ALBERTA

OIL SANDS HYDROLOGICAL RESEARCH

Prepared by

The Conservation and Utilization Committee

Oil Sands Hydrological Research Task Force

Approved and published

under the authority of

THE HONOURABLE W.J. Yurko, P. Eng.

Minister of the Environment

March, 1974

Alberta

ENVIRONMENT

Environmental Coordination Services

Office of
the Assistant Deputy Minister

403/425-1130
Telex 037-2006, TWX 610-831-2636
Milner Building
10040 - 104 Street
Edmonton, Alberta, Canada
T5J 0Z6

Dr. E.E. Ballantyne, Chairman
Natural Resources Coordinating Council

Sir:

Re: Alberta Oil Sands Hydrological Research

On behalf of the Conservation and Utilization Committee, I have the pleasure of submitting the Alberta Oil Sands Hydrological Research Task Force Report.

For many years the Conservation and Utilization Committee has functioned as the major inter-departmental resources committee of Alberta. Formerly advisory to the Minister of Agriculture, the Committee now makes its recommendations and report therein to the Natural Resources Coordinating Council and the Minister of the Environment. In the past the Conservation and Utilization Committee has itself authorized reports, appointed task forces, or recommended retention of consultants under its direction.

This report was prepared by a Task Force operating on behalf of the Conservation and Utilization Committee at the request of the Honourable W.J. Yurko, Minister of the Environment for Alberta. Due to the urgent need for environmental research on the Alberta Oil Sands, it is planned to outline such requirements in a series of task force reports on selected environmental research issues such as this one on hydrolology and others on land surface reclamation, climatology and meteorology, etc. These reports are intended to provide a focus for discussion.

Respectfully submitted,

H.W. Thiessen, Chairman
Conservation and Utilization Committee

Alberta

ENVIRONMENT

403/425-1130

7th Floor, Milner Building
Edmonton, Alberta, Canada T5J 0Z6

Office of
the Deputy Minister

The Honourable W.J. Yurko, P. Eng.
Minister of the Environment
Government of Alberta

Sir:

Re: Alberta Oil Sands Hydrological Research

The undersigned has the honour to transmit herewith the Alberta Oil Sands Hydrological Research report prepared by the Conservation and Utilization Committee Oil Sands Hydrological Research Task Force.

This report is one of a series of reports prepared by the Conservation and Utilization Committee on the environmental research needs of the Alberta Oil Sands. Since the reports are intended primarily to provide a focus for discussion, comments are invited on oil sands environmental research coordination and implementation, from industry, the academic community, private consultants and government research agencies. Comments should be directed to the Chairman, Research Secretariat, Alberta Department of Environment, Milner Building, Edmonton, Alberta.

Respectfully submitted,

E. E. Ballantyne

E.E. Ballantyne, D.V.M. P. Ag., F.R.S.H.
Chairman, Natural Resources Coordinating Council

ACKNOWLEGEMENTS

The contributions of the members of the Conservation and Utilization Committee Oil Sands Hydrological Research Task Force are hereby acknowledged:

Dr. R. Green (Chairman)	- Earth Sciences Branch Alberta Research
Mr. J. R. Card, and Mr. F. Davies	- Technical Services Division Alberta Environment
Mr. R. C. Davis	- Alberta Forest Service Alberta Lands and Forests
Dr. R. Gerard	- Highways and River Engineering Division Alberta Research
Dr. D. A. Hackbarth, and Dr. J. Toth	- Groundwater Division Alberta Research
Mr. J. B. Kemper	- Canadian Wildlife Service Environment Canada
Mr. M. O. Spitzer	- Inland Waters Directorate Environment Canada
Mr. O. Tokarsky, and Mr. H. A. Kerr	- Earth Sciences and Licensing Division Alberta Environment
Dr. J. P. Verschuren	- Department of Civil Engineering University of Alberta
Mr. G. R. Kerr (ex officio)	- Fish and Wildlife Division Alberta Lands and Forests

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1.0 INTRODUCTION

Extraction of bitumen from the Alberta Oil Sands by surface mining will have a major impact on the hydrology of the areas immediately adjacent to each mine, and an impact on any drainage system receiving discharge from the mining or processing areas. Conversely, the hydrology will have a major impact on the mining operations. The exact nature of the impacts is difficult to evaluate, because:

(a) both surface and subsurface hydrologic systems of the lower Athabasca River basin are poorly known,

(b) the exact nature, amounts and ultimate fate of effluent and tailings materials are uncertain,

(c) the degree of utilization of the waters within each basin and the possible physical changes to each basin are essentially unknown, and

(d) the nature and stability of the post-mining landscape, including particularly the success of reclamation and revegetation is open to speculation.

In fact, at present we cannot predict even the simpler natural hydrologic characteristics of the river, nor do we have any real idea of the effect of the effluents produced by the oil sands plants. In this context, we generally conclude that the main initial emphasis of hydrologic studies should be on gathering sufficient information that the questions implied in items (a), (b) and (c) can be answered, and hence item (d) appraised.

Sufficient data are needed to simulate surface runoff through the mining areas and to simulate groundwater flow systems in the mining areas; background data are needed on the physical and chemical characteristics of rivers and streams to determine present status, and so that pollution loads and other changes can be monitored. It is necessary to know, among other things: flood flows, to decide on the needs for and designs of stream diversions; the low-flow characteristics streams, for pollution control; and the severity of ice runs, again for flood information and diversion designs.

To obtain this information, a general two-phase approach is needed:

(1) an inventory of the hydrologic resources in the drainage basins likely to be affected by mining in the near future, and also in the Peace-Athabasca delta, and

(2) a detailed examination of existing operations, to study water use and water wastes, including drainage of mining areas, tailings ponds, etc.

To achieve this, specific study topics are set out below (in outline only, due to time constraints). These research needs should be formulated more specifically as projects, including scope, method, precision and timing before they are allocated and funded. In this respect, to help ensure that the desired results will be obtained and to obtain some measure of continuity, task force members consider that their respective agencies should have the opportunity of contributing more specifically to project formulation. Beyond this, hydrologic research needs will become apparent from the results of the first-phase investigations and the detailed nature of the mining developments, Definition of these needs is thus a continuing process; this report should not be considered the definitive and final document, but rather the initiation of a spectrum of projects.

It was particularly noted, however, that time and again discussion ultimately and inevitably led back to one key issue -- the nature and disposition of the tailings and plant effluents. These will determine the size of development impact on the hydrologic system -- either directly, or indirectly through the degree of success of reclamation, which is intimately dependent on the nature of the solids and liquids left in the mined-out regions.

The research needs are set out in two groups -- (1) describing existing hydrologic resources and (2) development impact studies. Within these two groups listing is in descending order of priority.

2.0 EVALUATION OF EXISTING RESOURCES

All projects in this sector should be implemented as soon as possible, as considerable lengths of records are needed before predictions can be made.

2.1 Establishment of hydrometric stations on all basins wherein mining is anticipated.

Hydrometric stations are needed to:

a) Provide data for the design of possible engineering works such as diversions, bridge and culvert crossings, intakes, etc.

b) Provide information on available water supplies whether for domestic or industrial use. (Including possible use as an effluent dilutant.)

c) Provide necessary flow information to calculate suspended sediment discharge. (Suspended sediment information without the flow information is useless.)

d) Provide flow information necessary to determine chemical constituent loadings (necessary to give background information prior to, during and after development).

The basic network of hydrometric stations needed is set out below. Stations denoted by an asterisk are sites proposed for new installations.

Baseline Network of
Alberta Oil Sands Hydrometric Stations

Stream	Hydrometric Station Location	Station No.	Drainage Area Above Station (sq. mi.)	Years of Stream flow
Athabasca River	below McMurray	7DA1	50,000	1957 - present
Athabasca River	Embarras Airport		58,700	1959 - 1971 stage only 1971 - present

Upstream of Fort McMurray				
*Horse River	near the mouth	7CC1	850	1930 - 31 only
Hangingstone River	near the mouth	7CD4	344	1965 - present
Clearwater River	Draper	7CD1	11,800	1957 - present
Clearwater River	above Christina River	7CD5	6,520	1966 - present
West of Athabasca River				
Poplar Creek	near the mouth	7DA7	100	1972 - present
Beaver River	near the mouth	7DA5	195	1972 - present
*Beaver River	above Syncrude Dam			none
MacKay River	near the mouth	7DB1	2,490	1972 - present
*Dunkirk	near the mouth			none
*Dover	near the mouth			none
*Ells River	near the mouth		1,080	none
*Ells River	below Gardiner Lake			none
*Joslyn Creek	near the mouth			none
*Tar River	near the mouth		133	none
*Calumet River	near the mouth		76	none
*Pierre River	near the mouth		63	none
*Asphalt Creek	near the mouth		120	none
*Creek north of Asphalt Creek	near the mouth		137	none
East of Athabasca River				
Steepbank River	near the mouth	7DA6	573	1972 - present
*Muskeg River	near the mouth above Hartley Creek		571	1973 - present none
Firebag River	10 miles above mouth	7CD1	2,300	1972 - present

*Station to be installed as part of the network

Gauging should begin as soon as possible. The short-term purpose of these gauging stations is to provide basin response characteristics that are needed to calibrate a mathematical model of the catchments, no matter how simple its form. Such a model is required to allow extreme flow predictions from the long-term meteorological records at Fort McMurray, and from the proposed precipitation network. Periodic suspended sediment measurements should be taken over a range of flow and catchment conditions. Suspended sediment data should probably be collected at each of the gauged locations but the type of program (that is daily sampling, periodic sampling, miscellaneous sampling) will vary from basing to basin. The sampling programs should be designed for each basin by the operating agency.

2.2 Collection of water quality data on all basins likely to be mined. This is needed to establish the natural background quality of both surface and groundwater in the tar sands area. Such data are required to evaluate the effects of development on natural water quality, and to properly enforce existing water quality standards.

[Relevant Parameters: Total dissolved solids; major cations (calcium, magnesium, sodium, iron); major anions (bicarbonate, sulphate, chloride, nitrate, phosphate); total organic carbon; chemical oxygen demand; pH; dissolved oxygen; water temperature; oils and grease; phenols; heavy metals (only toxic to aquatic organisms in their ionic form).

Minimum proposed frequency of sampling is at two samples per month for the first year, to be modified subsequently, depending on the variability of the results obtained: to be increased if variation in analyses is significant, and then to be reduced after several years' records.]

2.3 Collection of background meteorlogical data, to assist hydrological forecasting, i.e., for imput to runoff models of the catchments, for evaluation of water balance and to indicate how the long-term records at Fort McMurray might have to be modified to apply to the various areas.

These data are needed for each gauged basin, and each station location is strategic to gauge location.

Data are required on:

a) Precipitation

i) snowfall and snowpack

ii) rainfall amounts, intensity and areal distribution*

iii) nature of storms and storm patterns

b) Temperature

c) Humidity

d) Sunshine

e) Rates of snowmelt

f) Evaporation and evapotranspiration -- primarily in mining areas.

Most data are needed in enough detail to give a representative picture of the climate in the lower Athabasca drainage basin -- not only the area to be mined. (It is recognized that the definition of "enough detail" becomes a research project in itself.)

A coordinated, integrated network is desirable, involving hydrologic stations, meteorological stations, and groundwater observation sites.

2.4 Physiographic analysis (with the hydrologic application in mind) should be carried out on all basins in the mineable area and for the Clearwater, Christina and Hangingstone River basins.

A file should be prepared for each basin which includes maps of each of the parameters considered significant at a reasonably large scale. These maps are required to allow an appraisal of conditions affecting hydrologic response in the area; to allow a judicious selection of typical basins, and to allow an appraisal

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*Respecting precipitation, a radar station supplemented by tipping bucket rain gauges at Forestry Stations and strategic sites elsewhere, plus recording rain gauges at stream gauging stations, is probably the only practicable way of obtaining the necessary data.

of the applicability of information derived from the three catchments with long runoff records to the other basins affected by development.

Items that should be considered include:

a) Vegetation type -- e.g., muskeg, spruce -- these provide good indications of subsoil conditions as well as affecting significantly basin response and sediment production.

b) Slopes and slope stability -- this has an obvious effect on flood discharge and sediment production.

c) Soil type and surficial deposits -- does not have such a large effect on flood discharge but probably has considerable effect on groundwater, yield and sediment production.

d) Drainage density -- only an indication of the other factors above but should be kept in mind -- has a significant affect on flood flows.

e) Elevation -- perhaps -- really only affects input to the basin rather than basin response.

f) Locations of mineable oil sand bodies, their isopachs, overburden ratios, plant feed and reject material thicknesses, and so on.

g) Stream characteristics, including slope profiles, bed types, and so on.

2.5 Establishment of a groundwater monitoring network in the anticipated mining area and in adjacent areas.* The initial conclusion respecting groundwater hydrology was that a study be undertaken to determine the information needs. This 2-month study was undertaken by Alberta Research, to obtain background information in an essentially unknown area hydrogeologically; the prime conclusion was that background data are in effect nonexistent. The first step, then, is to establish a basic

*Detailed program proposals have been formulated on this aspect by Alberta Research and by Syncrude Canada.

network of 100 or more wells, at about 25 sites, to gather data so that the groundwater regime can be determined, and so that the effects of mining and of post-mining can be monitored and evaluated. (Site locations should be integrated with meteorological and hydrological network stations, where possible.)

The unknown factors relating to groundwater include: groundwater resources of the area; groundwater waste disposal needs and facitlities; potential pollutants from mining disturbance; whether groundwater resources are signigicant enough to have to worry about them; effects on groundwater regime by proposed mining operations; potential of groundwater to support revegetation in reclaimed areas; need for traditional resource evaluation (i.e., as a water supply source, and dewatering problem); knowledge of flow system distribution, both near-surface and deeper (? more saline waters) in the Devonian rocks; whether to select individual leases or type areas for study to determine flow densities, water quality changes, etc.

2.6 Study of selected basins to enable determination of:

a) Water balance for various environments to complement more abstract determinations of evaporation, evapotranspiration, infiltration, etc.

b) Response functions (e.g., unit hydrographs) of various simple environments to hydrologic input (rainfall, snowmelt, etc.). This type of information is required to make use of the long-term meteorological information at McMurray to generate equivalent long-term runoff records for the area.

This study also intends to determine the effects of mining on the hydrologic regime, the amounts of sediment produced, and to evaluate possible changes in the soil moisture regime, and changes in the water yield of any such basin.

3.0 DEVELOPMENT IMPACT STUDIES

3.1 Evaluation of the capacity of the Athabasca River and its major tributaries to receive additional suspended fines and discharge liquids. Preservation of the water quality of the Athabasca River must be maintained, because of the importance of the fish, waterfowl and aquatic vegetation in the Athabasca delta complex. Definition is needed of the effect of adding sediment and/or chemicals at various times of the year. Suspended sediment monitoring is being conducted on the Athabasca and Clearwater Rivers near Fort McMurray, and a miscellaneous program has been carried out on the Athabasca River at Embarras Airport. These programs should be continued, expanded to include water quality, and additionally refined to assist in assessing the suspended fines problem.

3.2 Evaluation of possible effects of suspended fines and discharge liquids on the Athabasca delta region. As waterfowl breed and some commercial fish species spawn in the delta lakes of the Athabasca River, damage to these lakes must be prevented. During periods of high water levels, water overflows from the Athabasca River into the perched, clear-water delta lakes. If as a result of mining and processing operations the river carries increased fine sediment loads and chemicals, a danger exists of damage to the life support systems in these delta lakes.

The effects of suspended sediment and waste discharges on the lakes and perched basins of the delta should be described. Both light penetration changes and the chemical and physical effects of the clays and other discharges on the biological food chains must be detailed. These studies should be geared to the needs of fish, waterfowl and aquatic mammal populations of the delta.

In addition, in the event that a tailings pond dyke should fail into the Athabasca River, the effects of this on the biological productivity of the perched basins and lakes should be examined.

3.3 Gathering of data on composition of tailings and of all plant effluents. Chemical, physical and·biological parameters are needed, as composition will significantly affect the environment, as well as suitability of tailings areas for revegetation. Changes in production process could significantly affect reclamation. For instance, the behaviour and characteristics of the effluents will affect the potential for re-establishing life in water bodies, in terms of toxicity, limitations on light pepetration, etc. Knowledge of settling rates, amelioration, etc. thus become important, particularly if these effluents are to be injected (deliberately or otherwise) into the natural hydrologic systems.

3.4 Evaluation of possible effluent seepage from tailings ponds (i.e., organic materials and clays), in order to evaluate the potential dissemination of tailings pond liquids into the groundwater and surface water systems, seepage from tailings ponds should be monitored for quality and quantity.

In addition, it is difficult to justify damage to or destruction of the downstream portions of major streams in the mining area, because of their aquatic life importance. It is difficult, however, to visualize how increased sediment from tributary streams draining mining areas can be prevented from reaching, and thus destroying the aquatic life of these rivers. Research is needed to find methods of preventing this.

4.0 ADDITIONAL STUDIES AND INFORMATION

As previously mentioned, lack of hydrologic knowledge in the Alberta oil sands region is a major problem in defining needs and progrmas. Gathering of data is proposed in the projects under category A, and the impact of development is to be studied under those listed in category B. In addition, so that complete evaluation can be made of changes in the hydrologic regime, background information is needed, by those undertaking the research and applying the results, on a number of subjects and on a continuing basis.

4.1 Knowledge is needed of company proposed mining plans, so that effects on the hydrologic regime can be predicted, especially those of dewatering programs and diversion projects. More specifically, information on Syncrude's hydrologic program and mining plans would be valuable, as the first proposed stream diversions and restorations are on this lease.

4.2 Knowledge is needed of hydrologic/soil moisture regimes of different plant communities (not only those native to the area) so that the communities potentially most useful for reclamation can be identified, and component species selected for reclamation work. This would also help determine the hydrologic significance of plant communities existing in the area.

5.0 COMMENTARY

The data-gathering projects should be implemented soon (i.e., 1974 at the latest), as 3 to 5 years of both hydrologic and meteorologic data are the bare minimum needed for prediction purposes. In the last few months (September to November, 1973) this need for early implementation has become more apparent, in view of the potential for increased rate of oil sands development, brought about by current energy problems.

