SUMMARY REPORT

ON

ATHABASCA RIVER POWER DEVELOPMENT
CROOKED RAPIDS SITE STUDY

Prepared by

ENVIRONMENTAL PLANNING DIVISION
ALBERTA DEPARTMENT OF THE ENVIRONMENT

April, 1975

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April 29, 1975

Hon. D. J. Russell
Minister
Department of the Environment

Dear Sir:

We have the pleasure of submitting to you *The Athabasca River Power Development - Crooked Rapids Site Study: Summary*. This study was undertaken at the direction of Hon. W. J. Yurko.

The purpose of the study was to provide a preliminary planning assessment of the feasibility of constructing a dam in the vicinity of Crooked Rapids for hydro-electric,power flood control and flow augmentation development.

Two potential damsites were identified; one for a High-Head Project with a 540 foot high dam, and one for a Medium-Head Project with a 255 foot high dam. Information presently available and studies carried out conclude that the high dam does not, at this time, with present technology and methods, seem feasible due to extremely poor geological and soil conditions. The consultants concluded that a Medium-Head Dam might be technically possible. However, a detailed analysis is required to confirm this point.

The estimated capital cost of the High-Head Dam is $1.1 billion with firm energy costs being 30 mills and total energy costs being 26 mills. The Medium-Head Dam is $400 million with firm energy costs being 26 mills and total energy costs being 46 mills.

It is recommended that before any detailed site investigation is initiated in the Crooked Rapids area of any other areas of the basin, an overall appraisal of the Athabasca River Basin should be undertaken.

.../2

This would be in an effort to identify the requirements, the possibilities, and the implications, of constructing a dam at one of the various potential sites. Included in this overall study should be the identification of sites with the most favorable economical, sociological, and environmental conditions.

Yours truly,

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Department of the Environment

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Chairman
Energy Resource Conservation Board

R.E. Bailey, P. Eng.
Assistant Deputy Minister
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for making background reports available.

Alberta Research Council

for information regarding surficial geology in the Fort McMurray Area

Alberta Department of Highways

for inforamtion on soils conditions encountered in the Fort McMurray Area

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1. Background Information

The Athabasca River is one of the larger rivers in Alberta. It rises in the Rocky Mountains near Mount Columbia and flows for nearly 1000 miles in a generally northeasterly direction before discharging into Lake Athabasca.

The river has been studied as a source of hydro-electric power since at least 1911. The most detailed study, although still very preliminary, was carried out in the early 1950's by the former Alberta Power Commission and Calgary Power Ltd. This study indicated that the Crooked Rapids Site, located about 25 miles upstream from Fort McMurray, was one of the most promising on the river.

4. Scope of Present Study

In December, 1973, the Environmental Planning Division of the Department of the Environment invited proposals for preliminary studies associated with a proposed dam on the Athabasca River in the vicinity of Crooked Rapids. This study was carried out in co-operation with the Energy Resources Conservation Board and under the direction of B.C. Doell study co-ordinator. In March, 1974, the study was awarded to Thurber Consultants Ltd. who had submitted a joint proposal with Crippen Engineering Ltd. and Northwest Hydraulic Consultants Ltd. The Consultants' report was submitted in two volumes in early February, 1975.

This is a summary of the Consultants' findings. It should be noted, however, that owing to the complicated

conditions at Crooked Rapids, a summary of reasonable length cannot cover all aspects of the situation. Consequently, Volume 1 of the Consultants' report must be read before a full appreciation of the various problems can be obtained.

A general location plan is shown in Figure 1 and a general view of the study area in Photo 1.

The Consultants were requested to carry out preliminary studies to determine the technical feasibility and estimated cost of constructing a dam in the vicinity of Crooked Rapids. The study was to encompass all engineering considerations of alternate dam alignments and heights, and was to include such items as site inspection, site mapping, hydrological and geological investigations, borrow investigation, shoreline stability problems, ice and sedimentation problems, predictable upstream and downstream effects, hyro power generation potential and potential for flood control. It was considered that the technical feasibility of constructing a dam at Crooked Rapids should be established prior to carrying out a detailed Environmental assessment. Therefore this did not constitute part of the consultants assignment.

The study was to assume that any dam which might be constructed at Crooked Rapids would be the first development on the river. Consequently, the project as proposed and studied did not have the benefit of any upstream storage.

3. Summary of Study and Findings

1. General

On the basis of topographic data obtained from airphoto mapping, (Fig. 2), two locations in the vicinity of Crooked Rapids were identified as having features most favourable for dam construction. The first, near the downstream end of the Crooked Rapids meander loop, would be suitable for a Medium-Head dam with a maximum height of less than 300 feet. The second, about 5 miles upstream, would be suitable for a High-Head dam, about 550 feet in height.

Early in the study, it was recognized that without the benefit of upstream storage the High-Head dam would yield much less expensive power than the Medium-Head dam but that the technical problems associated with construction of a dam would increase significantly as the height of the dam was increased. Consequently, it was decided to study a Medium-Head dam, height 255 feet, at the first location, and a High-Head dam, height 540 feet, at the second location. Views of these locations are shown in Photos 2 and 3.

2. Hydrology

The hydrological study showed that there is a seasonal variation in river discharge, with the maximum and minimum recorded mean monthly flows being 89,000 cfs and 2,000 cfs respectively. The long term annual mean monthly flow is 17,000 cfs.

Flood hydrographs are included in Figure 3. The 100-year flood was estimated to be 219,000 cfs, indicating the need for large diameter diversion tunnels.

The maximum probable flood was estimated to be 570,000 cfs. Since this flood would be the result of a series of late summer storms, when the reservoir would be at, or close to, maximum operating level, a large spillway would have to be provided.

3. Geology

The damsite geology is shown in Figure 4. Relatively competent limestone bedrock is exposed near river level and it is known that it extends to a depth of some 1700 feet. Overlying this limestone, the formations exposed in the valley walls are the Athabasca Tar Sands, shales and sandstones. Although technically these formations can be termed 'bedrock' a large proportion of the material consists of dense but

uncemented silts and fine to medium grained sands. An extensive investigation program would be required to confirm the design of seepage control measures in these very poor abutment materials. Dr. Arthur Casagrande, a world renowned expert (on Soils and Foundation Engineering, including large rock and earfill dams) who was consulted during the feasibility study, stated that 'The abutment materials (at Crooked Rapids) are much worse and pose more difficult problems than have ever been encountered for a high dam'.

4. Landslides

There is conspicuous evidence, along the Athabasca River, of valley slope instability (Figure 4). In the vicinity of Crooked Rapids the slides appear to be shallow seated, with none of them extending from river level to the top of the slope. The creation of a reservoir in the valley would undoubtedly cause additional, and possibly, larger slides.

However, providing certain slope stabilizing measures were taken in the immediate vicinity of the dam and ample dam freeboard was provided, slide-created waves are not likely to be a major hazard to development.

5. Construction Materials

The areas investigated for borrow material are shown on Figure 5. Exploratory drilling within a 10-mile radius

of Crooked Rapids generally encountered muskeg and windblown sand overlying lacustrine sandy silts and clays, or sandy silty clay till. Both the lacustrine and till materials have in-situ moisture contents considerably in excess of the optimum for construction, and thus could not be placed and compacted without drying. This is impracticable for large quantities of material. The nearest large deposit of reasonable borrow material is located about 25 miles south and east of Crooked Rapids. However, even this deposit may be too sandy for large-scale general use.

