ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

PLAN OF STUDY

PART C: VOL II
COMPANY QUALIFICATIONS

SEPTEMBI

ACRE

ACRES AMERICAN INCORPORATED

In Association with:

COOK INLET REGION INC./ HOLMES & NARVER INC.
R&M CONSULTANTS INC.
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FRANK MOOLIN & ASSOCIATES INC.
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PART C - VOLUME II - COMPANY QUALIFICATIONS

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ACRES

ENGINEERING AND MANAGEMENT SERVICES

AGRES

INTRODUCTION

This document has been assembled to set out the qualifications of Acres American Incorporated to provide engineering and management services for the design and construction of hydroelectric and pumped storage projects. The document not only describes the experience of the Company on past projects of a similar or related nature, but also describes the approach taken by the Company to the complex task of ensuring that a project is built on time, on budget, and to meet the client's functional requirements.

As a consulting engineering organization, a large part of this capability rests in the experience and know-how of our senior engineering and management personnel; all of the senior Acres people have held positions of responsibility from the inception through to the final commissioning of large hydroelectric and other power-related projects. The section entitled "Representative Personnel" includes summaries of the experience of a selection of those personnel who could be made available for a hydroelectric or pumped storage project.

A typical outline organization structure adopted by Acres for a large project such as a hydroelectric development is set out in Chart "A". The function and responsibilities of the various positions indicated in the chart are discussed in the following sections and may be considered under the following headings:

- Engineering Management
- Construction Management
- Cost Control and Monitoring
- Quality Control and Monitoring
- Schedule Control and Monitoring

At the start of the project, scopes of work for all functions in the organization chart are prepared in as much detail as possible. From these, engineering and administrative budgets are drawn up for inclusion in the total cost estimate for the project. These budgets are monitored by means of weekly reports produced by Acres in-house cost and production control system, allowing potential overruns to be identified early and appropriate collective action taken without delay.

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ENGINEERING AND MANAGEMENT SERVICES FOR HYDROELECTRIC AND PUMPED STORAGE PROJECTS

GENERAL APPROACH

It is Acres philosophy that the client's "right to know" and "right to decide" is paramount, and many of the procedures that are followed have been set up specifically to ensure that the client is kept fully informed not only of the progress of the work, but also of key decisions and the impact of these decisions on the cost, schedule and ultimate success of the project.

The successful construction of a venture as large as a hydroelectric or pumped storage development, with its complex technology, large number of different tasks and long construction schedule, calls for a special combination of management techniques and engineering skills. Scores of experienced people must be brought together to form a cohesive team capable of assuming the various responsibilities and discharging them successfully.

The primary objectives of this team must be:

(a) The development of a reliable initial estimate of cost for the facility, based on sound conceptual engineering from good exploratory field data.

(b) Environmental assessment and preparation of impact statement and related licensing documents.

(c) The identification of manageable construction and equipment package and the preparation of design documents, contract drawings and technical specifications to allow successive bids to be called to a strict timetable.

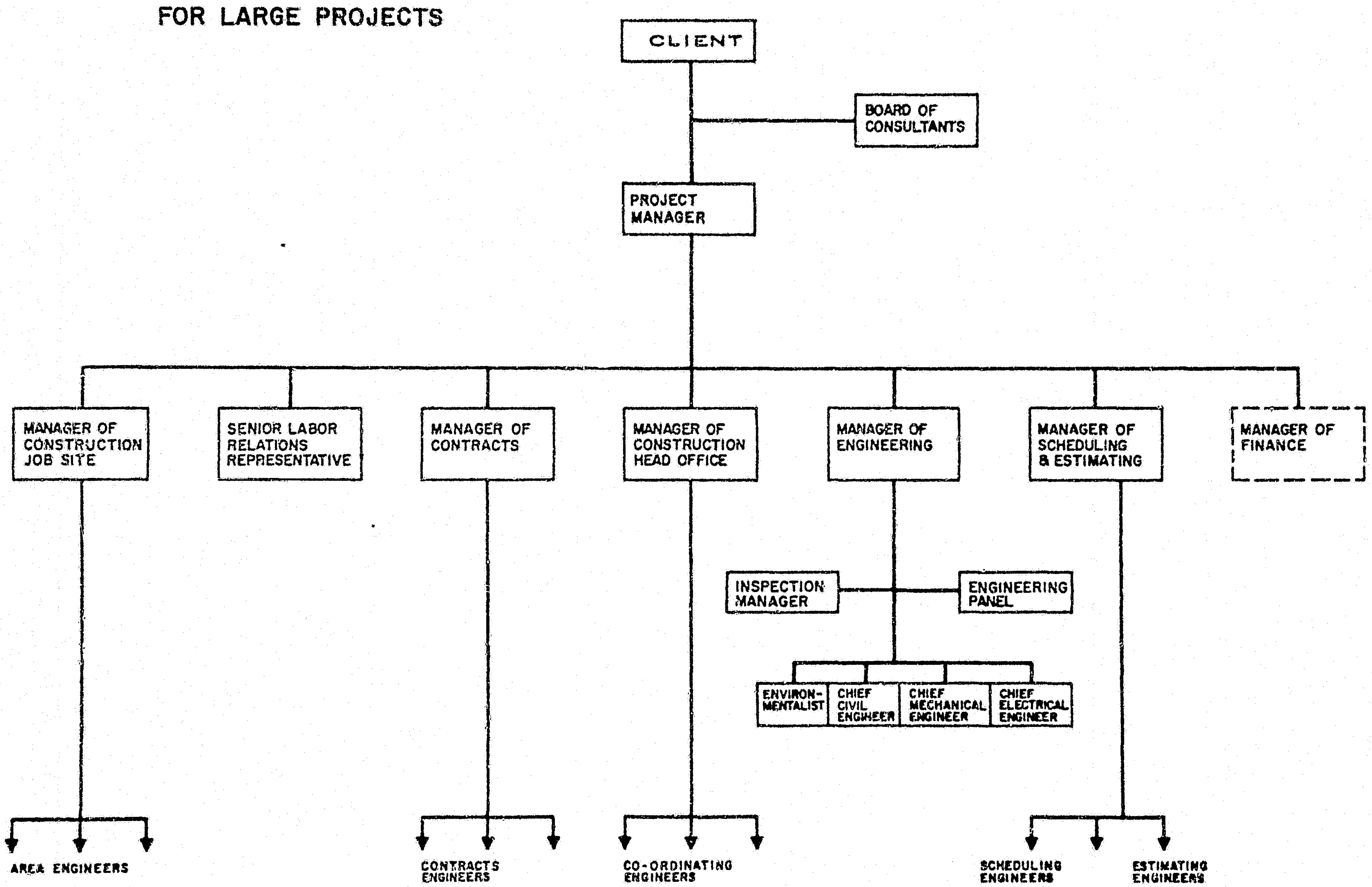
(d) The finalization of engineering work after contract award, the preparation of construction drawings, and the control of design changes.

(e) The supervision of the quality and schedule of construction both in the field and in fabrication shops.

To achieve these objectives, Acres follows a carefully established series of procedures which can be adapted to suit the degree of involvement in the management of the project required by the Owner. In the past, Acres involvement has ranged from solely the engineering design and preparation of specifications to complete responsibility for the project management, including financial disbursements and contract awards. Prior to the initiation of the engineering program, it is essential for the responsibilities and relationship of the owner and consultant to be carefully defined. The Plan of Study will provide the basis for the engineering of the complete Susitna Project.

CHART A

TYPICAL ORGANIZATION CHART FOR LARGE PROJECTS



ENGINEERING MANAGEMENT

Many important decisions are made early in the design phase of the project and often cannot be changed later except at considerable additional cost. Acres system of design reports, or "Design Transmittals" as they are called, is aimed at ensuring that the design concepts and their implications are fully explored.

The sequence of steps in the design of a major component in the development would be typically as follows:

(a) The initial feasibility study will have established the necessity for, and a rough cost estimate of, the component.

(b) The specific scope of work for the design and specification of the component is established, an engineering budget is assigned, and overall design criteria are assembled. During this phase the applicable regulatory design and safety codes and practices are identified and continuing monitoring procedures fully coordinated.

(c) A design transmittal is prepared describing the alternatives considered, the constraints and opportunities involved, and recommending a course of design action within the context of the estimated capital and operating costs. This transmittal, which is a key document in the design phase, is circulated for comment within the Acres organization and sent to the client. Equipment suppliers are also frequently brought in for discussion at this stage. Once approved, changes can be made only by a reissue of the document. Design transmittals are prepared for a wide range of components and, for major projects, may amount to as many as 150 transmittals for topics ranging, for example, from "Trash Handling Facilities in the Forebay" to "Powerhouse General Arrangement" and "Switchyard Insulation Levels".

(d) Next (at about 25 to 35 percent design completion) where appropriate, the contract packaging is established and "Scope Statements" are prepared, describing in detail the contents and scope of each contract related to the design transmittal.

At this point, the cost estimate for the component is keyed into the overall estimate for the project.

(e) Contract drawings (as many as five hundred for a large project) and technical specifications for the components are then prepared, and a contract package is assembled for final review prior to issue for competitive bidding. This phase would usually be undertaken concurrently with environmental assessments and preparation and submission of requisite licensing applications.

(f) Once a contract reaches bidding stage, it becomes the responsibility of the construction group. However, the contractor may require additional detail drawings. For a major project, for instance, as many as two hundred detailed civil drawings and approximately an equal number of schematics, interconnections and wiring diagrams may be required in addition to the original contract drawings. A key part of this work is to ensure either that no significant changes are made to the design as set out in the contract drawings or that any changes are fully explored and reviewed with the contractor to assess impact on schedule and cost. Acres uses a system of "Design Change Memoranda" to keep track of this aspect of the work.

(g) In summary, engineering cost and quality control is effected by

- the preparation of control estimates at key stages in the development of the design

- conducting critical technical review throughout the design phase, and by the maintenance at site of a resident engineer reporting to the manager of engineering to ensure that proper tests and controls are carried out

- assigning a project monitoring group to compare the estimated and actual design man-hours expended on each phase of the work. The details of Acres control system are fully described in our "Progress and Cost Reporting System User's Manual".

ENGINEERING PANEL AND CONSULTING BOARD

It is Acres usual practice, for projects with a significant design input, to set up an in-house "Engineering Panel" comprised of senior engineers within the Company, experienced in the various areas of expertise involved in the project. The function of this panel, which is responsible only to the project manager, is to critically review the engineering designs and recommendations developed in the course of the project. Presentations are made to the panel by the project design team at appropriate times throughout the period of design development, and approval of the panel is obtained before implementation of the design.

On projects such as a major hydroelectric development, which often involve innovative thinking, it has also been Acres practice to convene a consulting board which is essentially responsible to the owner. The consulting board comprises engineers from outside the Company, eminent in their various disciplines. The consulting board would normally meet once every 3 months to review, with owner's senior staff and project team staff, such matters as major design transmittals, scheduling and financial problems, or geological and other problems encountered in the field.

Among the engineers who have served on consulting boards for Acres projects are:

Churchill Falls Development

H. E. Barnett	Project Planning and Construction
W. L. Chadwick	Power Engineering
J. B. Cooke	Hydroelectric Structures
D. M. Farnham	High-Voltage Cables — Electrical Engineering
F. B. Slichter	General Civil Engineering
R. Rhodes	Engineering Geology

Mica Creek

J. B. Cooke	Hydroelectric Structures
C. V. Davis	Hydraulic Structures

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J. Gorman	Geologist
G. Watson	General Civil Engineering
Lt. Gen. R. A. Wheeler	General Civil Engineering Docks and Harbors

Lower Notch

Professor A. Casagrande	Soil Mechanics
Dr. F. A. Nickell	Geology
Dr. R. B. Peck	Soil Mechanics

Alto Anchicaya

Dr. D. U. Deere	Rock Mechanics
J. B. Cooke	Hydroelectric Structures

Major Hydroelectric Projects in North America

The climatic conditions in the area of the Susitna project are similar in severity during winter freeze-up to those at several major hydroelectric projects undertaken by Acres in Canada. The most prominent example is the Churchill Falls Development in Labrador. Others are the Kettle Rapids, Kelsey, Long Spruce and Limestone Hydroelectric Projects in Northern Manitoba. Although these sites are about 500 miles south of Susitna in latitude, they are within areas of discontinuous permafrost and close to the southern limit of continuous permafrost. Acres has also been involved in detailed studies and investigations for other major engineering projects as far north as Prudhoe Bay in connection with the petroleum industry.

This section of the proposal therefore addresses projects undertaken on the North American continent rather than the United States alone. In the United States, Acres has participated in the study, engineering, licensing and construction of numerous smaller projects involved hydroelectric generating stations, pumped storage developments, large earth dams, tunnels and other major underground excavations.

Detailed summaries of some of these projects are presented in Appendix C1 and summarized in the following tables.

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REPRESENTATIVE LIST OF PROJECTS UNDERTAKEN
IN NORTHERN REGIONS BY ACRES

Plate 1 shows the locations of the projects listed below.

1.0 - Mining and Petroleum Projects

	Location	Client and Project Description
1.	Seward Pennisula Alaska	Lost River Mining Corp. & City of Lost River. Integrated Open Pit Mining & Townsite Complex Hydrological & Geotechnical Investigation.
2.	Beaufort Sea	Artic Petroleum Operators Association (APOA) Offshore Drilling Structures Conceptual Design & Ice Studies.
3.	Venus Mines, Yukon	Venus Mines Ltd. Crushing & Concentrating Facilities & Tailings Storage Design & Construction Supervision.
4.	Thompson Lake, Lynn Lake, Mook Lake, Pipe Lake Manitoba	International Nickel Company Stripping & Drainage Design Study.
5.	Labrador City Smallwood Mine	Iron Ore Co. of Canada Rail Tunnel & Vertical Ore Pass Design & Construction Supervision.
6.	Labrador City Humphrey Mine	Iron Ore Co. of Canada Rail Tunnel and Ore Handling Facilities Design & Construction Management.
7.	Hay River & Upper Mackenzie, N.W.T.	Canadian Arctic Gas Northern Staging Areas Geotechnical Investigation & Facilities Design.
8.	Fort Simpson & Fort Providence,l N.W.T.	Canadian Arctic Gas Northern Staging Areas Geotechnical Investigation & Facilities Design.
9.	Strathrona Sound Baffin Island	Naniswik Mine Tailings Disposal for Lead-Zinc Mine Environmental Investigations.

2.0 - Hydro-Electric Investigation & Development Projects

	Location	Client and Project Description
10.	Nelson River Manitoba	Manitoba Hydro Hydroelectric Power Development (Kelsey & Kettle Rapids) Design & Construction Supervision.
11.	James Bay P.Q.	Hydro Quebec River Basin Power Potential Feasibility Study.
12.	Churchill Falls Labrador	Brinco Churchill Falls Hydroelectric Project Joint Project Management.
13.	Whitehouse Yukon Territories	Northern Canada Power Commission 139 kV Transmission Line Design & Construction Management.
14.	Hay River - Twin Gorges, N.W.T.	Northern Canada Power Commission Transmission Line Geotechnical Investigations.
15.	Yukon Territories	Northern Canada Power Commission Potential Power Sites Field and Office Studies.
16.	Yellowknife, N.W.T	Cominco Ltd. Hydroelectric Station Expansion Feasibility.
17.	Nelson Manitoba	Manitoba Hydro Churchill River Diversion Engineering Designs.
18.	Northern Manitoba	Manitoba Hydro Churchill River Diversion Engineering Designs.
19.	Nelson River Manitoba	Manitoba Design Long Spruce Generating Station Hydroelectric Project Engineering (Joint Venture).
20.	Northern Ontario	Ontario Hydro Limited Office Engineering for Hydroelectric Development on a Northern River.
21.	Churchill Falls Labrador	Churchill Falls (Labrador) Corporation Ltd. 735 kV Transmission Line Design.
22.	Churchill Falls Labrador	Churchill Falls (Labrador) Corporation Ltd. 230-735 kV Switchyard Design.

3.0 - Transportation Projects

	Location	Client and Project Description
23.	Prudhoe Bay Alaska	Esso Research Arctic Marine Terminal Design Review.
24.	Mackenzie Valley Highway, N.W.T.	Department of Public Works Geotechnical Investigations MP 346 to 450.
25.	Hay River, N.W.T.	Northern Transportation Co., Ltd. Geotechnical Investigations for Wharfs.
26.	Bridport Inlet, Mebrille Island,	Petro Canada LNG Toaker Terminal Ice Management Study.

4.0 - Townsite Planning

	Location	Client and Project Description
27.	Pond Inlet Baffin Island	Department of Northern Affairs Field Investigations and Town Planning Design Study.
28.	Cape Dorset Baffin Island	Department of Northern Affairs Field Investigations and Town Planning Design Study.
29.	Pangnirtung Baffin Island	Department of Northern Affairs Field Investigations and Town Planning Design Study.
30.	Port Burnwell N.W.T	Department of Norther Affairs Field Investigations and Town Planning Design Study.
31.	Gillan, Manitoba	Manitoba Hydro Long Spruce Generating Station - Enginering for a 2000 man Construction Camp.
32.	Notigi, Manitoba	Manitoba Hydro Notigi Control Construction Camp Services.

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5.0 - Hydrology Studies

	Location	Client and Project Description
33.	Northern Manitoba	Manitoba Hydro Churchill River Flood Forecast Study.
34.	N.W.T.	Department of Indian Affairs & Northern Development. Repard Flood and Waste Resource Study for Northwood Territory.

6.0 - Other

	Location	Client and Project Description
35.	Yukon Territory	Yukon Outfitters Association Grizzly Bear Management.

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SECTION C6: COMPANY EXPERIENCE

ACRES AMERICAN INCORPORATED

Consulting Engineers

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Washington D.C. 20006
(202) 393-2027

Suite 214
Northampton Building
3725 National Drive
Raleigh, North Carolina 27612
(919) 781-3150

Clark Building
717 Liberty Avenue
Pittsburgh, Pennsylvania 15222
(412) 765-3700

Suite 329
The Clark Building
Columbia, Maryland 21044
(301) 992-5300

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THE COMPANY

Acres American Incorporated is a consulting engineering and planning organization licensed and incorporated to perform professional engineering services under the laws of the States of New York, North Carolina, South Carolina, West Virginia, Maryland and Pennsylvania. Staff comprises professionals in the major disciplines of civil, electrical, mechanical, geotechnical, environmental, hydraulic and hydrological engineering together with technicians, draftsmen, and supporting staff totalling approximately 280. The engineering and related services are provided to utilities, government and state agencies, and industrial clients.

Acres American Incorporated, with additional offices in Columbia, Maryland, Washington, D.C., Raleigh, North Carolina, and a wholly owned subsidiary company in Pittsburgh, Pennsylvania, is a member of the Acres group which was founded in 1924 to provide engineering expertise for the development of hydroelectric resources. The resources, experience, and facilities of the entire Acres group are available, as required, to provide services necessary for the successful execution of projects on a worldwide basis.

Comprehensive company services are available, extending from preliminary hydrological, geological and feasibility investigations and economic analyses through planning, design, licensing, preparation of contract documents, drawings and specifications, evaluation of bids, contract negotiation, shop inspection, field engineering, construction supervision, project management, financial control, commissioning and initial operation. With a strength of over 1,500 engineers, specialists, and supporting staff, Acres has built up a wide range of skills to serve the power supply industry in North America, and is also structured to provide technical and planning services to other sectors of industry, including heavy civil engineering, transportation, mining, metals, fuels and other process industries.

The Company administration is based on a departmental structure, the major disciplines being electrical, mechanical, hydraulic, civil and geotechnical. Project teams, directed by an executive project manager, are staffed by engineers assigned from the appropriate departments. Specialist staff is also available from other departments of the Company to provide comprehensive service to our clients, ranging from economic analyses through quality control and commissioning services.

Specific expertise and experience are available in the following fields:

Chemical
Civil
Electrical
Environmental
Geotechnical
Hydraulic
Hydrological
Instrumentation
Mechanical
Metallurgical
Mining
Structural

Telecommunications
Thermal
Transportation
Architectural
Engineering Geology
Geographical
Meteorological
Regional and Urban Planning
Resource Conservation and Development
Economics
System Analysis

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The economists include specialists in the field of:

- Agriculture
- Agribusiness
- Communications
- Economy Forecasting
- Energy Resources
- Fisheries
- Forestry
- Industry
- Mineral Resources
- Recreation
- Transportation
- Water Resources

COMPANY FACILITIES

Acres American Incorporated is one of a few consulting engineering companies in the United States that operates its own research and development laboratories in addition to providing conventional design services.

Acres' facilities include laboratories for hydraulic, fluid dynamics and thermal modelling, soil and rock mechanics and biochemical analyses. Laboratories located in Niagara Falls, Ontario and Buffalo, New York have facilities for hydraulic and chemical/physical testing. These laboratories are also available for a wide range of structural and geotechnical testing, including consolidation tests and triaxial stress-strain tests on soil, and direct shear and biaxial compression tests on soil, native rock, or concrete core samples.

Acres has extensive computer facilities comprising a GE 415 processor and its attendant data storage and input/output peripherals, two Data General minicomputers, and in-house remote terminal communication. The latter allows access via compatible systems to programs or data stored virtually anywhere in the continental United States on a time-sharing basis. Acres' in-house program library includes nearly two hundred titles, many of which are devoted to problems in energy system development and design of hydroelectric and thermal power projects.

COMPANY EXPERIENCE

In the field of power generation and related facilities, Acres has been responsible for over 20,000 MW of installed hydroelectric capacity, 65 earth- and rock-fill dams and 30 concrete dams. The largest single project engineered by Acres was the 5225 MW Churchill Falls Development in Labrador, Canada which was completed in 1976. Acres American has also carried out a number of power systems planning studies such as the Power Alternatives Study for the Dickey-Lincoln School Lakes Project for the New England Division, Corps of Engineers.

The Acres group has for many years been responsible for the feasibility assessment, design and construction supervision of a considerable number of tunnels, shafts, and caverns in hard rock. This type of work has totalled some 70 miles of tunnels, 30,000 feet of shafts, and some of the largest underground cavities in the world, including the 1,000-foot long by 150-foot high by 80-foot wide caverns 900 feet underground for power plant installation at Churchill Falls.

The Company has also been responsible for the design and supervision of construction of mine shafts, tunnels, and associated railway tunnels for pipeline and pumping stations, airport fuel systems, and right-of-way studies.

Acres is currently managing for the Corps of Engineers the 14-acre Chesapeake Bay model in Maryland. Models constructed and tested in the Buffalo hydraulics laboratory include a large (200-foot by 100-foot) hydraulic model for the Corps of Engineers to simulate ice conditions in the Little Rapids cut section of the St. Marys River; a wind tunnel model of a nuclear power plant to study the dispersion of radioactive emissions (with Calspan Corporation); aerodynamic models of electrostatic precipitators and ductwork for fossil-fired utility plants, hydraulic models of an overflow spillway structure and tunnel for energy dissipation for American Electric Power; and cooling water intakes for a nuclear power plant in New Jersey for GPU Service Corporation. Recent geotechnical testing has included triaxial and shear box strength tests for weak clay materials from an American Electric Power fly-ash retention dam in West Virginia.

Most projects undertaken in the United States have included environmental studies, impact statements, public hearings, etc., and the Environmental and Special Services group has wide experience in these areas, as well as in dealings with all levels of government and various government agencies.

Among the clients for whom Acres American Incorporated is currently providing, or has recently completed, services are:

- American Electric Power Service Corporation
- American Standard Corporation
- Appalachian Power Company
- Atomic Energy Commission (as subconsultants to United Engineers and Constructors)
- Babcock and Wilcox Company
- Bethlehem Steel Corporation
- Boston Edison Company
- California Energy Commission
- Carborundum Company
- Central Electric Power Cooperative
- Central Hudson Gas & Electric Corporation
- Cleveland Electric and Illuminating Company
- Consumers Power Company
- Department of Energy
- Dirigo Electric Cooperative
- DuPont Corporation
- Electric Power Research Institute
- Environmental Protection Agency
- Federal Energy Administration
- General Public Utilities
- Georgia Power Company
- Great Lake Carbon Corporation (subcontractors to UTRC)
- Massachusetts Municipal Wholesale Electric Company

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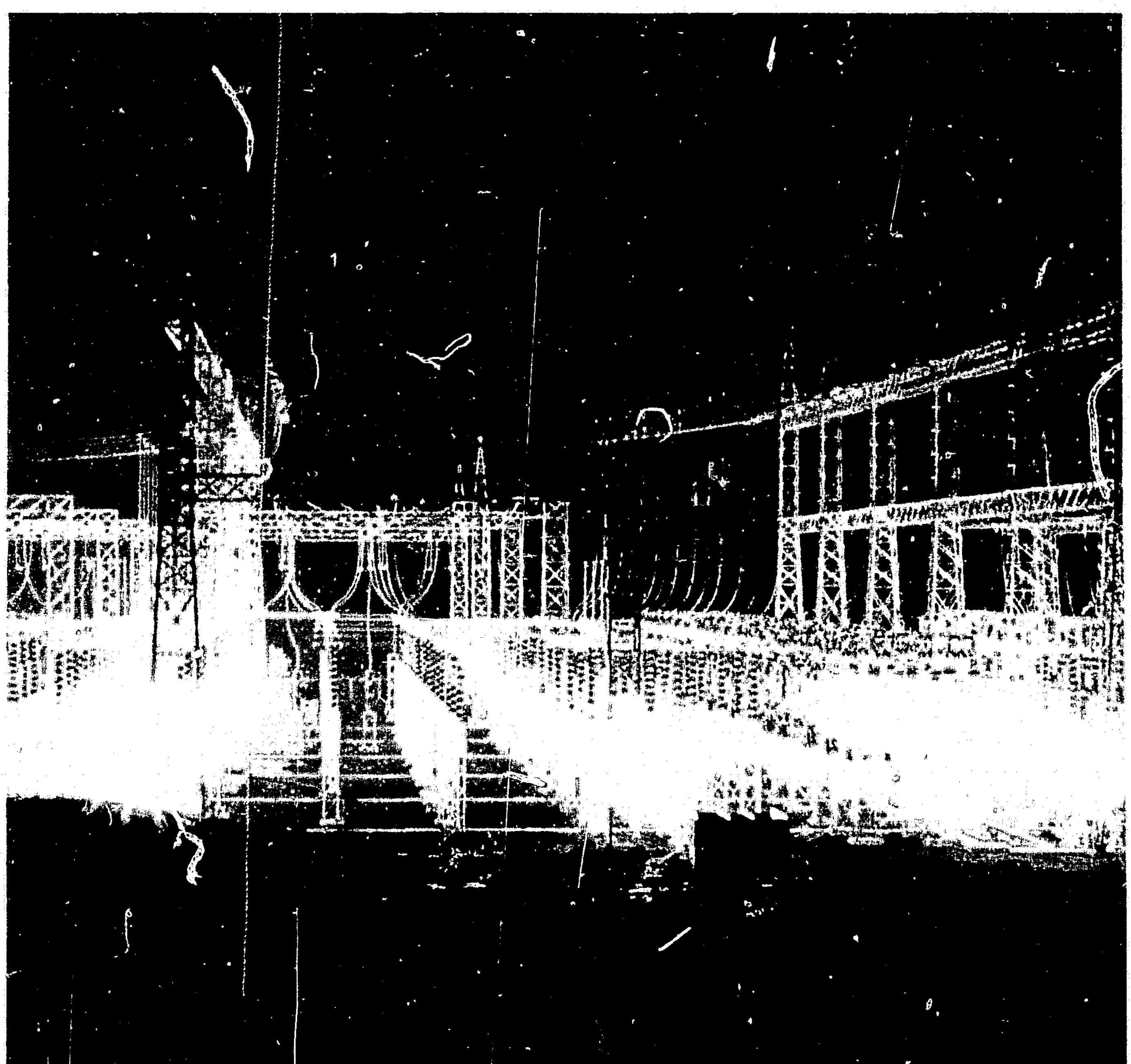
- National Rural Utilities Cooperative Finance Corporation
- National Science Foundation
- Nebraska Municipal Power Pool
- New York State Department of Environmental Conservation
- New York State Electric and Gas Corporation
- New York State Energy Office
- Niagara Frontier Transportation Authority
- Niagara Mohawk Power Corporation
- NUS Corporation
- Ohio Edison Company
- Potomac Electric Power Company
- Precipitair Pollution Control, Inc.
- Republic Steel Corporation
- Rochester Gas and Electric Corporation
- Studebaker Worthington, Inc.
- Tennessee Valley Authority
- Turbodyne Corporation
- United Technologies Research Corporation
- Union Carbide Corporatin
- U.S. Corps of Engineers, Buffalo, New York, Pittsburgh, Savannah and Detroit Districts, New England Division and the Waterways Experiment Station
- Vermont Electric Cooperative
- Virginia Electric Power Company
- Western Precipitation Division, Joy Manufacturing Company
- Wheelabrator-Frye Company

A short selection of descriptions of large hydroelectric projects engineered in northern regions is provided in Section A3.

PLANNING

The staff of Acres American has a wide range of experience in the provision of consulting services to the power utility industry in the following areas:

- Load Forecasting and Market Surveys
- Long-Range Planning and Power System Studies
- Economic Analysis
- Reliability Analysis
- Mathematical Models and Computer Simulation Programs
- Switching Surges and Resonant Phenomena
- Insulation Coordination Studies
- Plant Evaluation
- Rate Studies



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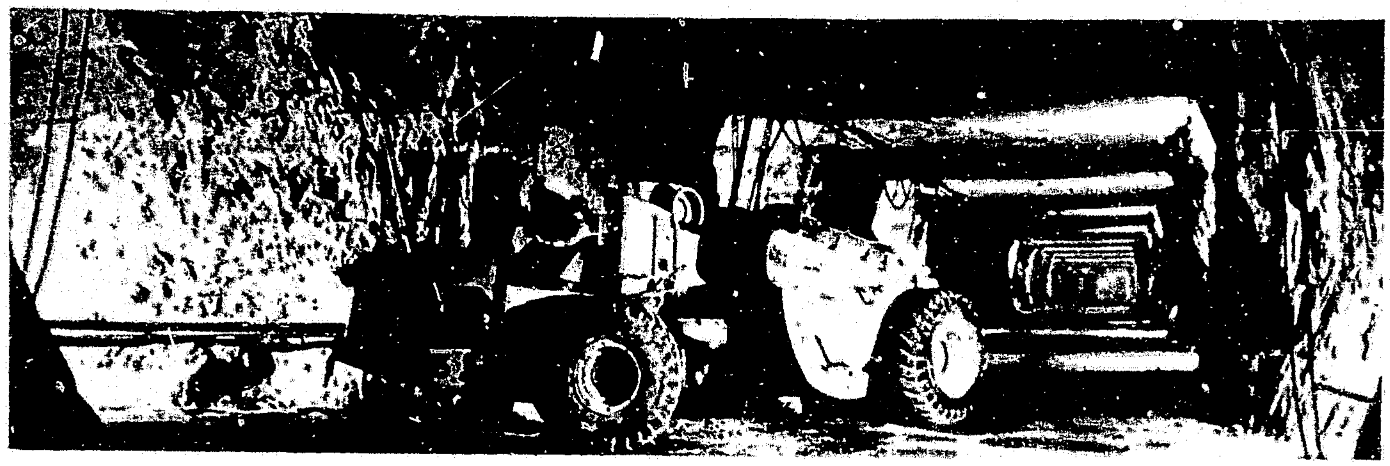

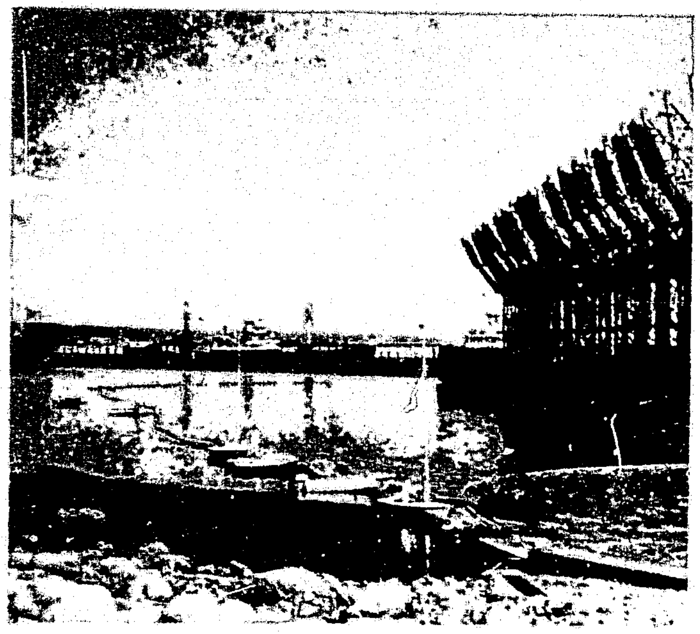

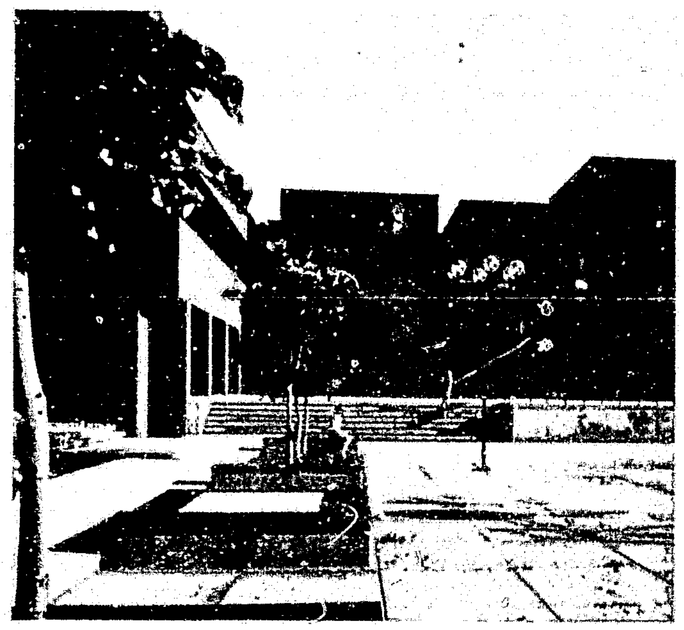

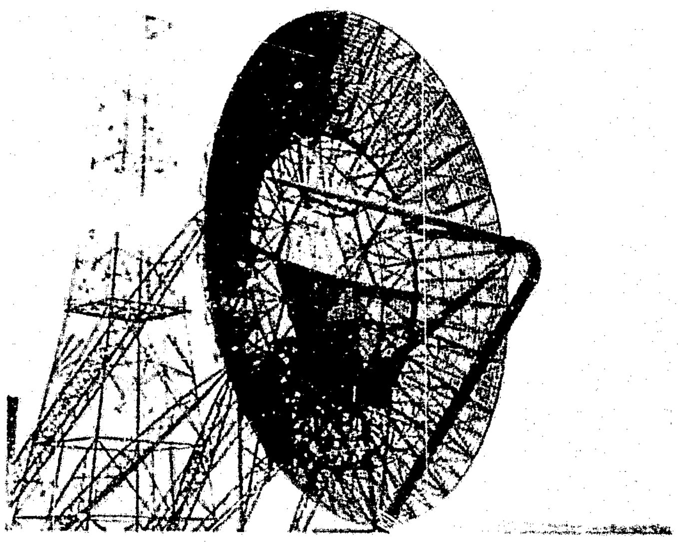

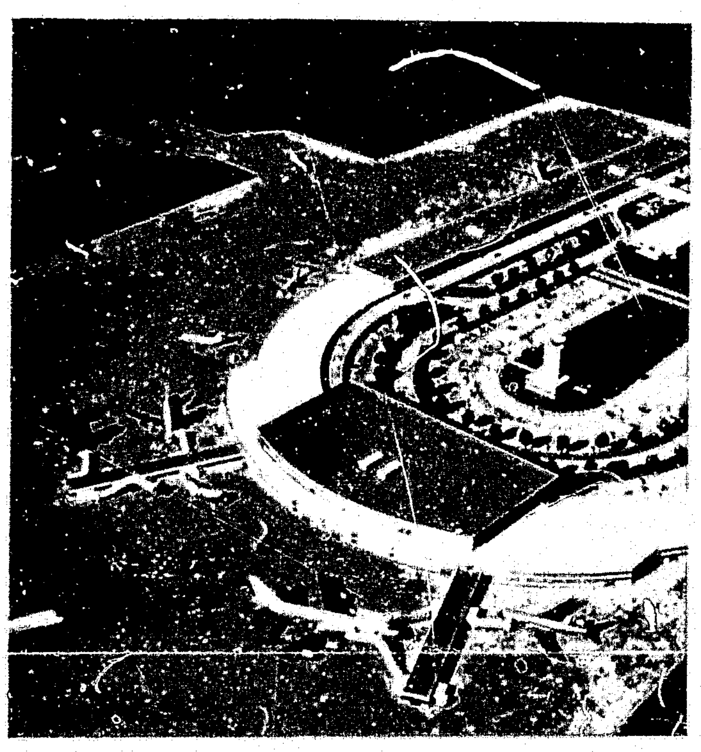

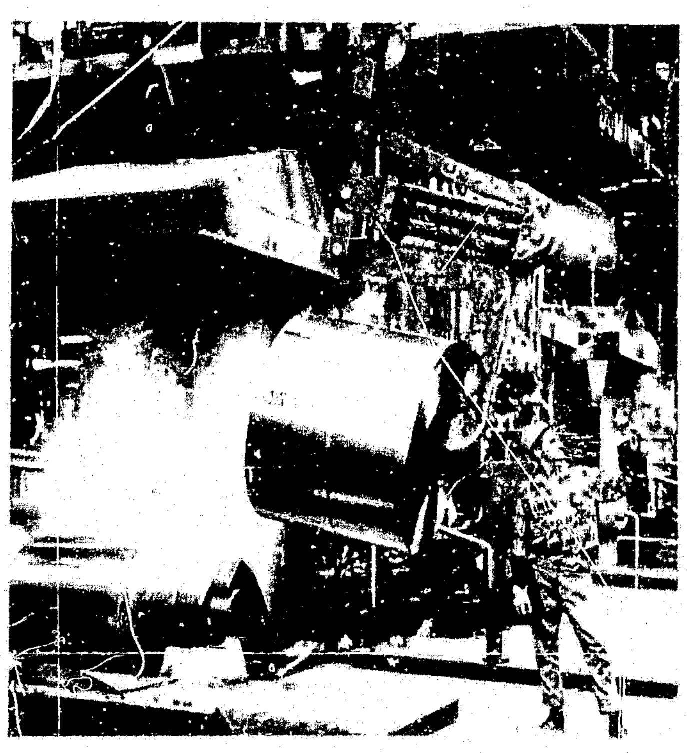

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LOAD FORECASTING AND MARKET SURVEYS

Serving the electric power utility industry since 1924, Acres has built up a considerable body of experience in the preparation of market surveys and load forecasts. An example of Acres work in this field was the preparation of a large-scale market survey relative to the import of power from the Churchill Falls project in Canada. The area studied in that instance was the whole of the New England region together with the area serviced by Consolidated Edison Company of New York.

On a more modest scale, Acres planning engineers have prepared numerous midrange market surveys and load forecasts for urban and municipal utilities, in order to evaluate the most effective way of modernizing their distribution systems or converting to a higher voltage class.

In connection with the more detailed planning studies, Acres engineers frequently have had occasion to prepare medium and long-range projections for major utility systems both at home and overseas. Such forecasts are usually prepared in conjunction with the client's engineers and Acres own staff, and they normally include national as well as regional trends. In the case of overseas clients, often located in developing countries, a more grass roots approach is called for. In such cases, market survey techniques are employed, which are based on all necessary economic indicators, such as consumption of power per capita or per ton of manufactured product. Acres American has access, through the main Acres group of companies, to a large staff of economists well versed in the requirements of such studies.

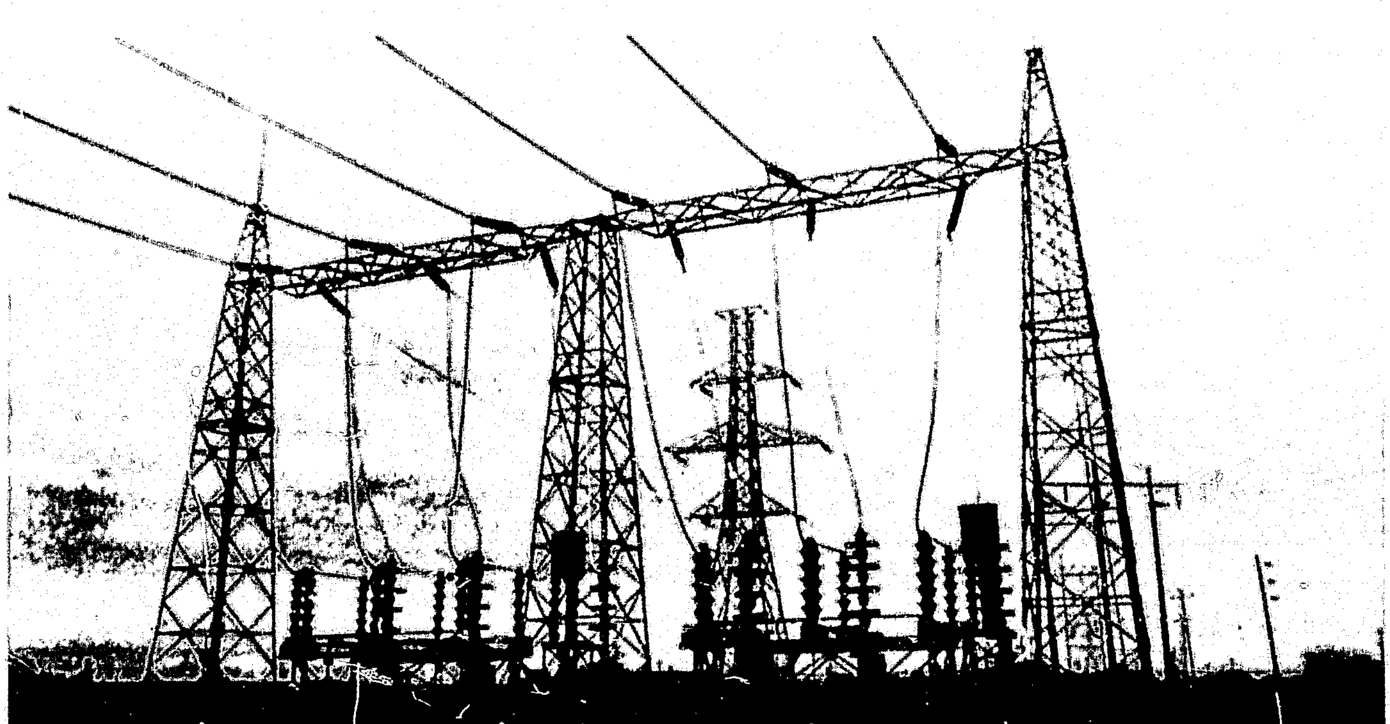
LONG-RANGE PLANNING AND POWER SYSTEM STUDIES

Acres American is in a position to provide a complete range of consulting services for long-range system planning studies. These studies, which can be done either independently or in close association with the client's engineers as required, might typically cover the following activities:

- Preparation of load forecasts and the formulation of a series of preliminary system expansion sequences
- Assembly of system data, component ratings, impedance data, and transformer tap ranges
- Conducting all necessary load flow studies to determine the timing of new plant additions, equipment ratings, transformer tap ranges, and the need for and location of VAR (voltage) control equipment
- Development of stage-by-stage single-line diagram and capital costs associated in the alternative system expansion programs
- Conducting of stability and fault level studies to modify or confirm the system configuration arrived at from load flow studies.

A recent new activity in this general sphere has been a series of studies on the economic integration of pumped storage hydro plants into existing power systems.

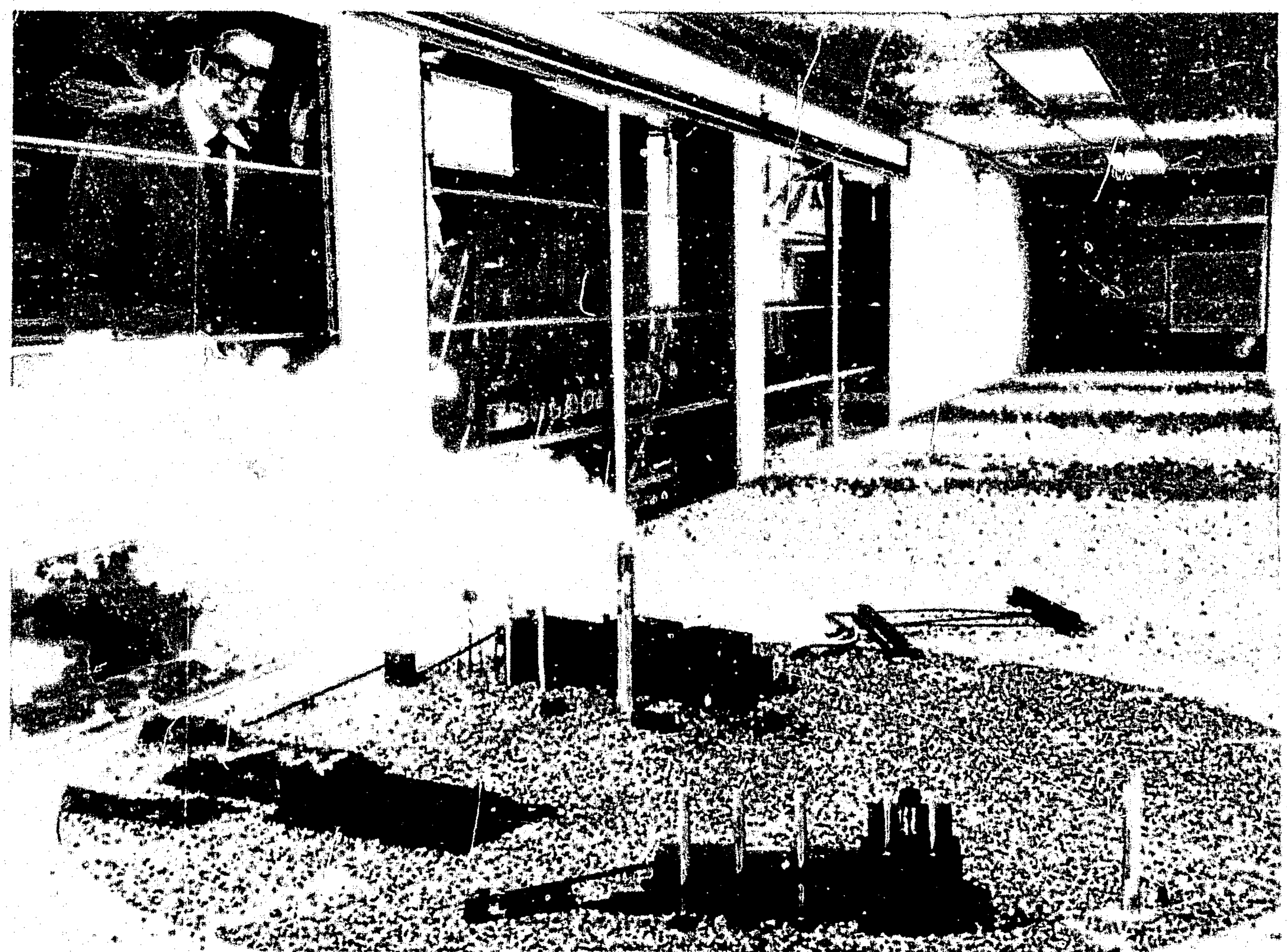
These studies have involved the year-by-year simulation of power system operations and determination of system operating costs for alternative system development programs. Operating costs are determined for a range of variations in key parameters, and these are combined with system capital costs to determine the total cumulative present worth cost of power supply. Comparison of the present worth costs of the various alternatives permits an easy determination of the expansion program and the pumped storage plant dimensions that minimize the power cost. It should be noted that Acres technical planning specialists and professional economists have a sound knowledge of the relevant techniques of economic analysis, particularly as they relate to electric utility problems.



LICENSING APPLICATIONS

During recent years, the Public Service Commissions in the majority of States have enacted regulations requiring utilities to secure regulatory agency approval before constructing major facilities. For example, the New York State Public Service Law on the construction of transmission lines at 100 kv and over requires utilities to file application for "Certificate of Environmental Compatibility and Public Need". Similar environmental requirements in most other states also regulate the procedures necessary for the siting of power generating plants. The application for these certificates must contain detailed information, some of which requires many in-depth studies. Acres experience in these activities enables our engineers to make valuable contributions in the following areas:

- Identification of potential sites and transmission line right-of-way, including study of alternatives
- Environmental impact statements
- Preparation of statements describing anticipated effects on local communications and the local economy
- Preparation of project descriptions and justification statements
- Assurance of compliance with local State and Federal regulations. Checking for the existence of possible conflicting cases filed by others
- Preparation of expert court testimony
- Modeling of air and water effluent dispersal by both physical and mathematical means.



EXPERT COURT TESTIMONY

During recent years, the already complex task of obtaining right-of-way for hv and ehv transmission lines has been further complicated by the need to take into account the various environmental considerations as well. In this field, as in others, Acres American has been moving with the times, and is in a position to offer the services of our professional staff, not only to prepare the detailed information necessary for the environmental impact statement itself, but to testify on behalf of the client before the County Zoning Boards, general public hearings, and the various State and other regulatory agencies.

An example of this type of service is the assistance our staff recently gave to Potomac Electric in connection with a public hearing for a 500-kv line. The testimony covered environmental considerations associated with the line and substation and included audible noise, radio and television interference, the generation of ozone and nitrogen oxides, electromagnetic radiation, electrostatic shock hazards, fuel ignition, biological effects and long-term health implications. Prior to the hearings, preparatory meetings with local regulatory and governmental authorities and health authorities were also held. Visual aids in the form of large scale charts, diagrams and architectural models and renderings were prepared and registered with the court as official exhibits.

SAFETY AND CODE REQUIREMENTS

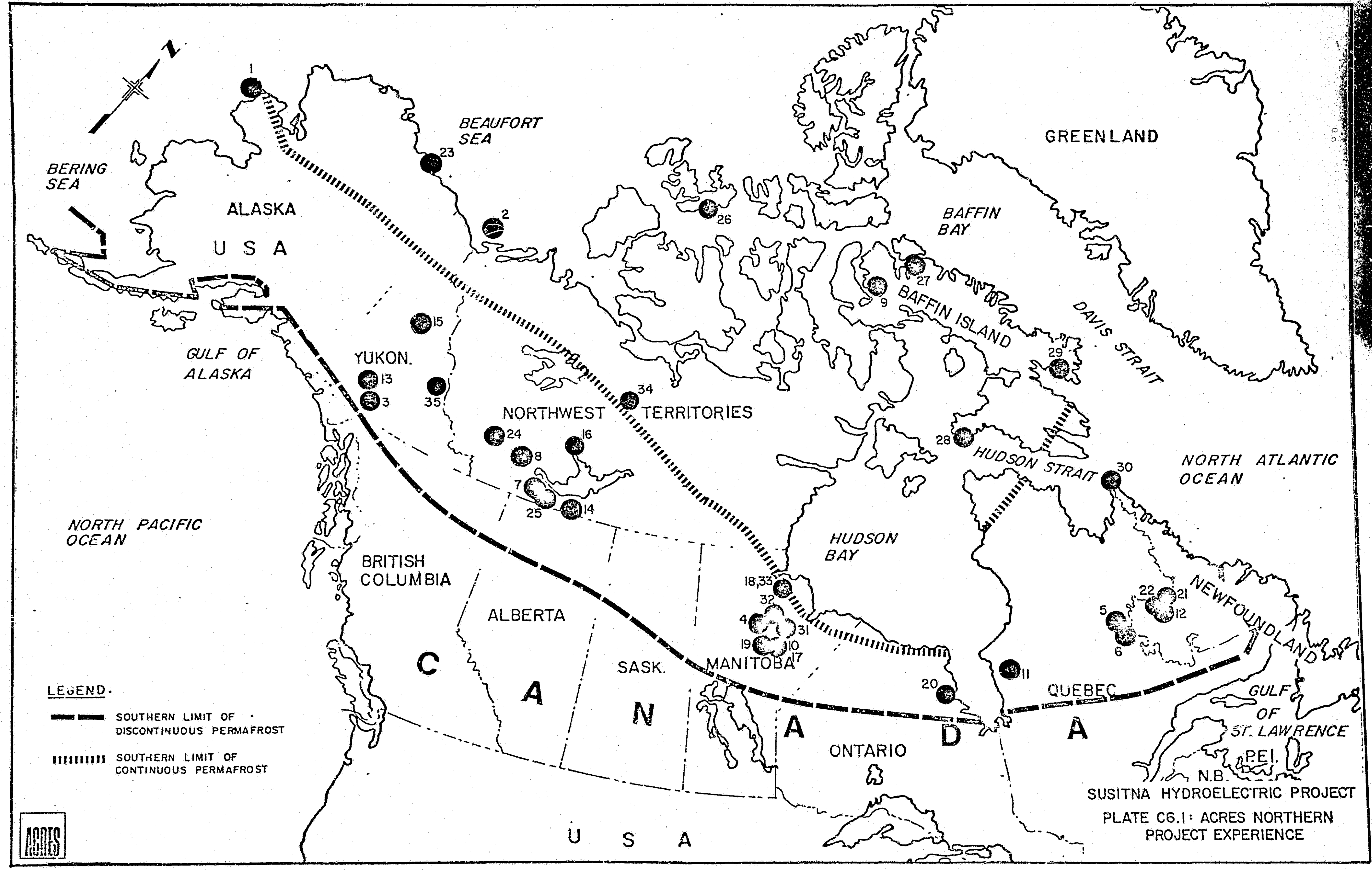
The National Electrical Safety Code (NESC) standard covers basic provisions for the safeguarding of persons from hazards arising from the installation, operation, and maintenance of overhead supply and communication lines associated equipment. It applies to all overhead systems operated by utilities or similar systems in an industrial establishment.

The existing sixth edition of Part 2, which was approved in 1960 as ANSI C62.2–1960 and published in 1961 as NBS Handbook 81, is being revised not only to overcome many of the inadequacies but also to extend the requirements to cover system voltages in the uhv range. If the proposed seventh edition is passed, it will impose even more stringent requirements on some aspects of design, construction, and operation of overhead lines—especially the ehv lines.

As an example, Section 23 on "clearances" proposes to stipulate required electrical clearances for various switching surge factors. This requirement, if passed, could have a significant impact on ehv and uhv transmission line costs, since the proposed tower window clearances would exceed the clearances normally used by many utilities to obtain acceptable flashover probabilities.

Other items relating to potential hazards associated with higher voltages, that will be recommended by NESC, should be carefully reviewed in the light of their effect on the design, construction and operation of forthcoming overhead systems.

Acres is in a position to offer the services of senior staff members with a sound knowledge of all these considerations.



SUSITNA HYDROELECTRIC PROJECT

PLATE C6.1: ACRES NORTHERN PROJECT EXPERIENCE

REPRESENTATIVE LISTING OF ACRES PROJECTS

NORTH AMERICAN HYDRO-ELECTRIC POWER DEVELOPMENTS

DEVELOPMENT AND CLIENT	INSTALLED CAPACITY		RATED HEAD
Churchill Falls Churchill River, Labrador, Newfoundland Churchill Falls (Labrador) Corporation Limited	11 units Underground powerhouse	5,225 Mw	313 m (1,025 ft)
Bersimis No. 1 Bersimis River, Quebec Quebec Hydro-Electric Commission	8 units Underground powerhouse	900 Mw	239 m (785 ft)
Chute-des-Passes Peribonka River, Quebec Aluminum Company of Canada Limited	5 units Underground powerhouse	750 Mw	160 m (540 ft)
John Hart Campbell River, British Columbia British Columbia Power Commission	6 units	125 Mw	119 m (390 ft)
Bersimis No. 2 Bersimis River, Quebec Quebec Hydro-Electric Commission	5 units	640 Mw	112 m (367 ft)
Lower Notch Montreal River, Ontario The Hydro-Electric Power Commission of Ontario	2 units	250 Mw	70 m (230 ft)
Manicouagan 2 Manicouagan River, Quebec Quebec Hydro-Electric Commission	8 units	1,000 Mw	70 m (230 ft)
Shipshaw Saguenay River, Quebec Aluminum Company of Canada Limited	12 units	900 Mw	63.5 m (208 ft)
Outardes Outardes River, Quebec The Ontario Paper Company Limited	2 units	52 Mw	63.5 m (208 ft)
Arnprior Madawaska River, Ontario The Hydro-Electric Power Commission of Ontario	2 units	78 Mw	21 m (68 ft)

DEVELOPMENT AND CLIENT	INSTALLED CAPACITY		RATED HEAD
Chute-a-Caron Extension Saguenay River, Quebec Aluminum Company of Canada Limited	2 units	100 Mw	50 m (165 ft)
Strathcona Campbell River, British Columbia British Columbia Power Commission	1 unit	31 Mw	42.5 m (140 ft)
Black River Extensions Black River, Quebec The Pembroke Electric Light Company Limited	3 units	6 Mw	38 m (125 ft)
Grand Falls Saint John River, New Brunswick The New Brunswick Electric Power Commission et al	4 units	60 Mw	38 m (125 ft)
McCormick No. 1 Manicouagan Power Company	2 units	85 Mw	37.5 m (124 ft)
McCormick No. 2 Manicouagan River, Quebec Manicouagan Power Company	3 units	134 Mw	37.5 m (124 ft)
McCormick No. 3 Manicouagan River, Quebec Manicouagan Power Company	2 units	120 Mw	37.5 m (124 ft)
Manicouagan 1 Manucouagan River, Quebec Quebec Hydro-Electric Commission	3 units	180 Mw	37.5 m (124 ft)
Ladore Falls Campbell River, British Columbia British Columbia Power Commission	2 units	52 Mw	37 m (122 ft)
Grand Rapids Saskatchewan River, Manitoba Manitoba Hydro	4 units	450 Mw	36.5 m (120 ft)
Mactaquac Saint John River, New Brunswick The New Brunswick Electric Power Commission	6 units	625 Mw	33.5 m (110 ft)

Major Hydroelectric Projects Overseas

The company has for a number of years been responsible for the complete engineering of numerous large hydroelectric projects overseas. We are currently providing comprehensive project management and engineering services to the Volta River Authority in Ghana for the $250 million, 150 MW Kpong Hydroelectric Project. This project is being financed by the World Bank and is scheduled for completion in 1981. In Iran, prior to the recent unrest, Acres had been retained to provide engineering and project management services for the $1,500 million Karun hydroelectric development. Work on this project is expected to restart in the near future.

Acres experience and accomplishments in a wide variety of conditions and circumstances overseas are considerable. A summary of more important projects is presented in the attached tables. Details of some of these projects are presented in Appendix C2.

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REPRESENTATIVE LISTING OF ACRES PROJECTS

OVERSEAS HYDROELECTRIC POWER DEVELOPMENTS

DEVELOPMENT AND CLIENT	INSTALLED CAPACITY	RATED HEAD
Alto Anchicaya Anchicaya River, Colombia Corporacion Autonoma Regional del Cauca	3 units — 340 Mw Underground powerhouse	430 m
Aslantas Ceyhan River, Turkey Government of Turkey State Hydraulic Works	3 units — 125 Mw	100 m
Mayurakshi Reservoir Mayurakshi River, India Government of Canada Colombo Plan Administration	2 units — 4 Mw	30 m
Kpong Rio Volta, Ghana Volta River Authority	4 units — 160 Mw	11.8 m
Los Esclavos Los Esclavos River, Guatemala Instituto Nacional de Electrificacion	2 units — 13 Mw	107 m
Nam Ngum Nam Ngum River The Laotian National Mekong Committee	2 units — 30 Mw	35 m
Salto Grande Uruguay River, Argentina-Uruguay Comision Tecnica Mixta de Salto Grande	12 units — 1,620 Mw	25 m
Shadiwal Upper Jhelum Canal, Pakistan Government of Canada Colombo Plan Administration	2 units — 12 Mw	7 m
Sirikit Nan River Electricity Generating Authority of Thailand	4 units — 500 Mw	76 m
Tarbela Rio Indo, Pakistan Water and Power Development Authority	2 units — 350 Mw	91.4 m
Warsak Kabul River, Pakistan Government of Canada Colombo Plan Administration	4 units — 160 Mw	44 m

SELECTED PROJECT DESCRIPTIONS

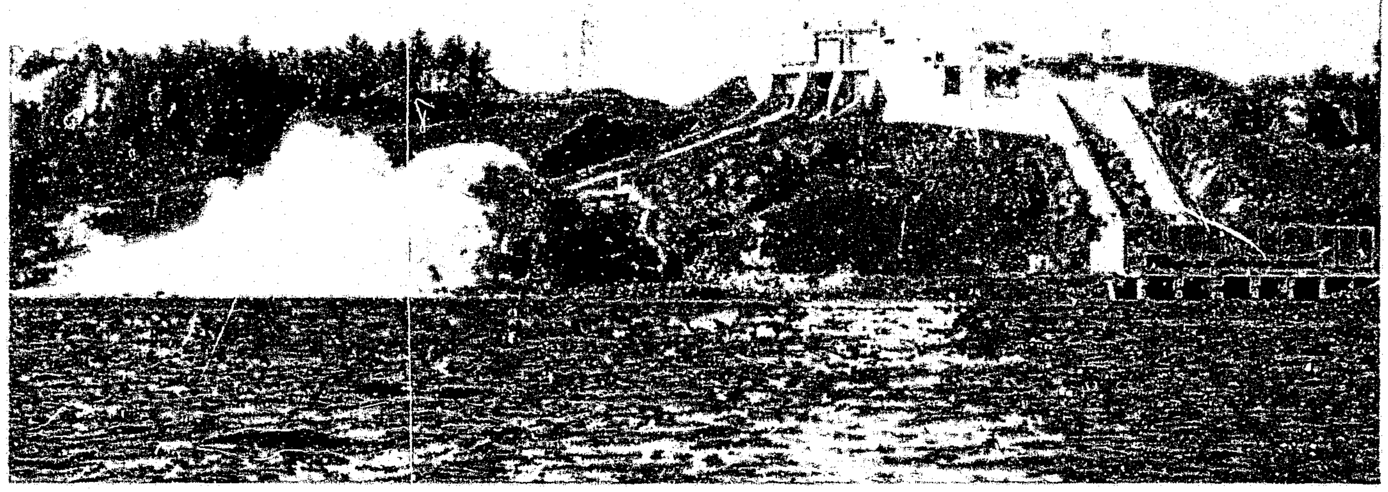
AGRES

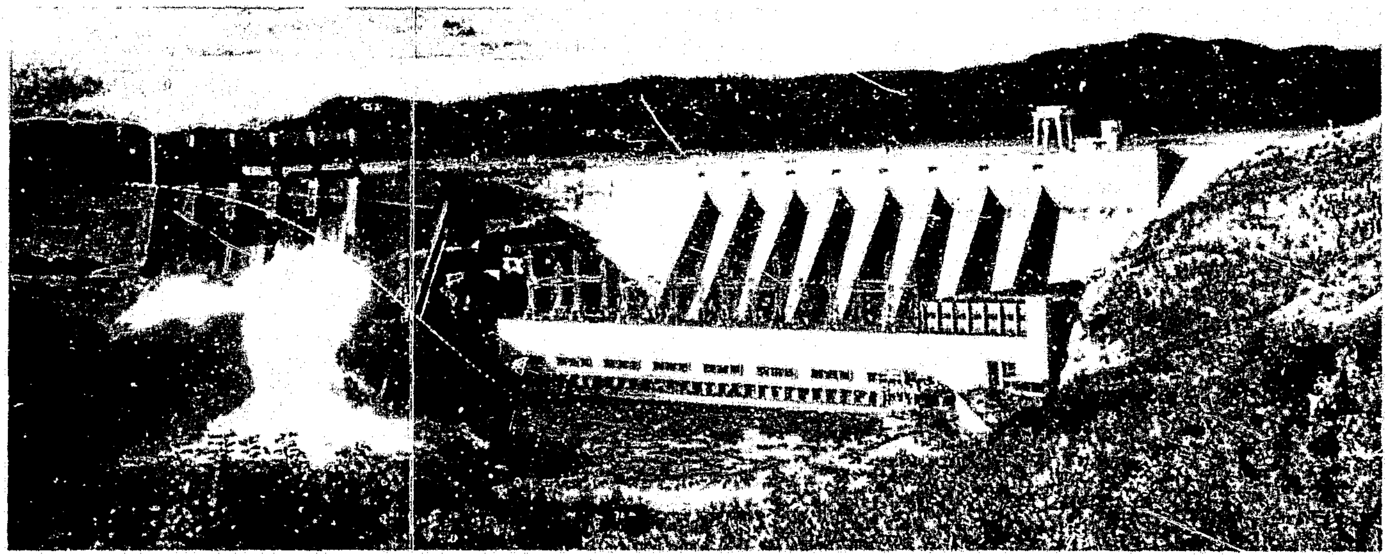
HYDROELECTRIC POWER DEVELOPMENT
EARTH-FILL, ROCK-FILL AND CONCRETE DAMS

An essential part of all hydroelectric developments is the design and construction of water-retaining structures. Generally the cost of these structures form a significant portion of the total development cost. Depending on the site, the economics of the dam can determine the economic viability of the project.

Acres has successfully engineered nearly one hundred dam structures of different types on foundations ranging from tropical soils to permafrost.

The following pages give representative listings of Acres projects involving earth-fill, rock-fill and concrete dams.





EARTHFILL AND ROCK-FILL DAMS

Since 1938 Acres has been responsible for the geotechnical investigations, engineering studies, final designs, and construction supervision for over sixty earth and rock-fill dams.

These dams are of a variety of types including homogeneous section and sloping and vertical core, and their construction involved the use of fill materials ranging from marine clays and weathered clay shales to uniform fine sands utilized as impervious core materials. The construction cofferdams for these projects included earthfill, rock fill, timber crib and cellular types, some of which were designed to overcome difficult foundation problems including underseepage, while others were "closed" in extremely fast water.

Several of the dams are founded on overburden presenting stability and seepage erosion problems. These foundation conditions varied from lenses of varved clays and silts in glacial till deposits (Bersimis No. 1) to the stiff weathered crust of sensitive marine clay deposits (Bersimis No. 2). A particularly difficult foundation problem was encountered in the founding of several small dikes directly upon varved clay overburden containing extensive permafrost (Kelsey).

Seepage and the uplift pressures in a deep pervious layer were controlled by means of a grout curtain in overburden and pressure relief wells at Strathcona, and a deep cement and chemical grout curtain was employed to reduce large underseepage in alluvial sands and gravels at Lake Ste Anne.

At the Manicouagan 2 Development, the cofferdam embankment consisted of a granular fill on highly pervious alluvium. To control seepage a concrete cutoff wall was installed through the fill, well into the alluvium. The excavation for the wall was made using a bentonite slurry trench technique.

CONCRETE DAMS

In general, Canadian dam sites have crest length to height ratios which dictate the use of gravity or buttress type structures while Canada's severe winter climate and the labour/material cost balance militate against the use of highly reinforced, thin section buttress dams.

Every dam site is, however, unique. Except where the choice is obvious, Acres evaluates the relative economy and safety of the alternative types of concrete dam which could reasonably be considered. These may include gravity, hollow joint gravity, arch, arch gravity, multiple arch, buttress, massive buttress, and prestressed structures.

The choice is made with due regard to the geology, geohydrology, topography and seismicity of the site. Labour and material requirements and their cost relationships, construction schedule, and climatic conditions all have a major bearing on the final selection.

Detailed attention is given to design of the optimum concrete mix for the various parts of the structure.

Final structural analysis is carried out by digital computer. The stress/deformation characteristics of the foundations and abutments are introduced. Seepage pore pressure distributions and the effect of pressure relief systems within the dam and in the foundations are included. Thermal and shrinkage stresses within the structure as functions of the properties of the concrete mix, pour schedule, construction joint arrangement, and extent of natural and artificial cooling are determined.

In the hollow joint dam at the Manicouagan 2 development the advantages of gravity and massive buttress type structures are combined. Completed in 1965, it is believed to be the only dam of its type in North America and, with a maximum height of 345 feet, possibly the highest of its type anywhere.

Two examples of more conventional gravity dams are Bersimis 2 in Quebec and Warsak in West Pakistan. Both are briefly described in the following pages.

In all, more than 20 concrete dams designed by Acres are listed in the accompanying summary.

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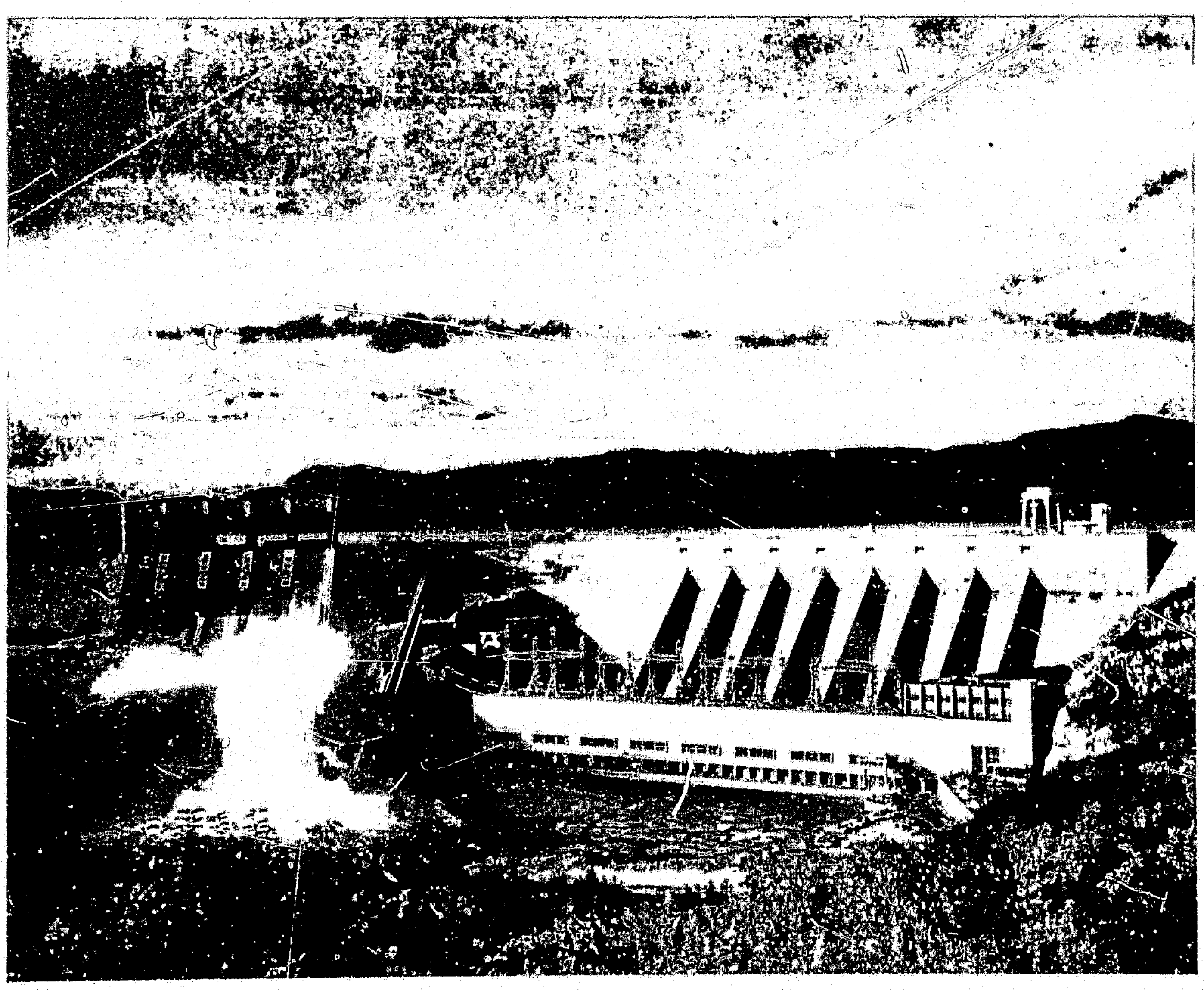
THE MANICOUAGAN 2 HYDROELECTRIC DEVELOPMENT MAIN DAM

The Manicouagan 2 Hydroelectric Development has a hollow joint gravity dam 2290 feet long and 345 feet high. The hollow joint dam was selected on the basis of an economic comparison which indicated that in comparison with a conventional gravity dam, there would be a 10% saving in concrete volume & a 7% reduction in capital cost. The high tailwater level at the site (about 100 feet above foundation level) was also a major factor favouring the hollow joint design.

A hollow joint dam is basically a gravity structure in which the transverse construction joints are formed as major cavities. At Manicouagan 2 the cavities are 16'-6" wide and the gravity blocks are 65'-6" wide so that large areas of rock are exposed t foundation level.

The hollow joints adopted at Manicouagan 2 reduced concrete quantities, and also created very effective relief of seepage pressures at the foundation and within the dam itself. As a result hydrostatic uplift forces were considerably reduced. The voids formed by the joints minimized inter-dependance of the concrete placing operations in adjacent blocks and permitted an accelerated construction schedule.

Efficient natural air cooling during construction was provided by the large area of exposed concrete at each joint, the need for artificial cooling systems being minimized as a result.



MAJOR EARTH- AND ROCK-FILL DAMS – 1

Project	Construction	Dimensions Metric		Imperial	Foundation Materials
Alto Anchicaya Power Development, Colombia	Compacted rock fill with upstream concrete face	140.3 270	m m	(460 ft h) (885 ft l)	Metamorphosed, sedimentary schist, diorite and hornfels
Amos Fly Ash Retention Dam, West Virginia, U.S.A.	Upstream compacted shale core, random and rock-fill support zone. Pressure relief system	68.6 610 2,750,000	m m m^3	(225 ft h) (2,000 ft l) (3,600,000 yd^3)	Carboniferous, sedimentary rock
Arnprior, Waba Dam Madawaska River Ontario, Canada	Earth fill, marine clay, homogeneous fill with central filter drain	18.3 1,036	m m	(60 ft h) (3,420 ft l)	Thick marine clay deposit
Asiantas Dam & Power Project, Turkey (Design only – under construction)	Compacted shale core, and support zone. Upstream and downstream weighting zones	33.6 750	m m	(110 ft h) (2,460 ft l)	Clay shale and sandstone (Flysch)
Beauharnois Power Development, Stage 3, Quebec, Canada	Forebay dike. Rock fill with thick central clay core	12 64 81,000	m m m^3	(39.3 ft h) (210 ft l) (106,000 yd^3)	Paleozoic sandstone
Bersimis No. 1 Power Development, Quebec, Canada					
Main Dam	Hydraulicly compacted rock fill with upstream rolled impervious core	64 641 2,800,000	m m m^3	(209 ft h) (2,100 ft l) (3,670,000 yd^3)	Precambrian metamorphic rock and glacial overburden
Des Roches Dam	Hydraulicly compacted rock fill with upstream rolled impervious fill core	69 335 1,100,000	m m m^3	(225 ft h) (1,100 ft l) (1,453,000 yd^3)	Precambrian metamorphic rock and glacial overburden

Major Earth- and Rock-Fill Dams – 2

Project	Construction	Dimensions Metric		Imperial	Foundation Materials
Pamouscachiou Dam No. 1	Gravel with sloping rolled impervious core	19 637 221,700	m m m^3	(75 ft h) (2,090 ft l) (290,000 yd^3)	Precambrian metamorphic rock and glacial overburden
Pamouscachiou Dam No. 2	Gravel with sloping rolled impervious core	19 427 145,300	m m m^3	(62 ft h) (1,400 ft l) (190,000 yd^3)	Precambrian metamorphic rock and glacial overburden
Bersimis No. 2 Power Development Quebec, Canada					
Auxiliary Dam No. 1	Vertical marine clay core, sand support zones, local sheet pile	30 1,010 845,000	m m m^3	(97 ft h) (3,310 ft l) (1,105,500 yd^3)	Marine clay and estuarine sand
Auxiliary Dam No. 2	Vertical marine clay core, sand support zones, local sheet pile	19.5 1,195 322,800	m m m^3	(64 ft h) (3,920 ft l) (422,300 yd^3)	Marine clay and estuarine sand
Binbrook Reservoir Ontario, Canada	Control dam – Earth fill	11 701 91,700	m m m^3	(36 ft h) (2,300 ft l) (120,000 yd^3)	Stiff brown clay
Cardinal Fly Ash Retention Dam Ohio, U.S.A.	Central compacted shale core, random and rock-fill support zone. Grout curtain, pressure relief system	76.2 762 1,300,000	m m m^3	(249 ft h) (2,500 ft l) (1,703,000 yd^3)	Carboniferous, sedimentary rocks
Clarabelle Lake Dam Ontario, Canada	Control dam – Rock fill	19.8 276.5 80,280	m m m^3	(65 ft h) (905 ft l) (105,000 yd^3)	3.05 to 4.57 m of organic material plus 4.57 to 7.62 m of soft varved clay over bedrock

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Major Earth- and Rock-Fill Dams — 3

Project	Construction	Dimensions			Foundation Materials
		Metric		Imperial	
Conestogo Dam Ontario, Canada	Control dam — Earth fill with protection thick central clay core riprap and concrete spillway section	29.3 546 458,000 72,600	m m m^3 m^3	(96 ft h) (1,790 ft l) (600,000E yd^3) (95,000C yd^3)	Dolomitic limestone with glacial till overburden
Fanshawe Dam Ontario, Canada	Control dam — Earth fill with thick clay core and concrete spillway section	30.5 655 344,250 143,700	m m m^3 m^3	(100 ft h) (2,150 ft l) (450,000E yd^3) (188,000C yd^3)	Limestone with till overburden
Grand Rapids Generating Station Manitoba, Canada	Earth fill with 30 km long, with up to 61 m deep grout curtain	33.5 25,600 7,100,000	m m m^3	(109 ft h) (83,900 ft l) (9,300,000 yd^3)	Karstic, dolomitic limestone
Horwood Lake Dam Ontario, Canada	Control dam — Earth fill with concrete sluiceway section	9.4 274 35,200 3,900	m m m^3 m^3	(31 ft h) (900 ft l) (46,000E yd^3) (5,100C yd^3)	
John Hart Development British Columbia, Canada	Main dam — Earth fill	622 83,200	m m^3	(2,040 ft l) (109,000 yd^3)	
Kelsey Generating Station Manitoba, Canada	Main dam — Rock fill with upstream impervious sloping core	36.6 291 220,000	m m m^3	(120 ft h) (955 ft l) (288,300 yd^3)	Precambrian metamorphic rock
	Cutoff dikes, two — Sand	6.1 1,189 74,400	m m m^3	(20 ft h max) (3,900 ft l total) (97,500 yd^3 total)	Permafrost

Major Earth- and Rock-Fill Dams — 4

Project	Construction	Dimensions Metric		Imperial	Foundation Materials
	Cutoff dikes, three — Clay	11.6 1,906 70,000	m m m^3	(38 ft h max) (6,250 ft l total) (91,600 yd^3 total)	
Kettle Generating Station Manitoba, Canada (In consortium)	Main dam — Earth fill	48.8 1,067 2,700,000	m m m^3	(160 ft h max) (3,500 ft l) (3,540,000 yd^3)	Precambrian rock and glacial soils
	Saddle dam — Earth fill	33.6 1,190 2,106,900	m m m^3	(110 ft h) (3,900 ft l) (2,760,000 yd^3)	
	Butnau River dam — Earth fill	18.3 3,355 1,039,800	m m m^3	(60 ft h) (11,000 ft l) (1,360,000 yd^3)	
	Reservoir dikes — Earth fill	4.6 5,490 390,000	m m m^3	(15 ft h) (18,000 ft l) (510,000 yd^3)	
Lady MacDonald Lake Dam Ontario, Canada	Control dam — Rock fill	6.4 305 19,020	m m m^3	(20 ft h) (1,000 ft l) (26,000 yd^3)	Approximately 2.13 m of organic material over bedrock
Lake St. Anne Reservoir Quebec, Canada	Main control dam — Rock fill with sloping silty core and concrete spillway section	38.4 278 449,500	m m m^3	(126 ft h) (910 ft l) (588,000 yd^3)	Precambrian metamorphic bedrock
	Cutoff dam — Earth fill	19.5 131 71,100	m m m^3	(64 ft h) (430 ft l) (93,000 yd^3)	Rock

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Major Earth- and Rock-Fill Dams — 5

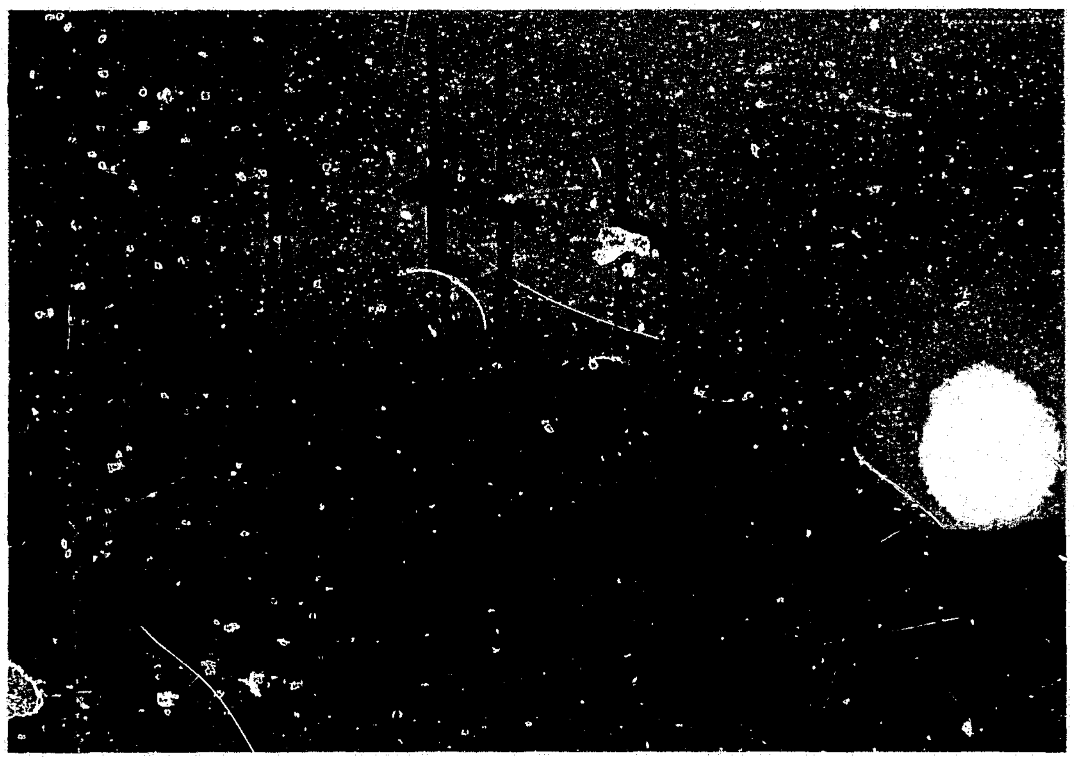
Project	Construction	Dimensions Metric		Imperial	Foundation Materials
Laurie River No. 1 Development Manitoba, Canada	Loon River east diversion dam — Earth fill	10.7 64.1	m m	(35 ft h) (210 ft l)	
	Loon River west diversion dam — Earth fill	7.6 99.1	m m	(25 ft h) (325 ft l)	
Laurie River No. 2 Development Manitoba, Canada	Main dam extension — Earth fill	116 32,800	m m^3	(380 ft l) (43,000 yd^3)	
	Dike A — Earth fill	10.7 128	m m	(35 ft h) (420 ft l)	
	Dike B — Earth fill	10.7 134.2	m m	(35 ft h) (440 ft l)	
Limestone Generating Station Nelson River, Manitoba, Canada (In consortium)	Central core earth fill	33 538 2,200,000	m m m^3	(110 ft h) (1,900 ft l) (2,800,000 yd^3)	Ordovician limestone
Long Spruce Generating Station Nelson River, Manitoba, Canada (In consortium)	Central core earth fill	39.7 754 2,300,000	m m m^3	(130 ft h) (2,500 ft l) (3,000,000 yd^3)	Precambrian
G. Ross Lord Conservation Dam Toronto, Ontario, Canada	Earth fill	19.8 366 267,000	m m m^3	(65 ft h) (1,200 ft l) (350,000 yd^3)	Glacial deposits
Lower Notch Generating Station Ontario, Canada	Main dam — Rock fill	131.2 366 1,689,600	m m m^3	(430 ft h) (1,200 ft l) (2,210,000 yd^3)	Precambrian rock

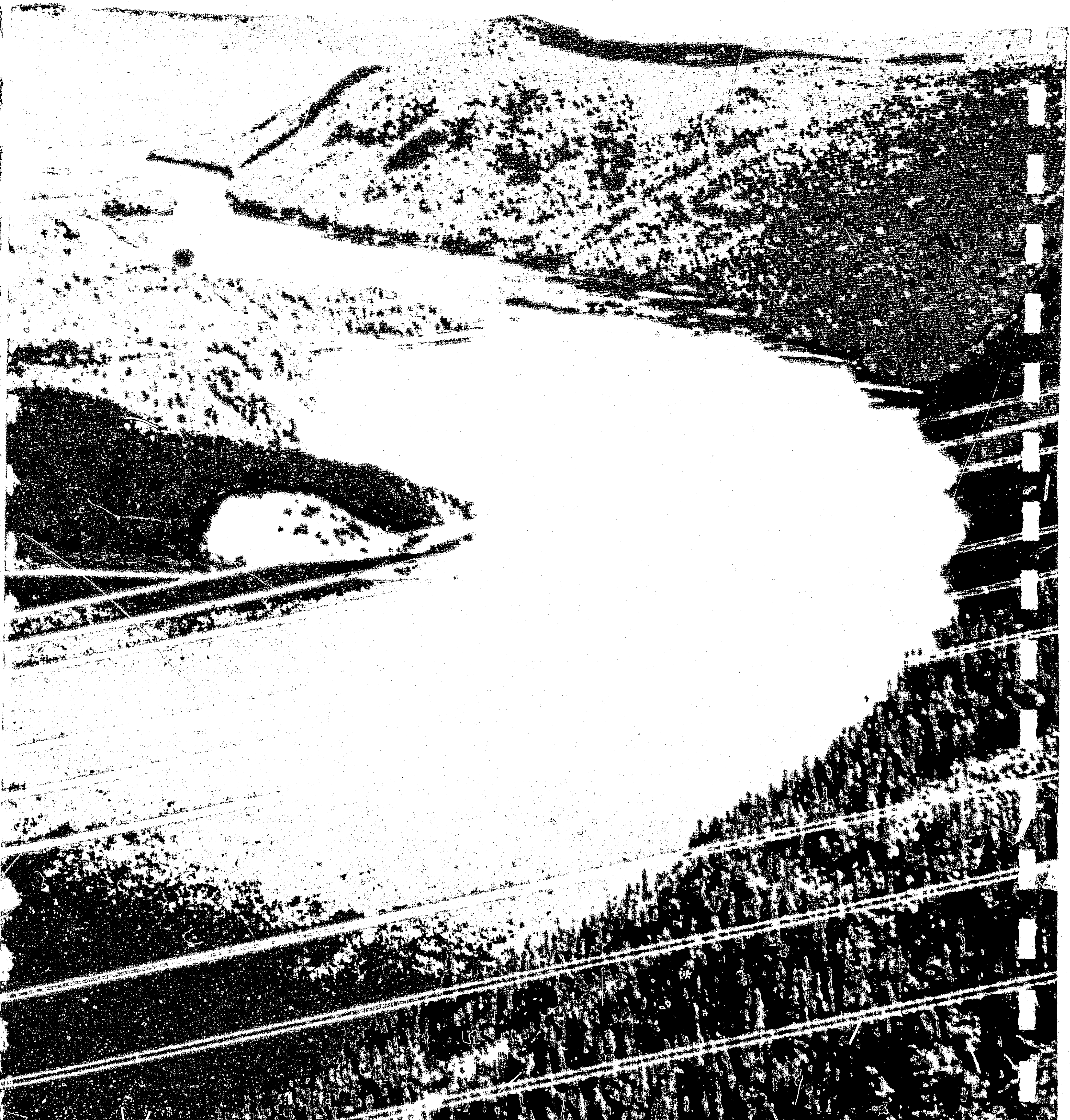
Project	Construction	Dimensions Metric		Imperial	Foundation Materials
	Reservoir dikes — Rock fill	1,098 450,300	m m^3	(3,600 ft l) (589,000 yd^3)	
Mactaquac Development	Main dam — Compacted rock fill with near vertical core of impervious glacial	46.7 518 1,223,300	m m m^3	(153 ft h) (1,700 ft l) (1,600,000 yd^3)	Slate and graywacke abutments — thick clay till and gravel in riverbed
Manicouagan 1 Development Quebec, Canada	Forebay dikes — Rock fill with sheet pile diaphragm	17.1 213 10,700	m m m^3	(56 ft h) (700 ft l) (14,000 yd^3)	
Manicouagan 2 Cofferdam Manicouagan 2 Power Station Quebec, Canada	Rock fill with Icos cutoff and sheet pile membrane	37.7 155 38,900	m m m^3	(123.5 ft h) (510 ft l) (50,900 yd^3)	Grenville granite
Marietta Fly Ash Retention Dam Ohio, U.S.A.	Central compacted shale core, random and rock fill. Grout curtain and pressure relief system	10.7 137 92,000	m m m^3	(35 ft h) (450 ft l) (120,300 yd^3)	Carboniferous sedimentary rock
McArthur Falls Development Manitoba, Canada	Cutoff dikes — Earth fill (homogeneous clay)	9.15 9,760 699,570	m m m^3	(30 ft h max) (32,000 ft l total) (915,000 yd^3 total)	Glacial till and rock
Mica Development British Columbia, Canada (In consortium)	Main dam — compacted granular material with near vertical core of impervious glacial till	198 244 762 22,936,800	m m m m^3	(650 ft h) (riverbed) (800 ft h) (rock) (2,500 ft l) (30,000,000 yd^3)	Schist and gneiss abutments — granular soils in riverbed
Shand Flood Control Dam Grant River, Fergus, Ontario Canada	Homogeneous compacted clay till with key wall	24 640 411,000	m m m^3	(78 ft h) (2,100 ft l) (537,600 yd^3)	Dolomite limestone
Strathcona Development British Columbia, Canada	Main dam — Earth fill with sloping clay core, deep grout curtain and concrete spillway section	51.8 549 1,987,800	m m m^3	(170 ft h) (1,800 ft l) (2,600,000 yd^3)	Volcanic rocks and glacial till with underlying aquifer

ACRES

Churchill Falls

an accomplished beginning





Introduction

The story of Churchill Falls illustrates one essential fact. Development of the requisite technology is only a preliminary. The critical ingredient is knowing how to put together the men, machines, and resources to apply that technology on a scale which challenges comparison with the Pyramids and the Great Wall of China — with the difference, pointed out by Prime Minister Trudeau, that the power project is "incomparably more useful."

The completion of the largest single-site power station in the western world at Churchill Falls, on schedule, and within cost estimates offers a model of how such vast projects can be accomplished.

The Falls, the Eskers and the Estimates

Certainly it needed no flash of inspiration to see the potential power of the mighty Churchill River's spectacular tumble from the glacier-gouged Labrador plateau. As early as 1894, in the infancy of hydroelectric power generation, A.P. Low of Canada's Geological Survey suggested this new technology could be applied to provide "several millions of horsepower". With remarkable prescience, he submitted that such power, turned to heat, could be used to reduce the local iron ores.

Twenty years later, W. Thibaudeau of the Régie des Eaux of the province of Quebec, surveyed the area. He saw that the river could be diverted above the Falls, and rechannelled further to the east to increase the head of water available, from 500 ft. at the Falls and upper rapids to more than 1,000 ft. at Portage Creek.

Such bold concepts awaited full economic justification for yet another generation.

Credit for the first practical initiative is due to British Newfoundland Corporation Limited, formed in 1953 by seven major British financial, resource and manufacturing companies, including Rio Tinto-Zinc Ltd. It received a charter to explore the Island of Newfoundland and Labrador for the government of Joseph Smallwood, who had just brought Newfoundland into the Canadian confederation.

The water power potential of the 110,000 square mile area was clear, but the energy available had to be quantified. In the mid-1950's it remained too remote for existing transmission techniques to deliver to available markets economically. It was accessible only by arduous canoe trip or hundreds of miles of flight by a float plane.

Brinco watched the opportunities for development unfold step by step. First, mining and processing of the iron ore deposits by other interests at Schefferville, Wabush and Labrador City, justified building the Quebec North Shore and Labrador Railway passing only 105 miles to the west of the Falls. Brinco added to the effort in 1960 by pushing a road from Esker, on the rail line, to the west bank of the Churchill. At Twin Falls, on the Unknown River, a few miles from Churchill Falls, Brinco built a modest 120,000 KW hydro-electric plant to serve the iron ore development and associated townsites. The harnessing of Labrador hydro power had begun.

Another link in the chain of feasibility was forged when Hydro-Québec, faced with developing the rivers of the north shore of the St. Lawrence for power, engineered and perfected a 735,000 volt Extra High Voltage (EHV) transmission system. Its successful application in carrying power from the Manicouagan River plants to Montreal in 1965 built confidence that it was the technical and economic solution to the problem of carrying Churchill Falls' power to market in the developing urban and industrial centres of Quebec at reasonable cost.

An emerging counterpoint to this matching of resources to markets was the growing hunger for power of the populous U.S. eastern seaboard. Jean Lessard, then chairman of Hydro-Québec, saw the opportunity to feed this U.S. market with relatively low cost power exports. With this added to Quebec's own need, the power of Churchill Falls could be fully developed at a single stroke.

In 1961, the Smallwood government granted a Brinco subsidiary, Churchill Falls (Labrador) Corp. Ltd. (CFLCo), a 99 year lease on the hydraulic resources of the 26,000 square mile watershed of the Upper Churchill.

But what engineering enterprise could be found to determine the optimum location to utilize this potential 1,000 foot head, to create a giant power complex in the midst of the muskeg and scrubby evergreens of the Labrador plateau, and to do it with assured quality within cost and time constraints that would make the venture attractive to financial institutions? For it would require the largest amount of capital ever committed in Canada for a private project.

A general view of the dyke structure

CFLCo's answer was to bring together two highly-qualified Canadian concerns — H. G. Acres & Company Limited and Canadian Bechtel Limited.

Through its affiliation with the Bechtel organization worldwide, Canadian Bechtel was able to provide virtually unmatched resources of experience in the construction and management of vast, remote, resource projects. Acres offered a wealth of expertise and experience in hydro-electric engineering.

They formed a joint venture — Acres Canadian Bechtel of Churchill Falls (ACB) — to engineer and manage the construction of this massive hydro-electric facility. By agreement, Canadian Bechtel became managing joint venturer for the contract.

An ACB team was already surveying in the field by 1963-64 supplementing the very considerable amount of data accumulated by other engineers from firms employed earlier by Brinco. Gray Thompson, an Acres member of the team, recalls that in spite of winter temperature so frigid that the bubbles in the transit level became sluggish, the survey circuit around the vast reservoir area was closed within an accuracy of one third of a foot. This was also a tribute to previous federal government and Quebec surveys whose old bench marks were picked up by the ACB team.

Calculations were accumulated, checked and cross-checked as to the optimum site, hydrological effects of snow accumulations and the size of reservoir needed to smooth the flow of the erratic Churchill, which varied from 10,000 to 300,000 cubic feet or more per second depending on season. The project was feasible — but the resources required to build it would be enormous. Irrefutable evidence that the project would be profitable was required before a sound approach to financing could be devised.

It took two more years of negotiation, and the expenditure of $17 million on preliminary engineering, before the breakthrough that triggered the leap from concept to construction. On October 13, 1966, Hydro Quebec's Jean Lessard, signed a letter of intent assuring that the Quebec utility would purchase the bulk of electricity generated from the site. By this time, the growth of Canada's energy demand made it unnecessary to rely on export to create a market. The moment for Churchill Falls power had arrived.

It was now up to ACB to meet the challenge.

The usual procedure for a hydro-electric project in Canada would be to proceed with detailed engineering of the various components of the project, put them out to tender, receive contractors' bids, sum the bid costs and thence proceed to make the necessary capital appropriation. However, in such a massive, remote project, undertaken by a utility company with relatively little in the way of assets and financial capability, a completely different approach was required.

ACB, as engineers and construction managers, had to organize a workplace in the middle of the wilderness, devise means to bring men and machines to it, and put together the whole complex schedule for a project which would stretch over nearly a decade. The packages into which the work was divided had to be tailored to the capacities of existing contracting firms in eastern Canada. It was upon ACB's estimates of the final cost of these packages that the delicate job of financing the project had to be based.

On March 7, 1967, CFLCo signed a contract with ACB covering engineering and construction management services to the end of the project. At almost the same time, it accepted ACB's estimate of direct construction cost of $522 million for the project. To this would be added $102 million to provide for escalation arising from price and wage increases over the life of the project and $41 million as a contingency allowance, giving a total direct construction cost of $665 million. Interest charges on money borrowed during construction, administration, working capital, overhead and other expenses would bring the total project cost to $946 million. This included more than $20 million spent in early studies and work by CFLCo up to March 31, 1967. It made Churchill Falls the largest civil engineering project ever undertaken in North America to that time.

A billion dollars isn't raised quickly.

It was Oct. 30, 1968, before Brinco Chairman Henry Borden reported to a special meeting of Brinco shareholders that terms of a $100 million general mortgage bonds issue had been settled, that arrangements for bank credit ($150 million from seven Canadian chartered banks) were well underway, that an offering in the United States of half a billion dollars of first mortgage bonds had been satisfactorily completed and that an offering in Canada of $50 million in first mortgage bonds had been arranged.

During the period required to set the stage for the major financing, funds came largely from equity capital, or shares, in CFLCo subscribed by its majority shareholder — Brinco (57%) — and its minority shareholders — Hydro-Québec (34%) and the province of Newfoundland (9%). In all, $83 million was raised this way. Substantial credit also was made available to Brinco by the Bank of Montreal.

Meanwhile, work at the site had been going on for two years. First attention was given to two prime engineering challenges: to create an all-weather access road to allow heavy freight haulage to the site, and commence the enormous job of building 40 miles of dykes.

The dykes, to provide a water barrier under any temperature conditions, had to form a perfect seal with the irregular surfaces of underlying rock. They were built using glacial till and rock where available, but the principal ingredients were materials from the eskers — ridges of gravel and sand formed within or under the glaciers, which chiselled the topography of this area, and left behind when the ice melted. Virtually nothing was shipped in to build the 26-million-cubic-yard dykes. The logistics task here was moving men and equipment, but it involved some of the biggest units available.

During the first year, the master project schedule and official plan were issued. The original size of the project was increased 15%, with the addition of an eleventh turbine generating unit, and uprating each unit to 475,000 KW instead of the 450,000 KW contemplated earlier. Total plant capacity was to be 5,225,000 KW, or just over seven million horsepower. The first units were committed to deliver contract power to Hydro-Québec by May 1, 1972.

The wisdom of choosing depth of corporate experience for the management of this vast project was amply proven by the tragic event of Nov. 11, 1969. CFLCo's twin jet was approaching Wabush airport in an overcast, when it crashed into a hill, killing all six passengers: Donald McParland, 40, President and Chief Executive Officer of CFLCo; Eric G. Lambert, 46, Vice-President, Finance, for Brinco and CFLCo; John Lethbridge, 35, McParland's Executive Assistant; Fred E. Ressegieu, 56, General Manager of Acres Canadian Bechtel; J. Herbert Jackson, 42, Assistant General Manager and Manager of Construction of ACB; Arthur J. Cantle, 42, Assistant Manager of Construction, ACB; and the crew of two.

All three ACB executives were seasoned engineers. In this emergency, the resources of Bechtel's world-wide organization were combed for replacements.

By the New Year, Steven V. White assistant to S. D. Bechtel, Jr., had stepped in to replace Ressegieu. Joseph Anderson, a Scot fresh from the Wells Hydro-Electric Project on the Columbia River, replaced Jackson in the field; Alan McConnell of Acres took over in the Montreal office.

Meanwhile after a brief period of pinch-hitting by Sir Val Duncan, chairman of the Rio Tinto organization, William Mulholland, a partner in the New York banking house of Morgan Stanley & Co., was elected president and chief executive of both Brinco and CFLCo.

Yet within a year after the tragic loss the project was well on its way to delivering first power — five months ahead of schedule!

The secret of such an achievement, is twofold, says S. M. Blair, who, as Chairman of Canadian Bechtel Limited, was chairman of ACB's Policy Board for most of the construction period. First, it was necessary to create a place to work and live productively in the wilderness; and second, to create the logistics to supply that workplace with equipment, supplies, and labour, on schedule.

Making a place for man

Most of the industrial installations built to date in the Canadian north have been transitory, such as mining or petroleum exploration camps. Generally, the facilities are temporary and the men who occupy them have little thought except to get their job done and leave.

Churchill Falls was different. The construction period was to be eight years, and the anticipated life of the station stretches toward the middle of the next century. The transition from construction camp to permanent community would be phased over the period 1971-1975.

The philosophy was this: a settled happy work force, with low turnover and a minimum of interruptions because of labour disputes, is the key to maintaining schedules and cost targets. The men should be happy *off* the job as well as *on* it. Special efforts were made to afford amenities far superior to the roughness and boredom of off-hours in a typical construction camp. Civilization must come concurrently with construction.

Even though final commitment of the project was not made until 1966, by 1967 plans for a permanent community near the power facility were drawn up. The 59 houses, four 12-unit apartment blocks and a service complex with stores, school, a hotel, theatre and indoor recreation facilities were first used by the longer-term construction staff, later by the permanent power plant operating staff.

Provision of all possible amenities began as soon as the first road camps — Esker, Bridge Camp and Mount Hyde Lake—opened. By Christmas, 1966, for instance, only two months after start of the project, John McGowan, Bona Vista Food Services manager, the caterer for the project, recalls that the Christmas dinner menu included cream of tomato soup, roast turkey with all the trimmings, and a cold buffet with salads, assorted pastries, two kinds of Christmas cake and three kinds of pie. The dinner was followed by a movie.

At the main camp, the men were housed in 20-man complexes — three trailers side by side, housing two men to a room. There were not only washrooms, but a clothes washer and dryer in most units. Janitorial services included even bed-making.

The inevitable feeling of isolation was reduced through access to the mobile radiotelephone, teletype and telegraph services that were established and linked to the continent-wide networks. At peak, the system had 1,366 telephones and 540 mobile radio units. Until the Churchill Falls airstrip was ready in 1969, scheduled flights operated from the Twin Falls airstrip, a 30 mile drive from the main camp.

When carpenter Leo Lane from Catalina, Nfld. stepped off the plane in March 1968 to become the 1,000th worker on the project, he found Hickeys and Ryans aplenty from his own province, together with Gagnons and Tremblays from Quebec: mechanics, drillers, drivers, pipe-fitters and scores of other skilled and semi-skilled trades. They were supported both on site and at the Montreal headquarters by engineers and draftsmen translating general plans and programs into detailed blueprints and schedules.

In June, 1968, the main camp became a place for women too as staff arrived to work at a new mess hall the length of a city block. Together with clerks, secretaries, nurses and teachers, they made up a group of 200 women working on the project. Their early presence on site, together with the civilized amenities, is credited with encouraging a remarkably clean, orderly, and liveable camp — "More like a town than a camp", as many workers described it.

Not that the camp lacked its lively side. A tavern (open morning and evening to accommodate shift workers) began operation in the recreation centre in late 1967, and sold four million bottles of beer in the next four years. Nor was there any lack of other recreational facilities — such as the baseball diamond, soccer field and skating rink; later the curling rink, bowling alley and swimming pool.

Geodetic survey of the intake site

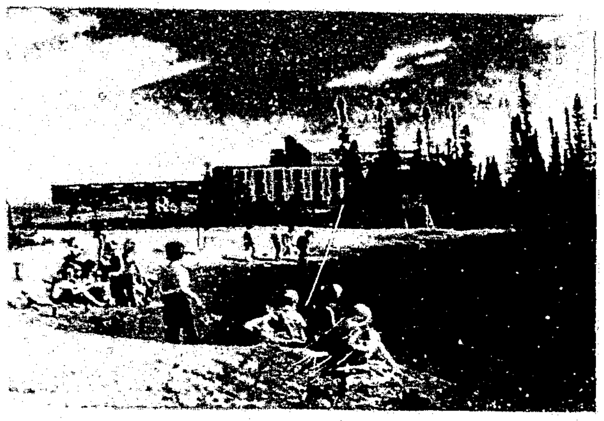
The great majority of men on site were not ACB employees, but worked for CFLCo and the scores of contractors and suppliers. But as well as managing their accommodation at the site, ACB co-ordinated the other essentials for a happy work force: a collective master labour agreement which was signed for an eight year period (1967-1975) between an association of employers working at the site and a council of Newfoundland-based locals affiliated with international building trade and service unions.

A substantial help to the general smooth running of the operation was the presence on site of full-time labour relations personnel trained to handle and resolve day-to-day problems on the spot.

ACB management is unanimous that this agreement was the single most important factor in achieving the high man-day productivity recorded during construction. The no-strike, no-lockout clause, together with an agreed formula for periodic wage adjustments, meant there was no interruption of work because of disputes, despite the many different employers on site. The 10-hour day and six-day week provided the 60-hour work week — paid at straight time and time and a half.

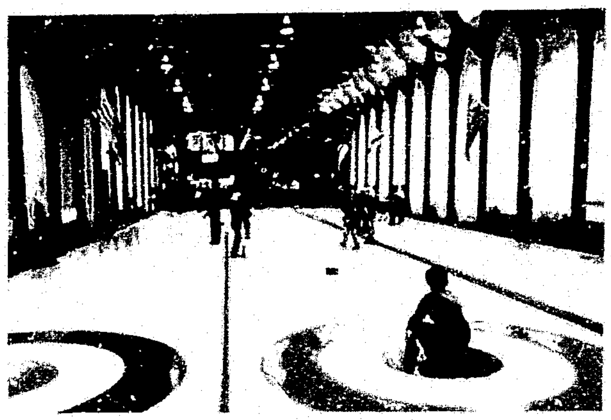
The massive demands of construction created needs for various

Aerial view of the permanent camp site



Schoolchildren beside Blueberry Lake

Swimming pool in the Town Centre



Curling rink in the Town Centre

skills, from that of the cutter clearing right-of-way for transmission lines, to the electronic expertise of the communications technician. But they all had to be able to take it: concrete pouring, for instance, continued (behind plastic shelters) even at thirty degrees below zero. Some 13 feet of snow fell each winter; clouds of black-flies were the only constant in the uncertain weather of the short summer.

At the same time that the air was filled with the roar of heavy earthmovers and the thump of blasting, a faint cry at Churchill Falls Hospital marked a new way to arrive on-site: Jeanette, daughter of school teacher John Byrne and his wife, was born March 8, 1969, with attendance of the Hospital's director, Dr. John Price of the International Grenfell Association. When a baby is born, a camp becomes a community.

Joseph Smallwood had had to make do with a shovel full of peat with caribou moss, for the official sod turning ceremony in 1967. By 1970 the principal streets of the townsite were paved and some of the glacial 'l was being upgraded to support the growth of lawns and gardens. Neighbours were competing to nurture sapling shade trees — a challenge in the rugged local climate.

In 1970 the field work force in Main Camp and 11 satellite camps stretching from Seahorse, at the end of the southwestward reach of the transmission corridor, to Sail Lake 200 miles distant at the north-eastern extremity of the reservoir, reached 6,245 men and women. The daily food order for this army required the delivery of 4.5 tons of meat, 2,600 dozens eggs, 3,100 loaves of bread, 13 tons of vegetables, and 2,300 gallons of milk.

The transition from camp to townsite took place smoothly over the next five years — a credit to ACB's planning.

Now home for approximately 1,000 permanent residents, Churchill Falls is one of Canada's newest northern centres. No effort has been spared to make it one of the most advanced and comfortable. To make facilities as accessible as possible during the long, cold,snowy winters, the community clusters compactly around a unique complex, the Donald Gordon Centre, grouping under one roof services such as school and stores, hotel, theatre, and sports facilities.

A pedestrian mall runs through the central core of the complex from the hotel to a high ceilinged concourse, which acts as the modern-day equivalent of a town square — indoors.

The Eric G. Lambert School in the Centre provided instruction in English and French. Each community facility was designed to serve several purposes. At night and on week-ends the school's resource centre becomes the community library. During week days, the movie theatre is used by the school as its auditorium and assembly hall.

The houses and apartments are grouped in a semi-circle around the Donald Gordon Centre. Houses are built on only one side of the street. This facilitates snow clearing. It also helps assure privacy — an important consideration in a small community where people see one another day in and day out at work. The use of electricity from the Falls for all heating helps make a remarkably clean place.

There is an interdenominational church, a regional hospital, a professional fire department, a small detachment of the RCMP and other amenities that go with modern civilization. Regular scheduled jet airliner service links Churchill Falls with Montreal and St. John's. The community is tied in to the continental telephone network. English and French radio and television (via microwave) are provided by the Canadian Broadcasting Corporation.

Bringing the world to Churchill Falls

The management organization evolved for Churchill Falls construction was an essential pre-condition for the achievement of the project's "on-schedule, within budget" objective.

At the summit of the organizational pyramid of the ACB consortium, responsible for complete engineering and construction management, was the "Policy Board" — itself an organizational innovation. The General Manager of ACB reported monthly to this board, composed of two senior executives each from Acres and Canadian Bechtel.

The group also provided liaison with outside engineering skills embodied in a panel of distinguished international consultants and a panel of senior engineers from Acres and Canadian Bechtel.

The main functions of the ACB organization were engineering, cost control and administration, scheduling and estimating, procurement and construction. The work at the project itself was further divided into four components: water storage; power complex; switchyard and transmission lines; and support facilities.

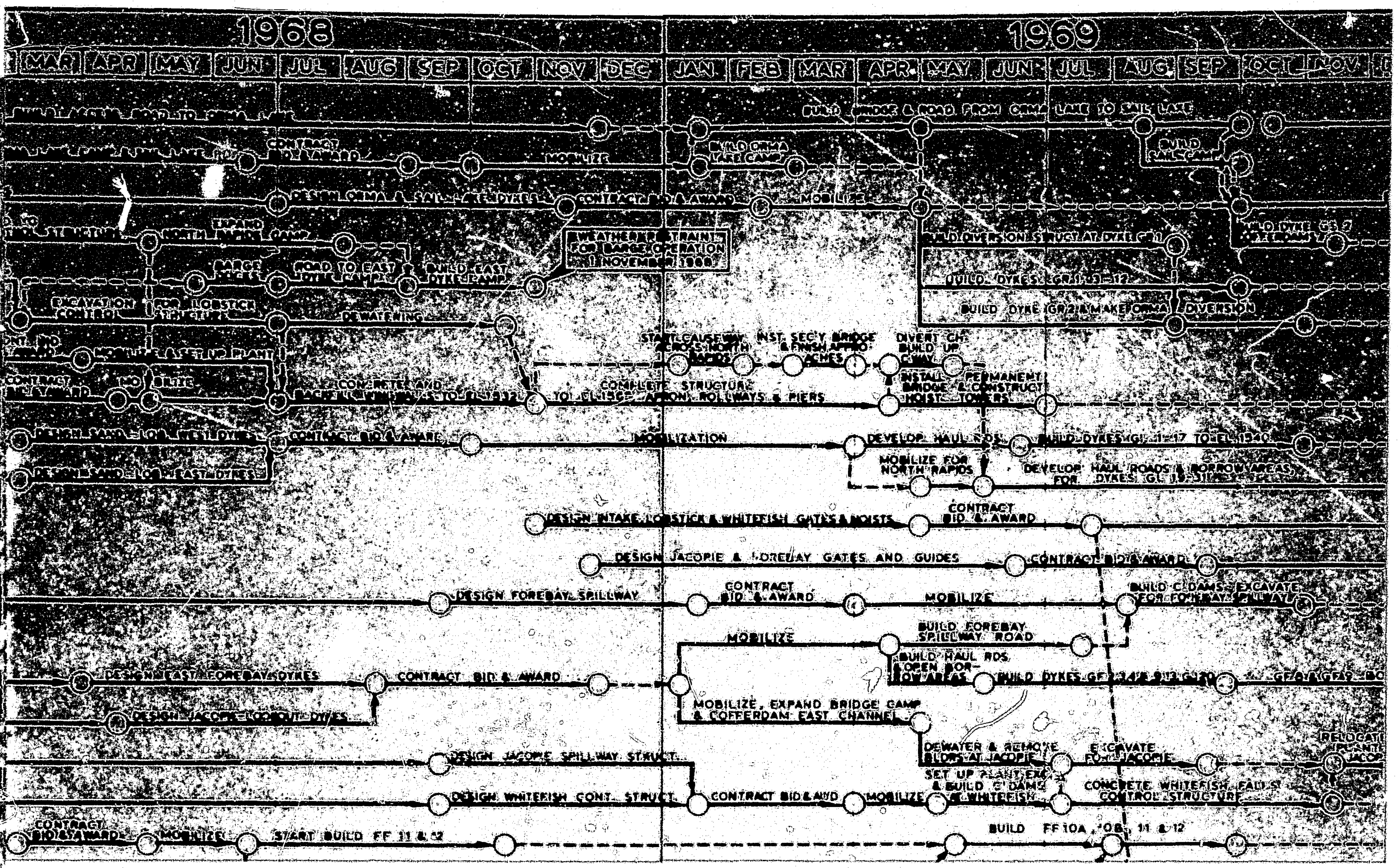
Because of the immense scope of the project, no general contractor was named. Instead, contract "packages" were developed by ACB in such a way as to encourage the widest response and competition from qualified bidders. Over 180 separate construction and service contracts were awarded, but none was for an amount in excess of $75 million. In addition, hundreds of major purchase contracts for the supply of major equipment were negotiated, mainly with Canadian firms.

It was decided early to relieve construction contractors of the responsibility for providing housing and board for their men on the site. These were provided at a stated subsidized cost per man-day by ACB. This meant the removal of a large item of uncertainty from the contractor's evaluation, thus resulting in lower and more consistent bids. In addition, the good standards of living and working conditions made an important contribution to the morale of workers on the project.

Transportation was contracted in volume packages to experienced, responsible carriers, such as Québecair and Eastern Provincial Airways. A total of 730,000 tons of material and equipment was moved to the site by air and surface transport, as well as 52,000 passengers.

The allocation of work between the different ACB divisions was as follows: Engineering, in which Acres personnel were predominant, established concepts, performed detailed design, monitored engineering assignments and obtained approvals. The remaining four divisions relied mainly on Canadian Bechtel's expertise: the Finance and Administration Divisions compiled cost data, processed progress payments and provided administrative support. The Scheduling and Estimating Division developed schedules, monitored progress and prepared control estimates for elements of the project during the engineering phase. The Operations Division covered the Contract Department, which developed contract documents, issued tenders, analyzed bids, recommended awards and organized quality control and expediting, and the Construction Department, which looked after operations on site.

One noteworthy feature of the contracting was the prevalence of the type of "consortium philosophy" inspired by the formation of ACB itself. The largest construction team on site, for instance, was Churchill Constructors Joint Venture, a consortium of six companies organized by Atlas Construction Ltd. Provision of the 11 hydro-electric generating units, a job which employed 600 men for two years at a cost of over $60 million, was contracted to The Churchill Falls (Machinery) Consortium, a joint venture of Canadian General Electric, Dominion Engineering Works Ltd. and Marine Industries Ltd. CGE and MIL divided the first 10 turbine generator contracts between them, with MIL being awarded the eleventh.



A section of the critical path which construction followed.

Of the total direct construction expenditure of $665 million, approximately $650 million — 98% — was spent in Canada, with 57% of the sum going to Canadian manufacturing industry, 17% to service industry, and 26% in direct labour costs.

But, in spite of the high Canadian component of manufacture, the consortium approach made available the best in North American and European technology. Both Canadian and French specialists, for instance, evolved their own designs for the turbine and generators; both groups pooled and shared their experience to the benefit of the project. Shafts for the huge units were forged in England, turbine models tested in Canada, France and Scotland, speed governors designed and built in the United States, and some transformers supplied from Sweden.

ACB's logistical management was tested to the utmost early in the project, when on May 10, 1969, a strike suspended operations on the Quebec North Shore & Labrador Railway for three months, at the peak of the heavy construction season, with 4,500 men already on site. An emergency airlift — "the biggest since the Berlin blockade" — was pulled together, with aircraft chartered from as far away as Florida and Alaska. It operated 1,153 flights from Sept Iles and Goose Bay, carrying in 650,000 gallons of fuel plus 11,617 tons of cargo, and supplies, including items as heavy as dismantled bulldozers.

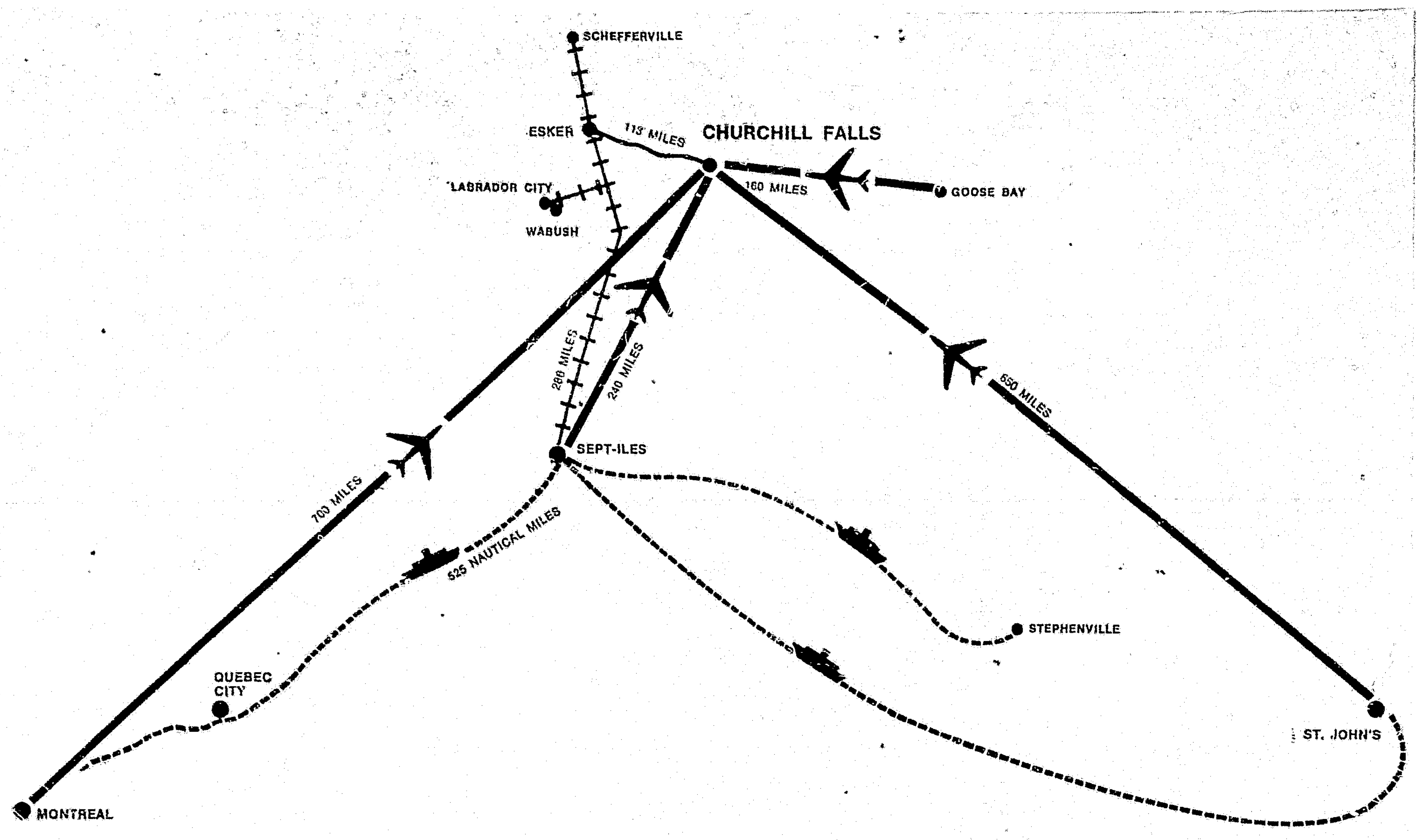
But the Churchill Falls achievement was not limited to a massive application of logistical and earthmoving skills. It involved, too, the most advanced and intensive engineering approach ever applied to a major hydroelectric project. Reliability and assured performance from the start of operation were vital to assure that power contract obligations were fully met. Features of the project had to meet the requirements of well proven experience as well as take the full cost/benefit advantages allowed by the scale of the project.

Turbines and generators were selected at the upper limits of output and size for the 1,060 ft. head. Thorough design analysis provided a high degree of confidence that all expectations would be realized. Electrical facilities made optimum use of a 230 KV/735 KV system with power carried from the underground transformers through 900 ft. long oil filled cables.

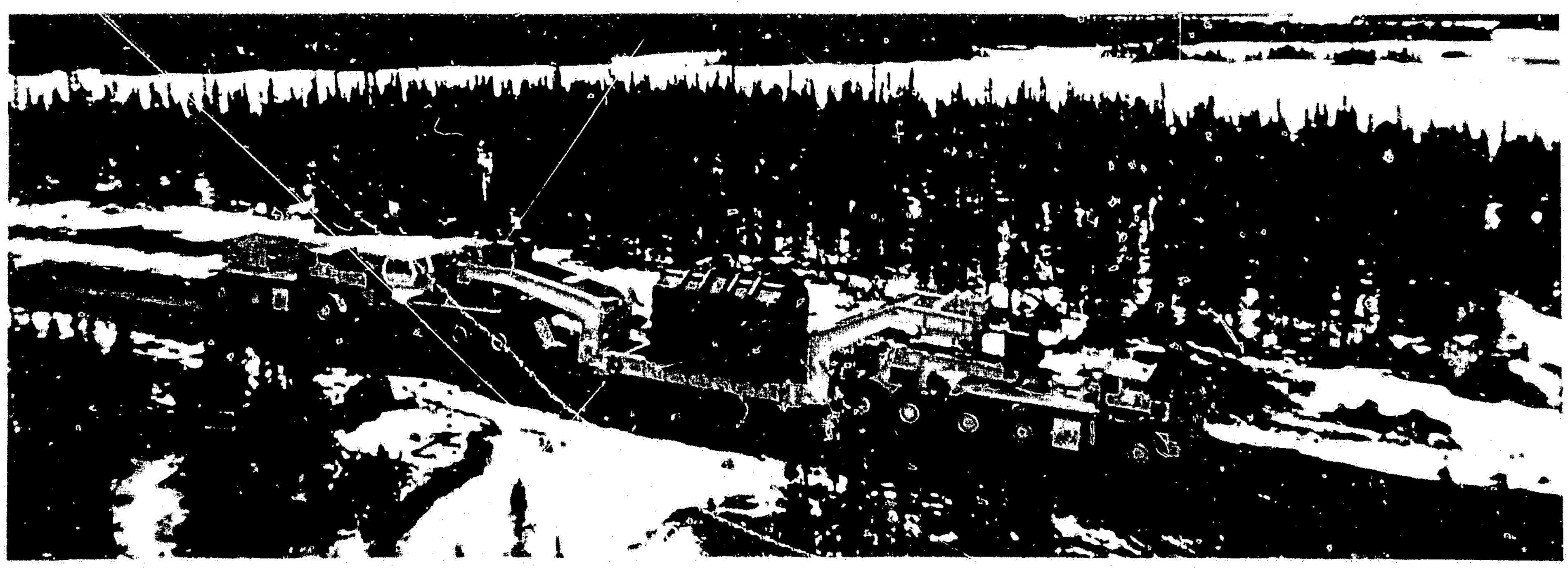
Engineering design of the excavated caverns for powerhouse, surge tank tunnels and galleries was greatly assisted by use of advanced finite element stress analysis. Close integration of engineering and construction techniques led to substantial economies.

Varied tasks demanded new engineering approaches from the massive hydraulic control gates to transport equipment specially designed for the project needs.

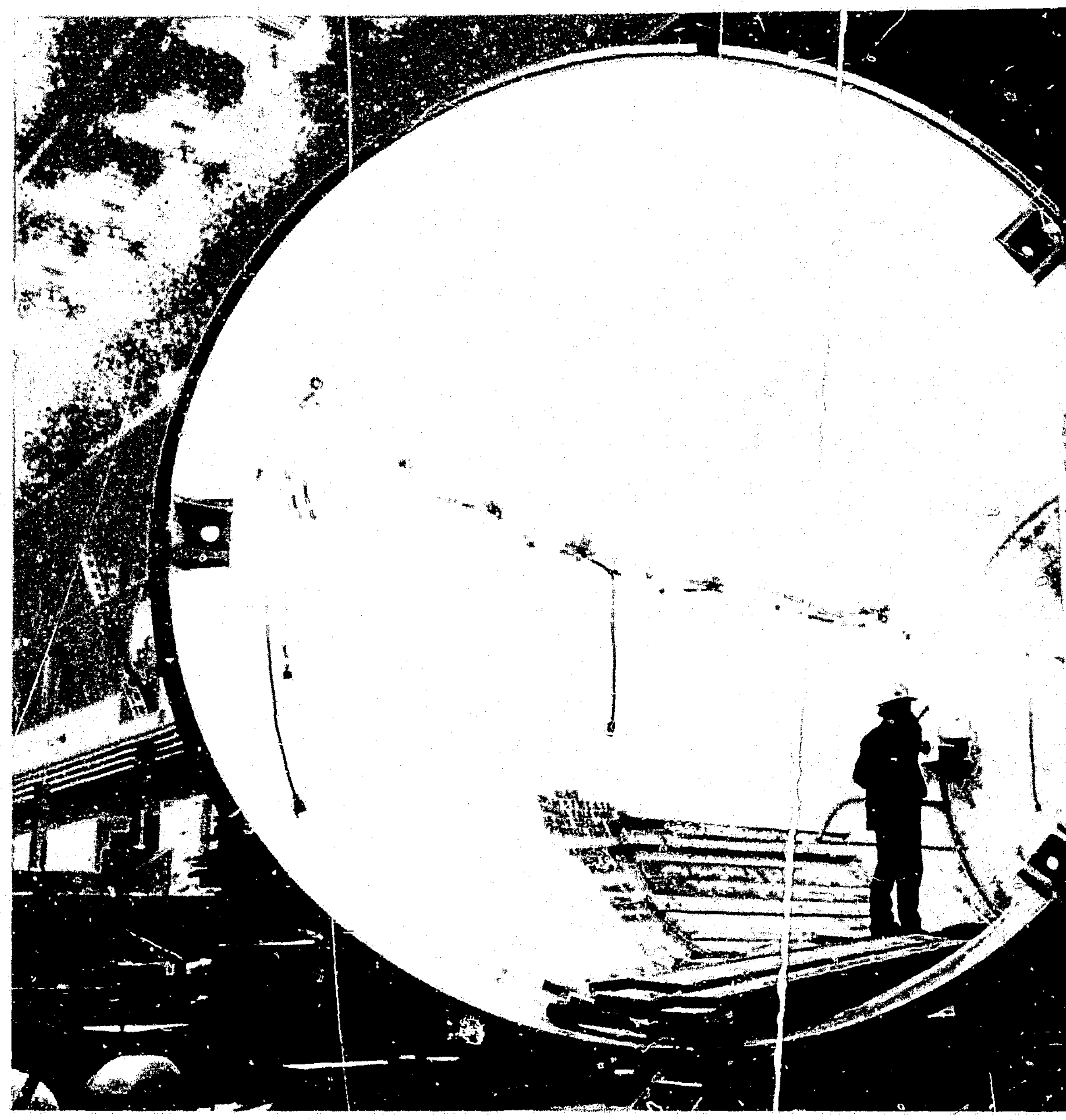
The gates are the crucial element in controlling the impoundment of 1,100 billion cubic feet of usable water for Churchill Falls power development. The series of reservoirs, a third the area of Lake Ontario, are formed by the skillful use of natural land forms, supplemented with 40 miles of dykes, ranging up to 117 feet in height. The key to directing this water is just six control structures — concrete spillways with sliding gates that can be remotely controlled electrically from



Logistics map of the project

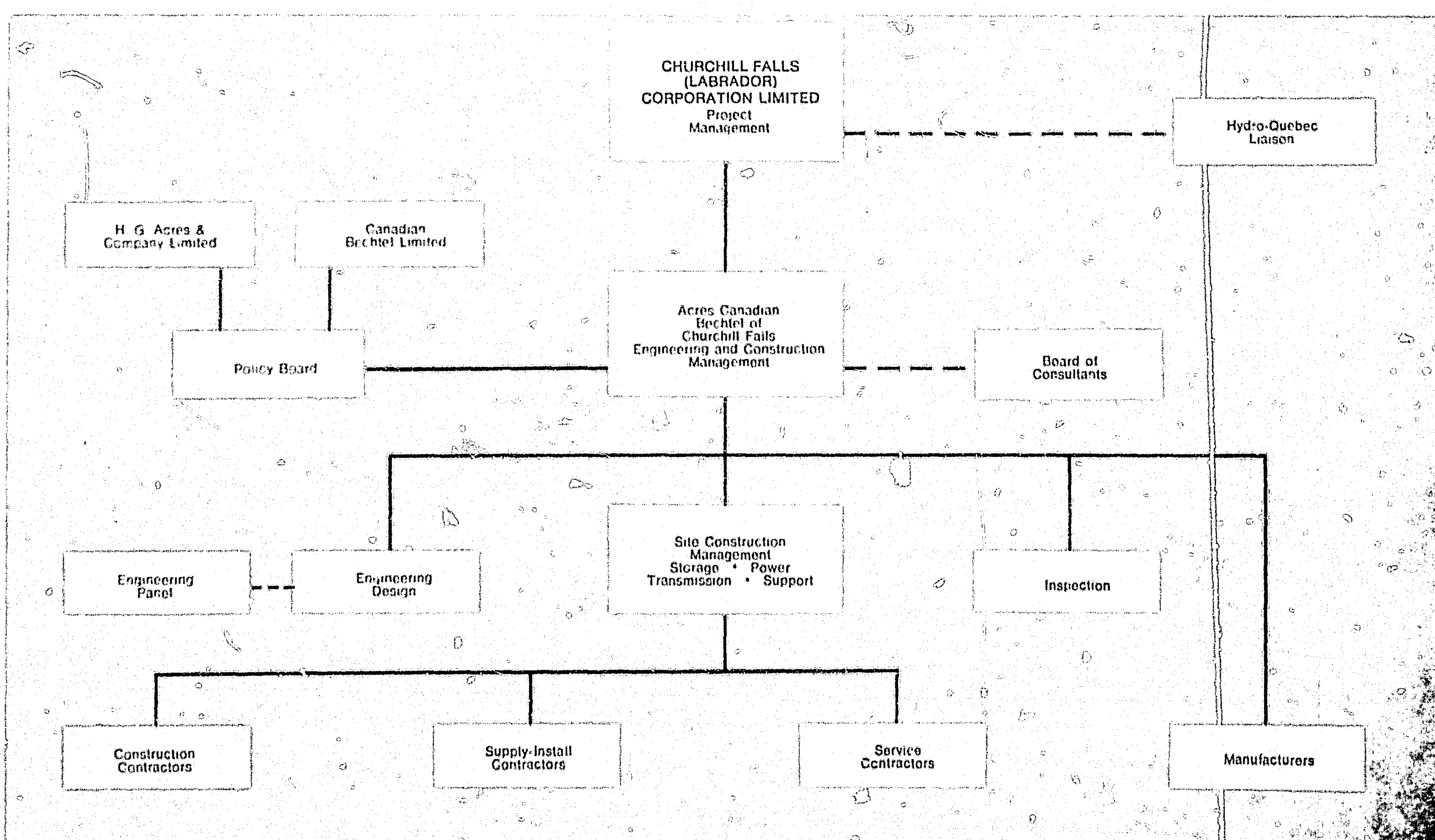


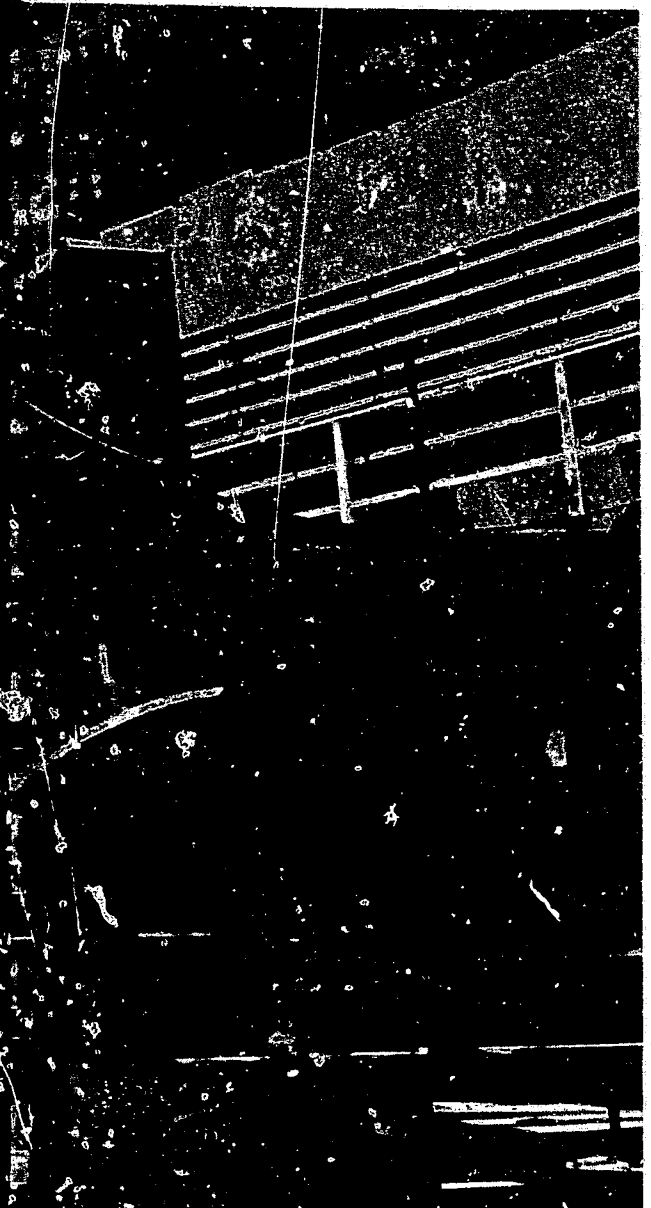
A unique 200 foot long transporter moves loads of up to 250 tons to the job site



Powerhouse scroll case section unit

Project organization chart





the Churchill Falls control room at a distance of up to 60 miles. To make these gates operate reliably when temperatures might be 50°F. below, with five ft. of ice on the reservoir, required many man months of modelling and design effort. The installations are heated in winter both by air circulation and electric resistance heaters, and electromechanically controlled by redundant, fail-safe, supervisory control circuits.

Another unique element of the project was the design and construction of a 250-ton transporter to take the 224-ton transformers (one for each generator set) from their special rail cars at Esker to the project site.

The vehicle finally developed had tires seven feet high, and two 700-horsepower six-wheel drive tractors. Its 198 foot-long body, was articulated in order to be able to negotiate the turns in the 28 ft. wide access tunnel to the underground transformer gallery. Early Churchill Falls residents still remember turning out at the intersection of Ressegieu Drive and Esker Road to see "the awesome convoy crawl past in full glory, yellow flashers whirling, at two and a half miles an hour."

The transformer transporter was only the largest of the enormous fleet of 2,000 transport and construction vehicles at the site: 600 tracked machines, ranging from bulldozers to self propelled drills; and 1,400 wheeled vehicles, from passenger cars to fuel tankers and 50-ton dump trucks.

Nor were the transformers the only heavy equipment beyond the carrying capacity of most vehicles: the turbine runners with a casting weight of 145 tons, and a finished weight of 100 tons set for Canada a world record for the largest castings ever made in stainless steel. The two cranes installed in the power house were coupled with a massive lifting beam to handle the 655 ton rotors and giant stators for the generator units, which were assembled on site and lifted into position.

Spanning the river gorge was a highlight for the transmission line crews. Their efforts linked the power plant with the Hydro-Québec substation at Montagnais, 130 miles to the southwest. For the last span a helicopter (one of as many as seven on site) hauled 7,500 feet of half-inch nylon rope across the river from the south shore. Increasingly heavier steel cables followed until finally the complete set of conductors stretched from three sets of 100 ft. towers, 6,200 ft. apart, 1,000 ft. above the waters of the Churchill.

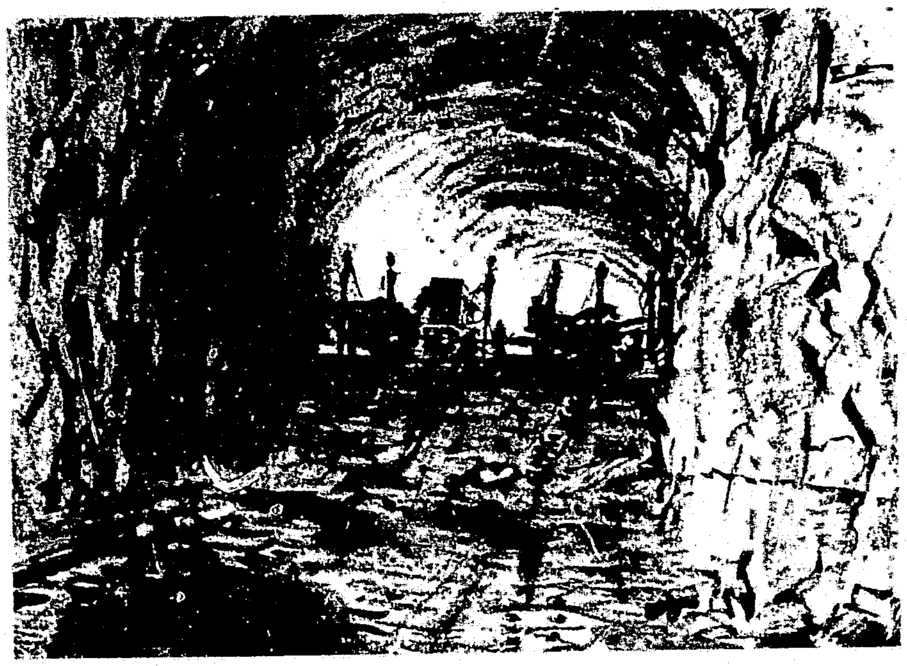
For each contract package, large or small, ACB's careful monitoring of cost, quality, and completion time was the essential factor in integrating every element into the smooth progress of the whole project.

Quality standards were clearly written into each contract document and purchase order, and ACB's quality control group not only monitored construction and manufacturing contracts, but also insisted that the contractors provide their own quality control systems.

Schedule control was achieved by monitoring progress on contracts every two weeks, and taking corrective action wherever possible before slippage became serious. Cost control was maintained from the initial estimate through design, and, after contract award, by monthly forecasting of final cost relative to budget. Thus, early warning of any significant variation enabled corrective measures to be taken in time to achieve control.

All this performance information would have been nearly useless unless systematized, computerized for easy retrieval, and integrated with another key factor: logistics. A given item of material for the project might meet cost, quality, and completion targets. But where was it? When was it shipped? When, and how, would it arrive on site? These were questions the Transportation Information System (TIS) used by ACB, was designed to answer. No soulless machine, TIS took the strenuous efforts of scores of men as well as masses of data processing equipment to keep tabs on the thousands of items of material in transit at any one time.

Safety beneath the shield



The heart of the Churchill Falls power plant is the great machine hall, housing the 11 generating units. Over 1000 ft. long, 81 ft. wide, and 154 ft. from floor to roof, it was carved out of the rugged granite of the Laurentian shield 900 ft. below the surface.

It might seem simpler to have sited the power plant above ground at the edge of the river. But, from the perspective of a hydraulic engineer, it is more practical to make the 11 penstocks which carry water to each turbine short and as steep as possible. When the 450 pounds per square inch pressure has spun the turbine, the spent water is discharged to a surge chamber, before flowing via two huge tailrace tunnels over a mile to the lower Churchill river.

The amount of excavation required was enormous: in addition to the penstocks and the machine hall and surge chamber a transformer gallery was excavated just above the powerhouse. And the concern of the engineers and geologists that the rock structure be "competent" to bear the blasting, tunnelling, and the surge of water, was thoroughly exercised by exhaustive drilling, sampling, and stress analysis. The area finally selected for the powerhouse had been proven to have the necessary integrity and "faultless" structure.

The first step was completion of a mile-long access road which curves down the steep slope toward the river. The second was to drive a mile deep tunnel at the end of the road, angled in to provide access to the underground works through which the heavy dump trucks were to remove much of the rock.

This accomplished, the major underground construction contract was awarded to Churchill Constructors: two contracts totalling $65.7 million, for all remaining underground excavation except completion of the tailrace tunnels; most of the concreting of the underground complex; installing of miles of embedded conduit and piping; and provision of tons of anchors and rock bolting, as well as installation of the main powerhouse cranes and gates. In excavation alone, this meant the removal of 2,300,000 cubic yards of rock. CCJV, as the consortium was called, was busy for three years at the job, employing at one time over 1,200 workers.

Safety — both for the construction crew and the operating staff who would follow them — was a prime consideration. Painstaking calculations had to take into account the changing stresses on the rock as the excavations grew in size.

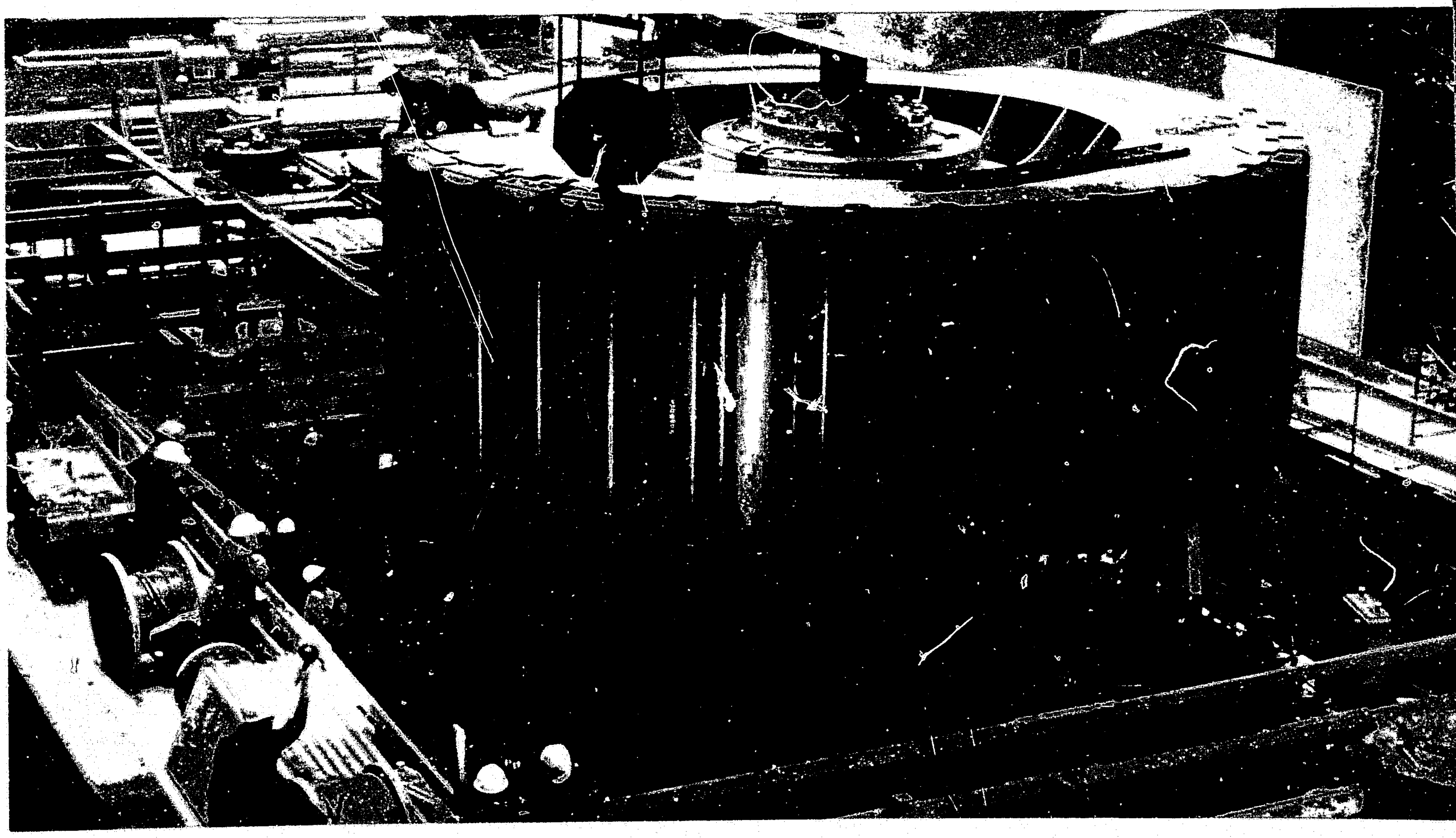
In the large chambers, excavation was carried out from the top down: first a pilot tunnel or heading was driven along what was to be the ceiling of the chamber. Then this would be "slashed" or excavated to full width. Finally the remaining layers of rock would be blasted and mucked away in a quarry-like operation.

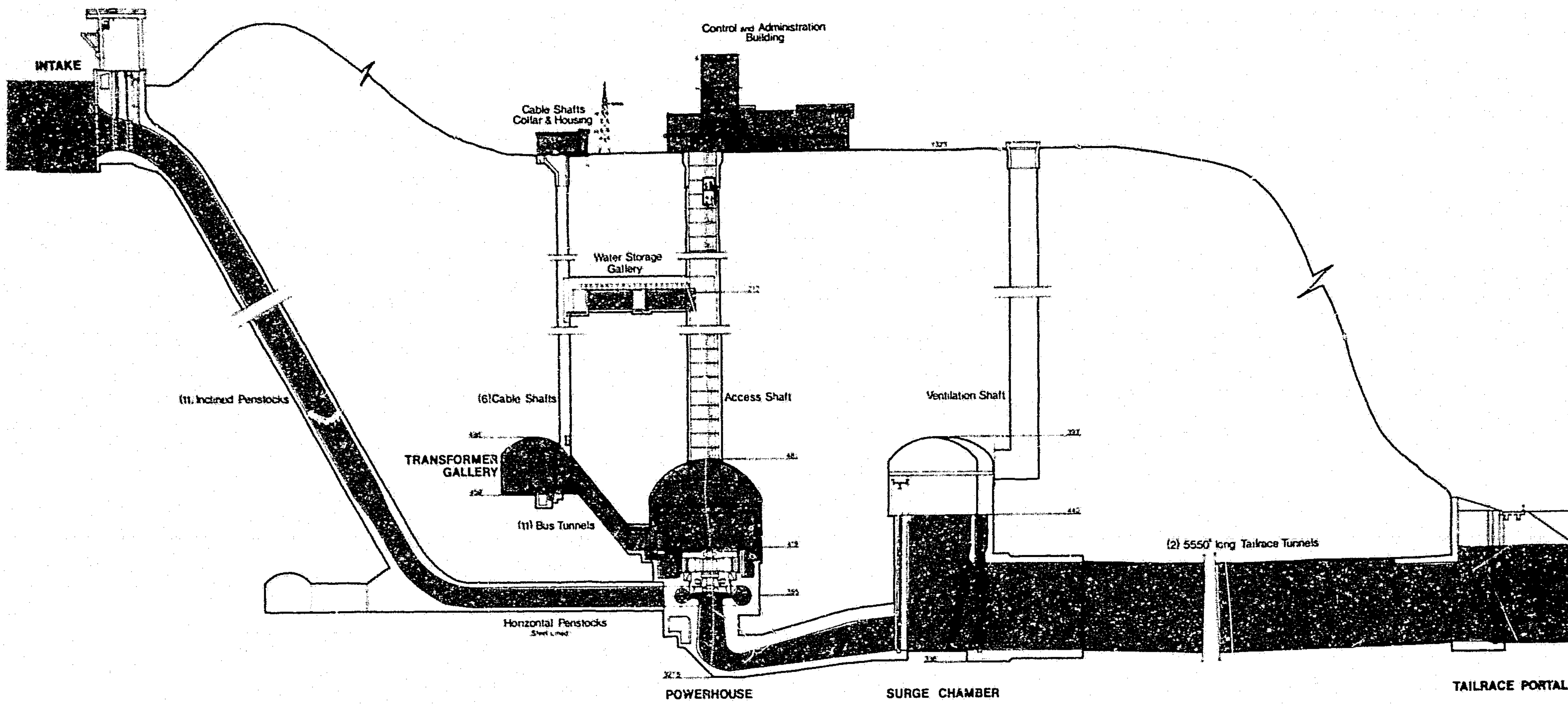
Excavation reached its peak in June 1969: within six days 45,600 cubic yards of rock were removed, enough for 2,800 truckloads of 33 tons each.

The penstocks, on the other hand, were started from the bottom, drilled from electrically-driven climbing

Excavation of the tailrace surge chamber

The 650-ton generator for Unit #2 is positioned inside the stator.





Cross section of the underground powerhouse complex.

platforms known as "Alimaks" and which enabled an eight by ten foot pilot shaft 1,200 ft. to the surface to be driven without intermediate stations. Yet, such was the accuracy of surveying (in which the latest technical devices such as laser beams had been employed) that the first shaft broke surface within inches of its target.

One of the most hazardous and difficult jobs remained: slashing the 11 pilot shafts to the designed 22 ft. by 28 ft. penstock dimensions.

The "slashing" was done by six drills on outriggers, mounted on a "jumbo" — a sort of flat-car which ran on steel rails laid on the almost vertical side of the tunnel.

Day after day the same sequence went on: the drills would whine into the rock, charges would be set, the jumbo would be hauled back 45 ft., and the blast fired. As tons of rock cascaded 1,200 ft. to the bottom, the jumbo would be advanced, another 14 ft. of rail laid, and the whole process would begin all over again.

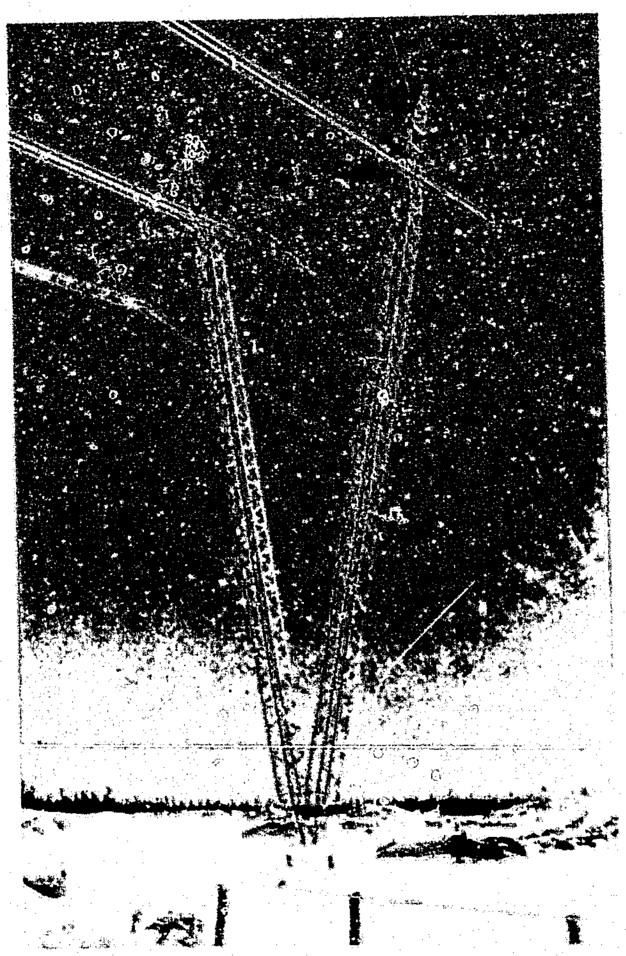
When the jumbos had finally bored their way down the shaft another hazardous job began — concreting. This was the task of covering the whole inside surface of the penstocks with a foot of concrete — to resist the rush of 400,000 gallons of water a second at full flow. The men who worked the barrel-shaped collapsible metal forms for the concrete called the frame at the top of the form "the headache rack" with good reason — even a small pebble comes down a 1,000 ft. tunnel inclined at 60 degrees like a ricocheting bullet.

On July 13, 1970, the final blast was fired at the bottom of No. 10 penstock, marking completion — less than 34 months after it started, of the underground excavation. Some five million pounds of explosive had been used. Yet, in spite of the scale of the operation, and the great heights and other hazards involved, lost time from work accidents was substantially lower than on most excavation jobs of this type.

The final horizontal section of the penstocks, which narrowed to 14 ft. seven in. diameter, was lined with high strength steel. (The length of the costly steel lining had been minimized by careful engineering analysis and judgement of the adequacy of rock and concrete to withstand the stress. Impressive economies were achieved.)

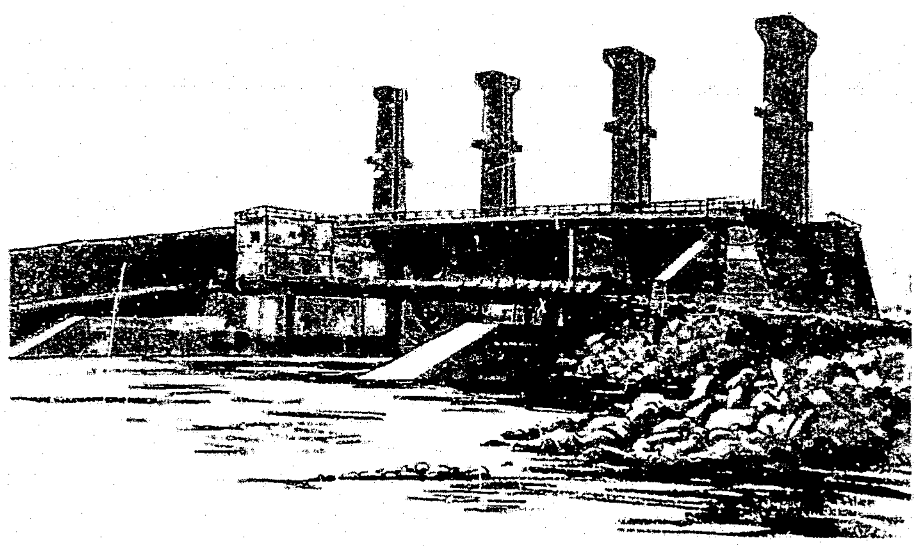
Excellence in both design and workmanship meant that full advantage could be taken of the remarkably solid rock formation. No supporting concrete was required for the roofs of the massive underground chambers. The powerhouse ceiling finally took the form of stainless steel sheeting suspended from bolts embedded in the vaults of rock above.

Jumper arrangement for the South Bank towers, river crossing line 1



Typical V-type guyed tower

Harnessing technology to improve ecology



When geologist A. P. Low climbed Labrador's Lookout Mountain in 1894, overlooking what is now the Churchill Falls power plant intake, he reported a bleak view: "over half of the surrounding country has been stripped bare by frequent fires. In the swamps and around the shores of the lakes...black spruce and larch of small size grow thickly together. On the sides of the hills these are more stunted...where the hillsides have been burnt years ago they are covered with a tangled mass of willows and alders, while the tops are coated with white moss and semi arctic shrubs."

