations were synoptic or screening studies to determine what impacts might be anticipated from development upon the structure and function of the boreal mixed with ecosystem in which Lease 17 is located. (Volume III).

Many of the principles which govern ecological relationships in this ecosystem are well-known, but how potential developments and changes in the landscape might effect the structure of the ecosystem in the Athabasca Tar Sands area was not known. Therefore, in order to make predictive statements regarding the effects and impacts of a particular activity, it was necessary to know the conditions and inter-relationships of the baseline or undisturbed ecosystem. These baselines have to be established in order to provide a control against which the effect of developmental activities could be measured.

Ideally, the following basic information on environmental and biological factors is desirable in order to assess inter-relationships and impacts on an ecosystem basis:

Soils:

A Survey of the soils and classification to the level of the soil family is necessary.

In addition, information about the soils such as their texture, structure, chemical composition, bulk density, erosibility, permeability, and moisture holding capacity should be obtained. Biological analysis of soil microbial populations should be attempted, as these relate directly to the effectiveness of the soil substrate in maintaining the nitrogen cycle. This information is still lacking for the study area but a three year survey of vegetation succession which includes some of this information was initiated in June 1973.

Vegetation:

Plant communities have been mapped to the faciation level i.e. groupings of dominant plant species. The State of ecological succession of each vegetative type was determined. (Productivity information relating to the bio-mass produced and its future trend must still be obtained from quantitative measurements.)

Included in this analysis are the effects on plant communities of forest fires, insects and diseases, surface and ground water and wildlife relationships. A first order estimation may be developed from the study results reported in Volume III.

Water:

Analysis of water begins with climatological data which delineate the amount and regime of moisture in the ecosystem. Further sub-divisions of water studies include a water budget which takes into consideration evaporation from soil surfaces, transpiration by green plants, percolation into underground water supplies, and surface run-off. Watersheds subjected to certain types of land treatment alter water relationships in three ways:

1) Change in the total amount of surface water, evapotranspired water, and ground water recharge.

2) The total amount of peak flow of surface water.

3) The regime or timing at which surface water run-off occurs.

A survey of this nature was initiated by Syncrude in May 1973 to collect this data and to serve as a "screening study" for a large scale study on an area basis in cooperation with the Alberta Government and the Oil Sands Environmental Study Group.

Wildlife:

An analysis of both primary and secondary consumers is required. This means that food chain and food web relationships, based on information from the vegetation survey, must be approximated for each habitat type. The presence, distribution, and population dynamics of all major species and representative minor species should be evaluated over the long term (approximately 10 years). Preliminary investigation have delineated habitat types and the animals indigenous within the type.

Mapping of key winter ranges is essential to any ecological study. The distribution and cyclic densities of upland game birds should be determined. Requirements for nesting and their relationship to other factors within the community must be understood. Presence and chronology of waterfowl species have been determined. It is essential to know that observed waterfowl are migrants within the study area and not summer residents.

The factors of natural environmental resistance and potential productivity remain to be assessed and estimations made of the populations' biotic potential. In addition to this, the present carrying capacity of the habitat must be determined in order to evaluate the extent of changes brought about by future human action. A first order estimate is included in Volume III.

Human Occupancy:

People living in close contact with their environment have different effects upon the ecosystem than those who are temporary visitors and who do not remain. Assessment of the ecological effects of human use by indigenous people and their dependence upon the ecosystem itself should be part of the analysis. A preliminary study of the demographic characteristics is included in Volume IV of this report.

OVERVIEW

SECTION 5.

ECOSYSTEM FUNCTION

SECTION 5

ECOSYSTEM FUNCTION

A. GENERAL

When considering the biological community and how it functions in relation to its physical environment, some of the principles that appear to govern organism-environmental relationships must be understood. Three of the most important of these are:

1) The principle of Limiting Factors.
2) The principle of Holocoenotic Environment.
3) The effect of Trigger Factors.

It can be said that the first principle is "organism centered" while the other two are "environment centered".

The principle of limiting factors is basically that an organism can increase only to the limit of the supply of the least available substance necessary for its growth. Beyond this limit it cannot expand. The corrollary to this is that where an excess amount of an essential element for growth is present, it may also have an inhibiting effect. For example, an organism can live within a range of circumstances caused by temperature, soil moisure, soil acidity or alkalinity, etc. or other factors of the physical environment. Between these limits it reaches maximum productivity. At the limit, the species may be present but not vigorous. Limiting factors of the physical environment may overlap. That is, where excessive heat may prevent plant growth at one extreme, excess moisture may retard growth at the other extreme. The range of circumstances in which an organism can persist is called "the Amplitude of Tolerance".

Holocoenotic (or biogeocoenotic) Environment, the second principle, means that there are no walls or barriers between the factors of the environment and the whole biotic community (Friedrich, 1927). The community reacts as a whole. It is practically impossible to isolate a single environmental factor in nature and control it at will without affecting the rest of the system. For example, if the environmental temperature is increased by ten degrees Centigrade, the warmer air can hold more water vapor. The temperature increase will also increase the vapor pressure of liquid surfaces. The combinations of events will result in an increased evaporation rate. This will increase the rate of transpiration which, in turn, increases absorption of soil moisture. Such reduction of free water in the soil allows air to be drawn into the soil and increases the dryness of the soil. The chain of events branches repeatedly. Thus, any change, no matter how small is reflected in some way throughout the ecosystem; no "walls" have yet been discovered that prevent these interactions from taking place (Billings, 1964).

The third principle is the effect of Trigger Factors. A trigger factor is that event in time which causes the replacement of one ecosystem by another. A trigger factor may initiate processes which have different end results and begin changes over long or short periods of time depending on the state of the physical environment when it takes place. A trigger factor usually results in the removal or creation of a limiting factor and causes conditions which favor replacement of one plant-animal community by another. The trigger factor simply begins a chain reaction. The successional sequence and/or direction of change in plant and animal communities is not always predictable.

Climate is considered by most ecologists to be the major controlling factor in the establishment of plant and animal communities in the long term. Under a given climatic regime, ecosystems over the surface of the earth function in similar ways. That is, the structure of the ecosystem changes, based on the response of the living organisms to long-term climatic change. For many hundreds of years, observers of nature have found that certain changes take place in plants and animal communities which are not the direct result of human action. From as early as the seventeenth century, ecologists noted that the vegetation was subject to certain patterns of change from time to time.

Succession is the term used to describe the somewhat orderly changes which take place sequentially over time through ecosystem development. Vegetation succession which begins on bedrock areas or other soil parent material where no soil exists to support communities of fascular plants is called "primary succession." Primary succession goes hand in hand with development of soil; it begins very slowly, and then the communities of plants and animals develop more rapidly during its middle stages. Succession then decelerates as climate rather than soil becomes the controlling factor. Primary succession starting on bare rock or soil parent material is particularly slow. The first plants to appear in primary succession on bare rock are usually crustose lichens. A major contribution to vegetation establishment is made by mosses and non-vascular plants growing in the soil which is created by the lichens or of soil particles which have drifted into the cracks in the rock. Mosses and some vascular plants succeed lichens on thin mantles of soil accumulated over bare rock by wind deposition and lichen growth. On the glacially polished rocks of the Canadian Shield, little or no vegetation or soil has yet been established.

In contrast to bare rock succession, succession in open water is relatively fast. In the forested bogs that were open water glacial lakes less than ten thousand years ago, vegetation is established much more quickly because of the favorable habitat. The first plants to appear in open bodies of water are algae, Elodea, and pondweed (Potamogeton sp.) Dead plant remains and sediments cause the pond to become shallower. At this state cattails, bullrushes, and sedges speed the filling process. Sphagnum or peat moss forms mats over shallow water surfaces. The soils developed through primary succession in bogs are usually made up of a mixture of organic peat and inorganic sediments.

The action of moisture and chemicals on the minerals in the parent material plus the action of weather from the physical environment determine the soil forming process. Plants contribute to soil formation by depositing organic matter in the upp-soil horizons. Once the soil has been developed, the vegetation over it can be destroyed by fire, grazing, or other surface disturbance; however, if the soil mantle is not disturbed badly by the method of removal of the original vegetation, it provides a satisfactory substrate for rapid revegetation. Natural revegetation or recolonization is called "secondary succession" because it is not dependent on initial soil development. Stability is relatively rapid and is reached in terms of a few hundred years as compared to thousands of years in primary succession.

When vegetation succession is carried to its final stage within a given climatic regime, the plant community is called "climax vegetation". In any climate where vegetation is protected from surface disturbance, particular types of plants will become dominant in which the seedlings are the same species as the dominant plants. This vegetation is in dynamic equilibrium with its environment. Introduction of other species in the community is almost impossible because of limiting factors. Climax vegetation's own growth is kept in check by climatic limiting factors.

In all ecosystems the same basic characteristics of succession occur. As the ecosystem tends toward autotrophic climax, community composition changes rapidly at first, then more gradually. Species diversity increases initially, then becomes stabilized or declines in mature stages. The total amount of living matter (biomass) increases as the community approaches climax conditions, as does the amount of non-living organic matter. Food chain relationships become more complex. Gross productivity of energy increases during the early phases of primary succession. Little or no increase of energy production is seen during secondary succession.

Secondary succession usually occurs when an ecosystem is disturbed through alteration of the vegetation and soil substrate. Destructive cultivation practices, mining, soil erosion, air and water pollution all contribute to retarding successional processes. The economic significance of this is that, although vegetation is produced more rapidly on pre-climax vegetation types, it seldom has the value of immediate utility as products. If Climax vegetation happens to be mature saw timber or herbaceous grasses of a high nutrient content, human action tends to manage the land in an attempt to hold successional states to those which have a higher economic value. Serious disturbances to the ecosystem lead to degradation and considerably increase the time necessary to produce climax vegetation. An example of this is the destruction of trees in the vicinity of industrial operations where air pollution by chemicals has eliminated many of the higher types of forest vegetation.