6. Layouts

In light of the above, and in particular the poor dam abutment conditions, a concrete dam is not a feasible proposal at Crooked Rapids. An earth-rock structure was therefore proposed. Dam sections were prepared by the Consultants on the basis of the extensive use of locally available quarried rock within a zoned earth-rock dam. Plans and sections of the Medium-Head and High-Head Projects are shown on Figures 6 through 8, and 9 through 11, respectively.

The impervious cores for both dams would consist of oil rich tar sand. This use for the tar sands is unprecedented. Extensive investigation and testing would have to be carried out to determine the engineering properties and confirm the acceptability of the tar sands for this purpose.

The main shells of both dams would be of quarried limestone. Again, further investigation and testing would be required to determine the quarrying characteristics and engineering properties of the limestone.

Transition and drainage zones would be required between the tar sands core and the limestone shells. These would probably comprise sandy materials from the required excavations and from washed sand and gravel, respectively. For the Medium-Head Project the sand and gravel could probably be obtained from nearby river terraces. For the High-Head Project it would have to be transported some 25 miles, since there is not enough suitable material available locally. Fine aggregate for the concrete structures would also have to be transported some 25 miles, though coarse aggregate could possibly be obtained from crushed local limestone.

Apart from the dam, each project would comprise 3

large diameter diversion/power tunnels, a large chute spillway, a surface powerhouse, and extensive seepage control measures. Large stabilizing excavations would also have to be carried out at each site.

Considering the geological conditions at the damsite, the design and construction of the diversion/power tunnels and of the spillway would be most difficult undertakings. The excavated diameter of the tunnels would be about 50 feet. In the case of the Medium-Head Project half of the tunnel cross-section would be in the tar sands and half in the underlying limestone. In the case of the High-Head Project, however, almost all the tunnel excavation would be in the tar sands. Considerable investigation would have to be carried out before adequate designs could be developed for these large underground excavations which are unprecedented in this material. A good proportion of the excavations for the large chute spillway would be through the uncemented sands and silts and careful consideration would have to be given to this in developing designs. The situation for the High-Head Project would be considerably worse than for the Medium-Head Project. For example, in the former case, the approach channel and spillway control structure would have to be

located at an elevation where it is believed a thick layer of highly plastic clay and clay-shale exists.

In an effort to avoid vertical or inclined intake shafts the layouts developed require the adoption of low level power intake structures at the upstream portals of the diversion tunnels, and underground gate chambers located about midway along the tunnels. In the case of the High-Head Project, the power intake structure would always be submerged under at least 200 feet of water. This would have to be considered in much more detail before a final decision on its feasibility could be arrived at. Similarly, the large underground excavations for the gate chambers, which would be entirely in the tar sands, would have to be very carefully investigated before they could be adopted.

Fortunately, in both postulated projects, the foundations for the power intake structure, the powerhouse and the spillway flip bucket would be in the relatively competent limestone found near riverbed level, as would be the spillway plunge pool.

7. Cost Estimate

A summary of the capital cost estimate for the two postulated projects, in terms of January, 1975 dollars, is as follows:

Table 1

SUMMARY OF ESTIMATED CAPITAL COST

ITEM	AMOUNT	
	Medium-Head Project	High-Head Project
CONSTRUCTION COST	$ 248,300,000	$ 625,800,000
CONTINGENCY (15%)	37,200,000	93,900,000
INVESTIGATION, ENGINNEERING and SUPERVISION (10%)	28,600,000	72,000,000
INTEREST DURING CONSTRUCTION (9% p.a.)	84,600,000	327,700,000
TOTAL CAPITAL COST	$ 398,700,000	$1,119,400,000

It is estimated that the Medium-Head and High-Head Projects would take 5 years and 7 years, respectively, to construct.

8. Power Generation

Assuming that either dam would be the first development on the river, and that the project would be operated for optimum power generation, the power potentials are as follows:

Table 2

SUMMARY OF POWER STUDY

ITEM	MEDIUM-HEAD PROJECT	HIGH-HEAD PROJECT
FIRM OUTFLOW	4300 cfs	13,530 cfs
FIRM POWER	60 MW(avg.)	420 MW(avg.)
FIRM ANNUAL ENERGY	526 GWh	3679 GWh
ANNUAL ENERGY OUTPUT IN AVERAGE FLOW YEAR		
Installed Capacity in Megawatts		
80 MW	663 GWh	
120 MW	860 GWh	
560 MW		4334 GWh
840 MW		4825 GWh

9. Energy Costs

The energy costs, not including the costs of

transmission, are estimated to be as follows:

Table 3

ENERGY COSTS

ITEM	MEDIUM-HEAD PROJECT	HIGH-HEAD PROJECT
INSTALLED CAPACITY	120 MW	560 MW
ANNUAL FIRM ENERGY OUTPUT	526 GWh	3679 GWh
AVERAGE ANNUAL ENERGY OUTPUT	860 GWh	4334 GWh
TOTAL CAPITAL COST	$ 398,700,000	$ 1,119,400,000
ANNUAL CHARGES	$ 39,900,000	$ 111,900,000
COST per INSTALLED KILOWATT	$ 3320	$ 2000
COST per FIRM KILOWATT HOUR	76 mills	30 mills
COST per TOTAL KILOWATT HOUR	46 mills	26 mills

These costs assume annual charges equal to 10 percent of the estimated capital costs.

10. Sedimentation

Limited reservoir sedimentation studies indicate that without upstream storage the Medium-Head and High-Head reservoirs, could silt up completely in periods of 100 and 600 years respectively. This means that the Medium-Head Project would soon become a run-of-the-river plant,

but sedimentation would have little effect on the High-Head Project. However, because of limited storage capacity, the Medium-Head Project would provide little control of the river even immediately after construction.

11. Downstream Effects

Limited studies indicate that the presence of a dam at Crooked Rapids would have some beneficial downstream effects. The river ice conditions would be altered to the extent that the flooding situation during break-up at Fort McMurray would be alleviated, especially if the High-Head Project were to be constructed. In addition, the presence of either dam would probably improve the navigation channels between Lake Athabasca and Fort McMurray. However, the physical and environmental effects on the river delta at Lake Athabasca resulting from a dam at Crooked Rapids, would have to be carefully investigated.

12. Upstream Effects

The upstream effects of a dam at Crooked Rapids were not studied in any detail. However, it is apparent that any recreational and other land use in the reservoir area would be affected by the slope instability problem mentioned under the heading 'Landslides'.

4. Conclusions and Recommendations

The major conclusions and recommendations from the Consultants' study are as follows:

1. Based on topographical features there are two locations near Crooked Rapids which are most favourable for consideration as dam sites: the first for a Medium-Head dam about 250 feet in height, the second for a High-Head dam about 550 feet in height.
2. Abutment foundation conditions at both damsites are extremely poor and rule out the construction of a concrete dam of any type. The remaining alternative is a zoned rock and/or earth fill dam.
3. There are no large deposits of good borrow material near Crooked Rapids. Hence a zoned earth-rock dam would have to be constructed from locally excavated oil rich tar sand, sandy material from project excavations and quarried limestone.
4. There are severe technical problems associated with any postulated development at Crooked Rapids and many of the features shown on the project layouts are unprecedented. These include the 50 foot diversion/power tunnels through very poor abutment materials, the use of the tar sands for an impervious core, and the very deep and extensive seepage cut-off wall shown for the High-Head dam.
5. The known and potential problems associated with both the postulated developments are of such a

magnitude that a much more detailed investigation, including exploratory drilling, laboratory testing and design studies, is required before the technical feasibility of either can be definitely established.