In implementation, primary emphasis should be given to the rivers and streams likely to be affected first by mining and processing operations.

The programs proposed doubtless will be expensive, but are considered necessary if damage to the environment is to be controlled.

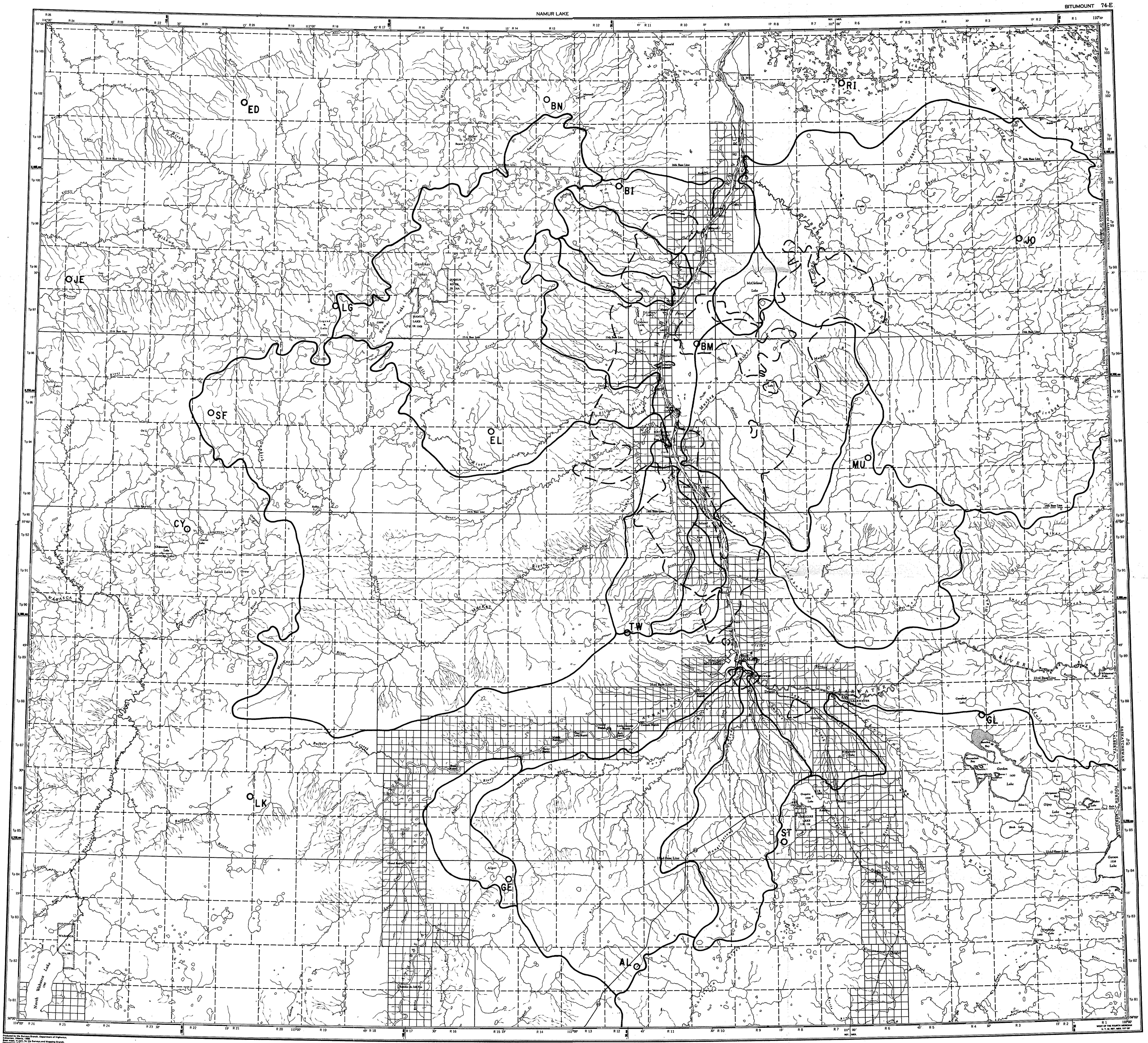
As pointed out on page 2, most projects need more specific formulation, and other research needs will doubtless become apparent as studies continue. Coordination of data-gathering activities, and of the research studies is necessary, on a continuing basis, as both industry (including consulting firms) and government personnel will likely be involved. Integrated programs are needed, without duplication of effort.

To satisfy these needs, two possible routes could be followed:

a) nomination of a hydrologic study coordinator, presumably from a government agency, to serve as supervisor of data-gathering activities, and as the comptroller of collected data; this is visualized as a full-time position;

b) establishment of a standing committee, consisting of representatives of companies active in the oil sands area, and government agency representatives; this has the advantage of offering a forum for discussion, but lacks a continuing focal point for access to data and for resolution of problems.

All projects outlined in this report have in mind the best interests of industry, government and the general population. Thus the basic data gathered should be available to all agencies with valid interests in the region, and should not be restricted by claims of confidentiality; availability should be ensured at an early stage in implementation.



LEGEND:

———— Basin Boundary

— — — Approximate area of bituminous sands having less than 200 ft. of overburden

o........ Alberta Forest Service Lookouts and Ranger Stations.

Alberta ENVIRONMENT

Technical Services Division

HYDROLOGY BRANCH

SUBMITTED	DESIGNED ....
DATE	CHECKED ....
APPROVED	DRAWN ....
DATE	TRACED ....

WATERSHED BASINS IN THE ATHABASCA TAR SANDS AREA

SCALE 1 : 500,000	SHEET 1 OF 1
DATE JULY 20, 1973	FIGURE

APPENDIX 1

HYDROLOGIC RESEARCH PRIORITIES

for the

ALBERTA OIL SANDS

COST ESTIMATE

for the

PROPOSED NETWORK OF HYDROMETRIC STATIONS

J.R. Card
Alberta Environment

M.O. Spitzer
Water Survey of Canada

January 1974

THE PROPOSED HYDROMETRIC NETWORK

The report of the Task Force outlines a basic network of hydrometric stations and the purpose of the program. This network of stations is a starting point and while the following cost estimates cover a five year period for the network as proposed, the approach in operation must remain flexible. This is essential since as information is gathered from the network, present assumptions may require modification and a change in the network may be necessary.

As presently envisioned, the hydrometric network consists of twenty-four stations, eleven of which are established and operational at present, and thirteen which are not in operation and which are proposed for installation early in 1974. It is recommended that the total network be kept functioning for at least five years. Evaluation of the program should be carried out during the five years and modifications made as required, and a major assessment of the program must be made at the end of the five years at which time future plans can be made.

A summary of total costs is presented in the following table. Details of the cost estimates and the related assumptions are provided in the remainder of this report.

SUMMARY OF TOTAL COSTS

		1974-75	1975-76	1976-77	1977-78	1978-79
A.	Operation of 11 existing stations	41,000	44,100	47,500	51,100	55,100
B.	Construction of 13 new stations	111,400	nil	nil	nil	nil
C.	Operation of 13 new stations	147,500	120,200	128,400	137,500	147,100
D.	Related investigations equipment	21,200	nil	nil	nil	nil
E.	Administrative costs	42,200	30,900	33,300	36,100	39,000
	TOTALS	363,300	195,200	209,200	224,700	241,200

A. The Existing Hydrometric Network

Eleven hydrometric stations as shown on the attached maps are presently operational and are the responsibility of Water Survey of Canada as a part of their total network. Although this group of stations is presently funded, the future role of Water Survey of Canada is under review at this time and therefore the cost of operating these stations may become a direct cost to the proposed program. In the very least it is worthwhile to indicate the costs even if they do continue to be funded by Water Survey of Canada so that an accurate assessment of the total costs can be made.

A-1 Annual Operating Costs 1973

These cost estimates are based on actual costs incurred in operating the existing Water Survey of Canada stations in the McMurray region in 1973. They were derived by determining average operating costs for various types of gauging stations. These types include:

	Average 1973 Operating Costs
12 month remote* sediment station	$5,134
12 month remote* hydrometric	$2,934
8 month remote* hydrometric station	$2,200
12 month accessible hydrometric station	$1,511
8 month accessible hydrometric station	$1,133

* accessible only by air

The average costs include salaries and field operating expenses (including aircraft charter, motor vehicle costs, maintenance, etc.) but do not include administrative costs such as office and warehouse rental or administrative staff salaries and expenses.

Of the 11 existing stations useful in the Oil Sands Hydrology Studies, three are 12-month remote sediment stations, four are 12-month remote hydrometric stations, two are 12-month accessible hydrometric stations, one station is an 8-month accessible hydrometric station, and one station is an 8-month remote station.

1973 costs were:

3	(12-R-S)	@	5134 each	=	15,402
4	(12-R-H)	@	2934 each	=	11,736
2	(12-A-H)	@	1511 each	=	3,022
1	(8-A-H)	@	1133 each	=	1,133
1	(8-R-H)	@	2200 each	=	2,200
				Total	33,493

R = Remote
H = Hydrometric
S = Sediment

1973 costs must also include lab analysis of sediment samples. In 1973 lab analysis costs averaged $940/year for a full program station, $670/year for a daily sampling station and $160/year for a partial station. Of the three existing sediment station in the Oil Sands region two are considered full program stations, and one a daily station.

Therefore Lab Analysis Costs:

2	@	$940	=	$1,880
1	@	$670	=	$ 670
			Total	$2,550

The total for 1973 thus becomes $36,043.

A-2 Future Annual Operating Costs

Using the 1973 value as the basic cost, the operation costs for the next five fiscal years are estimated as follows, and incorporate an upward adjustment of 8% per year.

1974-75	$39,000
1975-76	$42,100
1976-77	$45,500
1977-78	$49,100
1978-79	$53,100

A-3 Future Maintenance Costs

The operating costs do not include the costs of maintenance and repair to the existing installations. Since the loss of data due to a damaged station might be critical, it is suggested that a sum of $2,000 be budgeted each year to replace damaged equipment.

A-4 Other Considerations

As pointed out in A-1, the estimated sts do not include administrative costs, nor do they include the capital cost of establishing the stations or of equiping the people presently carrying out the work. These factors must be borne in mind if an agency other than Water Survey of Canada were to undertake a similar network.

A-5 Summary of Costs

	1974-75	1975-76	1976-77	1977-78	1978-79
Operation of 11 existing stations	39,000	42,100	45,500	49,100	53,100
Maintenance of 11 existing stations	2,000	2,000	2,000	2,000	2,000
Total	$41,000	$44,100	$47,500	$51,100	$55,100

B. Additional New Hydrometric Stations
Cost of Construction and Basic Instrumentation

A total of 13 new gauging stations are proposed for installation as illustrated on the attached map. This section includes costs for basic equipment and construction of shelters and measuring structures which are considered universal to all 13 stations, but does not include specialized equipment such as pumping samplers.

B-1 Equipment and Materials Required for each Station

A-71 Recorder	$ 900
Sta-Com Manometers	$1,300
Brytex Shelter	$ 550
Cableway Structure (Average Cost)	$ 750
Incidentals (Cement, Plywood, Bolts, etc.)	$ 300
Total	$3,800

B-2 Access Requirements for each Station

Rather than work out access costs for each station, this section considers the costs of transporting men and materials for an average station. It is anticipated that a helicopter will be utilized for three days at each gauging station site for the transporting of men and materials. It is felt that the construction crew would camp on site until such time as the gauge and cableway were completed.

Average helicopter time at each site 10 hours @ $250/hr. = $2,500.

B-3 Personnel Costs

It is assumed that for an average station a 3-man construction crew could complete the installation about 7 days.

Therefore, 21 man-days @ $60/man-day	=	$1,260
Camp supplies and equipment	=	$ 300
Total		$1,560

B-4 Construction of 13 Stations

With an estimated cost of 3,800 + 2,500 + 1,560 = $7,860 for each station, the total cost of establishing 13 new stations is therefore $102,180. This is to be budgeted only for 1974-75 and will not be repeated in the following four years.

B-5 Reconnaissance

Prior to the construction of the new stations, a helicopter reconnaissance will be required to establish the best location for each station. Approximately 10 days would be required and would involve two men for that period. Costs are estimated as follows:

Helicopter, 10 days @ 750	7,500
Men, 20 man-days @ 60	1,200
Expenses, 10 days @ 50	500
Total	$9,200

C. Additional New Hydrometric Stations
Cost of Operation and Maintenance

Operation of the new hydrometric stations is assumed to be independent of the existing network of Section A. Therefore the following estimates include personnel and equipment to carry out the work without relying upon the people, equipment, or facilities which now exist with Water Survey of Canada. However, it is reasonable to assume that if Water Survey of Canada were to undertake the operation of these new stations, similar expenditures for manpower and equipment would still be necessary for that agency.

C-1 Personnel

To operate the 13 new stations as a separate network would require two full time hydrometric technicians as well as summer student help.

2 man-years @ $12,000/man-year*	=	$25,000
½ man-year @ $ 9,000/man-year	=	$ 4,500
Total		$29,500

*(1974-75 values)

C-2 Helicopter Transportation

Under normal conditions it is anticipated that the hydrometric and sediment program can be carried out at the 24 stations in four days. This would entail using Ft. McMurray as the base of operations, returning to Ft. McMurray each evening. Using this assumption, four helicopter flights have been sketched out on the attacehd map. The average round trip (per day) is some 130 air miles. Thus minimum rates would not be utilized and the minimum of 3 hours flying time would have to be paid each day.

During high flow periods or for that matter, winter periods, one could not carry out the hydrometric and sediment programs in the four days but rather it would take about six days. It is anticipated that four trips would be made during the winter period. Six trips under normal conditions are anticipated.

Annual

6 trips of 4 day duration @ $750/day	=	18,000
3 trips of 6 day duration @ $750/day	=	13,500
4 trips of 6 day duration @ $750/day	=	18,000
Sub Total		$49,500

C-3 Miscellaneous Operating Expenses

This item covers such things as personal field expenses and field operating expenses.

Estimated annual total $5,000*

*Derived from expenses incurred by staff of Water Survey of Canada, Ft. McMurray and vehicle and equipment operating expenses of equipment situated in Ft. McMurray.

C-4 Laboratory Analysis of Sediment Samples

Based upon the same sediment analysis costs as described in section A-1, the cost for this network of new stations will be $6,170.

C-5 Additional Equipment Required for New Station Operation

(a) Hydrometric Equipment

Current Meters -	4 Open Water	@ $ 200	each	=	800
	4 Winter	@ $150	each	=	600
A-reel and bridge frames	2	@ $250	each	=	500
Stop Watches	6	@ $ 20	each	=	120
Computing Rods	2	@ $ 70	each	=	140
Ice Drills and Flighting	2	@ $200	each	=	400
Engineer Level	2	@ $300	each	=	600
Level Rods	2	@ $ 30	each	=	60
Winter Rods	10	@ $ 20	each	=	200
Tag Line	2	@ $ 15	each	=	30
Tag Line (Northern)	1	@ 150	each	=	150
Sounding Weights					
30#	15	@ 35	each	=	525
50#	10	@ 41	each	=	410
100#	2	@ 65	each	=	130

Head Sets	10 @ \$ 15 =	\$ 150
Spare Recorders	2 @ \$900 =	\$1800
Spare Manometers	2 @ \$1300 =	\$2600
	Sub Total	\$9,215

(b) Sediment Equipment

Samplers

DH-48	5 @ \$ 70	=	\$350
D-49	2 @ \$ 310	=	\$620
DH-59	3 @ \$ 150	=	\$450
Pumping Samplers	10 @ \$1600	=	\$16000
Samples Bottles and Cases (10 cases/station)	10 x 13 x 15.00	=	\$1,950
Miscellaneous Equipment			\$2,000
	Sub Total		\$21,370

(c) Other Equipment Requirements

2 Snowmobiles @ 1500 each	3,000
1 4-wheel Drive @ 7000	7,000
2 Light Boats (aluminum or collapsible)	1,500
2 Outboard Motors @ 1000	2,000
Sub Total	13,500

1974 Initial Expenditure for Equipment = \$44,085.

It is estimated that the repair, maintenance, and replacement of equipment will be \$8,000 per year after 1974.

C-6 Sediment Program for Stations Now in Existence but Operated on a Hydrometric Basis Only

Sediment programs of varying degree will be required on four stations which are currently being operated on hydrometric basis only. These stations are:

Poplar Creek near the mouth

Steepbank River near the mouth

Muskeg River near the mouth

Mackay River near Ft. Mackay

Additional annual costs for operating these stations as sediment stations would be about $2,000 per station and therefore 4 @ $2,000 = $8,000.

Plus additional Lab Analysis costs:

2 @ $940	=	$1,880	
2 @ $670	=	$1,340	
		$3,220	$3,220
			$11,220

C-7 Maintenance and Repair to the New Installations

A sum of $2,000 per year after 1974 is to be allocated for repairs and maintenance to the 13 new gauging stations.

C-8 Summary of Costs

	1974-75	1975-76	1976-77	1977-78	1978-79
Personnel	29,500	31,900	34,400	37,200	40,100
Helicopter transportation	49,500	53,500	57,700	62,300	67,300
Misc. Operating Expenses	5,000	5,000	5,000	5,000	5,000
Lab Analysis of Sediment	6,200	6,700	7,200	7,800	8,400
New Equipment	44,100	8,000	8,000	8,000	8,000
Sediment at 4 existing Stations	11,200	13,100	14,100	15,200	16,400
Maintenance of Stations	2,000	2,000	2,000	2,000	2,000
TOTALS	147,500	120,200	128,400	137,500	147,100

D. Related and Supporting Investigations

It is anticipated that the personnel and transportation facilities planned for the hydrometric work could also participate and assist in collecting water quality data, some meteorological data, and lake level data. While this would not increase personnel or transportation costs, there are some expenditures for equipment which are unlikely to be included in other estimates.

D-1 Water Quality

Equipment expenses for this are estimated elsewhere.