The general tendencies of plant community development in vegetative succession can be summarized as follows:

1) Communities are not static but are changing constantly under natural selection pressures.
2) Factors influencing change in the community may come from inter-community sources such as biotic competition and genetic development.
3) Changes may come from extra community sources such as climatic changes, grazing, timber cutting, mining, or agriculture.
4) Changes usually come from a combination of sources.
5) The result is a gradual change in community composition through time, with the appearance of new species that are suited to the environment.
6) Within each community smaller successional changes may take place.
7) Successional stages may be visualized as a series of changes from a pioneer stage to the climax.

Nutrients in the soil are affected by gravity flow. Nutrients tend to move in a down hill flow from the high mountains slopes into the valleys below. This flow of nutrients is cyclic in effect. Plants and animals utilize nutrients from the soil and air and relocate them upwards through food chains. Death of organisms returns the nutrients to the soil and air. Return of the nutrients to the soil may be followed by solution and removal to river, lake or sea.

For example, a nutrient salt impounded in an oak tree may take a century to pass through an acorn, a squirrel, a redtail hawk and a parasite before it enters the soil for another uptake role. The same particle may only take a year to pass through a corn plant, and a field mouse to the soil. Again it may pass through a grass, a cow, and a member of the human society, returning not into the soil but into a sewer and thence into a lake or river. Civilization shortens food chains and routes them into lakes and rivers instead of fields and pastures (Leopold, 1941).

SECTION 5

ECOSYSTEM FUNCTION

B. ECOSYSTEM FUNCTION SPECIFIC TO LEASE 17

The principles of ecosystem function are well established in the ecological literature. The primary concepts which must be understood are the principle of limiting factors, the principle of holocoenotic environment, the effect of "trigger factors", food chain and food web relationships and plant succession. The flow of energy within the ecosystem has been charted in a very crude form. Applications of these concepts are presented here at a broad level of generalization.

This analysis was approached in a number of steps:

1. Obtaining general information about the baseline conditions of the ecosystem prior to and resulting from any disturbance (See Volume III)
2. Considering the changes which may take place as a result of the Tar Sands Development. Major impacts of this development will include:
   a) Physical and chemical changes in soil structure and soil biota from mining which will lead to a changed plant environment.
   b) Vegetation removal on areas adjacent to mining area which will be used for roads, plant facilities, etc.
   c) Potential alteration of ambient water and air quality; e.g. chemical wastes, bitumen and clay minerals in water bodies; thermal pollution of water; SO_2, NO_x, H_2S, HCO Emissions; ground water changes
   d) Changes in behavior and dynamics of wildlife populations; e.g. creation of water clarification or diversion facilities; in winter, open water attractive to waterfowl.

e) Altered water balances--quantity and regime; ground and surface. e.g. resulting from cleared watersheds, changed ground water systems.

These areas of impact are shown by number in the ecosystem model which follows where they are most likely to cause great change.

3. Developing a hypothesis on the impact of change on the area and its surroundings, based on knowledge acquired from past experience in other areas; recommending general criteria for land use which apply to the ecosystem and its sub-units, which includes Lease #17.

   In order to complete the evaluation, three future steps will be required:

4. Continuous testing of the hypothesis through long-range studies to confirm the predicted general assessment of change.
5. Based on the results of continuing studies, make quantitative and qualitative assessments, leading to review of impacts with respect to regulatory requirements of responsible governmental agencies.
6. Implement recommended practices which will minimize environmental damage.

As can be seen from the ecosystem model, there are many potential points of impact. Below are some examples of areas for future study:

1. Change in soil productivity for plants; emphasis on soil stability, reforestation and/or wildlife forage on reclaimed land.
2. Change in animal components of the altered forest communities.
3. Change in plant and animal species and productivity in aquatic habitats.
4. Change in plant community composition resulting from altered soil moisture regime.
5. Change in sequence of natural plant and animal succession

during recolonization.

6. Change in water relationships (surface, capillary, ground water, storage).

O V E R V I E W

SECTION 6.
ENVIRONMENTAL IMPACT

SECTION 6

ENVIRONMENTAL IMPACT

A. GENERAL

The concept of "impact" is usually objectively defined: that is, the actual cause and its related effects. An impact is the result of change in the normal functioning of an ecosystem. It may occur at one or more levels of biological organization. It may also affect the non-living physical environment. The point of impact to be assessed is determined <u>subjectively</u> based on factors of concern at a particular level of generalization. It is necessary to consider the ecosystem concept and the principles of ecosystem function as discussed above in the establishment of any subjective criteria for what constitutes impact. The non-living portions of the physical environment and the biotic community, which together comprise the human environment, are subjected to impacts which result from the application of human technology. These impacts are increasing both in frequency and severity as increased amounts of energy (power) becomes available to humans in their attempt to modify their environment for their own purposes.

In order that definitions be understood uniformly and the scope and diversity of the problem of defining impacts be recognized, the following causes for impacts are proposed:

1. Any activity or process which alters the amount of energy entering an ecosystem.
2. Any activity or process which changes the rate at which chemicals are cycled within an ecosystem.
3. Any action or process which alters the non-living physical environment.
4. Any activity or process which alters inter-community structure, food chains, food webs, or

the roles of populations in the interaction at a rate which is significantly different from normal ecological succession taking place under the controlling influence of climate.

The above four points in themselves are impacts but not always measureable in a meaningful way.

Therefore, before the level of measurable change can be subjectively determined as constituting an "impact", it is necessary for an objective to be set. The objective generally reflects the judgment of the human planner as to what constitutes acceptable or non-acceptable restrictions on alternatives through which the ecosystem can supply the planner's wants and needs.

The definition of impact thus involves psychological, sociological, economic, and political inputs from which the objective is to be derived. Subjective definition of impact is especially difficult as society's objectives are not always the same as the objectives of the individual making the assessment of what constitutes impact. In addition, society's objectives and the proposed alternatives are not always clear.

One starting point in establishing impact might be the application of the trigger factor principle. A trigger factor, as previously stated, is the cause of the beginning of change which begins at a point in time, and which results in one ecosystem (or part of an ecosystem) being replaced by another.

Another criterion can be applied, once values are established relating to the subjective desires of the planner to maintain an ecosystem at a given state of maturity. This is a "safe minimum standard" criterion which ensures that certain functions of the ecosystem do not become unalterably changed in ways which are technologically or economically irreversible.

The principles of "even flow" and "sustained yield" are implicit in the conservation and management of renewable natural resources with "critical zones". A "critical zone" is a range of rates of use below which a decrease in flow cannot be reversed <u>economically</u> under presently foreseeable conditions.

The great variety and complexity of physical conditions which characterize critical zones in the depletion of various renewable resources make it generally impractical to define a safe minimum standard for each resource simply in terms of a single flow rate which is to be maintained. It is more practical to define a safe minimum standard in terms of practices designed to avoid the critical zone. Such a definition may be in terms of conditions to be maintained (Ciaracy-Wantrup 1952). For example, in soil conservation, the safe minimum standard may be defined as the avoidance of gullies or as a maximum rate of erosion in cubic feet per acre per year. In forest ecosystems, a safe minimum standard may be defined as a maximum rate of burn in percent of total area per year; or as the maintenance of a given plant association(s) within an ecosystem.

The study of plant indicators has made it possible for ecologists to make a practical definition of a plant association and to check its maintenance periodically. In the conservation of grassland ecosystems, a safe minimum standard may be defined in terms of certain minimum amounts of plant material left above the ground after the grazing season or, as in forest conservation, in terms of maintenance of certain plant associations. In the conservation of a plant or animal species, a safe minimum standard may be definedin terms of maintaining a certain breeding stock, or in terms of protecting a certain habitat. In the conservation of water resources, a maximum degree of pollution in terms of total or specific solids, bacterial count, oxygen conditions, etc., may be used for defining a safe minimum standard.

An understanding of the ecosystem concept and succession make it possible to set criteria and to choose alternatives which cause as little disturbance to natural conditions and functions of the ecosystem as possible. This will allow natural processes of maturing ecosystems to take place with minimum corrective human input. This concept is sensible both from ecological and economic viewpoints.

SECTION 6

ENVIRONMENTAL IMPACT

B. ENVIRONMENTAL IMPACTS SPECIFIC TO LEASE 17

Introduction

The initial study of July, 1971 identified several environmental considerations. The lack of quantitative ecological data specific to the area was a major limitation to providing definitive interpretation. As a result, many of the points noted in the July, 1971 report raise questions in anticipation of potential problems or define further research requirements.

The most significant ecological impact of the development pertains to the disruption of the Beaver Creek drainage. The development (of Lease #17 with one plant) would create complete ecological change in localized areas. However, in an initial and generalized assessment, the mining area to be most affected appears to be of fairly low productivity for biological resources (excluding the significance of Beaver Creek itself) and does not constitute a critical area for wildlife species or other land uses. These comments do not pertain to the entire lease area but to the areas noted as Mining Areas A and B.

The creation of a large tailings disposal pond and its role as an attractive hazard to waterfowl present a potentially serious problem. Further study is planned, both prior to the formation of the pond and following the onset of operations.

Impact on Fisheries

Results of Studies

The Baseline Study of Beaver Creek, September, 1971, (Volume III) showed that the habitat for sport fishes rated fifty-five percent of the optimum, based on pool-riffle ratio of 50-50 being 100% of optimum. This value was considered low. Fisheries habitat for Arctic grayling was considered marginal primarily due to habitat restriction. Creel-Sized Arctic grayling comprised .3% of the total number of fish obtained through sampling, indicating that sport fishery capability of the river is extremely low. Possible limiting factors to grayling production included lack of suitable spawning substrate, low dissolved oxygen concentrations occurring in the slack water area, and low production of benthic organisms in riffle areas thus limiting food supply. The lack of a catchable population precluded an economic analysis based on the existence of a harvestable fish stock. Data indicated that the creek was used primarily by residents of the Ft. McMurray area with angling only a part of the recreational value. The creek is used as a scenic attraction by campers and picnickers. Existing recreation demands on the creek were considered light. The most significant ecological impact was the construction of a diversion and tailings pond which would eliminate Beaver Creek per se.

The second study was initiated on April 5, 1973 at which time a preliminary field survey of fish spawning was carried out. A field camp was established on Beaver Creek near its confluence with the Athabasca River and was occupied from April 15 to May 15, 1973.