6. Conclusion 5, notwithstanding, it is believed with a reasonable degree of confidence that the problems associated with the Medium-Head Project could be overcome and that the project could be constructed within the capital cost estimated. However, many of the known and potential problems are considerably more severe for the High-Head Project than for the Medium-Head Project. As a result, the High-Head Project layout must, at this stage, be considered as only "conceptual".
7. The total capital cost of the postulated projects in terms of January, 1975 dollars, is estimated at 400 million for the Medium-Head Project and 1.1 billion for the High-Head Project.
8. The estimated firm and total energy costs, not including transmission, for the Medium-Head Project are 76 mills and 46 mills per KWh, respectively. These costs are extremely high.
9. The estimated firm and total energy costs, not including transmission, for the High-Head Project are 30 mills and 26 mills per KWh, respectively. These are

much less than for the Medium-Head Project but are still quite high when compared with current energy costs.

10. On the basis of limited studies, the non-power related benefits do not appear to be substantial. Consequently, the very high capital expenditures for a development at Crooked Rapids would have to be justified mainly on the basis of the benefits derived from the energy output. Although more would have to be known regarding the specific uses for the power, on the basis of the energy costs estimated in conclusions 8 and 9, it is most unlikely that a development at Crooked Rapids could be justified at this time.

11. Before detailed studies are carried out at Crooked Rapids, it is recommended that an overall appraisal of the Athabasca River be made in an effort:

    a) To locate an alternate site where geological conditions and the availability of borrow materials are more favourable, and/or

    b) To locate a site which could provide upstream storage and thus make development at Crooked Rapids more economical.

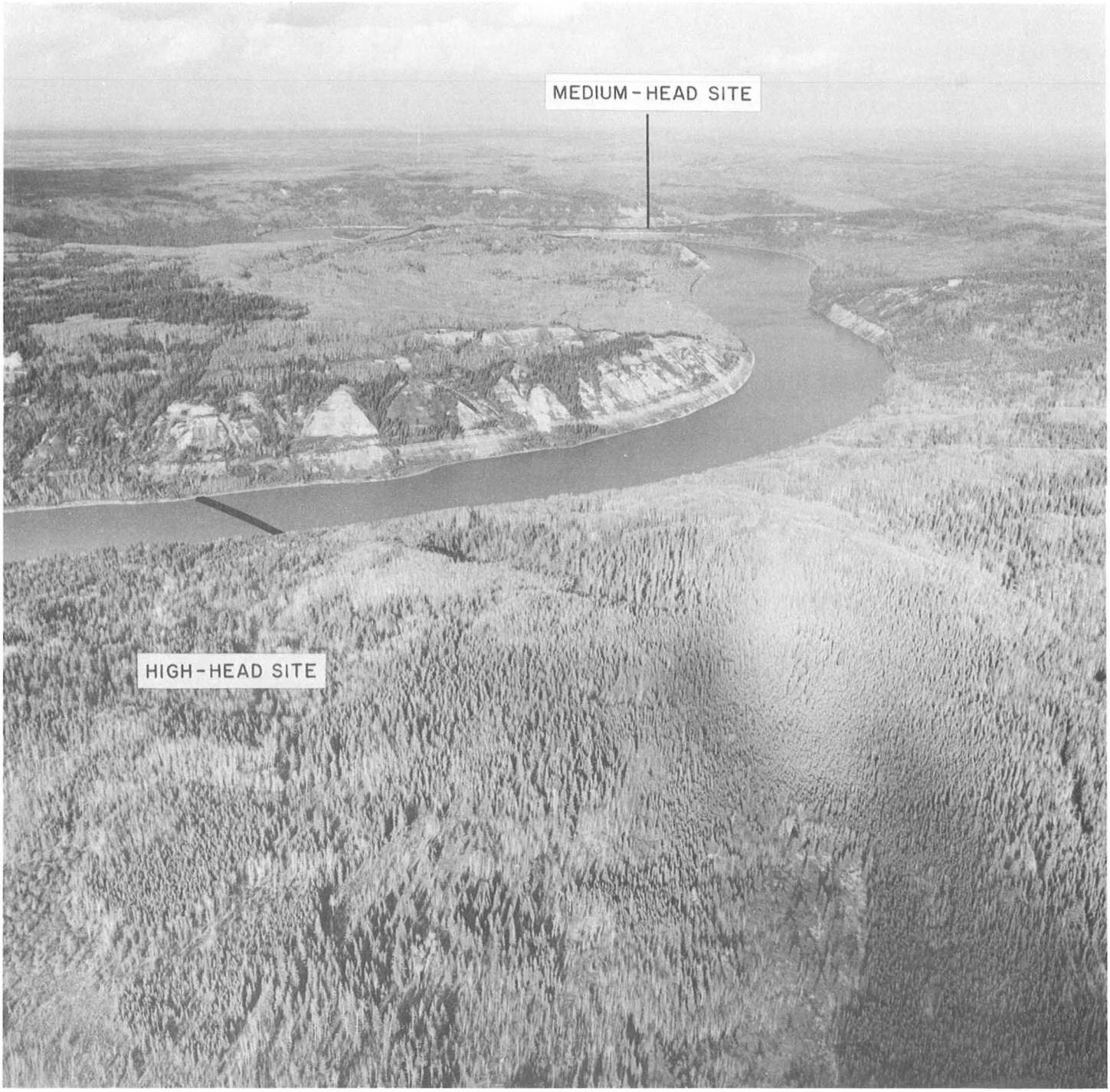

PHOTO 1. GENERAL VIEW OF DAMSITE STUDY AREA.
THE ATHABASCA RIVER FLOWS TOWARDS RIGHT. NOTE ANCIENT MEANDER IN FRONT OF PRESENT CROOKED RAPIDS MEANDER LOOP.