The animals that inhabit this harsh land lead a similarly precarious existence, and large mammals, such as the black bear and caribou, are few. While the unfished lakes provide a few whoppers, the concentration of nutrients, and therefore the density of aquatic life, is sparse. Labrador's Naskaupi Indians seldom visited the area, because of the scarcity of game and fish.

In working with and altering the terrain, man does not always need to oppose nature. It is, perhaps, significant that the new course along the edge of the plateau, into which the Churchill was directed, may in fact have been the original river bed before the east glaciation 20,000 years ago. Ecologically, the entire project can be studied as a model for resource development in the Canadian north.

From the standpoint of conservation, the regulation of flows passing through the power development should actually help to prevent the previous harmful erosion of the banks of the lower reaches of the Churchill, by uncontrolled spring freshets.

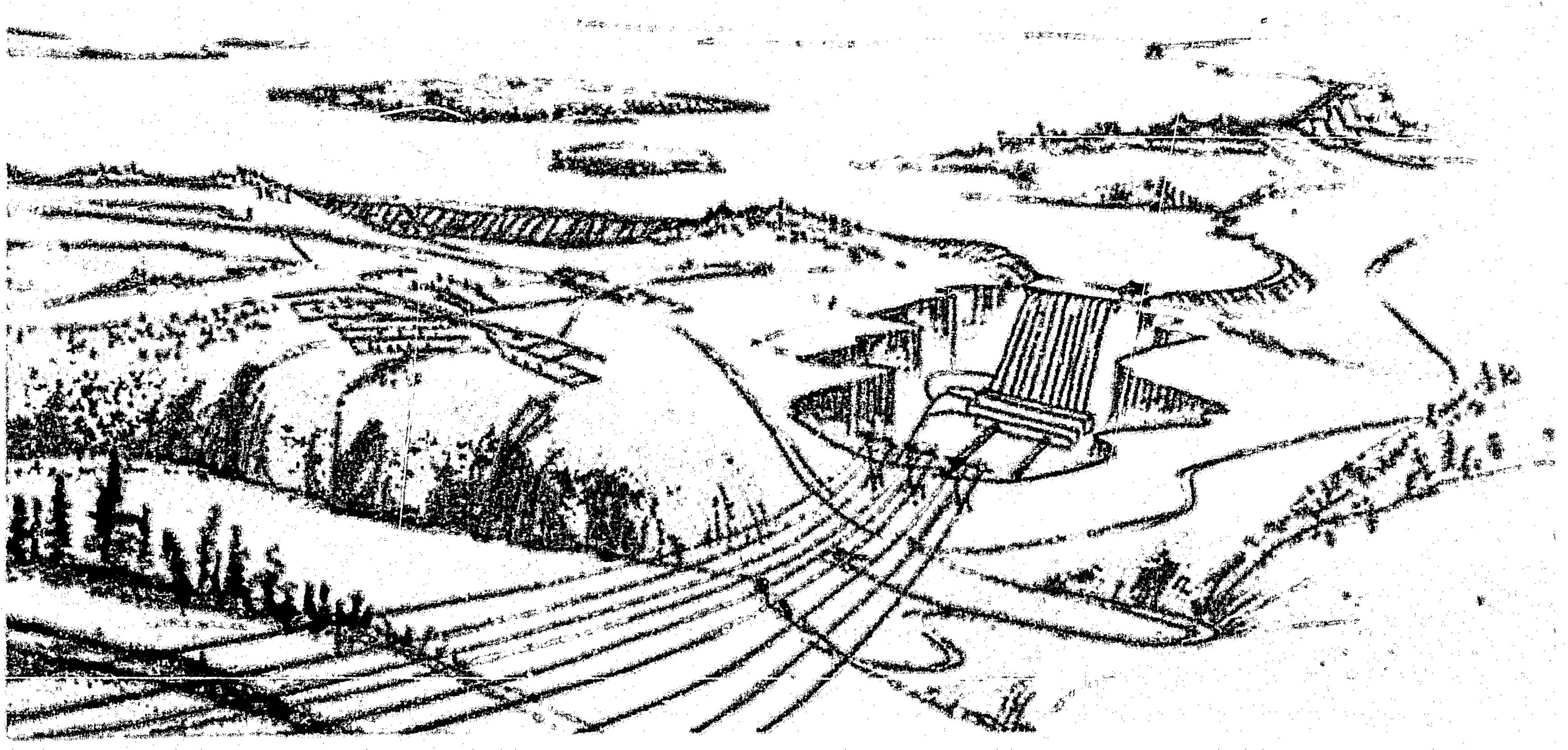
Again, the flooding of 2,500 square miles to create the reservoirs changed the face of the countryside. However, the slowness of the process, which took place over three years, meant that harmful impact upon land animals in the region was minimized. Careful studies by biologists have concluded that some overcrowding of smaller species occurred in some limited areas such as islands which were created as the waters rose.

And the fishing should be even better than before. Not only has the aquatic habitat been greatly enlarged, but the flooding of swamp and muskeg, biologists have found, increases the volume and concentration of small organisms which are the basis of the food chain which sustains, indirectly, the larger game fish.

Of the land submerged beneath the reservoir, a survey determined that it contained 65 per cent scrub bush growing on rock scantily covered with acid soil, four per cent barren land, nine per cent burned-over areas, and 20 per cent bog. Only two per cent consisted of trees over 30 ft. high.

ACB's concern for, and interest in, the environment was clearly demonstrated by the insistence that all



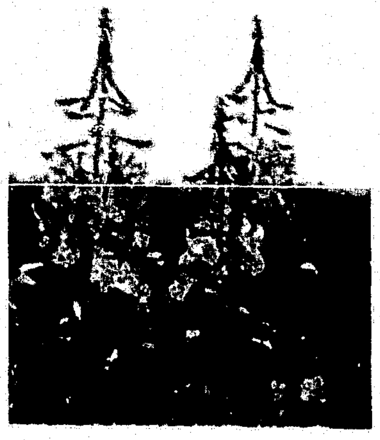


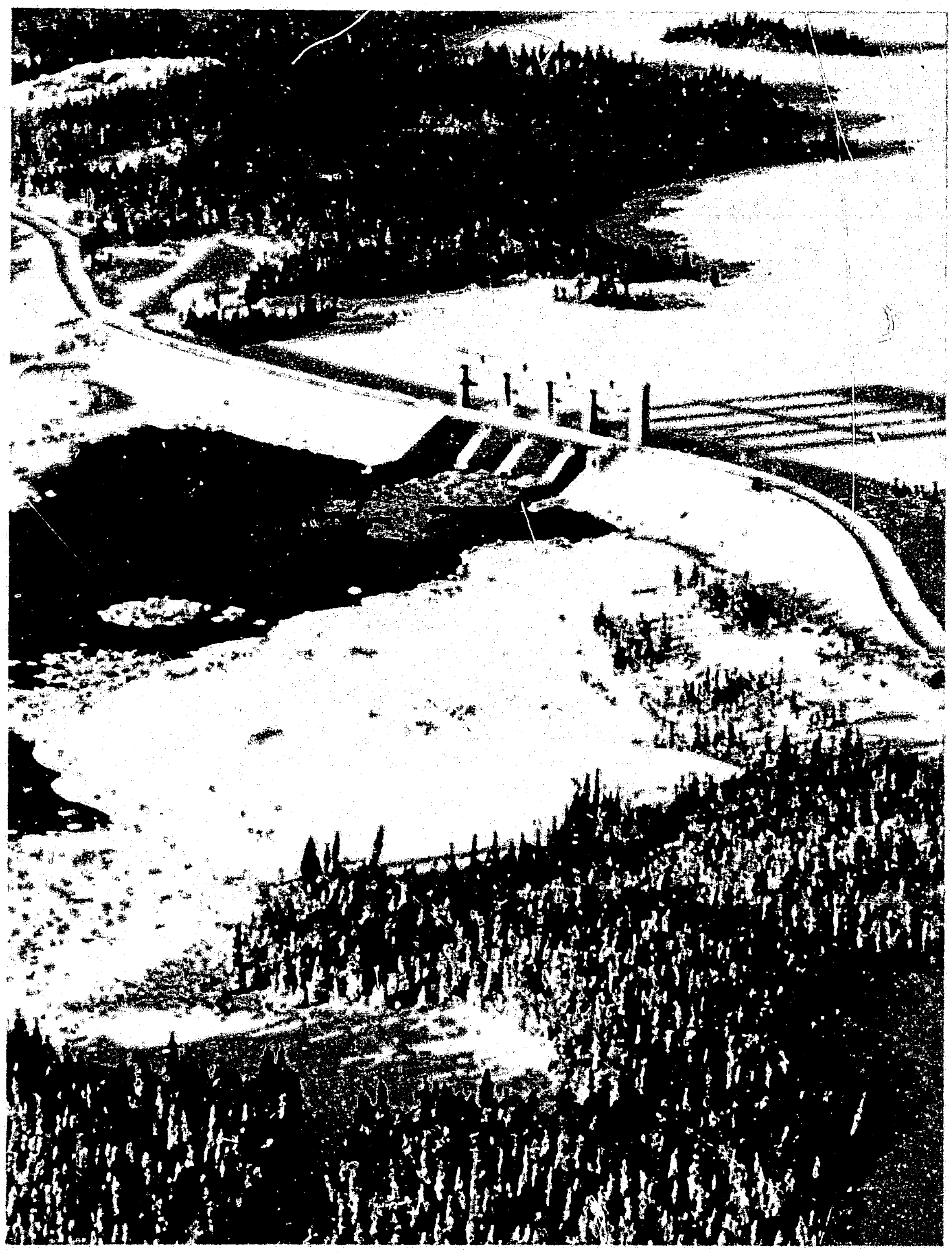
camps, even the remotest, should be equipped with sewage treatment facilities.

And the new human inhabitants, permanent and temporary, of the main camp and townsite appear to have quickly developed an awareness and appreciation of the unspoiled environment. Early issues of the weekly CFLCo paper *Churchill Falls News,* were full of suggestions for using such natural resources as caribou moss, partridge berries, and Labrador tea. And one of the hottest debates in its letters column was the vexed subject of whether female caribou have antlers. (Unlike the rest of the deer family, they do.)

It was this aspect of the project which captured the attention of Prime Minister Pierre Elliott Trudeau, when he inaugurated the development on June 16, 1972, with a speech titled "In harmony with nature."

"We should see," he said, "this gigantic installation as the unified and dynamic solution to a great many problems, using the contributions of a wide array of skills and knowledge. A truly human shape has thus been given to this source of raw energy without diminishing nature or disturbing the balance of the environment. The example of Churchill Falls shows that though man imposes his will on nature, he can do so in harmony with nature, and that this process can be noble and fruitful. *That is why I say without hesitation that our technology has produced here a masterpiece that commands double admiration.*"





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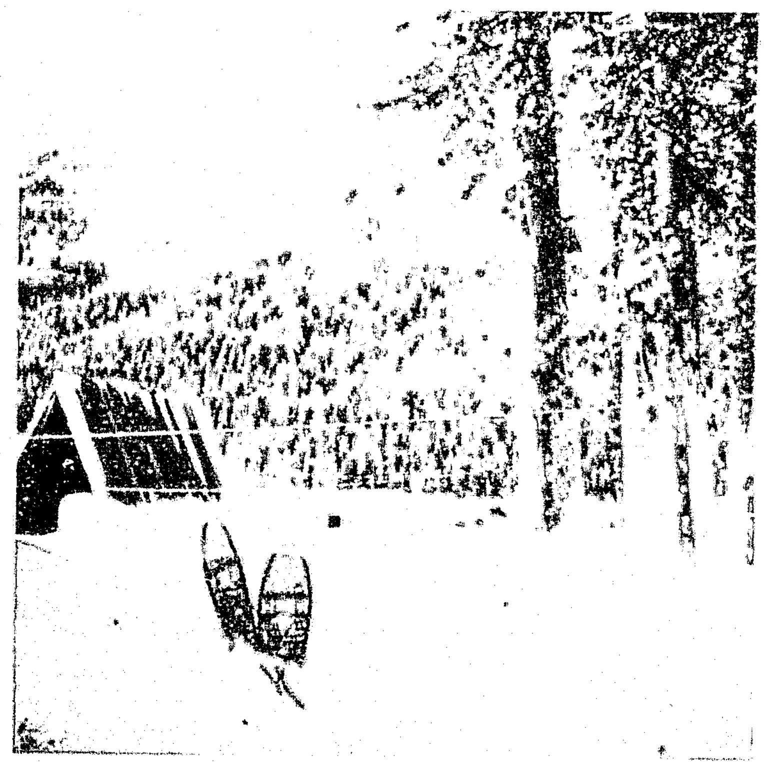
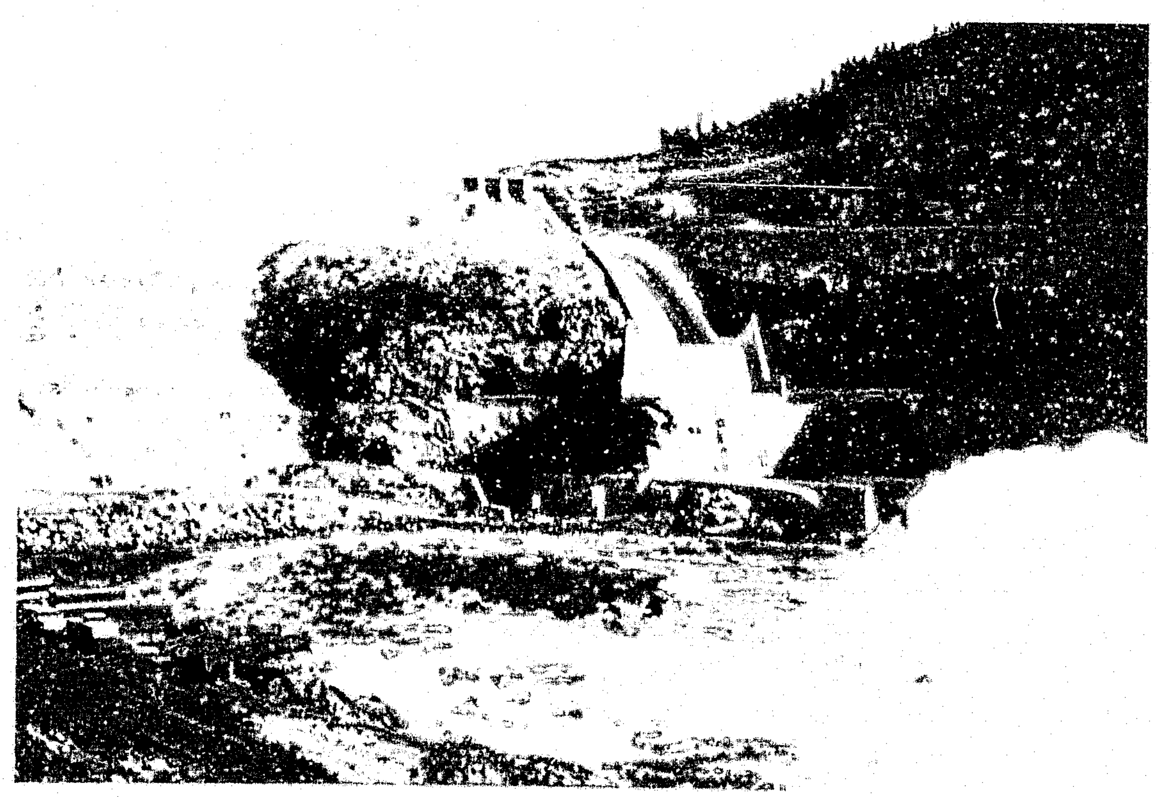
MICA
ACRES





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Mica Storage Project

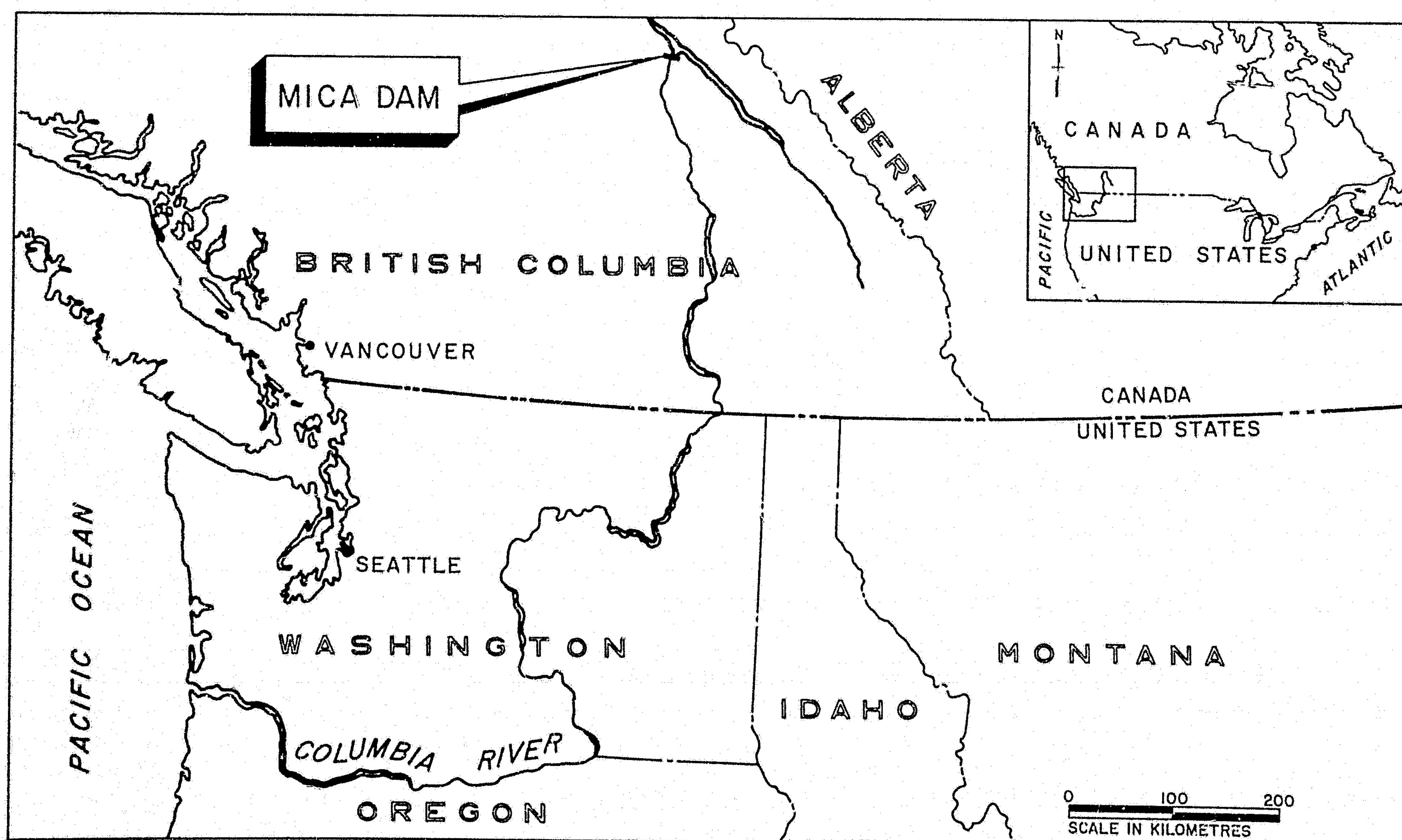
Located on the Columbia River, about 450 river km north of the Canada-United States border, Mica Dam is one of the higher earth-fill dams in the world. Completed in 1973, the dam towers 244 m above the lowest bedrock level and constitutes a major link in harnessing the water resources of the Columbia River system. A live storage capacity of $15{,}000 \times 10^6$ m^3 is operated to tame the mighty Columbia River and provide flood protection to downstream riparian land. By 1977, 1,740 MW of hydroelectric generating capacity had been installed by the owner, British Columbia Hydro and Power Authority.

The Mica storage project was engineered by the joint-venture company CASECO Consultants Limited.

H. G. ACRES AND COMPANY LIMITED* was one of the three parent engineering companies.

*The Company was renamed Acres Consulting Services Limited in 1969.

Acres Consulting Services Limited
5259 Dorchester Road
Niagara Falls, Ontario
Canada
L2E 6W1



History of the Mica Storage Project

The Columbia basin is an international river system with its headwaters located predominantly in the Canadian Rockies. The Columbia River flows southward into the United States, then turns westward and ultimately discharges into the Pacific Ocean. The mean annual discharge at the mouth is 6,300 m^3/s and the system is the fourth largest in continental North America.

In the early 19th century, the Columbia River was utilized as a major trading route for the fur industry. Goods and passengers were transferred to boats just north of the present Mica damsite for the journey to the Pacific Ocean. In 1865, a brief but furious gold rush erupted as miners and adventurers streamed toward the mines south of the Mica site.

Acres has been involved in the development of the water resources of the Columbia since the early 1950's, when conceptual designs were prepared for an earth-fill dam at the present Mica site. In the late 1950's, the Company developed schemes for a site on the Columbia in the vicinity of Murphy Creek.

In 1961, three major Canadian consulting companies—H. G. Acres and Company Limited, Shawinigan Engineering Company Limited, and Crippen-Wright Engineering—formed a joint-venture company called CASECO Consultants Limited. Dr. A. W. F. McQueen of Acres was President of CASECO between 1961 and 1967. CASECO was appointed as the consulting engineers for the Mica Dam project by the British Columbia Power Commission.*

CASECO involvement in the Mica storage project included

- river basin planning studies
- engineering and construction supervision for Mica Dam and associated structures
- design of townsite
- investigation of reservoir slides
- study of the Downie slide located downstream from the site.

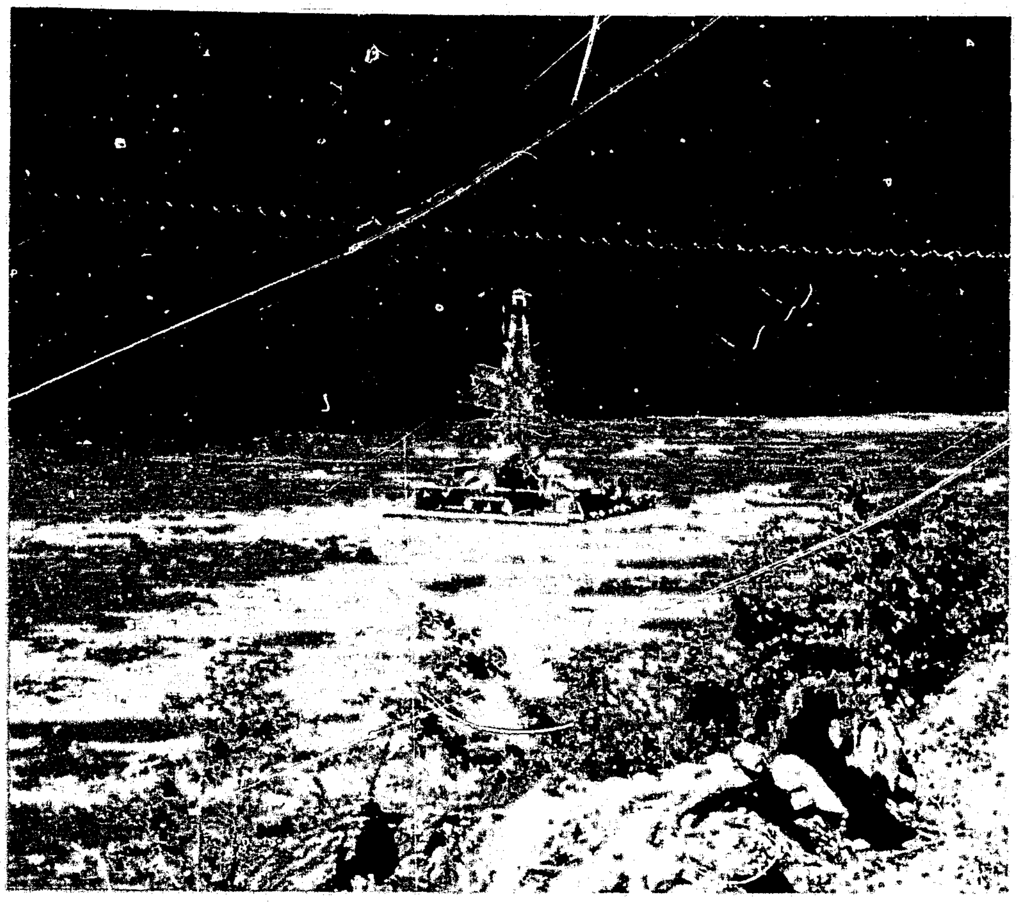
During the period 1961 – 1964, CASECO worked on an overall water resources development plan for the Columbia River basin in Canada. This work constituted the basis of the 1964 Columbia River Treaty between Canada and the United States. In terms of the Treaty, 3 storage dams – Mica, Duncan and Arrow – were to be built in the Canadian portion of the Columbia system.

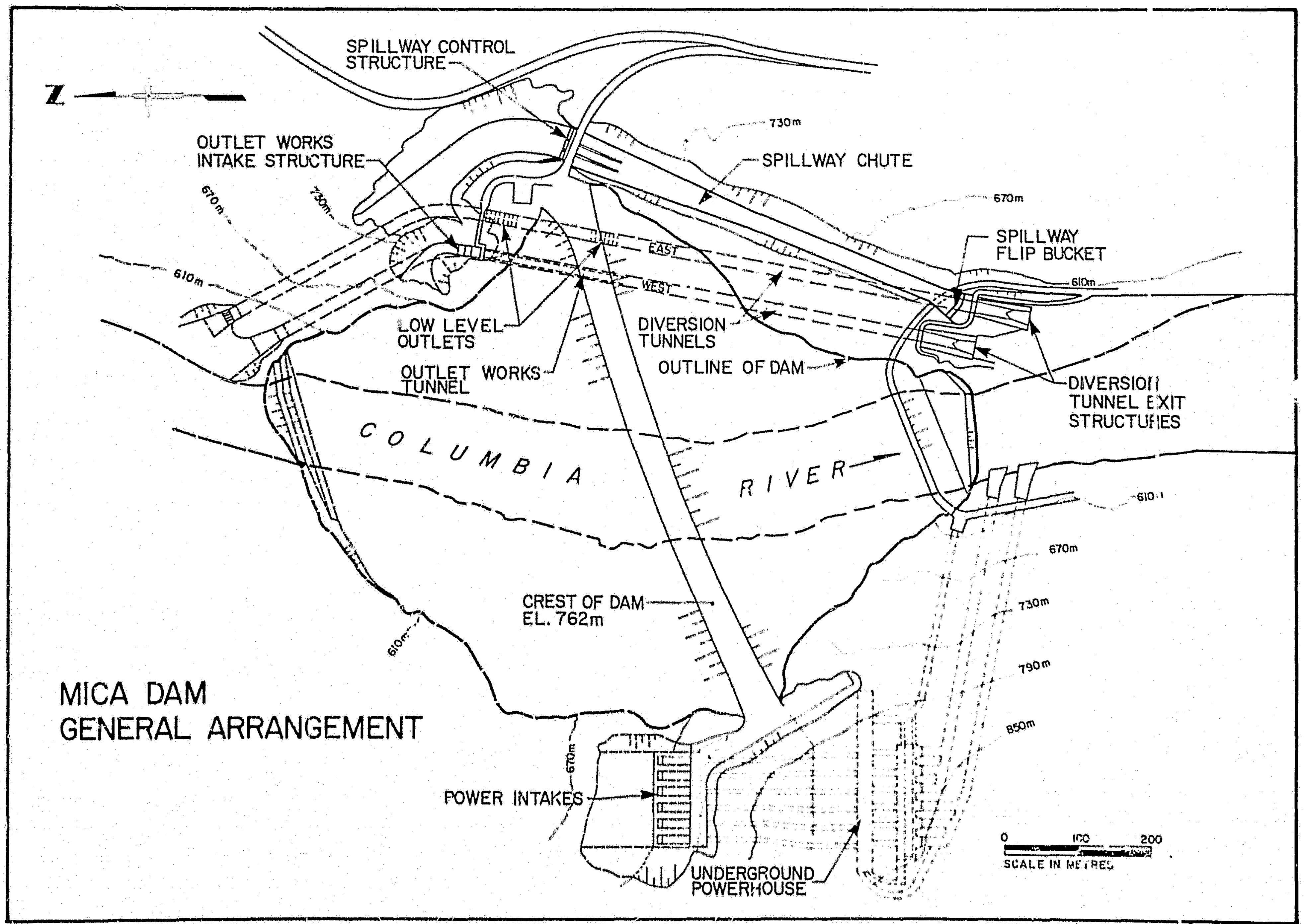
To fill key positions, CASECO initially drew senior engineering staff from the parent companies. Two senior members from each of the three engineering firms also served on a Board of Engineers for CASECO to provide technical guidance and expertise for the duration of the design and construction of the project. Dr. D. H. MacDonald and Mr. I. W. McCaig were the Acres members of the Board of Engineers for the major portion of the period between 1961 and 1978. In view of the approaching completion of the design phase of CASECO's work, Acres and Shawinigan sold their interests in the joint venture to G. E. Crippen and Associates Limited in 1967. However, as stipulated by the British Columbia Hydro and Power Authority, both Acres and Shawinigan retained technical responsibility and maintained membership on the Board of Engineers until completion of the work in 1978.

*The Commission was absorbed into the newly created British Columbia Hydro and Power Authority in 1962.

Mica Townsite

The townsite at Mica was designed to accommodate up to 4,000 people during construction of the dam. Full facilities were provided, including a shopping center, bank, recreation center, school, medical clinic, police station, hotel, and outdoor recreational facilities.





MICA DAM
GENERAL ARRANGEMENT

Main Dam

Mica Dam is located in rugged, glaciated terrain with mountains rising steeply to nearly 1,500 m above river level. During the Pleistocene epoch, Alpine and Continental glaciers covered the area with ice sheets up to 1,800 m thick. Bedrock consists generally of mica schist and granitic gneiss. The river valley beneath the dam was filled with 27 m of alluvium, underlain by up to 18 m of very dense glacial till.

Extensive field investigations were performed. Exploration was carried out over a period of 3 years by CASECO and included drilling and sampling, test pitting, trenching, seismic profiling, test fills, test blasts and pump tests. Over 2,000 drill holes, clamshell and backhoe test pits were used to confirm adequate sources of construction material.

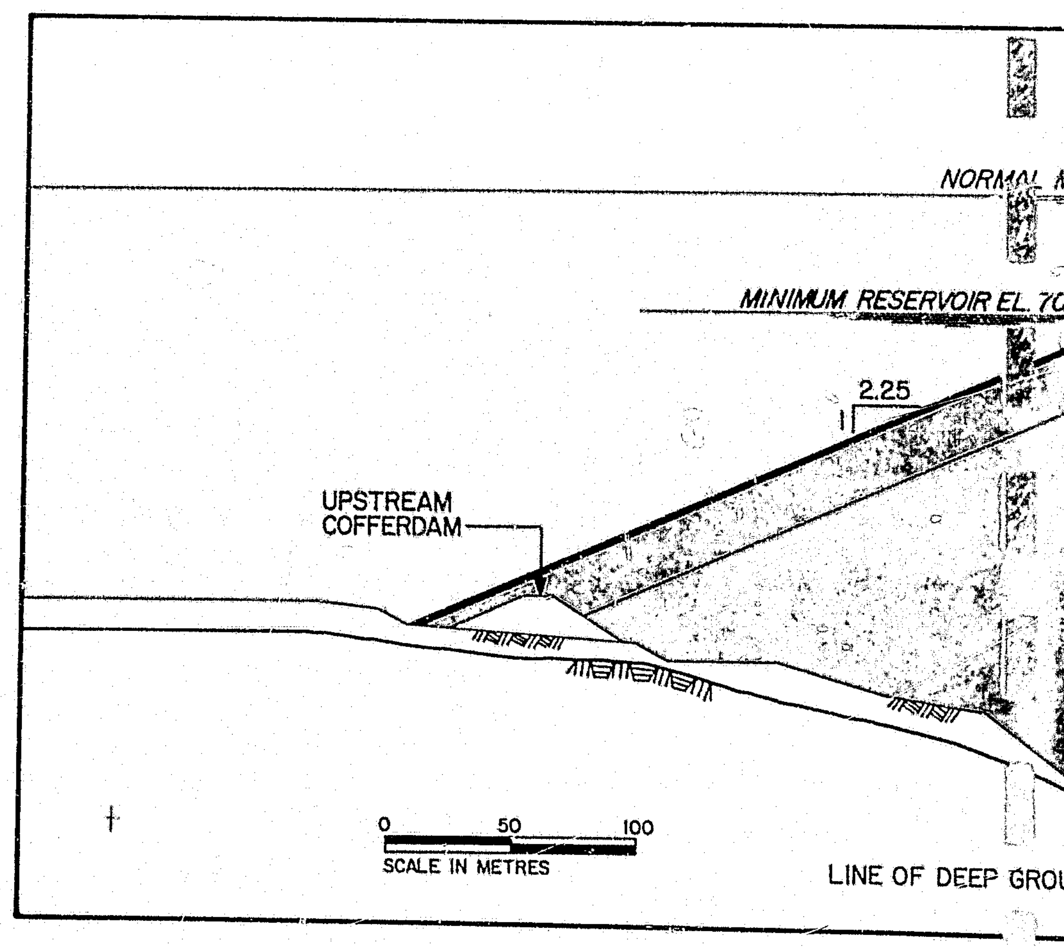
The main dam is a compacted earth-fill structure with a near-vertical impervious core of glacial till. Maximum height of the dam is 198 m above the riverbed level. The total volume of fill material is approximately 32.6 x 10^6 m^3. The inner and outer shell zones consist of sand and gravel, and rock fill, respectively. To prevent tension cracking within the shells and core zone of the dam, the following measures were incorporated in the design:

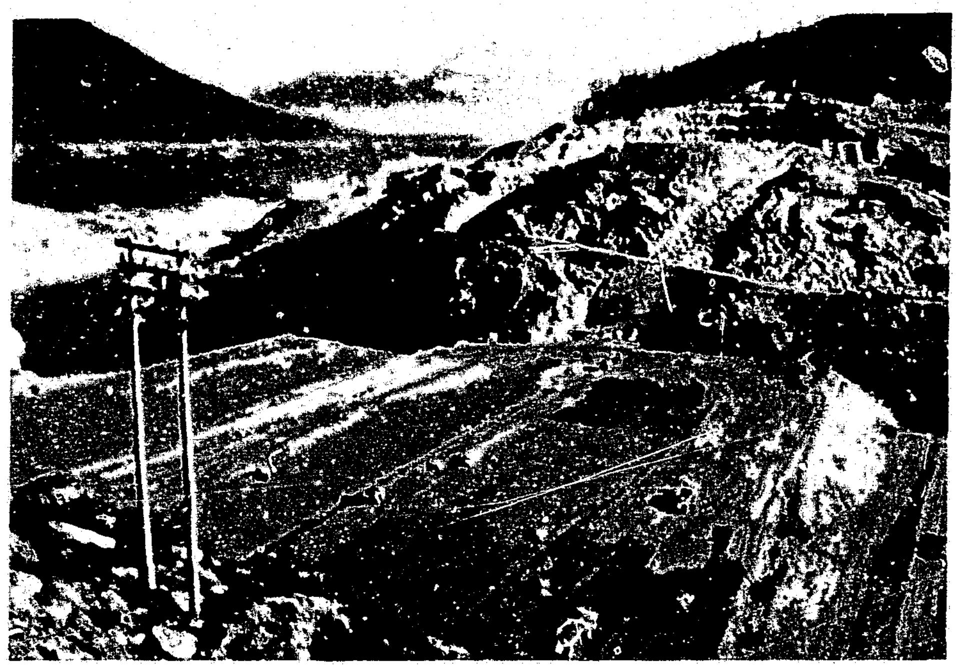
- selection of well-graded glacial till as a self-healing core material
- adoption of relatively flat slopes to minimize seismic-induced shear stresses
- upstream curvature of the dam
- high-energy compaction of fill materials
- shaping of abutments and core contact zones.

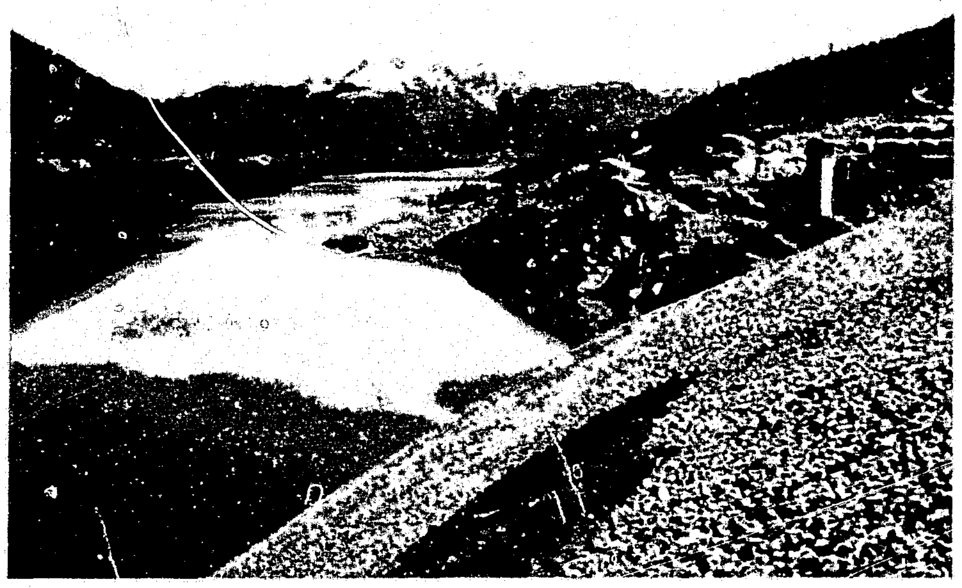
The foundation of the impervious core zone was excavated to sound rock. Overhangs and abrupt discontinuities were removed and the rock surface shaped, by blasting, to provide satisfactory contact areas with the fill. Foundation surface treatment comprised infill concrete to remove geometric irregularities, and shotcrete and slush grout to seal open joints in the bedrock surface.

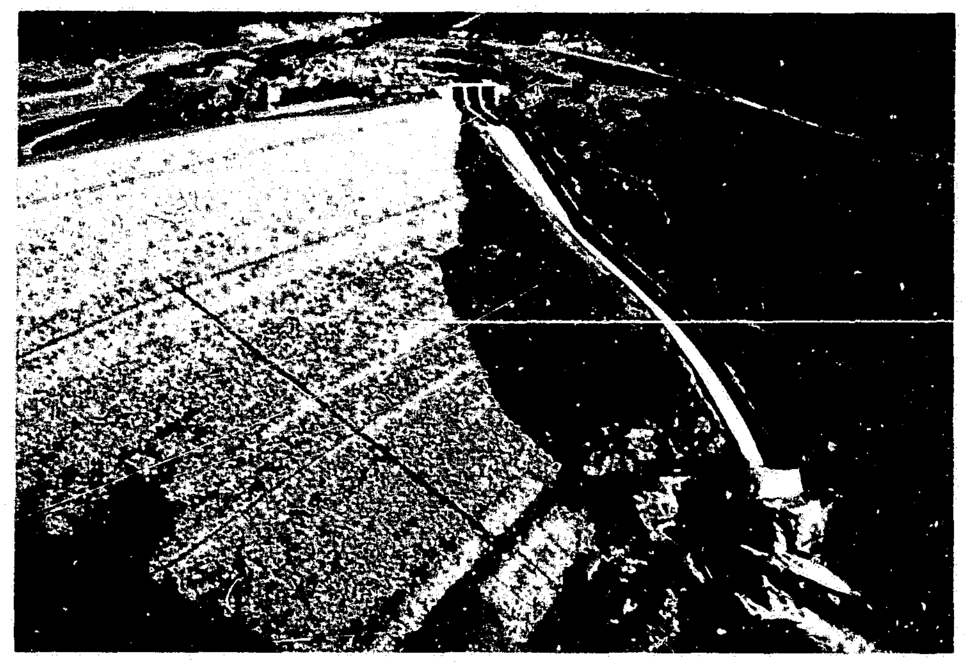
Within the riverbed area, the foundation of the supporting shell zones of the dam was placed on dense alluvium. The upper stratum of silty fine sand was excavated to avoid possible liquefaction under earthquake loads.

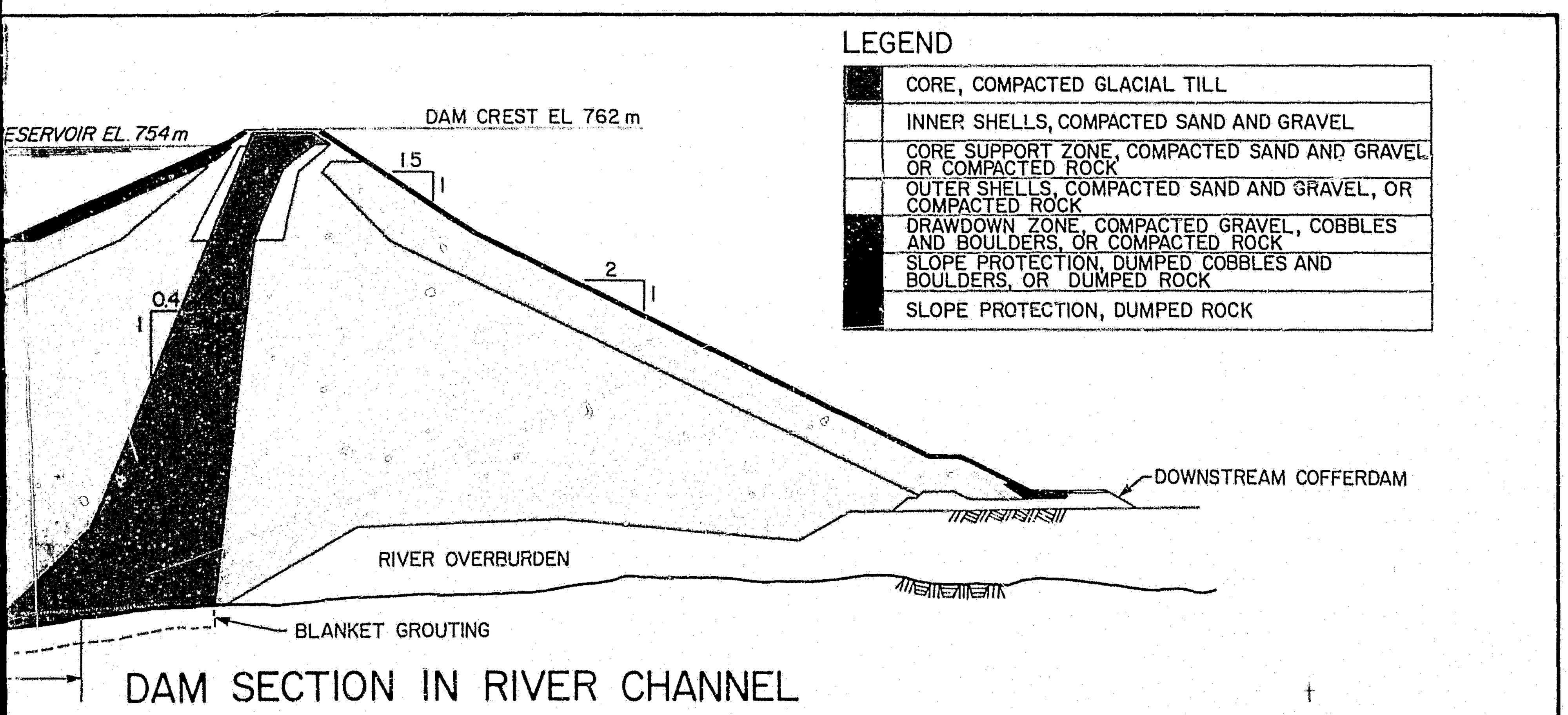
Instrumentation of Mica Dam is extensive. To monitor the performance of the dam and check its behavior with design assumptions, a wide range of instruments was carefully selected and installed, including piezometers, movement gauges, load cells and seismic recording instruments.





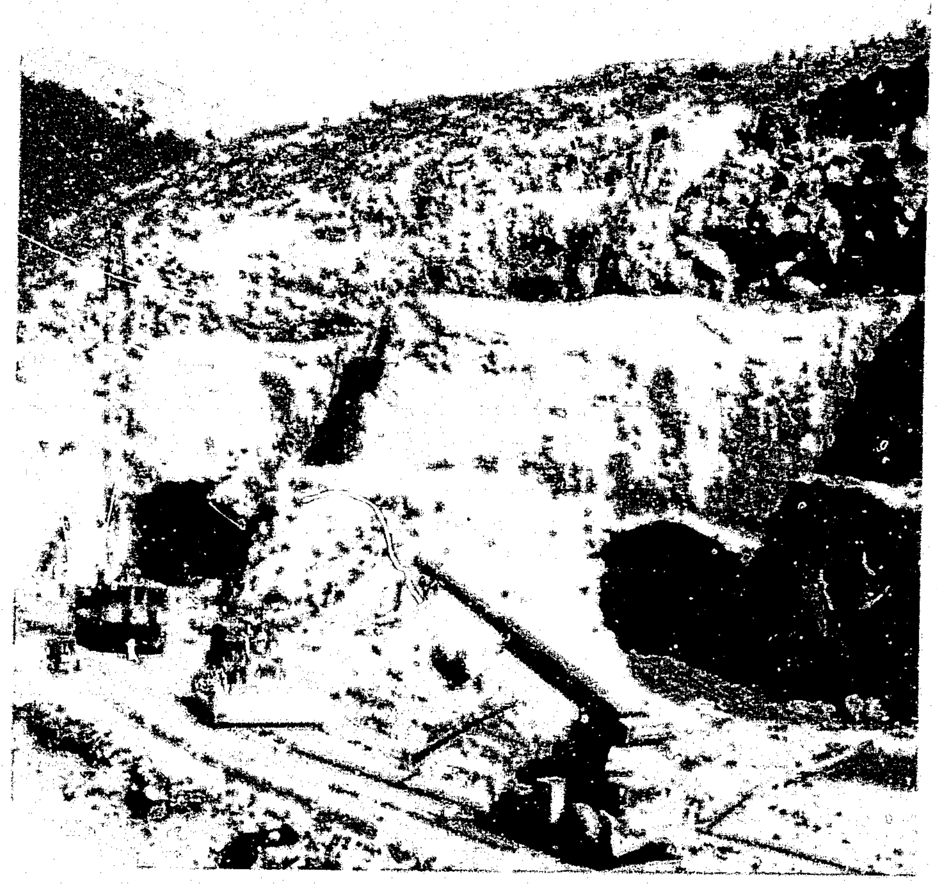





LEGEND
CORE, COMPACTED GLACIAL TILL
INNER SHELLS, COMPACTED SAND AND GRAVEL
CORE SUPPORT ZONE, COMPACTED SAND AND GRAVEL OR COMPACTED ROCK
OUTER SHELLS, COMPACTED SAND AND GRAVEL, OR COMPACTED ROCK
DRAWDOWN ZONE, COMPACTED GRAVEL, COBBLES AND BOULDERS, OR COMPACTED ROCK
SLOPE PROTECTION, DUMPED COBBLES AND BOULDERS, OR DUMPED ROCK
SLOPE PROTECTION, DUMPED ROCK
ESERVOIR EL. 754 m
DAM CREST EL 762 m
1.5
1
2
1
0.4
1
DOWNSTREAM COFFERDAM
RIVER OVERBURDEN
BLANKET GROUTING
DAM SECTION IN RIVER CHANNEL

River Diversion

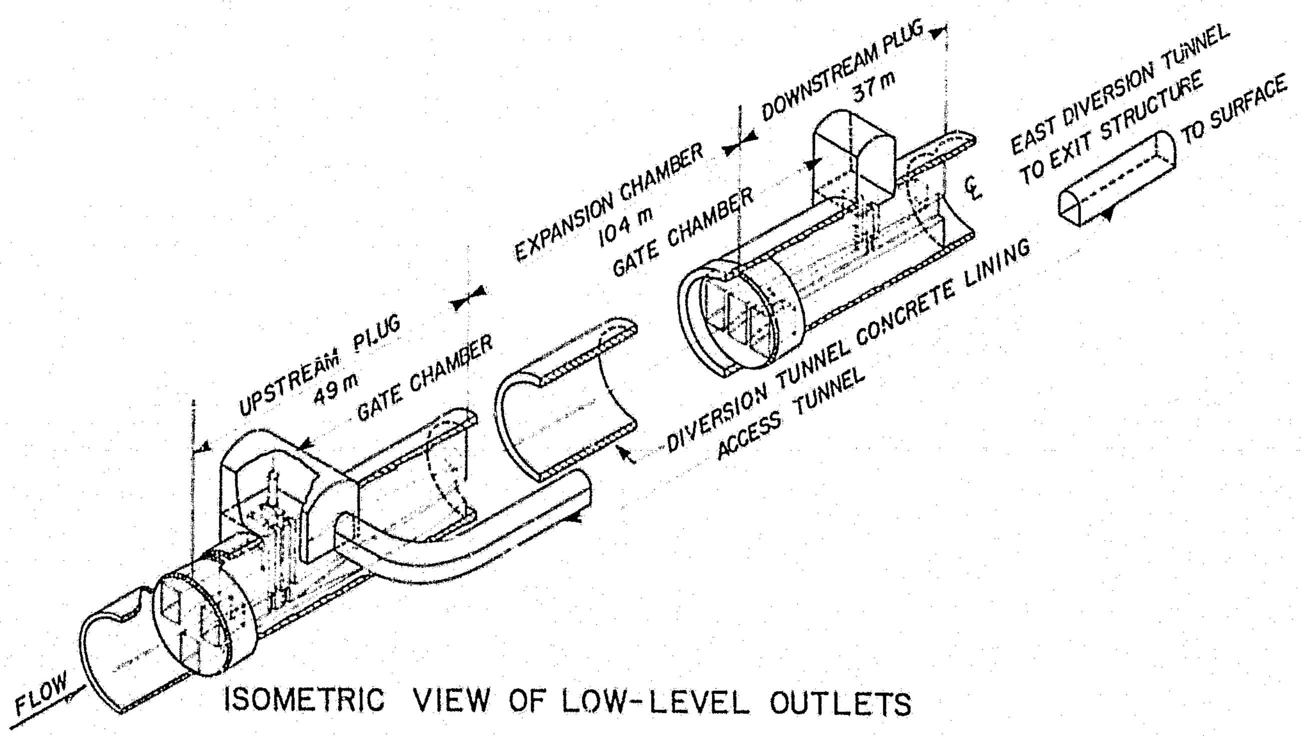
Diversion works consist of 2 concrete-lined tunnels, 13.7 m in diameter, each having a length of about 1,000 m. Designed as free-flow structures, the tunnels have a combined capacity of 4,250 m^3/s. Each tunnel incorporates a gated intake structure and an exit structure designed to contain the hydraulic jump.



River diversion through the tunnels was effected by 2 pairs of rock-fill dikes constructed across the Columbia River at the upstream and downstream limits of the main dam foundation area. For dewatering the dam foundation, zoned earth-fill cofferdams were constructed within these closure dikes. The cofferdams were largely incorporated into the dam embankment. Deep tube wells were installed through the river alluvium adjacent to the cofferdams for control of seepage into the core trench excavation.

Low~Level Outlets

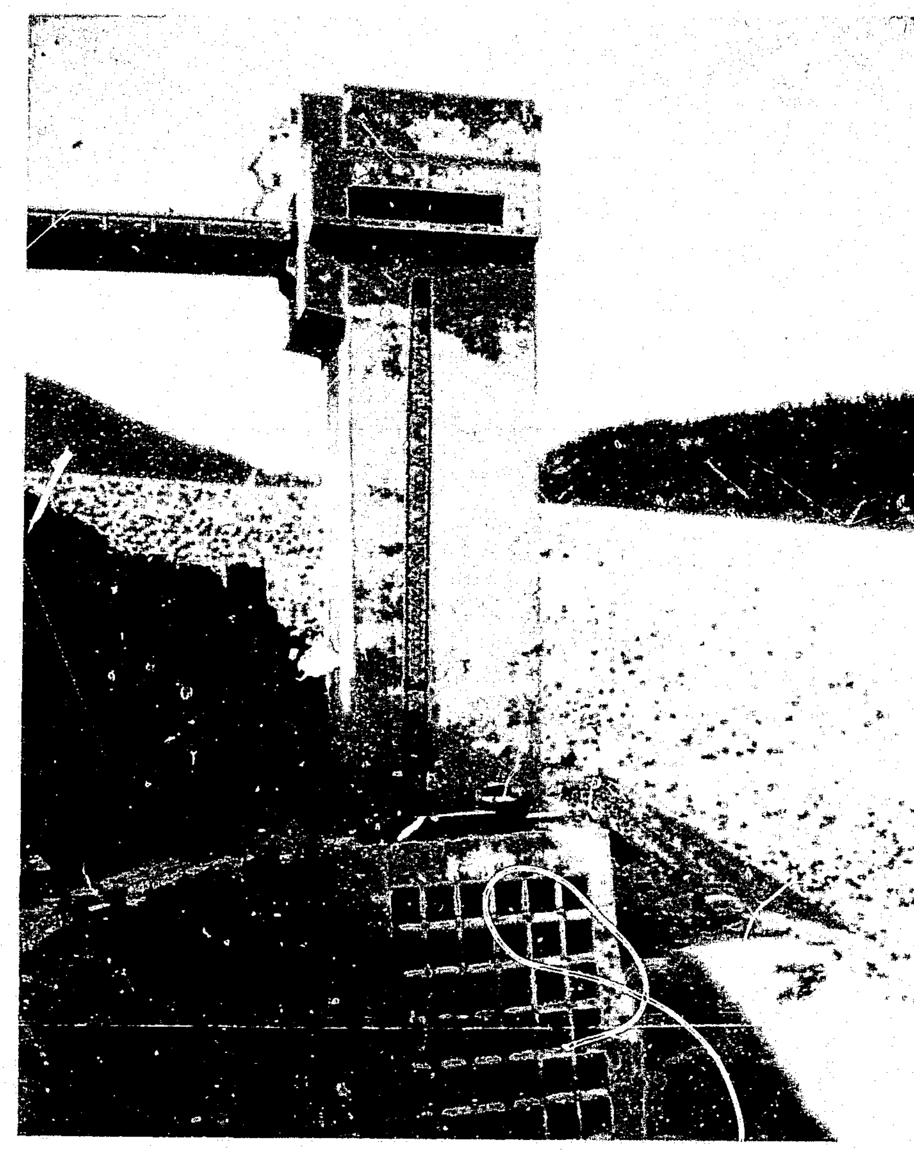
To allow flow releases during filling of the dead storage zone, a low-level outlet structure was constructed in the east diversion tunnel. This outlet employs an expansion chamber type energy dissipator which reduces the discharge head by approximately 50 percent. Extensive model tests were performed to develop the final arrangement consisting of 3 conduits and slide gates located in plugs at the upstream and downstream ends of the expansion chamber, formed by the original diversion tunnel walls.

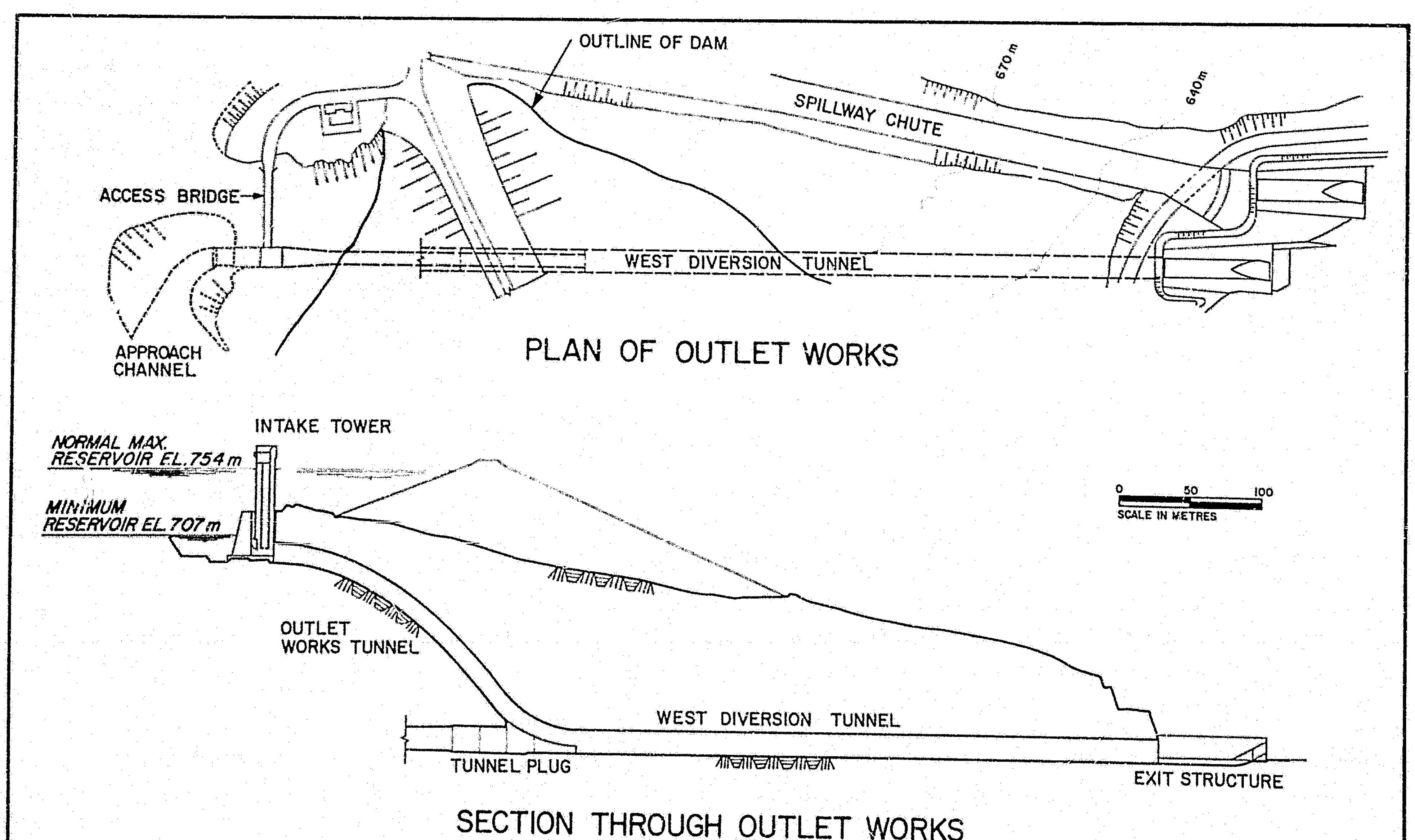


ISOMETRIC VIEW OF LOW-LEVEL OUTLETS

Outlet Works

The outlet works were constructed primarily to release water from live storage prior to the commissioning of the powerhouse in 1977. Released water passes through the gate-controlled conduits at the base of an intake tower into an inclined tunnel which discharges into the west diversion tunnel. The 2 fixed-wheel gates are operated by hydraulic hoists at the bottom of a dry shaft. Access to the top of the control structure is via a 2-lane bridge from the dam crest.

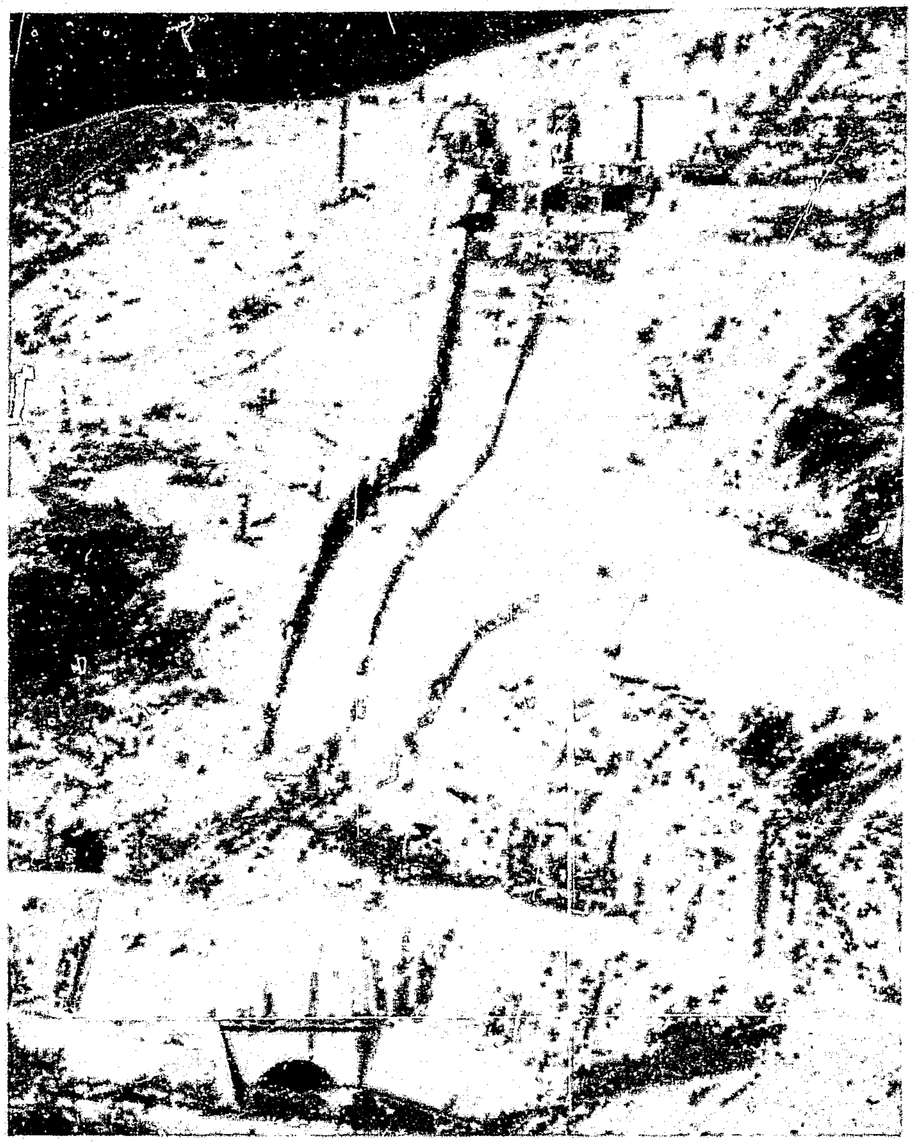


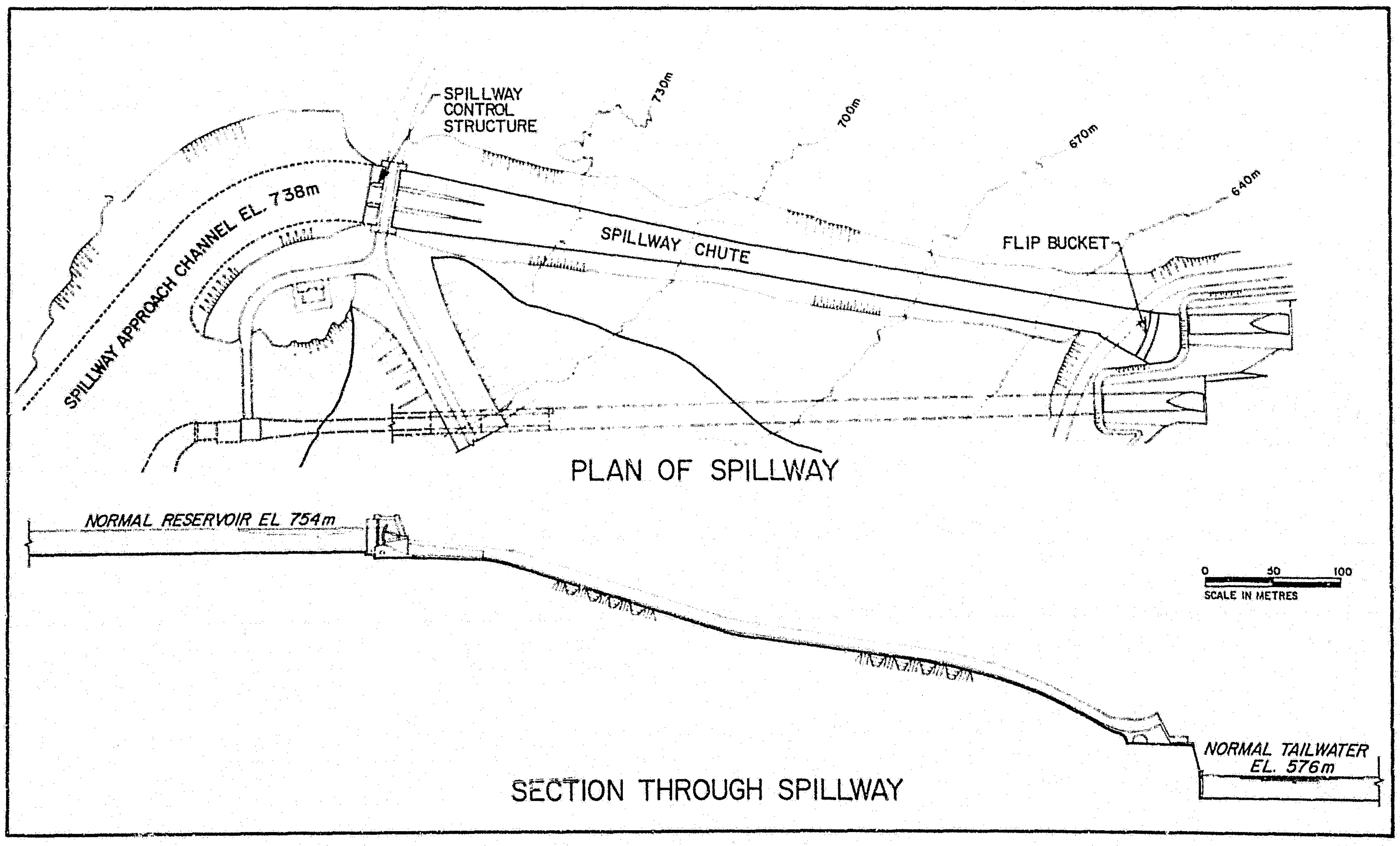


Spillway

The spillway structure consists of a control structure with 3 radial gates, a 530-m long concrete spillway chute and a mass concrete flip bucket. Design capacity of the spillway is 4,250 m^3/s.

The control structure is a low overflow weir with an ogee shape. Hydraulic model tests were used to develop a unique flow surface for the flip bucket, conforming to a skew cone with an inclined axis. A transverse drainage system and longitudinal drainage gallery run beneath the full length of the spillway chute floor.

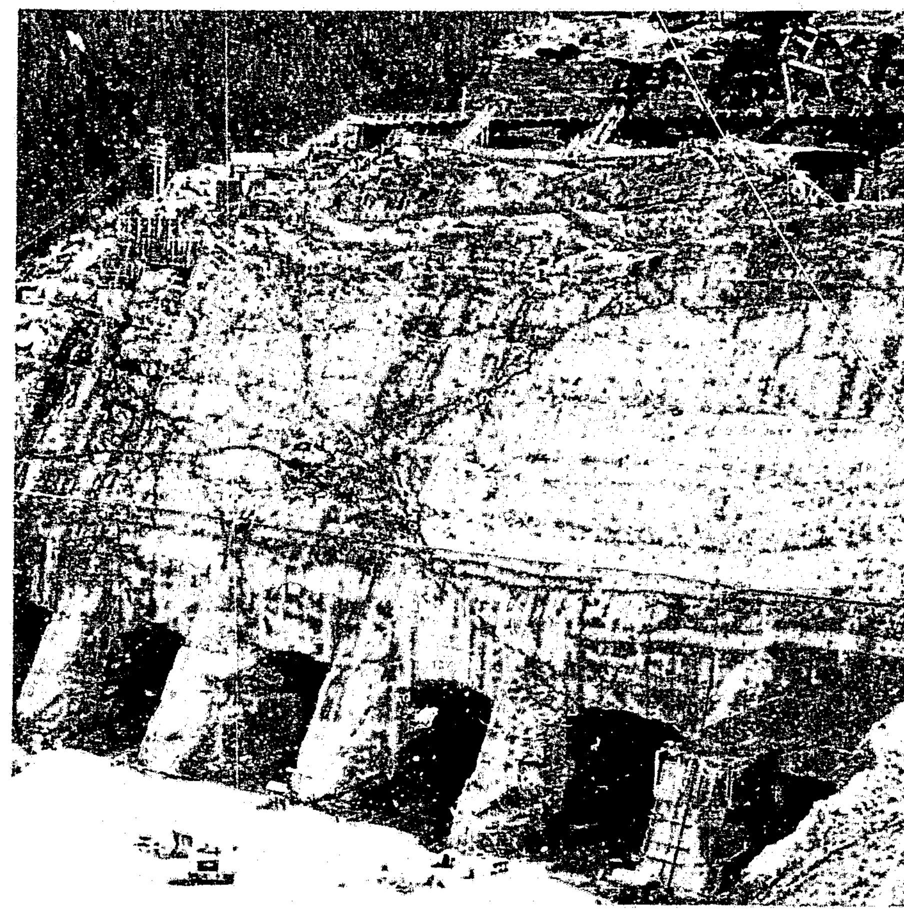


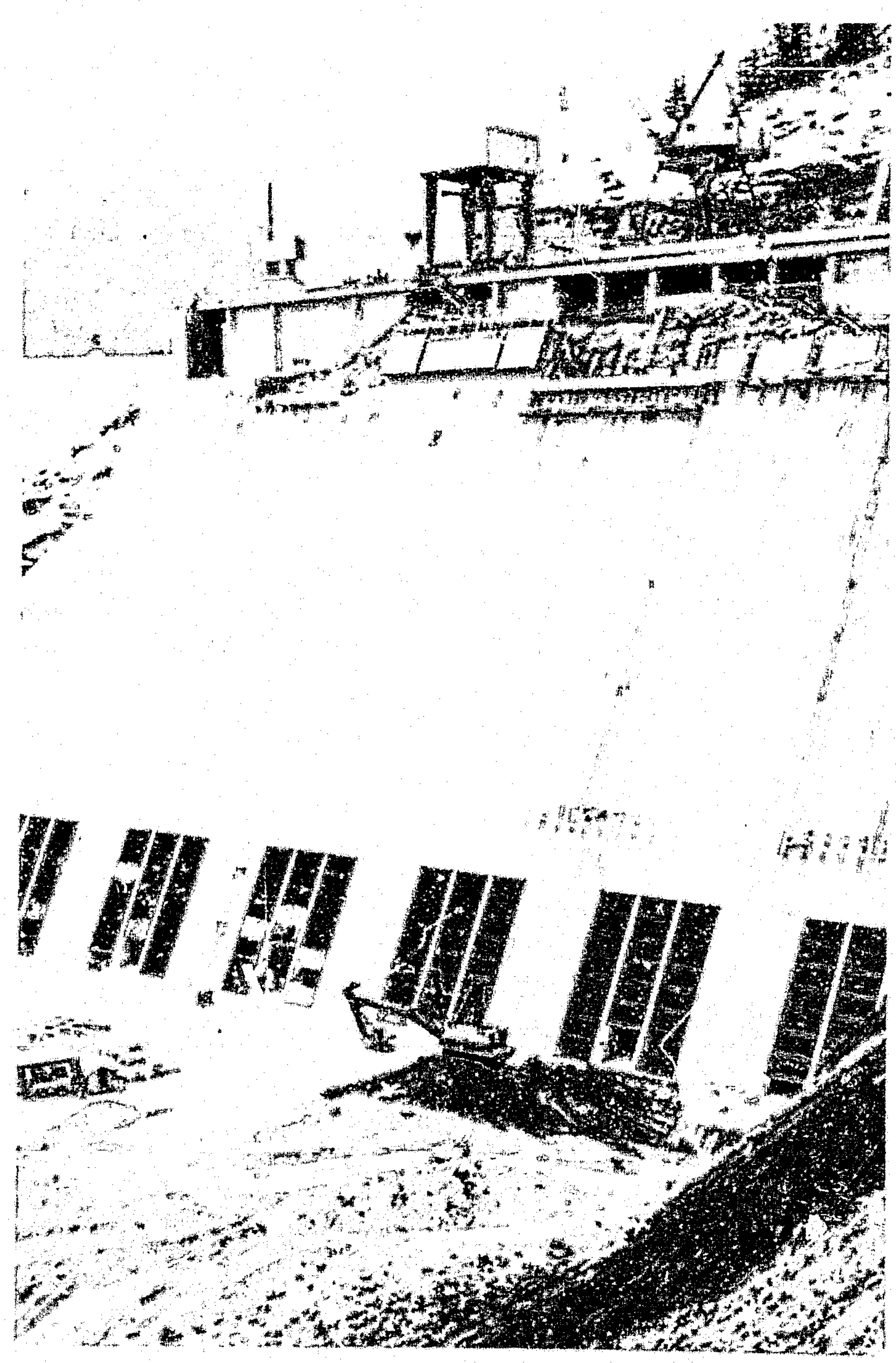


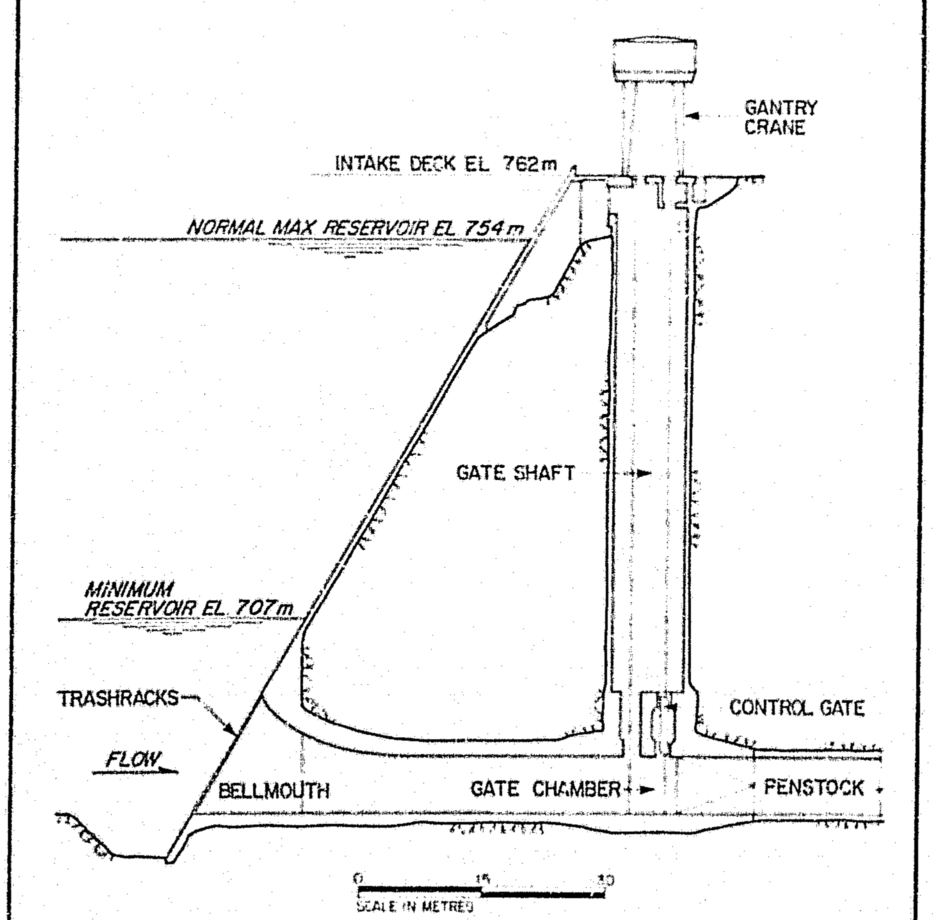
Power Intakes

The power intake structure was constructed as part of the main dam project and comprises an approach channel formed by a 76-m deep opencut rock excavation and 6 intakes. Each intake incorporates a bellmouth entrance, gate chamber and short concrete-lined stub tunnel. Flow control is accomplished by vertical fixed-wheel gates operated from 8.7-m diameter, 76-m deep gate shafts. The bellmouth entrances are covered by trashracks which are cleaned by a trash rake operated from the intake structure deck. Slip-forming methods were used to place the concrete for the face slab and gate shaft lining.

Engineering of the underground generating station at Mica was carried out by the British Columbia Hydro and Power Authority, largely subsequent to the completion of CASECO's work on the dam and associated structures.







SECTION THROUGH POWER INTAKES

MICA DAM PROJECT STATISTICS

General

Drainage basin area	21,250 km^2
Mean annual discharge	590 m^3/s
Reservoir storage — total	25,000 x 10^6 m^3
— live	15,000 x 10^6 m^3
Full supply level	754 m
Maximum tailwater level	576 m

Dam — Compacted Earth Fill, Near-Vertical Impervious Core

Height above bedrock	244 m
Crest — elevation	762 m
— length	792 m
— width	34 m
Base width	945 m
Volume	32.6 x 10^6 m^3

Diversion Tunnels — Two Concrete-Lined Tunnels

Diameter	13.7 m
Length — west	893 m
— east	1,036 m
Gate sill elevation	567 m
Design discharge	4,250 m^3/s
Number of vertical fixed-wheel gates	4

Spillway — Gated Chute with Flip Bucket

Number of radial gates	3
Gate dimensions	12.8 m high by 12.2 m wide
Gate sill elevation	742 m
Design discharge	4,250 m^3/s

Low-Level Outlets — Three Conduits Located in East Diversion Tunnel

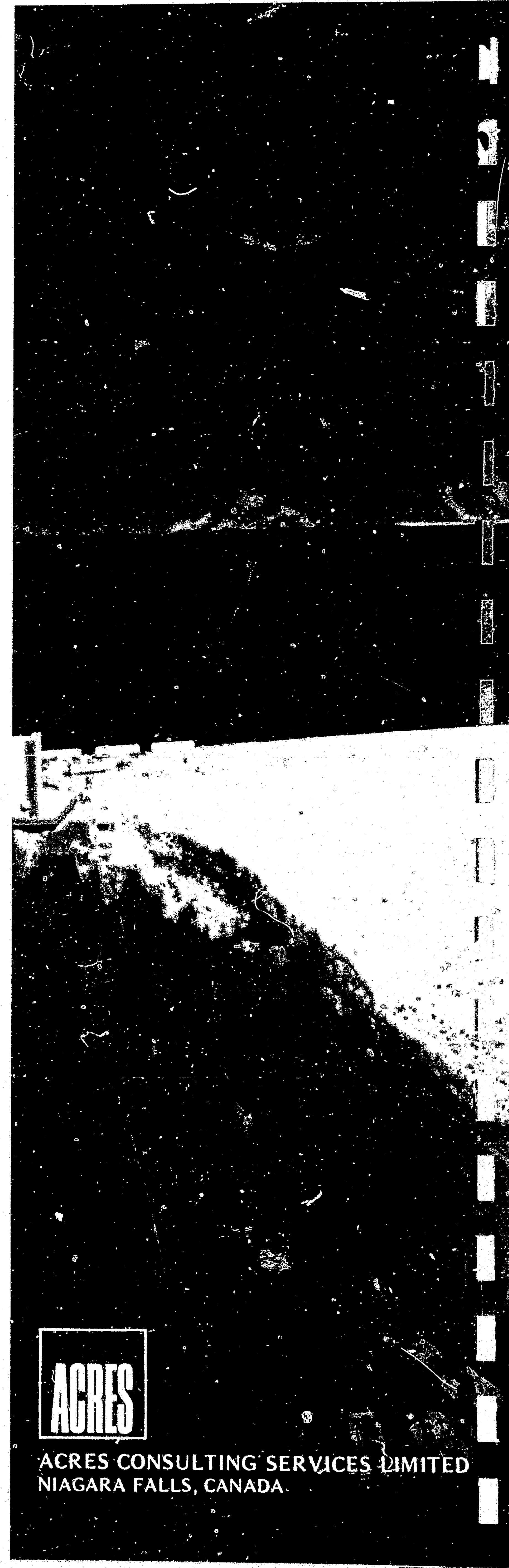
Conduit dimensions	2.3 m by 3.5 m
Maximum design head	174 m
Number of vertical slide gates	9
Design discharge capacity	850 m^3/s

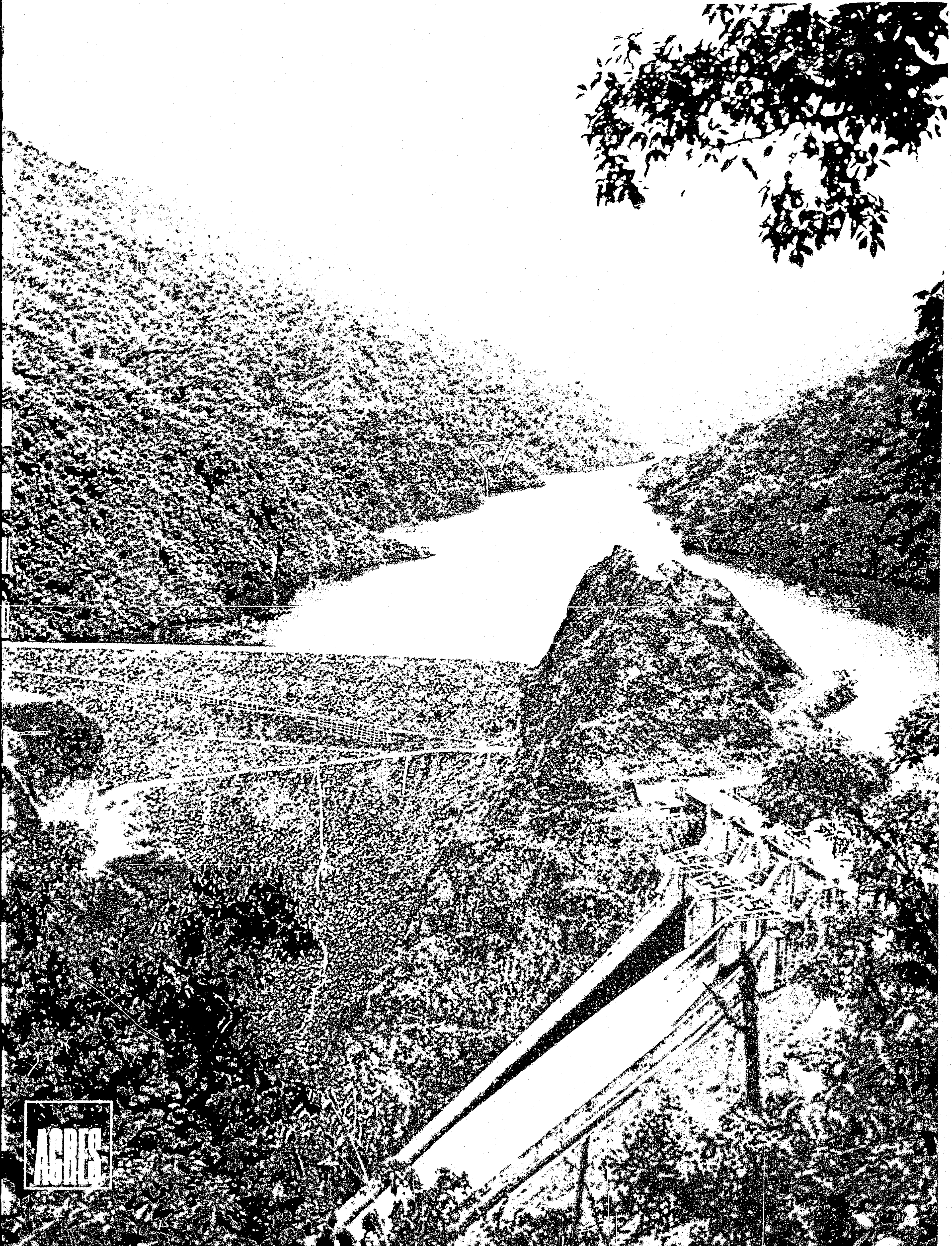
Outlet Works — Concrete-Lined Tunnel Linking to West Diversion Tunnel

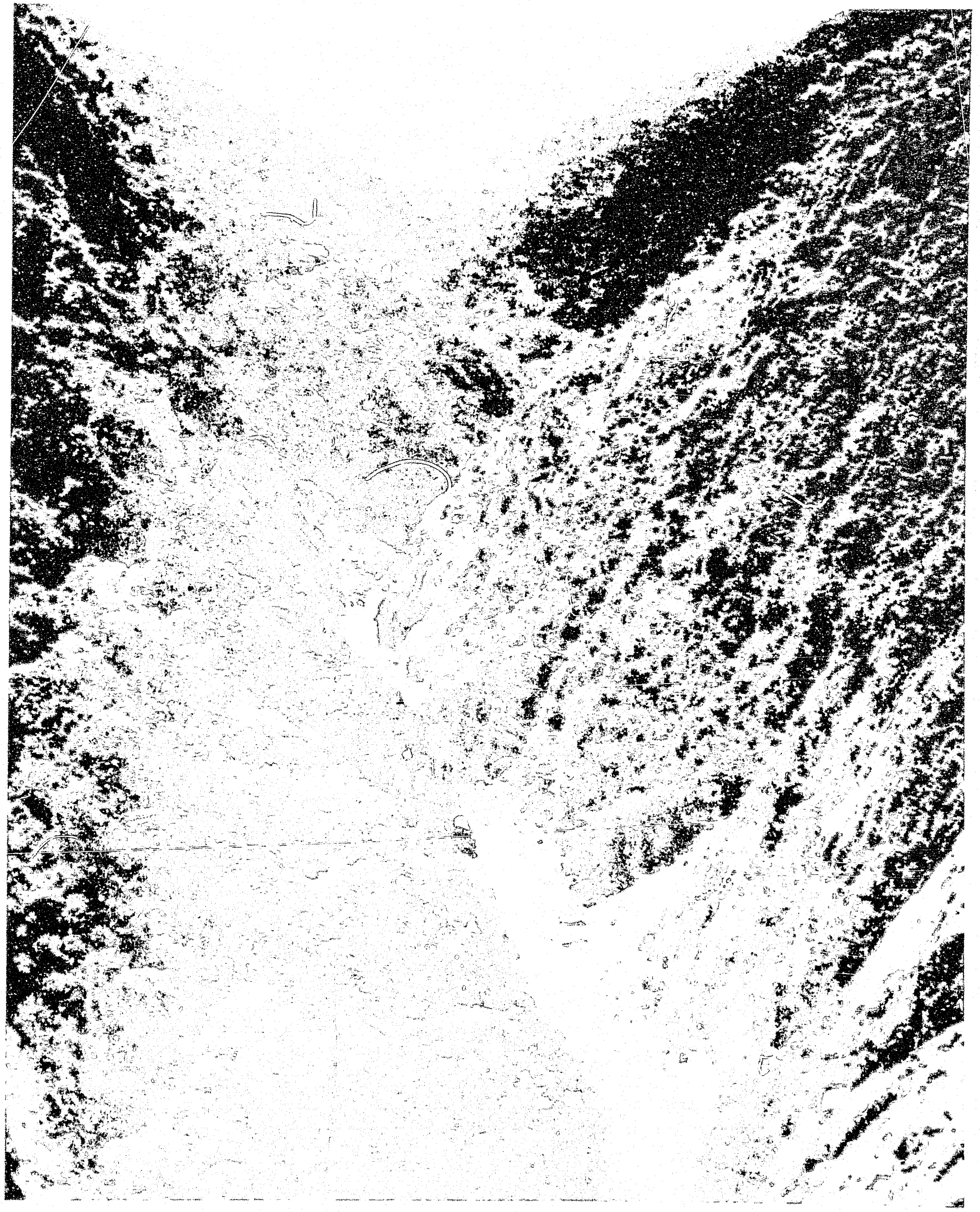
Number of intake conduits	2
Dimensions of intake conduits	3 m by 5.5 m
Number of vertical fixed-wheel gates	2 control, 1 guard
Inclined tunnel diameter	11 to 9 m
Design discharge capacity	1,060 m^3/s

Power Intakes — Six Individual Intakes

Intake conduit dimensions	5.2 m by 6.7 m
Maximum design head	68 m
Number of vertical fixed-wheel gates	6 control, 1 guard
Tunnel diameter	6.7 m
Total design discharge capacity	1,700 m^3/s




ACRES

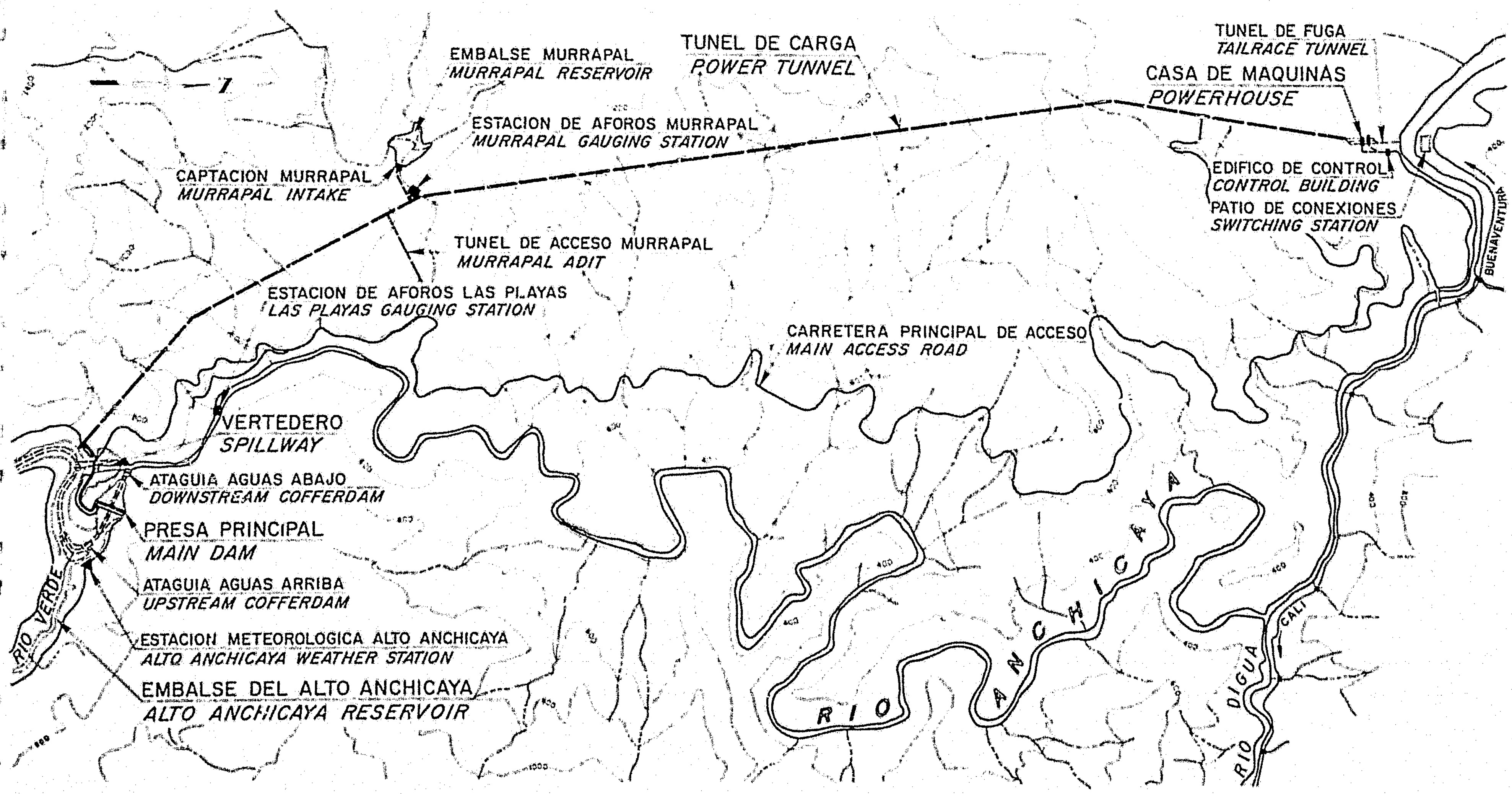


ALTO ANCHICAYA HYDROELECTRIC PROJECT

In the tropical rain forest of South America's Western Cordillera, the CVC of Cali, Colombia, owns and operates the world's highest concrete-faced rock-fill dam and a 340-MW underground power facility.

ACRES

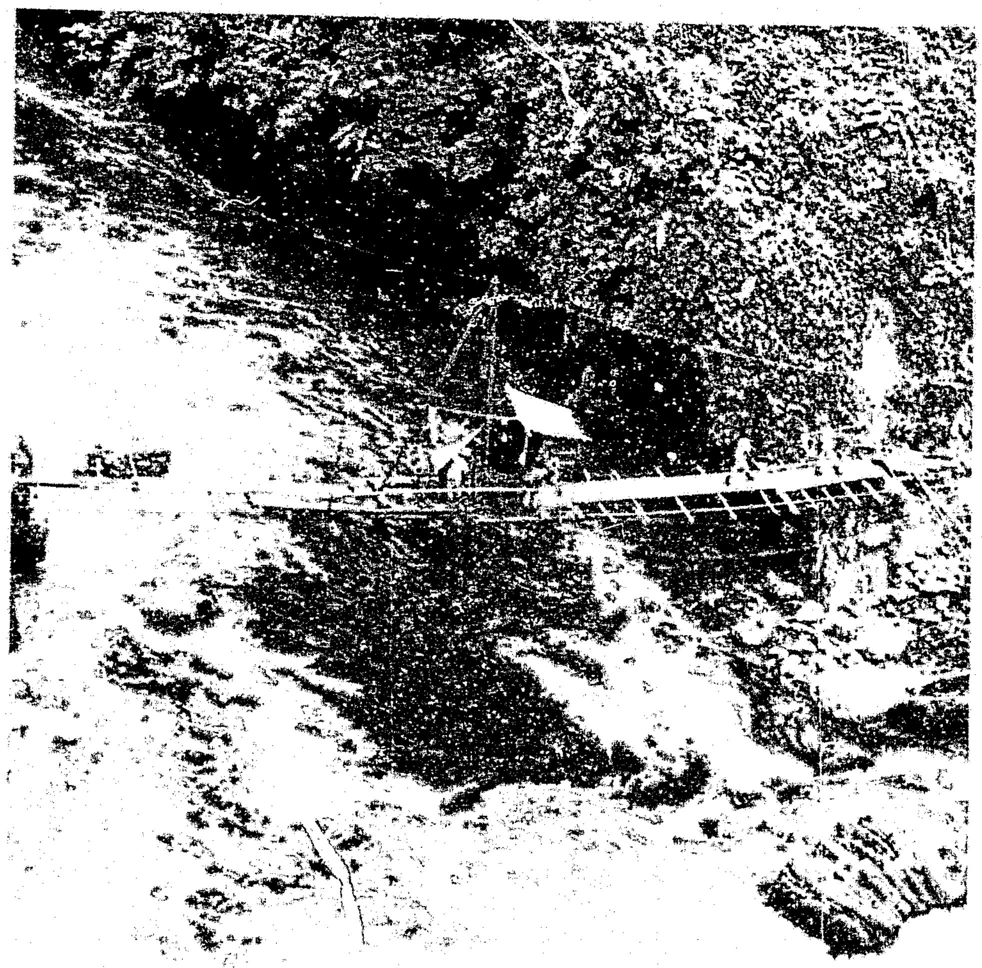
Acres International Limited
Consulting Engineers
5259 Dorchester Road
Niagara Falls, Canada



DISPOSICION GENERAL DEL PROYECTO

GENERAL ARRANGEMENT OF PROJECT

ESCALA 0 .2 .4 .6 .8 1.0 km
SCALE

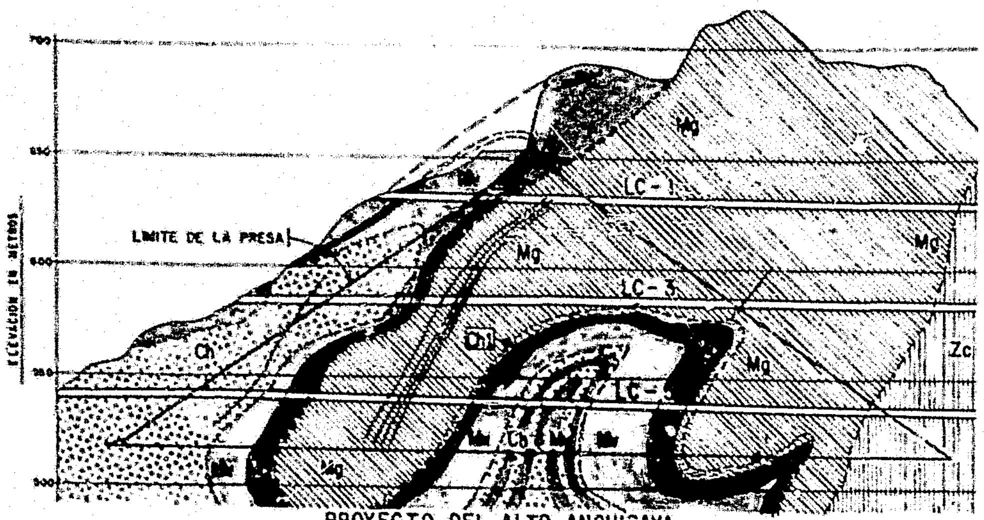


The Corporación Autónoma Regional del Cauca (CVC) of Cali, Colombia, with the help of its consultants and contractors, has completed the construction of the Alto Anchicayá hydroelectric project, including a 140-m high concrete-faced rock-fill dam, 8-km power tunnel, and 340-MW underground power station. The site is on the rugged Pacific slope of the Western Cordillera of South America, an area of precipitous mountains covered by tropical rain forest.

The CVC's engineering consultant, from the inception of the feasibility studies through detail design and construction, was Acres International Limited of Canada. The contractors for the major civil works were ICA of Mexico.

Slopes in the area of the project are very steep. Vertical cliffs are common. From its headwaters in the Farallones de Cali to its mouth near Buenaventura (a straight-line distance of only about 60 km) the river drops almost 3,000 m, and river gradients of 6 percent are found downstream from the damsite. Precipitation is very heavy, averaging about 4,800 mm per year near the powerhouse site, with 200 to 300 mm of rain even in the driest months. These features, which are favorable to hydroelectric development, made access very difficult in the early days. Men with picks and shovels hacked a 13-km trail over the slippery slopes, built a camp with planks sawn by hand in the jungle, dismantled the drilling equipment, and carried it, lashed to long poles, to the damsite to explore the rock in the dam foundations. When the track had been completed, mules and horses were able to undertake the haulage of supplies and equipment. Finally, when the feasibility of the project had been confirmed, the CVC undertook the major task of building motorable access roads to serve for the construction and operation of the project. Two years later, when the 20-km road was completed, the trip from the powerhouse site to the damsite was finally reduced from a muddy 5-hour trudge on foot or muleback to an easy 20-minute drive.

The earliest evaluations of the power potential of the upper reaches of the Anchicayá River were hampered by the complete absence of maps and even of aerial photographs (because of almost continuous cloud cover). Hardy pioneer engineers located the site of the Alto Anchicayá dam in the 1950's after arduous weeks of work in the jungle. These explorations resulted in in-house studies and a preliminary report on the economic feasibility of upstream developments which was submitted to the management of CVC in October 1966. In April of the following year, Acres International Limited, Consulting Engineers of Niagara Falls, Canada was retained to assist the hydroelectric department of CVC in the performance of a full-scale feasibility study, including site surveys, investigations of foundations, construction materials and earthquake risk, geologic and topographic mapping, hydrological, electrical system, and economic studies, preliminary designs and costs estimates, and all the related activities of such a study. A mixed team of Colombians and Canadians completed the work in a year, and the feasibility report was submitted to the Executive Director of CVC in April of 1968. It was concluded that the installation of 340 MW of capacity at Alto Anchicayá, with a load factor of 0.59, would contribute 1,760 GW·h to the CVC system in the average year, and that a financial rate of return of 14 percent could be expected, based on energy sale prices in effect at the time.



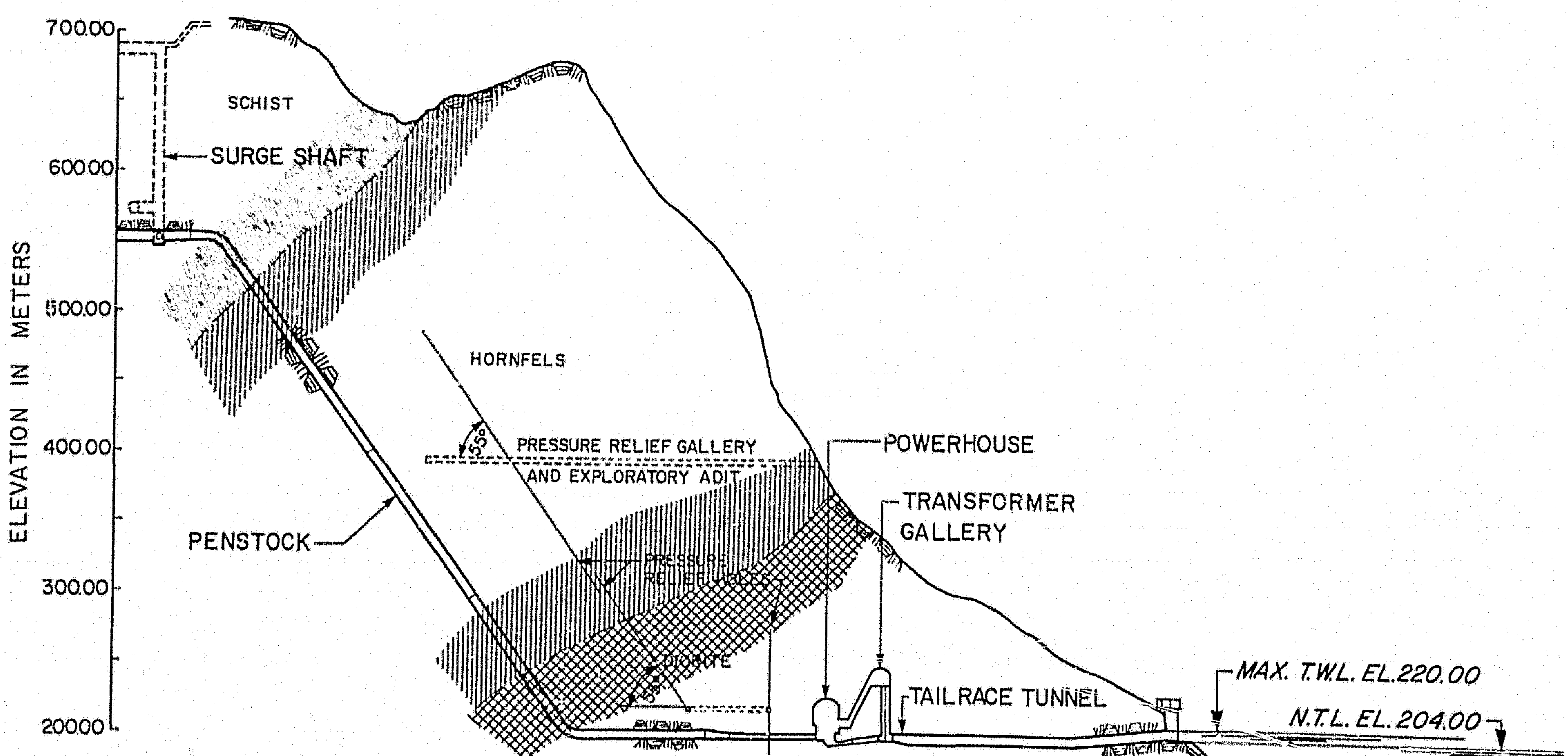
PROYECTO DEL ALTO ANCHICAYA
PRESA PRINCIPAL
ESTRIBO IZQUIERDO
CORTE POR EL EJE DE GALERIAS - GEOLOGIA

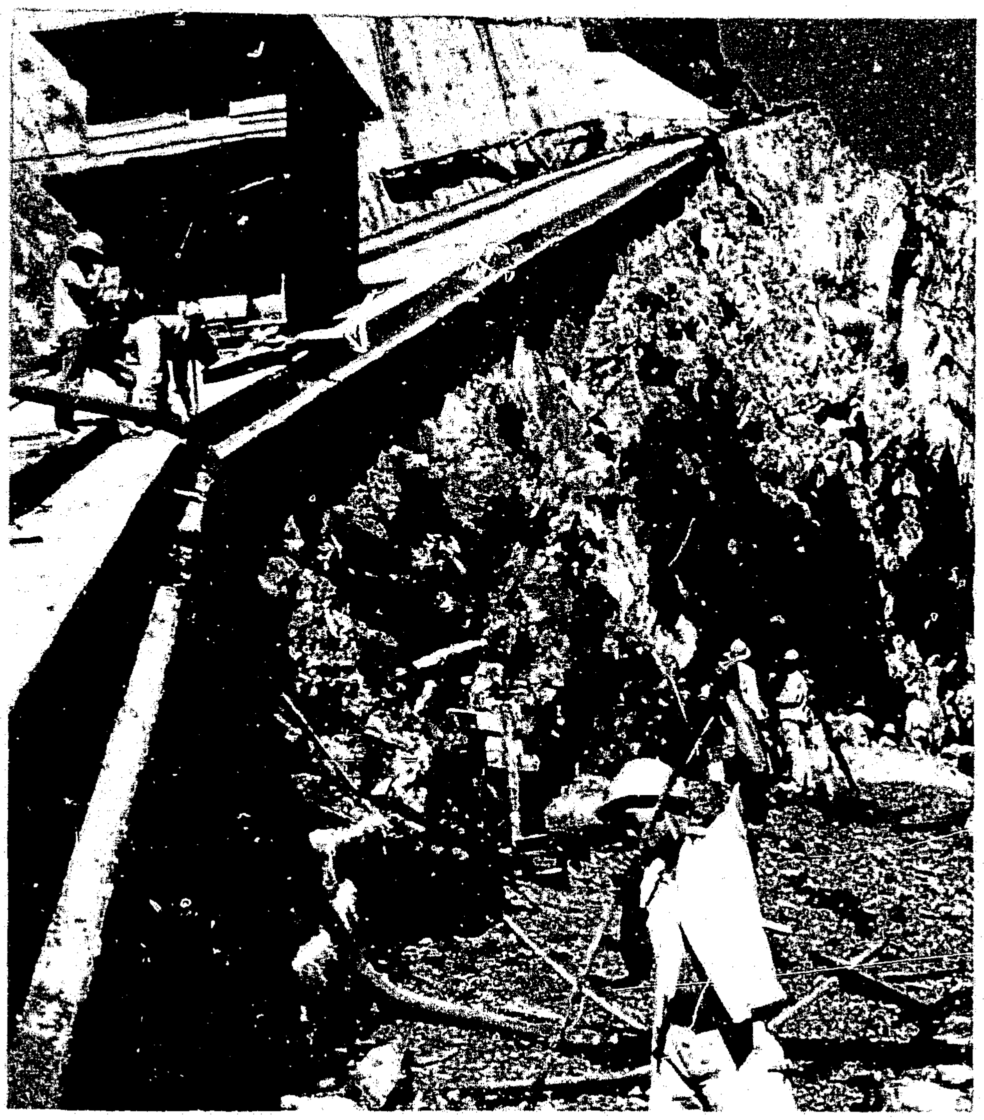
CONVENCIONES

- HORNFELSA
- ESQUISTOS NEGROS
- ESQUISTOS VERDES
- CALCAREOS - LIMO
- LIDITA
- LIDITA MASIVA
- CONTACTO GEOLOGICO
- ZONA CIZALLADA

The subsequent period was spent in obtaining financing for the construction of the project. The Inter-American Development Bank and the Government of Canada agreed to cooperate. Meanwhile, detailed investigations and studies continued to refine the engineering designs and insure that the optimal structures would be built.

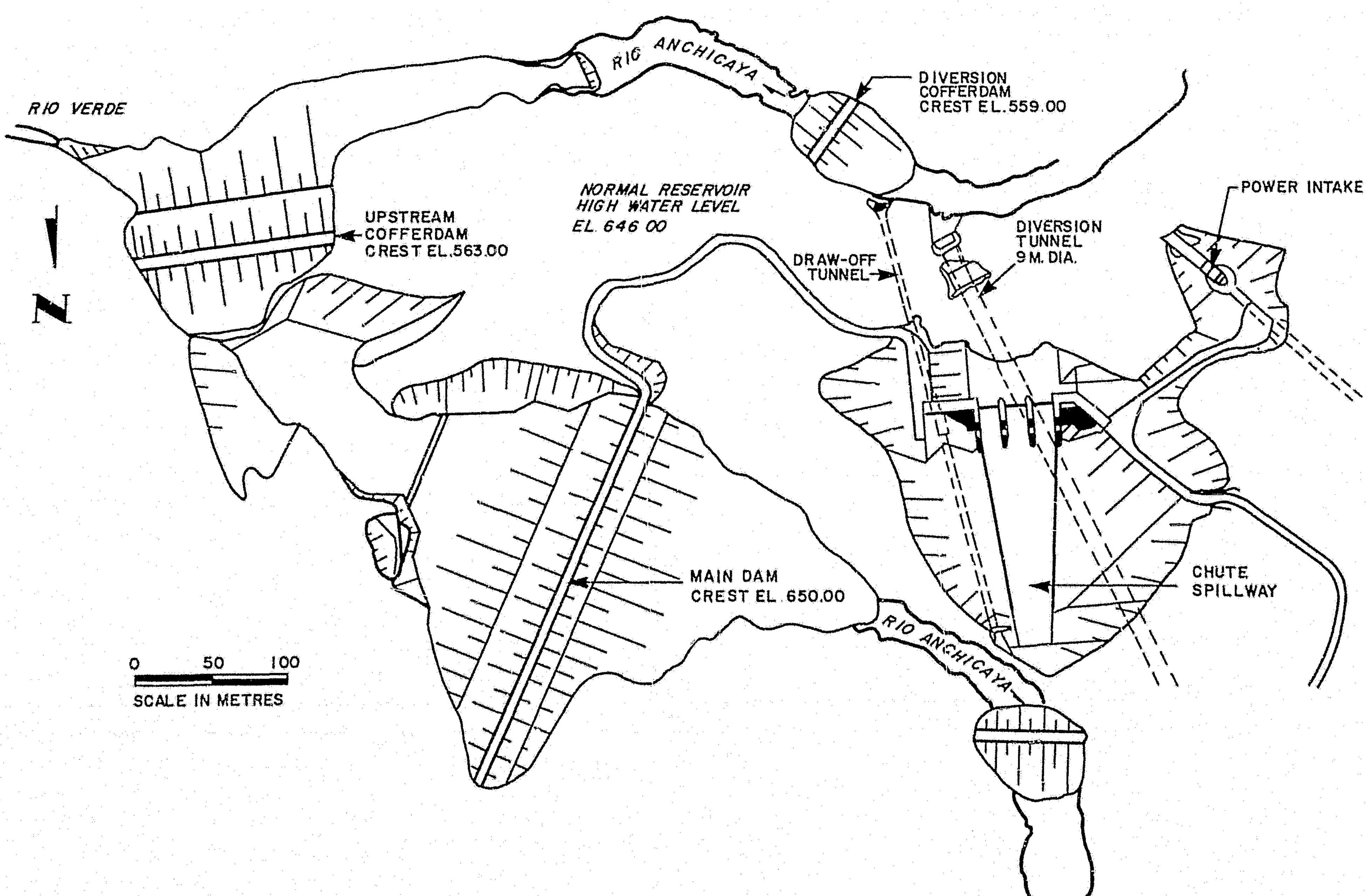
A comparison of all the applicable alternative types of dams was made and it was determined that the most economical would be a compacted rock-fill dam with an impervious membrane formed on its upstream face by cast in situ concrete. Since this would be the highest such dam ever constructed, great care was required in the design of each of its components and in the selection of materials and methods of construction. A finite element deformation analysis of the dam body and the concrete face was performed, and the assistance of three special consultants (Dr. D. H. MacDonald, Dr. D. U. Deere and Mr. B. J. Cooke) was obtained to advise on the selected design, its detailed fitness for the site, and the materials and method of construction. At the same time, the final location, orientation, shape and details of the underground powerhouse, surge shafts and penstocks, and of the tunnel and its construction portals and intakes were fixed. By September of 1969 the data had been prepared for the main civil contract tenders. This contract was ultimately awarded to the Mexican firm of Ingenieros Civiles Asociados (ICA).

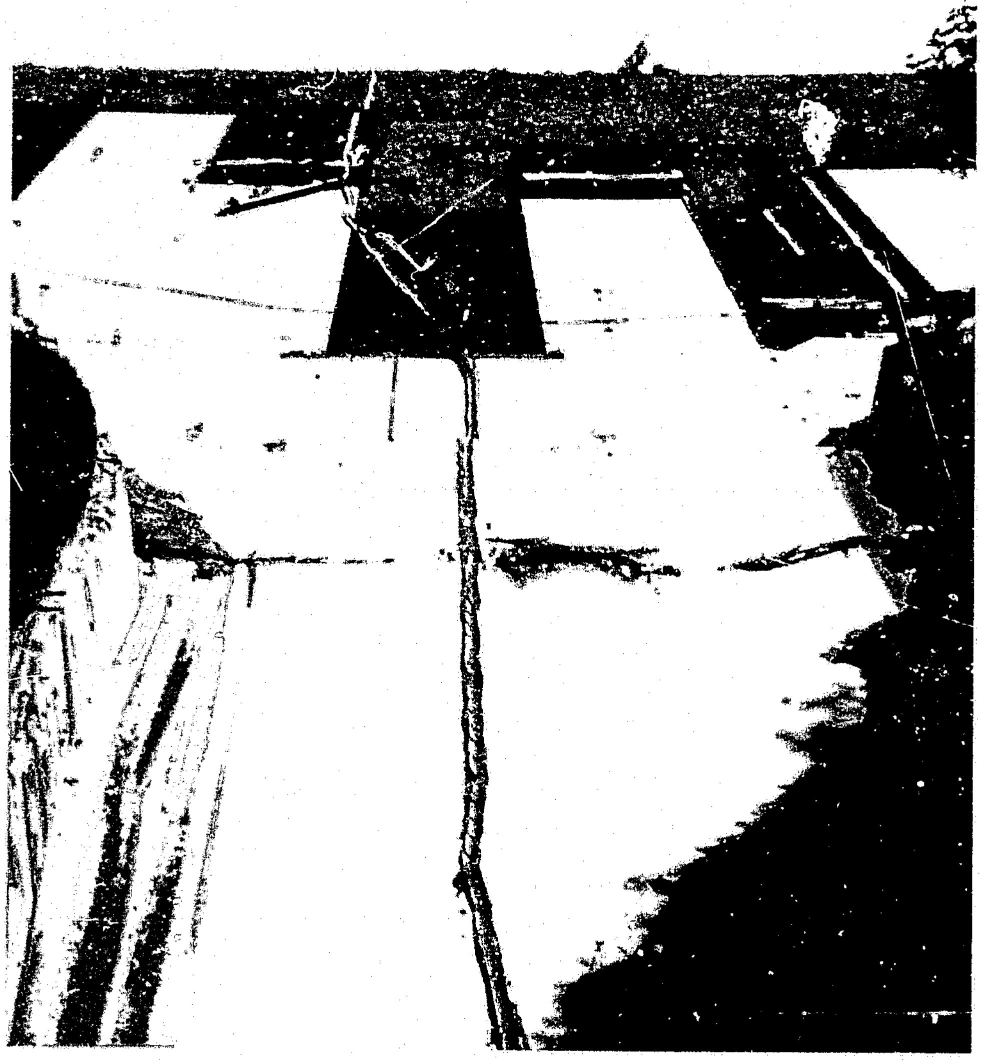




The left abutment of the dam was formed by a narrow sharp-crested ridge, around which the river formed a deeply incised horseshoe loop. In the complex folded schist bedrock within this ridge, a thick layer of rong chert provided a firm foundation for the upstream concrete diaphragm. An elborate system of tunnels and drill holes was installed within the ridge to control the seepage flows and pressures generated by the deep reservoir on its upstream side. (Similar but less extensive measures were also required on the right abutment.)

The siting of the spillway and the diversion and outlet tunnels also took advantage of the presence of this ridge to achieve the necessary water releases over the shortest practical path. In this area the bedrock consists of hornfels, a hard but fractured rock formed from the schists in the vicinity of a large body of diorite (an igneous intrusive rock).

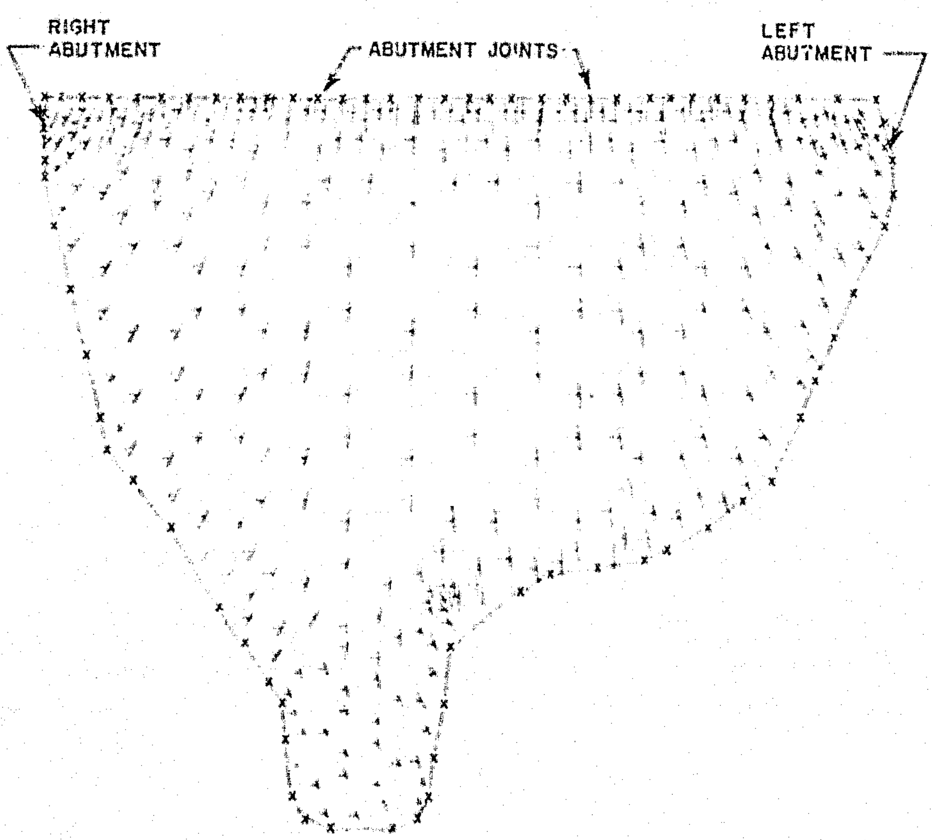


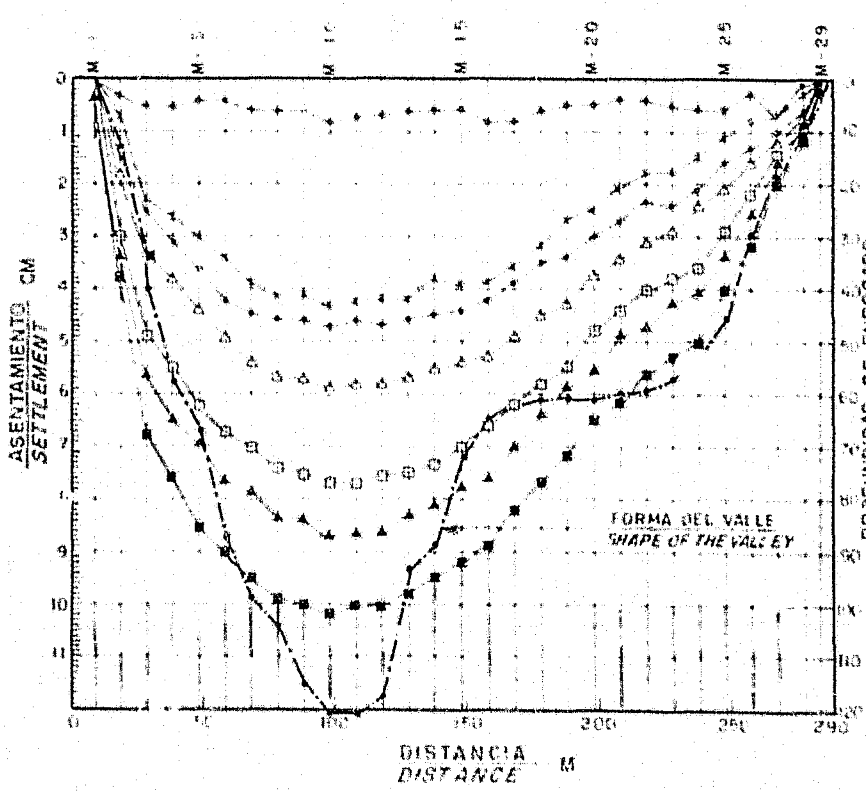


In order to control the ultimate deformation of the concrete face of the dam, great care was required in the design and construction of the rock fill in the body of the dam, including the selection of rock types, particle sizes and compaction methods. Only diorite and hornfels were permitted. They were obtained from quarries near the damsite and from the spillway excavation. The rock was dumped on the fill, sluiced, and spread in 60-cm layers with four passes of a 10-ton vibratory roller. Numerous tests were made to insure that the required density was being obtained, as too low a density might have permitted excessive deformation of the fill and hence of the upstream concrete diaphragm.

The concrete face itself was slip-formed on top of a special bedding layer of finer-grained rock fill. Again, careful detailed control was exercised to achieve the desired quality of the concrete and correct installation of all the design details. The thickness of the concrete slab varies from 30 cm to 70 cm.

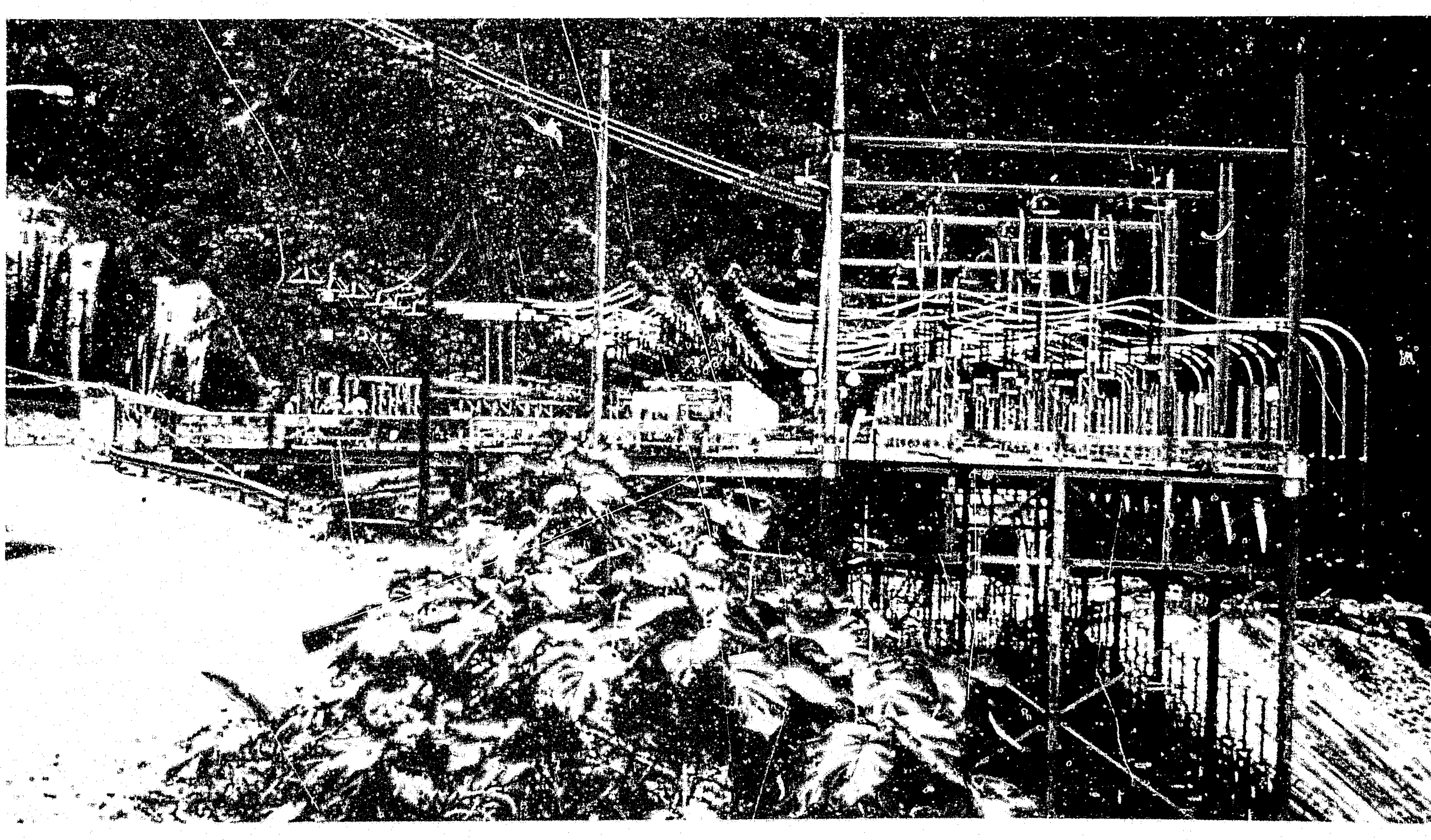
The 8.3-km long power tunnel was routed to take advantage of the terrain to provide adequate cover while permitting the use of intermediate construction adits and a small intake to pick up the inflow from the Murrapal tributary. Because the ground above the tunnel was inaccessible to drilling equipment, no subsurface investigations had been carried out along the line of the tunnel. The geological conditions had been deduced from geological mapping of the soils and rock outcrops alone. These predictions turned out to be quite dependable. The tunnel passes through all three rock types (schists, hornfels and diorite), but excavation was delayed because of geological conditions on only one occasion.





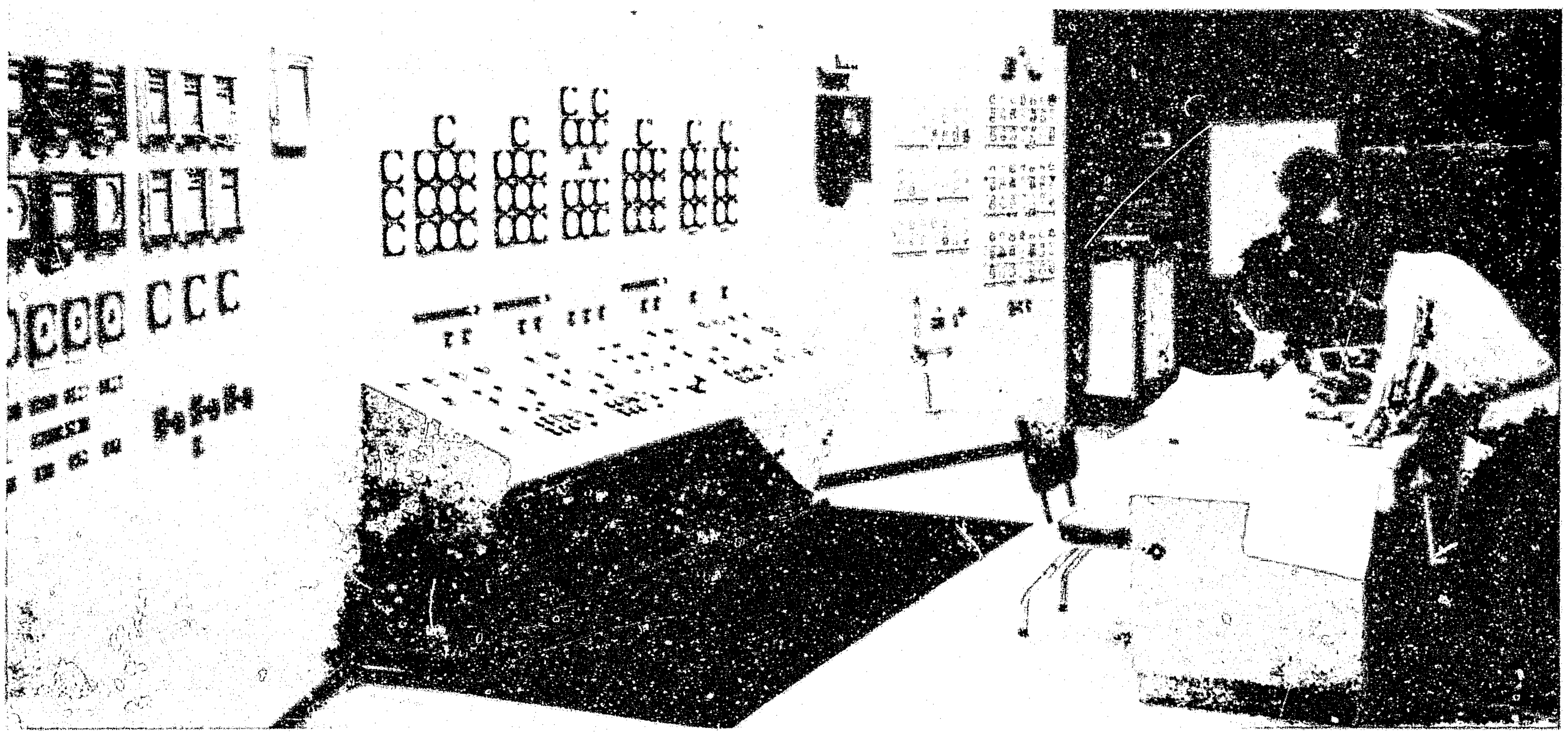
The layout of the underground structures in the powerhouse area was such as to take maximum advantage of the distribution of different types of rock. The whole powerhouse cavity is in a body of diorite. Local narrow zones of sheared and weathered rock had been discovered in exploratory drill holes and tunnels, and design details and construction methods had been adapted to accommodate them. The control room and erection bay are located at one end of the powerhouse, adjacent to the access tunnel. Three vertical-axis Francis type turbines were installed, rated at 160,000 mhp under a head of 400 m and a unit speed of 450 rev/min. The generators are rated at 126 MVA, 13.8 kV, 60 Hz, 90 percent power factor. Transformers are located in a separate underground gallery which also houses the crane to operate the draft tube gates.

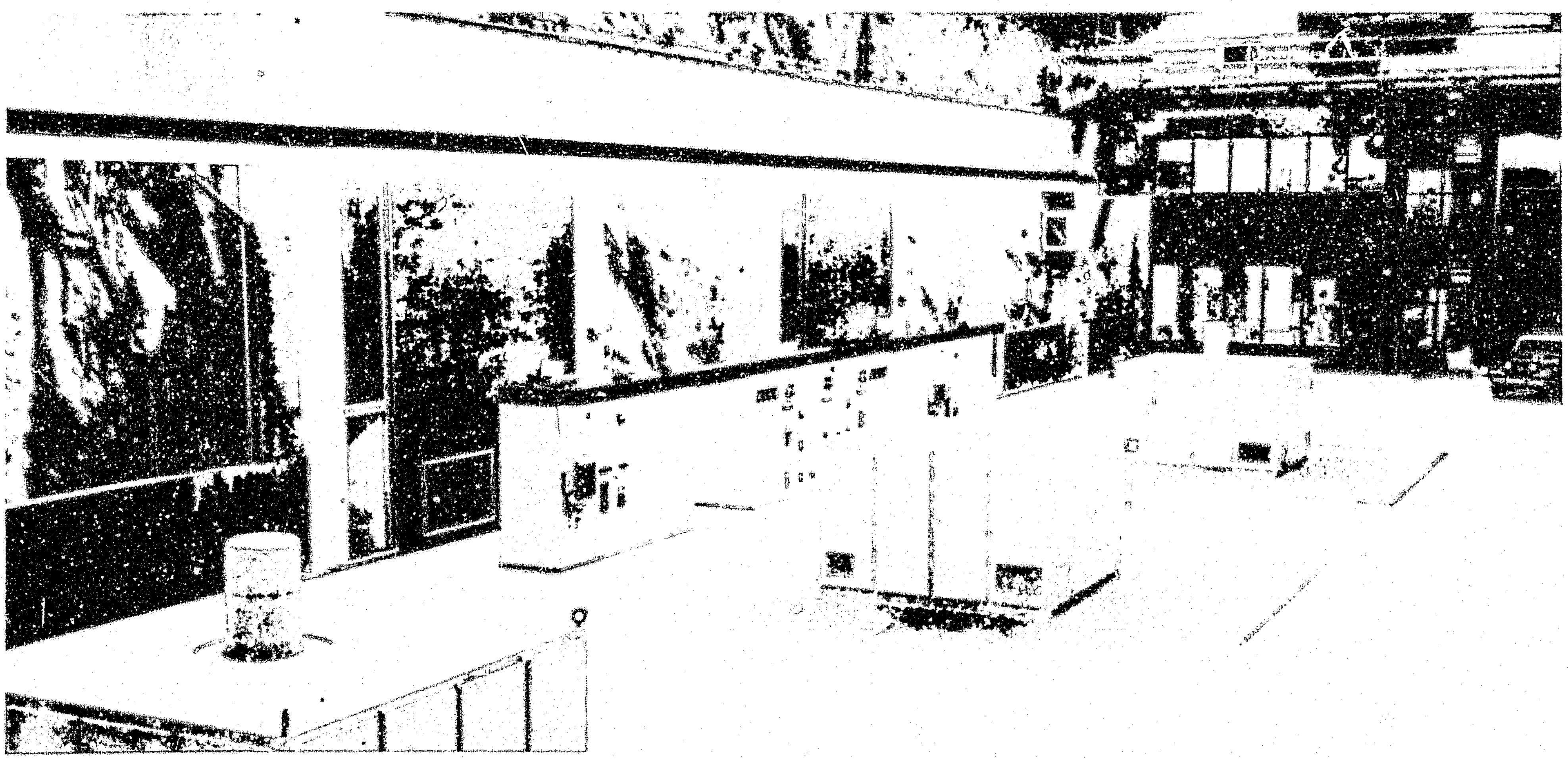
The absence of level ground in the area led to extensive studies prior to selecting the final location for the switching station. A two-level scheme was finally selected to be constructed on compacted rock fill on the riverbank, with suitable protection from erosion. From here the power is transmitted to the substations which serve Cali, 80 km away, by a double-circuit 230-kV transmission line, each circuit of which is designed for the entire generating capacity of the powerhouse.



The diversion tunnel gate at the damsite was closed on July 29, 1974 to permit the installation of a permanent concrete diversion tunnel plug. The project was formally inaugurated by the President of the Republic in a ceremony on July 31.

In 1976 Acres was honored by The Association of Consulting Engineers of Canada with its Award of Excellence in the category of civil engineering for its work on this project.



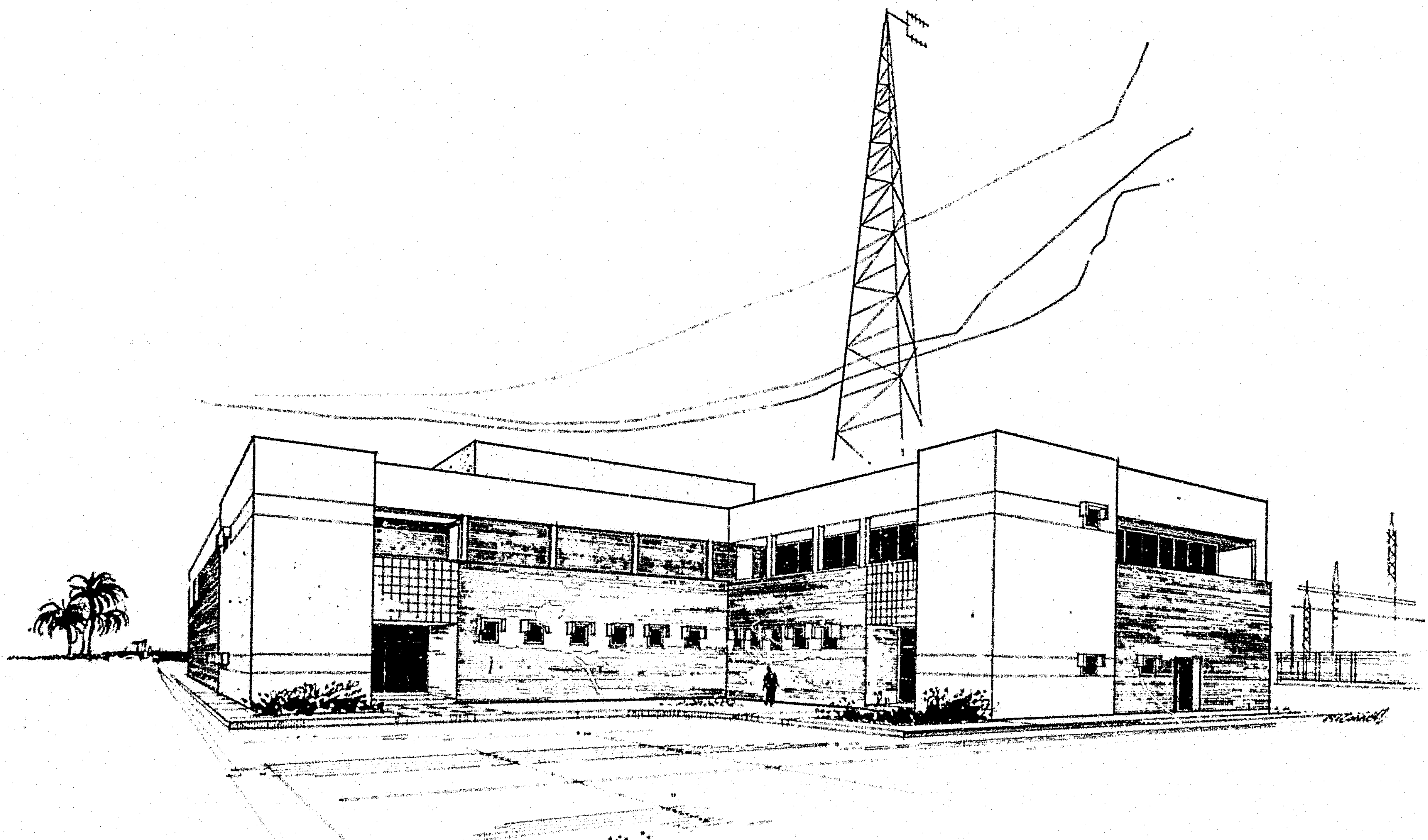


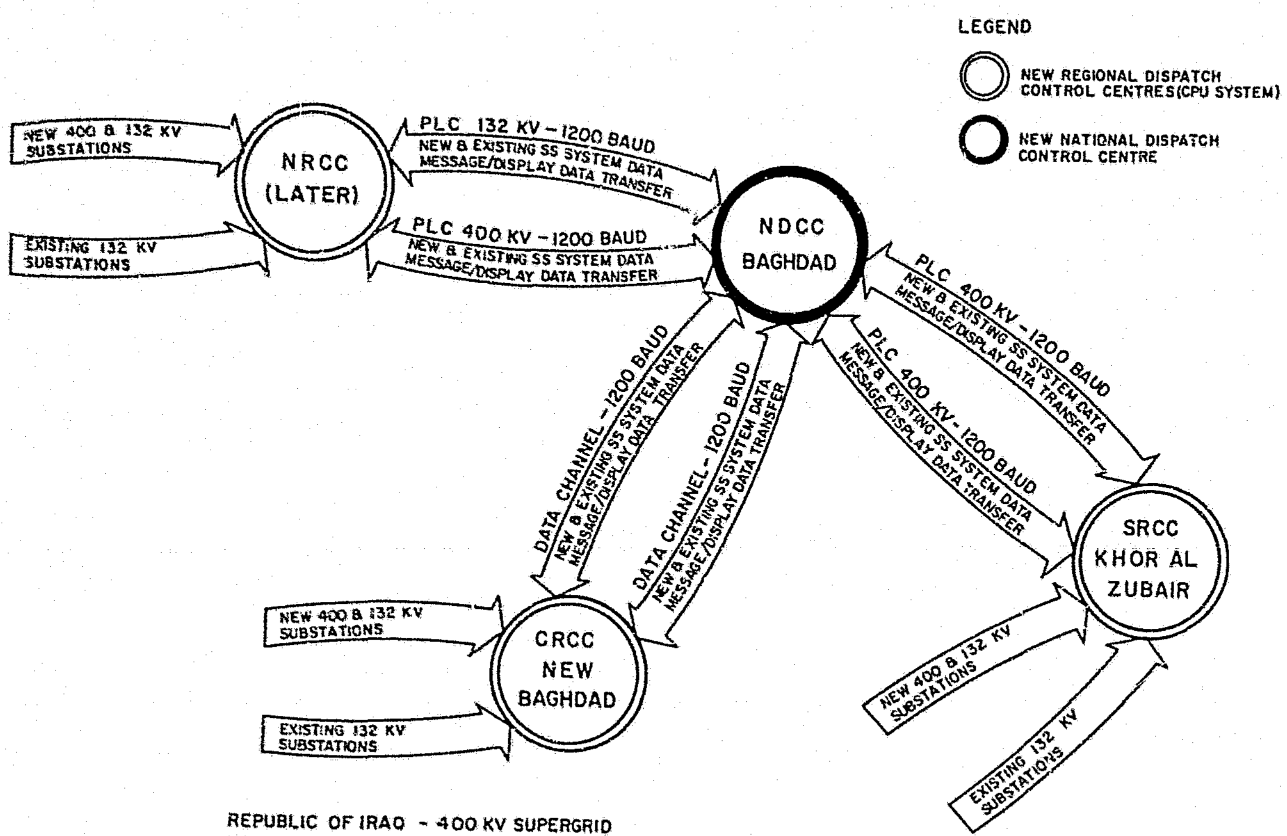
ALTO ANCHICAYA HYDROELECTRIC PROJECT STATISTICS

Long-term average flow	56.7 m^3/s
Firm flow	20 m^3/s
Drainage area	520 km^2
Reservoir live storage	30,000,000 m^3
Dam type: compacted rock fill with concrete upstream diaphragm	
— height	140 m
— volume of dam and cofferdams	2,705,000 m^3
— open excavation	219,000 m^3
— galleries	28,000 m^3
— grouting and drainage holes	71,000 m
Spillway type: gated chute with flip bucket	
— number of gates	3
— gate dimensions	13.5 m high x 13.67 m wide
— crest length	41 m
— design discharge	4,600 m^3/s
Power tunnel type: concrete-lined horseshoe	
— dimensions	6.2-m diameter x 8.3 km long
Power tunnel surge tank type: circular shaft with lower and upper expansion chambers	
— shaft dimensions	6.2-m diameter x 140 m high
— lower chamber dimensions	8-m diameter x 25 m long
— upper chamber dimensions	8-m diameter x 78 m long
Pressure tunnel type: concrete-lined inclined circular	
— design head for transient conditions	560 m
— dimensions	4.5-m diameter x 480 m long
Penstocks: steel lined	3 of 2.3-m diameter x 48 m long
Powerhouse type: underground	
— volume of cavity, approximate	37,000 m^3
— dimensions	62 m long x 20 m wide
Access tunnels—total length	390 m
Units type: vertical-axis Francis type turbines	
— number of units	3
— total installed capacity	340 MW

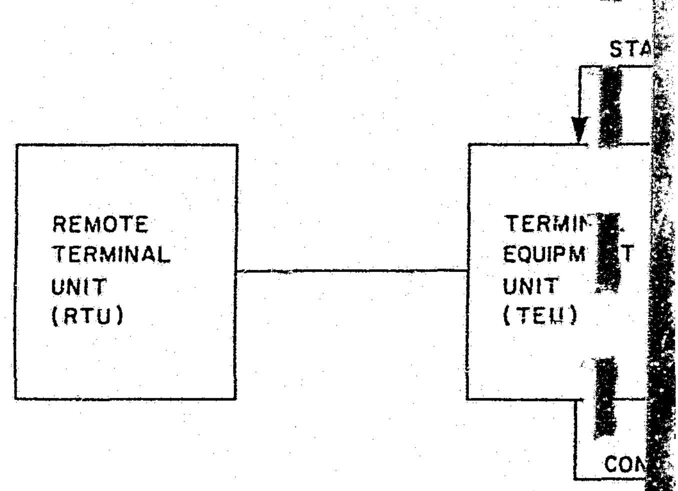
IRAQ 400~KV SUPERGRID
LOAD DISPATCH SYSTEM

ACRES





REPUBLIC OF IRAQ - 400 KV SUPERGRID
INTER CENTRE DATA FLOW DIAGRAM
1980 SYSTEM CONFIGURATION



REMOTE EQUIPMENT ARRANGEMEN

IRAQ 400-KV SUPERGRID LOAD DISPATCH SYSTEM

Acres involvement commenced with the preparation of a "Design Transmittal" which reviewed alternatives and made recommendations on the general type of hardware, software and operating philosophy best suited to the Iraq 400-kv supergrid. The recommendation of the Design Transmittal was that a SCADA type system be adopted and installed progressively in each of three regional centers,plus a main national center in Baghdad. The schedule is intended to be flexible with respect to time and to permit optimum usage of existing facilities.

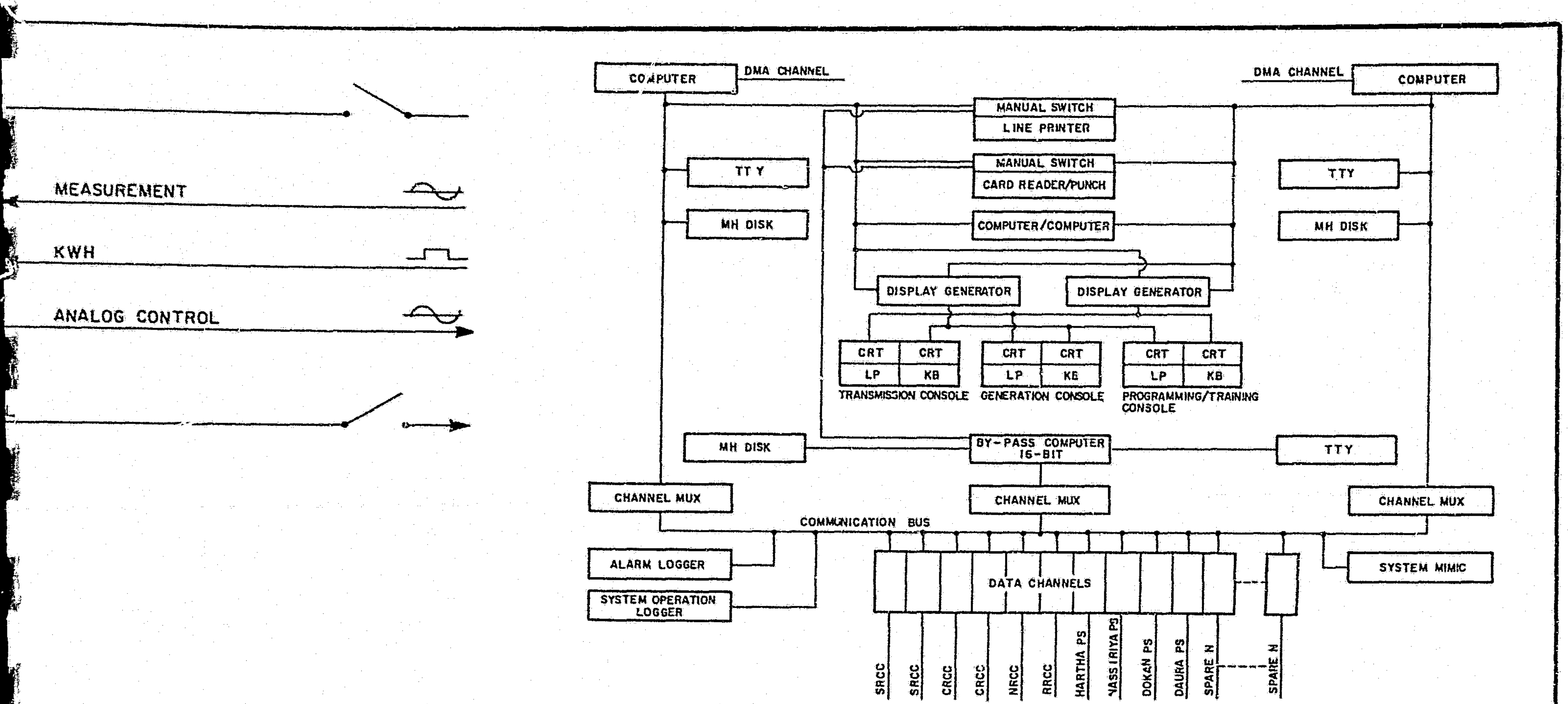
Each center will comprise dual redundant computer facilities. Each computer will be equipped with dedicated core and disc storage with shared line printer and other peripherals. Each computer will be designed to operate in either the primary or standby mode. The unit in the standby mode will, in addition to monitoring the primary unit, be available for extended real-time usage such as operator's load flow, etc.

The man-machine interfaces at each center will comprise a mimic wall diagram and a console equipped with 4 color CRT's. Two CRT's will be allocated to the system operator and 2 to the load dispatcher. Each CRT will be equipped with a light pen. Automatic generation control will also be provided on an in-plant basis, for control of selected thermal and hydroelectric stations.

The acquisition of data from each substation will be by means of a hard-wired microprocessor type RTU.

Close and detailed coordination with the system communication network is also required. A new 1,200 Baud microwave system is to be installed, but some of the existing substations are connected by 200-baud PLC circuits. In such cases care is exercised to avoid overtaxing the transmission rate of the equipment.

The system is tentatively scheduled for full implementation in 1985.



REPUBLIC OF IRAQ - 400 KV SUPERGRID
NATIONAL DISPATCH CONTROL CENTRE
BAGHDAD, STAGE I,- 1980 SYSTEM CONFIGURATION

FUNCTIONS

NATIONAL DISPATCH CONTROL CENTRE SYSTEM

POWER APPLICATION – STAGE 1

- 132-kv and 400-kv Transmission Grid System Monitoring Alarm and Data Logging
- Automatic Generation Control
- Economic Dispatch
- Load Forecasting
- System Topology Determination
- Operator's Load Flow
- Generation Schedule
- Contingency Evaluation
- Short-Circuit Analysis

COMPUTER FUNCTIONS

- Data Transfer and Communication
- Data Base and Data Base Management
- Man-Machine Interface
- Data Logging and Reporting

FUTURE POWER APPLICATION – STAGE 2

- System Security Functions
- Engineering Studies
- Engineering Design Support

IN-PLANT AUTOMATIC GENERATION CONTROL

- Data Acquisition and Data Base
- Automatic Generation Control
- Automatic Synchronization
- Unit Use History Accounting (Future)
- Limit Checking and Alarms (Future)
- Peak Generation Monitoring (Future)
- Hydraulic Flow Calculation (Future)
- Generator Protection (Future)
- Generator Substation Breaker (Future)

STANDBY FUNCTIONS

- Data Transfer
- System Mimic Drive
- Automatic Generation Control

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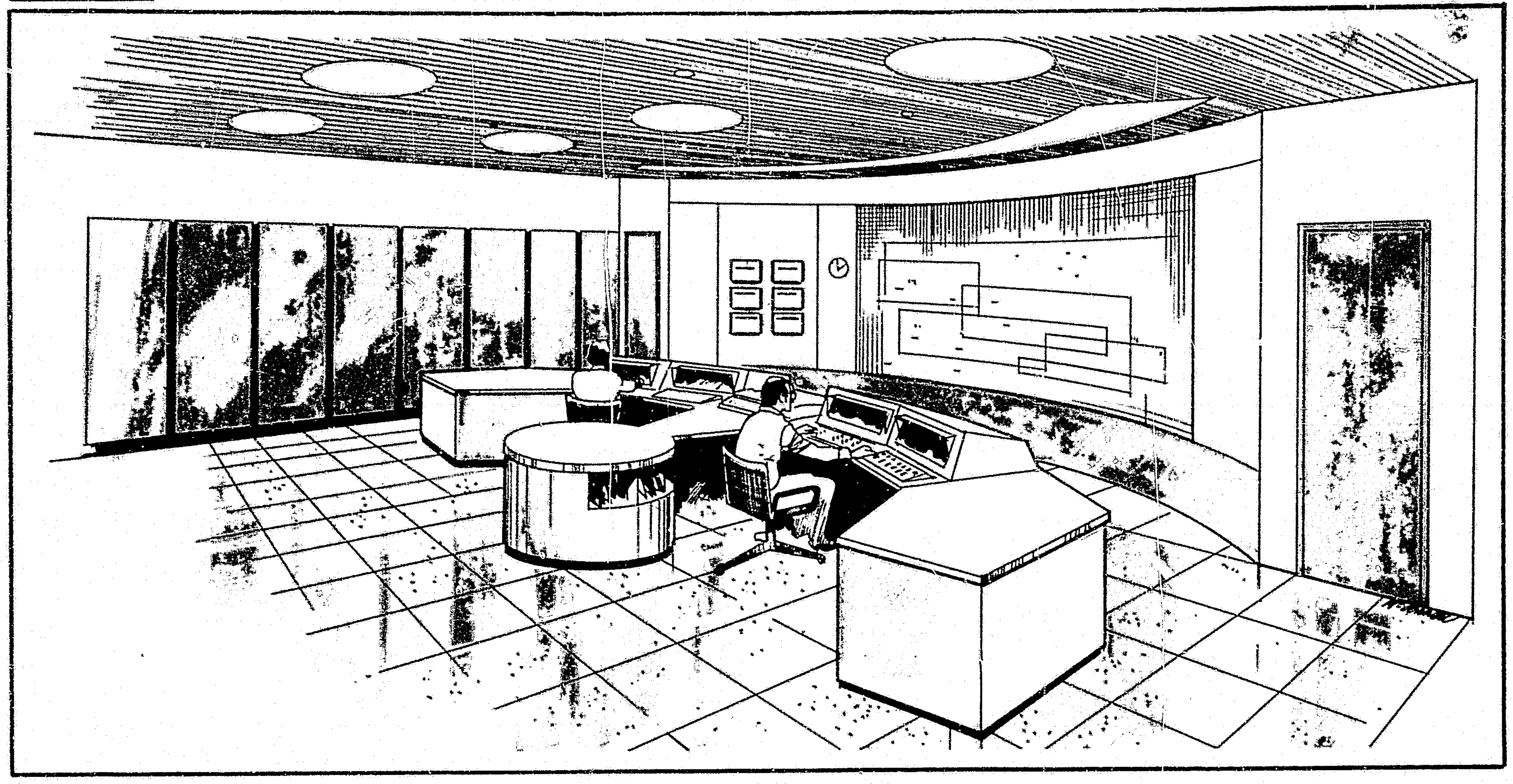
For further information contact:

ACRES CONSULTING SERVICES LIMITED

5259 Dorchester Road, Niagara Falls, Ontario



SOFTWARE

SYSTEM CONTROL

- Data Transfer and Communication
- Data Base and Data Base Management
- Man-Machine Interface

POWER SYSTEM APPLICATION — REAL TIME

- Power System Performance Monitoring
- System Topology Determination
- Logging and Report Generation
- Automatic Generation Control
- Economic Dispatch
- Local Forecasting (Hourly and Daily)

POWER APPLICATIONS — EXTENDED REAL TIME

- Operator's Load Flow
- Generation Scheduling
- Contingency Evaluation
- Short-Circuit Analysis

SUPPORTING SOFTWARE

- Data Base Compiler
- Display Compiler
- Diagnostics
- Programming Services

IN-PLANT AGC

- Real-Time Operating System
- Data Base
- Communication Control
- Automatic Generation Control

STURGEON POOL DAM
PHASE I – STRUCTURAL EVALUATION

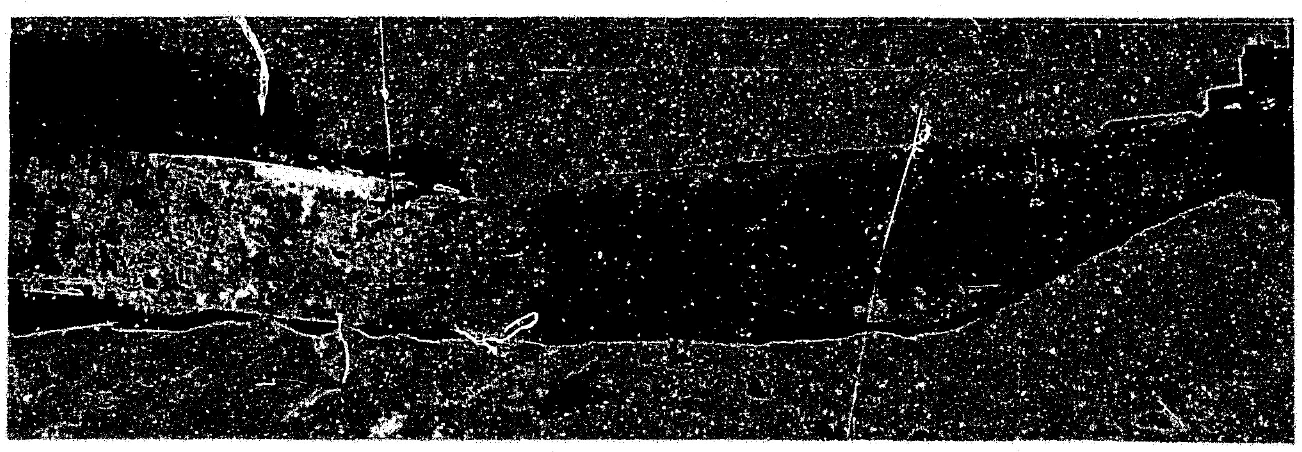
P5006.01

Location Wallkill River, New York

Client Central Hudson Gas & Electric Corporation

Year 1978

Structural evaluation of a 110-foot high concrete gravity dam on the Wallkill River north of Poughkeepsie, New York. The dam, which went into service in 1923, is founded on horizontally interbedded layers of shale and sandstone. The dam provides the storage pond for Central Hudson's 15,000 kw Sturgeon Pool hydroelectric plant. The evaluation includes a geological appraisal of the rock foundation, an inspection of the dam itself and a stability analysis of the structure.