The major objectives of the 1973 study were to determine the magnitude of the Arctic grayling spawning run into Beaver Creek; and to tag as many of the migrants as possible to facilitate a subsequent monitoring program.

In view of the results obtained during the 1973 spring investigation, the following conclusions are drawn concerning spawning migrations into Beaver Creek:

1. Arctic grayling utilization of Beaver Creek for spawning purposes was not substantial in 1973. In fact it is difficult to consider the 1973 migrants as being members of a common spawning population, but rather a group of stray individuals possibly from different stocks. Sufficient suitable spawning habitat in the lower section of Beaver Creek is capable of supporting a large

spawning population. It is postulated that the spawning population of Arctic grayling in previous years was greater than in 1973, in order to have facilitated the recruitment of the present member of immature grayling. Reduction in the present spawning population of Arctic grayling appears to have resulted from successive year class failures prior to 1973. Natural and unnatural disturbances in the watershed may have affected chemical or physical limiting parameters in the creek, thus creating conditions inimical to Arctic grayling reproduction. Although the initial stages of tar sands development has taken place, it is unlikely that the resultant alterations of the watershed substantially affected Arctic grayling spawning success. It appears more likely that the suspected previous year class failures resulted from unsuccessful competition with forage fish populations for suitable spawning habitat. In any event, the Arctic grayling population in Beaver Creek is very unstable and it is anticipated that under present conditions Beaver Creek will not support or produce a viable population of grayling in the future.

2. The large spawning population of white suckers in Beaver Creek, no doubt reflects the favorable nature of the habitat. Spawning habitat is certainly not limiting and a substantial portion of the spawning area is probably being utilized. Beaver Creek also provides excellent summer rearing habitat which was indicated by the large number of immature white suckers collected during August 1971. The extent of over-wintering of immatures is not known. The white sucker adults probably move downstream shortly after spawning in Beaver Creek. Beaver Creek white sucker population appears to be very stable with all year classes represented and is the dominant

species in the system. In fact the white sucker may be dominant to the extent that it regulates to some extent the population dynamics of other species, particularly Arctic grayling. Although significant spawning populations of northern pike and longnose sucker were recorded in Beaver Creek during the study it is apparent that they are not as successful as the white sucker in regards to recruitment and maintenance of their numbers. Spawning habitat for pike in Beaver Creek is extremely scarce. Possibly pike are utilizing suitable areas in streams tributary to Beaver Creek. Longnose sucker adults appear to leave Beaver Creek after spawning. A post-hatch movement of fry is evident from the August 1971 sampling in which no longnose sucker fry were collected. Beaver Creek does not function as a rearing area for this species to the extent it does for white suckers.

3. The collection of yellow walleye at Beaver Creek - Athabasca River confluence may be of extreme or minor significance depending on the importance of that particular habitat to the life history of the walleye population. Unfortunately it is not possible on the basis of the present study to determine the significance of the collection. The confluence area may be utilized for spawning, rearing of young, or feeding. These habitat functions are extremely important in determining the viability of a population. It is quite possible that spawning may have taken place during 1973 in the confluence and that it may have been regulated by flow and thermal characteristics of Beaver Creek. The size of the walleye population is not known due to the limited sample collected, however it may be substantial. Individual walleye were of a good size which increase their fishery value.

Impact

Based upon the above information we conclude that the disruption of Beaver Creek as an entity will be total; that is, the creek will be eliminated as the result of the project. However, the impact on fisheries is minimal as studies show that Beaver Creek is not a significant habitat for game fish and supports spawning of some rough fish in the lower reaches only at certain times of the year. Water diversion plans include maintaining a minimum flow in the lower reaches of Beaver Creek beyond the tailings pond.

The potential exists for improvement of fish habitat through improvement of water quality in Ruth and Mildred Lakes. Future studies will be made to quantify this potentially positive change.

Impact on Waterfowl

Results of Studies

In October, 1971, two aerial surveys of waterfowl (Volume III) was made to determine the use of the Syncrude lease area by fall migrants. Three hundred and two mallards were observed on Mildred Lake during the first survey and none during the second. In general, it was concluded that the Ft. McMurray region was not a heavily used migration stopover during the late autumn. Waterfowl that had migrated at this time were believed either to have flown non-stop through the area to the south, or flown southeast from the Athabasca Delta through the province of Saskatchewan. The Fish and Wildlife Officer at Ft. McMurray stated that the movement of geese through the area had occurred almost two weeks earlier. However, neither he nor the local residents observed any large migration of ducks through the area.

Data obtained on surveys indicate that the Ft. McMurray region in general is not a heavily used migration stopover during the late autumn. The 302 mallards observed on Mildred Lake was the largest number of ducks observed within the area in the Fall 1971. These birds likely represented a migrating flock since observations made on Mildred Lake during the summer

1972 did not reveal any more than a few scattered waterfowl, and these were primarily diving ducks. It is likely therefore that lakes and marshes in the area are used to some extent by migrating waterfowl, which probably originate in the Athabasca Delta. Present evidence indicates that the area is insignificant except as a staging or resting area for these populations. The largest proportion of migrants either overfly the area enroute to grain growing areas further to the south or utilize a route southeast from the delta passing through Saskatchewan. Since the area was surveyed immediately following reports of an exodus of waterfowl from the delta following freeze-up, any substantial use of the area would have been observed.

According to information obtained from a Ducks Unlimited observer at Ft. Chipewyan in 1971, resident (nesting) waterfowl in the Athabasca Delta migrated south gradually during September and October. A build up of populations from the north then occurred in the Delta and these birds remained until approximately October 24th when a general freeze-up triggered a large migration.

In view of the foregoing, periodic use of lakes in the lease could occur during the first prolonged migration. However, there has been no indication of extensive use by large numbers of waterfowl in the area. At present it appears that casual use of the area is made by small flocks for a short period of time.

Since northward spring migrations progress fairly slowly in response to weather conditions, 1972 and 1973 spring migration have been monitored to supplement existing survey data. In addition, surveys on fall migrations were repeated in 1972.

Twenty eight different species of ducks used the study area during spring 1972 migration, plus whistling swans, sand-hill cranes and great blue herons. A few geese also appeared to use the area at this time.

Twenty five different species of waterfowl were noted to pass through the study area during fall 1972 migration. Species recorded were similar to those of the spring migration except that no red-breasted mergansers, common loons, harlequin ducks, sandhill cranes, and great blue herons were noted. Canada geese were noted this fall but were absent in the spring 1972 survey.

Local weather conditions and the degree of air haziness affected identification of waterfowl. As well, a sample bias was produced by some species being more difficult to identify from the air than others. For example, mallards are easier to identify than teal or ruddy ducks. Additionally, sampling errors were produced in making estimates of large flocks where counts from the air were impossible. However, the sample biases and errors were considered to be relatively unimportant to the overall results of the data presented here.

A daily average of 1,037 birds from April 28 to June 2, 1972 indicates that the study area was not a major staging area but rather a stopover area. This daily average is conservative because some ducks hidden in vegetation were certainly missed during aerial surveys. Numbers of waterfowl using the study area would be expected to shift from year to year with fluctuations in duck populations and changes in migratory routes.

Unfortunately, the first aerial survey on September 18th, 1972 was initiated after the onset of fall migration. On that date, 1,800 birds were recorded in the area. Migration from the Peace-Athabasca Delta usually begins in early September (Ed Hennan, pers. comm.).

It is evident that, as in the spring, the study area is not a major staging area, but rather a casual stopover area. The average of the eleven flights was 1,465 birds per flight. However, Canadian Wildlife Service personnel conducting fall waterfowl counts in the area report large numbers of waterfowl staging or stopping on some of the larger lakes south of the Peace-Athabasca Delta especially in the Gordon Lake area, about 50 miles southeast of Fort McMurray. Craig Schick (pers. comm.) reported estimates of up to 100,000 ducks in the Gordon Lake area in September; 75-80% of these were diving ducks. This may account for the higher proportion of diving ducks to dabbling ducks counted in the surveys. Dabblers appear to swing to the east of the study area. Ducks Unlimited data indicates that 80% of dabblers banded on the Delta were recovered in Saskatchewan (Craig Schick, pers. comm.).

Twenty-five species of waterfowl and other birds of importance were noted to use the study area during spring 1973 migration. Species were similar to those seen during the spring 1972 migration except that no whistling swans, harlequin ducks, oldsquaw, common scoters, red-breasted mergansers, horned, eared or western grebes were seen. However pied-billed grebes were seen that were not observed last year.

Unfortunately the first survey on May 5, 1973, was initiated after the onset of spring migration. On that date, 1187 waterfowl were observed. By then the Athabasca River and all the lakes were thawed and many of the dabbling ducks had already reached their peak. It would appear that because of the unusually mild weather in April (average mean temperature of 37.5 F in 1973 as compared to 31.9 in 1972, Government of Canada, Department of Climatology, pers. comm.), spring break-up, and thus migration was about two weeks earlier than in 1972.

By mid-April flocks of Canada geese (Branta canadensis) were noted flying over the area. This is approximately when the Athabasca River first started to break-up, and probably coincided with the advancement of the 35 F. isotherm which Canada geese are known to follow in the spring migration (Lincoln, 1950).

Use of the study area during the period May 4 - June 4, 1973, averaged 1154.2 birds per day with a high count of 1469 birds on May 25. Average daily utilization was slightly higher than in 1972, but was probably a reflection of a more protracted migration, lasting into early June.

Coots were by far the most common species, followed by scaup (mostly lesser), common goldeneye, American Widgeon and mallard. Most waterfowl had already reached good numbers by May 4 and did not increase their numbers substantially after that date. Only the coot shows any marked increase after May 4.

Impact

The possible effects of the Suncrude development upon waterfowl has already been touched upon.

In light of the results of the waterfowl study, some aspects were thought worthy of enlarging upon.

Since the use of Mildred Lake as a fresh water impoundment is planned, some enhancement of Mildred Lake water quality for fish may occur. Some fluctuation which will occur will change the type of vegetation in the lake. The timing of drawdown should not directly affect waterfowl. However, if seepage from the tailings pond into Mildred Lake occurs, this may introduce change in the water chemistry.