D-2 Meteorological Data

Integral precipitation gauge and recorder at 15 hydrometric stations @ $200	$3,000
Snow pillow installations at 5 locations @ $1950	$9,750
Snow Survey equipment	$1,000

D-3 Lake Levels

Equipment for 5 installations @ 1500 $7,500

Total expenditure for this equipment in 1974 is therefore $21,200.

E. Administrative Costs

The total operational staff is proposed as 4 men. A team of 2 men will operate the existing stations and a second team of 2 men will operate the new stations. Daily supervision is not required, but an engineer will be required to devote about 3/4 of his time to the project during 1974 to provide direction to the field operations. Thereafter approximately 1/3 of his time will be necessary to review incoming data and assess the results. Additional temporary manpower may be required in periods of greater activity, such as station construction, but this will not affect administrative costs.

E-1 Office Accommodation

Office Space 1200 sq.ft. @ 7.00/yr.	$8,400
Utilities and Telephone	$4,800
Furnishings, 5 desks and Related Equipment	$5,000 (1974 only)

E-2 Warehouse Space

Storage of boat, truck, equipment, work area 2,000 sq.ft. @ $3.00/yr.	$6,000

E-3 Management

Engineer - 1974	Salary 75% of 16,000		$12,000
	Expenses $2,000		$ 2,000
		Total	$14,000
1975	Salary 30% of 17,600		$ 5,280
	Expenses $600		$ 600
		Total	$ 5,880

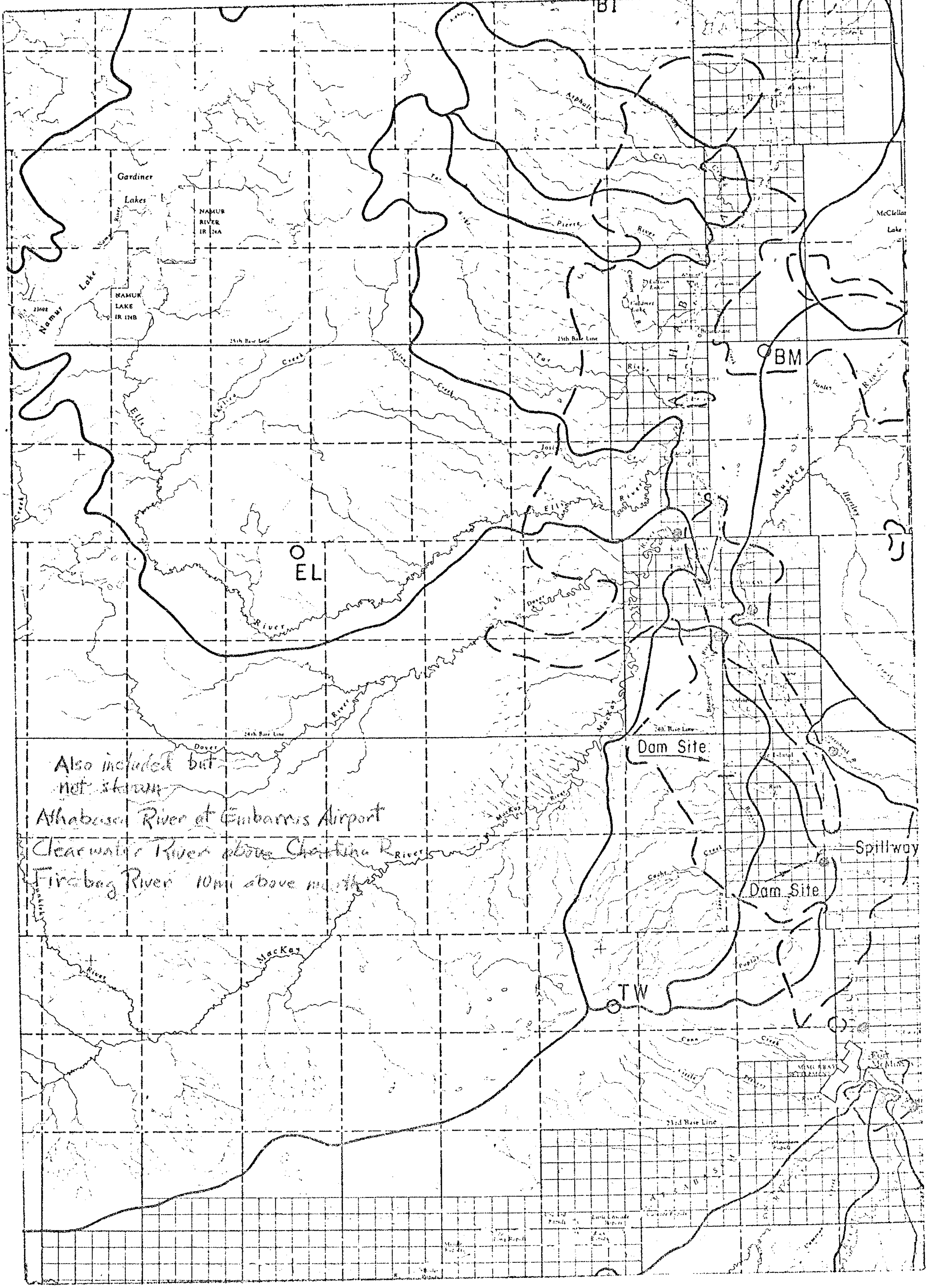
- Administration of payroll, purchasing, and accounting cannot be estimated without knowledge of which agency would be responsible.

- Secretarial services are estimated to require a clerk-typist at ½ time - $4,000

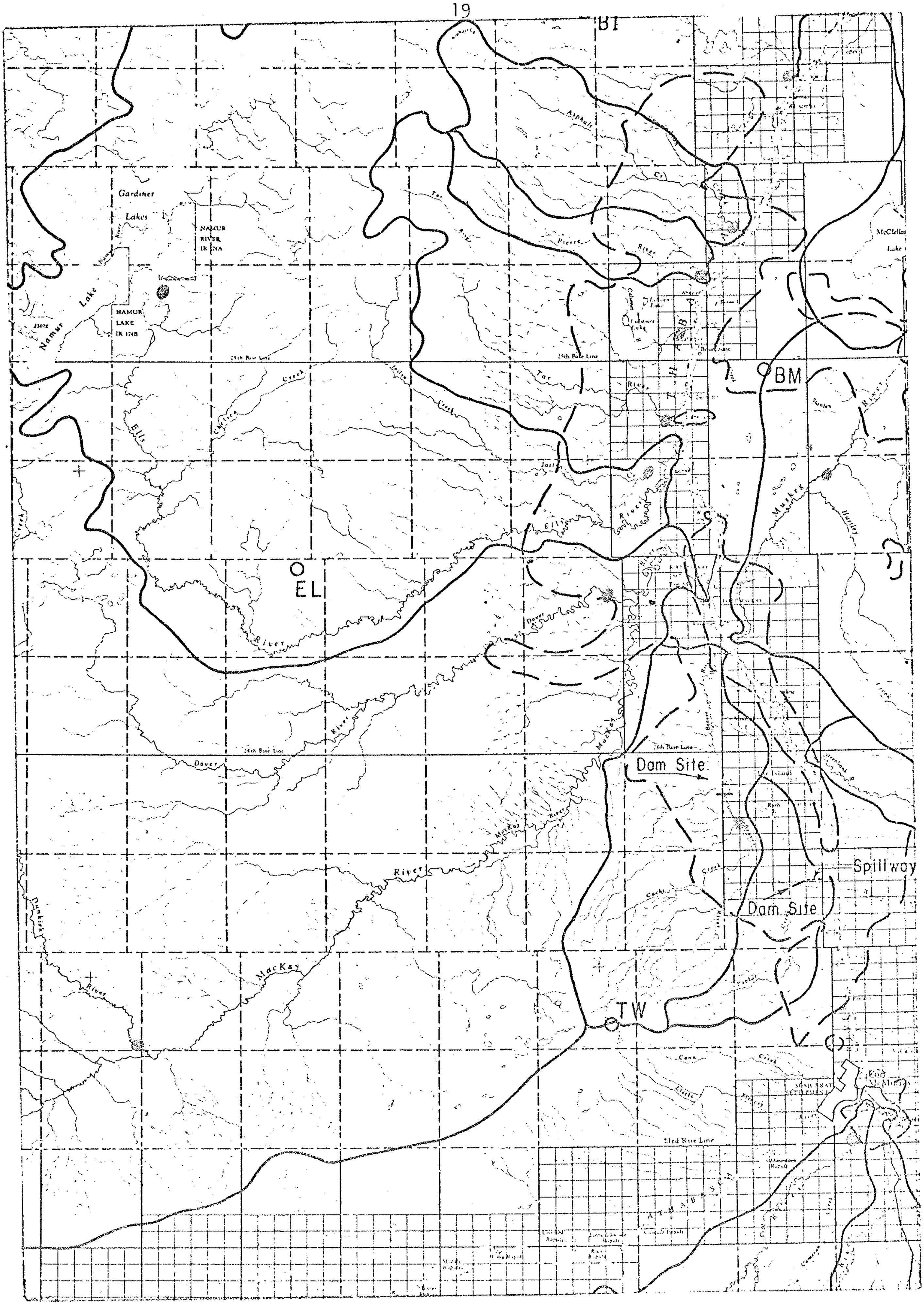
E-4 Summary of Administration Annual Costs

	1974-75	1975-76	1976-77	1977-78	1978-79
Office Accommodation	18,200	14,200	15,300	16,600	17,900
Warehouse Space	6,000	6,500	7,000	7,600	8,200
Management	18,000	10,200	11,000	11,900	12,900
TOTAL	42,200	30,900	33,300	36,100	39,000

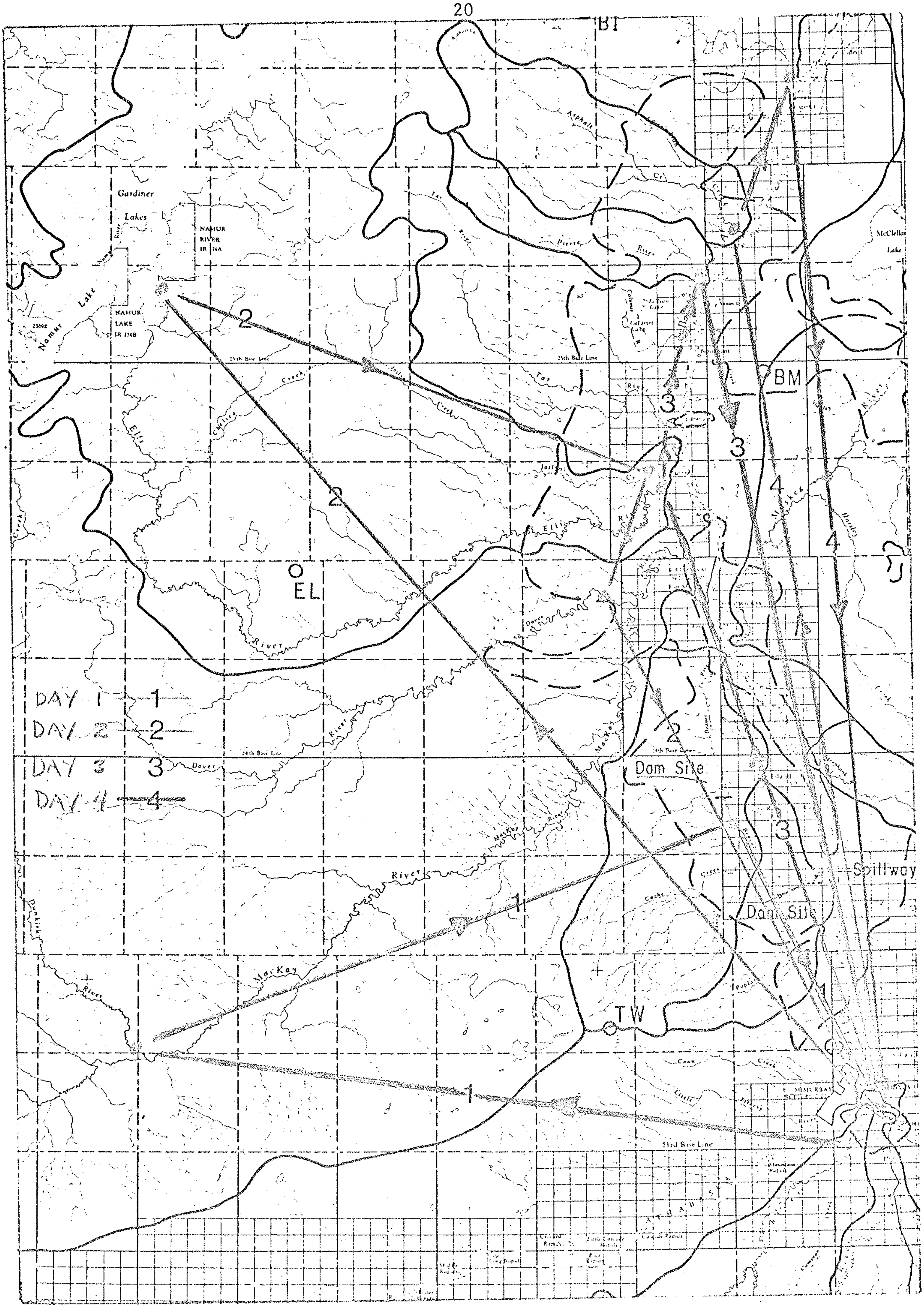
(Cost estimates increased by 8% each year)



EXISTING HYDROMETRIC STATIONS



NEW HYDROMETRIC STATIONS



HELICOPTER FLIGHTS TO NEW HYDROMETRIC STATIONS

APPENDIX 2

COST ESTIMATES FOR WATER QUALITY MONITORING OF THE ATHABASCA OIL SANDS AREA

M. O. Spitzer
Water Survey of Canada

Introduction

As the development of the oil sands progresses, huge tracts of land will be disturbed, immense tailings ponds will be constructed to trap plant effluents, processing plants will emit gases to the atmosphere and the human population will increase considerably. All these factors may effect the water quality of the surrounding and downstream regions. Thus it is essential that the streams, lakes and groundwater be quality monitored. It is necessary to begin this monitoring prior to development to determine background quality so that the effects of development can be ascertained and to ensure that water quality standards are being met.

To date a very limited water quality program has been carried out in the oil sands region. River water quality data are available only for the Athabasca River below Fort McMurray and for the Clearwater River near Draper. The Peace-Athabasca Delta project conducted water quality monitoring programs in the Lake Athabasca area and background data is therefore available for the region downstream of the mineable oil sands. Some analysis of GCOS plant effluents and stack emission analysis have also been made. However, there is no background water quality data available for streams flowing through the mineable areas, for the groundwater in the mineable areas nor for the lakes in the region.

Thus, this report on cost estimates will outline the locations where water quality monitoring is required, the types of parameters which should be monitored, the cost of analysing the samples for the concentrations of those parameters and the annual costs involved in conducting the water quality monitoring program.

Water Quality Monitoring Sites

To determine the effects of the oil sands development on the Athabasca River, and as a result its possible effects on downstream regions such as the Peace-Athabasca Delta, water quality monitoring programs must be conducted on the Athabasca River itself, both above and below the mineable oil sands area. Streams which flow through the oil sands region also require monitoring in order to determine the chemical constituent loadings attributable to each Athabasca tributary. Thus, if certain constituent concentrations exceed the prescribed limits, the offending area can be readily tracked down and appropriate remedial measures taken.

The huge tailings ponds for each plant are designed to trap the total effluent from the plant with the only method of escape of the liquids by evaporation or percolation. The waters in these tailings ponds are liable to have high concentrations of certain parameters and it is essential to determine how the percolation of these waters effects the groundwater quality.

Stack emissions may find their way into the surface waters of the surrounding area via media such as wind or rain, necessitating monitoring programs on nearby lakes and streams.

Following is a listing of sites where water quality monitoring programs should be conducted. In most instances these sites are coincident with stream gauging sites that are currently in operation or that have been recommended for installation.

1. Athabasca River above Fort McMurray
2. Athabasca River below Fort McMurray

3. Athabasca River at Embarras Airport
   (or possibly at a site just below the Firebag River)
4. Poplar Creek near Fort McMurray
5. Beaver River near Fort McMurray
6. MacKay River near Fort MacKay
7. Dover River near the mouth
8. Ells River near the mouth
9. Joslyn Creek near the mouth
10. Tar River near the mouth
11. Pierre River near the mouth
12. Calumet Creek near the mouth
13. Asphalt Creek near the mouth
14. An unnamed creek north of Asphalt Creek
15. Firebag River near the mouth
16. Muskeg River near the mouth
17. Muskeg River above Hartley Creek
18. Steepbank River near Fort MacKay
19. Clearwater River at Draper

Some of the streams, outside of the surface mineable area but in the near vicinity, should also be monitored for water quality changes but with a reduced monitoring schedule. Included in this list should be:

1. Hangingstone River at Fort McMurray
2. Horse River near the mouth
3. Dunkirk River near the mouth
4. Ells River below Cardinal Lake

Lakes which require water quality monitoring are:

1. Namur Lake
2. Gardiner Lakes
3. Legend Lake

4. McLelland Lake
5. Gregoire Lake
6. Gordon Lake

It is also required that water quality monitoring of the Lake Athabasca region be continued.

As far as groundwater quality monitoring is concerned it has been recommended that samples be taken at each of the wells. Alberta Research has recommended that 25 piezometer nest sites be installed in the region. Each of these piezometer nests has an average of 5 wells. (For details on the groundwater network consult Alberta Research report entitled "Hydrogeological Evaluation of the Athabasca Oil Sands Area, Alberta, a Project Proposed by the Groundwater Division.") Once the initial 25 nests have been installed, 5 additional nests are to be installed in each succeeding year.

Parameters to be Monitored and Individual Parameter Analysis Costs

Perhaps the most important aspect of water quality monitoring in the oil sands region is the analysis for oils and greases. The streams in their natural state carry a certain amount of bitumen which does not appear to cause a problem with regard to toxicity, taste or odour, but with development these concentrations require monitoring to ensure they do not exceed water quality standards. It is therefore essential to monitor this parameter in the water and in fact, in certain locations, the suspended sediments should be analysed for bitumen content.

