An Environmental Study

of

The Athabasca Tar Sands

REPORT AND RECOMMENDATIONS

to

ALBERTA DEPARTMENT OF THE ENVIRONMENT

by

Intercontinental Engineering of Alberta Ltd.

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Environment

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Terms of Reference

The following was the general concept of the work for which the Study was commissioned:

> *Identify the various methods that could be used for oil extraction and their comparative merits with respect to minimum adverse effects on the environment.*
>
> *In considering the Clark method of tar sands extraction (or its variations), it will not be necessary to study the effects on the environment within the area in which actual mining and extraction activities take place, but detrimental effects or impact on the otherwise undisturbed surrounding area are to be investigated.*
>
> *Other recovery methods, such as in-situ steam extraction, shall be evaluated in terms of impact or consequences on the immediate as well as the surrounding environment.*
>
> *Recommendations shall be made with respect to mining, extraction and processing methods and procedures that should be employed to eliminate or minimize adverse effects on the environment.*
>
> *Recommend constraints to be applied on plant location, plant capacity and number of plants per given area, as may be required to give effect to the above recommendations.*
>
> *Determine which effects or problems should be given priority in research efforts, the allocation of resources for abatement, and legislation. Investigations should include the recommendations for the establishment of a realistic balance between long and short term effects on the environment. The study should also enable the Government of Alberta to select optimum strategies in the implementation of long term tar sands development policies.*

The terms of reference were further defined in discussions with the Department of the Environment and with the Conservation and Utilization Committee. These negotiations culminated in a formal agreement for the project. It was agreed that the Study would be restricted to the Bituminous Sands Area as defined by the Province of Alberta. During the course of the Study instructions were received to exclude any consideration of product pipelines, and transportation corridors.

The Study was started in March, 1972 and completed in March 1973.

Acknowledgements

Intercontinental Engineering of Alberta Ltd. wishes to acknowledge the valuable contributions made to this Study, by its corporate principals and by the following participants:

Harold V. Page, P.Eng. — Project Director
Hydrocarb Consultants Ltd.
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Geoscience Research Associates Ltd.
Dr. C. G. Miller, P.Eng.
British Columbia Research
Dr. P. Gishler
John Starr, B.Sc.

The participating consultants were selected to represent a broad spectrum of complementary disciplines. Participants on the Project Team contributed working papers which provided the supporting information for this summary report. These working papers have been compiled and submitted to the Alberta Department of the Environment in two volumes, viz: the Progress Report of August, 1972, and a companion volume dated January 1973.

The Alberta Department of Lands and Forests and the Canadian Wildlife Service conducted ecological baseline surveys to determine the existing characteristics and conditions of the biological environment. Due to severe time limitations, their surveys were very preliminary. The Project Team received the raw data, assimilated it into the Study, and formulated the conclusions and recommendations presented in this report.

Valuable guidance was provided by the Department of the Environment. Members of the Alberta Conservation and Utilization Committee assisted in the early stages of scope definition. Significant consultations were held with members of the Federal Department of Energy, Mines and Resources and the National Research Council. Appreciation is extended to Great Canadian Oil Sands Ltd., and Syncrude Canada Ltd. for meetings and site visits.

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ACTIVITIES WHICH MAY CAUSE ENVIRONMENTAL IMPACT

General Observations

The environmental effects of eventual multi-plant operations over the extent of the Athabasca Tar Sands could be enormous, unless preventative measures are implemented.

The tar sands industry must improve its technology significantly to protect the environment against the possible impacts of the large scale expansion currently being contemplated. Existing technical information must be made available when required for the planning of environmental protection. Extensive additional research will be needed to develop new preventative techniques.

Some constraints will have to be applied to control the cumulative effects of emissions from tar sands plants upon the ambient environment.

More detailed ecological data is needed for the planning process, however it can be derived within the time required to conduct the technological research.

A unique opportunity exists for the comprehensive planning of orderly industrial development in the Bituminous Sands Area. Simultaneously, plans should be formulated for the regional development of the Area to provide optimal human habitat for the anticipated influx of residents. The basic premise for such plans will involve an objective allocation of environmental resources, both existing and future.

New government policies will be essential to guide the industrial and regional development of the area towards the long term interests of Albertans and other Canadians. This will necessitate, for example, a review of the existing bituminous sands lease regulations to ensure that the rights granted to lessees do not conflict with environmental considerations.

The report describes the magnitude of the potential problems and prescribes constraints and research priorities to protect the environment. The recommended research and planning should be conducted as a joint effort involving both Government and Industry.

Summary of Recommendations

PRINCIPAL CONSTRAINTS

Existing system for plant permits to be expanded to include: exploration, land clearing, overburden drainage;

Future permit applications to include more comprehensive environmental impact analyses;

Surface mining to be prohibited in exclusion zones to be defined by Government;

Permissable size, location and density of tar sands plants to be contingent upon compliance with ambient air and water standards;

Exterior tailings ponds to be more rigidly regulated for: size, location and duration of use;

Tailings ponds not to be constructed on shorelands of active rivers or lakes;

Exterior tailings dykes to conform to prescribed standards of design and construction;

Tailings to be placed into mine pit within 3 years after starting mining;

Liquid tailings not to be stored over permeable sink holes;

Fuels for power generation to be limited in sulphur content to 2% by weight;

Land clearing (ahead of surface mining) should be restricted to a 5-year operating area prior to commencing stripping; and restricted to a 2-year operating area after commencing stripping.

Overburden stripping to be restricted to one year ahead of surface mining;

Stream diversions to be strictly regulated and to be subject to prescribed design and construction standards;

Total consumption of water from Athabasca River should not exceed 10% of minimum monthly average flow;

Tighter control to be exercised over use of volatile liquids especially for viscosity control of bitumen.

PRIORITIES FOR RESEARCH, DATA ACQUISITION AND PLANNING

Establish master plan for industrial and regional development;

Continue working on the modified Canada Land Inventory;

Field research to develop reclamation procedures and standards;

Prepare long range land use plan;

Establish procedures and standards for land reclamation;

Publicize and enforce new policy of making available all information needed for environmental planning;

Establish tar sands research centre in Alberta;

Define exclusion zones for mining to preserve drainage basins and other essential features of the physical environment;

Define zones to be reserved for human habitat and recreation;

Devise methods to separate clay and bitumen from liquid tailings;

Improve bitumen processing methods to reduce stack emissions of sulphur, and nitrogen oxides and particulates;

Expedite and analyze surveys of atmospheric diffusion characteristics such as those conducted by the Federal Department of Energy, Mines and Resources;

Establish new measuring stations to obtain meteorological data;

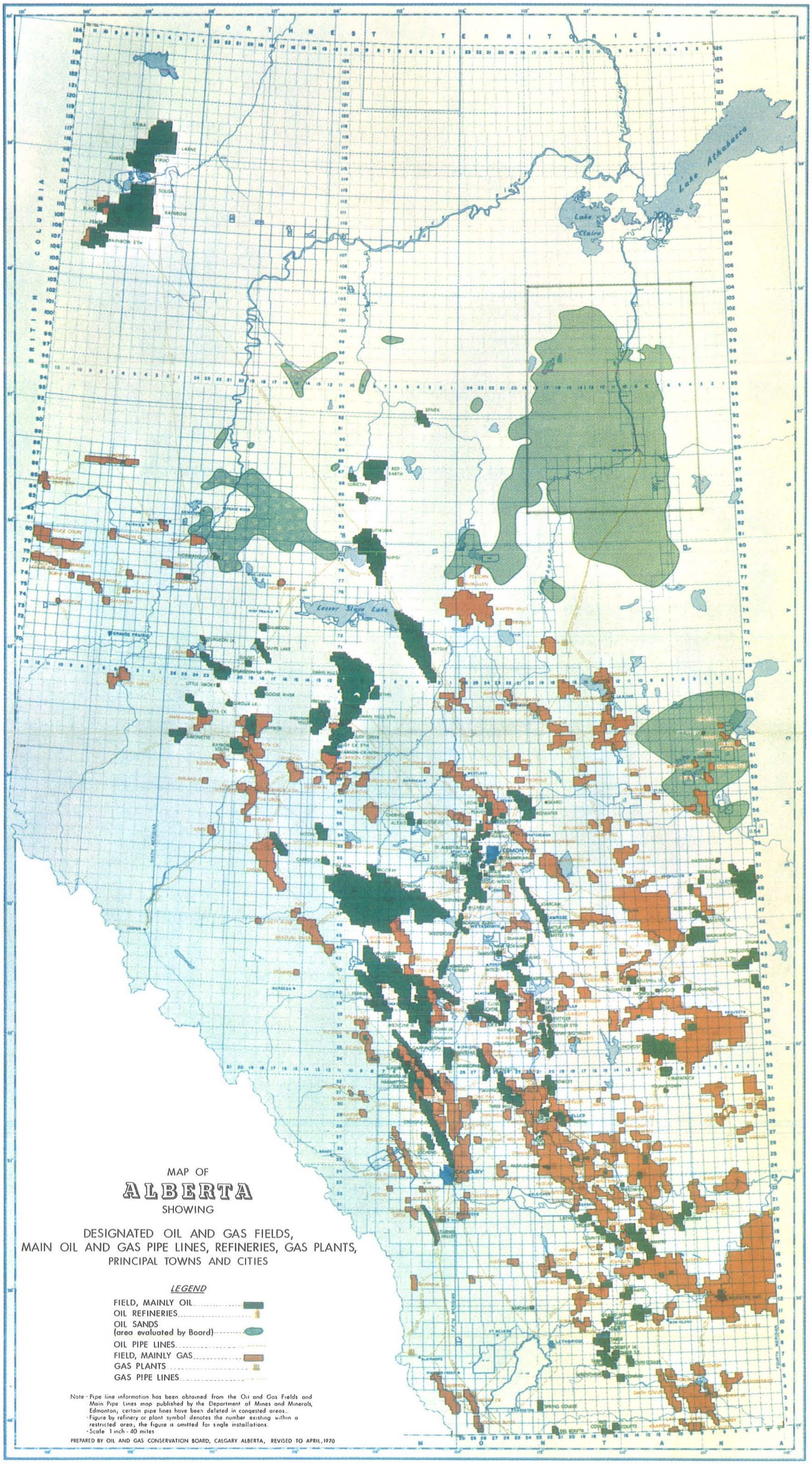
Conduct field measurements on inversions and ice fogs;

Develop procedures and specifications for the handling and disposition of muskeg;

Determine the toxic conditions and permissable limits for bitumen content of surface waters;

Expand current program for monitoring quality of Athabasca River;

Measure groundwater flow patterns.



NORTHWEST TERRITORIES
BRITISH COLUMBIA
Lake Athabasca
Lake Claire
Lesser Slave Lake
EDMONTON
CALGARY
LETHBRIDGE
MEDICINE HAT
MONTANA
MAP OF
ALBERTA
SHOWING
DESIGNATED OIL AND GAS FIELDS,
MAIN OIL AND GAS PIPE LINES, REFINERIES, GAS PLANTS,
PRINCIPAL TOWNS AND CITIES
LEGEND
FIELD, MAINLY OIL
OIL REFINERIES
OIL SANDS (area evaluated by Board)
OIL PIPE LINES
FIELD, MAINLY GAS
GAS PLANTS
GAS PIPE LINES
Note - Pipe line information has been obtained from the Oil and Gas Fields and Main Pipe Lines map published by the Department of Mines and Minerals, Edmonton; certain pipe lines have been deleted in congested areas..
- Figure by refinery or plant symbol denotes the number existing within a restricted area; the figure is omitted for single installations.
- Scale 1 inch - 40 miles
PREPARED BY OIL AND GAS CONSERVATION BOARD, CALGARY ALBERTA, REVISED TO APRIL, 1970

The Bituminous Sands Area

The Bituminous Sands Area occupies 11,340 square miles in north-eastern Alberta, and was originally designated by the Provincial Government to enable legislation and regulations pertaining to bituminous sands leases. The Area encompasses Townships 84 to 104 and Ranges 4 to 18 (west of the 4th Meridian) as shown on the photograph.

The Area includes most of the Athabasca Deposit which contains 88% of the total evaluated tar sands reserves of the Province. The Athabasca Deposit along with similar but smaller deposits, comprise naturally occurring sands impregnated with highly viscous hydrocarbon material. Unlike conventional crude oil, this hydrocarbon material is not recoverable in its natural state through a well by ordinary production methods. These deposits have been referred to in published literature by different synonymous terms such as: oil sands, tar sands, or bituminous sands. This report refers to them as tar sands.

The hydrocarbon material which occurs naturally in these deposits is designated as bitumen. It has a naphthene base, is black in colour and contains a characteristically high percentage of sulphur, nitrogen and trace metals. By comparison with conventional crude oils of the Province, it is heavier, having a gravity that varies considerably but which, over the Athabasca Deposit, averages 10 degrees A.P.I. at 60 degrees Fahrenheit.

The Athabasca Deposit contains more than 600 billion barrels of bitumen reserves in place. The immense size of these hydrocarbon reserves has prompted extensive interest in their commerical development.

Except for localized outcrops occurring along the Athabasca River and its tributaries, the tar sands are covered by overburden consisting of soil mantle and glacial drift. The thickness of overburden varies according to the topography. North of Township 90, the thickness of overburden is 100 feet or less in the vicinity of the Athabasca River. To the east, south, west and north, the overburden thickness increases to 600 feet, 1500 feet, 1600 feet, and 2000 feet respectively.

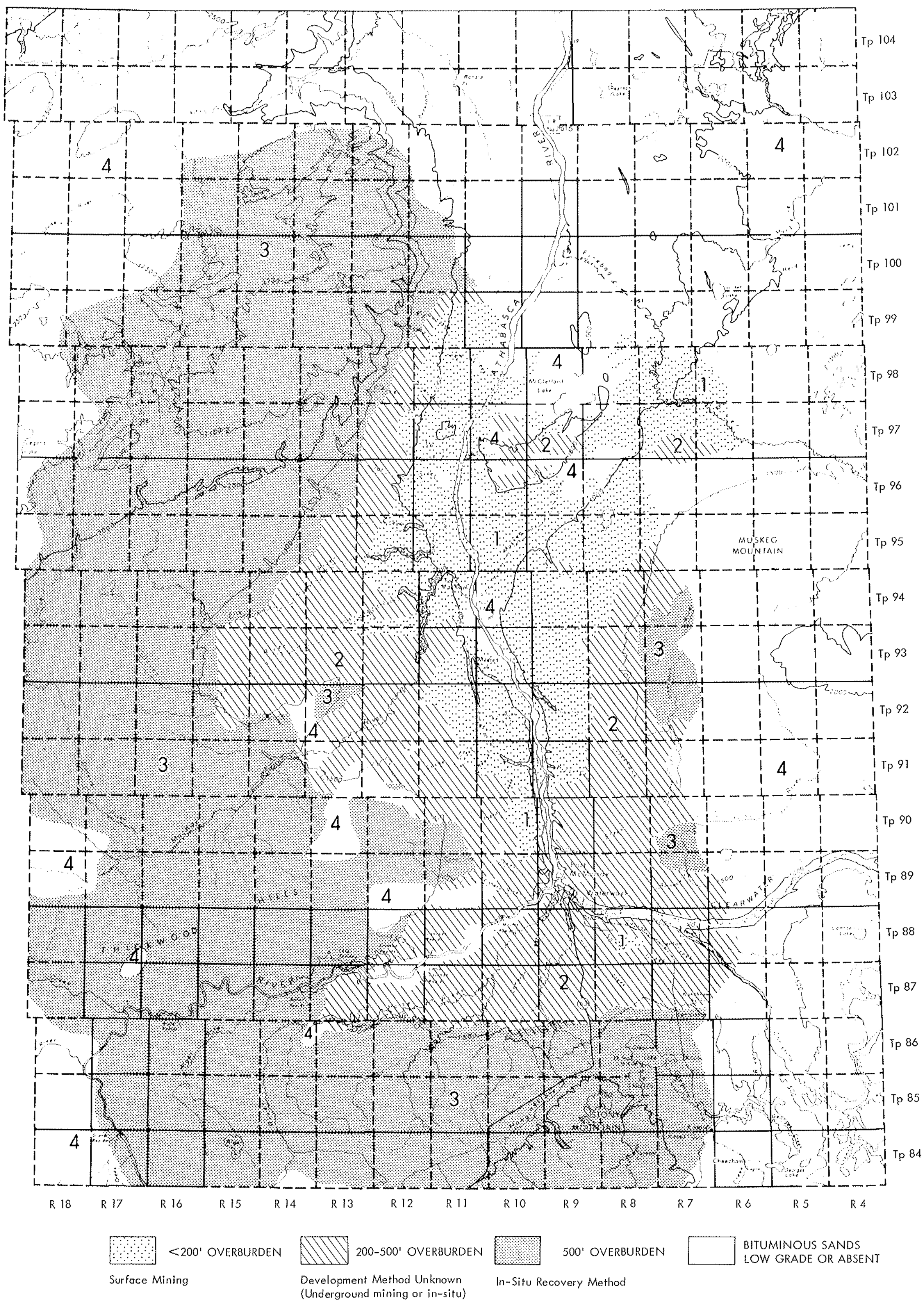
Overburden is a major factor in determining the methods to be used for recovering the natural bitumen resource. The recovery methods will influence the environmental impacts. The Area can be divided into four possible development regions according to the tar sands deposit and its overburden. These development regions are defined by the map.

The regions marked No. 1 represent 7.3% of the Area and contain tar sands which underlay 200 feet or less of overburden. The bitumen occurring within this region will probably be recovered by surface mining of the tar sands. The Study concentrated on the surface mineable region since it is the only one currently undergoing commercial development by the tar sands industry. It will continue to command priority attention by developers for at least the next 10 years.

The regions marked No. 2 comprise 11.4% of the Area and contain tar sands which underlay more than 200 feet and less than 500 feet of overburden. Developments in this region should be deferred pending the evolution of an appropriate recovery method.

The regions marked No. 3 represent 33.3% of the Area and contain tar sands which underlay more than 500 feet of overburden. The bitumen from this region will be recovered most probably by some form of in-situ technology. In-situ techniques are undergoing extensive experimentation and could reach commercial maturity within 10 years. The Study therefore included an analysis of this future probable technology and its potential impacts upon the environment.

The regions designated as No. 4 comprise 48% of the Area and contain no tar sands of commercial interest.



CATEGORIES OF DEVELOPMENT BASED ON DEPTH OF OVERBURDEN

The Tar Sands Industry

Alberta's tar sands industry is in its infancy when viewed in the light of its technology and growth potential. It is ideally suited, therefore, to a preventative program for environmental protection. The Alberta Government, as the custodian of the Province's natural resources, should guide the industrial and regional growth of the Area.

This new industry has many unique features. It requires massive production facilities and a large labour force. The recovery of the bitumen resource by conventional methods necessitates the disturbance of enormous quantities of earth. Huge volumes of water are consumed. Steam and electric power demands are supplied by large scale thermal generating plants. Processing facilities are needed to upgrade the bitumen to products.

The product which has stimulated the industry's growth to date is synthetic crude oil. The granting of a recent Government permit for a tar sands plant was predicated on a policy of preventing a decline in the life index of conventional crude oil below 12 to 13 years. This concept presupposes that products processed from bitumen will be used to supplement the supply of conventional crude.

Many projections have been published of the potential market demand for products from the tar sands. The conclusion from these estimates is that the demand for synthetic crude oil could amount to 1 million barrels per calendar day (BPCD) within 10 to 20 years. This projected industry level was used as the basis for quantifying future environmental impacts.

The unit ratios which interrelate tar sands, bitumen, and product have been compiled from the statistics published for the two authorized plants. These have been modified by judgment factors and then utilized to compute the quantities of bitumen and tar sands which would correspond to 1 million BPCD of product.

There is divergence of opinion on the rate at which the tar sands industry should attain this projected level as reflected in the 10 to 20 year range. Projections which are based primarily on the foreign demand for refinery feedstocks lead to the conclusion that the level of 1 million BPCD of synthetic crude should be attained within 10 years. This rapid rate of proliferation of new plants would jeopardize the technological improvements required to protect the environment. A more realistic rate of future tar sands development could be determined when commitments are made to the research recommendations in this report. Furthermore the future viability of the industry will be enhanced by the proposed research and planning.

Unit Ratios for Tar Sands/Bitumen/Products

	Units	Application to Amend Permit 540	Application to Amend Permit 1223	Study Calculations
Tar Sands mined	*TPCD	140,000	225,000	1.9 million
Bitumen recovered	**BPCD	85,000	140,000	1.25 million
Synthetic Crude Oil Produced	BPCD	65,000	125,000	1 million
CALCULATED UNIT RATIOS				
Barrels bitumen recovered per ton tar sands		0.61	0.62	0.65
Barrels product per barrel bitumen		0.76	0.89	0.8
Barrels product per ton tar sands		0.46	0.55	0.53

**Tons per calendar day*
***Barrels per calendar day*

Environmental Matrix

The interrelationship between the tar sands technology and environmental impacts is of such complexity that an organized format is required to analyze and present the subject. In the search for a suitable means of correlating and presenting the voluminous data, the procedure prescribed by the U.S. Environmental Protection Agency was examined. It requires consideration on the following principal topics:

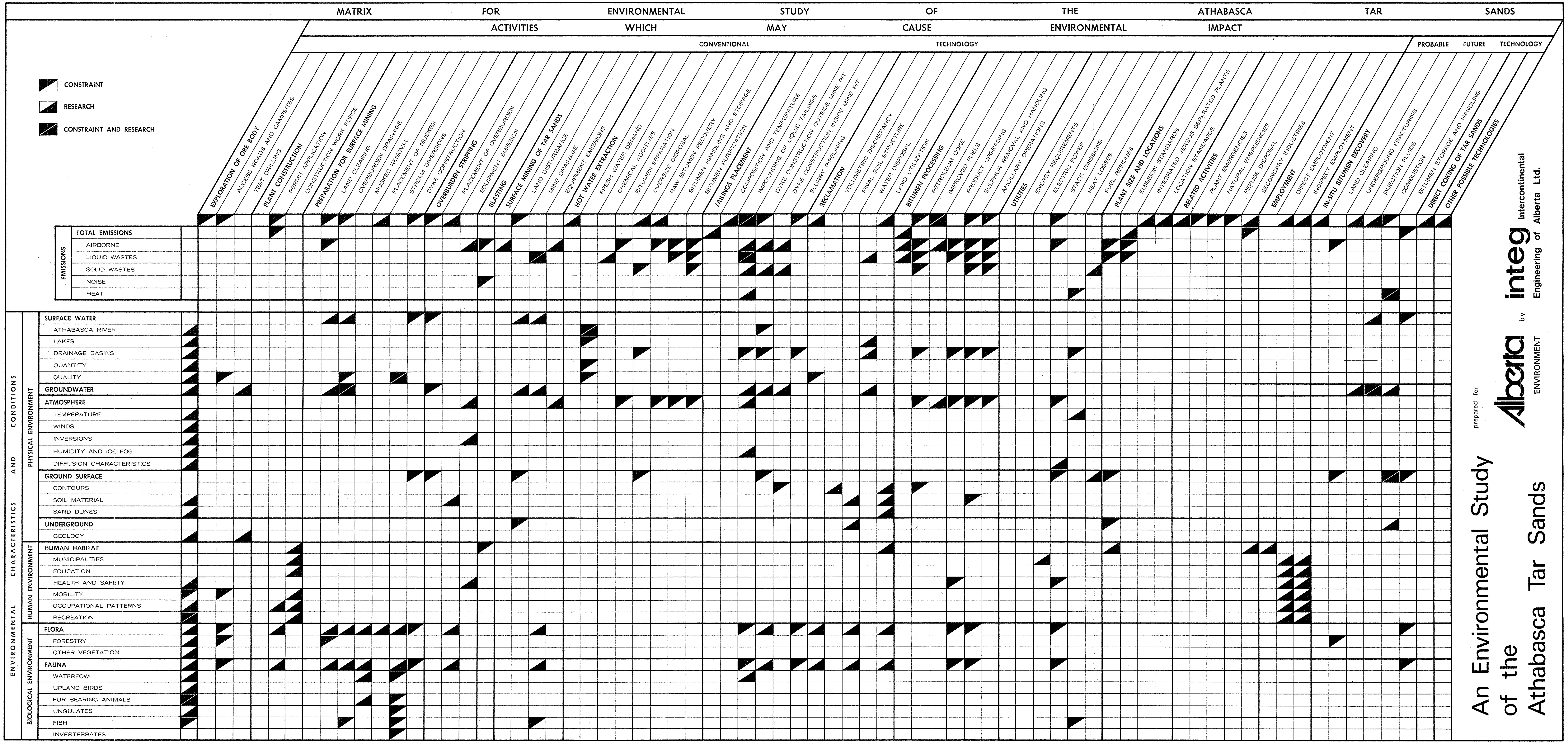
Description of the proposal,
Description of the environment,
The environmental impact of the proposed action,
Mitigating measures included in the proposed action,
Any adverse effects which cannot be avoided should the proposal be implemented,
The relationship between local short-term use of man's environment, and the maintenance and enhancement of long-term productivity,
Any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented,
Alternatives to the proposed action.

Another reference used was the "Procedure for Evaluating Environmental Impact" published as Geological Survey Circular 645. Utilizing the applicable portions of these two systems, an environmental matrix with descriptive text was devised specifically for the tar sands industry.

The characteristics and conditions of the Area are tabulated on the vertical axis. These are classified into: physical, human, and biological environments.

The activities which may cause environmental impacts are listed across the horizontal axis. These are specific to the tar sands industry. Most of them relate to conventional technology, i.e. methods approved for commercial operation. The balance of the activities pertain to probable new technology. Provision was made also to identify sources and types of emissions since these are often intermediary effects between an activity and an environmental impact.

The matrix was used as a check list to correlate the imputs of the project team and the ecological survey group. Recommended constraints and research priorities are designated on the matrix by a simple code. The relative magnitude and importance of the environmental impacts are set forth in the text and summary of recommendations. This matrix format could be expanded as additional data becomes available and could serve as a useful guide for future environmental impact analyses.



An Environmental Study of the Athabasca Tar Sands

prepared for

Alberta ENVIRONMENT

by

integ Intercontinental Engineering of Alberta Ltd.

Environmental Characteristics and Conditions

Athabasca River looking south from Fort MacKay

Surface Water

The Athabasca River and its drainage basins dominate the physical environment of the Area. It comprises a vital part of the total ecological system and will provide the principal source of water for future municipal and industrial requirements. The Athabasca plays an important role. In addition to being a commercial water route, the river supports many aquatic fauna species and provides natural recreation facilities.

Flow measurements in the Athabasca are available for the past 15 or more years taken at a station located just below Fort McMurray. These records show that the lowest mean annual flow was 17,000 cubic feet per second (c.f.s.) occurring in 1968, and the minimum monthly average flow was 3,700 c.f.s. in February 1964. The flow fluctuates seasonally depending upon conditions outside of the Area.

The natural silt content of the Area rivers also varies seasonally. Suspended sediment measurements have been recorded since 1969 at only two stations, one on the Athabasca River below Fort McMurray and the other on the Clearwater River at Draper. The historical data shows that the suspended and total solids concentrations have their lowest values during winter months and increase by a factor of 10 during summer months. Most of the sediment load in the Athabasca River originates upstream from the Area.

The land surface is well stabilized since virtually the entire region is covered by protective vegetation, being either forest or muskeg. This will be disturbed, however, by industrial activity in the surface mineable region. In order to provide baseline data for the prevention of erosion and sedimentation, the following research is recommended:

Examine all available data on sediment loads for the Athabasca and Clearwater Rivers.

Survey and plot the slope profiles of all streams traversing the surface mineable region and determine their vulnerability to erosion if disturbed.

Inspect and photograph all streams travering the surface mineable region in order to identify the composition of stream beds and banks, stream bank vegetation, natural bank and slope erosion, and tendency for channel shifting.