The influx of people to work on the Syncrude project will result in increased hunting pressures on waterfowl. Hunting is regulated by Federal and Provincial legislation; this is not considered to be a serious issue.

The most serious potential impact on waterfowl will be from possible oil contamination on 9.3 square mile tailings pond. Both the spring and fall waterfowl surveys have shown that appreciable numbers and varieties of ducks use lakes on or bordering the Syncrude Lease to rest and feed during migration. The creation of a body of water as large as the tailings pond will undoubtedly attract more waterfowl to the area, particularly as the Syncrude area appears to be on part of a broad flyway for large numbers of waterfowl. Gordon Lake, where an estimated 100,000 ducks staged this fall, is only 75 miles to the southeast. The Peace-Athabasca Delta, which has populations of up to 1.5 million ducks and 300 - 400 thousand geese during staging (Craig Schick, pers. comm.), is only 100 miles to the north.

Some alteration of waterfowl habitat has already occurred on Horseshoe Lake. A drainage canal was built at the north end of the Lake in the mid-1950's, thus reducing the water-levels on Horseshoe Lake and altering its nature by the inflow of water from the Athabasca River during the peak spring flow. This has probably reduced its attractiveness to waterfowl.

Creation of a fresh water sedimentation pond adjacent to Horseshoe Lake on the South should have no adverse impacts on waterfowl as noise/emissions are being kept to a low level through design of the facilities.

Damming Beaver Creek above the mining areas will create two detention storage reservoirs. This will create alternative waterfowl habitat adjacent to the lease area which may help alleviate the problem expected between waterfowl and the tailings disposal pond, by luring them south, away from the sphere of activity in the plant site area.

Some species of waterfowl appear more vulnerable to contact with oil than others. Experimental studies on mallards and scaup exposed to oil contamination showed scaup to be far more vulnerable when oil-soaked than mallards. Mallards recovered after cleaning but scaup died because of a loss of buoyancy and an elevation of metabolic rates to compensate for the loss of feather insulation (McEwan, et al, 1972).

The presence of an average of over one thousand ducks per day, many of these scaup, for over a month near the large tailings disposal pond, will undoubtedly lead to problems of oiled ducks. The magnitude of these problems, however, is difficult to predict, and will be expected to vary with the degree of surface pollutants, status of waterfowl populations, and weather conditons.

There is some evidence that waterfowl avoid the G.C.O.S. tailings disposal pond. No waterfowl were observed on the pond during aerial flight although fairly large flocks would sometimes be noted along the river immediately below the impoundment dyke. One of the senior officials involved with environmental control at G.C.O.S. stated that in five years he has noted only two oiled ducks at the plant site. One of these was found dead on the shore of the tailings disposal pond and another was found on the waste water disposal pond. He stated that ducks seem to avoid the G.C.O.S. water containment areas except for the sewage lagoon.

Mr. A. Boggs, Fish and Wildlife Officer at Fort McMurray, has had two oiled waterfowl, both loons, brought to him from the G.C.O.S. tailings pond over the past two years. Mr. Vincent Bouchier stated he found two ducks some distance upstream from G.C.O.S. this spring. (1972) The ducks were on the bank of the Athabasca River. He "collected" one, a mallard drake, whose wind and breast feathers were matted with oil. The duck was flightless. The other duck escaped into the brush. Thus, it would appear that some ducks may land in the G.C.O.S. pond and take off with their feathers coated with oil, and later suffer after-effects. Mr. Jim Farley, cook at the Syncrude Camp, said he rescued a duck from the Syncrude test plant pond last year but it did not survive.

Problems with waterfowl on the Syncrude tailings disposal pond might be expected to be greater than the G.C.O.S. because:

1. The Syncrude pond will be much larger, about 17 times larger than the size of Mildred Lake. This will create the second largest body of water proximal to the Athabasca River between Fort McMurray and Lake Claire near the mouth of the Athabasca River. It is well-known that large bodies of water attract waterfowl and create shifts in flyways of migratory waterfowl, (e.g. artical reservoirs in parts of U.S. have changedflight routes of migrant geese.)
2. The Syncrude pond will be much closer to larger concentrations of migrant waterfowl that stop over during the spring.

Problems may also be encountered with Mildred Lake should it become contaminated with pollutants that are harmful to waterfowl. The complexity of the problem is compounded by the fact that Mildred Lake and portions of the Syncrude tailings disposal pond will be available to waterfowl when other bodies of water are frozen -- either in late fall or early spring, thus serving as an attractant -- particularly during spring migration.

The most significant aspect of the tailings pond as an attractant to waterfowl is it's large size rather than as habitat. Waterfowl are characteristically attracted to large bodies during fall migrations because of the security they represent during resting periods. The proposed pond represents an extremely difficult problem since it will be necessary to achieve high use of peripheral areas and maintain the pond in an unattractive state to waterfowl.

Four lakes of 300 acres or more are located within a 3-mile radius of the proposed Syncrude tailings disposal pond. This is the greatest concentration of small lakes along the Athabasca River zone for at least 50 miles in either direction from the Syncrude Lease. This concentration of lakes attracts the greatest number of waterfowl that stop over in the area during spring migration. Lakes on Lease 17 accounted for 43% of all waterfowl counted throughout the survey. The most intensive use by waterfowl between Beaver Creek and Fort McMurray is concentrated on the proximal to Lease 17.

Use of these lakes occurs immediately after spring break-up and use of the Athabasca River decreases. The Athabasca River between G.C.O.S. and the mouth of Beaver Creek, and Horseshoe Lake, are prematurely open because of hot water emissions from the G.C.O.S. plant. These areas attract the first wave of migrants.

Dabbling ducks preferred Horseshoe Lake and shallow parts of Saline Lake, whereas diving ducks tended to prefer Mildred, Ruth, and deeper parts of Saline Lake. Saline Lake received the greatest use by waterfowl and a shift in concentration of coots and dabbling ducks was noted from other lakes to this lake as the season progressed. By the end of May the few waterfowl left on Ruth Lake and Mildred Lake tended to hide in the emergent vegetation along the shore. This and the build-up of pond-lily (Nuphar) made observations difficult. Utilization by shore birds appeared minor.

Limited evidence suggests waterfowl avoid the G.C.O.S. tailings disposal pond. Waterfowl oiling problems with the Syncrude tailings pond may be expected to be greater than with the G.C.O.S. tailings disposal pond because of larger area. Mitigation will be undertaken to reduce waterfowl oiling problems.

Possible Mitigative Actions

Careful monitoring will be required during the initial years of the development. Control measures should be initiated if a serious problem develops. Carbide cannons used to discourage waterfowl from crops might be used. Surface oil might be gathered in booms and contained in certain areas. Waterfowl rescue equipment will be made immediately available as a contingency action, but the main emphasis will be on research to prevent waterfowl losses.

Horseshoe Lake has been protected in development plans to maintain waterfowl. Horseshoe Lake is the first lake open when migrants arrive in the spring and will help to lure waterfowl away from the open water of the tailings disposal pond at a time when all other lakes are frozen. The canal at the north end of Horseshoe Lake could be filled in or a wing gage built to control water levels at optimum conditions for good waterfowl habitat.

While it is difficult to predict the magnitude of waterfowl oiling problems, a mitigation study will be initiated while the project is still in the planning stage. Such a study should include a review of the following factors:

1. Physical characteristics of proposed alteration and/or creation of water bodies and channels on Lease 17.
   - water temperatures and quality
   - volumes
2. Analysis of expected alteration and/or creation of water bodies on Lease 17 and surrounding area in relation to utilization by waterfowl. For example, clean water reservoirs created by the diversion of Beaver Creek will probably help to divert waterfowl from the tailing pond. Analysis of factors contributing to the attractiveness and unattractiveness of water bodies

to waterfowl on migration will be carried out. Results can be applied to the design of the tailings pond so that as many unattractive features as possible are incorporated. Additional habitat can be created to attract birds from the tailings pond.

3. Analysis of above factors in relation to present data on waterfowl in the area such as critical times when problems might occur.
4. Analysis of all literature available on mitigation of waterfowl - oiling problems.
5. Recommendations for mitigation based on all of the above facets. Examples might be:
   - Design alteration of the tailings disposal pond to create several smaller initial settling ponds which might confine surface oil to a smaller area rather than to the total surface of the tailings pond.
   - Disturbance techniques to frighten birds away from tailings pond during the period when there is an influx of waterfowl in the area.

Increased hunting pressure might lead to complications with a mitigation program designed to entice waterfowl to certain ponds. Hunters might drive ducks away from such ponds and it is possible that hunting restrictions would have to be instituted.

Additonal waterfowl surveys should be made as a follow-up to this study, including a brood count about mid-July to determine numbers and distribution of the breeding population of waterfowl. This would take only a few days, and while the breeding population would be expected to be small, the data would serve as baseline information. An extensive survey should be made to determine the use of the entire Tar Sands area during the full period of the fall migration.

Impact on Big Game

Results of Studies

In February, 1972, a big game survey was made to obtain quantitative data on big game populations present in the lease area. In addition, an attempt was made to ascertain the population's distribution during the winter and to note the location of any important winter areas and, conversely, any exceptionally poor areas. A total of 13 moose were observed on all transects, which covered 25% of the lease area. By extrapolation, a winter population of approximately 52 moose could be present on the lease or approximately .7 moose per square mile. No deer were seen on the lease and it can be assumed that there are very few present except in the riverbreak zone. The animal population appeared to be aggregated, with greatest concentrations along the west bank of the Athabasca River and unburned areas along the Mackay River. These areas appeared to be predominantly deciduous growth, particularly balsam poplar regrowth up to 30 feet high along the Mackay River and mature aspen-pine stands on the riverbreaks above the Athabasca River. Human activity and areas of poor wintering habitat over the majority of the lease probably account for the difference between actual numbers observed and an anticipated population based on averages for the Boreal Mixedwood Forest ecosystem. These populations usually range from 1 to 3 moose per square mile at carrying capacity, depending on the quality and local availability of habitat.