In addition to the normal parameter analysis for water quality samples, analysis should be carried out for heavy metals and trace elements, especially for those samples taken in the first year and then occasionally for samples taken as development progresses. The reason for concentrating on these parameters is that the oil sands appear to have relatively high concentrations of some of these elements (i.e., vanadium) and they can be emitted via the liquid effluent or in the fly ash. Also very small concentrations of some of these elements can be detrimental to the water quality.

The pH of water is a parameter normally monitored and in this case is very important in that the present processing techniques use sodium hydroxide resulting in effluent discharges that have a very high pH value.

Following is a list of parameters that require monitoring, and the unit cost of analysing the water quality sample for each of these parameters. The unit costs are based on present analysis costs as computed by the Water Quality Branch, Environment Canada. The costs include labour costs to perform the analysis, sample preparation costs and cost of chemicals and glassware but do not include capital cost (equipment purchase and replacement) nor do they include building rental or equipment rental costs.

Parameter	Unit Analytical Fee ($)
* Alkalinity	0.75
* Arsenic	2.50
Boron	1.45
BOD	4.55
* Calcium	0.85
Carbon (Total)	0.85
Carbon (Organic)	0.85
Carbon (Inorganic)	0.85
* Chloride	0.75
Colour	0.55
* Conductance	0.55
COD	2.45

* Parameters for groundwater sample analysis

Parameters	Unit Analytical Fee ($)
* Fluoride	1.30
* Hardness (Total)	1.30
* Magnesium	1.30
Nitrogen (NH_4)	1.40
* Nitrogen (NO_3 and NO_2)	0.75
Nitrogen (Total Kjeldahl)	4.50
* pH	0.55
* Phenol	1.35
Phosphorous (Ortho)	0.75
Phosphorous (Inorganic)	1.40
Phosphorous (Total)	1.40
* Potassium	0.75
Silica	0.75
* Sodium	0.75
* Sulphates	0.85
Turbidity	0.55
Oil and Grease (In Water)	35.00
Oil and Grease (In Sediment)	75.00
* Metals (In Water)	each 2.35
Metals (In Sediment)	19.00 (1)

* Parameters for groundwater sample analysis

(1) Analysis for metals in sediment $19.00 for first - each metal thereafter $1.50/metal

The initial samples should be analysed for the following heavy metals and trace elements.

Aluminum	Iron	Selenium
Barium	Lead	Strontium
Beryllium	Lithium	Thellium
Cardium	Mangenese	Tin
Chromium	Mercury	Vanadium
Cobalt	Molybdenum	Zinc
Copper	Nickel	

Annual Costs

This section details the anticipated annual costs of conducting a monitoring program as outlined. The major expenditure will be the costs involved in the analysis of samples, as it is anticipated that the required samples will be collected by those agencies involved in the groundwater monitoring and by those conducting the hydrometric and sediment operations. Thus, in this report, no provision has been made for additional staff to collect samples nor for transportation costs such as for aircraft charter.

For the first year it has been recommended that 2 samples per month be taken at each of the stream water quality monitoring sites. In addition 4 samples per year are to be taken at each of the groundwater wells and 2 samples per year at each of the indicated lakes. The samples for the first year should be analyzed for all the indicated parameters in order to ascertain which ones are relevant. Samples in subsequent years will probably have a reduced parameter anlysis schedule and in fact, the sample frequency can probably be significantly reduced.

Following is a breakdown of the costs of monitoring water quality of the region for the first year of complete operation:

A. Stream and Lake Samples

19 major stream monitoring sites	@ 20 samples/yr.	=	380 samples
4 misc. stream monitoring sites	@ 2 samples/yr.	=	8 samples
6 lake sites	@ 2 samples/yr.	=	12 samples
	Total	=	400 samples

Analysis costs for one sample = $110

Total Analysis Costs for Surface Water Samples .... $ 44,000

B. Sediment Quality Analysis

3 sites on Athabasca River @ 20 samples/yr. = 60 samples

Cost for sediment analysis for trace metals and oil = $125

Total Sediment Quality Analysis Costs .... $ 7,500

C. <u>Groundwater Quality Analysis</u>

25 piezometer nests at an average of 5 wells each = 125 wells

4 samples/yr. for each well = 500 samples

Analysis Costs for Groundwater Samples = $65

Total Analysis Costs .... $ 32,500

D. <u>Special Equipment Costs</u>

Include costs for equipment for on site tests such as pH, conductivity, temperature and dissolved Oxygen .... $ 6,000

E. <u>Investigative Costs</u>

This cost is to account for a professional (chemist or environmentalist) devoting part time to investigating analysis results with the intent of re-designing sample schedules and parameter analysis.

1/2 man-year @ 20,000/man-yr. .... $ 10,000

Total $100.000

The total costs for the first complete year of water quality operations would thus be $100,000. This cost only reflects laboratory analysis costs with some provision for field monitoring equipment and a part-time investigative officer. It does not include capital costs such as for major analysis equipment purchase or rental, nor does it include laboratory building rental costs.

The first year analysis costs will probably be significantly greater than those of subsequent years. In the first year of operation many samples must be taken and analysed for a wide variety of parameters in order to determine the natural variation in the concentration of each parameter and to determine the significance of each of these parameters. A more efficient program of sampling frequency and parameter analysis can be made after the first year of operation and it is expected that the number of surface water quality samples will be significantly reduced to an estimated 250 samples. Some of the parameters analysed for in the initial samples will prove to be irrelevant thus reducing laboratory analysis costs (particularly some of the heavy metal analysis may prove to be a waste of time). Thus, an estimate of $80 average per sample analysis may prove to be more realistic in the second year of operation.

The sediment quality sampling frequency would probably be reduced slightly after the first year of operation and some of the heavy metal analysis could be eliminated. Second year monitoring could be estimated at 50 samples at $110 per sample analysis.

The second year of groundwater quality monitoring would see an increase in the number of samples taken (5 additional piezometer nests installed each year) at a slight reduction in analysis costs because of reduction in heavy metal parameter analysis. Probably an average analysis cost of $60 per sample.

Equipment and investigative costs will probably not vary greatly from year to year although a decreased field equipment purchase is expected in the second year.

On the following page is a table depicting annual water quality monitoring costs.

These annual estimated costs could differ considerably should the monitoring frequency or parameter analysis schedule deviate considerably from that which is anticipated.

Annual Water Quality Monitoring Costs
(Number of samples in parenthesis

Year / Item	1974-75	1975-76	1976-77	1977-78
A. Surface Water Monitoring	(400) $ 44,000	(25) $ 20,000	$ 22,000	$ 25,000
B. Sediment Quality Analysis	(60) 7,500	(50) 5,500	6,000	7,000
C. Groundwater Quality Analysis	(500) 32,500	(525) 31,500	(550) 33,000	(575) 36,000
D. Equipment Costs	6,000	2,000	2,000	2,000
E. investigating Costs	10,000	10,000	10,000	10,000
Total	$100,000	$ 69,000	$ 73,000	$ 80,000

APPENDIX 3

COLLECTION OF BACKGROUND METEOROLOGICAL DATA

Basic meteorological data are needed to assist hydrological forecasting, both regionally and for each gauged basin. The Climatologic Research Task Force (see that report, P.W. Summers, Chairman) was informed of and has taken into account most of these needs, in formulating its meteorological research needs and network, thus no detailed estimate is presented here.

APPENDIX 4

PHYSIOGRAPHIC ANALYSIS

R. Gerard
Alberta Research

1. Objective

Physiographic analysis, with the hydrological application in mind should be carried out on *all* basins in the mineable area and for the Clearwater, Christina and Hangingstone River basins.

A file should be prepared for each basin which includes maps of each of the parameters considered significant at a reasonably large scale. These maps are required to allow an appraisal of conditions affecting hydrologic response in the area; to allow a judicious selection of typical basins, and to allow an appraisal of the applicability of information derived from the three catchments with long runoff records to the other basins affected by development.

Items that should be considered include:

a) Vegetation type -- e.g., muskeg, spruce -- these provide good indications of subsoil conditions as well as affecting significantly basin response and sediment production.

b) Slopes and slope stability -- this has an obvious effect on flood discharge and sediment production.

c) Soil type and surficial deposits -- does not have such a large effect on flood discharge but probably has considerable effect on groundwater, yield and sediment production.

d) Drainage density -- only an indication of the other factors above but should be kept in mind -- has a significant affect on flood flows.

e) Elevation -- affects input to the basin rather than basin response.

f) Locations of mineable tar sand bodies, their isopachs, overburden ratios, plant feed and reject material thicknesses, and so on.

g) Stream characteristics, including slope profiles, bed types, and so on.

These items and others are discussed below and cost estimates (for all catchments) listed. The list of major catchments to be considered are:

(i) Large (> Hangingstone catchment)

Ells[2], Dunkirk[2], Dover[2], MacKay[1], Horse[2], Hangingstone[1], Christina[1], Clearwater[1], Steepbank[1], Muskeg[1], Marguerite and Firebag[1].

(ii) Small

Redclay, Noname[2], Eymundson[2], Pierre[2], Calumet[2], Tar[2], Chelsea, Joslyn[2], Snipe, Beaver[1], Poplar[1], Conn[2], Saline[2], Saprae[2], Clarke, Wood, Hartley[2] and McLelland Lake.

COST ESTIMATE

A. Catchment characteristics

1. Elevation

Topographic maps at a scale of 1:250,000 with contours at 100 ft intervals exist for the complete Oil Sands area. These may prove sufficient for the larger catchments (Firebag, Ells, MacKay, etc.) but will be insufficient for smaller ones. They would also be insufficient for detailed planning around potential mining areas.

At present 1:50,000 scale topographic maps with contours at 25 ft intervals cover only a 1° longitude band approximately centred on the Athabasca River (about 10 - 20 miles on either side of the river) and the most important of these are only preliminary maps.

It is therefore *strongly* recommended that efforts be made to have the Federal Surveys and Mapping Branch to consider the preparation of 1:50,000 maps for NTS map areas 74D, 74E, 84A, and 84H as top priority. No estimate

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1 These streams should be given priority because of their existing hydrometric stations.

2 Because of the proposed hydrometric stations or imminent development on these streams they should come next in priority.

is given for this item.

From a topographic map of suitable scale an area - elevation diagram should be prepared for each catchment. In addition to being a useful summary of the topography this is needed for snow melt calculations and as input for an average catchment slope calculation.

(i)	Technician for 30 days		$ 1,200
(ii)	Draftsman for 15 days		600
(iii)	Reproduction, typing, etc.		200
		Sub total	$ 2,000

2. Catchment slope

This information is required for streamflow calculations (overland flow) and is also generally related to sediment production. In addition to the topographic maps described above a contour plan of the general slopes in each catchment should be prepared. Suggested groups for outlining are <0.5%; 0.5 - 2%; 2 - 5%; 5 - 10%; >10%.

(i)	Technician for 15 days		$ 600
(ii)	Draftsman for 15 days		600
(iii)	Reproduction, typing, etc.		200
		Sub total	$ 1,400

3. Catchment aspect

Again this feature of a catchment is related to snow melt. It is best described by the orientation and slope of a plane 'lid' fitted to the rim of the catchment (watershed).

(i)	Technician for 5 days	$ 200

4. Vegetation

Hydrologically, vegetation is a very significant feature of the catchment and either indicates or affects a multiple of facets such as subsoil condition, evaporation, interception, albedo, snow accumulation, snow melt and sediment production. The dominant hydrologically significant associations should be mapped for each catchment from the detailed vegetation maps available from Alberta Lands and Forests. The proportion of each group in the catchment should be listed.

(i)	Technician/draftsman for 50 days		$ 2,000
(ii)	Reduction, reproduction		200
		Sub total	$ 2,200

5. Soils

These will obviously have a large effect on a catchment's hydrological response. A map of the major soil types in each catchment is required together with a listing of the hydrologically significant features of each type. These features should include at least grain size distribution, organic content, permeability, infiltration capacity, field capacity and wilting point moisture contents. This information should be taken from a general soil and surficial geology survey that should be carried out for the Oil Sands area. This survey will of course have more universal use than for hydrology alone. Unfortunately only a very limited exploratory soil survey exists in the catchment areas of concern and the surficial geology of the Algar and Namur Lake map areas (NTS.84A, 84H) has not been completed. It will be expensive to get more detail than is now available but, although the expenditure cannot be justified on hydrological grounds alone, it is nevertheless highly recommended. On the basis of other soil and surficial geology surveys it is estimated that a soil/surficial geology survey of the 4 map areas of interest will be about $100,000. A surficial geology survey only of the two map areas not yet covered is estimated to cost $50,000.

(i)	Soil/surficial geology survey for map areas 74D, 74E, 84A, 84H	$100,000

6. Drainage density

Although somewhat arbitrary in its definition and reasonably correlated with parameters already listed, this feature and its distribution provides a convenient summary of the catchments drainage system which will obviously have an effect on its hydrological response. Maps should be prepared showing the general variation of this parameter (area/(length of channels)^2) over the catchment. The average density for the catchment should also be tabulated. The drainage density in any area can be determined from existing 1:63,360 planimetric maps.

(i)	Technician for 30 days	$ 1,200
(ii)	Draftsman for 10 days	400
(iii)	Reproduction	200
	Sub total	$ 1,800

7. Distance or time of travel distribution

This gives a good indication of the response time of the catchment. An *area - distance* diagram should be prepared initially. Then if the appropriate channel distances are multiplied by, say, $1/(\text{area}^{1/4} \times \text{slope}^{1/2})$ it should give a reasonable approximation to an *area - time* diagram.

(i)	Technician for 30 days	$ 1,200
(ii)	Draftsman for 15 days	600
(iii)	Reproduction, typing, etc.	200
	Sub total	$ 2,000

B. Stream characteristics

The characteristics of the stream are, of course, an essential feature of the catchment and give qualitative indications of stream flow history, sediment production and aquatic habitat as well as being quantitatively necessary for discharge calculations.

1. Longitudinal stream profile

These can be obtained from topographic maps.

(i)	Technician/draftsman for 30 days	$ 1,200
(ii)	Reproduction, typing	200
	Sub total	$ 1,400

2. Reach surveys

These include detailed surveys of local stream slope, cross sections, bed and bank material, high water and ice marks of 1 to 3 short but representative lengths of each major stream. This would involve some 40 surveys in all.

(i)	Field crew of 2 technicians for 20 weeks	$12,000
(ii)	Equipment rental	2,000
(iii)	Helicopter time for access to remote sites - 40 hours	8,000
(iv)	Technician/draftsman for data reduction and presentation - 25 weeks	5,000
(v)	Reproduction, typing, materials	1,500
	Sub total	$28,500

C. Summary of cost estimates

Catchment characteristics (without soil/surficial geology survey = $100,000)	$ 9,600
Stream characteristics	29,900
Total cost	$39,500

Total personnel requirements:

Technician	2 man years
Draftsman	1/3 man year

Note that administrative, secretarial, and accommodation costs have not been included in these estimates.

APPENDIX 5

HYDROGEOLOGICAL EVALUATION OF THE ATHABASCA OIL SANDS AREA, ALBERTA

a

PROJECT PROPOSED

by

THE GROUNDWATER DIVISION
RESEARCH COUNCIL OF ALBERTA

prepared by

D. A. Hackbarth
and
József Tóth

October 1, 1973 EDMONTON, ALBERTA

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INTRODUCTION

Generally, groundwater and related problems figure as important items in the development of any area that involves the physical disturbance of the Earth's crust. It may be anticipated that the projected mining and processing of the oil sands, the reclamation of land and the development of industrial plants and settlements in northeast Alberta also will be subject to the same rule. Groundwater and its occurrence may play a role of variable importance in problems involving: water supplies of towns and processing plants, dewatering of overburden and pressure relief of mine floors, in situ recovery techniques, disposal and storage of solid and liquid industrial waste products on the surface or underground, restoration and revegetation of disturbed land and so on.

In order to cope successfully with groundwater-oriented problems in the oil sands area hydrogeological investigations will have to be conducted both prior to and during any large-scale exploitation. This need has been recognized and expressed on various occasions and by several agencies including oil companies, consulting firms and government organizations. Particular importance is attached to an early development of the understanding of the groundwater conditions. Surprises of unexpected shortages, unwelcome abundances, unforeseen flow directions and other unanticipated conditions of groundwater have been notorious for their adverse effects on the technical operations and economy of many a surface mining project.

In spite of the generally acknowledged validity of these considerations no concentrated effort has yet been made to initiate a systematic and comprehensive groundwater study of the oil sands area, with the exception of the hydrogeological reconnaissance mapping projects of the Groundwater Division since 1971. This can probably be attributed to the difficulty to formulate a program that would satisfy both local and regional requirements and to the high cost involved. This proposal is thought to present a solution for this dual problem. It is based on the philosophy that a satisfactory and complete understanding of the groundwater conditions requires the combination of both regional and local studies. For an efficient and effective combination the regional studies will have to provide the basic framework while local studies will be fitted in when and where necessary. It is, therefore, mandatory that regional work precedes local development. Thus, it is suggested that regional investigations be a governmental responsibility and started immediately while local studies should be done by the developing companies in conjunction with their mining operations. The results of the local studies would be incorporated directly into the regional framework. This way every participant would be doing work within the scope of his own technical expertise, would have a direct interest in doing his share and would directly benefit from the results of other programs.

PROPOSAL

By means of the present document the Groundwater Division of the Research Council of Alberta proposes to undertake and execute a comprehensive study of the hydrogeology of the Athabasca Oil Sands Area. The study is proposed to start in April, 1974, would continue for five years, till 1979, with total estimated costs in the amount of $1,295,706. A central clearing house for hydrogeological information is suggested to be established and operated by the Groundwater Division.

The objective of the investigation would be to develop a hydrogeological response model for the oil sands area based on facts. The model thus would provide a reliable framework which is necessary for the solution of any technical problem related to the area's development and involving groundwater.

OUTLINE OF THE HYDROGEOLOGICAL MODEL

The model would consist of hydrogeological cross sections, electrical analogues and digital computer simulations. It would portray the:

- lithologies, hydraulic parameters and distributions of the hydrostratigraphic units;
- the geometries and intensities of the natural groundwater flow systems;
- the natural distribution of chemical constituents and temperature of groundwater;
- the natural variations of the groundwater regime parameters with respect to time.