Make periodic measurements of suspended sediment.

Study the past behavior of the Athabasca River especially through the surface mineable area with particular regard to flood levels, ice action, erosion and channel shifting.

Bitumen exposure on Steepbank River

Study ultimate disposition of suspended solids, for example, in the Athabasca Delta.

The general aspect of water quality in the Athabasca River has been the subject of several published reports and these indicate reasonably good quality. Most of the monitoring, however, has been done upstream from the surface mineable region. An extension of this testing program is required to ascertain the downstream water quality. The sampling system should be organized to cover all seasonal conditions.

Field observations confirmed the presence of natural bitumen in the Athabasca, Tar, MacKay, and Steepbank rivers; this originates from tar sands outcrops. The bitumen is found in many forms, e.g. either as a coating on the gravel in the stream bed, or adhering as particles to native gravel, or in suspension, or floating on the surface forming a small but distinct iridescent sheen in back eddies.

In this natural aquatic environment the bitumen concentration is not sufficiently high to injure the fish population. A bioassay was conducted to determine the effects of higher bitumen concentrations upon fish. A sample of tar sands was taken from an outcrop on the bank of the Steepbank River. In the laboratory the tar sands were added to dechlorinated water to give a sand to water ratio of 10%. After stirring for thirty minutes, test fish were introduced and the mixture was found to be nontoxic over an exposure period of 96 hours. After stirring for 16 hours, however, the mixture proved to be toxic to all test fish within a 6 hour exposure. The results of this bioassay indicate that under certain conditions bitumen can be toxic to fish. More research is required to define the particular conditions and to relate these to bitumen tailings from tar sands plants.

Water quality data for the Athabasca River below Fort McMurray was obtained from the Water Quality Branch of Environment Canada based upon sampling done from 1967 – 1972:

total dissolved solids – 171 to 339 mg./1,
pH – 7.8 to 8.2
turbidity – 8.1 to 125, J.T.U.
oxygen consumed – 5.4 to 12.1 mg./1,
total organic carbon – 10 to 30 mg./1,
iron – 0.01 to 0.34 mg./1,
total mercury – 0.00016 mg./1.

The total organic carbon and the oxygen consumed are of particular interest, because they relate to the oxygen sag in the river. This factor requires further investigation to determine the natural oxygen demands and the impact of effluents.

Narrows between Namur and Gardiner Lakes

LAKES

The Area includes several lakes having diverse characteristics.

Namur, Gardiner and other lakes found in the Birch Mountains at elevations of 2400 to 2600 feet, are exceptional for their beauty and water purity.

Gregoire Lake is at a lower elevation of 1,559 feet, but the quality of its water permits swimming and fishing.

Most of the other lakes occur in muskeg regions where they provide habitat for aquatic fauna species.

A preliminary investigation of the quality of water for the larger lakes revealed the following analyses:

	Alkalinity	pH
Namur Lake	20-30 ppm	6.8-7.1
Gardiner Lake	60-75 ppm	7.5
Gregoire Lake	50-55 ppm	7.6-7.8

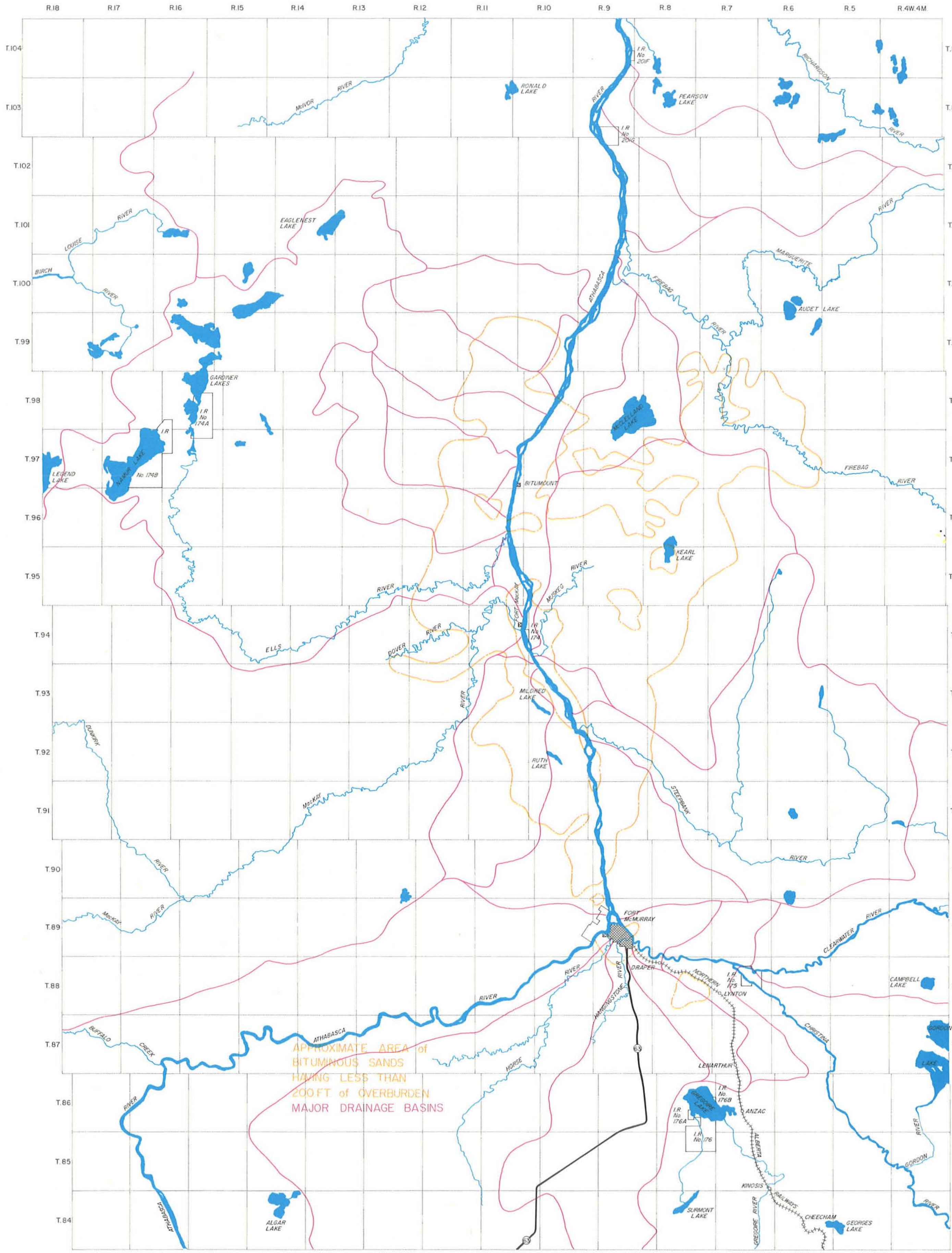
The measured pH values lie within the acceptable range of 6.5 to 8.5 for fish habitat. The alkalinity level, however, is not sufficient to ensure buffering against acidic pollutants. Recent studies on lakes in British Columbia suggest that alkalinity values of 250 or higher provide good buffering protection. Lakes in the Sudbury area suffered a decline in pH when exposed to SO_2 emissions.

DRAINAGE BASINS

Although long-term hydrological data for north-eastern Alberta are generally lacking, it is encouraging to note that several new stations have been established recently, and the Water Survey of Canada has opened an office in Fort McMurray to service these stations. A much more detailed definition of the characteristics and conditions of these drainage basins will be required to permit the planning of future industrial development. The drainage basins to the south and east of Fort McMurray are of particular interest because they contain the only hydrometric stations with two years or more of stream flow records.

The establishment of liquid emission standards will require knowledge of average stream flows and of their variations, both seasonally and from year to year. Data on minimum flows is important for planning industrial or municipal water supplies, and important also to determine pollution tolerance.

Many of the drainage basins traverse the surface mineable region. The total ecological function of these streams must be determined before planning any diversions or other types of disturbance.



APPROXIMATE AREA of BITUMINOUS SANDS HAVING LESS THAN 200 FT of OVERBURDEN
MAJOR DRAINAGE BASINS
FORT McMURRAY
BITUMOUNT
ATHABASCA RIVER
CLEARWATER RIVER
FIREBAG RIVER
MUSKEG RIVER
ELLS RIVER
DOVER RIVER
MacKAY RIVER
STEEPBANK
CHRISTINA
GREGOIRE LAKE
McCLELLAND LAKE
KEARL LAKE
MILDRED LAKE
RUTH LAKE
GARDINER LAKES
NAMUR LAKE
LEGEND LAKE
EAGLENEST LAKE
RONALD LAKE
PEARSON LAKE
AUDET LAKE
CAMPBELL LAKE
GORDON LAKE
SURMONT LAKE
ALGAR LAKE
GEORGES LAKE
DRAPER
LYNTON
LENARTHUR
ANZAC
KINOSIS
CHEECHAM
ALBERTA RAILWAYS
NORTHERN
T.84 – T.104
R.4W.4M. – R.18

Ells River

Siltation studies and controls are necessary since marine navigation on the Athabasca requires periodic dredging of the channel.

Mean annual precipitation is approximately 18 inches over most of the Area, whereas mean annual runoff is about 5 inches. The balance of 13 inches is dissipated in evaporation and transpiration. The extensive muskeg area plays a significant role in this water balance.

Five years of stream flow records are required to permit reasonable estimates of mean annual flows and 10 to 20 years of records are required to permit reasonable estimates of extreme flows. Flood flows are critical when considering erosive action or canalization.

The following data must be derived for all drainage basins within the Area:

Mean annual flows

All aspects of flood flows, viz:

mean annual floods and once-in-50-year floods.

streamflow and precipitation data for reported July 1970 storm in Clearwater-Christina basin.

extreme floods as estimated by unit hydrograph or related methods.

storm-flood relationships, compared with flood-envelope chart for Alberta stations.

past high water marks.

estimated flows by means of surveyed cross sections, slopes and channel roughness.

cross-sections of streams to estimate channel-forming flows.

mean annual floods and probable maximum floods.

Minimum flows on monthly and daily basis.

Lake levels.

Ice conditions; freeze-up and break-up dates, thicknesses, and effects of ice-jams on flood levels.

Ice break-up on Athabasca

Groundwater

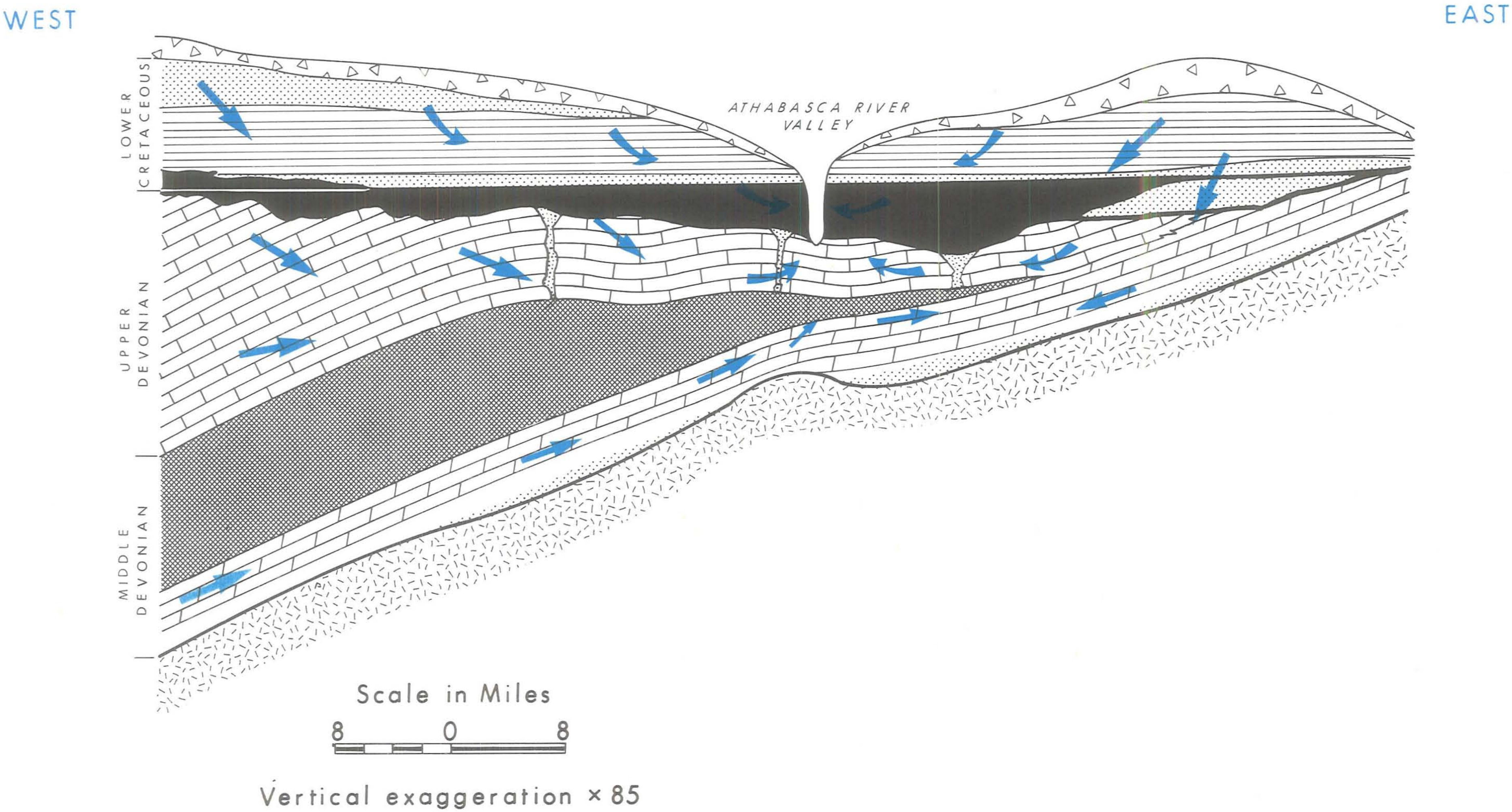
Preliminary work has been done by the Groundwater Division of the Alberta Research Council, and this program requires expansion in order to provide essential information regarding sub-surface water. The schematic diagram provides a general picture of the probable regional groundwater flow.

Sink holes occur at random locations in the limestone beneath the tar sands. These range in diameter from a few feet to several hundred feet, and may be quite deep. Most of the sink holes which were formed before the deposition of the tar sands are now filled with rubble and are inactive. Some, however, are still porous and post-Pleistocene collapse is evident. These permeable sink holes will have an effect on local and regional groundwater flows and, depending upon their location, may act as upward conduits for saline water, or as downward conduits for drainage water. The collapse areas are most prevalent north of Fort MacKay.

A survey using electric models should be conducted to establish the theoretical groundwater flow patterns especially for bituminous sands leases contemplated for development. The flow diagrams thus derived could then be adjusted to conform with field mapping of groundwater recharge and discharge phenomena to give a qualitative picture of the groundwater flow for the area. This type of data could be generated in approximately two years, thereby providing some guidance for preliminary planning.

More accurate and quantitative measurements of groundwater movement will necessitate extensive drilling and instrumentation of observation wells for continuous records of water levels over long periods of time. Groundwater monitoring by this technique should be incorporated into any authorized plan for exploration of the ore body.

SCHEMATIC DIAGRAM OF REGIONAL GROUNDWATER FLOW



Atmosphere

Long term climatic records from the Fort McMurray airport and historical weather data from Fort Chipewyan were assembled and analyzed. The information from these two sources was interpolated to provide an empirical model of the atmospheric conditions within the Area. Notwithstanding the localized nature of the source data, the validity of the atmospheric model has been confirmed by field observations.

Three air masses influence the meteorology of the Area. In summer, the Arctic Continental air mass tends to produce hot, dry weather, but, the Area is also affected by the Maritime Pacific air mass, which causes unstable conditions, cloud cover, and rain. Although infrequent, the Maritime Tropical air mass occasionally causes summer disturbances, such as very high temperature, high humidity, and thunder storms. The net result is that the summer atmosphere is unstable during the day and stable for only short periods of time during the night. This characteristic instability causes vertical mixing of the atmosphere thereby facilitating the dispersion of any airborne emissions.

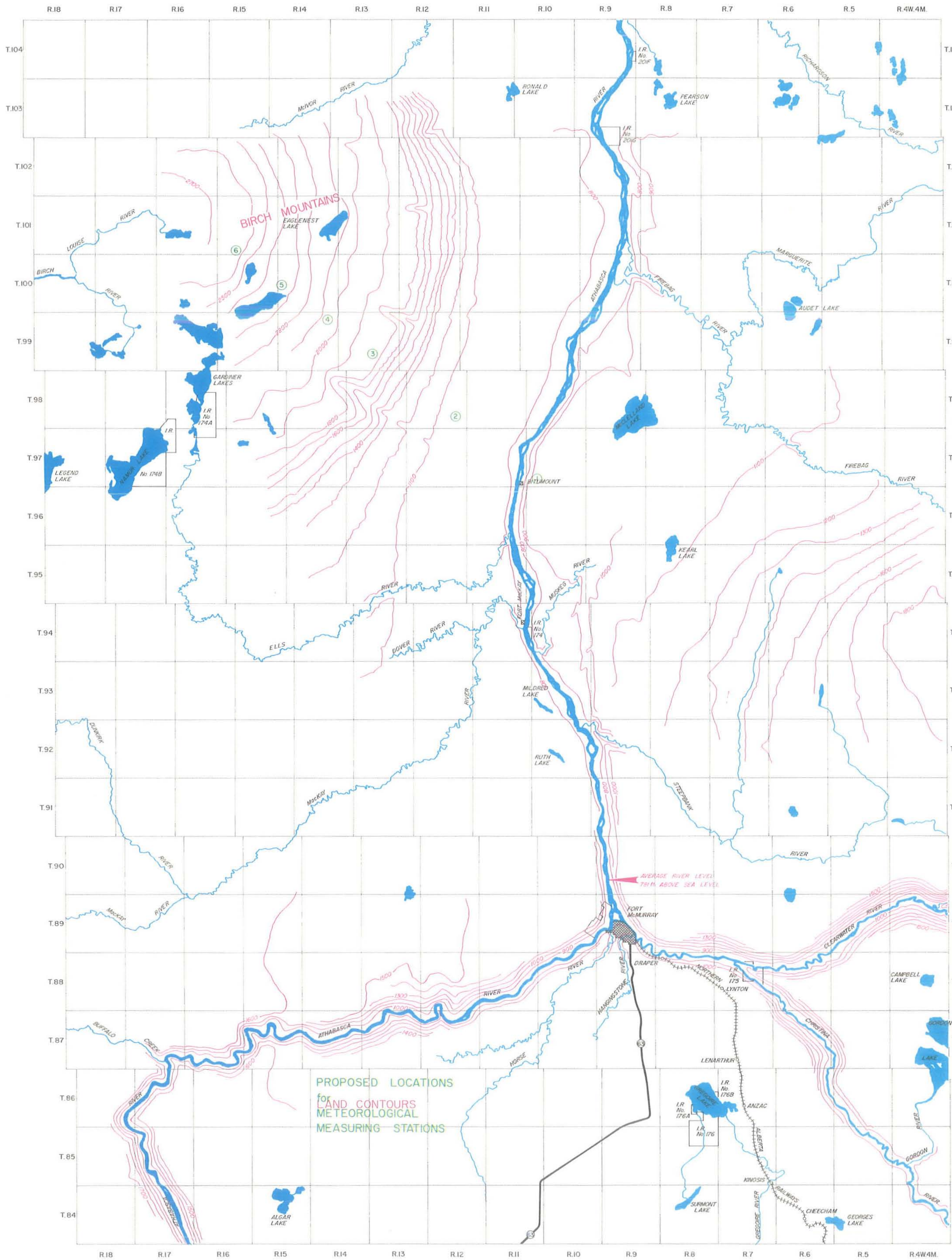
Winter conditions are much more critical, with regard to the atmosphere's tolerance for airborne emissions. The Arctic Continental air mass dominates, bringing relatively clear skies, very low temperatures, and light winds of less than 10 miles per hour. The Maritime Pacific air mass provides occasional moderation involving cloud cover, snow, and higher temperatures. Winter weather is generally very stable, with frequent and intense inversions that restrict the atmosphere's capacity for airborne emissions.

The average frequency of bad weather conditions was derived from a study of the hourly weather observations recorded at the Fort McMurray airport. The following are the results expressed in terms of percentage of observations:

Thunder storm	0.6%
Rain	5.5%
Freezing precipitation	0.3%
Snow	11.9%

The records used for this purpose covered the 10 year period from 1957 to 1966. This data provides a baseline for determining any future changes to this weather pattern which might be caused by industrial or other activities.

The baseline data for meteorological conditions in the Area must be expanded by establishing 6 new measuring stations to be located as shown on the map. The factors to be measured would be:



BIRCH MOUNTAINS
EAGLENEST LAKE
RONALD LAKE
PEARSON LAKE
McIVOR RIVER
LOUISE RIVER
BIRCH RIVER
RICHARDSON RIVER
MARGUERITE RIVER
FIREBAG RIVER
AUDET LAKE
GARDINER LAKES
MCCLELLAND LAKE
NAMUR LAKE
LEGEND LAKE
BITUMOUNT
KEARL LAKE
MUSKEG RIVER
ATHABASCA RIVER
ELLS RIVER
DOVER RIVER
FORT MacKAY
MILDRED LAKE
RUTH LAKE
STEEPBANK RIVER
MacKAY RIVER
DUNKIRK
AVERAGE RIVER LEVEL
781 ft. ABOVE SEA LEVEL
FORT McMURRAY
CLEARWATER RIVER
DRAPER
NORTHERN
LYNTON
HANGINGSTONE RIVER
CAMPBELL LAKE
CHRISTINA
GORDON LAKE
BUFFALO CREEK
HORSE RIVER
LENARTHUR
GREGOIRE LAKE
ANZAC
ALBERTA
KINOSIS
RAILWAYS
CHEECHAM
GEORGES LAKE
SURMONT LAKE
GREGOIRE RIVER
GORDON RIVER
ALGAR LAKE
PROPOSED LOCATIONS
for
LAND CONTOURS
METEOROLOGICAL
MEASURING STATIONS
R.18 R.17 R.16 R.15 R.14 R.13 R.12 R.11 R.10 R.9 R.8 R.7 R.6 R.5 R.4W.4M.
T.104 T.103 T.102 T.101 T.100 T.99 T.98 T.97 T.96 T.95 T.94 T.93 T.92 T.91 T.90 T.89 T.88 T.87 T.86 T.85 T.84

Station No. 1 — (base station located at Bitumount) — wind, temperature, humidity, precipitation, and radiation;
Stations 2, 3, 4, 5, — temperature only;
Station 6 — wind, temperature, humidity and rate of fall of precipitation.

Records are to be compiled for a period of at least one year and preferably much longer. The program will provide more reliable data for the planning of protection for the atmospheric environment. The vertical temperature profile from the valley floor to the top of the Birch Mountains will be especially useful to a better understanding of inversions.

TEMPERATURE

An analysis of temperature records from the Fort McMurray airport confirms that the highest temperatures occur traditionally in July and the lowest temperatures in January. January showed a mean daily maximum of 4 degrees F., and a mean daily minimum of -16 degrees F. The corresponding figures for the month of July show a mean daily maximum of 76 degrees F., and a mean daily minimum of 48 degrees F. Extreme temperatures in winter can reach -50 degrees F., and in summer, 90 degrees F.

The duration and severity of the winter season can be gauged by the freezing cycles of the Athabasca River. On the average, the river freezes by November 2nd, and break-up occurs on April 21st. This historical data can be used for measuring any future changes in the temperature of the general environment.

Ice fogs occur in the river valley especially from December through February. They are most severe when the temperature drops to the critical level of -30 degrees F., or lower.

The temperature pattern on a synoptic scale suggests that a more pleasant climatic regime exists in the Birch Hills area, as compared with the river valley. Due to the elevation difference, and other meteorological factors, a Birch Hills location is warmer in winter and cooler in summer, possibly by as much as 10 degrees on occasions. This elevated location is above the top of most inversion conditions, and therefore would be exposed less frequently to any atmospheric pollution created at lower levels.

WINDS

In the vicinity of Fort McMurray, wind direction is seasonal, with the prevailing winds between October and May being east and southeast, while those between June and August tend to be westerly. Wind velocities are relatively light on the average. A review of the records for a 10 year period indicates a relatively high frequency of winter days on which the wind velocity is less than 8 miles per hour. This condition contributes further to the low tolerance of the winter atmosphere for airborne emissions. No wind measurements have been taken outside of the Fort McMurray airport for a sufficiently long time to provide statistical validity.

INVERSIONS

An inversion occurs when the temperature of the atmosphere increases with height. This atmospheric phenomenon occurs frequently in the river valleys especially in cold weather. An analysis of the statistical data for 89 selected winter days indicates that inversion conditions prevailed at some time during 82% of those days.

Winter inversions are characterized by a high pressure zone of great depth, associated with a trough of low height aloft. The whole system remains relatively stable for prolonged time periods and winds are usually less than 10 miles per hour. Under these climatic conditions, the atmosphere's ability to disperse airborne emissions is drastically reduced.

Winter inversions in northern regions are aggravated by the low solar elevation angle, resulting in a higher rate of heat radiation, especially from a snow surface. Lower ground temperatures accentuate the inversion effects near the surface where environmental impacts are concentrated.

Nocturnal summer inversions also occur, but are of short duration.

In view of the importance of inversions to future environmental planning, a field survey is needed to ascertain the average height of the top of such inversions. This would be indicated by the possible presence of a "red belt," in the coniferous forest on the lee side of the Birch Mountains, since the upper interface of an inversion involves a sharp temperature change, causing discolouration of vegetation. It is essential to document the existing condition of the vegetation to provide a baseline reference. Future airborne contaminants such as SO_2 could cause a different type of colour change.

HUMIDITY AND ICE FOG

Water can exist as vapour in the atmosphere at temperatures down to -30 degrees F. but further cooling below this critical temperature causes most of the water to freeze as discreet crystals, ranging in size from 30 to 100 microns. These crystals remain suspended in the atmosphere, thereby causing an ice fog condition.

Ice fog tends to attract any water soluble airborne pollutants, since the ice crystals provide a large surface for absorption. These pollutants concentrate at the top of the fog layer due to a natural refluxing action at the temperature interface. Where possible, atmospheric emissions should be discharged above the top of the ice fog layer.

Ice fogs have been observed frequently in the Athabasca valley, sometimes extending for several miles. They are most prevalent and severe in the immediate vicinity of the tar sands plant. On occasions, the fog intensity has necessitated shutting down heavy industrial equipment.

Natural conditions can create ice fogs, but they are generally mild compared with those caused by the discharge of large quantities of water vapour to a localized atmosphere. A tar sands plant emits enormous volumes of water vapour especially from the hot liquid tailings.

The severity and duration of ice fogs are aggravated by inversion conditions.

More field studies are needed to obtain a reliable record of the current frequency and intensity of ice fogs and their cause and effect.

DIFFUSION CHARACTERISTICS

The ability of an atmospheric environment to accept and diffuse airborne emissions is a function of all of the factors previously described. The interrelationships of these factors are both complex and variable.

Extensive computations have been done to predict the pattern of diffusion of atmospheric emissions in the Area, but of necessity, these have included many assumptions. The available data on emissions and diffusion factors is not sufficient to permit reliable calculations.

Priority concerns must relate to the emissions which are discharged to or created in the atmosphere from stacks and later returned to ground level.

Obviously, the most direct approach to generate conclusive data for this purpose would be to monitor the existing pattern of diffusion and to develop therefrom more reliable formulae for future projections. In October 1971, a survey of this type was actually conducted as a

Hanging Valley and surrounding hills

joint venture for which the Mines Branch of the Fuels Research Centre of the Federal Department of Energy, Mines and Resources, provided aerial monitoring of the SO_2 dispersion from the tar sands plant. The resultant data is presented in graphical form in their classified report dated August 1972. The Department of the Environment must evaluate this important new data and promptly participate in continuing surveys of this type. This field data is vital for reliable predictions of dispersion patterns from future plants. The consideration of future plant locations relative to protection of the atmospheric environment will have to be predicated upon the most reliable dispersion data available.