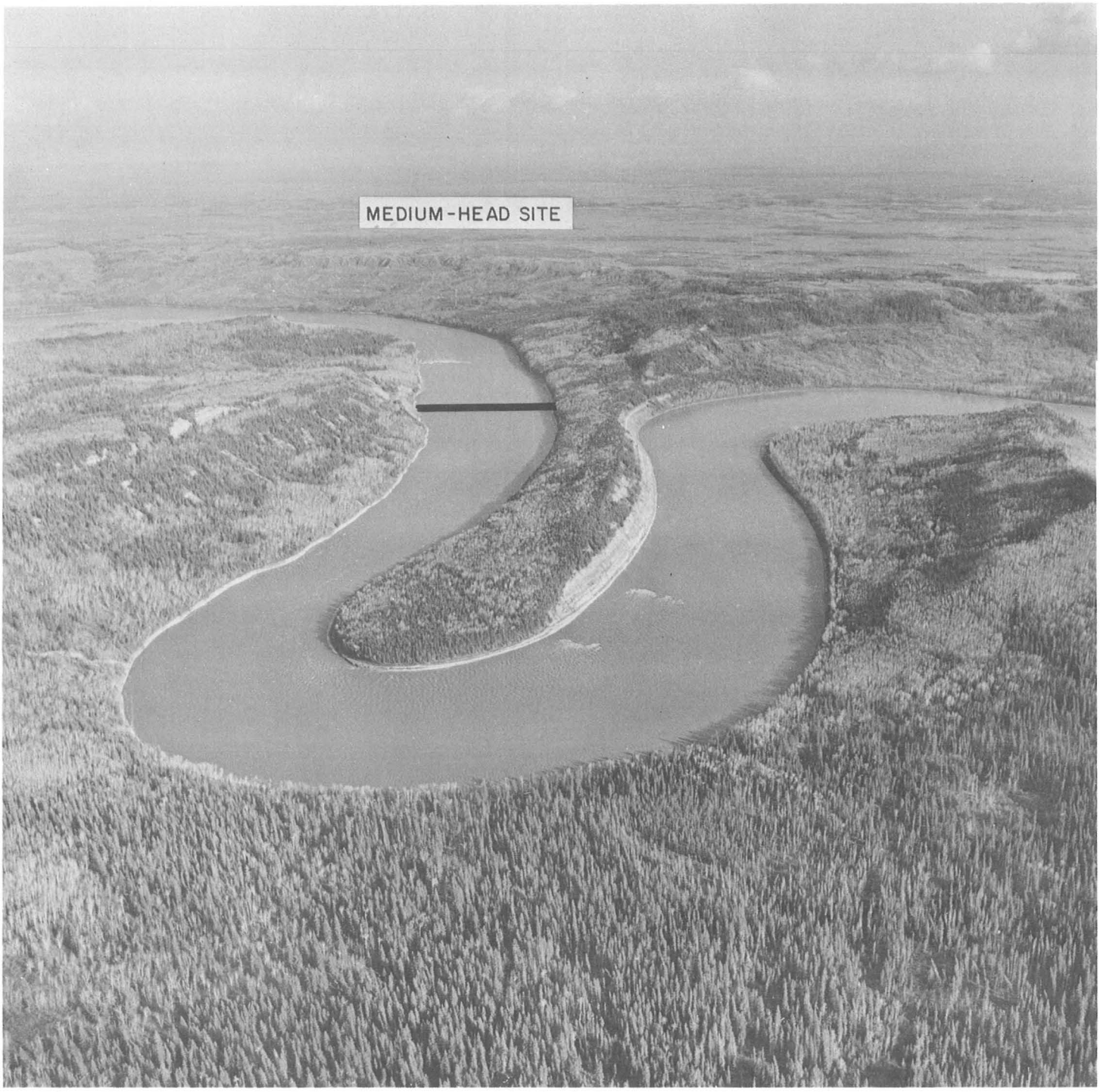

PHOTO 2. VIEW OF MEDIUM-HEAD SITE.
THE ATHABASCA RIVER FLOWS TOWARDS LEFT.

PHOTO 3. VIEW OF HIGH - HEAD SITE.
THE ATHABASCA RIVER FLOWS TOWARDS RIGHT.

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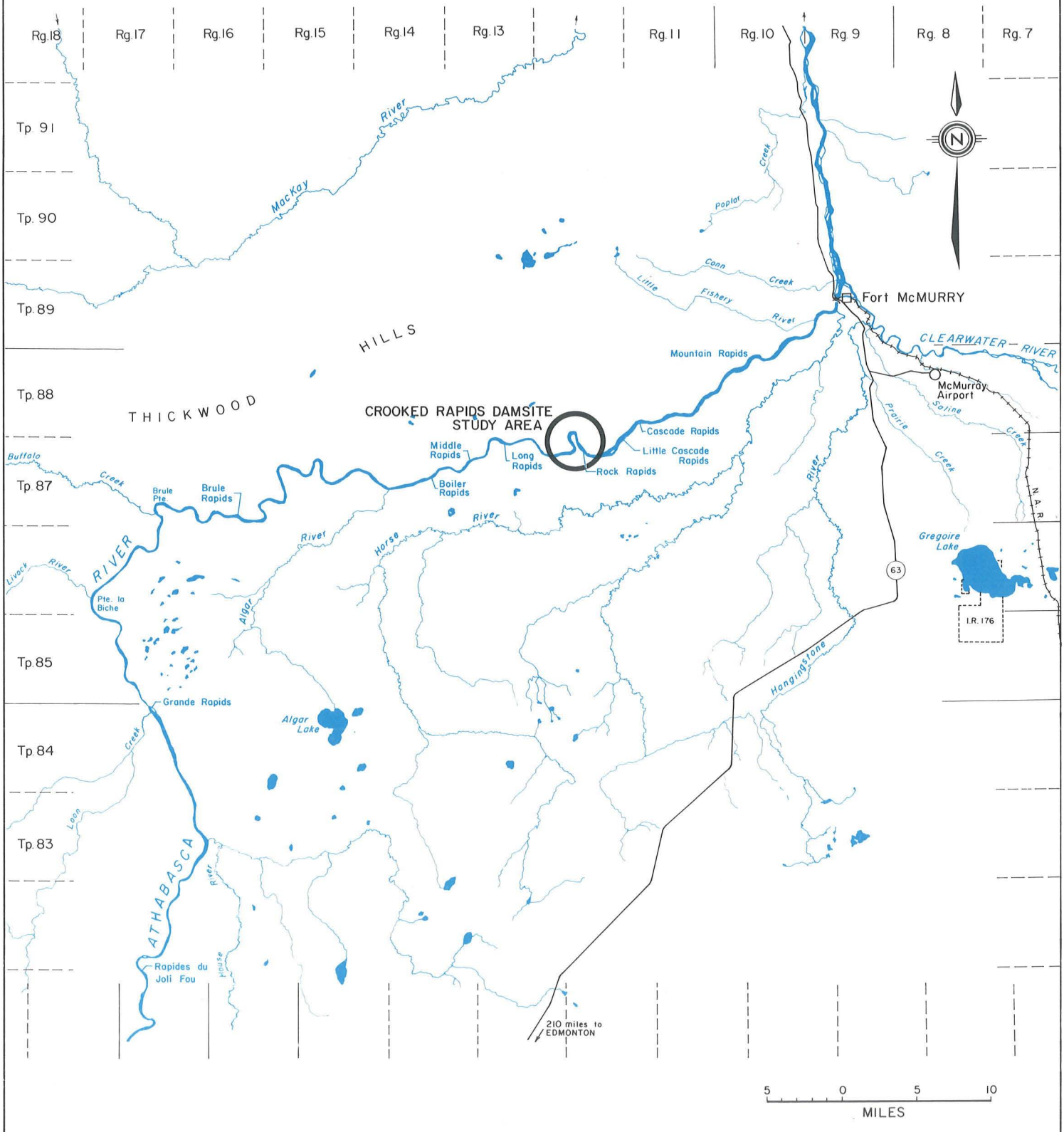
ATHABASCA RIVER POWER DEVELOPMENT
CROOKED RAPIDS STUDY