ACRES

CHURCHILL RIVER DIVERSION

P3663

Owner	Manitoba Hydro
Consortium	Crippen Acres Limited
Location	Churchill River, Manitoba
Value	Missi Control – \$53,000,000 South Bay Channel – \$69,000,000 Notigi Control – \$27,000,000

The project involved direction of investigations, preparation of contract documents and all engineering designs for control structures, dams and channels for diverting the Churchill River into the Nelson River to augment the power generated at hydroelectric plants on the latter river. There are principal structures at three separate locations.

At Missi on Southern Indian Lake the outflow of the Churchill River is controlled by a spillway and two earth-fill dams. The spillway is a concrete structure (33,000 yd^3) with six 40-ft high by 40-ft wide crest gates and a total discharge capacity of 154,000 cfs. The structure also incorporates a hydraulically driven generating unit to provide local power heating and gate operation. The earth-fill dams have a maximum height of 50 ft and a total volume of 400,000 yd^3.

The Churchill River waters are diverted out of Southern Indian Lake into the Nelson River Basin via a 6-mile long channel excavated at South Bay. This channel is designed for a flow of 30,000 cfs and is mainly in permafrost-affected soft clays and silts, and involved a total of 10,500,000 yd^3 of excavation.

The diversion flows into the Nelson River via the Burntwood River are controlled by a spillway and earth-fill dam at Notigi. The spillway is a concrete structure (15,000 yd^3) with three 40-ft wide by 40-ft high crest gates to regulate flows to a licensed maximum of 30,000 cfs. The earth-fill dam has a volume of 475,000 yd^3 and a maximum height of 120 ft.

AMOS DAM, STAGE 3 P3826.04
P3826.05

Location:	**Charleston, West Virginia**
Client:	**Appalachian Power Company**
Associate Consultant:	**Woodward-Clyde Consultants**
Year	**1976**
Value	**$11,000,000**

Design and construction supervision of the Stage 3 dam raising the Stage 2 dam to a total height of 250 feet.

The decision to undertake the Stage 3 raising was made prior to completion of the Stage 2 raising. This phase of the project consequently required detailed coordination between site and design office activities to insure safe and economic construction. Considerable use was made of bottom ash material from the John E. Amos coal-fired generating plant in drainage and filter zones in the dam.

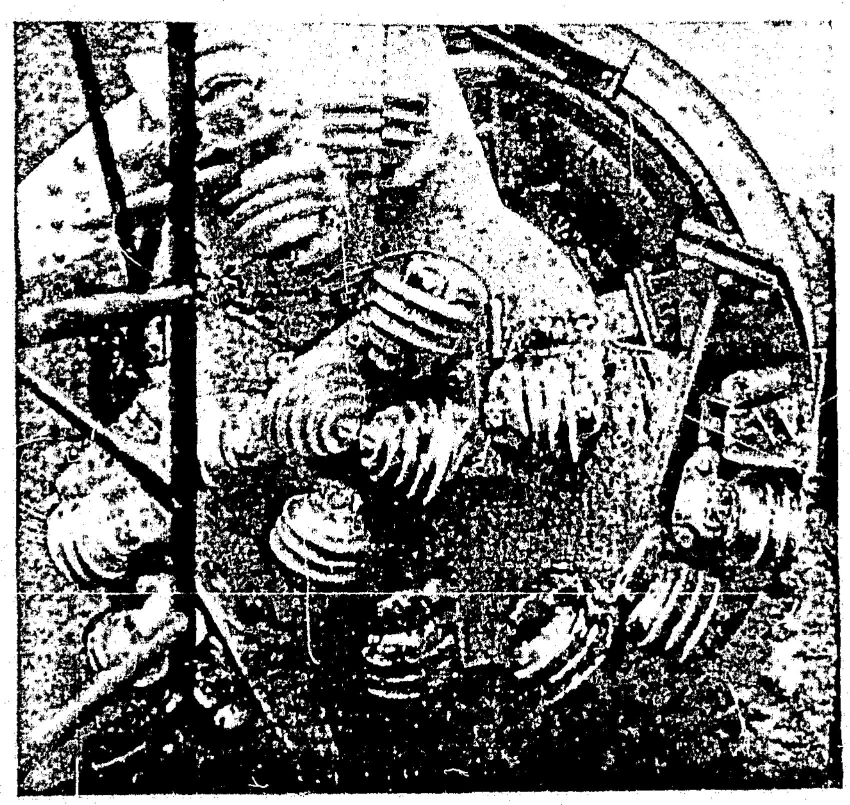
AMOS DAM, STAGE 2

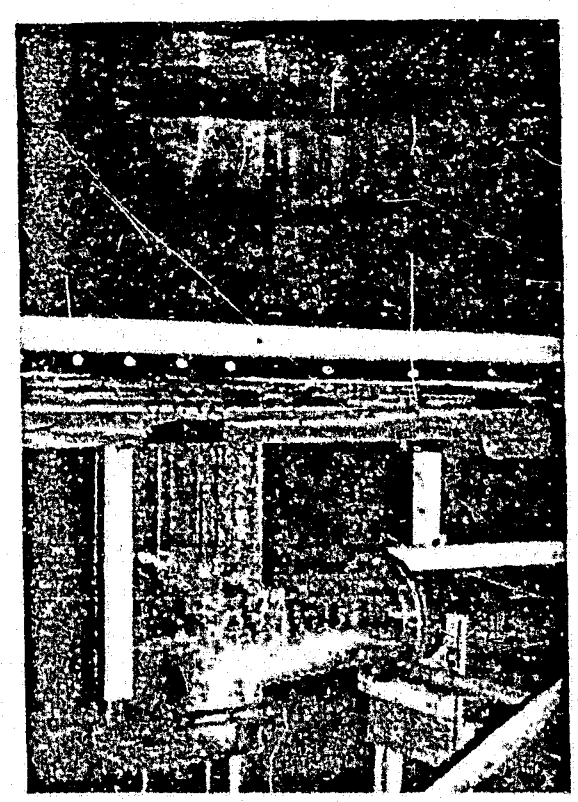
P3826

Location	**Charleston, West Virginia**
Client	**Appalachian Power Company**
Associate Consultant	**Woodward-Clyde Consultants**
Year	**1974**
Value	**$9,000,000**

Field exploration, design and construction supervision of the Stage 2 dam, raising the Stage 1 dam to a height of 220 feet and extending into the adjacent valley. The dam retains fly ash slurry from the John E. Amos thermal generating plant and comprises an upstream impervious zone of compacted clay from excavated overburden or quarried shale materials, and downstream zones of compacted sandstones, siltstones, shales and sand and gravel drains. The embankment is designed for a further 30 feet raising.

The project also incorporates an additional vertical concrete service spillway structure and a tunnel moled through the right abutment, also intended for use as an emergency spillway. Hydraulic model tests were conducted to prove the adequacy of the design.





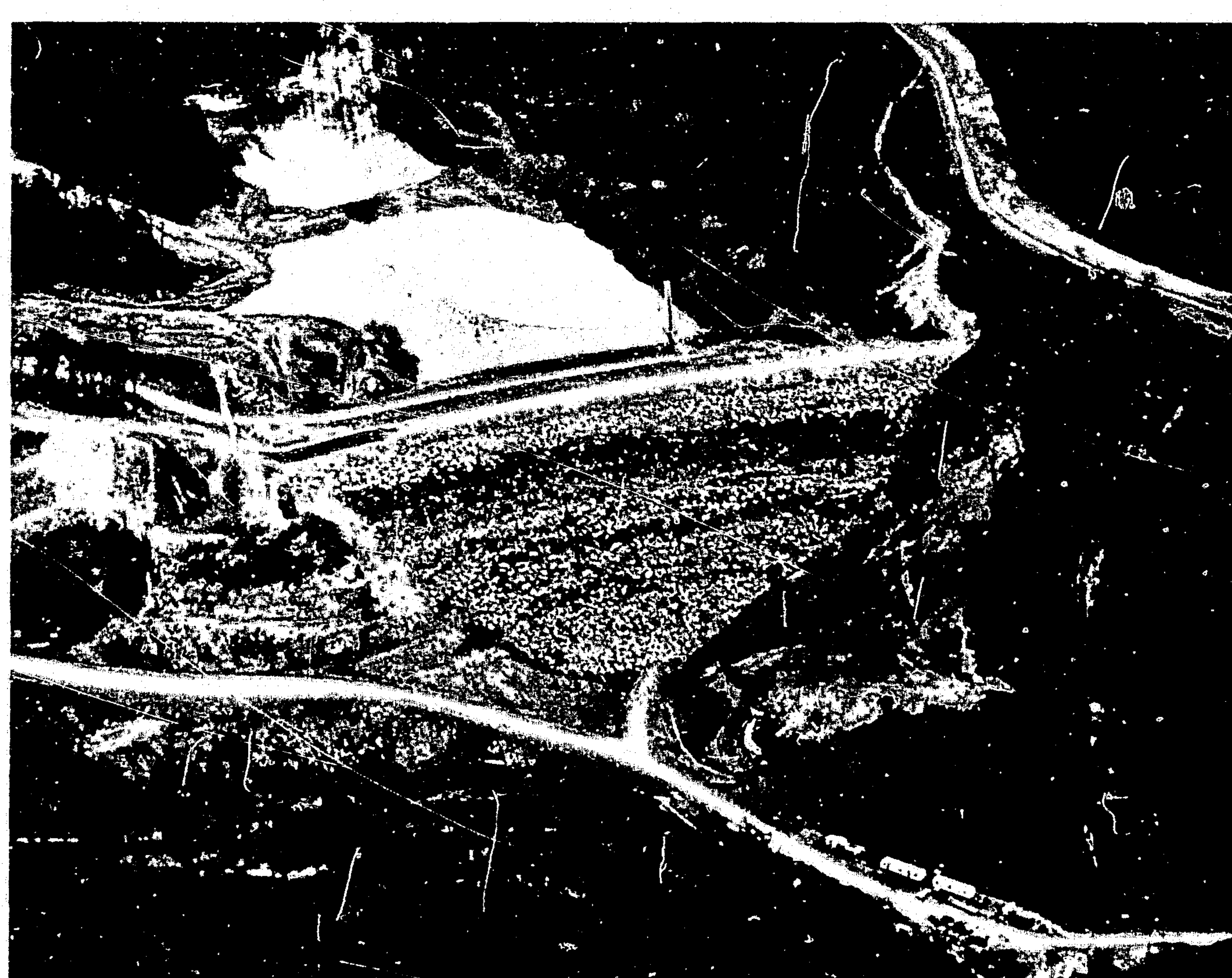
AMOS DAM

Location	Charleston, West Virginia
Client	Appalachian Power Company
Associate Consultant	Woodward-Moorehouse and Associates, Inc.
	1970
Value	$3,000,000

Field exploration, design and construction supervision of an earth and rock-fill dam (170 feet high designed to be raised to an ultimate height of 235 feet) for the retention of fly ash slurry from the John E. Amos thermal generating plant.

The dam comprises a zoned design incorporating compacted clay shale, excavated from an adjacent quarry, as the impervious membrane. The balance of the dam is constructed of sandstone with varying proportions of shale selectively excavated from the quarry.

The project incorporates a vertical concrete drawoff structure and associated floating skimmer, and a free-overflow emergency spillway.



ACRES

CARDINAL DAM P3134

Location Steubenville, Ohio

Client Buckeye Power Company
Ohio Power Company

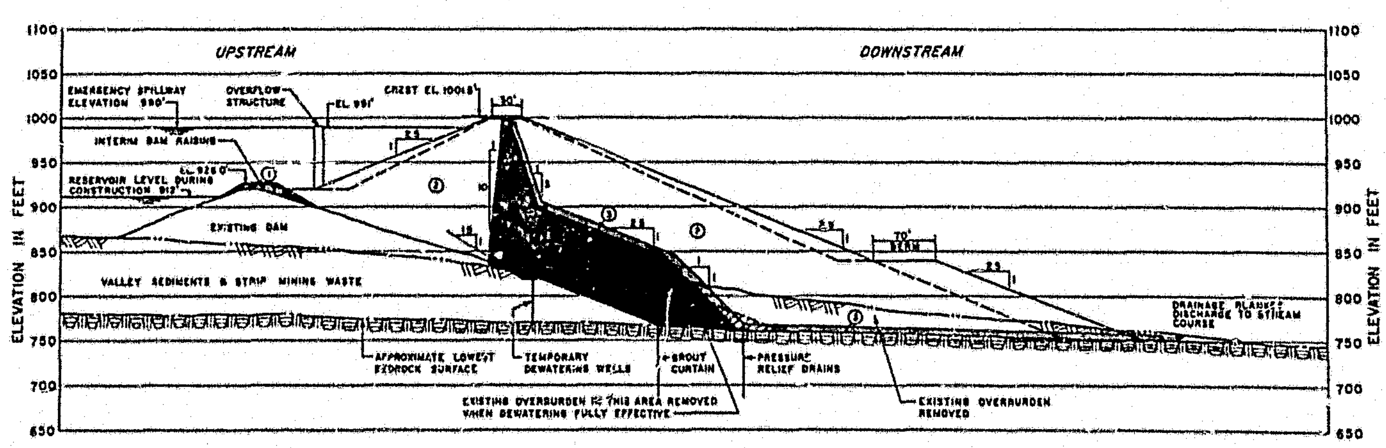
1973

Value $3,100,000

Field exploration, design and construction supervision of the raising of the existing earth and rock-fill dam to an ultimate height of 260 feet for the retention of fly ash slurry from the Cardinal thermal generating plant.

The dam is of zoned design, constructed primarily of mine waste from a nearby waste tip. Additional material was obtained from a major excavation for the emergency spillway. Construction included the provision of a well-point type dewatering system for the foundation excavation, and shallow cement grouting in the abutments of the existing dam.

- The project incorporates a vertical concrete drawoff structure and associated skimmer, together with multiple fly ash discharge pipelines from the power plant to the relocated pond.



LEGEND

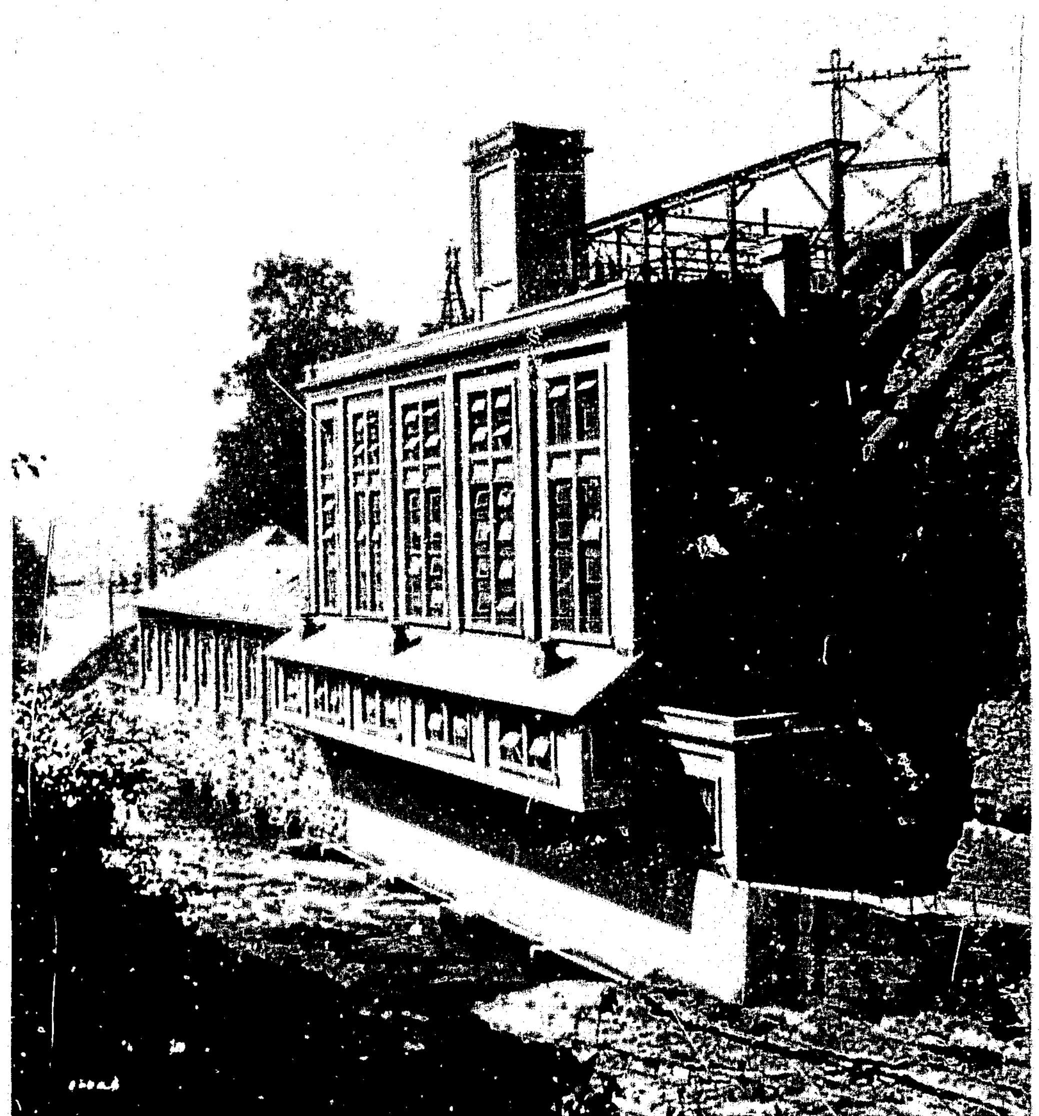
(1) IMPERVIOUS FILL (2) RANDOM FILL (3) FILTER ZONE & DRAINAGE BLANKET

TRENTON FALLS HYDRO DEVELOPMENT

P4984.00

Location	**West Canada Creek, New York**
Client	**Niagara Mohawk Power Corporation**
Year	**1978–1980**
Value	**$8,000,000 (Approximate capital cost)**

Feasibility study and detailed design for increasing the capacity of the existing Trenton Falls hydro development from 23,600 kw to 28,600 kw. The project involves replacement of four original units by a single 9,000 kw unit, reconstruction or rehabilitation of the associated powerhouse structure, replacement of two 3,500-foot long pipelines from the Trenton Dam to the power facilities, and rehabilitation of the existing power intake and surge tank. The program also includes rehabilitation of the equipment and structures for the existing powerhouse.



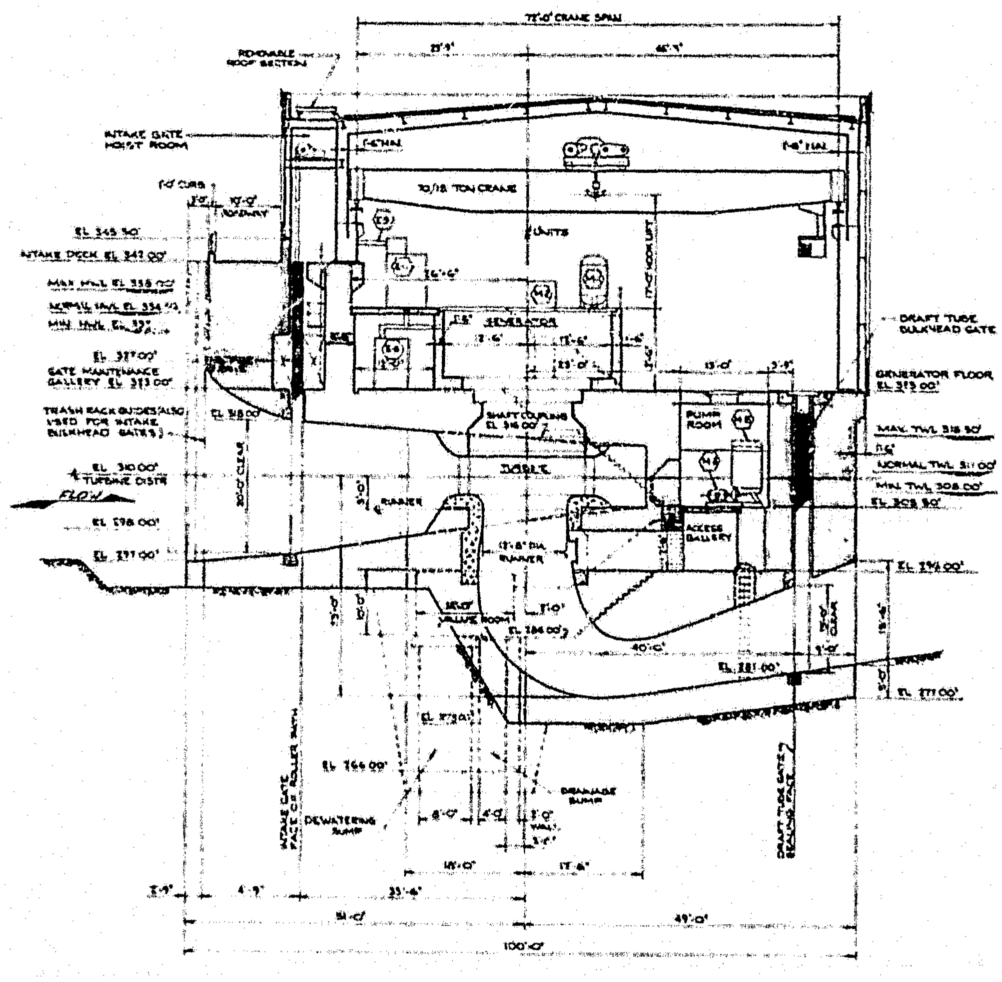
ACRES

Location **Fulton, New York**

Client **Niagara Mohawk Power Corporation**

Engineering for preliminary and detailed design of a 10 MW hydroelectric redevelopment of the existing Granby Plant on the Oswego River near Fulton, New York. The generating facilities will consist of an integral intake-powerhouse structure containing two 5 MW turbine-generator units operating under 23.5 feet of head. The station will be equipped for fully automatic operation at a remote source.

The scope of work for the project includes selection of turbine/generator equipment, final project arrangement, engineering design for controlled demolition of the existing plant, intake and powerhouse structures, coffer-dams and dewatering, powerhouse mechanical and electrical equipment and station equipment for automatic and manual operation.



CROSS SECTION AT UNIT 2 CENTER LINE

ST. MARY'S RIVER GENERATING STATION

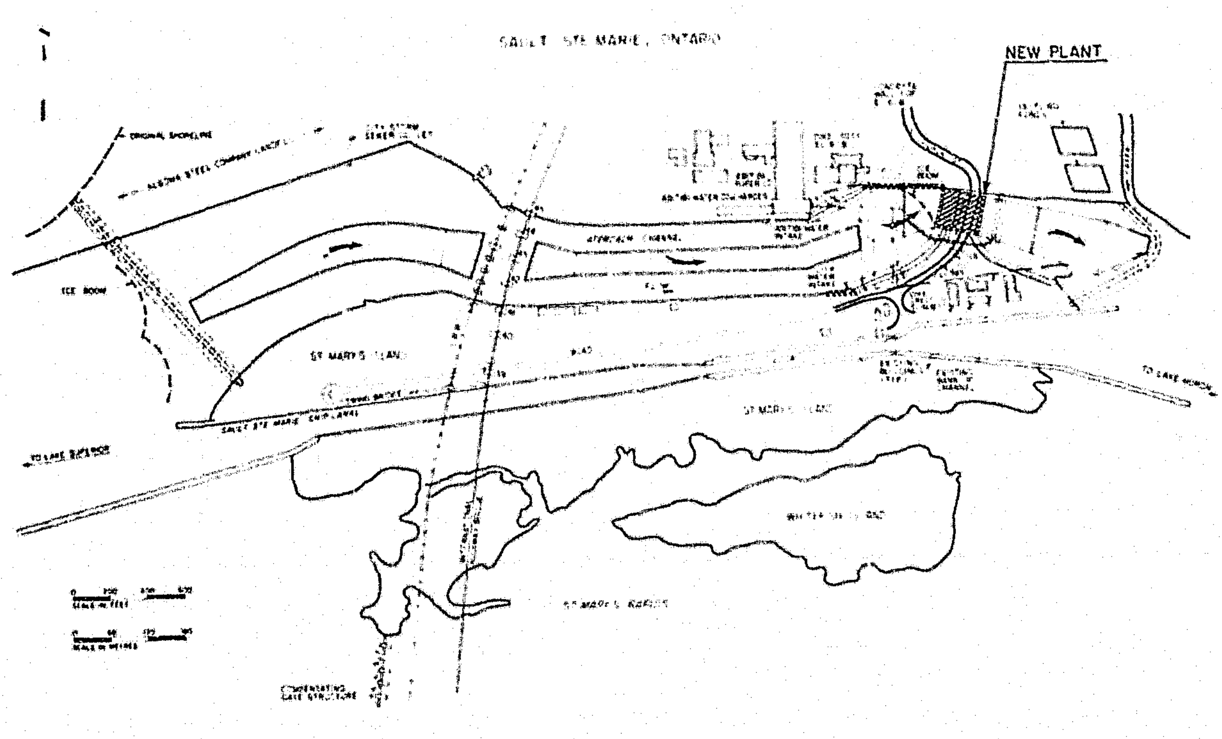
P4617

Client Great Lakes Power Corporation Limited
Utilities Division

Location Sault Ste. Marie, Ontario

1979

Engineering and construction management for the redevelopment of a hydroelectric generating station in the St. Mary's River. The new plant will have three 17.3-MW bulb type turbine generating units under a head of 5.7 m. The plant is designed to utilize Canada's full quota of water from the St. Mary's River.



General Arrangement

LIMESTONE GENERATING STATION

P3912

Owner Manitoba Hydro

Consortium Crippen Acres Limited

Commercial Power Scheduled for 1984

Location Nelson River, Manitoba

Value $1,200,000,000 (Approximate capital cost)

Engineering for a ten-unit run-of-river type hydroelectric power development with a total capacity of 1,070 MW. The first commercial power is scheduled for 1984 with the final unit expected to go on line in 1986.

The main dam of the development is approximately 1,300 m long. The two earth-fill sections of the main dam, which have a combined length of 800 m and a maximum height of 33 m, are founded on rock. The main dam and the upstream cofferdam comprise a total volume of 3.2 million m^3 of compacted gravel, crushed rock and impervious core.

The concrete overflow spillway has 7 vertical-lift gates, each 13.0 m wide by 15.8 m high, with a design discharge capacity of 9,500 m^3/s. During the final diversion stage, the river flow will pass through 7 low-level openings regulated temporarily with the permanent spillway gates.

The intake structure contains 30 gates, each 8.5 m wide by 14.3 m high. The powerhouse contains 10 vertical-shaft, fixed-blade, propeller type turbines rated at 107 MW under a net head of 26.2 m. The generators are of the umbrella type, each rated at 125 MVA at 0.8 power factor. The main transformers are rated at 90/120/150 MVA, 13.8/230 kV, 3-phase, 60 Hz, ONS/ONP. The powerhouse contains two overhead cranes, each having a capacity of 250 tonnes.

The spillway, intake, powerhouse and auxiliary concrete structures contain approximately 540,000 m^3 of concrete and will require 121,000 tonnes of cement and 27,000 tonnes of reinforcing steel.

River management during construction is complicated by major ice jamming during long winters and by daily peaking operation of upstream power plants. Heights of the 4-million m^3 cofferdams are governed by ice conditions rather than flood flows.

ARNPRIOR GENERATING STATION

P3197, 3176

Client Ontario Hydro

Location Madawaska River, Arnprior, Ontario

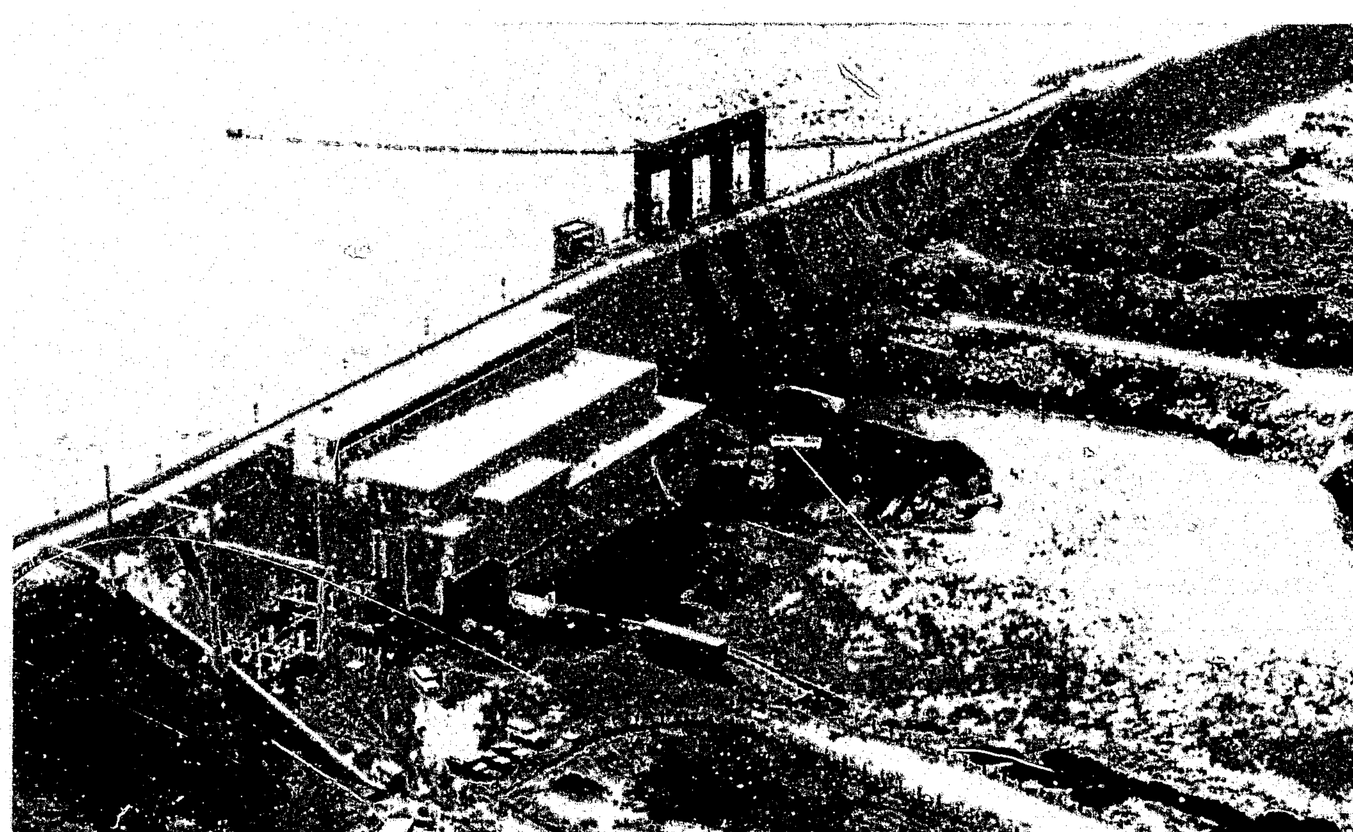
Engineering construction supervision and project management for a peaking type hydroelectric power development having two 54,000-hp turbine units under a head of 68 ft.

The main dam and powerhouse are located within the Town of Arnprior. The main dam (crest length 2,500 ft) consists of a headworks structure, gravity bulkhead sections, a sluiceway, an emergency sluiceway, and earth- and rock-fill dike sections. A close-coupled powerhouse is located immediately downstream of the headworks structure.

The 42,000-cfs capacity sluiceway incorporates three fixed-roller type sluice gates, each 24 ft wide by 32.7 ft high with wire rope hoists.

The four fixed-roller type headgates, 24.6 ft wide by 37.2 ft high, are operated by hydraulic hoists.

In June 1977 the Arnprior development received an Honor Award by the American Public Power Association (APPA) as an outstanding example of excellence in utility design. The award by the APPA was made in cooperation with American Institute of Architects, American Institute of Planners, American Society of Civil Engineers, and American Society of Landscape Architects.

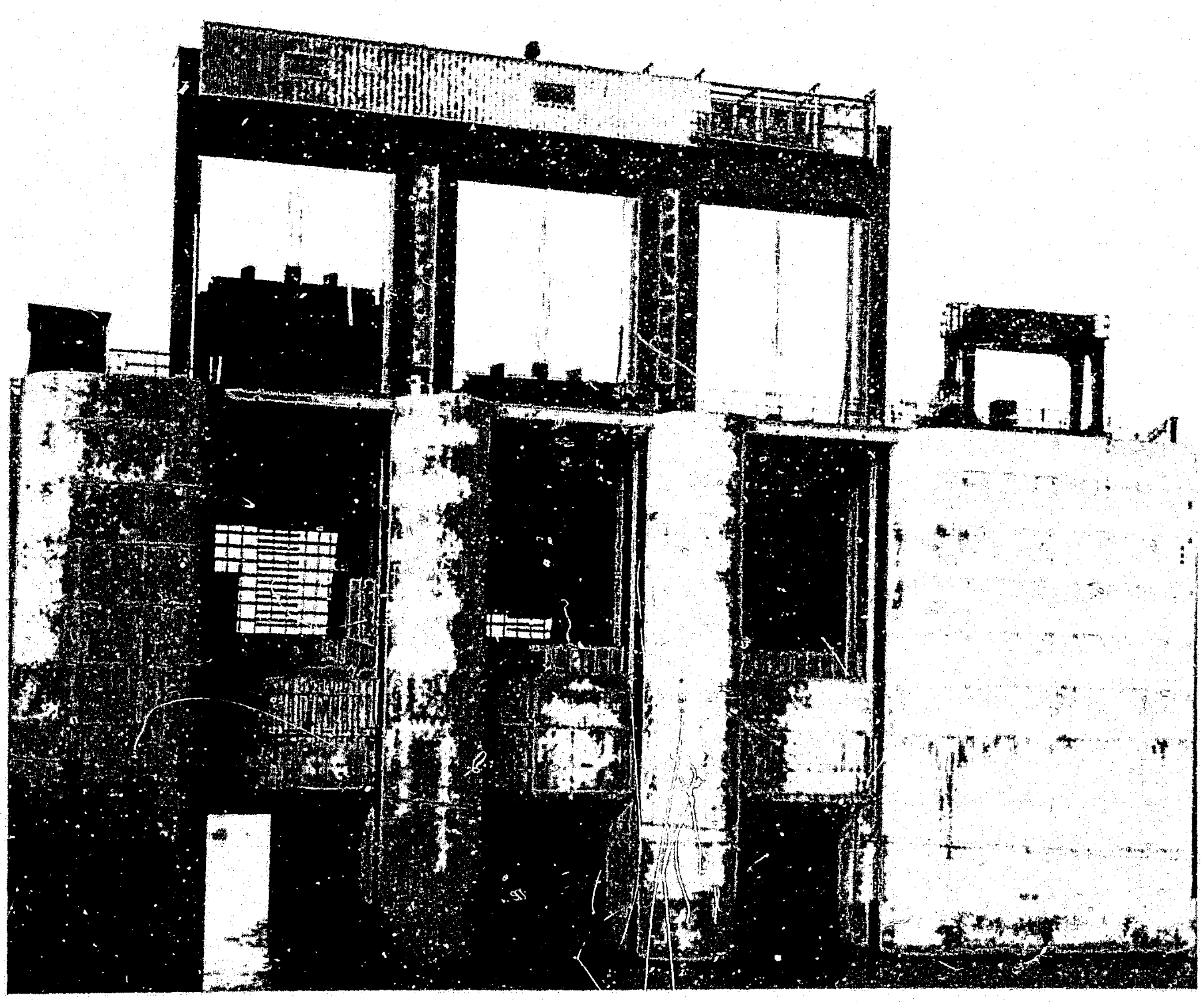


In addition to the main dam and powerhouse the following ancillary works were included in the development

- channel improvements to tailrace between the powerhouse and the Ottawa River (190,000 cu yd of rock)
- a 1,050-ft long semicircular tailrace control weir in the Town of Arnprior
- a two-lane, 1,150-ft long bridge over the head pond
- a 3,700-ft long zoned earth-fill saddle dam 56 ft high on a sensitive marine clay foundation
- relocation of 3.2 miles of CPR mainline track
- a four-lane, 704-ft long highway bridge over the Madawaska River in the Town of Arnprior.

Because of the proximity of the project to the Town of Arnprior, numerous utilities had to be relocated including 115-kV transmission lines, long distance telephone circuits, watermains, storm and sanitary sewers, a natural gas main and many overhead telephone and power distribution lines.

Acres, as Project Manager, arranged all contract packages, called tenders, let contracts and certified progress payments. Acres also maintained responsibility for project scheduling, budget, project safety, security and community relations.



ACRES

LONG SPRUCE GENERATING STATION

P2999

Location	**Nelson River, Manitoba**
Owner	**Manitoba Hydro**
Consortium	**Crippen-Acres Limited**
	Commercial Power Scheduled for 1977
Value	**$445,000,000** (Approximate capital cost)

Engineering for a ten-unit run of river type hydro-electric power development with a total capacity of 1,000 Mw. The first commerical power is scheduled for 1977 with the tenth and final unit expected to go on line in 1980.

The main dam of the development is approximately 4,000 feet long. The two earth-fill sections of the main dam, which have a combined length of 2,475 feet and a maximum height of 130 feet, are founded on rock and consist of a central impervious core, with 3 million cubic yards of compacted gravel and crushed rock supporting fills.

The concrete overflow spillway has 6 vertical-lift gates, each 42.7 feet wide by 57.5 feet high, with a design discharge capacity of 336,000 cfs. During the final diversion stage, the river flow will pass through 12 low-level openings located below the rollway crest.

The intake structure contains 30 gates, each 18 feet wide by 46 feet high. The powerhouse contains 10 vertical-shaft, fixed-blade, propeller type turbines, rated at 135,000 hp under a net head of 80 feet. The generators are of the umbrella type, each rated at 115-Mva at 0.85 power factor. The main transformers are rated at 100/133 Mva, 13.8/230kv, three phase, 60 hertz ONS/ONP. The powerhouse contains two overhead cranes, each having a capacity of 225 tons.

The spillway, intake, powerhouse and auxiliary concrete structures contain approximately 600,000 cubic yards of concrete and will require 110,000 tons of cement and 22,000 tons of reinforcing steel.

The principal structures are flanked by sand fill dikes on each side of the river. The dikes are constructed on permafrost and have a combined length of 45,000 feet, a maximum height of 32, feet and contain approximately 3,600,000 cubic yards of fill.

LOWER NOTCH GENERATING STATION

P1661

Location Montreal River, Cobalt, Ontario

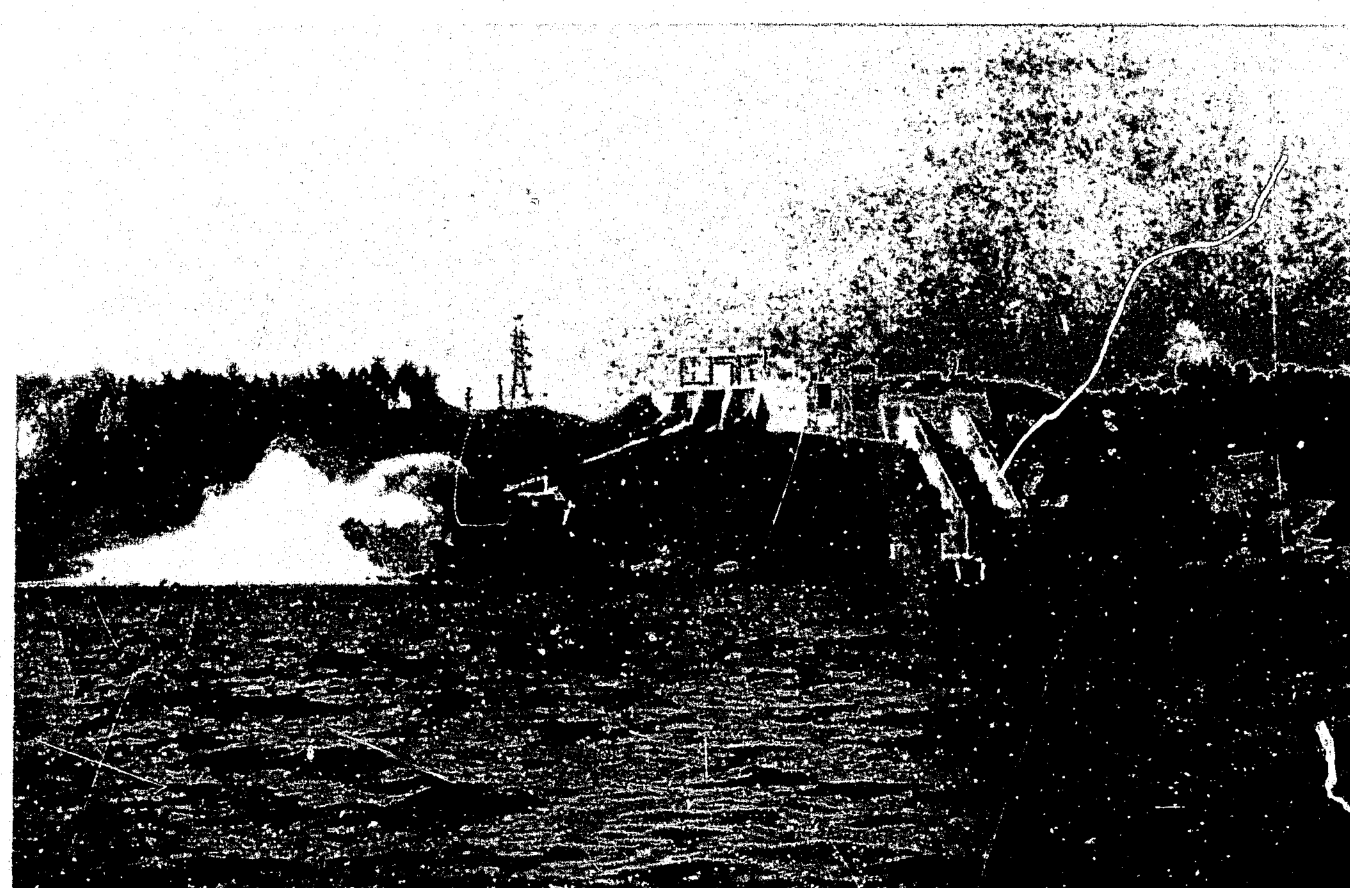
Client The Hydro-Electric Power Commission of Ontario

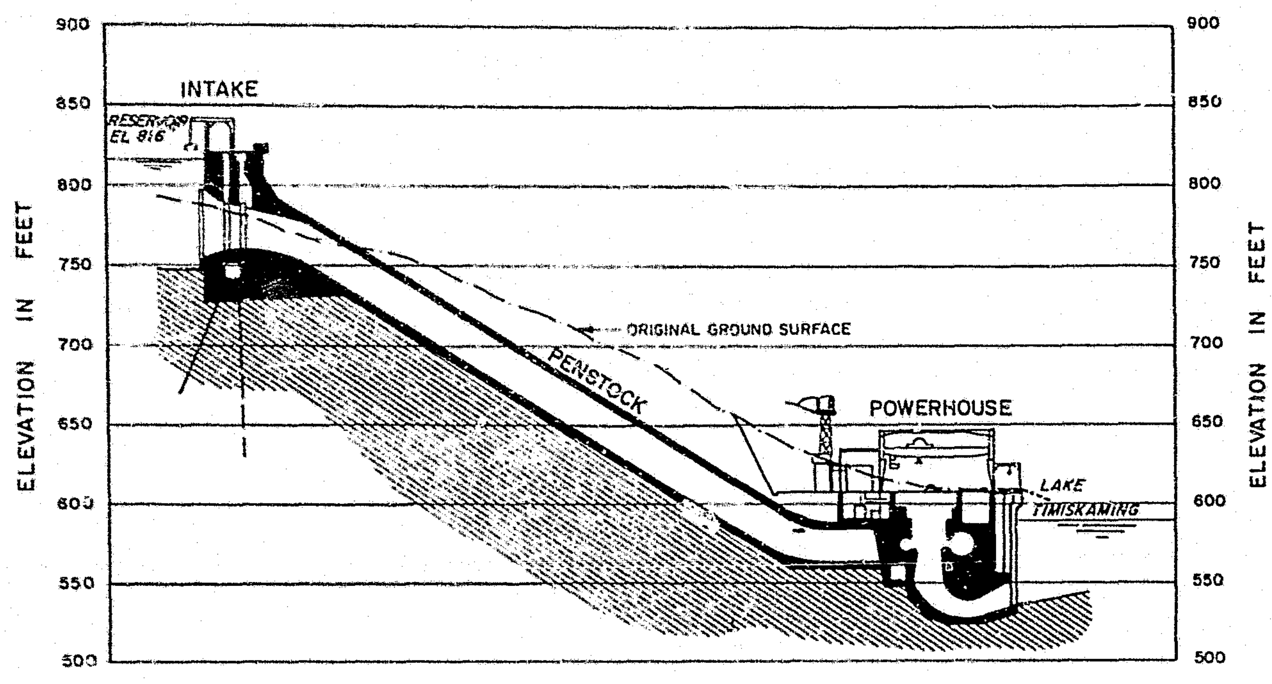
1967 – 1971

Value $60,000,000 (Approximate capital cost)

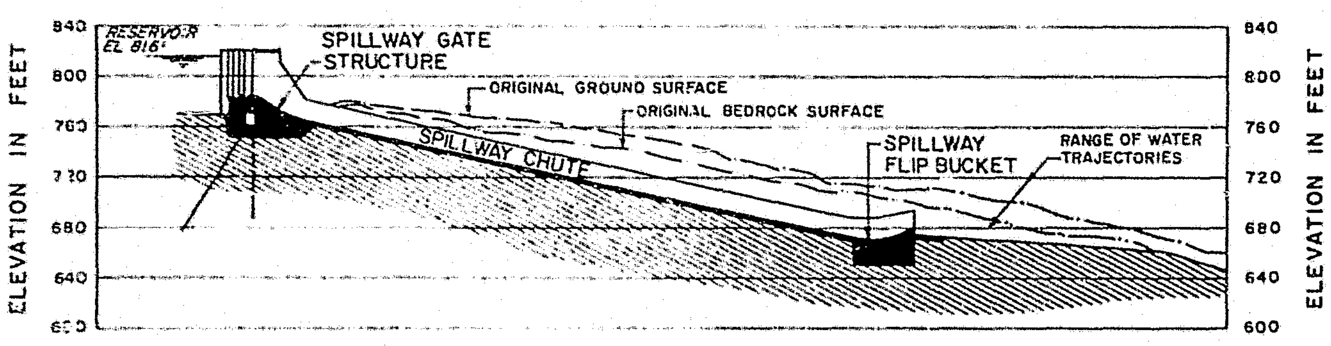
Engineering, construction supervision and project management for a peaking-type hydro-electric power development having two turbine generator units, each rated at 170,000 horsepower under a head of 230 feet (340,000 horsepower total capacity).

The development includes a D-shaped diversion tunnel (35 feet high, 34 feet wide, 2,000 feet long), and earth-and rock-fill dam and reservoir dike (crest 400 feet above foundations, 2,600-foot crest length, 2,200,000 cubic yards), earth-and rock-fill canal dikes (2,500-foot total length, 600,000 cubic yards), a flip bucket-type chute spillway with three vertical cable lift gates (each 32.5 feet high, 29 feet wide), an intake structure, two penstocks (23-foot diameter, each approximately 460 feet long) and a powerhouse.

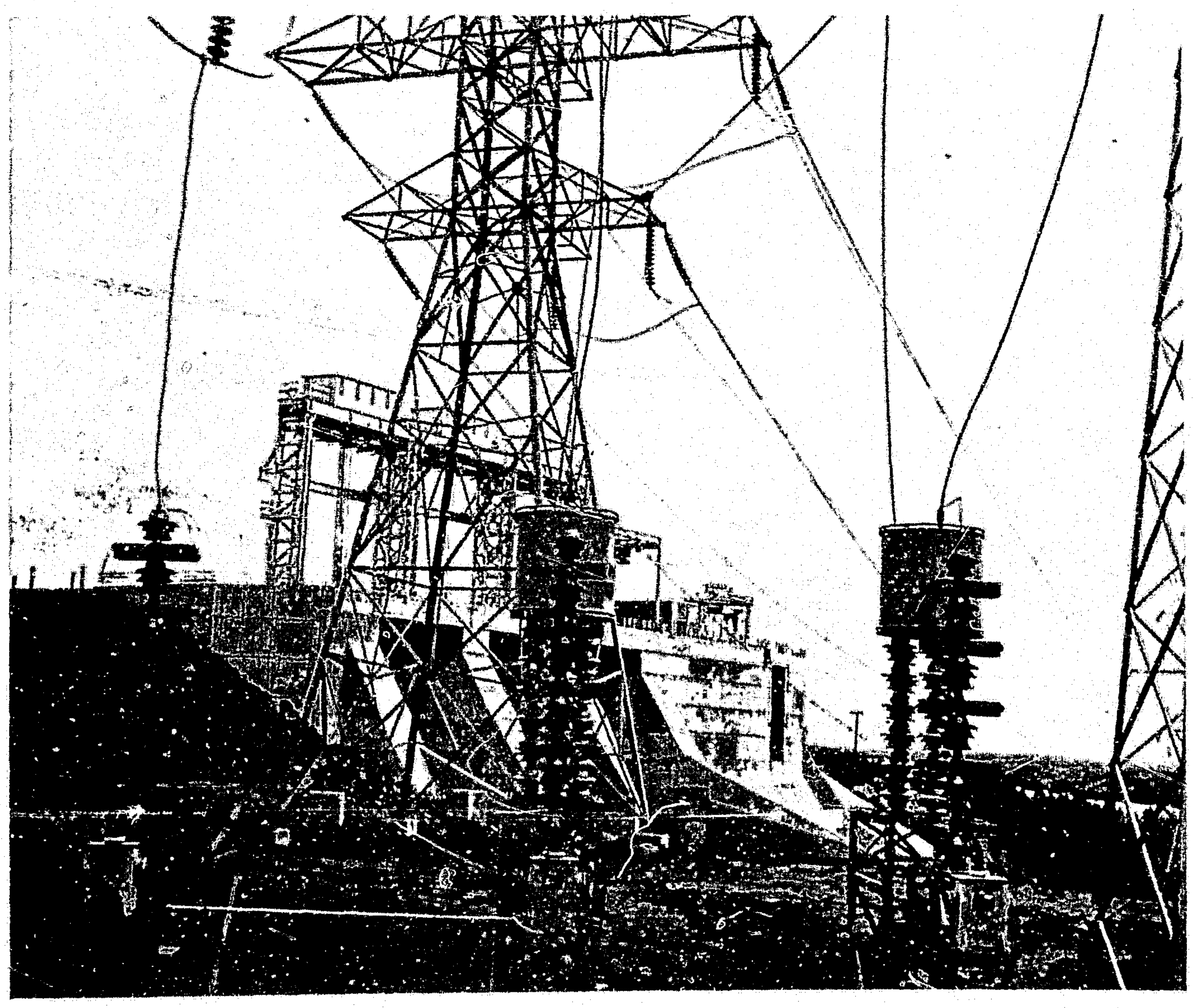




INTAKE, PENSTOCK AND POWERHOUSE



SPILLWAY



KETTLE GENERATING STATION

M101.1
P1432

Location	Nelson River, Manitoba
Client	Manitoba Hydro
	1966 – 1974
Value	$300,000,000

Engineering and liaison for construction of a 12-unit run-of-river type hydroelectric power development with a total capacity of 1,224 MW.

The two main earth-fill dams of the development total approximately 3,500 ft and have a maximum height of 150 ft. The reservoir dikes constructed on discontinuous permafrost have a total length of approximately 35,000 ft and average height of 15 ft. In addition to the dikes, a 4,000-ft long, 70-ft high dam was required across a local valley. Due to permafrost-affected weak materials in the valley, approximately 1,300,000 cu yd of materials had to be excavated to a depth of 50 ft, with subsequent dam fill of 2,300,000 cu yd.

The concrete overflow spillway has eight 38-ft wide by 48-ft high vertical-lift gates, with a design discharge capacity of 336,000 cfs. The intake structure contains thirty-six 19-ft 9-in. wide high gates, operated by hydraulic hoists. Intakes eight to twelve were utilized for river diversion, prior to the downstream powerhouse construction, and were stabilized by the addition of temporary concrete ballast blocks (total weight 86,000 tons) on the upstream side. The powerhouse contains twelve vertical-shaft, fixed-blade propeller type turbines rated at 140,000 hp at 98.5-ft head, each coupled to an umbrella type generator rated at 120 MVA at 0.85 power factor.

Construction quantities included 430,000 cu yd of excavation, 8,000,000 cu yd of earth-fill materials and 98,000 cu yd of concrete.

The work included extensive studies of the probable effects of ice jams on the heights of cofferdams required for the various stages of river diversion during construction. The studies focused primarily on the scheme for Stage II diversion through the partially constructed powerhouse intake. This scheme involved raising the water level and maintaining a stable ice cover immediately upstream from the site, in order to prevent ice from jamming in the narrow flow passages. The ice studies included field surveys to establish the natural ice regime of the Nelson River and simulation of ice jams in a 6-mi reach of the river, using an 85-ft long hydraulic model, to determine the minimum height of the upstream cofferdam.

Actual operation in the field during diversion was in accordance with the results of the ice model studies in all major respects. A stable ice cover was successfully formed at the recommended level, and was maintained until late spring when the weakened ice cover was safely sluiced through the control structure.

GRAND RAPIDS DEVELOPMENT

P1282, 826

Location	At the mouth of the Saskatchewan River, on the west shore of Lake Winnipeg, Manitoba
Client	Manitoba Hydro
	1965, 1968
Value	$140,000,000 (Approximate capital cost)

Engineering for a complete 450-Mw hydro-electric development and the subsequent installation of an additional unit.

The reservoir has an area of about 2,040 square miles and is formed by earth-fill dikes and cement grout curtains on its east boundary. The dikes have a maximum height of 110 feet and a total length of approximately 16 miles, and the grout curtains have a maximum depth of 200 feet and a total length of approximately 18 miles. The reservoir spillway has a capacity of 140,000 cfs, regulated by four 42.5-foot high by 40-foot wide gates with cable hoist mechanisms.

An intake structure of the mass concrete gravity type with eight hydraulically operated, vertical 36-foot high by 16-foot wide lift gates feeds the four penstocks of the development. The penstocks are of concrete-encased, steel construction and they are 29 feet in diameter and 200 feet long.

The powerhouse contains four units, each rated at 150,000 horsepower under a head of 120 feet. Power is generated at 13.8 kv and transformed by 30,000/40,000 kva, single-phase transformers to 230 kv for transmission.

ACRES

MACTAQUAC DEVELOPMENT P1140

Location Saint John River, New Brunswick

Client The New Brunswick Electric Power Commission

1968

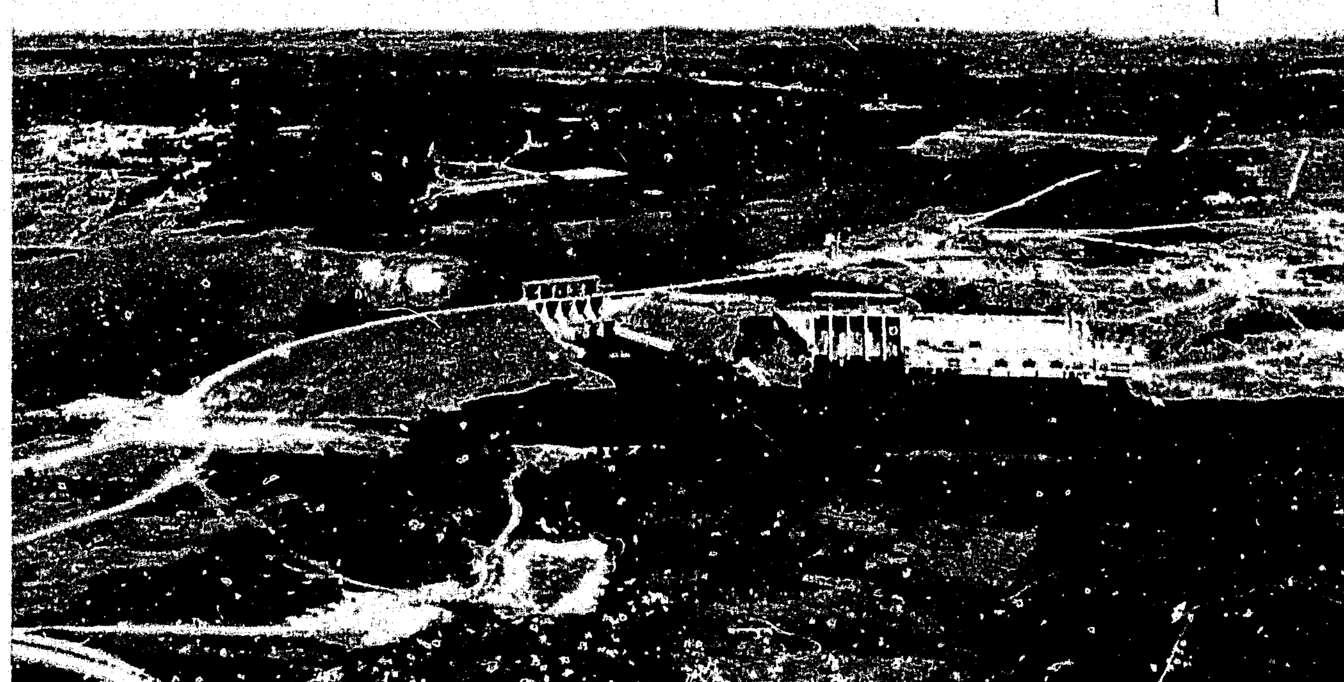
Value $110,000,000 (Approximate capital cost)

Engineering and supervision of construction for a run-of-river type hydro-electric power development having an ultimate total rated capacity of 625-Mw.

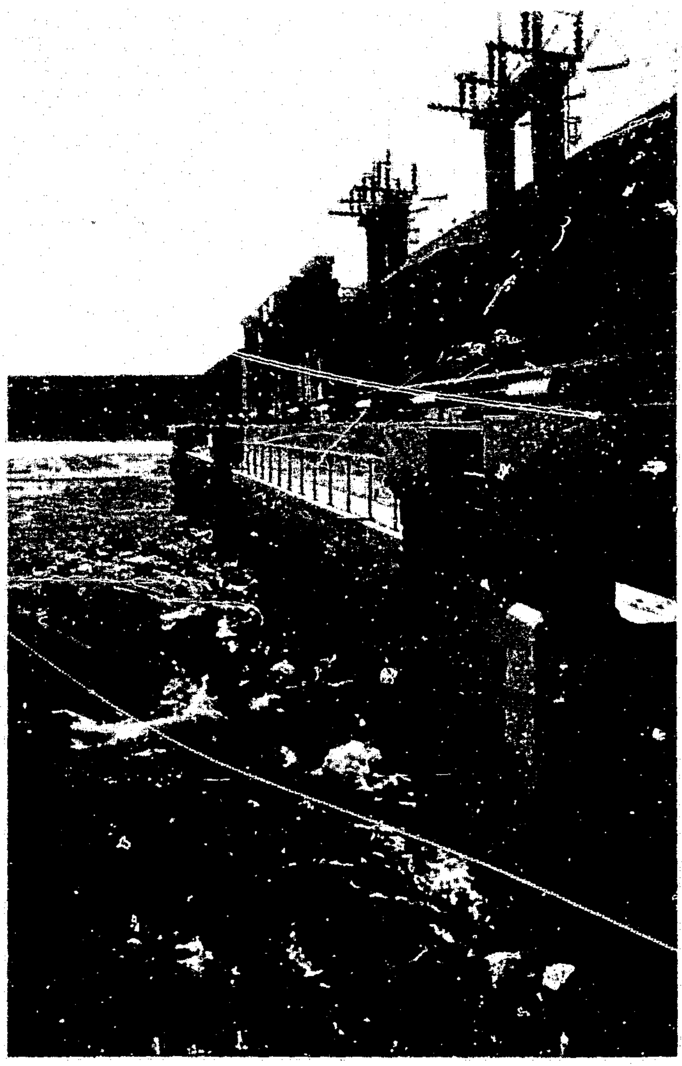
The dam of the development is constructed of compacted rock fill (3,741,000 cubic yards) with a near vertical core of impervious glacial till (745,000 cubic yards), and it is approximately 1,700 feet long with a maximum height of 184 feet. The foundation preparations for the dam included the dredging, by 30-inch cutter suction dredge, of approximately 2,000,000 cubic yards of material from the riverbed.

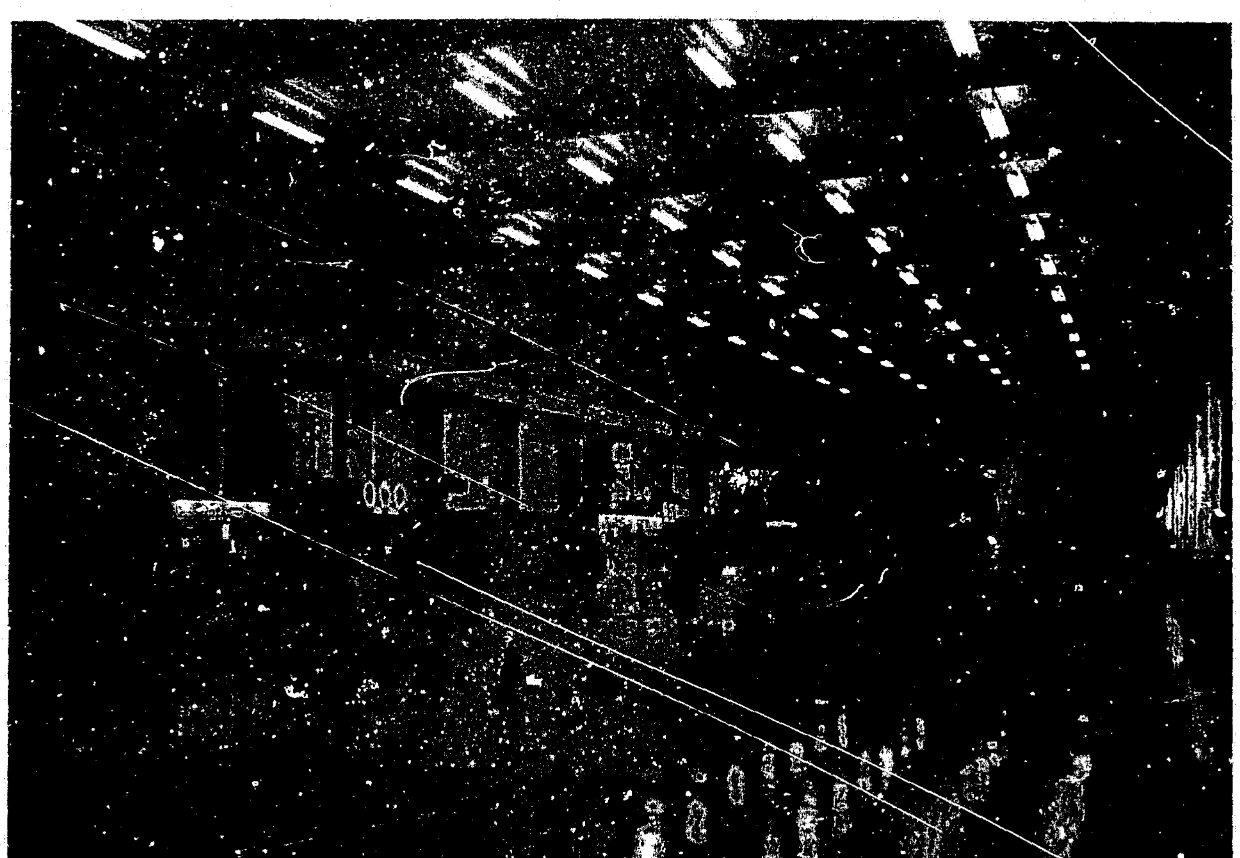
The development has two concrete spillway structures, each having five vertical lift crest gates (53 feet high by 45 feet wide) for a total design flood discharge capacity of 575,000 cubic feet per second. One spillway structure is located in the diversion channel and the other is joined to the powerhouse structure.

The conventional indoor surface-type powerhouse contains two vertical, 112.5-rpm, Kaplan-type units, each rated at 140,000 horsepower under a net head of 112 feet, and ultimately will contain six units for a total rated capacity of 840,000 horsepower. Each unit is supplied by one steel penstock, 29 feet in diameter and 178 feet in length with two vertical lift intake gates (34.5 feet high by 16 feet wide). One intake approach channel supplies both the powerhouse and the main spillway structure, and it is approximately 1,300 feet long, 500 feet wide and 55 feet deep.



Each of the unit step-up transformers is rated at 85.5/114 Mva, 13.8/138 kv, 3-phase, 60 hertz, ONS/ONP.





MANICOUAGAN 1 DEVELOPMENT P1096

Location Baie Comeau, Quebec

Client Quebec Hydro-Electric Commission

1967

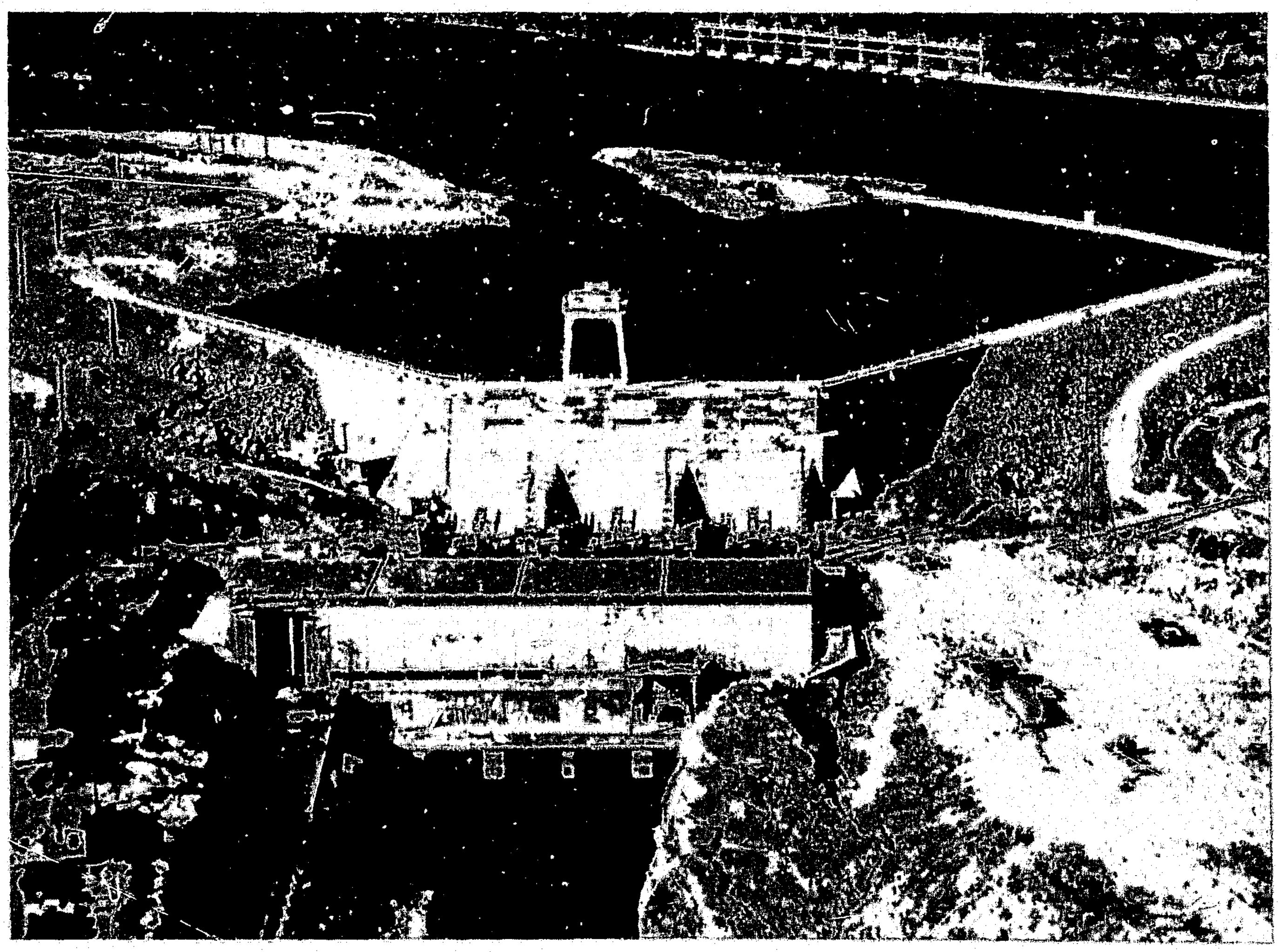
Value $20,000,000 (Approximate capital cost)

Engineering for a complete hydro-electric power development having three units each rated at 80,000 horsepower (61,500 kw) under a net head of 120 feet.

The development utilizes the forebay of the McCormick Development to which it is connected by means of an intake channel 120 feet wide and 600 feet long with a hydraulic depth of 50 feet.

The intake works contain three gates each 27 feet by 20.5 feet which supply three steel-lined, concrete penstock tunnels each 22 feet in diameter and 120 feet long.

The tailrace channel is 72 feet wide and 1,800 feet long with a hydraulic depth of 40 feet.



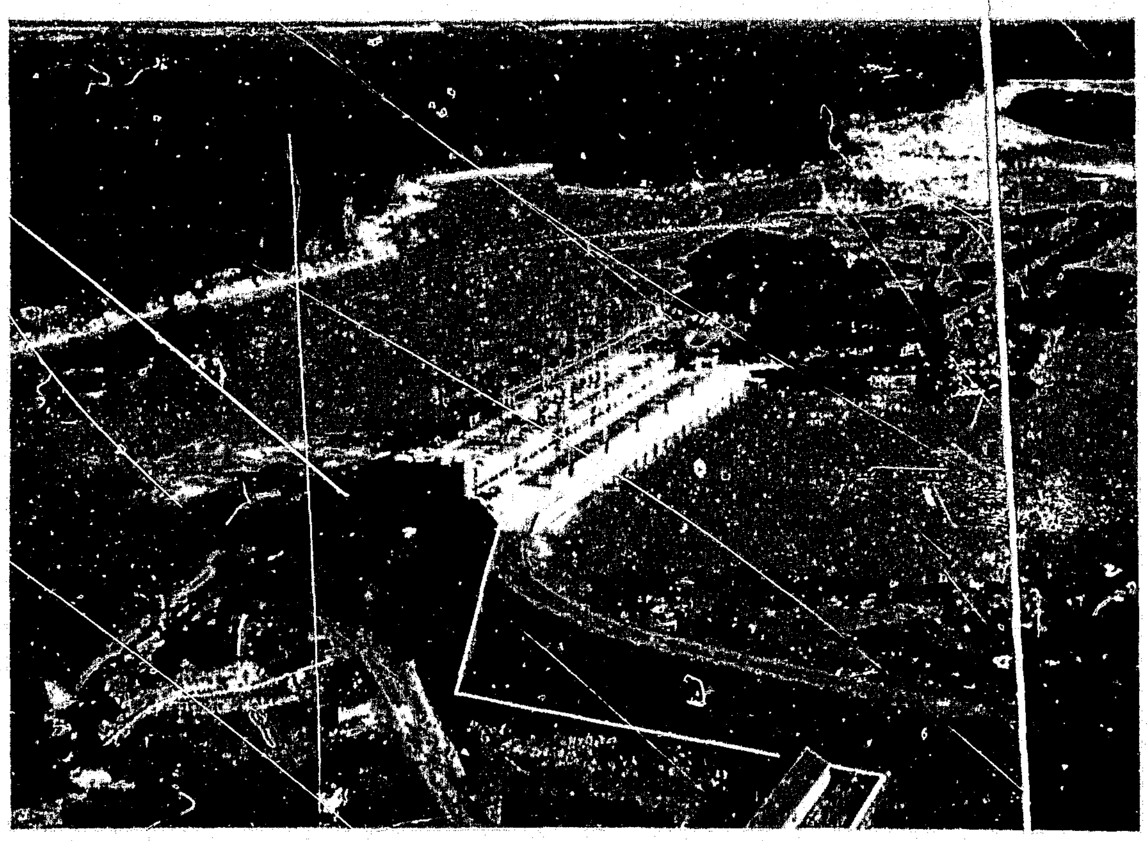
KELSEY DEVELOPMENT

Location	On the Nelson River, approximately 425 air miles north of Winnipeg, Manitoba
Client	The Manitoba Hydro-Electric Board
	1961
Value	$44,000,000 (Approximate capital cost)

Engineering and supervision of construction for a run-of-river hydro-electric power development. The development is designed on the unit basis and it has five turbine/generator/transformer units with provisions for the future installation of one additional unit.

The turbines are of the fixed-blade propeller type, rated at 42,000 horsepower under a head of 55 feet, and the generators are rated at 37,500 kva, 13.8 kv, 3-phase, 60 hertz. The step-up transformers are rated at 37,500 kva, 13.8/138 kv, 3-phase, 60 hertz, and they are located together with the switchyard equipment on the roof of the powerhouse. The development is arranged for local operation, or for remote control from Thompson by means of power line carrier.

The main dam is of the rock-fill type with an upstream impervious sloping core, and it has a maximum height of 120 feet, a crest length of 955 feet and a volume of 288,300 cubic yards. Adjoining the dam is a concrete sluiceway structure 66 feet high and 480 feet long with nine fixed-roller, crest-type gates (each 43.5 feet high by 40 feet wide). The sluiceway has a discharge capacity of 250,000 cfs. The development has 6,250 feet of clay dikes having a maximum height of 38 feet, and 3,900 feet of sand dikes (founded on permafrost) having a maximum height of 20 feet.



ACRES

MANICOUAGAN 2 DEVELOPMENT

Location	On the Manicouagan River approximately 12 miles north of Baie Comeau, Quebec
Client	Quebec Hydro-Electric Commission
	1967
Value	$120,000,000 (Approximate capital cost)

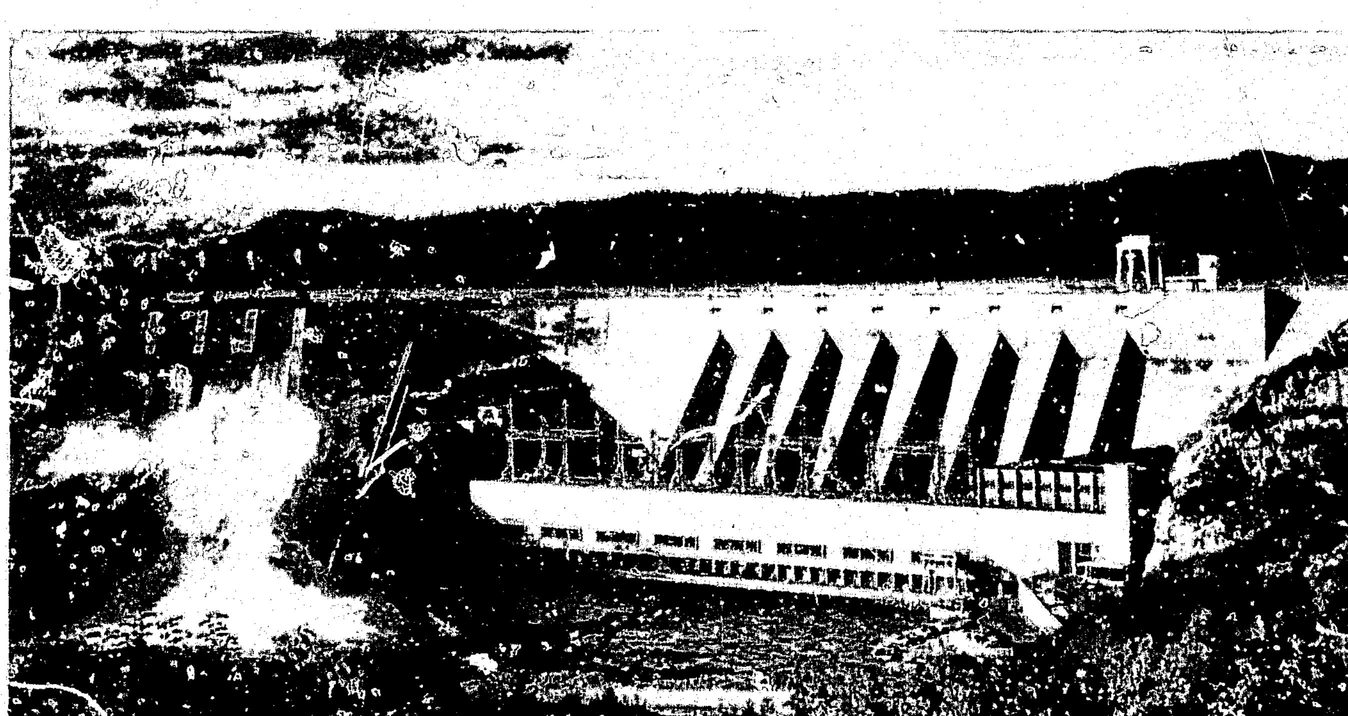
Engineering for a complete hydro-electric power development.

The development consists of a concrete gravity dam incorporating a spillway, a log sluice and an intake structure with the powerhouse located immediately downstream and parallel to the dam.

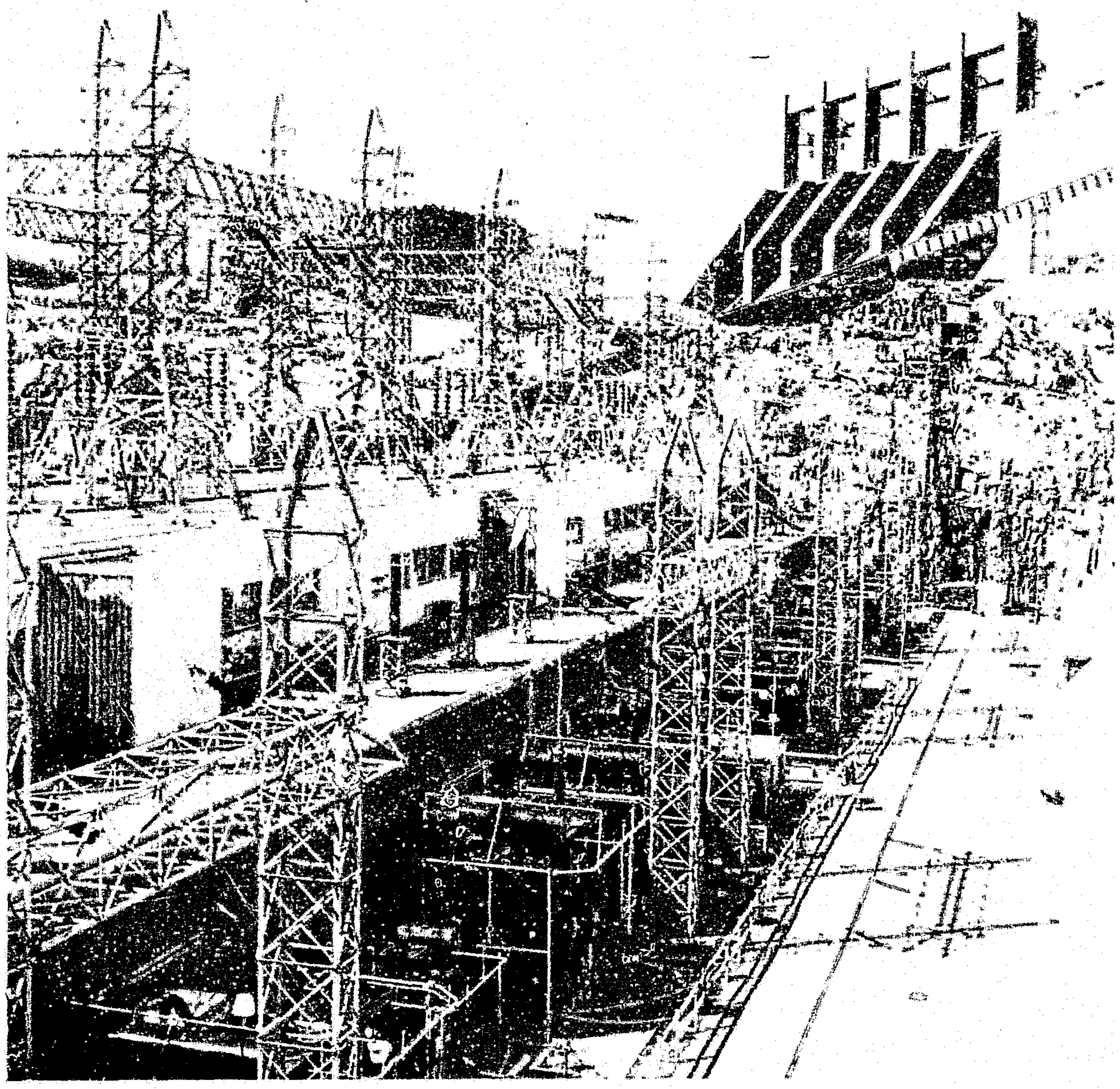
The intakes are located at the top of the dam and water is led from the intakes in steel penstocks, 23 feet 6 inches in diameter, down the downstream face from the dam to the generating units. The powerhouse contains eight 120-rpm, vertical, Francis-type turbine generator units each rated at 170,000 horsepower under a head of 230 feet.

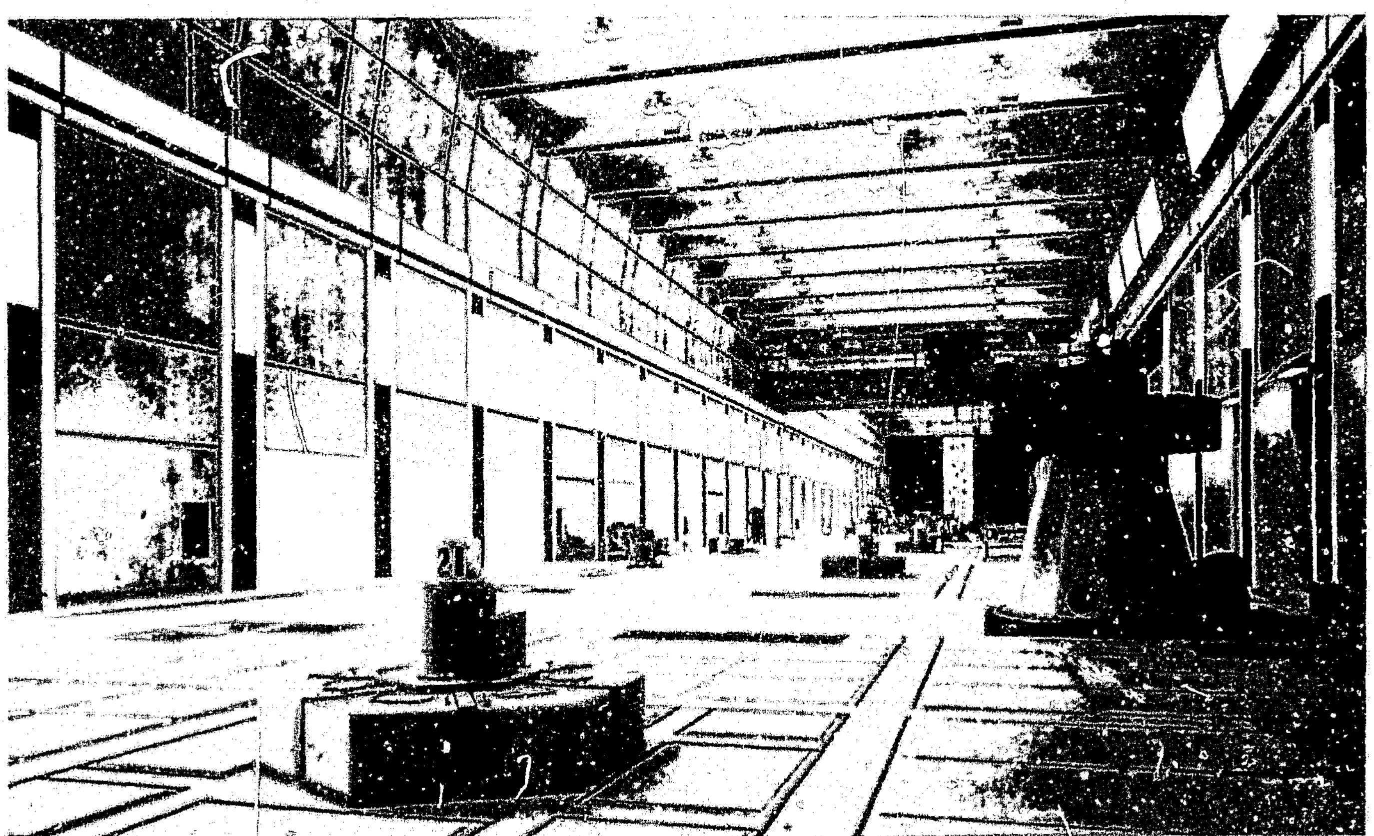
The spillway has five gates (each 40 feet by 40 feet) with sufficient capacity to discharge a flood flow of 200,000 cfs with no water passing through the powerhouse units. The log sluice is designed to take care of all future requirements for log driving on the river.

The type of dam chosen for this development is a section known as "Hollow Joint" Concrete Gravity Dam. This type of construction reduces concrete quantities by approximately 10 per cent, compared with normal gravity sections. In addition, the system of hollows and galleries provides a means of observing seepage and uplift pressures in the foundation of the dam, and remedial work, if required, can be carried out within the dam at minimum cost.



The main powerhouse transformers are located on the upstream side of the powerhouse between the dam and the powerhouse structure. The high-tension leads from the transformers are taken from a structure on the powerhouse roof to the switching station located on the west bank of the river some distance downstream.



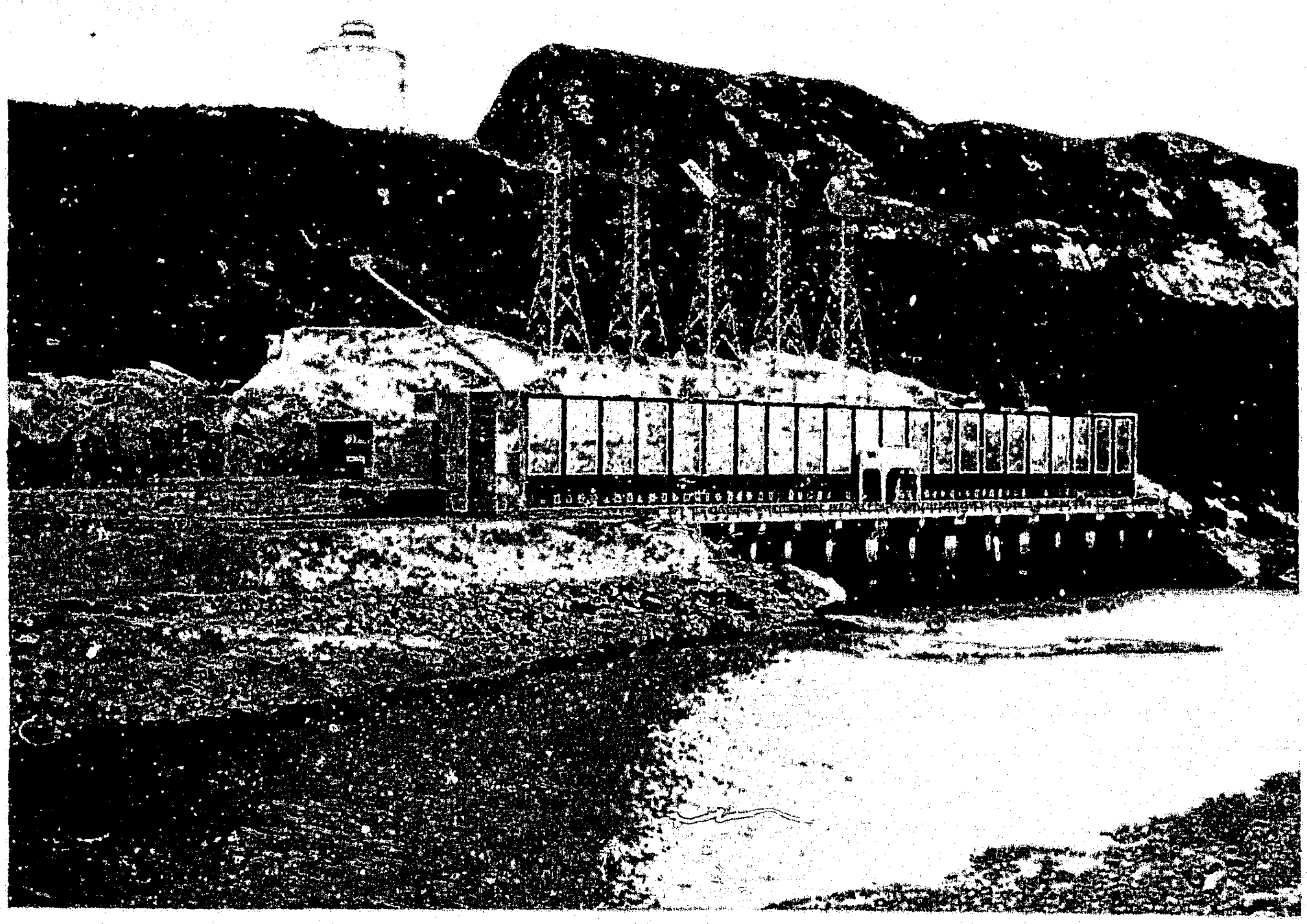


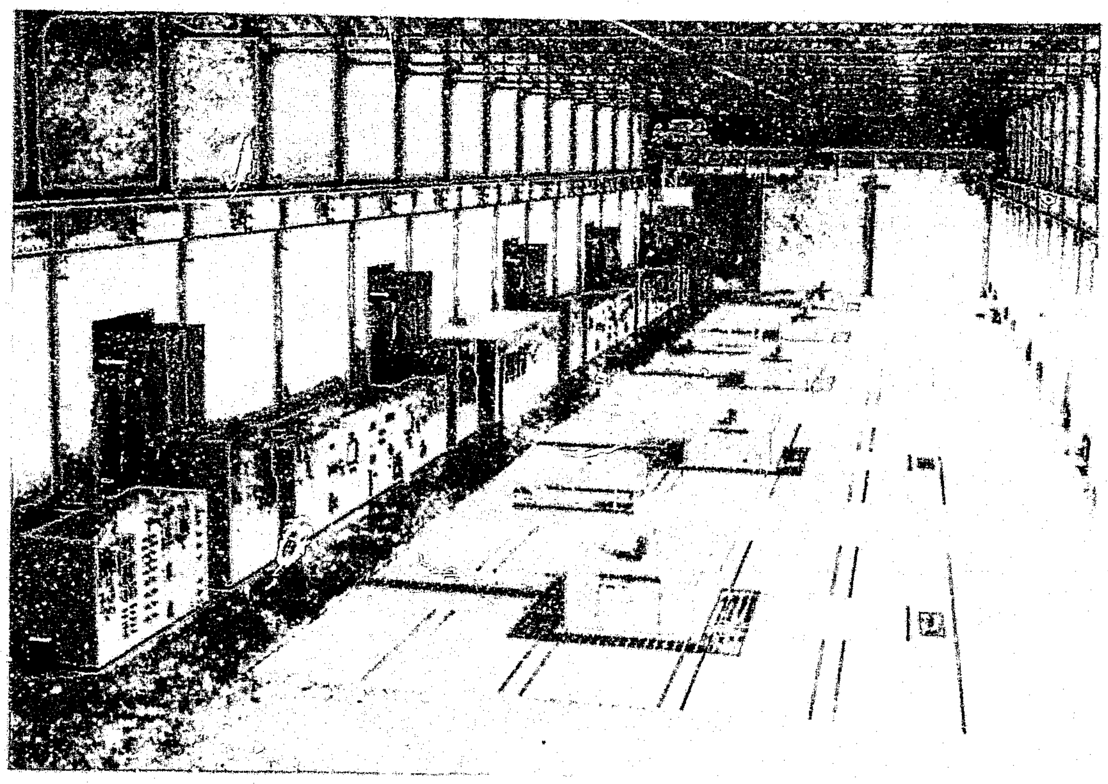
BERSIMIS NO. 2 DEVELOPMENT

Location	**On the Bersimis River approximately 170 miles north of Quebec City, Quebec**
Client	**Quebec Hydro-Electric Commission**
	1960
Value	**$120,000,000** (Approximate capital cost)

Engineering and field liaison for a complete hydro-electric power development having five 163.6-rpm units each rated at 171,000 horsepower under a head of 367 feet.

The development has a main dam and two auxiliary dams. The main dam is of the mass concrete gravity type 275 feet high and 2,110 feet long and it has an integral spillway section with six cable hoist-type gates each 31 feet high by 40 feet wide. The auxiliary dams are of the earthfill vertical clay core type. The first is 97 feet high and 3,310 feet long, and the second is 64 feet high and 3,920 feet long. The concrete-lined supply tunnel is 38 feet in diameter and 2,700 feet long, and it is protected by a steel surge tank of the orifice type, 100 feet in diameter.





LA BORUCA HYDROELECTRIC POWER PROJECT P5301

Client Instituto Costarricense de Electricidad

Location Rio Grande de Terraba, Costa Rica

Studies and engineering design of a 760 MW hydroelectric development which will include the highest rock-fill dam in the western hemisphere.

Objective of the study is to carry out geological and engineering investigations necessary to define the main components and a cost and economic evaluation. Acres will also conduct an environmental study of the area downstream of the project.

Acres responsibilities in the engineering design will include the power complex and switchyard consisting of

- underground powerhouse of four 190-MW units. Separate penstocks connect each unit to the power intake
- chute spillway controlled by 5 radial gates 15.2 m wide by 17.2 m high
- sloping core rock-fill dam, 260 m high having a total fill volume of approximately 43,000,000 m^3
- diversion of upstream and downstream cofferdams 50 and 20 m high respectively which will form part of the main dam and 4 diversion tunnels, 8 m in diameter and horseshoe shaped. The tunnels pass directly under the powerhouse and after diversion will serve as draft tube discharge tunnels
- 220-kV transformers and switchyard located on the surface directly above the powerhouse
- two double-circuit 220-kV transmission lines, 53 km long to transmit power to Uvita and a proposed aluminum smelter.

The project is located in an area having an average annual rainfall of approximately 4,000 mm. The foundation geology at the site consists of permeable limestone and a formation of sandstone and shale. The general region is seismically active and a major geological fault traverses the damsite.

ACRES

Location	Volta River, Ghana
Client	Volta River Authority
	1976 – 1981
Value	$240,000,000 (Approximate capital cost)

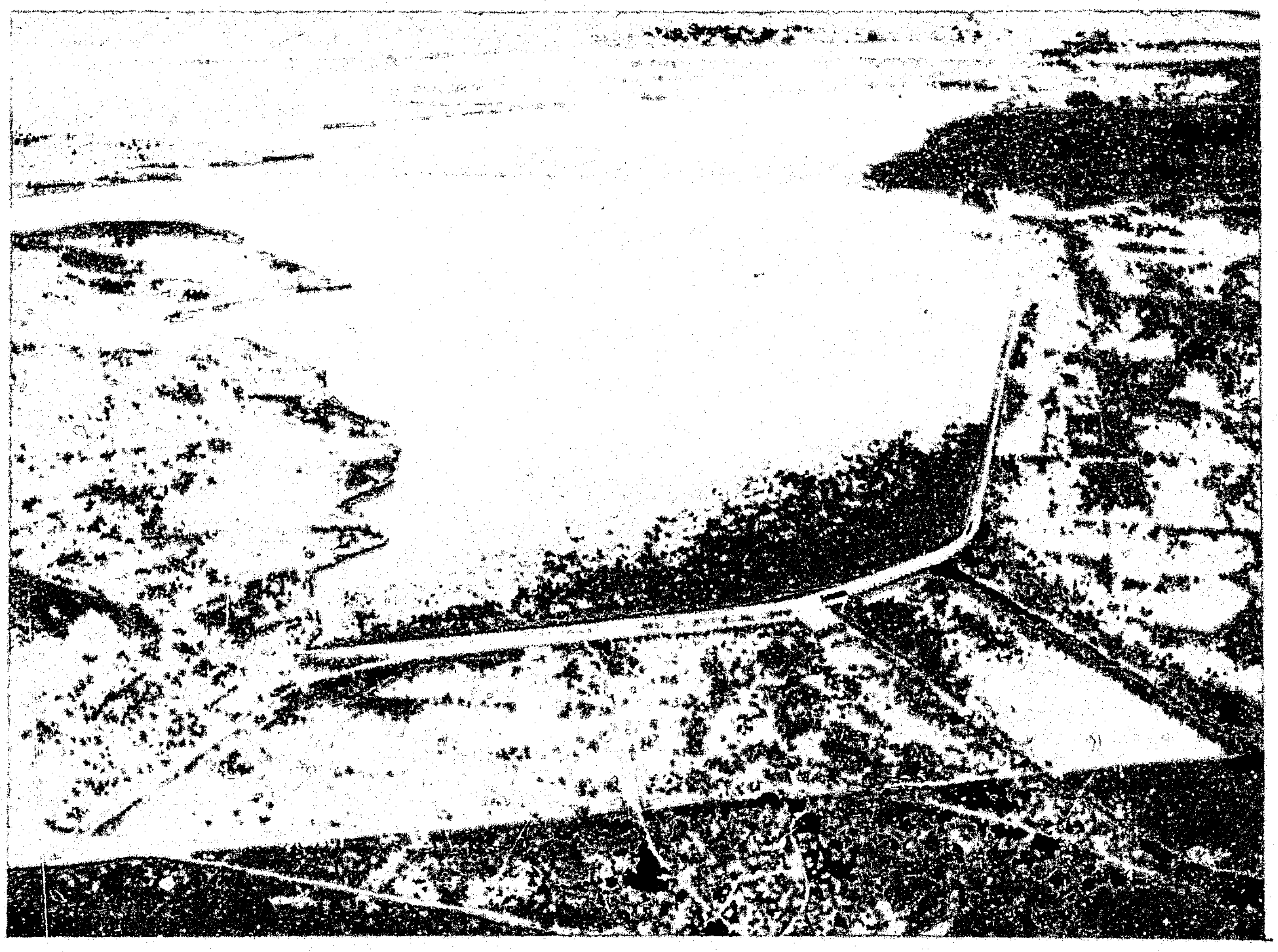
Engineering, construction supervision and general planning for low-head hydroelectric power development having four generating units rated at 40 Mw each, under a head of 11.75 metres.

The principal components of the project comprise a close-coupled intake/powerhouse structure, some 51 metres high above foundations, a spillway with 15 radial gates having a discharge capacity of 20,700 cu m/sec, an earth-fill dam section and a total of 4.5 km of dikes, a 4-story control building, switchyard and 52 km of double-circuit transmission lines. Provision will be made for future irrigating works.

The head pond of the project forms the tailrace for the existing Akosombo plant, and the Kpong plant will operate generally in tandem with the Akosombo plant.

Because of the very low head, the fixed-propeller turbines are extremely large with a runner diameter of 8.13 metres, currently the largest in the world.

The first unit is scheduled to go on line early in 1981.



TARBELA HYDROPOWER EXTENSION PROJECT

P4069

Location Tarbela Dam, Indus River, Pakistan

Client Water and Power Development Authority, Pakistan

Value $119 million (approximate capital cost)

Design and supervision of construction for extension to the existing powerhouse, to contain Units 5 to 8, and the installation of Units 5 and 6 with all electrical and mechanical auxiliaries.

The extension comprises

- a concrete powerhouse structure designed to accommodate four water-turbine generators

- a steel-lined concrete-encased penstock supplying water to the four units of the extension from one of the existing tunnels, used as a diversion tunnel during construction of the dam

- two vertical-shaft waterwheel generators of 175-Mw capacity, connected through 500-kv single-phase transformers to the switchyard

- four turbine inlet butterfly type valves.

Construction work will commence 1977. Units 5 and 6 are scheduled to be commissioned in 1980.

ACRES

WARSAK DEVELOPMENT

P602
P3963

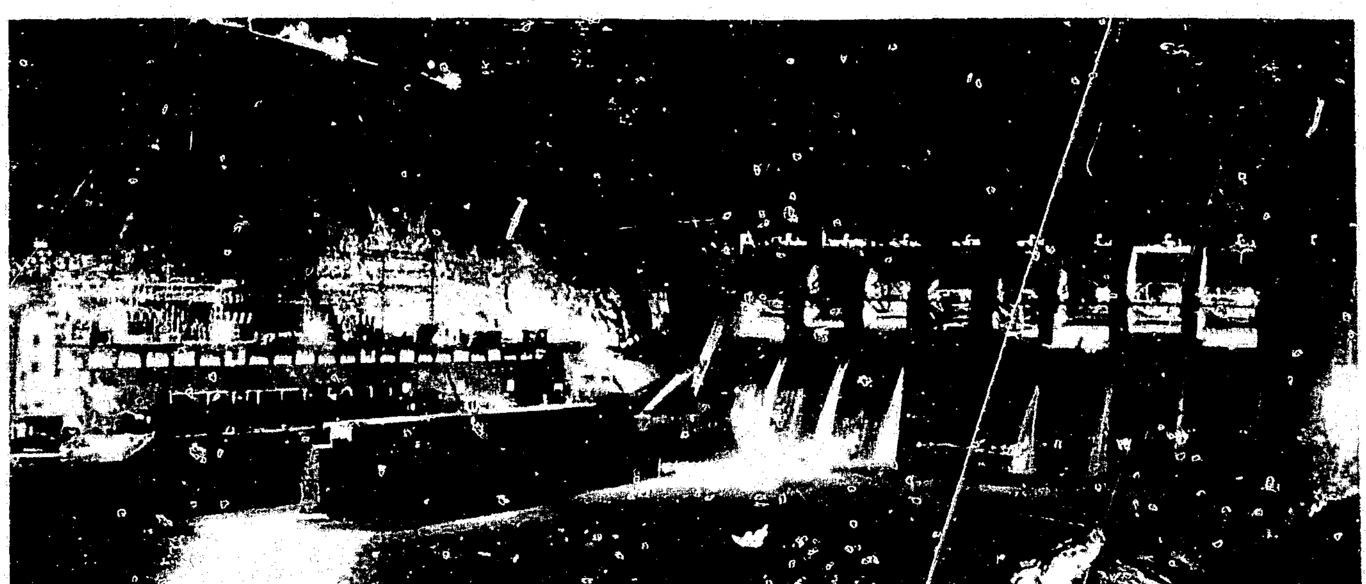
Location	On the Kabul River approximately 19 miles northwest of the City of Peshawar, Pakistan
Client	Government of Canada Department of Trade and Commerce Colombo Plan Administration in Canada Canadian International Development Agency — Units 5 and 6
Owner	Water and Power Development Authority, Pakistan
	1961 — 1978
Value	\$55,000,000 — Initial Installation \$15,000,000 — Units 5 and 6

Engineering and supervision of construction for a complete hydroelectric power development.

The initial development commissioned in 1961 had four units, each rated at 40 Mw under a head of 144 feet. Two additional units, each rated at 41.5 Mw are scheduled for commissioning in 1978.

The dam of the development is of the concrete gravity type, 250 feet high and 650 feet long, with the river section being a spillway (540,000 cfs) equipped with nine 40-foot by 40-foot taintor type gates. The reservoir created by the dam has a useful live storage volume of 25,000 acre-feet.

The intake of the supply tunnel is a fan-shaped concrete structure 138 feet long, with nine converging piers supporting trashracks and two steel headgates each 39 feet high and 17 feet wide. The concrete-lined supply tunnel is 689 feet long, has a circular cross section 39 feet in diameter, and terminates in six steel-lined penstocks, each 120 feet long and 18 feet in diameter. The diversion tunnel for the project was 1,650 feet in length and had a concrete-lined, horseshoe-shaped cross section 35 feet in diameter. The development includes a concrete-lined irrigation tunnel 17,100 feet long with a circular section 10 feet in diameter.



ASLANTAS DAM AND POWER PROJECT P2012

Location Ceyhan River, Adana, Southern Turkey

Associates Sofina — Traction, Brussels, Belgium
Su-Yapi, Ankara, Turkey

Client Directorate General of the State Hydraulic Works, (Devlet Su Isleri)

1972

Value $80,000,000 (Approximate capital cost)

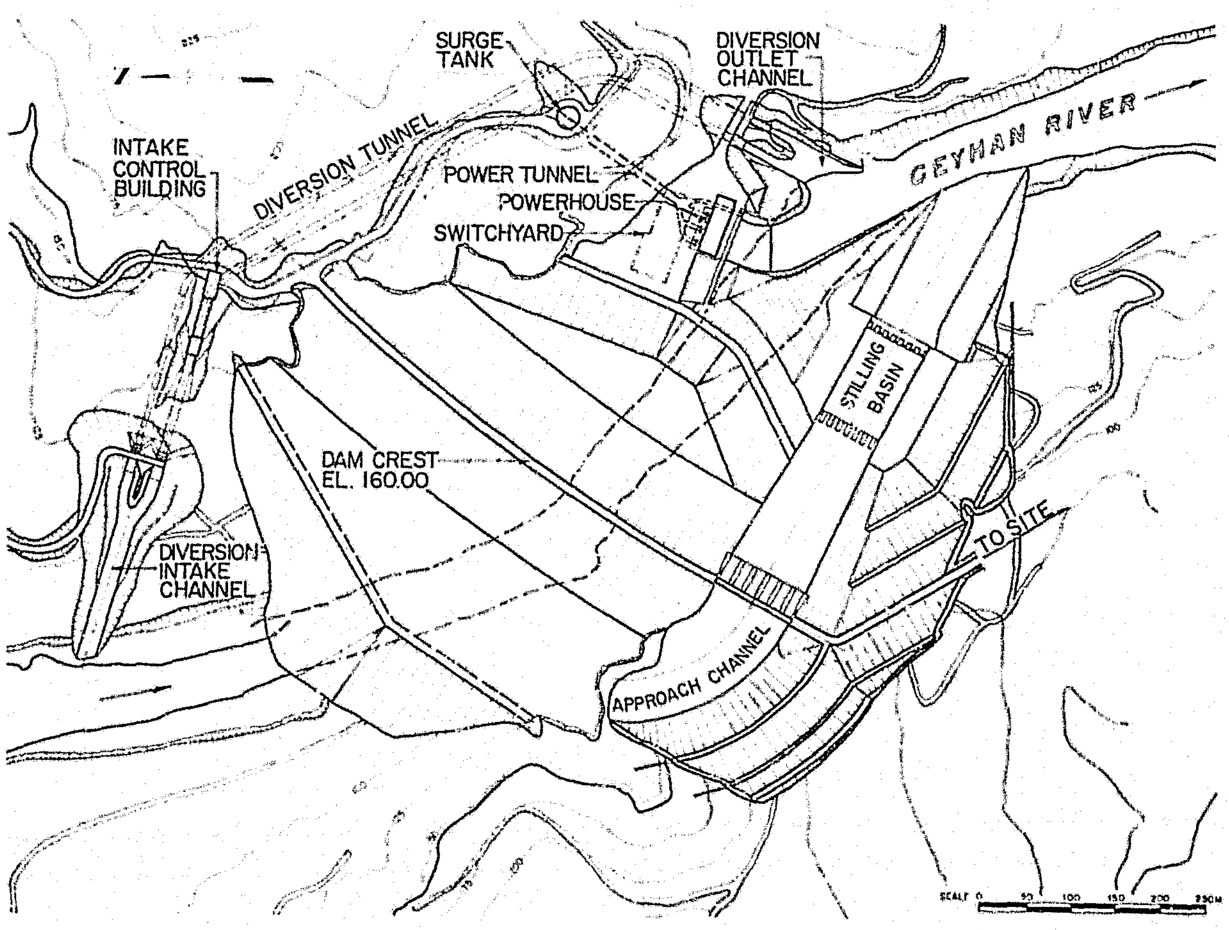
Engineering services for the design and specification of a dam and powerhouse on the Ceyhan River.

The project is the primary electric power generation, irrigation and flood control development in the Ceyhan Basin, and the principal features of the project are:

a 110-metre high earth-fill dam to create a reservoir having a capacity of 2,250 million cubic metres. Of the total capacity, 2,000 million cubic metres are for electric power generation and irrigation, and the remaining 250 million cubic metres of the capacity are for flood control purposes;

a three-unit 125-Mw powerhouse with 350-Gwh estimated average annual output;

a 60-km transmission line to Ceyhan.

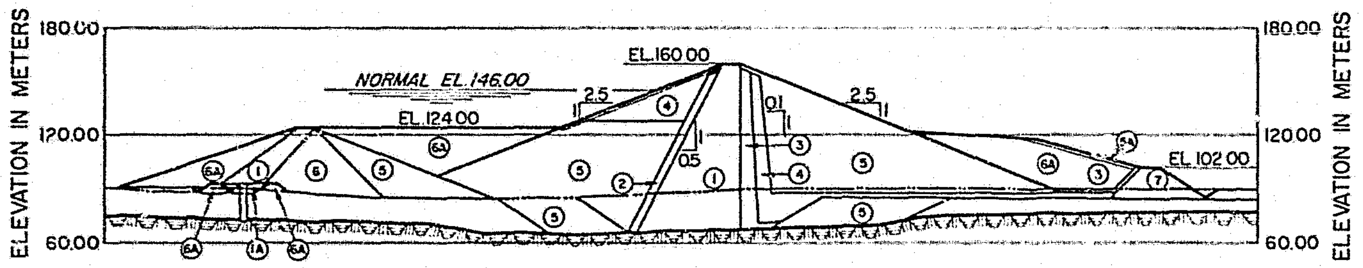


ASLANTAŞ PROJECT LAYOUT

The dam is founded on a layered sequence consisting predominantly of clay-shale, with minor amounts (15 per cent) of interbedded sandstone. This geological unit is referred to as Flysch. The clay-shale is composed of approximately 50 per cent calcite and 50 per cent montmorillonite with minor clay-mineral fractions, as established by X-ray diffraction. The dam is an earth-fill structure with an impervious core consisting of compacted clay-shale derived primarily from the excavations for the spillway and other structures. The section also includes upstream and downstream weighting berms to buttress the dam against sliding on the relatively weak foundation.

The excavations for the spillway and other structures involved the removal of several million cubic yards of clay-shale. Careful design of the excavation slopes was required to preclude stability problems associated with planes of weakkess parallel to the bedding of the clay shales and to other geological features which constitute weaknesses within these deposits.

The twin diversion/power tunnels (each 9 metres in diameter) of the project had to have continuous temporary support consisting of a combination of shotcrete with Perfo bolts or steel ribs. The permanent support for both tunnels consists of concrete linings.



LEGEND

- 1 CORE – *WEATHERED FLYSCH (MAX 6")*
- 1A DUMPED IMPERVIOUS SEAL – *WEATHERED FLYSCH (MAX 12")*
- 2 U/S TRANSITION – *SILTY, SANDY GRAVEL (PROCESSED)*
- 3 D/S TRANSITION – *SANDY GRAVEL (PROCESSED)*
- 4 DRAIN – *GRAVEL (PROCESSED)*
- 5 SHELL – *CONGLOMERATE OR RIVERBED ALLUVIUM*
- 5A SLOPE PROTECTION – *RIVERBED ALLUVIUM*
- 6 RANDOM ZONE – *UNWEATHERED FLYSCH*
- 6A RANDOM ZONE – *DUMPED UNWEATHERED FLYSCH*
- 7 D/S ROCK TOE – *BASALT ROCKFILL*
- 7A RIVER CLOSURE – *DUMPED ROCKFILL*
- RIPRAP – *BASALT*

ASLANTAS DAM – CROSS SECTION

ACRES

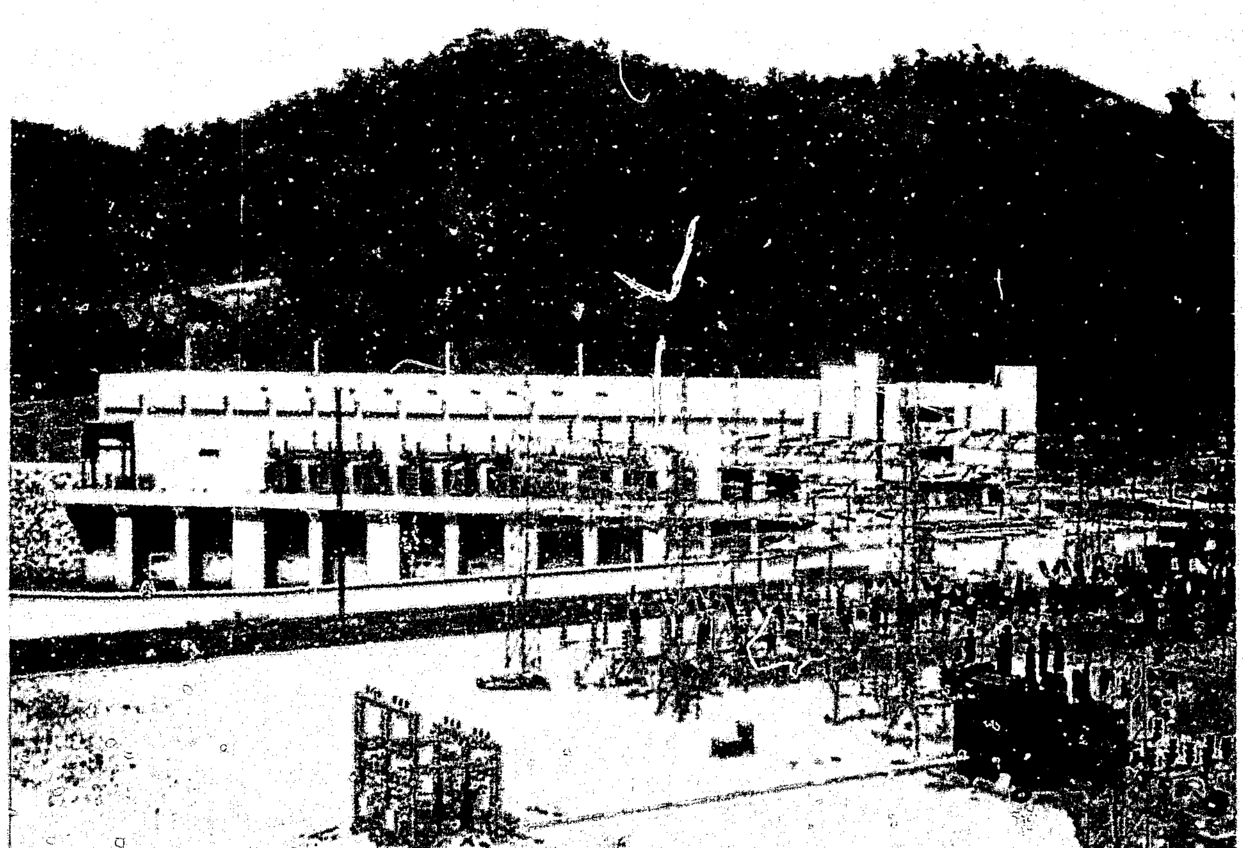
Client	Electricity Generating Authority of Thailand (EGAT)
Location	Nan River, Thailand
	1967 – 1976
Value	$50 million (Approximate capital cost)

Engineering layout studies, detail design and supervision of construction of the penstocks and powerhouse of the Sirikit multipurpose development.

The Sirikit development (for irrigation, power and flood control) was undertaken jointly by the Royal Irrigation Department, who were responsible for the dam, spillway, diversion works and irrigation outlet, and EGAT, who were responsible for the power facilities.

The power development has a capacity of 375 MW, comprising three units each rated at 125 MW under a head of 75 m. Space has been provided for a fourth unit. The plant commenced operation in 1973.

The project was originally called the Phasom power project.



NAM NGUM PROJECT

Location The Nam Ngum, 70 km north of Vientiane, Laos

Client The Kingdom of Laos
The Laotian National Mekong Committee

1966 – 1971

Value $29,000,000 (Approximate capital cost)

Engineering management and supervision of the design, construction and initial operation of the Nam Ngum Project.

As engineering management consultants, Acres was responsible for the administration and supervision of the execution of the project. Acres work included:

the review of proposed designs, schedules and construction procedures;

the control of the methods used for the supply of materials, equipment and services;

the review of specifications, the supervision of tendering and the awarding of contracts;

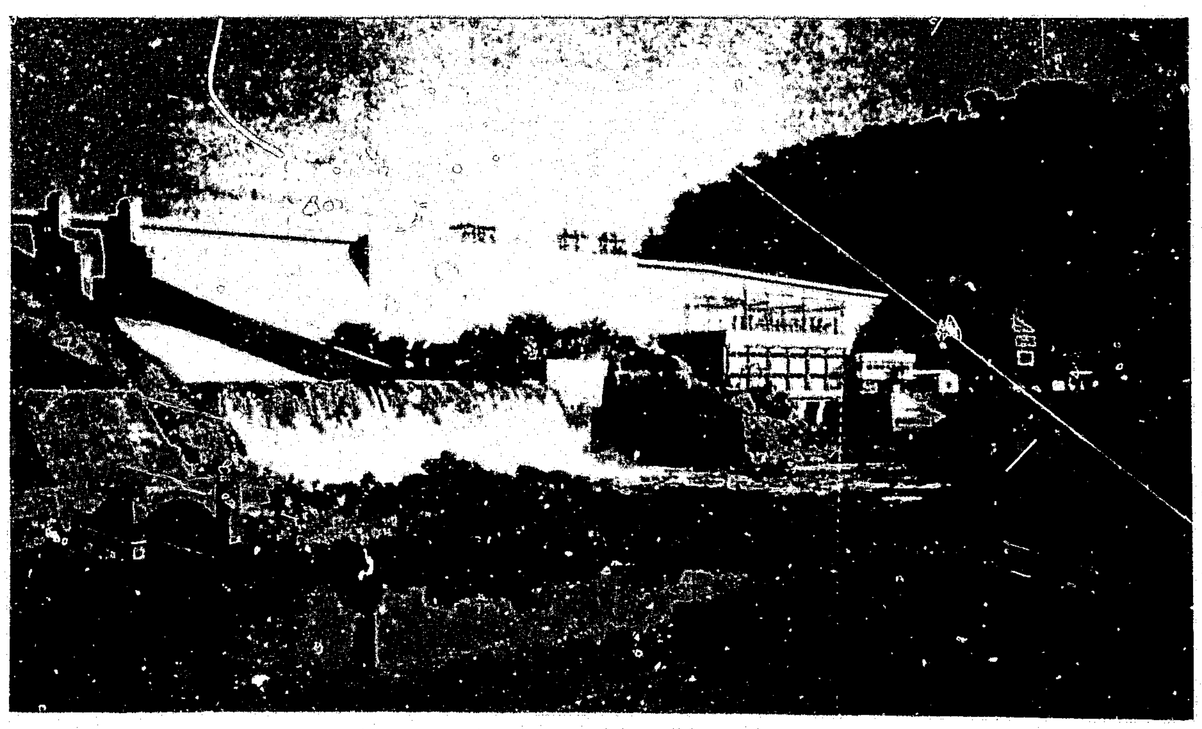
the certification of payments due;

the preparation of cost estimates and expenditure forecast;

the direction of accounting procedures;

the preparation of progress reports;

the supervision of initial operation, and training of operating and maintenance staff.



The project comprises:

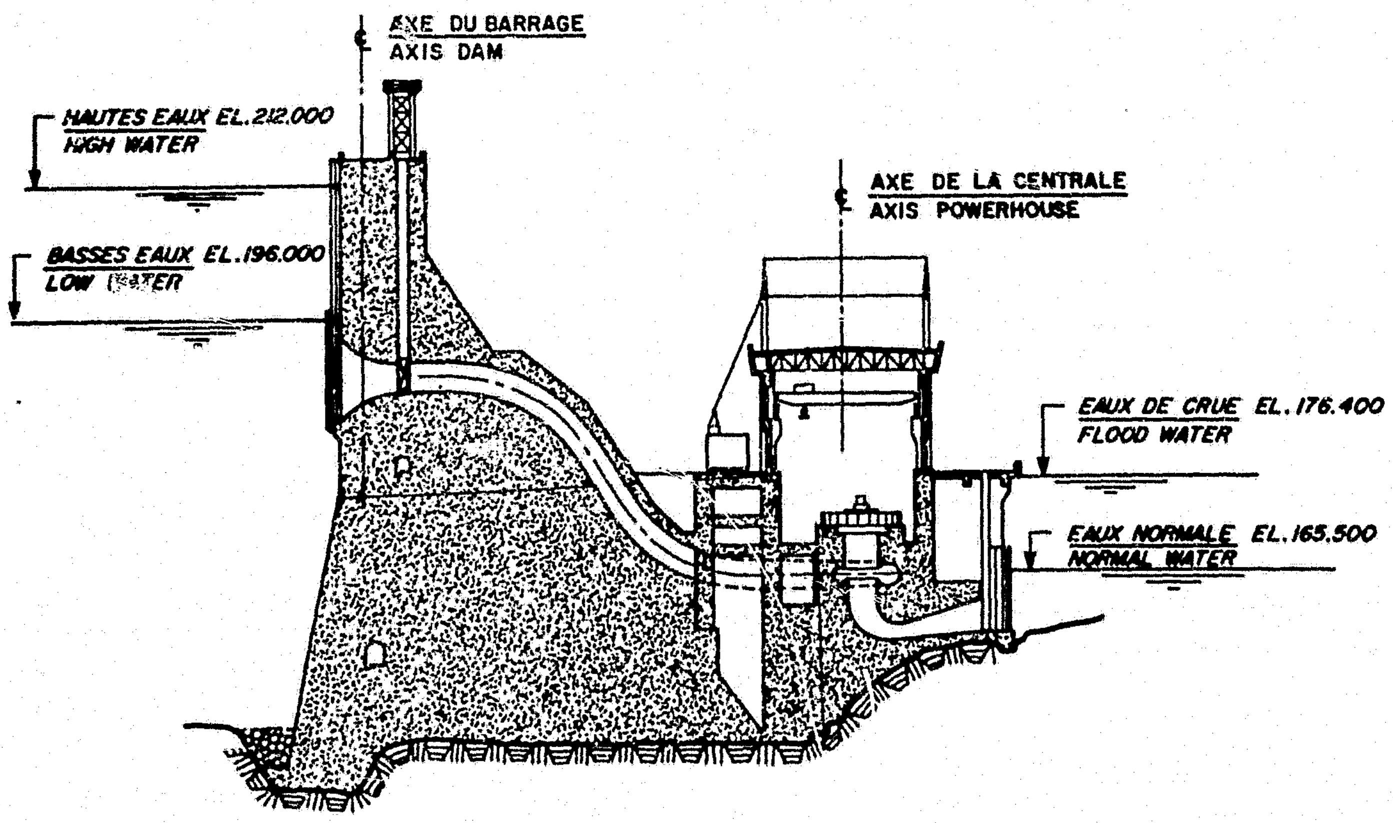
a dam approximately 66 meters high with a crest length of approximately 360 metres;

a reservoir having an ultimate live capacity of approximately 4,700 million cubic metres;

a powerhouse with two 15,000-kw units and provision for extension to an ultimate capacity of 135,000 kw;

a switching station and a single-circuit 115-kv overhead transmission line 140 km long;

serviced housing for operators.



ERDA/EPRI ENERGY STORAGE STUDY
UNDERGROUND PUMPED HYDRO

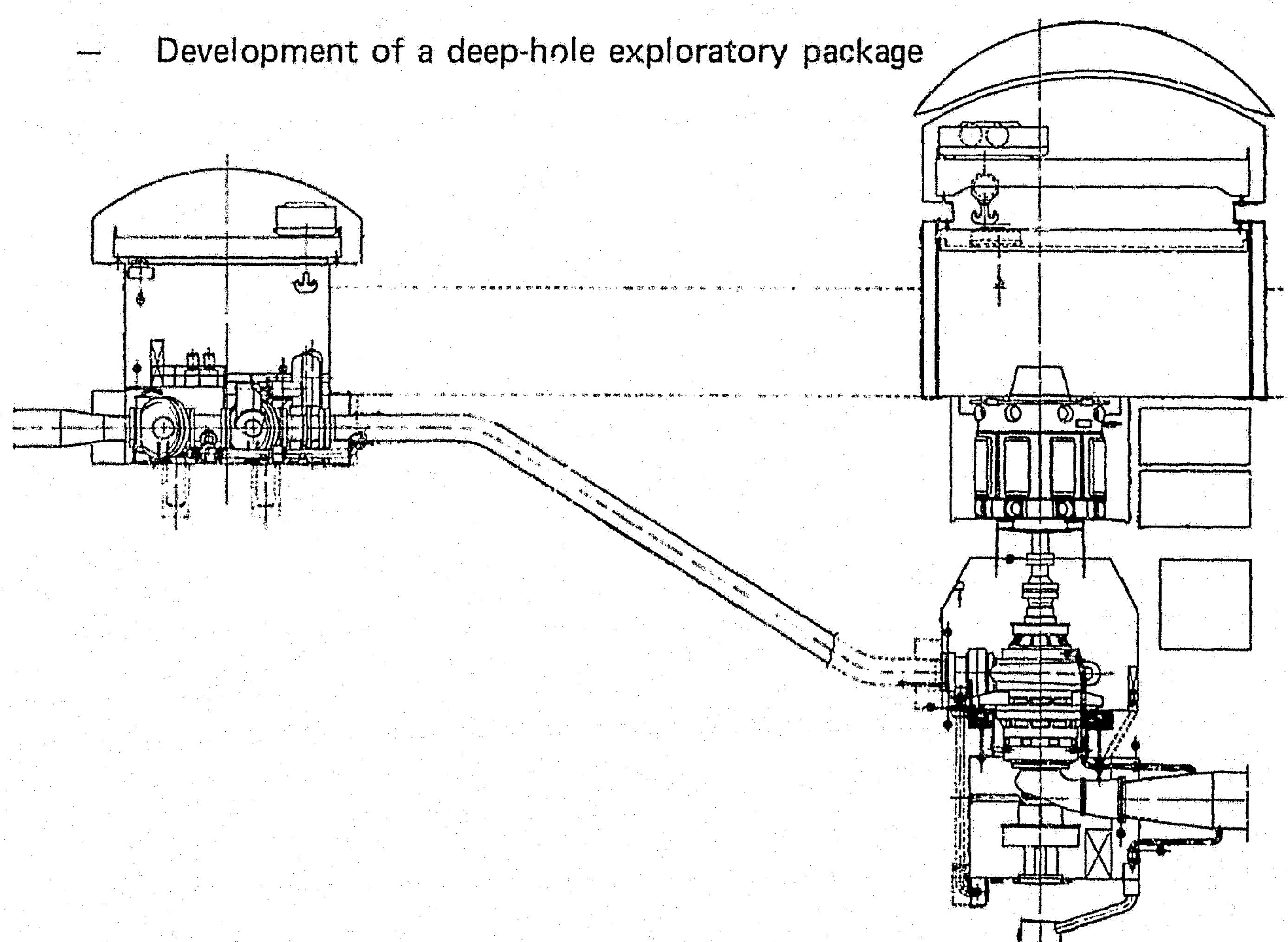
P4800

Client	**Potomac Electric Power Company** **Department of Energy** **Electric Power Research Institute**
Location	**Washington, D. C.**
Value	**$500 million (Approx. capital cost)** **$2 million (Approx. engineering cost)**

The study involves a program of both office and field investigation aimed at the development of site-specific preliminary designs and the comparative evaluation of both underground pumped hydro (UPH) and compressed air energy storage (CAES) systems. The program is devoted exclusively to hard-rock cavern siting applications, and includes the development of designs, outline specifications, and firm estimates of cost and schedule.

Specific objectives of the UPH study include:

- Identification of the most appropriate operating head in relation to available pump/turbine equipment
- Development of a suitable heavy hoist system
- Development of the least-cost approach to the excavation of the lower caverns
- Development of a deep-hole exploratory package



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— Identification of key safety and environmental issues

— Identification of appropriate energy storage requirements and system simulation approach

The study is being undertaken in a series of five primary tasks:

Task 1 — Establishment of design criteria and analysis of impact on power system

Task 2 — Selection of the site and preliminary field investigation, including exploratory drill hole to 5,000 feet and associated geophysical package

Task 3 — Formulation of the optimum facility configuration including the assessment of alternative machinery options and investigation of the economics of major underground openings

Task 4 — Preliminary review of the safety and environmental aspects of the project at the generic level and at the selected site

Task 5 — Preparation of layouts, arrangement drawings and outline specifications for both the proposed facility and for a demonstration facility

Subcontracting consultants to Acres for the study include Jacobs Associates of San Francisco, California, NUS Corporation of Rockville, Maryland, Terra Tek Incorporated of Salt Lake City, Utah, and G. W. Tiley & Associates of Burlington, Ontario.

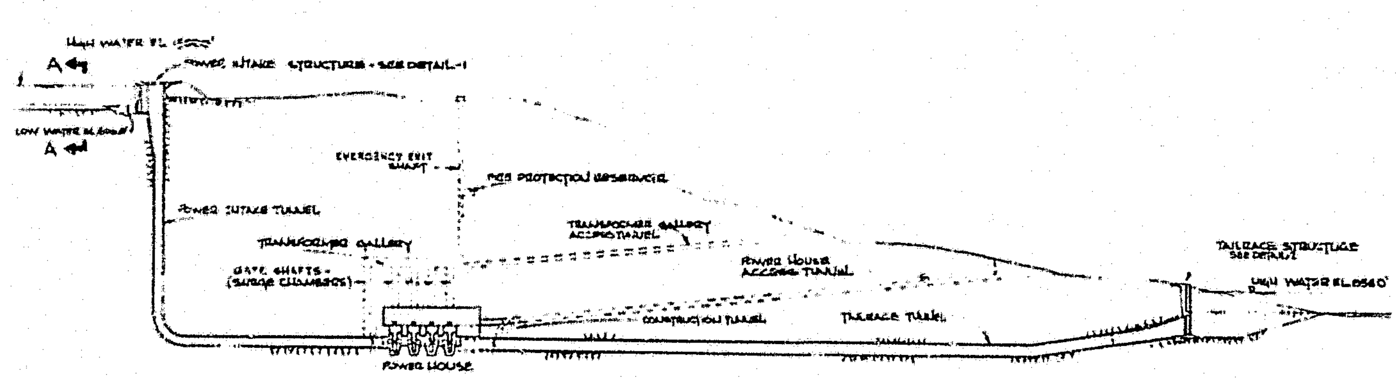
PUMPED STORAGE FEASIBILITY STUDY

Location	**North East United States**
Client	**Not For Release**
Year	**1976**
Value	**$265,000,000 (Estimated capital cost)**

A feasibility study and conceptual construction cost estimate for two conventional pumped storage facilities, utilizing a common upper reservoir. The first installation studied would comprise four reversible units totalling 825 MW at 550 feet net rated head in an underground powerhouse. The upper and lower reservoirs for this plant would be obtained by enlargement of the reservoirs associated with an existing 640 MW pumped storage plant already in operation. The facility would also include two main step-up transformers located in a separate gallery.

The enlarged upper reservoir would have an area of about 350 acres. The lower reservoir, about 600 acres in area, would require raising of existing dykes to a maximum height of 90 feet. A 120 foot high protective structure would also be required for the existing surface plant, to be constructed with minimal interruption of power generation.

The second installation would consist of a five unit 640 MW underground plant using the same upper reservoir and a lower reservoir planned to be constructed for flood control purposes.



PROFILE ALONG WATER PASSAGES

HYDROELECTRIC POWER GENERATION STUDY

P4944.00

Location **Massachusetts**

Client **Massachusetts Municipal Wholesale Electric Company**

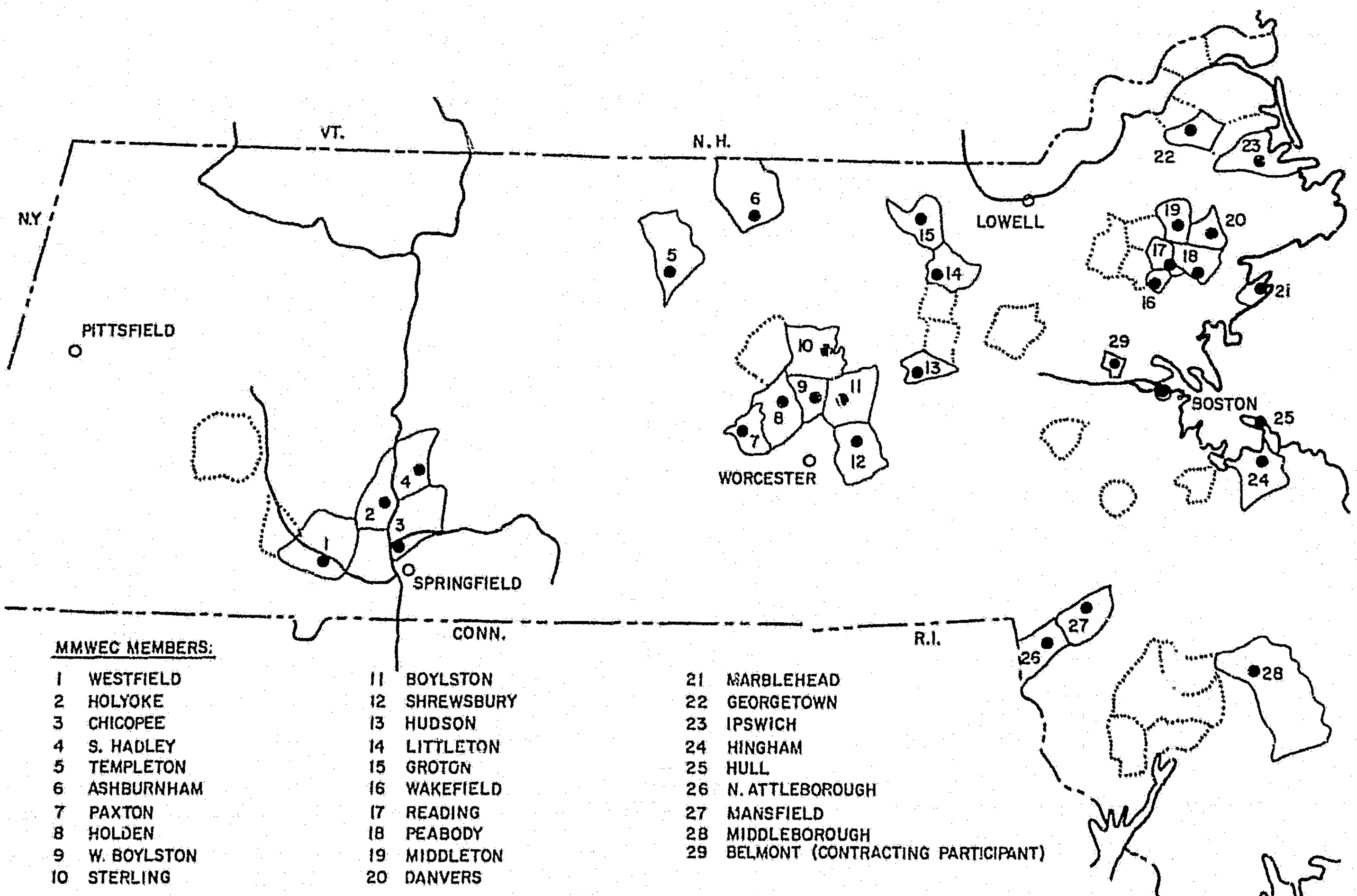
Year **1978**

Evaluation of the potential benefits of the MMWEC member utilities of the development of available hydroelectric facilities to meet forecast demands through the year 1989. The study includes the identification, evaluation and ranking of potential hydroelectric and pumped storage sites, including:

— construction of new facilities at hitherto undeveloped sites

— installation of power generation facilities at existing dams at which no such facilities currently exist

— rehabilitation, redevelopment and/or expansion of existing or abandoned hydroelectric installations.



MASSACHUSETTS MUNICIPAL WHOLESALE ELECTRIC COMPANY
HYDROELECTRIC GENERATION STUDY

MASSACHUSETTS MUNICIPAL ELECTRIC DEPARTMENTS

OSWEGO RIVER – HYDRO REDEVELOPMENT STUDY

P3648

Location Oswego River, New York State

Client Niagara Mohawk Power Corporation

Year 1974

An investigation of alternatives for increasing the hydro-electric power generation from existing plants along the Oswego River was completed. Optimizing storage development within the 5,000 square mile basin under existing flow regulation constraints combined with potential modification at plant sites were considered. The study provided a ranking of the possible alternatives available to Niagara Mohawk for redevelopment of the hydro-potential on the Oswego River.

Detailed analysis was made of the flow regulation constraints because the Oswego River is a major source of water supply for the Erie Barge Canal system. An important aspect of this study was the consideration of the "Finger Lakes" recreational area.

The capital cost of plan implementation was estimated as well as annual operating and maintenance costs based on Federal Power Commission Guidelines.

DICKEY LINCOLN PROJECT
POWER ALTERNATIVES STUDY

P4206

Location **New England**

Client **Corps of Engineers, New England Division**

Year **1976**

A study carried out as part of the environmental impact statement for the 830-MW Dickey-Lincoln School Lakes hydroelectric project in the state of Maine. The primary objective of the study was to evaluate the economic and environmental impacts of alternative power generation and energy storage options on the New England System through the year 2000.

Two system capacity and energy forecasts were derived for the study period, one under conditions of current load growth and energy conservation expectations, a second taking account of the probable effects of implementation of load management.

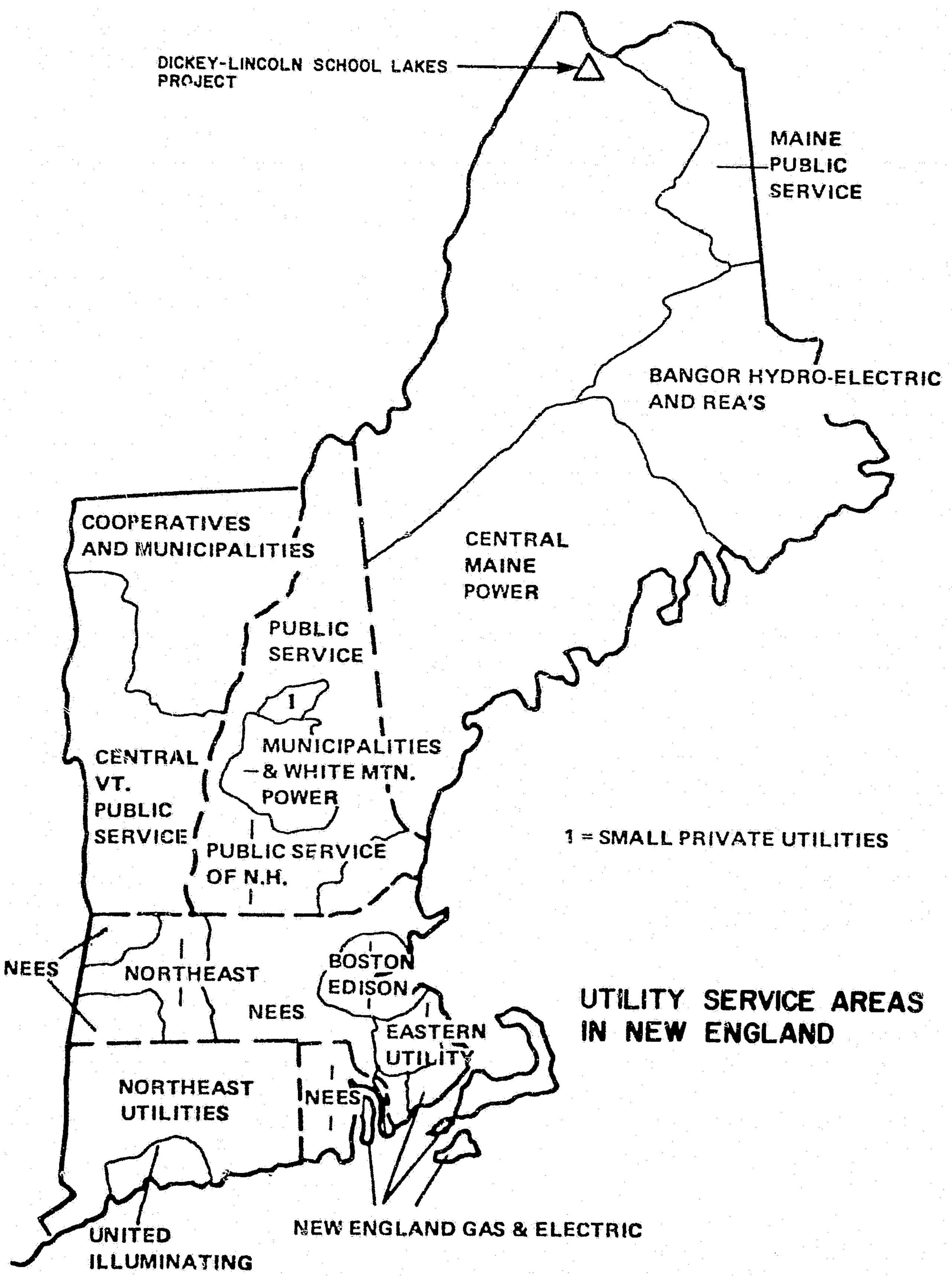
Annual system costs were computed for the 20-year period from 1981 using the General Electric OGP-3 program. A comprehensive range of potentially available generation and storage alternatives were considered, including nuclear, conventional thermal, gas turbines, hydroelectric, combined cycle, geothermal, tidal, fuel cells, magneto-hydro dynamic, solar, wind, conventional and underground pumped hydro, batteries, fly-wheels, superconducting magnetic storage, thermal storage and compressed air storage.

A total of ten options were selected for inclusion in system generation expansion plans on the basis of technical and economic feasibility within the considered time frame and minimum unit size requirements consistent with the scale of system expansion.

Capital and operating costs of the selected alternatives and optimum system expansion plans were developed for the two forecasts, using the OGP-3 program, both with and without the Dickey-Lincoln project. Two variants of the Dickey-Lincoln project incorporating pumped storage were also considered. System reliability, spinning reserve, scheduled maintenance and forced outage requirements were stipulated. Fixed, operating and maintenance and fuel costs for each option, including transmission, were factored into the evaluation of system costs for each year of the study period.

ACRES

Optimal generation expansion programs were thus developed on the basis of minimum cost. Results of the study were incorporated in a series of five reports, forming part of the environmental impact statement.



UTILITY SERVICE AREAS IN NEW ENGLAND

Location Vermont

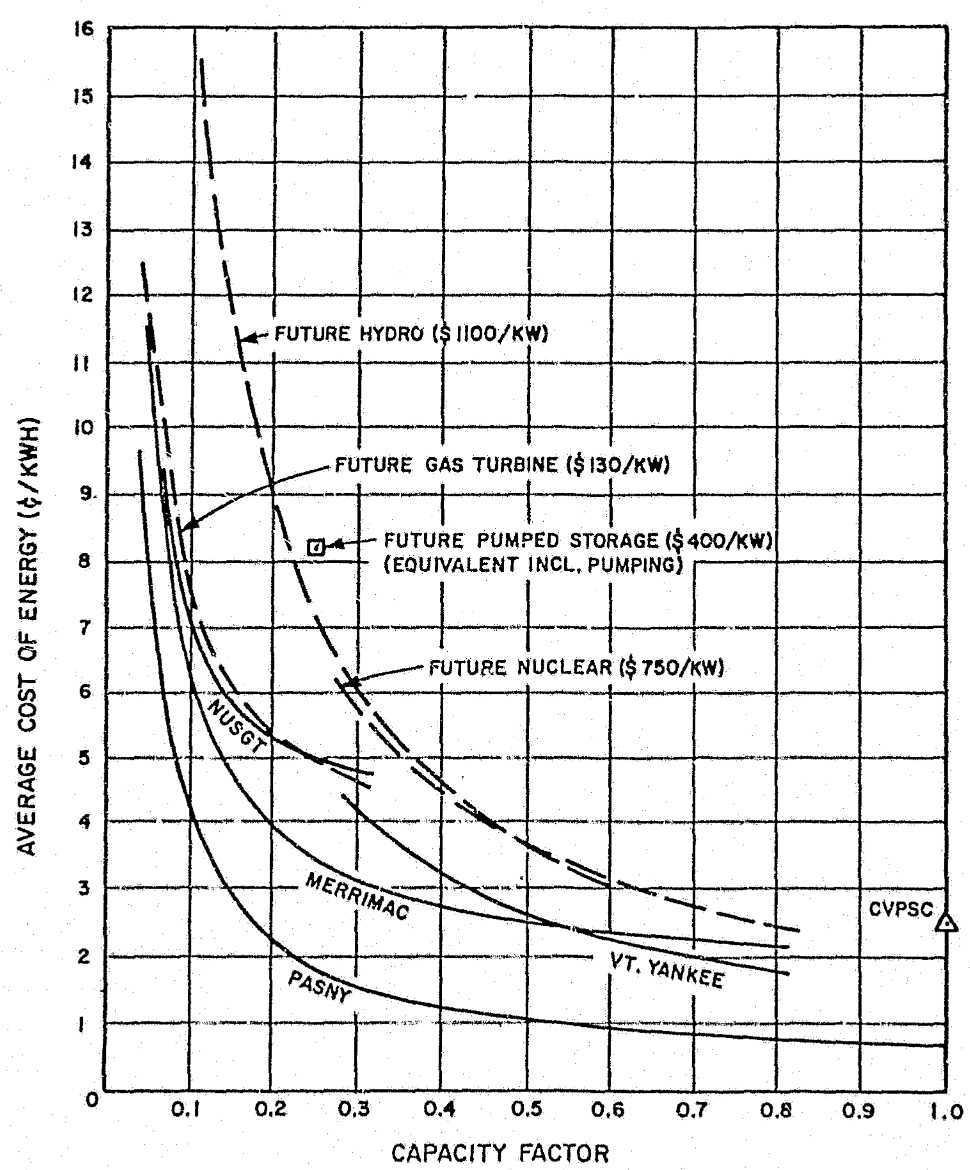
Client Vermont Electric Cooperative, Inc.

Year 1975

The primary objective of this study was to evaluate the potential benefits (if any) of the VEC system of the introduction of hydroelectric or pumped storage capability to meet forecast load demand to the year 1995.

This Cooperative has a peak demand of 25 MW and currently purchases all of its power requirements from large neighboring utilities. Sources include nuclear, coal-fired thermal, gas turbines and run-of-river hydroelectric plants in which VEC has various interests either in the form of part ownership or long-term power purchase contracts.

Potential hydroelectric and pumped storage developments were identified and ranked. Future system loads were evaluated to the year 1995 and power purchase costs for available New England sources were compared with fixed, operating, and maintenance costs of available hydroelectric or pumped storage sources.



GENERATION EXPANSION STUDY
KPONG HYDROELECTRIC PROJECT

P3796

Client: Canadian International Development Agency and Government of the Republic of Ghana

Location: Volta River, Ghana

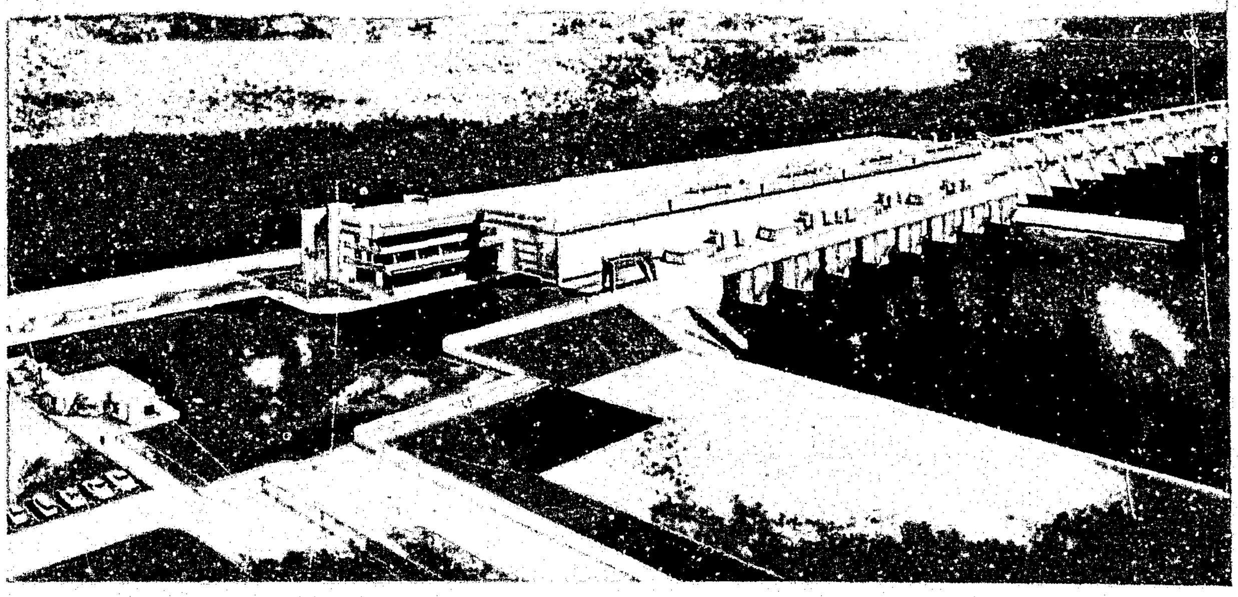
The study developed a generation expansion program to 1995, to meet the forecast electrical load of the Volta River Authority system. The prime undertaking was the detailed feasibility study of the development of the Kpong hydroelectric project on the Lower Volta River.

The feasibility study included hydrological, topographical and geologic surveys, drilling and test-pit exploration, ecological assessment, sociological impact, preliminary designs and cost estimates.

The existing generation and transmission facilities were studied to determine the present system capability. Available data on potential hydroelectric and thermal power projects in Ghana, including Kpong, were reviewed to establish a ranking order of the projects on the basis of energy cost and power capability. As a result of the studies, alternative generation expansion programs were studied by computer simulation of the VRA system to 1995.

Detailed economic analyses were carried out in selecting the best generation plan, and the plan was further subjected to economic sensitivity testing for capital cost, discount rate, fuel cost, and variations in foreign currency values.

A significant aspect of the project was the need to compress the study schedule in order to meet the foreseen critical construction program for the Kpong project. To meet the study deadline, the main engineering services were performed by a study team in the field.



APPRAISAL OF SITES FOR
UPH AND CAES FACILITIES

P4490

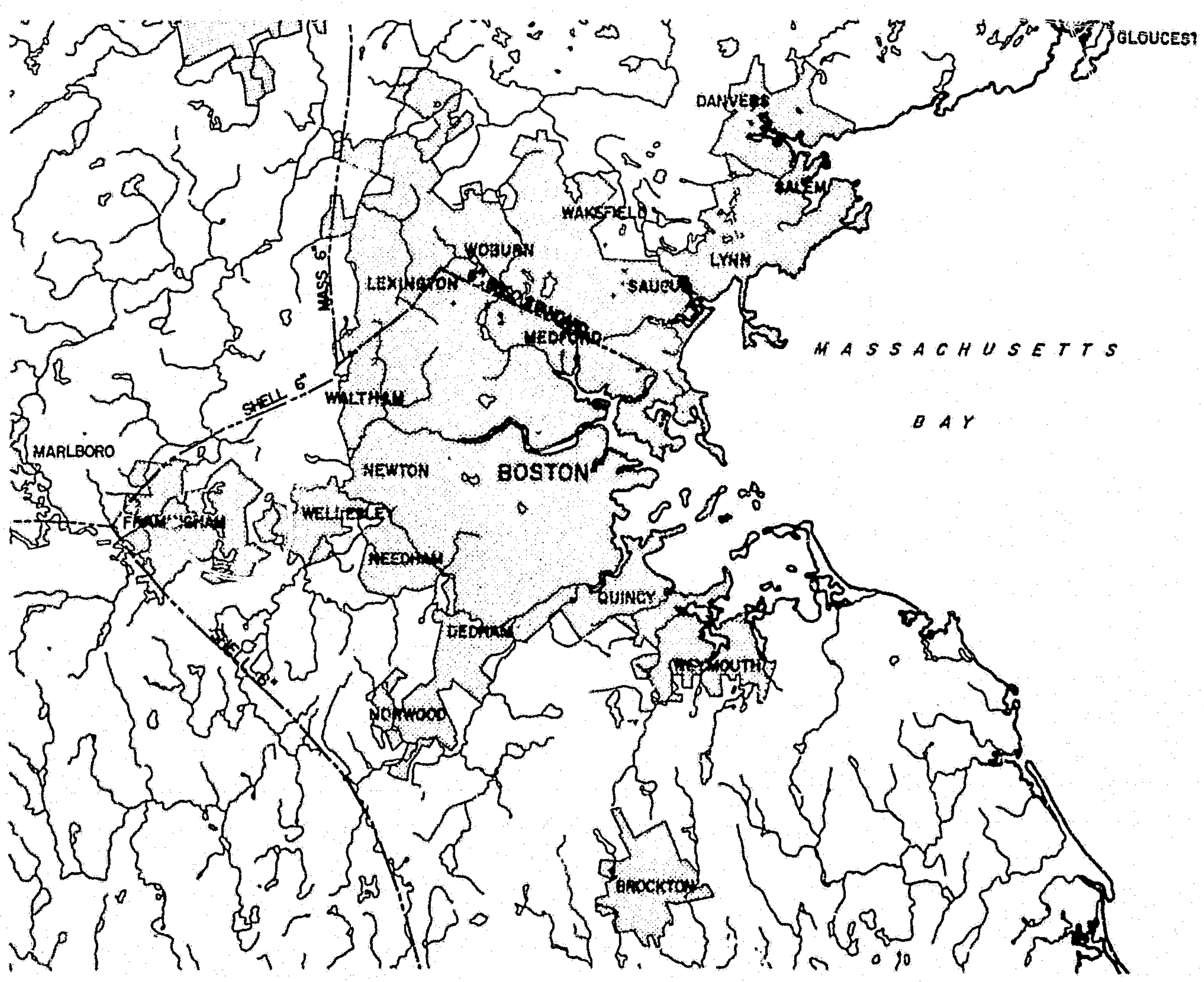
Location **Massachusetts**

Client **Boston Edison Company**

Year **1976–1977**

A preliminary study to identify potential sites for underground pumped storage (UPH) and compressed air storate (CAES) facilities for installed capacities of 500 and 2000 MW to serve the Boston Edison system.