When the results of the aerial surveys have been collated with ground level monitoring, a decision can be made on the possible need for a meteorological tower. Such a tower, equipped with sensitive instrumentation could provide data for calculating vertical and horizontal diffusion coefficients.

Constant level balloons should be used to measure the effects of terrain on mean plume paths and plume dispersions.

An evaluation of mathematical methods for computing atmospheric diffusion was undertaken. The result is an interim recommendation that a Gaussian diffusion model, which uses the plume rise formula of Thomas et al. and the Pasquill-Gifford diffusion coefficients be applied for estimating ground level air quality in the Area. Terrain effects should be incorporated into the model by subtraction of half the height of the hills from the plume rise formula.

The Area is susceptible to peculiar conditions of terrain and climate. Under adverse meteorological conditions ground level contaminant concentrations could be two or more times those values predicted under neutral atmospheric conditions. Detailed meteorological studies are required to determine the frequency and intensity of these occurrences.

Active sand dunes north of area

Ground Surface

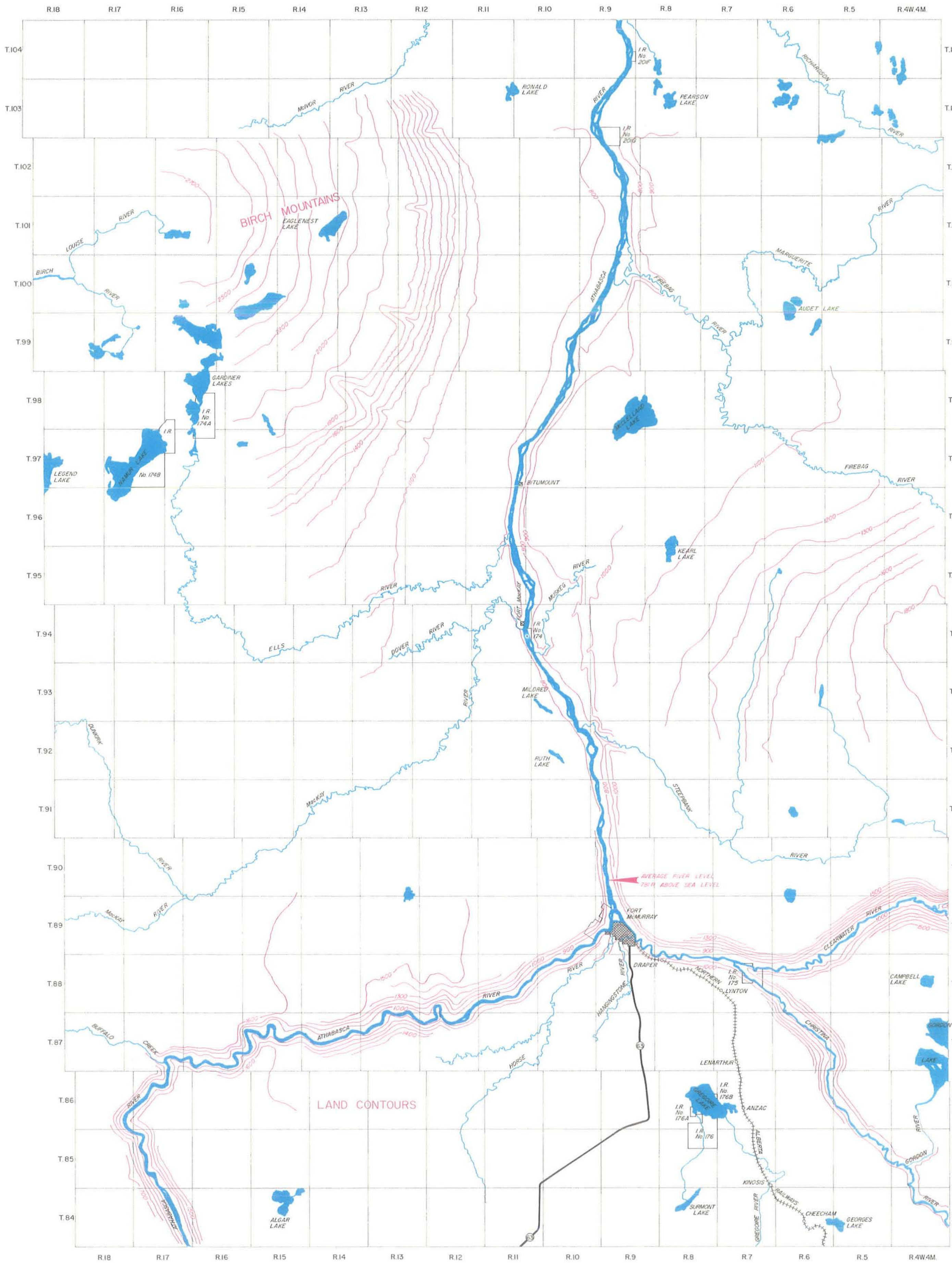
The contour map shows the general terrain of the Area. The reference elevation for the Athabasca River is 781 feet above sea level measured at a point below Fort McMurray and just upstream from the mouth of Clark Creek. The land contours exhibit steep embankments on the upper reaches of the Athabasca River and also along its principal tributary, the Clearwater River. The principal promontory within the Area, occurs in the northwest corner and is designated as the Birch Mountains, rising to an elevation of 2700 feet. A less pronounced promontory occurs in the central eastern section of the Area, as Muskeg Mountain, which reaches an elevation of 1800 feet.

The nature of the top soil varies with the topography. Silica sand and gravel comprise the outwash plains which represent approximately 55% of the Area. The melt water channels representing approximately 10% of the Area, are comprised of silica sand and gravel. Glacial till occurs in the ground moraine comprising about 10% of the Area. Silt is found along with clay in the lake plains and with sand in the flood plains.

The occurrence of major sand dunes has been studied by the Alberta Research Council and their locations have been identified. Most of the sand dunes within the surface mineable region are stabilized with vegetation, however, some active sand dunes occur to the north. Additional field research should be conducted in order to provide technical and biological data on these sand dunes to facilitate planning for re-vegetation.

Muskeg is prevalent throughout the Area, usually in discontinuous pockets. It contains 30% or more of water and therefore it will not support vehicular traffic except when frozen. The characteristic properties of muskeg are described in the Muskeg Engineering Handbook, published by the National Research Council.

Although most of the surface soil in the Area is reasonably well stabilized by natural vegetation, it is susceptible to minor disturbances such as those caused by road building on hillsides. This is evident from problems experienced with minor slides, for example, when building the roads from the airport to Fort McMurray and from the Townsite north.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BIRCH MOUNTAINS
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LEGEND LAKE
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BITUMOUNT
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MILDRED LAKE
RUTH LAKE
STEEPBANK RIVER
MacKAY RIVER
AVERAGE RIVER LEVEL 781 ft. ABOVE SEA LEVEL
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CLEARWATER RIVER
DRAPER
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ANZAC
ALBERTA
LAND CONTOURS
KINOSIS
RAILWAYS
CHEECHAM
GEORGES LAKE
SURMONT LAKE
GREGOIRE RIVER
GORDON RIVER
ALGAR LAKE
63

Muskeg south of McClelland Lake

Underground

The underground environment is described by the following excerpt from the working paper submitted by the Alberta Research Council.

The sedimentary succession overlying the Precambrian basement reaches its maximum thickness of about 3,000 feet at the southwestern corner of the area and thins fairly uniformly to zero at the edge of the Precambrian Shield in the northeast.

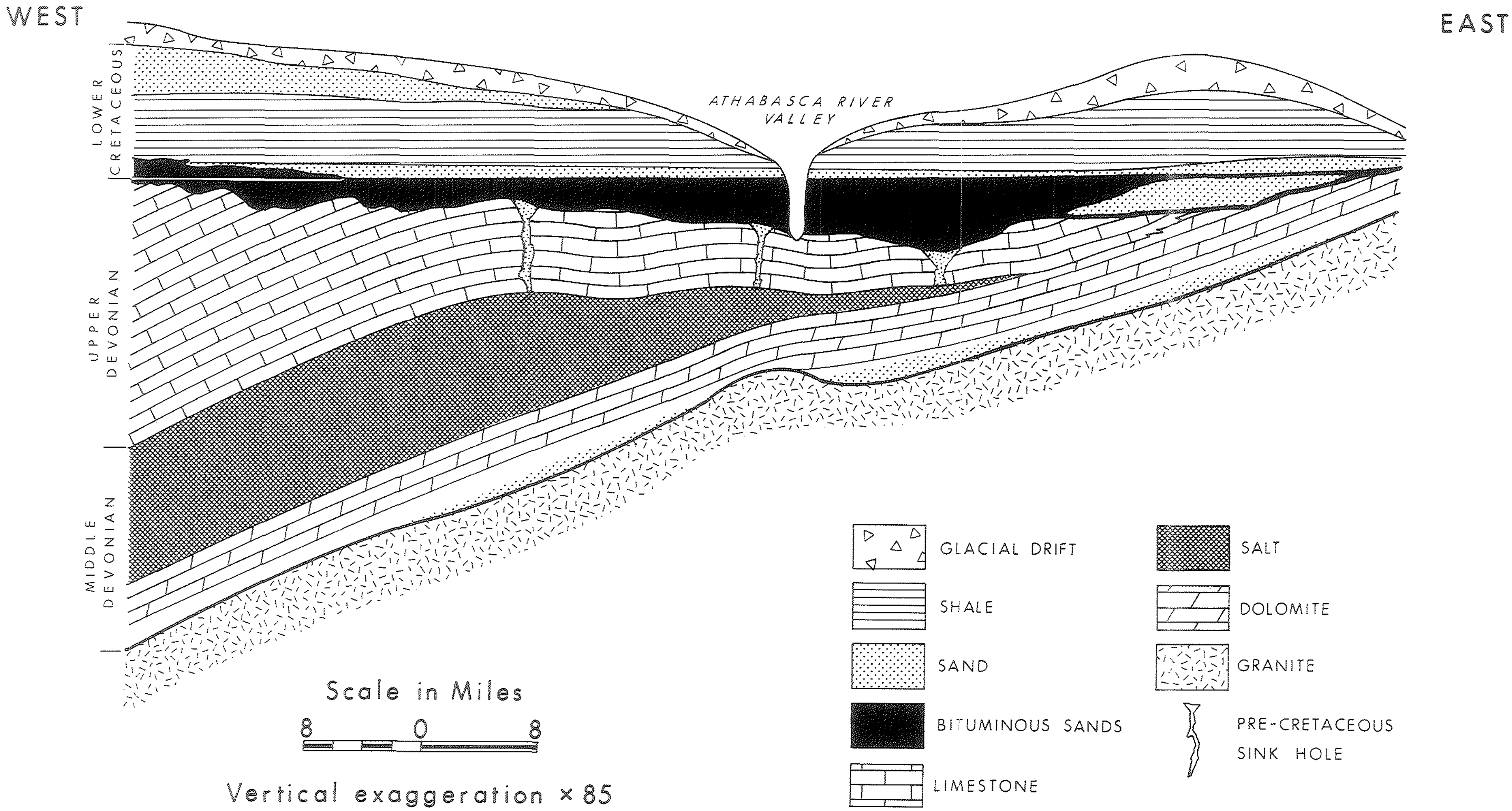
The Precambrian granites and gneisses are overlain disconformably by carbonate and evaporite strata of Middle to Late Devonian ages, which are inferred to underlie glacial deposits in the lowlands adjacent to the Athabasca River in the northeastern part of the Area. The Middle Devonian succession is composed of dolomite, minor dolomitic limestone, salt, shale interbedded with gypsum, and possibly anhydrite units of unknown thicknesses. The Upper Devonian Waterways Formation comprises a succession of interbedded limestone and argillaceous limestone, exposed mainly along the Athabasca, Muskeg, and MacKay River valleys in the central part.

Strata of Early Cretaceous age underlie much of the high plain adjacent to the Athabasca River in the southwest part of the Area, extending under the highlands to the northwest (Birch Mountains) and to the east (Muskeg Mountain). The Cretaceous succession consists of oil-impregnated quartzose sands and silty shale of the McMurray Formation. The bituminous sands are overlain by bentonitic marine shales and feldspathic sandstones of the Clearwater and Grand Rapids Formation. The youngest bedrock strata are well exposed outside of the Athabasca River valley and the lower reaches of its tributary streams.

The McMurray Formation consists of sediments of continental origin deposited in fluviatile, deltaic, lacustrine, and lagoonal environments and it rarely exceeds 200 feet in thickness. No fossils permitting precise age determination have been obtained from the McMurray Formation, but the current opinion is that it is of early Cretaceous age. The overlying Clearwater Formation carries a well developed marine macro- and microfauna of Cretaceous Middle Albian age (Mellon and Wall, 1956).

Although the beds of the McMurray Formation have a heterogeneous appearance due to the variation of grain size and bitumen content of the sediments, the petrographic characteristics of the formation are remarkably uniform. The major constituent of all grain sizes is quartz, with minor amounts of feldspar and mica. In the nonopaque heavy mineral fraction the most abundant minerals are tourmaline, chloritoid, zircon, and staurolite (Mellon, 1956). The clay-size material is composed of illite, kaolinite, chlorite and quartz.

SIMPLIFIED GEOLOGICAL CROSS SECTION SHOWING ATHABASCA BITUMINOUS SANDS



Fort McMurray, 1963

Human Habitat

The principal community within the Area is the Town of Fort McMurray, including Waterways. Its current population is approximately 7,000 people and this compares with 1,300 people recorded in 1964*. The increase of 5,700 people over the past 9 years is attributed to the advent of the first tar sands plant.

Although not shown in any official census figures an additional 175 men live at the plant site.

Anzac and its township, located 20 miles south of Fort McMurray accounts for 236 residents of whom 12 are registered as Indians.

The settlement of Fort MacKay and its township which is about 30 miles north of Fort McMurray on the Athabasca River, contains 410 people, of whom 180 are registered as Indians.

The Area includes 9 registered Indian reserves; except for those at Anzac and Fort MacKay, data is lacking on their populations.

The Metis Association advised that there are no officially designated Metis colonies in the area and that no separate census figures are available.

A few small settlements exist south of Fort McMurray along the Northern Alberta Railway.

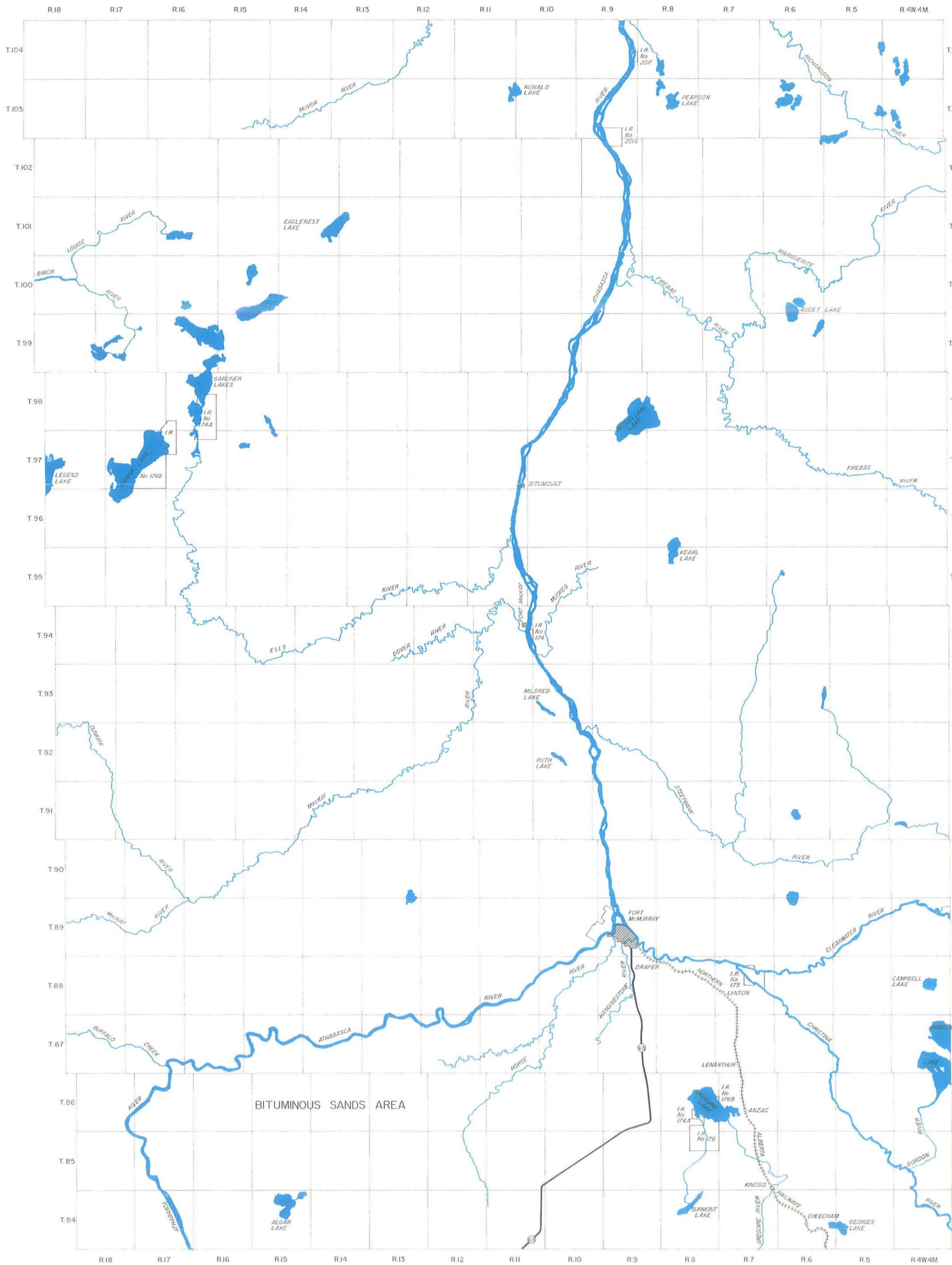
*Fort McMurray General Plan issued by the Provincial Planning Branch, Alberta Department of Municipal Affairs, January, 1972.

MUNICIPALITIES

The community of Fort McMurray is designated as a New Town, although it has achieved a considerable degree of local autonomy. The rapid influx of population over recent years has comprised mainly trained people seeking new employment or business opportunities. A relatively small proportion of the in-migration comprised native people in search of better education, training, job opportunities or living standards. From an environmental point of view the pertinent fact is that the growth trend is continuing. Planning is now in progress to accommodate a population increase to possibly 15,000 or more residents by 1980.

Local businesses which serve the public are subject to the established provincial standards and inspections for compliance with health standards, as are municipal sewage treatment facilities.

Some smoke is emitted from the burning of wood scraps at a small lumber operation south of the townsite. On infrequent occasions some residents have reported detecting odours which they ascribe to the tar sands plant. Although currently of relatively minor significance, such cursory observations are indicative of the need to incorporate environmental considerations into plans for growth of the community.



BITUMINOUS SANDS AREA
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ATHABASCA RIVER
FORT McMURRAY
FORT MacKAY
BITUMOUNT
DRAPER
LYNTON
LENARTHUR
ANZAC
KINOSIS
CHEECHAM
CLEARWATER RIVER
CHRISTINA RIVER
GORDON RIVER
GORDON LAKE
CAMPBELL LAKE
GEORGES LAKE
SURMONT LAKE
GREGOIRE LAKE
GREGOIRE RIVER
HANGINGSTONE RIVER
HORSE RIVER
ALBERTA RAILWAYS
NORTHERN
I.R. No. 175
I.R. No. 176
I.R. No. 176A
I.R. No. 176B
I.R. No. 174
I.R. No. 174A
I.R. No. 174B
I.R. No. 201F
I.R. No. 201G
BUFFALO CREEK
ALGAR LAKE
MacKAY RIVER
DUNKIRK RIVER
DOVER RIVER
ELLS RIVER
MUSKEG RIVER
STEEPBANK RIVER
MILDRED LAKE
RUTH LAKE
KEARL LAKE
McCLELLAND LAKE
FIREBAG RIVER
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MARGUERITE RIVER
RICHARDSON RIVER
PEARSON LAKE
RONALD LAKE
McIVOR RIVER
EAGLENEST LAKE
LOUISE RIVER
BIRCH RIVER
GARDINER LAKES
LEGEND LAKE
NAMUR LAKE
63

Fort McMurray, 1970

The Study included interviews with Fort McMurray residents on environmental subjects and these proved mutually beneficial. Given credible and authoritative information the local residents can provide useful inputs for environmental planning. In view of the special problems related to native people, supplementary efforts should be made to ensure their participation in communication programs.

EDUCATION

Educational institutions provide a medium for indoctrinating younger people in the principles of environmental protection. Many aspects of a country's cultural development are closely allied with education and also relate to the beauties and pleasures of the natural environment.

The Town of Fort McMurray provides both elementary and secondary schools which are part of the education system throughout the Province.

Fort McMurray has an adult vocational training centre to provide practical training for both resident and dormitory students.

The settlements of Fort MacKay and Anzac both have very modest educational facilities for young resident pupils. In both cases they provide instruction only in the first few elementary grades.

It is recommended that these educational institutions should provide guidance to the students for their appreciation of the natural environment as related to their futures.

HEALTH AND SAFETY

Fort McMurray's water supply is derived from the Athabasca River and undergoes treatment to prescribed health standards. The treatment of municipal sewage consists of minimal primary treatment using conventional lagoons before discharging to the Clearwater River.

Fort MacKay and Anzac present special problems requiring prompt review by appropriate authorities.

In view of the imminent probability of population growth, regional planning must include consideration of the facilities affecting the health and safety of residents in all parts of the

Fort MacKay

Area, for example: water supply, sewage disposal, fire protection, hospital services, and public health services.

Some of the public roads require improvements to their construction and maintenance. The Provincial Government should assume complete ownership and control of all public roads, notably the access routes between communities and approved plant sites.

MOBILITY

Highway No. 63 provides road access to the Area from the south. Regular commercial air transportation serves Fort McMurray. The Northern Alberta Railway system also supplies freight services to the area. Some marine freight still moves north on the Athabasca River from the Northern Transportation Company Ltd. base at Waterways. At the current level of activity the impacts of these transportation modes is generally slight.

Foreseeable environmental concerns might relate to the increasing size and frequency of commercial highway vehicles and also to the potential impacts of denser vehicular traffic under adverse weather conditions.

Ground transportation proceeding north from the Town of Fort McMurray is limited to a semi-private road to the tar sands plant on Lease 86. An unimproved extension to this road leads to the settlement of MacKay with a branch route leading to the new tar sands plant site on Lease 17.

The greatest density of personnel traffic involves commuting between the townsite and plant sites.

The existing ground transportation facilities are not constructed to the standards required even for the present demands. It is recommended that the Area be given a high priority in the Province's present program for upgrading transportation systems. Such improvements would enhance the human environment.

OCCUPATIONAL PATTERNS

The principal employment of the residents relates to new tar sands industry. The work force for the existing plant has been stated to comprise 1,500 people. Most of the additional job occupations for the Fort McMurray residents are created by service enterprises.

Occupational patterns comprise a basic factor in the human environment, therefore industrial and regional planning must be co-ordinated and expanded. Complimentary planning of education and training would assure the indigenous people an opportunity to benefit from any authorized changes in environmental utilization.

Athabasca River

RECREATION

As part of the ecological baseline survey, the Parks Planning Branch of the Alberta Department of Lands and Forests conducted a preliminary survey of the Area to assess its potential for outdoor recreation and tourism. From their descriptive report and pictures, the following information was obtained.

Being largely wilderness, the Area provides its residents with extensive opportunities for natural outdoor recreation and scenic touring, especially by water. It has the potential to accommodate the recreation needs for many more residents and tourists, provided that designated portions of the physical environment are preserved for such purposes. The Provincial Government has already established some recreational facilities in the Area comprising: two roadside campsites, one lakeside campsite and one lakeside provincial park. The Alberta Department of Lands and Forests is considering recreational reservations in several parts of the Area and their efforts should be encouraged and expanded.

The Athabasca River and its tributaries offer scenic beauty and access to an extensive area of camping and fishing sites. Above Fort McMurray, the Athabasca River contains several sections of white water, which offer an interesting challenge to the more adventuresome canoeists, as it did to the earlier explorers. North of Fort McMurray, the Athabasca is the marine route to Lake Athabasca, approximately 150 miles distant.

Although it has declined in volume in recent years, commercial freight is still transported by river barge from Waterways to Lake Athabasca. The maintenance of the river channel by dredging and navigation markers serves also to enhance the safety of the river for pleasure craft. The future potential for tourism resulting from the extensive and scenic water course is readily apparent.

The tributaries to the Athabasca provide additional scenic access to recreation locations.

There are several lakes in the Area suitable for recreation. Gregoire Lake, located 20 miles southeast of Fort McMurray, is accessible by road and therefore represents an important existing recreation facility. A new provincial park on the shore of Gregoire Lake is scheduled to be opened in 1973 and it is anticipated that several similar facilities will need to be created to satisfy the rapidly expanding demand.

In the Birch Mountains, approximately 90 miles northwest of the town of Fort McMurray, there are several lakes, having outstanding recreation capabilities. Except for a small private fishing and hunting lodge on Lake Namur, these lakes are still in their wilderness condition, because they are not yet accessible by road. Priority studies should be directed to this region

Tar sands outcropping along the Athabasca River

Gregoire Lake Provincial Park

to plan for its optimum utilization for recreation or possible permanent human habitation.

In the north-east corner of the Area, there exists a chain of lakes, the most westerly of which is Pearson Lake and this region also offers potential recreation use. The lakes in this region are interspersed with stabilized sand dunes. The lakes contain attractive sandy beaches with fragile backshores.

Although the natural water bodies provide the most obvious recreation facilities, there are inland locations, which when accessible, will offer other recreation opportunities. Various unique landforms and other topographical patterns exist and these could support a great diversity of activities, such as: viewing, hunting, nature studies, recording, hiking, gathering and collecting, camping and picnicking. Some historical sites exist within the Area, such as the Abasand and Bitumount Plant sites, and various river locations having significance to earlier exploration and fur trading.

The recreation map designates regions that should be reserved for that purpose pending more detailed study. Consultations with the Parks Planning Branch produced the following additional recommendations:

— assess the priorities and sequence of recreation developments.