PROPOSED WORK

The model would be useful in predicting the effects on the groundwater regime of physical and chemical disturbances caused by mining and related operations.

Summary of the proposed work

1. Compilation and preliminary analysis of available information (geologic, hydrogeologic, airphoto, company data, etc.). 1974 April - October.
2. Establishment of a data bank (manual and computer operated) to accommodate information also from outside sources. 1974 April - October.
3. Hydrogeological field mapping (reconnaissance). 1974 May - October (supplementary work during three subsequent summers).

4. Establishment of a comprehensive network of reference observation-wells, piezometers, and hydrogeological data points, including aquifer testing. 1975 January - March.

Supplementary additions:

1976 January - February; 1977 January - February; 1978 January - February.

5. Evaluation of the components of the model including electrical analogues,and synthesis of information.

1975 April - 1976 March (first date of tangible results).

Updating of the model by incorporating results of specific local studies by RCA, Industry, and other agencies: 1976 October - 1977 March; 1977 October - 1978 March; 1978 October - 1979 March. Project ends in March 1979, unless continuation is required.

6. Monitoring.

1975 May -- and onwards.

7. Conception and execution of follow-up subprojects, ancillary projects, with specific objectives (possibly in direct response to requests from industry, Government Departments, and so on).

1976 March and onwards.

A tabled summary of the timing for the various work items is given in figure 1.

Details of the proposed work

1. Data compilation

Prior to any major field installations it will be necessary to collect and interpret all of the available relevant information. This includes geologic and hydrogeologic information, airphotos, and company data.

2. Data bank

Correlative to number one above is the establishment of a data bank suitable for retaining in an orderly fashion all information collected under the auspices of the project. The file will probably operate under an optional combination of manual and automatic data storage and retrieval.

This file will be open to the public for perusal at Council just as is our current Central Data File.

3. Field mapping

Field reconnaissance during the summer of 1974 will take the form of selection of piezometer nest sites and modes of access to them. Criterion for site selection are outlined in number four below.

Supplementary hydrogeologic field mapping of surface features related to groundwater flow will take place in the summer of 1975. This will allow preliminary forms of the groundwater model to be used to help locate and identify the surface features.

4. Observation well network

General

A series of approximately 25 piezometer nest sites would be installed at sites noted on figure 2. (This map is intended for approximate budget purposes and does not imply specific site locations.)

The locations and number of nest sites were chosen to give adequate coverage of the oil sands area, both horizontally and vertically. Thus, both potentiometric maps and cross sections can be generated.

Actual nest sites would be chosen on the basis of:

- lease boundaries -- assuming that future disturbance of a site would be at a minimum there;
- muskeg distribution;
- existing permanent cultural features;

- consultations with ERCB, Mines and Minerals, Lands and Forests and leaseholders.

All sites will be selected so as to be as permanent as possible. The useful life span of the instrumentation might be in excess of 20 years.

Instrumentation over the entire area is deemed necessary at this time even though some techniques for development seems to be years in the future. There are two reasons for this: 1. only through a complete hydrogeologic picture can environmental concerns be adequately assessed; and 2. background data prior to development is essential. Delay at this time will lead to the same situation which now exists within the mineable area -- namely that development is imminent and no background data exists.

Work procedure

Most work must take place during the winter. The program costs have been set up to account for two drilling rigs working at the same nest site or at adjacent sites. Camp facilities could thus be provided from a single site.

It is estimated that the drilling of 62,750 feet of drill hole will take 126 rig-days of actual operation. Added to this figure is 24 rig-days of non-drilling operations (moving, standby, etc.). It is estimated that the operations would take about 75 days using two rigs at once.

Dozers must be provided for clearing trails, moving camp, and hauling pipe. The rental of two dozers has been included for various safety and convenience reasons. Operators for the dozers would be hired directly and are budgeted for under "Personnel."

Well completion

Individual wells would be completed in most of the major formations above the Devonian at each site. Completions in the Methy Formation and just above the Precambrian would take place at four sites. Approximate depths of the individual completed wells is indicated on figure 1, along with a site number.

All wells at a nest site would be constructed as individual units with 4 1/2 inch insert-joint well casing cemented into place. Completion in bedrock units would be open hole for five to 10 feet in a suitable part of the formation. Completion in the drift would be accomplished with five-foot stainless steel screens.

Instrumentation and monitoring

Type F Leupold-Stevens recorders equipped with monthly clocks will be placed at each well to monitor water levels.

Monthly access to the piezometer nest sites would be via helicopter. This cost is included under transport in the budget breakdown and also represents a major portion of the continuing cost.

It is suggested that initially water samples be obtained on a quarterly basis from each well.

Aquifer testing

A necessary feature of the proposed groundwater model is factual information on permeabilities. The utilization of a separate aquifer testing crew is desirable to reduce rig time costs. This crew would be equipped with: 1) a trailer-mounted generator, 2) a 4x4 three-quarter ton truck equipped to raise and lower pumps, 3) several submersible pumps.

Immediately upon completion of a well at a piezometer nest site this crew would start a 24- to 48-hour pump test. At this rate they would end up slightly behind the drilling but would be close enough to use the camp facilities. The personnel necessary for this task are discussed later.

Elevation survey

Precise vertical control is necessary to adequately assess the water level measurements obtained from the observation wells. An approximate price for this service from a commercial surveying company is included in the budget.

Timing

It is necessary for the drilling and instrumentation to take place during the winter of 1974-75. This will allow adequate time for coordination of activities and delivery of equipment.

A portion of the summer of 1974 will be spent in the field selecting the actual piezometer nest sites. Helicopter time has been budgeted for this purpose.

5. Evaluation of the model

As soon as the basic network of observation wells is installed data will begin to accumulate. This data will form the basis for the model which should be available in preliminary form by March 1976. The model will be reviewed and refined during the later part of each of the next three subsequent winters. The final model should be available in March 1979.

During the period of generation of the model it will be performing a role in groundwater-related problems of the oil sand area.

The project is scheduled to end as of March 1979. In all probability only this specific phase of the project will end as of that date. It is expected that utilization of the model will become quite great by that time and that offshoot investigations will have evolved.

6. Monitoring

Monitoring of the observation well network will be by means of continuously recording, float-driven, water level recorders. These will be equipped with clocks which necessitate chart changes once a month. Access will be most efficiently accomplished by helicopter. The cost of this represents a significant portion of the continuing costs and will remain even after the official termination of the project in spring 1979.

Water samples will be collected from all piezometers four times during the year during the lifetime of the project.

7. Follow-up projects

It is expected that major follow-up projects, financed by other groups, and arising as a result of the model and its observation well network, would begin to materialize after the spring of 1976. If warranted, the Groundwater Division may consider to undertake projects of this nature after that time.

PERSONNEL

Major additions to current divisional staff will be necessary to handle a project of this magnitude. Most of the additions could be appointed on a temporary basis.

The principal researcher, a professional hydrogeologist, would devote the major portion of his time to work on this project. Development of the model would be his major responsibility.

During the initial phases of the project an assistant professional hydrogeologist would be necessary to supervise field operations and ensure delivery of equipment and supplies. In later phases of the project this individual would work more and more with inquiries from outside groups. This responsibility would extend to conducting or organizing field work for these outside groups. A major responsibility would be to ensure that instrumentation by industry would be compatible with the existing government network -- he might also assume responsibility for collection of the industry-generated data.

The continuing technical employees are necessary to various phases of the project:

The Technician III would be charged with actual field supervision of the drilling operations and subsequently would monitor and care for the observation well network.

The Technician II's would conduct pumping tests, provide office support and possibly do work on the Data File.

The Technician I would work solely with the Data File.

Temporary employees would be involved in the following: Supervision of the two drilling rigs would require one technician per rig for each shift. To this must be added two additional technicians as "swing" men, thus allowing each technician to have every third week off. The total requirement for technicians for drilling supervision is eight. The aquifer testing crew would operate on the same four-man basis with two men from continuing staff and two temporary. Thus, the total technical base required would be 12 men.

As mentioned earlier, two dozer operators would be required for about three months.

A summary of the required personnel is given under the next heading: Budget.

BUDGET

A graphical breakdown of the total budget into salaries and operational expenses on a monthly basis is given in figure 3.

1974-75 Budget
April - October

	$	$
PERSONNEL		
Professional		
1 - Principal researcher	20,000	
1 - Assistant researcher	15,000	
Technical		
1 - Technician III	10,000	
2 - Technician II	16,000	
1 - Technician I	7,000	
Temporary		
8 - Technician I (logging of drilling operations)	56,000	
3 - Technician II (aquifer testing)	24,000	
2 - Bulldozer operators @ $1,000 per month for 3 months	6,000	
TOTAL		154,000
VEHICLES		
Purchase		
1 - 4x4 pickup truck equipped with winch, small derrick pipe, racks, etc.	8,000	
Rental		
2 - 4x4 pickups @ $500 per month for 3 months	1,500	
2 - Bulldozers @ $3,000 per month for 3 months	9,000	
TOTAL		18,500
TRANSPORTATION		
70 - P.W.A. round trips to Ft. McMurray	3,920	
100 - hours helicopter @ $150 per hour	15,000	
Travel to scientific conventions, meetings, etc.	3,000	
TOTAL		21,920

SERVICES AND SUPPLIES

Drilling (total footage of 62,750 feet)		
150 days @ $1,000 per day	150,000	
Fuel (drill rigs, dozers, trucks)	27,000	
100 - drill bits @ $40	4,000	
300 - bags, mud and bran @ $5	1,500	
1,500 - bags cement @ $1.50	2,250	
Instrumentation		
62,000 - feet, pipe @ $1.50 per foot	93,000	
Pipe delivery - 10 loads @ $700 per load	7,000	
50 - well screens and packers @ $150	7,500	
125 - water level recorders @ $300	37,500	
125 - water level recorder shelters @ $70	8,750	
Surveying		
Third-order horizontal and vertical control	20,000	
Aquifer testing		
1 - generator	3,000	
2 - submersible pumps	2,500	
Accommodation (Based on operation of 2 drilling rigs for 75 days)		
Base price (12 men) @ $350 per day	26,250	
Extra drill crew (10 men) @ $130 per day	9,750	
Extra for RCA (7 men) @ $110 per day	8,250	
TOTAL		408,250

EXPENSES

60 days @ $15 per day	900	900

TOTAL 1974-75 BUDGET	$603,570

1975-76 Budget

April - March

(except for salaries all costs are in terms of expected 1974 prices)

	$	$
PERSONNEL		
(Salaries adjusted upward by 10% from previous year)		
Professional		
1 - Principal researcher	22,000	
1 - Assistant researcher	16,500	
Technical		
1 - Technician III	11,000	
2 - Technician II	17,600	
1 - Technician I	7,700	
TOTAL		74,800
TRANSPORTATION		
150 - hours helicopter @ $150 per hour (includes monitoring)	22,500	
30 - P.W.A. round trips to Ft. McMurray @ $56 (includes monitoring)	1,680	
Travel to scientific conventions, meetings, etc.	3,000	
TOTAL		27,180
EXPENSES		
100 days @ $15 per day (includes monitoring)	1,500	
TOTAL		1,500
WINTER DRILLING PROGRAM		
Outlined elsewhere in this report (p.17)		83,770
TOTAL 1975-76 BUDGET		$ 187,250

1976-77 Budget

April - March

(except for salaries all costs are in terms of expected 1974 prices)

	$	$
PERSONNEL		
(Salaries adjusted upward by 10% from previous year)		
Professional		
1 - Principal researcher	24,000	
1 - Assistant researcher	18,150	
Technical		
1 - Technician III	12,100	
2 - Technician II	19,360	
1 - Technician I	8,470	
TOTAL		82,080
TRANSPORTATION		
100 - hours helicopter @ $150 per hour (monitoring)	15,000	
12 - P.W.A. round trips to Ft. McMurray (monitoring)	672	
Travel to scientific conferences and meetings, etc.	3,000	
TOTAL		18,672
EXPENSES		
80 - days @ $15 per day (monitoring)	1,200	
TOTAL		1,200
WINTER DRILLING PROGRAM		
As outlined elsewhere in this report (p. 17)		83,770
TOTAL 1976-77 BUDGET		$ 185,722

1977-78 Budget

April - March

(except for salaries all costs are in terms of expected 1974 prices)

	$	$
PERSONNEL		
(Salaries adjusted upward by 10% from previous year)		
Professional		
1 - Principal researcher	26,400	
1 - Assistant researcher	19,965	
Technical		
1 - Technician III	13,331	
2 - Technician II	21,296	
1 - Technician I	9,317	
TOTAL		90,309
TRANSPORTATION		
120 - hours helicopter @ $150 per hour (monitoring)	18,000	
12 - P.W.A. round trips to Ft. McMurray @ $56 (monitoring)	672	
Travel to scientific conferences and meetings, etc.	3,000	
TOTAL		21,672
EXPENSES		
80 days @ $15 per day (monitoring)	1,200	
TOTAL		1,200
WINTER DRILLING PROGRAM		
As outlined elsewhere (p. 17)		83,770
TOTAL 1977-78 BUDGET		$ 196,951

1978-79 Budget

April - March

(except for salaries all costs are in terms of expected 1974 prices)

	$	$
PERSONNEL		
(Salaries adjusted upward by 10% from previous year)		
Professional		
1 - Principal researcher	29,040	
1 - Assistant researcher	21,962	
Technical		
1 - Technician III	14,664	
2 - Technician II	23,426	
1 - Technician I	10,249	
TOTAL		99,341
TRANSPORTATION		
120 - hours helicopter @ $150 per hour (monitoring)	18,000	
12 - P.W.A. round trips to Ft. McMurray @ $56 (monitoring)	672	
Travel to scientific conferences and meetings, etc.	3,000	
TOTAL		21,672
EXPENSES		
80 days @ $15 per day (monitoring)	1,200	
TOTAL		1,200
TOTAL 1978-79 BUDGET		$ 122,213

TOTAL APPROPRIATION OVER 1973-79 LIFE OF PROJECT: $ 1,295,706

GENERAL BUDGET FOR SUPPLEMENTARY WINTER DRILLING PROGRAMS

(in terms of expected 1974 prices)

Annual additions to the network

In each of the following three subsequent winters additional piezometers will have to be installed to supplement and/or complement the ones installed during the winter of 1974-75. The additional sites will be chosen on the basis of the newly accumulating data. It is estimated that five new nest sites will be required in each of the three winters following 1974-75. The following budget follows a similar format to the previous one.

	$	$
PERSONNEL		
Professional and technical staff appropriated for elsewhere		
Temporary		
2 - bulldozer operators @ $1,000 per month for one month	2,000	
TOTAL		2,000
VEHICLES		
Rental		
2 - 4x4 pickups @ $500 per month	1,000	
2 - bulldozers @ $3,000 per month	6,000	
TOTAL		7,000
TRANSPORTATION		
20 - P.W.A. round trips to Ft. McMurray @ $56	1,120	
20 - hours helicopter @ $150 per hour	3,000	
TOTAL		4,120

SERVICES AND SUPPLIES

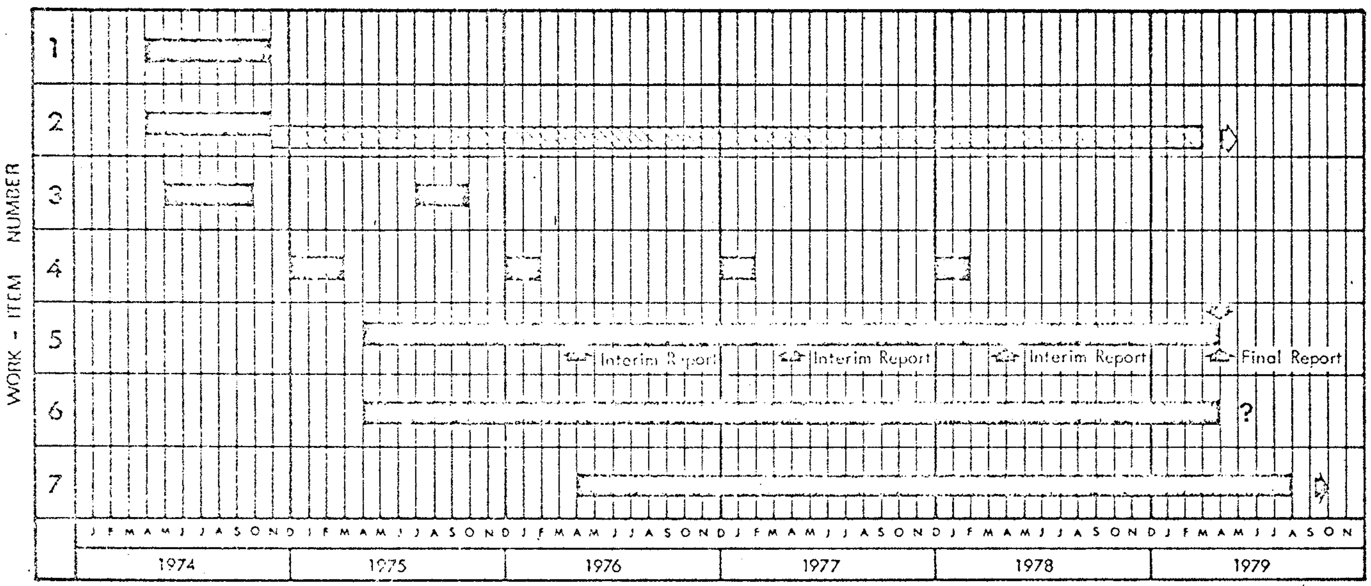
	$	$
(based on 25 days work)		
Drilling		
25 - days @ $1,000 per day	25,000	
Fuel (drill rigs, dozers, trucks)	4,500	
25 - drill bits @ $40	1,000	
60 - bags, mud and bran @ $15	300	
300 - bags cement @ $1.50	450	
Instrumentation		
10,000 - feet pipe @ $1.50 per foot	15,000	
Pipe delivery - 2 loads @ $700 per load	1,400	
25 - water level recorders @ $300	7,500	
25 - water level recorder shelters @ $70	1,750	
Surveying		
Third-order horizontal and vertical control	5,000	
Accommodations		
Base price (12 men) @ $350 per day	8,750	
TOTAL		70,650

TOTAL - SUPPLEMENTARY WINTER DRILLING PROGRAM: $ 83,770

Edmonton, October 1, 1973.