The study included collection of data and a comprehensive examination of the geology of Eastern Massachusetts. Consideration was given to potential sites in the sedimentary rocks of the Boston Basin as well as the more competent granitic rocks to the north and west. Siting criteria were established and potential sites were selected and ranked taking into account geological conditions, surface conditions, and environmental impact. Estimates of capital costs, operating costs, and preliminary construction schedules were prepared for the highest ranking sites. The study also included preparation of a detail engineering program for optimization and site exploration leading to license application for the selected site or sites.



July 1978

RESEARCH PRIORITY STUDY FOR UNDERGROUND PUMPED STORAGE

P4155

Location **Palo Alto, California**

Client **Electric Power Research Institute**

Year **1975**

A study designed to examine the technical and financial aspects of underground pumped storage which require research to confirm their viability and to provide the level of confidence necessary to encourage further development of the concept.

The study includes a review of all available material dealing with underground pumped storage. Potential areas of research required to bring the concept to demonstration plant stage are listed and were reviewed with utilities and manufacturers. The results of the study are presented in a comprehensive report to EPRI.

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UNDERGROUND PUMPED STORAGE STUDY P2969, 2892

Location **Muskingum, Ohio**

Client **American Electric Power Service Corporation**

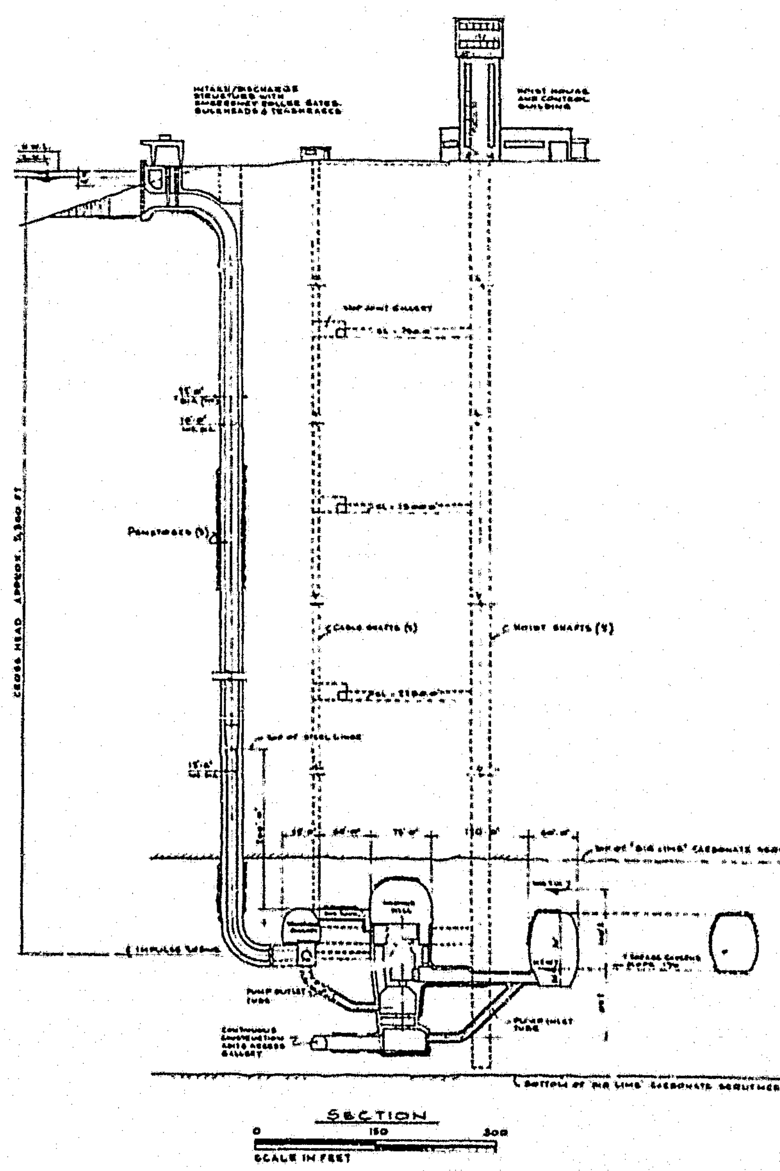
1972

Value **$434,000,000** (Approximate capital cost)

Two reports (Phase 1 — Preliminary, Phase 2 — Technical and Economic Assessment) of the feasibility of the construction of an underground pumped storage development at Muskingum, Ohio.

Feasibility study of an underground pumped storage plant to develop a gross head of approximately 3,300 feet between the surface pond and a lower reservoir to be excavated in a selected stratum of the Big Lime sequence. Installed generating capacity of 2,500 Mw operating for a daily 10-hour generating cycle.

The study included preliminary layout and sizing of the plant to house twelve separate pumps and turbines rated at 208 Mw. The study examined access, construction techniques, scheduling and equipment handling and installation. A detailed estimate of cost was developed for the project for comparison with conventional surface-type pumped storage.



ICE ENGINEERING CAPABILITIES

ICE ENGINEERING

Acres has extensive experience in appraising ice conditions in streams and waterways and in designing structures to cope with severe ice conditions. Four main areas of investigation are prominent in the projects which have been carried out. These relate to Thermal Regime, Mechanical Regime, Ice Forces and Ice Navigation.

THERMAL REGIME

The evaluation of heat transfer and temperature changes affecting lakes and streams is fundamental to appraisal of the ice conditions which will prevail. Much of this work has been carried out to predict dates of freeze-up, ice thicknesses, outflow temperatures or rates of ice production associated with reservoirs and the natural and man-made channels of northern hydroelectric power developments. These studies are complemented by Acres work on thermal input to the Great Lakes and dispersion of waste heat from thermal power stations.

MECHANICAL REGIME

Flow mechanics and the mechanics of materials determine the form which ice will take in the location of interest. The combined thermal/mechanical development of an ice cover on flowing water may involve

- growth of sheet ice over quiescent areas
- ice crystal formation at the surface of rapidly flowing water
- transport and deposit of frazil ice crystals and slush ice at the surface and under an established ice cover
- growth of border ice along stream banks
- progression of the ice cover upstream by arching or thickening and ice staging
- consolidation, shoving and freezing of the cover under hydraulic and wind loads
- erosion and melting of selective channels through the established cover
- break-up, melting and dispersal of the ice, sometimes involving jamming, during warming weather and increasing flows
- on lakes and at sea, the effects of the wind dominate in establishing a mechanical regime involving sheet ice, pressure ridging and rafting, and high pile-up on headlands. Tidal areas are subject to special ice forms.

Projects in which the mechanical regime was a principal factor have primarily been those in which changes to a river channel were proposed, an ice jamming problem was analyzed, or the effectiveness and effects of ice control measures were evaluated.

ICE FORCES

Forces imposed on structures or ice control works such as booms are related to the mechanical ice regime, the physical properties of ice and the setting in which interaction with the ice occurs. Forces may involve

— thermal expansion of the sheet ice

— impact of floes of sea ice several miles in extent

— wind and water forces on an ice jam

— the weight of grounded ice ridges.

Projects in which ice forces have been prominent among the governing design criteria are

— offshore drilling platforms and light piers

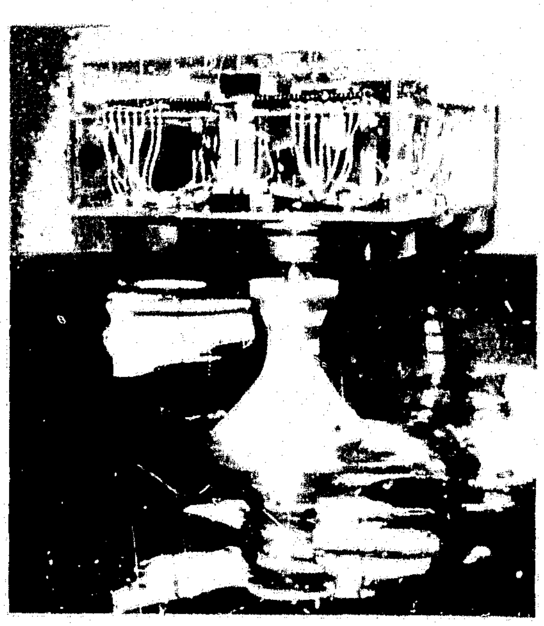
— bridge caissons in water depths of up to 100 feet

— spillway piers and gates

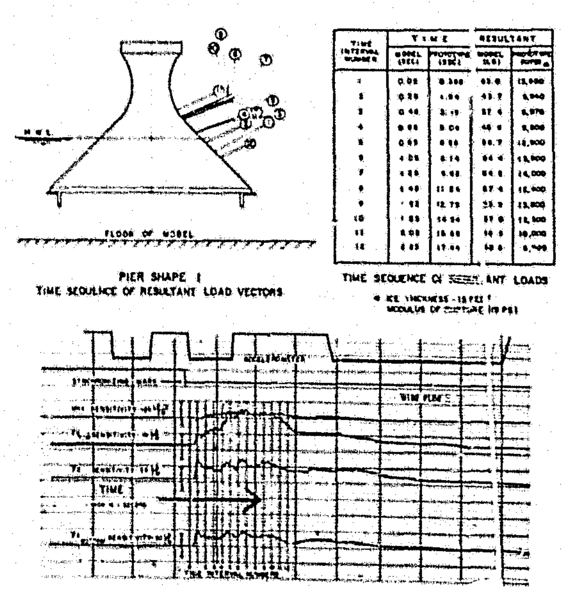
— flood control gates

— ice control booms.

Methods of determination of ice forces have included scale model simulation of ice loading situations and the application of finite element methods and advanced concepts of fracture mechanics.



DYNAMOMETER AND MODEL PIER

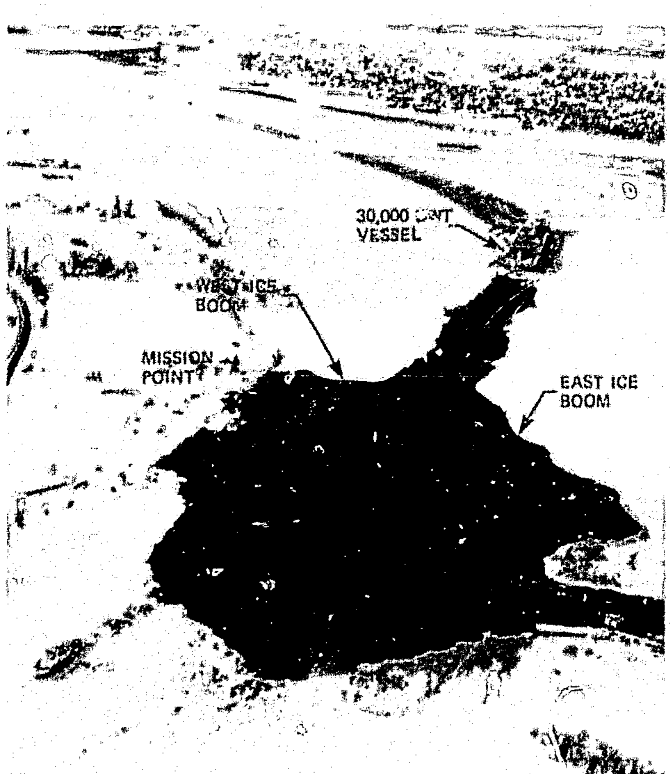


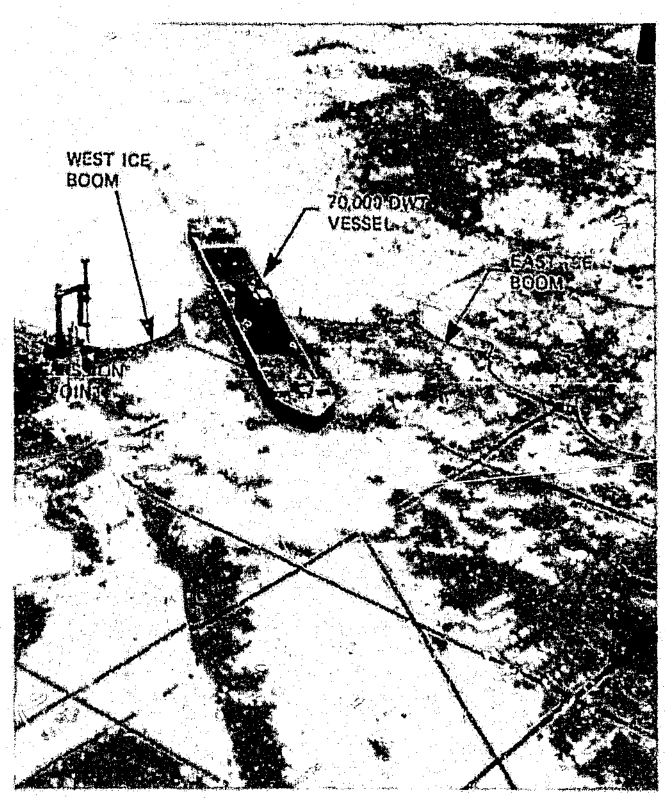
LOAD SEQUENCE FOR A WIDE FLOE

ICE NAVIGATION

Studies of prevailing ice conditions and the ability of various classes of vessels to cope with them have been central in a number of navigation projects. Although specialized vessels can make passage through polar seas, ice in temperate latitudes remains a very serious seasonal hindrance to more conventional vessels.

Ice navigation studies have been oriented to appraisal of new routes and to seeking means of extension of the navigation season on existing routes. Data from systematic aerial reconnaissance of ice conditions in most Canadian waters provide a statistical basis for analysis. Field surveys, hydraulic model tests and computer simulation are employed in resolving specific questions.





PRINCIPAL ICE ENGINEERING PROJECTS

Project Number	Project	Client	Description
P5312	Nuclear Icebreaking LNG Tankers (1979)	Petro-Canada	Conduct preliminary studies relating to the application of nuclear steam plants in LNG tankers.
P5260	Fort McMurray Ice Control Studies (1978)	Alberta Environment	Evaluate and select best remedial works concepts for ice control.
P5100	Ensemble of Ice Force-Time Histories (1978)	Confidential	Comprehensive literature review and compilation of ice-force measurement programs.
P4970	Assessment of Ice Boom Effects (1978)	State University of New York at Syracuse For New York State Department of Environmental Conservation and the U.S. Corps of Engineers	Evaluate the ARCTEC Inc. physical model of ice control booms in the St. Lawrence River to establish its ability to provide information for evironmental assessment. Make an analytical appraisal of changes in the hydraulic and ice regimes to permit an environmental assessment.
P4914	Bridport Inlet Ice Management Study (1978)	Petro-Canada	Establish the feasibility of management of Arctic sea ice at a proposed LNG terminal.
P4617	St. Marys River Generating Station Redevelopment (1978)	Great Lake Power Corporation Limited — Utilities Division	Design of facilities (ice boom, ice sluice and intakes) to permit the ice-free operation of a head-race channel as part of an overall hydroelectric generating station redevelopment in Sault Ste. Marie, Ontario.
P3912	Limestone Generating Station — Nelson River (1977)	Manitoba Hydro	Technical direction of physical hydraulic model study of ice management during construction of the project.
P4298	Saint John River Flooding (1976)	The New Brunswick Electric Power Commission	A study of the events leading to ice jam flooding on the Saint John River in the spring of 1976.
P4226	Bell Island Oil Storage Project (1976)	Wabanex Ltd.	A study of the effects of sea ice conditions on the feasibility of supertanker navigation to a major crude oil storage facility in Conception Bay, Newfoundland.
P3901	Gull Island Hydro Electric Project (1975)	Gull Island Power Company	Field observations, analysis and hydraulic model studies to evaluate the effects of severe winter ice conditions on river diversion.
P3855	St. Mary's River Ice Model (1975)	United States Army Corps of Engineers	A research and study program to develop feasible solutions to problems created by the frequent ice build-up in the narrow navigation channels on the St. Mary's River.

Principal Ice Engineering Projects — 2

Project Number	Project	Client	Description
P3912	Limestone Generating Station — Nelson River (1975)	Manitoba Hydro	Calculations to predict the ice regime and flow levels during construction of the project.
P3885	Northen Staging Area (1975)	Northcan/Canadian Arctic Gas	Study of flooding related to ice jamming of potential wharf sites on the Hay River and Upper Mackenzie River.
P3663	Churchill River (1975)	Manitoba Hydro	Calculations to predict the ice regime and flow levels following diversion of power flows through the Rat River — Burntwood River system. [1]
P3396	Lake Erie — Niagara Ice Boom (1974)	International Niagara Board of Control	Extended study of the environmental effects of use of the ice boom at the head of the Niagara River. [2, 3]
P3495	System study to extend the winter navigation season on the St. Clair and Detroit rivers (1974)	United States Army Corps of Engineers	Study of the ice problems encountered by shipping during winter navigation and evaluation of alternative measures for extending the ice season.
P3344HM	St. Lawrence Marine (1973)	CECOP Company Limited	Feasibility and hydraulic model study for constructing a terminal for tankers. Included were simulations of the effects of both tidal current and winds on ice movements and mathematical simulation of vessel delays caused by ice conditions. [4]
P3176	Arnprior Generating Station (1972 — 1975)	Ontario Hydro	Design of ice boom and other control works. Basic data were derived from detailed ice observations employing air cushion vehicles and from hydraulic model tests.
P2999	Long Spruce Generating Station (1971)	Manitoba Hydro	Calculations to predict the ice regime and flow levels during construction of the project.
P2904	Study of Lake Erie Ice Boom (1972)	Water Survey of Canada	Study of the effect of the Lake Erie ice boom on ice retention and dissipation in Lake Erie.
P2614	Offshore Structure Study (1971)	Bow Valley/Acres Santa Fe—Pomeroy	Feasibility study of exploratory drilling platforms to be used in the Beaufort Sea.

1 S. T. Lavender and J. E. Cowley. Convective Heat Transfer at an Ice Water Interface. NRC Research Seminar on the Thermal Regime of River Ice. Laval University, 1974

2 Acres Report published by the International Joint Commission, 1974.

3 R. R. Rumer, C. H. Atkinson, and S. T. Lavender. Effects of Lake Erie—Niagara River Ice Boom on the Ice Regime of Lake Erie. Third International Symposium on Ice Problems, Hanover, New Hampshire. 1975.

4 J. E. Cowley. Quantitative Application of Ice Climate Data to Winter Navigation Studies.

ACRES

Principal Ice Engineering Projects — 3

Project Number	Project	Client	Description
P2330	Arctic Marine Terminal Module (1970)	Van Houten Assoc. Inc. for Esso Research and Engineering Company	Review of the proposed design for a marine terminal module to be used for the collection of environmental data and as a loading terminal for ice-breaking oil tankers.
R40	Study of Offshore Drilling Structures (1970)	Acres Limited	Conceptual engineering studies for offshore oil drilling platforms operating in slow-moving pack ice.
P2084	Study of the Effects of Thermal Inputs to the Great Lakes (1970)	Government of Canada Department of Energy, Mines and Resources	Study of the sources, amounts and results of heated effluent discharges into the basin of the Great Lakes.
P2113	Ice Forces Measuring Systems (1969)	Government of Canada Department of Transport	Design, supervision of installation and commissioning of a system f measuring ice forces on lighthouses of various shapes.
P1140	Mactaquac Hydro Electric Project (1969)	The New Brunswick Electric Power Commission	Study of the mechanism of ice jams in the Saint John River above the Mactaquac Hydro-Electric Power Development. [5]
P2065	Evaluation of Ice Research Benefits (1969)	Government of Canada Department of Energy, Mines and Resources	Studies of the theory and nature of ice, its effect on various structures, the economics of ice control and preparation of a program for ice research. [6]
P1432	Kettle Rapids Generating Station (1968)	Manitoba Hydro	Studies of the ice break-up in the Nelson River and the passage of ice through the powerhouse openings during construction. (Included field observations, physical modeling and analytical assessment.) [7]
P1520	Churchill Falls Power Project (1968)	Churchill Falls (Labrador) Corp.	Study of the mechanism of formation, nature and behavior of ice covers, in a reservoir system and prediction of its effects on operation. [8]
P1000	Northumberland Strait Crossing (1967)	Government of Canada	Measurement of the forces exerted by ice floes on fixed structures in the field in conjunction with an extensive scale model study of ice forces on various pier shapes. [9]

[5] C. H. Atkinson. 1968 Ice Jam on the Saint John River Near Hartland, New Brunswick. Presented at the Seminar on Ice Jams in Canada, May 1973. NRC Technical Memorandum No. 107, Ottawa, July 1973.

[6] C. H. Atkinson, Problems and Economic Importance of Ice Jams in Canada. Presented at the Seminar on Ice Jams in Canada, May 1973. NRC Technical Memorandum No. 107, Ottawa, July 1973. Reprinted and published by the Department of Public Works of Canada.

[7] E. G. Macdonald and H.R. Hopper. Hydraulic Model Simulation of Ice Jamming During Diversion of the Nelson River. Awarded the Keefer Gold Medal of the Engineering Institute of Canada for 1972. Presented by C. H. Atkinson at the Seminar on Ice Jams in Canada, May 1973.

[8] C. H. Atkinson and T. Waters. Ice Regime at Churchill Falls, Labrador — A Comparison of Design Expectations with Actual Performance. Presented at the Symposium on Ice Problems, Lulea, Sweden, August 1978.

[9] J. E. Cowley. Ice Model Studies for the Northumberland Strait Crossing.

ACRES

Principal Ice Engineering Projects — 4

Project Number	Project	Client	Description
R53	Development of Model Ice Material (1966)	Acres Limited	Development of model ice material for use in a structural hydraulic model.
P1111	McCormick Dam Project No. 3 (1965)	Manicouagan Power Company	Prediction of ice formation in the forebay and winter water temperatures due to sequential development of upstream reservoirs.
P867	Mactaquac Hydro-electric Project (1962)	The New Brunswick Electric Power Commission	Prediction of ice conditions and the risk of ice jamming in the city of Fredericton following dam construction.
P826	Grand Rapids Generating Station (1960)	Manitoba Hydro	Study of ice conditions in Cedar Lake and prediction of winter temperature in the forebay. Probability analyses were made on the formation of ice cover in the forebay channel and of ice jams in the tailrace.
P776	Outardes and McCormick Power Development (1959)	Manicouagan Power	Study of the frazil ice conditions in the McCormick forebay. [10]
P724	Kelsey Generating Station (1957)	Manitoba Hydro	Study of the ice conditions to be expected in the forebay of the power station.
P608	Bersimis 1 Power Station (1955)	Quebec Hydro	Investigation of the formation of an ice cover in the forebay channel and the effect of heat storage in the water of the Lac Casse Reservoir.

10 O. M. Erickson, R. N. Millman and R. L. Clinch. Ice Problems at McCormick Dam — Tests on a Pilot Bubbler System.

ACRES

NUCLEAR ICEBREAKING LNG TANKERS

P5312

Client Petro-Canada Limited

Location Alberta

Exploration of the Canadian High Arctic in recent years has located substantial amounts of natural gas in the vicinity of Melville Island and in other areas. Methods of transporting the gas to markets in North America have been studied and the optimum solution under present circumstances appears to lie in the use of large icebreaking LNG tankers on a year-round basis. The venture is being planned by Arctic Pilot Project, a joint undertaking by Petrocan, Alberta Gas Trunk Line Co. Ltd., and Melville Shipping Ltd.

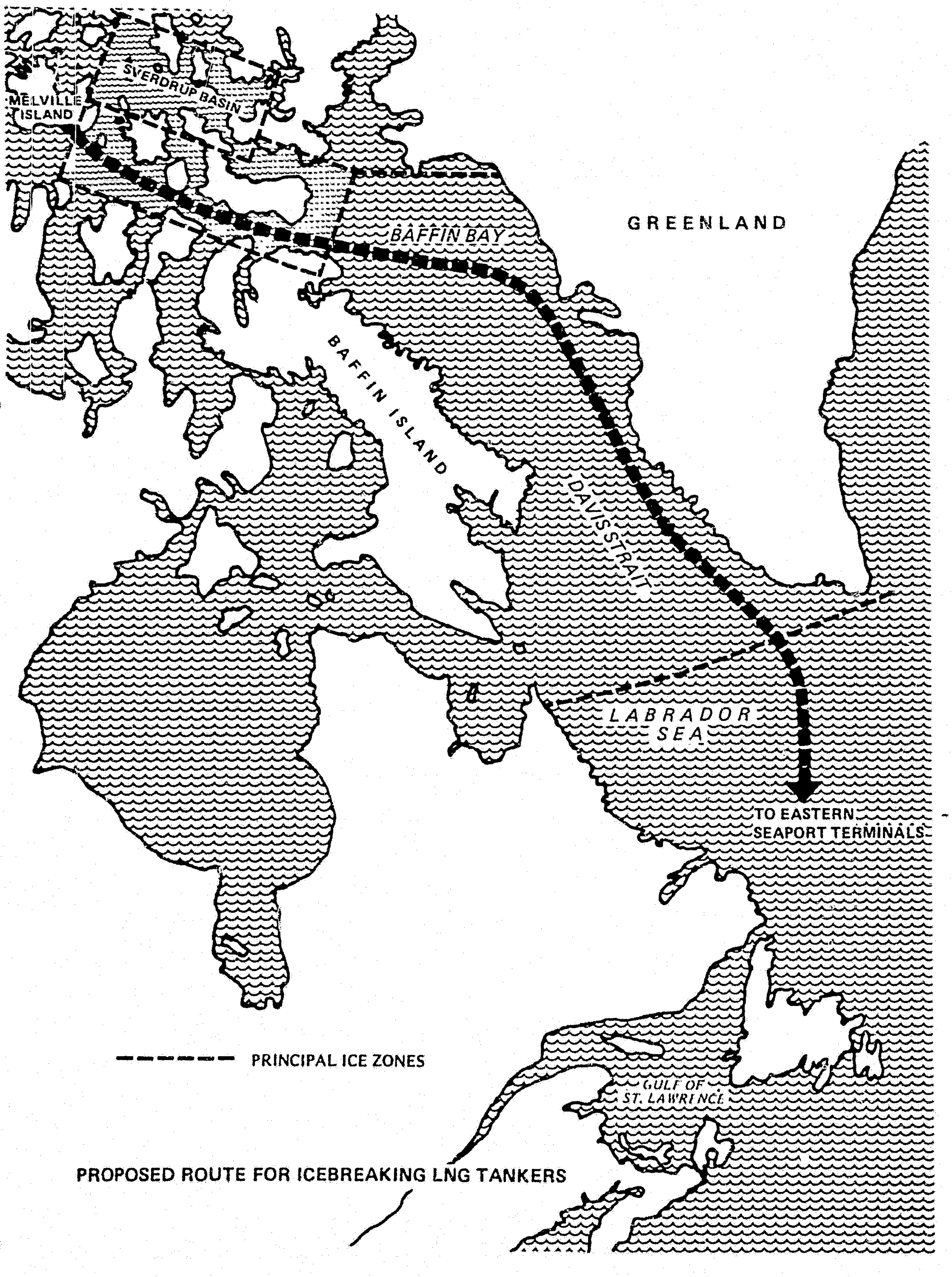
The initial scheme basically involves the construction of a pipeline from the gas fields to a barge-mounted liquefaction plant at Bridport Inlet on the south side of Melville Island (Ice management studies for this terminal are being carried out by Acres, Niagara Falls). The liquid natural gas would be loaded into tankers at a temperature of $-170^{\circ}C$ for transportation to ports on the east coast of North America.

Present plans envisage the construction by 1983 of two gas-turbine powered, electrically-driven icebreaker tankers each capable of maintaining 5 knots through 2.2 m of ice using 190,000 shaft horsepower, and carrying 140,000 m^3 of liquid natural gas (about 3 billion scf of gas).

These tankers may be augmented in the future by nuclear-propelled versions provided that this can be demonstrated to be technically and economically feasible. In January 1979, Acres were asked by Petrocan to conduct preliminary studies relating to the application of nuclear steam plants in these vessels.

Acres studies involve the consideration of existing nuclear marine reactor designs and the selection by Acres of the nuclear plant best suited to Petrocan's requirements. The work consists of a broad state-of-the-art survey of nuclear marine propulsion and available reactor designs, followed by a more detailed assessment of marine reactors that may be suitable for this application.

ACRES



PROPOSED ROUTE FOR ICEBREAKING LNG TANKERS

ICE CONTROL STUDIES

P5260

Client **Alberta Environment**

Location **Fort McMurray, Alberta**

Ice jams, characteristics of spring breakup in the reach of the Athabasca River, result in the increase in river levels causing intermittent flooding of lower Fort McMurray.

In this study all possible ice control measures were reviewed, and the suitability of each to alleviate the flooding problem was evaluated. The schemes were assessed based on the estimated effectiveness of these concepts, capital and annual cost, and their potential for conflict or combination with other river uses. Based on documentation of successful applications in other cases, and on the climatic, hydrologic and hydraulic characteristics of potential control sites on the Athabasca River, the best remedial works concepts were selected.

Conceptual engineering designs and cost estimates were developed. Final recommendations were made for more detailed site investigation and for an overflow weir/sluice, which will retain ice upstream from the townsite, to eliminate jamming.

ACRES

COMPILATION OF ICE FORCES AGAINST STRUCTURES

P5100

Client Confidential

1978

A study was conducted to develop an ensemble of ice force-time histories, generated from full-scale measurements on structures and small-scale laboratory tests.

The study involved a comprehensive literature review of ice-force measurement programs. Following compilation of a compendium of published ice-force measurements, reseachers were contacted and original data records obtained.

A representative sample of records was selected for each of a number of different ice-structures interaction types. Detailed data were gathered regarding related ice strength, temperature, crushing velocity, etc. This data was then recorded on tape along with digitized points from the ice-force measurements. The objective of this data digitization was to assemble a data base of structural design parameters and to enable further analysis and stochastic generation of artificial ice-force records.

ACRES

ICE STUDY FOR ST. LAWRENCE RIVER

P4970

Client: State University of New York
College of Environmental Science and Forestry for
New York State Department of Conservation, and
U.S. Corps of Engineers

Location: St. Lawrence River

Particular attention has been paid to the interface between the ice cover and critical habitats such as shoals and wetlands.

Hydraulic/ice model simulation and evaluation studies have been conducted. The purpose of the study has been

- to assess the potential ability of the proposed physical model and testing program to provide hydraulic and ice regime data necessary for environmental assessment, and
- to assess the possible outcomes of boom modifications and ice breaking on the hydraulic/ice regime and environment of the St. Lawrence River.

This latter task has been accomplished by means of analyses with available analytical techniques in combination with information of the St. Lawrence River in winter and the known influence of ice booms on river ice conditions elsewhere.

ACRES

LIMESTONE GENERATING STATION – ICE STUDIES P3912.01

Client	**Manitoba Hydro**
Consortium	**Crippen Acres Limited**
Location	**Nelson River, Manitoba**

Engineering for a complete hydroelectric power development having 10 generating units, each with a rating of 110 MW under a design head of 27 m. The first power is scheduled for 1984 with the final unit expected to go on line in 1986.

Under natural conditions at the site, ice jams up to 12 m in thickness form and raise water levels 13 m above summer stages. The work therefore included extensive studies of the probable effects of ice jams on the heights of cofferdams required in the two stages of river diversion during construction.

A mathematical computer model of ice processes in the Nelson River was developed initially for the preliminary studies. Later, detailed designs were based on a hydraulic model test program devised and supervised by Crippen Acres. The ice levels observed during the first year of construction compare closely with calculated and hydraulic model predictions.

ACRES

GULL ISLAND HYDROELECTRIC PROJECT
ICE STUDIES

P3901.11

Location Churchill River, Labrador

Client Gull Island Power Company

1975

Field surveys were undertaken to establish the interrelationship of the hydraulic, hydrologic and ice regimes of the natural river. Observations of development and dissipation of the ice cover and water levels were made in a 25-mile reach of the Churchill River from Gull Lake to about 20 miles upstream of the site of the proposed Gull Island power project over two winters, 1974—1975 and 1975—1976. Heavy ice conditions with staging in excess of 20 feet above the summer rating prevail in the lower reaches of the study area.

Hydraulic model tests of the river diversion planned for the project and ice stability analyses were combined in assessing the best approach to ice handling during construction. The requirements for regulating upstream water levels to maintain a stable ice cover were determined. It was concluded that the benefits of upstream control would not justify the cost of regulating gates. Cofferdam heights to allow for uncontrolled ice staging through the tunnels were established.

ST. MARY'S RIVER ICE MODEL

P3855

Location Sault Ste. Marie, Michigan

Client U.S. Corps of Engineers

1975

This project was part of a research and study program to develop feasible solutions to problems created by frequent ice buildups in the narrow channel between Sault Ste. Marie, Michigan and the area below the Little Rapid Cut area of the St. Mary's River, Michigan.

Broken and frazil ice float downstream into the cut. The resulting ice jams restrict commercial vessel passage and prevent regular ferry transportation to and from the mainland for the two hundred families who live on Sugar Island, located in the channel.

The model, verified against field observations, simulated the effects of relocating the ferry crossing, widening of the riverbed, the use of ice control booms and ice harvesting methods, the creation of ice-flow diversions and ice suppression systems.

The model riverbed and shoreline forms a Y shape in an area 120 feet by 200 feet, includes a model vessel, and utilizes specially treated polypropylene pellets to simulate ice.

The influence of discharges from power canals and industry, the effects of changes in ice supply due to vessel passage, the effects of size, various wind conditions and the impact of vessel size and speed on ice jamming and accumulation were studied.

Remedial measures recommended as a result of the study and put into service in the winter of 1975/76 have proven highly successful.

Location St. Clair and Detroit Rivers

Client U.S. Army Corps of Engineers

1973

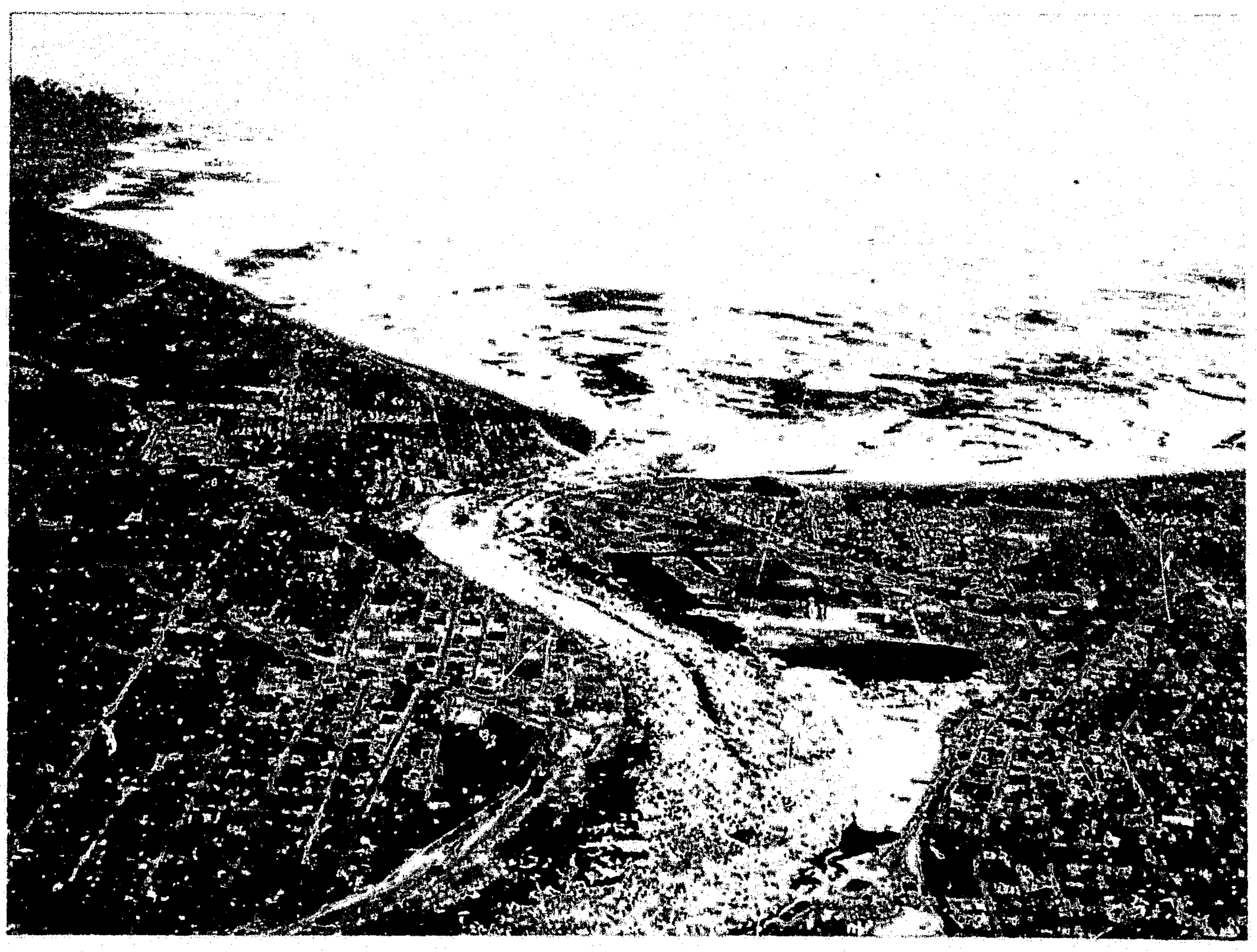
A study to determine what enabling measures would be necessary to extend the navigation season between Lake Huron and Lake Erie. Ice conditions, climatological and hydrological conditions, hydraulic characteristics of channels, and operating characteristics of vessels were investigated and the information used to develop design criteria for enabling measures.

Vessel operating capabilities in ice covered waters were developed as the key factor in the study. Design winter conditions were established from analyses of available data and problem reaches in the area were defined by relating these conditions to the vessel operating capability.

The enabling measures recommended included ice-breaker assistance, ice booms, pile clusters and air bubbler systems. These measures would permit year-round navigation.

Capital costs and annual operating costs for the selected scheme were developed.

A complete environmental assessment evaluating all relevant environmental, social and recreational factors in the study area resulting from the extended season navigation was also undertaken.



SITE INVESTIGATIONS FOR DEVELOPMENT OF A ST. LAWRENCE MARINE TERMINAL

P3344H

Location Grande Ile, St. Lawrence Estuary, Quebec

Client CECOP Company Limited:
Ashland Oil Canada Limited
New England Petroleum Company Limited

In support of a study of the feasibility of constructing a terminal for 300,000-dwt tankers at Grande Ile, site investigations were carried out to establish:

- tidal current conditions
- ice conditions
- local bathymetry
- geological conditions

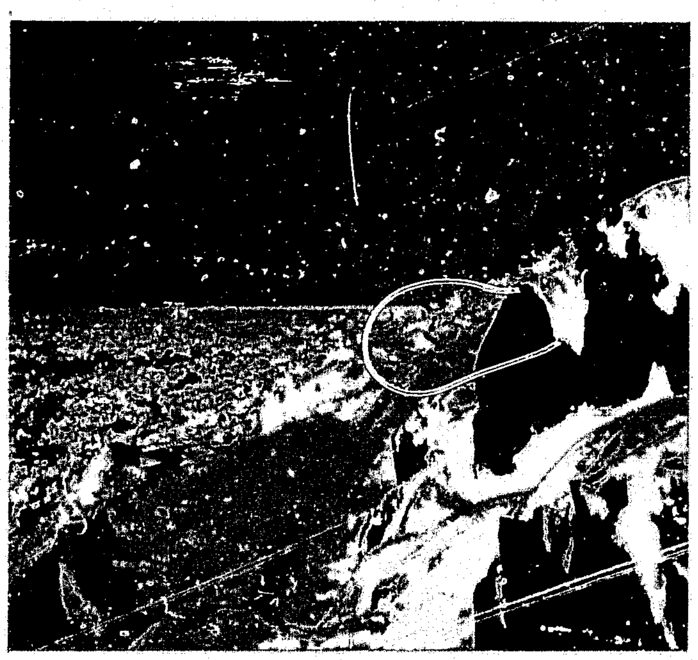
The field investigations supplemented analyses of regional and local climate, ice conditions, bathymetry, clearances, tides and currents along the approach route. They provided the more detailed knowledge required in the vicinity of the proposed terminal.

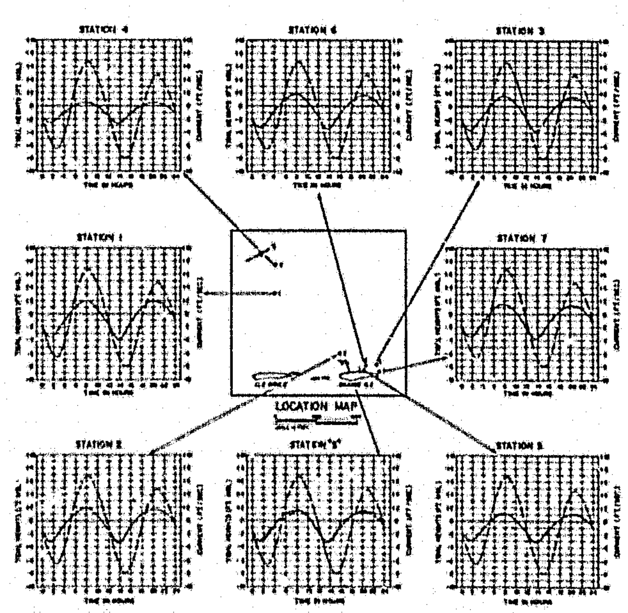
The tidal range at Grande Ile varies from 4 to 19 feet. The structure of adjacent tidal flows was established by measurement, over a period of 18 days of velocity and temperature/salinity relationships throughout the depth of the estuary at 8 stations. Details of surface eddies were established from shipboard observations, time-lapse aerial photography and simulation of flows in a hydraulic scale model.

Ice conditions were evaluated by field observations, aerial reconnaissance and mapping, and by detailed analyses of Ice Central records.

Bathymetry and underwater geologic structure were established by sounding and seismic surveys.

Geological conditions were established by reconnaissance, mapping, drilling, and laboratory analysis of samples.





CURRENTS RESULTING FROM MODERATE TIDES

HYDRAULIC MODEL STUDY FOR
A ST. LAWRENCE MARINE TERMINAL

P3344HM

Location Grande Ile, St. Lawrence Estuary, Quebec

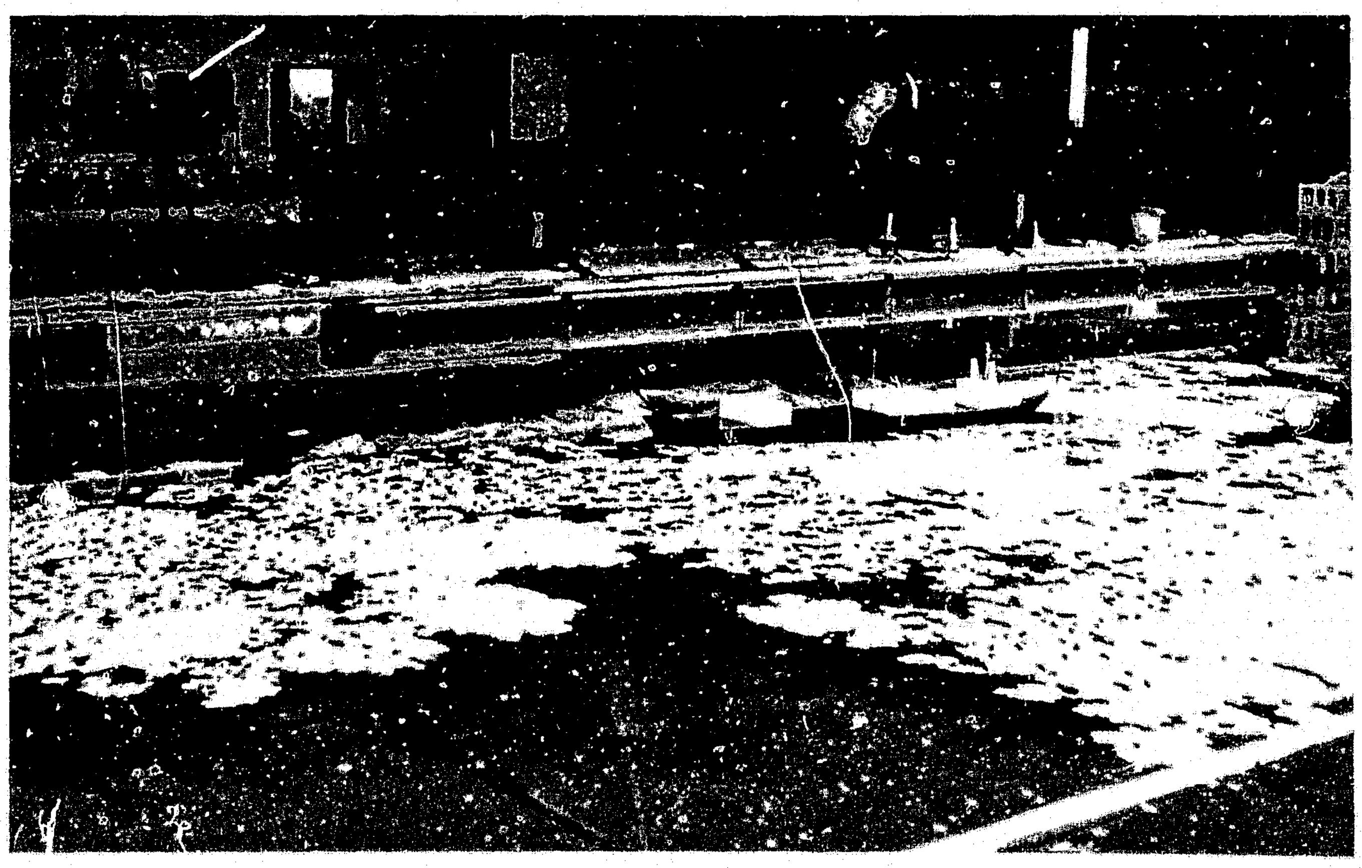
Clients CECOP Company Limited
Ashland Oil Canada Limited
New England Petroleum Company Limited

In support of a study of the feasibility of constructing a terminal for 300,000-dwt tankers at Grande Ile, a hydraulic model study was undertaken to establish

the effects of various structural alternatives on tidal currents in the approaches to the ship berths. The tidal range at the site is 18 feet and currents of up to 3 knots are experienced in the area.

the effectiveness of various alternatives for protecting the berths against floating ice fields without causing unfavorable changes in currents.

The model reproduced an area 1.3 by 2.6 miles at a scale of 1:200. A radio-controlled model of a 300,000-dwt vessel of 1,200-foot length and 50-foot draft was employed. The effect of tidal currents and winds on ice movements was simulated. Different arrangements of ice booms and ice control structures placed at each end of the docking area were compared. Skimming booms which restricted longshore ice movement without appreciable influence on strong tidal currents proved the most effective.



ICE STUDIES FOR EXPLORATORY DRILLING SYSTEM

P2614

Location Beaufort Sea

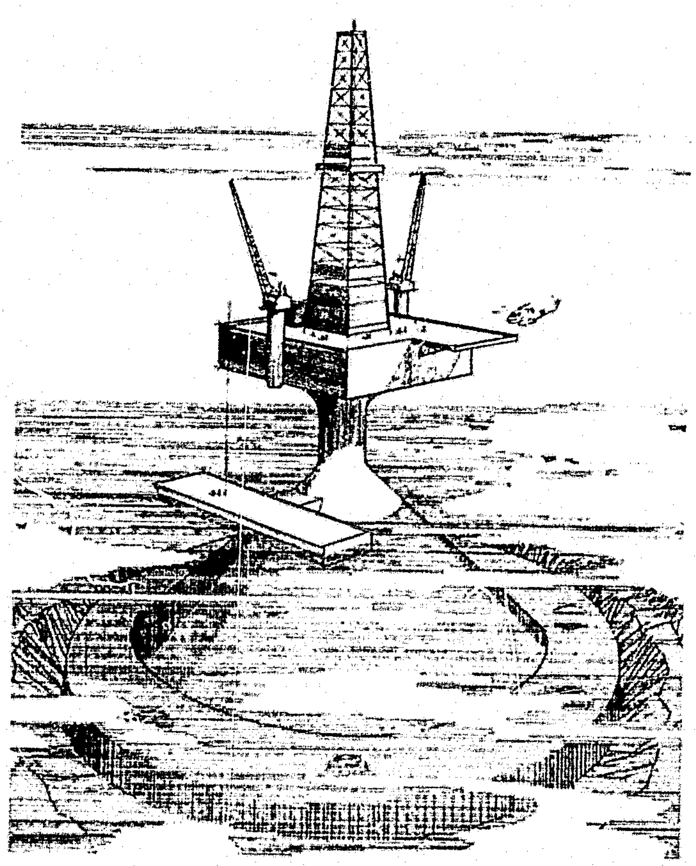
Client Arctic Petroleum Operators Association

1971

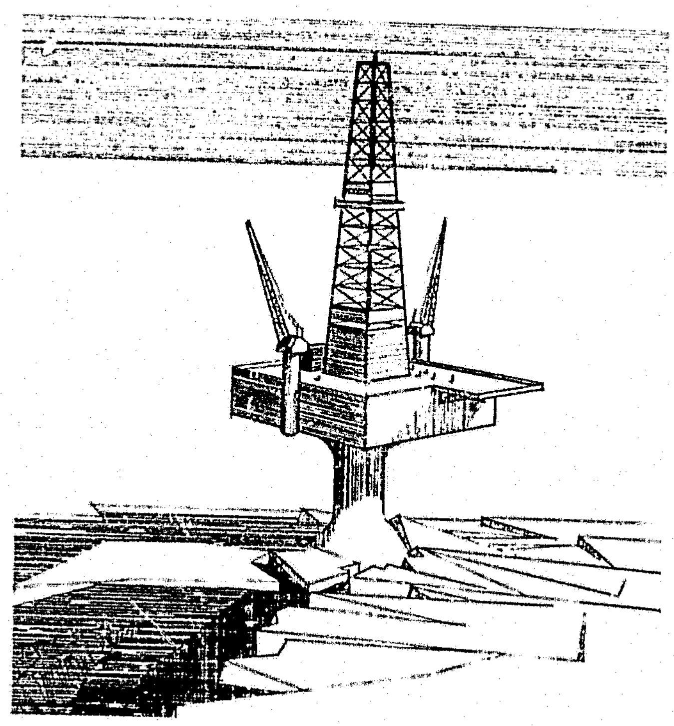
As part of an investigation of potential methods of exploratory offshore drilling in the Beaufort Sea, one area of major concern was the potential for ice damage to the drill platform.

An extensive review of available data from observations of the ice pack, controlled field testing and laboratory testing, as well as various theoretical analyses, were used to determine design loads for various structure types during both summer and winter conditions.

As part of this ice study the existing ice reconnaissance data was analyzed, and maps prepared with contours indicating annual periods with various probabilities of exceedance for a range of ice conditions. These maps give a picture of the ice conditions over the area of interest, in terms that can readily be translated into the statistics, describing the frequency distribution for the number of days available for various types of platforms. The analysis included consideration of forecasting ability, and required monitoring to ensure that a well could be safely abandoned ahead of incoming ice and then continued after the ice moved out.



Summer Loading



Winter Operation

ICE MOVEMENT STUDY

P1140.11

Location Saint John River, New Brunswick

Client The New Brunswick Electric Power Commission

1969

Study of the mechanism of ice jam formation in the Saint John River above the Mactaquac hydroelectric power development to determine what operation schedules of this and associated developments might reduce or eliminate the formation of ice jams and the resulting flooding and loss of power production during the spring ice break-up.

The work included the assessment of the value of mathematical and physical models for the simulation of dynamic ice regimes. This portion of the study indicated that simulation by means of mathematical methods is possible and that physical models are of limited usefulness due, mainly, to their inability to reproduce thermal effects.

The work also included an outline of the field work that must be undertaken to obtain the data for the development of a working mathematical model of the ice regime.

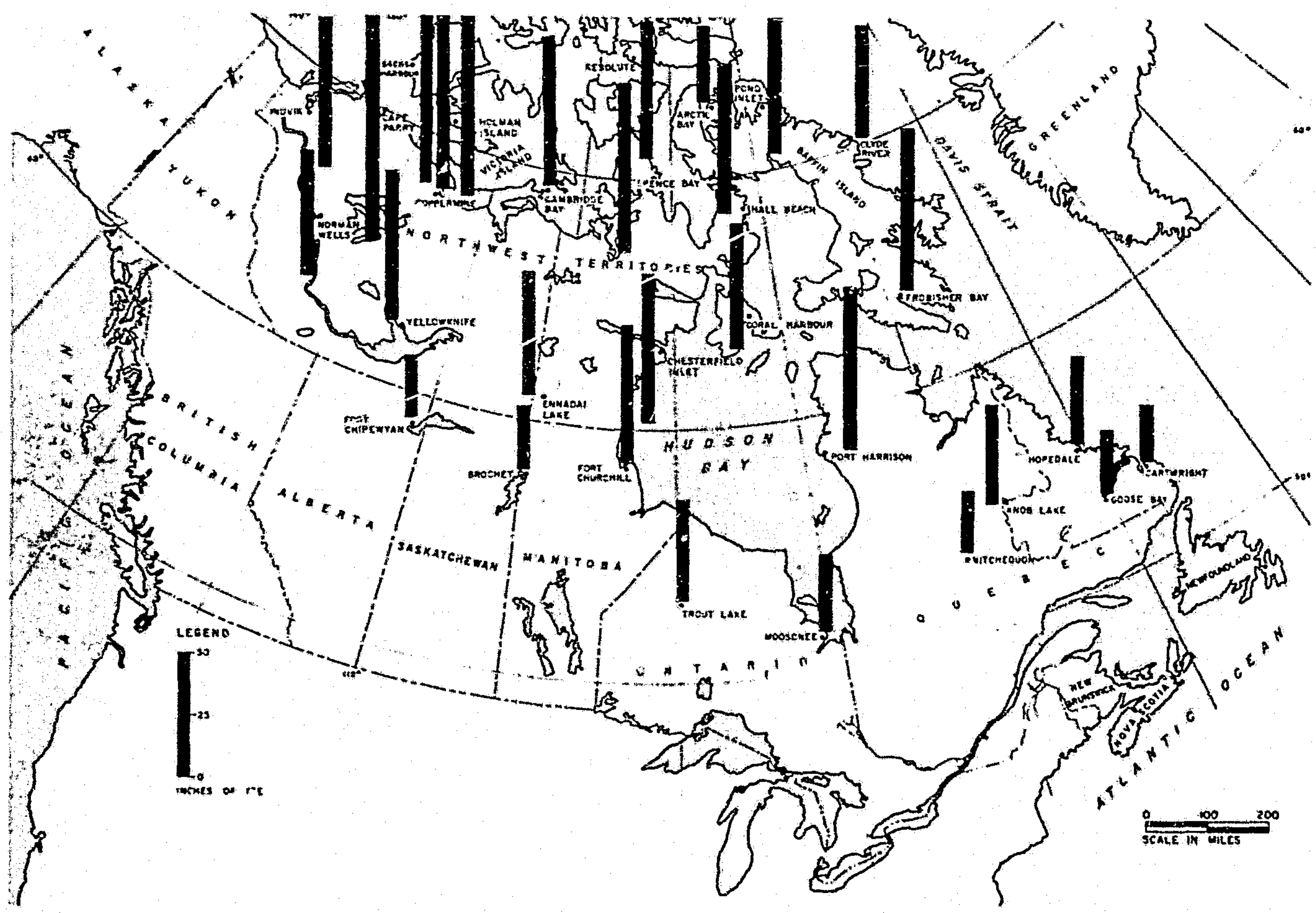
ACRES

EVALUATION OF ICE RESEARCH BENEFITS P2065

Client Government of Canada
Department of Energy, Mines and Resources

1969

Studies of the theory and nature of ice formation, the growth and decay of ice cover, the physical properties of ice, and the effects of ice on water control structures and waterways; evaluations of the economic aspects of ice effects on water control structures, water supply systems, navigation, climate ecology and water quality; reviews of the methods and economics of ice control; and preparation of a program for ice research, based on the greatest potential benefit scale.



Ice Thickness In Canada
(March 1966)

ARCTIC MARINE TERMINAL MODULE P2330

Location North Coast, Alaska

Client Van Houten Associates, Inc. for
Esso Research and Engineering Company

1969 – 1970

Independent review of the proposed design for a marine terminal module to be used initially for the collection of environmental data and possibly later as a mooring-loading terminal for ice-breaking oil tankers.

Location Northumberland Strait between New Brunswick and Prince Edward Island

Client Northumberland Consultants Ltd.
for Government of Canada

1967 – 1968

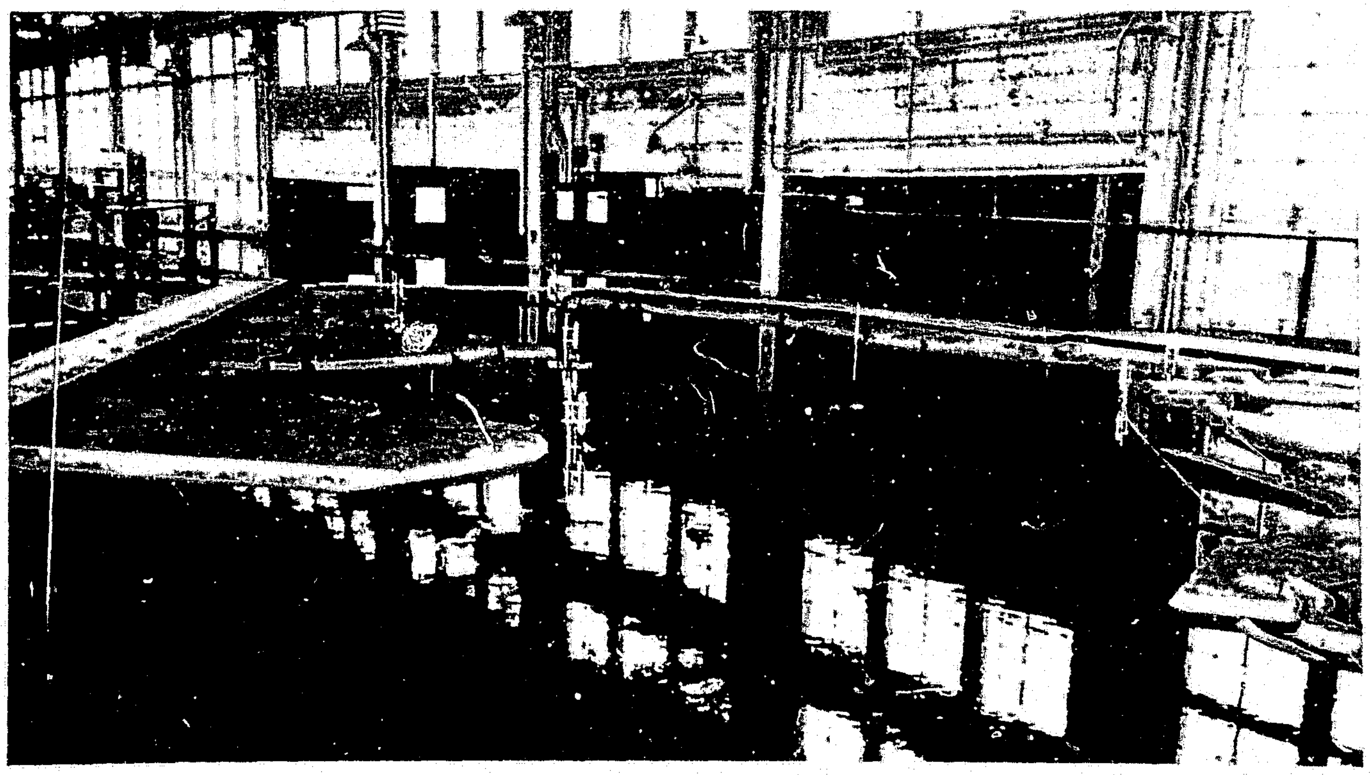
Engineering services were provided for the construction, calibration and testing of hydraulic models and apparatus to determine environmental changes which may have occurred to the tidal regime of the strait following the construction of a major crossing structure, and to investigate ice and wave forces likely to be encountered by the piers of the proposed crossing.

Tidal Model Study

The tests were conducted on a model having a vertical scale of 1:64 and a horizontal scale of 1:6400, and investigated the effects on the tidal regime of the strait that would have resulted from the construction of various types of structures.

Ice Floe Model Study

Tests were conducted on a model having a scale of 1:60; used a substance of special formulation which had appropriate mechanical properties to simulate the action of ice at the scale of the model and a dynamometer of special design which measured the forces on the model piers. The tests determined the magnitude and direction of the forces due to ice floes on the piers of bridge-type structures and the mechanics of the break-up of ice floes.



Ice Floe Forces Apparatus

The apparatus consisted of a pair of hollow steel panels with relatively flexible walls and containing a pattern of hydraulic flat jacks equipped with pressure-sensing devices that produced oscillographs of the forces exerted by ice at various elevations over various periods of time on the vertical faces of the pier. The tests determined the forces exerted by a large ice floe when driven by strong winds against the end of a pier at Port Borden, Prince Edward Island.

Flume Model Study

The tests were conducted at a scale of 1:20 in the 65-foot long wave flume of Acres Laboratory, Niagara Falls, and were used to determine the most economic combination of dike freeboard, dike slope, primary precast concrete armor units and secondary riprap requirements to protect the rock-fill core of the causeway section of the crossing from the combined effects of a 20-foot design wave, currents resulting from partial closure of the strait that is affected by 8-foot tides, and the movement of large ice floes.

Wave Action Model Study

The tests were conducted on a model having a scale of 1:60 with a working basin 60 feet long by 20 feet wide. The model was equipped with two pneumatic wave generators, each 10 feet long, which were capable of simulating the three-dimensional action of wave trains and tidal currents on submerged structures; and it was used to determine the effects of wave action and tidal currents on the causeway ends and on the bridge piers.

Wave Amplitude Test Apparatus

The measuring apparatus consisted of an electronic circuitry cabinet and an electrode probe mounted on a mast, 50 feet in length, that was anchored to the ocean floor 1 mile from the shore. The sensing devices on the mast were connected by a seven-conductor submarine cable to a power source and chart recorder located on the shore. The apparatus was capable of measuring waves having a maximum amplitude of 20 feet, and was used to determine the amplitudes, lengths and patterns of the waves in the strait.

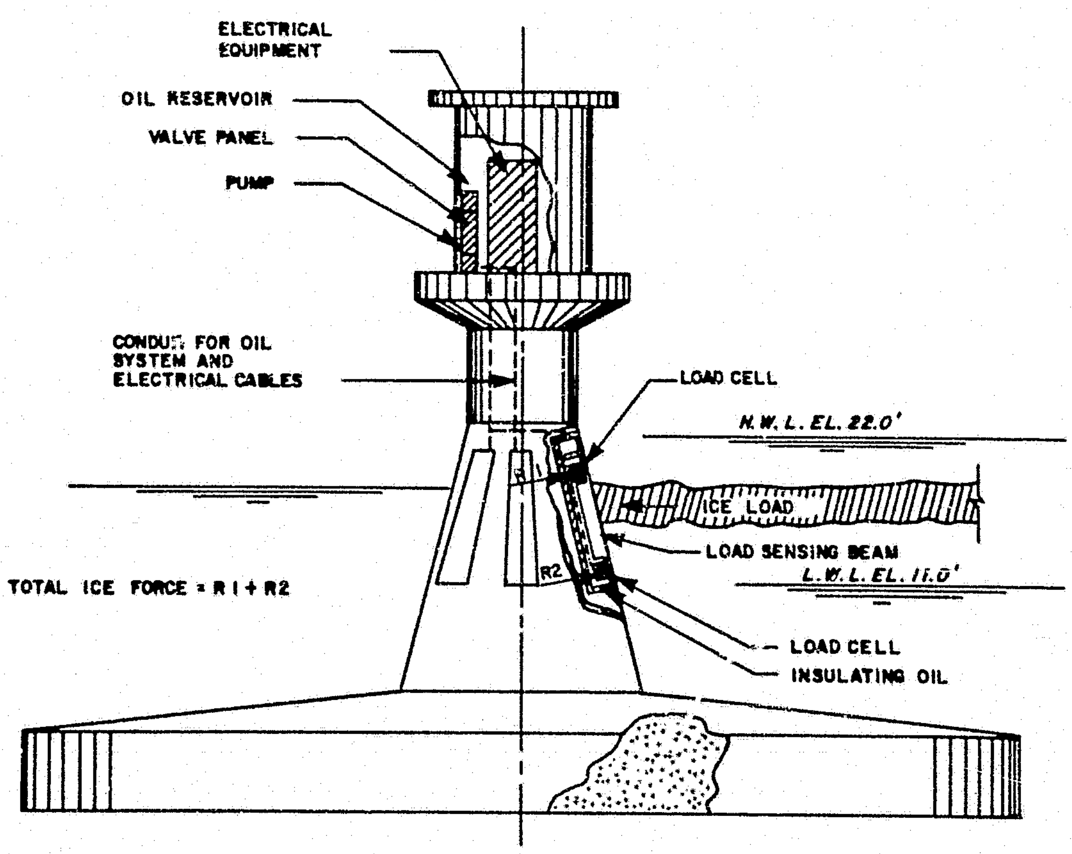
ACRES

ICE FORCES MEASURING SYSTEMS

P2113

Client Department of Transport, Government of Canada

Analysis of the characteristics of three given shapes for lighthouses, evaluation of the feasibility of developing systems for measuring ice forces on each of the lighthouse shapes, studies of the forms and characteristics of measuring components and systems, selection of a system most suitable for each lighthouse shape, and preparation of preliminary designs and cost estimates for each recommended system.



ICE FORCE INSTRUMENTATION

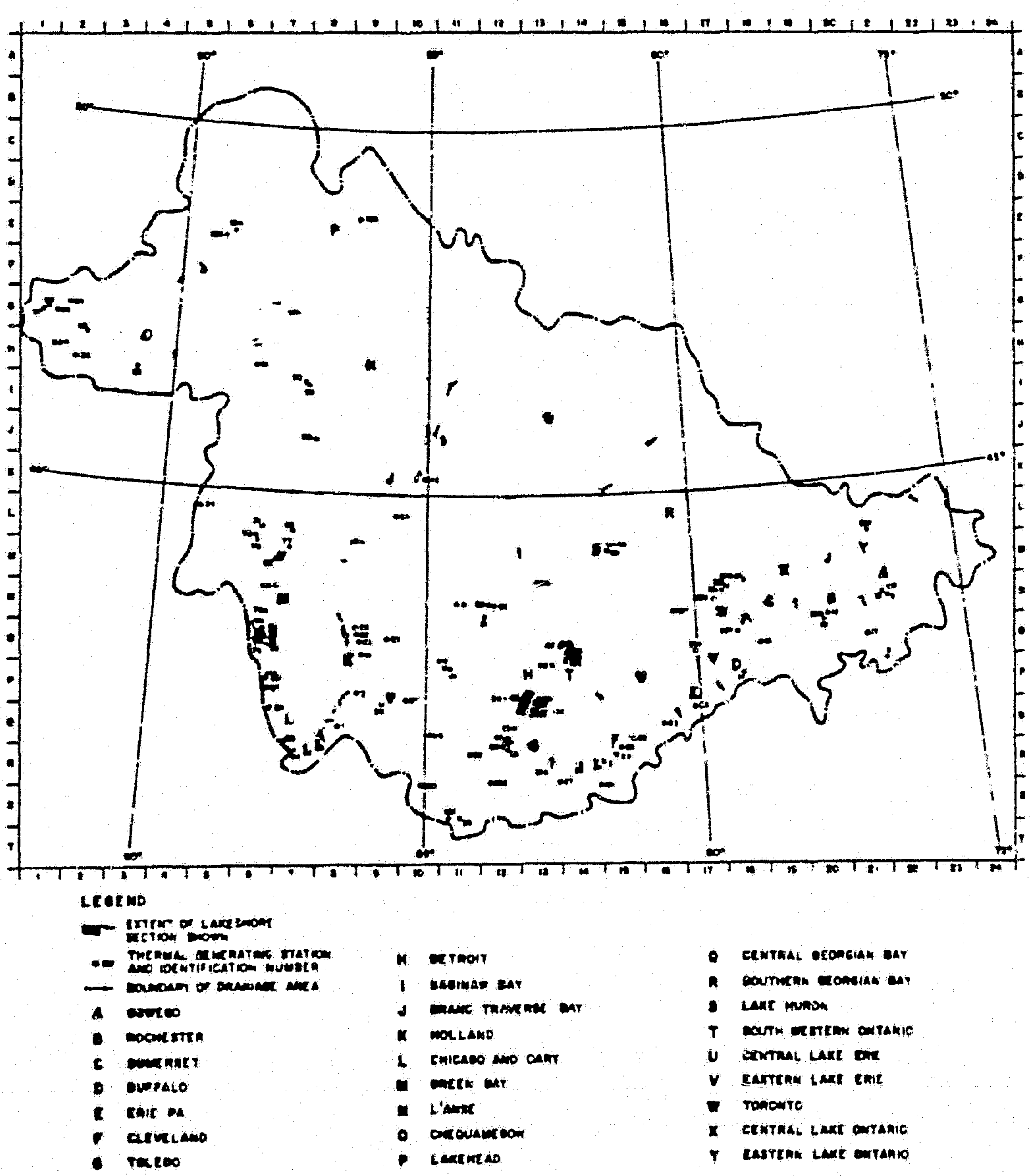
THERMAL POLLUTION STUDY P2084

Location Great Lakes Basin, Canada

Client Government of Canada
Department of Energy, Mines and Resources

1969

Survey of the sources of heated effluent discharges into the basin of the Great Lakes, Canada; forecasts of the amounts and patterns to the year 2000 of artificial thermal inputs; computation of resulting temperature changes using four mathematical models of transporation and diffusion; analysis of the effects of the thermal inputs on evaporation, ice, climate, ecology and economic factors; and preparation of a schedule of recommendations covering the nature and economic value of further research.



LAKESHORE SECTIONS AND LOCATIONS OF EXISTING AND COMMITTED THERMAL GENERATING STATIONS

KETTLE GENERATING STATION

P1432

Location	Nelson River, Manitoba
Owner	Manitoba Hydro
Consortium	Crippen Acres Limited
	1971
Value	$220,000,000 (Approximate capital cost)

Engineering for a complete hydroelectric power development having twelve generating units, each with a rating of 104 Mw under a design head of 98.5 feet.

The main dam (earth fill)/spillway/powerhouse structure of the development is approximately 5,586 feet long, and the reservoir dikes have a total length of approximately 35,000 feet.

The work included extensive studies of the probable effects of ice jams on the heights of cofferdams required for the various stages of river diversion during construction. The studies focused primarily on the scheme for Stage II diversion through the partially constructed powerhouse intake. This scheme involved raising the water level and maintaining a stable ice cover immediately upstream from the site, in order to prevent ice from jamming in the narrow flow passages. The ice studies included field surveys to establish the natural ice regime of the Nelson River and simulation of ice jams in a 6-mile reach of the river, using an 85-foot long hydraulic model, to determine the minimum height of the upstream cofferdam.

Actual operation in the field during diversion was in accordance with the results of the ice model studies in all major respects. A stable ice cover was successfully formed at the recommended level, and was maintained until late spring when the weakened ice cover was safely sluiced through the control structure.

CHURCHILL FALLS DEVELOPMENT
ICE STUDIES

P1522

Location	Churchill River Labrador, Newfoundland
Project Managers	Acres Canadian Bechtel of Churchill Falls
Owner	Churchill Falls (Labrador) Corporation Limited

Due to the northerly climate of Labrador, design problems related to ice were encountered in virtually every flow reach upstream and downstream of the Churchill Falls powerhouse. Frazil ice dams and spring ice jams observed in the natural regime had to be eliminated or bypassed through careful design in order to maintain flow to the powerhouse and avoid increase in tailwater levels.

An extensive field survey of ice thicknesses, water temperatures, flow velocities and bottom profiles was conducted through two winters on the large natural lakes, Michikamau, Lobstick, Sandgirt and Jacopie, which were joined to form the principal reservoir (2,200 square miles) and on the connecting channels between them, as well as on the Churchill River downstream of the powerhouse. These data were used to document the existing regime and to supply data for design calculations.

Thermal and mechanical analyses were applied to various schemes for channel, dike and control structure designs in order to decrease frazil production and ice jam formation to a level where energy production and structure security would not be affected.

In the initial years of operation of the Churchill Falls development, the ice control measures adopted in the design have proven to be effective, and ice has not been a problem.

ACRES

ARNPRIOR GENERATING STATION ICE STUDIES

P3176

Location Madawaska River, Ontario

Client Ontario Hydro

1972 – 1975

The Arnprior Generating Station has been built within the town of Arnprior on a reach of the Madawaska River which was historically subject to active ice jamming. Extensive investigations were carried out to establish the mechanisms controlling the natural ice regime so that the effects of peaking operation of the power station could be predicted.

Field surveys of natural river conditions were carried out over two winters. Surveys included periodic measurement of flow velocities, ice thickness and extent, and of the depth and form of frazil ice accumulation. A two-man hovercraft permitted observations to be taken in areas which would otherwise have been too hazardous to reach. Flows, water and air temperatures and the overall ice configuration were monitored daily.

Analysis of the field data and hydraulic model studies permitted establishment of the ice conditions to be expected after completion of the project. The tailrace improvements incorporated in the design will result in a significant reduction in the severity of ice conditions in the downstream reaches of the river.

LAKE ERIE – NIAGARA RIVER ICE BOOM STUDY P3396

Client Government of Canada
International Niagara Board of Control

The Lake Erie – Niagara River ice boom was originally installed in 1964 to control the amount of ice leaving Lake Erie in the winter season in order to minimize ice jamming and ice handling problems in the Niagara River, particularly at the power utilities intake structures. The boom is effective in attaining this objective, but caused concern over other possible environmental effects. Of particular interest was the effect of increasing the volume of ice in Lake Erie during the winter season and prolonging the period of ice cover at the end of the ice season. Prolongation of the ice cover is a possible factor in extending the spring inversion phenomenon which leads to air quality problems in the Buffalo area.

The specific objectives of this study were:

To determine to what extent, if any, the ice boom affects the thickness or extent of the ice field or changes the rate of dissipation of ice in Lake Erie and, hence, has any effect on navigation, recreation, weather, or other environmental considerations.

To determine criteria which would be used annually to establish a date for removal of the boom, which would minimize the impact of ice flows on intakes for power plants and shore property along the entire Niagara River without appreciable adverse effects on the other interests.

The report presented the results of an intensive study of the current state of knowledge of the ice dissipation process in Lake Erie and the possible boom effects on this dissipation process.

The investigation involved a detailed examination of the historical record of ice growth and dissipation in Lake Erie for preboom and postboom years. A statistical analysis was made of water temperature data proximate to the ice boom for preboom and postboom years. Ice melt mathematical models were reviewed and a simplified simulation of the ice dissipation process in Lake Erie was developed.

Photographs courtesy of the Power Authority of the State of New York

WABANEX OIL STORAGE – ICE CONDITIONS

P4226

Location: **Conception Bay**
Newfoundland

Client: **Wabanex Energy Corporation**

1975

An underground oil storage facility including a deep-water port has been proposed for the abandoned Wabana Iron Mine on Bell Island, Conception Bay, Newfoundland. As part of the feasibility study for the project, an investigation was conducted of the ice conditions in Conception Bay and their relation to navigation by both supertankers and smaller tankers.

Historical ice data were collected, collated and compared with comments of experienced mariners operating in the bay. This analysis produced statistics on the frequency and duration of ice conditions of various severities. The statistics were related to the ice navigation capabilities of supertankers and smaller tankers to obtain a quantified assessment of potential delays to both classes of vessel.

Related studies of currents, meteorological conditions and the biology of the area are being carried out to form a complete package suitable for terminal design and approval under the TERMPOL code.

ICE MANAGEMENT WITHIN BRIDPORT INLET

P4914

Client	**Petro-Canada** **Arctic Pilot Project**
Associate	**Nordco Ltd.**
Location	**Melville Island**

The Arctic Pilot Project was initiated by Petro-Canada to assist in the development of the natural gas resources of the Canadian Arctic. The project included the drilling and completion of a subsea well and flow line, the installation of a gathering and transmission system, and the installation of a liquefaction system with related marine transport facilities.

The Acres study was concerned with ice management problems at Bridport Inlet, Melville Island, which is the proposed northern LNG terminal. The study included the identification of potential ice management problems and the documentation of the present operators of ships and terminals in ice-infested waters.

A number of potential solutions were investigated, such as icebreaker tug support, bubbler systems, thermal discharge systems, surface heat control, ice removal and ice diversion systems. These solutions were assessed in terms of cost, effectiveness, reliability, environmental and other effects, with the result that several were recommended for implementation.

The study also included an outline of possible field or laboratory programs which may be needed for further design data.

INVESTIGATION OF 1976 ICE JAM ON THE SAINT JOHN RIVER

P4298

Location Saint John River, New Brunswick

Client The New Brunswick Electric Power Commission

1976

In April 1976 major ice jams formed above the head ponds of each of the three power developments on the Saint John River-Mactaquac, Beechwood and Grand Falls. Flooding occurred in the towns of Ste. Anne de Madawaska, Perth-Andover, Hartland and Woodstock. A study was undertaken which

- documented the meteorologic, hydrologic and ice events prior to and during the 1976 spring breakup
- placed the 1976 events in historical perspective with meteorologic, hydrologic and ice conditions of previous years
- assessed the reason for the severity of the 1976 jams and determined the extent to which changes in the operation of the power developments might lessen the impact of ice jams.

Extensive backwater calculations were made to facilitate analysis of the ice jam movements to determine the effectiveness of various possible power development operating procedures.

LABORATORY SERVICES

Our modern laboratory is equipped for

- biological analysis and bioassay
- chemical and physical analysis of solids, liquids and gases
- physical modeling to scale
- soil and rock mechanics testing
- hydraulic, aerodynamic, civil and architectural design evaluation.

Skilled and experienced technologists, with expertise in sampling, analysis and evaluation, work with engineering specialists. Standard commercial equipment, supplemented by special equipment designed by and manufactured specifically for Acres, is used for sampling and testing on site and in the laboratory.

Procedures for sampling and analysis are updated regularly to incorporate the most advanced methods. Programs are written for and run on the Acres computer to facilitate and accelerate the calculation of the test results. Standardized reports are prepared and documented to fulfill the requirements of the client and of government agencies.

Test results are used to establish design criteria for conceptual and remedial engineering. Often, these design criteria are confirmed and modified by physical testing on scale models.

ACRES

FLUID-DYNAMICS LABORATORY

The laboratory is equipped to operate models using liquids or gases as the testing media in closed-circuit tests. Modern electronic instruments are used to control the flow of fluids, measure the rapidly varying pressures of these fluids, and record the resulting strains in a model structure.

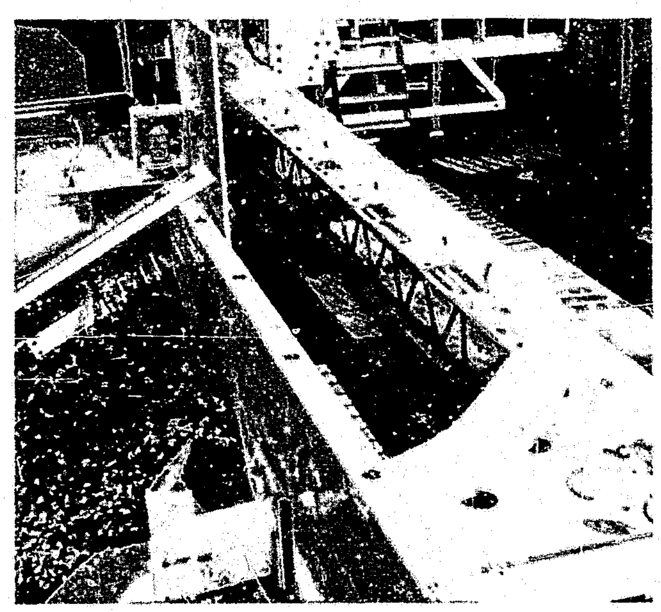
Designs can be confirmed or modified after observing the results of tests which simulate prototype conditions. These studies give assurance of the prototype's proper operation, and often result in considerable savings in construction and operating costs.

Recent advances in theoretical hydrodynamics and computer techniques developed from years of physical testing and field experience have alleviated the need for physical testing on surge tanks.

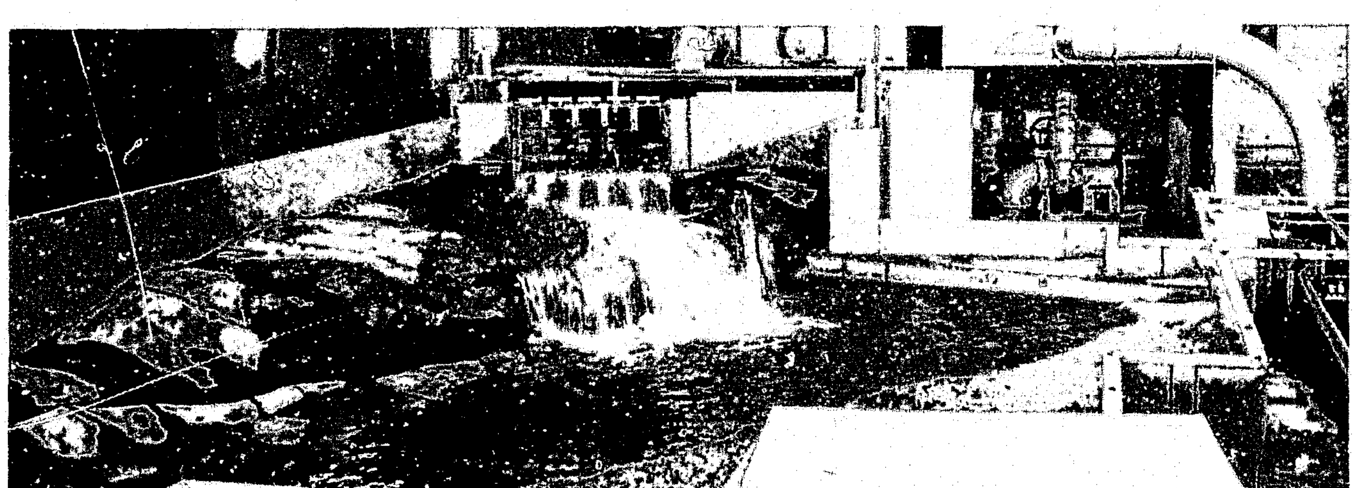
HYDRAULIC MODELING

Tests on models of complex hydraulic systems such as spillways, control and diversion structures and tunnels for hydroelectric developments are used to optimize designs, calibrate structures, and investigate energy losses, flow patterns, air entrainment, cavitation, bed erosion, energy dissipation and hydraulic loading.

Spillway



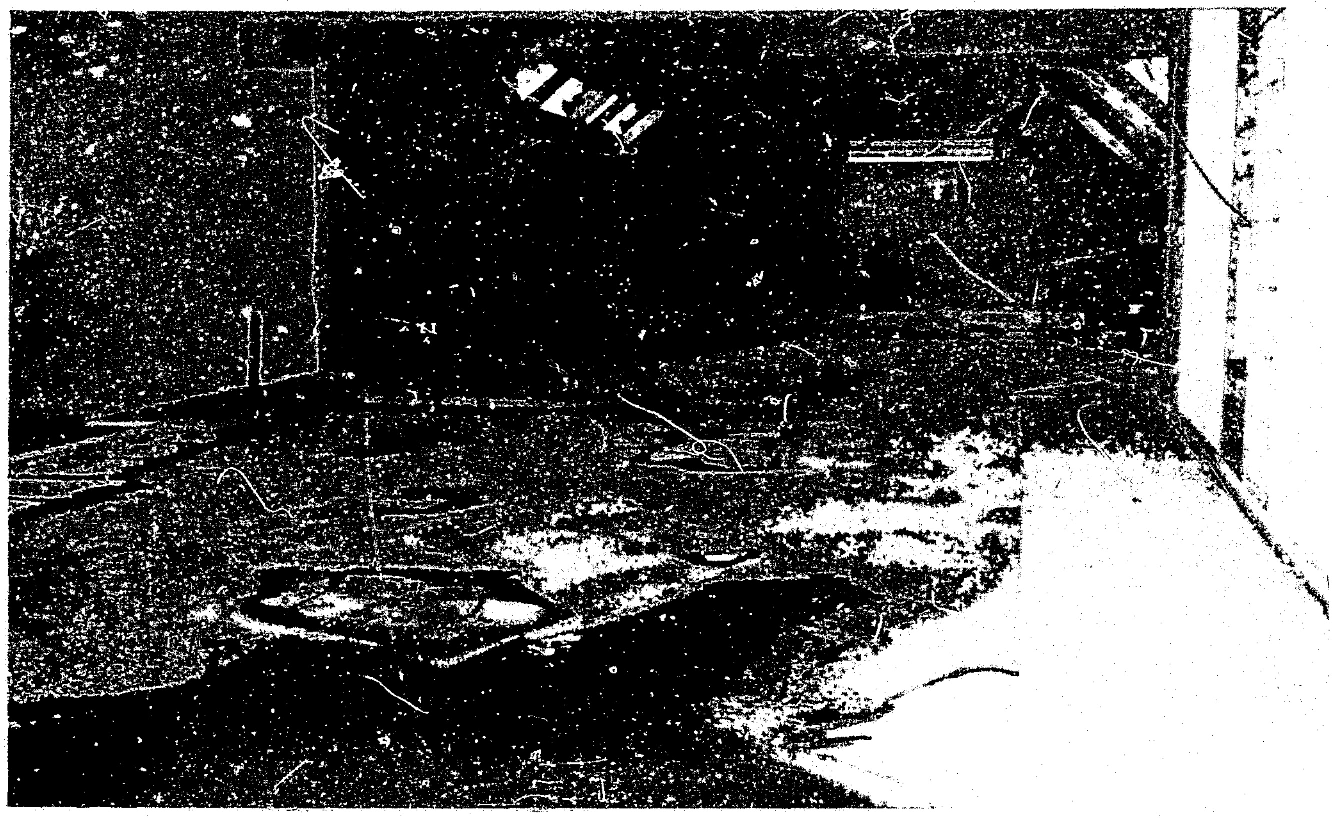
Diversion Tunnel



Control Structure

ICE MODELING

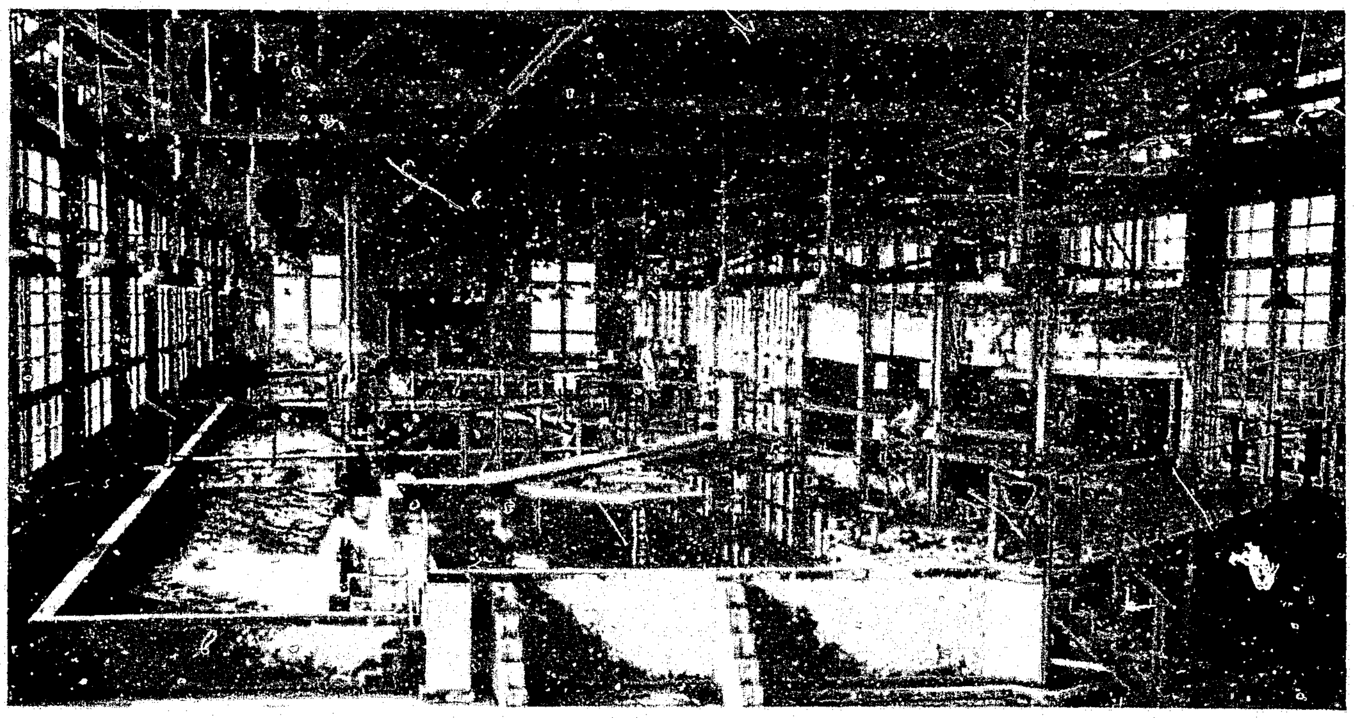
The build-up of ice can cause considerable problems in the effective operation and stability of hydraulic structures. Model testing using simulated ice is conducted to develop methods and operating procedures to minimize the effect of this hazard.



Model of the upstream rapids and inlet to the Kettle Rapids Generating Station on the Nelson River, Manitoba

WAVE ACTION AND TIDAL CURRENT MODELING

Models of coastal regions in which wave trains and tidal currents are reproduced to scale are used to determine the effects of topographical changes on coastal erosion and wave loading.

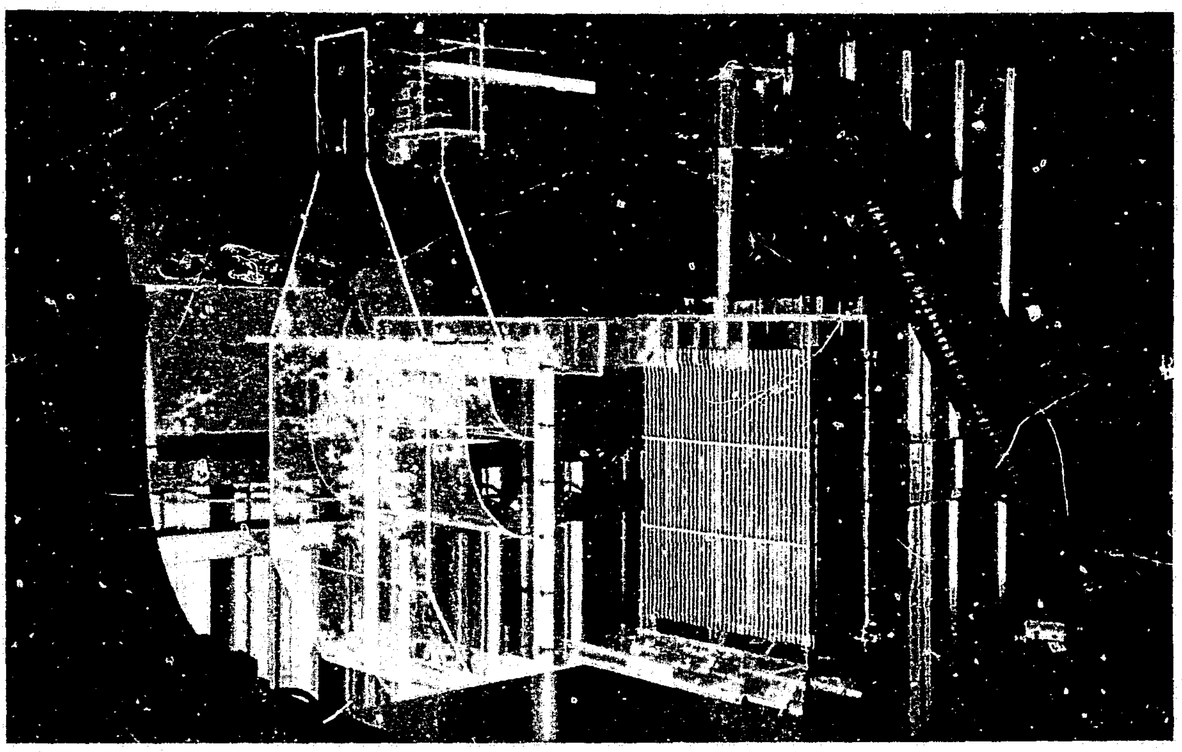


Model of a proposed causeway structure for the Northumberland Straits Crossing between New Brunswick and Prince Edward Island

FLUID-DYNAMICS LABORATORY

AERODYNAMIC MODELING

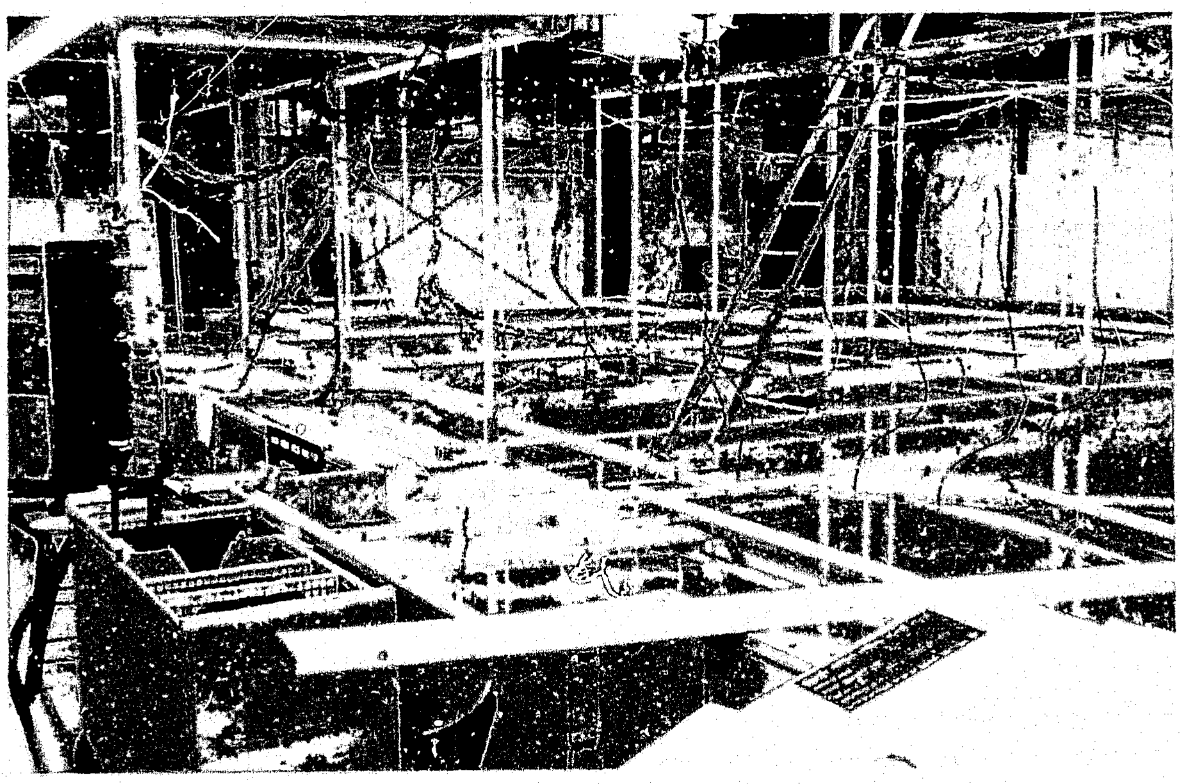
Test models of large gas systems, such as electrostatic precipitators, are used to determine the location of guide vanes, to check flow distribution and generally to refine the original design.



Model of hot electrostatic precipitator and ductwork at Niagara Mohawk, Dunkirk, New York

THERMAL DIFFUSION MODELING

The physical modeling of warm-water discharges was used to determine the effect on receiving water ambient temperatures.



Model of Oswego Harbor and Niagara Mohawk's Steam Station cooling water system, Oswego, New York

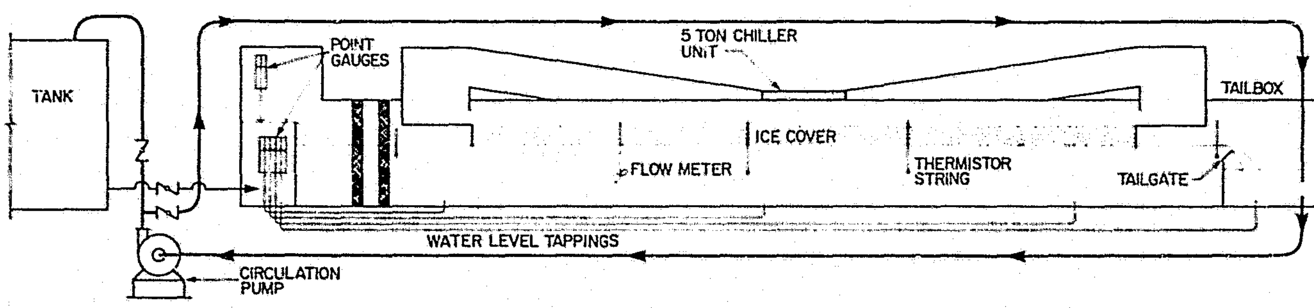
ACRES

ICE FLUME

Acres fully insulated flume (12 m long and 1.2 m^2) is capable of forming a continuous ice cover for laboratory scale testing of thermal and physical properties, instrumentation and equipment, or ice management techniques.

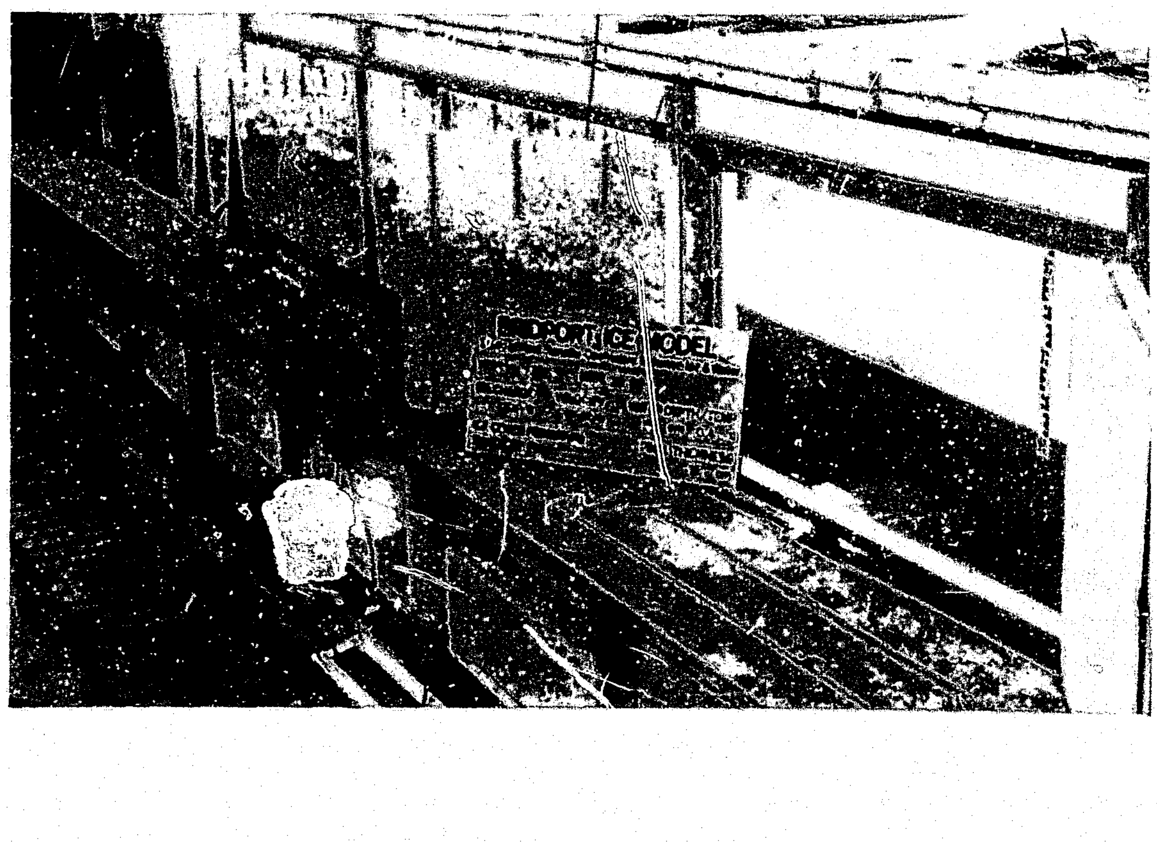
Maximum freshwater or salt water circulation rates of 0.3 m^3/s can be provided. The refrigeration unit forces $-20^{o}C$ airflow over the ice or water surface at a maximum velocity of 7.5 m/s.

The flume can operate under constant head with a 15,000-L head-tank capacity, or it can be modified to run under a continuous loop flow, with a variable-speed low-head pump. A 5.5-m length of Plexiglas window allows visual inspection of test events.



Testing configurations can be developed to suit specific study objectives. Instrumentation is available to record

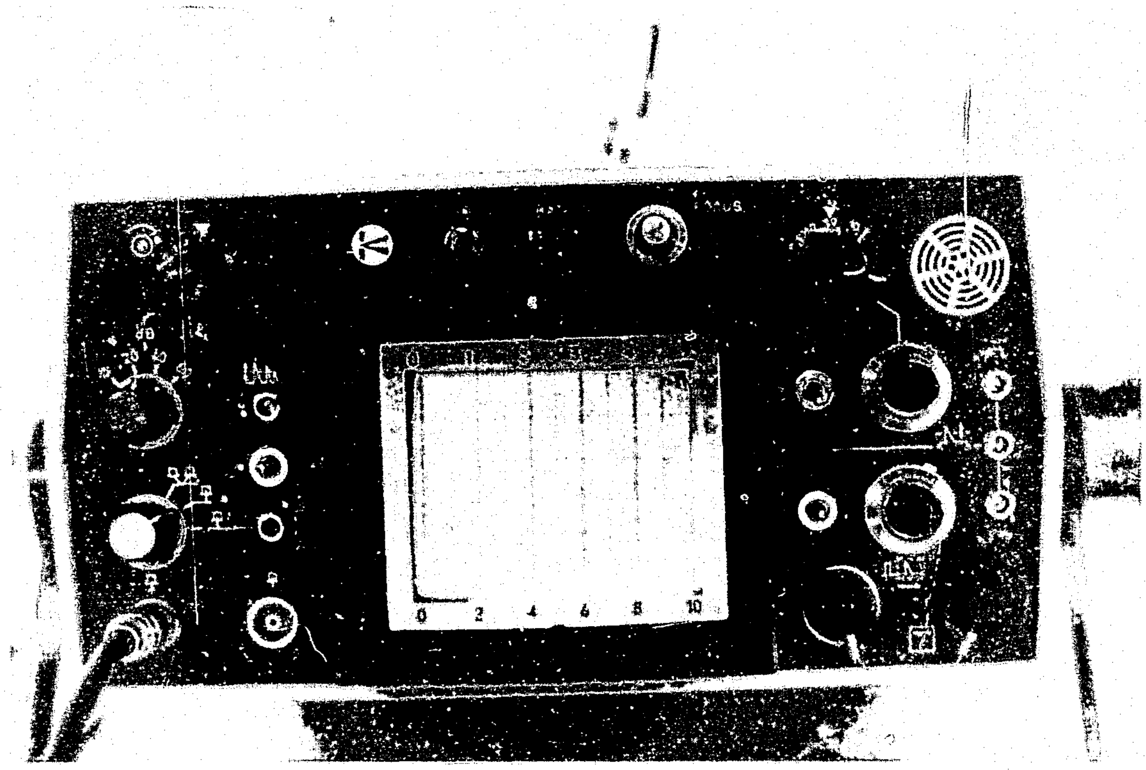
- temperature gradients in ice, air and water
- rate of ice cover growth or decay
- air and water velocities
- water and ice salinity
- head loss.



ACRES

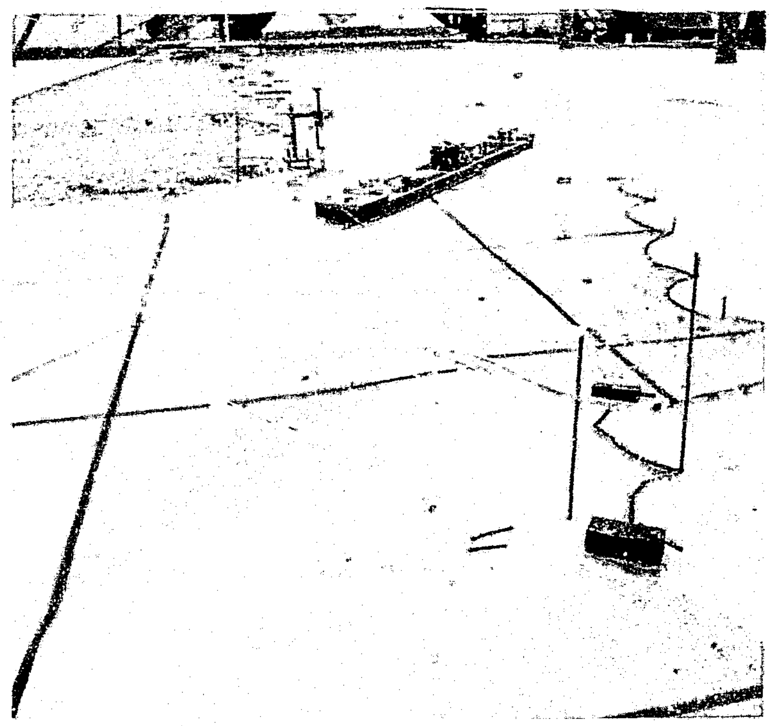
ICE THICKNESS MEASURING DEVICE

Acres is equipped for spot or profile ice thickness measurement using an Ultrasonic Thickness Gauge (UTG). Using the acoustic velocity characteristics of ice, the time lapse from sound pulse emission to reflection is recorded for conversion to thickness measurement. The actual ice thickness measurement is made with an oscilloscope, but a direct digital readout can also be supplied. The UTG allows high accuracy (± 1 mm) over a wide range of settings with minimum disruption of the ice cover. The instrument can also be used for thickness measurement of most metals, plastics and organic materials.



NAVIGATION CHANNEL MODELING

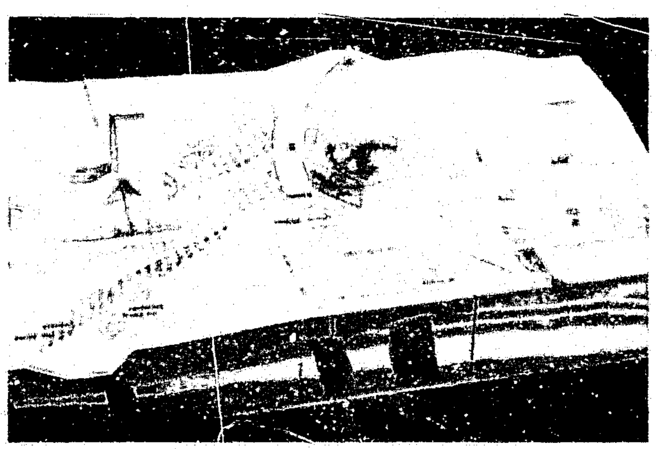
Model studies of ship navigation problems are conducted to improve and stabilize the flow conditions in the navigation channels. Radio-controlled ships are used to gauge the degree of improvement obtained.

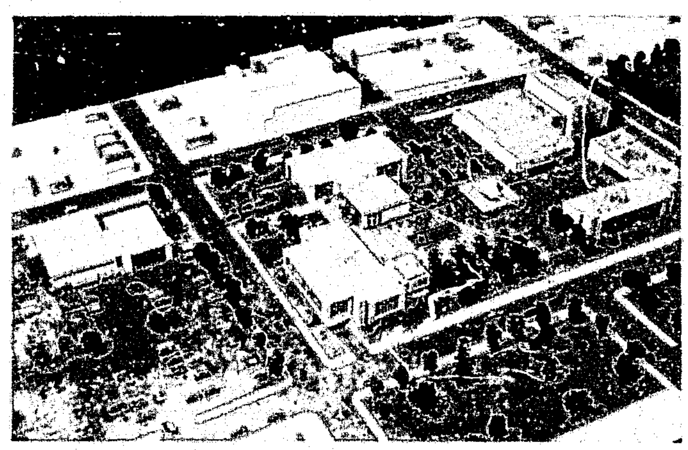


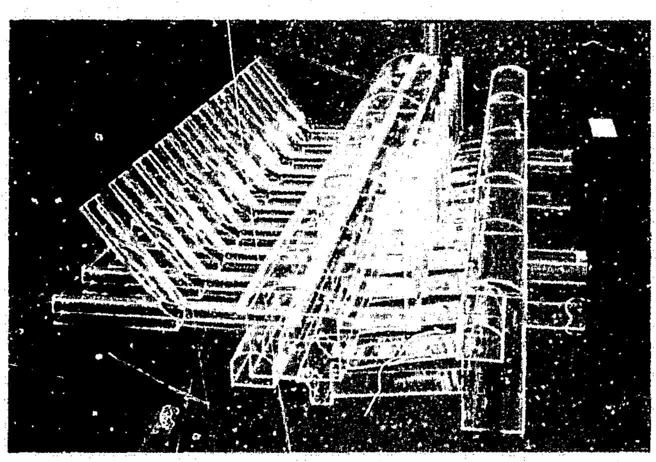
PHYSICAL MODELING

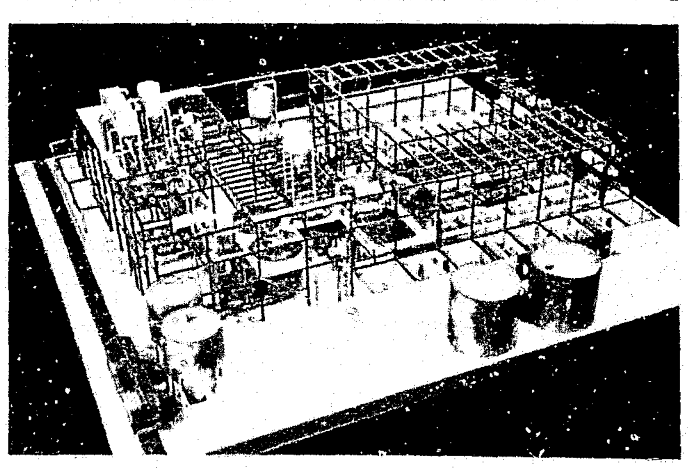
Scale models are prepared of river basins, canals, dams, townsites, airports, buildings, equipment, piping, and other structures and facilities.

Many are used as three-dimensional architectural, structural and mechanical design tools. Other models are used in the fluid dynamics and environmental laboratories to simulate the hydraulic and aerodynamic conditions that provide data for detail design.





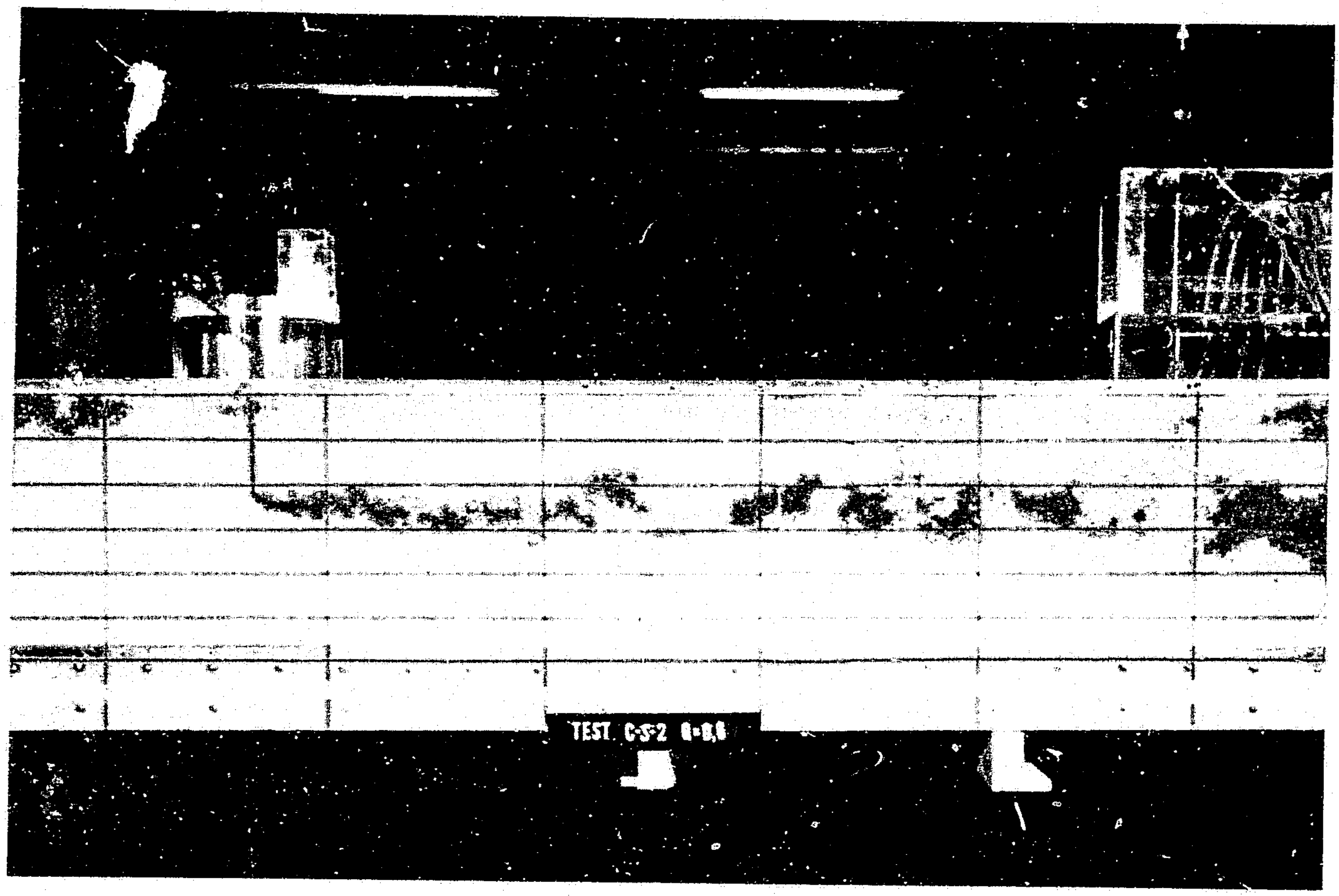




ENVIRONMENTAL LABORATORY

HYDRAULIC MODELING OF THE ATMOSPHERE

Simulation of inversions and other meteorological phenomena is difficult to obtain by aerodynamic modeling. Acres has designed and successfully developed a hydraulic model that simulates the atmosphere with stratified layers of varying brine concentrations. The model is used for prediction of stack plume behavior during various meteorological conditions.



ODOR TESTING

Odors are measured, and control systems for their elimination are developed. One typical project required the measurement of odor causing constituents in a starch plant emission, review of various control systems and testing and performance evaluation of the most promising prototype. Another project involved measuring the odor strength of various foundry vents and calculating the distance downwind required to dissipate the odor by dilution.

SOUND AND VIBRATION MEASURING

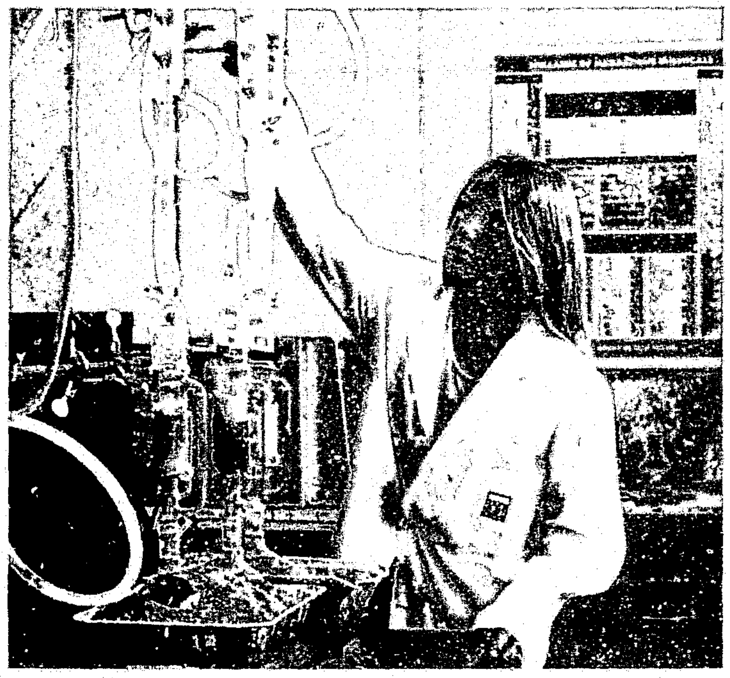
Experienced staff and detection equipment are available for field surveys and studies of sound and vibration problems.

The deleterious effects of excessive noise on health, safety and working efficiency are now well known. Legislation to control ambient noise in industry has led to extensive research in abatement measures. Recent legislation has also been enacted to control noise in both urban and rural environments to minimize disturbance of natural systems and people. Acres has specialist experience in sound-level measurement, and analysis for the development of sound and vibration absorption and attenuation systems.

ENVIRONMENTAL LABORATORY

PHYSICAL AND CHEMICAL ANALYSES

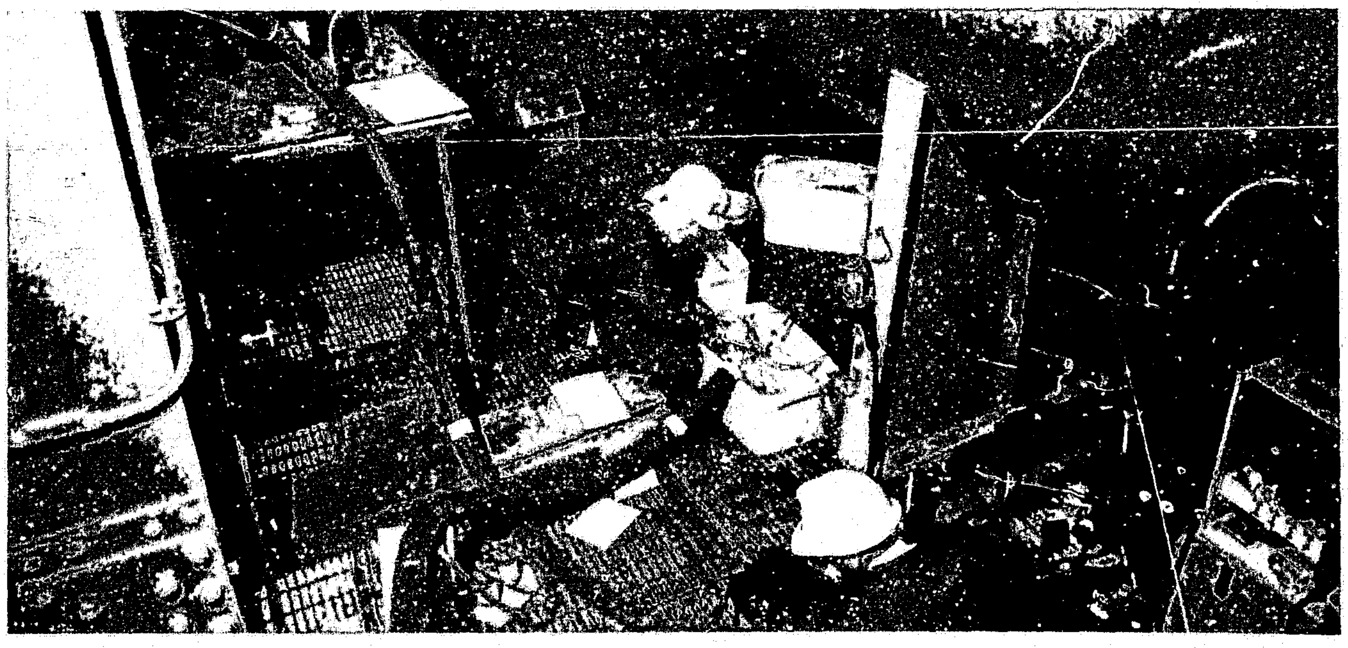
Solid, liquid and gaseous samples taken in the field are usually analyzed for physical and chemical characteristics at the Niagara Falls laboratory. When sampling is a remote location, determinations are done in the field on portable equipment taken to the site. Equipment is available for performing tests to ASTM or other standards.



AIR POLLUTION CONTROL STUDIES

Environmental engineers and technicians are available to:

perform field surveys to EPA standards utilizing EPA sampling trains;
develop feasible schemes for emission control;
determine operating costs and investment costs;
provide selections and recommendations;
provide engineering and design;
provide supervision of construction;
provide performance testing and operational efficiency evaluation.



ACRES

ENVIRONMENTAL LABORATORY

BIOLOGICAL ANALYSES

Our capability in field sampling, design input and computer analysis is backed by a comprehensive laboratory facility. Our biological laboratory is fully equipped to handle collection, sorting and identification of fish, planktonic and benthic samples. Work undertaken has included a large volume of sample analyses from a variety of water and benthos types, classification and identification of lichens, and tissue preparation and analysis for concentrations of contaminants.

The biological and chemical laboratories frequently work together on one project with interpretations being made on the basis of combined data. Raw data are fed directly to a computer for maximum efficiency in summarizing and carrying out statistical analyses.

BIOASSAY FACILITY

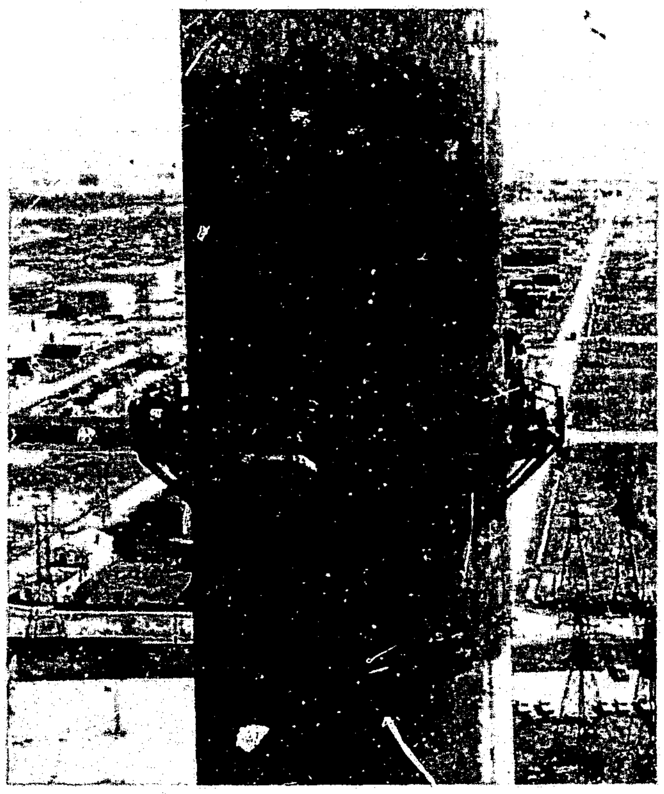
The laboratory includes a bioassay facility to handle toxicity testing as well as a radioassay facility for uptake work and a controlled temperature room. Toxicity tests can be carried out on a wide range of effluents, including those with a high BOD requiring special handling.

ACRES

ENVIRONMENTAL LABORATORY

EMISSION SURVEYS

Stack gas streams are sampled and analyzed for the various constituents, including dry particulates, wet particulates, SO_2, SO_3, NO_x, hydrocarbons, heavy metals, etc. Equipment and specialist staff are provided by Acres laboratories.

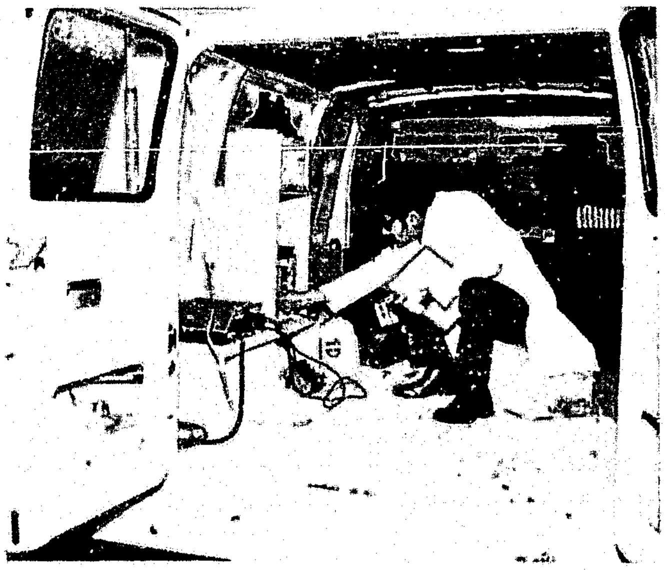


Stack Sampling Platform
Niagara Mohawk Huntley Station
Buffalo, New York

Sampling of SO_2 and SO_3

AMBIENT AIR SAMPLING SURVEYS

Mobile sampling of stack plumes, episode sampling, design of ambient sampling stations, planning of systems for data collection, and computer processing of information from sampler/analyzers and meteorological instrumentation are provided.

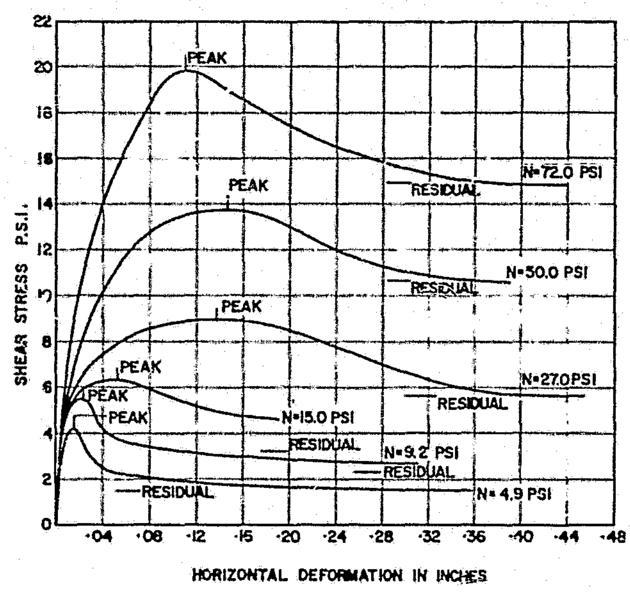


GEOTECHNICAL LABORATORY

DIRECT SHEAR TESTING

Direct shear testing machines are used primarily to determine the stress-deformation behavior and shear strength of soil or rock along existing geological planes of weakness.

These machines are equipped to provide both stress and strain rate-controlled loading on predetermined planes. Direct shear testing also allows the measurement of residual as well as peak shear strengths.

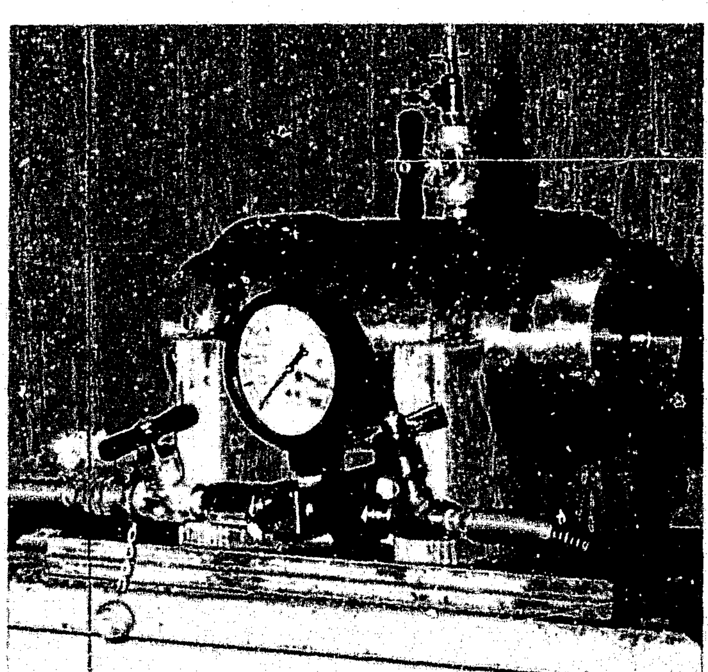


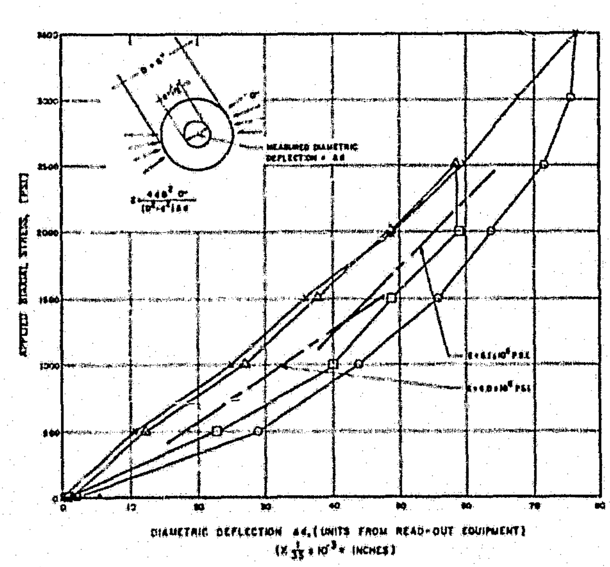
Direct Shear Test Results
Highly Plastic Clay

BIAXIAL COMPRESSION TESTING

Biaxial compression apparatus, designed and built by Acres to apply pressures up to 10,000 psi, is used to determine the modulus of elasticity of 6-in. diameter rock or concrete cores obtained from field overcoring tests.

Biaxial compression testing is used in conjunction with field overcoring tests to measure the in situ stresses present in a rock or concrete mass.





Biaxial Test Results
Granitic Gneiss

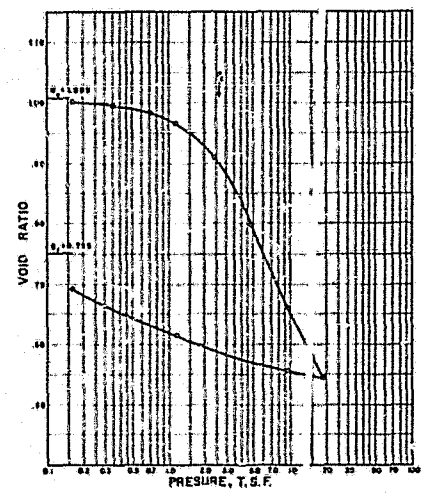
GEOTECHNICAL LABORATORY

CONSOLIDATION TESTING

Consolidation test apparatus is used to determine the stress-deformation-time characteristics of undisturbed soil samples.

The rate and magnitude of settlement of foundations can be predicted from these results.

The equipment is suitable for testing 1.5- to 3-in. diameter samples. Apparatus has been developed for testing 24-in. diameter samples of fine rock fill.



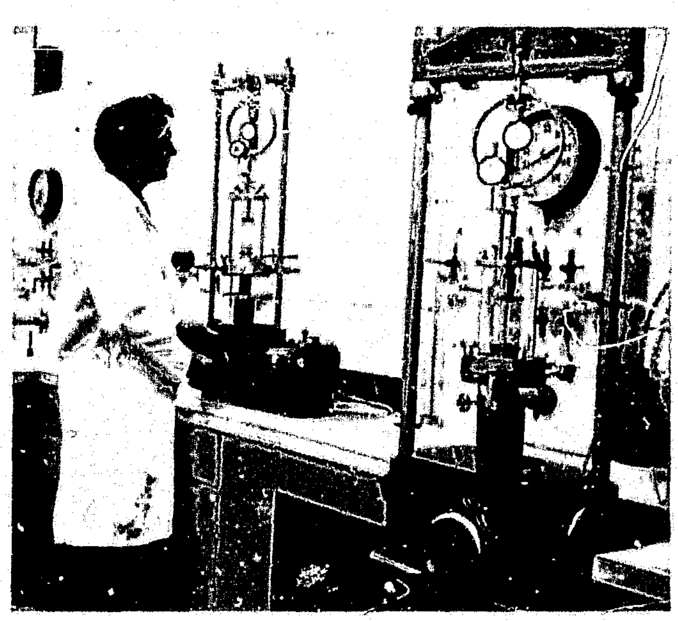
Consolidation Test Results
Lacustrine Clay

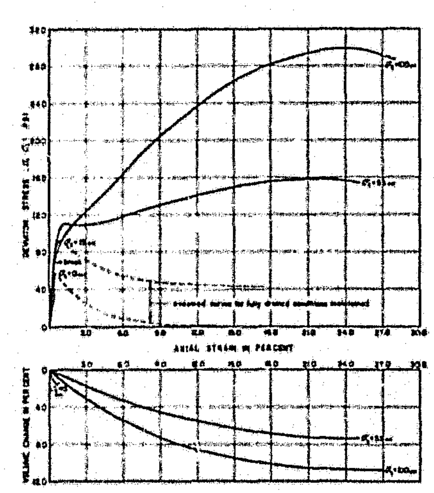
TRIAXIAL TESTING

Triaxial testing apparatus is used to determine the stress-deformation behavior and shear strength of natural and compacted soils when subjected to various stress conditions.

Stress or strain rate-controlled axial loading of cylindrical samples is applied in either compression or tension, and can be used for long-term creep tests.

Drained tests with volume change measurements or undrained tests with pore water pressure measurements can be performed.



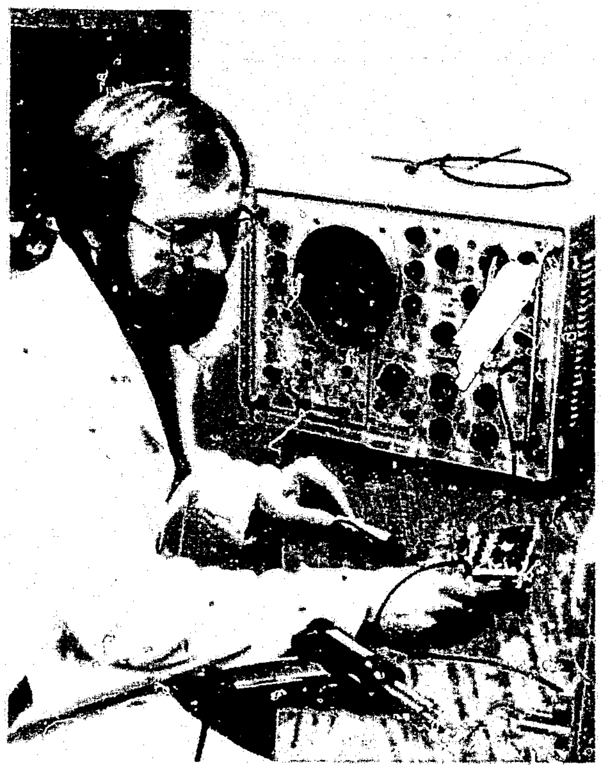


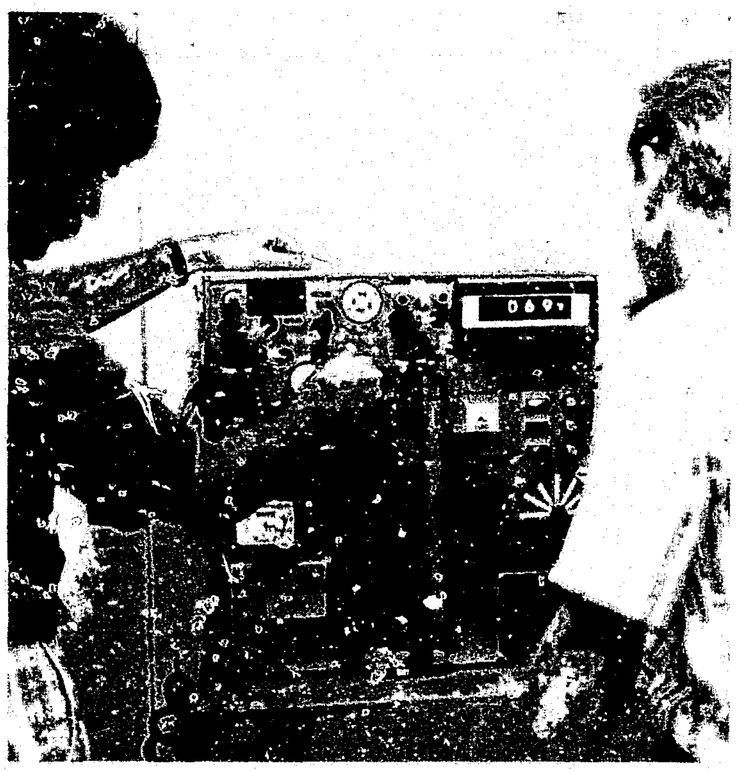
Consolidated Drained Triaxial Test Results
Estuarine Clay

INSTRUMENTATION LABORATORY

Acres Instrumentation Laboratory services include inspection and checkout of purchased equipment, site supervision and commissioning, and testing and troubleshooting of new and existing instrumentation systems.

In addition to utilizing off-the-shelf instruments, Acres has the expertise and facilities to modify or custom-fabricate specialized instrumentation designed for particular applications.





The following are some of the types of services our Instrumentation Laboratory has provided to meet client requirements.

Research and Development

- Ice force measurement
- Hydraulic thermal dispersion models
- Precipitator models
- On-line data processing for experimental testing
- Telementry of automotive remotely collected data.

Pollution Control Monitoring Systems

- Power plant precipitators
- Ash removal systems
- Neutralization facilities
- Sour water strippers
- Chemical processes.

Process Monitoring and Control Systems

- Ore crushing and milling
- Direct-reduction steel plant
- Rolling mill installations
- Pickle line installations
- Silicon carbide plant
- Wire drawing plant.

GEOTECHNICAL LABORATORY

BOREHOLE PHOTOGRAPHY

In many engineering projects it is sometimes necessary to know more about in situ rock conditions than can be determined from normal coring operations. Questions arise such as the reasons for lost core, orientation and openness of joints, or the presence of voids or solution features in soluble rock.

They can be answered using Acres borehole camera which photographs the walls of drill holes ranging in diameter from "N" size to 6 in., and to depths of up to 1,500 ft. The equipment is operated in the field by our experienced geotechnical staff. Data obtained on color film can be viewed by geologists. If necessary, our computer program can produce an output listing the depth, dip and azimuth of geological features.

This equipment and associated geotechnical engineering services are available to organizations involved in underground or surface works in rock.

BLAST MONITORING

Blasting operations in close proximity to human beings and structures can range from being hazardous at one end of the spectrum to uneconomical and time consuming at the other. The use of appropriate monitoring equipment in conjunction with design of blasting patterns, can result in the most economical and safe solution.

Acres staff has extensive experience in the design and supervision of delicate blasting operations for rock excavations immediately adjacent to operating power stations, tunnels, and other large structures in North and South America. We have also developed instrumentation to monitor underwater blasting shocks. Our current equipment includes a Sprengnether VS-1200, 3-axis seismograph which is capable of monitoring air shocks as well as ground motions.

CHESAPEAKE BAY HYDRAULIC MODEL P4655

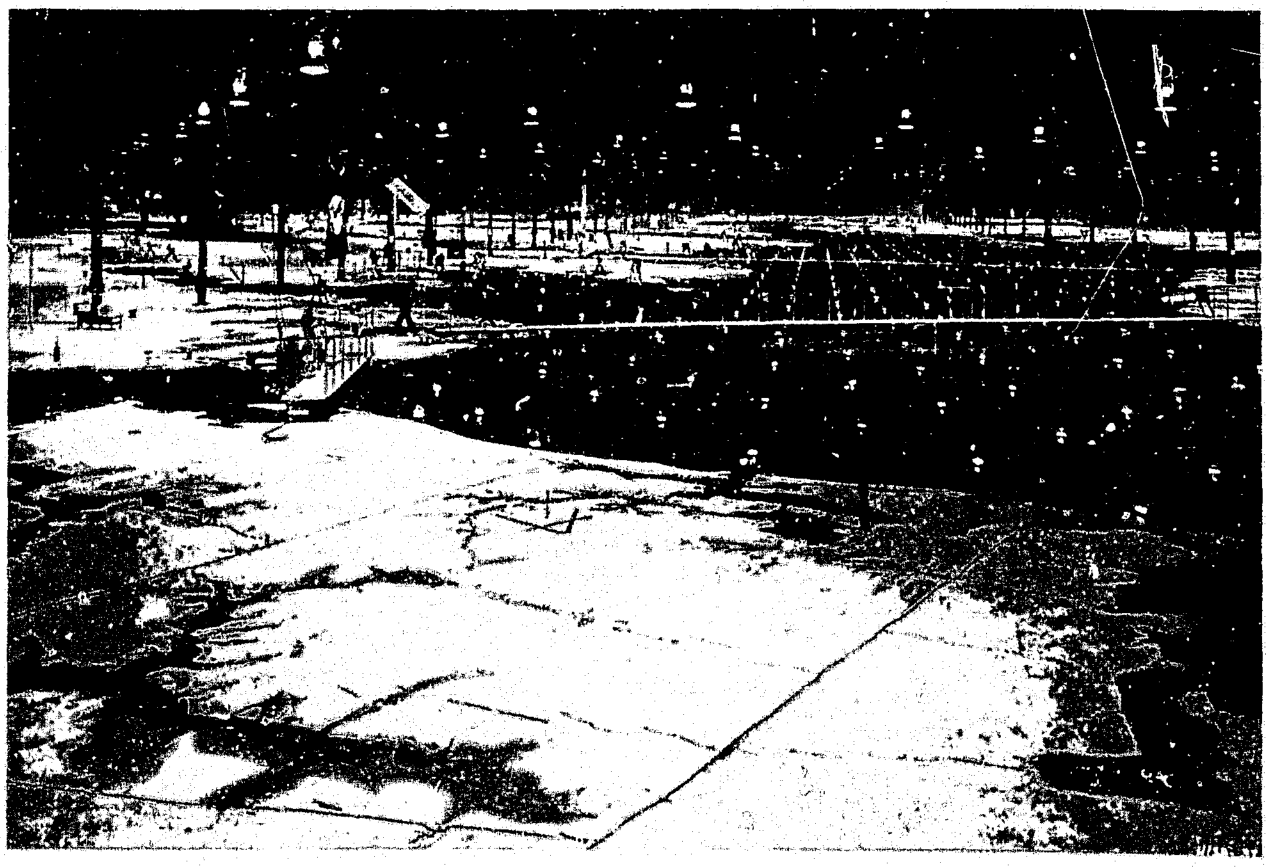
Location Annapolis

Client **U.S. Army Corps of Engineers**
Baltimore District and Waterways Experiment Station

Year **1977–1980**

The Chesapeake Bay hydraulic model was completed in May 1976 and covers an area of some 8 acres housed in a 14-acre shelter. The model is built to a horizontal scale of 1 ft. = 1,000 ft. and a vertical scale of 1 ft. = 100 ft. and is representative of the Chesapeake drainage basin covering 64,170 square miles and a water surface area of 4,300 square miles with a tidal shoreline of 7,300 miles. The model is used to study:

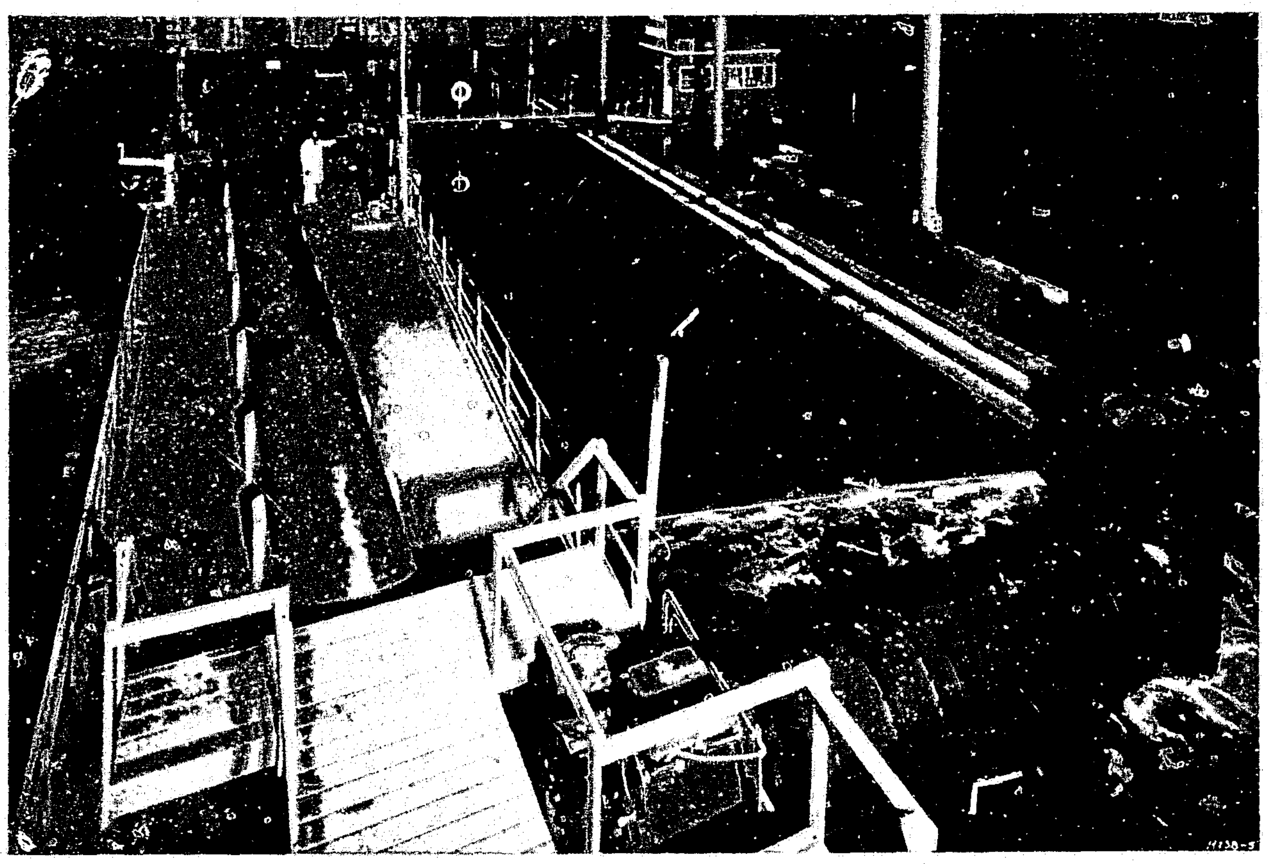
salinity distribution and saltwater intrusion
mechanics of estuary flooding
effects of upstream impoundment and basin diversions
effects of navigation projects and channel geometry
circulation and upwelling current patterns
site locations for sewage and other outfalls, port facilities
waste assimilation capacity of the bay
shoaling characteristics of the bay and tributaries
sources of ship handling problems
tidal flooding and effect of storm surges.



ACRES

By applying the knowledge gained from the Chesapeake Bay study and the hydraulic model, plans can be formulated that will insure a balanced approach to developing the Bay's resources while protecting the quality of the environment.

Acres is under contract to the U. S. Corps of Engineers for the total maintenance and operation of the facility and will be responsible for conducting an extensive series of studies over a prolonged period.



ST. MARYS RIVER ICE MODEL P3855

Client U.S. Corps of Engineers

Location Sault Ste. Marie, Michigan

This project was part of a research and study program to develop feasible solutions to problems created by frequent ice build ups in the narrow channel between Sault Ste. Marie, Michigan and the area below the Little Rapid Cut area of the St. Marys River, Michigan.

Broken and frazil ice float downstream into the cut and the resulting ice jams restrict commercial vessel passage and prevent regular ferry transportation to and from the mainland for the two hundred families who live on Sugar Island located on the east side of the cut.

The model was verified against field observations and employed to simulate the effects of relocating the ferry crossing, widening of the riverbed, the use of ice control booms and ice harvesting methods, the creation of ice-flow diversions and ice suppression systems.

The model forms a Y shape in an area 120 feet by 200 feet and includes a scaled riverbed, shoreline and model vessels, and utilizes polypropylene pellets to simulate ice.

It was also used to study the influence of discharges from power canals and industry, the effects of changes in ice supply due to vessel passage, various wind conditions and the impact of vessel size and speed on ice jamming and accumulation.

Remedial measures recommended as a result of the study were constructed and in service in the winters of 1975–1977.

LOWER NOTCH GENERATING STATION MODEL STUDIES

P1661HM

Location Montreal River, Cobalt, Ontario

Client The Hydro-Electric Power Commission of Ontario

1969

The engineering services provided for this 340,000-hp hydro-electric power development included the construction and testing at Acres Laboratory of a hydraulic model (scale 1:64) of the spillway, chute and flip bucket (50,000 cfs) to determine the design criteria for the structure, the extent of possible erosion below the flip bucket, the possibility of cavitation damage to concrete surfaces, the spillway rating curves, the flip bucket jet trajectories, and the flow patterns in the forebay for various flow ratings.

ACRES

SIRIKIT POWER DEVELOPMENT
Hydraulic Model Studies

P1616HM

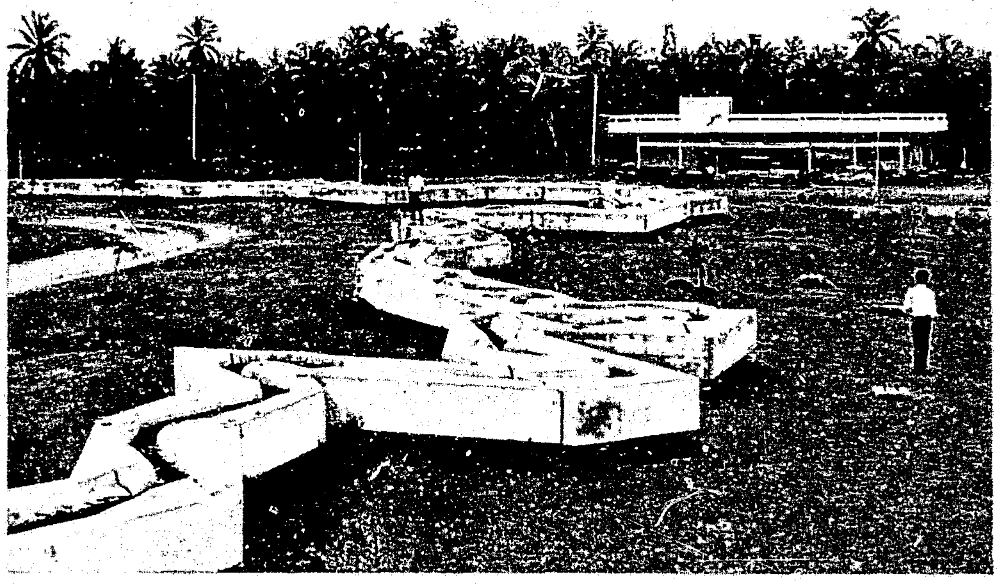
Location Bangkok, Thailand

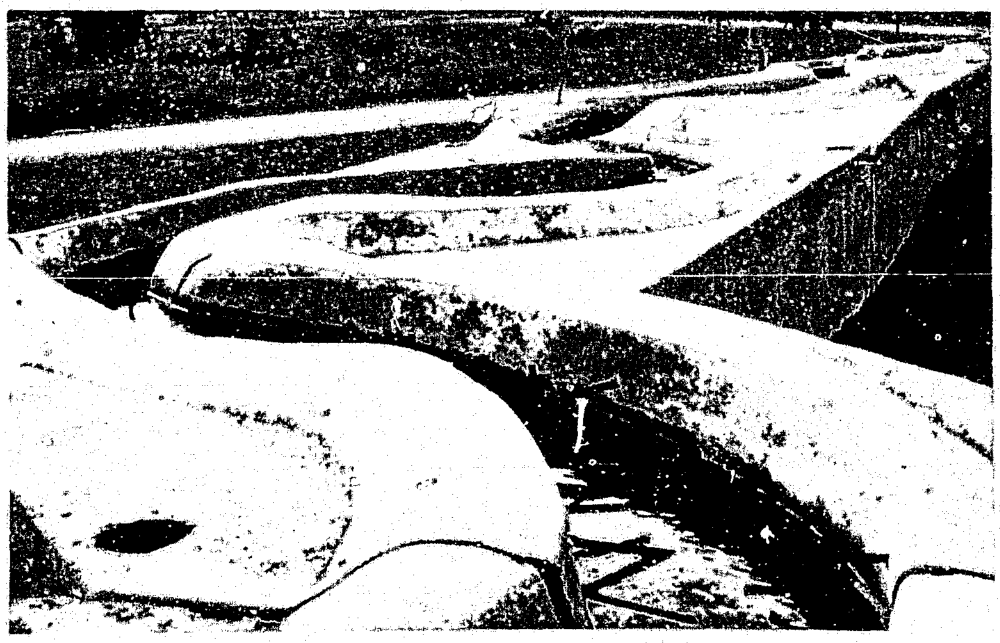
Client Electricity Generating Authority of Thailand (EGAT)

1969 – 1971

The design, supervision of construction, calibration and testing of a hydraulic model, to investigate the effects on irrigation and navigation resulting from various arrangements and operation schedules of the Sirikit Power Development. Of particular interest was the simulation of the operation of the power station at various plant factors in conjunction with two major irrigation diversion structures planned downstream.

The model reproduces flows in the 300 km of the Nan River immediately below the development (down to Phichit). It is of the fixed-bed type and is built to scales of 1:40 vertically and 1:600 horizontally. The flow capacities of the model are 5.3 litres per second to simulate a maximum discharge from the power plant of 800 cubic metres per second, and 19.8 litres per second to simulate flood flows in the river of up to 3,000 cubic metres per second.





RELEVANT EXPERIENCE

R&M CONSULTANTS, INC.

SLOPE STABILITY STUDIES CONDUCTED BY
R & M PERSONNEL

CLIENT:

Alaska Department of Highways

- Simpson Hill Slope Failure, Richardson Highway;
- Canadian Border Slide, Alaska Highway;
- Pillar Mt. Slide, Kodiak Island;
- Keystone Canyon Rock Fall, Richardson Highway

U.S. Geological Survey

- Post Earthquake Assessment - Old Valdez "Effects of the Earthquake of March 27, 1964 at Valdez, Alaska," H.W. Coulter and R.R. Migliaccio, 1966 (U.S.G.S. P.P. 542-C).