The survey was not intended to assess the status of the moose population but only to provide a basis for determining approximate numbers, and distribution on ranges requiring more intensive study on the ground. Population status requires more information collected over a longer time period. The spring, 1972 study began measurements of trend upon which status of population could be determined.

The habitat evaluation in the spring of 1972 (included in Volume III a) had two elements:

1. Consideration of the preferences and requirements of the animals, and
2. the ability of the area to satisfy those preferences and requirements.

This habitat evaluation was based on the concept that certain habitat types are more productive for certain types of wildlife than are others. Knowledge of the plant species most heavily utilized by large ungulates, birds, and other wildlife are relatively well-known for animals of the Boreal Mixedwood Forest ecosystem. Application of this information to the lease area indicated that certain plants which were preferred browse species had varying importance values depending upon the habitat type. (Importance value is the cumulation of the frequency, density and dominance of each species relative to the other.) High importance values indicate availability and presence of these plants. When animal preference and requirements were met in a habitat which had an abundance of preferred plant species of high importance value, the area constituted good wildlife habitat. It is on this basis, plus field checks for utilization percentages of preferred plants, that the judgements were made about habitat quality and carrying capacity.

Impact

It was found that mining Areas A and B will remove little in the way of important wildlife habitat from the Syncrude Lease #17, except some beaver habitat and minor nesting area for sandhill cranes. The tailings disposal pond will remove a portion of secondary wildlife habitat for wintering moose, grouse and beaver. The remaining areas appear to have a good composition of available and desirable shrub species and thus would act as a "buffer" for the moose displaced by the mining area and tailings disposal pond. Development will remove additional portions of potential moose range in the recent burn type, however, these ranges are not currently occupied.

The Boreal Mixedwood association constitutes the largest single type of moose winter range on the lease. However, the Riverine communities had the highest productivity per unit of area. Most of the key winter habitat occurs within 3 miles of the Athabasca in a strip parellelling the river on the west. Since most of this area occurs in the Riverbreak zone, special considerations are given to these habitats.

Further Impact Assessment

Much additional information relating to ecological baselines for soils, water regimes and quality, wildlife population status, waterfowl presence in migration, and the effects of human use is required. Additional studies, especially in soils, and surface and ground water regime are underway already. These two elements of the physical environment have less information on which to base ecological impacts than any other factors.

Finalization of the Program proposed for resource extraction and material processing and their sequence are required before final assessment of environment impact can take place. Once these elements are established, hypothesis will be formed on the impact of change and long-range studies designed to confirm the predicted general assessment.

Syncrude Canada Ltd. will continue to encourage and support activities of environmental agencies within industry and government in obtaining information about long-term ecological effects of these resource extraction operations.

O V E R V I E W

SECTION 7.

CRITERIA FOR THE EVALUATION, CONTROL AND MONITORING OF ENVIRONMENTAL IMPACT

SECTION 7

CRITERIA FOR THE EVALUATION, CONTROL AND MONITORING OF ENVIRONMENTAL IMPACT

A. INTRODUCTION

"Safe minimum standard" criteria for the protection of the environment are set by the Department of the Environment and the Department of Lands & Forests of the Government of Alberta. At present, most of the rigid standards and criteria relate to the chemical environments with less specific criteria for biological and physical environments. Air quality standards and water quality standards are established by regulations. Establishment of criteria for biophysical resources such as wildlife, vegetation and soils are most difficult as the element of time must be taken into account. Information, relating time to rates of production for various biological resources in the Syncrude Lease 17 area, is limited.

SECTION 7

CRITERIA FOR THE EVALUATION, CONTROL AND MONITORING OF ENVIRONMENTAL IMPACT

B. ESTABLISHMENT OF CRITERIA BY WHICH IMPACTS CAN BE EVALUATED

Ideally, an "ecosystem approach" is the most logical route to follow in establishing criteria for assessing impacts. Ecosystems have many subsystems which must operate if the entire unit is to function as a whole. Each subsystem can be analyzed for developmental impacts. For a development of the magnitude of the Syncrude development we feel that this is desirable. All factors of the physical environment and the living components of that environment should be considered as they are all interrelated.

However, from the practical standpoint, some factors influence each other more significantly than do others. Therefore, those parts of the system which have the greatest potential impacts on the environment resulting from change caused by the development should receive greatest attention. The communities in which the development is located are complex. We recognize that environmental impact studies, which are required for preparation of environmental impacts statements, must be carried out in six phases:

1) Background research to obtain "baseline" information about the working of the ecosystem(s) in the development area and those that are affected adjacent to it. This should be carried out prior to and concurrent with, development in other parts of the study area.
2) Identification of specific research needs based on "screening studies" for assessing specific impacts on the environment which may be caused by various

proposed mining and operating methods. Recommend possible mitigation or prevention measures.

3) Establishing hypothesis on the impact of change on the area and its surroundings, based on knowledge acquired from these studies and from past experience in other areas; recommending general criteria for land use which apply to the ecosystem and its sub-units, which includes Lease 17.

4) Testing the hypothesis through long-range studies and monitoring to determine if the general assessment of change is correct; and if so, to what extent. Determine what changes are naturally occurring and which are the result of the development.

5) Draw conclusions based on the results of studies and make quantitative and qualitative assessments; compare this assessment to objective criteria for permissible change provided by the responsible agency.

6) Implement modifications based on alternatives which will minimize environmental damage. This would include recommendations in detail for on-going studies which should be continued in the future.

SECTION 7

CRITERIA FOR THE EVALUATION, CONTROL AND MONITORING OF ENVIRONMENTAL IMPACT

C. CRITERIA FOR CONTROL AND MONITORING OF ENVIRONMENTAL IMPACT

Criteria for control and monitoring of environmental impact as related to air and water quality, are documented in permits to construct issued under the Alberta Clean Air and Clean Water Acts.

1. Air Quality

Pursuant to Section 4 of the Clean Air Act, a permit (73-AP-054) to construct an oil sands recovery plant for the production of synthetic crude oil and associated by-products from the Alberta oil sands located in Bituminous Sands Lease No. 17 was issued subject to the following terms, conditions and requirements on July 12, 1973.

PERMIT NO.
73-AP-054

TERMS, CONDITIONS AND REQUIREMENTS

ATTACHED TO PERMIT

SECTION ONE: DESIGN AND EMISSION STANDARDS

1.1 The plant referred to herein includes those buildings, structures, operating and storage facilities, and land located in Bituminous Sands Lease No. 17, Township 92, Ranges 10, 11 and 12, West of the 4th Meridian; Township 93, Ranges 10, 11 and 12, West of the 4th Meridian; and, as depicted in Drawing No. IE-SK-A-150 A.

1.2 The plant may be constructed to operate up to a maximum processing capacity of 190,000 barrels per stream day of bitumen feed to upgrading.

1.3 Any contaminants released from the plant boilers and the sulphur plants shall be discharged to the atmosphere through one main stack which shall be a minimum of 600 feet in height with a minimum flue gas emission temperature of 450 degrees Fahrenheit.

1.4 The concentration of sulphur dioxide in the flue gas being exhausted to the atmosphere from the main stack shall not exceed a maximum one-half hour average or 2700 parts per million by volume or a maximum 24 hour average of 2000 parts per million by volume.

1.5 The maximum rate of release of sulphur dioxide to the atmosphere from the main stack shall not exceed 287 long tons per day or 8.1 long tons in any half hour period.

1.6 The sulphur recovery units shall be operated to recover in the form of elemental sulphur not less than 95.0 percent of the sulphur contained in the raw gas delivered to the units during each three month period commencing January 1, April 1, July 1, or October 1.

1.7 In designing the plant layout, provision shall be made to accommodate a third sulphur recovery unit should the down-time of either of the proposed sulphur recovery units be of such duration to warrant the installation of this additional unit.

1.8 (a) The design of the plant shall be such that the release of sulphur dioxide to the atmosphere does not result in a calculated one-half hour average ground level concentration exceeding 150 micrograms per cubic metre (approximately 0.06 parts per million by volume).

(b) The operation of the plant shall be such that the release of sulphur dioxide to the atmosphere does not result in an ambient one hour average concentration exceeding 450 micrograms per cubic metre (approximately 0.20 parts per million by volume) or an ambient one-half hour average concentration exceeding 525 micrograms per cubic metre (approximately 0.20 parts per million by volume) of sulphur dioxide at ground level or at any other point of impingement.

1.9 (a) The design of the plant shall be such that the release of nitrogen oxides to the atmosphere from the main stack does not result in a calculated one-half hour average ground level concentration exceeding 110 micrograms per cubic metre (approximately 0.06 parts per million by volume) expressed as nitrogen dioxide.

(b) The operation of the plant shall be such that the release of nitrogen oxides to the atmosphere does not result in an ambient one hour average concentration exceeding 400 micrograms per cubic metre (approximately 0.20 parts per million by volume) expressed as nitrogen dioxide at ground level or at any other point of impingement.

1.10 The emission of particulates to the atmosphere from the main stack shall not exceed 0.20 pounds per 1000 pounds of gaseous effluent.

1.11 The flare stacks shall be a minimum of 235 feet in height and shall be equipped with a suitable guard to prevent the wind from extinguishing the flame and a pilot and an automatic ignition device to ensure continuous ignition of any vented gas.

1.12 In the event of an emergency necessitating the flaring of sour gas, a sufficient quantity of residue gas shall be added to the sour gas upstream of the flares to maintain the cumulative maximum calculated ground level concentration of sulphur dioxide below 0.20 parts per million by volume.

SECTION TWO: GENERAL

2.1 The oil sands recovery plant shall be constructed in accordance with the company's submissions of March 20, April 6, 12 and 13 and May 28, 1973 relating to an application under The Clean Air Act for a permit to construct facilities for the production of 45,625,000 barrels of synthetic crude oil per year.

2.2 All odorous materials are to be handled in such a manner as to prevent the emission of objectionable odors by confining them at the source.

2.3 Smoke resulting from either flaring operations or burn pit systems must comply with the limitations in the Clean Air (Maximum Levels) Regulations.