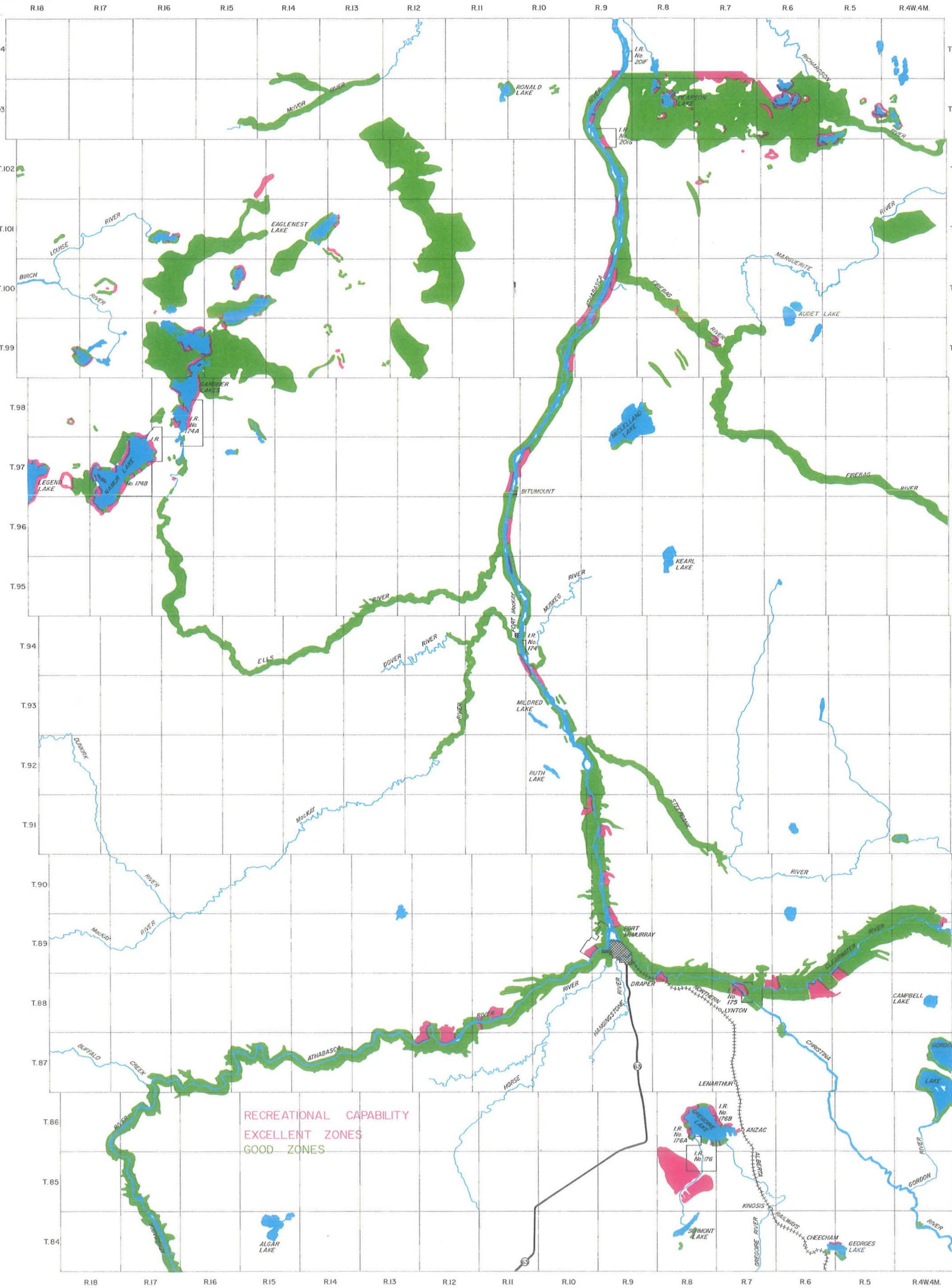
— incorporate recreation considerations into the regional plan.

— identify historic sites and objects; plan for their restoration.

Camping at the mouth of Coffee Creek

Pearson Lake beach with fragile backshores

Bitumount



RECREATIONAL CAPABILITY
EXCELLENT ZONES
GOOD ZONES
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McIVOR RIVER
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GREGOIRE LAKE
I.R. No. 176A
ANZAC
I.R. No. 176
ALBERTA
KINOSIS
GORDON RIVER
RAILWAYS
ALGAR LAKE
GREGOIRE RIVER
CHEECHAM
GEORGES LAKE

Forestry

The Alberta Forest Service conducted surveys in late 1972, to identify the types of trees and other ground cover existing within the Area. Aerial photography was done over 2 million acres selected to include the surface mineable region. This work produced 91 township forestry maps and lists pertaining to 22,440 stands. The detailed information was plotted by computer to prepare the forestry map which shows the distribution of different types of ground cover. The overview presented by the map is based upon stands of 200 acres or larger, whereas the input data included stands of 20 acre minimum size.

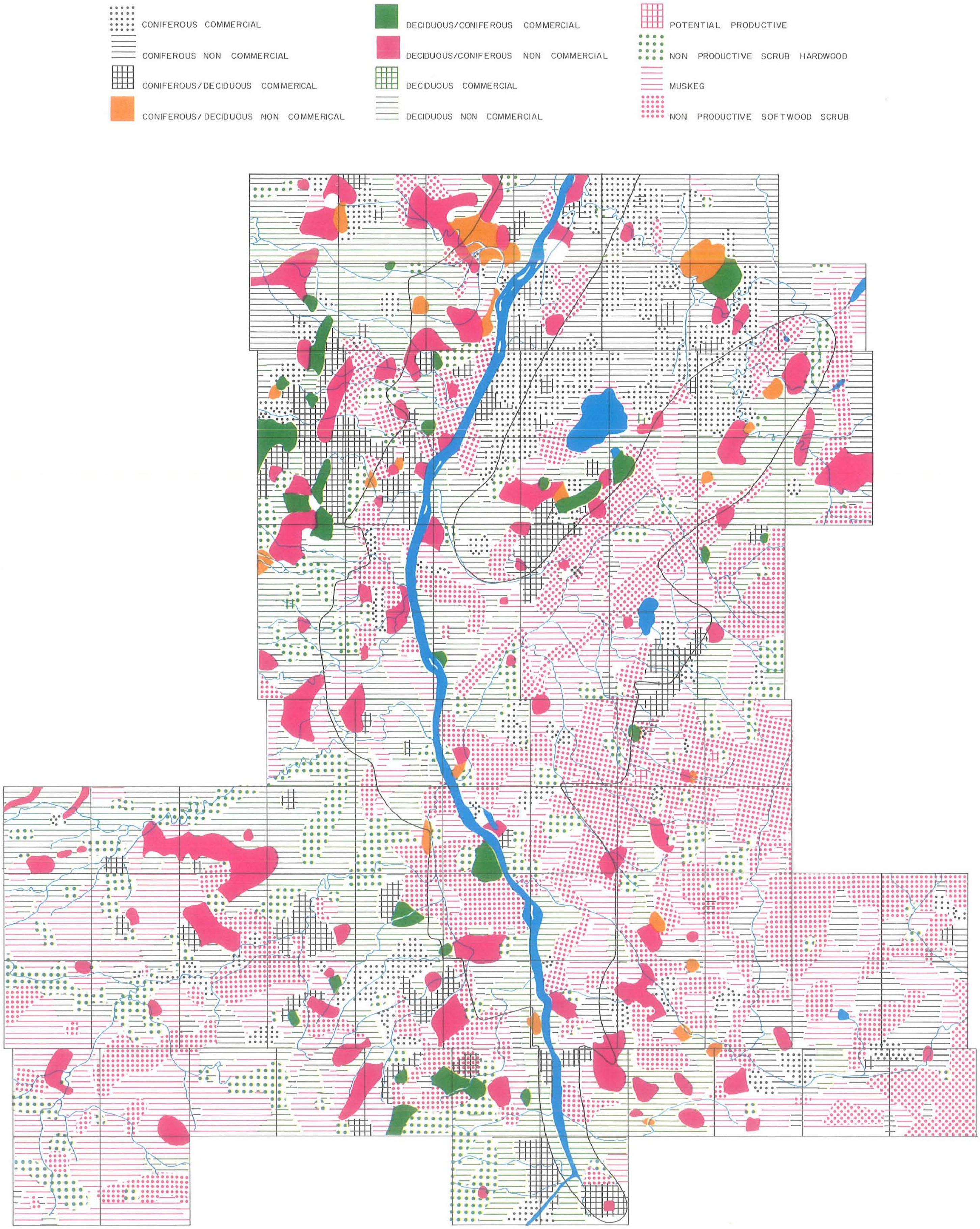
The surface mineable region contains a variety of tree species. In well drained areas, trembling aspen, white spruce, jack pine and paper birch are found. In the muskeg bogs, black spruce is common. Occasional large stands of tamarack can be found mixed with black spruce.

From a study of the photo-inventory data it was concluded that the forest values within the surface mineable region are similar to the surrounding regions. Both inside and outside the mineable region, two-thirds of the ground cover comprises the same four non-commercial types, viz: deciduous, softwood scrub, muskeg, and hardwood scrub. Likewise, commercial stands of coniferous and deciduous trees are found in similar proportions in both locations.

The term commercial is used to designate specified densities of trees suitable for lumber or pulpwood. Lumber species include white spruce and pine. Commercial roundwood comprises white spruce, black spruce, and pine.

Most of the 2 million acres surveyed for the preliminary study relate to Forest Management Units A5 and A7. The annual quota of allowable cutting on a sustained yield basis, for these two units, totals 16 million board feet. The corresponding annual value at $100 per thousand board feet is $1.6 million.

A MAP SUMMARIZING THE DISTRIBUTION OF FOREST TYPES



Fauna

WATERFOWL

Information pertaining to the existing biological environment for waterfowl was derived from a report by Canadian Wildlife Service, dated December 1972, entitled "Waterfowl Evaluation of the Athabasca Tar Sands Area."

According to their report, the Area has "low value for waterfowl production compared to prairie breeding habitat." Their application of the Canada Land Inventory classification indicates that most of the Area exhibits "moderately severe and severe limitations for waterfowl production." Gordon Lake is cited as an exception since it is "important as a production, migration and possibly a moulting lake." This lake will not be directly affected by any foreseeable development of the tar sands industry because it lies outside of the three areas of probable development. The Wildlife report also states that "Several wetlands have portions of good to fair habitat but are too small to receive a specific classification." This habitat is usually confined to creek inlets and outlets and islands in the individual wetlands. It is stated that the waterfowl populations of these wetlands tend to increase when water levels are low in prairie regions.

The principal importance attached by C. W. S. to the Area pertains to the migration of waterfowl. This in turn reflects its geographic relationship to the Peace-Athabasca Delta. Their field counts in September and October indicated a predominance of migrating ducks stopping especially at Gordon Lake and to a lesser extent at Garson, Mildred and Ruth Lakes. They also report brief stops being made by Whistling Swans.

They list several waterfowl species for which the Area is "host," eg. Lesser Scaup, Redhead, Common Goldeney, Bufflehead, Canvasback, Mallard, Blue-winged Teal, American Widgeon, White Pelicans. Migrants are listed as Whistling Swans, geese, Oldsquaw, and Surf Scoters.

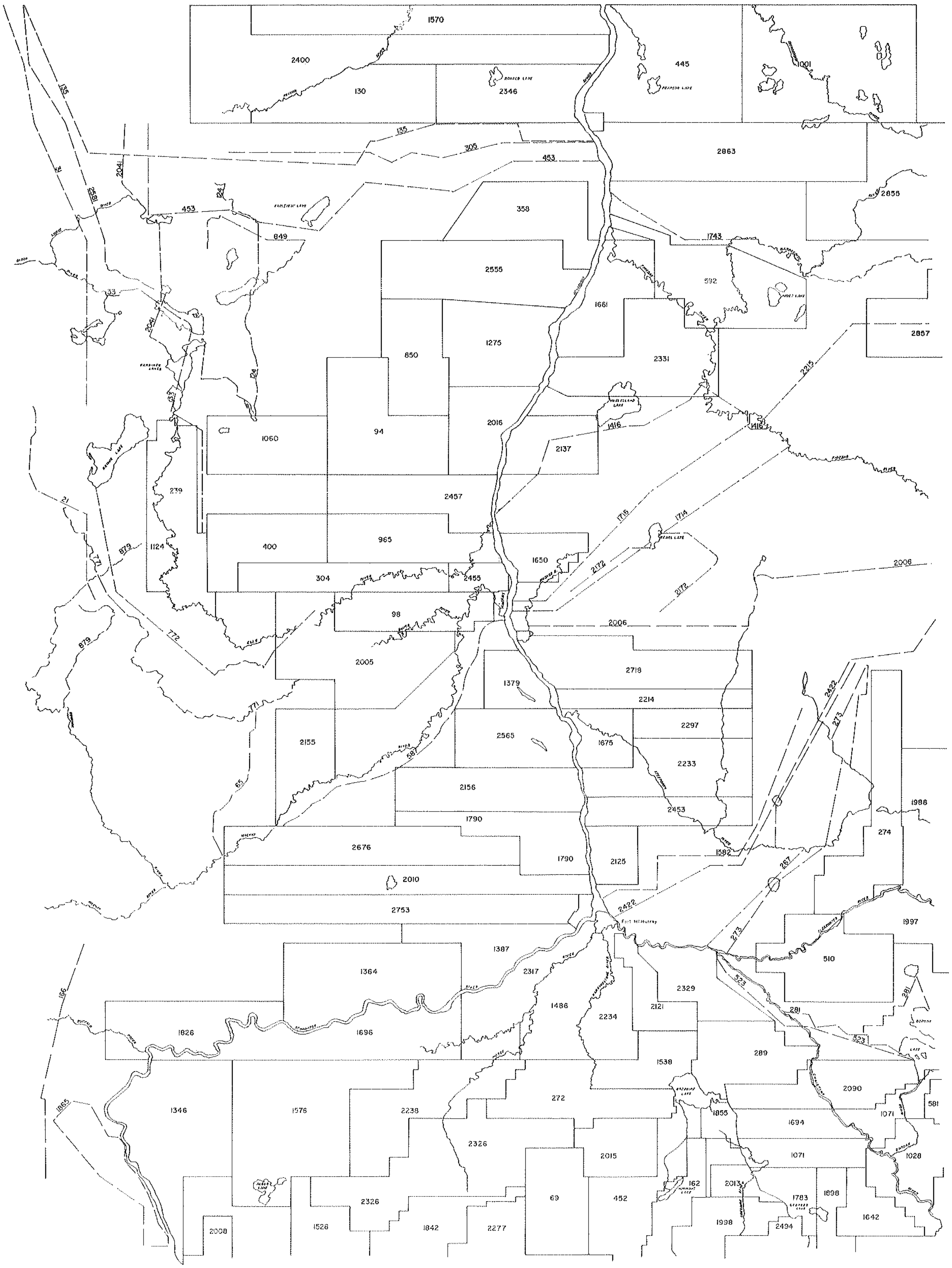
The time available for the total ecological survey was limited to the fall and early winter of 1972. For the waterfowl evaluation, this precluded any evalutation of spring migration and production periods.

UPLAND BIRDS

The timing of the ecological baseline studies did not permit gathering any data on upland birds for the Area. Field surveys should be conducted to develop an inventory of these species.

FUR BEARING ANIMALS

The Wildlife Division of the Alberta Department of Lands and Forests conducted a preliminary review of fur trapping within the Area.



TRAPLINES & TRAPLINE BOUNDRIES IN BITUMINOUS SANDS AREA

From their report the following data was derived.

The entire 11,340 square miles is divided into 94 registered traplines and trapping areas as shown on the map.

The average area of these 94 traplines is approximately 120 square miles.

126 trappers work these traplines, and of these, approximately 60% comprise Indians and Metis.

The 1971/72 trapping season contributed a total of $2,900.41 in crown revenues comprising the tax on pelts and the fees paid in annual renewal of registration. Beaver, lynx, and mink comprised the principal fur harvest. The average revenue per trapper was $750, but varied drastically from a minimum of $16.59 to a maximum of $3,608.24.

These statistics, however, do not reflect the real significance to the permit holders. The authentic trapper relies upon this financial income to supplement his living requirements. Furthermore, in light of recent fur sales, the revenue per trapper may double, i.e. to an average of $1,500 per trapper. Projections of future markets suggest a sustained demand for wild furs.

A scientific system for proper management of fur trapping in Alberta is currently being established. A new management system could increase the fur harvest by three or more times its current productivity. The harvest from fur trapping in the Area is less than 10% of the exploitable increment in fur bearing animals.

The estimated sustained potential fur yield in the Area is $375,000 per year.

Several species of fur bearers, e.g. beaver, mink, muskrat and otter utilize water as part of their habitat, and any deleterious impact upon that environment could affect these animals.

The annual permits issued for a trapline or a trapping area do not provide any rights beyond the one year period for which the permit is valid. The rights related to a bituminous sands lease reportedly take precedence over any trapline permits. An inventory of fur bearers should be required with any application for the development of a specific lease.

UNGULATES

A preliminary ungulate survey was conducted in the Area. November 13th to December 1, 1972, under the direction of the Fish and Wildlife Division of the Government of Alberta. The purpose of the survey was to obtain an ungulate density sample which could be used as a basis for mapping land capability for the production of the ungulate species.

A strip one-quarter mile in width was surveyed along each Township line and the following sitings of ungulates were recorded.

SUMMARY OF LINES FLOWN

Township lines	Moose	Caribou	Deer	Buffalo
81	8	4		
82	7	10		
83	17			
84	15	3		
85	31			
86	22	8		
87	13			
88	16		2	
89	22	2		
90	13			
91	9			
92	22			
93	17			
94	16			
95	14			
96	14			
97	13		2	
98	14			
99	6			
100	3			
101	19			
102	12	4		1
103	5	6		
104	8			11
105	6			
106	25			
107	3			
TOTAL	370	37	4	12

Namur Lake

The moose observed in the southern portion were concentrated in open burned or muskeg areas, where a good supply of short browse was available. Moose in the northwestern part of the survey area were found on the eastern slopes of the Birch mountains in a mixed wooded habitat. The area north and east of the Firebag River is covered with a pine forest and offers little browse for moose, thus only 21 moose were observed in 125 square miles flown in this area.

Caribou were observed in muskeg areas which consisted of open area surrounded by black spruce stands.

The buffalo observed were found in mixed wooded areas on the eastern slopes of the Birch Mountains and were transient animals from Wood Buffalo Park.

At the time of the survey the animals did not appear to be under any conditions of stress, as the snow was not deep. The animals observed during the survey appeared to have selected preferred wintering areas.

During the same time period another aerial survey of ungulate density was also conducted concentrating on the major rivers. Twelve hours of flying time were logged for this purpose, during which time 159 moose and 21 deer were sighted. Moose were found on the northern breaks of the rivers which presented a southerly exposure with aspen cover and a moderately sloping bank. The best areas were on the Clearwater River, Christina River and the Athabasca River south of Fort McMurray. The other rivers produced small moose population counts due to lack of suitable breaks and bad weather conditions for surveying.

Simultaneous to these ungulate counts a preliminary study was conducted to evaluate the habitat for ungulates. The reference data for this habitat study included: provincial forest cover maps, soil surveys published by the Research Council of Alberta, air photo interpretation, and extensive aerial survey of the Area. Land forms in the Area which influence the classification of land for the production of ungulates are the numerous river breaks, the Thickwood Hills and the Birch Mountains.

Based on Canada Land Inventory Standards overall productivity of the total Area is moderate for the production of ungulates. There are, however, localized habitats whose land capacity classifications for wildlife vary from excellent to poor.

Excellent winter ranges for moose can be found along the north river break of the Clearwater River. This area has a long undulating slope covered with open aspen stands which offer sufficient browse to winter a large moose population. The slight undulations offer shelter from prevailing winter winds.

Good winter ranges for moose can be found along the Horse River, Athabasca River south of Fort McMurray, Christina River at its confluence with the Clearwater River and the south river break of the Clearwater River. All these river breaks possess a predominantly aspen cover but are limited in their capability to support moose by either excessively steep banks or exposure to severe prevailing winds. The east slope of the Birch Mountains also provides good winter ranges for moose due to its low fertility and steeply sloping escarpment which offers some limitation to the area's ability to support ungulates.

Fairly good winter areas for moose are found along the Christina, MacKay, Ells, Firebag, Steepbank, portions of the Horse, and the Athabasca River north of Fort McMurray. These areas all have low or no river breaks and are flanked by areas which support small summer populations of moose. The Thickwood Hills and the southeast slope of the Birch Mountains may prove to be wintering areas for resident moose and possibly for some moose from surrounding muskeg areas.

Fairly good areas are also found south of Gregoire Lake and south of the Horse and Algar Rivers. These areas have sufficient forage to support a substantial population of moose in the summer time. Portions of the Thickwood Hills and the southeast slope of the Birch Mountains will also be included in this class.

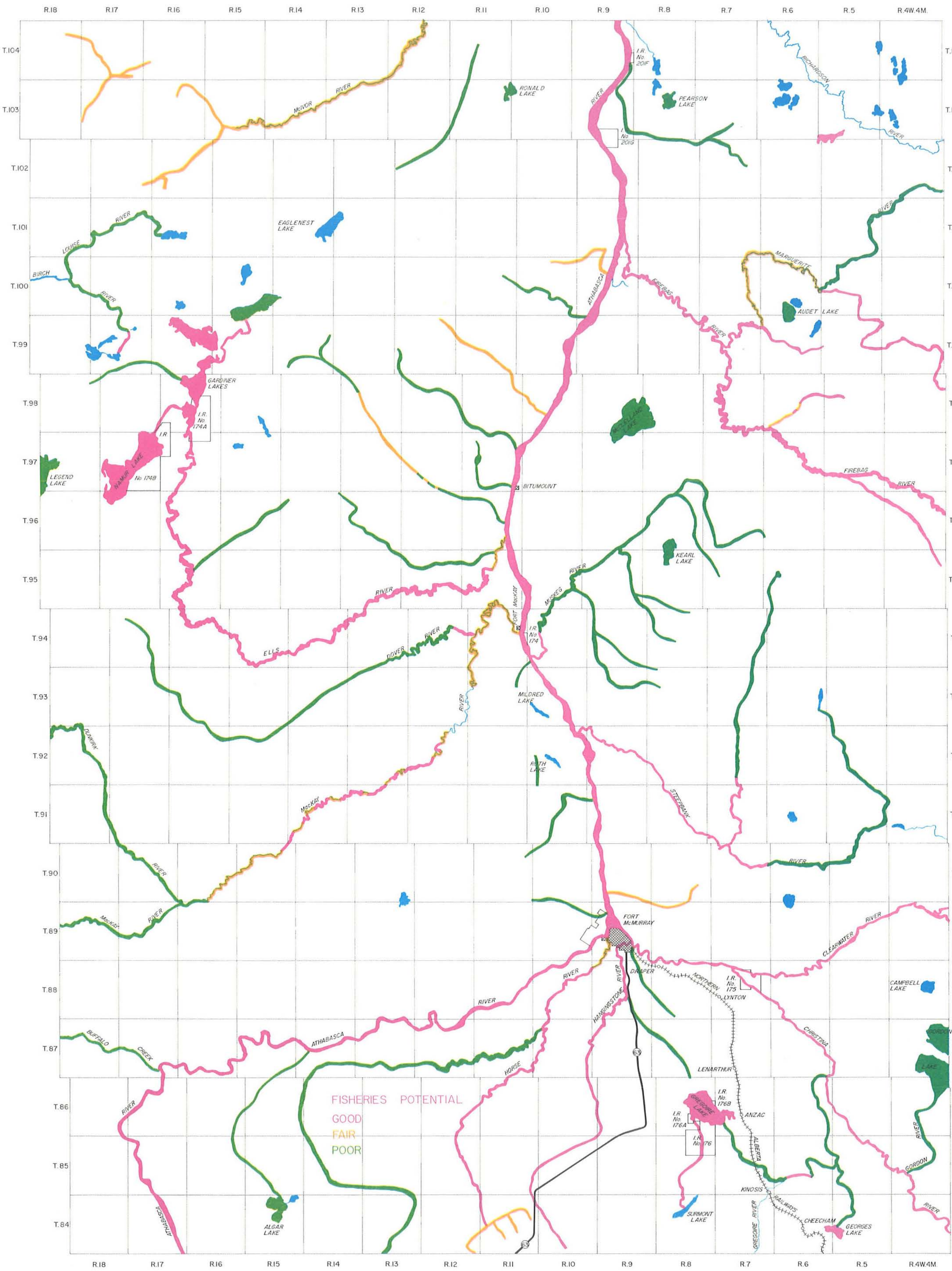
An excellent winter range for caribou is located south of the Area and consists of muskeg surrounded by black spruce stands. This type of habitat offers both shelter in the black spruce stands and an ample supply of food close at hand in the muskeg. Good winter ranges for caribou are found in the Algar Lake region and on the plateau above the escarpment of the Birch Mountains. Both areas consist of large open muskegs which offer little shelter.

Due to late fall and insufficient snow cover, the movement of moose onto winter range had not occurred at the time of the survey. The Wildlife Division is conducting a second survey. When additional field data becomes available, it should be possible to plot the wintering areas for ungulates and initiate mapping of wildlife in the Area.

FISH

The Alberta Department of Lands and Forests provided data on the fisheries potential of streams, rivers and lakes in the Area.

Streams and rivers were sampled to assess the current utilization by different species of fish. At each station, water samples were collected and an evaluation was made of the suitability for fish habitat. Additional observations by helicopter supplemented the on-site collection of field data. Fish were collected by a variety of



FISHERIES POTENTIAL
GOOD
FAIR
POOR
R.18 R.17 R.16 R.15 R.14 R.13 R.12 R.11 R.10 R.9 R.8 R.7 R.6 R.5 R.4W.4M.
T.104 T.103 T.102 T.101 T.100 T.99 T.98 T.97 T.96 T.95 T.94 T.93 T.92 T.91 T.90 T.89 T.88 T.87 T.86 T.85 T.84
McIVOR RIVER
RONALD LAKE
PEARSON LAKE
RICHARDSON RIVER
ATHABASCA RIVER
EAGLENEST LAKE
LOUISE RIVER
BIRCH
GARDINER LAKES
NAMUR LAKE
LEGEND LAKE
FIREBAG RIVER
MARGUERITE RIVER
AUDET LAKE
BITUMOUNT
KEARL LAKE
MUSKEG RIVER
FORT MacKAY
ELLS RIVER
DOVER RIVER
MILDRED LAKE
RUTH LAKE
DUNKIRK RIVER
MacKAY RIVER
STEEPBANK RIVER
FORT McMURRAY
CLEARWATER RIVER
CAMPBELL LAKE
DRAPER
NORTHERN
LYNTON
HANGINGSTONE RIVER
CHRISTINA
BUFFALO CREEK
HORSE
LENARTHUR
GORDON LAKE
GREGOIRE LAKE
ANZAC
ALBERTA
GORDON RIVER
KINOSIS
RAILWAYS
CHEECHAM
GEORGES LAKE
SURMONT LAKE
GREGOIRE RIVER
ALGAR LAKE

Poor fish habitat

methods and samples taken of the bottom fauna. The field data was analyzed and related to potential industrial impacts as a basis for recommendations.

The fisheries map shows the classification of lakes and streams according to their value for fish habitat.

Rivers rated excellent over their entire length within the Area include the Clearwater River and its tributary High Hill River. The Christina, Ells and Firebag Rivers are also considered to be of excellent potential over most of their lengths. The Hangingstone River and Surmont Creek are very good.

Frequently, a good rating is assigned to a portion of a river, although the river further upstream or downstream may be rated as poor in fisheries potential.

In the Clearwater River watershed, Gregoire River, Prairie Creek and Saline Creek are rated as poor over most of their lengths, although short stretches appear to be favourable.

The Steepbank and North Steepbank Rivers, for many miles below their respective headwaters, flow through flat muskeg country with extensive beaver activity. These portions of both rivers are rated poor. Further downstream the rivers flow more rapidly and show improved habitat characteristics, therefore, along these lower stretches, a good rating is applicable.

The Muskeg River is rated good over a relatively short stretch, not far from the river mouth, with a poor rating for the remainder of the river.

The Marguerite River, a tributary of the Firebag, is rated as poor over the uppermost 80 to 90% of its length; a good rating is assigned to the remaining 20 to 10%.

Clark Creek, Algar River and Grayling Creek are all rated as poor; they represent only minor watersheds on the east side of the Athabasca River.

Horse River is rated poor at the mouth, and over 70 to 75% of its remaining length; the lower portion is rated good. The most favourable fisheries potential in the watershed is offered by the large, unnamed tributary south of Horse River. This tributary is rated good below its headwaters.

The Beaver and MacKay Rivers both have major stretches rated good, but, poor ratings apply to other portions of both rivers. The Dover and Dunkirk, tributaries to the MacKay, are poor for almost their entire lengths.

The entire Ells River below Gardiner Lake and excepting the lowermost four to six miles is excellent. Namur River in the Ells watershed is suitable for support of a moderate level of sports fishing. Two unnamed streams, one flowing into Namur Lake and one into Gardiner Lake are

Good fish habitat

relatively unproductive with limited potential for angling. Joslyn and Chelsea Creeks, are unsuitable habitats for game fish production.