Alyeska Pipeline Service Company

- Route Slope Stability Parameter Assessment Task Group; (See attached Project Data Sheet)
- Terminal Site - Participated in design and stabilization of rock slopes;
- Solifluction Analysis & Recommendations "Solifluction and Related Mass Wasting Processes, 1974"
- Ft. Liscum Slide "Engineering Geology of the Fort Liscum Landslide, Port Valdez, Alaska, 1970"

Insurance Company of North America

- Lake Silvas Slide - evaluation/provide expert witness

SLOPE STABILITY ASSESSMENT TASK GROUP
GEOTECHNICAL ENGINEERING
-TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Allen Stramler, Engineering Coordinator

Acting on a recommendation by Dr. R.B. Peck, Alyeska Pipeline Service Company (Alyeska) formed a slope stability assessment task group in 1973 to consider, on a mile-by-mile basis, the parameters governing the stability of natural slopes along the proposed 760 mile pipeline alignment. Two R&M members of the five man task group were R.R. Migliaccio and J.W. Rooney.

The principal function of the task group was to establish the specific basis for analysis of the stability of each signficant slope under conditions judged by the group to be critical. Dr. Peck envisioned the work of the task group to consist of the following steps:

1. Examine the proposed layout of the pipeline on a mile-by-mile basis, considering each significant slope.
2. Agree on the geological features and engineering properties of the subsoil which are considered representative for each slope.
3. Consider carefully the conditions that are likely to prevail at any time, or times, which would prove critical with respect to stability.
4. Determine what constraints there may be upon the shape of the surface of sliding, and determine the shape, or shapes, that should be considered in the analyses.
5. Propose the appropriate physical parameters for use in the stability analyses.

The responsibilities of the task group did not include the actual performance of slope stability analyses. However, the results of the task group's study provided the basis for the best possible estimate of the stability of the slopes that could be obtained by the conventional analytical procedure making use of the results of soil and geological exploration, testing, and theory.

A number of personnel with R&M Consultants participated in this lengthy study and in the development of the final report.

R&M CONTACT:

Ralph Migliaccio, Anchorage Office, James W. Rooney, Anchorage Office

ROCKSLOPE DESIGN, DOCUMENTATION, DEWATERING, AND REINFORCEMENT, VALDEZ PIPELINE TERMINAL, ALASKA

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Michael C. Metz, Geotechnical Engineering

R&M provided a resident geologist who engaged in full-time consulting services for a period of three years. Activities began with geologic investigation of bedrock conditions by surface mapping and subsurface drilling and coring of bedrock. This geotechnical data was then used in the design effort to produce an extremely conservative design for the rockslopes and their reinforcement, such that the rockslopes would be stable during the design contingency earthquake (0.6 g lateral acceleration). A conservative design was required because of the height of the rockslopes (up to 230 feet) and their proximity to vital facilities of the terminal complex. Geotechnical input also included draft and revision of rock work specifications including drilling, blasting, and rock bolting techniques. During construction, activities included daily site inspections to document geotechnical conditions, to insure that excavation conformed to design, and to monitor the contractor's QC documentation. Also, as excavation progressed, unfavorable geotechnical conditions were encountered which required field modification of slope and reinforcement design. Encountered groundwater pressures also required the design of a weephole, inclined drain, and interceptor trench dewatering system for each rockslope, and the design and installation of a piezometer network for groundwater observation. R&M personnel prepared technical reports on these matters for governmental agency review.

In all, six different rockslopes were designed, excavated, reinforced and documented, as follows:

1. Powerhouse and Vapor Recovery Backslope
2. West Manifold Rockslope
3. Ballast Water Treating Backslope
4. Vapor Recovery Westslope
5. East Tank Farm Step
6. West Tank Farm Step

Slope angles varied from steep slopes of 1 horizontal to 4 vertical to more gentle slopes of 1 horizontal to 1 vertical. Reinforcing techniques used included tensioned, fully-grouted Dywidag rockbolts, wire mesh, toe buttresses, and shotcrete. All slopes possess a dewatering system with installed piezometers to monitor groundwater conditions.

R&M CONTACT:

Jim McCaslin Brown, Anchorage Office

CONSTRUCTION INSPECTION OF
BEDROCK CONDITIONS, BLASTING, AND STABILITY
KEYSTONE TUNNEL BYPASS PROJECT, VALDEZ

CLIENT:

State of Alaska, Department of Transportation and Public Facilities, Division of Highways

CLIENT CONTACT:

Mr. William Slater, Chief Geologist

Consultant services began after serious slope stability problems halted construction on this project. Initial R&M work involved participation in redesign of the rockslopes. Periodic inspections were performed after construction recommenced to examine excavated rockslopes and blasting results in order to maximize stability and safety. A stability analysis was conducted for the partially excavated rockslope west of the Lowe River. This analysis and other geologic data provided input for a Value Engineering study of alternatives for continuing the Bypass Project beyond the first construction season.

R&M CONTACT:

Jim McCaslin Brown, Head, Earth Science Department,
Anchorage Office

REINFORCED EARTH EMBANKMENTS
ALYESKA PIPELINE TERMINAL, VALDEZ, ALASKA

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Mr. M. C. Metz, Geotechnical Engineering

Two large embankments at the Valdez Pipeline Terminal were found to present severe limitations if constructed as conventional rockfill embankments, due to space and economic considerations. R&M personnel determined site and foundation conditions for the proposed Reinforced Earth Embankments and cooperated with Alyeska Engineering during review of the Reinforced Earth design for the East and West Tank Farm embankments. Efforts included review of earthwork specifications and recommendations on internal and basal drainage blankets of free-draining material to maximize embankment stability.

R&M personnel also performed daily construction inspection of materials and workmanship as the construction progressed, and monitored Quality Control personnel and documentation.

R&M CONTACT:

Jim McCaslin Brown, Project Manager, Anchorage Office

CONSTRUCTION MATERIAL SITES
ALYESKA PIPELINE TERMINAL
VALDEZ, ALASKA

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Mr. M.C. Metz, Geotechnical Engineering

Material requirements for the Valdez Terminal construction reflected the complexity of the terminal plant facilities. During the three year period of construction, requirements existed for numerous types of rock-fill and earth-fill products including concrete aggregates. R&M personnel were active in all phases of acquisition of these materials.

Potential on-site bedrock sources were investigated by diamond drilling and laboratory testing of the recovered cores. Several of these sources, including one major quarry, were developed and rock-fill products were produced. Select (high-quality) rock-fill products were produced by crushing and screening plants, while non-select rock-fill products were often pit-run material. In both cases, R&M personnel engaged in quality control functions to insure that the rock-fill products satisfied required specifications.

On-site sources of fine-grained, relatively impermeable earth-fill were required for surface sealing of containment dikes. Surface and subsurface investigations combined with laboratory testing and site conditions, such as length of haul and accessibility, were used to delineate suitable sources. These sources were within glacially deposited silty gravels.

No on-site sources of sands and gravels existed which were suitable for coarse and fine concrete aggregates. Because of this, off-site existing gravel pits owned by private firms and the State of Alaska were investigated. These were located at some distance from the terminal in the flood plain of the Valdez Glacier stream. Site selection among these commercial pits involved visual inspection of pit walls, laboratory testing of bulk samples, and examination of past production records. In addition, R&M performed the required laboratory testing and prepared a concrete mix design as well as a shotcrete mix design.

R&M CONTACT:

Jim McCaslin Brown, Head, Earth Science Department, Anchorage Office

GRAYWACKE QUARRY-EXPLORATION, DEVELOPMENT AND PRODUCTION ALYESKA PIPELINE TERMINAL, VALDEZ, ALASKA

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Mr. M. C. Metz, Geotechnical Engineering

The rockfill requirements for construction of the Alyeska Pipeline Terminal required 1.5 million cubic yards of competent rock for select rockfill products in excess of that obtainable from the rock excavations required by the facilities design. R&M personnel were major participants in all phases of the life of the quarry. These included site reconnaissance, exploration, development, excavation design, production and restoration.

A site evaluation reconnaissance based on surface geologic mapping located four potential sites. These were explored by diamond drilling (NX-Coring). Cores were logged in the field, including such parameters as rock type, fracture spacing, and Rock Quality Designator (RQD).

Selected cores underwent soundness (resistance to chemicals) and abrasion tests (resistance to physical forces) to determine the competence of the rock at the various potential sites. The best quarry site was then selected based upon the results of drilling and testing, accompanied by standard economic considerations such as length of haul, access to the site, and excavation methods.

A development Mining Plan was then drafted for the quarry which included design of the rock cuts for the proposed excavation, design of drainage measures both surface and subsurface, and design of haul roads. In addition, restoration plans with a Visual Impact Engineering report were included. An oral presentation by R&M personnel based on this document plus submittal of the document by Alyeska to the federal and state reviewing authorities resulted in the appropriate permits and notices-to-proceed.

R&M personnel monitored rock quality and excavation during production of the quarry to insure that the proper rock products were produced and that the resultant rock slopes were stable and safe during the life of the quarrying operation.

R&M CONTACT:

Jim McCaslin Brown, Head, Earth Science Department, Anchorage Office

SITE ANALYSIS AND ALTERNATIVE LAND USE PLANS FOR FEDERAL EXCESS LANDS

CLIENT:

Cook Inlet Region, Inc.

CLIENT CONTACT:

Mr. Carl Marrs, Land Manager, 1211 W. 27th Avenue, Anchorage, Alaska.

R&M carried out an extensive site analysis and land use planning effort to provide Cook Inlet Region, Inc., an overview of the development potential and land use alternatives for several Federal Excess Land sites being considered by the Native corporation for selection under the Native Land Claims Settlement Act.

The planning process consisted of two steps. Initially a site evaluation criterion was developed to screen all potential sites. Factors considered in the criterion included access to the site; availability of utilities; land terrain; soil conditions; vegetation type and density; flood, earthquake, and avalanche potentials; zoning and other comprehensive planning considerations. An extensive literature search and interpretation of aerial photos provided the data needed to develop the parameters used to make the first phase selections. Sites determined to have development potential in the first phase were then subjected to the second phase process which developed land use alternatives for those sites.

R&M CONTACT:

Mr. Theodore Smith, Project Manager, Anchorage Office.

SITE EVALUATION FOR PROPOSED
ALTERNATE U. S. COAST GUARD LORAN "C" STATIONS

CLIENT:

17th Coast Guard District, Juneau, Alaska

CLIENT CONTACT:

Mr. H. McPherson, Contracting Officer

R&M produced comprehensive site evaluations for proposed alternate Loran "C" Stations at Tok, Carroll Inlet, and Annette Island, Alaska. Comprehensive evaluations were also produced for sites at Sitkinak, Chiniak and Narrow Cape, Alaska, on Kodiak Island. Site surveys were performed at each site to produce the boundary and contour maps needed to develop the site layout plans and drainage systems. Extensive subsurface soils investigations were conducted to gather information needed to make recommendations on structural foundation designs, potential material source locations, sewage and solid waste disposal site locations, water supply well locations, and to evaluate potential problems with local groundwater conditions. Local climatic conditions and seismic probability were included in the evaluation process.

R&M CONTACT:

Mr. Mal Menzies, Vice-President and Project Manager, Juneau Office.

PRELIMINARY HYDROLOGIC STUDIES
ALCAN GAS PIPELINE PROJECT
DELTA JUNCTION TO THE CANADIAN BORDER

CLIENT:

Northwest Pipeline Company

CLIENT CONTACT:

Mark Luttrell, Senior Environmentalist, Gulf Interstate Engineering Company

This study was initiated by field reconnaissance of the proposed route using aerial and on-the-ground observation techniques. The field work was supported by office investigation using existing topographic maps and aerial photographs. The office review entailed a literature search of pertinent documents and analysis of the drainage basins involved, leading to the development of a computational method to obtain design discharge values. All the drainage basins were classified. The studies isolated fish streams, areas of aggradation, scour, outburst flood potentials, and general ground water conditions along the pipeline alignment between Delta Junction and the Canadian Border.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

HYDROLOGY AND RIVER HYDRAULICS STUDY
KUPARUK RIVER AND COASTAL PLAIN STREAMS
NORTH SLOPE, ALASKA

CLIENT:

Atlantic Richfield Company

CLIENT CONTACT:

Steve Jones; Atlantic Richfield Company

This project consisted of conducting a complete hydrological analysis of the Kuparuk River and provide baseline design parameters for a proposed bridge and pipeline crossing. An estimate of flood discharges was made utilizing the Corps of Engineers (HEC-I) Flood Plain Hydrology Computer model. Following the preliminary office analysis, an extensive field program was conducted during the spring breakup flood to obtain data for the calibration of the computer model and interpretation of river behavior.

Flood plain delineation, Flood water elevations, water velocities and depth of scour were determined for the Kuparuk River in the vicinity of the proposed crossing.

Three small Coastal Plain streams were investigated for providing a water supply for camp and drill rig usage. The quantity and quality of the water was determined, and the duration of time that each stream flows sufficiently to provide a water supply was identified.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

HYDROLOGY STUDY
KUPARUK RIVER
PRUDHOE BAY, ALASKA

CLIENT:

Atlantic Richfield Company

CLIENT CONTACT:

Mr. Stan Caldwell, Senior Project Engineer

For Atlantic Richfield's Kuparuk River crossing and Kuparuk Development Area, R&M performed a hydrology study which included a flood hazard analysis utilizing the Corps of Engineers' HEC-1 and HEC-2 computer models. This study, which consisted of both office analysis and field investigation, developed estimated discharges, water surface profiles, and scour depths for 25-, 50-, 100-, and 200-year recurrence intervals. Additionally, a water supply analysis was performed for the proposed "development area," to determine the feasibility of supplying water for a permanent camp of approximately 200 people.

The lack of base-line data, coupled with the extremely difficult field logistics, required both the technological ability to develop the computer analysis and the field experience to perform the in-stream work.

R&M CONTACT:

John E. Swanson, Project Manager

HYDROLOGY STUDY
PROPOSED NEW CAPITAL SITE
WILLOW, ALASKA

CLIENT:

Capital Site Planning Commission

CLIENT CONTACT:

Mark Fryer; Mark Fryer and Associates

As a portion of the initial physical planning effort for the proposed new capital site, R&M performed a hydrology and flood hazard study. The site is traversed by one major stream, Deception Creek, and the study included an estimate of the flood discharge for this creek as well as a general hydrologic review of the entire capital site study area. The review entailed compilation and analysis of precipitation and snowpack data available for the area, as well as analysis of the stream flow records for streams having similar hydrologic characteristics within this region. Drainage patterns were studied as they related to erosion potential, and recommendations were made concerning control of storm water runoff, icing hazards, and land use.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

RIVER MONITORING PROGRAM
ALCAN GAS PIPELINE PROJECT
DELTA JUNCTION TO THE CANADIAN BORDER

CLIENT:

Northwest Pipeline Company

CLIENT CONTACT:

Walfred Hensala, Environmental Coordinator

During the Spring of 1977, R&M monitored the break-up conditions in the five major rivers along the proposed gas pipeline route between Delta Junction and the Canadian Border. While the results of this effort were qualitative in nature, they provided valuable insight into the characteristics of these streams. Following the break-up period, a limited amount of in-stream work was performed in order to prepare a preliminary estimate of scour potential.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

HYDRAULIC DESIGN CRITERIA
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

A. Condo, Arctic/Civil Engineering Supervisor

R&M developed the design criteria for basic hydraulic structures required to intercept and route flows from defined drainages and surface runoff from undefined drainages across the pipeline workpad. Drainage structure selection criteria was developed based on varying soil types, thermal state of the soils, terrain, types of flow and configuration of the workpad. Design procedures permitted selecton of the most suitable drainage structure. Tables and charts were developed for sizing the most economic structures for the anticipated design discharge, as determined in the hydrology study of small drainage basins. The resulting manual enabled field construction personnel to specify and design the most suitable structures for differing or unusual field conditions during construction. This manual was ultimately incorporated into the erosion control manual used to restore the workpad and other work sites after construction.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

HYDROLOGY STUDY OF SMALL STREAMS
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Mr. A. Condo, Arctic/Civil Supervisor

R&M selected the computational method used to estimate the surface runoff for the small drainage basins intercepted by the pipeline right-of-way. The study included surveying several discharge computational methods, evaluating the available data and computing the design discharges for all runoff intercepting the 760-mile long pipeline alignment. Following this, preliminary recommendations for drainage structures were made. The initial design was accomplished in the office, with all results tabulated by computer, and the final design requirements were verified in the field before and during the construction process. R&M's overall participation in this effort extended over a four-year period and was expanded to include responsibility for various phases of erosion control and revegetation.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

GENERAL ENGINEERING AND GEOLOGICAL CONSULTING SERVICES
ALCAN GAS PIPELINE PROJECT

CLIENT:

Northwest Pipeline Company

CLIENT CONTACT:

Mr. John Viehweg, Chief Engineer

Testimony for F.P.C. hearings, chaired by Judge Litt in Washington, D.C., was prepared and presented. Subsequently, numerous short technical reviews have been conducted to establish background data for other hearings as well as for use in design planning. These reviews have included the geologic evaluation of various pipeline routing possibilities and the analysis of design and construction practicality. Conditions considered have included soil and permafrost conditions, frost heave potential, drainage characteristics, compatibility with existing and proposed man-made facilities, and natural hazards. Structure design, performance, and cost criteria relating to special northern environmental constraints, have also been reviewed.

R&M CONTACT:

Ralph Migliaccio, Fairbanks Office.

PRELIMINARY CENTERLINE SOIL INVESTIGATION
DELTA JUNCTION TO THE CANADIAN BORDER
ALCAN GAS PIPELINE PROJECT

CLIENT:

Northwest Pipeline Company

CLIENT CONTACT:

Don Nicol, Senior Engineer, Gulf Interstate Engineering Company

This program was designed and conducted to meet the need for preliminary soils, ground water and related data along the proposed route of the ALCAN Gas Pipeline. During the peak period of activity, seven rotary drill rigs were working two shifts per day spread out over as much as thirty miles of line. An extensive communication system involving portable radios and couriers was utilized to maintain close field coordination and sufficient logistical support including the transportation of large quantities of soil samples. Special care and equipment was necessary to maintain frozen and unfrozen samples in their natural thermal state during transport from the field to the testing laboratory in Fairbanks.

The field and laboratory data from this program is scheduled for use in the development of initial design concepts and in planning subsequent programs.

R&M CONTACT:

Robert L. Schraeder, Anchorage Office.

GEOTECHNICAL INVESTIGATION - PILLAR MOUNTAIN SLIDE
KODIAK ISLAND, ALASKA

CLIENT:

State of Alaska, Department of Highways

CLIENT CONTACT:

William Slatter, Chief Geologist, Department of Highways, College, Alaska

R&M Consultants, Inc. performed a geotechnical review of the Pillar Mountain slide on Kodiak Island, Alaska. Extensive surveys of the slide area were performed to determine correct placement of a monitoring network to warn of any further slide movement during future construction efforts. Project was performed in 1972.

R&M CONTACT: Mr. Jim Rooney, Vice President, Anchorage Office

GEOTECHNICAL INVESTIGATIONS, 17 PROPOSED SCHOOL SITES, LOWER KUSKOKWIM SCHOOL DISTRICT BETHEL, ALASKA

CLIENT:

Lower Kuskokwim School District

CLIENT CONTACT:

Mr. Dave Chauvin, Contract Manager, L.K.S.D., Anchorage, Alaska

Complete geotechnical investigations for seventeen villages in the Lower Kuskokwim School District (Bethel, Alaska area) were conducted in January and February of 1979. Three drill rigs were utilized to accomplish the fieldwork. One drill rig was mounted on an all terrain Nodwell; two were skid mounted and transported from site to site by Caribou or Sky Van aircraft. Test holes at each site were drilled to depths of 30 feet with split spoon and core barrel sampling. Many of the sites were underlain by permafrost. Soil profile temperatures were monitored at each site with thermistor strings. Field logistics and soil sample shipping were coordinated in Bethel. All soil samples were maintained in their original thermal state while being returned to Anchorage for laboratory testing. Foundation recommendations and other site geotechnical parameters were presented in a final report for each site. Foundation recommendations included conventional shallow footings, piles and refrigerated (passive) shallow foundations.

R&M CONTACT:

Dennis Nottingham or Gary Smith, Anchorage Office

GEOTECHNICAL INVESTIGATIONS
ALASKA STATE HIGHWAY SYSTEM
LIVENGOOD TO THE CANADIAN BORDER SEGMENT

CLIENT:

Alaska Department of Highways, Juneau, Alaska

CLIENT CONTACT:

William Slater, State Geologist or Doyle Ross, State Materials Engineer, Department of Transportation, Douglas, Alaska

R&M personnel have extensive supervisory and field experience on the Alaska Highway System. Specific studies that our personnel have participated in along the Livengood to the Canadian Border segment include centerline soil investigations, material site exploration, quarry exploration, and construction quality control. Some special studies also in this area include "An Investigation of the Canadian Border Slide," "Research on Aggregate Degradation," and "Routing Studies to Avoid Problem Areas."

Various personnel have acted in different highway department capacities including State Soils Engineer, State Foundation Geologist, District Geologist, District Materials Engineer, Field Geologist, and Materials Technician.

R&M CONTACTS:

J.W. Rooney; R.R. Migliaccio; R.L. Schraeder; W.T. Phillips; and D. Nottingham; Anchorage Office

ENVIRONMENTAL ASSESSMENT PROGRAM - PHASE I
SOURCE DOCUMENT NO. 3
GEOTECHNICAL STUDIES - GEOLOGIC MATERIALS AND HAZARDS ANALYSIS

CLIENT:

State of Alaska, Capital Site Planning Commission

CLIENT CONTACT:

Dr. Charles Behlke, CSPC Chairman, Geophysical Institute, University of Alaska, Fairbanks.

During September and October, 1978, R&M geologists spent one month in the field at the proposed new State Capital at Willow. This field investigation, performed for the Capital Site Planning Commission, was part of an investigation which applied the techniques of terrain unit analysis to a 100 square mile area. These procedures allowed the collection of considerable geotechnical data to be used for environmental assessment of the Capital Site for evaluation of geologic materials hazards.

Initial stages of data collection produced preliminary terrain and slope analysis maps of the planned development area of the capital site by air-photo interpretation. This was followed by field work. Initial efforts utilized helicopter-supported field crews with hand tools. This effort, which involved study of over 150 locations, was directed toward gathering ground-truth, validating the maps, and gaining a better understanding of on-site vegetation, soil, and water conditions. Detailed subsurface work consisted of backhoe test pits and four 100-foot deep drill holes, and took place within specific development areas to support the planning efforts at the Commission. These areas included the town center, airport site, power plant site, water well development area, and four residential areas. The backhoe operation was confined to areas with existing trails and the drilling operation used helicopter-transported drills.

The field-checked Terrain Unit Map with associated tables, field logs, and laboratory data is a convenient vehicle for storing and presenting considerable geologic and engineering data concerning the soils, bedrock, and groundwater for the 100 square mile development area. A Geologic Materials Map was derived from the Terrain Unit Map to describe the construction use and foundation suitability of the soils and bedrock. An Erosion Potential Map was derived from the Slope Map and the Terrain Unit Map. This described the potential for erosion during development and construction activities based upon topographic and soil conditions.

A final derivative map describes the type and severity of various geologic hazards. Hazards documented included permafrost thaw-settlement, settlement, slope stability, seismic ground shaking, seismic ground fracturing, and seismic liquefaction. The ground fracturing hazard is related to the Castle Mountain Fault in the area near the Little Susitna River at the east end of the capital site. A statistical study of the seismicity of the capital site was performed. One conclusion reached was that the capital site is in a somewhat less seismically active area than either Fairbanks or Anchorage.

R&M CONTACT:

Jim McCaslin Brown or Robert L. Schraeder, Anchorage Office

GEOTECHNICAL INVESTIGATION AND TERRAIN ANALYSIS
SOUTH WILLOW CAPITAL SITE

CLIENT:

State of Alaska, Capital Site Planning Commission

CLIENT CONTACT:

Mr. R. Moorehouse, Planner

A preliminary site evaluation was performed to obtain data required for the physical planning and design tasks of the client's Phase 1 Planning Process.

The terrain unit method of terrain analysis was employed during the geotechnical investigation of the South Willow Capital Site.

This method of investigation employs remote sensing techniques (specifically air photo interpretation) to define landforms and landform types within the study area. Eight terrain units were identified within the designated development area of the South Willow site. These terrain units were then investigated in the field by standard surface geology mapping methods supplemented by the subsurface soils techniques of drilling and sampling. Information thus obtained was augmented with local Electromagnetic (EM) Resistivity Surveys.

This information combined with laboratory testing of selected soil samples, and preliminary engineering evaluations produced a terrain analysis of the designated development area. Documents produced included:

- Slope Identification Map - Scale 1:24,000
- Terrain Unit Map - Scale 1:24,000
- Terrain Unit Evaluation Table
- Slope Analysis Map - Scale 1:6,000
- Geotechnical Limitations to Building Construction Map -Scale 1:6,000

R&M CONTACT:

Jim McCaslin Brown, Anchorage Office

THOMPSON PASS CABLEWAYS
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Taylor Rigging Company

CLIENT CONTACT:

William Taylor

Construction of the trans Alaska pipeline presented many diverse engineering problems including the movement of pipeline and related construction equipment to each site. At Thompson Pass, a particularly steep mountain face compelled the use of hi-lines for the transportation of materials and the construction operation. Designed by R&M to serve as overhead cableways, the two hi-line spans were 1,000 and 1,450 feet and each possessed a 20 ton load capacity. Representing some of the longest span structures built in Alaska, the hi-lines were each supported by two steel towers with a maximum height of 170 feet. The moveable towers supported track cables anchored to post-tensioned concrete deadmen.

R&M CONTACT:

Dennis Nottingham, Project Manager, Anchorage Office.

GULKANA RIVER PIPELINE BRIDGE
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Jim A. Maple, Supervisor Structural Analysis

The original engineering design plans for the Alyeska Pipeline Service Company hot oil pipeline crossing of the Gulkana River involved a buried underwater crossing. Alyeska's decision to bridge the river avoided innumerable associated problems and provided R&M's senior structural design engineers with some specific challenges. The bridge represents an imaginative approach to the sensitive problems of permafrost, ecology, time and materials limitations, as well as aesthetics.

A tied-arch design was developed for the bridge superstructure and construction was accomplished with steel available to the project. The 400 foot long bridge has a substructure composed of specially designed H-piles driven into permafrost. Bridge loads are transferred to the H-piles by supporting piers made from 48" and 18" diameter surplus project pipe. Project design and construction of the $2 million bridge was completed within a six month period.

R&M provided the following services:

- Schedule Control Services
- Design Drawings and Engineering Documents
- Environmental Assessment Including Subsurface Investigation
- Fabrication Quality Control
- Logistics Control
- Construction Inspection

R&M designers won a fifth place award for the bridge superstructure design and third place award for the pile foundation design in the James F. Lincoln Arc Welding Foundation, 1976 Awards Program for Improvement Through Welding.

R&M CONTACT:

Dennis Nottingham, Project Manager, Anchorage Office

YUKON RIVER BRIDGE

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

The involvement of R&M in design and construction of this 2300 foot orthotropic steel pipeline/highway bridge spanning the Yukon River was significant. Mr. Dennis Nottingham was originally in charge of design for this nationally significant structure while employed by the State of Alaska and won Lincoln Arc Welding honors for his contribution. Following his employment with R&M, this firm became a consultant to Alyeska Pipeline Service Company relating to this structure. Interaction with government review officials, analysis of substructures, review of pipeline erection procedures and design of new barrier railing were part of these efforts. Knowledge of ice forces, and analysis based on design of this structure and many previous large highway crossings was used to develop river ice and drift design criteria for all pipeline bridges with river piers on the Trans-Alaska Pipeline.

R&M CONTACT:

Dennis Nottingham, Project Manager, Anchorage Office

SAXMAN DAM
KETCHIKAN, ALASKA

CLIENT:

U.S. Public Health Service

CLIENT CONTACT:

John DeLapp

In order to provide an adequate water supply for the City of Saxman, near Ketchikan, the U.S. Public Health Service contracted with R&M to perform the design of a dam, reservoir, and treatment system. This included preliminary hydrologic and geologic investigations at the site, design of the dam and its appurtenant structures, and design of the access road, transmission line, and pipeline between the dam and the existing system.

Several alternative systems were investigated, and recommendations were made to U.S.P.H.S., based on the on-site investigations and on previous experience with similar projects in southeast Alaska.

R&M CONTACT:

Dr. Daniel Smith, Project Manager

HESS CREEK THERMAL EROSION TEST SITE
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

A.C. Condo, Arctic/Civil Supervisor

Thawing of ice-rich permafrost soils presents potential erosion problems, such as ground subsidence, downslope movement, redeposition of thawed slope material, headward erosion, and gullying. The Hess Creek Thermal Erosion Test Site was constructed by Alyeska Pipeline Service Company to provide a study area for evaluating the performance of different treatments of cut slopes to control erosion in the ice-rich silty soils traversed by the pipeline.

R&M Consultants designed and supervised construction of the test site. Test data were collected by R&M over a two year period.

Results from the test site study demonstrated that thermal degradation rates could be limited in a manner that allows stabilization of surficial slope disturbances. Proper insulation, drainage, and revegetation were identified as appropriate alternate solutions to the utilization of granular buttresses for control of erosion until natural re-establishment of vegetation and stabilization of the thermal regime could be accomplished.

R&M CONTACT:

James W. Rooney, Anchorage Office

PROSPECT CREEK THAW SETTLEMENT TEST SITE
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

A.C. Condo, Arctic/Civil Supervisor

Information regarding thaw induced settlement of permafrost soils was an essential requirement in defining acceptable criteria for burying the trans Alaska hot-oil pipeline. Prediction of thaw consolidation had essentially been based on laboratory or theoretically derived procedures. For certain soil conditions, the influence of in-situ or macro-structure effects could not be identified by the above procedures.

In order to ascertain in-situ performance of specific frozen soil types, R&M Consultants designed, monitored, and evaluated the Prospect Creek Thaw Settlement Test Site for Alyeska Pipeline Service Company. The test site consisted of a 50 feet wide by 200 feet long section of initially frozen silty granular soil. The site was artificially thawed by placement of an electrically heated "hot pad" covered by insulation. The fully instrumented test site was monitored for measurement of thaw melt rate, strain, excess pore pressure and heat flow. Ground thawing was extended to a depth of over 25 feet below original ground surface.

Results of the testing were utilized to confirm thaw consolidation strain values established in the laboratory and to investigate the anticipated influence of arching effects (associated with large scale strain adjustments).

Prediction of thawing and consolidation for various soil types was used to evaluate the potential for subsidence of buried pipeline, workpad, and disturbed ground, as well as to identify requirements for placement of overfill and drainage controls associated with long term time-dependent development of the thaw bulb in permanently frozen ground.

R&M CONTACT:

James W. Rooney, Anchorage Office, or James H. Wellman, Fairbanks Office

ROCKSLOPE STABILITY AT THE
VALDEZ TERMINAL, ALASKA
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company, P.O. Box 4-Z, Anchorage, Alaska 99502

CLIENT CONTACT:

Jim McPhail, Director of Engineering, Anchorage

R&M provided primary geotechnical consultant services for the trans Alaska hot oil pipeline terminal site which continued for a period of three years. Activities included geotechnical investigation and design of rock slopes; design and field modification of rockslope reinforcement; design and installation of piezometer network for groundwater observation; and design and field modification of rockslope dewatering systems. R&M personnel also performed field monitoring, documentation of construction, and prepared and presented technical material for governmental agency review.

Conservative practices were used consistently because of the height of the slopes (up to 230 feet) and their proximity to vital facilities of the terminal complex. Reinforcing techniques used included tensioned Dywidag rockbolts, chainlink wire mesh, rockfill toe buttresses, dewatering, and shotcrete.

R&M CONTACT:

Dr. J.M. Brown, Anchorage Office

EVALUATING DEVELOPMENT POTENTIAL FOR STATE-OWNED LANDS

CLIENT:

Knik Village Corporation

CLIENT CONTACT:

Mr. Andy Kamkoff, 610 "C" Street, Anchorage, Alaska.

R&M evaluated all State-owned land in a selected area north of Anchorage in the Mat-Su Borough to establish selection priorities for a proposed land swap between the Knik Valley Native Corporation and the State of Alaska. Each plot of land was evaluated by addressing site specific characteristics such as access, terrain units, resources, soil conditions, hazard potential, and land development potential. Each of these parameters was graded using a subjective five point evaluative methodology. The individual scores were totaled on the land parcel map and acquisition priorities were assigned each parcel according to the combined score.

R&M CONTACT:

Mr. Theodore Smith, Project Manager, Anchorage Office.

LOWER KUSKOKWIM SCHOOL DISTRICT SCHOOL SITE INVESTIGATIONS

CLIENT: Lower Kuskokwim School District; Bethel, Alaska
CLIENT CONTACT: Mike Franks

R&M Consultants, Inc., provided site evaluation and survey services for proposed high schools in sixteen villages within the Lower Kuskokwim School District. Investigations were conducted at Platinum, Chefornak, Eek, Tununak, Tuluksak, Kwethluk, Akiachak, Quinhagak, Tuntutuliak, Napaskiak, Goodnews Bay, Mekoryuk, Newtok, Nightmute, Oscarville, and Kasigluk in the Lower Kuskokwim Delta region. R&M Consultants' project role at each community was 1) to provide technical assistance during public hearings in which the local villagers selected a school site; 2) survey the selected site for property or use rights transfer; 3) from interviews and site investigations, compile site specific information to be used as a design aid for architects and engineers.

The scope of this project included the gathering, compilation, analysis, and presentation of information relevant to the design of new high schools, and was four phased as defined below:

Phase 1-of the project involved a literature search to obtain and compile site information from existing records. The search included State and federal agencies, private firms and organizations, and private individuals having first-hand experience of local conditions. Types of information gathered included the following:

- Survey Plats
- Aerial Photographs
- Maps and Descriptions of Existing Facilities
- Geotechnical Data
- Hydrological and Climatic Data
- Environmental Hazards
- Land Status
- Archeological Restrictions
- Topographic Data
- Community Population
- Transportation
- Economic
- Communication and Social Data.

Phase II-entailed site selections by the village residents. A representative of the Lower Kuskokwim School District (L.K.S.D.) accompanied by an engineer from R&M Consultants visited each village. During this initial visit, possible sites were reviewed, and a public hearing was held to explain the project to the local residents, who then selected a site. It should be emphasized that R&M Consultants' role was to provide technical information to the local residents, so that they could select a site. Possible sites were discussed during the public hearing, and vote tallies of all residents present were used to determine the final site selection.

Phase III-R&M Consultants, Inc., sent an engineer and two surveyors to each village to perform a boundary and topographic survey of the selected site, to verify information obtained from the literature search, and to gather additional site specific and local data found pertinent to construction of a new high school.

Phase IV-involved the compilation of all pertinent information into a final report for the proposed high school. This report included identification of the selected school site and presentation of the general design considerations, recommendations, and criteria to be used as a basis for design.

This entire project was completed within two-and-one-half months of Notice to Proceed.

R&M CONTACT: William Robertson, Project Manager, Anchorage Office.

TURNAGAIN ARM
TIDAL SCOUR STUDY

CLIENT:

Nikiski Alaska Pipeline Company

CLIENT CONTACT:

Mr. Ed Hartig

R&M performed a scour analysis to determine the feasibility of utilizing tidal forces to bury an exposed pipeline on the tide flats of Turnagain Arm. The analysis included computation of the shear force necessary to produce scour, flow-net analysis of a proposed scour-producing structure, and determination of the tidal velocities necessary to allow the structure to function as desired. Field measurement of velocities at the site will be conducted as soon as spring break-up permits.

R&M CONTACT:

John E. Swanson, Project Manager, Anchorage Office

ROUTE GEOMORPHOLOGICAL RECONNAISSANCE STUDY
ALCAN GAS PIPELINE PROJECT
DELTA JUNCTION TO THE CANADIAN BORDER

CLIENT:

Northwest Pipeline Company

CLIENT CONTACT:

Don Nicol, Gulf Interstate Engineering Company, Senior Engineer

This partial route reconnaissance involved extensive use of both color and black and white aerial photos supplemented by available published data and considerable field checking. The results were presented on 1"=1000' scale alignment sheets which showed the aerial extent of each recognizable soil unit along with a table indicating the interpreted thermal condition, soil type, ground water condition and other pertinent engineering and geologic properties. These "Terrain Unit Maps" are used to help select the optimum route and to plan the centerline soil investigation. These maps have been utilized as a part of the project planning and design package and would also be used through the construction and operation phases.

R&M CONTACT:

Ralph Migliaccio, Fairbanks Office

TERRAIN UNIT (SOILS) STUDIES FOR STATE OFFERED HOMESITES

CLIENT:

State of Alaska, Division of Lands

CLIENT CONTACT:

Mr. Claud Hoffman, ADL, 323 E. 4th Ave., Anchorage, AK 99501

The State of Alaska's Homesite Bill provided for 85 homesites, located in three areas of central Alaska, to be opened to the public for individual use. Before approving the bill, the State Department of Environmental Conservation required assurance that the soils at the 85 sites were suitable for the installation of on-site sanitary sewer systems.

To preclude the need for detailed investigations at each site in a preliminary assessment, R&M prepared generalized soils evaluations and a terrain unit map for the three areas. Soil type, expected distribution and soil suitability were outlined for each area based on the analysis of air photos and information gathered in a literature search. This data was supplemented by a limited field effort to verify office assessments.

The study effectively and inexpensively produced the soils information required to evaluate the needs and anticipated impacts at each site and to secure environmental approval.

R&M CONTACT:

Gary A. Smith, Senior Geologist, Anchorage Office

GLENNALLEN SURVEY, LAND USE ANALYSIS AND INVENTORY

CLIENT:

Alaska Division of Lands

CLIENT CONTACT:

Claude Hoffman, Cadastral Engineer, Alaska Division of Lands, Anchorage, Alaska

R&M's Alaska survey department was involved in the State of Alaska land disposal program mandated by the State Legislature. R&M was selected for the Glennallen project which consisted of approximately 4,500 acres of state owned land in and around the community of Glennallen.

The purpose of R&M's involvement was not only to survey the project boundaries, but also to classify the land for its suitability as homesite and recreational parcels, and make recommendations to the state as to size and location of development areas.

R&M had the project flown and photographed with a high precision mapping camera and subsequently photogrammetrically mapped at a scale of 1 inch = 200 feet with a 5 foot contour interval. The photographs were used by R&M geologists for the task of "Terrain Unit Mapping," a process whereby large areas of land can be generally classified as to soil type, vegetation, and presence of "near the surface" permafrost and general extent of the seasonal thaw zone.

After field truthing the Terrain Unit Maps, R&M geologists and geotechnical engineers developed a drilling program to further explore those areas that appeared suitable for subsurface sewage disposal. Those areas were then drilled, percolation tests performed, and soil samples returned to R&M's Anchorage Office for lab testing.

Though the use of the Terrain Unit Maps, field surveys, soils testing, contour maps, drilling and percolation test results, a useable land inventory map was prepared recommending useable land and parcel sizes. This useable land inventory and accompanying report was presented to the Alaska Department of Environmental Conservation who subsequently concurred with R&M's recommendations, and approved the plan for development of preliminary subdivision plats.

A land development master plan and preliminary plats were prepared and submitted to the Alaska Division of Lands where they were approved. R&M was then requested to prepare final subdivision plats on the portion of the project that appeared most suitable for immediate disposal. These subdivisions consist of approximately 2320 acres with lots ranging in size of from 1 acre to 40 acres.

R&M CONTACT:

Bob A. Dortch, Anchorage Office

SQUIRREL CREEK EROSION CONTROL PROJECT
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

A. Condo, Arctic/Civil Supervisor

As part of a comprehensive project-wide erosion control task performed for Alyeska Pipeline Service Company, R&M developed site specific grading, drainage, and revegetation design plans for the Squirrel Creek site near the Tonsina River. Alyeska's pipeline crossing at Squirrel Creek necessitated a through-cut in the adjacent high bluff of up to 70 feet in ice-rich, frozen soil, thus creating a slope of 30 percent along the work-pad driving surface. As a means of providing permanent access on this steep slope, it was necessary to design positive drainage control for both longitudinal and transverse drainage, including energy dissipators. The R&M drainage design, grading plans for the cut slopes and a complete revegetation schedule have produced a stable, trafficable and aesthetically acceptable crossing in an extremely difficult frozen ground location.

R&M CONTACT:

Ray Alexander, Project Manager

TOLSONA CREEK EROSION CONTROL
AND REHABILITATION PROJECT
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

A. Condo, Arctic/Civil Supervisor

Severe erosion problems were encountered at Mile 173 on the Glenn Highway following highway construction in 1969, which created a problem with siltation in Tolsona Creek. As a test of revegetation and erosion control techniques for Interior Alaska that R&M helped develop for Alyeska Pipeline Service Company, the site was subsequently rehabilitated under R&M supervision. Drainage control measures included interception of overland flow, energy dissipators, and siltation basins. The revegetation program involved hydroseeding, fertilizing, mulching with various test materials, and tacking the mulch when required to achieve maximum germination. As an immediate result of the application of these techniques, hydraulic erosion has been controlled, revegetation has been achieved on formerly barren slopes, and siltation of Tolsona Creek at this point has been mitigated.

R&M CONTACT:

James W. Rooney, Vice President, Anchorage Office

EROSION CONTROL PLAN
PUMP STATIONS AND TERMINAL
TRANS-ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

A. C. Condo, Arctic/Civil Supervisor

R&M participation in the erosion control and restoration planning effort encompassed all phases of the Trans-Alaska Pipeline Project. One of the major tasks was the preparation of an erosion control plan for the pump stations and the terminal facility. These documents utilized the procedures developed for Alyeska's overall erosion control efforts, applying them on a site-specific basis for each pump station and for the Valdez terminal.

For each site, consideration was given to clearing, earthwork, disposal, hydraulic and thermal erosion, revegetation, and maintenance. These items of work were keyed to specific soil erosion classifications and procedures developed in Alyeska's Erosion Control Procedures Manual.

R&M CONTACT:

James W. Rooney, Vice-President, Anchorage Office

PIPELINE WORK PAD AND DRAINAGE DESIGN
TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Mr. A. Condo, Arctic/Civil Supervisor

R&M participated in all stages of pipeline alignment evaluation and construction work pad design. Initial efforts included major full-scale workpad test site studies at Glennallen and Fairbanks. Workpad and drainage design criteria were established for a systems application to the 760 mile long pipeline alignment. Actual design was accomplished in the office on a preliminary basis and final design requirements were verified in the field during the construction process. R&M's overall participation in this effort has extended over a six year period and was expanded to include responsibility for various phases of erosion control, revegetation, and visual impact evaluation.

R&M CONTACT:

James W. Rooney, Vice President, Anchorage Office.

SITE REHABILITATION STATUS INVENTORY SYSTEM
CIVIL ENGINEERING- TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Mr. A. Condo, Arctic/Civil Supervisor

R&M developed this system for Alyeska Pipeline Service Company to inventory rehabilitation and erosion control related activites along the entire pipeline alignment and at pipeline facilities. Completion of this project involved the following tasks:

- Analysis of the structural organization and functions involved in the work activities.
- Design and development of a system to maintain updated field generated data concerning erosion control work.
- Design of field data forms for direct entry into the system.
- Supervision of programming, testing, and implementation.
- Training of systems users.
- System documentation and procedures manual.

This system was a management information report tool for monitoring the progress of erosion control activities. The system was used for budgeting related work as well as providing construction scheduling reports.

R&M CONTACT:

Mr. Russell Sandstrom, Anchorage Office.

LABORATORY DATA BANK - COMPUTER SYSTEM
GEOTECHNICAL ENGINEERING - TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

C. Whorton, Senior Engineer

This computerized data bank is utilized to store all soil index property data resulting from laboratory testing of soil samples from soil exploration holes drilled along the entire pipeline route. Key data pertaining to other soil variables is also stored for every boring in the data file. The system provided for the collection of all available laboratory data developed for various efforts along the alignment. The system was developed to allow continued updating of all related laboratory data records and reports through the project construction period. Data storage included detailed records for well over 5,000 test holes, 100,000 soil samples and results for on the order of 1,000,000 laboratory tests.

R&M was responsible for the performance of the following activities related to the development and completion of this task.

- Design of data input formats and handling techniques.
- Data bank system design specification.
- Supervision of programming.
- Design of output report formats.
- System testing and implementation.
- Preparation of user manual.
- Data collection and verification.
- Report publication.

R&M designed a special output format suitable for generating computer output at project field office locations. This concept was subsequently used extensively by Alyeska to accomplish the acceptance of computer generated output.

R&M CONTACT:

J. W. Rooney, Anchorage

MASS EARTHWORK VOLUME ANALYSIS
GEOTECHNICAL AND CIVIL ENGINEERING
-TRANS ALASKA PIPELINE SYSTEM

CLIENT:

Alyeska Pipeline Service Company

CLIENT CONTACT:

Mr. Kay Eliason, Assistant Construction Manager

Mass earthwork volumes for the project represented well over a one billion dollar expenditure. R&M Consultants, using a systems approach, developed a model and program for optimizing overall earthwork efforts while identifying earthwork construction requirements. This information was useful for defining equipment allocation and evaluating if sufficient quantities of material were available at material sources and for verifying requirements for placement and size of disposal site. The report was also used by Alyeska to verify actual quantity figures submitted by their construction contractors and served to provide support documentation to the reviewing agencies.

Geometric data were taken from the station cross sections for the entire pipeline length. From this data, calculations were made to determine excavation and embankment quantities. From landform information and ground profile analysis of soils identified in the laboratory data bank, it was determined what part of the excavation at each station could be utilized for embankment material and what part of the unusable amount would be left along the right-of-way. The net quantities thus derived were then used (along with data on the expected quantities available in the various material sources and disposal sites), to calculate haul quantities. The mass diagram report produced listing quantities at 100 foot intervals for the entire pipeline route. The haul analyses listed quantities including haul distance for approximately 1,300 material and disposal sites. Examples of processing activities included;

- Design of data bank system for data input and updates.
- Design of data input forms.
- Responsibility for data collection.
- Design of both printed and plotted output formats.
- Responsible charge of all phases of programming work.
- Testing and implementation of system.

R&M CONTACT:

J. H. Wellman, Project Manager, Fairbanks Office

RELEVANT EXPERIENCE

WOODWARD-CLYDE CONSULTANTS

WOODWARD-CLYDE CONSULTANTS

RELEVANT EXPERIENCE:

(A) GENERAL

(B) ALASKAN STUDIES

(C) RECENT DAM STUDIES

WOODWARD-CLYDE CONSULTANTS
Relevant Experience

General

Woodward-Clyde Consultants is a nationwide consulting firm practicing in the general fields of geotechnical engineering and environmental assessment. We offer such services as earthquake engineering, site selection, engineering, geology, seismology, environmental impact assessment, and decision analysis.

We have a staff of about 800 professional and support personnel, three-quarters of whom are graduate engineers and scientists or skilled technicians. Approximately 350 hold advanced degrees in the physical sciences (chemistry, geology, geophysics, hydrology, meteorology, physics, and physical oceanography), engineering (civil, geotechnical, mechanical, nuclear, chemical, and sanitary), the natural sciences (terrestrial and aquatic ecology and biological oceanography), and the social sciences (economics, land-use/urban planning, sociology).

Qualifications and Experience - Geology-Seismology-Geophysics

Woodward-Clyde Consultants maintains a talented, multi-disciplinary group of earth scientists engaged in geological, seismological, and geophysical investigations. The Director of the Geology-Seismology-Geophysics Professional Group is Lloyd S. Cluff, an internationally recognized expert in engineering geology and seismic geology. Until recently, the Chief Seismologist with Woodward-Clyde Consultants has been the late Dr. Don Tocher, a recognized authority in the fields of seismology and engineering seismology. The Geology-Seismology-Geophysics Group is composed of more than 125 professionals and is based in San Francisco, California. This group provides Woodward-Clyde Consultants with unmatched depth of experience and diverse capabilities in the earth sciences.

The Geology-Seismology-Geophysics Professional Group brings to the Susitna project, many hundreds of person-years involved with studies of regional seismicity, active faulting, and seismic hazard evaluation for major engineering projects. These past and present studies are worldwide in distribution and include extensive experience in Alaska. The fault study completed by Woodward-Clyde Consultants for Alyeska Pipeline Service Company in 1974 was a landmark investigation that established design parameters for active fault crossings and improved the knowledge of earthquake sources for the region of the Alyeska pipeline route. The area examined in detail in the study for Alyeska borders the study area for the proposed Susitna project. The Alyeska project demonstrated that the Woodward-Clyde Consultants project team has the capability to deliver the necessary and appropriate results of complex investigation carried out in Alaskan field conditions.

In addition, we have performed regional fault and seismicity studies for Alaska Outer Continental Shelf Sites and the proposed Northwest Alaska gas pipeline in Alaska; local fault, seismicity, and geophysical studies for marine terminal facilities proposed for Yakutat, Alaska, numerous seismicity and fault evaluations for nuclear power plant sites in California, Washington, Arizona, New Mexico, Texas, New York, Nicaragua, and Iran, regional seismicity and fault studies for numerous large dams, and fault mapping and earthquake recurrence evaluations in Alaska, California, Nevada, Arizona, Utah, Idaho, Washington, Italy, Venezuela, Argentina, Iran, Nicaragua, Guatemala, Colombia and Ecuador. The experience gained in these investigations has resulted in the development of methodologies to effectively acquire, analyze, evaluate, document, and defend varied data analyses and interpretations for major engineering projects under close scrutiny of regulatory agencies. The attached descriptions illustrate the experience and services we have provided in some of our past projects.

Qualifications and Experience - Earthquake Engineering

In its Western Region, WCC has a permanent group engaged in earthquake engineering studies. The director of the Earthquake Engineering Group is Dr. I.M. Idriss, who is an internationally-known expert in this field. A staff of 13 engineers currently comprises the Earthquake Engineering Group in the San Francisco office of WCC's Western Region. An additional three engineers in the Earthquake Engineering Group are located in our Orange, California office. This group of engineers provides a depth of experience and capabilities for a variety of earthquake engineering applications.

The types of services engaged in by the Earthquake Engineering Group include: a) characterization of earthquake ground motions for design purposes; b) characterization of soil dynamic properties and cyclic strength characteristics, c) nonlinear analyses of the response of soil desposits to earthquakes, including development of improved procedures for analyses and material characterization, d) evaluations of the potential for seismically induced ground failures, including liquefaction and slope instability and ground deformations, and development of remedial measures; e) dynamic analyses of soil-structure interaction.

For use in characterizing ground motions and conducting dynamic response analyses, WCC has a data bank on computer files of recorded earthquake ground motions. The motions on file include all those digitized and processed at the California Institute of Technology and many other records from Alaska, Japan, South America and other locations acquired, digitized and processed by WCC.

For support in the evaluation of soil dynamic properties and cyclic strength, WCC has one of the finest soil laboratories in the country in Oakland, California. The laboratory has extensive experience in dynamic testing of soils. In addition, the laboratory has conducted extensive testing of frozen soils, mostly for the Alyeska pipeline project. Field support services for evaluation of soil dynamic properties include a strong geophysics capability, including proven equipment and techniques developed by WCC for the in situ measurements of shear wave velocity.

The types of earthquake engineering services summarized above have been applied to a variety of construction projects, including dams, nuclear power plants, offshore oil and gas platforms, port developments, bridges, LNG facilities, pipelines, and many other industrial and commercial projects.

WCC has conducted studies for a large number of projects of the characteristics of site ground motions during earthquakes and of the potential for seismically-induced failure of in situ deposits and earth and rockfill dams. Several of these projects were in Alaska. The attached table summarizes the earth and rockfill dams for which seismic stability evaluations have been made by WCC. Our scope of work for several of these dams is described in the project summaries. The studies have ranged from regional to site-specific evaluations, and from feasibility to final design studies. The Offshore Alaska Seismic Exposure Study (OASES), which is summarized in the attachments, is particularly relevant to and useful for the probabilistic assessments of earthquake ground motions that will be made for the Susitna project.

SUMMARY OF EARTH OR ROCKFILL DAMS FOR WHICH
SEISMIC STABILITY EVALUATIONS HAVE
BEEN MADE BY WOODWARD-CLYDE CONSULTANTS

Arrowhead Dam
Lake Arrowhead, California
(owner: Arrowhead Homeowners Association)

Arroyo del Cerro Dam
Contra Costa County, California
(owner: U.S. Soil Conservation Service)

Big Canyon Reservoir
Newport Beach, California
(owner: City of Newport Beach)

Boruca Dam
near Palmar Norte, Costa Rica
(owner: Instituto Costarricense del Electricidad)

Cedar Creek Dam
Carbondale, Illinois

Chabot Dam
Alameda County, California
(owner: East Bay Municipal Utility District)

Chatsworth Dam
Los Angeles, California
(owner: Los Angeles Department of Water and Power)

Chulac Dam
Guatemala
(owner: Instituto Nacional de Electricic

El Salado Dam
Coca River, Ecuador
(owner: Instituto Ecuatoriano de Electricidad)

Farley Dam
Farley Nuclear Plant
Dothan, Alabama
(owner: Alabama Power Company)

Little Pine Creek Dam
Contra Costa County, California
(owner: U.S. Soil Conservation Service)

Marysville Dam
near Marysville, California
(owner: U.S. Army Corps of Engineers)

SUMMARY OF EARTH OR ROCKFILL DAMS FOR WHICH
SEISMIC STABILITY EVALUATIONS HAVE
BEEN MADE BY WOODWARD-CLYDE CONSULTANTS

Mission Viejo Dam
Mission Viejo, California
(owner: Mission Viejo Company)

Parks Bar Afterbay Dam
Yuba County, California
(owner: U.S. Army Corps of Engineers)

Perris Dam
Riverside County, California
(owner: State of California)

San Pablo Dam
Alameda County, California
(owner: East Bay Municipal Utility District)

Santa Clara Valley Water District Dams
Santa Clara Valley, California
(owner: Santa Clara Valley Water District)

Santiago Creek Dam
Orange County, California
(owner: Irvine Ranch Water District)

Sesquile Dam
Columbia, South America
(client: Ingetec, LTDA)

Shearon-Harris Dams
Shearon-Harris Nuclear Station
Wake County, North Carolina
(owner: Carolina Power and Light Company

Silver Lake Dam
Los Angeles, California
(owner: Los Angeles Department of
Water and Power)

Summer Dams
Virgil Summer Nuclear Station
near Columbia, South Carolina
(owner: South Carolina Power and
Light Company)

Upper San Leandro Dam
Alameda County, California
(owner: East Bay Municipal Utility
District)

Van Norman Dams
San Fernando, California
(owner: Los Angeles Department of
Water and Power)

Watauga Dam
X21-X22 Nuclear Plant
northeastern Tennessee
(owner: Tennessee Valley Authority)

ALASKAN STUDIES

ALYESKA PIPELINE EXPERIENCE

Project: Trans-Alaska Oil Pipeline System

Client: Alyeska Pipeline Service Company

Location: Prudhoe Bay to Valdez, Alaska

Assignment: Geotechnical Engineering Consulting Services

General Statement - Woodward-Clyde Consultant personnel participated very widely in the extensive geotechnical engineering effort associated with the trans-Alaska pipeline project. Our involvement covered

- the early conceptual studies and government submittals
- the main design phase
- the preconstruction and construction phases
- preparation for pipeline operation.

From February of 1971 to April of 1978, we provided personnel working hand-in-hand with Alyeska personnel on engineering tasks. Additionally, personnel located in our offices performed on many specific tasks or projects such as the VSM tests and the earthquake fault studies. All along we made laboratory tests on soil samples shipped from Alaska to our Oakland, California soils laboratory.

Throughout this period we also participated with Alyeska in preparing documentation for submittals and presentations to, and discussions with, government review personnel.

The major identifiable technical tasks performed by WCC personnel fall in the following categories:

- geotechnical data gathering
- pipeline construction mode and design aspects
- VSM field tests
- earthquake fault studies
- participation in pipeline construction
- preparation for pipeline operation

In addition to accomplishing these specific tasks, senior WCC personnel also contributed significant concepts and ideas that established direction for the project in the engineering, engineering-management and government-relations fields. Several such contributions are outlined in a later section, following the discussions of the specific technical tasks.

Geotechnical Data Collection

Soil Exploration - We participated in planning soil and geotechnical exploration programs. During the field exploration, WCC personnel technically evaluated drilling and sampling methods to provide for efficient field operation. At Valdez we made an offshore subsoil investigation utilizing a vibratory core sampler in support of the design of the ballast water outfall.

Laboratory Testing - In support of the design work, we conducted several laboratory test programs on samples recovered along the pipeline. These included tests to determine thaw strain due to thawing of initially frozen samples and the shear strength of initially frozen soil samples during and after thaw; the load-displacement-time (creep) behavior of frozen samples at controlled temperatures just below 32°F; the permeability to hot oil of compacted glacial till samples with and without bentonite admixture; and the thermal energy content (unfrozen moisture content) of frozen samples. Several of these testing programs were without precedent and required design of test equipment and development of test and analysis techniques.

Pipeline Design Aspects

Thaw Plug Stability - We investigated the "thaw plug" stability along the pipeline, i.e., the stability of the zone surrounding the buried pipeline or underlying the workpad of the elevated pipeline which is subject to thawing. We established design criteria for thaw plug stability, including consideration of earthquake forces, and made mile-by-mile evaluations for it. The results of this evaluation impacted on construction mode selection. An extensive program of field measurement of pore pressures and shear strengths in developing thaw bulbs complemented this effort.

Thaw Settlement - We participated in evaluation of methods to determine thaw settlement of thawing soils based on extensive thaw strain tests, and made mile-by-mile thaw settlement evaluations for use in determining construction modes.

Construction Mode Selection - For the most part, geotechnical considerations governed the selection of construction modes - conventionally buried, specially buried, and elevated on VSM bents. We participated in this selection both in preliminary studies and in detailed mile-by-mile evaluations.

Buried Pipeline Design - We investigated soil restraining characteristics (lateral and longitudinal) for bends and straight sections of buried pipeline, for both conventional and special burial. We also generated mile-by-mile geotechnical parameters for use in buried pipeline design, and evaluated foundation design for buried mainline valves.

Elevated Pipeline Design - WCC personnel had major responsibility in developing the types of VSM used for support of elevated sections of the line, in developing design criteria for these supports, and in generating mile-by-mile geotechnical information for use in mile-by-mile VSM design. This work was based in large part on the VSM field tests described later. A computer system to design each pile along the pipeline alignment was developed under the technical management of Woodward-Clyde personnel. The system was designed such that new pile designs for above ground pipeline sections could be generated rapidly if field conditions were found to be different during construction than assumed during design. The loadings for the piles were taken from an existing program which produced the mile-by-mile design for the above-ground pipe accounting for thermal and structural loads.

As Built Data - Following up the design, computer systems were developed that recorded "as-built" pile data, materials used, and other related data. Also a system was set up to record and aid in evaluation of data generated during the hydrotesting that preceded the operational loading of the pipeline.

Pipeline Bridges - WCC personnel has major responsibility during the field investigation, design and construction of the foundations for all pipeline bridges except the Yukon River Bridge.

Remote Valve Sites - We developed foundation recommendations for the equipment building and propane tanks at all remote gate valve sites.

Construction Zone Design - WCC personnel participated in developing initial criteria for construction zone grading; i.e., need for and extent and details of grading, and determination of cut and fill slopes for different thawed or frozen materials. Individual cases of grading problems were evaluated and resolved.

VSM Field Tests

WCC personnel had responsible control of three generations of VSM field tests for the project. The first set of tests, conducted in 1970, resulted in initial design criteria, but also demonstrated that driven VSM without thermal protection would need to be unreasonably long. The second set of tests, in 1972, resulted in second-generation criteria and indicated the superiority of installing VSM in oversized predrilled holes and slurrying the annulus. The third set of VSM tests, in 1975, confirmed the tentatively adopted design criteria for thermal VSM in different soil types. The three sets of tests were instrumental in the evolution of VSM types and design criteria for the project, and resulted in the finally adopted design. WCC also participated in planning and documentation of other field VSM load tests made during construction, and supervised laboratory VSM load tests at the University of Illinois.

Earthquake Fault Studies

WCC geologists conducted a detailed study of potential active fault displacements along the pipeline route. This study permitted the pipeline designers to minimize the risk from possible future surface faulting, by delineating potentially active faults, estimating the "design" fault motions, and thus permitting specific pipeline design for these motions. Aerial reconnaissance and detailed analysis of aerial photographs were used to locate all linear features or lineaments which might be potentially active faults. Photogeologic interpretation included the use of Earth Resources Technology Satellite (ERTS) imagery, radar imagery and special low sun angle photography in selected locations. A later fault evaluation along the alignment of the suspected Clearwater Lake fault permitted elimination of any special design provision in this area.

Participation in Pipeline Construction

Preparation of Field Design Change Manual - WCC personnel generated the concept of the Field Design Change Manuals (FDCM) and prepared several drafts of both Volume I for VSM Construction and Volume II for belowground construction.

Field Engineering - WCC provided personnel for different field engineering functions, ranging from VSM hole logging to field engineering supervisor. In these capacities the personnel participated in all levels of field engineering work and decision making on pipeline construction. The work of the field engineers included inspecting construction, instructing the contractor, design change implementation and field documentation.

Office Support for Field Engineering - All through construction, WCC personnel were involved in office support of field engineering activities, including review of design changes, documentation, government interface, special field studies, and so forth. The fields for which WCC personnel took major responsibility included all aspects of VSM construction, belowground pipeline construction, and pipeline bridge foundations. For VSM in particular, there was further development of geotechnical design criteria, work on lateral load criteria, updating mile-by-mile design, and assistance to field engineers in solving VSM installation problems. For belowground construction there was review of bend design and development of overfill concept for as-built bends with insufficient cover.

Valdez Terminal and RCA Communication Towers - We provided field geotechnical engineering personnel for the Valdez Terminal and the RCA communication tower foundations. At Valdez we also participated in the evaluation of rock slope stability and embankment stability.

VSM Reliability Evaluation - The WCC Decision Analysis group made a fault tree analysis of the failure potential of elevated pipeline due to settlement of the VSM. The analysis showed extremely low probability of pipe wrinkling due to VSM settlement.

Preparation for Pipeline Operation

Surveillance and Monitoring Manual - In 1976 WCC personnel prepared a Geotechnical Surveillance and Monitoring Manual for the pipeline, pump stations and Valdez Terminal. This manual is being utilized by surveillance personnel.

Maintenance and Repair Manual - WCC personnel participated in preparing Maintenance and Repair Manuals for geotechnical aspects of both aboveground and belowground sections of the pipeline.

Major Concepts and Ideas

The previous paragraphs highlight the specific WCC accomplishments on the project. While these accomplishments were vital to the project, we believe that our contributions to the project in the form of concepts and ideas were just as significant. Several examples of these are presented below:

- A WCC team developed many of the concepts for pipe support in the early studies for the pipeline. These concepts form the basis for much of the stress analysis of the pipeline.

- We foresaw the need for a major field engineering and quality control effort and documented this with various memos to Alyeska. These memos developed into the organizational structure that was adopted and to the Field Design Change Manual, the concept of which was developed by WCC personnel

- WCC introduced the concept of the use of heat pipes for controlling degradation of the permafrost. The early concept was the use of heat pipes to permit burial of the pipe in high-ice-content soils. This concept did not work out, however, it progressed to the use of heat pipes in the VSM which became the basic design solution for the elevated pipeline.

- WCC promoted the concept of task-oriented organization rather than discipline-oriented organization resulting in a reorganization of the engineering effort which was successful in completing the design of the pipeline.

- WCC personnel developed the concept of prequalification of manufacturers of the heat pipe and pushed this concept through to successfully deliver heat pipes to the project to meet schedule needs.

- WCC personnel participated in developing many of the strategies that were adopted in developing the design and construction plan and securing approval from the Federal agencies. As a part of this effort, assistance was provided in detailed planning to support the strategies adopted.

Project: Proposed Northwest Alaskan Gas Pipeline

Client: Northwest Alaskan Pipeline Company, and Fluor Engineers and Constructors, Inc.

Location: Prudhoe Bay to Alaska/Yukon Border

Assignment: Geotechnical Engineering Consulting Services

Since 1977 Woodward-Clyde Consultants has been assisting the Northwest Alaskan Pipeline Company in their geotechnical efforts directed toward construction of the Alaskan portion of the Alaska Highway gas pipeline from Prudhoe Bay to the U. S. Midwest and West. Our work has included the following major tasks:

- Monitoring and evaluation of blasting tests
- Geotechnical and environmental data review
- Environmental review of access routes and realignments
- Fault study
- Laboratory testing of soil samples

These tasks are described in the following paragraphs.

Monitor and Evaluate Blast Tests

Woodward-Clyde Consultants monitored a series of trench blast tests conducted near Fairbanks, Alaska. The purpose of these tests was to demonstrate that effective trench blasting could be conducted very close to the trans-Alaska oil pipeline without generating damaging blast effects. At each of three test sites, geotechnical conditions were assessed using borings, trenches, aerial photography, geophysical techniques, and probings. Ground vibrations and air blast levels from each blast were monitored using seismographs to measure the particle velocities generated. The data generated were analyzed and presented in a detailed report which described all aspects of the tests, the data, and the theory to demonstrate that these blasts would not have significant impact on the oil pipeline. The report has been used by Northwest to demonstrate to the appropriate agencies that the Northwest construction blasting plans are credible.

Geotechnical and Environmental Data Review

Woodward-Clyde Consultants was retained to examine, catalog, describe, and evaluate existing data that could be used in the design of the Northwest Alaskan Gas Pipeline. This study covered open literature and proprietary data. In the open literature review technical publications, University of Alaska data, USGS information, Alaska Highway Department information and many other miscellaneous sources were examined and cataloged.

Proprietary data evaluated included the Canadian Arctic Gas files and the El Paso Natural Gas Company files relating to their efforts to bring Prudhoe Bay gas to the Continental U.S.

The final phase of this study was a review of the data generated by Alyeska Pipeline Service Company. The review included examination of the extensive data base, and appraisal of the validity and utility of the data to the gas pipeline project.

Environmental Review of Access Routes and Realignments

This project invo.ved office and field investigations of access and alignments for the Delta Junction - Canada portion of the proposed gas pipeline. Biological, hydrologic, and land use evaluations were made. A preliminary office review of 250 access routes identified by Northwest was conducted using interpretation of aerial photographs (color 1:24,000), USGS topographic maps, marked alignment sheets, and literature available describing regional and local environmental characteristics. Based upon the results of our preliminary review, Northwest eliminated 51 routes from further consideration. The remaining 199 access routes were evaluated in the field in January 1978. Northwest used the evaluations to select environmentally suitable routes for its permit applications to State and Federal agencies.

Fault Study

This project identified candidate significant faults in the section of the gas pipeline between Delta Junction, Alaska, and the Alaskan-Canadian border. One objective of the study was to develop a definition of the term "significant fault" for the purpose of designing and constructing the pipeline. The study utilized existing seismographic records to identify microseismic clusters along the pipeline corridor, as these clusters may relate to faults. Geologic studies included extensive interpretations of aerial photographs and satellite images, and compilations of available geological data. A field reconnaissance of selected geological features of interest was included as part of the study. The results of the study were utilized to identify candidate significant faults and to assess the necessity of detailed field studies along these features.

Laboratory Testing of Soil Samples

The WCC Oakland laboratory conducted a massive laboratory testing program for the project, in support of the subsurface exploration program in the alignment section from Delta Junction to the Canadian border. The program included every-other-day pickup of samples along the alignment (a round trip of 750 to 800 miles out of Anchorage), an airlift of samples from Anchorage to San Francisco, and testing on a large scale in the Oakland laboratory. A total of about 1,500 samples from 150 borings were received; about two-thirds of the samples were frozen when they were recovered, and this frozen state was maintained from the recovery through shipment to Anchorage, San Francisco Airport and eventually to Oakland, where the samples were stored in a large freezing room. The large majority of the over 3,000 tests were index property tests, but a limited number of engineering property tests were also made.

Project: Earthquake Fault Studies, Alaska

Client: Alyeska Pipeline Service Company

Location: Prudhoe Bay to Valdez, Alaska

Assignment: Active Fault Study

In 1973, a team of 15 geologists from Woodward-Clyde Consultants conducted a study of active faults in Alaska for Alyeska Pipeline Service Company. The study covered an area of Alaska that extended from Juneau on the south to west of Anchorage, and north to Prudhoe Bay. The study was mainly conducted as an exploration effort to search for active faults, although land erosion and fill, and geomorphic processes were also considered.

A thorough review of all pertinent geological literature of Alaska was completed, followed by geologic photointerpretation of Side-Looking Airborne Radar (SLAR), Earth Resources Technology Satellite (ERTS) imagery and mosaics, infrared (IR) imagery, low-sun-angle aerial photography, and standard black-and-white aerial photography that covered an area larger than 240,000 square miles of Alaska. The interpretation of these images and the literature review produced approximately 8,000 lineaments that were evaluated in the field for their possible relationship to recent fault activity. Field studies of these lineaments and of other features noted in the field were concentrated into a four-month flight hours of helicopter time and 800 hours of fixed-wing aircraft time were utilized. The field studies consisted mainly of on-site evaluation of landforms and geologic units, and included geophysical studies at selected locations. Special low-sun-angle aerial photogrpahs were taken by the Woodward-Clyde Consultants' staff and interpreted during the field season.

The studies resulted in identifying and mapping more than 25 potentially active faults in Alaska, some of which were previously unknown, and providing significant new data with regard to surface fault activity and tectonics in Alaska. Detailed studies were undertaken of four potentially active faults crossed by the pipeline route, and design parameters were generated for pipeline design at fault crossings.

Project: Clearwater Lake Scarp Study

Client: Alyeska Pipeline Service Company

Location: Clearwater Lake

Assignment: Investigate Possible Active Earthquake Fault

The Clearwater Lake escarpment, near Big Delta, Alaska, was interpreted by a 1973 WCC study as possibly being related to active faulting. The escarpment is only a few miles from the pipeline route, and its projection toward the route raised the question of whether or not it was due to faulting and, if so, where it may have crossed the pipeline.

Geophysical studies were made in 1976 that consisted of detailed gravity, ground magnetic, aeromagnetic, and electromagnetic surveys of an area larger than 100 square miles. These studies were oriented toward determining the configuration of the bedrock surface beneath the Quaternary sedimentary fill of the area and toward identifying zones of fault gouge.

Detailed logging of the pipeline trench was part of the goelogic study as well as new trenches that cross the escarpment. Quaternary geology of the area was mapped , and age dating was accomplished by carbon-14 and paleomagnetic dating and by studying pollen chronology and minerology in the Quaternary materials.

Field work was accomplished under conditions of low temperature and safety problems of unstable trench walls. Results of the study showed that no fault is present.

Project: Kodiak Shelf Geotechnical Study

Client: Confidential

Location: Kodiak Outer Continental Shelf, Alaska

Assignment: Preliminary Evaluation of Geotechnical Conditions

Woodward-Clyde Consultants provided a preliminary evaluation of geotechnical conditions on the Kodiak Outer Continental Shelf, designated as a potential lease sale area for offshore oil and gas development. The purpose of this study was to interpret the geologic history of the area to provide preliminary evaluations of the characteristics of the foundation materials to be encountered and to identify, map and discuss active faults and other potential geologic hazards in the area such as slope instability, liquefaction, strong ground shaking and tsunamis. The study was conducted using available published records and maps and offshore marine geophysical survey results.

Project: Gastineau Channel Bridge No. 740

Client: State of Alaska Department of Highways

Location: Juneau, Alaska

Assignment: Evaluation of Liquefaction Potential in the Foundation Soils

Woodward-Clyde Consultants conducted studies to evaluate the liquefaction potential of the foundation soils underlying the bridge piers and abutments.

The studies included a preliminary assessment of the cyclic strength of the material on the basis of the blow count data determined from field borings.

Using currently available empirical procedures, the potential for liquefaction of the foundation soils was evaluated for specified design earthquakes occurring on faults in the vicinity of the structure. In addition, the study provided a qualitative assessment of the possible lateral movements in sloping ground at the location of one of the bridge piers.

Project: Providence Hospital Additions

Client: Skidmore, Owings & Merrill, Architects

Location: Anchorage, Alaska

Assignment: Foundation Investigation and Ground Response Studies

A soil investigation was made and foundation recommendations presented. The regional seismicity was assessed to establish a design earthquake. Ground response analyses were made for the design earthquake and site response values obtained for use in the structural design.

Project: Proposed LNG Plant at Yakutat, Alaska

Client: Pacific Alaska LNG Co. and California Alaska LNG Co.

Location: Monti Bay - Yakutat, Alaska

Assignment: Preliminary Site Investigation

A preliminary study involving geology, seismology, geophysics, oceanography, and static and dynamic geotechnical engineering was performed on a 400-acre site and the surrounding area to determine the feasibility for a major plant site. The site is located on a terminal moraine underlain by outwash deposits. Major faults with a history of major earthquakes lie within a radius of 50 miles from the site. Tsunami effects have been recorded. Sufficient information was developed to warrant continued consideration of the site for the plant location.

Offshore Geophysics - Boomer, Sparker and Sidescan Sonar surveys were conducted over approximately 2.5 square miles of the bay to develop bathymetry, estimate thicknesses of various subsurface strata and to identify shoals or other shipping obstructions.

Geology and Seismology Studies - Using existing data and field reconnaissance, the geologic and seismic regimes which would constrain the use of the site were evaluated. Preliminary design earthquakes were established and tsunami and land level change potentials estimated.

Earthquake Engineering - Available data were analyzed in conjunction with the preliminary design earthquakes to develop preliminary design response spectra and to evaluate the potential for ground instability such as liquefaction or spreading. Bluff stability at the shoreline was also evaluated.

Foundation Engineering - Soil data were evaluated to establish preliminary design parameters for plant foundations.

Site Selection - Using results of the geophysical, geologic, seismologic, earthquake engineering and foundation engineering studies together with economic studies of grading and pier costs, recommendations were made as to the most suitable location of the plant within the site area.

Project: Yakutat Marine Terminal

Client: Earl & Wright, Structural Engineers

Location: Yakutat, Alaska

Assignment: Geotechnical Investigation for Onshore and Offshore Facilities

An investigation was made of two potential sites for a marine terminal. The proposed facilities include a timber dock at one site and a concrete dock pier to be supported on steel H piles at the other site. Proposed onshore facilities consist of storage tanks and buildings.

Woodward-Clyde Consultants monitored a field investigation consisting of several borings and test pits onshore and five offshore borings. Laboratory testing by another firm was reviewed and evaluated.

A study was made of regional and local geology and regional historic seismicity. This study included an assessment of earthquake effects, including potential surface faulting, liquefaction and tsunamis.

Recommendations were made for preliminary criteria for site development and foundation design, including allowable bearing pressures for spread footings, pile capabilities, site grading rip-rap, and slope stability.

Project: Offshore Alaska Seismic Exposure Study (OASES)

Client: Consortium of Oil Companies

Location: Gulf of Alaska

Assignment: Assessment of Seismic Exposure in Offshore Alaska

This study was conducted for a group of twenty-one oil companies and had as its principal objective the assessment of seismic exposure on stiff ground in nine future oil and gas lease areas in offshore Alaska. The key results of the study consisted of probablistic estimates of the amplitudes of earthquake ground motions throughout the lease areas.

The study involved three broad steps. In the first step, offshore and onshore seismic sources were characterized in terms of their location, geometry, and the recurrence of earthquakes of various magnitudes. In the second step, the attenuation of ground motions with distance from the sources was characterized by developing probabilistic attenuation relationships. In the third step, the seismic exposure, i.e., the probability of exceedance of given amplitudes of ground motions within given time periods, was calculated for numerous locations within each lease area, and contour maps and tables were prepared to depict the results.

The study incorporated several special features not generally present in seismic exposure studies. First, several ground motion parameters of significance to design of offshore platforms, including peak accelerations, peak velocity, RMS acceleration, RMS velocity, and response spectral values at several structural periods were studied, rather than just a single parameter such as peak acceleration. Second, the most current knowledge of plate tectonics was incorporated to supplement the historic seismicity in assessing the frequency of occurrence of earthquakes in space and in time. Specifically, seismic "gaps" on major fault systems were assessed as having a higher potential for causing large future earthquakes in the recent past. For these assessments, formal analysis of probabilities of occurrence were facilitated using subjective (Bayesian) probability analysis procedures. Third, the different tectonic character of some of the seismic sources was explicitly incorporated in defining a seismic source model and in developing attenuation equations. Specifically, it was found that the ground motions caused by earthquakes at large depths in major tectonic subduction zones would have a significantly different character than the ground motions caused by shallow-focus earthquakes. Thus, the attenuation relationships were developed by sorting available recorded data into two groups associated with different seismic source characteristics. In addition, separate attenuation relationships were developed for rock and stiff-soil subsurface conditions. As part of the study, analytical studies of ground response, including body-wave and surface wave analyses were also made.

The results of the seismic exposure studies were compared with current standard criteria describing seismic inputs to be used in the analysis and design of offshore platforms.

Project: Offshore Drilling Platforms

Client: Consortium of Oil Companies

Location: Gulf of Alaska

Assignment: Earthquake Ground Response Studies

Woodward-Clyde Consultants has performed a series of studies in 1973-1977 to evaluate the seismic response of soft clays offshore in the Gulf of Alaska. This was done for a group of oil companies, prior to and after lease sales, as part of preliminary seismic design studies for drilling platforms.

In one part of these studies, clay samples from one offshore boring and from onshore were subjected to laboratory cyclic loading tests to determine the stress-strain behavior of the soil during earthquakes. On the basis of the measured behavior of these and other clays, a new stress-strain model was developed and a new ground response computer program was written.

In another part of these studies, the seismic response of one offshore site was evaluated using the new computer program as well as existing state-of-the art procedures. The evaluation included estimating the ground shaking characteristics near ground surface for seismic design of the structure, the deformations of the soil at different depths for seismic design of piles, and the evaluation of the stability of the ground under the induced seismic loading. This was done for a range of assumed earthquake rock motions which could affect the site.

The most recent part of the studies involved a new series of cyclic tests, from which results the stress-strain model and computer code was extended to enable prediction of seismic deformations of soft clay profiles underlyi g mildly sloping seafloors. In addition the stress-strain characteristics of overconsolidated clays were investigaed.

RECENT DAM STUDIES

PROJECT: Auburn Dam

CLIENT: U. S. Bureau of Reclamation

LOCATION: Auburn, California

ASSIGNMENT: Earthquake Evaluation Studies

The proposed Auburn Dam is to be located on the American River near the town of Auburn, California, on the western margin of the Sierran foothills. Earthquake evaluation studies for the proposed dam were undertaken by Woodward-Clyde Consultants for the primary objectives of:

1) Evaluating the maximum credible earthquakes of significance to the dam site;

2) Characterizing earthquake ground motions to which the proposed Auburn Dam site may be subjected and the probability of exceedance of response spectra developed for the site;

3) Evaluating the potential for reservoir induced seismicity as a result of impoundment of the proposed Auburn Reservoir; and

4) Evaluating the surface faulting potential in the foundation of the proposed dam.

These studies involved the contributions of more than 50 geologists, geophysicists, and geotechnical engineers, and represented a combined effort of 16 man-years. The studies included detailed fault investigations in the western Sierran foothills and an examination of bedrock relationships in the foundation excavation for the dam. Assessments of earthquake potential were made by applying the "active fault concept", using the U. S. Bureau of Reclamation Proposed Fault Classification and Investigation Criteria for defining fault activity.

PROJECT: Chabot Dam

CLIENT: East Bay Municipal Utility District

LOCATION: Alameda County, California

ASSIGNMENT: Evaluation of the Seismic Stability of Existing Dam and Proposed Crest Modifications

Woodward-Clyde Consultants conducted dynamic stability analyses of the existing Chabot Dam, which was originally completed as a rolled fill dam in 1875 by "wagon fill" methods. It was subsequently reinforced on the downstream slope by a sluiced fill buttress in the period from 1875 to 1888. The hydraulic fill buttress was raised between 1890 and 1891, then further raised between 1891 to 1892 to its full height.

The dam was in operation at the time of the 1906 earthquake along the San Andreas fault in the San Francisco area. No damage was reported from that earthquake.

The re-evaluation, completed in 1974 by WCC, was initiated by the owner after the near failure of the San Fernando Dam during the February 1971 earthquake.

WCC was retained to perform seismic stability evaluation for a postulated maximum credible earthquake, using recently developed techniques of static and dynamic finite element analysis. Static and dynamic laboratory testing procedures as well as field geophysical measurements were used to determine properties of the foundation and embankment soils. The results indicated that some additional freeboard would be needed.

The additional freeboard will be provided at the same time as the spillway is modified to contain the PMP flood. The seismic evaluation of the modified section was conducted utilizing new techniques which considered the potential for detrimental strains caused by shaking, in addition to the ratio of available dynamic strength to induced dynamic stress.

PROJECT: San Pablo Dam

CLIENT: East Bay Municipal Utility District

LOCATION: Contra Costa County, California

ASSIGNMENT: Full Range of Consulting Services, Including Geotechnical, Geological, and Earthquake Engineering

Woodward-Clyde evaluated the seismic stability of the existing 190-foot high hydraulic-fill San Pablo Dam in 1973. The owner became concerned about the seismic stability of its old hydraulic fill dams as a result of the damage to the Van Norman Dams during the February 1971 San Fernando Earthquake. Staff from the San Francisco office were selected as part of a team of engineers and geologists assembled by the District. This team included the District's professional staff and an independent consulting board.

The existing San Pablo Dam was found to have inadequate dynamic strength to resist ground shaking of a maximum credible earthquake. As a result, the District decided to lower the reservoir in preparation for modifying the upstream slope.

Woodward-Clyde Consultants subsequently contributed to additional dynamic analyses of various alternatives which have been considered and finally has evaluated the proposed modified section which will be constructed in 1979.

We have also been involved in multi-phase studies for this project, which have included: cyclic triaxial testing of soil samples; static and dynamic finite element analyses to determine the stresses and strains in alternative embankment sections both before and during postulated earthquake events; geologic and geophysical investigations of the foundations and borrow areas; geologic mapping, and general geotechnical engineering services.

PROJECT: Lower Pine Creek Watershed Project

CLIENT: Soil Conservation Service

LOCATION: Contra Costa County, California

ASSIGNMENT: Dynamic Stability Analyses and Geologic Review and Seismicity Evaluation

Woodward-Clyde investigated the seismic stability of two proposed compacted earth dams, using recently developed techniques of static and dynamic finite element analysis. In these studies a design bedrock acceleration time-history, predicated on knowledge of the seismicity of the area, was used to analyze the stability of the dam and its foundation. Static and dynamic laboratory testing procedures, as well as field geophysical measurements, were used to determine the properties of the foundation and embankment soils. Results of these stability analyses were then evaluated, using criteria of the appropriate regulatory agency.

PROJECT: Upper San Leandro Dam

CLIENT: East Bay Municipal Utility District

LOCATION: Alameda County, California

ASSIGNMENT: Full Range of Consulting Services, Including Geotechnical, Geological, and Earthquake Engineering

Woodward-Clyde investigated the seismic stability of the 50-year old hydraulic fill dam (approximately 170 feet high) using recently developed stability analysis techniques based upon postulated ground motion patterns, dynamic as well as static soil properties, and saturation patterns. The study was initiated by the owner because of growing concern over safety considerations for such dams in seismically active areas which have also become highly congested metropolitan centers. The near catastrophe of the Lower San Fernando Dam in the San Fernando earthquake of February 1971 certainly highlighted the vulnerability and consequences of failure of such structures.

The analysis, completed in 1972, indicated the existing section had inadequate dynamic strength to resist ground shaking postulated for a maximum credible earthquake event. The owner decided to replace the dam with a new structure just downstream of the existing dam and to utilize a modification of the existing spillway and the existing outlet and control works.

The owner retained Woodward-Clyde as part of the design team to conduct analyses of the newly selected embankment and to provide consulting geologic and geotechnical engineering support to the District engineering staff.

Construction of the new dam and modifications of the major appurtenances were completed in 1977, and the reservoir refilled in the winter of 1977-1978. Woodward-Clyde also provided consulting geologic and geotechnical support to the District staff during the construction phase.

Our firm has been involved in multi-phase studies for these projects, which have included: cyclic triaxial testing of soil samples; static and dynamic finite element analyses to determine the stresses and strains in the embankments before and during postulated earthquake events; geologic investigations of the foundations and borrow areas and geologic mapping during construction; and geotechnical engineering services.

PROJECT: New Melones Dam

CLIENT: U.S. Army Corps of Engineers

LOCATION: Stanislaus River, near Sonora, California

ASSIGNMENT: Seismic Geology Studies

In January, 1977, Woodward-Clyde Consultants began earthquake evaluation studies of the New Melones dam site on the Stanislaus River for the U.S. Army Corps of Engineers. The objectives of the study were to: (1) evaluate the potential for surface faulting along bedrock faults traversing the dam site, (2) evaluate faults that may be the sources of future earthquake activity in the vicinity of New Melones Dam and to estimate the maximum earthquake that may be generated on these faults, and (3) assess the potential for reservoir induced seismicity resulting from the impoundment of New Melones Lake. Black-and-white, color infrared and low-sun-angle photography were examined for lineament trends and fault-related features, and geologic mapping and trenching investigations were conducted in the vicinity of the dam site.

PROJECT: Zayante Dam

CLIENT: City of Santa Cruz

LOCATION: Santa Cruz, California

ASSIGNMENT: Preliminary Seismic Geology Study

Woodward-Clyde Consultants recently completed a preliminary geologic and seismologic evaluation of the proposed Zayante Dam site for the City of Santa Cruz. The evaluation was based on aerial photographs, geologic mapping at the dam site, and the correlation of historic seismicity with faults. The objectives were an assessment of the significant sesimic design parameters, such as maximum credible and maximum probable earthquakes, and estimated peak acceleration and duration of shaking.

Project: Boruca Dam

Client: SNC-ACRES-TIL CONSORÇIO

Location: Costa Rica

Assignment: Preliminary Geologic, Seismologic, and Earthquake Engineering Studies for Proposed Rockfill Dam

Woodward-Clyde Consultants is conducting preliminary seismic studies for the detailed feasibility study of a major hydroelectric project in Costa Rica. The major project element is the proposed Boruca dam, an 850 feet high rockfill structure with a central impervious core. The scope of WCC's activities includes: field and office geologic and seismologic studies to define active faults of significance to the project and the magnitudes of maximum credible earthquakes on these faults; and engineering studies to estimate the ground motions at the dam site due to maximum credible earthquakes, to estimate the properties of embankment materials, and to assess the seismic stability of the dam.

Project: Watauga Dam

Client: Tennessee Valley Authority

Location: northeastern Tennessee

Assignment: Evaluation of Seismic Stability

Watauga Dam is a 320-feet high dam having a clay core and rockfill shells. The seismic stability study of the dam included static and dynamic finite element analyses, characterization of the cyclic strength of core and shell materials based on laboratory test results and published data, evaluation of the potential for pore-water-pressure dissipation in the pervious shells, and evaluation of the seismic stability of the dam.

Project: Perris Dam

Client: State of California Department of Water Resources

Location: Riverside County, California

Assignment: Seismic Stability Evaluations

Perris Dam is a 120-feet high compacted earthfill embankment having a sloping clay core and shells of silty sand. Foundation soils consist mainly of silty and clayey sand alluvium. The dam was constructed as part of the State of California's water project carried out in the late 1960's and early 1970's.

A cyclic testing program was conducted by the State to characterize the cyclic strength characteristics of the embankment and foundation soils. Utilizing the results of this program, Woodward-Clyde Consultants conducted seismic stability studies of the dam. These studies included an evaluation of the potential for failure of the alluvium beyond the toe of the dam to progress toward the dam and the potential effect of this phenomenon on the behavior of the dam.

Project: Study of the Van Norman Dams

Client: State of California Department of Water Resources; Los Angeles Department of Water and Power; and National Science Foundation

Location: San Fernando, California

Assignment: Evaluation of Behavior of Van Norman Dams due to 1971 Earthquake

The upper Van Norman Dam (upper San Fernando Dam) and the lower dam (lower San Fernando Dam) suffered considerable damage as a result of the February 9, 1971 San Fernando earthquake. The upper dam moved laterally approximately 5 feet; its crest settled approximately 3 feet. A major liquefaction-induced landslide, extending to a depth of 40 to 50 feet, took place upstream in the lower dam.

Shortly after the earthquake, an investigation was initiated to evaluate the causes of the observed damage to the dams. The investigating team was headed by Professors H. B. Seed and K. L. Lee of the University of California at Berkeley and Los Angeles, respectively, and included as key participants Dr. F. I. Makdisi of the University of California, Berkeley and Dr. I. M. Idriss of Woodward-Clyde Consultants. For their report of these studies, the above-mentioned individuals received the 1977 Norman Medal of the American Society of Civil Engineers.

Project: Shearon-Harris Nuclear Plant Dams

Client: Ebasco Services, Incorporated

Location: Wake County, North Carolina

Assignment: Evaluation of Seismic Stability of Class I Dams and Dike

Seismic stability evaluations were made for two proposed earth and rockfill dams and a dike at the Shearon-Harris Nuclear Power Plant. Each dam and the dike consisted of a cohesive core and rockfill or random rockfill shells. The scope of studies included: insitu testing to determine dynamic properties of foundation materials; laboratory static and cyclic testing to assess dynamic properties and cyclic strength characteristics of foundation soils and core materials; evaluation of dynamic properties and cyclic strength characteristics of rockfill and filter materials based on published data and insitu measurements in similar rockfills; static and dynamic finite element analyses; and evaluations of the seismic stability and potential for deformations.

RELEVANT EXPERIENCE

TERRESTRIAL ENVIRONMENTAL SPECIALISTS, INC.

Relevant Experience - TES

TES staff members have experience in all aspects of environmental studies. This experience includes designing programs, supervising data collection, writing reports, and managing the business aspects of projects. This combination of scientific capability with business experience will enable TES to manage the proposed environmental team on not only a scientific basis but also in a cost-effective business manner.

TES has performed excellent work in all aspects of environmental assessment as it pertains to hydro development. Hydro-related work has included such services as endangered species surveys, socio-economic analyses, archeological investigations, terrestrial and aquatic ecology studies, land use analyses and preliminary site selection surveys. The firm has either prepared or is in the process of preparing environmental assessments for five proposed hydroelectric stations and has prepared an endangered species report for a sixth proposed hydro project. As a result of these studies, TES has established a strong working knowledge of the federal regulatory process and is intimately familiar with the hydroelectric licensing procedures of the Federal Energy Regulatory Commission. The following are brief project descriptions of each TES hydro project.

As a subcontractor to Acres American, Inc., TES provided environmental and economic assessments as part of a feasibility study for various hydroelectric generation options at the Tygart Dam and Reservoir, Grafton, West Virginia. This study was conducted for the U. S. Army Corps of Engineers - Pittsburgh District. Important considerations during this evaluation included the impacts associated with the recreational use of the reservoir, the effects upon natural aquatic and terrestrial systems, and a variety of land-use and socio-economic considerations.

TES prepared an environmental report for the proposed renovation of the Colliersville Hydroelectric Facility at Goodyear Lake on the Susquehanna River, Otsego County, NY. In addition, TES also prepared an environmental report for the proposed renovation of the Village of Potsdam Hydroelectric Facility on the Raquette River, St. Lawrence County, New York. These studies were designed in accordance with the Federal Energy Regulatory Commission guidelines for impact statements required under the National Environmental Policy Act (NEPA). Considerations included ecological aspects of the proposed action on plant and animal communities in addition to socio-economic and land use factors.

TES was selected to conduct ecological, land use, and socio-economic studies relevant to the selection of a potential hydroelectric generating station site on the Black River, Oneida County, New York. Working closely with Acres American, Inc., TES tasks included identification of the potential for impacts of the hydroelectric facility upon fish and wildlife, vegetation, unique habitats, land use, local economics, and cultural resources.

For a major proposed hydroelectric construction project on the north Hudson River, TES conducted studies on the regional and local land use and socio-economic factors and evaluated the impacts of the proposed project on land use, aesthetics, and socio-economic considerations. This study was designed to comply with Federal Energy Regulatory Commission Guidelines. TES also conducted a survey for endangered plant species in regards to this hydro project.

Niagara Mohawk Power Corporation contracted TES to assist in evaluating the potential impact of a hydro project on an endangered bat species. This study was conducted on the Black River in New York.

This previous hydro environmental study experience has required TES to develop investigational and report production procedures that conform to strict budgetary and schedule requirements. The firm's skillful project management has resulted in meeting deadlines on time and within cost estimates and has allowed clients to meet license application filing requirements.

TES staff members have extensive experience in identifying both short and long term impacts on terrestrial and aquatic ecosystems. A multidisciplinary approach has been applied to impacts associated with hydroelectric, fossil-fueled, and nuclear generating stations.

In addition to facility siting studies, TES has professional personnel who are experienced in various corridor routing studies. Staff members have developed a corridor selection technique employed in the siting evaluation of electric transmission lines ranging from 115 kV to 765 kV.

TES, under contract to Rochester Gas and Electric Corporation and Niagara Mohawk Power Corporation, prepared an update to an environmental analysis for a proposed 765 kV transmission line. This project included the analysis and comparison of primary and alternative routes for a proposed 66-mile transmission line, and the recommendation of new route segments where warranted.

TES was selected by Niagara Mohawk Power Corporation to provide a routing analysis and impact assessment for a 115 kV transmission line in Jefferson County, New York. The determination of primary and alternative routes was a result of consideration for various types of constraints, such as: urban development, geology, topography and soils, wetland areas, land use, visual exposure, and cultural resources.

TES was contracted to conduct an environmental assessment and routing analysis for a 138 kV transmission line in east-central Pennsylvania. This study was designed to comply with the regulations of the Public Utilities Commission of Pennsylvania for siting and construction of electric transmission lines. Among the important considerations for routing the line were coal resources, natural resources, topography, land use, and socio-economic factors.

In addition to hydro and transmission line experience, TES has demonstrated its capabilities on several other large projects. The one most similar in magnitude and duration to the Susitna Project was a study performed for General Public Utilities Service Corporation. TES was selected to conduct a five-year construction impact monitoring program at the site of the Forked River Nuclear Power Station. This program includes the collection of baseline floral and faunal data for the initial year and a series of monitoring studies during the following four-year period. These studies will be used to assess construction impacts of a salt water cooling tower upon plant communities and important faunal populations. TES staff members will also gather baseline data concerning local vegetation stress over a three-year period. These data, gethered from color infrared photography and ground reconnaissance, will be corrdinated with the collection of air quality data to assess the possible effects of the salt drift field from cooling towers.

It is the intent of TES to draw upon the aforementioned experience of its staff members to coordinate and manage the execution of the Susitna environmental studies outlined in this document. Because the Susitna Project requires the expertise of a highly specialized group of scientists, TES has successfully attempted to locate, and secure the participation of, individuals who have demonstrated previous project experience ideally suited for this study.

The Susitna Project Study Team assembled by TES will bring to this project a wide array of previous project experience. In order to adequately address the needs of the Susitna Project, key team members selected for this must have demonstrated successful performance on other projects of similar nature and dimension. The list of studies that follows serves as adequate documentation that the members of the group TES proposes to involve in the Susitna Project are unequalled in their ability and appropriateness to participate in this important study. The following lists of previous studies are organized by major disciplines and include the experience of all key team members within each discipline. An attempt was made to select only appropriate projects for inclusion on these lists; therefore, the lists do not include all projects in which key team members have participated.

Socio-economic Analysis

- examination of economic implications of alternative marketing strategies for Interior Alaska forest products
- economic aspects of outdoor recreation facility management on Forest Service lands in Alaska
- analysis of potential impacts of Outer Continental Shelf petroleum development on various commerical fisheries in Alaska.
- development and implementation of a methodology to forecast credit demand for Alaska's agricultural industry
- economic and financial feasibility and planning studies in support of the Comprehensive Regional Salmon Enhancement Plan for Prince William Sound, Alaska
- estimation of current and future levels of credit demand from the commercial fisheries industry of Alaska
- determination of the economic impact of Outer Continental Shelf Oil Development on the razor clam fishery of the Northern and Western Gulf of Alaska
- economic analysis and load projections (contributor) - Alaska Power Survey

Recreational and Cultural Resources Analysis

- numerous archaeological surveys in Alaska, including: Point Hope, Healy Lake, Amchitka Island, North Slope, Yukon River Region, Sagavanirktok River Valley, Bering Sea, St. Matthew Island, Porcupine River Caves, Atigun River Valley, Dry Creek, Nenana River Gorge, Lake Clark, and Fort Wainwright
- archaeological survey and salvage from the Brooks Range to Prudhoe Bay, for Alyeska Pipeline Service Company
- Lower Cook Inlet cultural resource study
- analysis of archaeological potential along the Upper Susitna River
- archaeological survey and excavation along the Alyeska Pipeline Service Company haulroad and pipeline alignments
- evaluation of wilderness potential of the roadless areas in the Medicine Bow National Forest
- decision-making model: how the commercial camper chooses his campground
- Snake River corridor study, for the National Park Service
- snowmobiler preferences in the Snowy Range, for the Wyoming Recreation Commission
- planning report examining the economic, environmental and social impacts related to the development of a county-wide system of winter recreational trails
- technical aspects related to the development plans of an area including campsite, beach, and boat-launching site

Fisheries Analysis

- salmon research in the Cook Inlet area and a cooperative study of the proposed development of the Upper Susitna River for hydro-electric power
- extensive research on fish passage problems on the dams of the Columbia River
- general biological, entrainment and impingement studies at the Nine Mile Point Nuclear Station and the Oswego Steam Station
- escapement and other studies on the salmon spawning grounds in the Fraser River
- physical, chemical and biological investigations on Lake Ontario, Hudson River, and Lake Champlain
- impacts on fish and wildlife, Bonneville Environmental Study
- effects of power peaking on survival of juvenile fish at Lower Columbia and Snake River dams
- model development and systems analysis of the Yakima River Basin (Fisheries)
- engineering and biological study of proposed fish passage at four dams on the Susquehanna River
- report on the fisheries problems created by the development of power in the Nechako-Kemano-Nanika River Systems
- studies of fish behavior in thermal discharges at three sites
- study on the fish facilities and fisheries problems related to the Fraser and Thompson River dam site investigation

Wildlife Ecology

- Potsdam hyroelectric station, impact evaluation
- canid interactions along an Alaskan transportation and utility corridor
- 138 kV transmission line, routing analysis and impact assessment
- mammal survey, Delta Barley Project
- Tanana Valley avian survey, performed for the Northwest Alaska Pipeline Company
- mammalian and avian monitoring studies, Forked River Nuclear Station
- Project Chariot, ecological investigations
- Glenn Park Hydro Project, endangered mammal study
- avian field survey, Alyeska haul road
- fossil-fueled generating station; game mammal habitat evaluation and impact assessment
- mammalian reconnaissance, Skayway-Haines area
- ecology study of wolverines in Interior Alaska
- baseline mammalian and avian surveys, eight electric generating station sites
- analysis of radio telemetry data in studies of home range
- fluctuations of coyote populations

Plant Ecology Analysis

- vegetation mapping, plant type classification, and vegetation descriptions in the Susitna River Basin
- vegetation mapping using satellite imagery and computer coding, field checks and quantitative sampling in the tundra vegetation of the Reindeer Range
- range types and productiveties for ungulates in portions of Cook Inlet Basin
- endangered and threatened plant species surveys
- mineral nutrient studies on arctic tundra
- tundra rehabilitation research
- vegetation descriptions, vegetation mapping, and impact assessment on several power plant sites
- reclamation of Alaskan lands damaged by oil spills
- natural succession on mine spoils of Interior Alaska
- routing analysis and environmental reports for transmission lines
- measurements of transpiration in tundra vegetation
- phytosociological and plant ecological studies in Alaska
- the monitoring of construction impact of a power plant on vegetation
- composition and successional relationships of some herbaceous communities in south central Alaska
- the ecology of Sitka Alder in the subalpine zone of south-central Alaska
- revegetation of various disturbed areas in Alaska

- vegetation assessment, impact statement review and preparation of testimony for portions of the gas line in Alaska
- exploratory botanical work, vegetation mapping, endangered species surveys, and general vegetation descriptions for the Alyeska project

<u>RELEVANT EXPERIENCE</u>

<u>COOK INLET REGION, INC./HOLMES & NARVER, INC.</u>

CHARTER OF

COOK INLET REGION, INC.
AND
HOLMES & NARVER, INC.

EXTRACT

1. INTRODUCTION

This operation plan was an outgrowth of several discussions between key personnel from both Cook Inlet Region, Inc., (CIRI) and Holmes & Narver, Inc., (H&N). The aim of the document is to distill from all these previous discussions the strategies and objectives that will form the basic operating procedures for a long-term teaming relationship. This document sets forth a general strategy for short- and long-term business development. It also describes the general philosophy of the venture.

The overriding operating philosophy is to seek out those types of projects that will give the venture a long term presence in Alaska either through obtaining extended term projects and/or by establishing an Alaskan reputation in a specific field that will generate a continual flow of smaller projects. In both of these areas, when specific projects are identified, they must be compatible with the present capabilities of the venture partners and lead to a financial position which will allow a high degree of financial autonomy at an early date.

1.1 GOALS

The goals of the venture are as follows:

To open areas of the Alaskan marketplace presently not accessible to either of the participating companies operating as a separate entity;

To establish a widely recognized presence in Alaska based on providing professional and technical services;

To use this presence as a building block to the entrance of market areas outside of Alaska for both the individual participating companies or the venture;

To upgrade the skills and professional talents of CIRI stockholders, and to provide employment and training opportunites for the CIRI stockholders;

To capture sufficient major long term contracts to fully utilize the manpower resources of both corporations.

1.2 CIRI Shareholders

CIRI has a unique relationship with its shareholders due to the requirements of the Settlement Act. Under the Act, CIRI shareholders cannot sell their stock until 1991. This fact and other requirements under the Act mean CIRI has an added responsibility beyond maximizing profits.

An important goal of the venture is to provide employment and training opportunities for CIRI shareholders. As part of the effort to realize this goal the venture intends to do the following:

> To complete a skills inventory of CIRI shareholders in order to identify shareholders already qualified to work on venture projects;

To identify, on the basis of the skills inventory and the expect types of future operations, appropriate areas for the training of Native labor;

To set up scholarships at local schools for professional and technical disciplines which will be made available to Native students.

QUALIFICATION STATEMENT
SUPPORT SERVICES
COOK INLET REGION, INC./HOLMES & NARVER, INC.

SUSITNA HYDROELECTRIC POWER PROJECT FEASIBILITY STUDY

Prepared for

ACRES AMERICAN, INC.
Suite 329, The Clark Building
Columbia, Maryland 21044

August 1979

6. PROJECT EXPERIENCE

CIRI/H&N's project experience in colder regions is based on fourteen years of work in the Arctic and Antarctic under various contracts. Through the continuing involvement with scientific and military efforts in these extreme environments, CIRI/H&N has maintained an awareness of the unique requirements for camp and support facilities, logistics, and technical support services for projects being carried out in the most remote and coldest regions of the world.

The qualifications of CIRI/H&N in providing the type of services outlined in this proposal are highlighted in the following brief descriptions of selected project experience.

CIRI/H&N

PROJECT EXPERIENCE

TURNKEY CAMP FACILITIES

SUPPORT AND CONSTRUCTION SERVICES

Client: ***U.S. Air Force Alaskan Air Command***

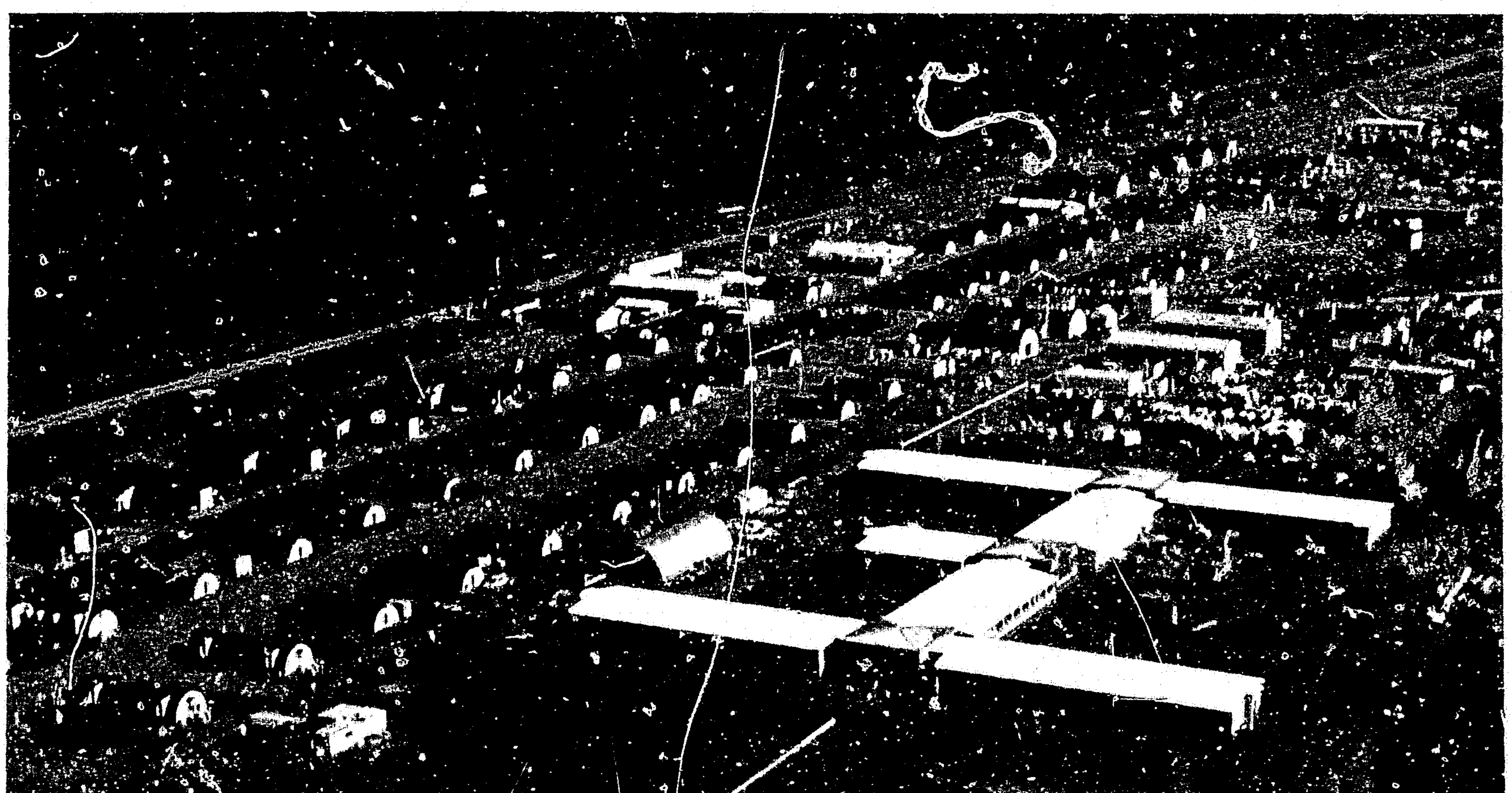
Location: ***Point Barrow, Alaska***

Under a contract from the *U.S. Air Force Alaskan Air Command,* Holmes & Narver provided support, and construction assistance to the Naval Arctic Research Laboratory at Point Barrow, Alaska. During our contract period, an important construction project in this remote arctic location was the drilling and subsequent operation of natural gas wells. Uninterrupted production from these wells was vital since they constituted the only source of heat for this operational site and the village of Barrow.

Holmes & Narver was aware and familiar with the unique problems confronting drilling, well completion, and related maintenance of subsurface facilities in deep permafrost conditions. This knowledge, and our experience in deep permafrost and year-round maintenance of scientific down-hole and surface facilities, enhanced by personal experience of many of our engineers, geologists, and administrative personnel who had worked under contract in arctic Naval Petroleum Reserve regions, and in Antarctica, brought the project through to a successful completion.

Also during the contract period, engineering, construction, and facility modifications were accomplished. The major items, in addition to the gas wells and systems, included modification and installation of new turbogenerators and shelters; a telephone dial (PABX) system; fire alarm and detection systems; site preparation and fill for new structures; a runway extension with laying, welding, and painting of steel plank; a water treatment plant; jet fuel facilities, and telephone line modifications.

Other support functions included housing, feeding, recreation, and the operation and maintenance of facilities including power plants and distribution lines; POL tank farm; air terminal; water supply and distribution systems; fire department; sanitation systems; safety and medical facilities; boiler plant; laundry; refrigeration plant; maintenance shops; warehousing; supply; roads and ground; accounting; administration; and communications.



Naval Arctic Research Laboratory—Point Barrow, Alaska.

TRANS-ALASKA PIPELINE SUPPORT CAMPS

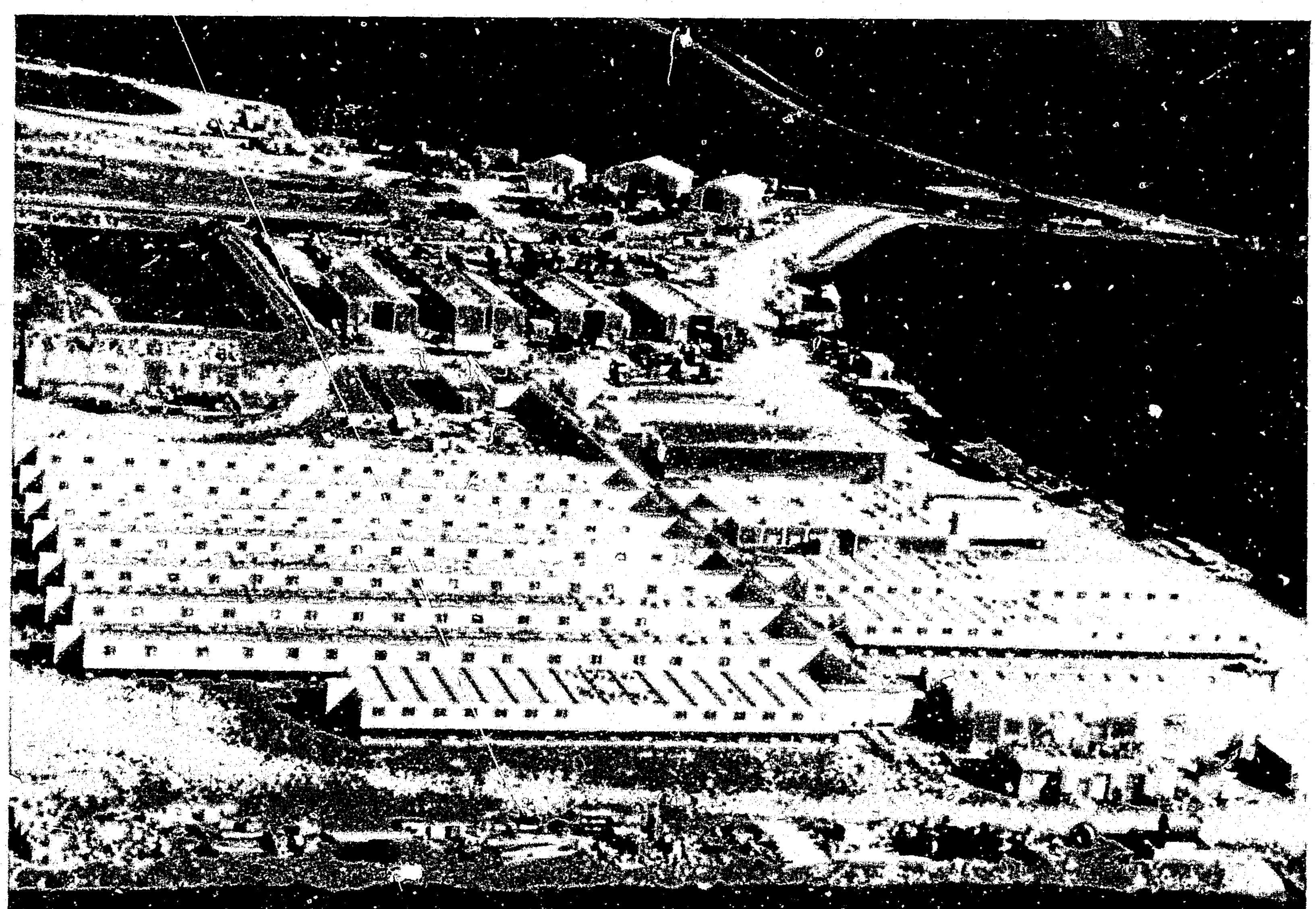
Client: *Bechtel Corp.*
Location: *Alaska, North of the Arctic Circle*

Holmes & Narver designed the northern camps used to house pipeline and road construction workers and, later, operations and maintenance personnel for the $7 billion Trans-Alaska Pipeline. Of a total of 20 such camps along the 800-mile pipeline, Holmes & Narver designed the ten above the Arctic Circle.

In addition to designing and engineering these camps, Holmes & Narver provided procurement, follow-up services, and construction management consulting services for the amenities that made the camps liveable: dormitories and offices, water supplies and sewerage systems, power and HVAC, vehicle and equipment repair facilities, kitchen/diners, recreational facilities, and landing strips. The environmental impact statements and the ancillary documentation required to obtain building permits from a large number of federal and state agencies were also prepared by H&N personnel.

The Trans-Alaska Pipeline Support Camps project is prototypical of the array of specialized services required to design a camp for maximum liveability. It is often assumed that the manufacturers of mobile modular units both make and install their products. Such is not the case. The multitude of amenities provided by life support systems like water supply, waste disposal, and communications need the professional design and engineering services of experienced specialists like Holmes & Narver. The coordination of all camp components to achieve a finished and usable complex is an activity which has occupied H&N's technical personnel for many years.

Holmes & Narver was commended by the Alyeska Pipeline Company, through Bechtel, for completing its assigned tasks on time and within budget in the framework on an accelerated schedule.



Typical Arctic Construction Camp

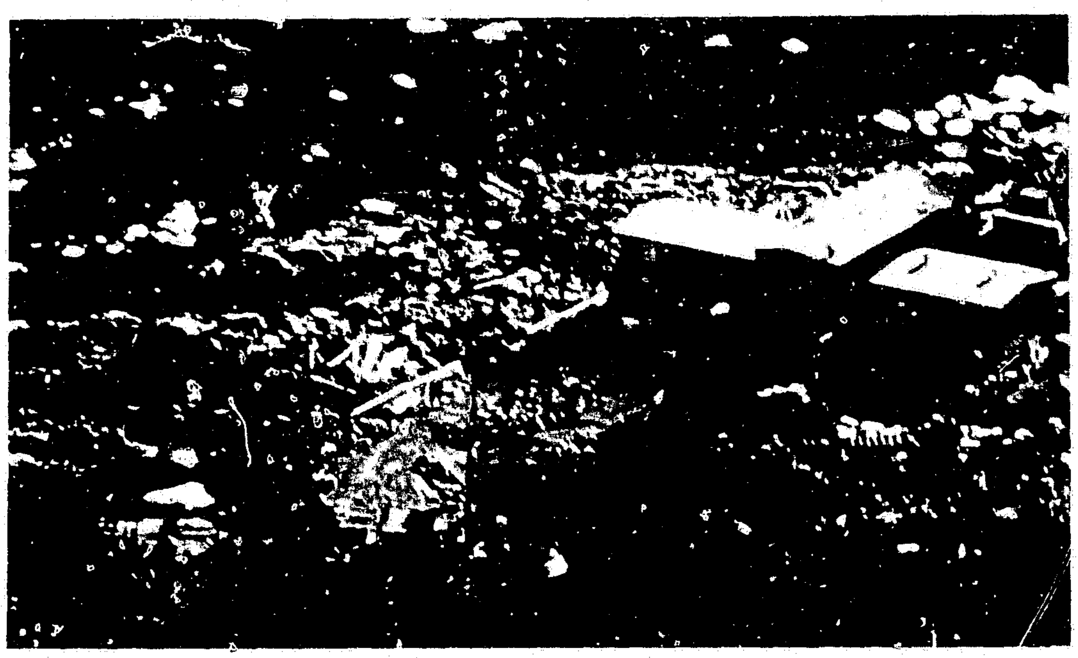
ANTARCTIC OPERATIONS & MAINTENANCE

Client: *National Science Foundation*
Location: *Palmer Station, Antarctica*

On September 12, 1973, the *National Science Foundation* awarded a 5-year contract to Holmes & Narver for the operation of the research-science motor/sailing vessel RV *HERO,* and the maintenance and operation of the Palmer Station in the Antarctic Peninsula. In addition to providing such functions as housing, feeding, resupply, maintenance and utility operations at Palmer Station, Holmes & Narver maintains and operates the Biological Laboratory.

To support this project, Holmes & Narver established a separate logistical operation because Palmer Station's location near South America did not allow use of the logistical supply line in service for other bases in the Antarctic. This logistical operation, from procurement to delivery through South American ports and airfields for final delivery at Palmer Station, requires an active and continuous materials monitoring, expediting and tracking system to ensure that the compressed shipping schedules are maintained.

The scientific support contractor's close and enthusiastic cooperation with the *National Science Foundation,* the U.S. Naval Support Force, and the scientific research community has been essential to conducting a diverse program in this isolated, adverse environment. Holmes & Narver personnel have continuously demonstrated their ability to perform their tasks with dispatch, which engenders the cooperation of all participants.



Palmer Station—Antarctica.

ANTARCTIC SUPPORT FACILITIES

Client: *National Science Foundation*
Location: *Antarctica*

Under a contract to the *National Science Foundation,* Holmes & Narver provided scientific support services to the U.S. Antarctic Research Program (USARP) during the period September 1968 through March 1973. The services consisted primarily of support to the USARP and the scientific personnel involved in the program.

In April 1973, a new 5-year contract was awarded to Holmes & Narver for continuation of these support activities. In carrying out these responsibilities, scientific support activities extended many thousands of miles and included the operation of the Berg Field Center, the Eklund Biological Center, the Earth Science Laboratory, and the Vehicle Maintenance Center at McMurdo Station. Technical and support assistance was also extended to Byrd Station as well as medical services, and the operation and maintenance of Siple and South Pole Stations.

Other support operations included assistance to the U.S. Army Cold Regions Research and Engineering Laboratory with the deep-hole ice drilling at Byrd Station during the austral summer of 1968-69. Facilities were also operated and maintained in the western part of the Antarctic continent at the largest Antarctic Base, McMurdo Station, and at Byrd Station and other field locations in the interior. Traverse Engineers provided support to scientific parties on research expeditions to various remote areas of the Antarctic continent such as Victoria Land, the Ross Ice Shelf, and the Transantarctic Mountains.

The logistics supply line which entered the U.S. Navy system at Davisville, Rhode Island, required an unrestricted corridor 12,500 miles long. The resupply lead time for ever-changing scientific investigations is 12 months minimum. Effective planning and control of supply were, to say the least, essential!

During the same contract period Holmes & Narver was awarded a contract modification for the construction of the Administration Building at McMurdo Station. Construction supervision was transferred from other corporate offices to perform this function during a very limited construction season, but both time and cost schedules were underrun. This was the first time in the history of the U.S. Antarctic Research Program that a civilian contractor was chosen to do construction work.

McMurdo Station — Antarctica.

READY-MIX CONCRETE FACILITIES PROGRAM SAUDI ARABIA

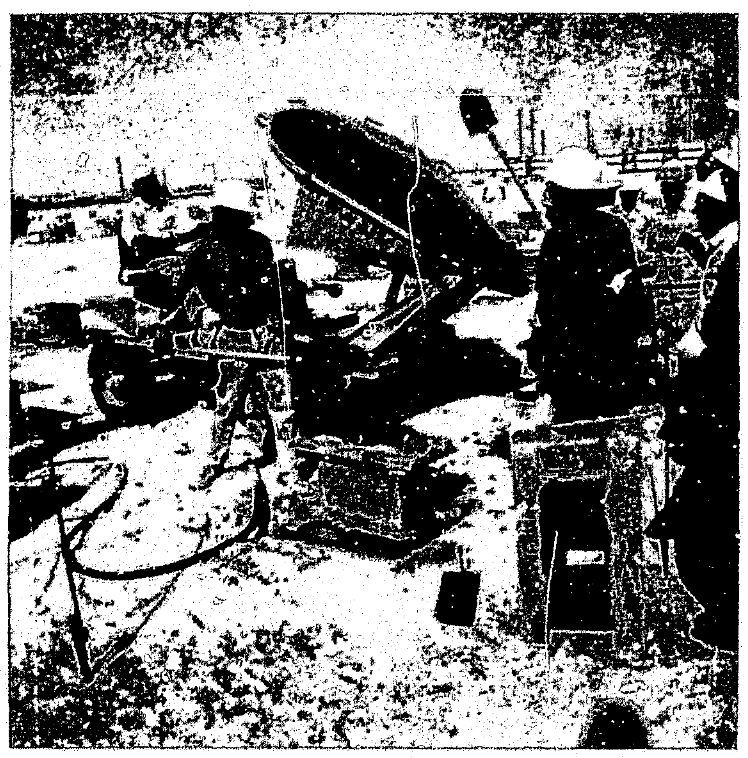
Client: ***Arabian American Oil Company***
Location: ***Saudi Arabia***

The Arabian American Oil Company (Aramco) will be required to produce and deliver more than one million cubic yards of high quality concrete over a three-year period to construct facilities for the gas gathering system in the eastern regions of Saudi Arabia. Holmes & Narver furnished Aramco with a broad range of technical assistance in definition and in implementation of a program to provide the raw materials, production facilities, and rolling stock required to deliver ready-mix concrete to the widely scattered construction sites. The program resulted in the development of two rock quarries and aggregate production sites; eight batch plants; a centralized bulk cement receiving, handling, storage, and distribution system; a fleet of mobile equipment for moving rock, sand, water, cement, and mixed concrete between the sites; and quality assurance laboratory facilities.

Holmes & Narver provided engineering support in consolidating the program requirements, in selection of rock quarry and crusher sites and batch plant locations, in projection of production rates, and in specification of all fixed plant, portable equipment, and vehicles required. The engineering also included the preparation of all plant site development plans and the tie-in with electrical, water, and communications utilities. The identification of suitable rock quarry sites in the north was a major problem, and it was eventually found necessary to haul competent rock some 200 kilometers. An incremental program was instituted wherein cement was initially supplied in 50-kilo sacks, then progressed to one-ton bags and, finally, to bulk distribution in trailers and storage silos.

A major portion of the facilities and equipment required for the program was purchased by Holmes & Narver. Some of the items included two 200-ton-per-hour portable aggregate crushing, screening and stockpiling plants, four 100-cubic-yard-per-hour low-profile batch plants, air compressors, rock drills, generators, lighting units, 13 quarry trucks, 85 truck tractors, 50 bottom dump trailers, 22 cement hauler trailers, 60 mixer trucks, 22 front-end loaders, water tanks, bag breakers, hoppers, and spare parts.

The installation of the initial batch plant was accomplished by Holmes & Narver. We also prepared the specifications and contract for operation and maintenance of the ready-mix concrete facilities.



Pouring Ready-Mix

Concrete Batch Facility

REMOTE SITE DEVELOPMENT

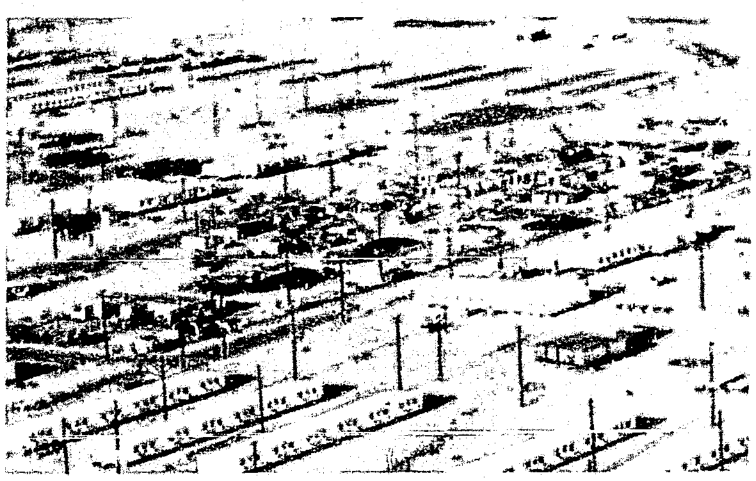
Client: *Arabian American Oil Company*
Location: *Saudi Arabia*

Holmes & Narver provided engineering, procurement, and construction management services, in support of the Saudi Arabian Eastern Province Construction Camp Facilities Capital Program, based on criteria developed by H&N in Dhahran, Saudi Arabia. Once the Aramco-approved criteria were established, design work was initiated. Concepts of construction camp configurations were developed considering prevailing weather, availability of water, camp size variations from 200- to 7,500-man, family housing, schools, recreation facilities, and other community requirements.

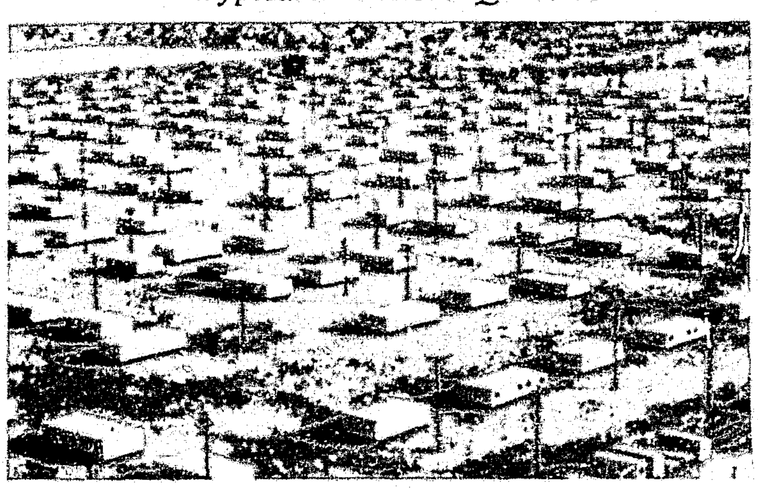
Layouts for four types of camps were prepared, with details for each size and function of building or structure, and requirements for electrical power, water systems, and sewage systems. These services represented efforts in and out of Saudi Arabia. Both semipermanent and portable construction camp facilities were involved. One camp accommodates a population exceeding 8,000 persons. The total population of all camps is 35,329.

Engineering services included the preparation of approximately 2,500 final engineering drawings depicting camp layouts, facilities, and utility systems. U.S. and international procurement services included purchasing, inspection, accounting, expediting, and traffic. Construction management services included planning and controls, contract administration, construction engineering, material coordination, construction operations, administration, and industrial relations.

Holmes & Narver was also responsible for the engineering, procurement, and construction management of 891 one- and two-bedroom homes, a construction central and shipping/receiving center at Dhahran, and warehouse/office complexes at five construction camp locations.



Typical Bachelors' Quarters



Typical Family Housing

Dhahran Office Complex

CIRI/H&N

PROJECT EXPERIENCE

LOGISTICAL SUPPORT

LOGISTICAL SUPPORT

Client: ***Various***
Location: ***Worldwide***

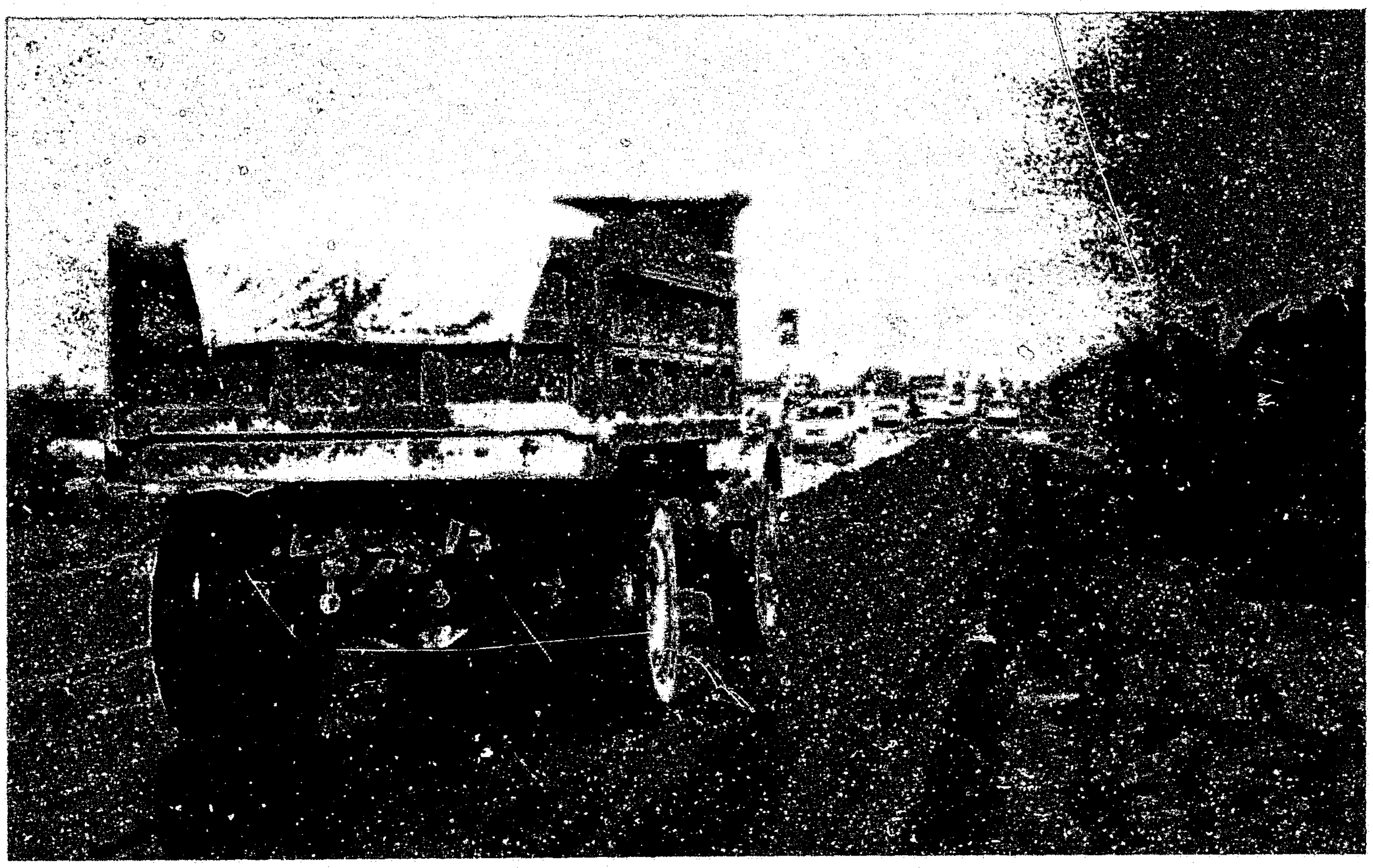
A significant portion of Holmes & Narver's labors around the world has been logistical planning and development and material and operational support for projects in such remote parts of the world as the Pacific islands, Australia, Alaska, Saudi Arabia, and Antarctica. These support services include the establishment of depot and warehouse facilities at various ports of embarkation and job sites; the design and implementation of a materiel control system that includes procurement, expediting, receipt, and accountability of all materials and equipment; and the scheduling, manifesting and shipping of all cargo in accordance with the operational schedules required at remote site operations.

Holmes & Narver has provided various support services which include management, engineering, construction, maintenance, and operations of facilities on Johnston, Bikini, and Enewetak atolls and on Christmas, Fanning, and Palmyra islands from shortly after the end of World War II until the present. For example, Holmes & Narver provided support services for meteorological experiments conducted by the National Center for Atmospheric Research on Christmas, Fanning, and Palmyra islands and for radar testing facilities on the Phoenix Islands.

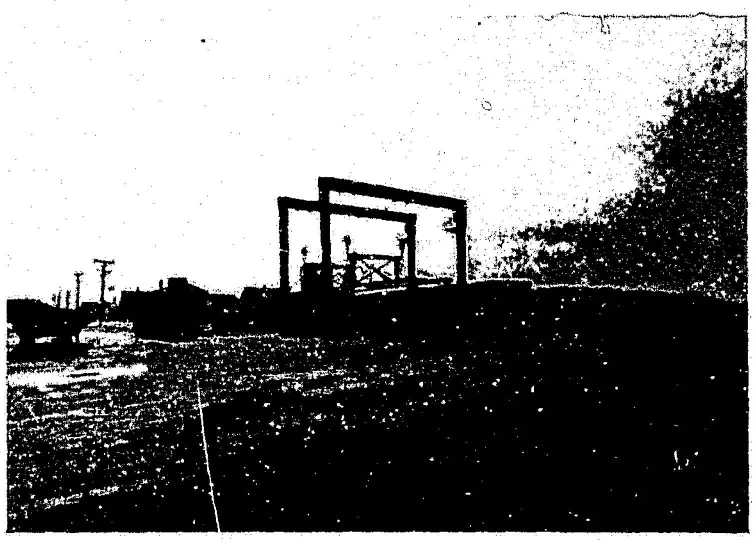
For the U.S. Department of Defense and the U.S. Atomic Energy Commission, Holmes & Narver planned, designed, built, supplied, and maintained an "instant city" of 4,500 on Johnston Atoll. More recently, Holmes & Narver provided engineering and environmental impact studies related to the return of native inhabitants to Bikini and Enewetak Atolls. As managing firm of a joint venture under contract to the U.S. Navy, Holmes & Narver provided engineering, construction, and support services at a very low frequency transmitting facility at the Northwest Cape, Australia.

Holmes & Narver has also provided necessary support services for military and scientific projects in the coldest parts of the world. Under a contract from the U.S. Air Force Alaskan Air Command, Holmes & Narver provided support and construction assistance to the Naval Arctic Research Laboratory at Point Barrow, Alaska. For the National Science Foundation, Holmes & Narver has provided support services at half a dozen camps and remote sites since 1968. Support functions at such relatively inaccessible places include housing, dining, and recreational facilities for personnel; operation and maintenance of power plants and distribution lines, water supply and distribution systems, sanitation systems, and safety and medical facilities; and maintenance shops, warehousing, accounting, administration, and communications. With a lead time of 12 months, at some sites, effective planning and control are essential and well within the capabilities of Holmes & Narver's personnel.

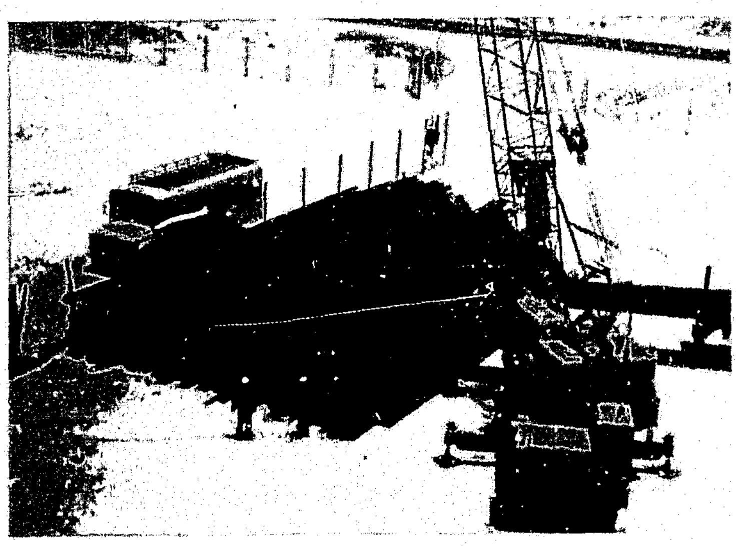
Holmes & Narver also provided engineering, procurement, and construction management services in support of the Saudi Arabian Eastern Province Construction Camp Facilities Capital Program. Definitive layouts for four types of desert/environment camps were developed with details for size and function of each structure and requirements for electrical power and water and sewage systems. Population at the camps was approximately 30,000.



Local Hauler



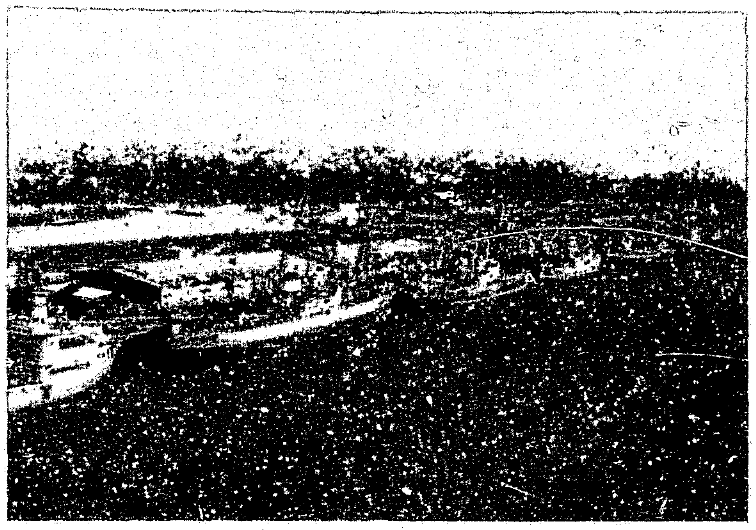
Portable Bridge Crane, Material Yard



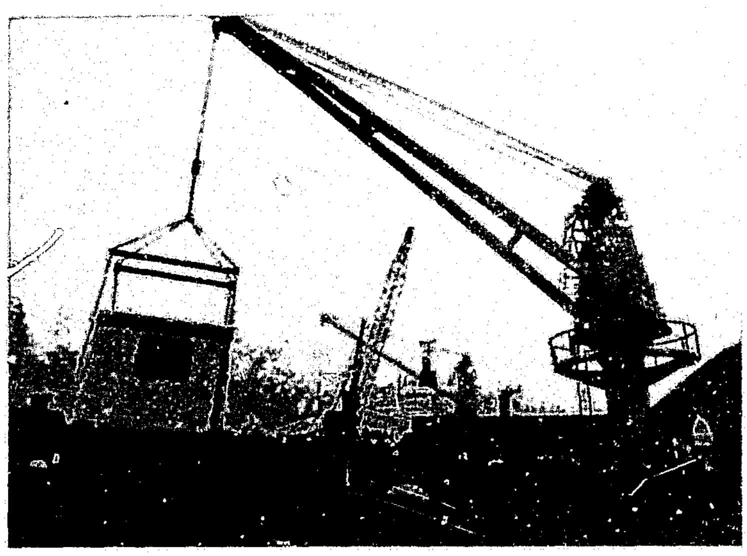
Pipe Yard

Crushing Plant

Deep Water Pier, Medren Island, Enewetak Atoll



Pier, Arabian Gulf



Offloading Housing Module, Arabian Gulf

Housing Module Storage Yard

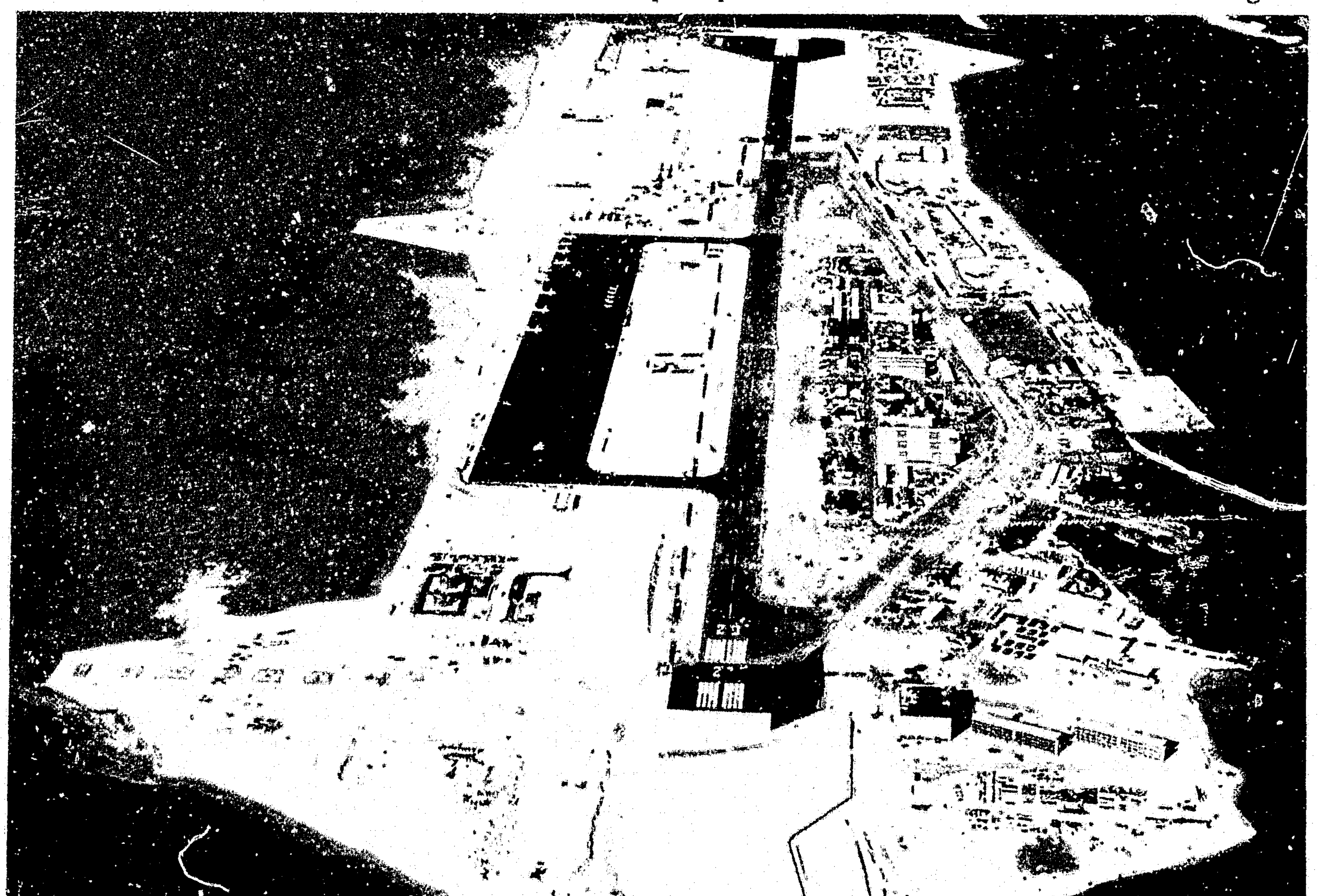
LOGISTICS SERVICES

Client: *U.S. Department of Defense*
U.S. Atomic Energy Commission
Location: *Johnston Atoll, Central Pacific*

Holmes & Narver planned, designed, built, and is presently supplying and maintaining a completely modern city of 4500 inhabitants on this remote atoll 700 miles southwest of Hawaii. The site for this "instant city," which was built for the *U.S. Department of Defense* and the *U.S. Atomic Energy Commission,* was originally a small landmass of 60 acres. A unique hydraulic landfill operation, using dredges to claim fill materials for the surrounding coral reef, increased it more than tenfold to 690 acres on which the city was built. Men, materials and equipment were transported from distances of more than 3000 miles to the site.

The logistics planning for this operation was exceptional in scope and complexity. Not only was it necessary to properly schedule men and materials for the initial "brick and mortar" construction program, but it was also necessary to simultaneously fulfill requirements and design criteria for special test structures and installations being developed by the AEC and its numerous scientific contractors. All materials, special equipment, and special manpower skills had to be defined, located, procured, and transported to Johnston Atoll at the proper time. Material control and distribution at the test site were, in themselves, a major effort.

The success of this project depended on the effective operation and maintenance of several deep water piers, numerous barge landings, and ancillary equipment and facilities. The project covered every aspect of the logistics cycle from harbor and depot operation to material control and stevedoring.



Johnston Atoll, an island city 700-miles southwest of Hawaii.

CIRI/H&N

PROJECT EXPERIENCE

TECHNICAL SUPPORT

ENVIRONMENTAL SERVICES

HOLMES & NARVER has a thorough understanding of the environmental impact documentation requirements for proposed major projects and of the operational methods of governmental agencies of jurisdiction. H&N's environmental services activities have served a variety of clients since passage of the U.S. National Environmental Policy Act and the 1973 issuance of guidelines by the President's Council on Environmental Quality.

Holmes & Narver can provide total management services for the preparation of environmental impact documents through the draft and final versions. In addition, H&N has a thorough understanding of the requirements and operational methods of governmental agencies of jurisdiction that are either directly or indirectly involved in the review of environmental consiuerations and the approval routes of applications for permits for construction and operation of industrial facilities. This capability has developed over the years through work in the energy industry. In general, the flow of activities and events necessary to provide these management services for a typical industrial facility are depicted in Figure 13 and described below.

- **Review Available Baseline Data** that have been developed.
- **Identify and Contact Agencies** of jurisdiction that will be involved in granting all the necessary approvals required to bring the facility into operation. Determine the submittals and the environmental data packages required.
- **Develop Permits Schedule and Environmental Data Requirements** for submittals identified. (Develop additional data as required.) Indicate required interface activities between agencies and the critical path for obtaining necessary project approvals.
- **Prepare Material for Briefing of Agencies or Interested Groups.** The level of effort and scope of work will be determined for any given project according to the frequency by contacts with all agencies, and the extent of interest expressed by third parties.
- **Prepare Submittals** for the appropriate agencies, maintaining agency contact.
- **Submit Applications and Data to Agencies per Schedule.** Maintain contact during review of submittals through the various bureaus and agencies up to approval, participate in hearings in support of the applicant as required, and update applications with the latest information whenever this is necessary to expedite the procedure.

In summary, these environmental services are supplementary to the primary role of Holmes & Narver as an engineering design, procurement and construction services company. They provide support during the preliminary engineering phases of a project when alternative courses of action regarding costs, technology, construction schedule, and environmental impacts are being considered. They also ensure the timely development, objectivity, and accuracy of all licensing applications and environmental impact documentation required to obtain the necessary project approvals.

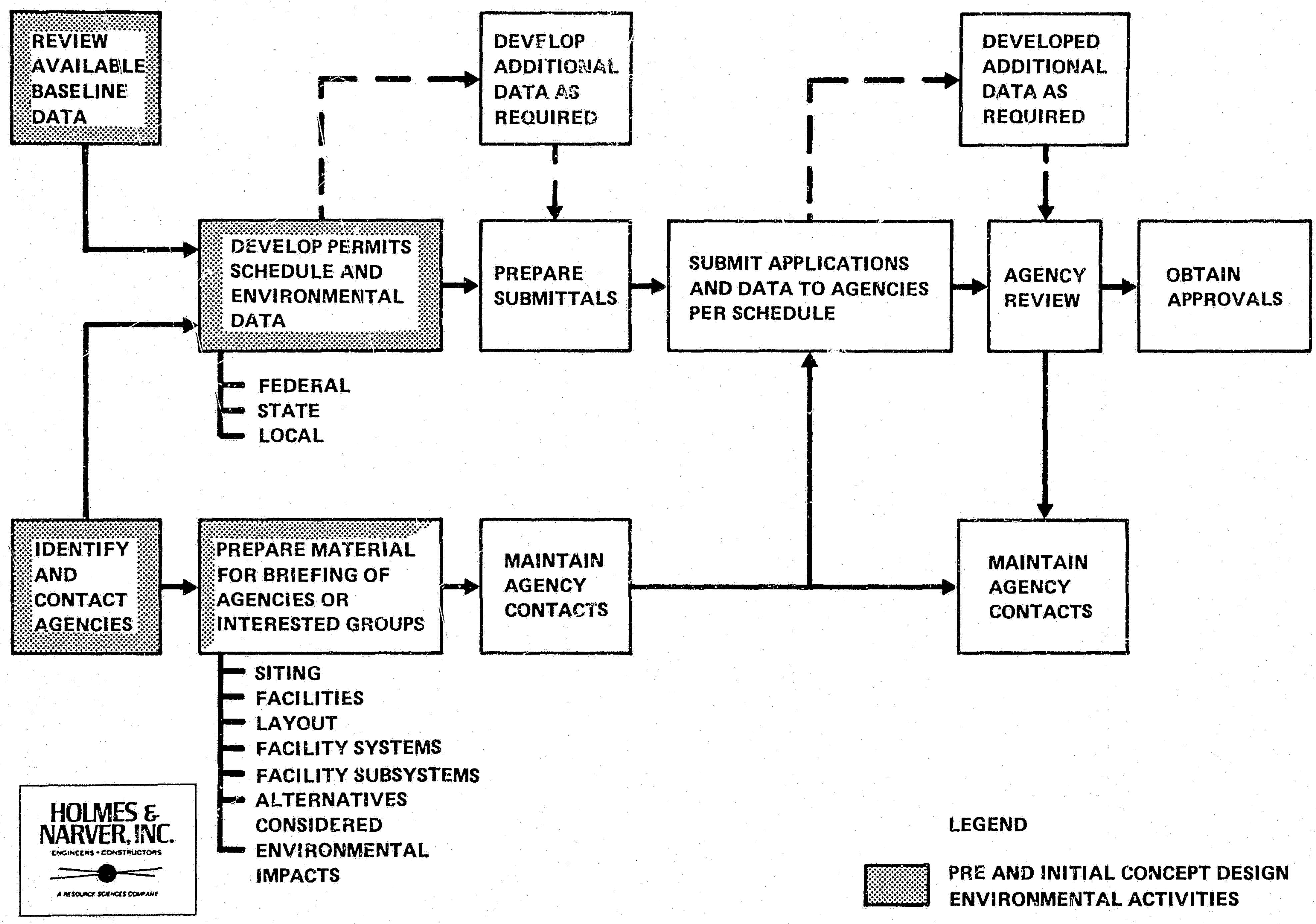


Figure 13
Environmental Permits/Approvals Task

2

POWER PLANT ENVIRONMENTAL AND SITE EVALUATION

Client: ***Hawaiian Electric Company, Inc.***

Baseline inventories were developed for the characteristics of a principal proposed site and an alternative site for a fossil fueled power plant to be located on the Northwest Coast of the island of Hawaii.

Archaeological walk-through surveys developed an inventory and location sketches of archaeological remains. An assessment of the value of the remains and recommendations for salvage operations prior to site development were made.

Inventories of the terrestrial flora and fauna were made over extended time periods to account for seasonal variations. Transects were established to provide consistency in the inventories and control plots were identified for comparative monitoring during power plant operation.

Meteorological surveys were made including measurements of weather data over a one year period, pilot balloon observations, aircraft soundings to detect temperature inversions, and air quality data. Air quality predictions were made using computerized diffusion models.

Geologic and hydrologic profiles of the principal site area were obtained from core borings and evaluation of core samples by experts in Hawaiian geology and hydrology. Evaluation of aquifers proposed for use as a cooling water was based on pumping tests of a 20-inch well and injection into the receiving stratum. An underwater survey of off-shore geologic and hydrologic conditions was also made.

An inventory of marine biota was made for the nearshore zone of thermal diffusion and the thermal impact was assessed.

The results of the baseline surveys are included as part of an Environmental Impact Statement (EIS) provided to the client for use in site approval applications. This report also included evaluation and comparison of alternatives regarding cooling water disposal methods, fuels, methods of generation, sites, and power sources as well as a description of the proposed project, present environmental setting, impacts during construction and operation, and long and short term effects.

TRANS-CANADIAN CRUDE OIL PIPELINE

Client: *Canadian and U.S. Governments*
Location: *Alaska and Canada*

Environmental studies were performed in a two-phase program for a 48-inch crude oil pipeline system from Prudhoe Bay, Alaska, to Edmonton, Alberta as follows:

- Review of all available baseline data related to the pipeline project and its environmental setting.
- Assessment of environmental impacts for the proposed system based upon the baseline data.

Project guidelines were prepared by the Canadian Government (Department of Indian Affairs and Northern Development and Energy, Mines and Resources) and the U. S. Department of the Interior.

The proposed pipeline system would be 1,738 miles long and include major facilities related to the project such as tank farms, pump stations, air strips, and maintenance bases. In addition to the pipeline itself, a report was prepared to present information relevant to the pipeline project, its environmental setting, and potential social, economic and environmental impacts.

Both beneficial and detrimental impacts were discussed such as development of arctic engineering technology, increased regional incomes during construction, physical changes in the terrain, effects on flora, fauna, and marine biota, and oil spill prevention and containment. Many suggestions and recommendations were made to enable better definition of environmental impacts prior to construction. The pipeline will cross relatively primitive terrain where the population is centered in small undeveloped villages. The social and economic impact of construction and operation of the pipeline included investigation of the effects of training and employing natives, changes from a subsistence economy to a wage economy, increases in access routes, cultural changes caused by increased outsider contact, and associated problems caused by subsequent unemployment and welfare economics. The impact assessment included both short term and long term effects and secondary effects of the increased economic activity. These included increased demands for supplies and services and additional requirements for health, retail, and education facilities. Also included were the effects of inflation and the impact on land use, aesthetics, and archaeological activities. The towns of interest included not only those on the pipeline route, but also those on supply routes and other major cities in Alaska and Canada. Other portions of the impact assessment centered around the biological and geotechnical effects of the pipeline. This included impacts on native wildlife habitats, migration routes, and the surrounding vegetation.

WEST COAST PORT FACILITIES
SITE EVALUATION AND FEASIBILITY STUDY

Client: ***SOHIO Transportation Company***
Location: ***Southern California***

Holmes & Narver conducted a site evaluation and feasibility study on the movement of massive amounts of oil through proposed port facilities in California. Five candidate sites were analyzed on the basis of requirements for preparation of an Environmental Impact Report (EIR) required by the State of California and an Environmental Impact Statement (EIS) required by the federal government.

A list of environmental considerations was derived in order to evaluate impacts of the proposed facility at each candidate site according to three basic conditions:

1. Impacts of the facility at each particular site location.
2. Impacts during facility construction.
3. Impacts during facility operation and maintenance.

A more detailed breakdown was made for these three conditions to analyze impacts on physical and biological environments. The site location category included consideration of environmental impacts which are due to the fact that the facility would be located in a specific area; and the latter two categories, construction and operation and maintenance, addressed themselves to specific periods of time. The candidate facilities were evaluated in accordance with these considerations and conclusions regarding the site preference were made.

As a part of this study, a list of all the California agencies involved and permits required was compiled so that the permit requirements, agency interfaces, and schedule impacts could be identified in the initial project stages to aid in the orderly progress of the project.

As an indication of the complexity of the process it is noted that 50 state agencies have been identified as having some impact on projects located in the coastal regions of the State of California.

As a result of this experience, Holmes & Narver has a thorough understanding of the most efficient methods of obtaining and compiling information relating to government organizations having authority over industry projects.

TANKER TERMINAL FEASIBILITY AND PERMITTING STUDY

Client: ***SOHIO Transportation Company***
Location: ***Southern California***

One of the major markets and transfer points for Alaskan oil lies in southern California. Holmes & Narver conducted an environmental feasibility study on the movement of massive amounts of oil through proposed port facility in this region. Five candidate sites were analyzed on the basis of requirements for preparation of an Environmental Impact Report (EIR) required by the State of California and an Environmental Impact Statement (EIS) required by the Federal Government.