GENERAL LOCATION PLAN



Apr. 1975 FIGURE 1

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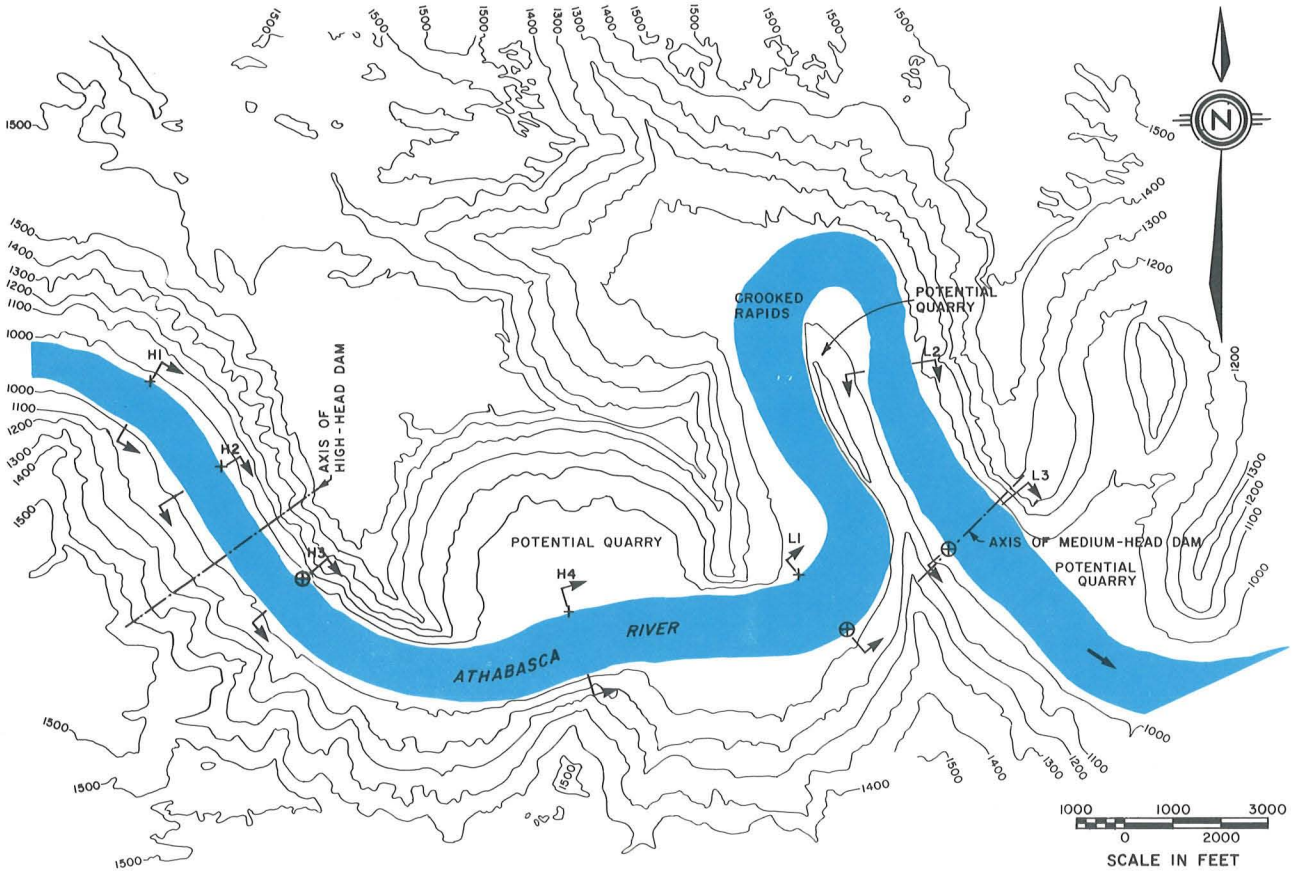
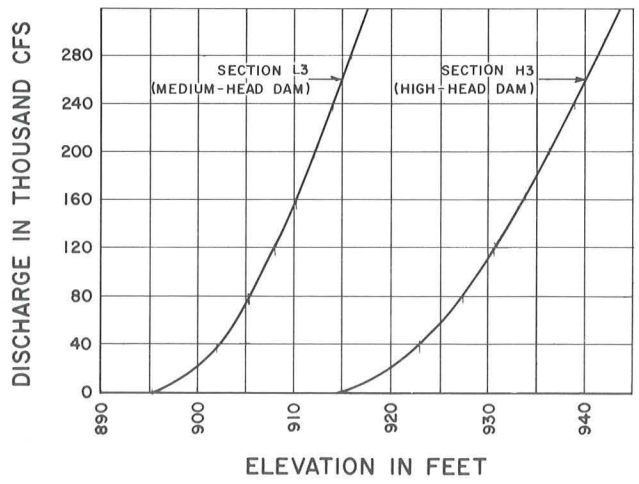
ATHABASCA RIVER POWER DEVELOPMENT

CROOKED RAPIDS STUDY

LOCATION OF DAM AXES, QUARRIES & RIVER SECTIONS



TAILWATER RATING CURVES



LEGEND

- LOCATION OF RIVER CROSS-SECTION
- + TEMPORARY BENCH MARK ONLY
- ⊕ TEMPORARY BENCH MARK AND STAFF GAUGE

NOTES

1. CONTOURS OBTAINED FROM AIR PHOTO MAPPING BY NORTHWEST SURVEY CORPORATION LTD. JUNE, 1974 ELEVATIONS ARE ABOVE G.S.C. DATUM.
2. TAILWATER RATING CURVE CALCULATED BY SLOPE-AREA METHOD.

DRAWING BASED ON WORK CARRIED OUT BY CRIPPEN ENGINEERING LTD. & NORTHWEST HYDRAULIC CONSULTANTS LTD.

DATE: MAY, 1975

FIGURE 2

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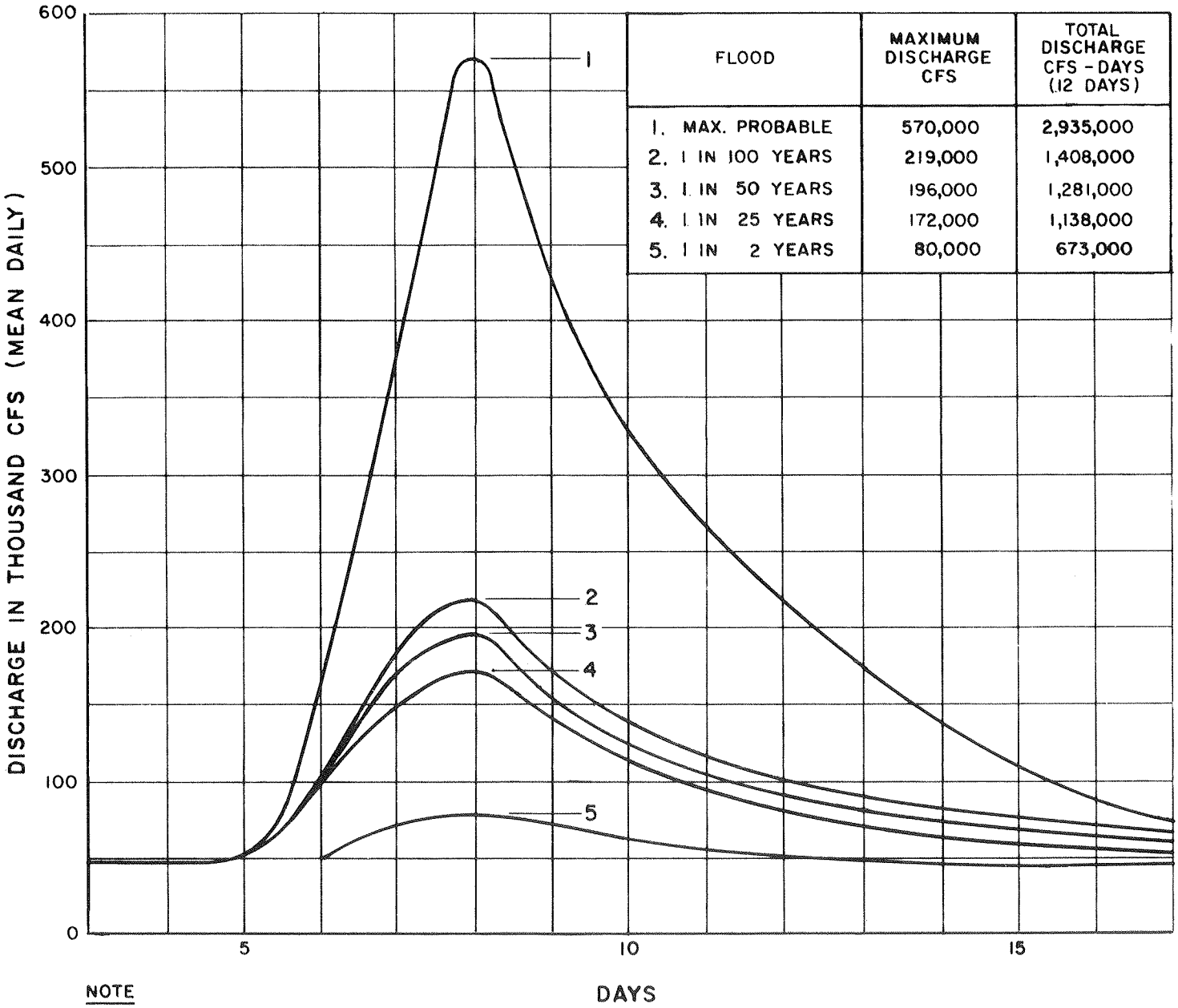
ATHABASCA RIVER POWER DEVELOPMENT