2.4 All tankage shall be designed and equipped for vapor and gaseous emission control as follows:

(a) All tanks that are over 50 feet in diameter holding stocks with a vapor pressure of 3 to 12 pounds per square inch absolute shall be provided with a floating roof designed with a closure seal or seals to close the space between the roof edge and the tank wall or such other equally effective method of vapor control as may be approved by the Director of Standards and Approvals.

(b) All stocks with a vapor pressure greater than 12 pounds per square inch absolute shall be stored in closed vessels or pressure spheres.

2.5 In a manner satisfactory to the Director of Standards and Approvals, final plans and specifications of air pollution abatement equipment and plant operating procedures shall be submitted to the Director for his approval.

SECTION III: MONITORING

3.1 In a manner satisfactory to the Director of Standards and Approvals

(a) The flue gases in the main stack shall be:

i) Automatically monitored on a continuous basis for sulphur dioxide, particulates, volume flow rate and exit temperature.

ii) Stack surveyed eight times per year and the following determinations made:

- the rate of flow of sulphur dioxide, oxides of nitrogen, particulates, carbon dioxide, nitrogen, oxygen and water vapor;

- the flue gas volume flow rate and temperature.

(b) A minimum network of forty static exposure cylinder stations for the detection of hydrogen sulphide and total sulphation shall be maintained at suitable locations around the plant.

(c) A minimum network of eight sulphur dust-fall stations shall be maintained at suitable locations around the sulphur storage area.

(d) Representative samples of particulate matter being exhausted from the main stack shall be analyzed for total heavy metals content at approximately three month intervals for the first year of operation and in subsequent years at a frequency to be determined by the Director.

(e) A five-station continuous ambient air quality monitoring system for the purpose of determining the concentrations of sulphur dioxide and hydrogen sulphide, wind speed and wind direction shall be maintained and operated on a continuous basis.

3.2 In order to determine existing background levels, the ambient air quality monitoring stations specified in clauses 3.1 (b) and 3.1 (e) shall be established one year prior to plant start-up and the monitoring information reported to the Director of Pollution Control on a monthly basis.

<u>SECTION FOUR: EXPIRY DATE</u>

4.1 Pursuant to and in accordance with the provisions of The Clean Air Act, the Minister of the Environment may issue a stop order to the company or any person where the provisions of the Act, regulations and orders thereunder, or the conditions of this permit have been contravened, or where the Minister considers any structure or thing to be a source of air pollution representing an immediate danger to human life or property or both.

In a stop order, the Minister may require that the person to whom it is directed

i) cease the contravention specified in the order, and

ii) stop any operations, or shut down or stop the operation of any plant, equipment, structure or thing either permanently or for a specified period.

4.2 Pursuant to and in accordance with the provisions of The Clean Air Act

(a) no person shall commence the operation or use of a plant, structure, or thing unless he is the holder of a licence in respect to the plant, structure or thing;

(b) upon or shortly before completion of the construction of a plant, structure or thing, the person who proposes to operate or use the plant, structure or thing shall apply to the Director of Standards and Approvals in accordance with the regulations, for the issue of a licence; and

(c) no person shall alter, add to or in any other manner change a plant, structure or thing that is the subject of a permit unless a permit to alter, add to or otherwise change the plant, structure or thing is issued by the Director of Standards and Approvals.

4.3 Notwithstanding the terms, conditions and requirements of this permit, should construction of the new facilities not commence by August 1, 1974, this permit shall be deemed null and void. In the event of this occurrence, the company shall make a new application for a permit to construct.

2. Water Quality

Pursuant to Section 4 of the Clean Water Act, a permit (73-WP-038) to construct an oil sands recovery plant for the production of synthetic crude oil and associated by-products from the Alberta sands located in Bituminous Sands Lease No. 17 was issued on 12th of July, 1973 subject to the following terms, conditions and requirements.*

PERMIT NO.
73-WP-038
....

TERMS, CONDITIONS AND REQUIREMENTS
ATTACHED TO PERMIT

SECTION ONE: GENERAL

1.1 The plant referred to herein includes those buildings, structures, production and storage facilities, and land located in Bituminous Sands Lease No. 17, Township 92, Ranges 10, 11, and 12, West of the 4th Meridian, and Township 93, Ranges 10, 11, and 12, West of the 4th Meridian, and as depicted in Drawing No. IE-SK-A-150A.

1.2 The "reference bitumen charge rate" is defined as the projected maximum design amount of bitumen feed stock in barrels per stream day that can be charged to the fluid coking unit.

1.3 The plant may be constructed to operate at a process reference bitumen charge rate of 190,000 barrels per stream day of bitumen feed.

1.4 The oil sands recovery plant shall be constructed in accordance with the company's submissions of March 19, 1973 and May 24, 1973 relating to application under The Clean Water Act for a permit to construct facilities for the production of 45,625,000 barrels of synthetic crude oil per year.

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*Included in this permit are terms, conditions, and requirements related to the Alberta Land Surface Conservation and Reclamation Act.

1.5 Upon commencement of shipment of solid sulphur, adequate precautionary measures to control any sulphur dust shall be implemented to avoid damage to the surrounding land and watershed area.

1.6 The disposal of heterogeneous solid waste material shall be conducted in a manner that minimizes potential ground water contamination.

1.7 The company shall at all times conduct and control their operations in such a manner as not to create a hazard to the public and shall take all reasonable precautions to protect and safeguard the lives and property of the public and adjacent property owners.

SECTION TWO: INFORMATION REQUIREMENTS

2.1 In a manner satisfactory to the Director of Standards and Approvals, the company shall submit duplicate copies of the following information for his approval of related facilities:

(a) Design information related to water and waste water management and disposal systems, including the disposal of process waste water, sanitary sewage, and surface run-off.

(b) Information related to plant processes and operations in sufficient detail to permit evaluation of environmental factors.

(c) Projections of changes of water quality and fisheries of all watercourses that are directly affected by the following actions:

i) The diversion and relocation of portions of Beaver Creek;

ii) The diversion of Athabasca River for water supply for plant operations;

iii) The use of Mildred Lake for tailings disposal and intake water storage;

iv) The anticipated increased volume flow rates of river flow in Poplar Creek;

v) The release of any waste waters resulting from land clearing, mine pit drainage, surface run-off control external to the plant process and mining areas, re-channeling of other natural watercourses, and sanitary sewage treatment.

2.2 In a manner satisfactory to the Director of Water Resources and pursuant to The Water Resources Act, the company shall submit duplicate copies of the following information for his approval:

(a) Plans and reports relating to the diversion, storage, and use of water from the Athabasca River;

(b) Plans and reports relating to the diversion of Beaver Creek;

(c) Full details of any other diversions not specified in sub-clause (a) and sub-clause (b) above or works which will affect any watercourse or the ground water regime.

2.3 In a manner satisfactory to the Chairman of the Land Conservation and Reclamation Council and pursuant to the Land Surface Conservation and Reclamation Act and any regulations thereunder, the company shall submit duplicate copies of the following information for his approval within one year prior to mining:

(a) An environmental impact assessment specific to the surface disturbance;

(b) A security deposit as determined by regulation and sufficient to cover reclamation costs;

(c) A description of procedures to be used and corrective actions to be taken in the abandonment of any ponds, pits, and waste water disposal facilities;

(d) A description of the overall development and reclamation plan for the mined-out area including proposals respecting the final topography and revegetation of these areas;

(e) The overall plans for final abandonment of the area including equipment and structures.

2.4 In a manner satisfactory to the Minister of the Environment and prior to commencement of construction, the company shall submit duplicate copies of reports containing an assessment of the environmental impact of the construction and operation of the oil sands recovery plant.

SECTION THREE: WASTE WATER RELEASE PROHIBITIONS

3.1 The release of any waste waters resulting from mine pit drainage, land clearing, re-channeling of natural water courses, and sanitary sewage treatment to the surrounding watershed area during the period of construction is prohibited unless permission has been obtained from the Director of Standards and Approvals.

3.2 The company shall provide waste water treatment facilities for the plant to ensure compliance with the requirements of clauses 3.3 to 3.7 inclusive.

3.3 All waste waters and water contaminants from the mining area and from the extraction and upgrading sections of the plant shall be directed to the sludge retention tailings pond (hereinafter called the tailings pond).

3.4 All waste waters originating from surface run-off and precipitation from the production and storage areas of the plant, including the sulphur and coke stockpile areas, shall be directed to the tailings pond.

3.5 The release of waste water from the tailings pond to the surrounding watershed area is prohibited.

3.6 The release of untreated sanitary sewage to the surrounding watershed area is prohibited.

3.7 Waste waters originating from surface run-off and precipitation external to the plant process and mining areas shall be controlled and diverted to the existing watershed area.

SECTION FOUR: MONITORING AND REPORTING - DURING CONSTRUCTION

4.1 In a manner satisfactory to the Director of Standards and Approvals, the company shall:

(a) Monitor the environment of the surrounding watershed area before, during, and after construction and after plant operation has commenced.

(b) Monitor ground water movement and quality in the vicinity of the tailings pond before, during, and after construction and after the plant operations have commenced as follows:

i) monitored for water table level and estimated seepage volume flow rates;

ii) subject to analysis of representative grab samples and analyzed according to the following schedule:

Monthly - chemical oxygen demand, oil and grease, pH, phenolics, total sulfides, sodium and alkalinity
Yearly - heavy metal analysis

(c) Establish continuous, automatic monitoring stations on Mildred Lake, the Athabasca River, and Beaver Creek.

(d) Monitor the efficiency of the sewage treatment plant.

4.2 In a manner satisfactory to the Director of Standards and Approvals, the company shall submit a six-month progress report on July 1 and January 1 of each year during the period of construction. The report shall contain all pertinent information including the following:

(a) The results of the analytical determinations, volume flow rates, and monitoring information specified in clause 4.1.

(b) The quantity of waste water contained in any waste water treatment pond including any sewage lagoons or evaporation ponds during the first day of each month and expressed in terms of Canadian gallons and in terms of the percentage capacity occupied relative to the total volume of each respective pond.

(c) Remarks relative to the intensity and duration of local precipitation and run-off and ground water hydrology.

4.3 In a manner satisfactory to the Director of Standards and Approvals and six months prior to operation, the company shall provide facilities and recording methods to monitor and report the following:

(a) The daily average production in terms of barrels per day of bitumen mined based on one operating month.