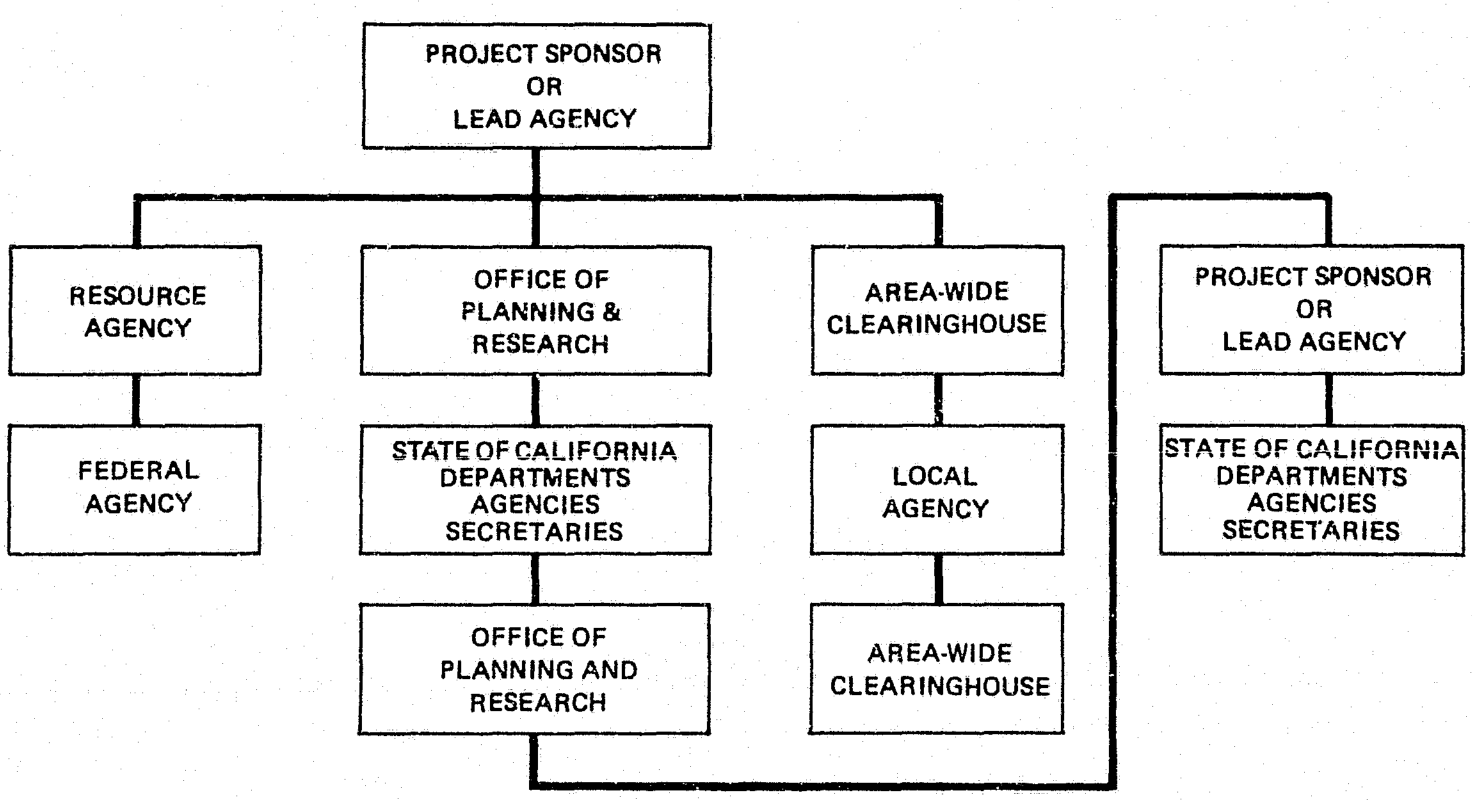
A list of environmental considerations was derived in order to evaluate impacts of the proposed facility at each site according to three basic conditions:

- Impacts of the facility at each particular site location
- Impacts during facility construction
- Impacts during facility operation and maintenance

A more detailed breakdown was made for these conditions to analyze impacts on physical and biological environments. The site location category included consideration of environmental impacts that are due to the fact that the facility would be located in a specific area; the other two categories — construction and operation and maintenance — addressed themselves to specific periods of time. The candidate facilities were evaluated in accordance with these considerations and conclusions regarding the site preference were made.

A list of all the California agencies involved and the permits required was compiled and organized into a network so that permit requirements, agency interfaces, and schedule impacts could be identified in the initial stages of the project to aid in the orderly progress of that project. As an indication of the complexity of the process. it is noted that 50 state agencies have been identified as having some impact on projects located in the coastal regions of California.

As a result of this project, Holmes & Narver has a thorough understanding of the most efficient methods of obtaining and compiling information relating to government organizations that have authority over industrial projects.



State of California Review Process

SEISMICITY EVALUATION AND DEVELOPMENT OF SEISMIC CRITERIA FOR A CRUDE OIL TANKER TERMINAL

Client: ***SOHIO Transportation Company***
Location: ***San Pedro Bay, California***

The SOHIO Transportation Company has responsibility for the distribution of oil produced at the North Slope of Alaska. This oil will be transported to Southern California where SOHIO plans to construct a terminal for receiving and distributing this oil into the Mid-United States by a pipeline.

During the preliminary planning and design phase for the terminal facilities, Holmes & Narver prepared data and provided reports for input to the site feasibility evaluations. The Holmes & Narver inputs provided for (1) a comparative study of geologic and seismic factors between proposed sites for the terminal under consideration at the time, (2) an evaluation of the seismicity and generation of ground motion parameters for the Long Beach Harbor site which was finally selected and (3) the development of seismic design criteria for the tank farm which comprises a significant portion of the proposed terminal. The requirements of the regulatory agencies responsible for the construction and operation of this terminal called for ground accelerations to be used in design that were more severe than the motions implied by code seismic requirements applicable to conventional structures. As a result, seismic criteria developed for the terminal was based upon the seismicity of the site.

Site seismicity was evaluated from a survey of available literature regarding the location and activity of faults, the location and magnitude of past earthquakes in the vicinity of the site, and the seismic resistance of other projects in the harbor area. The general approach recommended for the design of the terminal facilities was a two-level seismic design. This approach allows the facilities to be designed to remain operational and sustain no major structural damage for a moderately severe earthquake which has a reasonable probability of occurrence during life of the facility. This level of design earthquake is called the Maximum Probable Earthquake (MPE). The second level provides designs to protect against loss of life or serious environmental impact through sustaining damage short of total collapse for an extremely severe seismic event called a Maximum Credible Earthquake (MCE). Such an earthquake would have a very small probability of occurrence during life of the facility.

In utilizing the above approach, ground motion in suitable form for design of the facilities for both an MPE and MCE were defined. The recommended ground motion was defined in the form of ground motion peak parameters and response spectra for each design level earthquake.

SEISMICITY EVALUATION AND EARTHQUAKE DESIGN BASIS FOR A CRUDE OIL PIPELINE

Client: *SOHIO Transportation Company*
Location: *Southern California*

The purpose of this effort was to provide the basis for the seismic design of the California segment of a major pipeline which transports crude oil that originates in Alaska across the United States. The Holmes & Narver effort included the defining of the route seismicity, evaluating associated geological and soils considerations, and outlining pipeline design procedures for seismic effects. This approach enables the pipeline to be designed based upon rational earthquake design criteria that reflects the seismicity of the pipeline route as well as significant geologic features along the route.

The procedure utilized for determining earthquake design parameters such as peak ground accelerations, velocities, and displacements, as well as elastic response spectra, are well known and accepted methods from the work of leading experts in the field of earthquake engineering. Wherever possible, more than one method or procedure was employed in order to further substantiate some of our final conclusions. The design criteria outlined in the report we prepared was based upon modern state-of-the-art procedures or techniques in the field of seismic design as well as structural and soils engineering.

Earthquake resistant design of the SOHIO West Coast Mid-Continent pipeline in accordance with the seismic input excitations and design provisions developed and presented in the Holmes & Narver reports will (1) insure that the pipeline will remain operational during the frequent seismic events which occur in Southern California and (2) will minimize environmental problems and the threat to public safety during the rare greater seismic events which are possible in the Southern California region.

The initial phase of this work evaluated the pertinent ground shaking effects for design purposes on the basis of the route seismicity. These effects include peak ground acceleration, velocity and displacement, duration of strong ground motion, and response spectra. The pipeline route was divided into isoseismic zones as a practical expedient, enabling design for the same forces within each zone. For such a long structure as a pipeline, seismic design zones minimize the required design effort as they provide the means of expressing the seismicity for the site in a useful quantitative format for design purposes, and very often are helpful in reducing the apparent costs.

In a subsequent phase of this work, the pipeline route was further divided into zones where other seismic hazards might impact the pipe design. In particular, areas where fault surface displacements might occur, areas of potential liquefaction and locations where slope instability need to be considered were approximately identified and located. Detailed field investigations were recommended for these regions prior to final pipe design, but the seismic design zones based upon seismic hazards other than shaking defined in our reports provided the basic information from which the further detailed work could be accomplished. Pipeline zones subject to potential faulting or seismic soil instability were determined from available published reports or maps and some field examination (aerial and brief ground reconnaissance).

Holmes & Narver provided specific and detailed recommendations for the seismic loadings, design procedures and analytical methods to be utilized in the pipeline design for each potential seismic effect (i.e., ground shaking, fault rupture, liquefaction, and slope stability). Based upon the results of this work, the pipe designer is able to properly account for all earthquake effects in the design of the pipe and all related structures.

ARCO GATHERING SYSTEM

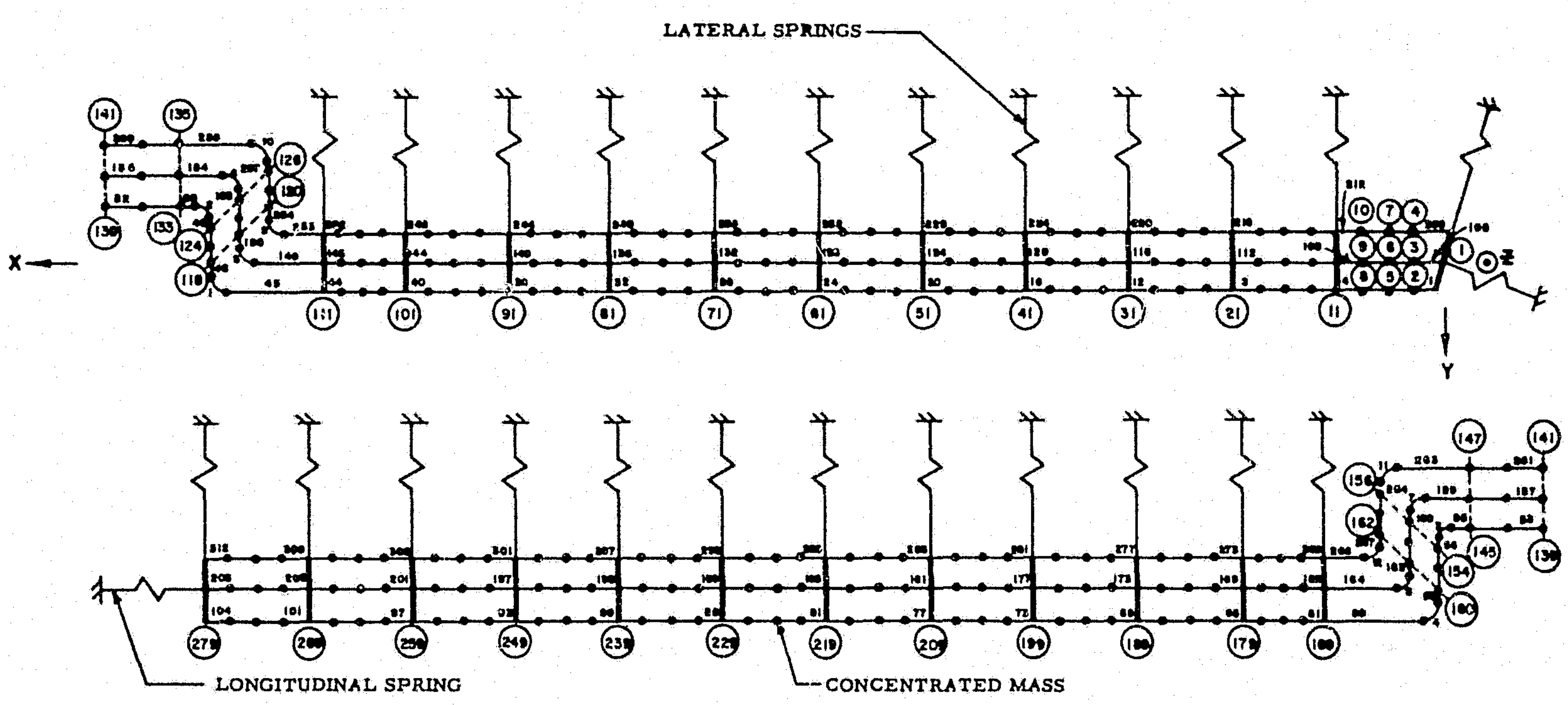
Client: ***Williams Brothers Engineering Company***
Location: ***Prudhoe Bay, Alaska***

Williams Brothers Engineering Company is designing the gathering system for the gas and crude oil from the wells being drilled by ARCO at Prudhoe Bay on the North Slope of Alaska. The crude oil will be piped to the northern terminal of the Trans-Alaska Pipeline. Some of the gas will be used as fuel and some will be reinjected. The pipes are supported above the permafrost with several different sized pipes on each support. At regular intervals the pipes are anchored. In between anchors, expansion loops are provided.

As a subcontractor to Williams Brothers Engineering, Holmes & Narver computed the stresses in the pipes, pipe supports and anchors due to earthquake motion. The earthquake input was provided by ARCO for this work in the form of Response Spectra. Response Spectra were given for both a Design Contingency and a Design Operating Earthquake.

Four different sections, representing different types of terrain and different combination of pipes, were selected for analysis. Each section consisted of the run of pipes between two anchors including the expansion loop. In each case, mathematical models were constructed of the pipes, pipe supports and pipe anchors for three directions of earthquake motion.

Both the winter condition with ice on the pipes, and the summer condition with the permafrost partially melted were considered.



NOTES

1. (N) - NODES
2. N - MEMBERS
3. ANCHORS - ALL D.O.F. RESTRAINED EXCEPT X AND Y DISPLACEMENTS
4. ANCHORS HAVE TWO SPRINGS IN HORIZONTAL PLANE ALONG THEIR PRINCIPAL AXES
5. PIPE SUPPORTS - Z DISPLACEMENT RESTRAINED
6. SUPPORTS ON STRAIGHT SECTIONS HAVE SPRINGS IN THE Y DIRECTION
7. WEIGHTS OF THE FUTURE LINES ARE CONCENTRATED AT THE SUPPORTS
8. SLIDING PIPE SUPPORTS ARE SHOWN
9. DRAWING NOT TO SCALE

MANIFOLD AND SCRAPER TRAP

Client: ***Atlantic Richfield Company***
Location: ***Prudhoe Bay, Alaska***

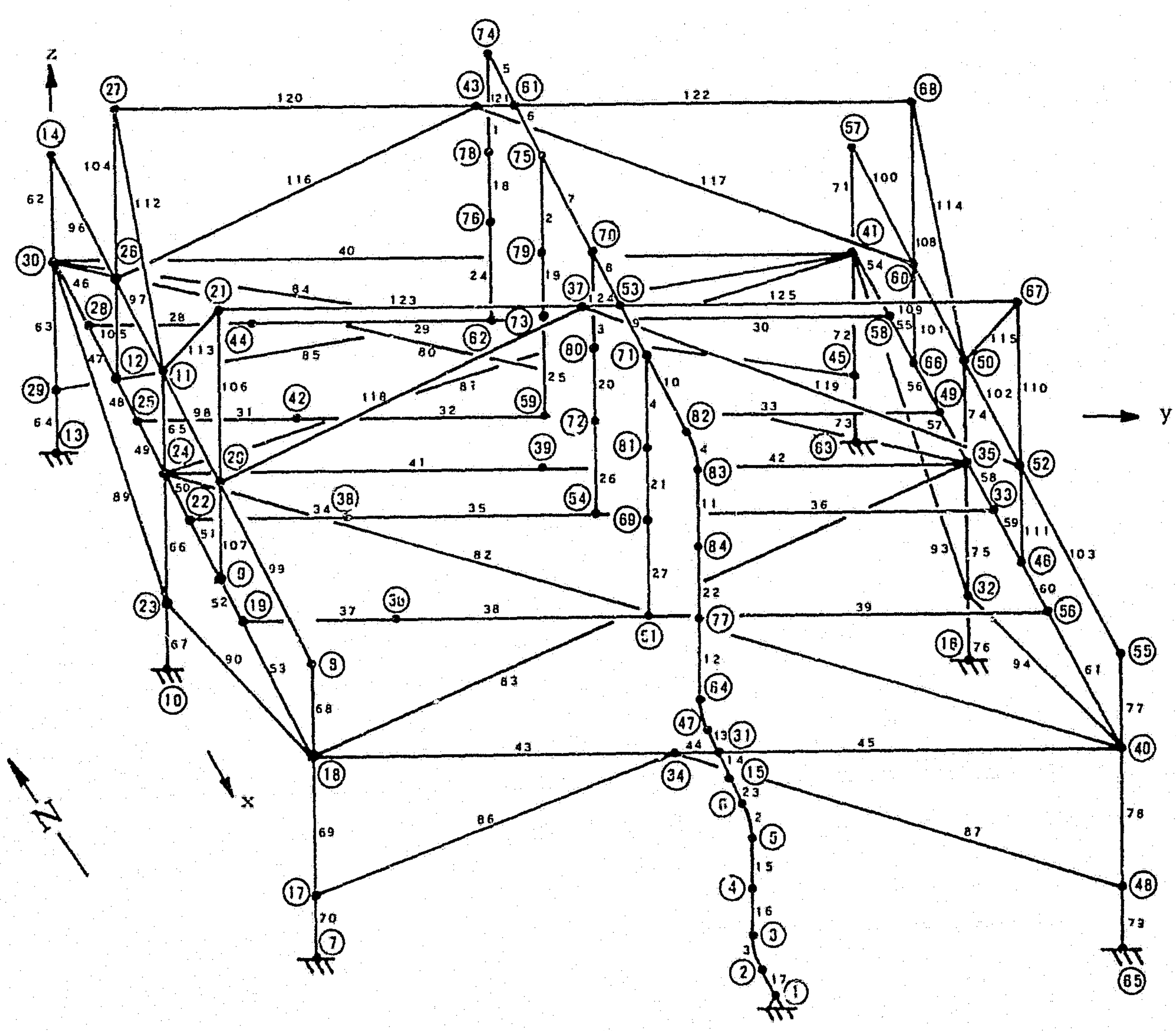
The crude oil and gas at Prudhoe Bay on the North Slope of Alaska will be recovered by the *Atlantic Richfield Company* (ARCO). ARCO has wells at several sites and a gathering system for the crude oil and gas. The crude oil will be transported to the northern terminal of the Trans Alaska Pipeline System and the gas will be reinjected.

As each of the drill sites, the well lines enter the Manifold and Scraper Trap Building where they are interconnected with the gathering lines and the lines to the separators by means of manifolds. The manifolds will be preassembled on skids and shipped to the drill sites where they will be installed in the building. The scraper traps will be assembled on skids at the drill site. The Manifold and Scraper Trap Building is a steel shed type structure with a reinforced concrete floor. The concrete floor is supported on steel piles approximately 12 feet above the permafrost. The skids are bolted directly to the reinforced concrete floor.

A stress analysis of the manifolds, scraper traps and associated piping and the mounting skids was required to show that the units as designed will meet the specification for the project. A stress analysis for seismic motion was performed.

Separate mathematical models were made of the lower and upper manifolds. The lower manifold is supported on the base f ame of the skid and is therefore effectively supported at the level of the concrete floor. The upper manifold is supported entirely on the skid frame.

The seismic analysis was done using a modal analysis technique with the responses from each of the modes summed by means of the SRSS method. The seismic loads were applied to the models using In-Structure Reponse Spectra.



RELEVANT EXPERIENCE

SALOMON BROTHERS

Salomon Brothers

Salomon Brothers was founded in 1910 as a partnership with an initial capital investment of $5,000 and a membership on the New York Stock Exchange. Through the years, we have maintained our partnership structure, because of its inherent flexibility and responsiveness, and built our capital thourgh the retention of the firm's profits.

Today, Salomon Brothers is the nation's largest privately held investment banking firm as measured by capital position, which is in excess of $208 million.

The firm has a total complement of some 1,615 men and women with 49 General Partners and 421 Vice Presidents. In addition to our headquarters in New York, we have regional offices in Atlanta, Boston, Chicago, Cleveland, Dallas, Los Angeles, Philadelphia and San Francisco, and international offices in Hong Kong and London.

Salomon Brothers is dedicated to performance. No matter how difficult the market conditions, we are committed to placing our capital at risk to raise money for our clients at the best best possible price and to provide liquidity for our customers in all investment quality securities, in virtually any amount.

Qualifications for Participating in Acres' Report

Salomon Brothers' comments in the accompanying memorandum are based on involvement with various projects in Alaska and extensive experience in public power financings, as well as excellence in municipal bond underwriting, sales and trading. In addition, the firm provides a variety of non-municipal investment banking services. The following sections offer additional insights into the firm's experience in these areas.

Involvement in Alaska

Salomon Brothers maintains relationships with several major oil companies with operations in Alaska.

The firm acts as sole debt placement agent for the only consortia financing done by the Alyeska Group for the North Slope, an unsecured lease debt financing of equipment utilizing short-term notes.

Salomon Brothers has also advised a major multi-national oil company on the long-term financing associated with a $420 million production payment financing in Alaska that combines commercial bank and long-term funds for non-producing property financing.

Experience in Public Power Financing

Salomon Brothers currently serves 27 public power clients. These clients are listed on the following pages, together with the facilities being financed and the amount of bonds issued or proposed to be issued:

ARIZONA POWER AUTHORITY	66% participation in the 1,000 mw Montezuna Pumped Storage Project.	$ 500,000 (proposed)
**BOISE PROJECT BOARD OF CONTROL, IDAHO	Lucky Peak Power Plant Project, a hydro-electric power generating facility with a total installed capacity of 79 mw.	70,000 (proposed)
*BROWNSVILLE, TEXAS	Advance refunding of outstanding bonds and capital improvements to electric, water and sewer systems.	33,765

*Salomon Brothers is senior managing underwiter.
**Salomon Brothers is co-senior managing underwriter.

Clients	Facilities	Bonds ($000)
*DELTA, COLORADO	Proposed 35 mw hydro-electric project.	50,000 (proposed)
ELECTRIC POWER SYSTEMS AUTHORITY, LOUISIANA	Participation in two 540 mw coal-fired generating stations.	500,000 (proposed)
FLORIDA MUNICIPAL POWER AGENCY	Bulk power supply projects for 26 member utility systems, including generating and transmission facilities.	1,000,000 (proposed)
*GAINESVILLE, FLORIDA	Advance refunding of outstanding bonds.	230,000
GRAND RIVER DAM AUTHORITY, OKLAHOMA	1. Electric system improvements.	8,800
	2. Construction of 490 mw coal-fired generating station and related facilities.	421,260
**GRANT COUNTY PUBLIC UTILITY DISTRICT NO. 2, WASHINGTON	Hydro-electric generating expansion at Priest Rapids and Wanapum Dams.	380,000 (proposed)
*ILLINOIS MUNICIPAL UTILITIES ASSOCIATON	No facilities yet authorized.	
LEWIS COUNTY PUBLIC UTILITY DISTRICT, WASHINGTON	Cowlitz Falls Project, a 60 mw hydro-electric power generating facility	100,000 (proposed)
MASSACHUSETTS MUNICIPAL WHOLESALE ELECTRIC COMPANY	1. 3.2% participation in the 1,150 mw Millstone No. 3 nuclear generating plant.	26,100
	2. Participation in five nuclear, one oil-fired and one coal-fired generating plants and construction of 511 mw of intermediate and peaking generating capacity.	560,870 468,130 (proposed)

*Salomon Brothers is senior managing underwiter.
**Salomon Brothers is co-senior managing underwriter.

Clients	Facilities	Bonds ($000)
MICHIGAN PUBLIC POWER AGENCY	Purchase of an ownership interest in one coal-fired and two nuclear generating plants being constructed by Consumers Power Company.	500,000 (proposed)
MUNICIPAL ELECTRIC AUTHORITY OF GEORGIA	1. 17.7% participation in the two 807 mw Edwin I. Hatch Nuclear Units; 17.7% participation in the two 1,150 mw Alvin W. Vogtle Nuclear Units; 10% interest in the two 865 mw coal-fired Wansley Units and in the four 810 mw coal-fired Scherer Units.	725,000 875,000 (proposed)
	2. Integrated trasmission system with Georgia Power Company.	
NEBRASKA PUBLIC POWER DISTRICT	1. Completion of the 800 mw Cooper Nuclear Station.	116,100
	2. Expansion of electrical generating and transmission facilities.	175,000
	3. Completion of the 650 mw Gerald Gentlemen Station No. 1 and 650 mw Gerald Gentlemen Station No. 2.	300,000
NORTH CAROLINA MUNICIPAL POWER AGENCY NO. 1	Participation with Duke Power Company for 75% ownership interest in Unit 2 of Catawba Nuclear Plant.	550,000 365,000 (proposed)
NORTH CAROLINA MUNCIPAL POWER AGENCY NO. 2	60 mw of peak-shaving generation.	150,000 (proposed)
NORTHWEST KANSAS MUNICIPAL ENERGY AGENCY	Participation with Sunflower Rural Electric Coop in coal-fired generating station.	70,000 (proposed)
PIEDMONT MUNICIPAL POWER AGENCY	25% ownership interest in Unit 2 of the Catawba Nuclear Plant.	300,000 (proposed)

Clients	Facilities	Bonds ($000)
***POWER AUTHORITY OF THE STATE OF NEW YORK	1. Completion of the 1970 Project consisting of the 800 mw James A. FitzPatrick Nuclear Power Plant, the 1,000 mw Blenheim-Gilboa Pumped Storage Power Project, and certain transmission lines.	80,000
	2. General Purpose Projects, consisting to date of the 775 mw Astoria 6 oil-fired generating plant, the 965 mw Indian Point 3 nuclear plant, and the 134 mile 765 kv Massena-Marcy transmission	1,610,000
	3. Future Projects, including a 1,000 mw pumped storage power project and 700 mw coal/refuse fired power plant.	1,500,000 (proposed)
***SALT RIVER PROJECT, ARIZONA	Additional electric generation, transmission and distribution facilities.	110,000 1,565,000 (proposed)
**TENNESSEE VALLEY PUBLIC POWER ASSOCIATION	1. Assist Tennessee Valley Authority (TVA) to finance the completion of several TVA facilities presently under construction.	$10,000,000 (proposed through 1988)
	2. Assist TVA in conjuction with its regular financing of several new generation and transmission facilities.	

**Salomon Brothers is co-senior managing underwriter.
***Salomon Brothers is a rotating senior manager.

Clients	Facilities	Bonds ($000)
*TEXAS MUNICIPAL POWER AGENCY	1. Construction of the 400 mw Gibbons Creek Project, Unit No. 1, and lignite mine. 2. 6.2% participation in the two 1,150 mw units of the Comanche Peak Nuclear Plant. 3. Transmission facilities.	$600,000 562,566 (proposed)
VERMONT PUBLIC POWER SUPPLY SYSTEM	Ownership of a proposed 50 mw hydro-electric facility and a participation in the Burlington, Vermont wood-chip generating plant.	150,000 (proposed)
+WESTERN FUELS ASSOCIATION, INC.	Coal mining equipment and unit trains for the Missouri Basin Power Project and other consumer owned electric generating stations.	37,000
*WESTERN MINNESOTA MUNICIPAL POWER AGENCY	1. 7.6% participation in the 1,500 mw coal-fired Missouri Basin Power Project. 2. 60 mw peaking turbine.	100,000
WESTERN WISCONSIN MUNICIPAL POWER GROUP	50 mw participation in the Alma 7 coal-fired plant to be constructed by Diaryland Power Cooperative.	75,000 (proposed)

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*Salomon Brothers is senior managing underwriter.
**Salomon Brothers is co-senior managing underwriter.
+Salomon Brothers served as financial agent.

LEADERSHIP IN MUNICIPAL BOND UNDERWRITING, SALES AND TRADING

Salomon Brothers is a leading underwriter and distributor of state and local municipal tax-exempt bonds and notes.

The following 1978 fiscal year figures show the important role the Municipal Department plays in the overall business of Salomon Brothers.

	Total Firm	Municipal Department
Total purchases and sales of securities	$502.0 billion	$29.1 billion
Average daily inventory of securities	$ 1.7 billion	$44.7 million
Underwriting and private placement of securities offerings	$ 25.1 billion	$10.5 billion
Sales personnel	277	24
Finance personnel	129	27

Municipal Bond Underwriting

The firm has managed or co-managed 655 issues of tax-exempt bonds in the total amount of $48.3 billion since January 1, 1974:

- Of these 655 issues, Salomon Brothers has served as senior managing underwriter for 201 issues in the total amount of $21.2 billion.
- Of these 655 issues, Salomon Brothers has purchased through negotiated sale 229 issues in the total amount of $26.6 billion.

These financings include some of the largest and most complex issues ever undertaken. A sample is listed below together with Salomon Brothers' role in them:

- Senior manager for the largest tax-exempt issue in history, the $3.8 billion State of New York Tax and Revenue Anticipation Notes on April 11, 1978. The firm also served as senior manager for the $3.6 billion State of New York Note issue in 1977 as well as the most recent $3.1 billion issue in April 16, 1979.

- Co-senior managing underwriter for the largest tax-exempt bond financing in history, the initial $1 billion bond issue of the Municipal Assistance Corporation for the City of New York on July 2, 1975. The firm has been senior manager for the Corporation's last six issues totaling $1.33 billion.

- Co-senior managing underwriter and "ran the books" for the largest tax-exempt general obligation bond financing and advance refunding in history, the $632.8 million General Obligation Refunding Bonds of the Commonwealth of Massachusetts on August 4, 1978. The firm was also senior manager for the $535 million General Obligation Public Housing Bonds of the Commonwealth of Massachusetts on March 5, 1976.

- Co-manager of the largest tax-exempt private placement in history, the $610 million General Purpose Bonds of the Power Authority of the State of New York on January 20, 1976.

- Co-manager of the largest publicly offered tax-exempt electric revenue bond issue sold to date, the $421 million Grand River Dam Authority, Oklahoma, Revenue Bonds, 1978 Series, July 13, 1978.

Municipal Bond Sales

The ability to sell new issues is one of the firm's key strengths. In fiscal year 1978, for the tenth consecutive year, Salomon Brothers sold more than one and one half times its underwriting commitments. All of the firm's 277 sales personnel sell municipal bonds and notes. Moreover, 24 of them are municipal specialists who concern themselves full time with the municipal market.

The firm is one of the nation's leading distributors of securities to institutional investors. The firm also reaches individual investors through its strong associations with large retail and influential regional firms around the country; through customers such as bond funds, financial advisors, and bank trust departments, who in turn place the securities purchased into thousands of individual accounts; and through other broker-dealers for whom the firm positions and wholesales securities in size for distribution to the individual market.

Municipal Bond Trading

Salomon Brothers' market making activities are the foundation on which our successful securities distribution capabilities have been built. Across the full range of institutional grade securities, Salomon Brothers stands ready to buy or sell for its own account to maintain liquidity in the marketplace.

Broad and active secondary trading markets are maintained in all types of municipal securities. As an indication of this activity, our daily inventory of municipal securities last year was generally in excess of $44 million. The gross volume of municipal purchases and sales for the same period exceeded $29 billion.

Municipal Notes

In addition, we are one of the few dealer firms actively underwriting and trading short-term municipal obligations. In fiscal year 1978, the firm managed or co-managed over $8.1 billion of new municipal note issues. The average daily position of municipal notes in our trading inventory is generally in excess of $50 million.

OTHER INVESTMENT BANKING ACTIVITIES

In addition to its role in the tax-exempt municipal bond and note markets, the firm is a leading market maker and managing underwriter of domestic corporate securities, U.S. Government securities, international securities and a major agent in the private placement of long-term debt.

Market Making

The firm makes markets in almost every kind of investment security, ranging from those in the short-term area including tax-exempt municipal notes, commercial paper, certificates of deposit, bankers acceptances, U.S. Treasury bills and Federal agency notes to long-term securities including bank, industrial, municipal, public utility and transportation bonds, equipment obligations, U.S. Government bonds, common and preferred stock and Canadian and Eurocurrency securities.

Indicative of market making activity was the volume of purchases and sales of securities in the 1978 fiscal year, which totaled $502 billion. These purchases and sales in the past ten years have amounted to over $1.9 trillion. The average daily inventory of securities was $1.7 billion in the past fiscal year.

Corporate Securities

Salomon Brothers has been one of the five leading corporate underwriting syndicate managers in every year since 1965. According to statistics compiled by the Investment Dealers' Digest, we ranked second among all investment bankers in managing or co-managing corporate public offerings and private placements of securities in calendar year 1978 with a total of $10 billion.

We ranked second in managing or co-managing corporate public offerings won at competitive bidding, with issues totaling $4 billion in calendar year 1978. The firm was first in ten of the last thirteen years in this category.

In calendar year 1978, Salomon Brothers ranked first in managing or co-managing negotiated debt offerings with a total of $5.4 billion.

U.S. Government Securities

In U.S. Treasury securities, Salomon Brothers is probably the largest market maker in the world. As a recognized dealer in these issues since 1917, the firm has traded Treasury securities longer than any other bank or non-bank dealer now active.

Indicative of Salomon Brothers' involvement in Federal agency debt financing has been its position either as lead manager or co-manager for the following Federal Agency issues during the past five years:

- Farmers Home Administration
- Federal Home Loan Banks
- Federal National Mortgage Association
- General Services Administration
- Government National Mortgage Association
- Private Export Funding Corporation
- Small Business Administration
- Tennessee Valley Authority
- U.S. Department of Agriculture
- U.S. Export-Import Bank
- U.S. Postal Service
- Washington Metropolitan Area Transit Authority

Salomon Brothers' Government Bond Department has supplied government securities on a competitive basis for a number of municipal issuers for various escrow and trustee accounts which are related to bond issues.

International Securities

Salomon Brothers has rapidly become a major underwriter and market maker of international securities. With offices in London and Hong Kong, Salomon Brothers makes active markets in Eurodollar certificates of deposit, foreign shares, Eurobond issues and Yankee dollar bonds during an international trading day which lasts 20 hours.

In calendar year 1978, Institutional Investor ranked Salomon Brothers first in the underwriting of foreign debt sold in the United States with a dollar value of over $3.5 billion.

Private Placements

According to Investment Dealers' Digest, Salomon Brothers ranked second in private placements for calendar year 1978 with over $2.8 billion in financings.

Salomon Brothers arranges loans and negotiates the placement of securities with institutional investors for a wide range of issuers. The firm's private placement capabilities include a detailed knowledge of institutional buyers' attitudes regarding rates and an ability to accomodate issuers' needs for operating flexibility, while structuring terms acceptable in the marketplace.

Bond Market Research

The Bond Market Research Department, headed by Dr. Henry Kaufman, is one of the oldest and most respected in the investment banking industry. It is continually evaluating the effects of many factors in the market, including the near-term calendar of future public offerings, seasonal pressures in the markets, seasonal demands for securities, the outlook for short-term and long-term interest rates, expectations in large Treasury financings, and anticipated changes in monetary policy. Among this Department's regular publications are Bond Market Roundup, International Bond Market Roundup, and Comments on Credit, published weekly; Bond Market Review, published quarterly; The Review of the Bond Market and Supply and Demand for Credit; published annually. Other frequent publications include The Cost of Money for Corporate Finance and An Analytical Record of Yield and Yield Spreads.

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Major Hydroelectric Projects Overseas

The company has for a number of years been responsible for the complete engineering of numerous large hydroelectric projects overseas. We are currently providing comprehensive project management and engineering services to the Volta River Authority in Ghana for the $250 million, 150 MW Kpong Hydroelectric Project. This project is being financed by the World Bank and is scheduled for completion in 1981. In Iran, prior to the recent unrest, Acres had been retained to provide engineering and project management services for the $1,500 million Karun hydroelectric development. Work on this project is expected to restart in the near future.

Acres experience and accomplishments in a wide variety of conditions and circumstances overseas are considerable. A summary of more important projects is presented in the attached tables. Details of some of these projects are presented in Appendix C2.

Major Hydroelectric Projects in North America

The climatic conditions in the area of the Susitna project are similar in severity during winter freeze-up to those at several major hydroelectric projects undertaken by Acres in Canada. The most prominent example is the Churchill Falls Development in Labrador. Others are the Kettle Rapids, Kelsey, Long Spruce and Limestone Hydroelectric Projects in Northern Manitoba. Although these sites are about 500 miles south of Susitna in latitude, they are within areas of discontinuous permafrost and close to the southern limit of continuous permafrost. Acres has also been involved in detailed studies and investigations for other major engineering projects as far north as Prudhoe Bay in connection with the petroleum industry.

This section of the proposal therefore addresses projects undertaken on the North American continent rather than the United States alone. In the United States, Acres has participated in the study, engineering, licensing and construction of numerous smaller projects involved hydroelectric generating stations, pumped storage developments, large earth dams, tunnels and other major underground excavations.

Detailed summaries of some of these projects are presented in Appendix C1 and summarized in the following tables.

ENGINEERING AND MANAGEMENT SERVICES FOR HYDROELECTRIC AND PUMPED STORAGE PROJECTS

GENERAL APPROACH

It is Acres philosophy that the client's "right to know" and "right to decide" is paramount, and many of the procedures that are followed have been set up specifically to ensure that the client is kept fully informed not only of the progress of the work, but also of key decisions and the impact of these decisions on the cost, schedule and ultimate success of the project.

The successful construction of a venture as large as a hydroelectric or pumped storage development, with its complex technology, large number of different tasks and long construction schedule, calls for a special combination of management techniques and engineering skills. Scores of experienced people must be brought together to form a cohesive team capable of assuming the various responsibilities and discharging them successfully.

The primary objectives of this team must be:

(a) The development of a reliable initial estimate of cost for the facility, based on sound conceptual engineering from good exploratory field data.

(b) Environmental assessment and preparation of impact statement and related licensing documents.

(c) The identification of manageable construction and equipment package and the preparation of design documents, contract drawings and technical specifications to allow successive bids to be called to a strict timetable.

(d) The finalization of engineering work after contract award, the preparation of construction drawings, and the control of design changes.

(e) The supervision of the quality and schedule of construction both in the field and in fabrication shops.

To achieve these objectives, Acres follows a carefully established series of procedures which can be adapted to suit the degree of involvement in the management of the project required by the Owner. In the past, Acres involvement has ranged from solely the engineering design and preparation of specifications to complete responsibility for the project management, including financial disbursements and contract awards. Prior to the initiation of the engineering program, it is essential for the responsibilities and relationship of the owner and consultant to be carefully defined. The Plan of Study will provide the basis for the engineering of the complete Susitna Project.

THE COMPANY

Acres American Incorporated is a consulting engineering and planning organization licensed and incorporated to perform professional engineering services under the laws of the States of New York, North Carolina, South Carolina, West Virginia, Maryland and Pennsylvania. Staff comprises professionals in the major disciplines of civil, electrical, mechanical, geotechnical, environmental, hydraulic and hydrological engineering together with technicians, draftsmen, and supporting staff totalling approximately 280. The engineering and related services are provided to utilities, government and state agencies, and industrial clients.

Acres American Incorporated, with additional offices in Columbia, Maryland, Washington, D.C., Raleigh, North Carolina, and a wholly owned subsidiary company in Pittsburgh, Pennsylvania, is a member of the Acres group which was founded in 1924 to provide engineering expertise for the development of hydroelectric resources. The resources, experience, and facilities of the entire Acres group are available, as required, to provide services necessary for the successful execution of projects on a worldwide basis.

Comprehensive company services are available, extending from preliminary hydrological, geological and feasibility investigations and economic analyses through planning, design, licensing, preparation of contract documents, drawings and specifications, evaluation of bids, contract negotiation, shop inspection, field engineering, construction supervision, project management, financial control, commissioning and initial operation. With a strength of over 1,500 engineers, specialists, and supporting staff, Acres has built up a wide range of skills to serve the power supply industry in North America, and is also structured to provide technical and planning services to other sectors of industry, including heavy civil engineering, transportation, mining, metals, fuels and other process industries.

The Company administration is based on a departmental structure, the major disciplines being electrical, mechanical, hydraulic, civil and geotechnical. Project teams, directed by an executive project manager, are staffed by engineers assigned from the appropriate departments. Specialist staff is also available from other departments of the Company to provide comprehensive service to our clients, ranging from economic analyses through quality control and commissioning services.

Specific expertise and experience are available in the following fields:

Chemical
Civil
Electrical
Environmental
Geotechnical
Hydraulic
Hydrological
Instrumentation
Mechanical
Metallurgical
Mining
Structural
Telecommunications
Thermal
Transportation
Architectural
Engineering Geology
Geographical
Meteorological
Regional and Urban Planning
Resource Conservation and Development
Economics
System Analysis

RELEVANT EXPERIENCE

FRANK MOOLIN & ASSOCIATES, INC.

FRANK MOOLIN & ASSOCIATES, INC.

Relevant Experience

Project Planning Guide - Alaska Natural Gas Transportation System

During the winter of 1977/78, Frank Moolin and Associates personnel prepared a Project Planning Guide for Northwest Alaska Pipeline Company. This guide was structured to serve two different, but related uses. First. it was intended to be used by the client to identify the specific planning efforts required to advance the project. Second, it was intended to be used by the eventual project management contractor to help identify those products essential for the overall planning and management of the project.

The decision to produce the Project Planning Guide was made at a time when the Gas Pipeline Project faced a number of circumstances not unlike the APA is facing with the Susitna Hydropower Project. These circumstances included:

- The tentative decision had been made to proceed with the project.
- The client was suddenly involved in his first multi-billion-dollar project.
- The client's "in-house" staff was in the early organizational development and staffing phase.
- The decision had been made to award a project management contract.
- The project management contract award was in the candidate screening phase.
- The client recognized the need for an executive project management study to do early planning for the project.
- The client awarded a contract to Frank Moolin & Associates for an Executive Project Management Study.

We believe this is the first time a formal "Plan for the Plan" has been prepared for a major project. This planning guide was intended to define, in considerable detail, the planning efforts required to advance the project.

The client also effectually utilized Frank Moolin & Associates senior personnel for presentations to governmental agencies and financial institutions on behalf of the project.

Obviously the products of this class of study are exceedingly important. They must be concise, complete and contain a level of detail sufficient to demonstrate the additional level of input that must be required for the successful advancement of the project. The products of this study are outlined as follows:

A) <u>A Project Master Schedule</u>

- Showing in graphical form major milestone dates for planning products/events/decisions

- Offering at a glance a quick picture of planning actions required

B) <u>A Consolidated Construction Schedule</u>

- Identifying the major construction activities and showing their required start and finish dates in bar chart format

C) <u>15 Specific Work Packages</u>

Detailing the planning required for each of the following functional areas:

1. Corporate
2. Engineering
3. Permits/Land
4. Construction support
5. Support services
6. Project control
7. Labor relations
8. Contracts
9. Quality assurance/Quality control
10. Camps
11. Communications
12. Procurement & Logistics
13. Permanent materials
14. Construction equipment
15. Construction

Relevant Company Experience (Continued)

Each package explaining in detail its respective functional area including:

- An explanation of the objective of the work package
- A detailed scope of work outlining the planning products/ activities to be developed within its area
- Situations and factors to be considered in developing the planning products
- An estimate of the manpower level required to produce the planning products
- A detailed critical path network showing the precedence relationship and logical relationship to other work packages.

D) A Critical Path Analysis

Showing duration, early start date, late start date, early finish date, float and critical path for all major activities.

E) An Estimate of Manpower Required for the Planning Effort

F) An Estimate of Manpower Required for the Pre-Construction Effort

These individual products were combined into a manual titled the "Project Planning Guide".

The cost of producing this Project Planning Guide was 0.01% of the estimated project cost, but when implemented, will produce a time saving, cost effective, workable plan that will result in the successful advancement of the client's project. A similar study in support of the Susitna Hydropower Project has been included in the POS under Subtask 8.2.

Nikiski LNG Project Permits Study

In the fall of 1978, Frank Moolin and Associates personnel performed a preconstruction survey to identify the permit requirements required for the construction and operation of an LNG terminal facility and associated gathering systems in the state of Alaska. The study contained summary, schedule and detailed information for the myriad of permits required in support of the project. The study also identified situations and factors that could affect the acquisition of various permits and anticipated permit problems associated with the various agencies.

Relevant Company Experience (Continued)

The study was prepared with two basic objectives in mind. First, it complilled in one report the necessary information for all known permits, so that the client could proceed to file for permits in an orderly, cost-effective manner. Second, and most important, it delineated a schedule of submission of permit applications with enough lead time to ensure that construction was not delayed due to permit problems.

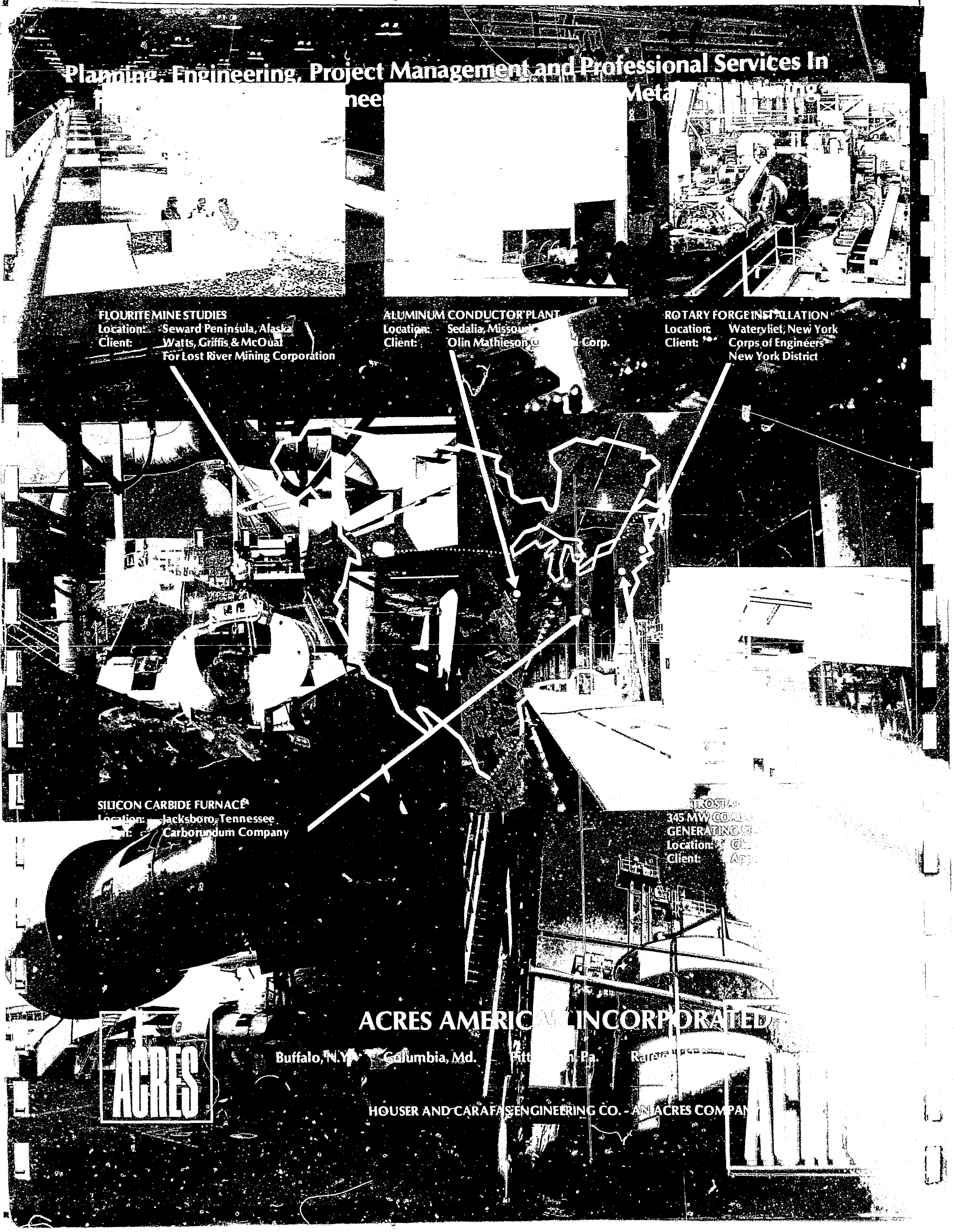
The study was prepared by Frank Moolin and Associates managers who had first-hand experience in the planning, permit acquisition and construction of the Trans-Alaska Pipeline Project and other Alaskan projects. This type of study is indicative of the early pre-planning efforts required to support large projects and typifies the type of effort that will also be required to advance the Susitna Hydropower Project to the construction phase.

SECTION C7: COMPANY DESCRIPTION

ACRES

Planning, Engineering, Project Management and Professional Services In Power, Heavy Civil Engineering, Fuels, Industrial, Metals and Mining

ACRES


Planning, Engineering, Project Management and Professional Services In
FLOURITE MINE STUDIES
Location: Seward Peninsula, Alaska
Client: Watts, Griffis & McOuat
For Lost River Mining Corporation
ALUMINUM CONDUCTOR PLANT
Location: Sedalia, Missou
Client: Olin Mathieson
Corp.
ROTARY FORGE INSTALLATION
Location: Watervliet, New York
Client: Corps of Engineers
New York District
SILICON CARBIDE FURNACE
Location: Jacksboro, Tennessee
Carborundum Company
345 MW
GENERATING
Location:
Client:
ACRES
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ACRES
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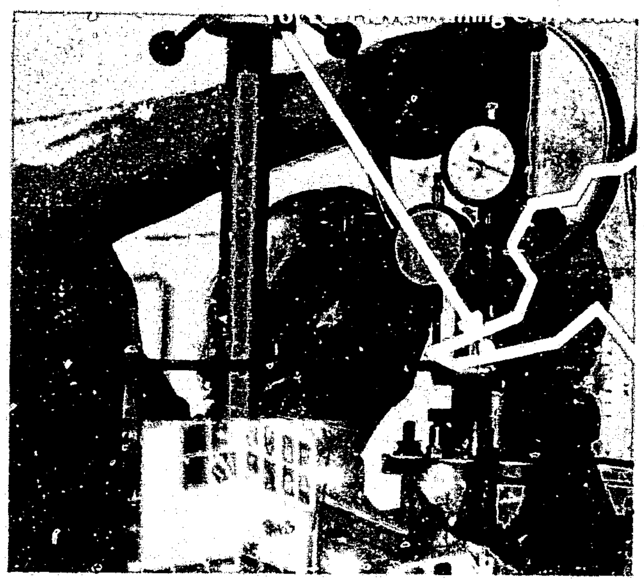
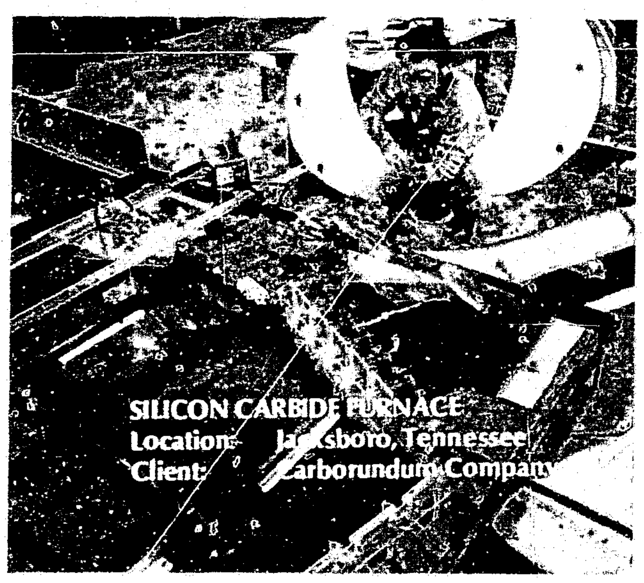
Columbia, Md.
Pa.
HOUSER AND CARAFA ENGINEERING CO. - AN ACRES COMPAN





Our Services

Acres is a major international consulting organization which undertakes planning, engineering and project management in many diversified fields including:

Power and Heavy Civil Engineering

Airports
Bridges and highways
Cogeneration and energy recovery
Electrical power systems
Energy storage systems
Flood Control
Foundations
Hydraulic structures and dams
Hydroelectric power
Irrigation
Marine structures and dredging
Ports, harbors and docks
Thermal and nuclear power systems
Transmission, switching and distribution
Tunnels and subways
Underground facilities
Water resource development

And Special Services Including:

— air quality monitoring
— biological laboratory testing
— chemical laboratory testing
— computer services
— economics and planning
— environmental assessment
— geotechnical services
— hydraulic laboratory testing
— operations research
— project management
— research and development
— special engineering studies

ACRES

. . . Our Services

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Pow ... ter
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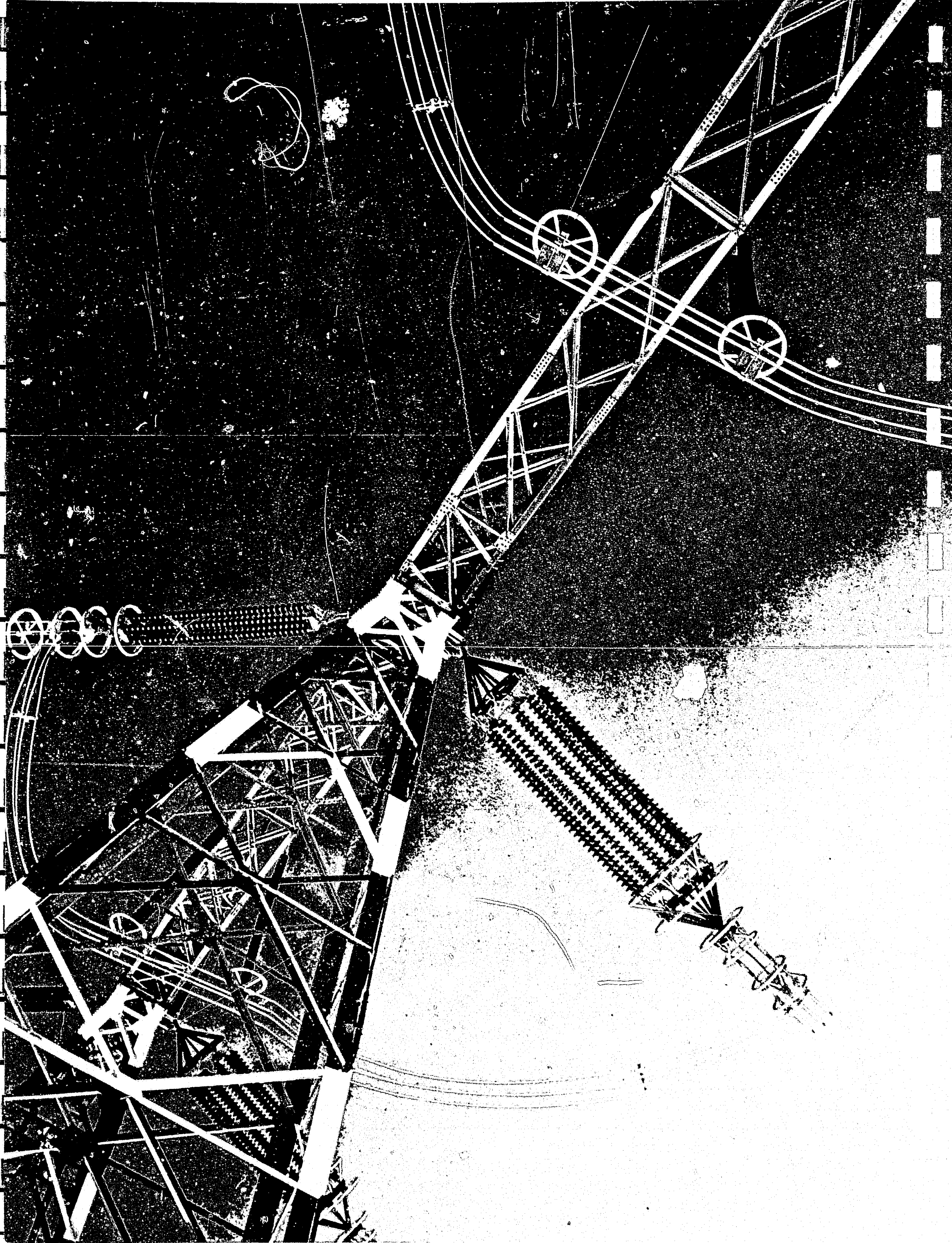
Pulp, paper
Rehabilitat
Uranium
And spec ... elds

Work un ... s from studies, p ... ing, to construction su ... management, scheduling, ... d expediting as well as design ... uct work where the Company accepts responsibility for the completed facility.

The end results of projects on which Acres provides consulting services have enormous impact upon industry, the overall economy and our lives in general. Steel for construction projects and automobiles, crushed rock for highway construction, uranium and coal for power generation and basic metals for industrial and consumer products provide excellent examples from the firm's industrial activity . . .

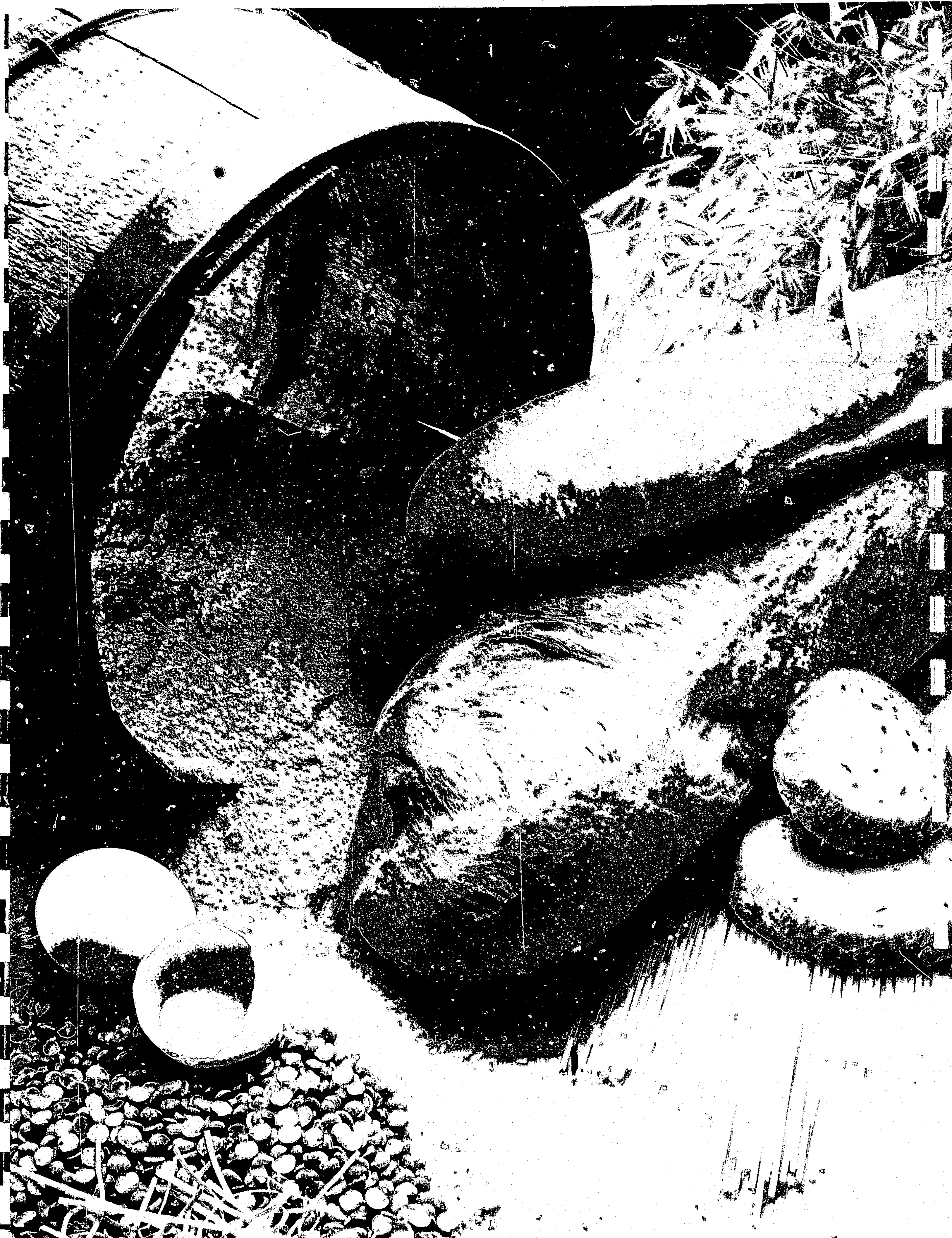


Our Qualifications

Acres is a company of people; — skillful, imaginative, innovative and resourceful — and representing a wide spectrum of education, background and experienceproved. But in today's work involving sophisticated methods and technology, it is not enough just to have the very best people. They must be backed by in-depth resources, excellent general facilities and laboratories and an outstanding record of relevant experience.

In terms of size and capability Acres American has the people and access to resources able to handle large power, industrial or resource planning, development and construction programs. In terms of general facilities, the Company's engineering offices, computer and other facilities rank with the best in the consulting business. Further, Acres modern laboratory facilities are well equipped for: physical modeling to scale; soil and rock mechanics testing; hydraulic, aerodynamic, civil and architectural design evaluation; biological laboratory services; and chemical and physical analysis of solids, liquids and gases. As for a solid background of experience, Acres has a history of over 55 years of consulting work and engineering for projects throughout the world.

Electrical power for economic growth, industrial development and human comfort, bridges and tunnels which facilitate vital road transportation and fuels to heat our office buildings and our homes represent examples from Acres Power and Heavy Civil Engineering activities . . .



ACRES

Our Organization

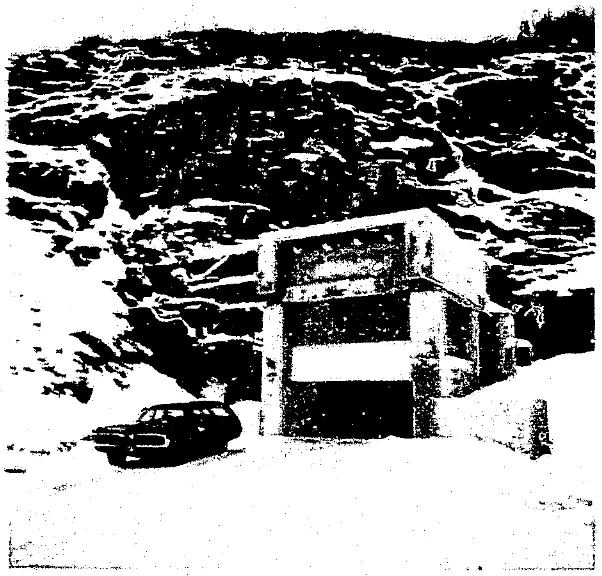
Acres is privately owned by members of the staff engaged directly in the day to day activities of the Company.

Acres' services are focused on distinct technology-oriented fields of activity through the two groups of divisions (Power and Heavy Civil Engineering; and Industrial) into which the Company is organized. These groups are supported by a well-balanced organization of technical departments and project services.

Acres American Incorporated is licensed and incorporated under the laws of the State of New York. The Company operates from engineering offices in Buffalo, N.Y., Columbia, Md., Raleigh, N.C., Pittsburgh, Pa., and Washington, D.C. and provides services nationwide. Through its international and Canadian affiliations Acres can draw on the resources of a staff of over 1200.

In certain instances Acres acts in joint venture with others in order to provide comprehensive services or to undertake particularly large or special projects.

Food from highly-automated processing plants, long-range agricultural planning from in-depth study programs, a cleaner environment from industrial water and effluent treatment plants and more enjoyable leisure hours from carefully planned and developed recreational facilities are just a few examples of the areas where Acres provides international services.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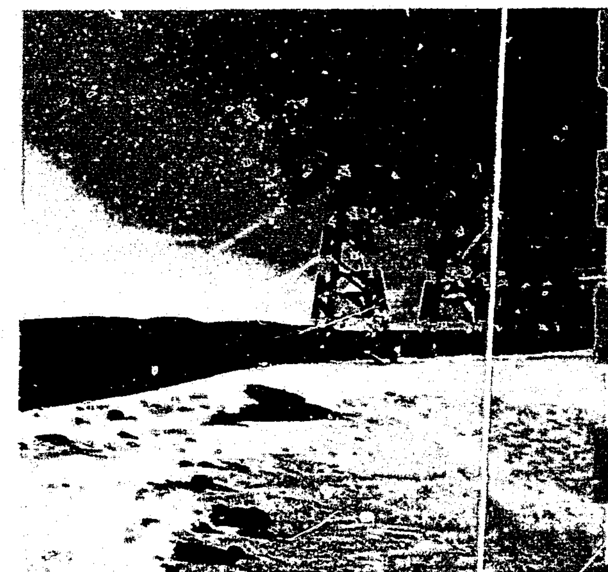
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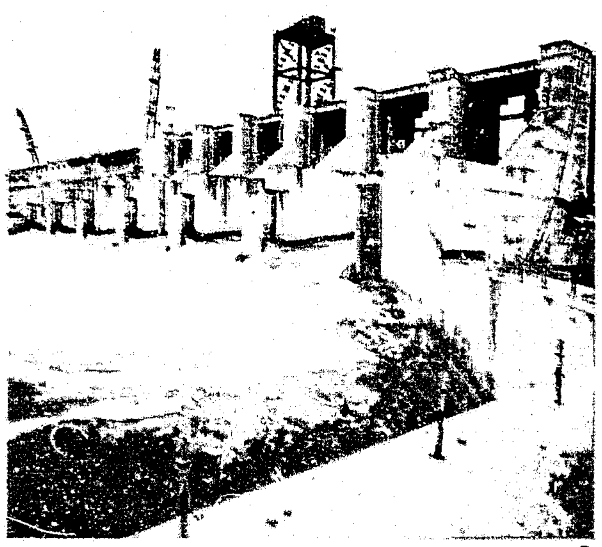
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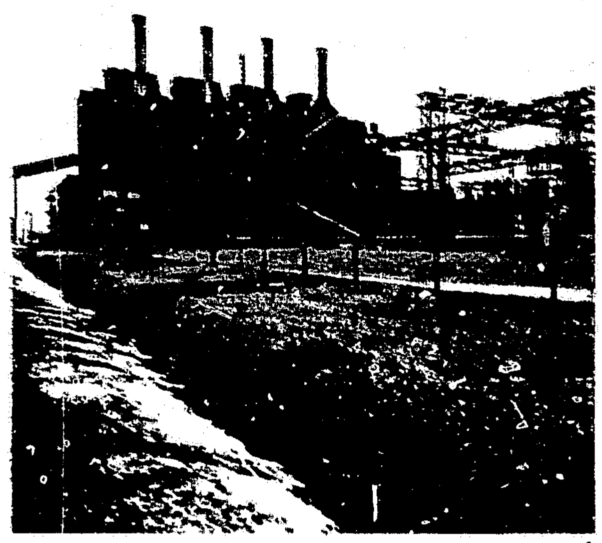
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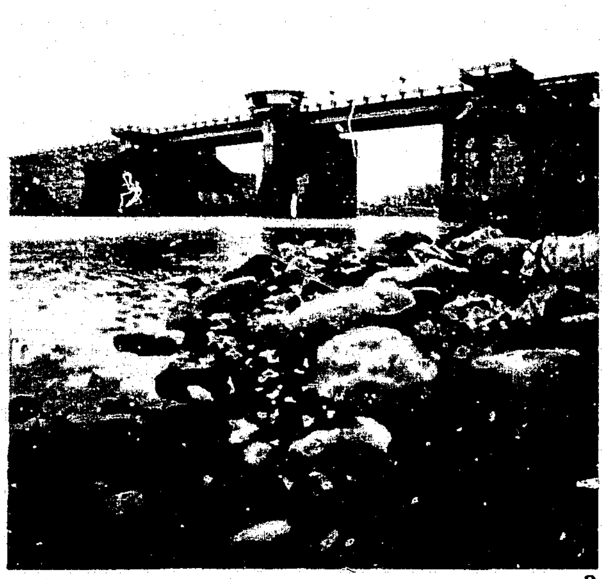
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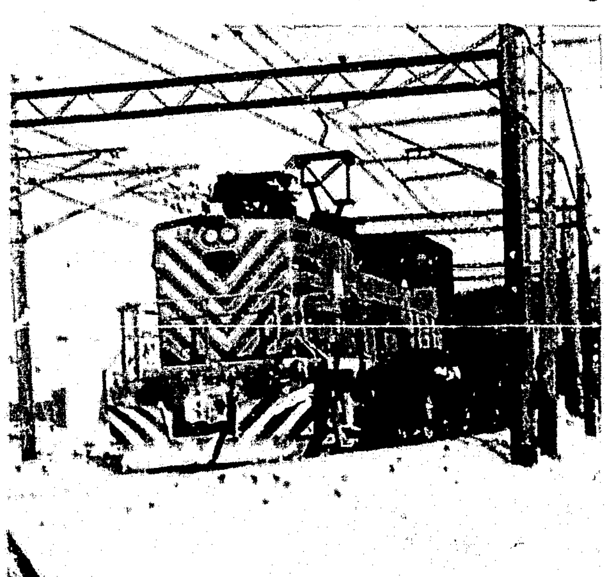
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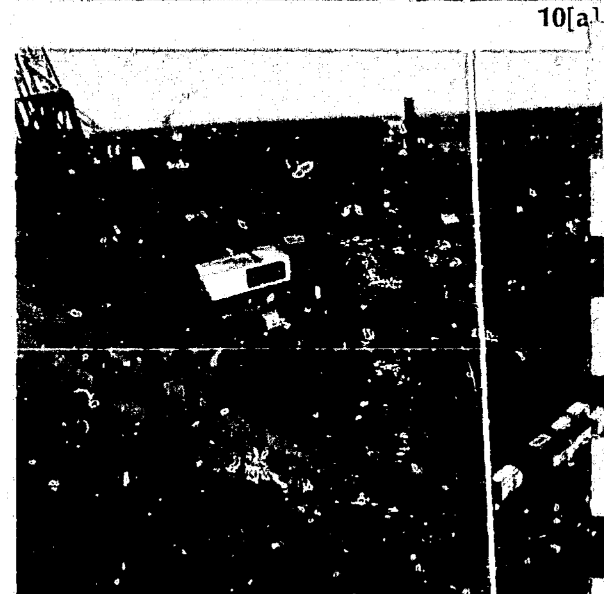
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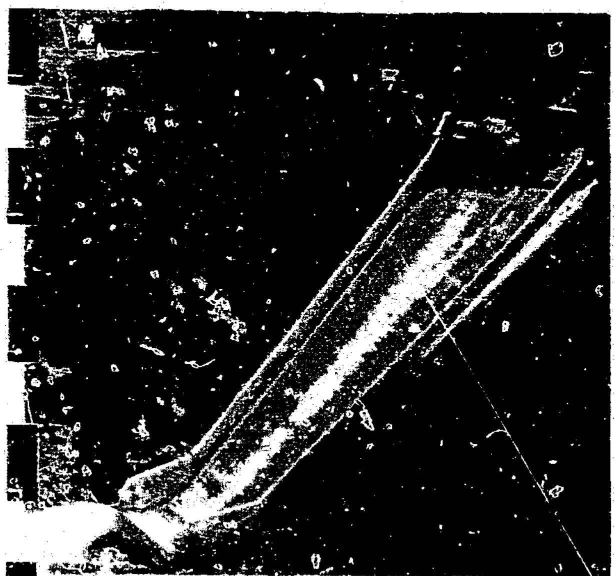

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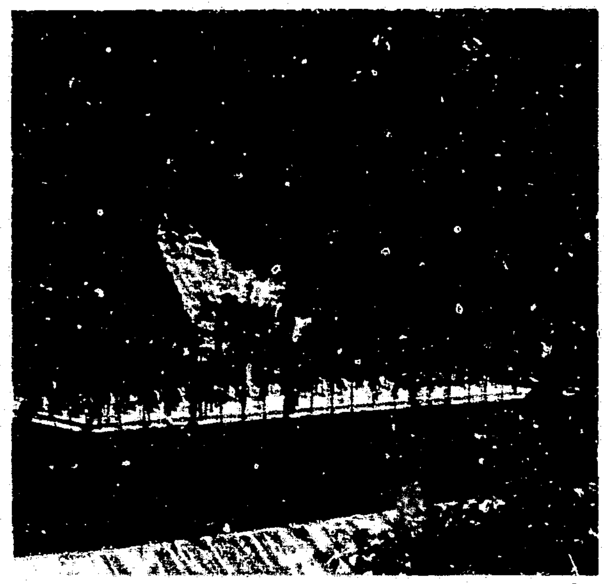

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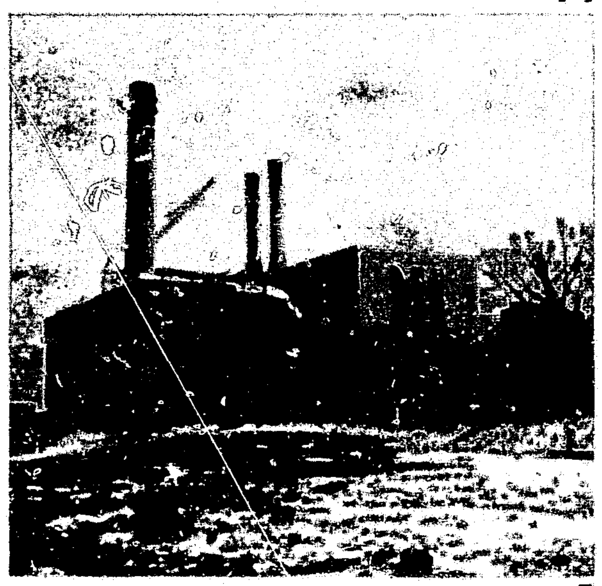

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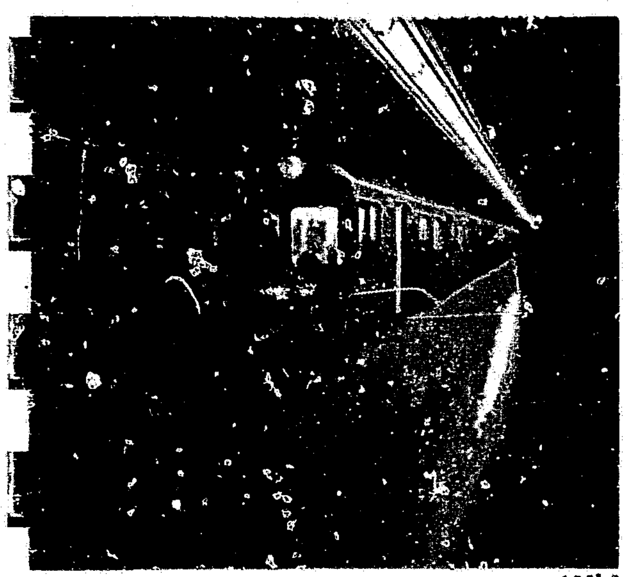

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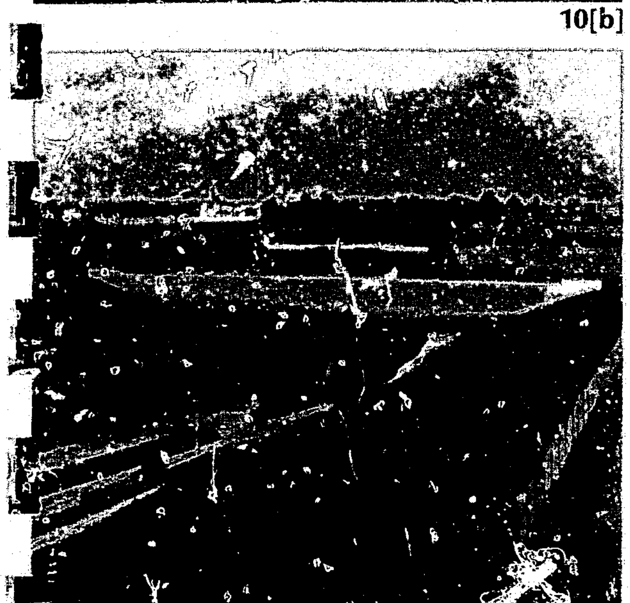

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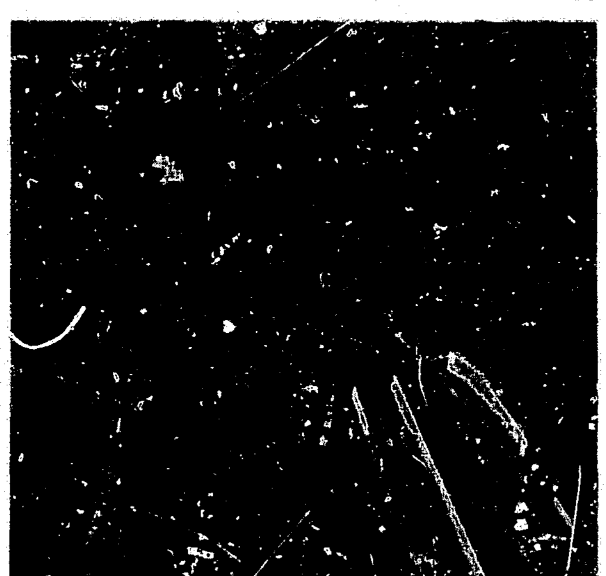

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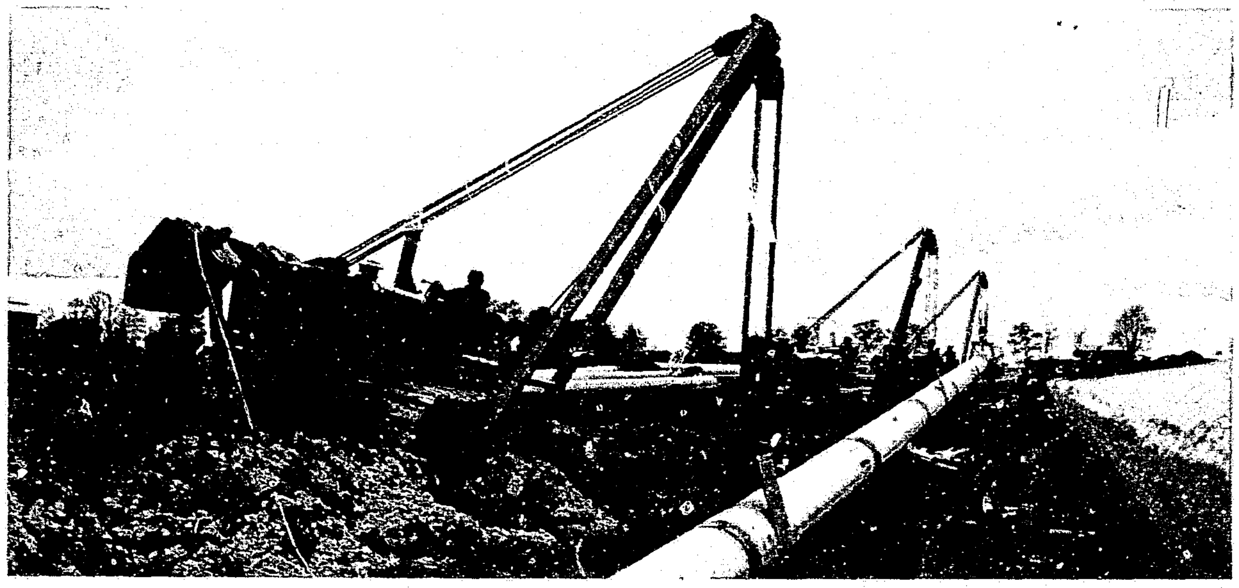
ACRES

Some of Our Power and Heavy Civil Engineering Projects

1. Engineering and construction management, in joint venture, for the world's largest underground hydroelectric power plant at Churchill Falls, Labrador: [a] entrance to the mile long access tunnel; [b] the 5,225,000 KW powerhouse; [c] 735,000 KV transmission lines crossing the Churchill River.
2. Alto Anchicaya, Colombia: [a] the world's highest concrete faced rock fill dam; [b] specially-designed two-level switching station.
3. Low head hydroelectric plant in Northern latitudes.
4. Engineering and construction supervision for Ontario Hydro's first coal fired thermal generating station — J. Clark Keith — Windsor, Ontario.
5. Thermal generating station in Mid West.
6. Overall project management and engineering for hydroelectric power developments and pumped storage facilities.
7. Electrostatic precipitator "retrofit", Niagara Mohawk Power Corporation, Dunkirk, N.Y.
8. River flood control works.
9. Conservation works and river basin management.
10. [a] and [b]: Civil engineering and construction supervision for subway and rapid transit systems.
11. Underground engineering, tunnelling and excavation works for a wide range of applications including storage of petroleum products.
12. Planning, engineering and construction management for transportation projects involving all modern modes.
13. Container handling facilities at East Coast port.
14. Engineering and construction management for marine terminals.
15. Highway tunnel under the St. Lawrence Seaway Canal.
16. Combined road and rail tunnel including railroad and highway relocations.



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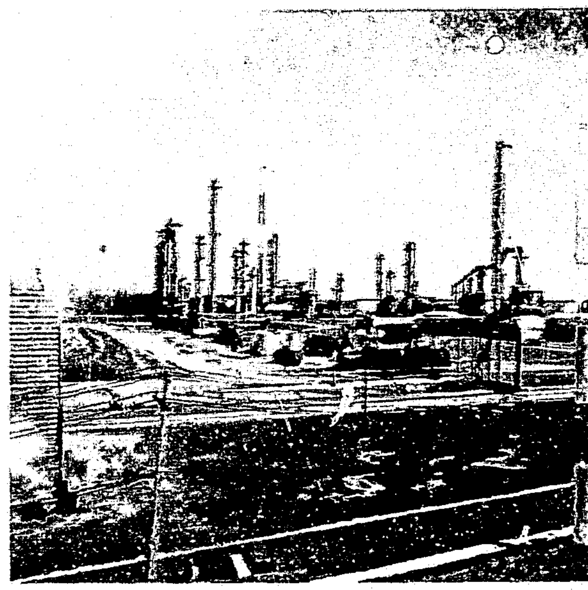

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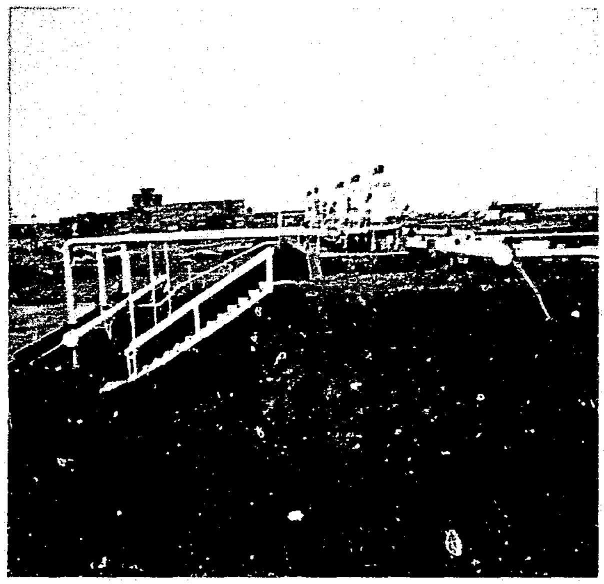

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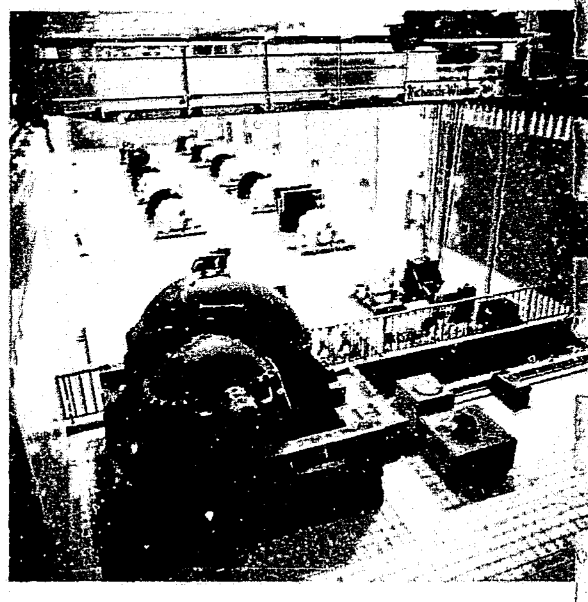

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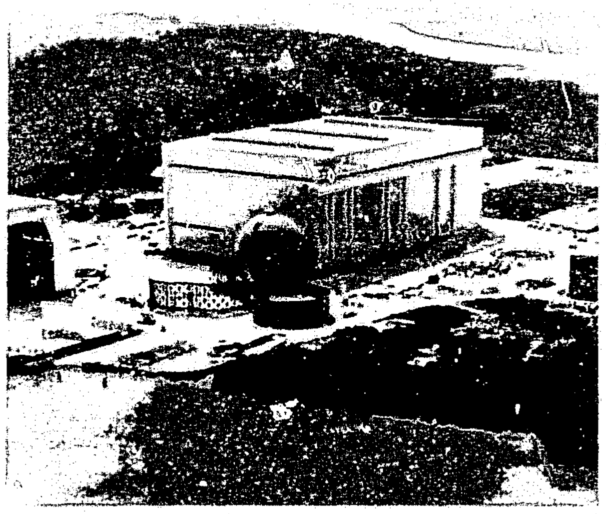

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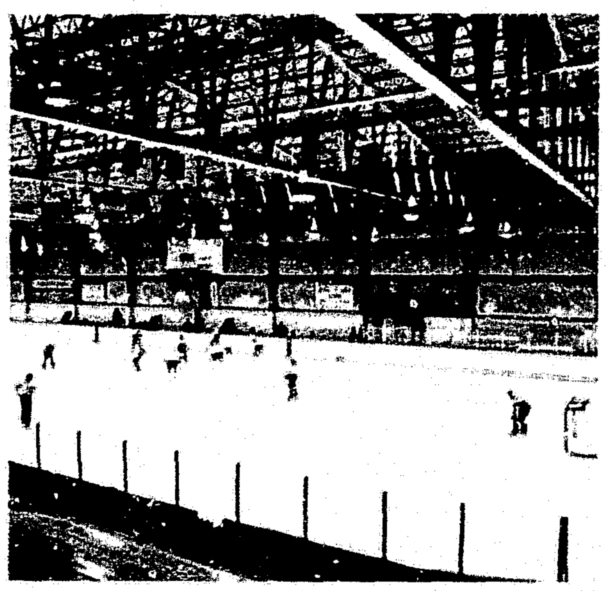

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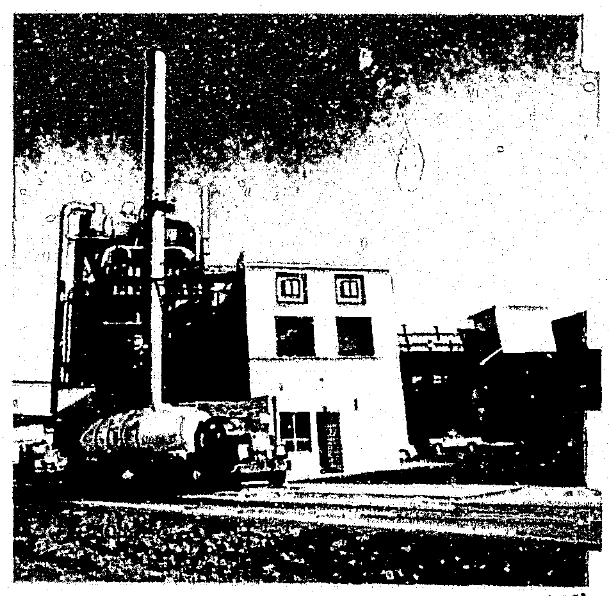

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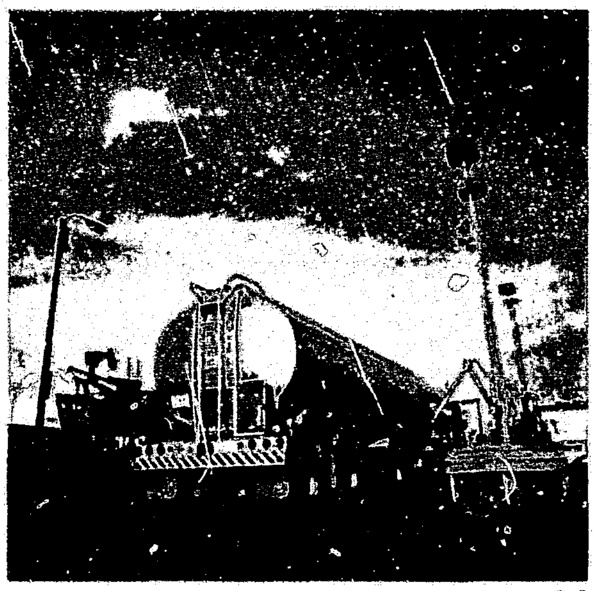
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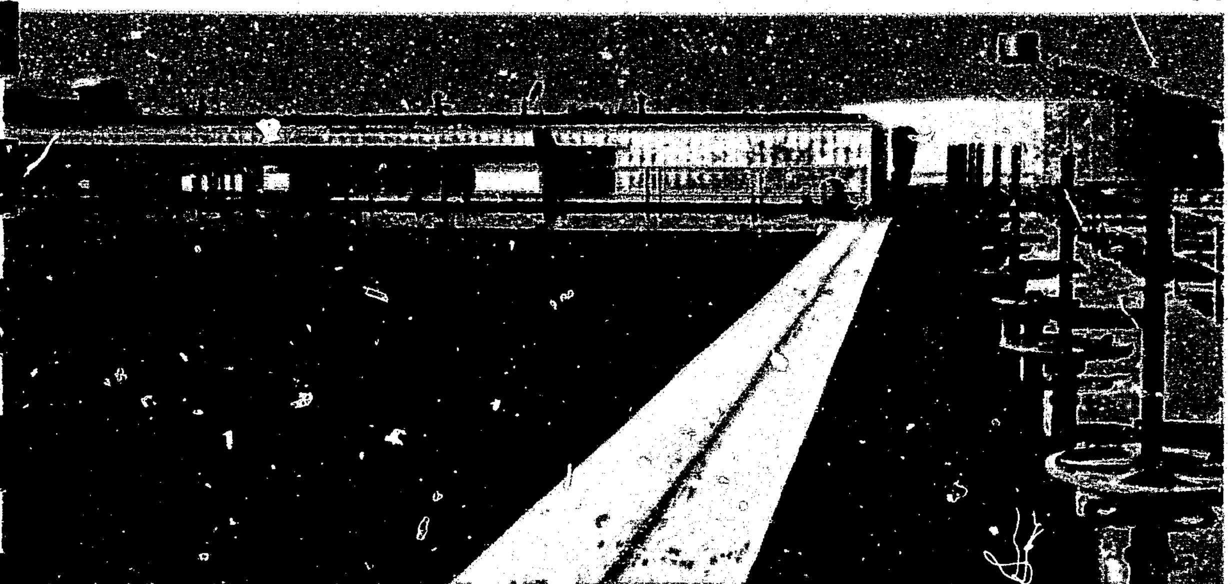
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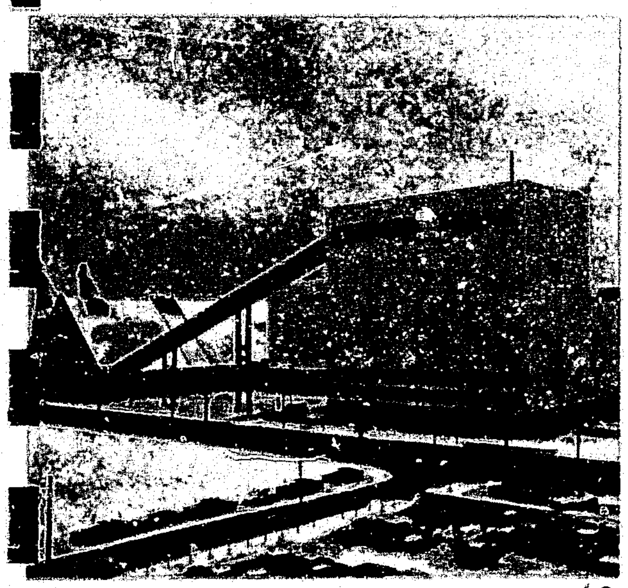
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13

Some of Our Industrial Projects

1. Engineering and field services for a pipeline to carry ethane from Kerrobert, Saskatchewan to Green Springs, Ohio.
2. [a], [b] and [c]: Planning, engineering and construction supervision services for the oil and gas industry including developmental work on oil extraction from tar sands and engineering design/construction of process units for the petrochemical industry.
3. [a] and [b]: Refuelling systems and jet fuel terminals for airports.
4. Engineering and construction supervision of water purification plant including concrete lined intake tunnel.
5. Municipal sewage treatment facilities.
6. Shipyard planning, engineering and construction management services for expansion of shipyards and drydocks.
7. Engineering and construction management for large L.N.G. cargo sphere container production plant for General Dynamics, Bushy Park, S.C.
8. Extension of a John Deere manufacturing plant.
9. Engineering and construction supervision for food production and process plants including wharves and unloading facilities for a sugar refinery.
10. Recreational facilities: an indoor sports arena.
11. [a] and [b]: Food production plants.
12. Central utility heating and chilled water facilities for institutional complexes.
13. Engineering for the synthetic fibres industry.

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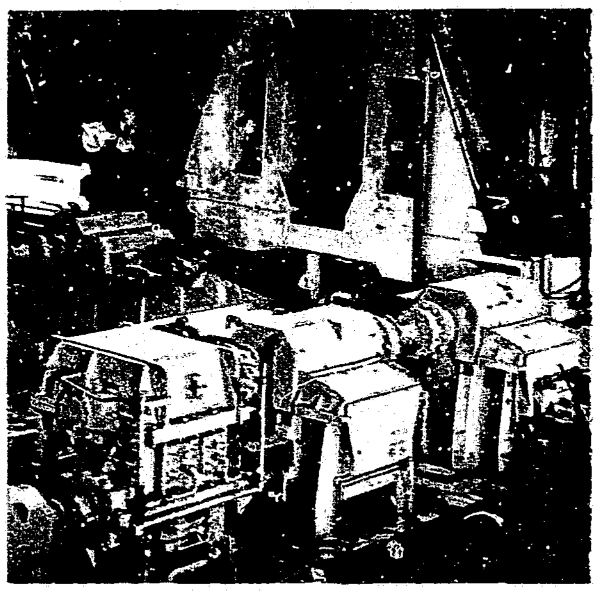

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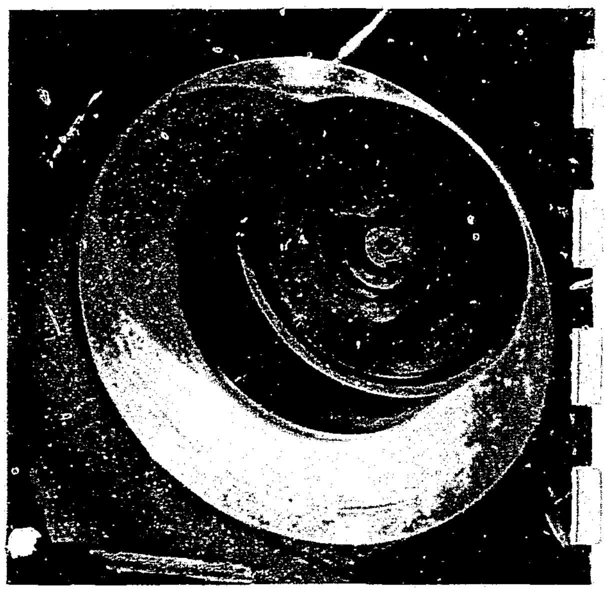

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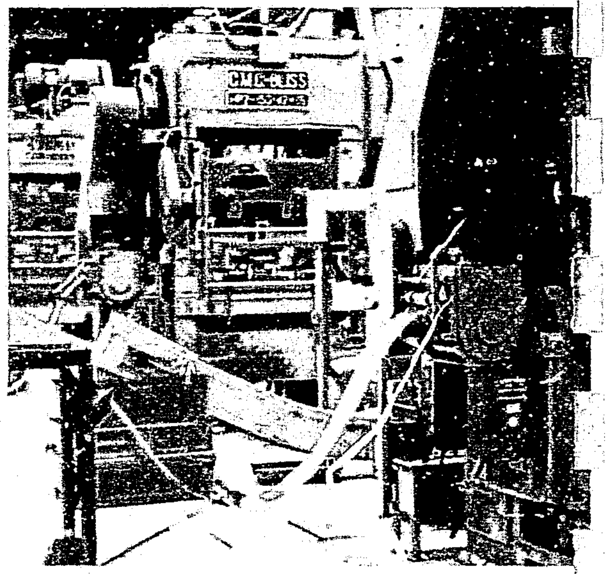

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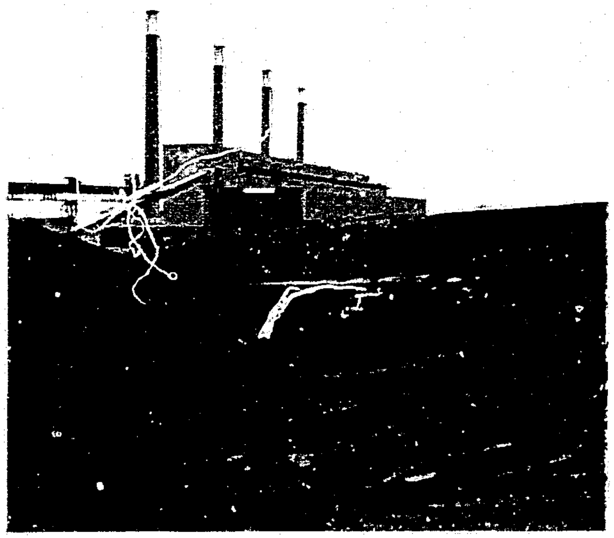

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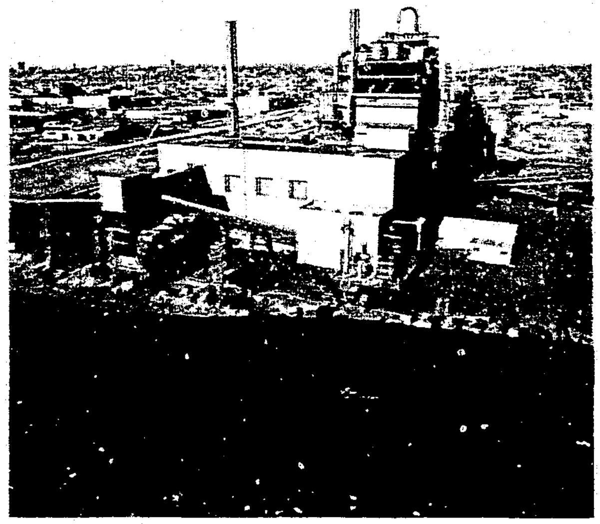

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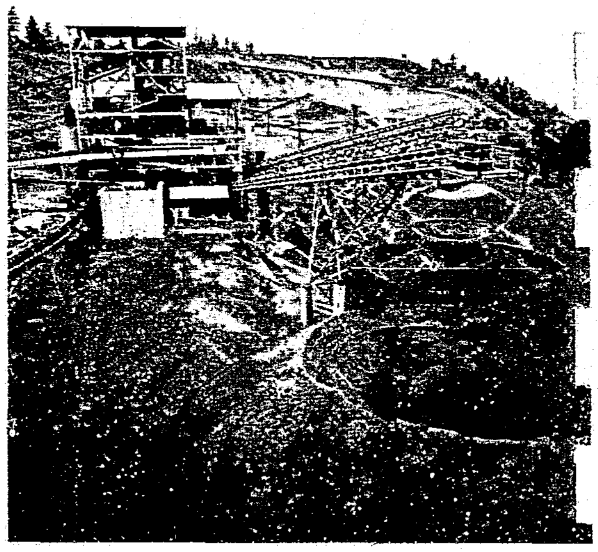

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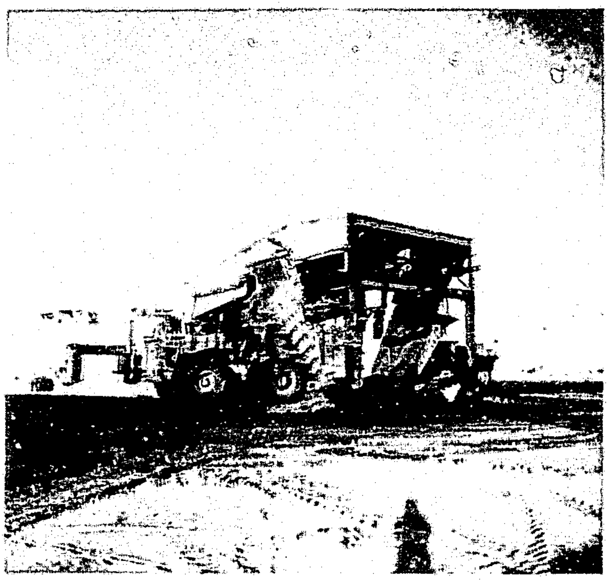

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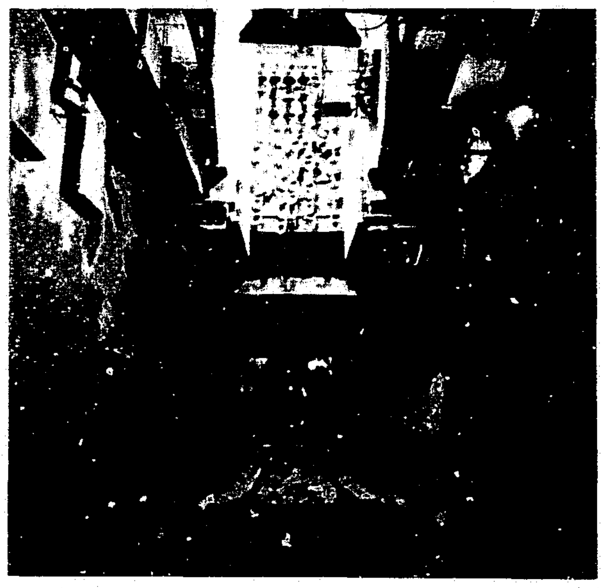
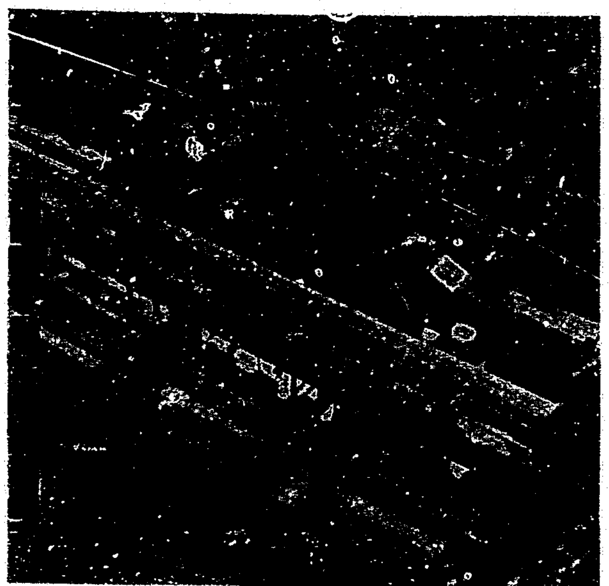


8[b]

8[



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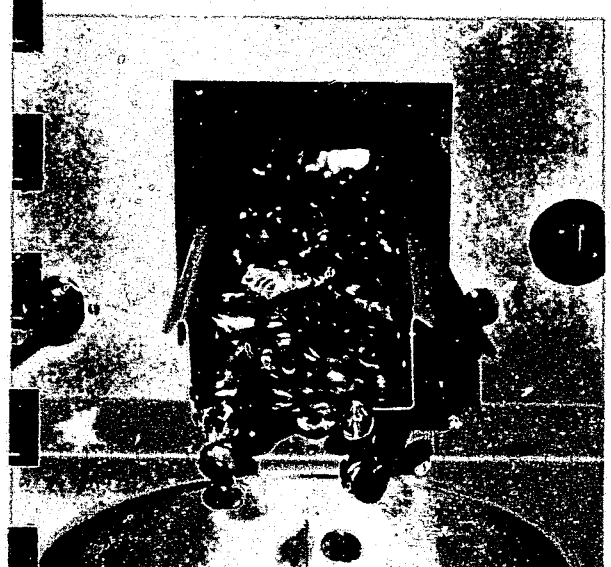

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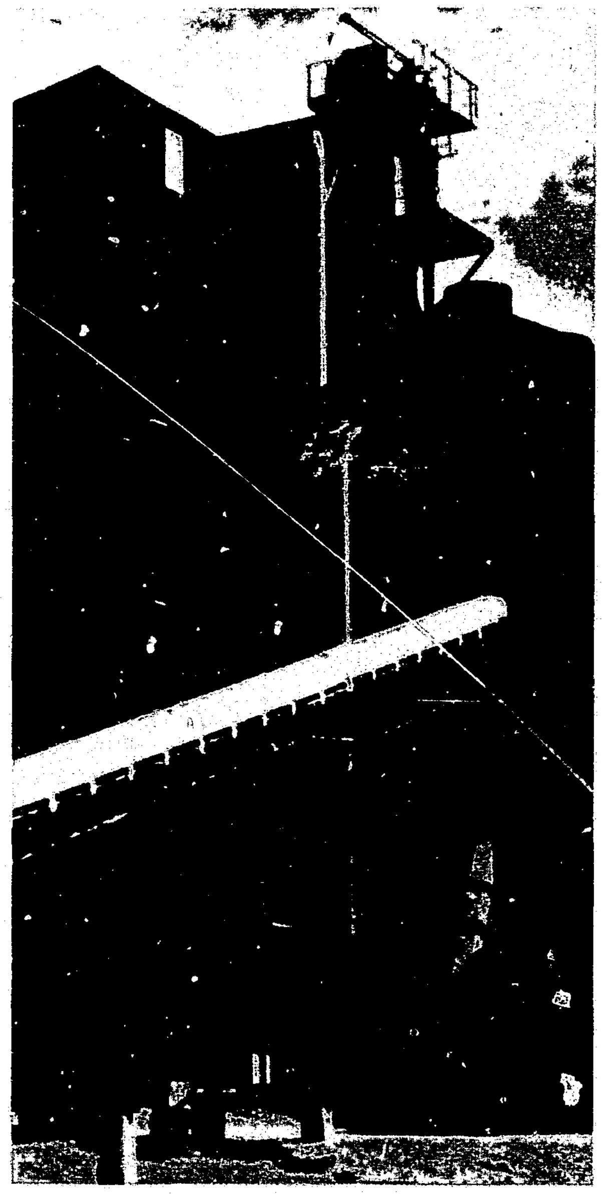

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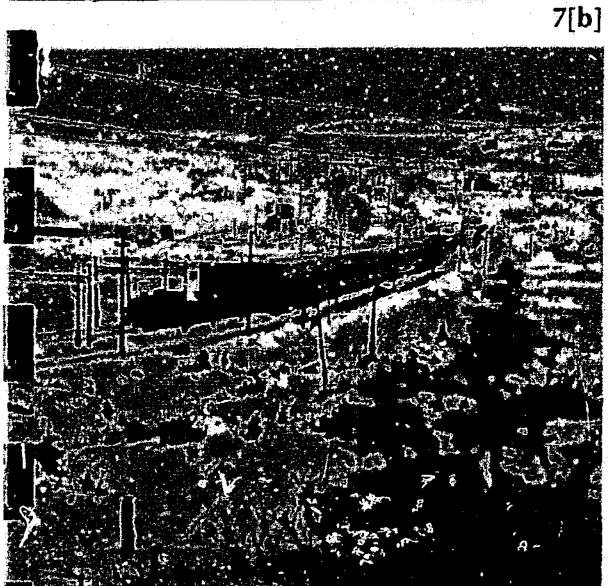

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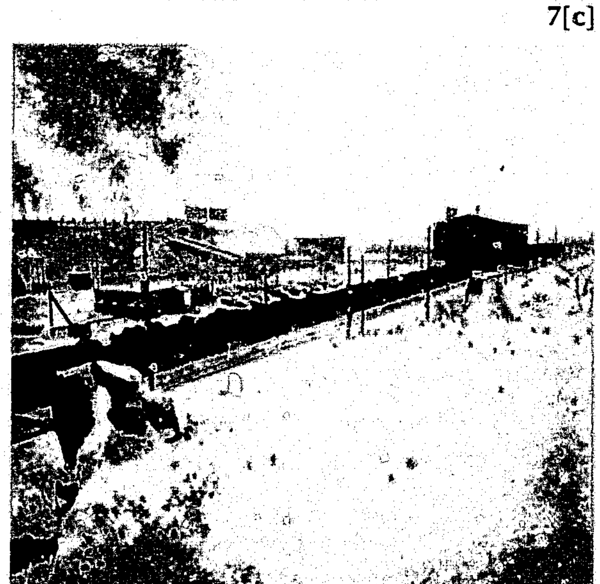
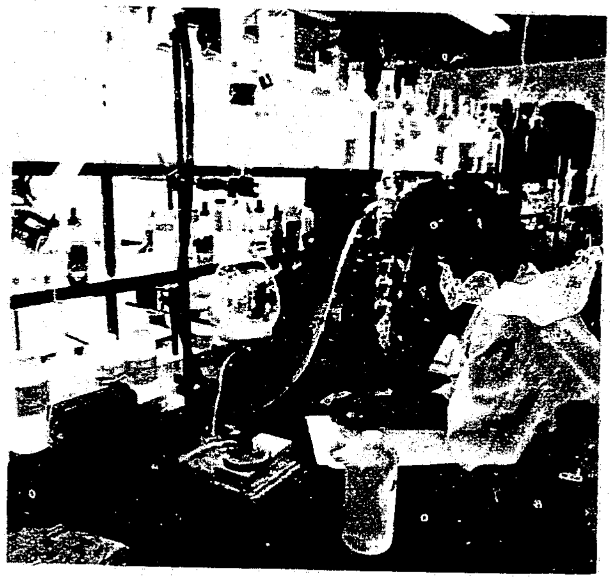


8[e]

ACRES

... More of Our Industrial Projects — Metals and Mining

1. [a], [b] and [c]: Through a long associati n with major companies producing ferrous and non-ferrous metals, Acres has developed effective techniques to complement the engineering capabilities of the Company's clients. Typical assignments have included sintering and beneficiation processes, blending systems, hot and cold rolling mills, melt shops, billet reheating facilities, nonferrous metallurgical and other processes.
2. Modeling techniques are applied to piping runs and plant arrangements.
3. [a], [b] and [c]: Engineering, development of process systems and project management for coinage production facilities for a national mint.
4. Assignments for The Carborundum Company including a silicon carbide furnace plant Jacksboro, Tenn.
5. With the increasing concern over oil and gas reserves, coal has regained prominence in the energy field. Acres undertakes development of mining systems, planning, engineering and construction supervision of new or expanded facilities - both strip mined and underground.
6. Beneficiation and waste recycling: engineering and project management of a fly ash process plant.
7. [a], [b], and [c]: Material production and processing plants for construction aggregates.
8. [a], [b], [c], [d] and [e]: Engineering services for mining projects; geotechnical investigations, underground works, ore passes, railroad and material handling facilities.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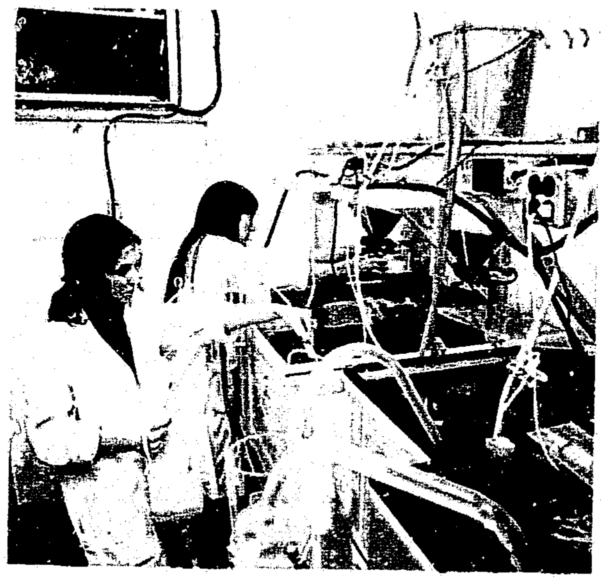
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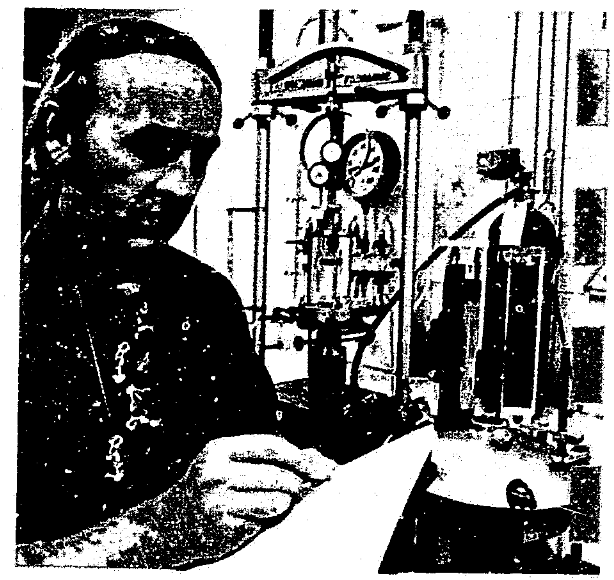
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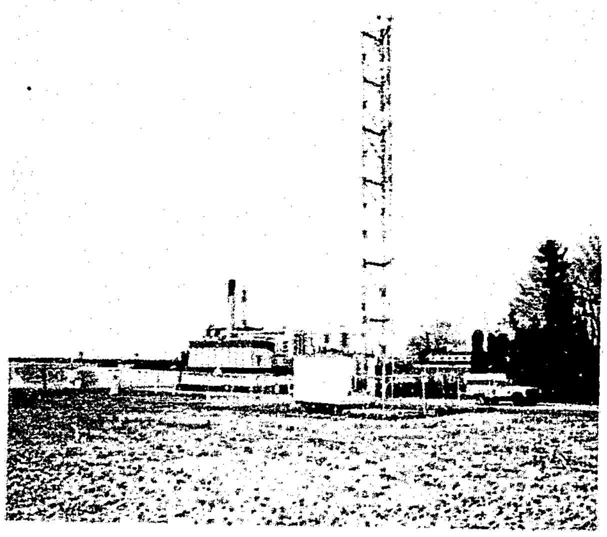
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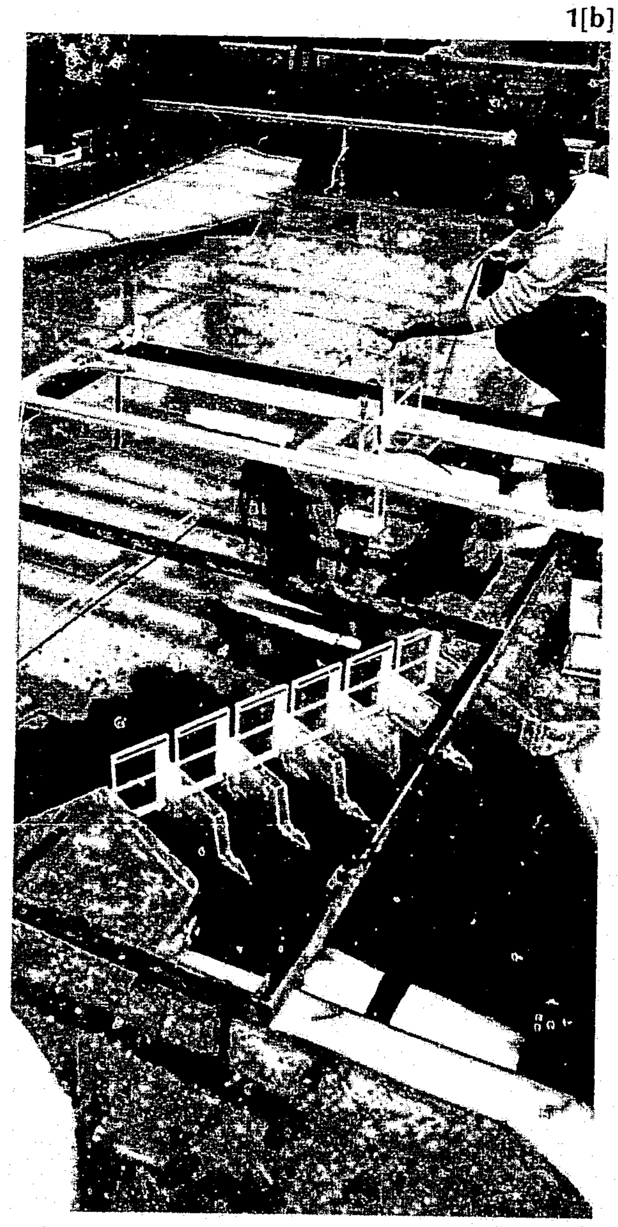
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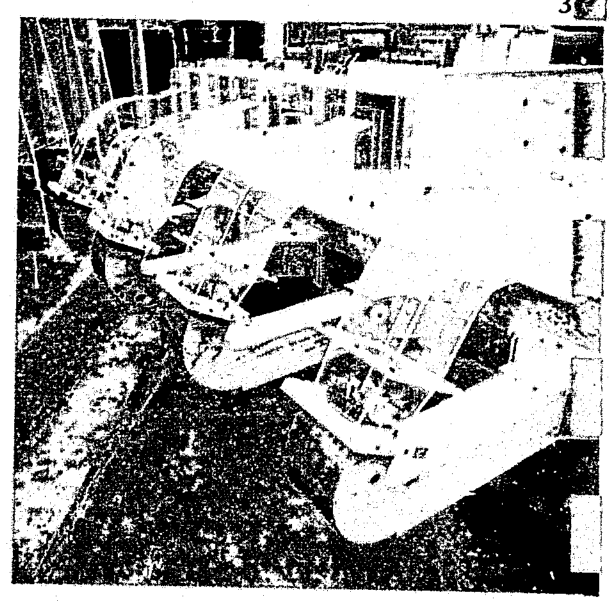
3

2[c]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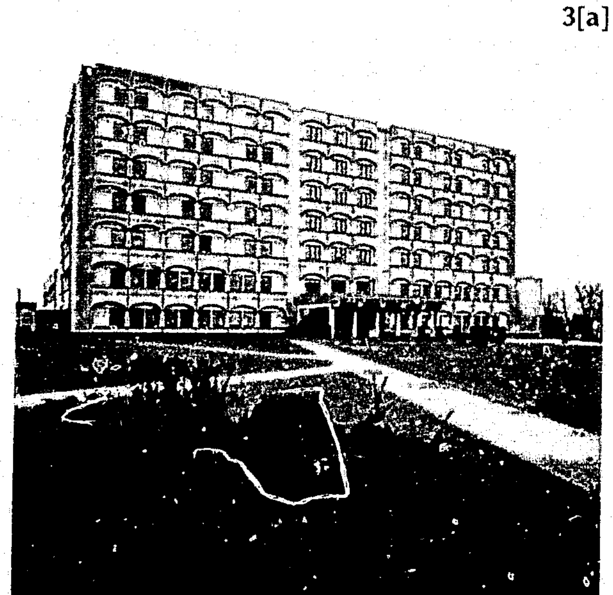
6[a]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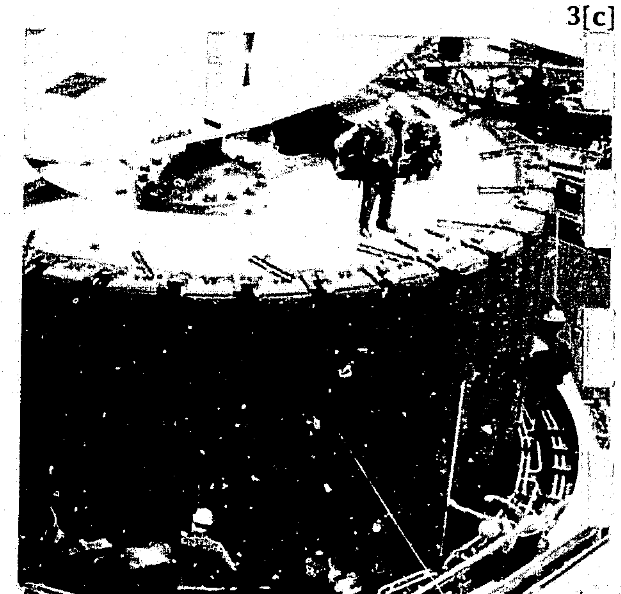

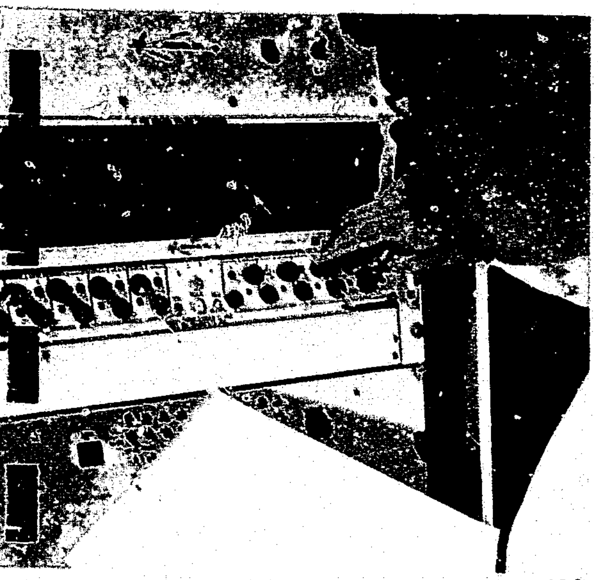

1[d]

2[a]

3[d]

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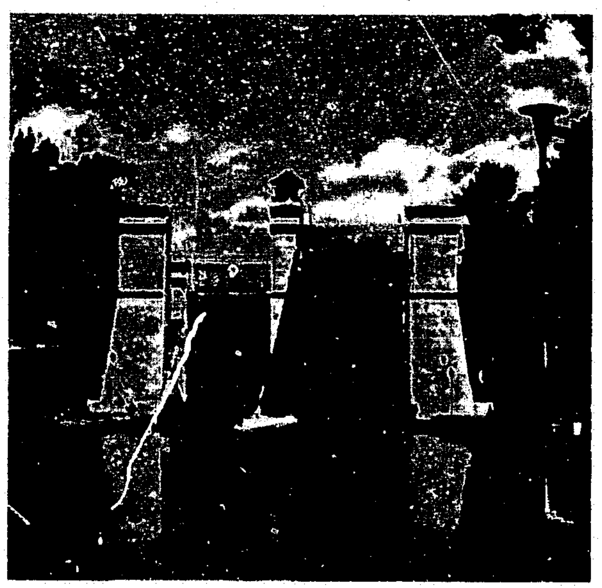

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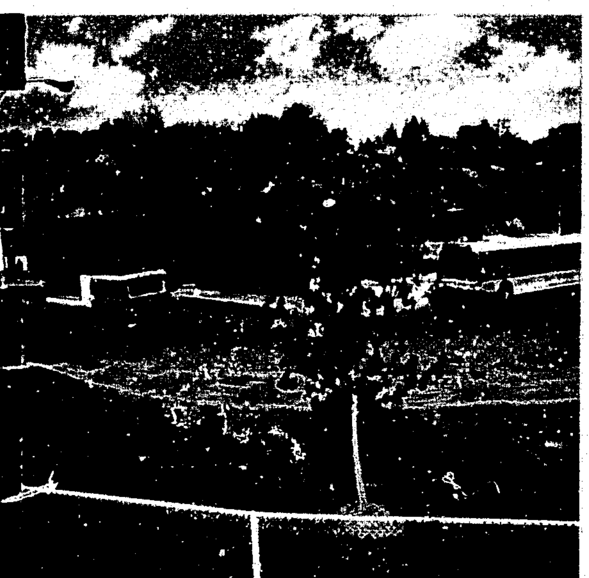


8[a]

8[b]

Special Services

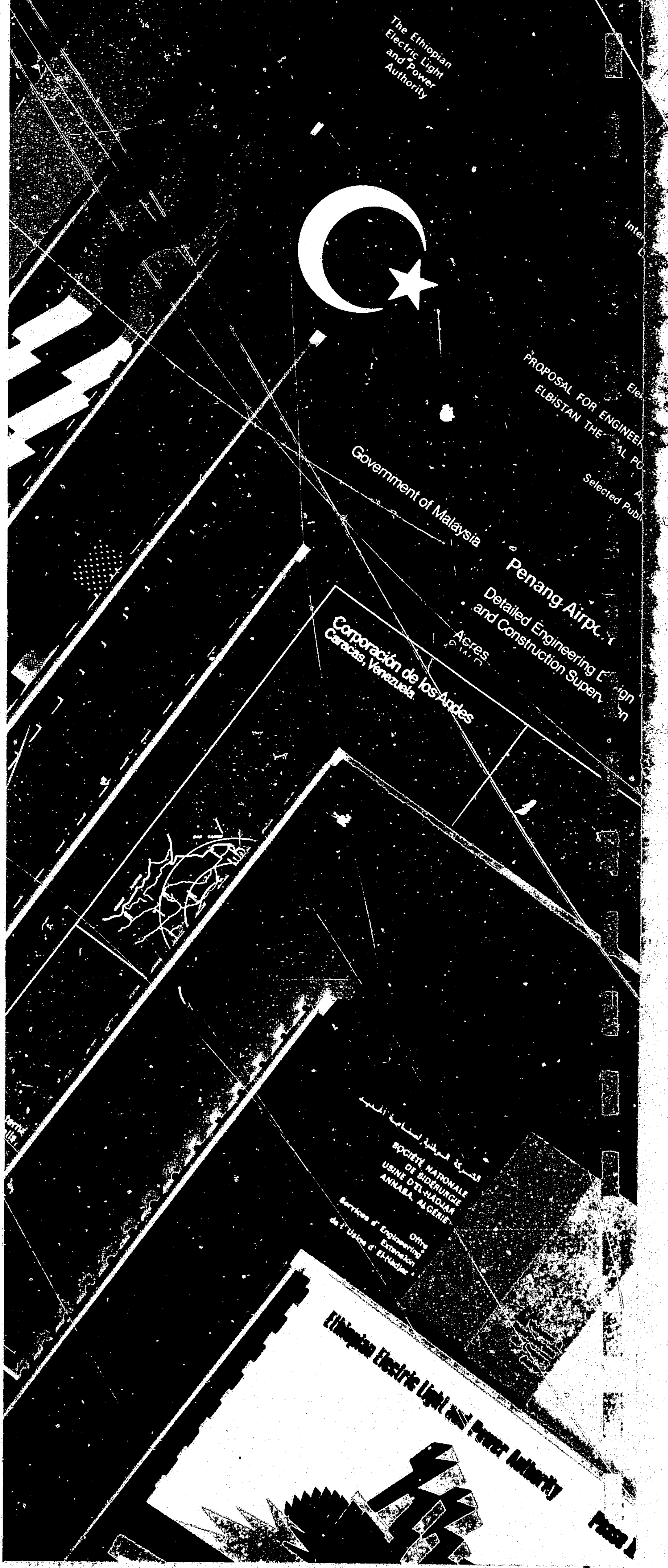
1. [a], [b], [c] and [d]: Laboratory facilities available for chemical, physical, geotechnical, aerodynamic, hydraulic, thermal and general investigations.
2. [a], [b] and [c]: Environmental assessment capabilities cover the full range of scientific capability with mobile and fixed location monitoring services.
3. [a], [b], [c] and [d]: Hydraulic and aerodynamic flow investigations are carried out by Acres in Company Facilities for hydroelectric, irrigation, marine projects and for precipitator/flue gas clean up equipment design.
4. Acres has a full range of geotechnical and geological capabilities. Foundation design and engineering of underground facilities are special fields. Modern techniques using equipment such as this borehole television camera are available for sub-surface investigations.
5. Mathematical simulation models are extensively used such as one developed and implemented by Acres for operating a forty-eight reservoir river system.
6. [a] and [b]: Modern techniques and management systems must be applied to bring large complex projects to successful completion. Acres has considerable experience in scheduling and controlling human, material and financial resources through project management and construction services.
7. Quality assurance, inspection and expediting services are provided by the Company both for projects it undertakes and for clients requiring specific assignments of this type.
8. [a] and [b]: Acres provides economic and planning services. Working in both the private and public sectors, the firm has carried out economic analyses, business forecasts and studies in transportation, forestry, mining, petroleum, power, energy, finance, merchandising and in many other areas.

ACRES

International Projects

INTERNATIONAL PROJECTS RECENTLY COMPLETED OR UNDERWAY:

Antigua	Water Supply Study
Argentina	Parana de las Palmas Navigation Channel Salto Grande Project Studies Cordoba Nuclear Power Plant
Uruguay	Telecommunication Study
Bangladesh	Transmission Line Crossing Jamuna River General Consultancy WAPDA
Brazil	Belem Thermal Power Project Airport Feasibility Study Irrigation
Canada	Many power, transportation, heavy civil and industrial projects
Colombia	Alto Anchicaya Hydroelectric Project
Dominican Republic	Yaque del Norte Irrigation Project
Ecuador	Steel Industry Studies
Ethiopia	Hydroelectric Power Studies
Ghana	Kpong Hydroelectric Project
Indonesia	Civil Aviation Sectoral Study Jakarta Airport Master Planning
Iraq	400 kV Supergrid Transmission
Kenya	Lower Tana River Basin Study
Korea	Wolsung Nuclear Power Plant
Laos	Nam Ngum Hydroelectric Project
Malaysia	Air Transportation Study and National Airport Plan; Sabah Forestry Study
Mexico	Review of Systems Expansions Engineering for Oxygen Blown Reduction Plant
Nepal	Kathmandu Airport Improvements
Pakistan	Warsak Hydroelectric Power Project Units 5 and 6; Energy Resources Study Tarbela Hydroelectric Power Project
Peru	Engineering and Construction Services for ports on the Amazon
Sri Lanka	Tea Industry Study; Irrigation
Sweden	Radioactive Waste Depository Studies
Tanzania	Power System Planning Studies
Thailand	Sirikit Hydroelectric Project Irrigation Studies
Trinidad and Tobago	Fisheries Study
Turkey	Aslantas Dam and Powerhouse
United Kingdom	Risk Analysis on North Sea Oil Projects Pumped Storage Sitting Studies
West Africa	Telecommunications Network
Yugoslavia	Shipyard Planning Studies



Partial List of Clients

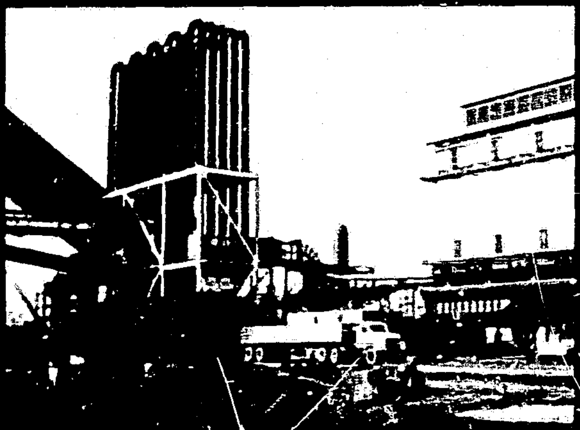
Allegheny Electric Cooperative, Inc.
Allied Chemical Corporation
American Air Filter Company, Inc.
American Electric Power Service Corporation
Appalachian Power Company
Argonne National Laboratories
The Babcock & Wilcox Company
Baltimore Gas & Electric Company
Benson (N.C.) Electric Department
Bergen (N.Y.) Municipal Electric Department
Bethlehem Steel Corporation
Blue Ridge (N.C.) Electric Membership Corporation
Boston Edison Company
C.F. Industries Inc.
California Energy Commission
The Carborundum Company
Central Hudson Gas & Electric Corporation
Colorado Fuel & Iron Steel Corporation
Compania Minera Autlan S.A. de C.V.
Consumers Power Company
Dan River Incorporated
Dirigo Electric Cooperative, Inc.
Dresser Industries, Inc.
E.I. Du Pont de Nemours & Company Incorporated
Electric Power Research Institute
Evaluation Research Corporation
Ford Motor Company
FMC Corporation
General Dynamics Corporation
General Motors Corp. Chevrolet Division
Great Lakes Carbon Corporation
Gulf Interstate Engineering Company
Hojalata Y Lamina, S.A.
Hooker Chemicals & Plastics Corporation
International Telephone & Telegraph Corporation
Ironton Coke Company
Jones & Laughlin Steel Corporation
Kaiser Aluminum & Chemical Corporation
Koppers Company
Martin-Marietta Aggregates Inc.
Massachusetts Municipal Wholesale
Electric Company

National Science Foundation
Nebraska Municipal Power Pool
Newco Chemical Waste Systems, Inc.
New York Energy Office
New York Power Pool
New York State Electric & Gas Corporation
Niagara Frontier State Park &
Recreation Commission
Niagara Frontier Transportation Authority
Niagara Mohawk Power Corporation
North Carolina State Department of Transportation
Northern Telecom Incorporated
Ohio Edison Company
Ohio Power Company
PPG Industrial Incorporated
Pennsylvania Power & Light Company
Pittsburgh-Des Moines Steel Company
Potomac Electric Power Company
Republic Steel Corporation
Raytheon Service Company
Research-Cottrell Incorporated
The Research Foundation of State
University of New York
Rochester Gas & Electric Corporation
Tennessee Valley Authority
Turbodyne Corp. — Gas Turbine Div.
Union Carbide Corporation
United Technologies Corporation
U.S. Steel Corporation
Vermont Electric Cooperative, Inc.
Wabanex Energy Corporation
Western Precipitation Div. (Joy Mfg. Co.)
Westinghouse Electric Corporation

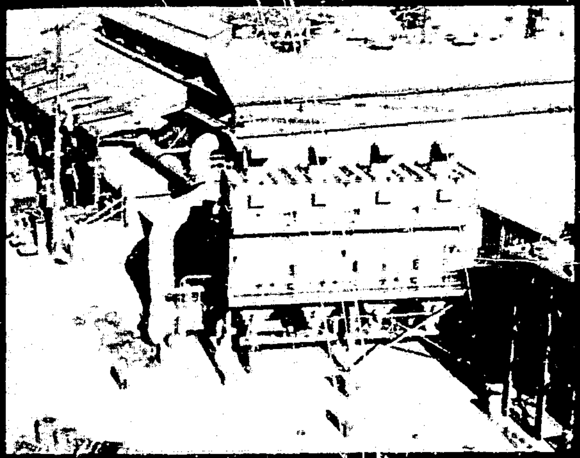
Federal Agencies

Corps of Engineers
Department of Energy
Environmental Protection Agency
General Services Administration
Housing and Urban Development
Naval Facilities Engineering
Command

SLAG TAILINGS WASTE POND
Location: Marietta, Ohio
Client: Union Carbide Corporation



OXYGEN BLOWING FACILITY
Location: Marietta, Ohio
Client: Union Carbide Corporation



ELECTRIC MELTING FURNACE
FUME EVACUATION SYSTEM
Location: Oil City, Pennsylvania
Client: U. S. Steel Corporation

Partial List of Clients

Allegheny Electric Cooperative
Allied Chemical Corporation
American Air Filter Company,
American Electric Power Servi
Appalachian Power Company
Argonne National Laborat
The Babcock & Wilcox Co
Baltimore Gas & Electric Company
Benson (N.C.) Electric Department
Bergen (N.Y.) Municipal Electric Department
Bethlehem Steel Corporation
Blue Ridge (N.C.) Electric Membership Corporation
Boston Edison Company
C.F. Industries Inc.
California Energy Commission
The Carborundum Company
Central Hudson Gas & Electric Corporation
Colorado Fuel & Iron Steel Corporation
Compania Minera Autlan S.A. de C.V.
Consumers Power Company
Dan River Incorporated
Dirigo Electric Cooperative, Inc.
Dresser Industries, Inc.
E.I. Du Pont de Nemours & Company Incorporated
Electric Power Research Institute
Evaluation Research Corporation
Ford Motor Company
FMC Corporation
General Dynamics Corporation
General Motors Corp. Chevrolet Division
Great Lakes Carbon Corporation
Gulf Interstate Engineering Company
Hojalata Y Lamina, S.A.
Hooker Chemicals & Plastics Corporation
International Telephone &
Ironton Coke Company
Jones & Laughlin Steel Corp
Kaiser Aluminum & Chemical Corporation
Koppers Company
Martin-Marietta Aggregates Inc.
Massachusetts Municipal W
Electric Company

National Science Foundation
Nebraska Municipal Power Pool
Newco Chemical Waste Systems, Inc.
New York Energy Office
New York Power Pool
New York State Electric & Gas Corporation
Niagara Frontier State Park & Recreation Commission
Niagara Frontier Transportation Authority
Niagara Mohawk Power Corporation
North Carolina State Department of Transportation
Northern Telecom Incorporated
Ohio Edison Company
Ohio Power Company
PPG Industrial Incorporated
Pennsylvania Power & Light Company
Pittsburgh-Des Moines Steel Company
Potomac Electric Power Company
Republic Steel Corporation
Raytheon Service Company
Research-Cottrell Incorporated
The Research Foundation of State University of New York
Rochester Gas & Electric Corporation
Tennessee Valley Authority
Turbodyne Corp. — Gas Turbine Div.
Union Carbide Corporation
United Technologies Corporation
U.S. Steel Corporation
Vermont Electric Cooperative, Inc.
Wabanex Energy Corporation
Western Precipitation Div. (Joy Mfg. Co.)
Westinghouse Electric Corporation

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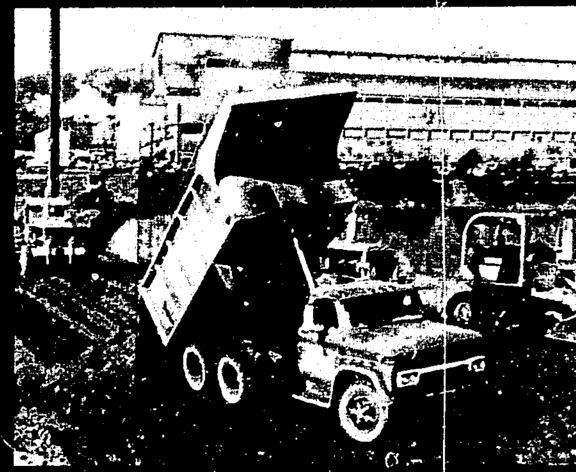
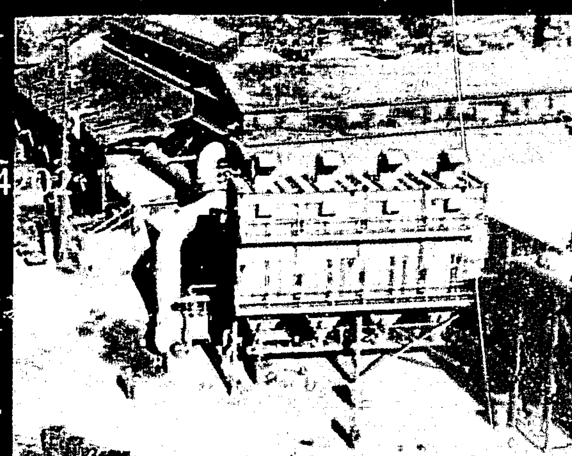
Department of Energy
Environmental Protection Agency
General Services Administration
Housing and Urban Development
Naval Facilities Engineering Command



SLAG TAILINGS WASTE POND
Location: Marietta, Ohio
Client: Union Carbide Corporation

OXYGEN BLOWING FACILITY
Location: Marietta, Ohio
Client: Union Carbide Corporation



ELECTRIC MELTING FURNACE FUME EVACUATION SYSTEM
Location: Oil City, Pennsy
Client: U.S. Steel Corp

ACRES AMERICAN INCORPORATED

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Raleigh
Suite 214, Northampton Building, 3725 National Drive,
Raleigh, North Carolina 27612
Telephone (919) 781-3150

Washington
Suite 1105, 1750 Pennsylvania Avenue N.W., Washington, D.C. 20006
Telephone (202) 393-2027

Columbia
Suite 329, Clark Building, Columbia, Maryland 21044
Telephone (301) 992-5300
Washington Line 596-5595

HOUSER AND CARAFAS ENGINEERING CO. - AN ACRES COMPANY

Pittsburgh
301 Fifth Avenue, Pittsburgh, Pa. 15222
Telephone (412) 471-9929

Printed in U.S.A.

The objective of our firm is to provide a total scope of professional-technical assistance for solving engineering and environmental problems related to development in the subarctic and arctic as well as more temperate regions. In many cases, with careful planning and innovative design, special environmental or engineering problems can be converted to assets rather than obstacles that must be overcome.

The need for development of natural resources and the associated population growth will require new transportation systems, utilities and communications systems. These are just a few of the broad areas which require professional Engineering, Geologic, and Planning analysis.

R & M maintains a staff of nearly 200 Engineers, Geologists, Planners, Landscape Architects, Surveyors, Technicians, and other support personnel as well as four fully equipped and staffed Materials Testing Laboratories. This combination of personnel and facilities allows us to offer a comprehensive range of professional services, combining multi-disciplinary expertise with modern equipment and techniques. We have offices and laboratories in Anchorage, Fairbanks, Juneau, Valdez and Wasilla, giving our firm a statewide scope, and we look forward to continued expansion in the future.

The following pages of this brochure contain brief descriptions of the services offered by R & M along with support information describing our specialized expertise and capabilities.

We look forward to the opportunity to discuss your objectives, respond to your specific needs and assist you in whatever way necessary to carry out your objectives.

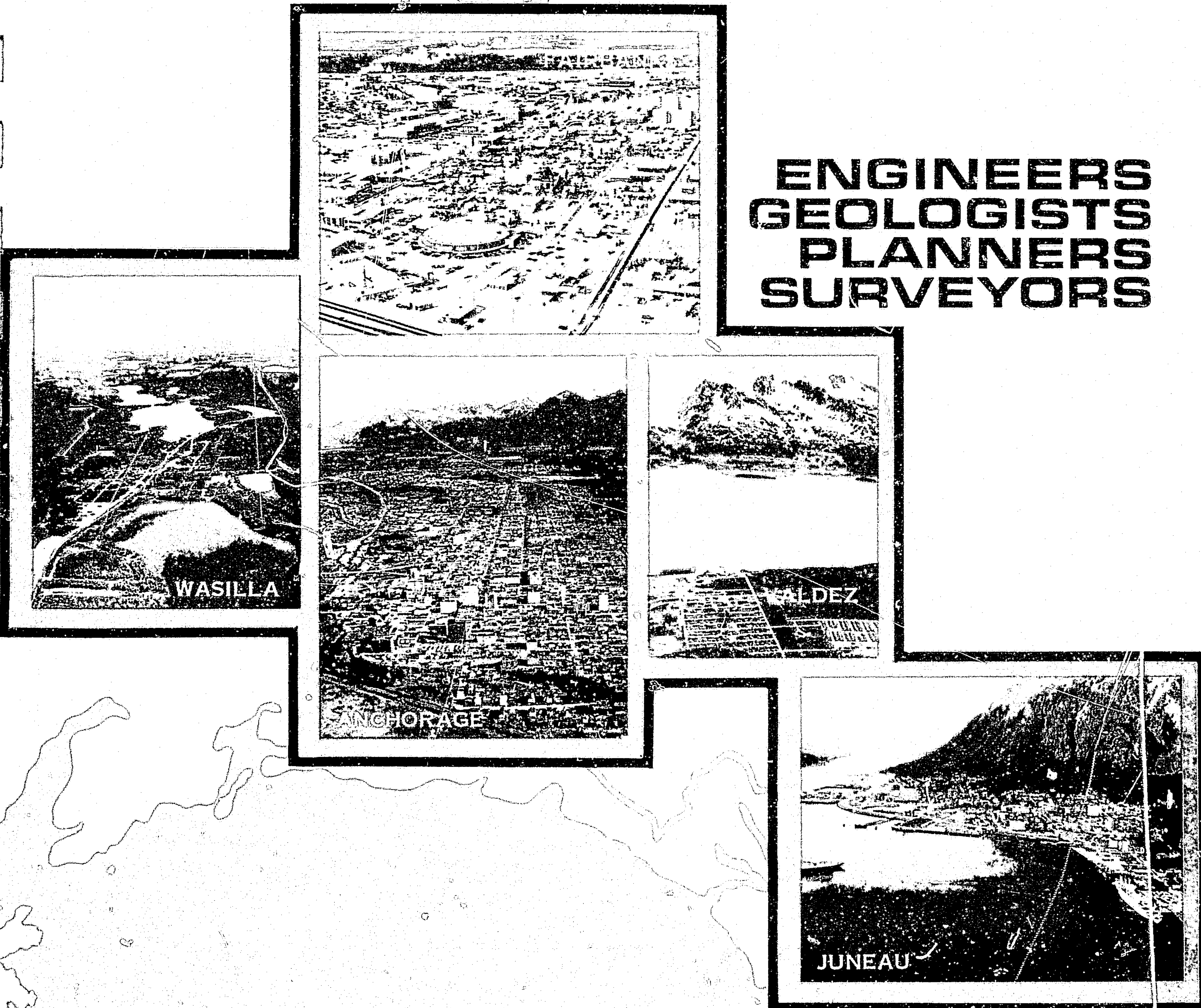
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

R & M Consultants, Inc. is a major consulting firm with established offices located in the principal Alaskan cities of Anchorage, Fairbanks, and Juneau, and branch offices in Wasilla and Valdez. Commencing from the time of the firm's inception in 1969, R & M personnel have endeavored to maintain a definite orientation toward superior performance and high professional standards.

Initially, the firm offered to its clients all engineering services associated with the civil and geological fields. During the course of the firm's growth and continuous development, other complementary Engineering and Earth Science disciplines were included under the R & M service capability. Presently, highly qualified, experienced staff also provide full or supporting services in the areas of Environmental, Electrical, and Mechanical Engineering, as well as in Planning, Landscape Architecture, Oceanography, and Range Management. This broadening into other fields occurred naturally as a result of the nature and size of projects in which R & M participated and the realization that maximal coordination and a total multidiscipline approach were thereby facilitated and enhanced.

A continuation of this multidiscipline approach has been prompted by the need for response to particular Alaskan demands. New requirements have been placed on the Engineering community in Alaska as a result of the State's overall development and its unique position and increasing importance in the area of natural resources. R & M has entered into the vital field of Planning because of a desire to assist in the identification and development of solutions for problems occasioned by economic development and population pressures. It is felt that a strong base of Geotechnical and Engineering expertise particularly qualifies R & M for providing total Planning services.

The particular combination of talents and expertise which exists in the firm, coupled with a philosphy directed toward cooperative problem solving, favorably equips R & M for creating sound contemporary project solutions.



ENGINEERS
GEOLOGISTS
PLANNERS
SURVEYORS

ENGINEERING

STRUCTURAL ▪
ENVIRONMENTAL ▪
TRANSPORTATION ▪
HYDROLOGIC ▪
GEOTECHNICAL ▪
MECHANICAL ▪
ELECTRICAL ▪

EARTH SCIENCES

GEOLOGY & ENGINEERING GEOLOGY ▪
ENVIRONMENTAL SCIENCES ▪

PLANNING & LANDSCAPE ARCHITECTURE

PLANNING ▪
LANDSCAPE ARCHITECTURE ▪
VISUAL COMMUNICATIONS & GRAPHICS ▪

SURVEYING SERVICES

SURVEYING ▪

MATERIALS & TECHNICAL SERVICES

MATERIALS ENGINEERING ▪
TECHNICAL SERVICES ▪

SPECIAL AREAS OF SERVICE

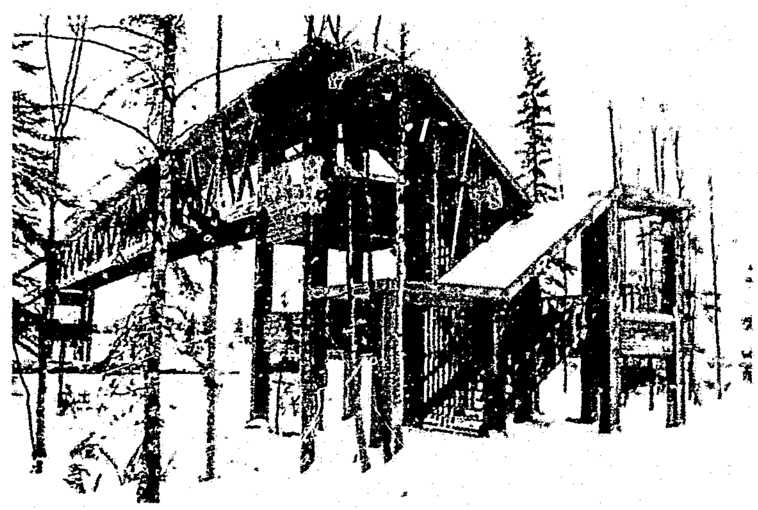
NORTHERN DEVELOPMENT ENGINEERING ▪
SYSTEMS ENGINEERING & CONSTRUCTION MANAGEMENT ▪
ELECTRONIC DATA PROCESSING ▪

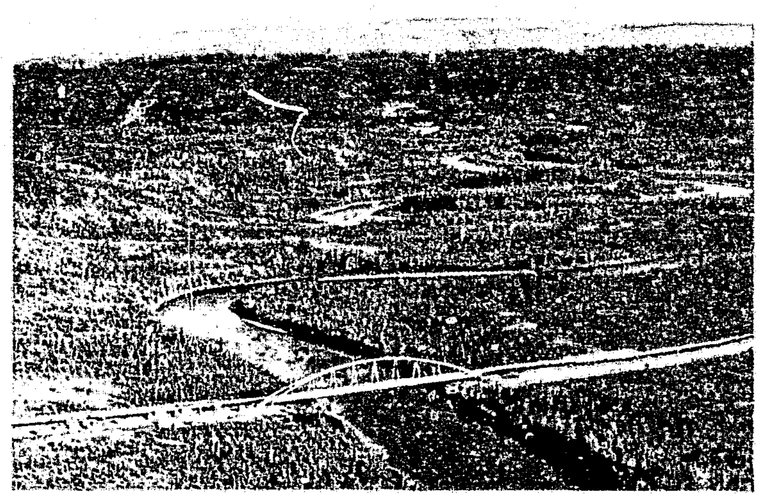
Engineering services provided by R & M include virtually every aspect associated with the planning, designing, and construction supervision for any physical structure or improvement. An extremely wide range of professional services is encompassed under this discipline; R & M has the capability of performing with competent, experienced specialists in all areas of Engineering.

Opportunities to demonstrate professional competence and engineering creativity have been provided by State and Federal agencies along with Municipal and Borough governments. The firm has also participated extensively on engineering projects initiated by private enterprise. Involvement has occurred on projects of both major and minor scale with considerable effort being directed to transportation, pipeline, commercial, and industrial development, as well as subdivision and other local improvements.

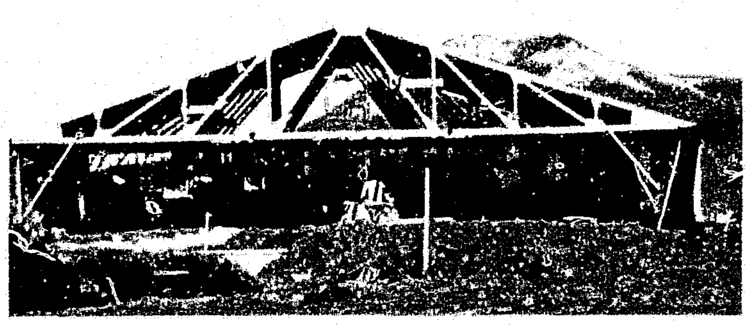
ENGINEERING

ENGINEERING
STRUCTURAL

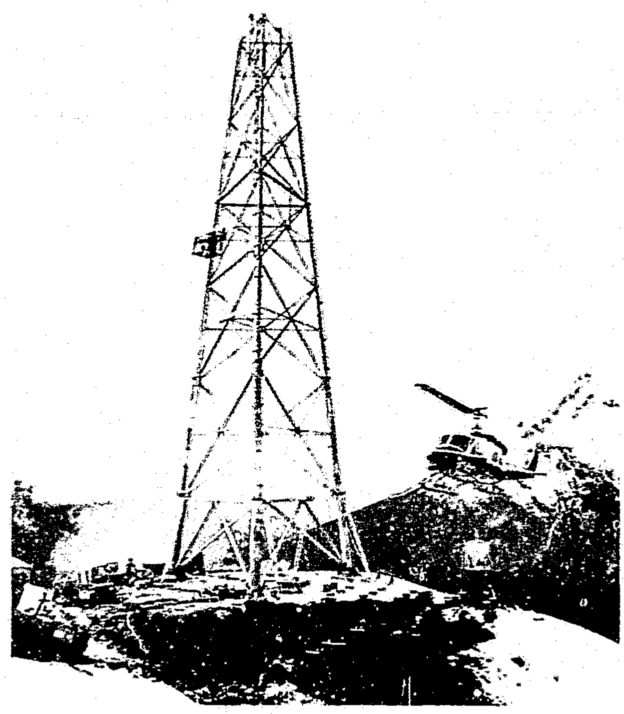




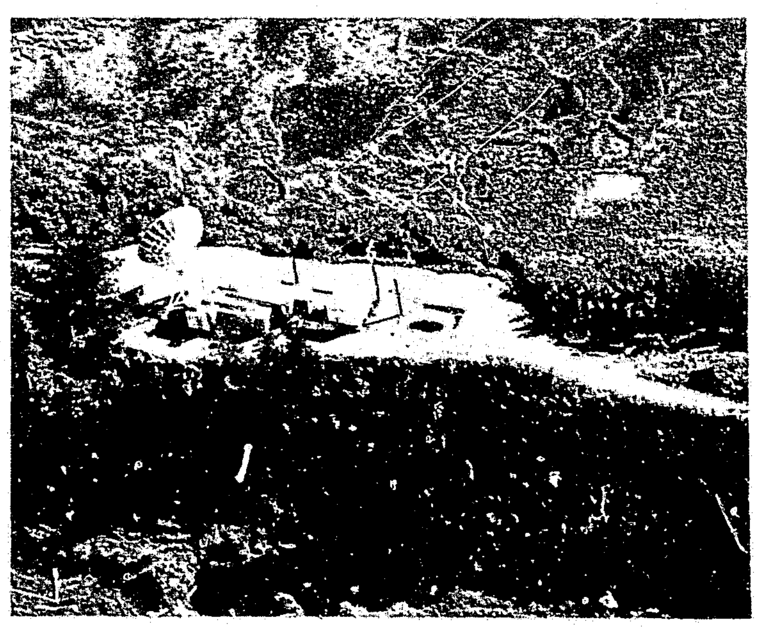
The professional experience of R & M personnel is constantly being updated by new information and understandings obtained through project performance, research, and participation in pertinent technical sessions. This combination of knowledge and experience allows our firm to provide a realistic evaluation of project feasibility, engineering requirements, time schedules, logistics, and total costs for projects.