József Tóth,
Hydrogeologist,
Head, Groundwater Division.

D. A. Hackbarth,
Hydrogeologist,
Research Officer.



DESCRIPTION OF WORK ITEM
(See "Details of Proposed Work")

1. Compilation and preliminary analysis of available data
2. Establishment of a data bank
   Operation of data bank
3. Hydrogeological mapping and field work
4. Establishment of and supplements to the regional observation well network
5. Evaluation of the components of the model
6. Monitoring activities
7. Follow-up subprojects in conjunction wi[illegible] other groups

FIGURE 1. SUMMARY OF TIMING FOR THE VARIOUS WORK ITEMS

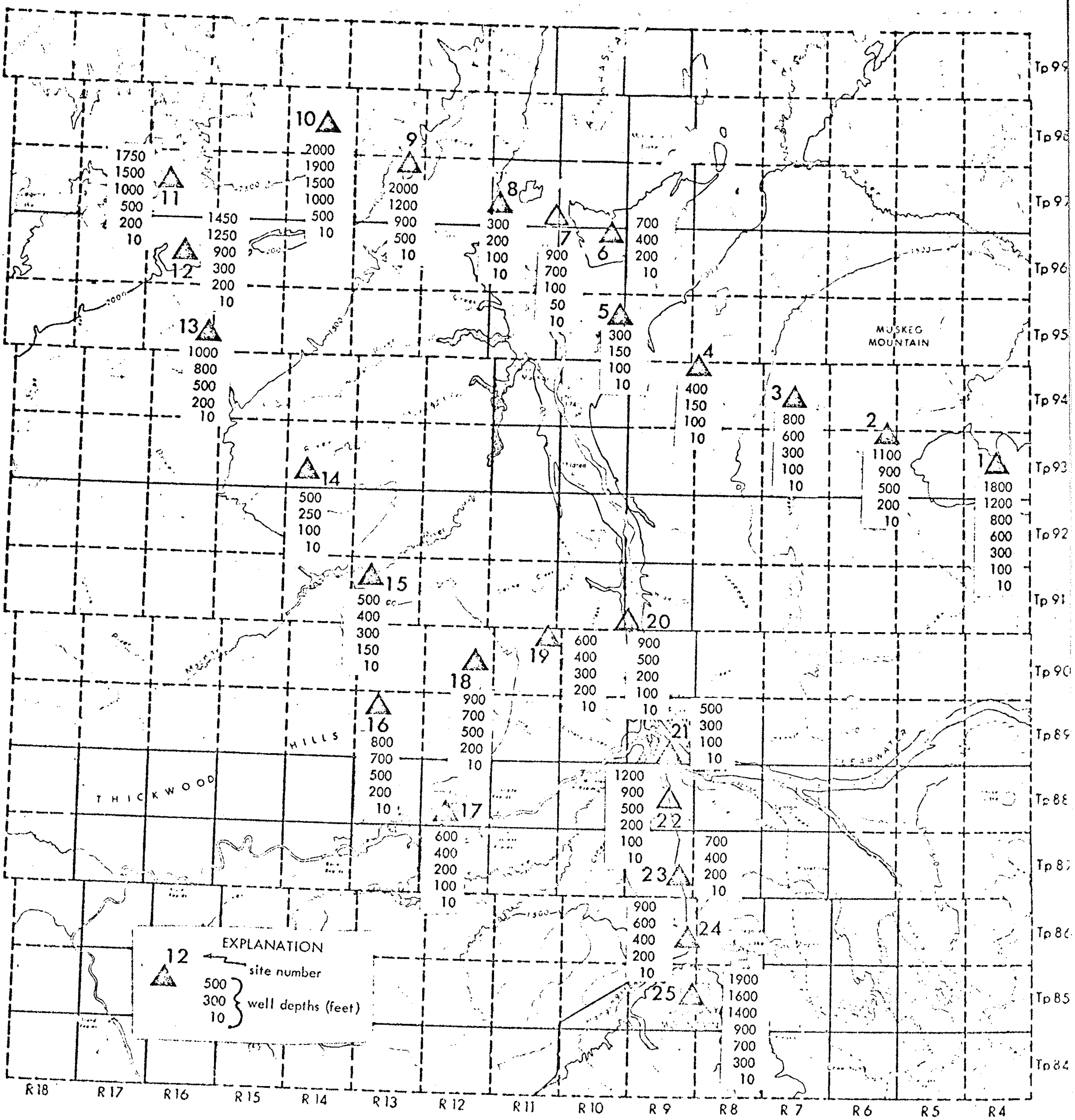


FIGURE 2. PROPOSED PIEZOMETER NEST SITES
OIL SANDS AREA

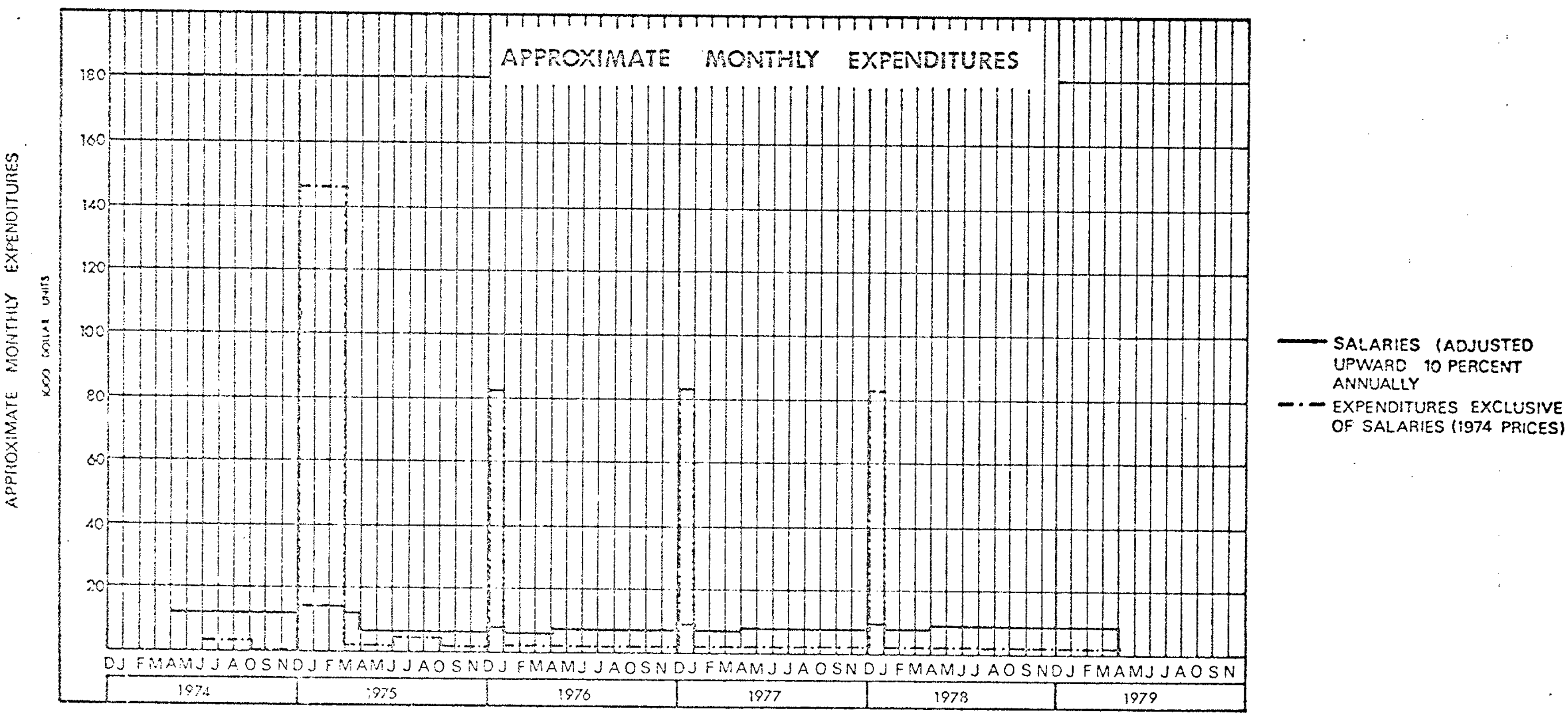

APPROXIMATE MONTHLY EXPENDITURES
APPROXIMATE MONTHLY EXPENDITURES
1000 DOLLAR UNITS
180
160
140
120
100
80
60
40
20
D J F M A M J J A O S N D J F M A M J J A O S N D J F M A M J J A O S N D J F M A M J J A O S N D J F M A M J J A O S N D J F M A M J J A O S N
1974
1975
1976
1977
1978
1979
SALARIES (ADJUSTED UPWARD 10 PERCENT ANNUALLY
EXPENDITURES EXCLUSIVE OF SALARIES (1974 PRICES)

FIGURE 3.

APPENDIX 6

STUDY OF SELECTED BASINS

R. Gerard
Alberta Research

1. Objective: To enable determination of

   a) Water balance for various environments to complement more abstract determinations of evaporation, evapotranspiration, infiltration, etc.

   b) Response functions (e.g., unit hydrographs) of various simple environments to hydrologic input (rainfall, snowmelt, etc.). This type of information is required to make use of the long-term meteorological information at McMurray to generate equivalent long-term runoff records for the area.

To achieve this objective it is envisaged that several 'second order' research basins be established. The data collected should be such as to allow indices and correlations to be determined as is required, for example, in such mathematical models as the SSARR* model developed by the U.S. Army Corps of Engineers, North Pacific Division.

Such basins would fit into a hydrometric hierarchy as shown below:

First order : Research basins: very intensive instrumentation required to investigate the mechanics of the physical processes effecting the hydrological regime of an area.

Second order: Mission oriented: required to allow development of indices and correlations required for deterministic runoff models and for the transposition of climatic data collected some distance from the region of interest. This approach is required to generate the required but non-existent *long-term* streamflow records from *remote long-term climatic* records and *local short-term* hydrometric measurements.

Third order : Mission oriented: similar to the above but on catchments an order of magnitude larger and much less intensive instrumentation : required to check and if necessary modify mathematical model for application to large-scale catchments. These will be provided by the general hydrometric and climatic monitoring described elsewhere in the recommendations.

Fourth order: Standard network hydrometric stations operated by Water Survey of Canada.

---

* Streamflow Simulation and Runoff Routing.

2. <u>'Second order' basin selection criteria</u>:

These basins should be small enough that they

(i) be physically more or less homogeneous (topography, vegetation, soils, etc.) and

(ii) do not require an inordinate amount of instrumentation

but they should be large enough to

(i) give a meaningful average appraisal of the hydrology of the particular physical environment,

(ii) to have a well-defined outlet channel, and

(iii) to have a well-defined boundary.

There should be a sufficient number of basins to sample the dominant physical environments in the region of interest and, most important, they should all have ready access.

In the McMurray region it is suggested that the most hydrologically significant parameters are slope and vegetation.

The following combinations of these parameters should be sampled by the selected basins:

Vegetation \ Slope	Flat < 1%	Medium 1% - 5%	Steep > 5%
Muskeg/treed muskeg	SH, TW or MU	MU or ST	
White spruce/poplar		TW, EL or BI	BI
Jack pine		MU	

Maps of the general distribution of these parameters in the region are attached. Because of access problems the selected basins should be as close as possible to Fort McMurray, a road, a forestry lookout or a river in that approximate order.

The letters in the above table refer to Forestry Lookouts or Mining Camps, shown on the accompanying maps, near where the particular combination may be found.

3. Measurements required on the basins:

Passive features

(i) Physiography - size, shape, slope, orientation, elevations, stream distribution, stream characteristics, storage, etc.

(ii) Vegetation - composition, density, distribution.

(iii) Soils - classification, distribution (in area and depth) engineering properties, infiltration, permeability, storage capacity (includes organic layer).

(iv) Surficial geology - engineering properties of subsurface material.

(v) Geology.

Active features

(i) Rainfall
- quantity
- temporal distribution
- spatial distribution.

(ii) Snow accumulation
- quantity (depth, density)
- spatial distribution.

(iii) Meteorologic data - temperature (maximum, minimum), humidity, wind, sunshine. Correlate with McMurray data.

There are long-term records of the above parameters available at Fort McMurray (except for spatial distributions).

(iv) Soil moisture
- quantity
- temporal distribution
- spatial distribution (in depth as well as area).

(v) Evaporation - potential evaporation - Class A pan.

(vi) Groundwater
- depth to water table
- temporal and spatial changes in water table
- direction of flow of groundwater.

To be concerned with only those strata above the first aquiclude that underlays the whole basin.

(vii) Runoff
- quantity
- temporal distribution
- some idea of spatial distribution.

(viii) Sediment - quantity
- temporal distribution
- some idea of spatial distribution

i.e., source areas (channel banks, erosion, etc.)

- grain size distribution
- suspended and bed load.

(ix) Water quality

(x) Aquatic fauna - ecology of community.

4. Period of operation of basins:

Five years would be about optimum; three years a minimum. However useful data will accrue from the first discharge measurement.

5. Minimum requirements:

The instrumentation, analysis and operations outlined below represent that necessary if the task is to be done properly. However something like 60% of the useful information would be supplied by the items marked by an asterisk in the section "Cost Estimates". These items also represent the minimum requirements for the selected basins to form a useful supplement to the other hydrological research in the area.

It is emphasised that the estimates listed below are just that and hence are quite approximate. They are based on 1974 costs.

6. Summary of cost estimates for each selected basin:

Regular per basin

(i)	Establishment and equipment		$ 91,800
(ii)	Operation		23,500
(iii)	Personnel requirements:	Professional	1/8 man year
		Technical	1/2 " "
		Draftsman	1/8 " "

Minimum per basin

(i)	Establishment and equipment		$ 23,000
(ii)	Operation		8,000
(iii)	Personnel requirements:	Professional	1/10 man year
		Technical	1/5 " "

7. Total cost of selected basin programme:

Regular

(i)	Establishment and equipment		\$459,000
(ii)	Annual operation		117,500
(iii)	Personnel requirements:	Professional	3/4 man year
		Technical	2-1/2 " "
		Draftsman	3/4 " "

Minimum

(i)	Establishment and equipment		\$115,000
(ii)	Annual operation		40,000
(iii)	Personnel requirements:	Professional	1/2 man year
		Technical	1 " "

In the analysis above no allowance has been made for a basin within the mining area to monitor the effects of mining on the hydrologic regime. The efficacy of such a basin is now in some doubt. The objectives of such a basin could probably be met by information derived from the general hydrometric and pollution control network that will be set up in the area and that derived from the reclamation research programme.

Also neglected are administrative and accommodation costs. This would include work by secretary/typists (estimated about 1/2 man year in total), accountants, computer programmers as well as physical support such as office space, furniture, telephone, etc.

COST ESTIMATE

A. Passive features

1. Physiography

To evaluate this a detailed topographic map of the basin is required. The contour interval should not be more than 25 ft and in flat areas considerably less. This map will be prepared from air photos which are already available. It will probably be necessary to provide further ground control within the basin. On this basis the following costs are suggested.

	Item	Man power and/or equipment	Cost
(i)	Ground control for air photo interpretation	Survey crew of 3 men for 2 weeks	$ 2,000
(ii)	Air photo interpretation	Air photo interpreter and machine plotter for 2 weeks	700
(iii)	Map preparation and reproduction	Draftsman for 2 weeks	450
* (iv)	Interpretation of contour map and analysis of basin physiographic features (e.g., average slope, drainage density, etc.), presentation of this analysis, etc.	Technician/draftsman for 1 week	200
		Sub total	$ 3,350

2. Vegetation

The major vegetation associations can also be evaluated from existing air photos. Again some ground control data will be required to give some information of the finer details of these major associations such as foliage density, associated undergrowth, etc.

(i)	Ground control	Field crew of 2 men and transport for 1 week	$ 800
(ii)	Air photo interpretation	Air photo interpreter for 1/2 week	250

		Item	Man power and/or equipment	Cost
*	(iii)	Map preparation and reproduction	Draftsman for 1/2 week	$ 250
			Sub total	$ 1,300

3. Soils

At present only an exploratory soil survey exists in the area of concern. This involves the analysis of one soil sample taken in each township. Considerably more detail is required within each experimental basin, but this will vary with the degree of uniformity of the soil cover which it is hoped will be quite high. It is suggested that some 15 traverses across the basin be made with some 50 preliminary samples in all being taken to classify soil types. This will then have to be followed by detailed investigations of the characteristics of each soil type, which should involve some 10 test sites and about 5 soil tests at each site.

*	(i)	Preliminary survey and soil classification	Field crew of 2 men and portable auger for 2 weeks	$ 1,400
*	(ii)	Preparation of soil map; photo interpretation; reproduction	Technician/draftsman for 1 week	250
	(iii)	Detailed soil sampling at 10 sites	Field crew of 2 men, sampling equipment and transport for 1 week	700
	(iv)	Laboratory analysis of 50 samples @ $20		1,000
	(v)	Preparation, typing and	Soil scientist 1/2 week.	100
			Technician, draftsman, typist, etc. 1 man week	200
			Sub total	$ 3,650

4. Surficial geology

This should be done in conjunction with the soil survey above and geological survey to be outlined below.