Among the rivers in the northwest corner of the Area, only the upper four to five miles of Birch River are good. The headwaters of Alice Creek in the Birch River watershed, and an approximate 15-mile portion of McIvor River are fair. The remaining stretches in The Birch River, McIvor River and Bucton Creek watersheds are poor.

Several smaller streams drain directly into the Athabasca from the west, of these the Tar River and Eymundson Creek have stretches where the fisheries potential is fair. The remaining streams are poor, viz Red Clay Creek, Conn Creek, Buffalo Creek, Poplar Creek, Pierre River, Calumet River, and an unnamed River in Township 99, Range 9.

Fourteen lakes representing eight different watersheds, were surveyed and are listed below in descending order of their fisheries potential:

LAKE	WATERSHED	POTENTIAL
Namur Lake	Ells River	Very good
Gardiner Lake	Ells River	Very good
Unnamed (Twp.99, Rge. 16)	Ells River	Good
Gregoire Lake	Clearwater River	Good
Georges Lake	Clearwater River	Good
Unnamed (Twp. 103, Rge.5)	Richardson River	Good
Legend Lake	Mikkwa River	Fair
Unnamed (Twp. 100, Rge. 15)	Ells River	Fair
Pearson Lake	Eleanor Creek	Fair
Algar Lake	Algar River	Fair
Audet Lake	Firebag River	Poor
McClelland Lake	Firebag River	Poor
Kearl Lake	Muskeg River	Poor
Gordon Lake	Clearwater River	Poor

A typical slow moving meandering river

The Namur and Gardiner Lakes, both in Ells River watershed, contained substantial populations of valuable fish species. The lake whitefish collected in both lakes were heavily infested with tapeworm cysts. Namur Lake contained an appreciable quantity of lake trout. In Gardiner Lake, northern pike and walleye were readily collected.

In the unnamed lake in Township 99, Range 16, whitefish were heavily infested with tapeworm cysts. Yellow walleye were present in commercially exploitable quantities.

These particular parasites are reported to be harmless for human consumption, but they detract from the commercial value of the fish. Lakes containing these infested fish should be reserved for sports fishing.

The Gregoire and Georges Lakes in the Clearwater River watershed have been intensively fished in the past. Both lakes provide good habitat for game fish and yielded: walleye, cisco, pike and perch. In Gregoire Lake, whitefish, burbot and longnose suckers were collected.

The unnamed lake in Township 103, Range 5, in Richardson River watershed had a good population of lake whitefish. The tapeworm infestation in the collected specimens was low. White suckers were plentiful and northern pike were present.

In Legend Lake, the whitefish, pike and cisco were comparatively small for their age and the whitefish were heavily infested with cysts. Species of suckers were found, the white variety being plentiful and fast growing as compared with the slower growing longnosed species.

Pearson Lake, in Eleanor Creek watershed, yielded one good-sized pike, but the lake is relatively small, and the whitefish and cisco were heavily infested with tapeworm cysts.

The Algar, Audet, McClelland, Kearl and Gordon Lakes are all shallow and poor in fisheries potential.

The remaining lakes surveyed have little or no potential for commercial or recreation fishing.

The ratings for both recreation and commercial fishing in the existing water bodies within the Area are influenced by topographical features. A substantial portion of the river systems originate in bog and muskeg country where the streams form slow moving, meandering channels with few riffles and predominance of pools. Frequent beaver activity tends to restrict the movement of fish, and these areas are low in fisheries potential.

Where the stream gradient is steeper, the fish habitat improves, particularly where other environmental factors are also favourable. The

Steepbank, North Steepbank, Firebag, Marguerite, Beaver and MacKay Rivers, and to a lesser extent the Muskeg, Horse, Dover and McIvor Rivers all originate in muskeg with low habitat rating, but gradually change character and become more favourable to several species of game fish.

There are some exceptional cases where streams originate in hills, and the water flow in the upper reaches is too fast to provide suitable fish habitat. Further downstream, where the gradient declines, good fish habitat exists.

INVERTEBRATES

Aquatic insects and insect larvae were collected from bottom samples of the streams and rivers and identified in the laboratory. This new data was correlated with existing information from earlier surveys, and distribution studies were done for insects, larvae and other aquatic invertebrates.

The specific species were identified and it is interesting to note that there exists a high degree of diversity in the distribution of insects. On the average, 4 genera were identified at each of the locations, with a maximum of 12 genera.

The diversity of species found in different locations correlate with the ratings for fish habitat. Gregoire River, with the highest observed diversity of insects (12 different genera), is rated good for a typical stretch where the sample was obtained; whereas the rest of the river is poor. High Hill River, which has the highest fisheries potential of the smaller rivers within the Area, yielded only 6 different genera of insects.

Midge larvae constitute an important source of food for fry and adult fish. Other lake invertebrates, particularly the plankton forms, affect the productivity of lakes to a limited extent.

Activities Which May Cause Environmental Impact

Legend Lake — beach damaged by access road

Exploration of Ore Body

Exploration is a preliminary activity to define the ore body in any given location. The conventional technique involves drilling from the surface through the overburden, and through the tar sands down to the Devonian limestone base. Visual examination of the drill turnings is one means of determining the depth of overburden and the thickness of tar sands. Some of the wells are logged electronically to provide a more quantitative examination of the underground structure. Some of the test wells are core holes by which means cylindrically shaped samples of both overburden and tar sands are obtained and analyzed in a laboratory.

In the past there has been relatively little exploration done on many of the bituminous sands leases, but increasing activity is now evident to evaluate leases for potential development. Considering the heterogeneous nature of the tar sands, a large number of test holes must be drilled to provide a reliable estimate of the bitumen reserves and to enable sound conceptual engineering for its recovery.

ACCESS ROADS AND CAMPSITES

The principal environmental impact of exploration involves the clearing of temporary access roads and small campsites. The density and locations of the test holes will dictate the extent of the tree clearing for this activity.

Most of the exploratory drilling to date has been done in winter months, with the result that vehicular movements have caused little permanent damage to the ground surface. The observed and anticipated increase in test drilling, however, may possibly lead to an extension of the drilling season into warmer months, with attendant greater potential for damage to ground surface and natural drainage. Access roads must not be permitted to damage the shorelands of lakes or streams.

The lessee should be required to file an exploratory plan, at least three months before commencing field work. Within this time period, the Government should examine the plan and prescribe any local constraints necessary to protect the environment. With appropriate knowledge of the flora and fauna, the exploration plan could possibly be designed to enhance the environment. Both humans and animals would have greater access and the cut lines could improve the smaller vegetation.

DRILLING

The drilling operation is relatively simple, especially in the mineable region; if properly planned it could have beneficial effects.

Exploratory drilling can contribute to a better understanding of the underground environment and such information could facilitate effective planning for its protection. This is especially applicable to core hole drilling which provides an actual sample core of the underground structure.

Government geologists should study all existing test hole data to evaluate its usefulness as environmental baseline information. On this basis, the Department could establish its requirements for drilling data and these could be incorporated into the lessee's authorized exploratory program.

Plant Construction

The current practice of requiring a formal application and public hearings as prerequisites for construction of a tar sands plant should be continued. A greater emphasis should be placed upon preventing ecological damage, and to this end, the applications should include comprehensive environmental impact analyses. The matrix used in this report is a prototype for this purpose.

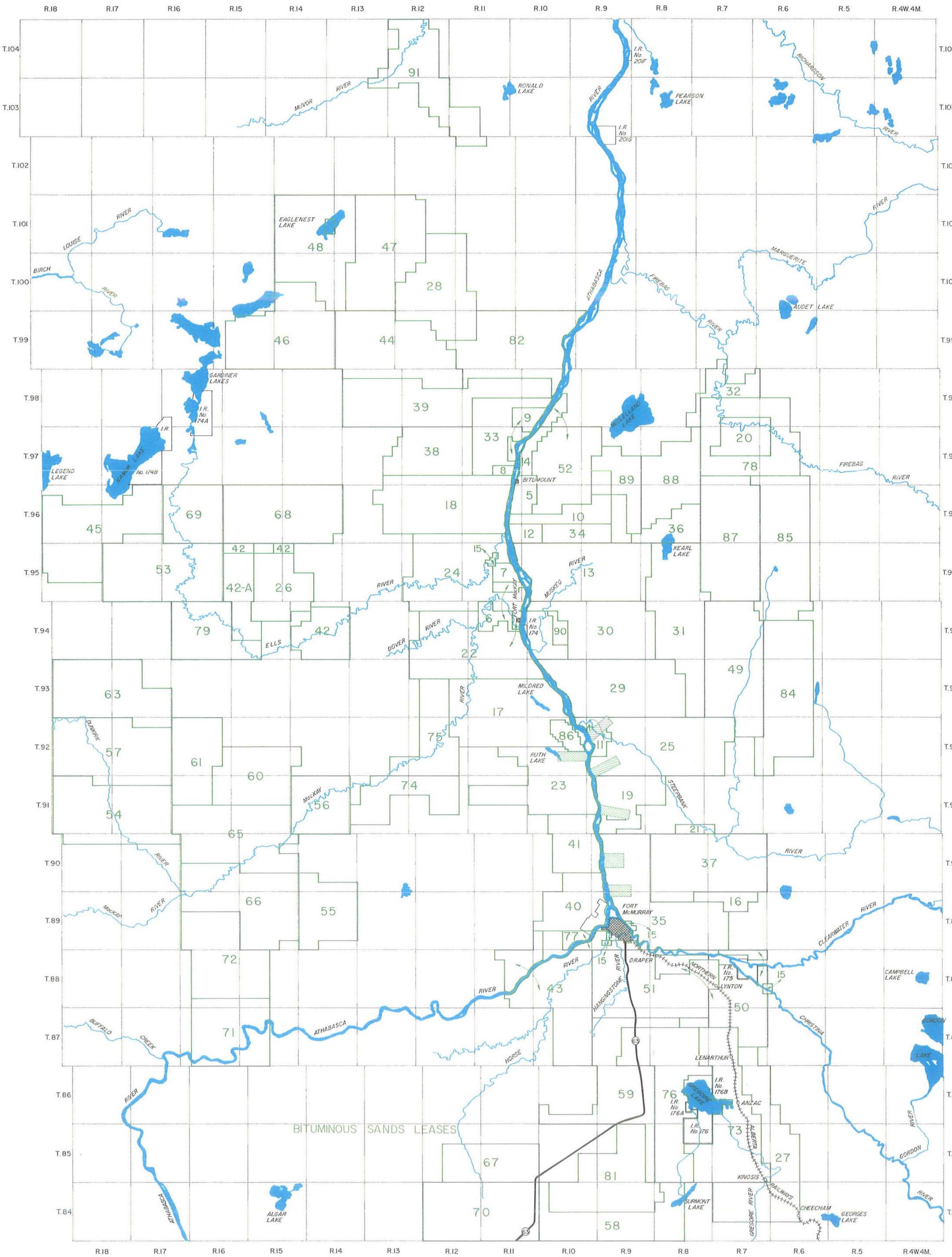
When a permit is issued, authorizing the construction of a tar sands plant, there ensues a period of three to five years during which time site preparation is undertaken and a multitude of materials and equipment are transported to the site for plant erection.

During this construction period, several impacts can be exerted on the environment, for example, intensive transportation activities, gravel pit developments, site clearing. Because this is a temporary activity, there is a tendency to disregard the environmental effects. Construction activities merit attention, especially since they are often executed by companies and people who may not intend to reside permanently in the Area.

CONSTRUCTION WORK FORCE

The construction labour requirements for the second tar sands plant are estimated to be 11 million man hours. At peak demand, this may involve a work force of 2,000 to 3,000 workers.

In all fields of construction, extensive efforts have been made over the years to improve the cyclic pattern of construction labour requirements. The most serious problems result from the fluctuations in demand for housing and public services. The tar sands industry offers an unusual opportunity for coordinated planning to alleviate this problem. Cooperative efforts by the Provincial Government, the construction industry and potential developers must be directed towards some degree of synchronization of successive projects. The human environment would be enhanced by the assimilation of more construction workers and their dependents into organized communities as normal residents.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McIVOR RIVER
RONALD LAKE
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PEARSON LAKE
I.R. No. 201G
RICHARDSON RIVER
ATHABASCA RIVER
BIRCH
LOUISE RIVER
EAGLENEST LAKE
MARGUERITE RIVER
FIREBAG RIVER
AUDET LAKE
GARDINER LAKES
I.R. No. 174A
I.R.
No. 174B
LEGEND LAKE
BITUMOUNT
KEARL LAKE
MUSKEG RIVER
FORT MacKAY
I.R. No. 174
DOVER RIVER
ELLS
MILDRED LAKE
RUTH LAKE
STEEPBANK
DUNKIRK
MacKAY RIVER
FORT McMURRAY
CLEARWATER RIVER
DRAPER
NORTHERN
I.R. No. 175
LYNTON
HANGINGSTONE RIVER
HORSE
BUFFALO CREEK
CHRISTINA
CAMPBELL LAKE
GORDON LAKE
GORDON RIVER
LENARTHUR
GREGOIRE LAKE
I.R. No. 176B
I.R. No. 176A
I.R. No. 176
ANZAC
ALBERTA
KINOSIS
RAILWAYS
CHEECHAM
GEORGES LAKE
GREGOIRE RIVER
SURMONT LAKE
ALGAR LAKE
BITUMINOUS SANDS LEASES
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Preparations for Surface Mining

From the preceding review of existing environmental values, it is apparent that certain physical features must be preserved, such as vital drainage basins, recreation zones, and some fauna habitats. Subject to the recommended additional studies, the Government should prohibit surface mining or other industrial activities in locations which could destroy the designated features. The industrial development plan will define these mining exclusions for the Area, and thus guide the issuance of future permits.

In preparing an approved site for surface mining, extensive field activities are necessary, e.g. land clearing, overburden drainage and muskeg removal. If the authorized mine plan includes any stream diversions or exterior dyke construction, such activities would normally be conducted at an early stage of the construction program.

LAND CLEARING

The first activity in initiating a development scheme for mining of a bituminous sands lease involves clearing the trees. This is done to permit the sequential operations of draining and stripping the overburden followed by actual open-pit mining.

Projections for environmental impacts were related to the future mining of 1.9 million TPCD, or 700 million tons of tar sands per year. The relationship between the quantity of tar sands mined and the corresponding land area will vary with the bitumen content and tar sands thickness. On the average, the land area supporting surface mining at the projected level, will approximate 2,200 acres per year. This factor can be used to compute the extent of necessary land clearing and disturbance.

When contemplating the issuance of a permit, the Government shall define a permissable zone for tar sands mining. At this point, the Alberta Forest Service should review the forest values, and prescribe what stands should be salvaged.

At the projected industry level, a total of 22,000 acres of land would be disturbed – (allowing 6,600 acres ahead of mining, 6,600 acres being mined, and 8,800 acres being backfilled and revegetated). Using average values from the forest survey, this area would contain:

1 million cu. ft. of commercial lumber
1.5 million cu. ft. of commercial roundwood
1 million cu. ft. of high uncommercial forest
4.6 million cu. ft. of uncommercial forest

The forest management plans would be adjusted to allow for the permanent reduction of the commercial values from the specific Units. The present cutting schedules are based upon sustained yield, and unless reclamation methods for commercial trees can be devised, the mining operations will decrease the growing stock. During the first harvesting cycle, the

Overburden drainage ditches

annual quantity of 5.2 million board feet of commercial lumber available from mine clearing will be less than the current annual quotas for Management Units A5 and A7.

With reference to pulpwood (roundwood), its permanent removal from 22,000 acres of the surface mineable region would not jeopardize the future possibility of a pulp mill in the general area. This reflects the fact that the quantity involved is very small compared with commerical requirements.

Land clearing will remove the habitat for fauna. At the projected industry level, the total land disturbed for mining represents only 4% of the Area. The Alberta Department of Lands and Forests should be consulted regarding alternative habitat possibilities. In the case of fur bearing animals, the licensed trappers who are affected should be compensated in accordance with a consistent policy.

Reclamation studies are required to ascertain the tree species which could be grown by revegetation. Part of the research should be directed towards re-establishing commercial stands.

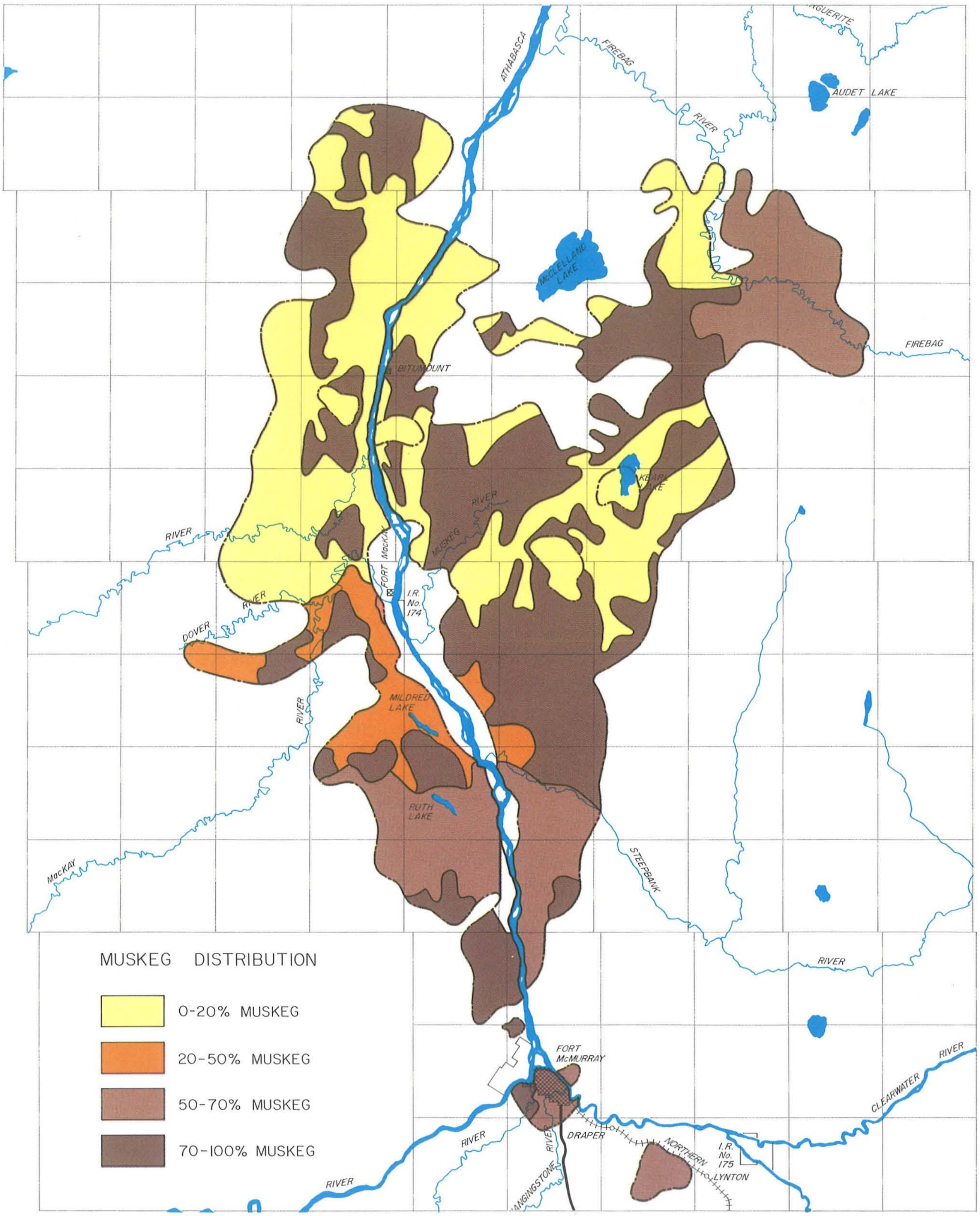
OVERBURDEN DRAINAGE

The practice of physically digging the overburden and hauling it away from the area to be mined necessitates draining as much of the water as possible from the overburden. This can be done either by digging drainage ditches down to the top of the tar sand, or by a system of wells.

The term overburden is used to denote muskeg, glacial till and lean tar sand all of which must be removed in order to permit open pit mining of the commercial tar sands. The cut-off point between lean and commerical tar sands is a function of the basic economic parameters incorporated into the feasibility study and the plant design. Unless new conservation restraints were introduced, future developers would probably choose a cutoff point for bitumen content between 5 and 10% by weight.

The Pleistocene deposits, overlying most of the Area, are composed of boulder clays containing sand and gravel lenses. Some of these loose sands and gravels are waterlogged, and may pose potential problems during the stripping cycle. An excavating machine, may expose such an aquifer in an overburden face, causing a deluge of sand and water to enter the workings, creating a hazard for men and equipment. In order to minimize this problem it is necessary to drain excess water from the overburden prior to its removal. The dewatering operation is continued for about one year before the overburden is stripped.

Prior to draining overburden, the groundwater flow pattern should be known. This would permit identifying the area to be drained and the environmental impacts. Buffer zones must be


MUSKEG DISTRIBUTION
0-20% MUSKEG
20-50% MUSKEG
50-70% MUSKEG
70-100% MUSKEG
ATHABASCA
FIREBAG
RIVER
AUDET LAKE
McCLELLAND LAKE
FIREBAG
MUSKEG
RIVER
FORT MacKAY
I.R. No. 174
DOVER
RIVER
MILDRED LAKE
RUTH LAKE
MacKAY
RIVER
STEEPBANK
RIVER
FORT McMURRAY
CLEARWATER
RIVER
DRAPER
NORTHERN
I.R. No. 175
LYNTON
HANGINGSTONE
RIVER
RIVER
RIVER

Exceptional example of dehydrated muskeg

provided to protect the designated surface drainage basins. The drainage of large areas in the vicinity of streams could have possible effects on the stream flow rate with resultant impacts on fish habitat.

The quantity and quality of drainage water should be monitored to determine its permissible disposal. When discharge to streams is authorized, the flows should be regulated to avoid any damage, such as erosion or disruption of fish habitat.

Developers should be required to submit plans for overburden drainage.

MUSKEG REMOVAL

Muskeg is comprised predominantly of organic matter and water and will not support heavy equipment except during winter. Consequently the muskeg is excavated when frozen and it is transported out of the way of the stripping operation.

The disposition of the muskeg represents an interesting environmental dilemma. Its organic content is a good mulch for revegetation and it has already been used in a modest way for this purpose. Even with the recommended constraints however, there will be a time lag of 10 years between initial muskeg removal and revegetation of the mined out area. The handling and storage of muskeg during this time period will present environmental problems due to the high water content. Dykes would be required to retain the muskeg in its melted condition or alternately storage heaps would be required from which the water could drain. Either alternative poses obvious problems involving water disposal, and ground surface disturbance.

After a mine has been in operation long enough to initiate reclamation of the mined out area, the muskeg could be transported directly to the area of reclamation. The muskeg excavated from one lease could be transported directly to a reclaim area of an adjoining lease, however, the transportation costs could be prohibitive.

Given an alternative mulch material for revegetation, the muskeg could be discarded into the mine pit.

Research is needed to determine whether or not the organic material in muskeg must be preserved. If the conclusions are affirmative, then additional research work should be done to develop acceptable methods for its storage and handling.

STREAM DIVERSIONS

Future applications for tar sands mining may seek permission to divert streams, or otherwise modify natural drainage basins. These applications will relate to the designated boundaries

Tailing dyke on Athabasca

for specific bituminous sands leases. As indicated by the map, the lease boundaries within the surface mineable region do not bear any logical relationship to the surface drainage.

Certain portions of the drainage systems will have to be preserved because of their ecological values. Preliminary assessments have been undertaken, but additional work will be required to complete the evaluation.

The streams and lakes were classified according to their importance to fish population and habitat, resulting in the following recommendations:

– streams and lakes having good potential should not be disturbed;

– those having fair potential should not be disturbed pending more extensive investigation;

– those having poor potential for fish occur generally in muskeg. They may be considered for possible diversion – subject to constraints other than fish.

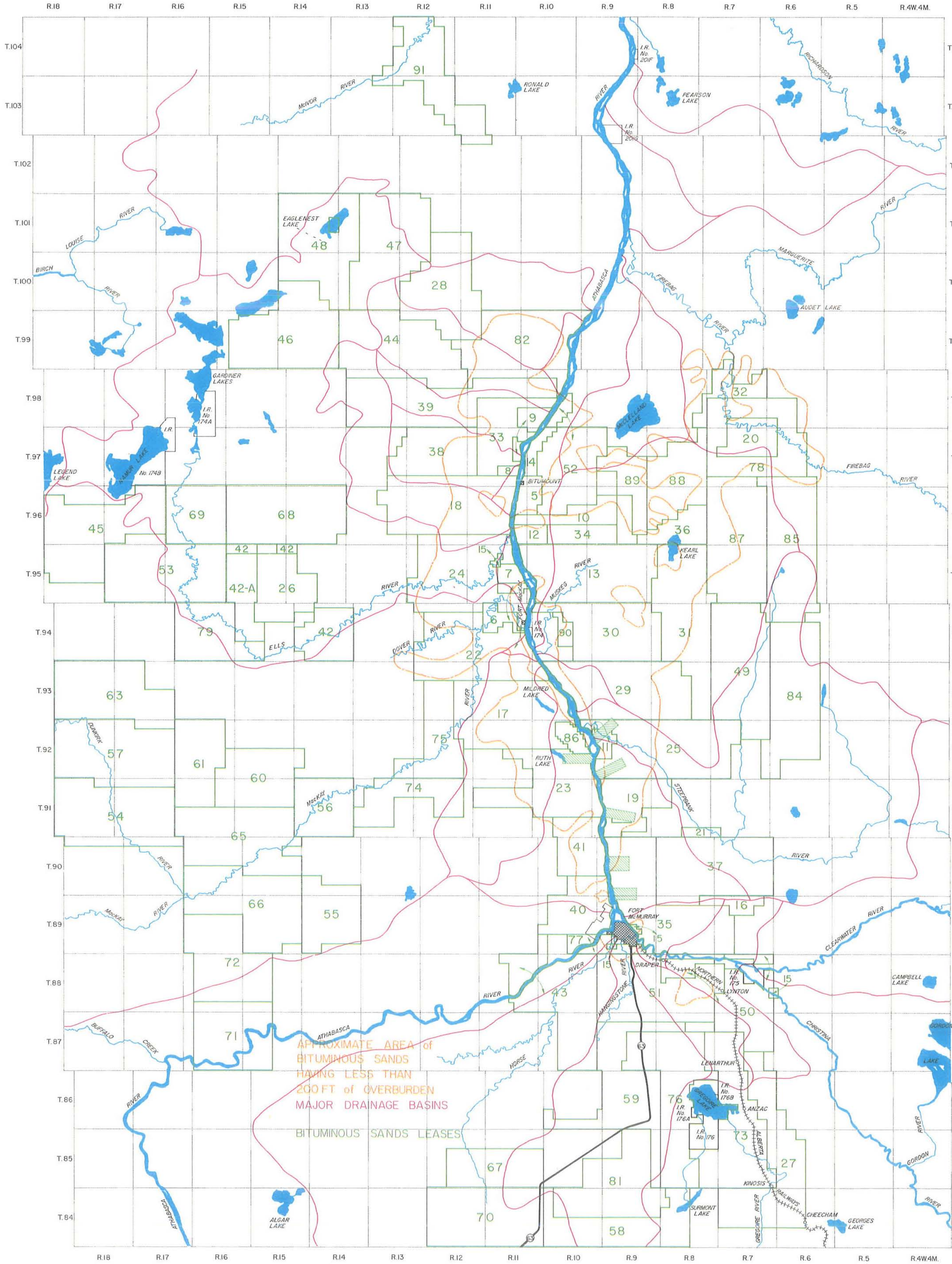
The baseline ecological survey also included the utilization of these natural waters by other fauna species such as: fur bearing animals, waterfowl, and ungulates, but current information is not sufficient to permit mapping. The biological studies should be continued to generate the data required for more comprehensive classification. When this additional work has been done, more meaningful conclusions can be derived on permissible diversions.