ENGINEERING
STRUCTURAL



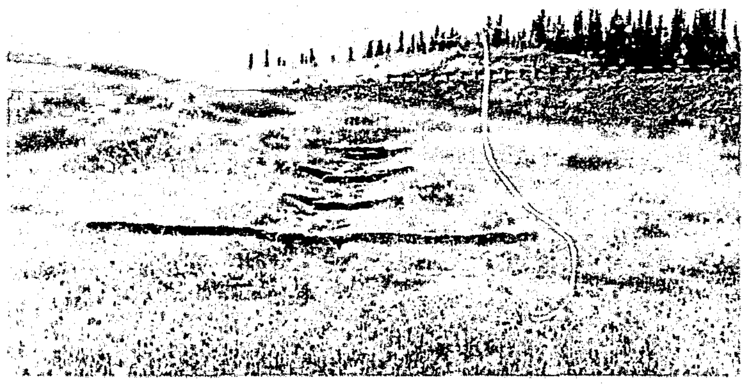
Structures other than bridges on which R & M has performed with the same degree of design inventiveness have included, but are not limited to, private, commercial, residential, and institutional structures, tunnels, construction bulkheads, cofferdams, retaining walls, earth filled dams, foundations for satellite stations and communication towers, and marine facilities.



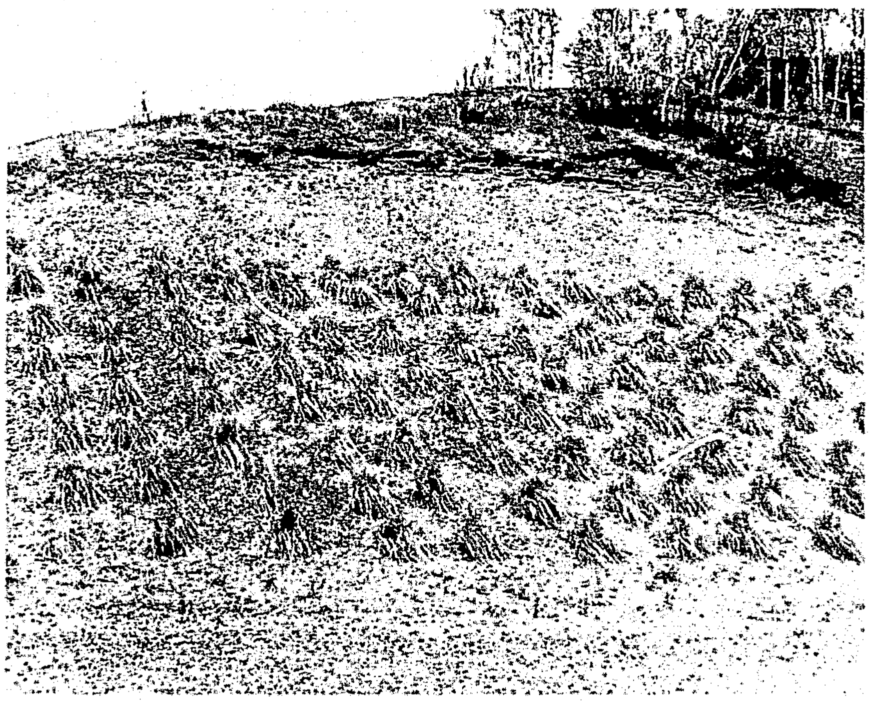
Foremost in the minds of our structural specialists is the intention to arrive at final designs which meet all necessary physical, social, economic or individual requirements and yet represent an advanced application of knowledge within the field.

ENGINEERING
ENVIRONMENTAL

Falling under the purview of Environmental Engineering at R & M is a wide range of services all of which in some way identify and solve problems related to environmental protection of our water and waste disposal. Specific services offered include the preparation of environmental assessment reports for all types of projects; investigations and assessments of deficiencies in existing systems and possible improvements; and complete design services of systems which improve public living conditions while both protecting and enhancing the environment.



R & M's service potential in Environmental Engineering is particularly effective due to the existence of complete laboratory facilities within the firm. Prompt responsible analysis of laboratory test results contributes materially to efficient and economical design solutions.



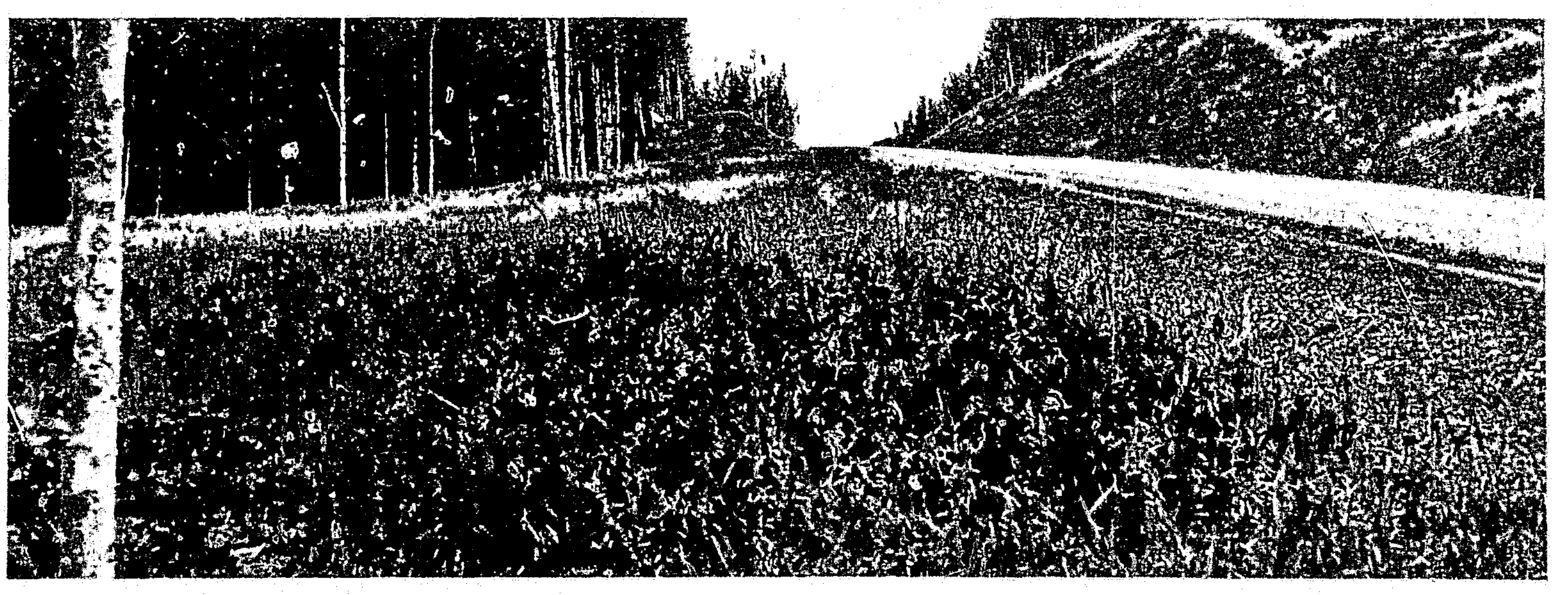
The various services related to Environmental Engineering which R & M personnel have provided include:

Development, transmission, treatment, and distribution of water.

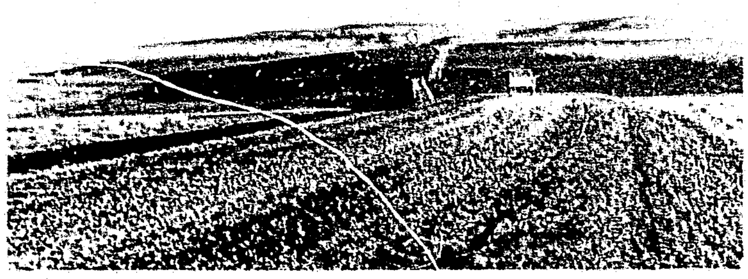
Collection, treatment, and disposal of sanitary wastes.

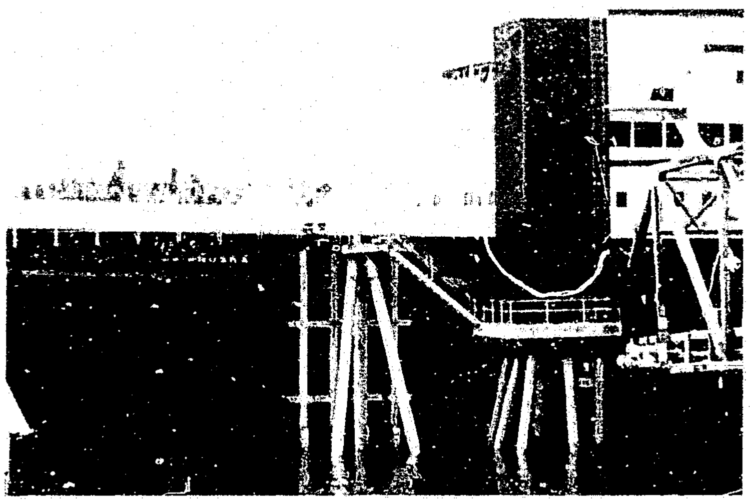
Solid waste disposal system design.

Erosion control and revegetation systems for disturbed construction areas.



ENGINEERING
TRANSPORTATION





R & M personnel have actively participated in the major phases of highway, airport, and marine facilities engineering commencing with the initial planning and design and proceeding through to inspection and control of actual construction. Project services provided by the firm are as follows:

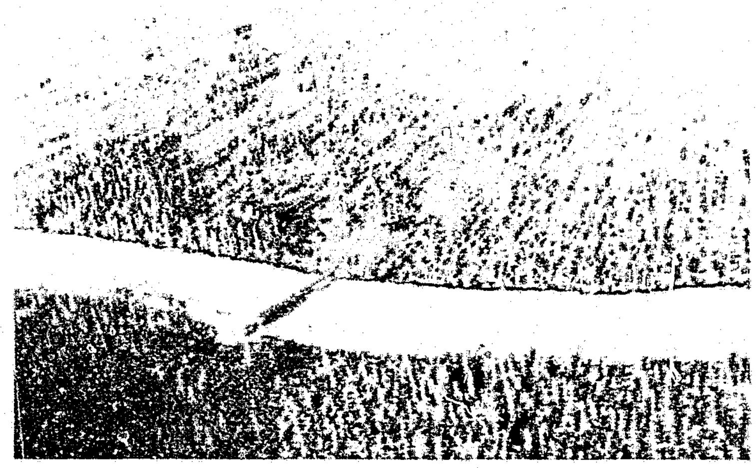
- Systems Planning
- Program Planning
- Feasibility Studies
- Conceptual Design
- Reconnaissance Studies
- Environmental Impact Assessment and Statements
- Preparation of Design Plans
- Quality Control
- Highway, Airport, and Marine Design
- Construction Scheduling, Management, and Inspection

Because the firm combines the services of Planning, Engineering, and Geology, it is able to approach the multifaceted nature of problems which can arise on Transportation Systems projects by offering coordinated technical solutions. The extent of involvement by R & M in the design of various Transportation Systems has been relatively extensive as indicated by the above listing of services. This overall capability has allowed a generally comprehensive approach to project solutions.

ENGINEERING
HYDROLOGIC

R & M has a broad engineering capability in numerous areas of hydrology and hydraulic design. Experience has been acquired on Private developments, Municipal and State projects and from extensive participation on both oil and gas pipeline projects. Computer applications have been developed in analysis of drainage basins, stream flow prediction and design of drainage structures.

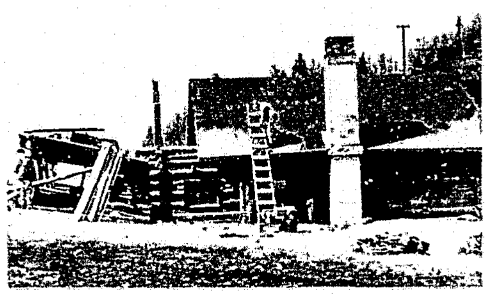
Key personnel at R & M have directed major river studies, dam design and construction, analysis and design of highway drainage structures, and design of water supply systems for planned developments and major fish hatchery facilities.



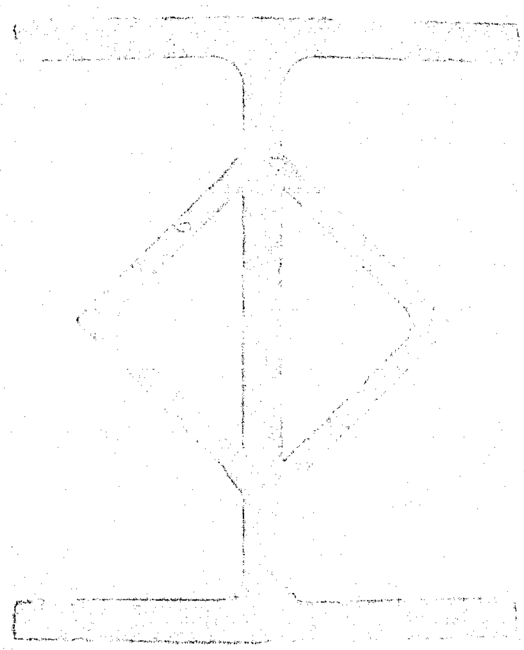
A general lack of available published data and unique hydrologic problems peculiar to arctic and subarctic regions dictates a reliance for many projects not only on technical expertise but also on individuals possessing extensive experience in these regions. R & M personnel have an accumulated experience base of many years acquired in northern regions.

ENGINEERING GEOTECHNICAL

Geotechnical Engineering involves the technical analysis of complex soil, permafrost, and other geological conditions, along with the provision of recommendations for appropriate design solutions. Adequate soil and foundation information will insure that engineering works such as utility systems, residential structures, buildings, bridges, and highways can be confidently designed with a stable or controlled foundation throughout their planned lifetime.



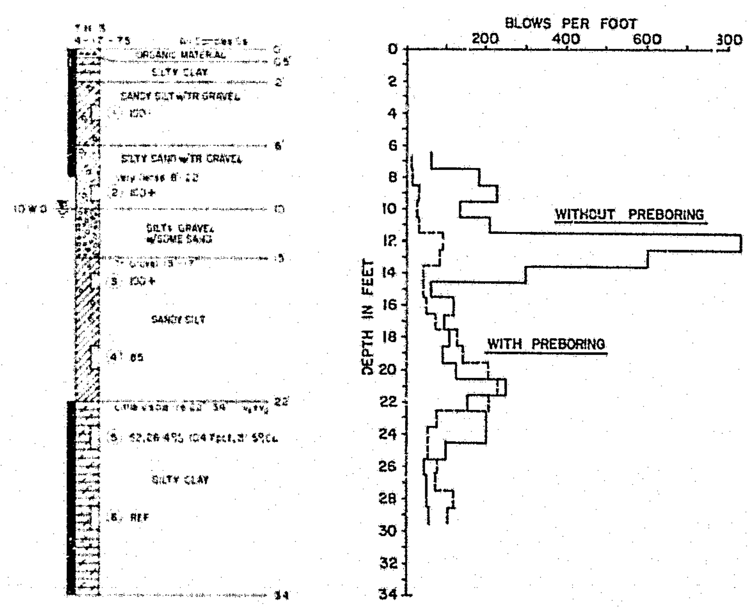
Detailed subsurface investigations and analyses are particularly imperative in arctic and subarctic regions due to unique and highly variable geologic conditions, commonly prevalent permafrost conditions, the scarcity of published information, and the general lack of empirical data on soils and foundations. Such studies make it possible to identify potential foundation difficulties which might occur within the planned life of a facility.



DRIVEN H-PILE FOUNDATIONS IN FROZEN SANDS AND GRAVELS

Our staff of Soil Engineers, Engineering Geologists, and Engineering Specialists possess a highly developed expertise in solving problems related to both general and special subsurface soil and foundation conditions.

BORING LOG AND DRIVING RECORD

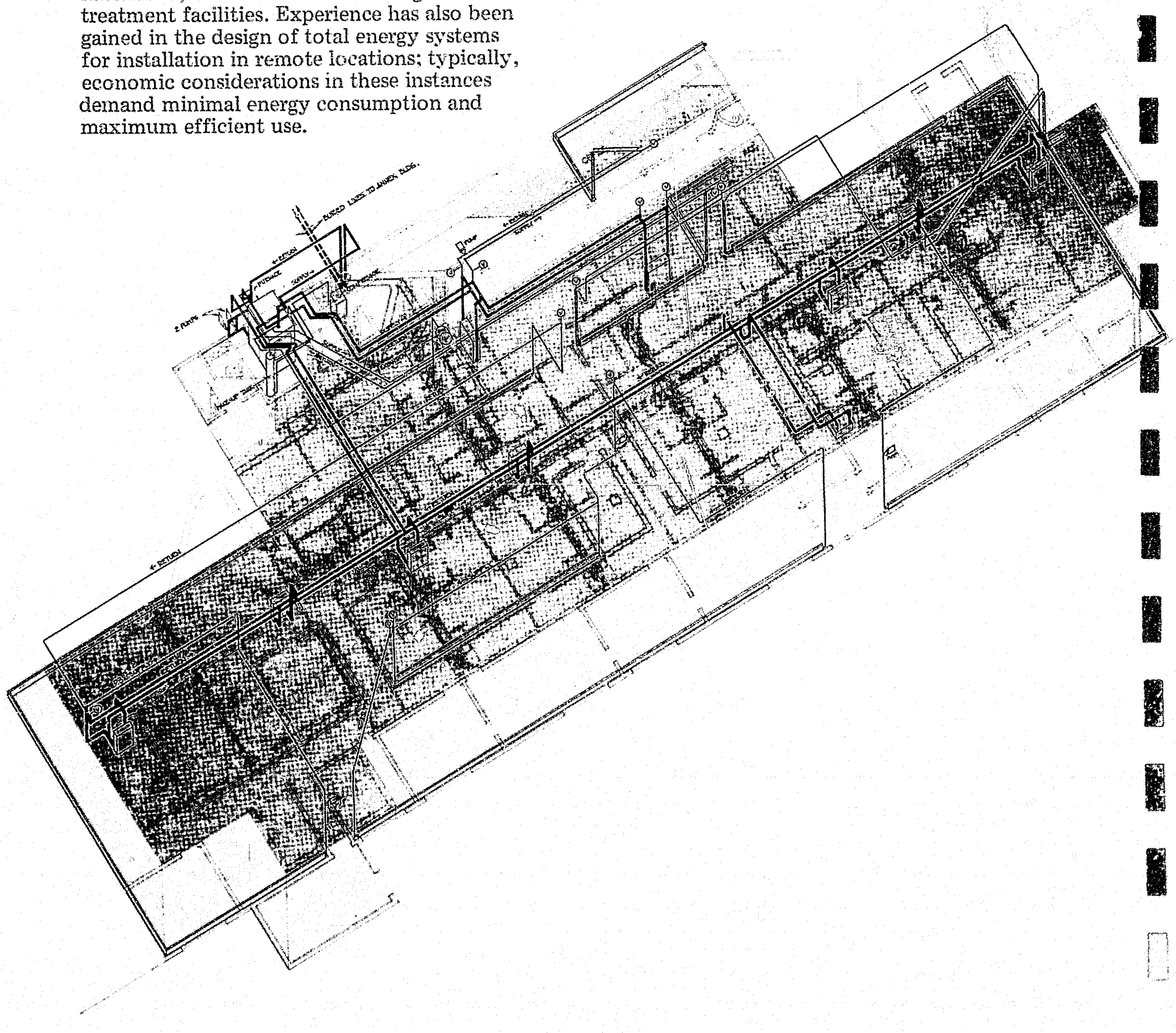


ENGINEERING

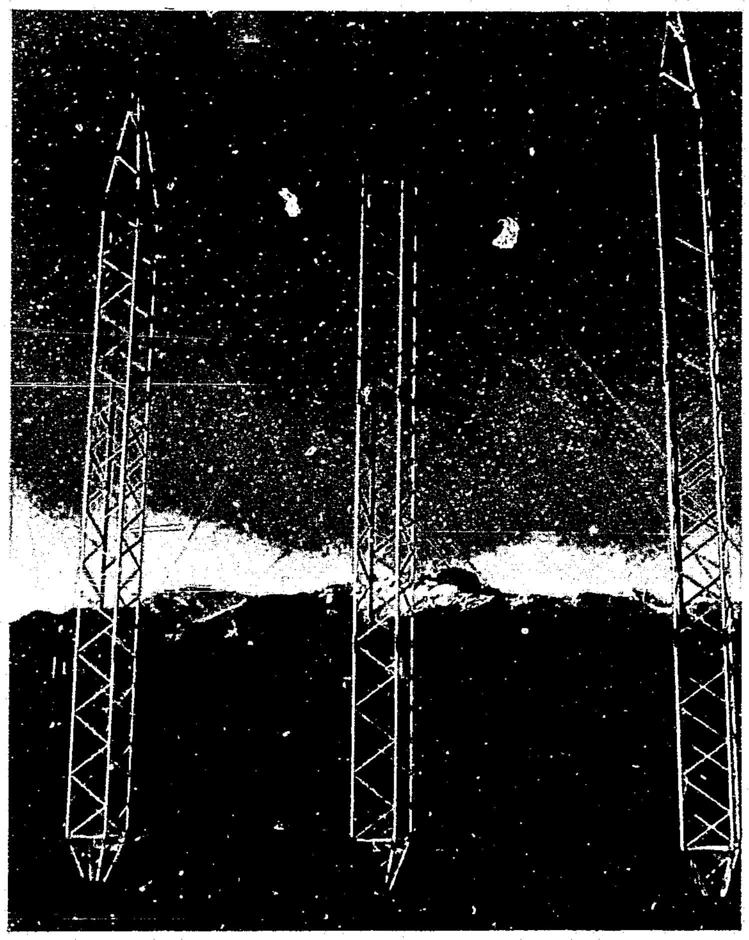
MECHANICAL

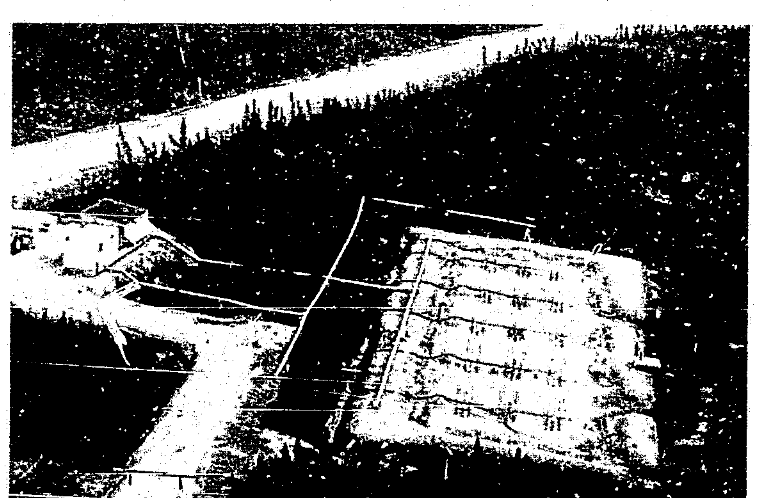
A wide variety of technical and design services are provided in the field of Mechanical Engineering by R & M Consultants. These services range from the design of piping and heating systems for buildings, to the design of special systems for arctic regions where heat loss, heat transfer and operating conditions require special design considerations.

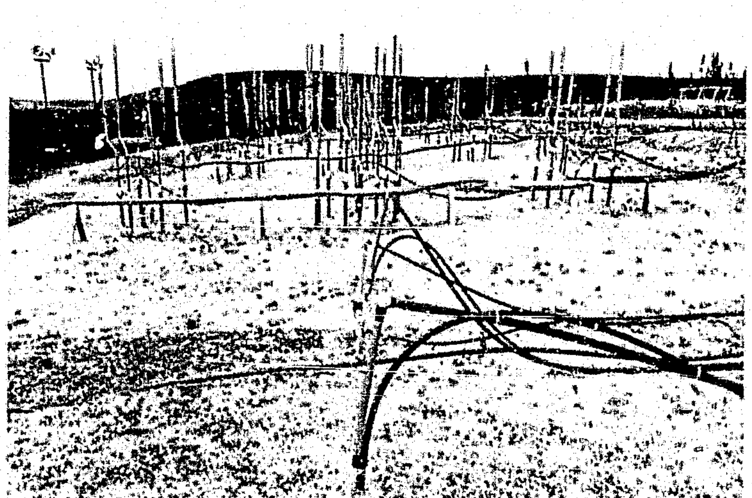
R & M personnel have been involved in the design of special piping systems for conditions of high temperature and pressure; for fish hatcheries; and for water and sewage treatment facilities. Experience has also been gained in the design of total energy systems for installation in remote locations; typically, economic considerations in these instances demand minimal energy consumption and maximum efficient use.



ENGINEERING
ELECTRICAL







R & M Consultants' service capability in Electrical Engineering resides in the expertise and experience of professionals who have been active in the following areas of the field:

- Power Generation
- Power Transmission and Distribution
- Equipment Control and Monitoring Systems
- Commercial and Industrial Building Systems
- Precision Temperature Measurement
- HF and VHF Communication

R & M's involvement in these several phases of the electrical and electronic disciplines typically commences with concept development and terminates at the point of commercial operation. R & M's multidisciplinary make-up assures that all Electrical Engineering efforts are coordinated with other relevant engineering considerations.

Electrical design efforts have involved complete electrical design for building facilities; design of complete electric systems for Alaskan villages; feasibility, preliminary design, final design, and construction monitoring for generation projects up to 30,000 KW capacity. Specific oil pipeline related work has included assisting in the development of electrical instrumentation and techniques for grounding systems in frozen soil; for thermally (electric) induced thaw settlement; and for thermal scanning verification.

In addition to its design capability, R & M operates an electronics manufacturing and testing facility in Fairbanks for the production and calibration of thermocouple and thermistor strings, corrosion testing, and instrument testing and maintenance.

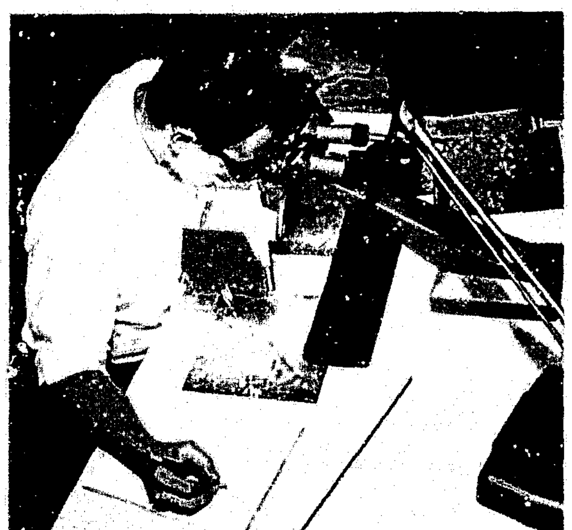
R & M Consultants, Inc. was initiated and has undergone substantial development because of the general need for evaluation by specialists In Engineering Geology of a wide range of environmental conditions; evaluation was required in order to design systems in Alaska's diversified environment. Today in our Earth Science Department, professional specialists in Biology, Forestry, Oceanography, and Range Management have joined our geologists in the evaluation of parameters for the establishment of effective design criteria. This expansion of our Earth Science professional profile was accomplished to assist us in our involvement with the disciplines of Marine Biology and Aquaculture, Photogeology, and the Environmental Sciences.

EARTH SCIENCES

EARTH SCIENCES
GEOLOGY & ENGINEERING GEOLOGY

Prior to the design of any structure, foundation investigations are required for proposed construction sites. Such studies are essential in determining the suitability of a proposed site and in evaluating the interrelationship of the site with the proposed engineered facility.

Geology and Engineering Geology represent a major phase of the work performed by R & M. Our geologists, by way of illustration, have been intimately involved during the planning, design, and construction phases of the Trans Alaska Hot Oil Pipeline project. Similar comprehensive efforts have also been provided on other major developments such as gas pipelines, transportation systems and large building complexes.



R & M Consultants, Inc. offers comprehensive engineering geological services. Accompanying our experience in the multiple phases of Geology is a developed skill in scheduling field work, logistics, manpower, supplies, equipment, and knowledge of construction possibilities, particularly in arctic and subarctic regions. Some of the geological services which we have performed for individual clients, for private organizations and public agencies include:

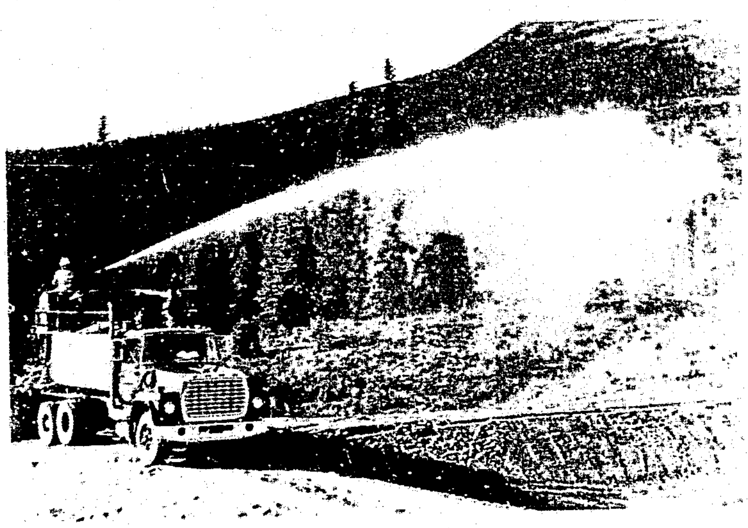
Engineering Geology
Photogeology
Subsurface Investigations
Ground Water Evaluation
Material Site Exploration and Evaluation
Permafrost Investigations
Seismicity Evaluation
Site Geology Studies
Erosion Potential Evaluation
Soil Resistivity Surveys
Seismic Interpretation
Water Well Design
Exploratory Drilling Support

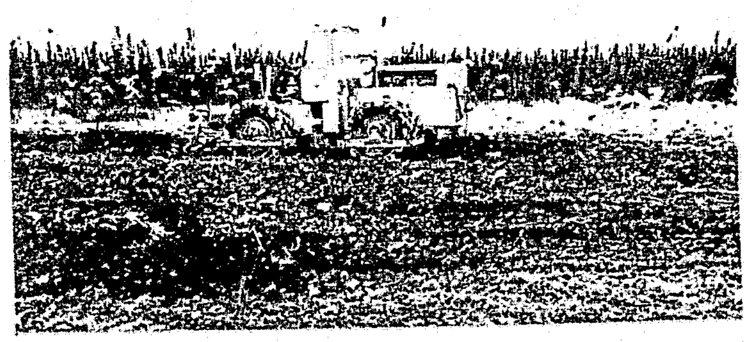
EARTH SCIENCES
ENVIRONMENTAL SCIENCES

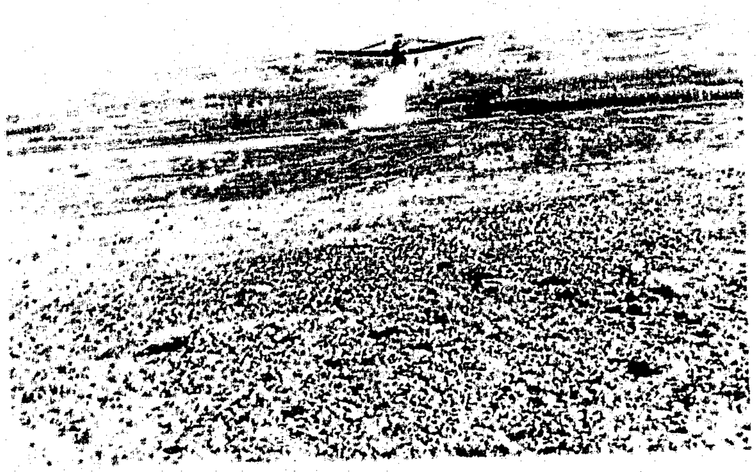
In the application of Environmental Science at R & M, major consideration is given to the effects that any product of engineering will have on the environment. Environmental Sciences are represented in the firm by unique study teams which might be composed of: Biologists, Marine Geologists, Oceanographers, Agricultural Engineers, and Geologists. Employing flexible study teams permits R & M to address itself to special environmental problems. Areas of concentrated activity and interest have included problems related to coastal engineering, the remote Interior, permafrost degradation or stabilization, aufeis problems, and sea and river ice problems.

Specific services provided include:

- Impact Analyses and Statements
- Environmental Assessments and Studies
- Marine Studies
- Grassland Ecology Surveys
- Range Surveys
- Revegetation Programs
- Erosion Control Studies
- Natural Vegetation Re-Invasion Studies
- Outfall Analysis
- Sanitary Land Fill Studies







PLANNING &
LANDSCAPE
ARCHITECTURE

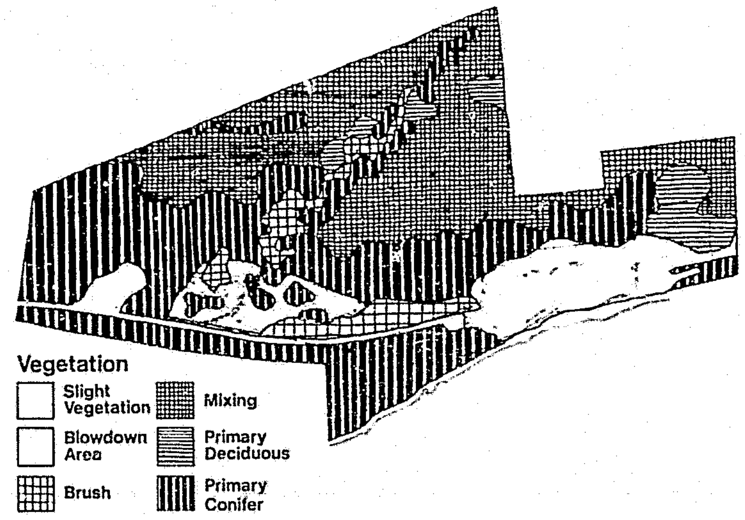
PLANNING &
LANDSCAPE
ARCHITECTURE

R & M Consultants, Inc. provides Planning and Landscape Architectural consulting services for public agencies and private clients. The firm is involved in community and regional planning, urban design, environmental planning, land use planning, site selection and suitability, analysis, park and recreation planning, and landscape architecture. A wide range of professional experience at R & M Consultants, Inc. enables the firm to provide well integrated services on both a regional and site planning scale. Experience gained at the regional level will have major implications for detailed site design and construction documentation; conversely, information gained at the site design scale, regarding land use requirements and impacts, is invaluable when brought to the regional or community scale land use planning process.

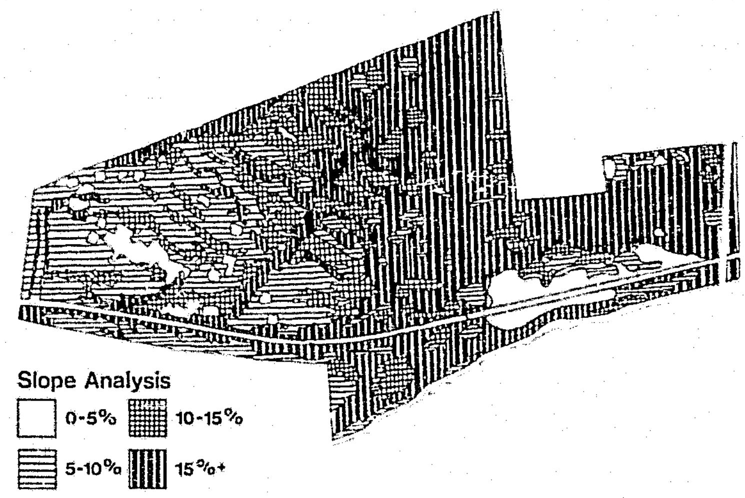
PLANNING & LANDSCAPE ARCHITECTURE

PLANNING & LANDSCAPE ARCHITECTURE

PLANNING

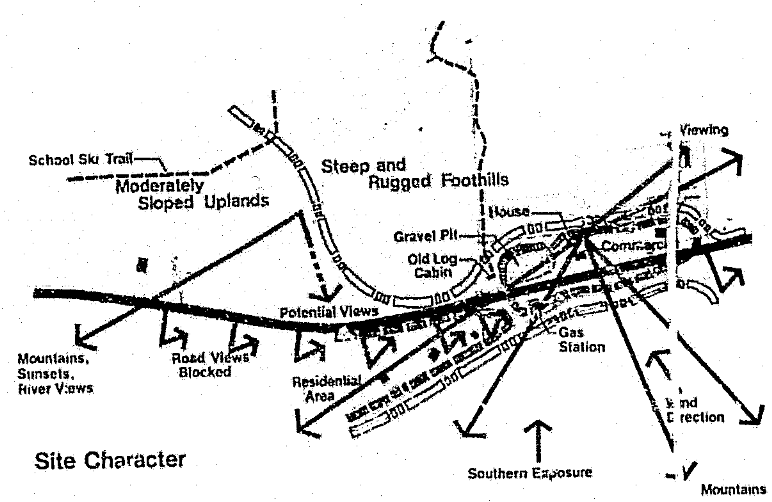


Planning defines a professional activity which is area oriented: it may involve a large region, subregion, or community, each of which is composed of various cultural and physical resources. The planning activity may be related to specific proposed land uses or activities or to more general systems planning and identification of goals, objectives, and priorities.

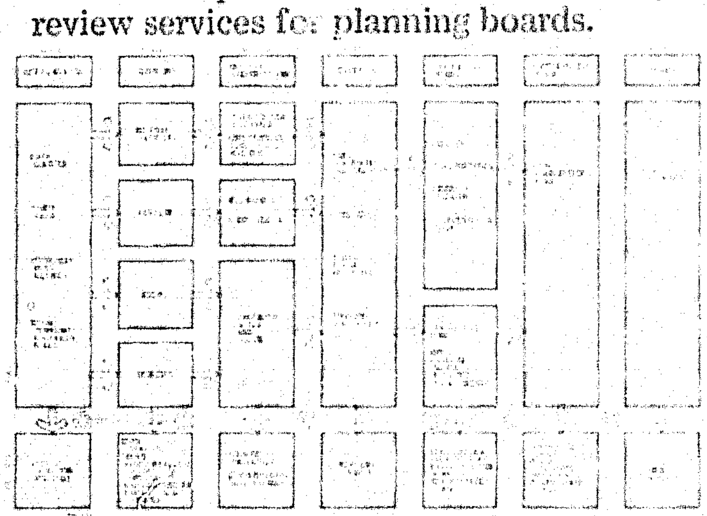


The diverse mixture of educational and professional backgrounds found within each department at R & M Consultants allows for the formulation of planning teams with an optimum expertise and experience mix for each project.

A typical planning team might be composed of: Regional Planner, Geologist or Geotechnical Engineer, Natural Resource Specialist, Botanist, Landscape Architect, and Soil Scientist. In addition to the talents found within the firm, R & M has also established a close working relationship with other firms whose special services might fill a particular project's requirements.



R & M personnel have a broad range of experience in regional and environmental planning. This experience includes award winning urban design projects, environmental planning, land use planning and zoning, farmland preservation, master plans, environmental impact statements, environmental management, and the development of land use performance standards and plan review services for planning boards.

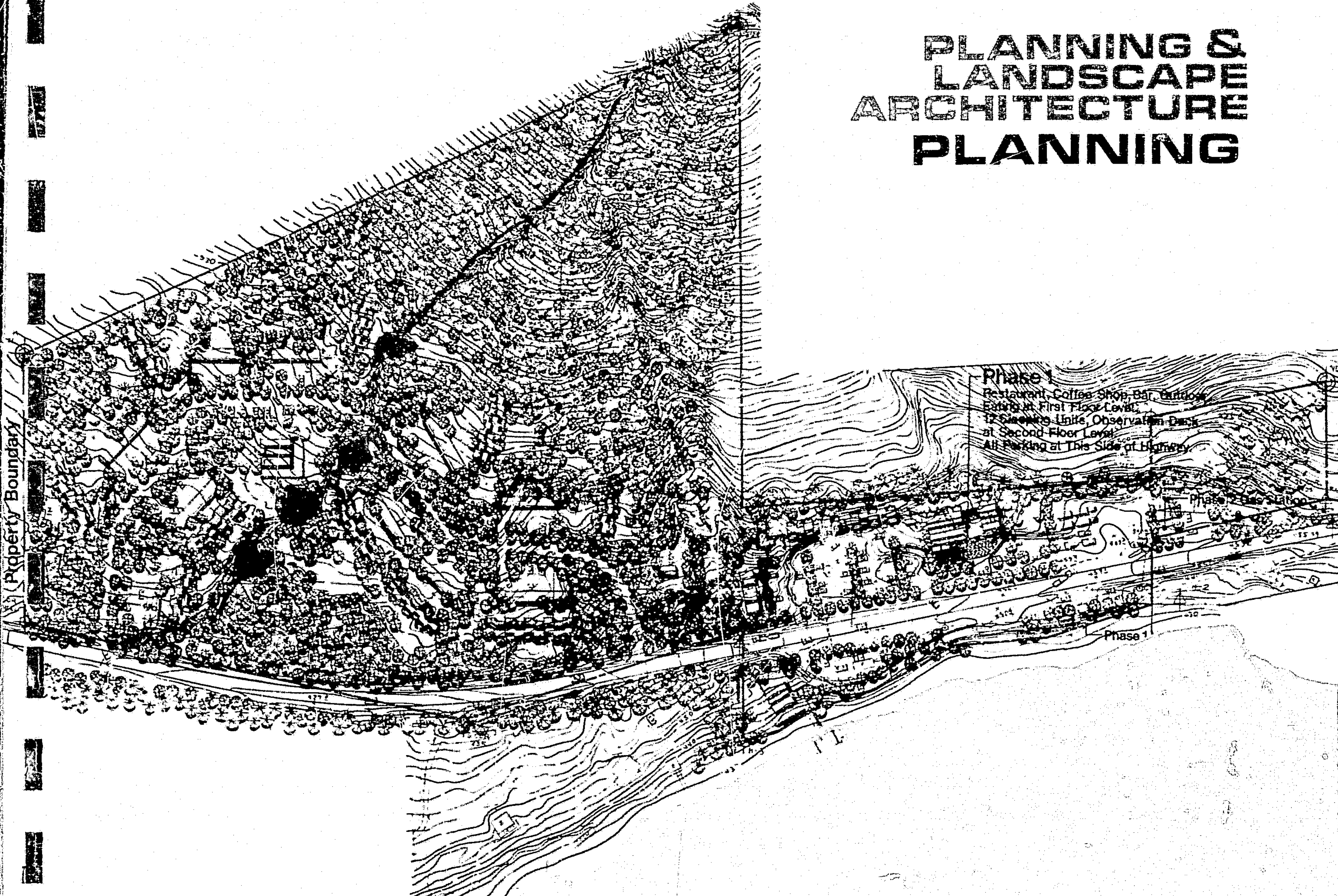


COMMUNITY COMPREHENSIVE PLANNING PROCESS
R&M CONSULTANTS,INC.

In general, the methodology used in the planning process includes inventory, analysis, and interpretation of pertinent social, economic and environmental information; development of alternative plans with analysis of the social, economic and environmental impact of each alternative, and more detailed development of the selected alternative.

Techniques found useful in the above process include, aerial photo analysis; computer applications for natural and demographic information; community interviews and participation; and other applicable state-of-the-art planning methods and techniques.

PLANNING & LANDSCAPE ARCHITECTURE
PLANNING

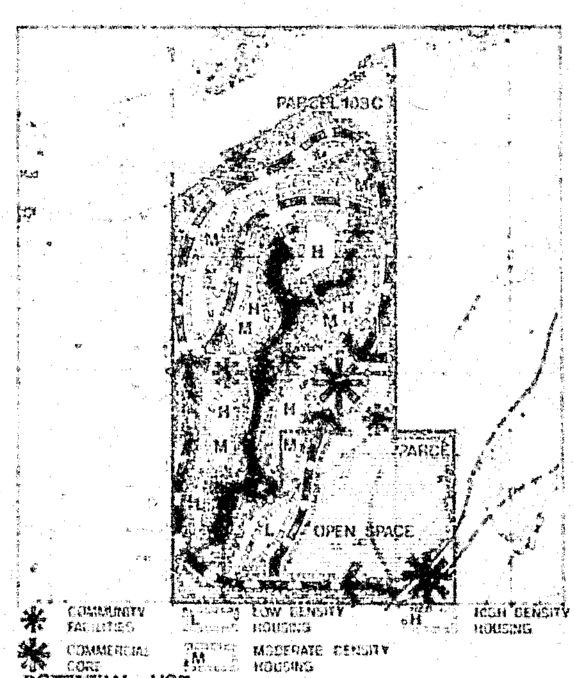


Future Land Use Plan

At R & M, the primary focus is centered on the planning process rather than on a static end product. This emphasis aids in involving all participants in the planning process, contributing substantially to the development of planning recommendations for implementation.

Planning services available at R & M include:

- Community and Regional Planning
- Environmental Planning
- Natural and Cultural Resources Inventory and Analysis
- Recreation, Open Space and Conservation Planning
- Scenic Resources Assessment and Planning
- Environmental Impact Studies
- Land Management, Development Guidelines and Performance Standards
- Site Selection, Evaluation and Feasibility Studies
- Land Use and Transportation Planning
- Urban Design
- Comprehensive Planning
- Zoning, Development Controls and Design Guidelines



POTENTIAL USE

PLANNING & LANDSCAPE ARCHITECTURE

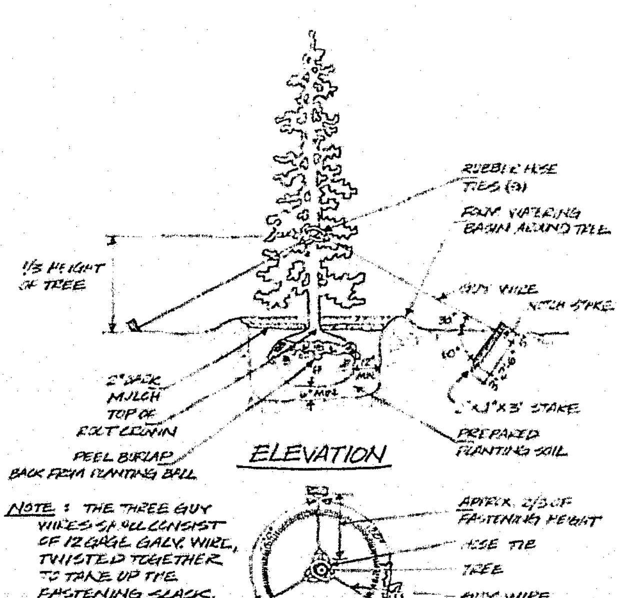
LANDSCAPE ARCHITECTURE

Landscape architectural and site planning activities are concerned with the appropriate arrangement of predefined land uses. The site planning process initially involves site analysis, development of land use program and functional analysis, and then synthesis of land use requirements to site characteristics. This analysis is followed by a schematic design phase, which geographically locates land uses on appropriate areas of the site. A preliminary design phase follows which brings the schematic design to a detailed design level. At this stage, contract drawings and specifications can be developed and finalized. Throughout the construction phase, R & M personnel can provide construction supervision to insure design and construction quality control.

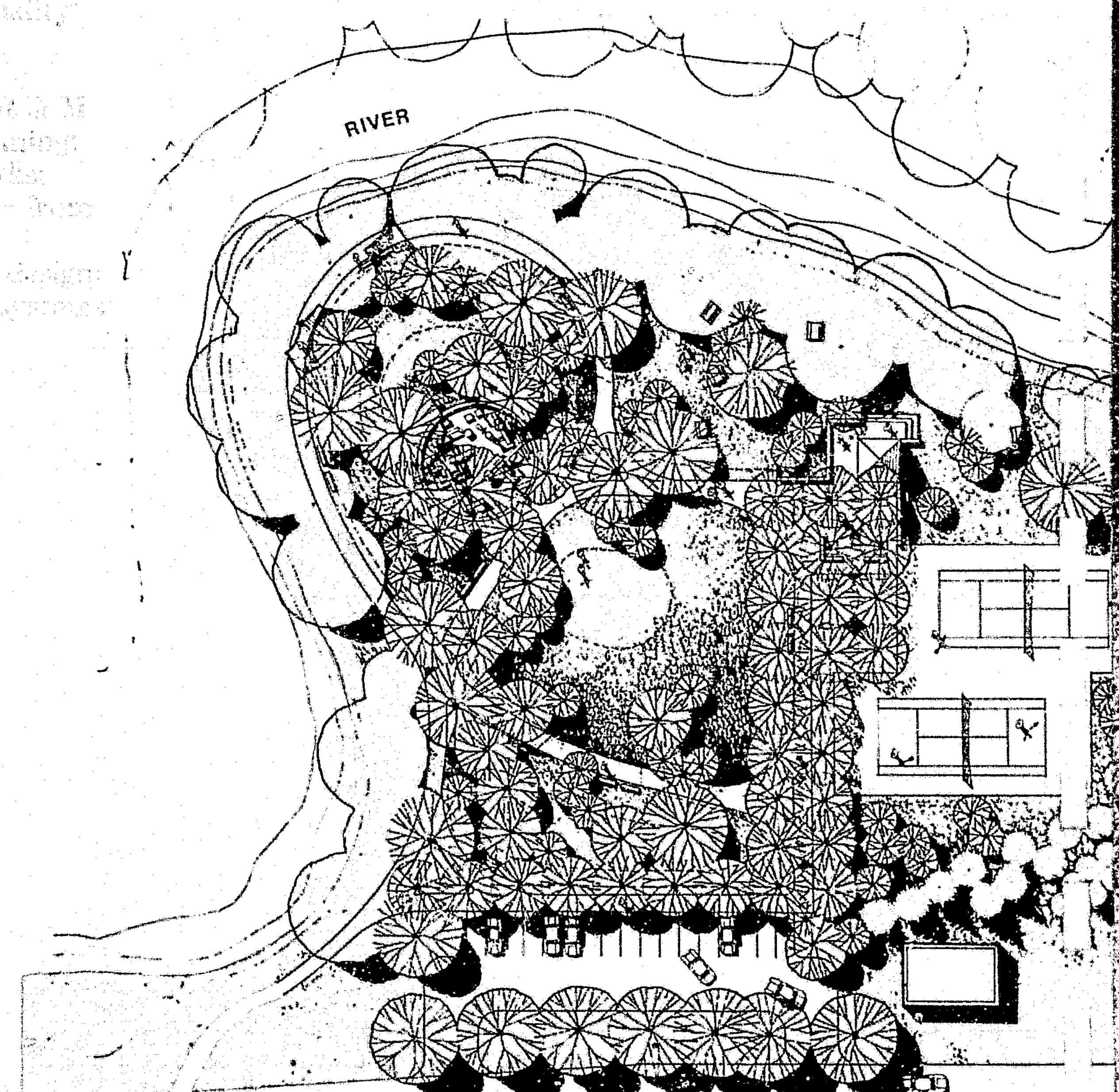
Site planning services are provided by R & M personnel and [illegible] site planning: recreation areas, urban and suburban parks, housing developments of all scales — from individual residences, clusters and developments, to new town and urban design [illegible] and regional parks.

Landscape architectural services provided by R & M include:

- Land Development Planning and Design
- Park and Recreation Design
- Planned Unit Developments
- Visual Impact Assessment and Amelioration
- Site Development Design, Contract Documentation
- Site Construction Inspection
- Site Selection and Analysis
- Feasibility Studies
- Program Analysis and Formulation
- Commercial, Industrial and Institutional Development Design
- Street Furniture and Street Graphics Systems Design



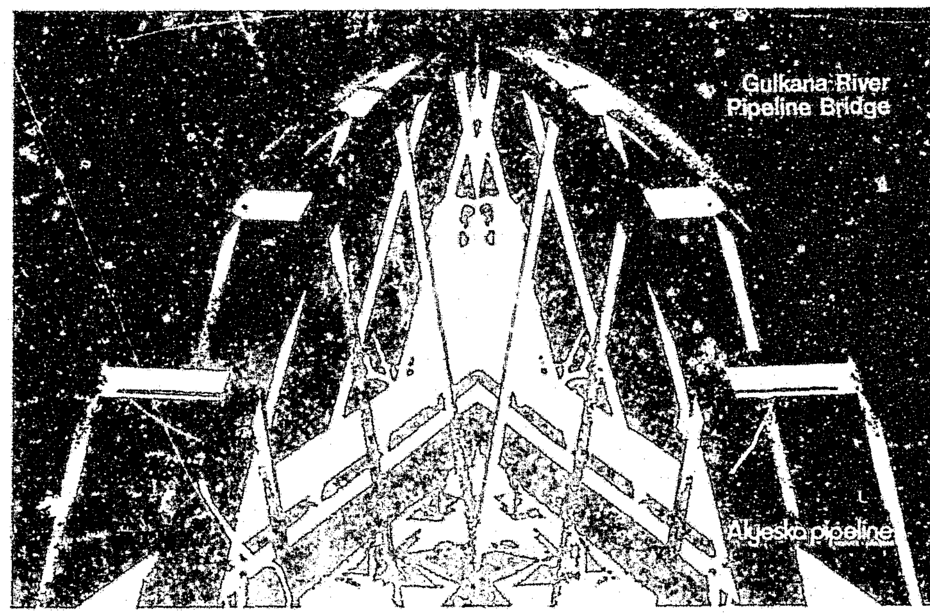
12/1D NON-TRAFFIC TREE PLANTING AND GUYING N.S.

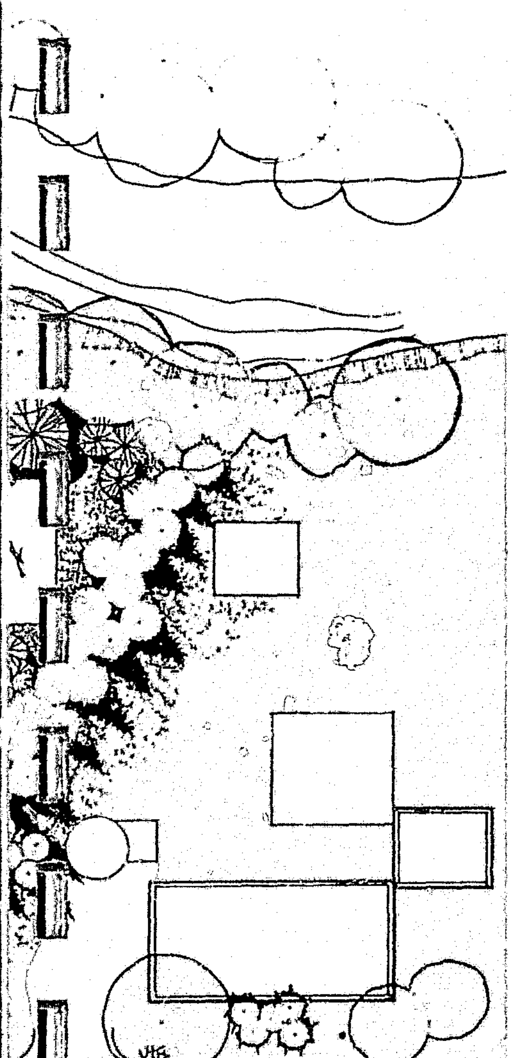


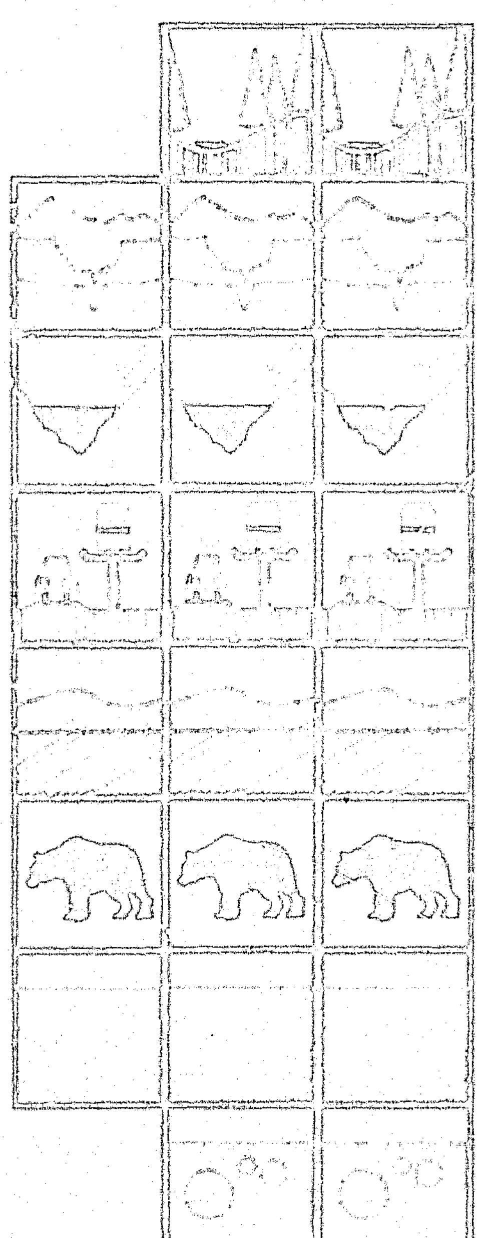
RECREATION PLANNING

PLANNING & LANDSCAPE ARCHITECTURE

VISUAL COMMUNICATIONS & GRAPHICS







The importance of visual communications and the graphic art reproduction of data and report recommendations has become an increasingly valuable client service at R&M as well as an in-house support activity used by all the departments.

R&M graphics personnel are skilled in the design and production of visually communicative elements consisting of symbols, colors, artwork, and typography in conjunction with the creative use of printing materials and photo-mechanical reproduction techniques.

Visual communications services available at R&M include:

- Reports, proposals, and technical paper graphics production
- Photographic media presentations
- Street graphics, sign schemes and user manuals
- Pictograms and logotypes
- Annual Reports
- Corporate identity programs

the drilling company, inc.

SURVEYING
SERVICES

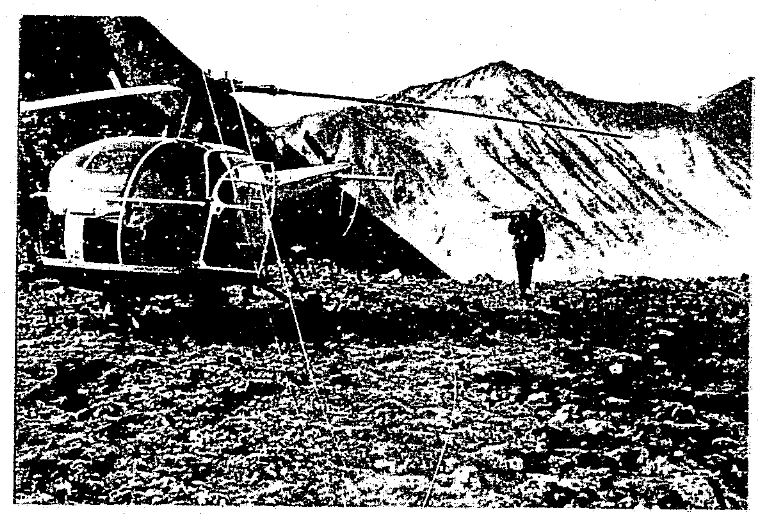
Land Surveying in Alaska and the Arctic provides unique challenges due to accelerated community (urban and rural) development, remote locations, extreme weather conditions, common lack of primary control, elevation changes, and water to land discontinuities. R & M meets these challenges with thoroughly trained surveyors and survey technicians utilizing the most advanced state-of-the-art instrumentation. Employing the most modern instruments and computer systems enables our staff to maintain the required accuracy while promoting, at the same time, survey economies. Survey Services provided by R & M range from individual lot location surveys to extensive geodetic networks. Types of surveys performed by R & M fall into the categories of property, cadastral, mining, subdivision, topographic, aerial, and construction surveying.

**SURVEYING
SERVICES**

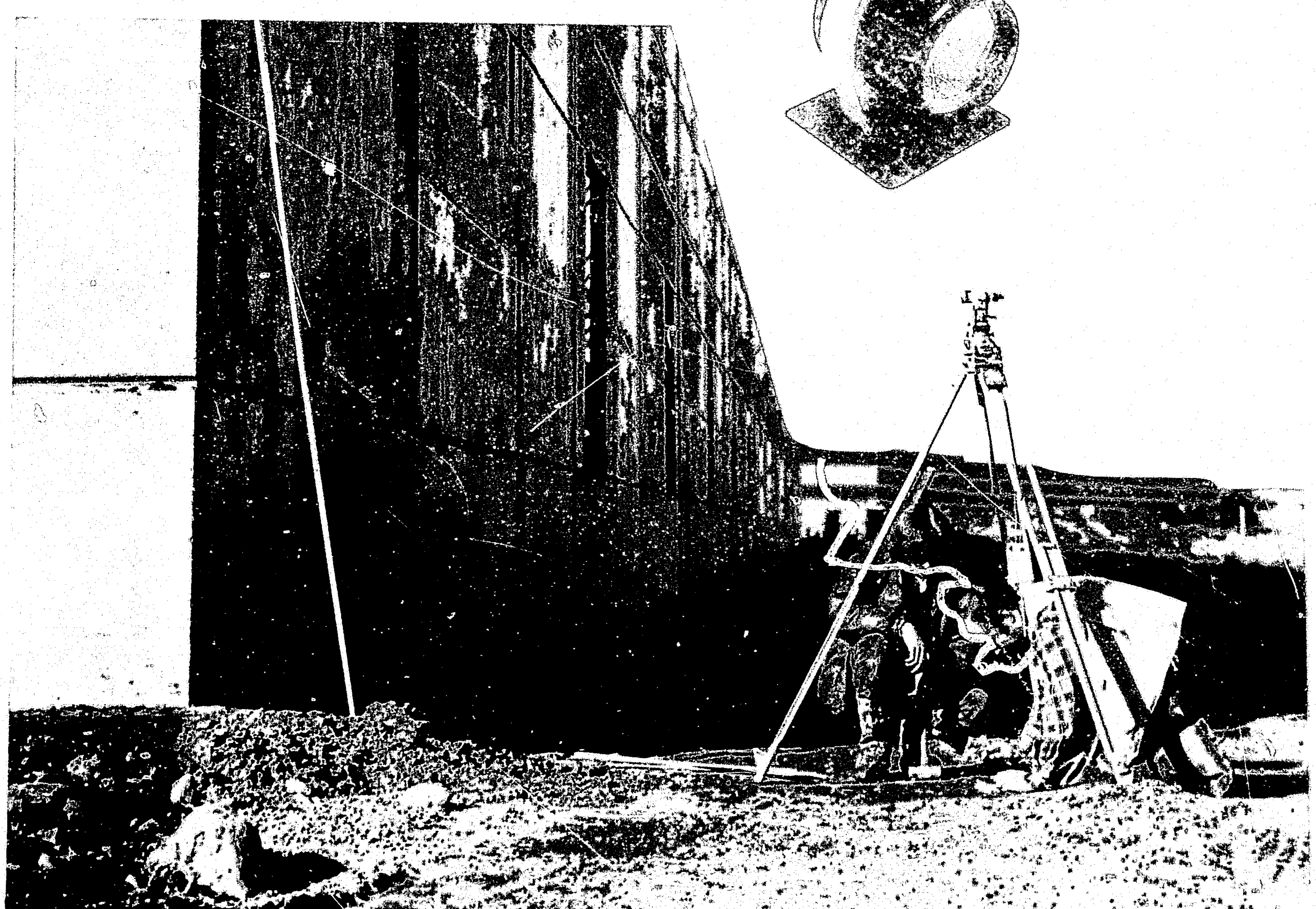
SURVEYING SERVICES

SURVEYING

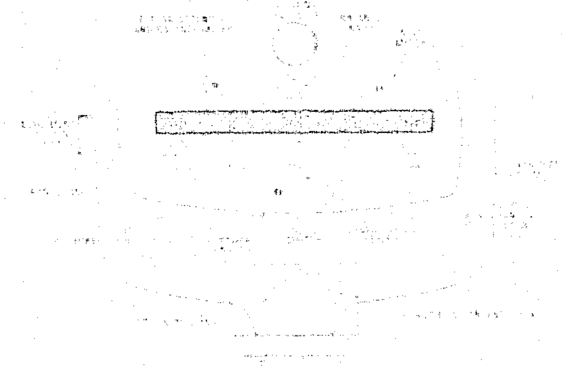
Precision surveying conducted in the most economical manner is a practice our professional survey staff continuously strives to maintain in the provision of services for R & M clients. The advantages obtained from using the most advanced field techniques and instrumentation allow the following specific survey services:

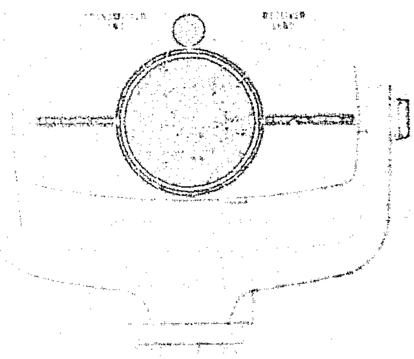


- Land Subdivision and Lot Surveys
- Tideland Surveys
- Topographic Surveys
- Route Location and Bridge Surveys
- Aerial Photo Surveys
- Right-of-Way Surveys
- Photogrammetric Ground Control Surveys
- Borrow Pit and Quarry Site Surveys
- Transmission Line Surveys
- Construction Measurement Surveys
- Hydrologic Surveys
- Tunnel Surveys
- Navigational Surveys
- Cadastral Surveys



SURVEYING SERVICES
SURVEYING





MATERIALS & TECHNICAL SERVICES

R & M's Technical Services Department is organized to permit the firm to respond to a full range of engineering and testing requirements.

Thoroughly experienced materials technicians, geologists, and field engineers have operated extensively in Alaska and in the Arctic's diverse physical environments. Services have been performed in major metropolitan areas, i.e., Anchorage, Fairbanks, and Juneau, and at remote Alaskan communities and villages.

MATERIALS & TECHNICAL SERVICES

MATERIALS & TECHNICAL SERVICES

MATERIALS & TECHNICAL SERVICES

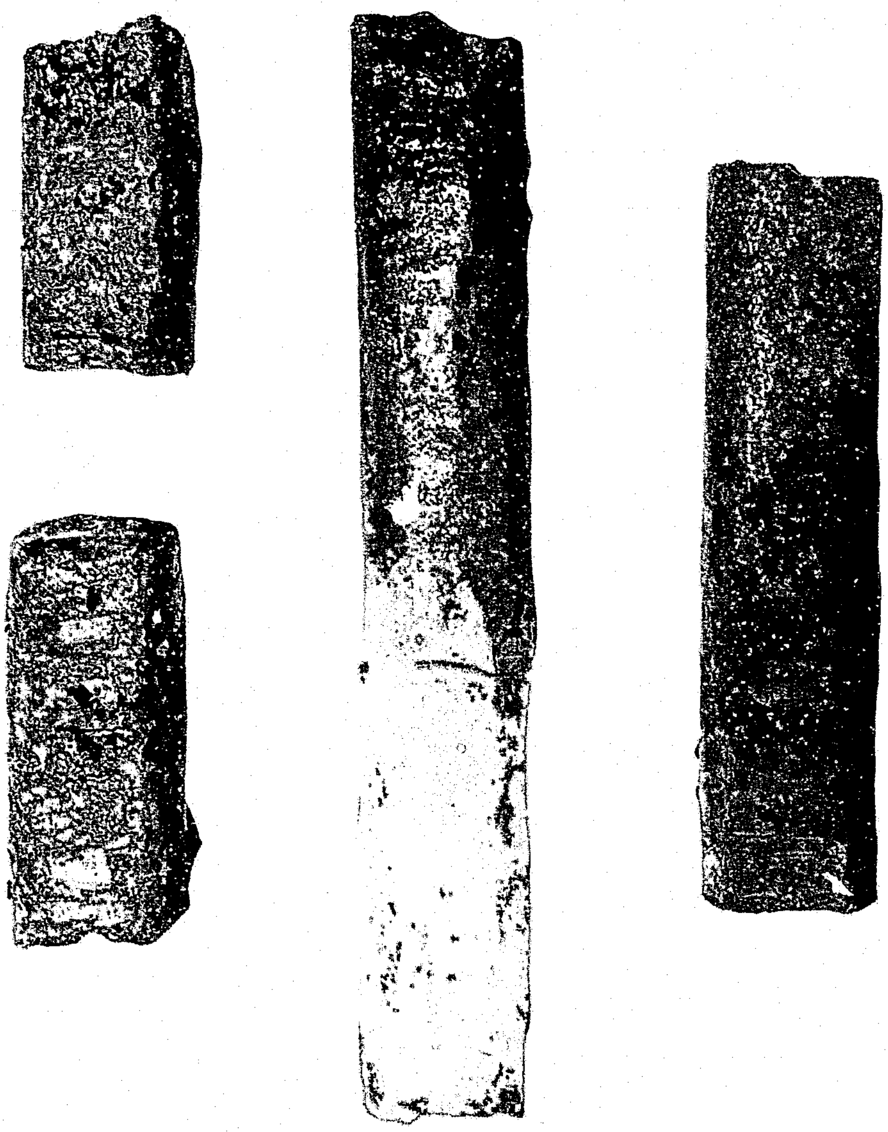
MATERIALS ENGINEERING

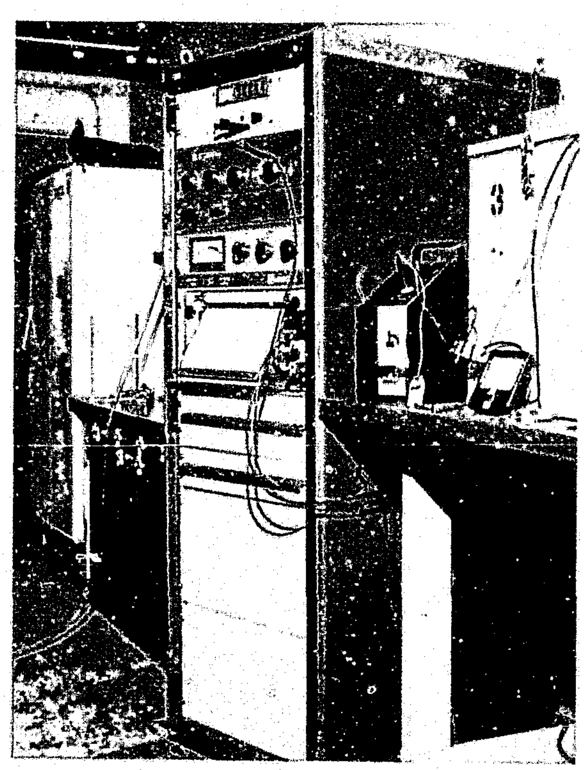
Our Materials and Technical Services involve us in the functions of field investigations and laboratory testing.

The successful performance of field investigations requires principally an in-depth understanding of critical logistical and climatic problems which affect performance efficiency as well as equipment maintenance and repairs in the field.

R & M's accomplishments in the field have been realized, in part, through the coupling of experienced personnel to flexible, responsive organization.

R & M Consultants, Inc. maintains modern laboratory facilities and testing equipment. These services are available independently of or in association with our own Engineering, Arctic Engineering, Geological, Environmental, and applied research endeavors. Services include soil, rock, and materials testing, as well as chemical analysis.



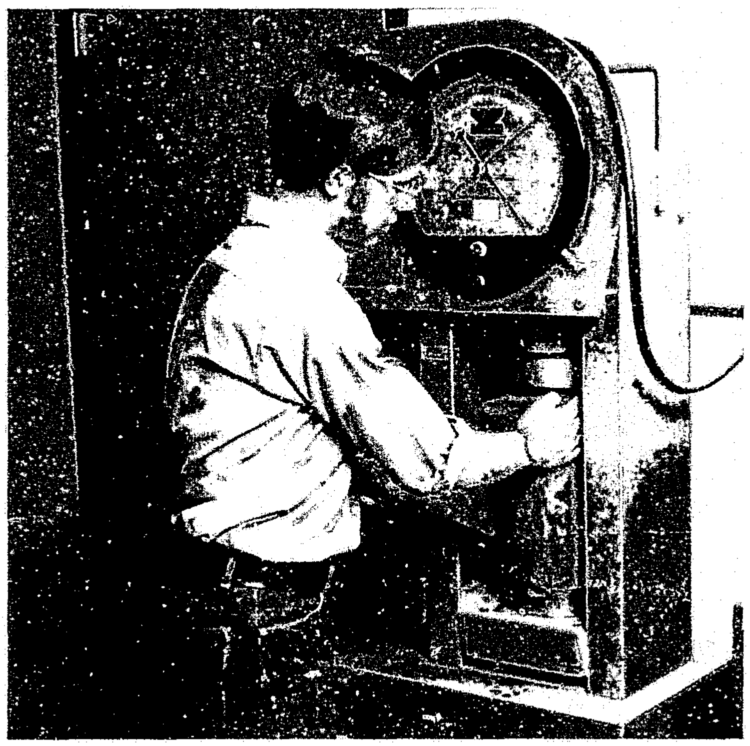


MATERIALS & TECHNICAL SERVICES

TECHNICAL SERVICES

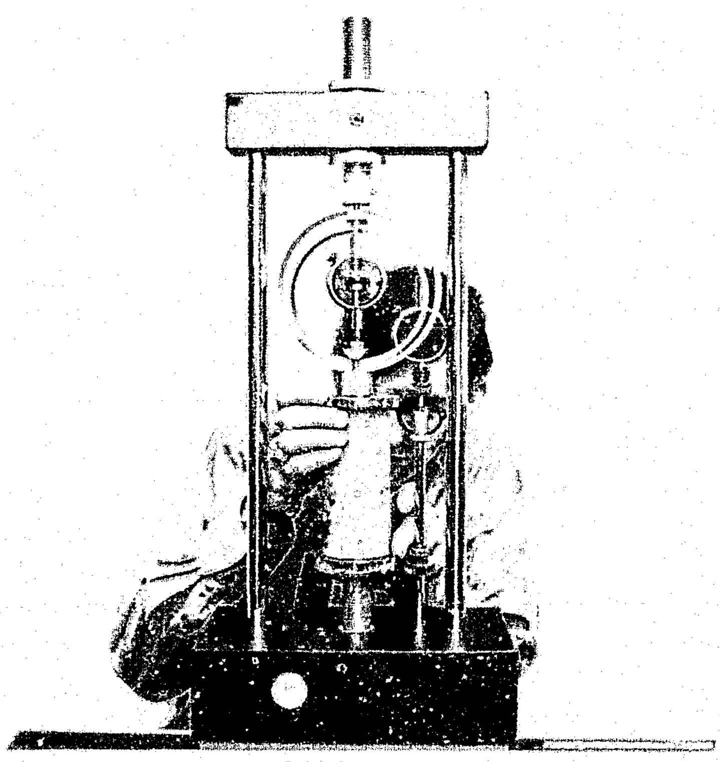
Testing equipment is maintained for conducting standard and frozen soil tests, and our laboratories are also equipped to perform physical tests on soils such as:

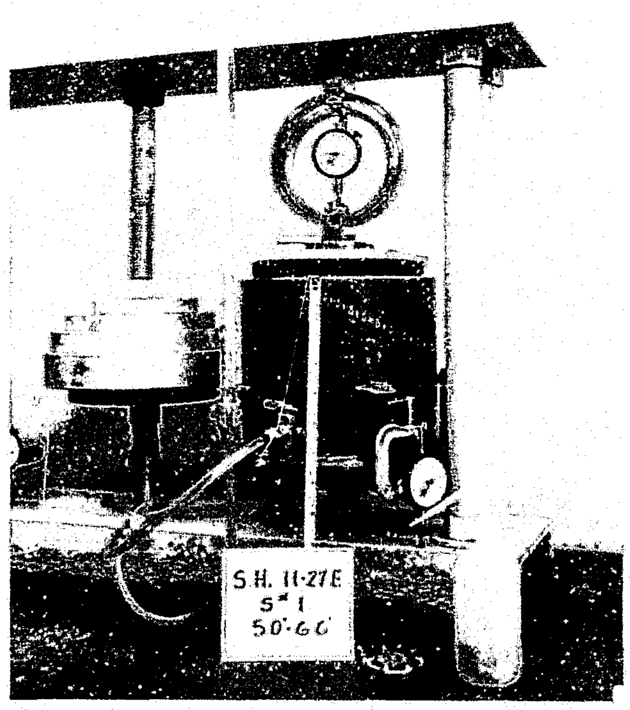
- Triaxial Shear
- Consolidation
- Unconfined Compression
- Permeability
- Thermal Conductivity



Asphalt, concrete, and aggregate testing equipment includes, in addition to all necessary equipment, for complete laboratory analysis and field testing:

- Compression Machines
- [illegible] testing Machines
- Sieve Shakers
- [illegible]





SPECIAL AREAS
OF SERVICE

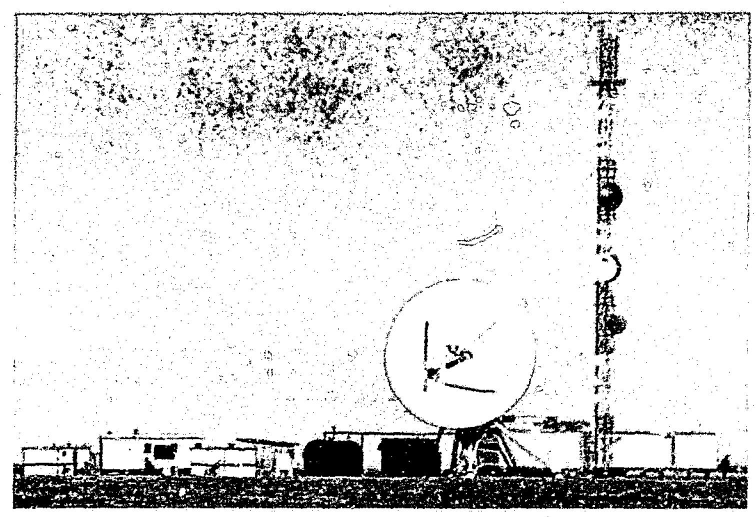
SPECIAL AREAS OF SERVICE

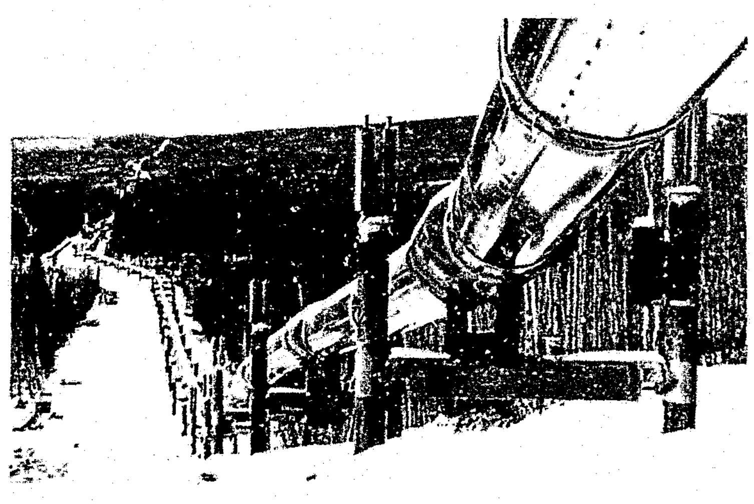
Some of the services provided by R & M cannot be easily categorized under the conventional classifications used to identify service potential within particular fields. Although it is sometimes not possible to completely convey the full scope of one's service capability and performance, particularly to accommodate ever-present changes, this section represents an attempt to adequately treat, in some measure, other services being performed by our firm.

SPECIAL AREAS OF SERVICE

SPECIAL AREAS OF SERVICE

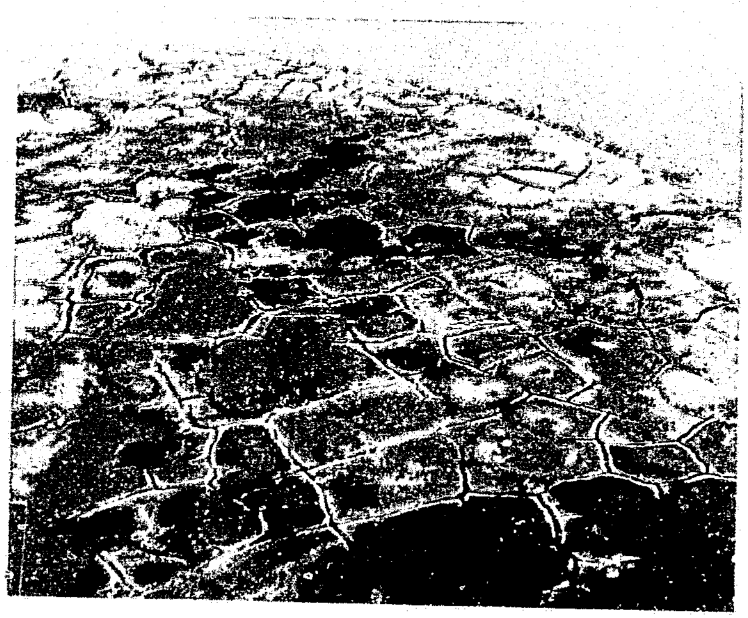
NORTHERN DEVELOPMENT ENGINEERING





SPECIAL AREAS OF SERVICE
NORTHERN DEVELOPMENT ENGINEERING

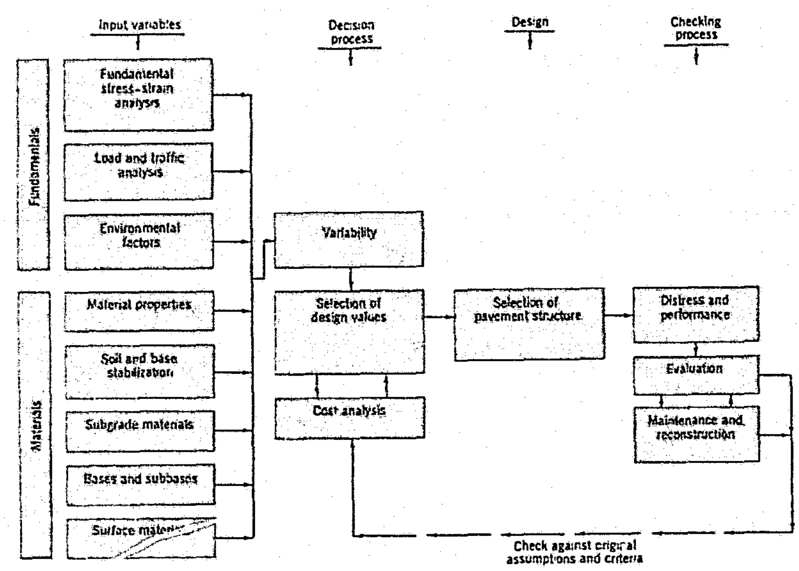
Arctic and subarctic regions of Alaska and Canada constitute an area of special concern at R & M because these regions have unique conditions which commonly require more than a conventional engineering solution. Soils, geology, permafrost, climate, and the increasing general awareness of the special requirements for this environment are a few of the conditions which demand a specifically altered engineering approach. R & M personnel have extensive experience in developing solutions related to Engineering, Planning, Surveying, Geology, and environmental problems in arctic and subarctic regions.



SPECIAL AREAS OF SERVICE

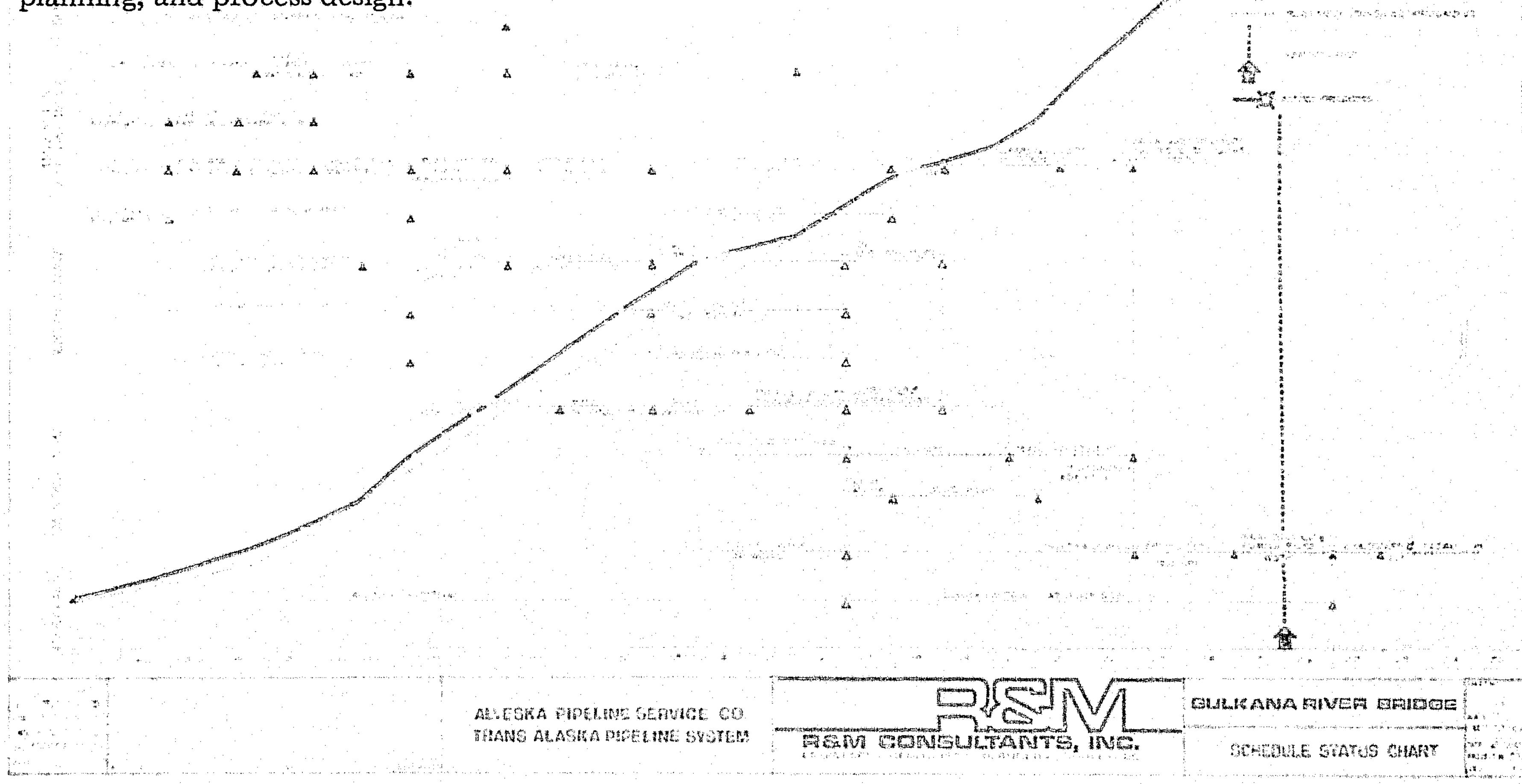
SYSTEMS ENGINEERING & CONSTRUCTION MANAGEMENT

The successful execution of large, complex projects — involving multidiscipline efforts — requires the application of systems engineering methodologies. The "systems analysis" approach has become an integral ingredient for design and development solutions in Alaska. Experience with projects involving the coordination of people, materials, and schedules in remote and urban areas has produced a broadly based technology which is applied at R & M Consultants to Engineering, Geotechnical, and Planning projects. We offer this technology as a service to our clients because of its demonstrated capacity to produce project economies. Complex projects, whether in inaccessible areas or in major urban settings, have common features in logistics, scheduling, and cost control which are managed optimally by a systems engineering approach.



Principles involved in the design process.

As applied to construction projects, Systems Engineering is termed Construction Management; R & M personnel are thoroughly experienced in this field. Other Construction Management Services offered by R & M include inspection and quality control, project planning, and process design.

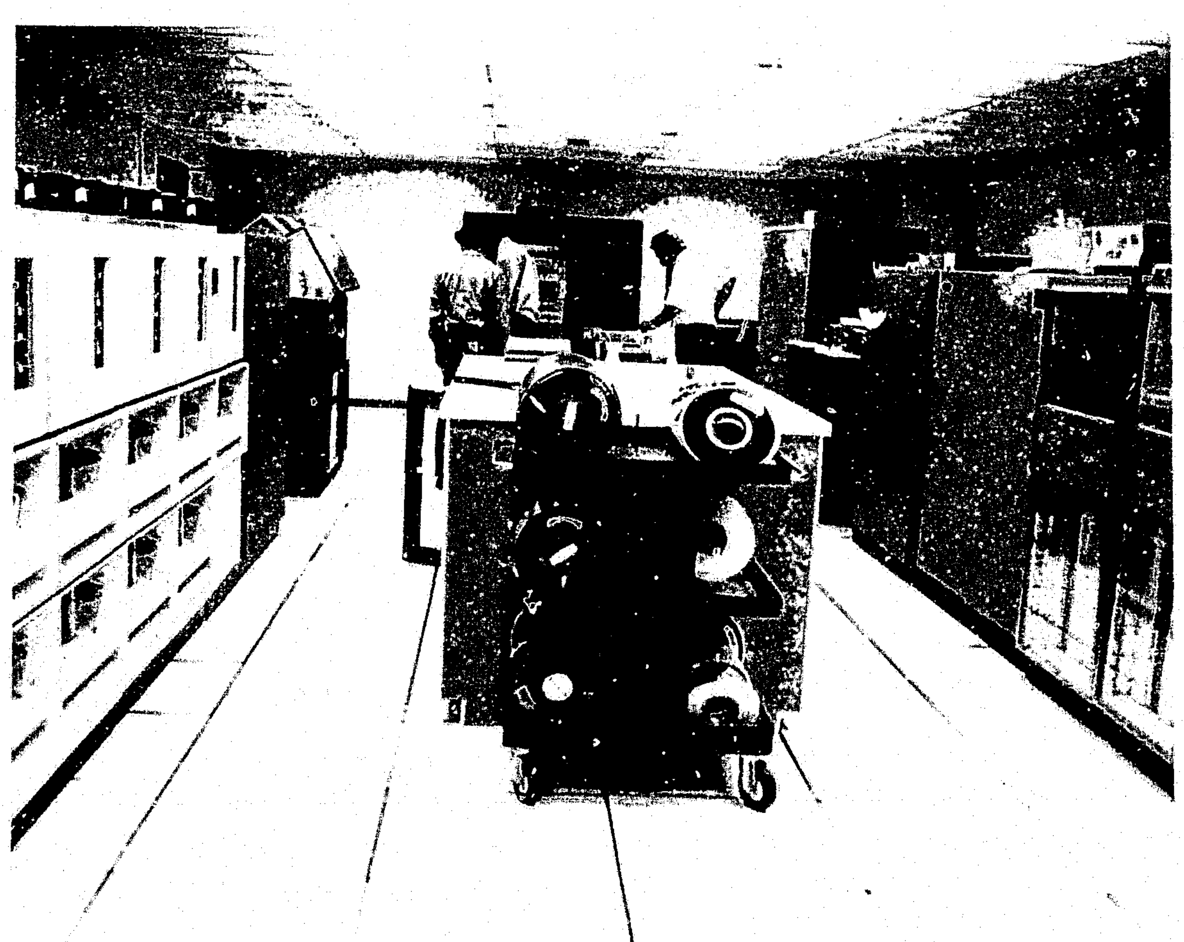


SPECIAL AREAS OF SERVICE

ELECTRONIC DATA PROCESSING

R & M possesses an in-house computer system with tie lines between the principal offices. This capability provides a valuable resource and tool for performing services in Engineering, Survey, Planning, and Business applications. A complete staff of systems designers, programmers, and operators allows efficient utilization of this resource on a variety of projects and supporting tasks. Our computer services are also available to other user firms.

Systems have been developed by R & M computer specialists for the Trans Alaska Pipeline System that have involved the storage, retrieval, and analysis of extremely large quantities of technical information. Computer applications have involved the firm in the design and operation of management information systems constructed to solve project related work.



REPRESENTATIVE CLIENT LIST

INDUSTRY

Construction

A & G Construction
Alaska Aggregate Corp.
Alaska Asphalt Paving
Alaska Constructors
Alaska Excavation Contractors
Alaska General Haskell Amelco
Alaska International Construction
Alaska Redi-Mix Inc.
Allied Concrete Co.
Anchorage Sand & Gravel Inc.
Barnett Construction
Baugh Belarde Construction Co.
Bona Fide Contractors
Brady Construction, Inc.
C & R Builders
Central Construction Co.
Christian Construction Co.
Cook Inlet Asphalt
Dawson Construction Co.
Earth Movers of Fairbanks
Fairbanks Builders
Federal Construction Co.
Ghemm Construction
Green Construction Co.
Hazard Phelps Construction
Hilton Sand and Gravel
Howard Lowe Construction Co.
Joe's Trucking
John Wayne Construction Co.
L. B. Anderson Construction Co.
Landbrook Construction
M-B Construction
Manson & Osberg Construction Co.
McNabb Construction Co.
Modern Construction
NANA Construction Co.
Northwestern Construction
Pacific Construction Company
Pacific-[illegible] Construction Company
Paving Products, Inc.
Peninsula Excavation Company
Peter Kiewit & Sons
Rivera General Construction Co.
Rogers and Babler Construction Co.
S & S Contractors
Stevens Construction Co.
Spruce Construction
Stephan & Sons
Taku Construction
Tate & Company Contractors
T. G. Paddock Construction
Triplett Construction Co.
Western & Associates, Inc.
Woodland Construction

INDUSTRY

Industrial Development

Alaska Electric Light & Power Co.
Alaska Lumber & Pulp Co.
Alcan Pipeline Co.
Alyeska Pipeline Service Co.
Anchorage Natural Gas
ARCO
Cities Service Oil Company
City of Anchorage-Municipal Light and Power
Exxon USA
Gas Arctic/Northwest Project Study Group
Gulf Interstate
Hamilton Brothers Oil Company
Juneau-Douglas Telephone Company
Mobil Oil Corporation
Municipal Utilities System - City of Fairbanks
Noranda Exploration, Inc.
Pipeline Technologists Inc.
Resource Exploration Consultants, Inc.
[illegible]-Wrangell Lumber Company
[illegible] Lumber and Pulp Company
Tesoro Oil Corporation
The [illegible] Co., Inc.
Union Oil of California
U. S. Underseas Cable Corporation
White Pass and Yukon Railway

INSTITUTIONAL

Alaska [illegible] Federal Credit Union
Alaska Federal Savings & Loan
Alaska National Bank
Alaska State Bank
Bank of Petersburg
[illegible] Memorial Institute
B.M. Behrends Bank
Church of Jesus Christ of Latter Day Saints
First Federal Savings and Loan
First National Bank of Anchorage
Mt. McKinley Savings and Loan
National Bank of Alaska
St. Patrick's Catholic Church
University of Alaska

REPRESENTATIVE CLIENT LIST

INDUSTRY

Private and Commercial Development

Ahtna Corp.
Alaska Federation of Natives
Alaska Pacific Ventures
Alaska State Housing Authority
Alpac Corp. (Pepsi Cola)
Blomfield and Associates
Bristol Bay Native Corp.
Calais Corp.
CCC/HOK
CH2M-Hill
Cook Inlet Native Association
J. D. Coolidge
Dames & Moore
Design Group
DNH Development Corp.
DOWL Engineering
Development & Resources Transportation Co.
Ellerbe Alaska
Explosives Corporation of America
George Filler & Associates
Graham Associates Architects
Gray, Rogers, Myers and Morgan
Harold Wirum, Architect
Hickel Investment Corporation
John Graham & Associates
K & L Distributors
Kenai Lake Lodge, Inc.
Knik Village Corporation
Koniag Native Association
Lane, Knorr & Plunkett
Lion Forest & Associates
Longs Drug Stores
Midnight Sun Broadcasters
M.K. Mathews
Modern Electric, Inc.
Mukluk Freight Lines
NANA Development Corp.
Nancy Lake Marina, Inc.
Northern Commercial Co.
Northwest Design Associates
Philco Engineering Co.
Polar Realty
RCA Service Co.
Ryan & Haworth
Scott & Schneider
Seth Yerrington Architects
Sitnasuak
Stack Steel
Taylor Marina
Tryck Nyman & Hayes
Tudor, Kelly & Shannon
W. J. Wellenstein, Architect
Westbrook-Jansen Architects
Y.M.C.A.

GOVERNMENT

Federal

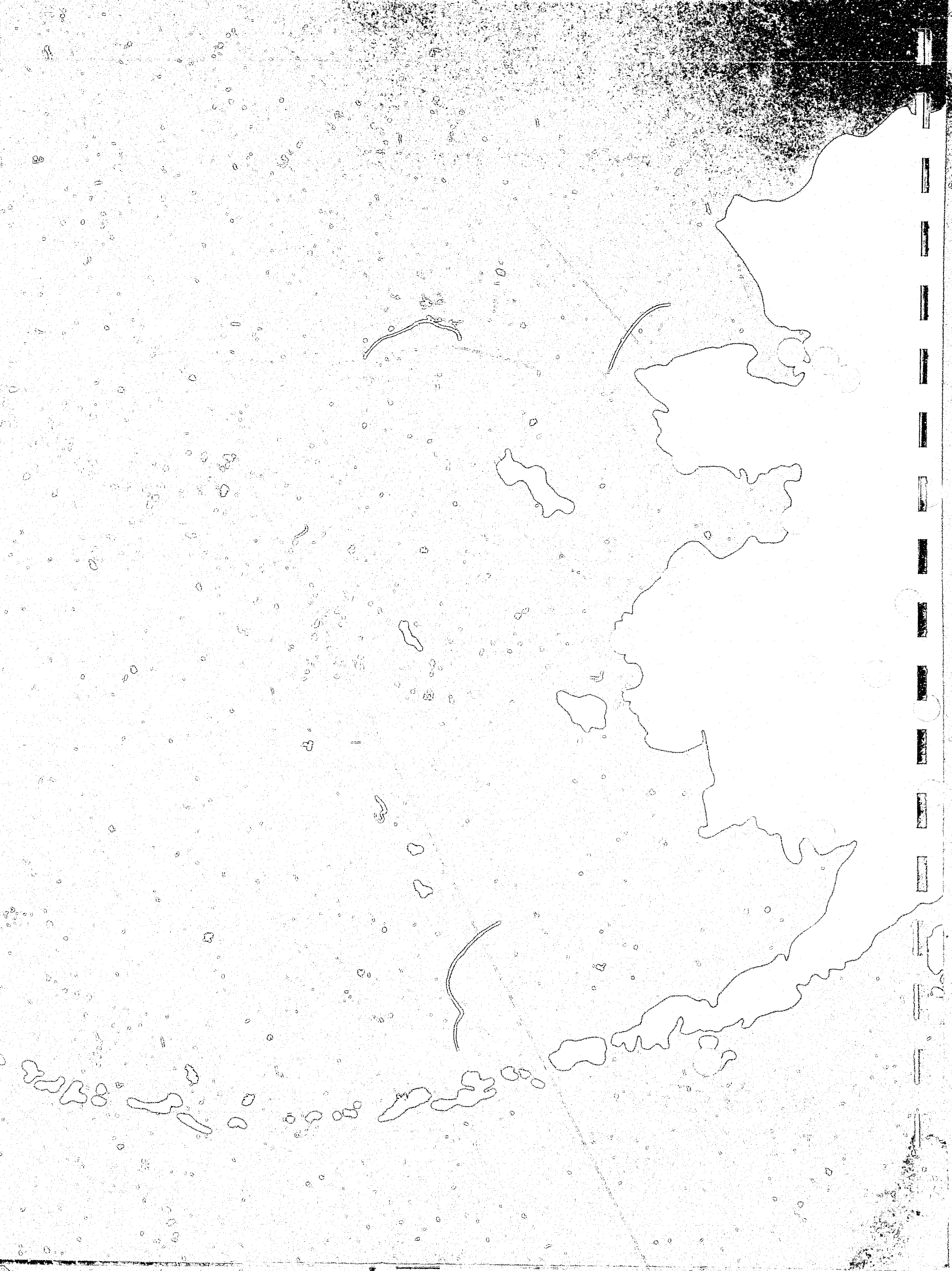
Air Force
Army Corps of Engineers
Bureau of Land Management
Bureau of Mines
Coast Guard
Department of Agriculture
Department of Commerce
Department of Interior
Department of Navy
Department of Transportation
Federal Aviation Administration
Federal Highway Administration
Federal Housing Administration
Forest Service
General Services Administration
Geological Survey
Housing and Urban Development
Post Office Department
Public Health Service
Veterans Administration

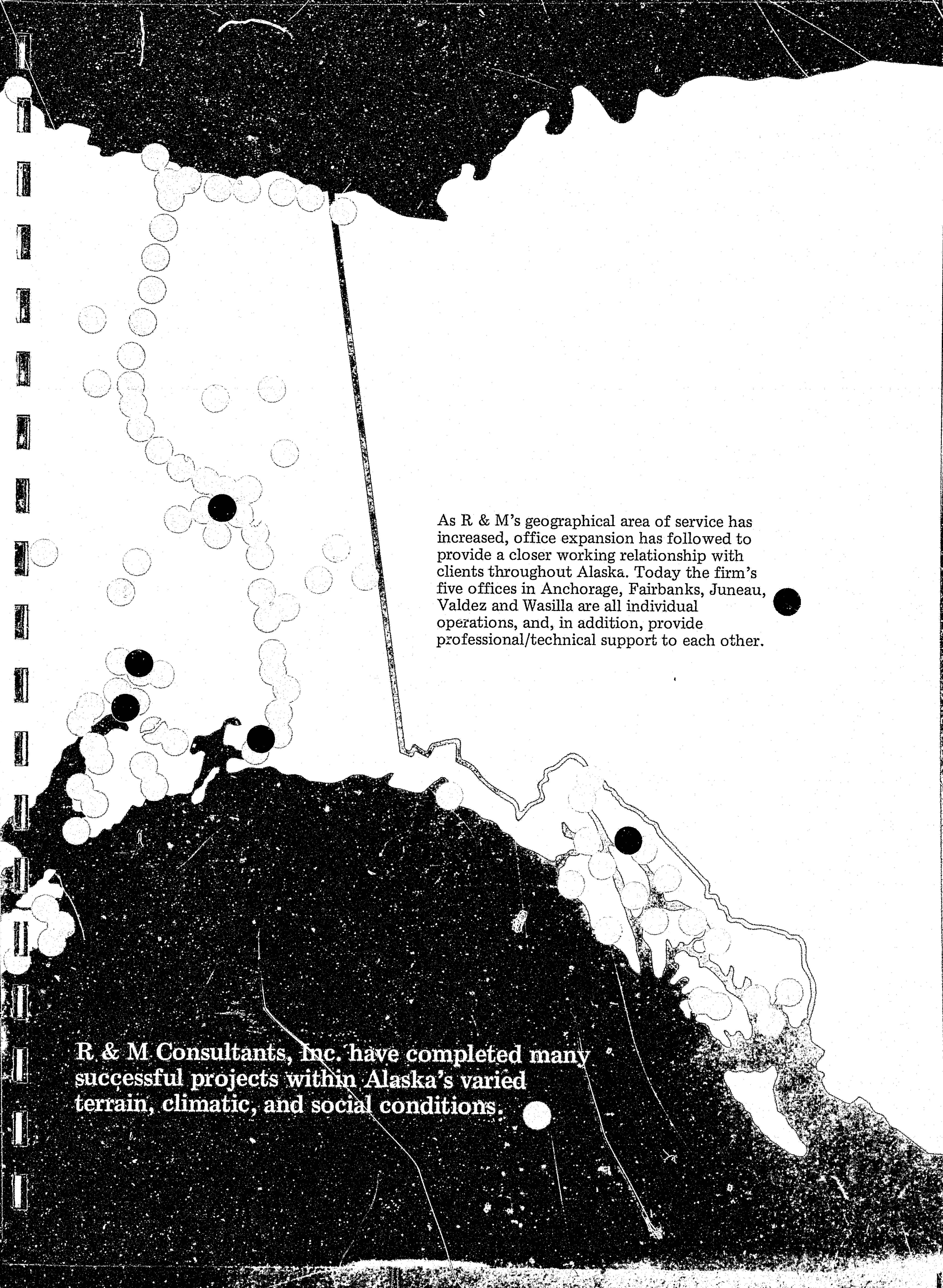
State of Alaska

Department of Commerce
Department of Community and Regional Affairs
Department of Environmental Conservation
Department of Fish and Game
Department of Highways
Department of Natural Resources
Department of Public Works
Division of Aviation
Division of Buildings
Division of Waters and Harbors
Office of the Governor
Pipeline Coordinators Office

Local

City and Borough of Juneau
City of Fairbanks
City of Haines
City of Homer
City of Kake
City of Ketchikan
City of Pelican
City of Soldotna
City of Valdez
City of Wasilla
Fairbanks – North Star Borough
Greater Kenai Borough
Ketchikan Gateway Borough
Mat Su Borough
Municipality of Anchorage





As R & M's geographical area of service has increased, office expansion has followed to provide a closer working relationship with clients throughout Alaska. Today the firm's five offices in Anchorage, Fairbanks, Juneau, Valdez and Wasilla are all individual operations, and, in addition, provide professional/technical support to each other.

R & M Consultants, Inc. have completed many successful projects within Alaska's varied terrain, climatic, and social conditions.

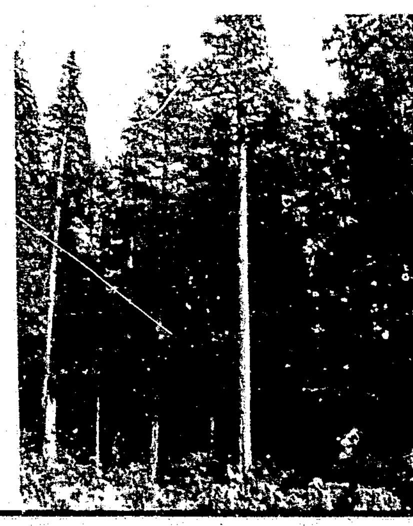
R & M Consultants, Inc. is a financially independent organization which is privately held by the officers and associates of the firm. R & M's corporate officers are Ralph R. Migliaccio, founder and president, Malcolm A. Menzies, vice-president, James W. Rooney, vice-president, and James H. Wellman, secretary-treasurer.

Ralph Migliaccio assumes major responsibility for corporate management and directs all geological studies in the Fairbanks office. He has a B.S. degree in Geology from Brigham Young University and he has taken advanced studies in Engineering Management at the University of Alaska. Mr. Migliaccio has performed numerous geotechnical and geological studies and he has served as special consultant on major projects including the hot oil Trans Alaska Pipeline System and cold gas line studies. He has authored many technical papers and he has been accorded national recognition for his work in the geotechnical field. He is a member of the Association of Engineering Geologists, American Institute of Professional Geologists, Highway Research Board, and the American Association for the Advancement of Science. He is a member of the Fairbanks City Council, past area commander for the Civil Air Patrol, and presently on the Board of Directors for both the Fairbanks and State Chamber of Commerce.

James Wellman shares responsibility for the direction of the Fairbanks office where he is the principal directly in charge of all civil engineering and land surveying projects. Mr. Wellman is a graduate of Oregon State University where he took degrees in Civil Engineering, and in Business and Technology. Mr. Wellman's early professional experience was gained in transportation engineering with the Alaska State Highway Department. Joining R & M with Malcolm Menzies in 1969, he assumed joint responsibility with him for the direction and engineering effort involved in the initial 56 miles of Alyeska's pipeline haul road, and he has been involved both in criteria development and engineering review of earthwork and grading design for the pipeline system. His experience in private consulting includes major civil engineering and surveying projects. Notable expertise and competence have been demonstrated by Mr. Wellman in the area of engineering problems associated with arctic and subarctic conditions. He is a member of the American Society of Civil Engineers, the American Congress of Surveying and Mapping, and the American Society of Photogrammetry.

James W. Rooney serves as corporate vice-president and is the principal in charge of the direction of the Anchorage office. He earned his undergraduate and graduate degrees in Civil Engineering from Wayne State University while specializing in soil mechanics and planning. Previous professional experience includes 12 years in private practice, and four years in public service. Mr. Rooney has been a special consultant for the hot oil Trans Alaska Pipeline System and for gas pipeline studies. His knowledge and experience in planning, civil engineering, and geotechnics have qualified him for repeated service on major projects and as an expert witness in legal matters. Mr. Rooney has attained prominence in the solution of engineering problems related to arctic and subarctic soil conditions. He is a member of the National Society of Professional Engineers, American Society for Testing and Materials, the Transportation Research Board and the American Society of Civil Engineers. Also, he is currently serving as a member of the Geotechnical Commission for the Municipality of Anchorage.

Malcolm Menzies shares corporate management responsibilities as vice-president and he is the principal in charge of the direction of the Juneau office. He holds a [illegible] degree in Civil Engineering from Chicago Technical College and he is a registered professional civil engineer and land surveyor. Joining R & M in [illegible] to perform engineering functions connected to the design, survey, and construction supervision of the initial 56 miles of the Alyeska Pipeline Haul Road, Mr. Menzies has since been active with major engineering and survey projects. His knowledge and experience in civil engineering and surveying have allowed his participation on a series of special projects in addition to serving as expert witness on land surveying and contract claims. Mr. Menzies has also been a member of the Juneau City and Borough Planning Commission, the National Society of Professional Engineers, the American Society of Civil Engineers and the Alaska Society of Professional Land Surveyors. As an active member of the American Congress of Surveying and Mapping, he has written for their publication several papers related to surveying systems in Alaska.



R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

Woodward-Clyde Consultants

Consulting Engineers, Geologists, and Environmental Scientists

Woodward-Clyde Consultants is a firm of professionals practicing in geotechnical engineering, and in the earth and environmental sciences. We undertake assignments worldwide, ranging from individual consulting to multidisciplinary team efforts.

Founded in 1950 by three partners as a consulting practice in soil and foundation engineering, the firm has expanded from a single office serving the San Francisco Bay Area, to a firm with offices throughout the United States.

Our principal objective has been to provide our clients with consulting services of high professional standards and technical competence. This has been accomplished by bringing together leading professionals in the particular disciplines and specialties that constitute our practice, and supplementing this group with well-trained technical staff members, state-of-the-art laboratories and field instrumentation, and active programs of professional development.

Whether your project is small or large, a principal of our firm is charged with the overall management responsibility. Project staff is organized and assembled, drawing on skills of staff members in other offices, if the job requires. Our companywide quality assurance program is applied to all portions of our professional practice and technical support services.

Presently, our consulting staff consists of approximately 550 professionals, most of whom hold advanced degrees in their specialization. Our staff members have authored or coauthored many technical papers and reports, and other contributions include three texts entitled *Earth and Earth-Rock Dams, Drilled Pier Foundations,* and *Age Dating of Geologic Materials.*

To convey the scope of our practice, a description of our capabilities is presented in the following pages and includes:

Engineering Services
- Geotechnical Engineering
  - Foundation Engineering
  - Earthquake Engineering
- Mining Engineering

Earth Sciences
- Geology and Seismology
- Hydrogeology
- Terrestrial and Marine Geophysics

Environmental Studies, Systems Analyses, and Planning

Other Technical Services
- Laboratory Services
- Field Instrumentation
- Earthquake Data Bank
- Remote Sensing
- Research and Development

Special capabilities are described more completely in our supplementary brochures and *Statements of Capabilities.*

Our services are offered to assist you in developing innovative, practical, and cost-effective solutions to your problems, whether related to construction, resource development, or environmental considerations.

When either your project or activities require the types of services we can provide, we would be pleased to discuss your needs with you.

Engineering Services

Geotechnical Engineering

Changes in the earth's surface resulting from construction activities, whether altering a surface feature, excavating an underground cavity, or applying external static or dynamic loadings, must be studied to predict their effects and to provide engineering solutions to potential problems. Nature-induced occurrences, such as areal subsidence, landslides, and earthquakes, must also be fully considered. This is the role of geotechnical engineering.

We have provided geotechnical engineering services for a wide range of earth-related structures, including foundations for buildings and bridges, earth dams and embankments; excavations and underground cavities; offshore and harbor facilities; pipelines and transmission lines; highway and airfield pavements; reservoir and canal linings; residential and commercial developments; hydroelectric, fossil-fueled, and nuclear power plants; and industrial plants and refineries.

The types of services we provide include:

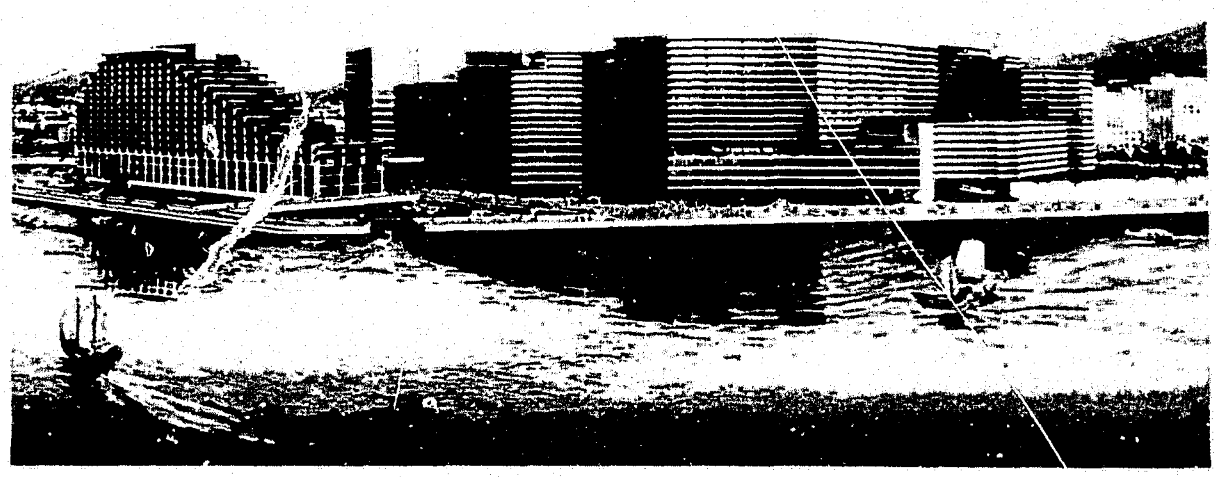
Soil Investigations
Field explorations and sampling
Laboratory testing
Engineering analysis
Design recommendations

Soil Stabilization Studies
Design of stabilization systems
Wind and water erosion, and dust control studies

Soil Dynamics Analyses
Consultation on vibration problems
Wave-propagation analysis
Field measurement of in-situ soil moduli

Frozen Soil Engineering and Cryogenics
Laboratory tests and studies on frozen material
Foundation design recommendations for permafrost conditions
Field investigations in arctic locations
Underground, cryogenic, gas-storage studies

Artist's Rendering of New World Centre, Hong Kong



Field Measurements

Planning, placing, and monitoring systems, using piezometers, pressure cells, and tiltmeters
Measurement of porewater pressure, vibrations and movements in earth masses, rebound in excavations, and fault creep
Borehole photography
Instrumentation program design
Shear-wave velocity measurements

Construction Consultation

Guide specifications
Location and quality evaluation of materials
Prebid evaluations on borrow areas, dewatering, underpinning, and shoring
Consultation on contract claims
Contract administration
Field inspection of pile driving and earthwork

Rock Mechanics Studies

Field tests and investigations of in-situ conditions
Consultation on rock reinforcement
Engineering analysis and research studies on stability, stresses, and rock properties
Special laboratory studies and tests

Earthquake Investigations

Engineering seismicity and seismic geology
Fault investigations
Development of ground response spectra and acceleration time histories
Assessment of soil failure potential
Stability evaluation of earth dams and slopes
Soil-structure interaction studies
Earthquake risk assessments

Pavement, Lining, and Membrane Studies

Engineering properties of paving materials
Evaluation of existing pavements
Design of pavements for highways and airports
Development of pavement management systems
Design of linings for canals and reservoirs
Research studies in the design of pavement systems
Design of waterproof membrane systems

Foundation Engineering

Foundations for ground-supported structures function to transfer structural loadings to the underlying soil and rock formations, generally within certain constraints of allowable structure movement or ground disturbance. To assist our clients in selecting, designing, and constructing the most technically suitable, practical, and cost-effective foundations for their projects, the following types of studies are undertaken:

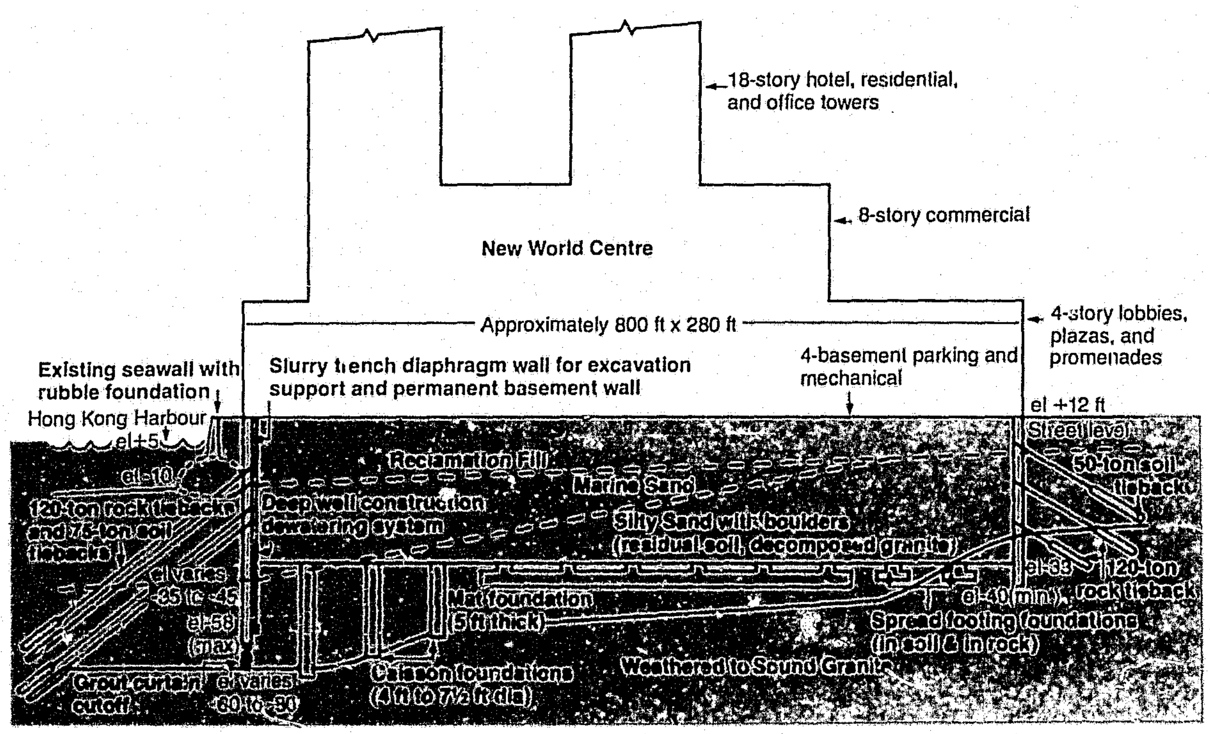
Evaluation of regional geologic features for their potential affects on the site

Exploration of site-specific ground conditions by coring and sampling procedures or in-situ testing

Characterization of the soil and rock properties by carrying out appropriate field and laboratory tests

Analysis of all factors and specific recommendations for foundation design parameters and construction-related constraints.

Generalized subsurface conditions and foundation schematic.



New World Centre, a waterfront complex of hotels, business offices, apartments, parking facilities, shopping mall, and promenades, is being constructed on the tip of Kowloon Peninsula overlooking Hong Kong Harbor and Hong Kong Island. As geotechnical consultant to the New World Development Company, Ltd., Woodward-Clyde Consultants reviewed the preliminary subsurface explorations and designed additional subsurface investigation programs. Assistance in developing a slurry trench diaphragm wall and tieback supporting scheme was provided to the architect, Skidmore, Owings and Merrill. Some of our other responsibilities included directing the field tieback testing program, providing design parameters for the construction dewatering system, and selecting foundation design criteria.

Earthquake Engineering

Earthquake engineering is a practice within geotechnical engineering that involves two broad classes of studies: (1) evaluation of the characteristics of ground shaking for which an engineered structure should be designed, and (2) evaluation of the potential for ground failure (e.g. landslides, liquefaction, settlement, or rupture) caused by earthquake forces. Assessment of the seismic environments, including magnitudes and distances of potential earthquakes, are made by our seismic geologists and seismologists. The earthquake engineering studies are then made, using various procedures, including field and laboratory testing to determine soil dynamic properties, dynamic analyses of soil and soil-structure systems, analyses of pertinent data obtained from past earthquakes, and statistics and probability to evaluate level of risk. Outputs of these studies include engineering characterizations of earthquake ground motion (e.g., design-response spectra or acceleration time histories), evaluation of soil failure potential, and recommendations for remedial measures, if needed.

Our earthquake engineering group has pioneered the development of many of the analytical procedures that are widely used by the engineering profession. The group's experience and a practical approach are used to develop realistic criteria and solutions for engineering projects.

Mining Engineering

Mining engineering is the development of cost-effective means of extracting and transporting mineral ore.

In performing the necessary studies to develop a mine design, the concept of optimization of the system and of each subsystem is necessary to develop an economically feasible mining operation. Optimization frequently requires comparing alternative mining methods, selecting optimum bench heights for strip mines, determining cutoff grades, and establishing ore control systems. Mine design includes the sizing and selecting of equipment best suited for drilling, blasting, excavating, and transporting material.

Major factors to consider during mine design include mining method, capital costs, operating costs, geology, rock mechanics, availability of skills and permit requirements. A mining engineer must be capable of assessing the importance of and incorporating data from many disciplines into his design.

A typical mining study would include specialized mining engineering studies and would incorporate services from many of the disciplines described elsewhere in this brochure. We provide mining engineering services from initial prospect evaluation through feasibility studies, to mine design and start-up scheduling. Some of the capabilities and services we provide include:

Exploration and Mine Development Geology

Economic geological evaluations of mineral deposits, from initial reconnaissance or prospecting, through exploratory investigations and detailed mapping leading to mine design
Program planning, design, and coordination to optimize field and drilling programs and data quality
Interpretations of orebody geometry and geology
Computerized estimates of reserves
Development of geological cross-sections of orebody for mine layout

Mine Design, Surface and Underground

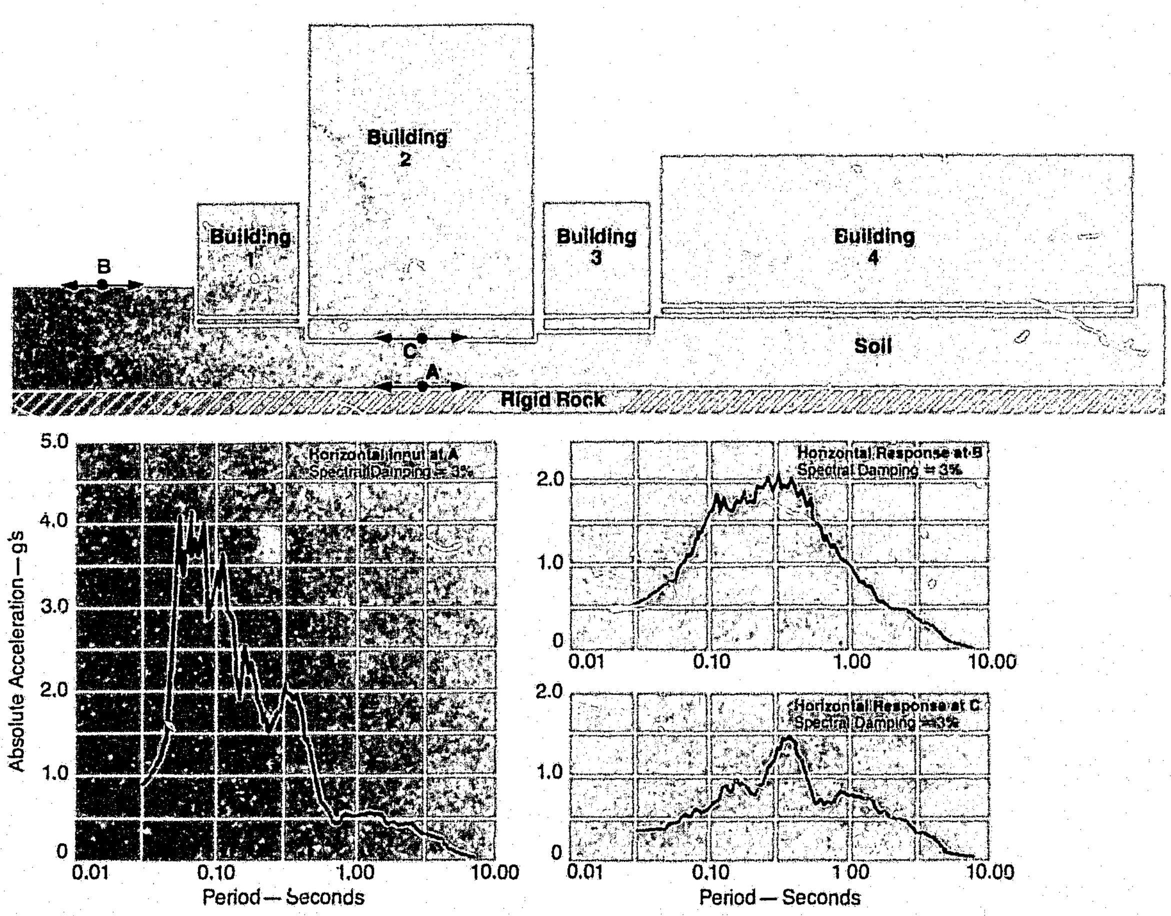
Mining methods and transportation system development
Mine layout, shaft and plant site selection
Shaft design, mine dewatering design, ventilation system design, equipment selection, and blasting program design
Preproduction plan development, production buildup, schedules, and short- and long-range planning

Feasibility Studies

Analysis of alternate sites
Analysis of economic impact of environmental requirements
Analysis of reclamation regulations
Development of alternative mining methods and transport systems
Estimates of daily or annual ore tonnage rates
Projections of capital and operating costs

Operations Assessment

Mine safety program reviews
Methods analyses
Operating systems analyses and efficiency studies
Mineral evaluation and application



The soil-structure system shown at left is for a nuclear power plant. The system was modeled by finite elements and analyzed for an input earthquake motion at rock (Input at A). The response was computed at several points of the system, including point B away from the buildings and point C beneath a building. The difference in the response at points B and C illustrates the importance of soil-structure interaction. The computed response was used in the seismic structural analysis of the buildings.

Earth Sciences

Geology and Seismology

Geologic Hazard Evaluation

Locating and delineating potential geologic hazards (e.g., surface fault rupture, landslides, liquefaction, volcanic eruptions, subsidence, collapse, swelling clay, and flooding) is a significant part of our practice. In these investigations, surface and subsurface explorations, which often involve new techniques or innovative approaches, are made to document regional or site-specific geologic conditions. When geologic hazards are identified and evaluated, they often can be avoided or their effects mitigated by using adequate zoning procedures and geologic data in land-use planning. When the hazard is quantified, design criteria can be developed and the risk assessed.

Engineering Geology

In our engineering geology practice, geologic conditions are evaluated for location, design, construction, and operation of engineering structures. An understanding of the surface and subsurface conditions is essential to foundation design and to evaluations of stability and safety of existing or proposed dams, bridges, tunnels, highways, pipelines, and industrial sites.

Seismology

Seismology is the study of earthquakes and related phenomena (e.g., faulting and the propagations of seismic waves) and the effects they produce. A principal factor in assessing seismic risk is our computer-based listing of the major national and worldwide catalogs of earthquake locations, magnitudes, and other significant data. Seismographic instrumentation can provide supplementary data for a specific site when the historical records are inadequate.

Seismic Geology

Seismic geology integrates the disciplines of geology and seismology to evaluate earthquake hazards. Geologic mapping, interpretation of remote sensing imagery, geophysical surveys, exploratory trenching, and age dating of geologic materials are combined with studies of regional tectonics and historical seismicity, and the monitoring of microearthquake activity to provide data for estimating the maximum credible earthquake, the earthquake recurrence interval, and the maximum potential displacement that may affect a site.

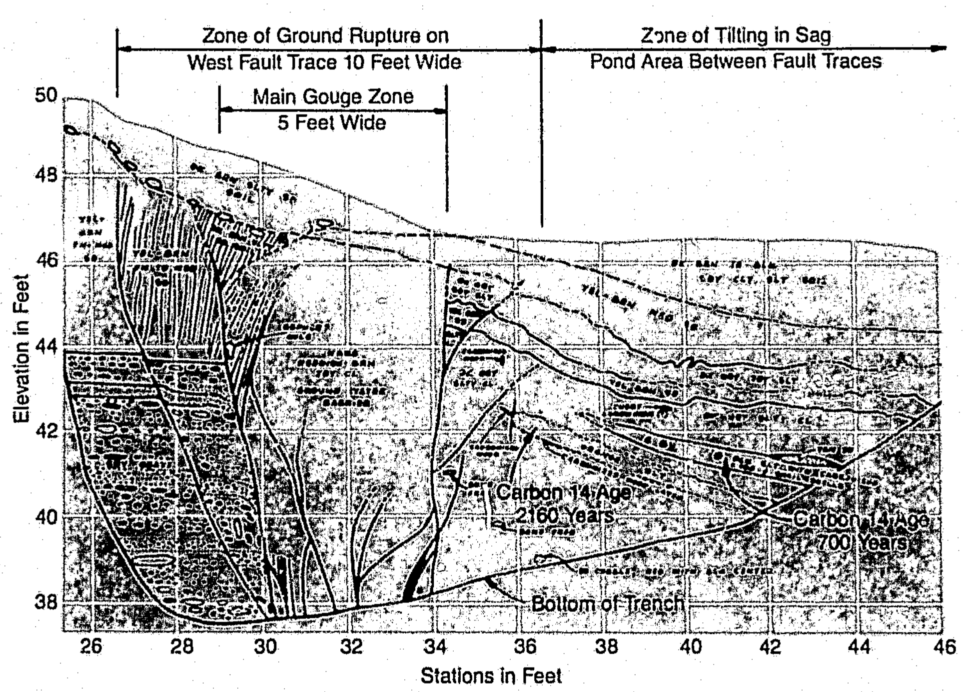
Engineering Seismology

For many engineering purposes it is essential to provide estimates of credible and appropriately conservative design earthquake accelerations, durations, and recurrence intervals. These analyses are made by the engineering seismologist and are based on empirical and theoretical considerations and on geologic data and records of historical earthquakes.

Geologic and seismologic problem-solving techniques are applied in the following areas:

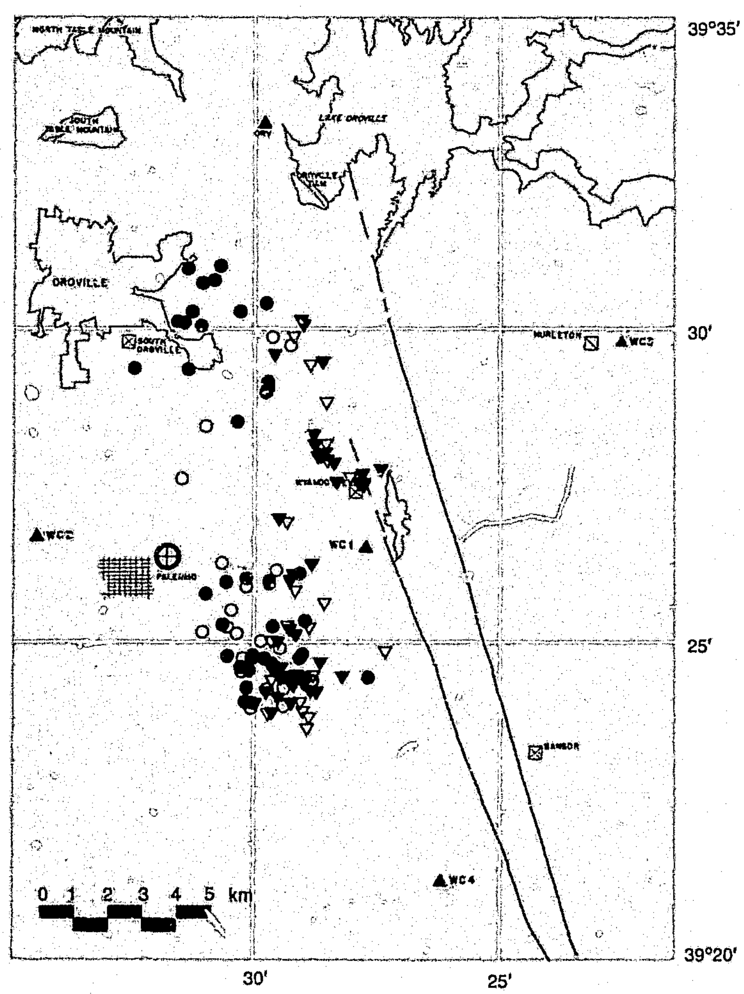
- Regional tectonic and fault studies
- Geologic hazards evaluation
- Land-use planning
- Site-specific investigations for surface, subsurface, and offshore construction
- Microearthquake monitoring
- Ground-shaking magnitude and frequency estimation
- Resource evaluation and development
- Site selection studies, including hazardous waste storage

Detail of fault trace exposed in trench.

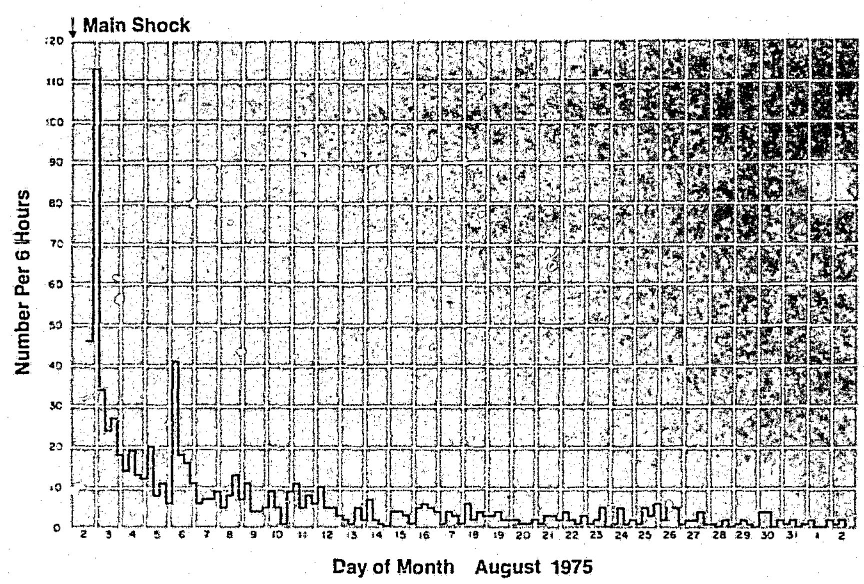


Immediately following the August 1, 1975, Oroville earthquake a team of seismologists and geologists was mobilized to instrumentally monitor aftershocks and to look for geologic effects of the magnitude 5.7 earthquake. The microearthquake recordings were used to determine the epicentral pattern and dipping fault rupture and guided geologists to the small surface fault displacement along a previously identified geologic structure. Because the earthquake took place very close to the Oroville dam and reservoir, these studies have been critical in evaluating this possible case of reservoir-induced seismicity.

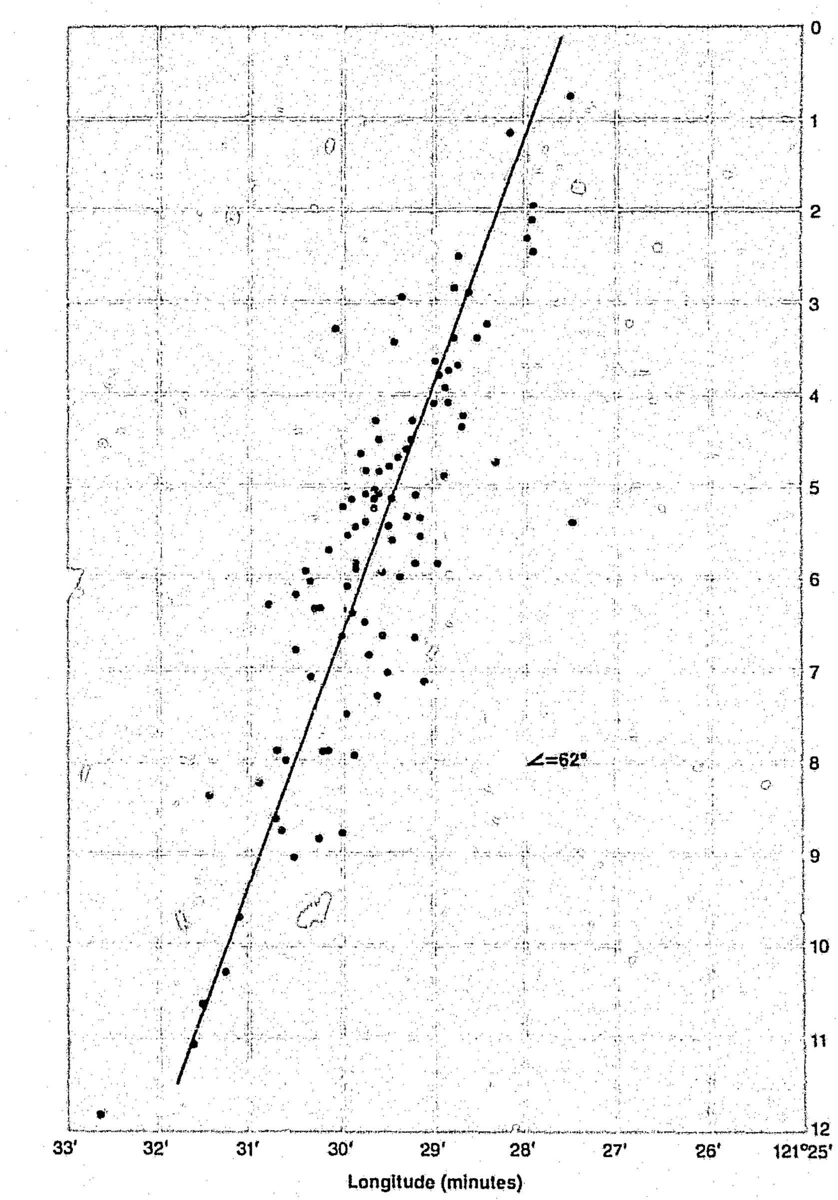
Aftershock locations of the magnitude 5.7 Oroville, California earthquake of 1 August 1975. Circles: focal depth ⩾ 5.5 km; inverted triangles: focal depth < 5.5 km; triangles: seismograph stations; large circle with cross: epicenter of main shock; monitoring period: 2 August to 1 September 1975.



Aftershock frequency versus time. Daily numbers of shocks having magnitude ⩾ 1 is proportional to $t^{-1.1}$, typical of many naturally-occuring earthquake sequences.



Hypocenters of aftershocks for the first week (2 to 9 August 1975) after the main shock, projected on an east-west cross-section.



The services we provide in these areas include:

Photogeologic Interpretation
Remote-sensing imagery
- Side-looking airborne radar (SLAR)
- Land satellite (LANDSAT)

Aerial photography at various scales
- Conventional black and white, and color
- Low-sun-angle
- Color infrared (IR)

Geologic Mapping
Surface and subsurface
Photogeologic mapping
Soils mapping

Field Exploration
Aerial and ground reconnaissance
Test borings
Trenching and trench logging
Sampling
Geophysical surveys
Seismographic instrumentation

Age Dating
Paleomagnetic measurements
Radiometric dating

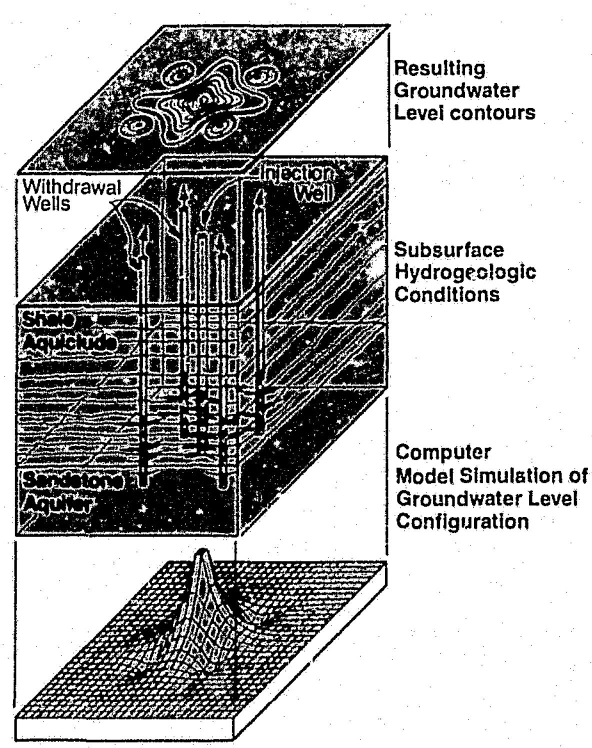
Earthquake Evaluations
Historical seismicity investigations
Microseismic network design
Microearthquake monitoring
Strong motion monitoring
Time and frequency domain analyses
Tectonic stress analysis
Evaluation of surface faulting potential and fault creep

Earthquake Data Bank
Computer access to catalogs of local, regional, and world-wide historical events
Computer produced epicenter plots
Site-related listings of events by location and magnitude

Environment-Related Studies
Impact of geologic hazards
Land use planning
Seismic zoning

Seismic Studies
Regional geologic and seismologic evaluations
Detailed site-related mapping and testing
Documentation for licensing

Evaluation of the effects of simultaneous deep well injection and withdrawal on groundwater levels



Hydrogeology

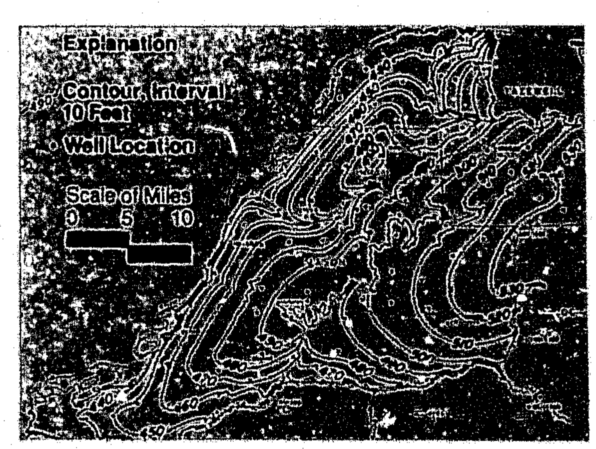
Historically, growth in population, industrial use, and irrigation farming, compounded by periodic droughts, have demonstrated the importance of our water resources. This implies a need for careful planning, development, and management.

Water is a renewable mineral resource; therefore, planning for development of a basin should begin long before water needs become acute. This phase of planning relies heavily upon accumulation, analyses, and interpretation of basic data. After the data have been analyzed, determinations should be made about water-handling methods, such as reservoirs, well fields, and delivery systems. An important aspect of the planning phase is consideration of long-term quality and quantity, both for the initial consumer and for other downstream users in the system. Consequently, a manageable system is a major objective of planning and is frequently developed through computer-assisted analysis.

Following and overlapping the planning phase is the development process. During this phase, dams are sited, designed, and built; water works are designed and constructed; well fields are installed; and methods of delivery are implemented.

Consideration of management systems begins in the planning phase and continues for the life of the project. A thorough understanding of the mechanics of the system is thus essential to good management. Frequently, this requires the application of computer techniques to properly and efficiently operate the system.

Water table elevation map



Our staff members have been involved in all three of these phases of water resource projects. Typical projects include:

- State-of-the-art modeling of ground and surface water systems
- Design of water supply, including dams and delivery systems
- Water-orientated environmental assessments
- Groundwater pollution studies
- Water rights analyses and appraisals
- In-situ mining modeling
- Reservoir routing and flood plain studies
- Basin-wide evaluation of groundwater resources
- Solution of specific hyperbolic, elliptical, and parabolic partial differential equations

We have developed in-house analytical procedures and techniques, and have available a large number of state-of-the-art computer programs that are frequently used in planning, development, and management of water resource projects. Our hydrogeologic practice offers the scope of services listed below.

Field Surveys
Stratigraphic investigations of water-bearing formations
Hydrogeologic mapping
Water well inventory and monitoring
Groundwater sampling

Field Testing
Stratigraphic borings
Core drilling and sampling
Piezometer network installation and monitoring
Pumping tests for aquifer coefficients
Packer permeability tests
Percolation tests
Geophysical well logging
Chemistry of groundwater
Tracer studies
Seismic refraction
Electrical resistivity

Analytical Studies
Bedrock fracture systems
Groundwater resources inventory and evaluation
Dispersion in groundwater
Hydrogeologic systems analysis
Digital and analog modeling
Digital data analysis of groundwater networks
Seepage evaluations
Thermal changes in groundwater
Ash or mine waste leaching
Deep-well waste disposal feasibility

Planning and Design
Safe yield evaluation
Groundwater data collection networks
Well-field design
Artificial groundwater recharge systems
Dewatering systems
Monitoring well networks
Site selection for sanitary land fills and waste lagoons

Environment-Related Studies
Groundwater quality evaluations
Wastewater and sewage disposal
Regional groundwater availability
Impact of groundwater extraction on areal subsidence
Impact of mining on groundwater
Groundwater contamination and pollution monitoring
Salt water intrusion
Radioactive waste disposal

Groundwater Management
Rights and allocations
Basin management
Development permit preparation
Utilization cost analyses

Terrestrial and Marine Geophysics

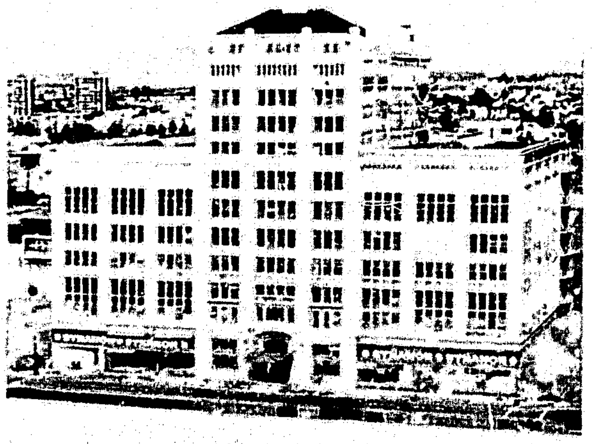
A knowledge of the physical properties and geometry of the subsurface is essential to our practice. Our terrestrial and marine geophysics programs provide this knowledge through the application of state-of-the-art technology in measurement and analytical techniques.

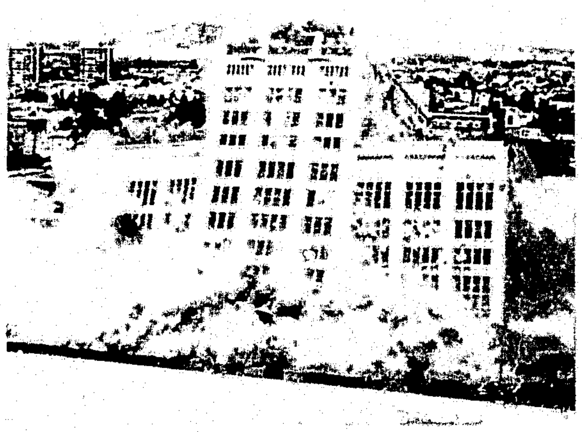
Seismic monitors and seismograph station installations gather information about the location, frequency, and effects of earthquakes and man-made explosions. These seismic investigations use the most recent developments in signal sources and digital data acquisition for generation and enhancement of both compressional and shear waves.

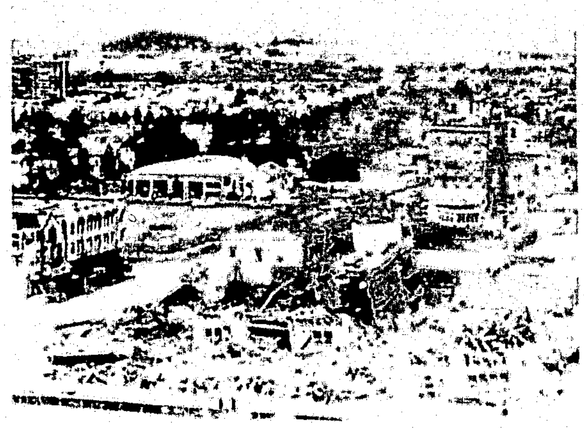
Gravimetric, magnetic, and electric resistivity techniques use field theory to analyze subsurface structures in both terrestrial and marine environments. Soil and rock profiling obtained by seismic refraction and reflection, and by downhole electric logging, are used with other geologic studies for evaluating the lateral extent of strata and mineral resources. Geophysical techniques are used in resource development for exploration and for selection of the most effective mining methods and procedures.

Specialized marine geophysical techniques such as side-scan sonar, sparker and boomer reflection surveys, bottom sampling using dart and grab samplers, and marine magnetic surveys are used to provide information about the ocean bottom and sub-bottom structure.

Our firm was retained by Controlled Demolition, Inc. to measure the ground vibrations that were caused by the blast demolition of the 12-story Synanon building in Oakland, California. The approximately 50 year old steel-reinforced-concrete structure was to be demolished by judicial placement of approximately 500 pounds of 70 percent dynamite. The blasting pattern was designed to initiate at the rear center of the building and progress radially outward. All blasting effects were to be contained within the building site. Based on the data obtained from our vibration monitoring, we concluded that the blast-induced vibrations and the fall of the building occurred at a very safe level with no damage to adjacent buildings.







Our activities in terrestrial and marine geophysics include:

- Site selection or verification
- Development of design parameters for soil and rock
- Subsurface profiling
- Resource exploration and development
- Environmental impact assessment

Following are the types of services provided:

Subsurface Profiling Surveys

Fault location
Soil profile and geologic structure delineation
Landslide slip-plane location
Three-dimensional orebody delineation

Field Measurement Systems

Gravimetric
Seismic refraction and reflection
Magnetometer
Electric logging of test borings
Electric resistivity

Shear-Wave Velocity Measurements (in situ)

Crosshole using our in-house developed shear-wave hammer
Downhole with surface impulse

Analytical Studies

Processing and mapping of geophysical data
Subsurface structural modeling
Vibration and blast monitoring and analysis
Rippability of rock in roadways, mines, and quarries

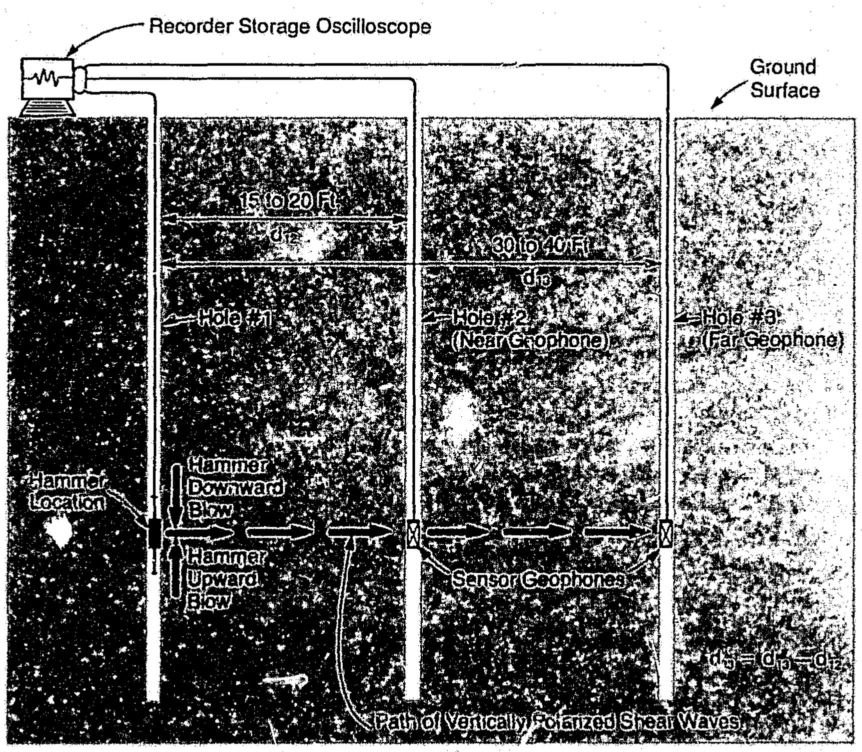
Planning and Design

Geophysical field exploration programs
Mineral search and mining procedures
Blasting charges and arrays

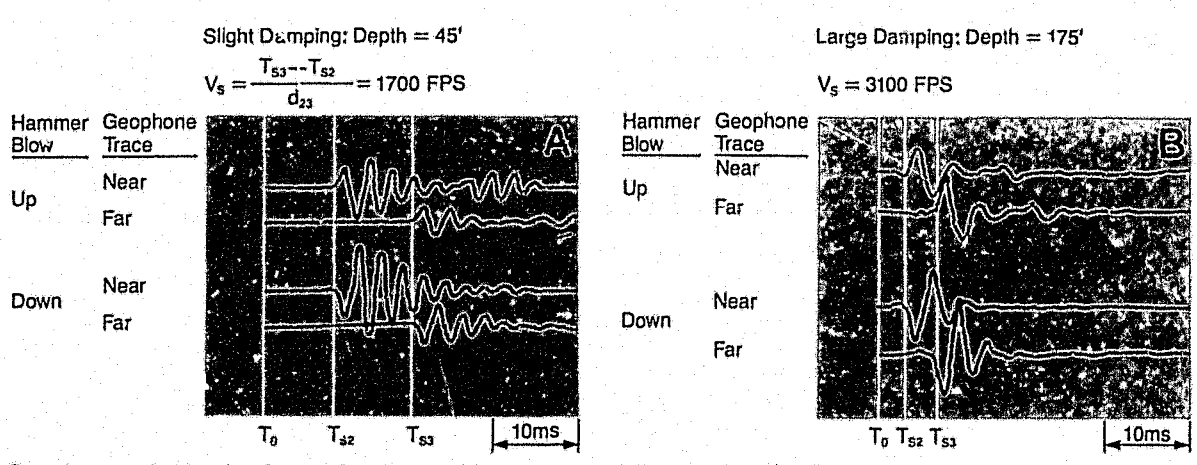
Environmental Assessment

Noise source and level monitoring
Blasting effects on adjoining areas and facilities
Mitigating measures

Shear-wave measurements were made in four 300-foot-deep arrays at the site of a proposed nuclear power station near Termoli, Italy. The measurement for this survey was 5 feet. This study was performed for the Italian National Power Authority (ENEL) as part of an earthquake response analysis.



Schematic Arrangement of Crosshole Shear-Wave Measurements



Sample Records Showing Shear-Wave Reversals and Exponentially Decaying Signals

Environmental Studies, Systems Analyses, and Planning

With the enactment of the National Environmental Policy Act in 1969, concern for the environment became a major consideration in the planning of new facilities. Consequently, professionals on our staff have been continuously engaged in such activities as impact assessments for a wide variety of projects, development of solutions to mitigate or reduce adverse impacts, and application of decision- and risk-analysis techniques to assist industry, government, and the public in evaluating the impact of proposed projects.