5. Geology

Because of the large amount of mineral exploration the geology of the area is reasonably well known. However such items as depths to the first impervious layer, porosity of overlying strata, orientation of aquifers, presence of sink holes must be evaluated on each basin in more detail. On the basis that the first impervious layer (aquiclude) is not deeper than 50 feet on the average the following costs are suggested:

	Item	Man power and/or equipment	Cost
(i)	Drill exploratory holes	Drill crew and drill operating for 4 days : travel 2 days	$ 2,500
* (ii)	Interpretation of drill cores, evaluation of existing bore-hole data	Geologist for 1 week	300
* (iii)	Presentation of data, reproduction	Technician/draftsman/ typist for 1 man week; materials	300
		Sub total	$ 3,100

6. Access and basin selection

The various investigations outlined above will require access to and from the basin site and more importantly, within the basin. This will require the clearing and maintenance of cut lines to and within the basin. It is estimated that some 40 miles of cut line will have to be cleared on each basin. It is assumed that movement over these cut lines will be by ATV* or else carried out during the winter so that nothing more than clearing is required. Each basin will require an ATV to be left on-site for use to monitor the installations on a regular basis. This should probably be a small tracked or balloon tired vehicle capable of carrying 2 men and equipment. One will be required for each basin.

Access to and from the basins will be required at least fortnightly during the months of May to November and at least monthly during the winter. This access will be by helicopter.

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* All-terrain vehicle.

	Item	Man power and/or equipment	Cost
(i)	Cut lines to the site for access by drill crews, etc: an average of 20 mi/basin	Bulldozer and operator : some hand clearing, $700/acre	$14,000
(ii)	Cut lines on basin for access by drill crews, ATV's, etc: an average of 20 miles/basin	Bulldozer and operator for 4 weeks	14,000
* (iii)	A.T.V. for access around the basin		2,000
* (iv)	Basin location selection	A professional and technician for 1 week : expenses for 3 days in the field and 2 hours of helicopter time	1,000
		Sub total	$31,000

B. Active features

*1/3† 1. Rainfall

Both the spatial and temporal distribution of storm rainfall is required. This can be supplied by 3 tipping bucket recording gauges supplemented by 9 (3 at same location as tipping bucket gauges) standard raingauges that should be read at least at 48 hr intervals during rainfall events and weekly at other times.

(i)	3 tipping bucket recording rain gauges and installation		$ 4,500
(ii)	9 standard raingauges and installation		200
		Sub total	$ 4,700

2. Snowfall

The primary concern of this item is monitoring the temporal and spatial distribution of snow accumulation particularly immediately before and during the spring melt (there being very little probability of significant melting at other times during the winter). To monitor this the following is suggested: 2 snow pillows, one in an open area (but not affected by drifting), the other

† Minimum required is 1/8 of cost estimate.

in a well protected location. The information from these should be supported by 3 snow courses on each basin, in stratified locations and surveyed at least each fortnight near spring. At least one of the recording raingauges should be heated and designed and located to be able to measure snowfall.

	(i)	2 snow pillows and installation	$ 4,000
	(ii)	Heated and modified raingauge	500
*	(iii)	Snow survey equipment	1,000
		Sub total	$ 5,500

3. Heat, humidity, wind and evaporation

This information is required for snowmelt and evapotranspiration determination. It is assumed that one installation per basin will be sufficient. It may also be possible to dispense with the hygrothermograph if daily reading of temperature and humidity are carried out.

	(i)	1 recording hygrothermograph	$ 2,000
	(ii)	1 recording anemometer	2,000
	(iii)	1 solar sphere (sunshine)	50
*	(iv)	Wet and dry bulb thermometers : max - min	30
	(v)	Class 'A' evaporation pan, thermometer	120
		Sub total	$ 4,200

*1/8 4. Soil moisture

This should include measurements of the soil moisture distribution in the top 10 ft or so of soil or to the water table and should be carried out at at least 3 sites located in different environments with two tubes at each site. These measurements should be carried out at least weekly.

(i)	Neutron moisture meter	$ 4,000
(ii)	Purchase and installation of 60 ft of access tube	400
	Sub total	$ 4,400

5. Groundwater

The only concern of this item is to monitor the behaviour of the unconfined aquifer under the basin - i.e., from the water table down to the first aquiclude. To achieve this three water table wells large enough for float recording should be drilled. A fourth smaller diameter well can be drilled near the basin outlet for at least 48 hour readings so avoiding the expense of another recorder. It is also suggested that 3 piezometer nests, of 3 piezometers each, be installed around the boundary of the basin to be used for flow direction determination. One of these may be the water table well.

(i)	Purchase and install to 20 ft 3 - 6 inch diameter wells screened over the range of water table variation, including access time for drill rig.	$ 4,500
(ii)	Purchase and install 9 piezometer tubes to 50 ft, including access time for drill rig	3,000
(iii)	3 float-activated water level recorders	2,400
	Sub total	$ 9,900

* 6. Streamflow

This is the most vital measurement of the whole programme and, with the raingauges and temperature measurements, would account for the major portion of the useful information to be derived from the selected basins. For basins of the size suggested, and their homogeneity, one recording station supported by two other crest gauge installations, monitored after each significant runoff event, should be sufficient. The recording station should be operated year around and it is desirable that some form of weir be installed for low flow control. This could be combined with a trap for bed load sediment discharge measurements.

The value of the stage records taken by the recorder are only as good as the definition of the stage-discharge curve at the station. This curve will require at least 10 special trips of approximately one day each to establish this curve with any degree of accuracy.

(i)	Construction of 1 hydrometric station (see Hydrometric Network Proposal, Item 1, for detailed breakdown of costs)	$ 7,000
(ii)	Purchase and installation of 3 crest gauges	200
(iii)	Special trips to determine stage-discharge curve (including helicopter time for transport to and from the site)	5,000
(iv)	Weir and trap construction	2,000
	Sub total	$14,200

7. Suspended sediment discharge and water quality

Because the same samples can be used to determine both of these parameters they have been grouped together. These do not require elaborate field installations but do however require extensive laboratory analysis of which the first year would be exploratory and relatively expensive. It can therefore be considered an establishment expenditure. The specialised equipment for on-site tests for pH, dissolved oxygen, etc. are included in the hydrometric network proposal. It is assumed that the same equipment can be used for these sub-basins.

Bed load sediment discharge is perhaps best measured on these small streams by a trap. This could be combined with a weir for low flow measurements and is included under item 6 : streamflow.

(i)	Laboratory physical analysis of sediment samples	$ 1,000
(ii)	Laboratory chemical analysis of limited sediment samples - say 20 per year	2,500
(iii)	Laboratory chemical analysis of water quality - say 20 per year	2,000
	Sub total	$ 5,500

*1/3 C. Annual operational requirements

From the above description it will be noted that some simple measurements (primarily the standard raingauges) should be read each 48 hours during rainfall. It is hoped that if these basins are located reasonably close to Fire Towers this could be made part of the duty of the observer, especially as fire and rainfall observations should not conflict. In this way regular visits to each basin can be reduced to no more than one per week during the summer. On the assumption that each basin can be fully monitored each week by one person in two days the following costs are suggested:

(i)	One professional for 1/8 man year for supervision and analysis	$ 2,000
(ii)	One technician 1/2 man year	4,000
(iii)	Draftsman for 1/8 man year, drafting materials, reproduction	1,000
(iv)	Subsistence and travel	4,500
(v)	Helicopter flights to and from basins: helicopter for 1/2 hr/week in summer and 1/4 hr/week in winter	5,000
(vi)	Maintenance of equipment and installations at 1% of installed value	5,000
(vii)	Routine laboratory analysis of sediment and water quality samples	2,000
	Sub total	$23,500

APPENDIX 7 A

EVALUATION OF THE CAPACITY OF THE ATHABASCA RIVER TO ACCEPT ADDITIONAL SEDIMENT

R. Gerard
Alberta Research

1. Objective

Evaluation of the capacity of the Athabasca River and its major tributaries to receive additional suspended fines and discharge liquids. Preservation of the water quality of the Athabasca River *must* be maintained, because of the importance of the fish, waterfowl and aquatic vegetation in the Athabasca delta complex. Definition is needed of the effect of adding sediment and/or chemicals at various times of the year. Suspended sediment monitoring is being conducted on the Athabasca and Clearwater Rivers near Fort McMurray, and a miscellaneous programme has been carried out on the Athabasca River at Embarras Airport. These programmes should be continued, expanded to include water quality, and additionally refined to assist in assessing the suspended fines problem.

This item and #8, which include the problem of how much additional sediment will be produced by the development, are probably the most indefinite and difficult to deal with of the items listed. For this reason the proposals and cost estimates outlined below are an order-of-magnitude less definite but it is hoped they will give some indication of what is involved.

2. Approach

The problems caused by the increased sediment load that is inevitably to be produced by development in the area can be classified into two broad groups: effect on the river itself and effect on the ecology of the delta.

A. Effect on the river

This is associated with the deposition of the introduced sediment over many years and the consequential aggradation of the river and accelerated growth of the delta. The gradual raising of the river bed may have detrimental effects on any development located on the active floodplain of the river such as Fort McMurray and the GCOS plant. It will also cause an increase in the dredging required to maintain navigation.

There is at present no reliable method of predicting what sediment will be introduced by what development. The only alternative then is to attack the problem in reverse and to decide what sediment load can be tolerated in the river at various times and then set up a sediment monitoring programme on the major tributaries in the catchments of which development is taking place to ensure that this tolerable load is not exceeded. This should be supplemented by relatively intense monitoring of the sediment production of each type of disturbing activity close to the site of the disturbance. With this information more rational decisions can be made to control sediment production. An important aspect of this latter monitoring is to include an investigation of the rate of propagation and attenuation of this increased sediment load along the drainage system.

Because of our present ignorance of the finer details of sediment transport in a natural stream it is probably best to attack this problem using the, hopefully, conservative assumption that the river is in equilibrium and that, over the long term, its bed, bank and wash load have been 'adjusted' so that its sediment transporting capacity is satisfied for all grain sizes. This infers that, again on an average over a long period, all sediment introduced into the river will be deposited*. The question then is where along the river will this happen.

A first order estimate of the answer to this question can be provided by calculating the travel distance of various grain sizes after they have been placed in the river. In reality of course this is an extremely complex question. However by making sufficient simplifications a crude estimate of the length of travel of each particle size can be determined for several stream discharges.

Then, knowing the average grain size distribution and sediment load of the tributary, and the discharge in the Athabasca, an estimate can be made of the final distribution along the length of the river of the deposited material

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* It is noted in passing that the construction of a dam upstream of Fort McMurray would remove a large portion of the sediment carried from upstream and hence probably increase the capacity of the river to carry sediment from the Oil Sands area.

and hence the order of magnitude of results of the aggradation involved. This will be supplemented by the field investigation outlined below. On the basis of the allowable average rate of aggradation defined by navigation, flood levels, ecological (in the delta) or other considerations a decision can be made on the allowable sediment load from the tributary streams.

Information required

(i) Average hydrograph,

(ii) Existing sediment discharge, and

(iii) Grain size distribution of existing sediment loads of both the Athabasca River and its major tributaries on the catchments of which development is expected. It will be the difference between the existing sediment load and the monitored future load that will be deposited. This existing sediment discharge regime will take at least five years to define. Hence a start should be made on collecting baseline data as soon as possible.

(iv) Sediment production from various forms of development.

Required research

Within the context of the above simplifications the following investigation is suggested:

(i) Establishment of full-programme sediment stations on the Athabasca River upstream and downstream of the Oil Sands Area and on tributaries to be effected by development in the forseeable future. This item is dealt with elsewhere in the recommendations for the extended hydrometric network.

(ii) Monitoring sediment production of various forms of development (cut line construction, exploration, clearing, draining, mining, etc.). This will involve a variety of activities but the dominant ones would be the installation of crest gauges and self filling sediment samplers on various salient small streams with intensive field measurement support during times of significant runoff.

(iii) An investigation of the present sediment transport regime of the river. This will involve surveys of the thalweg profile and cross sections, preparation of a large scale plan of the present river bank or trim line from existing air photos (to be repeated at a maximum of 5 years), detailed bank and bed material surveys and suspended and bed load discharge measurements at at least five sections between Fort McMurray and Embarras at various river discharges.

B. Effect on the delta ecology

This will be primarily associated with the clouding of the Athabasca Delta lakes and its effect on the ecology of the area. Probably the only material that will have to be considered is that fine enough to remain in suspension from the Oil Sands area. This maximum or critical size can be estimated theoretically for various flow discharges.

To allow a reasonably rational approach to the problem it will be necessary to relate the turbidity or sediment concentration of the lakes after flooding to that at the Embarras hydrometric station and to monitor the behaviour of this sediment in the lakes. Given a critical maximum concentration of sediment in the lakes by an ecologist (a vital piece of information without which the exercise is pointless) it should then be possible to estimate the allowable sediment load that can be added by the Oil Sands area tributaries for various discharges in the Athabasca River. To reiterate, this will require a relation to be established between the lake sediment and the river sediment concentration at Embarras and between this latter and the sediment concentration (in the sizes finer than the 'critical' size) in the tributary streams.

This should give a guide to the amount of sediment that can be tolerated in the tributary streams but it is certainly not sufficient on its own. It is paramount that the condition of the delta lakes continue to be monitored after the initial investigation.

The above outline is an extremely simplified version of a particularly complex subject. Because of this relative simplicity the suggested line of attack may well prove to be pointless from a practical viewpoint. Nevertheless if the processes are to be comprehended at all the procedure outlined above seems to be a good starting point and should at least be attempted.

In the final analysis, however, decisions will have to be based on the results of the essential monitoring programme in the delta area*. Hopefully there will not be such a large lag between the action in the Oil Sands area and the reaction in the Delta that the action cannot be altered in time to avoid permanent damage.

Information required (in addition to that outlined under river effects)

(i) Correlation between Delta lakes sediment (of various sizes) concentration after flooding and that of the river at Embarras.

(ii) Critical levels of sediment concentration in the Delta lakes at various times.

(iii) Relation between the concentration of the relevant sized material at Embarras and that in the tributaries in the Oil Sands area.

Again five years is about the required time period needed to make some reasonable progress.

Required research (in addition to that suggested under river effects)

(i) Sediment survey of selected delta lakes, including Lake Athabasca in the area affected by Athabasca River sediment. The selection should sample a variety of the following parameters:

(a) Distance from the river.

(b) Elevation.

(c) Size.

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* This investigation will also provide information of considerable value to the Peace-Athabasca Delta investigation.

3. Cost Estimates

A. River effects

(i) Estimated elsewhere (hydrometric network).

(ii) Monitor sediment production by various modes of development.

On the basis that this will involve some 10 separate sites, the following is suggested for each site:

Establishment:

Investigation and selection of suitable locations. Professional for one week	$ 400
Site survey, installation of crest gauge and self filling sediment samplers. Technician for one week plus purchases	400
Site establishment	$ 800

Operations:

10 regular visits per year at 2 days per visit. Technician for 20 days	$ 1,200
Laboratory analysis of 100 samples at 10 samples per regular site visit	500
5 special visits per year for discharge and detailed suspended sediment measurement 3 days per visit. 2 technicians for 15 days	1,800
Laboratory analysis of samples at 20 samples per visit	500
Analysis and presentation of data. Technician/draftsman for 2 weeks	400
Operating expenses	$ 4,400/yr/site

Total cost of item (ii)

Establishment	$ 8,000
Operating	44,000 per year
Personnel requirements:	Professional 1/5 man year Technician 2-1/2 man years

(iii) Investigation of sediment transport regime of Athabasca River

Establishment:

26 ft jet boat	$10,000
P-61 sediment sampler	1,000
Bed load sampler	500
Preparation of large scale plan of present river bank from existing air photos: technician for 1 month	1,000
	$12,500

Operations:

Thalweg surveys : 2 per year at different discharges : field crew for 1 week	$ 1,000
Cross section surveys : 30 sections each year at different discharges : field crew for 4 weeks	4,000
Preparation and analysis of data : technician for 1 month plus professional supervision	1,000
4 suspended sediment and bed load discharge measurements at 5 sections each year : field crew for 2 months	8,000
Laboratory analysis of samples taken	5,000
Preparation and analysis of data : technician for 1 month plus professional supervision	1,000
Rental on survey equipment, supplies, etc.	1,000
	$21,000

Personnel requirements:

Professional	1/4 man year
Technician	2 man years
Summer assistants	6 man summers

B. Delta effects

It is estimated that some 20 lakes will need to be monitored plus the western reaches of Lake Athabasca and the eastern reaches of Lake Claire. The parameters that should be measured include:

(i) Surveys of physical features of the lakes (plan, depth, drainage, etc.).

(ii) Water level.

(iii) Wind.

(iv) Sediment concentration or turbidity.

(v) Periodic low level aerial photography of larger lakes with film or sensors designed to maximize sensitivity to sediment concentration.

Establishment:

(i) Surveys of lakes

It is assumed that this information is already available for Lakes Athabasca, Claire and Mamawi.

Survey crew for 20 weeks		$20,000
Analysis and presentation of data, technician for 2 months		1,600
Access for survey crew by helicopter : 20 hours		5,000
	Sub total	$26,600

(ii) Water level

Water level recorders on 10 lakes at $3,000 each		$30,000
Staff gauges (to be installed by survey crew)		1,000
	Sub total	$31,000

(iii) Wind

The information supplied at Fort Chipewyan should be sufficient for continuous records. This need only be supplemented by mean wind velocity and direction measurements taken at each lake during the routine fortnightly inspection that will be required.

2 portable anemometers	$ 1,000

(iv) Sediment concentration or turbidity

Unfortunately there do not seem to be any suitable recording turbidity meters on the market that can be used in remote locations. Reliance will therefore have to be placed on manual surveys carried out as soon as possible after each flooding (or refilling) and periodically thereafter. The latter data should correlate closely with the wind data. This will therefore provide the semblance of a continuous record. Nevertheless an effort should be made to either locate or develop a reliable remote recording turbidity meter. No estimate is included for this.

Total establishment	$67,600

Operations:

It is estimated that about 3 special trips per year will be required due to flooding, each lasting about a week for each lake and involving a field crew of two technicians. At other times a periodic survey of one day once a fortnight will suffice. These surveys will only take place during the summer although a sporadic check during the winter months would provide useful information on the delta ecology.

2 Technicians for 20 weeks at $300 each per week	$12,000
2 Summer assistants for 20 weeks at $250 each per week	10,000
Helicopter transport: 100 hours at $250 per hour	25,000

Analysis and presentation of data, 2 Technicians for 20 weeks, at $200 each per week	$ 8,000
Professional supervision: 3 months at $1,200 per month	3,600
Maintenance of installations, supplies, etc.	3,000
Sub total	$61,600

(v) Periodic low level photography : No estimate given.