When stream diversions are authorized, the new water course must be designed and built to avoid erosion and to maintain the desired level of aquatic life. Experimentation under the guidance of qualified professionals will be required. In some cases, stone-lined channels may have to be specified with controlled elevation changes to regulate water velocity. In the case of small streams, carefully installed culverts may be permissible. Fish and wildlife authorities should be consulted prior to undertaking any such diversions.

Many of the tributary streams cross lease boundaries. When the environmental value of these streams has been assessed, consideration may have to be given to adjusting some lease boundaries.

DYKE CONSTRUCTION

Future mining plans will involve the construction of large dykes for temporary tailings impoundment exterior to the mine pit. The authorized size and location of these ponds will determine the magnitude of the environmental impacts. The creation of such ponds involves: the destruction of the flora, modifications to the land contours, and the transfer of millions of cubic yards of earth.


APPROXIMATE AREA of BITUMINOUS SANDS HAVING LESS THAN 200 FT of OVERBURDEN
MAJOR DRAINAGE BASINS
BITUMINOUS SANDS LEASES
R.18 R.17 R.16 R.15 R.14 R.13 R.12 R.11 R.10 R.9 R.8 R.7 R.6 R.5 R.4W.4M.
T.104 T.103 T.102 T.101 T.100 T.99 T.98 T.97 T.96 T.95 T.94 T.93 T.92 T.91 T.90 T.89 T.88 T.87 T.86 T.85 T.84
FORT McMURRAY
BITUMOUNT
ATHABASCA RIVER
CLEARWATER RIVER
FIREBAG RIVER
MUSKEG RIVER
STEEPBANK
MacKAY RIVER
HANGINGSTONE RIVER
CHRISTINA RIVER
GORDON RIVER
RICHARDSON RIVER
MARGUERITE RIVER
McIVOR RIVER
BIRCH RIVER
LOUISE RIVER
DOVER RIVER
ELLS
HORSE RIVER
BUFFALO CREEK
GREGOIRE RIVER
RONALD LAKE
PEARSON LAKE
EAGLENEST LAKE
GARDINER LAKES
NAMUR LAKE
LEGEND LAKE
McCLELLAND LAKE
AUDET LAKE
KEARL LAKE
MILDRED LAKE
RUTH LAKE
CAMPBELL LAKE
GORDON LAKE
GREGOIRE LAKE
SURMONT LAKE
ALGAR LAKE
GEORGES LAKE
DRAPER
LYNTON
LENARTHUR
ANZAC
KINOSIS
CHEECHAM
NORTHERN ALBERTA RAILWAYS
I.R. No. 174
I.R. No. 174A
I.R. No. 174B
I.R. No. 175
I.R. No. 176
I.R. No. 176A
I.R. No. 176B
I.R. No. 201F
I.R. No. 201G
63

Overburden spoil heap

The dyke building activities represent potential sources of siltation in streams and lakes. Artifical siltation of river beds and lake bottoms affects the fish habitat by changing the surface structure of rocky and gravel shallows, some of which are utilized as spawning grounds by several species such as: goldeye, whitefish, cisco, grayling, white sucker, and walleye. In addition siltation influences the composition of bottom flora and invertebrate fauna. A detrimental effect on the bottom dwelling components of the regular river or lake food chain subsequently affects the availability of a normal diet to fish inhabiting the exposed water bodies. In extreme cases increased water turbidity may reduce the availability of light in the trophic zone and affect the metabolic rate of the community in the photosynthetic level.

The design standards for dyke construction must be rigidly specified to guarantee the safe containment of millions of gallons of liquid tailings. A major failure would have serious environmental consequences. The safety features of the design and construction of these massive dykes is part of the developer's responsibility. One of the recommended references for this purpose is the "Tentative Design Guide for Mine Waste Embankments in Canada," Technical Bulletin TB-145, Department of Energy, Mines and Resources, March, 1972.

Overburden Stripping

In order to expose the commercially valuable tar sands the overburden must be physically removed. The overburden comprises the top layer of soil which contains no bitumen plus the upper layer of tar sands whose bitumen content is not sufficient to justify mining and extraction. The ratio of overburden to commercial tar sands varies greatly throughout the Area. Although the present technology is best suited to ore bodies having 120 feet or less of overburden, allowance has been made for possible technological improvements in the designation of the probable region of surface mining to overburden thickness of 200 feet.

The quantities of overburden which will be relocated are enormous. On some of the preferred leases the ratio of overburden to commercial tar sands can be as low as 1:3; however, on other leases this ratio reaches 1:1 or higher. At the projected level of industry growth, the gross annual quantity of overburden to be stripped could represent between 230 to 700 or more million tons. The potential environmental effect of disturbing these quantities of soil are correspondingly great. A report recently published by the Alberta Environment

Overburden stripping and hauling

Conservation Authority* provides some pertinent recommendations for precautions. There are, however, additional considerations that are specific to the tar sands.

The nature of the impacts resulting from overburden stripping depend to a considerable extent upon the total mine plan involving both overburden stripping and tar sands excavation. Some mining plans necessitate transportation of part of the overburden to spill areas outside the mine pit, whereas others will enable direct placement of the overburden into the mine pit. The difference lies primarily in the selection of equipment and the development plan for the total mine.

One conventional scheme involves digging and hauling the overburden using diesel equipment. The locations to which the overburden is hauled depends on its classification. The major portion of overburden is suitable for building retention dykes and it is used for that purpose either inside or outside of the mine pit. A portion of the overburden is too permeable to permit its use for dyke building and it is hauled to spoil piles. Another scheme would relocate the overburden directly into the bottom of the mine pit; this would eliminate the problem of exterior spoil piles.

*Report and Recommendations on The Impact on the Environment of Surface Mining in Alberta, published by the Alberta Environment Conservation Authority, January, 1972.

When overburden is stripped as a separate operation, it should be restricted to one year in advance of tar sands mining. At the projected industry level this could add a maximum of 2,200 acres to the permissible gross area of disturbance. This allowance will not be required for mining schemes which cast the overburden into the pit.

Since overburden comprises 50 to 100 feet or more of top soil layer, its removal affects the ground surface, the underground and the water patterns. Some very preliminary field work has been initiated to study some of these impacts. This top layer contains the supporting soil for the existing vegetation, and conventional mining schemes will remove it permanently. Research studies are required into this subject to determine reclamation techniques, which may require preserving part of the top soil.

Future mining schemes might utilize large scale diesel-type equipment. At the projected industry level, the exhaust fumes from such equipment could be a significant source of atmospheric emissions. It is conceivable that diesel consumption could reach 5,000 gallons per day for this purpose, at which point, the pollutants* would be as follows:

U.S. Public Health Service Bulletin 999-AP-29

aldehydes	50 lb per day
carbon monoxide	300 lb per day
hydrocarbons	900 lb per day
oxides of nitrogen	1,110 lb per day
oxides of sulphur	200 lb per day
organic acids	155 lb per day
particulates	550 lb per day

Substantial quantities of water vapour will also occur in the engine exhausts. These emissions would be distributed amongst perhaps 8 mine sites. Under inversion conditions in a mine pit, the effects of these pollutants would be aggravated.

Blasting

Blasting of the tar sands facilitates their excavation, especially in winter. The environmental impacts of large scale blasting in several future mine pits would involve primarily considerations of noise.

The noise factor relative to human habitat could be controlled by the location of future community developments, and there are many other factors which would make it advisable to regulate this distance.

We would not anticipate that repetitive blasting noise would have any significant effect on wild game in the area. Field tests in other locations have indicated that big game such as deer exhibit some initial fright to abnormal noise but soon become adapted to it when the noise is repetitive.

Tar Sands mine

Surface Mining of Tar Sands

Following the removal of the overburden, the tar sands can be physically excavated. At the projected level for industrial activity, this will involve the open pit mining of 1.9 million TPCD which equates to approximately 700 million tons of tar sands per year. The total void space created will be 11,200 million cubic feet per year. This basic activity extends the depth of the excavation initiated by overburden stripping by an estimated 100 to 150 feet down to the Devonian limestone. Several significant environmental impacts can be related to this operation.

One effect is the extension in time and magnitude of ground disturbance. For the preceding activities of land clearing, overburden drainage and overburden stripping, the recommended constraints allowed a total of 6,600 acres representing three years operation. To this must be added a time allowance for the mining of tar sands. It is recommended that 3 years be permitted between commencement of tar sands mining and the initiation of backfilling operations. The corresponding extension of disturbed area would represent 6,600 acres, which when added to the previous calculations, brings the total to 13,200 acres of disturbed land.

The excavations created by the mining of these massive volumes of tar sands will also affect the surface water and groundwater flow patterns. The drainage water from mines should be monitored to determine its source, quantity and quality, to permit assessing more precisely the impacts upon the ambient land environment. The quality of the mine drainage water will determine its permissible disposition.

Some field research should be conducted to ascertain the extent of hydrocarbon emissions resulting from the disturbance of the tar sands. This may prove to be a minor environmental factor, but on the contemplated scale of operations it would justify further investigation.

Transportation of the tar sands to the extraction plant should not cause any significant environmental effects unless diesel equipment were used in which case the vehicle emissions should be regulated and monitored.

Oversize spoil pile

Hot Water Extraction

The tar sands comprise a mixture of quartz sand, fine mineral matter, water, and bitumen. The sand particles are enclosed by an envelope of water which is surrounded by a film of bitumen. Water and bitumen together account for 18% by weight of the mixture, the remainder being mineral matter.

The composition of the tar sands varies over very short distances, both horizontally and vertically.

The bitumen content of the tar sands varies from 0 to 18% by weight. The bitumen content tends to increase from the top to the bottom of the tar sands deposit. The two plant permits issued to date authorize rejection of lean tar sand having less than 8% and 6% respectively, of bitumen content by weight.

The conventional technique for recovering the bitumen from the tar sands is by extraction with hot water. This involves initially mixing the tar sands feed with an approximately equal quantity of hot water. Unless there are some early technological improvements, the total use of water at a production level of 1 million BPCD of product will amount to 350 c.f.s. The estimate makes allowance for municipal requirements which are modest compared with the industry's consumption. The projected water demand represents 10% of the minimum monthly average flow in the Athabasca River — and this is a recommended maximum. Appropriate precautions should be taken to ensure that approved water consumptive plans do not cause any significant lowering in the level of lakes or rivers.

Some caustic soda or other chemical may be added as required to adjust the pH to 8.0-8.5 since the separation of bitumen is thereby facilitated. The mixture is thoroughly agitated and sparged with live steam. Any soluble additives introduced at this point will reside in the tailings water with resultant effects on the ultimate disposition of the liquid tailings and their possible environmental impacts.

During this initial extractive step another environmental impact becomes evident in the odours which are detectable. These odours are attributable to the more volatile hydrocarbons in the approximate range of gasoline heavy ends comprising 2% of the bitumen. There is a need for more thorough monitoring of these vapour emissions to quantify their impact on the air quality and their effect on health and safety.

The next step in the extractive process involves screening of the mixture to remove oversize materials such as rocks and clay agglomerates. The agglomeration of clay at this point in the process may provide a possible clue to alleviate the overall problem of mineral fines, and additional research should be done on the subject. The rejected solids represent 1½% of the tar sands processed. Whenever they can be returned directly to a mined out area the environmental impact will be negligible. If they are discarded outside of the mine pit, precautions are required in locating the spoil piles. The drainage water from discarded oversize must be contained and treated since it is a potential source of bitumen and caustic contamination.

The bulk of the bitumen can be separated from the mixture by conventional ore dressing techniques such as settling or flotation involving aeration of the bitumen at elevated temperatures to reduce its density. Normal design practice would permit the bitumen froth to be exposed to the atmosphere in an enclosed building; this represents another potential source of odour emissions. As the industry expands towards a recovery level of 1.25 million BPCD of bitumen, design improvements should be made to contain these vapours.

The raw bitumen contains residual water and mineral particles. It is a black asphaltic material which is very viscous. Future plant design concepts could involve the storage of large volumes of raw bitumen, necessitating some means of lowering its viscosity. The conventional approach to viscosity reduction involves dilution with a volatile petroleum liquid, and this is a source of hydrocarbon fumes. The design of handling and storage facilities must incorporate appropriate environmental safeguards whenever volatile diluents are used.

The raw bitumen is purified to remove the residual water and mineral particles. The techniques authorized to date involve centrifuging and thermal dehydration. Although technological improvements can be expected in future plants, these will probably not change the environmental considerations. Any purification technique will be a source of hydrocarbon vapours which will impinge upon the immediate working environment. Engineering precautions should be taken in the plant design to ensure proper containment of the vapours and their disposal in a satisfactory manner.

The handling and storage of purified bitumen will require the same constraints as apply to raw bitumen.

Tailings pond

Tailings Placement

The disposal of tailings from the hot water extraction process represents the most imminent environmental constraint to the future expansion of this recovery method. The tailings comprise the spent sand plus most of the water which was used for extraction and in which are suspended mineral fines and unextracted bitumen. The tailings originate as waste streams from the bitumen separation and purification steps.

One of the problems pertaining to the handling and disposal of tailings relates to the large volume of the mixture. At our projected level of treating 1.9 million TPCD of tar sands, the resultant volume of tailings material will be 42 million cubic feet per day.

The composition of the tailings stream must be understood in order to comprehend the nature of the environmental problem.

The relatively coarse silica sands enter the tailings stream from the bitumen separation step. At this stage the sand is relatively clean and can be easily separated by gravity settling from an aqueous medium.

Practically all of the water which is used for the extraction and separation steps remains in the tailings stream. Its temperature at this point is about 150 degrees F. The conventional technique utilizes this water as a slurrying medium to transport the spent sand to the prescribed disposal area for tailings.

Suspended in the tailings water are fine mineral particles which cause a serious environmental problem. These fines originate in the minus 325 mesh portion of the ore body. The proportion of mineral fines in the ore body can vary from 8% to 35% by weight. They comprise silt (i.e. particles between 44 microns and 2 microns in size) and clay whose particles are smaller than 2 microns.

The liquid tailings contain additional contaminants. Even allowing for substantial improvements in the extractive efficiency of future bitumen plants, 5% or more of the bitumen present in the tar sands feed will be lost to the tailings stream. The following analysis was obtained from the files of the Department of the Environment for 1971/72:

pH – 9.3,
chemical oxidation demand – 560 mg./1,
total alkalinity – 460 mg./l,
non-filterable residue – 1700 mg./1,
oils and grease – 240 mg./1.
phenols – 970 ppb,
chlorides – 33 mg./1,
nitrates – 0.3 mg./1,
sulphates – 665 mg./1,
iron – 10 mg./1.

Dyke from River

The concentration of these contaminants would have to be reduced significantly to permit any discharge of the liquid wastes.

The tailings stream will ultimately go back into the mine pit. It is not feasible to do so, however, until the volume of the excavated pit is sufficient to accept the tailings mixture without interfering with the mining operation. Since several years are required to develop a mine pit of the required capacity, the practice has arisen whereby temporary tailings ponds for impounding the tailings mixture, are built outside of the mine pit.

About half of the tailings stream is comprised of contaminated water and, therefore, impermeable dykes are required to contain the liquid tailings. Selected overburden can be used to provide an impermeable core for such dykes. The height of the dykes can be continually built up simply by depositing the coarse sand component and compacting it in place. All other ingredients of the tailings mixture collect within the dykes as a fluid mass.

Impounding liquid tailings from an ore treatment process is fairly common in the mining industry, but its viability is usually dependent upon the water being clarified sufficiently in the tailings pond to permit either complete recycling to the process or discharge to the fresh water source.

The present technology for handling tailings from the hot water extraction of tar sands does not provide adequate clarification of the water to permit total recycling. The amount of tailings water which can be recycled is limited by suspended contaminants, primarily the clay fines. Furthermore, both the clay and bitumen contaminants preclude the discharge of tailings water to the Athabasca River. The net result is a massive accumulation of liquid tailings, the control of which poses several environmental problems.

The actual effect of tailings impoundment upon the groundwater is not known. It is reasonable to expect some influence on the water table and some groundwater pollution. Apart from an emergency, such as a dyke failure, the principal concern relates to possible seepage. The amount of seepage, will be a function of the permeability of the walls and floor which constitute the tailings pond. Quantitative information is not available, and an extensive program of monitoring existing dykes is required to assess these factors.

Underground sink holes occur in some regions of the Devonian limestone, and these should be either avoided or sealed when storing liquid tailings.

The Athabasca River or its related natural drainage basins could be polluted by any substantial leak in the pipeline movement of tailings slurry. The probability of leaks is enhanced by the abrasive nature of the silica sand.

The possibility for pollution of the surface waters will exist wherever impounding of liquid tailings is permitted.

Any tailings ponds built along river banks, especially on the Athabasca, are susceptible to dyke erosion. In the event of a dyke failure, there is no possibility of secondary containment. In future, tailings ponds must not be constructed on shorelands.

The potential pollution of surface water is reduced when the liquid tailings are impounded within the mine pit. This applies particularly if the mine pit is located a considerable distance from the Athabasca and its tributaries.

Tailings must be placed into the mine pit at the earliest possible date, and not later than three years after initial tar sands mining.

The atmosphere will experience significant impacts from a profusion of large tailings ponds. As discharged to the pond, the liquid tailings will have a temperature of approximately 130 degrees F., hence considerable heat will be evolved. Large quantities of water vapour will enter the atmosphere thereby increasing its humidity. Under winter conditions this will increase the frequency and severity of ice fogs. Although this humidity effect would be most pronounced in the immediate vicinity of the individual tailings ponds, it will spread depending upon the atmospheric conditions. Ice fogs will create many hazards such as: poor visibility; ice formation on roads, power lines, and equipment; concentration of atmospheric pollutants.

Hydrocarbon vapours will be emitted from surficial bitumen and from volatile liquids contained in the tailings. Characteristic odours will be associated with the hydrocarbon vapours. In order to quantify these atmospheric emissions field measurements should be taken and correlated with the pond and atmospheric conditions. Such data will facilitate formulating necessary constraints.

The ground surface will be altered wherever tailings dykes are permitted outside of a mine pit. The extrapolation of current practice could result in such dykes reaching heights of 300 feet or more above ground. The attendant impacts upon local drainage, contours, and aesthetics are obvious. If the dykes are constructed from spent sand, then vegetation must be established promptly on the dyke faces to prevent wind erosion.

All of the flora and fauna habitat will be destroyed wherever a tailings pond is established. For tailings ponds exterior to mine pits this will represent added land utilization. In addition to the direct impact within the space occupied by a tailings pond there will be some ambient effects upon surface water, groundwater and atmosphere. Field research on this subject must be correlated with monitoring programs.

Tailings ponds located remote from human activities may attract waterfowl, and it is unlikely that they could survive the heat, bitumen or other contaminants. Additional field observations by wildlife specialists will be required to clarify this matter in relation to waterfowl migration and habitat.

The liquid tailings represent the most probable source of bitumen which could escape to surface waters. The addition of significant amounts of bitumen to the streams or lakes could prove toxic to fish. Excess bitumen floating on the surface of water will introduce several problems to the biological community, and fish that feed on terrestrial insects will be affected. The arctic grayling is a habitual surface feeder and is highly susceptible; other species including goldeye, lake trout, lake and flathead chub intermittently feed on terrestrial insects. Insects whose larvae are aquatic are susceptible to oil film on the water when the eggs are deposited. The release of adult insects from the aquatic larval stage will be impeded. The aquatic larvae of terrestrial insects are the dominant invertebrate forms in many water bodies in the Area, and constitute an important dietary source to many species. Lake and mountain whitefish, cisco, white and longnose sucker, flathead and lake chub, and American perch are some of the species which feed on the aquatic larvae of insects. Depletion of the insect larvae in streams and lakes will significantly affect the fish habitat.

An investigation was conducted on the vanadium content of bitumen and its possible toxicity to fish. In a limited number of samples, the vanadium content ranged between 210 to 290 ppm, and this exceeds other trace metals, i.e. nickel – 82 to 100 ppm, iron – 75 ppm, copper – 2 to 5 ppm. Although the extent of testing was necessarily limited, there is evidence that vanadium is toxic to fish. This adds further emphasis to the necessity of avoiding the discharge of any bitumen to streams. Vanadium should be added to the list of heavy metals in water monitoring programs.

A considerable amount of research has already been directed towards solutions to the

Stabilized sand dune in surface mineable region

serious problem of tailings from the conventional hot water extraction process. The techniques cited as being tested include the following:

flocculation and settling,
filtration,
centrifuges or cyclones,
freezing,
evaporation and distillation,
ultra-filtration,
electrophoresis,
biological processes.

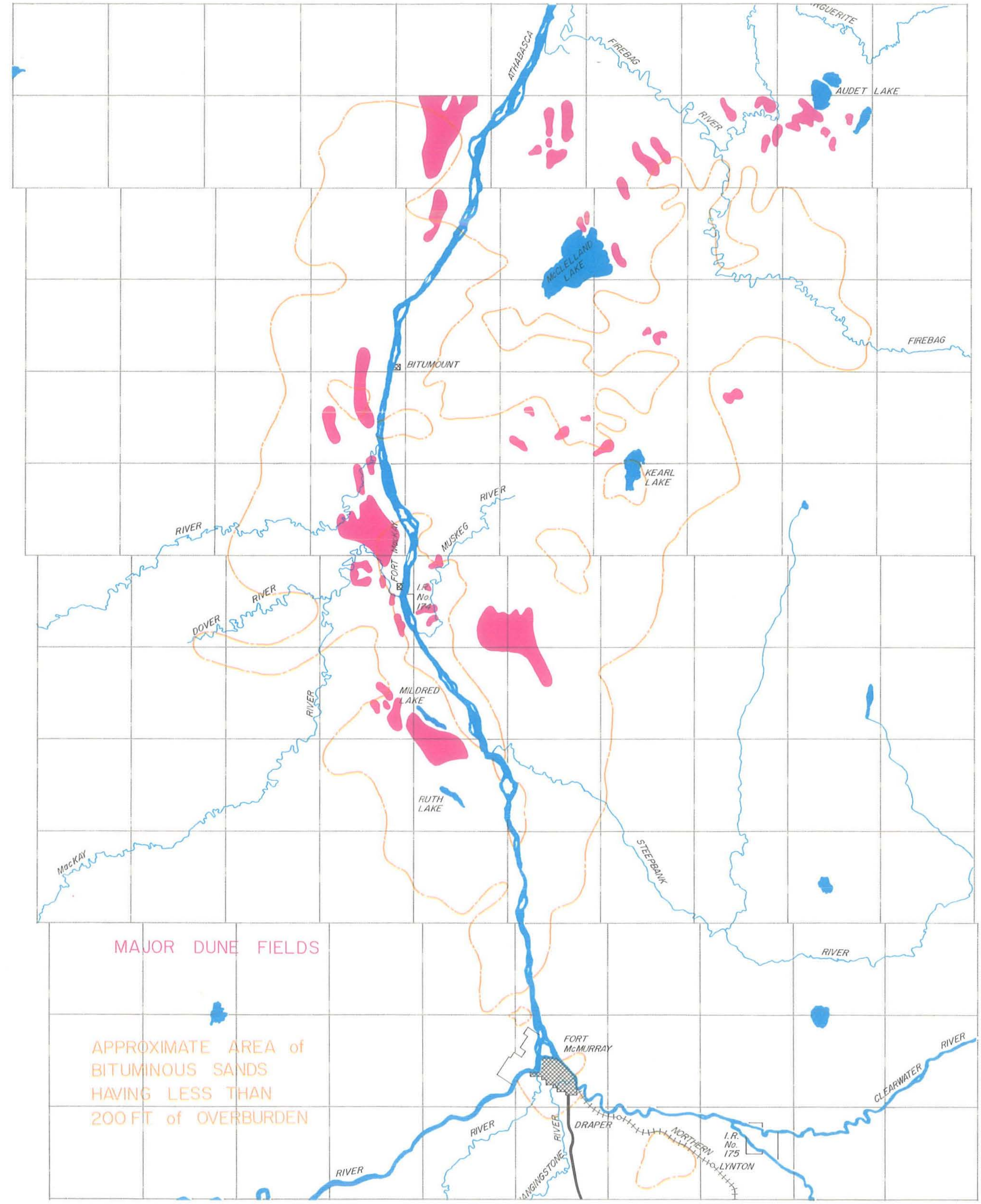
The magnitude and significance of the tailings problem could deter the future development of the tar sands industry. As a short term constraint, it is imperative that exterior tailings ponds be restricted in their size, location and duration of use. The ultimate resolution of the problem will require intensive and coordinated research by qualified agencies, to eliminate the continuous accumulation of liquid tailings.

Reclamation

The published concepts for land reclamation from tar sands mining are vague and do not provide adequate assurance for re-establishment of a satisfactory physical environment. This is perhaps understandable in view of the current lack of reliable data especially with regard to the soil structure after backfilling of the mine pits. Field research must be undertaken and continued for several years to determine the optimum techniques for reclamation.

The contemplated technique for backfilling the mined out area will involve placing therein the total tailings stream. This will result in a gradual buildup of spent sand containing a pond of liquid tailings. As this process continues within a given dyked enclosure, the volume available for liquid tailings decreases and ultimately some means must be found for removing the accumulated liquid.

One of the problems associated with reclamation of a tar sands mine is the fact that the waste products will occupy a much larger volume than the void space created by the mining operation. The residual waste products created by the hot water extraction from one ton of tar sands will occupy a volume of 22 to 23 cubic feet as compared with a void space of 16 cubic feet created by the mining. As a consequence of this volumetric discrepancy, the final elevation of a reclaimed mining area will be


ATHABASCA
FIREBAG
RIVER
AUDET LAKE
McCLELLAND LAKE
FIREBAG
BITUMOUNT
KEARL LAKE
RIVER
RIVER
MUSKEG
I.R. No. 174
DOVER
RIVER
RIVER
MILDRED LAKE
RUTH LAKE
MacKAY
STEEPBANK
RIVER
MAJOR DUNE FIELDS
APPROXIMATE AREA of BITUMINOUS SANDS HAVING LESS THAN 200 FT of OVERBURDEN
FORT McMURRAY
CLEARWATER
RIVER
RIVER
RIVER
RIVER
DRAPER
NORTHERN
I.R. No. 175
LYNTON

more than 60 feet higher than the original terrain. It is not known at this point how much settling will actually occur with time and this must be one of the subjects for field research. Another subject will involve the optimum contours for the final terrain to accommodate the difference in elevation.

The soil structure for a depth of 200 feet or more becomes completely re-arranged during mining and backfilling. The original tar sands will be replaced with relatively clean and more pervious sand. Much of the upper strata will comprise the silt and clay which have a very high retention for water. The unextracted bitumen and the soluble contaminants will be concentrated in this upper layer. Research is needed to ascertain whether the restructured soil would support desirable vegetation, and if not, what adjustments are required. The vegetation that stabilizes the existing surficial sands may provide some useful information for reclamation planning. The Sand Dune map shows these locations.

Techniques for clarifying or draining the tailings water must be devised. This will have to be correlated to new flow patterns for surface and groundwaters. The permeability of the spent sand could be one hundred times that of the original tar sands, according to earlier research. The pH and other chemical properties of the water will require investigation especially since the liquid tailings are alkaline.

The re-establishment of flora species will be contingent upon the ultimate soil and water conditions. The trees selected for new growth should exclude those species that are susceptible to damage by snowshoe hares and microtimes. A balanced vegetation pattern is desired to avoid domination by specific flora or fauna species.

A long-term field research program must be initiated promptly to develop reclamation procedures and standards. This will require the excavation of test cells to be backfilled with tailings under controlled experimental conditions. In this manner, specific reclamation problems will be isolated and resolved by qualified professionals. The total program must be well planned and coordinated and will include participation by several Government departments.