Environmental Impact Assessment

Our firm has conducted environmental impact assessments and prepared the related EIR's and EIS's on many projects to meet federal, state, county, and city requirements. Preparation of these reports has involved a combination of some or all of the following efforts:

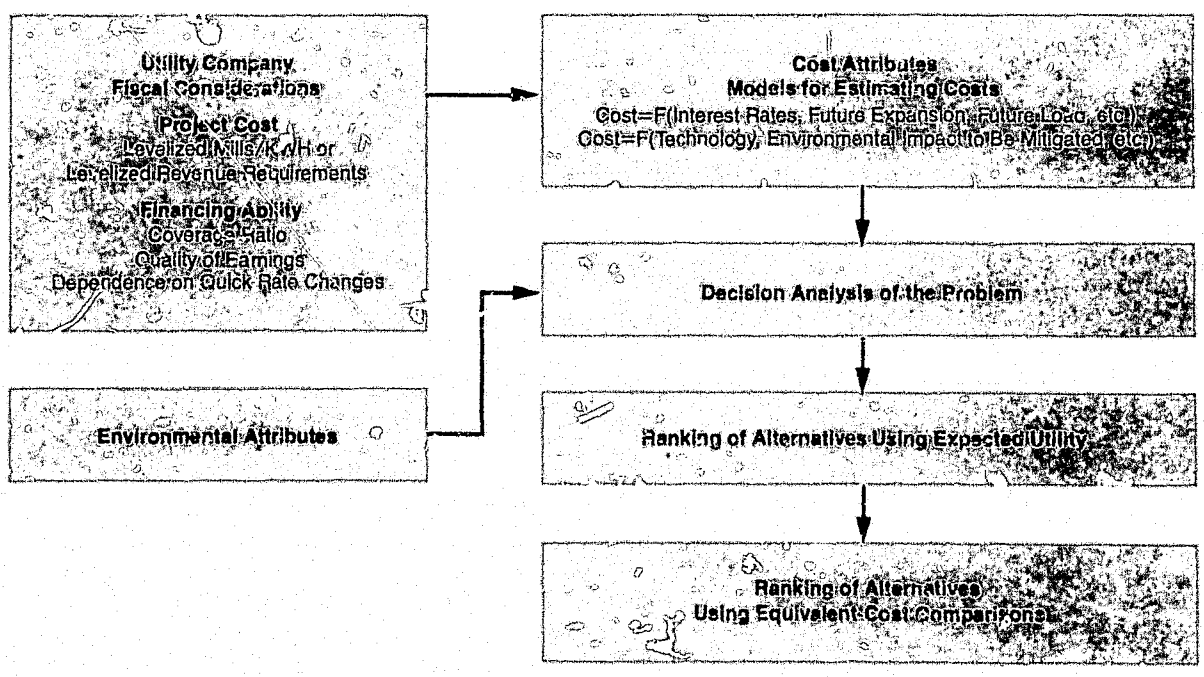
- Reconnaissance to determine which studies would be necessary to complete data bases and satisfy regulatory requirements
- Comprehensive baseline studies, including field data collection
- Design and application of computerized and manual systems for data management
- Design, calibration, and operation of meteorological, air-quality, water-quality, and groundwater monitoring systems
- Projection of demographic, employment, and land-use requirements
- Analysis of beneficial and adverse effects, and development of mitigating measures
- Evaluation of alternative sites and designs
- Hearings, public meetings, and expert testimony

Our staff conducts studies in all major disciplines required under the guidelines issued by review and licensing agencies. The diversity and magnitude of these studies have enabled our staff to develop valuable in-house experience with the complex local, state, and federal environmental laws and regulations governing the granting of construction and operating permits.

Decision and Risk Analyses

Decision analysis provides a sound theoretical basis for addressing decision problems under uncertainty. Decision analysis can often assist in reaching better engineering and environmental decisions by providing a consistent and logical framework in which to consider the uncertainty present in problems and the preferences of the decision-makers and other interest groups. The application of these techniques to environmental and geotechnical problems has been pioneered by our firm. Risk analysis has several applications, each of which emphasizes particular aspects of decision analysis.

A methodology for environmental impact assessment was developed and applied to solar power plant systems under a contract with the Electric Power Research Institute. The methodology, based on decision analysis, was designed to assist in the examination of environmental, economic, social, and other issues as parts of the larger framework of total costs and benefits in energy decisions. This figure illustrates how the cost-equivalence methodology fits into the decision analysis approach to comparing energy-conversion systems.



Decision analysis techniques have wide applicability to many types of complex problems. Some applications developed by our staff members include:

- Siting of major facilities and transportation corridor selection
- Risk analysis for LNG tanker and terminal operations
- Determination of the probability of pipeline rupture using fault-tree analysis
- Comparison of underground and surface sites for nuclear power plants
- Analysis of technical uncertainties related to storage devices for electric cars
- Algorithm for evaluating proposals to develop a large-scale solar experiment
- Design optimization for offshore platforms
- Scope definition for environmental and engineering studies

Site Selection

We have developed and applied a site-selection methodology based on decision analysis. This approach results in a clear documentation of the criteria, data, and rationale for siting decisions, allowing the decision process to be updated as new information or criteria are developed over time. The viewpoints of individual citizens, environmental groups, or public agencies can be incorporated into the decision analysis framework to see how they might affect the results of the decision process.

The siting process may involve the preliminary screening of large geographic areas to locate areas that conform to a previously defined set of criteria. We have developed techniques for both manual map-overlay and computerized methods to identify candidate siting areas. Field visits are usually made to confirm that the areas identified meet all the screening criteria. The candidate sites are then subjected to further consideration to rank them in order of preference.

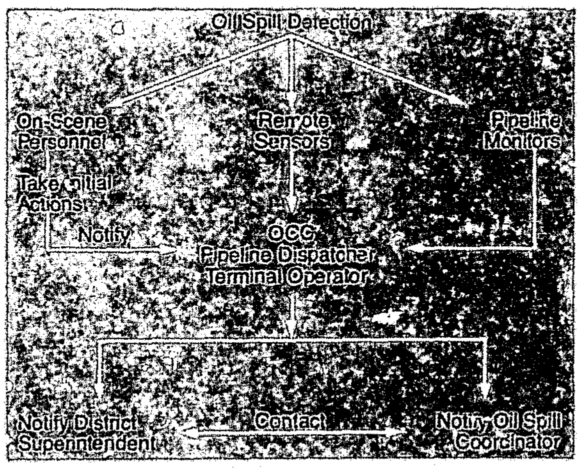
Our experience in this area includes comprehensive site-selection studies for:

- Nuclear and fossil-fueled power plants
- Pumped-storage hydroelectric facilities
- Electric transmission line routes
- Pipeline corridors
- Industrial facilities

Oil-Spill Contingency Planning

Consulting services are provided in oil-spill contingency planning for existing and proposed facilities that produce, transport, or store petroleum products. Our services include:

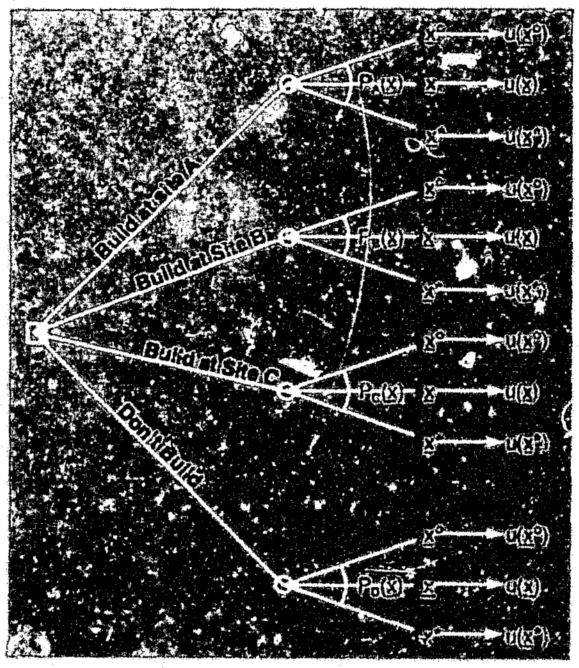
- Developing detailed response plans specifying "what to do" and "how to do it"
- Preparing technical reports documenting the history, cleanup procedures, and environmental (ecological, social, economic) effects of oil spills
- Providing guidance and training to immediate-response teams in spill recovery and disposal operations
- Conducting surveys and investigations to predict possible environmental impacts of spills
- Evaluating effects of spilled materials on the aquatic, marine, and terrestrial biological communities
- Supplying on-site management and planning of oil-spill cleanup procedures and operations

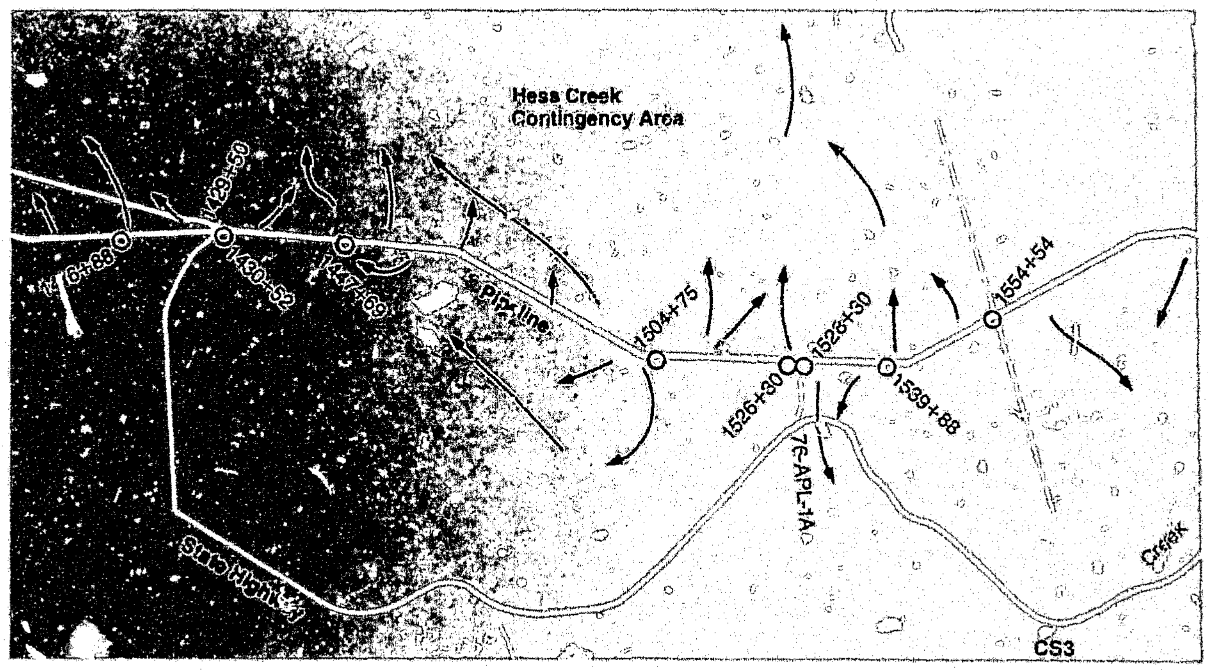


Left: Oil-spill contingency plans for the trans-Alaska pipeline, terminal facilities at Valdez harbor, and tanker routes through Prince William Sound were prepared for Alyeska Pipeline Service Company. Specific action flow charts defined the quick-response actions to be taken in the event of notification of a spill event, and individual personnel were trained to take the necessary actions in case of a spill. The entire pipeline route was mapped to show probable flow directions for oil spills initiating from various points on the line and potential containment basins. The contingency plans will be kept up-to-date for maximum effectiveness in controlling the effects of a potential spill.

Below left: A comprehensive siting study was conducted over a tri-state region in the Pacific Northwest for Washington Public Power Supply System. Suitable sites for fossil-fueled and nuclear power plants were identified through a map-overlay process using screening criteria to narrow down the study area on the basis of engineering, cost, environmental, and health and safety considerations. This figure shows a simple model of the ranking process, using decision analysis.

Below: Possible oil flow direction was plotted by our geographers to prepare oil-spill contingency plans for the Alyeska pipeline.





Other Environmental Consulting Services

Other services offered relating to environmental planning and systems analyses are listed below.

Ecology

Terrestrial, marine, and aquatic biology
Research, field, and laboratory techniques
Provision of practical recommendations
Comprehensive biological inventories
Monitoring programs
Effects-prediction
Ecosystem damage assessment
Ecosystem changes

Meterology and Air Quality

Design, installation, and operation of meteorological and air-quality monitoring stations
Collection and interpretation of data
Computation of present and predicted ambient pollutant concentrations
Prediction of dispersion, fogging, and evaporation
Design and installation of supplementary control systems for gaseous emissions for industrial facilities
On-site measurements, including local air flow, ambient air pollution concentration, and climatological parameters

Water Quality

Evaluation of environmental effects, including:
- quantity management (infiltration reduction, residential and industrial water conservation, charge systems)
- wastewater management: treatment (biological, physical, and chemical and nonstructural methods)
- wastewater management: disposal (groundwater recharge, land irrigation, surface water disposal, sludge disposal-incineration, digestion, and landfill)

Design of sampling and monitoring programs for water quality and availability
Development of mitigating measures to reduce environmental problems, including source control and feasibility of treatment methods
Formation of areawide wastewater management plans, including evaluation of point and nonpoint sources of pollution loads
Measurement, prediction, modeling, evaluation, and control of urban runoff

Oceanographic Studies

Bathymetric and side-scan sonar surveys
Current and wave analyses
Water sampling and in-situ analysis
Thermal diffusion studies
Drogue drift and dye diffusion studies
Industrial and power plant heat-dissipation systems evaluations, including: measuring and mapping of thermal-discharge plumes; modeling of alternate conceptual designs for intake and discharge systems

Social, Economic, and Planning Studies

Identification and prediction of primary and secondary impacts of construction projects
Evaluation of population and urban growth
Demography
Requirements for public services and facilities, demands on transportation systems, taxation, etc.
Changes in social and political structure

Community and Land-Use Planning

Comprehensive strategies for community growth
Integrated economic, social, and environmental analyses of commercial, tourist and recreational, transportation, power, and water system developments
Development and implementation of public involvement and participation programs
Economics, operations, and public policy analyses

Sociology

Population and human ecology
Hazard assessment and warning systems
Study of complex organizations, communities, and regional and state political systems

Transportation Systems

Multimodal transportation analyses
Economic analyses
Organization, financing, and operations of transportation departments and systems
Design and feasibility analyses for specialized transportation systems
Policy formulation for cost allocations
Tax program development

Mitigating Measures Development

Development of alternatives
Cost-benefit evaluation

Other Technical Services

Laboratory Services

Our laboratories include facilities for engineering and geological testing and evaluation of soils and rock, and for chemical and biological testing and evaluation of environmental parameters (e.g., air and water quality).

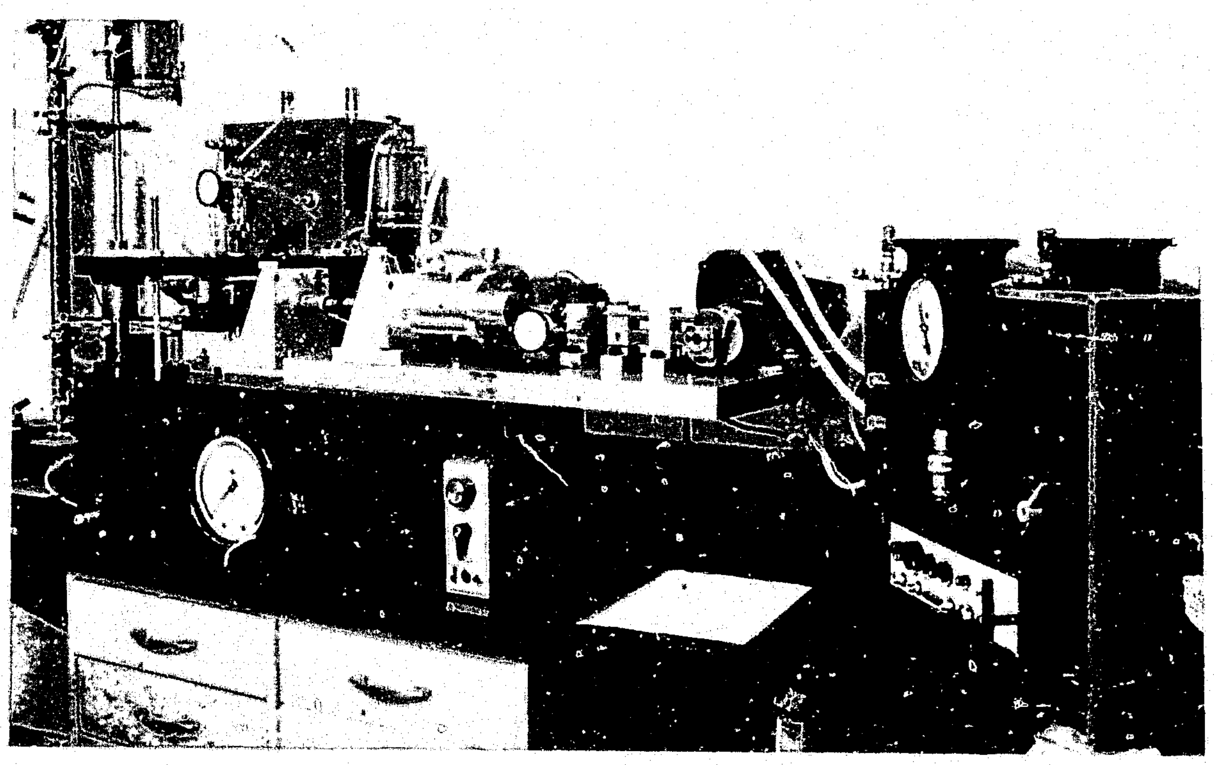
The following sections describe the types of laboratory services available.

Simple Shear Testing

Our simple shear laboratory equipment allows the application of a loading system that produces a mode of deformation that approaches pure shear and that simulates the deformational behavior of soil along failure surfaces for several types of field stability problems. The disc-shaped specimen that is tested is confined in a wire-reinforced membrane that provides almost complete radial restraint while offering little resistance to shear deformation. Either unidirectional or cyclic shear loads can be applied. The cyclic shear loads are provided by an electro-pneumatic loading system.

The unique feature of this equipment is that the specimen can be placed in a chamber that allows independent control over the vertical and radial confining pressures. The chamber also makes it possible to back-pressure simple shear specimens, thereby ensuring saturation, while at the same time allowing the measurement of the pore water pressures that are generated during the shearing phase of a test.

Cyclic simple shear testing equipment



Frozen Soil Testing

In dealing with arctic soil and permafrost problems, testing services are provided for determining the deformation and settlement characteristics of frozen soil specimens upon thawing at controlled rates. Special refrigerated containers keep the soil in its frozen state during transport and during storage until ready for testing. A high-response closed-loop cascade control system is used during testing to establish and control precisely preselected temperatures or temperature gradients, which are used as forcing functions in varying the critical factor of specimen temperature. The cascade system employs two feedback controllers arranged so the output of one controller is the setpoint for the other, resulting in a narrowed proportional error band setting. The refrigeration unit is capable of a maximum temperature pull down to 15°F. and the total two-state system performs to a tolerance of ±0.15°F.

Among the test values determined on frozen soils are shear strength in triaxial compression at various states of consolidation and drainage, volumetric thaw strain, axial thaw strain, water expulsion ratio, soil permeability, and thaw consolidation.

Soil and Rock Testing

Testing services are provided for the identification and classification of soil and rock and for the characterization of their engineering properties. In addition to facilities for conventional tests, a number of special testing facilities are available, including:

- High-response, electro-hydraulic, closed-loop servo systems with the ability to apply very precise loads and deformations to test specimens under both static and dynamic conditions over a range of 0 to 50 kips
- A triaxial cell, developed by our personnel, with the capability of independently applying vertical and lateral static or cyclic pressure to a cylindrical specimen and measuring both vertical and lateral deformations
- A high-pressure (10,000 psi) triaxial cell for testing rock or salt cores from deep underground cavities (i.e., up to 6000 feet)
- A back-pressure saturation permeameter for determining the coefficients of permeability of undisturbed and remolded specimens of relatively low porosity

Although testing of soil is usually performed on specimens carefully prepared from relatively undisturbed samples taken during field explorations, special techniques are also available in the laboratory for the remolding of realistic test specimens from disturbed samples.

Geologic Testing

Laboratory analyses are performed to determine the geologic characteristics of soil and rock samples collected during field exploration. Sample collecting and testing procedures vary with the needs of each project. The information derived from the laboratory investigations is applied to solve geologic problems (e.g., age dating of geologic materials, stratigraphic correlation, and mapping of bedrock structure).

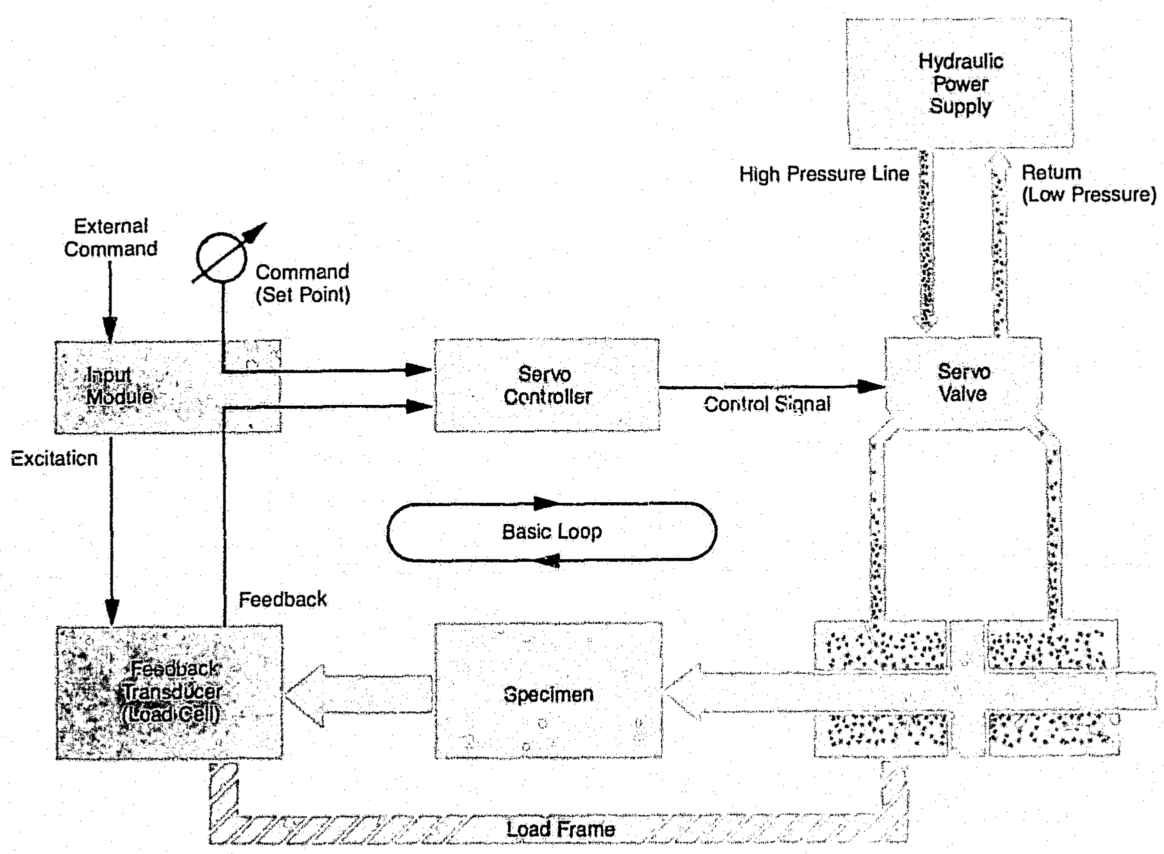
Sample Collection

Special procedures for collecting samples are used that consider the nature of the sampled material and the type of testing to be performed. During the collection and transportation of samples for age dating and paleomagnetic investigations, precautions are observed to avoid physical and chemical alteration or contamination of the samples. Samples collected for paleomagnetic analysis must be oriented to the earth's geographic coordinates during sampling. Several techniques are employed in collecting oriented samples of unconsolidated materials, including use of small cutting and trimming devices and collection of large impregnated blocks. Another very useful technique is carving a pedestal, placing a plastic cube over the pedestal, orienting the cube, and removing the oriented sample encased in the plastic cube. A small rock drill is often used to collect oriented samples of consolidated material.

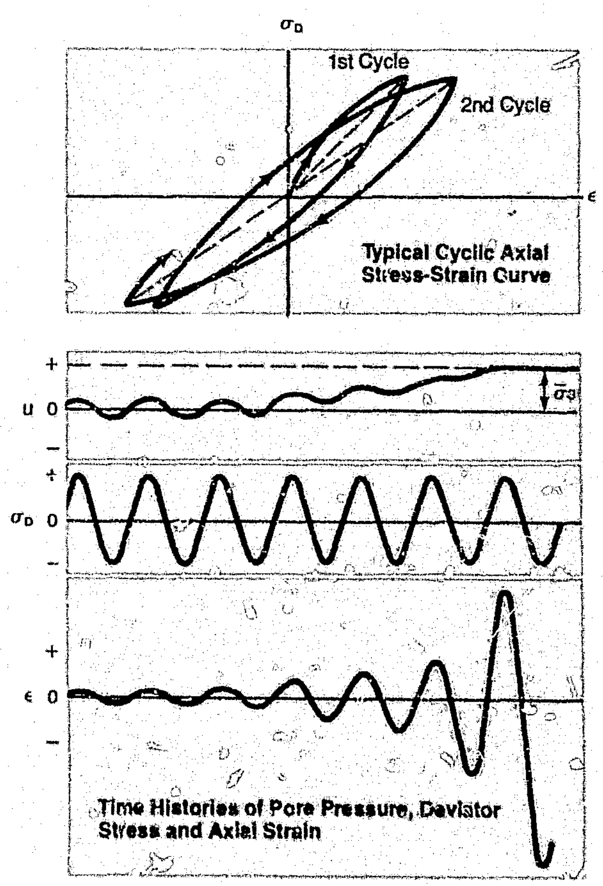
Petrographic Analysis

The mineralogy and structural relationships of rock samples are determined by petrographic analysis. Microscopic examination, together with physical and chemical testing, is used to identify and classify rock specimens. Petrographic analysis is a valuable aid in mapping and in understanding bedrock and structural features.

Cyclic loading tests to simulate earthquake conditions were made on soil samples from the bottom of the bay for the BART Transbay Tube, and an analysis was made of the possibility of liquefaction failure. Cyclic and static triaxial compression tests were made and evaluated using the closed-loop, high response electrohydraulic servo-system.



Typical results of cyclic triaxial liquefaction test



Paleomagnetic Measurements
We have highly sensitive equipment to determine the residual magnetic field in both bedrock and unconsolidated samples. The residual magnetic field, combined with the stratigraphic position and known orientation of a rock sample in situ can be used in some circumstances to correlate and date geologic formations. The procedure is based on the concept that, in geologic time, magnetic pole reversals have occurred periodically. One such event, known as the Brunhes-Matuyama reversal, occurred 700,000 years ago. This and other dated magnetic pole reversals can be used with other dating techniques to provide timelines for dating formations associated with faults, and to provide some information on the time of the most recent fault displacement.

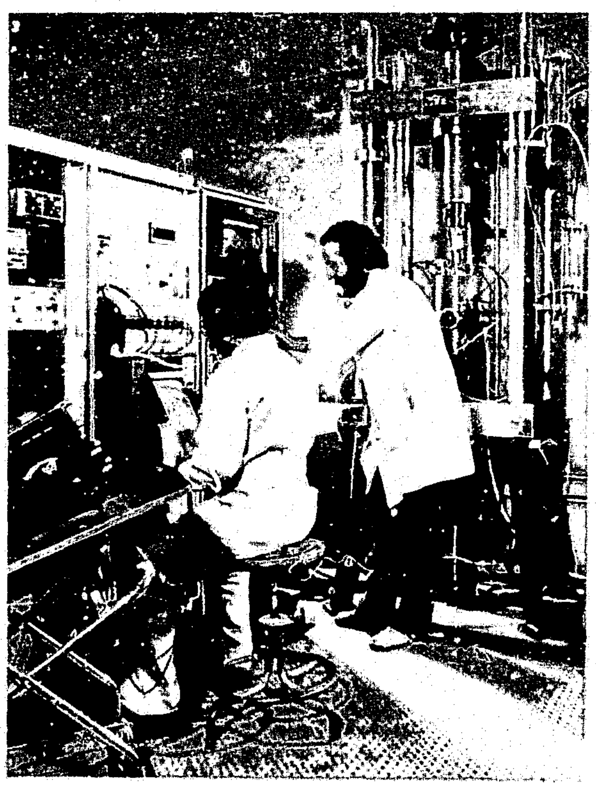
Biological and Chemical Testing

Aquatic (Marine and Freshwater)
Chlorophyll and other pigment readings using spectrophotometers for productivity determination, plankton species identification, and quantitative estimates of organisms per unit volume
Sorting of biological samples and species identification using microscopic analysis
Biomass determination using Mettler balances (wet and dry weight)
Reference collection of preserved invertebrates and fish for comparison and species identification
Sediment grain size analysis

Terrestrial
Microscopic and visual dissection and examination of birds, small mammals, and reptiles to determine species type, reproductive condition, stomach contents, etc.
Collection of voucher specimens of small mammals and reptiles (skins and skeletons dried and preserved) for comparison and species identification
Herbarium collection of pressed samples of plant species for species identification and comparison
Drying oven for preparing biological and plant samples for preservation or weighing

Oceanographic and Water Quality
Chemical analyses of samples for dissolved oxygen (DO), salinity, and pH determination
Turbidity metering (both laboratory and on-site), transmissivity, and irradiated light determination
Specific conductivity measurement of samples, both laboratory and on-site
Sediment grain size analysis
In-situ measurements of temperature, wave velocity, and current speed and direction
Infrared radiometer remote sensing

Seismic foundation design criteria were developed through static and dynamic testing of the soil properties at the site of San Onofre Nuclear Generating Station. The dynamic properties were stiffness and hysteretic damping for both low-level and high-level strains. The low-strain properties were determined by field seismic methods, using refraction, crosshole and downhole techniques. The high-strain properties were determined by cyclic triaxial methods. Site dynamic response spectra were then computed by simulating earthquake motions and calculating the propagation of those motions through the soil overburden to the base of the plant structure.



Paleomagnetic laboratory (left to right): teletype for computer interface, strip chart recorders that monitor the digital-volt-meter signal levels of three magnetic directions, CRT for immediate data presentation, digital-volt-meter readouts, with control module with scope and signal generator, helium flow gauge, and superconducting rock magnetometer. (Out of view: PDP-8 computer, and alternating field demagnetization unit.)

Field Instrumentation Services

Included in our practice are the design, installation, and operation of instrumentation systems for field measurements. These systems serve a range of functions — from determining in-situ properties of soil and rock and baseline data for environmental studies for use in analytical and design studies — to monitoring geotechnical and environmental parameters for use in evaluating the validity of predicted performance.

Services for the planning and design of field instrumentation systems are provided for specific projects to cost-effectively produce the data that are most essential. Some of the instrumentation systems we have used are briefly described in the following sections.

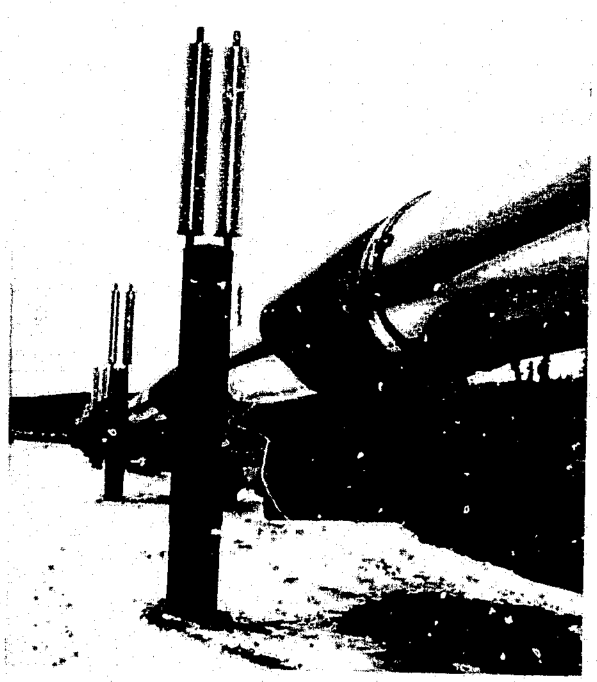
In-Situ Field Testing

Among the specialized field testing equipment available for measuring in-situ ground motions or soil and rock properties are:

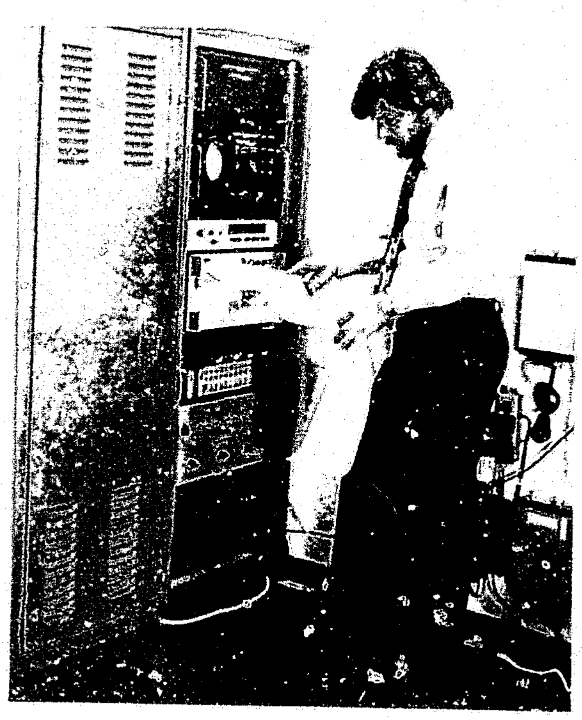
- *Multipurpose In-Situ Testing System (MITS)* — tethered bottom supported platform capable of running cone penetration tests to depths of 20 feet below the sea floor in water depths up to 1000 feet
- *Microearthquake Recording System* — recording seismometer, which can be used with other units in a microseismic network (including centralized telemetric data collection) to measure microearthquake activity near important facilities
- *Crosshole Shear-Wave Hammer* — a mechanical borehole impulse generator developed by Woodward-Clyde for inducing shear waves that travel laterally between boreholes with the measured velocity of shear-wave travel used to calculate the in-situ shear modulus of the soil or rock formation between adjacent boreholes.

Various other instruments are available for incorporation into instrumentation systems as needed, including pressure cells, strain gauges, piezometers, accelerometers, and linear variable displacement transducers (LVDT).

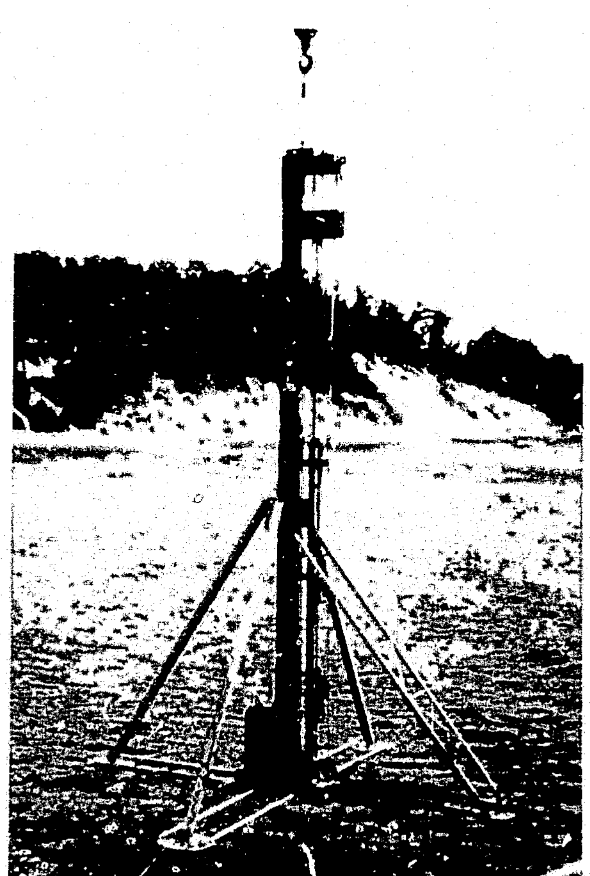
Field load tests were performed on eight prototype thermal piles for the elevated sections of the trans-Alaska pipeline. The instrumentation system for these load tests was designed to control test loading and temperature; and to measure and record load, temperature, strain, displacement, and force.



Data from networks of field-installed vertical and three-component seismometers are telemetered via data-grade telephone lines to central recording terminals in our offices, as illustrated. In one study for a nuclear generating station in a seismically active area, the records of 30 seismometers at 28 locations are automatically logged and recorded for subsequent data reduction and analysis.



Multipurpose in-situ testing system



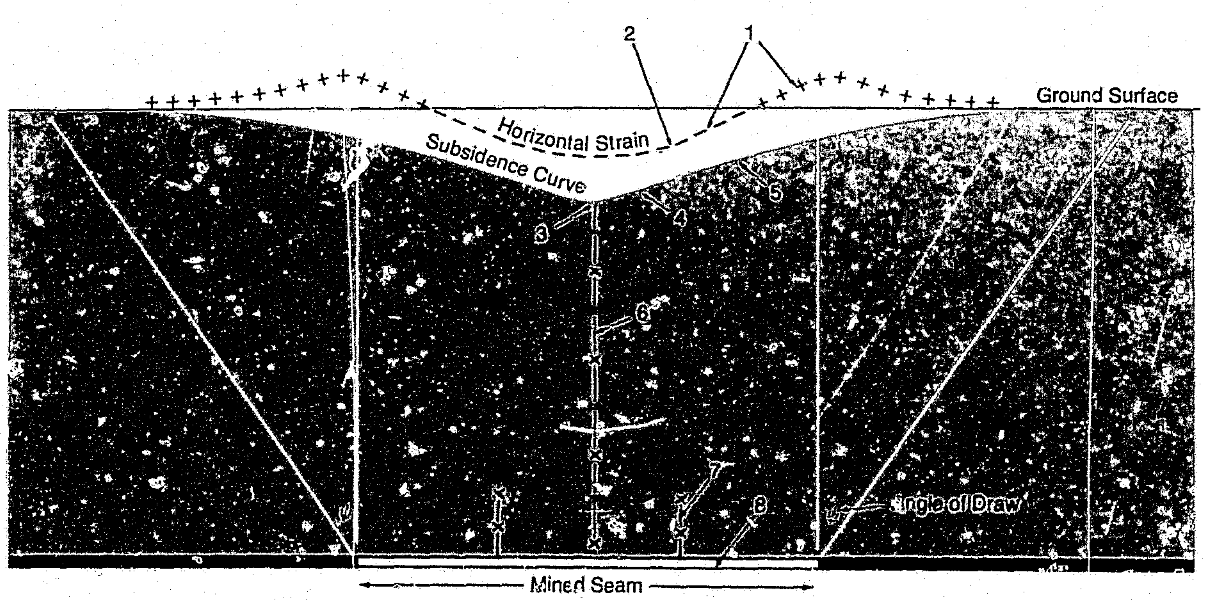
Performance Monitoring
Underground facilities and foundations, more than any other type of construction, involve design assumptions based on limited data. Performance instrumentation provides a means of verifying design assumptions or of detecting variations from those assumptions during construction so that changes in design or construction methods may be made where required. Performance instrumentation also makes it possible to continuously evaluate the behavior of the project during its service life and may permit rapid determinations of stability and safety after critical loading events such as earthquake shocks.

Installed instrumentation systems include structural steel and reinforced concrete stress and strain instruments and the following types of soil and rock stress and deformation instruments:
- Stress meters
- Pressure cells
- Strain gauges
- Borehole extensometers
- Embankment extensometers
- Tiltmeters
- Heave and settlement measuring devices
- Piezometers
- Seismic motion devices
- Deflection gauges

Some of the types of construction in which performance monitoring has proven to be most effective are:
- Tunnels and underground chambers
- Earth dams and embankments
- Deep excavations and foundations
- Pavements
- Dewatering operations

Environmental Parameters
Instrumentation systems are also installed for the field measurement of air and water quality and biological parameters. Generally, this equipment is suitable for remote, unattended operation. Some of the specialized instrumentation systems used for this purpose are:
- Water quality
  temperature
  dissolved oxygen
  pH
  specific conductivity
- Air quality
  active systems: SO_2, NO_x, total suspended particulates, total hydrocarbons, CO, odor, photochemical oxidants, coefficient of haze, H_2S
  passive systems: settled particulates, reactive sulphur, nitrogen oxides
- Meteorology
  wind speed and direction
  air temperature
  solar radiation
  precipitation
  relative humidity

Subsidence movement characteristics and possible modes of measurement



Key To Instrument Systems	1 Surface Strain Extensometers 2 Soil Pressure Cells 3 Single Point Settlement Sensor	4 Full Profile Settlement Gage 5 Surface Tiltmeter 6 Surface Borehole Extensometer	7 Mine Roof Extensometer 8 Piller Stress Meter

Earthquake Data Bank

We have developed an earthquake data bank that processes seismicity data and produces printouts of earthquake catalogs and epicenter maps. This comprehensive earthquake storage and retrieval system is stored on magnetic tapes that are used to sort, catalog, and map basic data necessary for seismicity and tectonic studies and for earthquake risk evaluations.

The uniqueness of the data bank is in: (1) its continually updated compilation of local, regional, and worldwide earthquake data sources, and (2) the many options available for sorting, including by epicenter location, by magnitude of event, and in chronological order of occurrence.

Parameters that can be used to select earthquakes are occurrence within a defined time interval; and occurrence within any region defined by map coordinates of latitude and longitude, magnitude, intensity, depth of focus, and quality of location. Additional data on each event, such as felt area, local intensities, damage, and event documentation are given as comments.

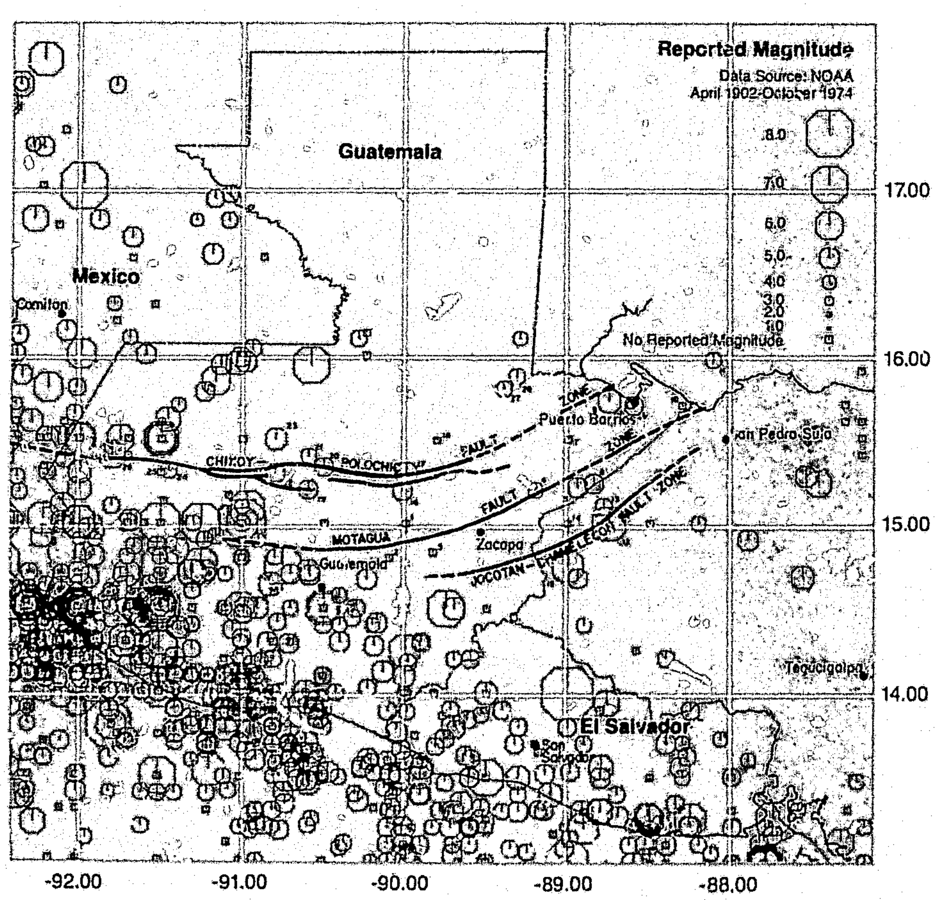
Typical results of a data bank search consist of a catalog of events, sorted as prescribed, and a corresponding inked epicenter plot up to 30 inches wide and unlimited length, with geographical coordinates and grid points marked. Symbols of various shapes and sizes denote the intensity or magnitude of the event. Consultation services are provided to make seismological, geological, and engineering interpretations and evaluations of the data.

Research and Development

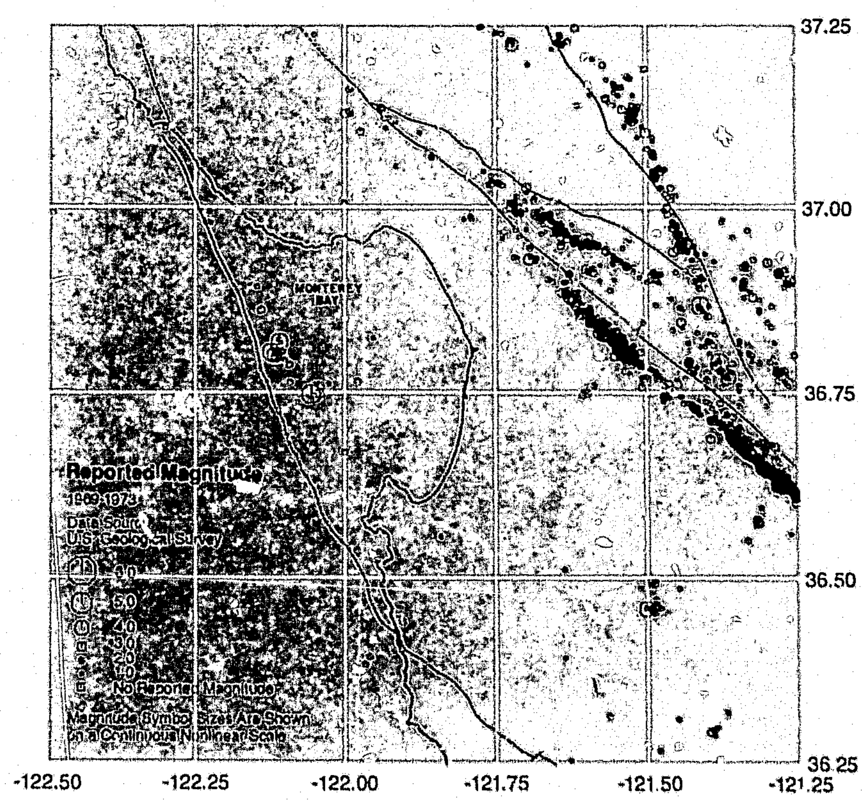
Our firm has carried out research and development studies both for ourselves and for others. When practicing at a high state-of-the-art level, the results of research and development are often immediately implementable and, thus, of direct benefit to our clients.

Consequently, projects are continuously underway, either funded by contracts from government agencies or from private institutions, and range from research on basic properties of materials to the development of analytical techniques or systems.

Historical seismicity data for Guatemala is an essential element in identifying the active large-scale tectonic elements in the region and in estimating the recurrence of major seismic events. The data source used is updated monthly for worldwide earthquakes larger than magnitude about 4.



The Woodward-Clyde Consultants' earthquake data bank includes the U.S. Geological Survey tabulations of earthquakes in central California. The San Andreas, Hayward-Calaveras, and related faults are clearly delineated by microearthquake epicenters since 1969.



Results of research and development activities are generally published in technical papers appearing in the journals of various technical or professional societies or in the proceedings of technical conferences. However, research reports prepared by members of our firm are often published by the agency sponsoring the work.

Our services are available to assist in the planning, formulation, and execution of research and development projects on specific topics within our areas of knowledge.

Remote Sensing

Systematic use of remote sensing techniques is an everyday part of our practice. Of the various techniques available, a selection is made of the most appropriate to fit the problem, whether it be related to land usage, resource development, or environmental monitoring.

Although the human eye sees the spectrum of color, it registers only a part of the total electromagnetic spectrum. Moreover, the eye is not capable of isolating the contribution of each frequency band nor of "seeing" the very small or very high wave lengths. Multiband photography, however, can be used to isolate the imagery produced by a specified range of wave lengths and, with additional sensors, can detect and record terrain-energy interactions over a wider range of the electromagnetic spectrum. The adjacent chart shows the areas of applicability of some remote sensor instruments and illustrates the use of remote sensing.

Since electromagnetic energy-terrain interaction is detectable at all frequencies, choice of a particular detector (i.e. sensing technique) is predicated on a combination of factors such as demonstrable value, flexibility of unit, cost-benefit ratio, and efficiency under given terrain and atmospheric conditions. Each factor must be understood for image interpretation and mission planning, which requires knowledge of platform requirements, system operation, terrain features to be sensed, and terrain-sensor parameter interaction.

Among the remote sensing services widely used in our geotechnical and environmental practices are:

- Conventional and low-sun-angle aerial photography
- Infrared imagery
- Side-looking airborne radar (SLAR)
- Land satellite (LANDSAT)

Areas of application for some remote sensor instruments and technology

Application

Remote Sensing Instrument or Technique

	Agriculture/ Forestry	Geology	Hydrology	Oceanography	Geography
Visual Photography	Soils Plants Vigor Disease	Surface Structure Surface Features Hazards Rock & Soil Discrimination	Drainage Patterns Erosion Sedimentation	Sea State Erosion Turbidity Hydrography	Cartography Land Use Transportation Terrain & Vegetation Characteristics Thematic Mapping
Multispectral Photography and Scanning (LANDSAT)			Soil Moisture Wetland Mapping	Sea Color Productivity Sea Ice	
Thermal I.R. Imagery and Spectroscopy	Terrain Composition Plant Condition	Thermal Anomaly Minerals Geothermal Exploration	Areas of Cooling	Ocean Currents Sea Ice Wetland Mapping	Energy Resource Currents & Land Use
Radar: Ranging Imagery & Scatterometry	Soil Characteristics Vegetation & Forest Identification	Geosutures Surface Roughness Tectonics Surface Structures	Soil Moisture Run-Off Slopes Drainage Pattern	Sea State Ice Flow & Ice Tsunami Warning	Land Ice Cartography Geodesy
R.F. Reflectivity*		Subsurface Layering Minerals	Soil Moisture	Ice Thickness Sea State	Land Ice Thickness Vegetation
Passive Microwave Radiometry & Imagery*	Thermal State of Terrain	Subsurface Layering	Snow Ice		Snow & Ice
Absorption, Gamma Ray Spectroscopy (Remote Geochemical Sensing)*		Mineral Deposits Trace Metals Oil		Surface Flora	
Analog & Digital Image Processing	Vegetation Types Crop Surveys	Mineral Deposits Soil & Rock Types	Water Quality Pollution	Pollution	Land Use Resource Inventory
Sonar		Subaqueous Structural Mapping	Erosion	Subsea Search & Damage Assessment	

*Experimental

Partial List of Clients

U.S. Air Force
Alaska Department of Fish and Game
Alaskan Arctic Gas Company
Allied Chemical Corporation
Alyeska Pipeline Service Company
AMAX, Inc.
American Electric Power Service Corporation
American Natural Resources Company
American Petroleum Institute
Anheuser-Busch, Inc.
Arab Republic of Egypt, Ministry of Electricity
Arco Pipeline Company
U.S. Army Corps of Engineers
Atlantic Richfield Company
Atomic Energy Organization of Iran
The Austin Co.

BP Alaska, Inc.
Baltimore Gas & Electric Co.
Battelle Pacific Northwest Laboratories
Bay Area Rapid Transit District
Bechtel, Inc.
Bethlehem Steel Corporation
Black & Veatch
Booz, Allen & Hamilton Inc.
Brown & Root, Inc.
U.S. Bureau of Indian Affairs
U.S. Bureau of Land Management
U.S. Bureau of Mines
U.S. Bureau of Reclamation
Burns & Roe, Inc.

California Department of Water Resources
California Division of Mines and Geology
Carolina Power & Light Co.
Chas. T. Main, Inc.
Chevron Oil Company
Chin & Hensolt, Inc.
Cities Service Co.
Cleveland Electric Illuminating Co.
Climax Uranium Co.
Colorado Water Conservation Board
Columbia Gas System, Inc.
Commonwealth Associates, Inc.
Commonwealth Edison Company
Consolidated Edison Company of New York, Inc.
Continental Oil Company

Leo A. Daly Company
Daniel, Mann, Johnson, & Mendenhall
Dow Chemical Company
Dravo Corp.
E.I. DuPont de Nemours and Company

Earl and Wright Consulting Engineers
East Bay Municipal Utility District
Ebasco Services, Inc.
Electric Power Research Institute
El Paso Natural Gas Company
U.S. Energy Research & Development Administration
U.S. Environmental Protection Agency
Ethyl Corporation
Exxon Corporation

Farmland Industries, Inc.
U.S. Federal Highway Administration
Fenix & Scisson, Inc.
Fish Engineering & Construction, Inc.
Fluor Engineers and Constructors, Inc.
Ford, Bacon & Davis Construction Corp.
Franki Foundation Co.

GPU Service Corporation
Gardinier, Inc.
General Atomic Company
General Dynamics Corp.
General Electric Company, Nuclear Energy Division
U.S. Geological Survey
Gilbert/Commonwealth
Greeley and Hansen, Engineers
Gulf Energy & Minerals Company
Gulf Oil Corp.

Henningson, Durham & Richardson
Homestake Mining Company
Horner Coal Company
Houston Lighting & Power Company
Howard Needles Tammen & Bergendoff

ICOS Corporation of America
Idaho Power Company
Illinois Power Company
International Engineering Company, Inc.
International Telephone and Telegraph Corp.
Intrusion-Prepakt Inc.
Iowa Power and Light Co.
The Irvine Company

Jersey Central Power & Light Co.

Kaiser Engineers
Kansas City Power & Light Co.
M.W. Kellogg Co.
Kennecott Copper Corp.
Kennedy Engineers
Kerr-McGee Corp.
Peter Kiewit Sons' Company

Lawrence Livermore Laboratory
Long Island Lighting Co.
Los Angeles Metropolitan Water District
Los Angeles, Port of
Louisiana Power & Light Co.
The Lummus Company

Marathon Oil Company
Arthur G. McKee
Metropolitan Edison Company
Meurer, Serafini and Meurer, Inc.
Michigan-Wisconsin Pipeline Co.
Middle South Utilities, Inc.
Midwest Research Institute
Mississippi Power & Light Company
Mobil Oil Corporation
Morrison-Knudsen, inc.

National Science Foundation
U.S. Navy
Nebraska Public Power District
New York Department of Water Resources
New York State Electric & Gas Corp.
Norfolk & Western
North American Coal Corp.
North Carolina Phosphate Corporation
Northwest Pipeline Corp.
U.S. Nuclear Regulatory Commission

Oakland, Port of
Occidental Oil Shale
Olin Corporation

Pacific Alaska LNG Company
Pacific Architects and Engineers Incorporated
Pacific Gas & Electric Company
Pacific Power & Light Company
Pan American Petroleum Corporation
Parsons, Brinckerhoff, Quade & Douglas, Inc.
The Ralph M. Parsons Co.
Peabody Coal Co.
I.M. Pei & Partners
Phelps Dodge Corporation
Philadelphia Water Department, City of
Phillips Petroleum Company
Portland General Electric Company
Public Service Company of Colorado
Public Service Company of New Mexico
Public Service Electric & Gas Company

Raymond International Inc.
Rocky Mountain Energy Co.
The Rust Engineering Co.

Safeway Stores, Inc.
San Diego, City of
San Diego Gas & Electric Company
Sandia Laboratories
Santa Fe Engineering Services Company
Sargent & Lundy
Sears, Roebuck and Company
Shell Oil Company
Skidmore, Owings & Merrill
SOHIO Petroleum Company
South Carolina Electric & Gas Co.
Southern California Edison Company
Southern California Gas Company
Southern Ohio Coal Company
Standard Oil Company of California
Standard Oil Company of Indiana
Stanley Consultants, Inc.
Stearns-Roger Incorporated
Stone & Webster Engineering Corp.
Sun Company, Inc.

Tenneco Chemical Company
Tennessee Valley Authority
Texaco, Inc.
Texas Eastern Transmission Corp.
Tipton & Kalmbach
Toledo Edison Co.
TOSCO Corporation

Union Oil Company of California
Union Pacific Railroad Company
United Engineers & Constructors, Inc.
Utah International, Inc.

Washington Public Power Supply System
Weidlinger Associates
Western Oil and Gas Association
Westinghouse Electric Corporation
State of West Virginia Coal Refuse and Dam Control Section

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CORPORATE

QUALIFICATIONS

Terrestrial
Environmental
Specialists, Inc.

CORPORATE
QUALIFICATIONS

TERRESTRIAL ENVIRONMENTAL SPECIALISTS, INC.
RD # 1, Box 388, Phoenix, New York 13135
(315) 695-7228

Terrestrial Environmental Specialists, Inc. (TES) is a firm providing research and consulting services in the areas of impact assessment, botany, zoology, land use planning, wildlife management, and other related fields. Services are available to industry, government, private concern groups, individuals, and other professional organizations.

TES was established with the goal of providing consulting services that can be effectively used to insure environmental quality while providing the client with a practical evaluation of the environmental constraints.

TES provides experienced professional personnel to perform or assist with the following services:

IMPACT ASSESSMENT

ECOLOGICAL RESEARCH

STATE AND LOCAL ENVIRONMENTAL QUALITY REVIEW

FACILITY SITING STUDIES

CORRIDOR SITING STUDIES

NATURAL RESOURCE INVENTORIES

VEGETATION AND WILDLIFE SURVEYS

RESOURCE MANAGEMENT AND PLANNING

UNIQUE HABITAT IDENTIFICATION

WETLANDS STUDIES

LAND RECLAMATION PLANNING

GAME MANAGEMENT

URBAN WILDLIFE MANAGEMENT

QUALITY ASSURANCE PROGRAMS

ENVIRONMENTAL EDUCATION

INFORMATION SEARCHES

EXPERT TESTIMONY

IMPACT ASSESSMENT

TES staff members have extensive experience in identifying both short and long term impacts on terrestrial ecosystems. A multidisciplinary approach has been applied to impacts associated with hydroelectric, fossil-fueled, and nuclear generating stations.

The process of impact assessment includes not only identifying potential impacts but also recommending possible alternatives or mitigating actions. In all cases the assessment of environmental impacts incorporates ecological, socio-economic, and aesthetic factors in producing sound recommendations which strive to balance the needs of society with environmental parameters.

ECOLOGICAL RESEARCH

TES personnel have experience in the design and implementation of many types of environmental and ecological research projects and have prepared reports or published articles on a wide variety of subjects.

TES has the capability to design and implement ecological research projects designed to solve multiple aspects of environmental, management, and land use problems. Experience in such research includes efforts to predict potential impacts, urban wildlife habitat requirements, the use of prescribed burning as a vegetation management technique, and a variety of other topics.

STATE AND LOCAL ENVIRONMENTAL QUALITY REVIEW

State and local governmental agencies are increasing their participation in environmental assessment and permit application processes. TES has experience in working with state and local agencies and is thus able to assist clients in determining their needs with regards to a particular project. TES helps to assure the incorporation of only relevant material into a project impact assessment or permit application and thus expedites review processes.

FACILITY SITING STUDIES

The staff of TES has prepared terrestrial ecology baseline studies and participated in the impact assessment phase of numerous facility siting studies. This experience has provided for the development of efficient and effective study designs and high quality reports that comply with federal and state siting regulations.

Additional experience with facility siting includes the preparation of written testimony and interrogatory responses, the presentation of oral testimony at public hearings, and the critical analyses of existing environmental reports.

CORRIDOR SITING STUDIES

TES has professional personnel who are experienced in various corridor routing studies. Staff members have developed a corridor selection technique employed in the siting evaluation of electric transmission lines ranging from 115 kV to 765 kV. Key staff personnel also have experience with the impact assessment of high pressure gas transmission line routing and corridor selection for highway projects.

NATURAL RESOURCE INVENTORY

TES is capable of preparing Natural Resource Inventories for any size land area. Among the topics covered in such documents are: physical features (topography, bodies of water, drainage systems, soil characteristics), present land uses (open space, agriculture, urban), and suitability of lands for other types of development. By identifying natural conditions for various land uses, these documents are useful tools for site selection and review processes. They enable local decision makers to incorporate environmentally sound goals in the development of master plans. Such inventories are also useful in the preparation of environmental impact statements as required by law.

UNIQUE HABITAT IDENTIFICATION

The recognition of unique habitats or unique populations of flora and fauna are important considerations in mitigating environmental impact. TES has the capabilities to recognize these unique areas or populations and to evaluate their ecological importance.

The personnel of TES have taken an active part in many studies involving threatened or endangered species and related critical habitats as defined by the Endangered Species Act of 1973. The recognition of these species and associated habitats along with the legal implications of any findings are important considerations in environmental planning.

CULTURAL RESOURCES

TES can provide professional personnel to evaluate potentials for encountering cultural resources at proposed facility sites or along proposed corridors. TES is familiar with federal and state regulations regarding historic sites, historic structures, archaeological findings, and other cultural resources. The identification of such sites is accomplished using recommended procedures to comply with federal and state regulations.

VEGETATION AND WILDLIFE SURVEYS

Inventories of the existing flora and fauna are fundamental to the understanding of the ecology of a given area. TES has completed several intensive inventory studies and integrated this knowledge into reports that provide an understanding of the many aspects of ecosystem organization and dynamics. This inventory information comprises a reliable data base which, along with an understanding of the inter-relationships, is used to predict and mitigate environmental impact. TES has expertise in the design and implementation of ecosystem studies with emphasis in the following specific fields of terrestrial ecology:

PLANT ECOLOGY	- cover type maps - species composition - community dynamics - forestry inventories - aerial photograph interpretation
HERPETOLOGY	- species composition - habitat requirements - breeding distribution
ORNITHOLOGY	- seasonal occurrence - breeding populations - game populations
MAMMALOGY	- population dynamics - game species abundance - movement patterns
INVERTEBRATES	- pest species - economics - habitat surveys

RESOURCE MANAGEMENT & PLANNING

A wide range of experience is available to provide clients with natural resource plans of varying degrees. Key staff members are capable of assisting planning commissions, government agencies, private industry, and architectural firms in developing master plans which encompass all facets of natural resources.

The TES staff has a working knowledge of the requirements of the National Environmental Policy Act of 1969 (NEPA) and the regulations that apply to the Comprehensive Planning Assistance Program. TES is fully capable of preparing environmental assessments concerning proposed master plans for the development of land areas. TES is experienced in preparing reports dealing with impact assessment, long and short term environmental effects, irreversible commitment of resources, and alternative plan impacts.

WETLANDS

TES is capable of providing wetlands inventories and surveys of specific land areas to comply with various state legislation and requirements. Since wetlands are defined by vegetation characteristics, such surveys would include identification of vegetation cover, inspection, and analyses of the area in question. Drainage patterns and seasonal water levels are also taken into account. These surveys are undertaken to clarify and define applications of legal requirements to specific land areas.

GAME MANAGEMENT

TES has expertise in managing both avian and mammalian game species. Habitat surveys, game inventories, and management recommendations can be produced to improve the suitability of land areas for game species. TES personnel have designed and used habitat evaluation techniques on several large tracts of land. In order to insure the proper implementation of management plans, experienced game biologists are available to organize and supervise habitat improvement programs.

URBAN WILDLIFE MANAGEMENT

TES can provide expert services in the field of urban/suburban wildlife management. Having conducted extensive research on bird populations and habitat in many types of residential areas, staff personnel have thorough knowledge of the habitat requirements of both desirable and undesirable species. This enables TES to cooperate with landscape architects and developers to establish plans that encourage songbirds and other desirable species while discouraging pest species. Recommendations can also be made to improve the wildlife habitat of existing developed areas or to control wildlife problems.

COMPUTER CAPABILITIES

TES has access to the computer facilities at Pneumo Services Corporation in Liverpool, New York. This IBM 370/158 system, as well as the software and technical support available at this computer center, provides TES with extensive electronic data processing capabilities.

The efficient and accurate analysis of large volumes of vegetation data has been made possible by the development of an automatic data processing procedure that extends from the recording of field data directly onto coding forms to the production of report-ready tables of summarized data, produced by a series of FORTRAN programs. Other programs have been developed to facilitate the analysis of data on faunal populations, such as the computation of diversity indices. A series of programs for standard statistical procedures is also available. In addition, TES has the in-house capability to develop new computer programs to meet specific needs.

Literature search efforts can also be aided by computer. Information retrieval systems are utilized, such as the Fish and Wildlife Reference Service and the National Technical Information Service.

QUALITY ASSURANCE

An important facet of any environmental study is providing a thorough quality assurance (QA) program designed to assure the client, and reviewing agencies, that the data were collected and analyzed in an appropriate and accurate fashion. TES staff members have extensive experience in the design and implementation of QA programs and are capable of both organizing internal QA programs and also providing QA services to other firms.

Project-specific QA programs are organized prior to the execution of a study. Quality Assurance procedures are designed to be dynamic, appropriate, and easily interpreted by both clients and reviewing agencies. QA programs include the calibration of instruments, internal audits, technical review by experts in the appropriate field, and use of standard, proven techniques for sampling and data analysis.

ENVIRONMENTAL EDUCATION

The staff of TES has experience in providing educational services on the elementary, secondary, and college levels. Staff personnel have served as instructors to various groups and have presented seminars, lectures, and demonstrations concerning a variety of ecological subjects.

TES has lecture programs and slide presentations available to educational institutions and other organized groups. Educational programs and in-service training programs are available and can be adapted to fit many situations.

INFORMATION SEARCHES

TES is experienced in a wide variety of information searches including literature searches, document searches, referral systems, and current research identification. Information sources at the disposal of the TES staff permit rapid, comprehensive compilations of the available body of knowledge on any specific aspect of the environmental sciences.

The staff of TES maintains a library that includes numerous professional journals, periodical publications, and over 400 other volumes in the fields of ecology, botany, zoology, land use planning, and related fields. In addition, the staff maintains an extensive file of reprints and technical publications. The current list of professional journals received by the staff of TES includes the following:

American Scientist
Auk
Audubon Field Notes/American Birds
Bioscience
Bird Banding
Bulletin of the Ecological Society of America
Bulletin of the New York Herpetological Society
Bulletin of the Torrey Botanical Club
Castanea
Catalogue of American Amphibians and Reptiles
Condor
Copeia
Ecology
Ecological Monographs
Herpetologica
Herpetological Review
Jack Pine Warbler
Journal of Forestry
Journal of Herpetology
Journal of Wildlife Management
Kingbird
Mammalian Species
North American Bird Bander
Raptor Research
Rhodora
Science
The Wildlife Society Bulletin
Wildlife Monographs
Wildlife Review
Wildlife Abstracts
Wilson Bulletin

The staff's familiarity and experience with state, county, and local agencies allows for efficient collection of documents, records, maps, and other materials. Such information often is required in the preparation of exhibits for environmental assessments.

TES is familiar with the use of referral systems, current research identification systems, and computer assisted literature searches. Efficient use can be made of such systems for accurate, complete, and up-to-date information.

AQUATIC BIOLOGY

Staff biologists have been involved in the study of a variety of aquatic-related subjects, such as the impacts of hydroelectric and fossil fuel generating stations on aquatic ecosystems, construction impact on stream organisms, and floral and faunal inventories of both salt and freshwater marshes. TES can provide experienced personnel to perform complete aquatic ecosystem sampling and analysis programs. TES is capable of working on studies involving marine, estuarine, and freshwater environments.

SOCIO-ECONOMIC CONSIDERATIONS

TES is experienced at determining the socio-economic impacts associated with a variety of projects. TES has assessed population growth trends, industrial growth, economic development, transportation trends, tax base and per capita income on local, county, and regional scales and has assessed the effects of project development on such factors. The staff is experienced at obtaining the most current data that is available from local, county, regional, state, and federal agencies and synthesizing this information into an understandable, project-related description of existing and developing socio-economic trends.

GEOLOGY

TES has available expertise in the field of geology, including the related subjects of geohydrology, hydrogeology, and soils engineering. Geologic, surface water, drainage, watershed, aquifer, and soils characteristics have been addressed in the studies conducted by TES. This expertise can be utilized in the preparation of environmental reports and impact statements for sewage systems, landfill operations, wastewater treatment facilities, recreational facilities, housing developments, and other projects.

EXPERT TESTIMONY

The TES staff has experience in the preparation of written testimony and the presentation of oral testimony for a variety of environmental projects. Staff members have also prepared responses to interrogatories concerning baseline data, impact assessments, and testimony. Such experience has been in regards to facility siting projects, electric transmission siting studies, and proposed gas transmission line corridors.

Testimony has been presented on a variety of specific areas related to various projects. Such areas have included preparing testimony relevant to sampling techniques, floral and faunal population characteristics, impact of habitat disturbance, and impact assessment.

CORPORATE EXPERIENCE

NIAGARA MOHAWK POWER CORPORATION (NMPC) SYRACUSE, NY

TES has provided a wide variety of services to the Environmental Affairs Department and Systems Legal Affairs Department at NMPC. TES designed and conducted a series of studies that formed the terrestrial ecology monitoring program for the baseline studies at the proposed 1700 MW Lake Erie Generating Station complex. In the Article VIII (N.Y.S. Public Service Law) proceedings, TES also provided written and oral testimony before the New York State Public Service Commission with regards to the baseline and monitoring studies.

TES has also designed and conducted studies for NMPC concerning existing land use, socio-economic considerations, and endangered species at proposed facility sites. For a major proposed hydroelectric construction project on the north Hudson River, TES conducted studies on the regional and local land use and socio-economic factors and evaluated the impacts of the proposed project on land use, aesthetics, and socio-economic considerations. This study was designed to comply with Federal Power Commission Guidelines. At the request of NMPC, TES has also prepared reports on prescribed burning as a right-of-way management technique, slash disposal volume estimates for a proposed power plant site, the life history of an endangered vertebrate species, and a survey for endangered plant species. The latter three studies were conducted at proposed fossil-fueled or hydroelectric plant sites.

WEGMANS FOOD MARKETS, INC. ROCHESTER, NY

TES prepared an environmental report under the guidelines of the New York State Environmental Quality Review (SEQR) Act for the proposed Wegmans Mall and Store, Auburn, NY. The nature of this proposed urban development project required that emphasis in the environmental report be given to community factors and socio-economic considerations, such as traffic, parking, and employment. Design considerations, such as the proposed drainage system, were also given special consideration.

DURYEA AND WILHELMI, P. C. SYRACUSE, NY

TES prepared an environmental report on the proposed rehabilitation of Sylvan Beach, NY. The project included both the rehabilitation of the central business district of the village and the construction of a seawall and recreation area along the lakefront. This report emphasized potential disturbances to Oneida Lake and the impacts of disturbances on local flora and fauna, particularly fish.

F. W. E. STAPENHORST, INC. MONTREAL, QUEBEC

TES prepared an environmental report for the proposed renovation of the Colliersville Hydroelectric Facility at Goodyear Lake on the Susquehanna River, Otsego County, NY. This report was designed to comply with the New York State Environmental Quality Review (SEQR) Act and Federal Power Commission Guidelines for impact statements required under the National Environmental Policy Act (NEPA). Considerations included ecological aspects of the proposed action in addition to socio-economic and land-use considerations.

CHASE ARCHITECTURAL ASSOCIATES, P. C. SYRACUSE, NY

Serving as a consultant to CAA, TES prepared the terrestrial ecology, air quality, and hydrology/water quality sections of an environmental report on the construction of a Holiday Inn in Auburn, NY. This report was designed to comply with the requirements of the New York State Environmental Quality Review (SEQR) Act and required emphasis on the urban environment.

DEPARTMENT OF PUBLIC WORKS CHAUTAUQUA COUNTY, NY

TES prepared an environmental impact evaluation in accordance with the New York State Environmental Quality Review (SEQR) Act, for a proposed sanitary landfill in the Town of Ellery, NY. Issues that were addressed included impacts on traffic, noise, hydrology, water quality, terrestrial and aquatic ecosystems, and socio-economic factors. In addition, TES conducted an on-site investigation of the flora and fauna of the Ellery site and made recommendations for restoration and management plans for the landfill site.

NAVAL SURFACE WEAPONS CENTER DAHLGREN, VA

For the Naval Surface Weapons Center/Dahlgren Laboratory, TES designed and conducted surveys of the plants, fish, shellfish, amphibians, reptiles, birds, and mammals on the approximately 4,300 acres that compose this naval facility. This year-long study was designed to provide baseline information for use in the preparation of an environmental impact assessment for facilities operations.

AIR FORCE CIVIL ENGINEERING CENTER EGLIN AFB, FL

TES was selected by the U. S. Air Force to prepare a Handbook of Bird Management and Control and an accompanying slide and tape presentation to be used as a teaching aid. This manual is to be used by Air Force personnel for the identification, evaluation, and control of pest bird problems at U. S. Air Bases throughout North America.

ROCHESTER GAS AND ELECTRIC CORPORATION ROCHESTER, NY

TES, under contract to Rochester Gas and Electric Corporation and Niagara Mohawk Power Corporation, was selected to prepare an update to an environmental analysis for a proposed 765 kV transmission line. This project included the analysis and comparison of primary and alternate routes for a proposed 66-mile transmission line, the recommendation of new route segments where warranted, and the presentation of testimony under Article VII requirements of New York State Public Service Law.

GENERAL PUBLIC UTILITIES SERVICE CORPORATION PARSIPPANY, NJ

TES was selected to conduct a five-year construction impact monitoring program at the site of the Forked River Nuclear Power Station. This program includes the collection of baseline floral and faunal data for the initial year and a series of monitoring studies during the following four-year period. These studies will be used to assess construction impacts of a salt water cooling tower upon plant communities and important faunal populations.

TES staff members will also gather baseline data concerning local vegetation stress over a three-year period. These data, gathered from color infrared photography and ground reconnaissance, will be coordinated with the collection of air quality data to assess the possible effects of the salt drift field from cooling towers.

NIAGARA MOHAWK POWER CORPORATION (NMPC) SYRACUSE, NY

TES was selected by NMPC to provide a routing analysis and impact assessment for a 115 kV transmission line in Jefferson County, New York. The determination of primary and alternative routes was a result of consideration for various types of constraints, such as: urban development, geology, topography and soils, wetland areas, land use, visual exposure, and cultural resources. The report produced as a result of this study forms an integral part of the New York State Public Service Law Article VII application to the New York State Public Service Commission.

PENNSYLVANIA POWER AND LIGHT COMPANY — ALLENTOWN, PA

TES was selected to conduct an environmental assessment and routing analysis for a 138 kV transmission line in east-central Pennsylvania. This study was designed to comply with the regulations of the Public Utilities Commission of Pennsylvania for siting and construction of electric transmission lines. Among the important considerations for routing the line were coal resources, natural resources, topography, land use, and socio-economic factors.

ONONDAGA COUNTY WATER AUTHORITY — SYRACUSE, NY

TES prepared a critique of a draft environmental impact statement on a stream reclassification proposal for the Onondaga County Water Authority. Important criteria considered in the preparation of the critique were stream water quality, trout populations, recreational fishing potential, and the socio-economic impacts of the reclassification of the stream.

DEPARTMENT OF PUBLIC WORKS — CHAUTAUQUA COUNTY, NY

TES prepared two environmental impact assessments for proposed bridge construction and highway relocation projects. Among the impacts investigated were soil erosion and sedimentation, effects on traffic patterns and volume, and changes in existing noise levels. The alternatives, renovation of the existing bridges or construction of new bridges at sites other than those proposed, were also evaluated.

RIST-FROST ASSOCIATES — GLENS FALLS, NY

TES prepared an environmental report for the proposed renovation of the Village of Potsdam Hydroelectric Facility on the Raquette River, St. Lawrence County, New York. This study was designed in accordance with the Federal Power Commission guidelines for impact statements required under the National Environmental Policy Act (NEPA). Considerations included ecological aspects of the proposed action on plant and animal communities in addition to socio-economic and land use factors.

ACRES AMERICAN, INC. — BUFFALO, NY

As a subcontractor to Acres American, Inc. TES provided environmental and economic assessments as part of a feasibility study for various hydroelectric generation options at the Tygart Dam and Reservoir, Grafton, West Virginia. This study was conducted for the U. S. Army Corps of Engineers - Pittsburgh District. Important considerations during this evaluation included the impacts associated with the recreational use of the reservoir, the effects upon natural aquatic and terrestrial systems, and a variety of land-use and socio-economic considerations.

DONALD R. ANDRES, P. E. — SAN JOSE, CALIFORNIA

TES was subcontracted to perform an assessment of a proposed sanitary landfill site in Onondaga County, New York. This qualitative study characterized the vegetation communities and wildlife of the site, and assessed the probability for occurrence of noteworthy species, including threatened or endangered plants and animals.

CONSUMERS POWER COMPANY — JACKSON, MICHIGAN

TES was contracted by Consumers Power Company to perform environmental studies at two potential power plant sites in Michigan. These year-long investigations included surveys of soils, vegetation, fauna, historical and archaeological resources, and recreational uses.

ACRES AMERICAN, INC. — BUFFALO, NEW YORK

TES was selected to conduct ecological, land use, and socio-economic studies relevant to the selection of a potential hydroelectric generating station site on the Black River, Oneida County, New York. Working closely with the prime contractor, TES tasks included identification of the potential for impacts of the hydroelectric facility upon fish and wildlife, vegetation, unique habitats, land use, local economics, and cultural resources.

TES STAFF PUBLICATIONS

TES personnel, in addition to environmental reports, have published a variety of journal articles and technical reports. The TES staff has produced the following list of publications dealing with: plant community descriptions, plant morphological and anatomical variation, predator-prey interactions, avian and mammalian behavior, capture techniques, avian diversity, urban wildlife, vertebrate population studies, and other subjects.

Lucid, V. J. 1971. The birds of Bissell's Cove. Rhode Island Resources 17 (4): 8-10.

Lucid, V. J. 1971. Utilization of Bissell's Cove salt marsh by birds of the families Anatidae and Laridae. M.S. Thesis, University of Rhode Island, Kingston.

Reed, E. T. 1972. More than game. Pennsylvania Game News.

Roelle, J. E., and R. S. Slack. 1972. The distribution, abundance, and diversity of birds on Edgewood Arsenal's chemical agent test area. EATR 4646: 34 pp.

Slack, R. S., J. E. Roelle, F. P. Ward, and C. F. A. Pinkham. 1972. Reptiles and amphibians on Edgewood Arsenal's chemical agent test area. EATR 4593: 23 pp.

Baumgartner, C. A. 1973. Comparative rates of desiccation and rehydration in two species of salamanders: Desmognathus fuscus fuscus and Desmognathus ochrophaeus ochrophaeus. M.S. Thesis, Pennsylvania State University, University Park.

Conner, R. N., D. C. Chamberlain, and V. J. Lucid. 1973. Some aerial maneuvers of the common raven in Virginia. The Raven (J. Virginia Soc. Ornithology) 44 (4): 99.

Lucid, V. J. 1973. Bird utilization of residential areas of different ages and types of development. Presented at the 39th Annual Meeting of the Virginia Society of Ornithology, Mountain Lake, Virginia. The Raven 44 (2): 52 (abstract).

Slack, R. S. 1973. Sparrow hawk preys on young killdeer. Bull. Okla. Ornith. Soc. 6: 20-21.

Slack, R. S. 1973. The effects of size and coloration of prey on loggerhead shrike predation. M.S. Thesis, University of Oklahoma, Norman.

Abler, W. A., D. E. Buckland, E. T. Reed, R. L. Kirkpatrick, and P. F. Scanlon. 1974. Breeding behavior of captive female white-tailed deer. Va. J. Science 24 (3): 112 (abstract).

Buckland, D. E., W. A. Abler, E. T. Reed, R. L. Kirkpatrick, and P. F. Scanlon. 1974. Breeding behavior of captive male white-tailed deer. Va. J. Science 24 (3): 112 (abstract).

Chamberlain, D. R., R. G. Hooper, V. J. Lucid, and R. N. Conner. 1974. Interspecific associations of common ravens in Virginia. The Raven (J. Virginia Soc. Ornithology) 45 (4): 79-81.

Conner, R. N., V. J. Lucid, and I. D. Prather. 1974. A sora rail on Tinker Mountain. The Raven (J. Virginia Soc. Ornithology) 45 (2): 38.

Lucid, V. J. 1974. Species diversity of breeding birds in residential areas. Va. J. Science 25 (2): 66 (abstract).

Lucid, V. J. 1974. Nocturnal activity and vocalization by a ruffed grouse. Bird-Banding 45 (2): 179.

Lucid, V. J. 1974. Bird utilization of habitat in residential areas. Ph.D. Dissertation. Virginia Polytechnic Institute and State University, Blacksburg.

Lucid, V. J., and R. N. Conner. 1974. A communal common raven roost in Virginia. Wilson Bulletin 86 (1): 82-83.

McMullen, J. M. 1974. Anatomical and morphological variation in Podophyllum peltatum L. due to aspect and elevation. M.S. Thesis, West Virginia University, Morgantown.

McMullen, J. M., and J. F. Clovis. 1974. Anatomical variation in Podophyllum peltatum L. due to aspect and elevation. W. Va. Academy of Science Proceedings. Biology Section 274-280.

Reed, E. T. 1974. Effects of fall orphaning on white-tailed deer fawns. M.S. Thesis, Virginia Polytechnic Institute and State University, Blacksburg.

Reed, E. T., B. S. McGinnes, and B. N. Reed. 1974. Parturition site in relation to subsequent home ranges of white-tailed deer fawns. Va. J. Science 25 (2): 68 (abstract).

Scanlon, P. F., R. E. Mirarchi, and E. T. Reed. 1974. Immobilization of white-tailed deer with succinylcholine chloride. Va. J. Science 25 (2): 68 (abstract).

Baumgartner, C. A., J. McMullen, V. J. Lucid, and R. S. Slack. 1975. Breeding Bird Census: 78. Shrub Community. American Birds 29 (6): 1113.

Groves, D. L., G. H. Cross, V. J. Lucid, and V. B. Cauley, Jr. 1975. A planning model for the utilization of natural resources in high density population areas. Ekistics 239: 287-290.

Lucid, V. J. 1975. Cooperation in nature. Virginia Wildlife 36 (12): 14-15.

McMullen, J., R. S. Slack, V. J. Lucid, and P. G. Kalka. 1975. Breeding Bird Census: 79. Shrub Community II. American Birds 29 (6): 1113-1114.

Reed, E. T. 1975. The future of passerine banding. EBBA News 38 (2): 84-85.

Slack, R. S. 1975. Effects of size of prey on loggerhead shrike predation. Auk 92 (4): 812-814.

Slack, R. S., C. A. Baumgartner, and J. McMullen. 1975. Breeding Bird Census: 143. Open Field. American Birds 29 (6): 1138-1139.

Slack, R. S., C. A. Baumgartner, and V. J. Lucid. 1975. Breeding Bird Census: 144. Vineyard I. American Birds 29 (6): 1139.

Slack, R. S., L. Braband, and H. E. Slack III. 1975. Breeding Bird Census: 145. Vineyard II. American Birds 29 (6): 1139.

Slack, R. S., H. E. Slack III, and P. G. Kalka. 1975. Breeding Bird Census: 60. Scotch Pine Plantation. American Birds 29 (6): 1104-1105.

Slack, R. S., P. G. Kalka, V. J. Lucid, and J. McMullen. 1975. Breeding Bird Census: 3. Red Maple Forest. American Birds 29 (6): 1082-1083.

Conner, R. N., and V. J. Lucid. 1976. Interactions between nesting birds and carpenter ants. Bird-Banding 47 (2) 161-162.

Lucid, V. J. 1976. Songbirds in suburbia. Virginia Wildlife 37: 7-9, 24.

Pinkham, C. F. A., M. R. Braid, J. E. Roelle, and R. S. Slack. 1976. Effects of tests with military chemicals on the mammals of Carroll Island. Edgewood Arsenal Technical Report EO-TR-76071.

Slack, R. S., and J. M. McMullen. 1976. Red-tailed hawk preys on common gallinule. The Kingbird 26: 202.

Reed, E. T. 1977. Is your banding of any value? North American Bird Bander 1: 178-179.

Slack, R. S. and C. A. Baumgartner. 1977. A possible New York State dickcissel breeding colony. The Kingbird 27: 26-27.

Baumgartner, C. A., and R. S. Slack. 1977. Breeding Bird Census: 76. Shrub Community I. American Birds 31 (1): 58.

Baumgartner, C. A., and R. S. Slack. 1977. Breeding Bird Census: 153. Vineyard III. American Birds 31 (1): 87.

Lucid, V. J., P. G. Kalka, and R. S. Slack. 1977. Breeding Bird Census: 77. Shrub Community II. American Birds 31 (1): 53.

McMullen, J. M., and R. S. Slack. 1977. Breeding Bird Census: 4. Mixed Hardwoods Forest. American Birds 31 (1): 30.

McMullen, J. M., R. S. Slack, and V. J. Lucid. 1977. Breeding Bird Census: 3. Mixed Hardwoods. American Birds 31 (1): 29-30.

Slack, R. S. 1977. Breeding Bird Census: 154. Vineyard IV. American Birds 31 (1): 87.

Slack, R. S., and C. A. Baumgartner. 1977. Breeding Bird Census: 152. Open Field. American Birds 31 (1): 86-87.

Slack, R. S., C. A. Baumgartner, and V. J. Lucid. 1977. Breeding Bird Census: 67. Scotch Pine Plantation. American Birds 31 (1): 54.

Slack, R. S. 1978. An unusual Black-capped Chickadee at Phoenix, New York. North American Bird Bander 3: 56-57.

Slack, R. S. 1978. Life expectancy of newer-issue size 1-A bands. North American Bird Bander 3 (3): 99.

Slack, R. S., and H. E. Slack, III. 1979. An unusual Common Grackle in central New York State. North American Bird Bander 4: 14.

JEFFREY O. BARNES

Terrestrial Environmental Specialists, Inc.

Education

B.S. Zoology (Major), Botany (Minor): State University of New York College of Environmental Science and Forestry, Syracuse, New York, 1971.

Professional Experience

Environmental Scientist, Terrestrial Environmental Specialists, Inc., Phoenix, New York, 1976 - present.

Terrestrial Ecologist, Niagara Mohawk Power Corporation, Syracuse, New York, 1972-1975.

Teacher/Demonstrator, Environmental Matters, Nine Mile Point Nuclear Station Progress Center, Niagara Mohawk Power Corporation, Oswego, New York, 1971-1972.

Awards and Offices

Certificate of Completion, Short Course on Environmental Siting of Transmission Lines, from Bruce Howlett, Inc. Brewster, New York, 1973.

Certificate of Completion, Natural Resource Inventory Workshop, Atmospheric Sciences Research Center, Wilmington New York, 1975.

Secretary - Treasurer (1974-1977); Vice President (1977-1978); The Wildlife Society - New York Chapter.

Memberships

National Audubon Society
National Wildlife Federation
The Smithsonian Institution
The Wildlife Society
The Wildlife Society - New York Chapter

Consulting and Related Experience

- supervised and reviewed impact analyses of six 115 kV to 765 kV electric transmission line sitings.
- devised a Site Sensitive Avoidance Technique for transmission line corridor selection studies and utilized this technique on two 115 kV and one 765 kV study in New York State.

Consulting and Related Experience (Continued)

- prepared and presented oral and written testimony at public hearings regarding electric transmission line siting studies.

- prepared exhibits to fulfill regulations governing the licensing and relicensing of hydroelectric generating facilities.

- supervised feasibility study on technique selection for aquatic biology and water chemistry studies.

- supervised and participated in a study to assess prescribed burning as a vegetation management technique for rights-of-way.

- presented testimony at public hearings regarding proposed electric generating plant siting studies.

- supervised and reviewed impact analyses for siting of high pressure gas transmission lines.

- worked upon the preparation of an environmental update for a proposed 765 kV transmission line and the evaluation of the environmental compatibility of proposed routes.

- supervised the preparation of a critique of a proposed stream reclassification report.

CATHIE A. BAUMGARTNER

Terrestrial Environmental Specialists, Inc.

Education

B.A. Biology (Major); Douglass College, Rutgers University, New Brunswick, New Jersey, 1969.
M.S. Zoology; Pennsylvania State University, University Park, Pennsylvania, 1973.

Professional Experience

Environmental Scientist, Terrestrial Environmental Specialists, Inc., Phoenix, New York, 1976 - present.

Associate Environmental Scientist (Director of Herpetological Studies), Equitable Environmental Health, Inc., Woodbury, New York, 1975.

Assistant Environmental Scientist (Herpetologist), Environmental Analysts, Inc., Garden City, New York, 1973-1975.

Instructor, Pennsylvania State University, Altoona, Pennsylvania, 1973.

Assistant Curator of Herpetology, Pennsylvania State University Museum, University Park, Pennsylvania, 1973.

Graduate Teaching Assistant (Zoology, Ecology, Ornithology), Pennsylvania State University, University Park, Pennsylvania, 1967-1973.

Undergraduate Laboratory Technician, Department of Biological Sciences, Rutgers University, New Brunswick, New Jersey, 1969.

Awards

National Science Foundation Grant - Summer Science Program - Paterson State College, Wayne, New Jersey, 1964.

National Science Foundation Grant - Summer Science Program - Fairleigh Dickenson University, Rutherford, New Jersey, 1963.

Phi Sigma (National Biological Honor Society), 1971-1973.

Sigma Delta Epsilon (Graduate Women in Science), 1972-1973.

Memberships

American Association for the Advancement of Science
American Birding Association, Inc.
American Ornithologists' Union
American Society of Ichthyologists and Herpetologists
Eastern Bird Banding Association
Ecological Society of America
Federation of New York State Bird Clubs, Inc.
Raptor Research Foundation
Society for the Study of Amphibians and Reptiles
Wilson Ornithological Society

Consulting and Related Experience

- designed and implemented herpetofaunal surveys at four proposed nuclear power plant sites.

- designed and supervised herpetofaunal surveys at two proposed fossil fuel power plant sites.

- authored herpetofaunal sections of environmental impact statements for 6 proposed power plant sites.

- authored testimony and responses to interrogatives on the environmental assessment of a proposed electric generating facility.

- supervised and coordinated production of a report on a major baseline terrestrial ecology study conducted for a proposed electric generating facility.

- designed, implemented, and authored report on study of vegetation mapping of a small impoundment.

- critically analyzed sections of an environmental assessment for two proposed power plant sites.

- participated in data collection on peregrine falcons as part of a nation-wide effort.

- conducted literature search on ecological parameters of selected marine fauna in conjunction with generation facility feasibility study.

- conducted literature searches on habitat requirements, distribution, and predator-prey interactions of selected vertebrates of the northeast.

- conducted study on habitat ecology of several species of stream vertebrates.

- collected ornithological data at 6 proposed power plant sites.

Consulting and Related Experience (Continued)

- designed and supervised studies of amphibian, reptilian, and fish resources of a 4,300 acre naval facility.
- assisted in the collection of baseline breeding bird data to be used to monitor the impacts of power plant construction activities.
- participated in the preparation of a report assessing impacts of an urban redevelopment project..
- supervised the preparation of a report assessing a lake shoreline development project in central New York.
- participated in the preparation of a report assessing the impacts of the renovation of a small hydroelectric facility.
- supervised and coordinated a route selection study for a 115 kV transmission line.
- participated in data collection and report preparation for an environmental assessment of a proposed sanitary landfill.
- designed and implemented data collection for a baseline and herpetofaunal monitoring program assessing the impacts of construction of a nuclear power plant.

LEWIS M. CUTLER

Terrestrial Environmental Specialists, Inc.

Education

B.S. Biology; State University of New York, Albany, New York, 1971.
M.S. Botany; State University of New York College of Environmental Science and Forestry, Syracuse, New York, 1975.

Professional Experience

Associate Environmental Scientist, Terrestrial Environmental Specialists, Inc., Phoenix, New York, 1978 - present.

Plant Protection Aid, U. S. Department of Agriculture, Animal and Plant Health Inspection Service, Syracuse, New York, 1977.

Botanical Consultant, The Nature Conservancy, Adirondack Conservancy Committee, Elizabethtown, New York, Summer 1977 and 1976.

Research Assistant in Forest Botany, State University of New York College of Environmental Science and Forestry, Syracuse, New York, Fall 1973.

Laboratory Teaching Assistant, College of Environmental Science and Forestry, Syracuse, New York, Spring 1973.

Temporary Assistant, New York State Herbarium, New York State Museum and Science Service, Summer 1971.

Awards

BBB Biology Honor Society

Sigma Xi (Scientific Research Society of North America)

Memberships

Society of American Foresters

Consulting and Related Experience

- conducted a vegetation survey using aerial photograph interpretation and field sampling, as part of a preservation plan for a 1,000 acre estate in northern New York.

Consulting and Related Experience (Continued)

- conducted vegetation surveys on two parcels of land in the Adirondack Mountains including: a map and description of plant communities, a list of vascular plants by community type, a list of rare and endangered species, and unique natural features.

- prepared a natural vegetation resource survey of the Tug Hill Region, N. Y. including: a vegetation and land-use type map, a plant species list by cover type, an analysis of the region's forest inventory, a rare plant species list, and a list of unique natural areas.

- participated in a search for endangered plant species at a proposed hydroelectric redevelopment site.

- collected soil samples to determine the extent of an agricultural pest infestation.

- assisted in the collection, identification, and preparation of herbarium specimens at the New York State Herbarium.

- conducted studies of the vegetation of a watershed, including a forest community study in relation to vegetational response to past site disturbances, an annotated plant species list, and a key.

- served as project investigator for the data collection and report preparation for an environmental assessment for the renovation of a retired hydroelectric facility.

- assisted in the collection and analysis of vegetation data for an intensive baseline study at a nuclear power plant site.

- participated in the data collection and analysis for a transmission line routing study.

- served as project manager for a hydroelectric site selection study and coordinated the investigation of land use, biological aspects, and local economics of the area.

FRANK M. DICKINSON

Terrestrial Environmental Specialists, Inc.
Consultant

Education

B.S. Geology; Syracuse University, Syracuse, New York, 1956.
M.S. Geology; Syracuse University, Syracuse, New York, 1958.

Certification

Certified Professional Geologist

Professional Experience

Research Associate, Terrestrial Environmental Specialists, Inc. Phoenix, New York, 1978 - present.

Associate, Stearns & Wheler, Cazenovia, New York, 1966 - present.

Senior Project Geologist, Dames & Moore, New York, New York, 1965-1966.

Staff Geologist, Watershed - River Basin Planning Staff, U. S. Department of Agriculture, Syracuse, New York, 1961-1965.

Project Geologist, Geophysical Analyses Company, Syracuse, New York, 1957-1961.

Assistant Division Engineer, Department of Engineering, City of Syracuse, New York, 1957-1959.

Awards

Thesis honors from Sigma Xi (1958), "Hydrogeology of Upper Tonawanda Creek Watershed, Batavia, New York".

Listed in "Leaders in American Science".

Memberships

American Geophysical Union
American Institute of Professional Geologists
Association of Engineering Geologists

Consulting and Related Experience

- a total of 19 years of responsible geologic experience in the specific fields of engineering geophysics, engineering and environmental geoscience, geohydrology, hydrogeology, and soils engineering.

Consulting and Related Experience (Continued)

- environmental impact analyses and preparation of environmental assessment and impact statements for projects such as --

    - EI Statement for the Horizon Corporation - a planned urban development of 7,000 units on 25,000 acres in St. Lawrence County, New York, including recreation facilities and artificial lakes.

    - EI Statement for Greek Peak, New York - a 1,400 unit, 4-season recreational facility

- project site and engineering investigations for wastewater treatment plants, sewers, sanitary landfills, dams and numerous other projects.

- county-wide comprehensive water supply studies.

- exploration, design, installation and development of numerous large-capability municipal and industrial groundwater supplies, sanitary landfills and earth dams.

- engineering planning studies and environmental assessment for planned urban development projects.

- hydrologic studies and analyses including discharge frequency and flood routing for hydrologic structure design and aquifer analyses and sustained safe yield analyses of watersheds and river basins.

- authored numberous papers which have been presented before the annual meetings of the Association of Engineering Geologists.

MATTHEW P. KILLEEN

Terrestrial Environmental Specialists, Inc.

Education

B.S. Environmental and Resources Management (Forest Management): State University of New York College of Environmental Science and Forestry, Syracuse, New York, 1974.

M.S. Resource Management and Policy: State University of New York College of Environmental Science and Forestry, Syracuse, New York, 1978.

Professional Experience

Associate Environmental Scientist, Terrestrial Environmental Specialists, Inc., Phoenix, New York, 1979 - present.

Environmental Planner, Essex County, Elizabethtown, New York, 1978 and 1979.

Graduate Research Assistant, Applied Forest Research Institute, College of Environmental Science and Forestry, Syracuse, New York, Spring, 1977.

Graduate Teaching Assistant (Outdoor Recreation Planning and Management), State University of New York College of Environmental Science and Forestry, Syracuse, New York, 1975 - 1977.

Planning Assistant, Essex County Planning Office, Elizabethtown, New York, Summer, 1976.

Memberships

National Wildlife Federation

Consulting and Related Experience

- designed, implemented and prepared a planning report examining the economic, environmental and social impacts related to the development of a countywide system of winter recreational trails.

- prepared a management plan for the winter use of an outdoor education center and served as the director of the center.

- prepared a plan for the development of a countywide system of winter recreational trails, including layout and design of trails, and provided direction and supervision for crews constructing and/or improving more than 100 miles of trails.

Consulting and Related Experience (Continued)

- provided technical information related to the development plans of a municipal recreation area including campsite, beach, and boat-launching site.

- participated in a research project aimed at classifying the users of forest research materials.

- was responsible for the development and implementation of an outdoor educational program at a summer camp for boys.

- performed major portions of an environmental feasibility study for hydroelectric generation at a flood control dam in north central West Virginia.

- participated in a hydroelectric site selection study designed to identify significant ecological, social, economic, and cultural impacts.

VINCENT J. LUCID

Terrestrial Environmental Specialists, Inc.

Education

B.S. Zoology; University of Rhode Island, Kingston, Rhode Island. 1968.
M.S. Animal Science (Wildlife Management); University of Rhode Island, Kingston, Rhode Island. 1971.
Ph.D. Wildlife Biology; Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 1974.

Professional Experience

Director of Environmental Studies, Terrestrial Environmental Specialists, Inc., Phoenix, New York, 1976 - present.

Environmental Scientist (Senior Terrestrial Ecologist/ Project Manager), Equitable Environmental Health, Inc., Woodbury, New York. 1976.

Associate Environmental Scientist (Terrestrial Ecologist/ Quality Assurance Coordinator), Environmental Analysts, Inc., Garden City, New York. 1975.

Graduate Research and Teaching Assistantships, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 1971 - 1974.

Graduate and Post-graduate Research Assistantships, University of Rhode Island, Kingston, Rhode Island. 1970 - 1971.

Biological Aide, U.S. Bureau of Commercial Fisheries, Biological Laboratory, Boothbay Harbor, Maine. 1966.

Awards

Phi Kappa Phi (National Honor Society). 1973.

Phi Sigma (National Biological Honor Society). 1973.

Sigma Xi (Scientific Research Society). 1974 - Present.

Memberships

American Ornithologists' Union
International Oceanographic Foundation
National Audubon Society
National Wildlife Federation
The Nature Conservancy
The Wildlife Society
Virginia Society of Ornithology
Wilson Ornithological Society

Consulting and Related Experience

- designed and managed a comprehensive study of the effects of fossil fuel effluents on agricultural crops.
- designed and implemented quantitative data analysis of terrestrial ecology studies at two proposed power plant sites.
- coordinated quality assurance programs for aquatic ecology and water quality studies at two proposed power plant sites and five existing stations.
- designed and managed a critical analysis of an environmental assessment for two proposed power plant sites.
- authored terrestrial ecology sections of a report on regional impact issues for electric generation development in the Pacific Northwest.
- authored major sections of a preliminary report on the environmental impact of the XIII Olympic Winter Games.
- compiled and analyzed background information for environmental assessment of a proposed theme park development.
- critically reviewed and conducted computer analysis for a series of terrestrial ecology monitoring studies.
- authored responses to interrogatories concerning testimony on the environmental assessment of a proposed electric generating station.
- authored a report on slash disposal following land-clearing for construction purposes.
- authored sections of a report on the use of private lands for outdoor recreation.
- designed and conducted a comprehensive analysis of bird populations and habitat in residential developments.

Consulting and Related Experience (Continued)

- designed and conducted a study of bird utilization of a tidal marsh.
- coordinated and participated in the preparation of an environmental impact statement for the proposed renovation of a hydroelectric generating facility.
- provided technical input in the comparison of environmental impact of two proposed highway routes.
- managed and prepared major portions of an environmental impact statement for a proposed urban redevelopment project, and authored the biological and physical environment sections of a report on another urban project.
- coordinated and participated in floral and faunal surveys at a U. S. Navy installation.
- authored major sections of a bird pest control handbook for the U. S. Air Force.
- conducted major portions of an environmental analysis of proposed routes for a high voltage electric transmission facility.
- coordinated a terrestrial ecology monitoring program at a nuclear power plant construction site.
- coordinated environmental studies at two potential power plant sites in the Midwest.
- performed the faunal portion of a floral/faunal assessment for a proposed sanitary landfill site in central New York.

JOSEPH M. MCMULLEN

Terrestrial Environmental Specialists, Inc.

Education

B.S. Biology (Major); Saint Francis College, Loretto Pennsylvania, 1971.
M.S. Biology (Botany, Ecology); West Virginia University Morgantown, West Virginia, 1974.

Professional Experience

Environmental Scientist, Terrestrial Environmental Specialists, Inc., Phoenix, New York, 1976 - present.

Associate Environmental Scientist (Director of Plant Ecology), Equitable Environmental Health, Inc., Woodbury, New York, 1975.

Assistant Environmental Scientist (Plant Ecologist), Environmental Analysts, Inc., Garden City, New York, 1975.

Graduate Teaching Assistant (General Biology, Botany), Department of Biology, West Virginia University, Morgantown, West Virginia, 1971-1974.

Awards

Grant-in-aid of research from The Society of Sigma Xi, 1972.

Memberships

American Institute of Biological Scientists
The Wildlife Society (New York Chapter)
Society of American Foresters
Southern Appalachian Botanical Club

Consulting and Related Experience

- designed, implemented, and prepared reports for botanical studies of hardwoods forests, plant succession, and threatened and endangered species.

- prepared vegetation cover type maps for 12,000 acres of mixed communities.

- assisted in the development of two FORTRAN programs for the analysis of vegetation data.

Consulting and Related Experience (Continued)

- collected data and assisted in writing the botanical portion of a study of prescribed burning as a vegetation management technique.
- prepared written testimony and interrogatory responses concerning plant communities and related impact of power plant construction.
- critically reviewed botanical portion of a baseline terrestrial ecology study for two power plant sites.
- supervised technical personnel conducting a botanical survey on a total of 8,000 acres of land.
- collected, analyzed and interpreted data for plant ecology studies on the primary and secondary sites for a proposed major electric generating station.
- provided technical information for slash disposal estimates following land-clearing operations for construction purposes.
- authored vegetation section concerning the environmental impact of a proposed beach and town rehabilitation project.
- prepared sections on soils and vegetation for an environmental report on the renovation of an existing, non-operating hydroelectric generating facility.
- prepared a report on the status of endangered plant species in the vicinity of a proposed hydroelectric facility.
- supervised the preparation and authored various sections of a comprehensive draft environmental impact statement prepared under the guidelines of the New York State Environmental Quality Review Act for a proposed county sanitary landfill.
- designed and supervised the data collection and report preparation for an intensive study of vegetation and designed a five-year monitoring program to assess the impacts of the construction of a nuclear power plant in New Jersey.
- provided input for an environmental assessment and routing analysis for a 138 kV transmission line in Pennsylvania.
- participated in an environmental assessment and routing analysis for a 115 kV transmission line in northern New York.
- prepared a vegetation cover map and flora survey for a 4,300 acre naval base in Virginia.

EDWARD T. REED

Terrestrial Environmental Specialists, Inc.

Education

B.S. Science Education; Pennsylvania State University, University Park, Pennsylvania, 1967.
M.S. Wildlife Management, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 1974.

Professional Experience

Environmental Scientist, Terrestrial Environmental Specialists, Inc., Phoenix, New York, 1976 - present.

Associate Environmental Scientist (Director of Mammalian Studies), Equitable Environmental Health, Inc., Woodbury New York, 1974-1975.

Graduate Teaching Assistant (Silviculture), Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 1973.

Biology Instructor, Upper Dublin High School, Fort Washington, Pennsylvania, 1967-1972.

Awards

Gamma Sigma Delta, 1974.

Phi Kappa Phi, 1974.

Memberships

The Wildlife Society
The American Society of Mammalogists
Eastern Bird Banding Association
Editorial Board of Eastern Bird Banding Association
The Ruffed Grouse Society of North America

Consulting and Related Experience

- collected and analyzed data and prepared reports for mammalian studies on six proposed power plant sites.

- critically reviewed an environmental assessment for two proposed power plant sites.

- designed, implemented, and analyzed a technique to assess the habitat suitability of 8,000 acres for selected game species.

Consulting and Related Experience (Continued)

- monitored populations of mammalian species in respect to potential impacts of power plant sitings.

- evaluated the behavioral impact of sport hunting on white-tailed deer.

- designed, implemented and prepared the report of a study to determine species composition of bat populations on proposed power plant sites.

- provided ornithological input to an impact study for a proposed hydroelectric project.

- prepared written testimony concerning mammalian populations and related impacts of power plant construction.

- provided critical review and advice on an impact evaluation of two proposed power plant sitings.

- authored responses to interrogatories concerning baseline ecology studies and related impacts.

- prepared descriptions of the ecology of aquatic fauna and the aquatic impact assessment for a proposed lake shore construction project.

- authored major sections of a comprehensive draft environmental impact statement for a proposed county sanitary landfill.

BARBARA J. ROOT

Terrestrial Environmental Specialists, Inc.

Education

B.S. Biology; State University of New York College of Environmental Science and Forestry, Syracuse, New York, 1976.

Professional Experience

Botanist, Terrestrial Environmental Specialists, Inc., Phoenix, New York, 1977 - present.

Assistant to the Area Director, U.S. Department of Agriculture, Syracuse, New York, 1977.

Soil Sampler, U.S. Department of Agriculture, Syracuse, New York, 1976.

Environmental Technician, Terrestrial Environmental Specialists, Inc., Liverpool, New York, 1976.

Consulting and Related Experience

- assisted in the collection of field data for a study of plant community succession at a proposed fossil fuel power plant site.

- participated in the collection of data to assess hardwood forest stands on two proposed power plant sites.

- assisted in a survey of protected plant species on two proposed power plant sites.

- collected soil samples as part of two federally sponsored programs on parasite distribution.

- collected agricultural samples used to assess a natural biological control program on insect pest.

- participated in the collection and analysis of vegetation data for an intensive study at the nuclear power plant site.

- collected vegetation data for the monitoring of construction impact of a nuclear power plant in New Jersey.

ROY S. SLACK

Terrestrial Environmental Specialists, Inc.

Education

B.S. Zoology (Major); Marshall University, Huntington, West Virginia, 1968.
M.S. Zoology (Ornithology, Ecology); University of Oklahoma, Norman, Oklahoma, 1973.

Professional Experience

Environmental Scientist, Terrestrial Environmental Specialists, Inc., Phoenix, New York, 1976 - present.

Associate Environmental Scientist (Director of Avian Studies), Equitable Environmental Health, Inc., Woodbury, New York, 1975.

Assistant Environmental Scientist (Ornithologist) Environmental Analysts, Inc., Garden City, New York, 1974-1975.

Graduate Teaching Assistant (Ecology, General Zoology, Ornithology), Department of Zoology, University of Oklahoma, Norman, Oklahoma, 1971-1974.

Veterinary Animal Specialist, U.S. Army Biomedical Laboratory, Edgewood Arsenal, Maryland.

Field Ecologist, Test Area Ecology Program, Department of Veterinary Medicine, 1970-1971.

Veterinary Surgical and Research Assistant, Department of Veterinary Medicine, 1968-1970.

Undergraduate Laboratory Assistant, Department of Biological Sciences, Marshall University, Huntington, West Virginia, 1966-1967.

Awards

American Ornithologists' Union, Undergraduate Student Membership, 1968.

Honor Graduate, United States Army Veterinary Animal Specialist Course, Walter Reed Army Medical Center, 1968.

United States Army Certificate of Commendation, U.S. Army Medical Research Center, Edgewood Arsenal, Maryland, 1971.

Memberships

American Ornithologists' Union
American Society of Ichthyologists and Herpetologists
Cooper Ornithological Society
Eastern Bird Banding Association
Ecological Society of America
Raptor Research Foundation
Wilson Ornithological Society

Consulting and Related Experience

- collected and analyzed data and prepared reports for ecological studies on four proposed nuclear power plant sites.

- designed and implemented population studies of avian species not readily censused by standard techniques.

- supervised staff biologists conducting baseline biological investigations for electric generating plant siting studies.

- designed a study and supervised staff biologists conducting an ornithological study on 8,000 acres of mixed habitat.

- conducted literature searches concerning subjects such as censusing techniques, avian habitat requirements and breeding biology, and population dynamics of avian species.

- provided technical information on habitat requirements and the distribution of avian species for a large river channelization project.

- assessed the possible effects on chemical contamination of habitat for vertebrate populations.

- collected data on peregrine falcons as part of a nation-wide endangered species research program.

- prepared written testimony concerning avian populations and the related impact of power plant construction.

- designed, implemented, and prepared report for a study to determine the impact of migratory bird collisions with power plant structures.

- designed and supervised field data collection and authored a report on an avian population monitoring program.

- served as project field manager for biological surveys conducted on a 4,300 acre naval facility.

Consulting and Related Experience (Continued)

- authored the fish and wildlife resource exhibit for the environmental report for a proposed hydroelectric facility renovation.

- authored major sections of a handbook for the control of pest bird species.

- participated in the preparation of an environmental analysis of proposed routes for a high voltage transmission line.

- authored major sections on land use and socio-economic considerations for an environmental report regarding a proposed major hydroelectric development project.

- designed and supervised data collection and authored the reports for baseline studies being conducted as part of a five-year program to monitor the impacts of power plant construction upon bird populations.

- conducted baseline studies of avian populations in order to assess the impact of construction and operation of a county sanitary landfill.

- supervised and participated in the screening and evaluation of alternative plans for hydroelectric generation at an existing flood control and stream flow augmentation dam in West Virginia.

- supervised and participated in an environmental assessment and site selection study for a proposed major hydroelectric facility.

ROBERT W. WILLIAMS

Terrestrial Environmental Specialists, Inc.
Research Associate

Education

B.S. Biology; State University of New York, Oswego, New York, 1966.
M.A. Zoology; University of Vermont, 1969.

Professional Experience

President and Owner, Aquatic Equipment Company, Minetto, New York, 1976 - present.

Assistant Adjunct Professor, Syracuse University, Syracuse, New York, 1976 - present.

Director, Oswego Laboratory, Quirk, Lawler and Matusky Laboratories, Inc., Oswego, New York, 1973-1976.

Project Biologist, Quirk, Lawler and Matusky Engineers, Nyack, New York, 1972-1973.

Technical Coordinator of Biological Programs, Quirk, Lawler and Matusky Engineers, Nyack, New York, 1972-1973.

Assistant Director of Laboratory, Quirk, Lawler and Matusky Engineers, Nyack, New York, 1971-1972.

Project Biologist, Quirk, Lawler and Matusky Engineers, Nyack, New York, 1971-1972.

Biologist, Quirk, Lawler and Matusky Engineers, Nyack, New York, 1970-1971.

Memberships

International Association of Great Lakes Research

Consulting and Related Experience

- coordinated general biological, entrainment and impingement studies at the Nine Mile Point Nuclear Station and the Oswego Steam Station.

- coordinated and supervised studies on fish behavior in thermal discharges at three sites for Ontario Hydro.

Consulting and Related Experience (Continued)

- set up and oversaw the execution and quality of field and laboratory studies at the Nine Mile Point Nuclear Station and the Oswego Steam Station.

- coordinated technical biological programs with administrative responsibilities for biological programs on the Hudson River and Lake Ontario.

- coordinated manpower, technical skills and equipment for many projects at the Bowline Generating Station, Lovett Generating Station, Danskammer Point Generating Station, and the Roseton Generating Station.

- participated in power plant siting studies on the Hudson River.

- managed physical, chemical and biological activities associated with intensive projects on lake and river systems in New York.

- managed biological programs for environmental reports on the Hudson River and Lake Ontario.

- participated in physical, chemical and biological investigations on Lake Ontario, Hudson River and Lake Champlain.

QUALIFICATION STATEMENT
SUPPORT SERVICES
COOK INLET REGION, INC./HOLMES & NARVER, INC.

SUSITNA HYDROELECTRIC POWER PROJECT
FEASIBILITY STUDY

Prepared for

ACRES AMERICAN, INC.
Suite 329, The Clark Building
Columbia, Maryland 21044

August 1979

CIRI - H&N

August 1, 1979

Mr. Charles A. Debelius, Mgr. Engr.
Acres American, Inc.
Suite 329, The Clark Building
Columbia, MD 21044

SUSITNA HYDROELECTRIC POWER PROJECT FEASIBILITY STUDY SUPPORT SERVICES

We are pleased to submit 30 copies of the CIRI/H&N qualification statement for providing support services necessary to perform the feasibility analysis for the Susitna Hydroelectric Power Project.

The CIRI/H&N qualification statement generally outlines our perspective of support service requirements for this project, and describes our related project experience in performing similar services throughout the world.

We firmly believe that CIRI/H&N is uniquely qualified to accomplish the services you require and look forward to supporting your engineering team.

E. Gilmore

Earl P. Gilmore
Senior Vice President
Holmes & Narver, Inc.

HOLMES & NARVER, INC
3201 "C" STREET
SUITE 201
ANCHORAGE, ALASKA 99503
(907) 278-1577

COOK INLET REGION, INC
CIRI BUILDING
2525 "C" STREET
ANCHORAGE, ALASKA 99503
(907) 274-8638

CIRI/H&N PERSPECTIVE

OF

SUPPORT SERVICES REQUIREMENTS

1. INTRODUCTION

Feasibility analyses evaluating the development of the Upper Susitna River Basin Hydroelectric Power Project can be enhanced through technical support which is familiar with local conditions and requirements for base camp facilities, logistics, and technical field studies. Cook Inlet Region, Inc., (CIRI), in association with Holmes & Narver, Inc., (H&N) has considerable experience with providing a broad range of these services in Alaska. Consequently, it is believed that CIRI/ H&N would complement the extensive capabilities of your engineering firm by furnishing one or all of the following services:

- Turnkey camp facilities
  - Design and construction
  - Operation and maintenance
- Logistics
  - Procurement
  - Transportation
- Technical support
  - Environmental impact statement and permit preparation
  - Seismic engineering studies
  - Surveying

Our understanding of the general work requirements for each of these activities, and the joint venture's related experience, is discussed as follows. Your review of CIRI/H&N experience may bring to your attention additional support services required to efficiently and effectively carry out the Susitna Feasibility Analysis. Such services could easily be incorporated with the other proposed work activities of CIRI/H&N.

2. TURNKEY CAMP FACILITIES

2.1 DESIGN AND CONSTRUCTION

In remote or isolated areas where accommodations for personnel are not normally available, a significant facet of mobilizing for and operating a project is the provision of living quarters, dining facilities, and other amenities and services for the work force. This will be a major requirement for the successful undertaking and completion of the work on the Susitna Hydroelectric Project Feasibility Analysis. Camp and support facilities designed and built by CIRI/H&N incorporate a quality personnel support program that will result in increased project productivity by attracting and holding highly competent personnel.

2.2 OPERATION AND MAINTENANCE

Upon completion of the design and construction of camp and support facilities, maintenance and operation services must be provided. Such services can include, at least, the following:

- Food Service
  - Menu preparation
  - Food preparation
  - Dining hall operation
  - Coffee and tea service

- Housing and billeting
- Housekeeping
- Janitorial and camp cleanup
- Laundry, personal and industrial
- Recreational
    - Canteen
    - Mail service
    - Movie theatre
    - Barber shop
    - Sports and exercising facilities
- Medical and dental care
- Security
- Fire protection
- Power generation and distribution
- Water supply, treatment, storage and distribution
- Fuel storage and distribution
- Sewage disposal system

- Sanitation and solid waste disposal

- Road and grounds maintenance

- Building and structure maintenance

- Warehousing and supply

- Communications

- Heating, refrigeration, air conditioning, and mechanical ventilation equipment

- Purchasing of food and supplies

In providing the above services, CIRI/H&N will implement, if required, a work and performance control system to affect economy in the maintenance and operations. This system will provide for the planning, inspection, coordination, record keeping, and documentation required for professional management control and reporting.

3. LOGISTICS

3.1 INTRODUCTION

In order to optimize each movement of cargo or field personnel, CIRI/H&N can ensure that logistical support will include consideration of material and supply procurement, control, transportation, storage, handling, and scheduling. Through the use of proven techniques established by CIRI/H&N during numerous worldwide support operations, there is great opportunity to achieve not only considerable cost reductions, but also improvements in quality control and on-time performance.

Since the project area is situated in the remote, sub-Arctic environment of Alaska's Southcentral Railbelt area, special attention will need to be directed to the consideration of procurement and transportation. CIRI/H&N's general approach to these considerations are as follows.

3.2 PROCUREMENT

CIRI/H&N recognizes that the shipping cycle requires prior planning to ensure the receipt and delivery of material and supplies well in advance of the time these items are required for use. This requirement generates a need for experienced procurement management to determine consumption trends and forecast the total weight of all materials, equipment and supplies so that staging and transportation requirements can be analyzed before camp and support facilities are used. This information is regularly updated throughout the project in conjunction with overall project planning.

3.3 TRANSPORTATION

Development of transportation alternatives can be developed through the use of previously determined consumption trends, storage capacities, and weight forecasts. However, the ultimate choice of transportation modes will largely be influenced by project planning and scheduling as well as weather conditions.

Transportation logistics must also consider and make provisions for the weathering of aircraft, vehicles, and equipment to operate in a sub-Arctic environment. In addition, field operations must be considered in terms of available transportation support for field parties and alternate emergency transport modes and routing.

4. TECHNICAL SUPPORT

4.1 INTRODUCTION

The development of base camp facilities and the accomplishment of field studies and analyses required for the Susitna Hydroelectric Power Project will necessitate the performance of other technical support activities such as environmental impact statement and permit preparation, seismic engineering studies, as well as land surveying.

4.2 ENVIRONMENTAL IMPACT STATEMENT AND PERMIT PREPARATION

CIRI/H&N is extremely familiar with the environmental and permit processes required to integrate environmental considerations into the next evaluation phase of the proposed Susitna Hydroelectric project. The environmental experience of CIRI/H&N can be of considerable assistance to your project team through the development of a systematic environmental and permit program that must address the concerns of your project team, the Alaska Power Authority, the State Department of Environmental Conservation, the U.S. Department of Energy, the U.S. Department of Interior, as well as numerous other Alaskan and national environmental organizations. Since an environmental impact statement has already been developed for this project by the U.S. Army Corps of Engineers, Alaska District, more specific environmental assessment and impact investigations will be required during the feasibility phase of this project. It is likely that such studies will be directed toward environmental issues already being discussed by federal and state agencies, as well as the preparation of other impact statements and local permits for the first phase of the project.

An important aspect of this entire process will be the coordination of all field investigations and analyses with appropriate federal and state agencies, environmental organizations, and the general public in order that the work of your project team can be completed in a timely manner. With its knowledge of Alaska and federal governmental agencies, CIRI/H&N is ideally suited to assist you in this important task.

4.3 SEISMIC ENGINEERING

The siting of structures in seismic areas will continue to be an important consideration for the Susitna Hydroelectric Power Project. The seismic threat could include fault displacement, soil liquefication, landslides, and ground shaking. The results of siting studies, which can be conducted by CIRI/H&N, will generally give recommended ground motions in the form of response spectra and/or time histories for use in design and analysis.

In the past, CIRI/H&N has been able to provide this basic seismic criteria to its clients. During the last few years, our firm has specialized in designing structures to resist seismic effects, and utilizes geotechnical firms that specialize in ground motion studies to provide the seismic criteria.

In 1957, CIRI/H&N's seismic capability was applied to the nuclear industry through participation in the development of an engineering guide on earthquakes and the development of earthquake resistant designs for nuclear reactors which culminated in the preparation of the Atomic Energy Commission's (AEC) publication TID-7024, "Nuclear Reactors and Earthquakes," in 1963. Subsequently, this capability has been sustained and enlarged through contracts with the Energy Research and Development Agency, the Nuclear Regulatory Commission, the Department of Energy, the Department of Interior, and private industry through the performance of seismic resistant and structural design or design reviews of structures, industrial plants and facilities, and major pipelines.

4.4 SURVEYING

CIRI/H&N can provide all land surveying capability that will be required to supplement available aerial and topography base maps of the area for your project team. The size of the project area and the magnitude of considerations encompassed in the Susitna project will likely require considerable variability in control requirements and field conditions. For example, the development of any additional aerial topographic maps for the remote project area will likely necessitate the use of a survey management and ground party team which has considerable prior experience in the establishment of horizontal and vertical ground controls for aerial surveys.

In order to match the variability in aerial and land surveying applications, the performance of all surveying activity will require highly qualified supervisory and ground party personnel which possess considerable technical competence and adaptability in remote environments. These capabilities are available from CIRI/H&N through its experience with both routine and first order instrumentation and procedures in the following areas:

- Alaska
    - Kotzebue
    - Point Barrow
    - Amchitka
- Okinawa
- Enewetak and Bikini atolls
- Weather stations throughout the Pacific area
- Other locations in the southern and western United States

In addition, H&N has managed the aerial surveying contract for the U.S. Department of Energy's Nevada Test Site for more than 20 years.

CIRI/H&N

GENERAL QUALIFICATIONS

AND

RELATED PROJECT EXPERIENCE

5. GENERAL QUALIFICATIONS

5.1 COOK INLET REGION, INC./HOLMES & NARVER, INC. (CIRI/H&N)

In early 1979, Holmes & Narver, Inc., (H&N) and Cook Inlet Region, Inc., (CIRI) entered into an agreement to provide a combination of management and technical strengths and a depth of experience in Alaska that would be unique on the Alaskan scene. This association provides clients with a highly cost-effective professional service and an unparalleled combination of technical capability.

The two parties of this agreement form a solid viable operating unit which has the operating flexibility to participate in a specific project as demanded solely by the project scope. In this particular project, H&N will team with CIRI to provide a task-force organization. Both corporations have a local Alaskan presence and an understanding of Alaskan requirements; together, CIRI/H&N has an extended ability to draw from the more comprehensive technical and informational base available in the lower 48 states.

CIRI/H&N's combined experience in Alaska ranges from master planning and financial feasibilty studies to the construction and operation of major industrial facilities and commercial ventures. Our record of service to Alaskan clients is indicated by projects completed on schedule and within budgets that have sensitively taken into account all economic, social, technical, ecological, and environmental factors.

Our proposal to provide support services is predicated on the assignment of a dedicated team of CIRI/H&N Alaskan experts with the required backgrounds in engineering, logistics, construction, operation and maintenance of camp facilities, and environmental services. A compact team of this experience mix, having the ability to work closely with all elements of community organizations, governmental agencies, and the private sector will assist your firm in producing a superior feasibility study for the Susitna Hydroelectric Power Project.

5.2 COOK INLET REGION, INC.

CIRI is one of 12 regional corporations established under the Alaska Native Claims Settlement Act. CIRI is the native corporation whose boundaries encompass 2,380,000 acres known as the Cook Inlet area. It is headquartered in Anchorage and has over 6,000 Alaska Native Shareholders. Shareholders of CIRI include the village corporations of Knikatnu, Chickaloon, and Tyonek which are also major landowners in the Susitna Project area. Under the Alaska Native Claims Settlement Act, village corporations in the Susitna Project area acquire title to the surface estate of the lands they receive. The subsurface estate of such lands, which includes mineral rights, oil and gas rights, and the ownership of sand and gravel, is titled to CIRI. Consequently, Cook Inlet Region, Inc., often assumes the responsibility for protecting and promoting village interests, as well as the interests of its nonvillage shareholders.

CIRI has an excellent working relationship with the other native regional corporations, as well as the Alaskan Federation of Natives and the Alaska Native Federation. This closeness to the native community means that CIRI will be particularly sensitive to native input and involvement in the Susitna project and will have ready access to those groups and individuals who can help develop the appropriate mechanisms to maximize this input. CIRI already understands the various types of relationships, structures, and institutions in the native community and the Anchorage community, which will especially aid in the development of environmental impact statements and local permits.

CIRI has developed a land status research and land assessment capability unmatched by that of any other Alaskan Company. CIRI's professional staff has compiled an extensive inventory of soil reports, legal status maps, land characteristics data, aerial photos, ecological information, and other land planning information. In addition, CIRI has developed strong working relationships with a number of Alaska state and U.S. federal agencies responsible for the regulation of Alaska's land and mineral resources.

5.3 HOLMES & NARVER, INC.

Holmes & Narver, Inc., a Resource Sciences Company and subsidiary of United States Filter Corporation, was founded in 1933 as an engineering partnership. Our firm is a completely integrated organization, solidly based on classic engineering principles, and active in the exploration of advanced fields of technology and their appropriate applications to engineering problems. With a background of 46 years of growth and expansion in fields related to technology, we have provided services throughout the world to industry and government in technology, engineering, construction, logistics, maintenance, operations, and management. Company corporate offices are in Orange, California, with supplementary corporate or project offices in Anchorage, Alaska; Honolulu, Hawaii; Oakland, California; and Las Vegas, Nevada. In addition, offices outside the United States have been established in the United Kingdom, Trust Territory of the Pacific Islands, New Zealand, and Saudi Arabia.

Holmes & Narver has a long and prestigious record in the design and construction of complex technical facilities, process plants, industrial plants, communications systems, as well as the support of scientific test programs, nuclear facilities, and missile and space programs.

Because we are constructors as well as engineers, our designs reflect the knowledge and economics of construction methods and procedures. Since many of our projects require several years of support in remote locations, Holmes & Narver has developed a proficiency in design, procurement, construction management, and operation and maintenance of construction camp facilities. Camps have been designed to support from 40 to 7500 bachelor and family residents in extreme climatic environments such as those that exist in Alaska, Antarctica, the Pacific Islands, and Saudi Arabia.

Major services of Holmes & Narver, Inc., are offered in four individual categories:

- Systems and facilities design and engineering
- Procurement and logistics
- Construction
- Operations and maintenance

Joined together, the four individual categories constitute the total service spectrum associated with the complete life cycle of a system. The service spectrum includes the following specific services:

- Economic and technical feasibility evaluation of facilities and systems
- Master planning of sites, facilities, and utility systems
- Environmental impact assessment
- Design and engineering facilities and systems
- Systems analysis of facilities
- Operations analysis and system safety analysis
- Procurement of facilities, equipment and material
- Construction management
- Quality assurance service
- Turnkey construction
- Operations and maintenance

FRANK MOOLIN & ASSOCIATES, INC.

(AN ALASKA INTERNATIONAL INDUSTRIES COMPANY)

INDEX

STATEMENT OF QUALIFICATIONS

OBJECTIVES

- WE WANT YOU TO USE FRANK MOOLIN & ASSOCIATES AS YOUR CONTRACTOR FOR ONE OR MORE OF OUR SERVICES:

    + PROJECT PLANNING & STUDIES.
    + PROJECT & CONSTRUCTION MANAGEMENT.*
    + CONSTRUCTION INCLUDING "TURNKEY" RESPONSIBILITIES.
    + FACILITIES OPERATION & MAINTENANCE.

- TO PRESENT YOU OUR STATEMENT OF QUALIFICATIONS:

    + WHAT WE ARE.
    + OUR EXPERIENCE.
    + OUR CAPABILITIES AND RESOURCES.
    + OUR "BUILDING BLOCK" CONCEPT FOR YOUR PROJECT.
    + PROJECT MANAGEMENT PHILOSOPHIES.
    + COMMERCIAL TERMS.
    + HOW WE EXPECT TO WORK.

* APPENDIX "E" - "WHY USE A PROJECT OR CONSTRUCTION MANAGEMENT CONTRACTOR" MAY BE OF INTEREST TO YOU.

"WHAT WE ARE"

FRANK MOOLIN & ASSOCIATES (FMAA):

- ANCHORAGE BASED.
- NO GEOGRAPHICAL LIMITS.
- PROVIDING INDUSTRY AND GOVERNMENT WITH SERVICES IN:
    - PROJECT PLANNING AND STUDIES.
    - PROJECT AND CONSTRUCTION MANAGEMENT.
    - CONSTRUCTION INCLUDING "TURNKEY" RESPONSIBILITIES.
    - FACILITIES OPERATION AND MAINTENANCE.
- UNIQUE RESOURCES AND EXPERTISE FOR COMPLEX PROJECTS IN REMOTE AND DEVELOPING AREAS OF THE WORLD.
- PROVIDING A BUSINESS-ORIENTED APPROACH.

WE ARE A WHOLLY-OWNED SUBSIDIARY OF ALASKA INTERNATIONAL INDUSTRIES (AII):

- THE PRIVATE SECTOR'S LARGEST ENTITY HEADQUARTERED IN ALASKA.
- REVENUES ANTICIPATED TO BE $120 MILLION IN 1977.
- OPERATING AIRLINE, TRUCKING AND CONSTRUCTION COMPANIES IN ADDITION TO FRANK MOOLIN & ASSOCIATES.
- EXTENSIVE ALASKAN INVOLVEMENT AND KNOWLEDGE OF THE ALASKAN "SCENE".
- "KNOWS" THE REMOTE AND DEVELOPING AREAS OF THE WORLD.

AS A SUBSIDIARY OF A $120+ MILLION ALASKAN COMPANY WE HAVE THE FINANCIAL STRENGTH, MANAGEMENT DEPTH AND GEOGRAPHICAL PRESENCE THAT NO OTHER ALASKAN-BASED CONTRACTOR HAS.

A COPY OF THE 1976 ANNUAL REPORT AND THIRD-QUARTER CONSOLIDATED STATEMENT IS INCLUDED AS APPENDIX "D".

WHY USE AN ALASKAN-BASED ORGANIZATION-?

- WE HAVE AN UNUSUAL POOL OF PROJECT MANAGEMENT TALENT AVAILABLE THAT WAS TRAINED ON THE BIGGEST AND MOST DIFFICULT PROJECT IN THE WORLD...THE TRANS-ALASKA PIPELINE.

- IF YOUR PROJECT IS IN ALASKA IT OBVIOUSLY MAKES SENSE TO TAKE ADVANTAGE OF FRANK MOOLIN & ASSOCIATES AND AII'S OTHER RESOURCES.

- IF YOUR PROJECT IS OUTSIDE ALASKA -- LOOK AT A GLOBE...ANCHORAGE IS:
  + CLOSER TO THE MID-EAST THAN LOS ANGELES.
  + CLOSER TO LONDON THAN HOUSTON.
  + MID-WAY BETWEEN THE FAR EAST AND THE MIDDLE EAST.

ALASKA HAS 20% OF THE LAND AREA OF THE U.S. AND HAS THE LARGEST RESERVES OF OIL, COAL AND OTHER MINERALS IN THE U.S.A. ... IT IS DESTINED TO BECOME THE RESOURCE CAPITAL OF THE COUNTRY. THE NEW DEVELOPMENTS IN EXTRACTING RESOURCES FROM REMOTE AREAS ARE GOING TO BE SPAWNED IN ALASKA.

OUR EXPERIENCE AND RESOURCES

THE KEY TO ANY SUCCESSFUL EFFORT IS THE PEOPLE RESOURCES YOU ASSEMBLE. WITHIN FRANK MOOLIN & ASSOCIATES WE HAVE SELECTED KEY INDIVIDUALS WITH:

- MANY YEARS OF "HANDS-ON" EXPERIENCE WITH VARYING SIZES AND TYPES OF PROJECTS, INCLUDING THE RESPONSIBILITY FOR CONSTRUCTION OF THE TRANS-ALASKA PIPELINE, A $4.2 BILLION EFFORT (PIPELINE PORTION OF THE PROJECT*).
- A MULTI-DISCIPLINED BACKGROUND.
- DEDICATION TO ACHIEVE GOALS.
- ALASKAN AND OTHER REMOTE AND DEVELOPING AREA EXPERIENCE.
- AN UNUSUAL COMBINATION OF ENERGY INDUSTRY AND HEAVY CONSTRUCTION EXPERIENCE.

THE NEXT SEVERAL PAGES ARE A PERSONNEL MATRIX PROVIDING A "THUMBNAIL" SKETCH OF KEY INDIVIDUALS.

OUR 24 MANAGERS HAVE A TOTAL OF 130 YEARS IN THE ENERGY INDUSTRY AND 342 YEARS IN HEAVY CONSTRUCTION.

COMPLETE PESUMES OF KEY INDIVIDUALS ARE INCLUDED AS APPENDIX "B".

*To learn more about some of the people who make up FMAA we suggest you read:

-- "800 Miles to Valdez" by Jim Roscow, published in hardback by Prentice-Hall. This is the first objective book about the pipeline project. If you write to us we will send you a copy.

-- Alyeska Reports - Last Issue.

-- Appendix "A" - "Engineering News-Record's Construction Man of the Year - 1976".

KEY PERSONNEL

EXPERIENCE/QUALIFICATIONS MATRIX

INDIVIDUAL	DEGREES HELD (B.S.; M.S.; B.A.)	LICENSES (P.E.; C.P.A.)	PROJECT MANAGEMENT EXPERIENCE (YEARS)	ALASKAN EXPERIENCE (YEARS)	POSITIONS HELD
FRANK P. MOOLIN, JR.	BSCE MBA (part)	(PE) Ill. Mich Ohio Cal. N.J. S.C. Singapore	17	4	Senior Project Manager, heading Alyeska Pipeline Construction. Project Manager, DuPont Atomic Energy Commission Bedrock Waste Storage Project. Project Engineer, Resident Engineer & Project Manager on major refinery projects in Far East. Project Engineer coordinating civil & structural work on the Bay Area Rapid Transit System (BART) Resident Engineer on several major bridge & other projects in the Middle West.
KAY E. ELIASON	BSAE	(PE) Iowa Ala. Minn	26	7	Manager of Pipeline Construction for Alyeska. Project Manager for 1/3 of the Yukon to Prudhoe Bay Haul Road for Alyeska Pipeline. Design Team Member for the Alyeska Pipeline. Project Manager for ARCO Chemical. Chief Engineer - Metal Building Manufacturer. Vice President, Shriver Construction Company. Owner, Eliason Construction.
DAVID W. HAUGEN	BA BSCE MS		7	11	Project Manager South of Yukon Completion for Alyeska. Project Manager Section II for Alyeska. Project Manager Section IV for Alyeska. Senior Project Engineer on Yukon to Prudhoe Bay Haul Road Construction for Alyeska. U.S. Postal Service - Dist. Industrial Engineer. Survey Party Chief - Ocean Technology, Ltd.

KEY PERSONNEL

EXPERIENCE/QUALIFICATIONS MATRIX

INDIVIDUAL	DEGREES HELD (B.S.; M.S.; B.A.)	LICENSES (P.E.; C.P.A.)	PROJECT MANAGEMENT EXPERIENCE (YEARS)	ALASKAN EXPERIENCE (YEARS)	POSITIONS HELD
WILLIAM D. FOWLER	BBA MBA	(CPA) Texas Alaska	6	6	Alaska Division Manager, Majestic-Wiley Contractors, Ltd. Project Admin. Manager, Perini-Arctic Associates - Section II Alyeska Project. Senior Vice President & General Manager, J. L. Cox & Son, Inc. Manager, Falcon Transport, Ltd. Project Manager, Alaska Division - Al Renk & Sons, Inc., Alyeska Project. Controller, Coates Contracting Company. Lead Auditor - Exxon Co., U.S.A. Corp. Audit Staff.
GARY R. BOCK	BSCE	(PE) Wash Alaska	7	3	Project Manager for 147-mile North Slope Fuel Gas Line for Alyeska. Manager of Radiographic Services for Alyeska. Senior Project Engineer, Construction Headquarters Staff for Alyeska. Design Team Leader for Freeway Projects. Construction Engineer on Heavy Constr. Projects.
RICHARD LIPINSKI	BSCE MBA	(PE) N.Y.	12	3	Supervisor, Cost & Schedule Control of the Trans-Alaska Pipeline. Senior Projects Engineer for the construction of commercial buildings. Construction Engineer on heavy constr. projects -- bridge foundations, navigational locks & dams.
LON R. McDERMOTT			24	5	Executive Vice President & Chief Operating Officer, Alaska International Industries. President, Alaska International Construction. President, Burgess Construction Company. President & General Manager - Reel Contracting Co. Vice President - Construction Operations, Fisher Contracting Company.

KEY PERSONNEL

EXPERIENCE/QUALIFICATIONS MATRIX

INDIVIDUAL	DEGREES HELD (B.S.; M.S.; B.A.)	LICENSES (P.E.; C.P.A.)	PROJECT MANAGEMENT EXPERIENCE (YEARS)	ALASKAN EXPERIENCE (YEARS)	POSITIONS HELD
BRENT STONEBRAKER	BSCE		12	5	Vice President - Building Division, Alaska International Construction. Asst. Project Manager, Section V for Alyeska. Owner, Construction Management Services, Inc. Project Manager, Eldridge & Son Construction Co. Project Manager, Clarence P. Huckle Company. Field Supervisor, James Bryon Company.
MARTIN J. NELSON	BSCE		17	13	Vice President, Alaska International Construction. Manager, Alyeska Operations Equipment Department. Manager, Alyeska Weld Repair Program. Project Manager, Pipeline Section III for Alyeska. Self-employed Construction Consultant. Alaska/Utah District Manager, S.S. Mullen Constr.
THOMAS W. HENDRIX	BSCE	(LS) Alaska	13	13	Vice President, Alaska International Construction. Vice President-Engineering, Burgess Construction Co. Project Engineer, Alaska Department of Highways.
KENNETH R. ALLEN			4	3	Director of Personnel, Alaska International Industries. Personnel Manager, Alaska International Construction. Labor Relations Officer for Alyeska. Assistant District Representative, Operating Engineers Local No. 3. Project Superintendent, Polich & Benedict Co.
ROBERT REDENBAUGH	BS	CPA		3	Controller, Alaska International Industries. Vice President-Finance & Treasurer, Sir Speedy, Inc. Supervising Senior Accountant, Peat, Marwick, Mitchell & Co.

K E Y   P E R S O N N E L

EXPERIENCE/QUALIFICATIONS MATRIX

INDIVIDUAL	DEGREES HELD (B.S.; M.S.; B.A.)	LICENSES (P.E.; C.P.A.)	PROJECT MANAGEMENT EXPERIENCE (YEARS)	ALASKAN EXPERIENCE (YEARS)	POSITIONS HELD
NEIL G. MEYERS	BA Bus Admin		28	2	Cost & Schedule, Building Division - Alaska International Construction. Supervisor, Construction Planning & Cost Control Pipeline Section V for Alyeska. Architect/Engineer Representative - Kirk, Wallace, McKinley & Associates. Assistant Project Manager, Pittsburgh-Des Moines Steel Company. Assistant Project Manager, Stewart-Erickson, Inc. (Engineers & Contractors). Construction Manager, Henry Klien & Associates (Architects). Project Manager - Kirk, Wallace, McKinley & Assoc. Partner, W.G. Meyers & Sons, General Contractors.
GEORGE A. LASKY	BA Chem	Gen Cont	28	2	Manager, Marketing Development - Alaska International Construction. Manager, Contract Development & Supervising Contracts Engineer for Alyeska. Vice President - Construction & Development, Rossmore Corp. General Manager, PBS Corp. (Developer). Exec. Vice President - S & L Building Corporation. Program Manager - Ford Motor Co., Aeronutronic Div. - Aerospace (Director of Administration). Senior Applications Engineer - Marquardt Corp.
WILLIAM S. McDERMOTT	BSCE			4	Safety Engineer/EEO Officer, Alaska International Construction. Safety Engineer/EEO Officer, Burgess Construction Company. Safety Engineer/Personnel Officer, Shawnee Construction Company.

KEY PERSONNEL

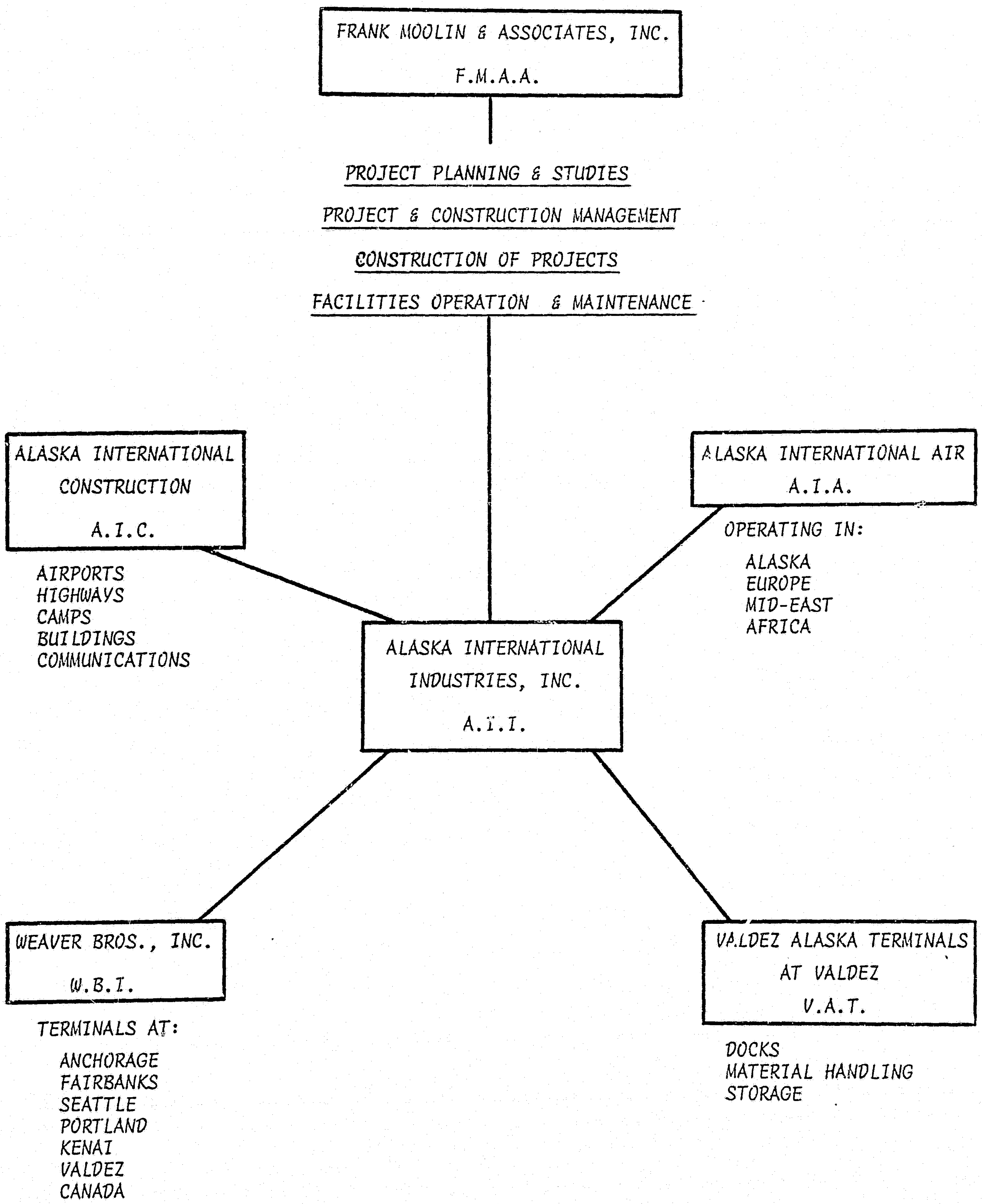
EXPERIENCE/QUALIFICATIONS MATRIX

INDIVIDUAL	DEGREES HELD (B.S.; M.S.; B.A.)	LICENSES (P.E.; C.P.A.)	PROJECT MANAGEMENT EXPERIENCE (YEARS)	ALASKAN EXPERIENCE (YEARS)	POSITIONS HELD
CLIFFORD A. RALSTON			11	8	Project Manager - North, Alaska International Construction. Project Manager, Burgess Constructoin Company. General Superintendent, S.S. Mullen Constr. Co. Superintendent, Sims Construction Company.
ROBERT D. HEATH	BBA	(CPA) Alaska Texas		15	Vice President Finance, Alaska International Industries. Vice President Finance, Burgess Construction Company. Controller-Treasurer, Anchorage Natural Gas. Accountant, Trunkline Gas Company.
JAMES C. VAUGHN	BSCE	EIT Wash	2	2	Supervisor of Turnover to Operations for Alyeska. Senior Project Engineer - Construction Headquarters Staff for Alyeska. Engineered Materials Engineer for Alyeska. Project Engineer - Civil Consulting Firm.
CHARLES E. GIBSON	BA MIM			7	Assistant to President, Alaska International Industries. Specialist in International Business & Management. Prior experience with: Japan/Alaska Trade. Alaska State Legislature. U. S. Department of Interior. Alaska Native Associations.
FRED W. HAYS	BA		17	3	Assistant Project Manager - Section I for Alyeska. Supervising Contracts Engineer for Alyeska. Program Manager, Honeywell, Inc. Marine Systems Div. for Offshore Platforms & Field Logistic Support. Vice President, Willamette Construction Co.

KEY PERSONNEL

EXPERIENCE/QUALIFICATIONS MATRIX

INDIVIDUAL	DEGREES HELD (B.S.; M.S.; B.A.)	LICENSES (P.E.; C.P.A.)	PROJECT MANAGEMENT EXPERIENCE (YEARS)	ALASKAN EXPERIENCE (YEARS)	POSITIONS HELD
DAVID N. LITTLE	BSCE MS		8	3	Supervisor, Cost Analysis & Forecasting - Alyeska. Senior Cost Control Coordinator, Arthur McKee Co., Oil & Petroleum Division. Field Engineer, Arthur McKee Company.
JACK E. LAMBERT	BA	PE		3	Senior Project Engineer - Michael Baker, Jr., assigned to the Alyeska Pipeline Project. Construction Manager - Sourdough Camp - Alyeska Pipeline. Project Engineer - Ft. Wainwright Renovation - Alyeska Pipeline. Sales Engineer - Holiday Manufacturing Co. Lt. Colonel - U.S. Corps of Engineers.
THOMAS J. ALLEN	BSCE MBA	PE	10	3	Supervisor, Schedule Control & Reporting - Alyeska Pipeline. Design Engineer, Simpson Timber Company. Maintenance Engineer, Shell Chemical Co.
DANIEL R. MELLON	BA		8	8	Purchasing Agent - Alaska International Construction. Purchasing Manager - Alaska Constructors, Inc. Purchasing Manager - Burgess Construction Co. Captain - U. S. Army.


FRANK MOOLIN & ASSOCIATES, INC.
F.M.A.A.
PROJECT PLANNING & STUDIES
PROJECT & CONSTRUCTION MANAGEMENT
CONSTRUCTION OF PROJECTS
FACILITIES OPERATION & MAINTENANCE
ALASKA INTERNATIONAL CONSTRUCTION
A.I.C.
AIRPORTS
HIGHWAYS
CAMPS
BUILDINGS
COMMUNICATIONS
ALASKA INTERNATIONAL AIR
A.I.A.
OPERATING IN:
ALASKA
EUROPE
MID-EAST
AFRICA
ALASKA INTERNATIONAL INDUSTRIES, INC.
A.I.I.
WEAVER BROS., INC.
W.B.I.
TERMINALS AT:
ANCHORAGE
FAIRBANKS
SEATTLE
PORTLAND
KENAI
VALDEZ
CANADA
VALDEZ ALASKA TERMINALS AT VALDEZ
V.A.T.
DOCKS
MATERIAL HANDLING
STORAGE

OUR EXPERIENCE AND RESOURCES (CONTINUED)

THE AII CORPORATE FAMILY INCLUDES OTHER RESOURCES IN ADDITION TO FRANK MOOLIN & ASSOCIATES:

- ALASKA INTERNATIONAL CONSTRUCTION,
  A HEAVY CIVIL AND BUILDING CONTRACTOR (PERFORMED OVER $175 MILLION OF WORK ON THE TRANS-ALASKA PIPELINE).

- ALASKA INTERNATIONAL AIR,
  THE C-130 HERCULES FREIGHTER FLEET OPERATING THROUGHOUT THE WORLD.

- WEAVER BROTHERS, INCORPORATED,
  ALASKA'S LARGEST TRUCKING COMPANY.

- VALDEZ ALASKA TERMINAL, INCORPORATED,
  PROVIDING DOCKS, MATERIAL HANDLING AND STORAGE AT VALDEZ, ALASKA.

THIS PROVIDES YOU A VERY UNIQUE COMBINATION OF RESOURCES UNDER OUR CORPORATE STRUCTURE.

OUR "BUILDING BLOCK" CONCEPT FOR YOUR PROJECT

FIRST, LET'S EXAMINE WHAT A PROJECT NEEDS IN A VERY GENERAL WAY:

PROJECT MANAGER

KEY MANAGERS

ANY PROJECT FUNCTIONALLY NEEDS

SOME OR ALL OF THE FOLLOWING

PROJECT PLANNING
DESIGN
PROCUREMENT
CONTRACTING
CONSTRUCTION
EQUIPMENT
PROJECT CONTROL -
(SCHEDULE/COST/FINANCIAL)
FIELD ENGINEERING
QUALITY CONTROL
QUALITY ASSURANCE
TRANSPORTATION
MANAGEMENT INFORMATION SYSTEM
SUPPORT SERVICES (CAMPS)
AGENCY INTERFACE
SAFETY
COMMUNICATIONS
TRAINING

OUR CONCEPT IS TO FURNISH THE "BLOCKS" OF MANAGEMENT AND "DO IT" RESOURCES NECESSARY TO "BUILD" THE ORGANIZATION REQUIRED FOR YOUR PROJECT. SO...WE CALL THIS OUR "BUILDING-BLOCK" CONCEPT.

MORE ON THIS LATER IN THE "HOW WE EXPECT TO WORK" SECTION OF THIS PROPOSAL.

OUR PROJECT MANAGEMENT PHILOSOPHIES

- PROJECT SUCCESS RESTS SQUARELY WITH THE PROJECT MANAGER. HE MUST PUT TOGETHER A "PROJECT TEAM".
- THE "PROJECT MANAGER" AND HIS "PROJECT TEAM" MUST BE:
  - TIMELY DECISION MAKERS.
  - INTEGRATORS.
  - ARBITRATORS.
  - COORDINATORS.
  - INNOVATORS.
- THE "PROJECT MANAGER" AND HIS "PROJECT TEAM" MUST PRACTICE "PAC":
  - PARTICIPATION (IN PLANNING).
  - ACCEPTANCE (OF GOALS).
  - COMMITMENT (TO THE ACHIEVEMENT OF THE GOALS).
- EFFECTIVE "FRONT-END" PLANNING FOR A PROJECT IS A KEY DETERMINANT OF A PROJECT'S SUCCESS.
- COST/SCHEDULE/FINANCIAL CONTROL DEVELOPMENT MUST PARALLEL AND BE A PART OF FRONT-END PLANNING AND DESIGN. IT MUST BE IMPLEMENTED EFFECTIVELY.
- RECENT STUDIES HAVE SHOWN THERE ARE SIX MAJOR VARIABLES THAT AFFECT THE SUCCESS OF PROJECTS*:
  - PROJECT MANAGER.
  - PROJECT TEAM.
  - PARENT ORGANIZATION.
  - CLIENT ORGANIZATION.
  - MANAGERIAL TECHNIQUES.
  - PRE-CONDITIONS.

*APPENDIX "G" is an Excerpt from "DETERMINANTS OF PROJECT SUCCESS" by David Charles Murphy, et al.

WHAT ARE WE (FMAA) OFFERING THAT IS DIFFERENT-?

- A BUSINESS-ORIENTED APPROACH TO THE DELIVERY OF COMPLEX PROJECTS WHICH MEANS DEVELOPMENT OR PERFORMING SOME OR ALL OF THE FOLLOWING, DEPENDING UPON THE NEEDS OF THE PROJECT:

  + PROJECT'S EMBRYO PHASE:
    -- FEASIBILITY ANALYSIS.
    -- PROJECT'S STRATEGY PLAN.
    -- RESOURCE APPRAISALS.
    -- RISK ASSESSMENTS.
    -- ALTERNATE APPROACHES.

  + PROJECT DEVELOPMENT/DESIGN PHASE:
    -- FRONT-END PLANNING.
    -- POLICY DEVELOPMENT.
    -- VALUE ASSESSMENTS.
    -- ORGANIZATIONAL STRUCTURE INCLUDING MATRIX TYPES.
    -- CONTRACTING STRATEGIES.
    -- CONSTRUCTABILITY ASSESSMENTS.
    -- FINANCIAL PLANNING.
    -- CASH FLOW PROJECTIONS.
    -- MANAGEMENT INFORMATION SYSTEM (M.I.S.).
    -- COST/SCHEDULE DEVELOPMENT.
    -- OBTAIN PERMITS.
    -- GOVERNMENT LIAISON/APPROVALS.
    -- DEVELOP FALL-BACK POSITIONS.
    -- CONTINGENCY PLANNING.

  + PROJECT EXECUTION PHASE:
    -- STAFF THE ORGANIZATION.
    -- IMPLEMENT POLICIES.
    -- DEVELOP BID SLATE.
    -- BID REVIEW/SELECTION.
    -- IMPLEMENT COST/SCHEDULE/FINANCIAL/INVENTORY/QUALITY/PROCUREMENT CONTROLS.
    -- COORDINATE AND CONTROL MULTIPLE CONTRACTORS.
    -- PERFORM AND/OR MONITOR CONSTRUCTION AND ALL OTHER FUNCTIONS.

WHAT ARE WE (FMAA) OFFERING THAT IS DIFFERENT-? (CONTINUED)

+ PROJECT EXECUTION PHASE (CONTINUED):

  -- MANAGE/NEGOTIATE CLAIMS.
  -- EVALUATE ALL OPERATIONS PERIODICALLY.
  -- ESTABLISH INDEPENDENT FINANCIAL/QUALITY/MANAGEMENT AUDITS.
  -- PERSONNEL AND LABOR RELATIONS OBJECTIVES/EVALUATIONS.
  -- DE-MOBILIZE THE PROJECT IN AN ORDERLY FASHION.
  -- PLAN/ORGANIZE FOR START-UP/OPERATION/MAINTENANCE.
  -- PERFORM GOVERNMENTAL LIAISON/APPROVALS.

+ PROJECT'S START-UP/OPERATIONS/MAINTENANCE PHASE:

  -- STAFF FOR START-UP/OPERATIONS/MAINTENANCE.
  -- IMPLEMENT PLANS.
  -- PUT THE PROJECT "ON STREAM".
  -- MAINTAIN THE PROJECT.

- FRANK MOOLIN & ASSOCIATES IS PREPARED TO PERFORM ANY OR ALL OF THE ABOVE FUNCTIONS/TASKS WITHIN THE FOUR BASIC FMAA SERVICES:

  + PROJECT PLANNING & STUDIES.
  + PROJECT & CONSTRUCTION MANAGEMENT.
  + CONSTRUCTION INCLUDING "TURNKEY" RESPONSIBILITIES.
  + FACILITY OPERATION & MAINTENANCE.

- THE TRADITIONAL APPROACH HAS BEEN TO INUNDATE A PROJECT WITH PEOPLE TO HANDLE THE BUSINESS-ORIENTED FUNCTIONS. WE'RE DIFFERENT BECAUSE WE HAVE A RELATIVELY SMALL GROUP OF WELL-QUALIFIED INDIVIDUALS EACH OF THEM HAVING EXPOSURE TO THE NECESSARY FUNCTIONS.

- WE'RE A YOUNG...SCRAMBLING ORGANIZATION.