CROOKED RAPIDS

FLOOD HYDROGRAPHS



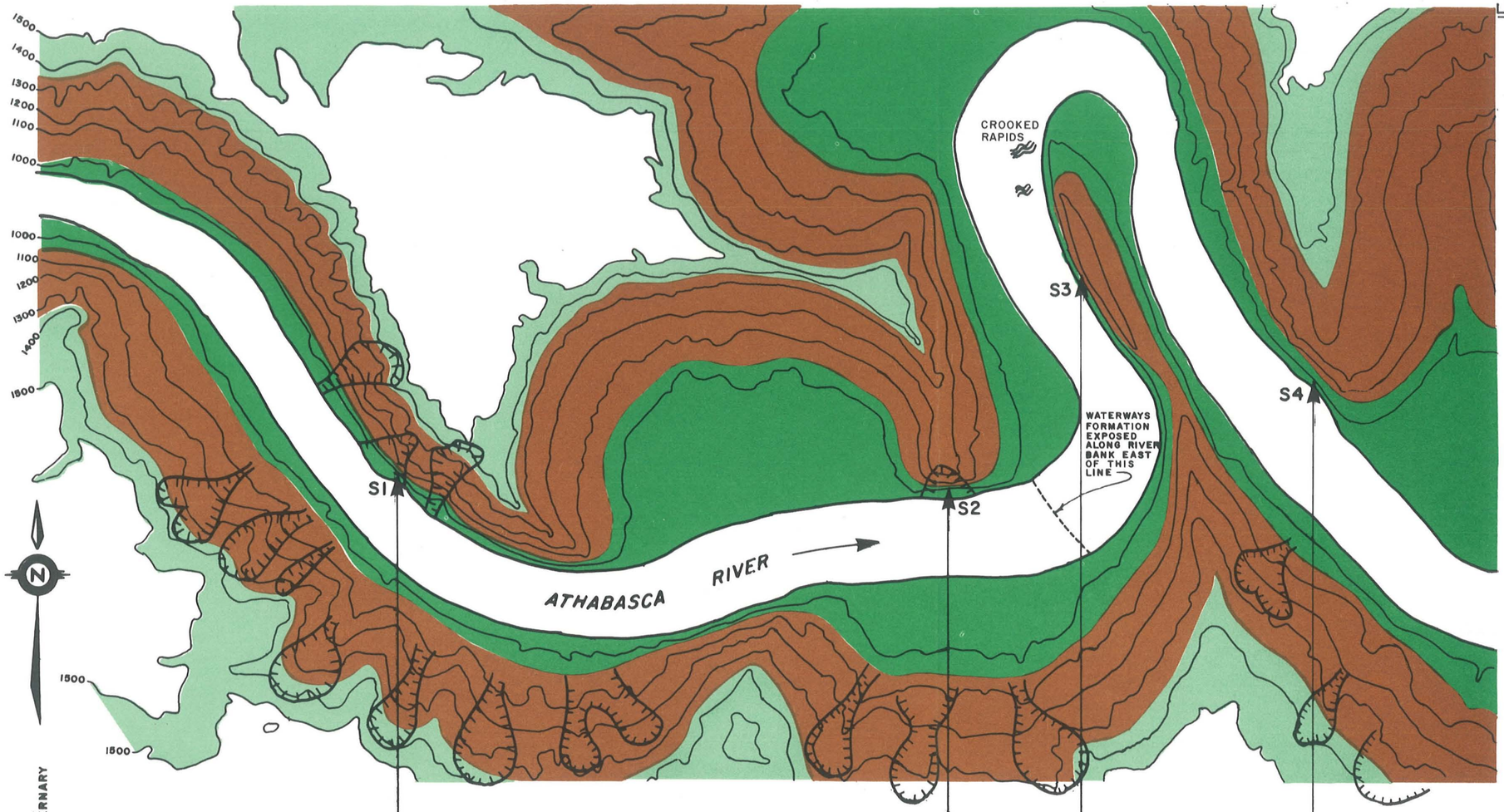
FLOOD	MAXIMUM DISCHARGE CFS	TOTAL DISCHARGE CFS - DAYS (12 DAYS)
1. MAX. PROBABLE	570,000	2,935,000
2. 1 IN 100 YEARS	219,000	1,408,000
3. 1 IN 50 YEARS	196,000	1,281,000
4. 1 IN 25 YEARS	172,000	1,138,000
5. 1 IN 2 YEARS	80,000	673,000