Simultaneously there must be comprehensive land use studies, similar to those already conducted for other regions of the Province, but in more depth. This will involve sequential and progressively more sophisticated analyses of present and future environmental values. The land use studies will have to be synchronized with industrial and regional planning, to ensure optimal allocation of all resources.

Bitumen Processing

Bitumen is a mixture of long chain and cyclic hydrocarbons, and aromatics that are deficient in hydrogen.

As a minimum requirement, sufficient processing of the bitumen must be done at the production site to render it transportable.

In the absence of any abundant and cheap source of external energy the bitumen must also supply the fuel requirements for its own recovery and processing. 17% of the energy contained in the natural bitumen is needed to supply the power requirements of an integrated tar sands plant. The type of fuel produced from the bitumen is critical to environmental considerations.

The bitumen contains 5% by weight sulphur and the ultimate disposition of this sulphur after processing the bitumen will determine the nature and magnitude of the resultant environmental impacts. If much of the sulphur is permitted to remain in the bituminous fuel then it will be emitted to the atmosphere as oxides of sulphur from the combustion stacks. Environmental considerations dictate that the maximum possible proportion of sulphur in the processed bitumen should be converted to H_2S and subsequently to elemental sulphur.

Similar considerations apply to the nitrogen content of bitumen which analyzes between 0.3 and 0.6% by weight. Upon combustion, nitrogenous compounds produce oxides of nitrogen as atmospheric emissions.

The simplified schematic diagram shows the steps involved in processing bitumen. The primary step involving the conversion of part of the bitumen to fuel, offers many alternatives to the process designer. The method selected will determine the environmental quality of the fuel.

The conventional approach involves coking whereby the bitumen molecules are fragmented by thermal cracking. When bitumen is subjected to coking treatment, a portion of it is converted to carbon in the form of petroleum coke. From the environmental point of view this petroleum coke is not a clean fuel since it usually contains about 6% by weight sulphur. The sulphur from the converted bitumen remains in the coke and additional sulphur migrates to the coke thereby causing a concentrating effect. All of the sulphur contained in petroleum coke used for fuel will be emitted as oxides of sulphur discharged to the atmosphere.

Coking processes tend to generate more petroleum coke from bitumen than required for a balanced fuel demand. Unless the surplus coke can be sold or used for export power, it constitutes a solids disposal problem.

Petroleum coke has to be stockpiled to ensure a continuous supply of fuel to the power house. It is thus exposed to rain or snow and resultant contaminated surface drainage, which must be contained or treated.

Solid fuel stockpiles are vulnerable to spontaneous combustion which is an occasional source of smoke and requires the use of water to suppress the fires.

Delayed coking is a batch process whereby the petroleum coke is discharged hot to open pits. This hot coke emits steam and other vapours contributing to localized atmospheric impacts.

Fluidized techniques for continuous coking represent a future possibility but they would not by themselves eliminate the major environmental disadvantages inherent in coking.

The quantity of petroleum coke required to power a multi-plant operation processing 1.25 million BPCD of bitumen exceeds 35,000 TPCD.

The exclusive use of high sulphur fuels for future tar sands plants must be discouraged.

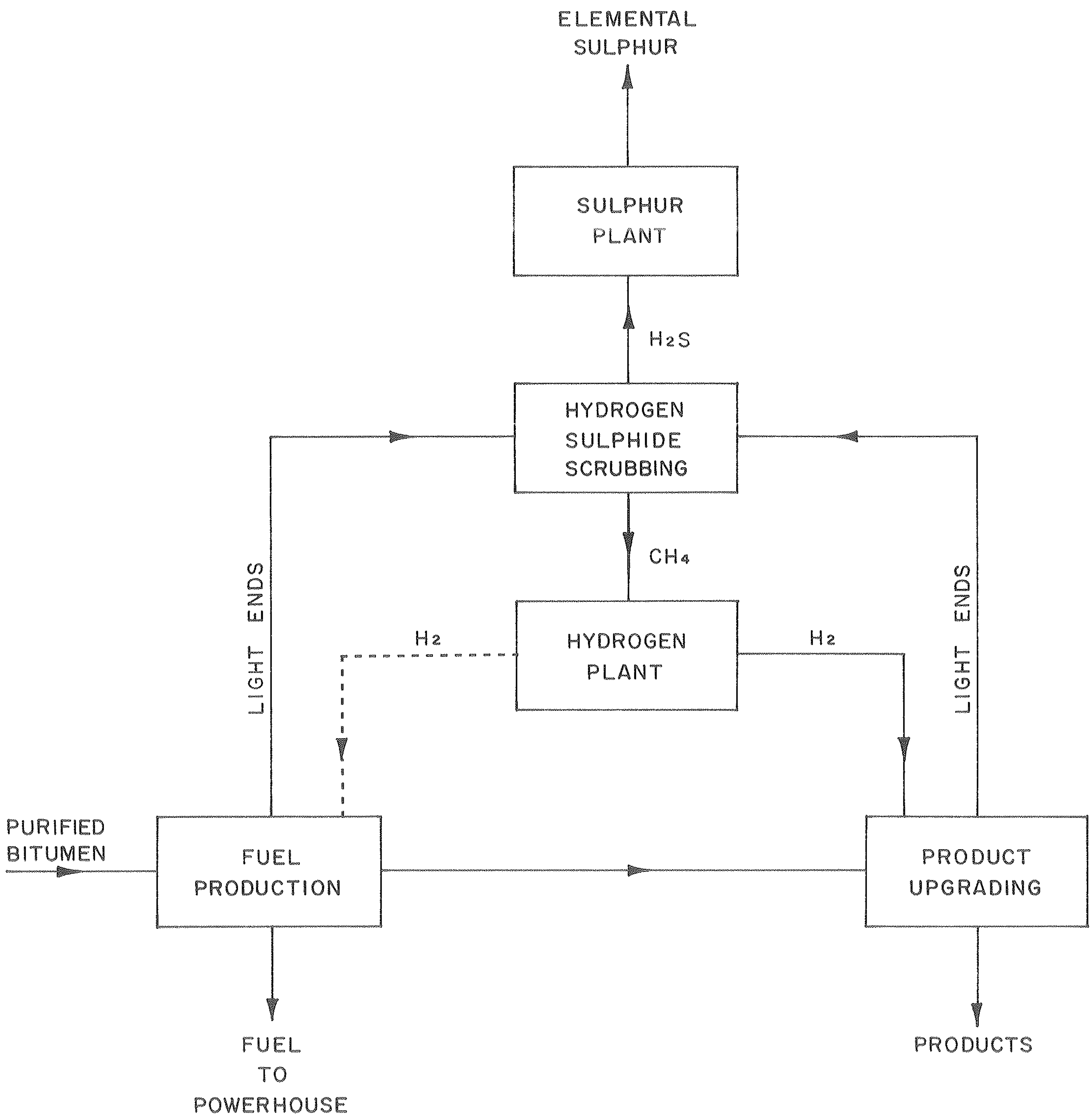
A research program is needed to develop cleaner fuels from bitumen. The principal research thrust should involve hydrogen treatment of the bitumen. Published literature* and consultations with the Fuels Division of the Federal Department of Energy, Mines and Resources, tend to confirm that some combination of hydrogen treating and coking with gasification of the residues could produce cleaner fuels.

This processing concept also improves the yields of product streams. A cursory feasibility study of one hypothetical process combination suggests that the potential revenues from improved yields could justify the added investment.

The research should be a coordinated team effort involving both Industry and Government agencies. Patented and proprietory processes should be evaluated. The Federal Department of Energy, Mines and Resources can supply valuable inputs, and their current research programs need to be accelerated and expanded. An estimated expenditure of $10 million would support a comprehensive Canadian research program of 5 years duration to develop a feasible process. The urgency and importance of the problem justifies both industry assessments and government grants.

The secondary stage of bitumen processing involves the upgrading of product streams. The normal market demands for end use products and their transportation dictate that the processor should reduce to their economic

*A. W. Hyndman, "Athabasca Bitumen High Conversion to Synthetic Crude," published September 19, 1972.



SIMPLIFIED SCHEMATIC DIAGRAM
for
BITUMEN PROCESSING

minimum the levels of sulphur and nitrogenous compounds. The conventional method for doing this involves reaction with hydrogen and the technical and commercial feasibility of hydrogen treating fluids has already been well demonstrated. Concern for environmental protection requires that adequate design and engineering criteria be utilized to ensure that the reaction products are contained within the prescribed emission limits.

The fuel-making and product-upgrading steps both generate light ends, being gaseous mixtures comprising CH_4, and H_2S and other ingredients. This plant gas stream is similar to a sour natural gas. It requires conventional scrubbing to remove the H_2S and convert it to elemental sulphur. Additional hydrogen treatment of bitumen will increase the production of elemental sulphur proportionately.

The environmental impacts of removing H_2S and converting it to sulphur are well known in the Province and constraints are defined which apply to the tar sands industry.

The handling, storage and transportation of elemental sulphur cause other environmental impacts pertaining to dusting and water drainage. Here again, the Province has experience with the problems involved and should apply the same constraints as those already developed for the sulphur industry.

The methane content of the plant gas will be used either as clean fuel, or as feedstock to make hydrogen or possibly for both purposes. The manufacture of hydrogen is of special interest to environmental planning since it correlates with the proposal to extend the hydrogen treating process. The potential viability of large scale hydrogen production, especially from heavy hydrocarbons or water, should be investigated because this is a key factor in controlling emissions.

The type of plant facilities required for bitumen processing are similar to those found in the chemical and petroleum refining industries. Such plants involve a multitude of ancillary activities which are potential sources of pollutants. A typical list of such operations would include the following:

Separation processes:
- fractionation
- absorption/stripping
- filtration

Intermediate purification:
- e.g. amine purification and blow-down

Removal of impurities by caustic washing, etc.

Physical processes:
- materials handling
- direct fired process heaters

Catalyst regeneration:

catalysts in hydrocracking and hydrotreating require periodic regeneration, which is normally carried out by a controlled combustion process. Products of this combustion which may contain noxious materials are normally vented to the atmosphere unless special precautions are enforced.

Transfer losses and tank venting

Process vent collection and emergency flaring.

More detailed process flowsheets and material balances are required with future plant applications to identify all emissions.

Some preliminary monitoring has been done on the liquid wastes from bitumen processing. The analytical data obtained from the files of the Department of the Environment indicates the presence of trace metals in this liquid effluent as shown in the following table:

arsenic – 0.015 mg./1,
cadmium – 0.002 mg./1,
chromium – 0.008 mg./1,
cobalt – 0.004 mg./1,
copper – 0.003 mg./1,
manganese – 0.050 mg./1,
nickel – 0.037 mg./1,
selenium – 0.010 mg./1,
zinc – 0.039 mg./1.

Although the current detection factors are sufficient to allay concerns, the advent of additional plants with similar effluents will warrant careful monitoring and improved sampling. The presence of other trace metals should also be investigated, for example, mercury.

Utilities

ENERGY REQUIREMENTS

The schematic diagram shows the sources and distribution of the energy demands for steam and electric power in an integrated tar sands plant.

The total energy requirements for a product capacity of 125,000 BPCD are 8,500 million B.T.U. per hour. When the product level is extrapolated to 1 million BPCD the corresponding energy demands increase to 68,000 million B.T.U. per hour.

In order to be self sufficient in its energy requirements a conventional plant consumes 17% of the energy contained in the natural bitumen. Any significant improvement to this fuel factor will alleviate the environmental impacts and improve the project economics.

ELECTRIC POWER

In projecting power requirements, and related fuel demands, it was assumed that thermal generation would continue for the foreseeable future. It should be noted that there are some potential hydro electric power sites on the upper reaches of the Athabasca River system.

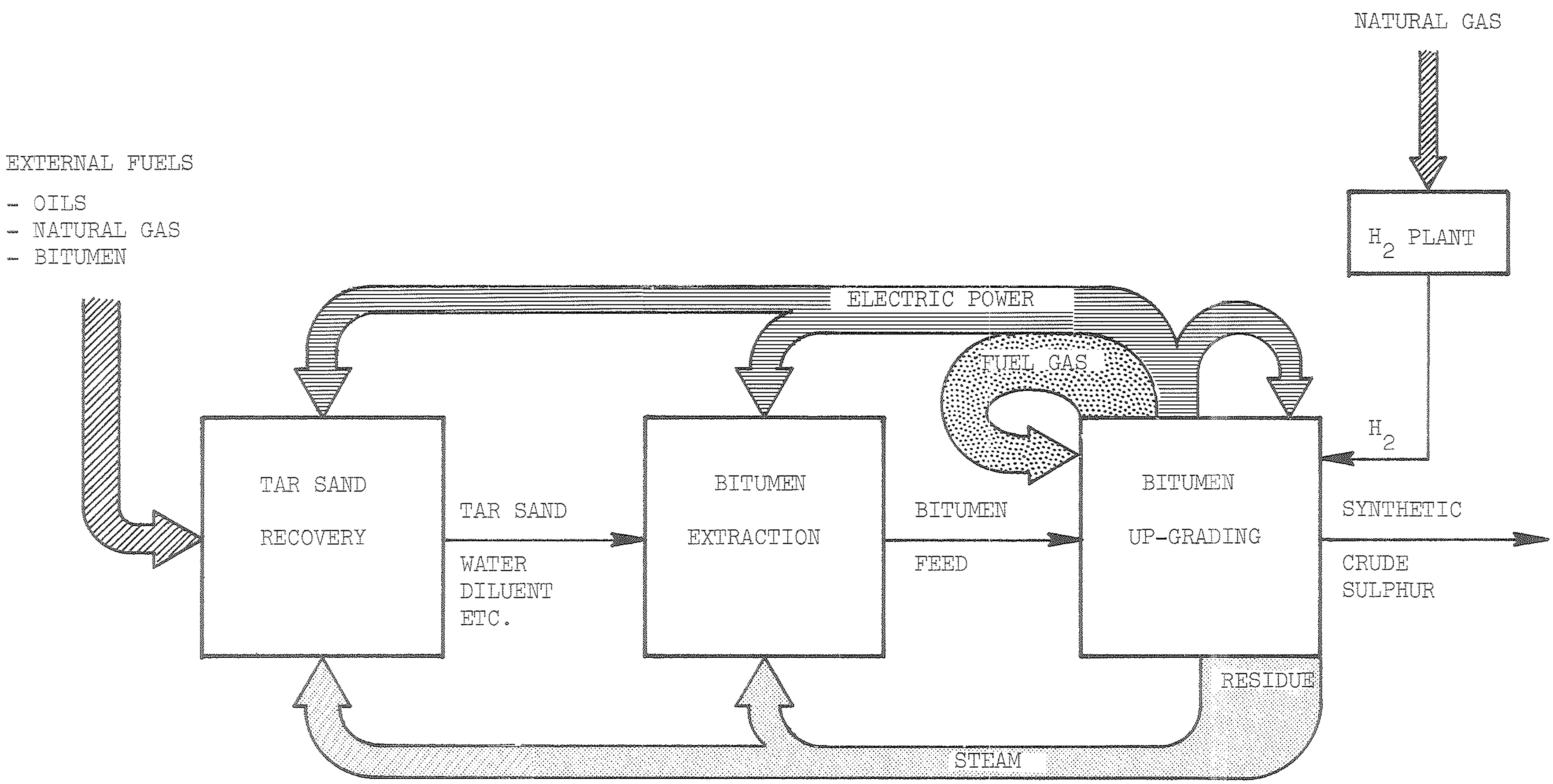
In addition to the industry's requirement for electric power, consideration must be given to the needs of communities. At the projected level of industry growth, the municipal power demand will be 215 megawatts as compared to the 1,000 megawatts required for tar sands plants. Environmental impacts could be reduced by generating this energy in a central electric power station. The benefits would accrue from plant site location and design factors.

The distribution of electric power by overhead power lines could be of some environmental significance. Part of this impact could be beneficial if tree clearings for power lines were laid out in an orderly fashion. Controlled clearing of this type produces an edge effect which tends to improve the vegetation especially for ungulates. Such clearings also increase the accessibility for hunting but this is controllable by the existing game regulations. When clearing corridors of this type, caution is required with the type of cutting and in the use of herbicides in the vicinity of streams.

STACK EMISSIONS

As indicated earlier, the type of fuel produced from bitumen is a function of the design of the processing unit. The most critical aspect of the fuel relates to its sulphur content because its combustion products pollute the atmosphere

ENERGY SOURCES & DISTRIBUTION



through stack emissions. The sulphur oxides are dispersed by the stack plume and eventually deposited at ground level. With the current technology using solid fuel, the powerhouse is the principal source of SO_2 emissions.

The necessity of using cleaner fuels for thermal power generation is now being recognized. The tar sands industry is contemplating using natural gas to the extent that its supply and economics will permit. Some natural gas is currently piped into the Area where it is used to a limited extent in the existing plant, and to generate power for Fort McMurray. Exploration is continuing to locate additional accessible gas fields. If a pipeline is built up the MacKenzie Valley, more gas may become available to the industry. Considering the probable restrictions to the use of natural gas, and the nature of bitumen processing, future tar sands plants will have to generate at least part of their full requirements. Constraints will therefore be necessary to control stack effluents.

There are three basic approaches to controlling the emissions from power house stacks, viz:

- raising the stack height to achieve greater dispersion of emissions. There are distinct limitations to this technique, especially in the Area where winter inversions are common,
- scrubbing of stack gases. This approach is receiving a great deal of attention and many different methods are now available. All of these systems, however, will result in other environmental impacts, such as liquid or solid wastes, and maintenance problems.
- reduce the level of sulphur in the fuel. This is the ultimate and preferred solution.

Standards must be introduced to limit the permissible sulphur content of total fuels consumed by the tar sands industry for energy generation. 2% by weight is recommended as a preliminary specification with allowance to be made for stack scrubbing. This constraint could be implemented in stages, but any unwarranted delay in its adoption could deter the development of the industry. For any given atmospheric regime with prescribed tolerance, the number of permissible plants will be reduced according to their individual SO_2 emissions. Environmental regulations can and should stimulate technical development to produce cleaner fuels.

Although it is accepted practice to compute atmospheric dispersion models based on SO_2, the thermal generation of steam and electric power, especially from solid fuels is a source of other atmospheric emissions, notably oxides of nitrogen and particulate matter.

Oxides of nitrogen occur in the stack gases from the high temperature combustion of bituminous fuels. They are the combustion products of nitrogenous compounds present in the fuel and air. Their concentration in the stack gas is a function of the time temperature relationship in the furnace and hence a function of the furnace design and operation. Although most of the nitrogen in the fuel is emitted from the stack as NO, it changes to higher oxides in the atmosphere. Under certain conditions these oxides can react with other atmospheric components to form compounds irritating to humans. Oxides of nitrogen deposited at ground level can damage vegetation. The preferred remedy for these problems is to remove the nitrogenous compounds from the fuel.

Particulate matter is an additional atmospheric emission from the combustion of solid or liquid bituminous fuels. Sixty percent of the ash from burning petroleum coke will be emitted to the atmosphere as fly ash unless special precautions are taken. Airborne fly ash is unpleasant aesthetically and gross buildups can affect the normal radiation phenomena with possible resultant detriment to vegetation and human habitat. The fly ash from petroleum coke is known to contain trace metals, some of which have potential toxic effects. Containment techniques are available such as electrostatic precipitation, mechanical separators or scrubbers.

HEAT LOSSES

The cooling water used for the auxiliary control of thermal power generation represents a potential impact upon the surface water if it is discharged. This is controllable provided that good design and operating practices are followed. Any liquid emissions should not be permitted to raise the ambient water temperature more than three centigrade degrees.

The recycle of all condensate to boiler feed water should be a mandatory feature of future plant designs.

FUEL RESIDUES

The development of cleaner fuels will be a progressive program: consequently during the earlier stages of the industry's expansion, declining quantities of solid residues may have to be burned or discarded. These solid wastes should be contained in a harmless location and the drainage water should be treated. This includes bottom ash and fly ash.

Plant Size and Locations

A critical feature in planning the industry's future will be the permissible size, locations, and density of tar sands plants. Guidelines must be established for this purpose, based primarily upon environmental considerations. There are several criteria to be applied in formulating the master plan.

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The cumulative impact of atmospheric emissions upon the ambient environment is of paramount importance. In order to evaluate this parameter, the following information is required:

- the composition and quantities of atmospheric emissions from each source;
- the diffusion characteristics of the atmosphere, with particular regard to adverse conditions;
- the selected locations for human habitat;
- thorough assessment of the biological environment.

Some work has been done of this nature, in connection with the two plant authorizations. The available data is not adequate to permit a definitive analysis, and therefore more reliable data should be obtained.

No combination of plant size, location, or density should be permitted that would cause deterioration of the ambient air quality (and related ground effects) beyond the standards prescribed for Alberta.

This constraint will regulate the combined effects of size and location for new power houses and bitumen processing plants since they are the principal sources of air emissions.

Pending the availability of the prescribed data, the onus should continue to rest with the applicant to demonstrate that the ambient air quality standards will not be exceeded. When more reliable data is acquired, projections can be done to predict allowable combinations of tar sands plants.

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Surface mining exclusions represent a criterion for the permissible size and location of tar sands mines.

For the surface mineable region, the Government should identify those additional environmental features which must not be disturbed. These pertain to the physical, human, and biological environments. The preceding text provided a multitude of specific examples and emphasizes the need for research and planning.

No surface mining should be permitted in exclusion zones to be designated by the Alberta Government.

The Government will probably receive mining applications before all the exclusion zones can

Liquid retention ponds on Athabasca

be defined. Under these circumstances, the developer should consult the appropriate authorities, with sufficient information and advance notice to enable the Government's assessment of the local environmental values. These evaluations must transcend lease boundaries, and in some cases it may be necessary to adjust those boundaries.

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Liquid emissions represent an additional criterion for regulating the size and location of future plants.

Each section of a tar sands plant (i.e. bitumen production, bitumen processing, power generation) emits liquid wastes. These effluents may be either: contained (e.g. tailings) or treated (e.g. refinery wastes) or discharged directly to streams (e.g. overburden drainage). The important environmental concern relates to the combined effect of all source effluents upon the ambient environment.

No combination of plant sizes and locations should be permitted which would cause the quality of surface water to deteriorate beyond the standards prescribed by the Alberta Department of the Environment.

The implementation of this constraint necessitates complete identification of all liquid effluents and a better knowledge of the regional hydrology.

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The two tar sands plants authorized to date are both integrated facilities, i.e. the plants for bitumen production, bitumen upgrading and power generation are sited together within the confines of a lease. As the industry grows, this engineering concept may be modified with resultant changes to the size and relative locations of plant units. The environmental criteria already proposed will accommodate this potential trend since they relate to cumulative impacts.

Related Activities

EMERGENCIES

Industrial operations are susceptible to occasional emergencies, some of which could have impacts upon the environment. Such incidents include: accidental release of fluids, equipment failures, pipeline breaks, fires, explosions, process plant upsets, and other unscheduled events. In order to minimize the probability of such emergencies, the developer should report on the contemplated design and operational precautions at the time of permit application. These planned precautions should be scrutinized to ensure that adequate emergency facilities are provided, e.g. shut-off valves, inspections, accounting for materials, evacuation procedures.

Regulations already exist which require the reporting of specific types of emergencies. In the event of such a report, competent government personnel should respond on a priority basis by actual field investigation. The Government inspectors must be properly trained for the task, and must have access to all pertinent information.

The possibility of natural emergencies cannot be completely dismissed for the Area. These might include forest fires, land faults, floods or other freaks of nature.

Operators of tar sands plants should be required to have contingency plans to cope with emergencies, however caused. Such plans must be coordinated in advance with local, regional, and national Emergency Measures Organizations. The levels of responsibility and the allocation of vital services should be pre-planned.

REFUSE DISPOSAL

Tar sands plants generate some miscellaneous refuse including such things as discarded packaging materials, paper and similar items which are typical of large industrial operations. Appropriate provisions should be made for their safe disposal.

SECCNDARY INDUSTRIES

The industry creates a substantial demand for supplies, spare parts, and services which represent major opportunities for additional industrial growth. The investment ratio for the tar sands industry is 6:1, i.e. for every $100 million directly invested in a tar sands plant, an additional investment of $600 million is required somewhere to provide the materials, equipment and services to build and operate the plant. This

Lumbering site on Clearwater

must be taken into account in the proposed master plan for development. This secondary investment may occur in many different geographical locations, either within the Area, or elsewhere in Alberta, or elsewhere in Canada, or outside of Canada. Their actual locations will depend upon many business and industrial factors and also upon location incentives.

A separate development study should be undertaken to determine which of these secondary industries could locate in the Area so that provision can be made for their optimum siting. Many such facilities are classified as light industries whose environmental impacts would be significantly less than those of the tar sands industry itself.

The number of supply and support industries located in the Area should increase with the number of tar sands plants and this trend could be expedited if aggressive action were taken to encourage it. This represents another important dimension to the comprehensive planning for environmental, regional and industrial development.

The amount of industry attracted to the Area to date by the one existing tar sands plant has been almost insignificant relative to the total potential.

Some sawmills exist in the Area; annual quotas allotted to logging operators are in the range of 2 to 10 million board feet per year. The predicted increase in the regional population will affect the local demand for lumber and wood products with possible expansion of the forest industry. The future of the forest products industry in the Area needs to be studied in more depth.

Employment

Each new tar sands plant will create many jobs; some will relate directly to the plant operations, and others will result from secondary industry and services. This will cause an in-migration of workers and their dependents into the Area. Significant impacts will be exerted upon the human environment because of the additional needs of thousands of new residents for community services, recreation and related amenities. Sound regional planning will be required to accommodate this projected influx.

The one existing tar sands plant created a work force demand for 1,500 people. The corresponding increase in the town population was 5,700 people. The second tar sands plant will be the principal factor in a projected population increase in Fort McMurray to 15,200 people or more by 1980. A further addition of 50,000 area residents related to direct employment will result from the industry's projected growth. Secondary industries and services could cause a simultaneous influx of an additional 50,000 or more residents. Thus, the growth of all industry beyond the second plant could cause a population increase in the Area of 100,000 people within 20 years or less. These rough projections could be higher if more secondary industries were encouraged to establish in the Area.

A great deal of advanced planning will be required to regulate the complex interrelationship between human factors and occupational demands. A regional plan is required to ascertain the optimum locations for human habitat and this can only be done in conjunction with an orderly industrial development program. Furthermore, environmental planning is fundamental to both.

The basic question confronting regional planners is whether or not to develop new communities and if so, where they should be located. The recommended research will facilitate determining an environmentally acceptable industrial growth pattern which in turn would enable longer range regional planning. In the planning process priority consideration must be assigned to human habitat when allocating the Area's environmental resources.

One basic option is to continually expand the existing community of Fort McMurray. The principal advantage of this approach would accrue from the increasing viability of better public services with greater population density. The principal disadvantage would be the commuting problem involving – at the extreme – distances of 70 miles between community and place of work. In this latter regard, the regional planners should weigh the potential effects of new trends such as transit systems and the compressed work week.

The other basic option is to establish one or more new communities. The main potential advantage of this approach would be the opportunity to select one or more locations offering the optimum human environment including, for example, clean atmosphere, pure water, scenery. The principal disadvantage would be the fragmentation of community services for the Area residents.

Any employment program affecting the Area should make special provision for extending training and occupational opportunities to the northern residents including native people. This will also necessitate due consideration for their living accommodation.

Experimental In-Situ Site

In-situ Bitumen Recovery

One third of the Area comprises tar sands underlying 500 feet or more of overburden. The reserves amount to an estimated 180 billion barrels of bitumen. Intensified efforts are being directed to finding a viable recovery method.

The most promising concept to date is the in-situ method by which the bitumen will be displaced from the tar sands without stripping the overburden or removing the tar sands. The bitumen thus produced will contain water and mineral particles and to this extent it would be similar to the raw bitumen produced by the mining and hot water extraction method. In effect a successful production scheme for producing bitumen by in-situ will replace several activities which are inherent in the conventional method, viz: draining and removing overburden, mining tar sands, and bitumen separation.