(b) The daily average production in terms of barrels per day of bitumen feed charged to the upgrading plant based on one operating month.

(c) The daily intake of raw water from the Athabasca River in terms of Canadian gallons per day based on one operating month.

(d) Remarks relative to the sediment removal efficiency of the tailings pond.

(e) Remarks relative to the performance of the complete waste water control program.

(f) Remarks relative to the rate of evaporation of water from the tailings pond.

(g) A monthly material balance statement indicating the quantity and character of incoming process raw materials and chemicals to the plant including chemical additives for process and waste water treatment and their disposition as related to air, water, and land in terms of thousand barrels of crude bitumen charged to the upgrading plant per operating stream day.

(h) Four representative grab samples of waste water from the geometric center of the tailings pond shall be collected at four sampling points ranging from the pond surface to the bottom. The samples shall be collected and analyzed for the same water contaminants specified in sub-clause 4.1 (b) (ii) during the month of April and September of each year.

(i) The concentration of ambient levels of oil and grease and total suspended solids contained in the Athabasca River which is used as a raw water supply for the operation of the plant shall be monitored daily. A 24-hour composite sample shall be collected and the analytical data shall be summarized. The extent of pre-treatment of raw river water during the period of high natural river turbidity (March 1 to September 30) with respect to removal of ambient levels of suspended solids and oil and grease in river water shall be noted.

(j) The daily recycle rates and solids content composition of tailings pond water that is returned to the extraction plant shall be monitored.

(k) The crude bitumen feed stock that is charged to the upgrading plant shall be analyzed for heavy metals (total) on a monthly basis.

(l) The daily production of synthetic crude oil in terms of barrels per calendar day as well as associated by-products in appropriate units of production.

(m) The daily rate of bitumen feed stock charged to the coking unit of the upgrading section of the plant in terms of barrels per calendar day and the highest average daily rate of bitumen feed stock charged to the coking unit based on five consecutive stream days.

(n) The daily rate of discharge of waste waters from the extraction plant to the tailings pond in terms of Canadian gallons per day.

(o) The daily recycle rate of tailings pond water returned to the extraction plant in terms of Canadian gallons per day.

(p) The daily average solids content composition of the recycle water returned from the tailings pond to the extraction plant and the general quality of the waste water in the tailings pond.

(q) The daily rate of feed of tar sands charged to the extraction plant in terms of tons per day.

4.4 All uncontrolled releases of waste waters and water contaminants from the plant, accidental spills of water contaminants to the adjacent watershed area, and significant occurrences of non-compliance with any condition of this permit shall be reported to the Director of Pollution Control within 24 hours.

of discovery. The company shall immediately activate contingency procedures to prohibit water pollution or any other environmental hazard.

4.5 The company shall compensate the province of Alberta or any person suffering loss or damage as a result of any accidental spill of waste waters or petroleum products which originate from the oil sands recovery plant and are released to the surrounding watershed area howsoever caused.

4.6 The company shall report or confirm to the Director of Pollution Control any awareness of the occurrence of non-compliance with any condition of this permit in writing within 72 hours of their becoming aware of such contravention.

4.7 An annual summary and evaluation report of the performance of all waste water treatment facilities and control systems during the period of construction shall be prepared and forwarded to the Director of Pollution Control by February 14. This annual report shall include remarks on extensions and alterations and photographs or 35 mm. slides of all waste water treatment facilities.

SECTION FIVE: EXPIRY DATE OF PERMIT

5.1 Notwithstanding the terms and conditions of this permit, the company shall comply with any other requirements by ordinance relative to all waste water treatment facilities.

5.2 Pursuant to and in accordance with the provisions of The Clean Water Act, the Minister of the Environment may issue a stop order to the company or any person where the provisions of the Act, regulations and orders thereunder, or the conditions of this permit have been contravened, or where the Minister considers any structure or thing to be a source of water pollution representing an immediate danger to human life or property or both.

In a stop order, the Minister may require that the person to whom it is directed;

i) cease the contravention specified in the order, and

ii) stop any operations, or shut down or stop the operation of any plant, equipment, structure, or thing either permanently or for a specified period.

5.3 Pursuent to and in accordance with the provisions of The Clean Water Act,

(a) no person shall commence the operation of a plant, structure, or thing unless he is the holder of a licence in respect to the plant, structure, or thing;

(b) upon or shortly before the completion of the construction of a plant, structure or thing, the person who proposes to operate or use the plant, structure, or thing shall apply to the Director of Standards and Approvals in accordance with the regulations for the issue of a licence;

(c) no person shall alter, add to or in any other manner change a plant, structure, or thing that is the subject of a permit or licence unless a permit to alter, add to or otherwise change the plant, structure, or thing is issued by the Director of Standards and Approvals.

5.4 The requirements specified in this permit shall be effective the date of this permit or as otherwise noted in the relevant sections relating to emission standards and waste water release prohibitions, reporting of monitoring information, and general plant construction or such other dates as approved in writing by the Director of Standards and Approvals.

5.5 Notwithstanding the terms, conditions and requirements of this permit should construction of the facilities not commence by August 1, 1974, this permit shall be null and void. In the event of this occurrence, the company shall make a new application for a new permit to construct the plant.

O V E R V I E W

SECTION 8

SUPPLEMENTARY INFORMATION AND
ON-GOING PROGRAMS

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SUPPLEMENTARY INFORMATION AND ON-GOING PROGRAMS

A. SUPPLEMENTARY INFORMATION

The succeeding three volumes contain background information which supplement this volume. An explanation of the format and content of the supplements is in order.

Volume II appends section 3 of Volume I and includes information required to give some perspective to the sequence of events leading to the present design of the Syncrude project. It incorporates applications from 1962 through 1973 to the appropriate governmental departments.

Volume III appends section 4, 5 and 6 of Volume I and contains supporting ecological and environmental research reports. These include a habitat evaluation, a Beaver Creek baseline survey, a migratory waterfowl report and air and water quality baseline information.

Volume IV is an accumulation of documents relating to studies completed in support of project engineering and management activities. Four major study areas are incorporated: economic and social impact of the Syncrude project; water management planning; site reclamation and air quality studies.

SECTION 8

SUPPLEMENTARY INFORMATION AND ON-GOING PROGRAMS

B. ON-GOING PROGRAMS

SECTION I. General

A. Assessment Procedures and Monitoring Program

The Syncrude Project will have certain impacts on the environment with localized operational areas severely affected. The project design, including pollution control equipment and procedures, attempts to restrict these impacts to the plant site and mining area and to keep overall environmental impacts within allowable and acceptable limits. Emissions are not the only concern however. Changes in the land surface and the vegetation on the area, as well as the animal component dependent on that habitat, must also be considered. Thus, to assess the effectiveness of controls and the affects of mining and extraction processes, environmental parameters will be monitored on a regular basis. These observations will not only check the performance of the controls themselves, but they will also include verification of the environmental predictions used in the design of the control measures. Besides information on the effectiveness of pollution abatement programs, regular environmental reports of both a general and specific nature insure better protection against the advent and/or continuation of environmental damage.

In order to facilitate a periodic environmental review of pertinent data, it is convenient to prepare a compendium of the parameters which influence or would be influenced by the operation. The need for this information may be for baselines to solve special ecological problems, for engineering design criteria, or to meet the requirements under government permits and licenses. A chart is being designed to contain this information and will allow the reviewer to trace any particular variable of interest, from the inception of the program, the baseline conditions up to the current monitoring report. Data can be transferred from detailed field reports in each area of interest and the status of studies noted.

B. Current and On-Going Syncrude Programs.

Studies required for engineering design and the acquisition of permits generally fall within the direct responsibility of the company concerned. Therefore, Syncrude Canada Limited is continuing to carry out studies required for these purposes. On-going studies in surface and sub-surface hydrology are being carried out by L.G.L. Environmental Research Associates, E.W. Brooker & Associates, Hydrogeological Consultants Limited, other consultants, and the Syncrude staff. Revegetation studies are being carried out in cooperation with the Alberta Department of Agriculture and the Oil Sands Environmental Study Group. A potential damage inventory is being carried out by Mach Air, and C.L. Sibbald Group in Calgary through colour and false-colour infrared photography. These are screening studies on which to develop approaches to major identified areas of concern in the future. The studies are being done systematically over the entire lease.

Specific problems relating to air quality and multiple tarsands plants are discussed in a report commissioned by Syncrude and prepared by Intercomp of Calgary. Information from these studies occurs in Volume 4 of this report.

Specific problem solving studies such as waterfowl deterents for the tailings pond and an assessment of potential productivity for fish and waterfowl in the Beaver Creek diversion scheme are under discussion with Renewable Resources Consulting Services and L. G. L. Environmental Research Associates of Edmonton, Alberta. A classified count by age and sex of the moose population is needed to further establish potential productivity of this herd.

Some evaluation should also be made of the annual harvest and other unusual mortality. Three short aerial surveys are planned per year for the months of February, May and November.

Major considerations in an Environmental Monitoring Program for long term projects include our assessment of ecological changes and the relationship of these changes to industrial operations and natural factors. It is first necessary to establish permanently protected areas in representative habitat types adjacent to the mining and processing areas. These can be of various sizes depending upon the requirements of the studies to be carried out. These "ecological benchmarks" are presently being established by the Syncrude Environmental Field Staff; they will be used for measurements applicable to the plant-animal relationships within these representative communities.

In connection with the 1973 Revegetation Field Study Program, in cooperation with the Alberta Department of Agriculture under Dr. Vaartenou, soil samples will be analyzed for chemical and structural components for each vegetation community type. The intensity will be determined by the degree of heterogeniety of the initial samples taken. Further work will be required to classify the soils to at least the soil family level. This work is necessary as baseline information and is needed for comparisons in future studies of air quality and its effects on soils and vegetation, and for assessment of change in vegetation resulting from altered soil composition.