NOTE

DAY ZERO IS START OF
DIRECT RUNOFF IN HEADWATERS

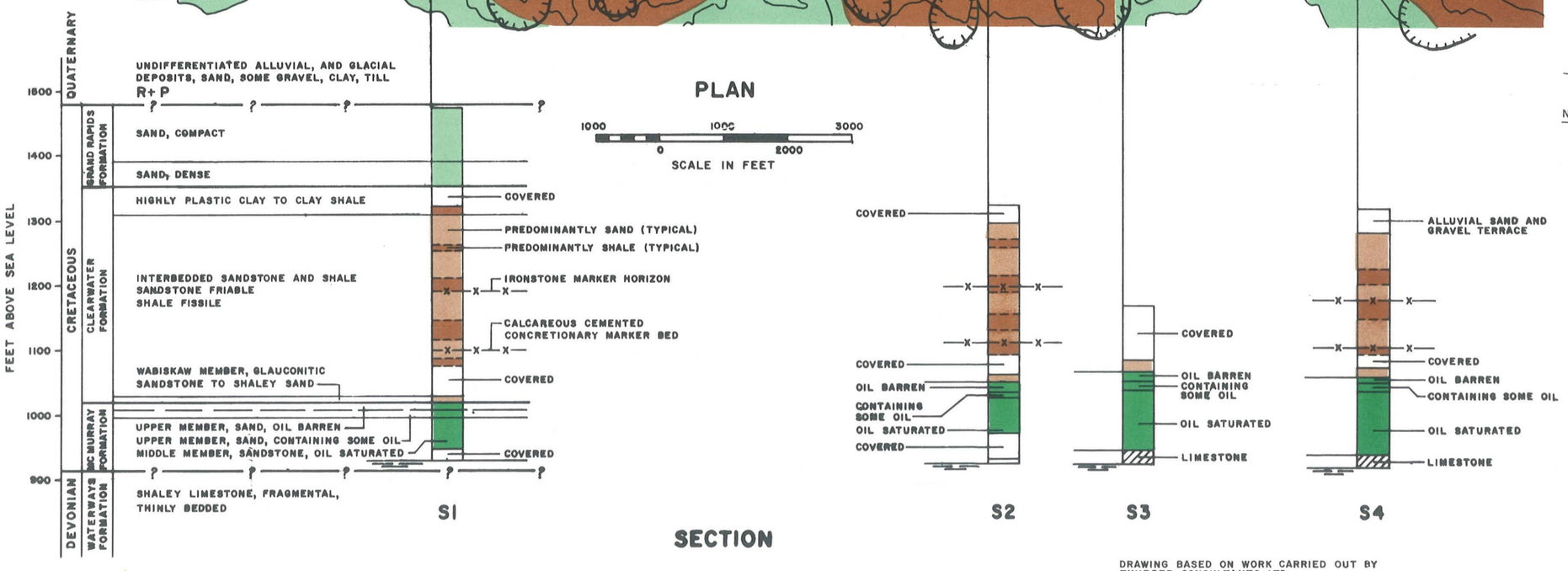
DRAWING BASED ON WORK CARRIED OUT BY
NORTHWEST HYDRAULIC CONSULTANTS LTD

Figure 3



PLAN

SCALE IN FEET 1000 0 1000 2000 3000



SECTION

DRAWING BASED ON WORK CARRIED OUT BY THURBER CONSULTANTS LTD.

LEGEND

GEOLOGY

QUATERNARY

RECENT

R UNDIFFERENTIATED ALLUVIAL SAND, SOME GRAVEL

PLEISTOCENE

P UNDIFFERENTIATED GLACIAL SAND, CLAY AND TILL

CRETACEOUS

LOWER CRETACEOUS

GRAND RAPIDS FORMATION
MAINLY BROWN FINE TO MEDIUM GRAINED COMPACT TO DENSE SAND

CLEARWATER FORMATION
MAINLY BROWN TO GREY INTERBEDDED SANDSTONE AND SHALE
WABISKAW MEMBER
GREYISH GREEN GLAUCONITIC SANDSTONE TO COMPACT SHALEY SAND

MC MURRAY FORMATION
UPPER MEMBER
LIGHT GREY TO LIGHT BROWN MEDIUM GRAINED SANDSTONE TO DENSE SAND, CONTAINING ZERO TO SOME OIL, HORIZONTALLY BEDDED
LOWER MEMBER
MAINLY GREY TO BLACK, MEDIUM-GRAINED SANDSTONE, SATURATED WITH OIL, CROSS-BEDDED

DEVONIAN

WATERWAYS FORMATION
MAINLY LIGHT GREY SHALEY LIMESTONE FRAGMENTAL AND THIN BEDDED

LOCATION OF MEASURED GEOLOGICAL SECTION

GEOLOGICAL CONTACT

GEOLOGICAL MARKER HORIZON

SLIDE SCARS AND SLUMPS

RAPIDS

RIVER LEVEL JUNE 21, 1974

NOTES

1. LOCATION OF CONTACTS BETWEEN VARIOUS GEOLOGICAL FORMATIONS KNOWN ACCURATELY ONLY AT MEASURED GEOLOGICAL SECTIONS, S1 THROUGH S4
2. SLIDE SCARS AND SLUMPS ARE ONLY LOCATED APPROXIMATELY
3. CONTOURS OBTAINED FROM AIR PHOTO MAPPING BY NORTHWEST SURVEY CORPORATION LTD. JUNE, 1974 ELEVATIONS ARE ABOVE G.S.C. DATUM
4. **GEOLOGICAL MAPPING DID NOT EXTEND ABOVE 1500 FEET ELEVATION**

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ATHABASCA RIVER POWER DEVELOPMENT
CROOKED RAPIDS STUDY
DAMSITE GEOLOGY

DATE: MAY, 1975

FIGURE 4

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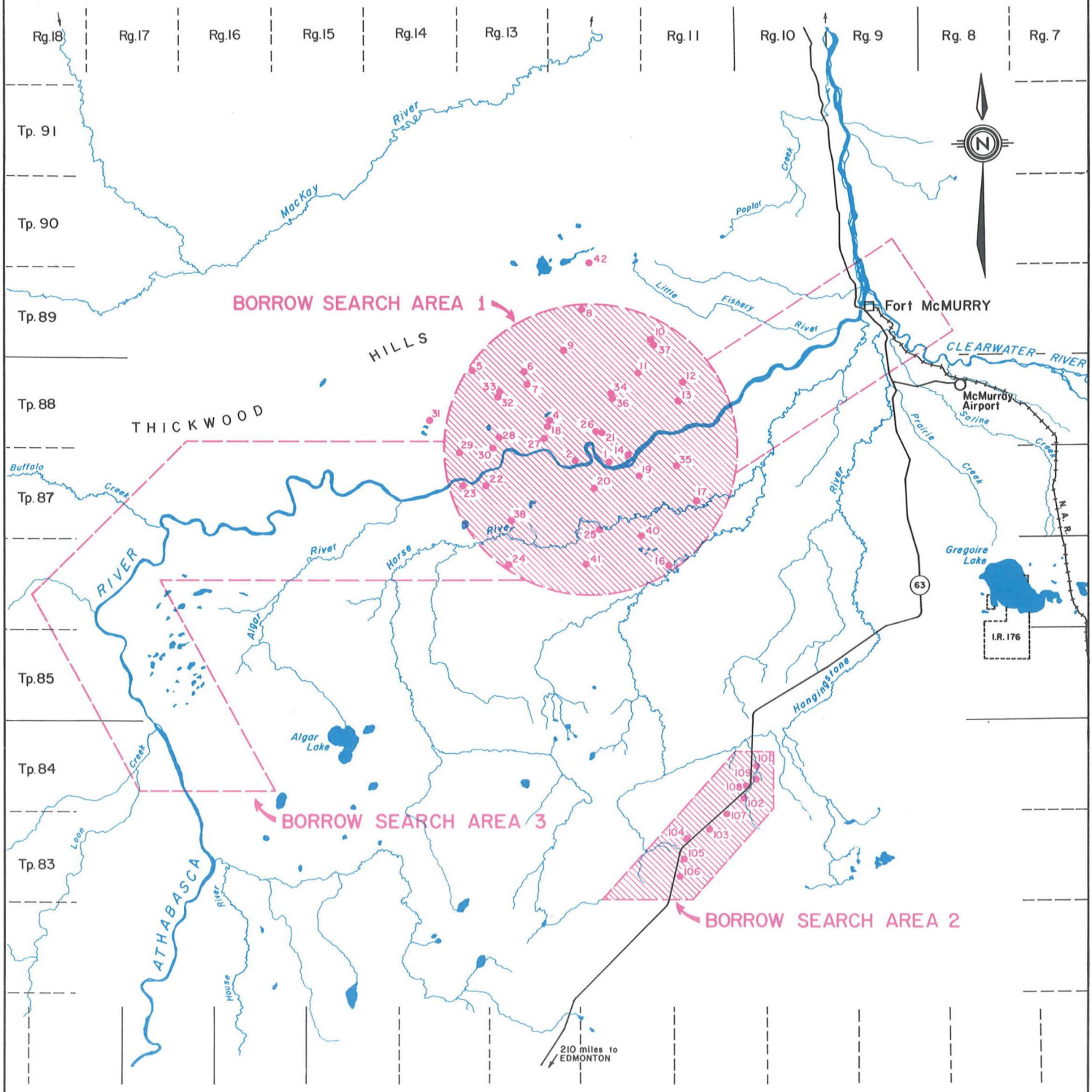
ATHABASCA RIVER POWER DEVELOPMENT
CROOKED RAPIDS STUDY