Total costs:

Establishment	$67,600
Operation	61,600 per year
Personnel requirements:	
Professional	1/4 man year
Technician	2 man years
Summer assistants	2 man summers

APPENDIX 7B

Hydrology Task Force - Alberta Oil Sands

EVALUATION OF THE ASSIMILATIVE CAPACITY OF THE ATHABASCA RIVER AND ITS MAJOR TRIBUTARIES

Ron Davis
Alberta Forest Service

OBJECTIVE

To evaluate the capacity of the Athabasca River, and its major tributaries, to receive discharge liquids that may result from oil sands development.

JUSTIFICATION

To control pollution of the Athabasca River and its major tributaries.

The assimilative capacity of these surface waters will be a major factor in determining the impact of development on Athabasca delta environments.

DATA REQUIREMENTS

The paucity of baseline water quality data presents a major constraint to such an evaluation. The following information is required.

1. Knowledge of the natural water quality, including the nature and regime of suspended sediment loads, of the Athabasca River and its major tributaries is prerequisite. Establishment of hydrometric stations and water quality monitoring networks will provide such data in the long run.

2. Knowledge of the chemical composition of tailings and effluents is also prerequisite. This will enable the determination of relevant water quality parameters to be evaluated in surface waters.

3. Identification of sources of sediment production and discharges of potential chemical pollutants in the active development area.

POSSIBLE SHORT-TERM INVESTIGATIONS

1. Evaluation of water quality data collected to date in the oil sands area.

2. Determination of the effects of G.C.O.S. refinery effluent discharges on the quality of the Athabasca River.

PROPOSAL 1: EVALUATION OF EXISTING DATA

OBJECTIVE

To evaluate water quality data in terms of attaining the long-term objective, ie. determination of the assimilative capacity of the Athabasca River and its major tributaries.

AVAILABLE DATA

Water quality: Athabasca River below Fort McMurray 1967 - (Water Quality Branch - Environment Canada).

WORK REQUIRED

Correlate water quality data with streamflow discharge. Generate chemical constituent hydrographs for the period of record.

Recommend the refinements necessary in the existing and proposed monitoring networks with regard to:

a. Sampling frequency required.

b. Determine chemical constituents to be emphasized in monitoring.

COST

One professional for 3 months @ $1200/month

Total: $3600

PROPOSAL 2: THE EFFECTS OF G.C.O.S. REFINERY EFFLUENT DISCHARGES ON THE QUALITY OF THE ATHABASCA RIVER

BACKGROUND

The G.C.O.S. outfall constitutes the only direct source of industrial waste associated with oil sands development at the present time. Syncrude and Shell plan to pond all their upgrading plant wastes.

Effluent from the upgrading plant has been described as being similar to that from a normal oil refinery, ie. high phenols, high threshold odor, oils and grease; significant oxygen demand associated with soluble hydrocarbons.

Available data consists of 6 analyses (1968-72), and one heavy metal analysis (November 24, 1971).

The average volume of effluent discharged into the river is 3,000 I g.p.m. This constitutes a 500 to 1 dilution at the minimum monthly average river flow of 3731 c.f.s.

Source of information: Report submitted to INTEG entitled 'Sources, Volumes, and Pollutional Aspects of Water' by P. H. Bouthillier (July, 1972).

OBJECTIVE I

To determine the chemical composition of plant effluent at different discharge volumes and at different temperatures.

Methods

Monitoring of plant effluent - measurement of effluent volume, temperature, and concentration of chemical constituents.

Plant effluent should be sampled throughout the year to determine its variability, ie. 2 times per month. Flow volume, temperature, and pH should be determined at the time of sample collection.

Parameters and unit costs for each sample analysis are presented in Table I. Unit costs are based on present analysis costs as computed by Water Quality Branch, Environment Canada.

<u>Costs</u>

Laboratory analysis of samples 24 samples @ $100 per sample -	$2400
Miscellaneous costs	600
TOTAL	$3000

Manpower costs, ie. costs of sample collection, should be incidental at this sampling frequency.

TABLE I

Parameter	Unit Cost
Alkalinity	$ 0.75
Chloride	0.75
Sulphide	(1.00)[1]
Threshold Odor	?
Biochemical Oxygen Demand	4.55
Chemical Oxygen Demand	2.45
Total Organic Carbon	0.85
Nitrogen (Total Kjeldahl)	4.50
Total Residue, Ignition Loss, Non-filterable residue	(10.00)
Phenol	1.35
Oil and Grease	35.00
Carbon Chloroform Extract	(10.00)
Methyl mercaptan	(10.00)
Metals:	
Arsenic	2.50
Iron	2.35
Lead	2.35
Nickel	2.35
Selenium	2.35
Vanadium	(2.35)
Zinc	2.35
TOTAL	$97.80

[1] Unit costs in parantheses are crude estimates

OBJECTIVE II

To determine the capacity of the Athabasca River to assimilate waste discharges from the G.C.O.S. plant, ie. the duration of downstream effects at various stages of the annual hydrograph, and at various effluent volumes.

An initial study is proposed for February (1975) - the time of minimum river flow - and therefore the time of lowest dilution. If pollution is not evident during this period, further studies at other stages of the annual hydrograph are probably not required.

Two components to this initial study are envisaged: (1) a preliminary mixing study, and (2) monitoring the effects of plant wastes on the quality of the Athabasca River.

Investigation of Mixing

A study of lateral and longitudinal mixing in the Athabasca River downstream from the G.C.O.S. outfall is required to determine the location and number of sampling points required to effectively monitor the effects of the waste discharge.

This study should be completed in January.

Method

The dye dilution technique will be used. This involves the introduction of a measured amount of Rhodamine dye into the Athabasca River at the G.C.O.S. outfall, and tracing it downstream with a fluorometer.

Costs

Rhodamine dye:	
150 lbs. (15 gal.) @ \$2/lb.	\$ 300
Manpower:	
6 men @ \$200/week for 1 week	1200
Expenses:	
Transportation, snowmobile rental, equipment	1000
TOTAL	\$2500

Effects of Wastes on the Quality of the Athabasca River (February, 1975)

The preliminary investigation of mixing will define the point downstream at which longitudinal mixing of plant wastes with the river flow should be complete; and will also determine the number of sampling points required to evaluate the rate of oxidation or decomposition of unstable constituents.

Thus the result of the mixing study will determine the costs of this study. Cost estimates have been made without this information, but should represent an upper limit.

Two phases of study during the month of February are envisaged.

a. Monitoring of the Athabasca River above and below the G.C.O.S. outfall.

Sampling Frequency

1 sample/day during the month of February (5-day week),
ie. 20 samples of plant effluent;
20 samples from the Athabasca River upstream from the outfall; and
20 samples from the river at the point downstream where mixing is complete.

Parameters

Samples will be analyzed for those parameters indicated in Table I. Temperature, flow volumes, and pH must be determined at the time of sample collection.

Laboratory Analysis Costs

60 samples @ $100 per sample: $6000

b. Monitoring of unstable constituents to evaluate the capacity of the Athabasca River to assimilate oxygen - demanding constituents of the plant effluent.

Sampling Frequency

During one day out of each week, the Athabasca River will be sampled at various locations downstream from the outfall until the point where mixing is complete. The number and location of these points will be determined by the mixing study. Thus the proposed sampling frequency, and resultant costs, is a crude estimate only.

20 sampling locations between the outfall and the point of complete mixing should represent an upper limit.

At least 2 samples per day should be taken at each location. The sampling frequency could be increased to 4 per day at those locations nearest to the outfall.

Parameters

To determine the rates of change in the concentration of unstable constituents with time, each sample should be analyzed for the following parameters: biochemical oxygen demand, chemical oxygen demand, total organic carbon, nitrogen (total Kjeldahl), phenol, carbon chloroform extract.

In addition, water temperature and dissolved oxygen concentration should be measured at the time of sample collection. This will allow an assessment of the reaeration rate in the river, and of the duration and magnitude of any oxygen sag downstream from the waste source during the low flow, under-ice condition.

Laboratory Analysis Costs

Cost per sample: $25

Theoretical maximum number of samples: 200

(based on 20 locations x 2 samples/location/day x 4 days).

TOTAL COST: $5000

Manpower Requirements and Costs

It is assumed that the same personnel would be involved in both phases of this study.

The services of 1 professional and 3 technicians would be required. The professional would supervise sample collection, determine sampling locations and the frequency of sampling required to meet the study objectives. A professional would also be required to interpret the results of laboratory analyses and to prepare a report summarizing the results.

SUMMARY OF COSTS

Manpower:	Wages for one month	$ 4,500
	Food and lodging	2,500
Transportation:	Includes rental of 2 snowmobiles	1,500
Equipment:	Dissolved oxygen and pit meters; miscellaneous equipment required at sampling locations	2,500
Laboratory analysis of samples:		11,000
Additional costs for data interpretation and report writing (2 months)		3,000
	TOTAL COST	$25,000

APPENDIX 8

EVALUATION OF POSSIBLE EFFECTS OF SUSPENDED FINES AND DISCHARGE LIQUIDS ON THE ATHABASCA DELTA REGION

B. Kemper
Canadian Wildlife Service

No cost estimates could be made for this appendix, for the reasons outlined in the letter following.

The basic recommendation made is that the topic deserves consideration by a separate task force.

Environment Canada | Environnement Canada
Lands, Forests and Wildlife | Terres, Forêts et Faune

Your file Votre référence

Our file Notre référence

Room 1110
Canadian Wildlife Service
10025 Jasper Avenue
EDMONTON, Alberta
T5J 1S6
February 15, 1974

R. Green
Chief
Earth Sciences Branch
Research Council of Alberta
87 Avenue & 114 Street
EDMONTON, Alberta

Dear Mr. Green:

Re: Hydrologic Task Force Report and Study Outlines

For the last several weeks I have been endeavoring to fulfill your request for a study outline pertaining to section B8 of our task force report.

The information and advice which I have been able to collect from our limnological staff suggest that the designing of such studies in a comprehensive fashion is beyond the means of our Service. From our discussions and those at the task force meetings, it would seem that a proper evaluation of the section B8 must include a detailed survey of the aquatic primary productivity of the delta lakes and perched basins. Concomitant with those investigations should be a series of bio asseys, toxicity and LD50 studies, probably done in the lab, on the entire fauna and flora which comprise the delta's primary productive system. These studies would probably more properly fit into a wildlife and fisheries task force or study group.

The physical hydrological studies proposal in the task force report and the expanded study outlines supplied by the members are completely adequate in providing the basis for more detailed biological interpretation at a later date.

The original terms of reference for our group will be met if we provide a comprehensive, integrated series of studies which adequately meet the need of other disciples in terms of physical hydrographic information. The addition of detailed biological investigations, while urgently needed, appear to be outside the main stream of our task force's effort at this time.

Sincerely,

A.H. Macpherson
Regional Director
Canadian Wildlife Service

APPENDIX 9

GATHERING OF DATA ON COMPOSITION OF TAILINGS AND OF ALL PLANT EFFLUENTS

As pointed out by Davis (Appendix 7), some basic chemical data on effluent quality are available. Doubtless other information on physical and chemical parameters exists, in company files. Where additional data of this type may be needed, the general costs involved are adequately outlined in appendix 2.

Long-term changes in quality of plant effluents can be monitored, as can long-term changes in a filled or abandoned tailings pond; the sampling required is routine, probably in the order of a few samples per year.

Annual costs for this project are thus likely small, in the order of $2,000 - $5,000, depending on the amount of fieldwork involved.

APPENDIX 10

EVALUATION OF POSSIBLE EFFLUENT SEEPAGE FROM TAILINGS PONDS

O. Tokarsky
Alberta Environment

1. Objective

Determination of: (a) whether any significant amount of effluent seepage takes place through or beneath the dykes of tailings ponds in the surface mining area of the oil sands; (b) the chemical quality of any such effluent.

2. Approach

The estimates are based on a theoretical 20-piezometer installation in and adjacent to the tailings pond dykes of one tailings pond complex. All piezometers should be installed in the water table zone; installations should be made so that profiles can be drawn across the tailings pond dykes, and thus that water table profiles across the dyke can be determined.

3. Estimates

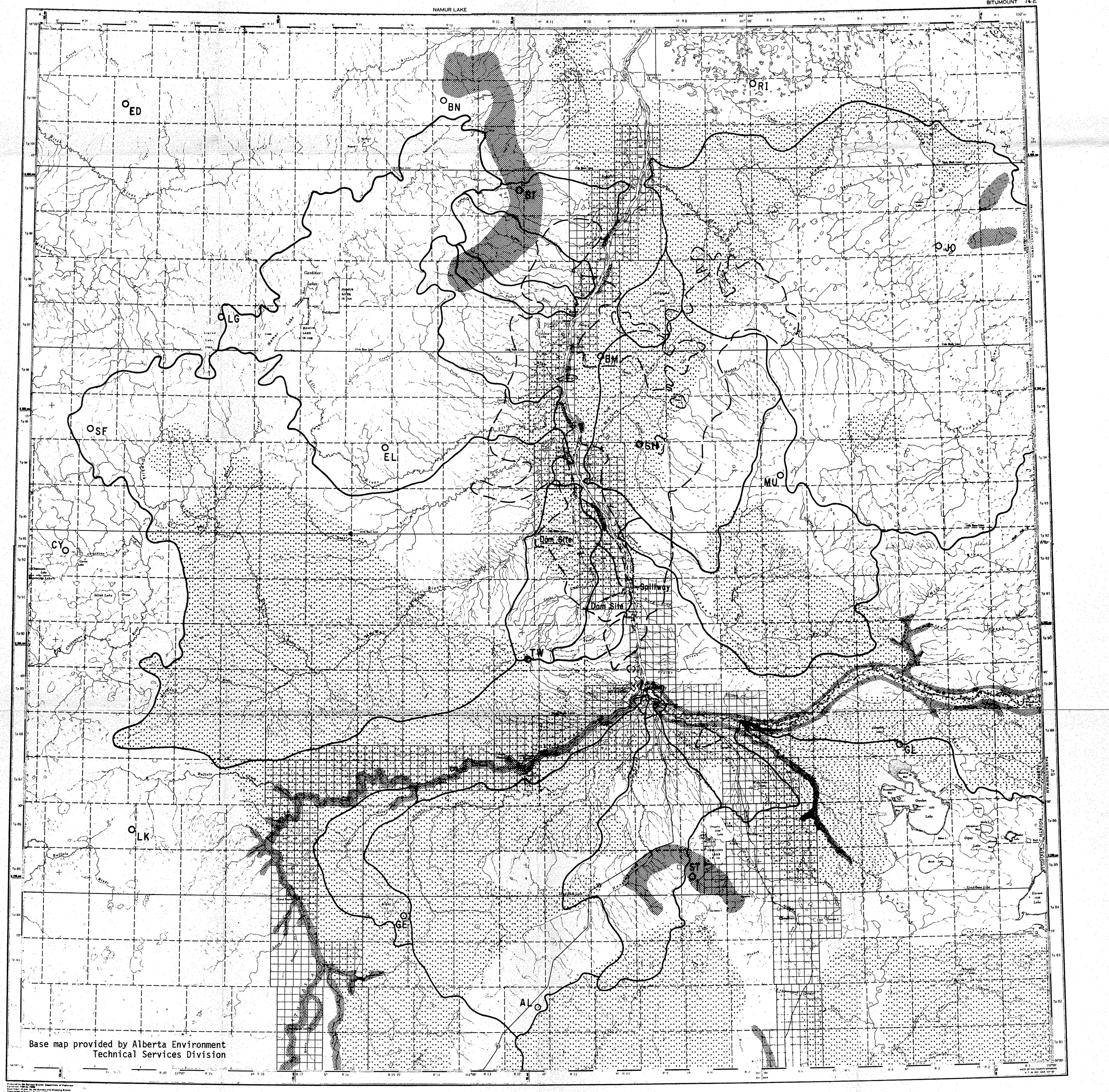
1) Exploration, drilling and installation costs

a) 10 to 15 test holes	$ 2,250.00	
b) moving costs	1,000.00	
c) piezometer installation costs (20)	4,500.00	
d) cost of materials: casing, PVC, cement, etc.	2,500.00	
e) recorder costs 6 @ $800.00	4,800.00	
f) cost of shipping materials	100.00	
	$ 15,150.00	$ 15,150.00

2) Surveying costs		
2 man crew for 2 days, plus travel and expenses	$ 820.00	15,970.00
3) Lab analysis costs		
4 samples per well per year @ $65.00 per sample (assume 1/2 year operation the first year)	$ 2,600.00	18,570.00
4) Manpower costs (field)		
Professional at $18,000 per year for 1 month	$ 1,500.00	
Technician at $10,000 per year for 6 weeks	1,150.00	
Travel and subsistence	2,050.00	
	$ 4,700.00	$ 23,270.00
5) Manpower costs (office)		
Professional - 2 weeks	$ 750.00	
Technician - 4 weeks	770.00	
	$ 1,520.00	$ 24,790.00
6) Office materials, drafting costs	$ 510.00	$ 25,300.00
7) Field materials - sample bottles, amprobe, tapes	$ 200.00	$ 25,500.00

This $25,500.00 represents the first year costs of installation and operation of a 20 piezometer system. Annual operating costs, thereafter would be approximately as follows:

1) Lab analysis costs		
4 samples per well per year	$ 5,200.00	$ 5,200.00
2) Manpower costs		
Professional - 2 weeks	750.00	
Technician - 1 month	770.00	
Travel and subsistence	600.00	
	$ 2,120.00	$ 7,320.00
3) Miscellaneous	180.00	$ 7,500.00



Slope:

Flat < 1%

Medium 1 - 5%

Steep > 5%

Legend:

——— Catchment boundary

— — — Approximate area of bituminous sands having less than 200 ft of overburden

o-------- Alberta Forest Service Lookouts and Ranger Stations

SLOPE DISTRIBUTION IN ALBERTA OIL SANDS AREA

5 0 5 10 15 Mi

Date: January 29, 1974

[redacted]

Highway and River Engineering Division