Although there is not yet any significant commercial production of bitumen from an in-situ system, several sites have been established and more are being contemplated to determine the technical and economic feasibility of this method. The results of these authorized experiments are classified as confidential.

Secondary recovery methods which are widely used in the conventional oil industry were undoubtedly the source of the basic idea behind the in-situ concept for tar sands. There are three distinct features of the Athabasca Tar Sands and its bitumen which necessitate special recovery techniques, viz:

The bitumen is so viscous at the low formation temperature of 32 to 60 degrees F. that it must be either heated, dissolved or emulsified to enable it to flow;

High pressures are required to move the bitumen and this factor determines the minimum depth at which in-situ displacement can be practised. 500 feet or more of overburden is required to contain this pressure and this defines the in-situ region;

The bitumen occupies up to 90% of the pore space between the sand granules, and the tar sands ore body is almost impermeable in its natural state.

The technology for in-situ bitumen production and its potential impacts upon the environment can be analyzed from published literature and the application of geological principles.

Holes are drilled from the surface through the overburden into the tar sands ore body. In plan view these holes form a symmetrical pattern comprising a central control hole and four or more peripheral holes equi-distant from the centre. Steel casing is cemented into the holes and hence the term wells is commonly applied.

Permeability of the ore body is accomplished by fracturing from the bottom of the central (i.e. the injection) well to the peripheral wells. The most common technique for creating controlled fractures in underground soil formations utilizes high pressure water.

When communication is established between the injection well and the production wells, the next activity is to render the bitumen mobile and force it to flow to the peripheral (i.e. the production) wells. One proposal would inject high pressure steam to extract the bitumen in place. Other experimental systems would employ solvents or surfactants to separate the bitumen; these chemicals could be used in conjunction with steam or water injection. Another technique which has shown considerable promise involves burning part of the bitumen in place to generate sufficient heat and pressure to enable the unburned bitumen to flow to the production wells. Periodic steam or water injection is required to maintain communication between the injection and production wells.

The map shows the locations of authorized in-situ experiments.

At the present rate of development, 8 to 10 additional years of research will probably be required to devise a commercially viable technique for in-situ bitumen production. Within this estimated time scale, production units could evolve in the capacity range of 50 million barrels per year of bitumen. In order to quantify the environmental impacts, this production level was selected as a basis for projections.

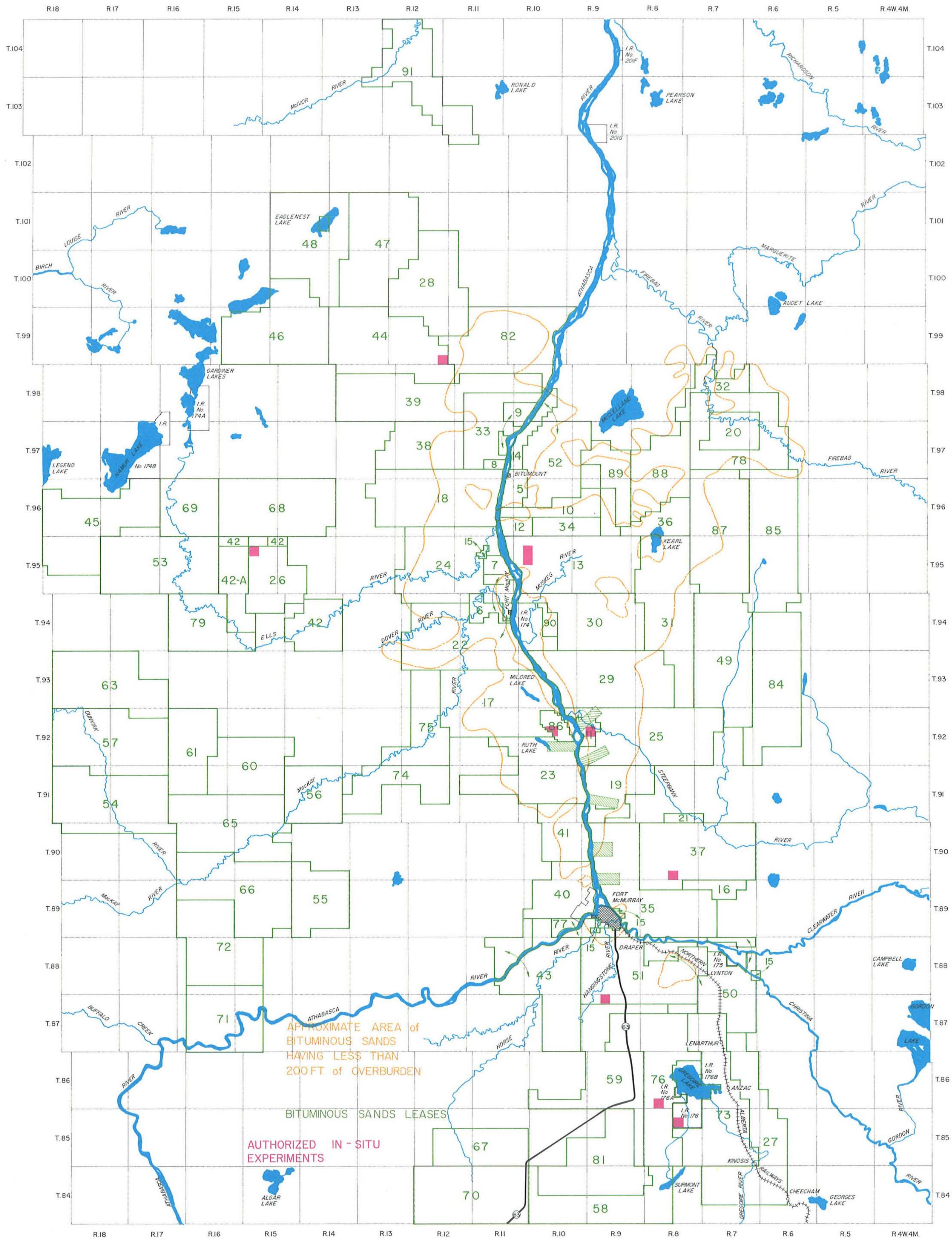
LAND CLEARING

Land clearing will be required to accommodate drilling sites, pipeline gathering systems, and access roads.

Bitumen production at the projected level will require 1600 operating wells, spaced less than 300 feet apart, over an area of 5 square miles. The land will be occupied by active wells for an average period of 7 years.

As the well sites become larger, some constraints will be needed on clearing patterns, and where practicable, 50% of the trees and other vegetation should be preserved. The extent of land clearing must be restricted to the minimum required by the authorized surface operations.

Muskeg presents a problem for vehicle access; however it is possible to circumvent this, either by scheduling work in muskeg patches for winter, or by using special vehicles. Either of these precautions would prevent environmental damage.


APPROXIMATE AREA of BITUMINOUS SANDS HAVING LESS THAN 200 FT of OVERBURDEN
BITUMINOUS SANDS LEASES
AUTHORIZED IN-SITU EXPERIMENTS
FORT McMURRAY
ATHABASCA RIVER
CLEARWATER RIVER
FIREBAG RIVER
R.18
R.17
R.16
R.15
R.14
R.13
R.12
R.11
R.10
R.9
R.8
R.7
R.6
R.5
R.4W.4M.
T.84
T.104

UNDERGROUND FRACTURING

The fracturing of underground tar sands to provide flow paths for the displaced bitumen should be regulated to avoid opening fissures beyond the intended production zone, otherwise the injection fluids will migrate along uncontrolled routes. In the vicinity of natural drainage regimes, buffer zones will be required to prevent contamination of surface waters. Monitoring will be necessary to establish acceptable control techniques to localize the impact upon the underground environment.

INJECTION FLUIDS

In-situ methods will result in water displacing about 60% of the bitumen in place, and displacing also some of the finer mineral particles. In view of the extent and thickness of the tar sands some research should be directed to determine the ultimate possible effects upon the water table and the groundwater flow pattern.

The in-situ development regions are farther away from the Athabasca River, and hence water supply could pose a serious problem. This matter should be assessed when the hydrological data for the Area is available. Since the bitumen will be recovered as a water emulsion, the same consideration of liquid tailings will apply as discussed for the hot water extraction method.

Underground reclamation contraints should ensure that the production zone is flushed with compatible formation water after production has ceased.

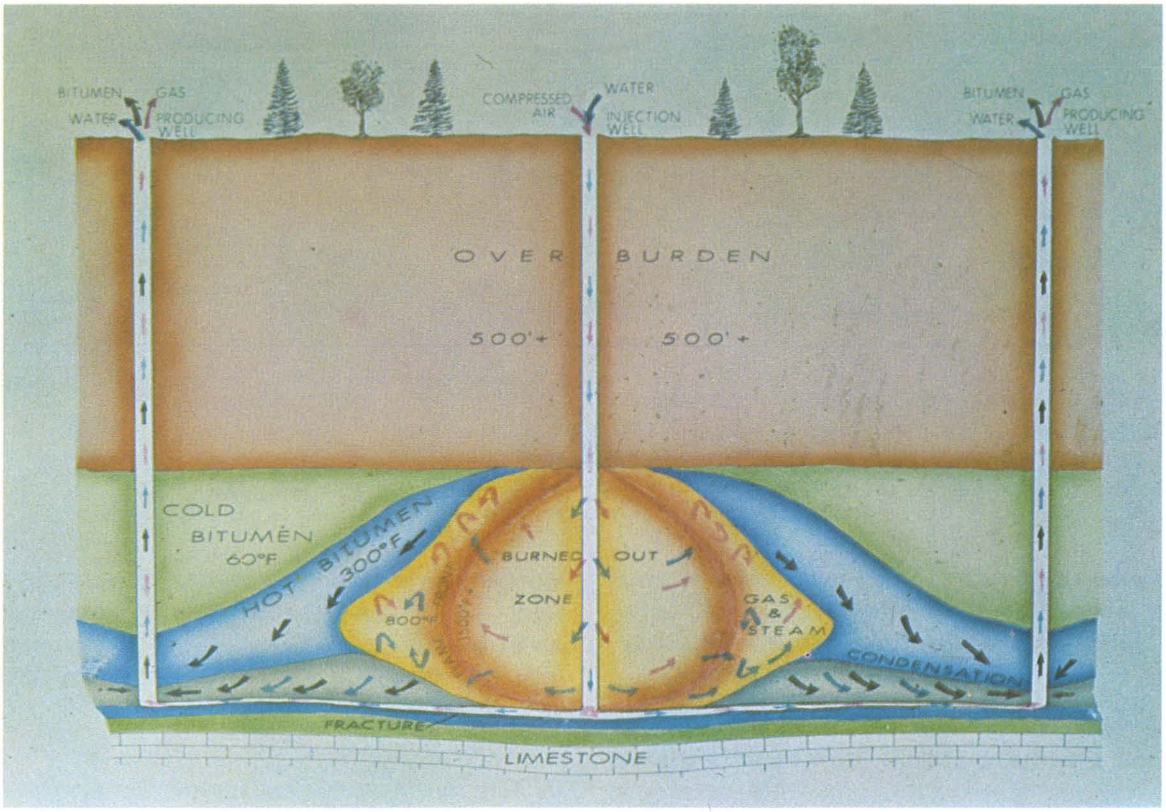
A steam injection system for 50 million barrels per year of bitumen production would utilize 55 cubic feet per second of water, and contraints will be required to ensure maximum recycling of water to minimize the storage or discharge of liquid contaminants.

The use of chemical additives to facilitate fracturing or displacement requires monitoring to ensure their containment.

COMBUSTION

Any methods which depend upon combustion of in-situ bitumen will create large underground heat sinks, with temperatures as high as 1500 degrees F. being generated at the centre of an underground combustion zone. The temperature required to render the bitumen mobile is in the range of 200 to 300 degrees F. Given proper control of the combustion process it is possible to limit the underground temperature at the overburden interface to 300 degrees F. or lower.

IN-SITU BITUMEN RECOVERY
by
UNDERGROUND COMBUSTION



By restricting the in-situ operations to regions having at least 500 feet of overburden, it is unlikely that any detrimental effects would occur at the surface due to heat dissipation. There is cause for concern regarding the increase in the temperature of the underground water and this must be monitored to determine the ultimate effects upon the physical and biological environment.

BITUMEN STORAGE AND HANDLING

One problem which could inhibit the development of in-situ technology is the disposition of the bitumen produced.

Most of the in-situ bitumen produced to date has been stored in open pits at the site. For small quantities in remote locations this practice exerts a modest impact on the environment; but these effects will be magnified as the scale of operations increases.

Both environmental and economic factors will necessitate the processing of the bitumen at some stage, and the site location is a pertinent factor. Raw bitumen can be transported either batch-wise by tank truck, or continuously by pipeline if justified by the available quantity.

Any handling or processing facilities permitted at the site must conform to the precautions already specified.

IN-SITU RESEARCH

Because of the early stage of this technology, the opportunity exists to plan for protection of the environment. The Alberta Research Council should be authorized and commissioned to examine all information pertaining to in-situ experiments in Alberta, primarily to assess the environmental impacts. This would be done on a regular basis to keep the information up to date. The Department of the Environment would be advised of any matters requiring its attention.

The designation of the probable in-situ development region at 500 feet of overburden is based on available data and this must be reviewed when additional information is obtained. As techniques improve, this recovery concept might be applicable to thinner overburden. From an environmental point of view this is important because the in-situ method avoids the necessity of removing massive volumes of earth and the resultant reclamation problems.

The initial ecological surveys concentrated on the surface mineable region. These should be expanded to encompass the in-situ region and the intermediate region.

Direct Coking of Tar Sands

Several years ago, the National Research Council conducted pilot studies to determine the feasibility of a process for the direct coking of tar sands. The schematic diagram indicates the unit operations which would be involved for such a scheme.

In principle, part of the tar sand feed is converted directly to coker distillate and the balance to petroleum coke. If successful, it would replace three of the steps in the conventional process, viz: hot water extraction, bitumen purification, and fuel production.

There would be some environmental advantages since the process does not generate any liquid tailings. The mineral fines remain with the sand, and their disposal would not present a problem.

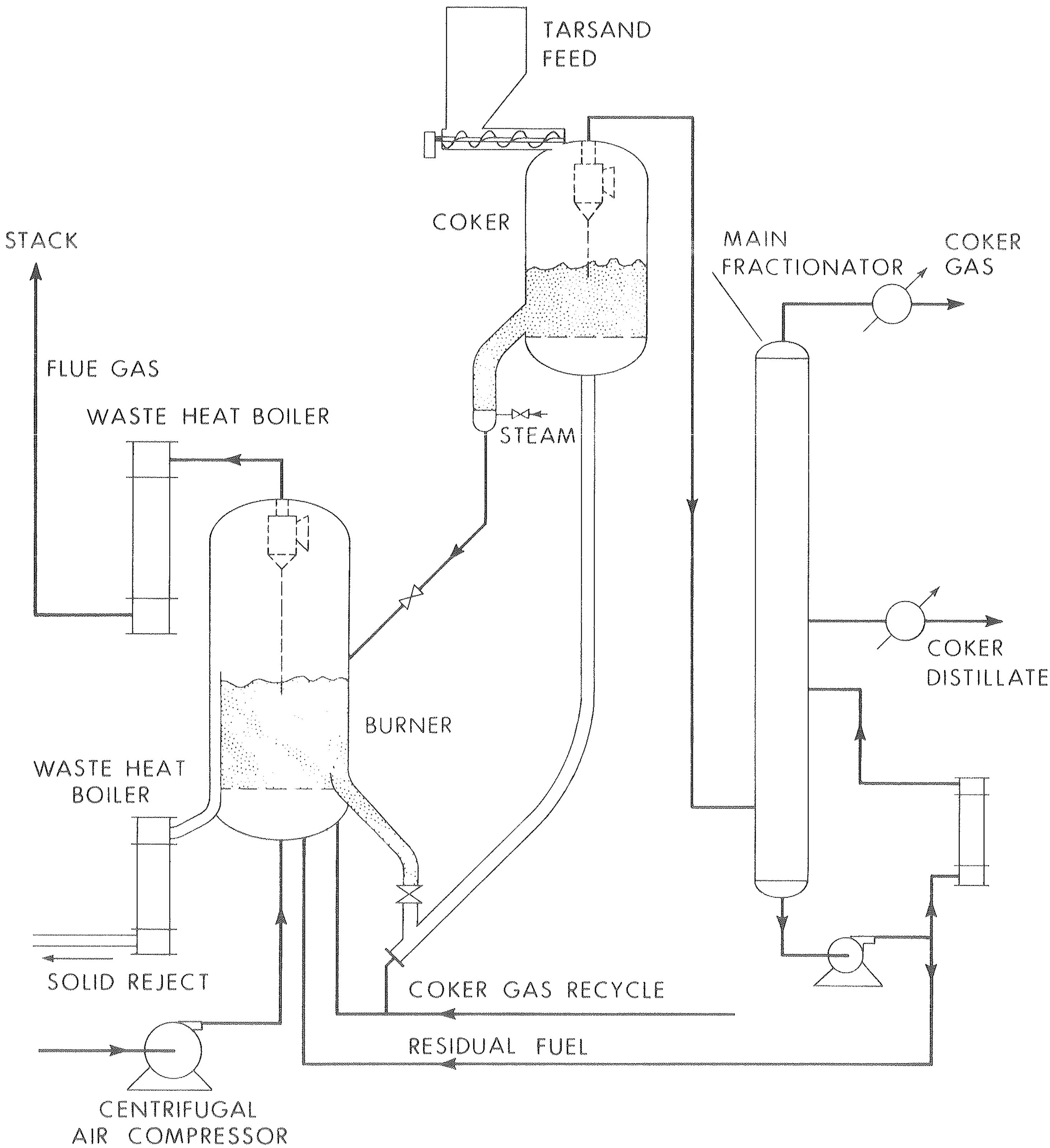
The principal disadvantage of the process is the high sulphur content (6% by weight) of the coke which on burning, produces SO_2 emissions to the atmosphere. There appears to be no practical way of removing the sulphur from the coke in this process.

The research work served to demonstrate the technical feasibility of the process on a small scale. It was also concluded, however, that the process would not be economically viable unless the tar sands feed could be enriched to at least double their normal bitumen content. This economic restraint results from the large heat load required to raise the temperature of the tar sands to 900 to 1000 degrees F. Some promising research work has been conducted by the National Research Council in an attempt to find a practical benefication technique.

Experimental work was done to reject sand from a tar sands sample using a bitumen agglomeration technique. Utilizing two stage agglomeration of the bitumen, it was demonstrated that the bitumen concentration could be increased to 73%, the balance being sand and water. Initially, water to tar sands ratios as high as 5:1 were used, and this was unacceptable because of the tailings problems. Subsequently pilot scale studies succeeded in reducing the water to tar sands ratio to less than 1:1.

The National Research Council has also done a preliminary investigation on the possibility of agglomerating mineral particles. It is conceivable that this technique may be useful in the clarification of liquid tailings from the conventional hot water extraction process.

A complete review of this research work would be warranted with a view to planning further experiments having specific objectives for improving tar sands technology.



DIRECT COKING OF TARSAND

Other Possible Technologies

A multitude of ideas have been advanced over many years for different methods to mine tar sands or extract bitumen. These concepts could have various environmental impacts, but most of them are too nebulous to warrant more than passing reference.

In 1959 a lessee proposed an experiment to test the feasibility of extracting bitumen by the explosion of a nuclear device beneath the Athabasca tar sands. Although the proposal never obtained Federal approval, a technical committee appointed by the Government of Alberta did study the possible radioactive contamination. If the proposal is revived, the committee's report* will provide a useful reference for assessing environmental impacts.

Many proposals have been made for underground mining of the tar sands. Some of these schemes might be field tested in the foreseeable future. The ideal environmental objective would be to avoid disturbing the overburden, and replace the mined sands with solid tailings.

*Alberta Technical Committee report to the Minister of Mines and Minerals and the Oil and Gas Conservation Board, August 1959.

Emissions

Most of the environmental impacts caused by industry result from gaseous, liquid, or solid emissions. Heat and noise are additional emission factors. The tar sands industry creates a multitude of individual emission sources, which have been identified in this report and summarized in the matrix.

Atmospheric and liquid emissions justify priority concern, because, being fluid, they disperse and two or more source emissions can combine to produce cumulative effects. It is necessary therefore to differentiate between source concentrations and ambient concentrations, since the latter comprise the accumulated effects that determine the impacts on the ambient environment.

The Alberta Government recently announced new standards for ambient air quality. This Study included an appraisal of the new standards related to tolerance levels for the biological, human, and physical environments. Based upon published data, the conclusion was that adequate safeguards will be provided by adherence to these ambient standards.

It will be in the industry's best interests to minimize source emissions, otherwise their ambient impacts could restrict the size and location of new plants. To this end, the following atmospheric source emission criteria are recommended:

Pollutant	Amount and Measurement of Concentration	Time Period
SO_2	0.2 ppm by volume*	Half hourly average
	Fuel sulphur content of 2% or less is recommended, or scrubbing used to reduce stack concentration below equivalent levels in ppm.	
NO_x	0.2 ppm to air by volume**	Hourly average
H_2S	0.012 ppm to air by volume	Half hourly average
Particulates	0.2 pounds per 1000 pounds of effluent adjusted to 50% excess air	

Pollutant	Amount and Measurement of Concentration	Time Period
Dustfall	As for existing regulations	
SO_3	1 microgram per cubic meter maximum ground level concentration	
CO	13 ppm to air by volume	Hourly average
	(60 ppm ambient air quality above in-situ bitumen fired sites)***	Hourly average
Heavy Metals		
—Vanadium	Limits to be established	
—Beryllium	0.01 micrograms per cubic meter of air	Half hourly average
Fluorides	10 ppb of air by volume	Half hourly average

* *SO_2 is the most important air emission product. The 0.2 ppm suggested is for local dispersion concentrations. The fuel content restriction is suggested to restrict the local stack concentrations to more acceptable levels. This regulation could be established in steps, as was done in Ontario. Scrubbing equipment would allow use of higher sulphur fuels when available.*

** *NO_x is suggested at a similar level to SO_2 for dispersion. Emission levels within the stack could be proposed but are not suggested until more information is available on achievable levels.*

*** *CO levels are likely to be higher over in-situ production fields where bitumen firing underground is in progress.*

Liquid emissions from tar sands plants likewise have a variety of individual sources. Their cumulative impacts affect the quality of the surface water. The Prairie Provinces recently established certain criteria for ambient surface water quality. These are reproduced in the following table, and should be incorporated into the standards for the Area.

Parameter	Criteria
1 Bacteriology (Coliform Group)	(a) In waters to be withdrawn for treatment and distribution as a potable supply or used for outdoor recreation other than direct contact, at least 90 percent of the samples (not less than five samples in any consecutive 30-day period) should have a total coliform density of less than 5,000 per 100 ml and a fecal coliform density of less than 1,000 per 100 ml. (The Maximum Permissible Limit of total coliform organisms in a single sample shall be determined by the Provincial Board of Health based on the type and degree of pollution and other local conditions existing within the watershed.)
	(b) In waters used for direct contact recreation or vegetable crop irrigation the geometric mean of not less than five samples taken over not more than a 30-day period should not exceed 1,000 per 100 ml total coliforms, nor 200 per 100 ml fecal coliforms, nor exceed these numbers in more than 20 percent of the samples examined during any month, nor exceed 2,400 per 100 ml total coliforms on any day.
2. Dissolved Oxygen	A minimum of five mg/1 at any time.
3. Biochemical Oxygen Demand (BOD_5)	Dependent on the assimilative capacity of the receiving water. The BOD_5 must not exceed a limit which would create a dissolved oxygen content of less than five mg/1.

Parameter	Criteria
4. Suspended Solids	Not to be increased by more than 10 mg/1 over background value.
5. pH	To be in the range of 6.5 to 8.5 pH units but not altered by more than 0.5 pH units from background value.
6. Temperature	Not to be increased by more than 3 degrees C. above ambient water temperature.
7. Odour	The cold (20 degree C.) threshold odour number not to exceed eight.
8. Colour	Not to be increased more than 30 colour units above natural value.
9. Turbidity	Not to exceed more than 25 Jackson units over natural turbidity.

10. Organic Chemicals

Constituent	Maximum Concentration (mg/1)
Carbon Chloroform Extract (CCE) (includes carbon Alcohol Extract) . .	0.2
Methyl Mercaptan	0.05
Methylene Blue Active Substances	0.5
Oil and Grease	Substantially absent no iridescent sheen
Phenolics	0.005
Resin Acids	0.1

11. Pesticides	To provide reasonably safe concentrations of these materials in receiving waters an application shall not exceed 1/100 of the 48-hour $T1_m$. Persistent insecticides such as DDT, Aldrin, Dieldrin, Endrin, Heptachlor should not be used on or near surface waters.

12. Inorganic Chemicals

Constituent	Maximum Concentration (mg/1)
Boron	0.5
Copper	0.02
Fluoride	1.5
Iron	0.3
Manganese	0.05
*Nitrogen (Total Inorganic and Organic)	1.0
*Phosphorus as PO_4 (Total Inorganic and Organic)	0.15
Sodium (as percent of cations)	Between 30 and 75
Sulphide	0.05
Zinc	0.05

These Criteria are presently under study and may require adjusting according to naturally occurring concentrations or conditions.

NOTE: The predominant cations of sodium, calcium and magnesium and anions of sulphate, chloride and bicarbonate are too variable in the natural water quality state to attempt to define limits. Nevertheless, in order to prevent impairment of water quality, where effluents containing these ions are discharged to a water body the permissable concentration will be determined by the Provincial Board of Health in accordance with existing quality and use.

13. Toxic Chemicals

Constituent	Maximum Concentration (mg/1)
Arsenic	0.01
Barium	1.0
Cadmium	0.01
Chromium	0.05
Cyanide	0.01
Lead	0.05
Mercury	0.0001
Selenium	0.01
Silver	0.05

14. Radioactivity	Gross Beta not to exceed 1,000 pCi/1. Radium 226 not to exceed three pCi/1. Strontium 90 not to exceed 10 pCi/1.
15. Unspecified Substances	Substances not specified herein should not exceed values which are considered to be deleterious for the most critical use as established by the Provincial Board of Health.

Conclusions

This report has defined many urgent programs of preventative action. In conclusion, it would seem appropriate to present some observations on the responsibilities for implementing the recommendations.

The Government and the Lessees must devise more effective means of cooperating in planning the orderly development of the tar sands industry. The Alberta Government should provide the necessary initiative and leadership. Environmental problems are of paramount concern, and their resolution should involve participation by the people most directly affected, viz the residents of the Area, the Province and Canada.

The industry must be recognized as a distinct new entity necessitating specific Government regulations and legislation.

Developers must assume responsibility for control of pollution at the source. This includes: identification of planned emissions, monitoring by independent analyses, reporting to the Government on any deviation from source standards.

The Government must establish both source and ambient standards and enforce their compliance. Periodic review will be required to maintain standards that optimize the environment for humans, fauna, and flora.

Responsibility for monitoring the quality of the ambient environment should be shared between the Developers and Government, with the prime onus being on the former.

The Study has identified a vast amount of research required to generate essential data. Most of this data pertains to the industry's technology, which in turn influences the environmental impacts. It is imperative that the Government participate in these technological developments by establishing a research centre in Alberta for the tar sands industry. The research facilities should comprise field units in the Bituminous Sands Area supported by laboratories in Edmonton.

Research participants would include: Alberta Research Council, the Lessees, Alberta universities, Federal Department of Energy, Mines and Resources, and the National Research Council. Specific projects would be commissioned on a contract basis to permit specialized technical contributions from independent Canadian sources. Provisions would also be made for utilizing global expertise.

This research body should be organized as a corporation. Its revenues would include: lease assessments, Government research grants, and the sale of know-how.

The recommendations provided in this report will enable the Government of Alberta to select optimum strategies in the implementation of long-term tar sands development policies.