C. Co-operative Program

The Oil sands Environmental Study Group, an association of twenty tar sand lease holders, was formed in the spring of 1973. Syncrude was a prime mover in the formation of this organization. In order to achieve our purposes and objectives in environmental research, a significant part of Syncrude's research effort will be channelled through this organization which operates cooperatively on studies between member companies. The Oil Sands Environmental Study Group has identified nine subject areas for study. They are as follows:

1) Climatology
2) Hydrology
3) Soils
4) Recreation use
5) Wildlife
6) Vegetation
7) Impact assessments
8) Archaeological-Historical
9) Formation water

Items number 1, 2, 3, 5, 7, 8, and 9 are already under investigation by Syncrude and its consultants in 1973 and most studies will continue for the next three years.

Included in these headings are subdivisions such as ambient air quality, habitat classification, fish spawning, etc. The Oil Sands Environmental Study Group recognizes that many of these subjects of study are interrelated; for instance, climatology studies are necessary to supplement hydrology studies. Vegetation studies are necessary to classify wildlife habitat.

The Oil Sands Environmental Study Group, in cooperation with the Climatology Task Force, Research Council of Alberta and the Research Secretariat, Alberta Department of the Environment, is preparing a proposal for the fullscale cooperative study of climatology and hydrology of the tarsands area. It is hoped that this study can get under way in order to obtain information during the winter of 1973-74.

SECTION II. Environmental Baseline Information

A. Air Quality Monitoring on Lease 17

During April 1973 a mobile air quality monitoring station was put into operation on Syncrude's proposed plant site on lease 17 near Fort McMurray. (See map for exact location).

The station contains the following equipment:

1 - Bridge Trailer complete with electric heater, wind instrument mounting and instrument cabinet;

1 - Philips SO_2 analyzer complete with a Leeds & Northrup Speedomax Type H Recorder and automatic zero-calibrate option;

1 - Research Appliance Company H_2S Tape Sampler modified to record half hour cumulative averages;

1 - Dominion Instruments 540 Windflo complete with a 2-pen Philips recorder for wind speed and direction;

Installation of this air quality monitoring station, more than four years in advance of commercial operations, was undertaken to provide comprehensive baseline information.

In addition to generating baseline information the station provides advanced operating experience, particularly during the severe winter conditions in the McMurray Area.

Reporting

Reporting to the Department of the Environment has already started and is being done in a manner consistent with the D.O.T.E. Monitoring Directive 73-1. The station leasor reads and interprets all charts and prepares a comprehensive report in the required format. SO_2 concentrations exceeding 0.05 p.p.m. and all H_2S concentrations of 3 p.p.b. or greater are listed on separate tables and are correlated with wind speed and direction. Half hourly, hourly, daily, and monthly averages are tabulated for SO_2 concentrations. A table and a plot of average velocity for each wind direction, and the frequency of readings for each direction are provided. Examples of the data obtained to date are contained and summarized in the May and June, 1973 reports which follow. Plans are to continue the ambient air quality monitoring program until the end of 1973 the gathering of baseline air quality information and operating experience using the Wester Research and Development mobile trailer at its present site. The program will be expanded considering the following items.

- Determine the background concentrations of total and non-methane hydrocarbons.
- Locate and establish 4 additional ambient air quality monitoring sites as required in Syncrude's Permit to Construct (Section 3.1 (e)).

- Initiate work on locating suitable locations for a network of forty static exposure cylinder stations for the detection of hydrogen sulphide and total sulphation (Section 3.1 (b)).
- Set up laboratory facilities at the Syncrude Camp site.

Twelve environmental consultants based in Alberta have contributed to the environmental information compiled by Syncrude which appears in this Environmental Impact Assessment. Syncrude's in-house staff is continuing to work with qualified consultants in continuation of existing studies, future studies, and an on-going monitoring program.

The expanded surface water quality monitoring program that was initiated in September 1972 will continue. At year end (1973) the data collected will be reviewed to determine the quality variations particularily the seasonal changes.

Currently the program includes the sampling every two months of the Athabasca River (McMurray bridge and Syncrude camp dock), Beaver Creek (McKay highway and Lease 17 southern boundary) Poplar Creek (McMurray highway), Mildred Lake and Mining pit waters (ground and formation water). Chemical and Geological Laboratories Ltd. are doing the analyses (the data obtained is listed in volume IV).

The program is continuously reviewed and plans are to include when necessary the following:

- monitor ground water quality as required under the Permit to Construct in support of Syncrude's consultants.
- establish continuous automatic monitoring stations as required.
- set-up Syncrude field laboratory in support of water quality measuring program in particular in-situ monitoring work.

B. Surface Water Quality Monitoring on Lease 17

An on-going program to monitor the quality of surface water on or near Syncrude's Lease 17, began several years ago.

ENVIRONMENTAL RESEARCH PROGRAM 1973

SUBJECT OF STUDY	STUDY CORRELATES DIRECTLY WITH OTHER STUDIES	Need for Study: Baseline	Specific	Ecological	Problem	Engineering	Permits	STATUS OF KNOWLEDGE FROM FORMER STUDIES x Completed	GROUPS RESPONSIBLE OR PROPOSED FOR ASSIGNMENT * in progress Aug.73 x Completed	SEASON FOR STUDY TO TAKE PLACE (year)
Climatology	Hydrology	X		X		X			* Weather office but not yearlong	Yearlong
Air Studies									* Alberta Forest Service	
Ambient Air		X							x Intercomp	
Quality								x GCOS 7 years (on going)	* GCOS continuous	Yearlong
Hydrology	Climatology	X		X		X	X	Environment Canada - Water Survey		Spring thru Fall
Surface	Vegetation	X		X		X	X	Syncrude 1962 to present	* LGL Ltd. Consulting by Syncrude 1973	
Quantity	Surface disturbance							x PACE-Federal Task Force	* Syncrude - 1962 to present	
Quality										
Ground and Formation		X					X	x GCOS - Preliminary 1950's	* Hydrogeological Consultants by Syncrude 1973	
Quantity								x Shell - 1972		
Quality								x ARCO - Nuclear Study 1961		
Soils	Vegetation	X		X		X		x Very Limited Study by Alberta		
Fertility	Reclamation land form						X	Research Council, 1960		Spring - fall
Structure	Reclamation revegetation			X			X	Syncrude - Lab studies	x Syncrude - Dames & Moore	
Water relations								x Shell - 1972		
Classification & Mapping										
Recreation Use	Wildlife Social Impact	X						x CLI Study - Dept.of Environment (INTEG)	Provincial Parks	Yearlong
Wildlife, incl. fish & non-game birds	Vegetation (surface disturbance)	X		X		X	X	x Dept. of Lands and Forests 1972 Study on fish and Ungulate (INTEG)		Big game Dec.-Feb. Fish-spring thru fall Non-game birds-summer Waterfowl-spring thru fall
Species (census)		X						x Syncrude - 1971		
Habitat	Infrastructure					X	X	Syncrude - 2 years		
Classification	Highway Construction Urban Development							Canadian Wildlife Service - many yrs. x Syncrude Environmental Monograph #1, 1973		
Furbearers, incl. Traplines	Social Impact Study			X			X	x Lands & Forests records	Syncrude 1972 * Renewable Resources Consulting by Syncrude	Prior to mining when water temp. rises to 35°F
Fish spawning	Hydrology	X		X			X		Shell Canada Ltd. Dept. of Environment	Spring 1973
Vegetation	Wildlife Soils	X X		X		X X	X X	x Lands & Forests-1972 Forest cover maps(INTEG)		
	Reclamation (revegetation)			X			X	x GCOS dykes	* Dept. of Agriculture Plant Science	Summer
	Hydrology							Syncrude lab plots	Alberta Research Council	Growing Season
General overview, Ecological Baseline (for prop. of Impact Statements)	All above	X		X			X	x Syncrude-report 6/72 x Environmental Impact Assessment	*Renewable Resources Consulting Service *INTEG - Dept. of Environment Released Apr.30/73 Shell	Yearlong Yearlong Spring 1973
Archaelogical - Historical		X					X	x Syncrude Study		

The raw data obtained to date and remarks on a few relevant details are contained in this report.

No major attempt has been made to interpret the chemistry of the waters in relation to water quality or make comprehensive comparisons against government criteria at this stage of the program. The prime purpose is to collect baseline information recognizing certain limitations such as sampling techniques and accessibility of suitable sampling locations.

In September of 1972, the program was expanded by doing more extensive chemical assays and by adding more sampling points. The field sampling is done by Syncrude personnel and the chemical analyses performed by Chemical and Geological Laboratories in their Edmonton Laboratory. The data obtained is contained in Volume II Section II.

Sampling Locations

Athabasca River - Every two months several samples (the number of samples taken depending on the chemical pretreatment required for sample preservation described below) are taken at two locations: at the McMurray bridge and off the dock at the Syncrude camp. During the winter months, the ice was augered and a weighted bottle was used to obtain a grab sample.

Beaver Creek - Two sample sets are obtained every two months; where the creek crosses lease 17 boundary (upper) and at the government campsite on the Fort McMurray highway. The samples were taken in fast flowing zones and an ice auger used when required. Accessibility to the Upper Beaver Creek sampling point has been difficult and is reached either by hiking in or by snowmobile during the winter.

Poplar Creek - One set of samples are taken every two months before the culvert where Poplar Creek crosses the highway. Sampling was missed during January 1973 because of heavy ice cover.

MacKay River - Sampling was done below the bridge on the Fort McKay highway. This sampling has been discontinued.

Mildred Lake - Surface water was sampled approximately 100 yards off the center of the north shore line. Sampling was started in mid-1973.

Sample Preservation

Special sample box containers were constructed by Chemical and Geological Laboratories Ltd. All samples were taken in glass bottles that had been carefully cleaned particularly when trace metals were to be determined. It is recognized that preservation techniques can only retard chemical and biological changes that inevitably continue.

Thus considerable effort was made to deliver the treated samples to the Chemical and Geological testing laboratory as soon as possible, generally within 24 hours, but frequently within 8-10 hours. The methods of treatment followed (Syncrude personnel applied these treatments in the field) are outlined in Clean Water, Methods for Chemical Analysis of Water and Wastes, 1971, Environmental Protection Agency, Water Quality Office, Analytical Quality Control Laboratory, Cincinnati, Ohio.