BORROW INVESTIGATION
DRILL HOLE LOCATION PLAN



LEGEND

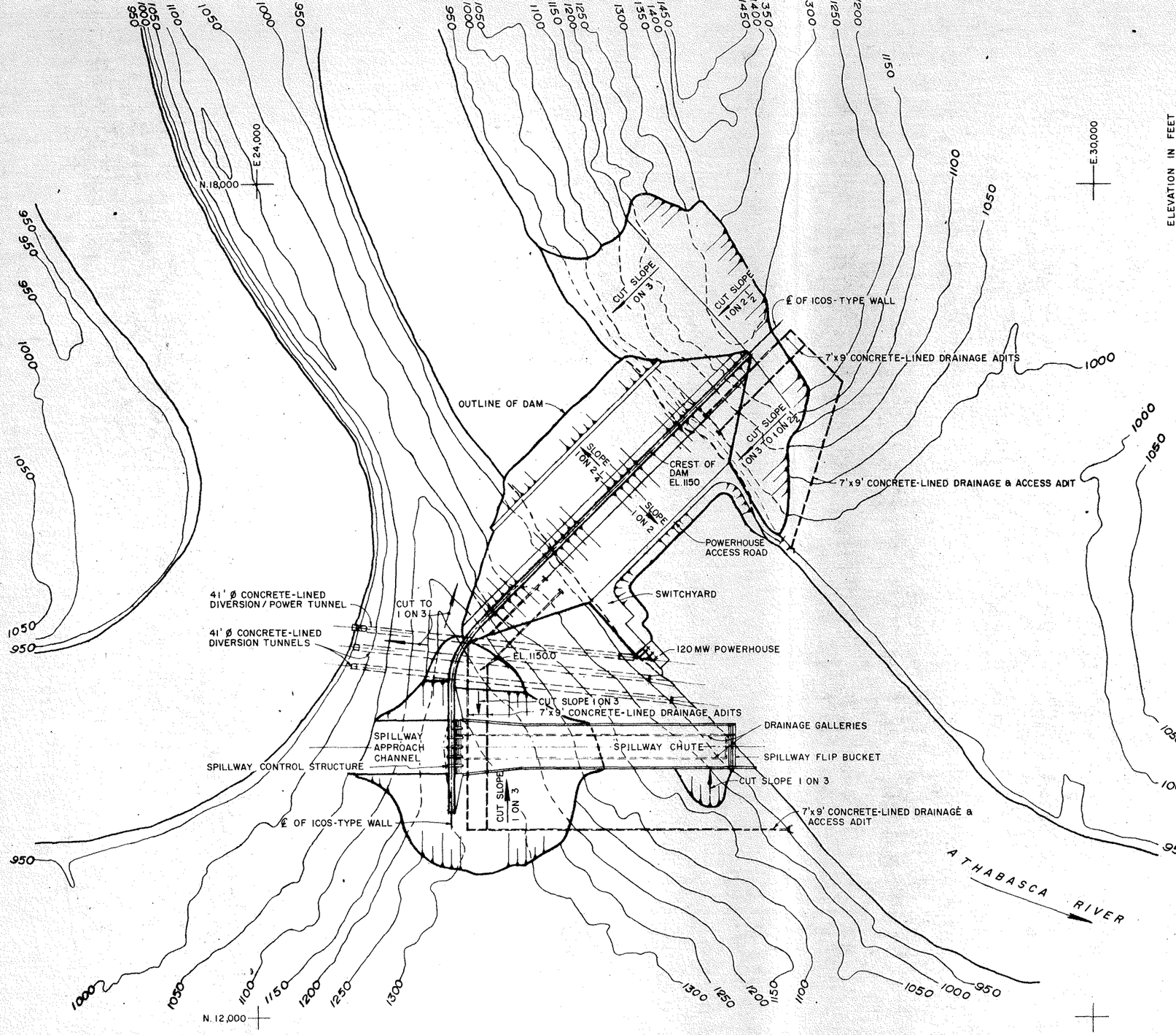
- AREA COVERED BY DETAILED AIR PHOTO STUDY
- AREA COVERED BY GENERAL AIR PHOTO STUDY
- ● 12 EXPLORATORY DRILL HOLE

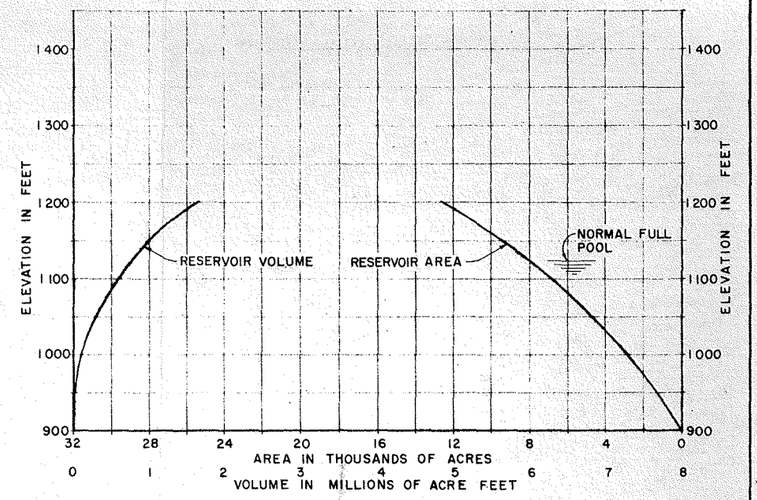
5 0 5 10
MILES

DRAWING BASED ON WORK CARRIED OUT BY Thurber Consultants Ltd. AND Crippen Engineering Ltd.

Apr. 1975

FIGURE 5





RESERVOIR STORAGE CURVES

NOTES

1. FOR SECTIONS OF DAM SEE FIGURE 7
2. FOR SECTIONS ALONG SPILLWAY AND TUNNELS, AND THROUGH POWERHOUSE SEE FIGURE 8
3. SLOPES ABOVE UPSTREAM PORTALS OF TUNNELS AND ABOVE UPSTREAM SLOPE OF DAM ON RIGHT BANK TO BE CUT TO 1 ON 3. FOR CLARITY CUT LINES NOT SHOWN ON PLAN. SEE SECTIONS FIGURES 7 & 8
4. FOR SLOPE OF FILL OVER CUT AND COVER SECTIONS OF TUNNELS SEE FIGURE 8
5. CONTOURS OBTAINED FROM AIR PHOTO MAPPING BY NORTHWEST SURVEY CORPORATION LIMITED, JUNE 1974. ELEVATIONS ARE ABOVE G.S.C. DATUM
6. RESERVOIR VOLUME CURVES OBTAINED FROM ROUGH CONTOUR MAPS SUPPLIED BY CALGARY POWER LTD.
7. SPILLWAY APPROACH CHANNEL & CHUTE TO BE LINED
8. SITE ROADS NOT SHOWN

400 0 400 800 1200
SCALE IN FEET

DRAWING BASED ON WORK CARRIED OUT BY CRIPPEN ENGINEERING LTD.

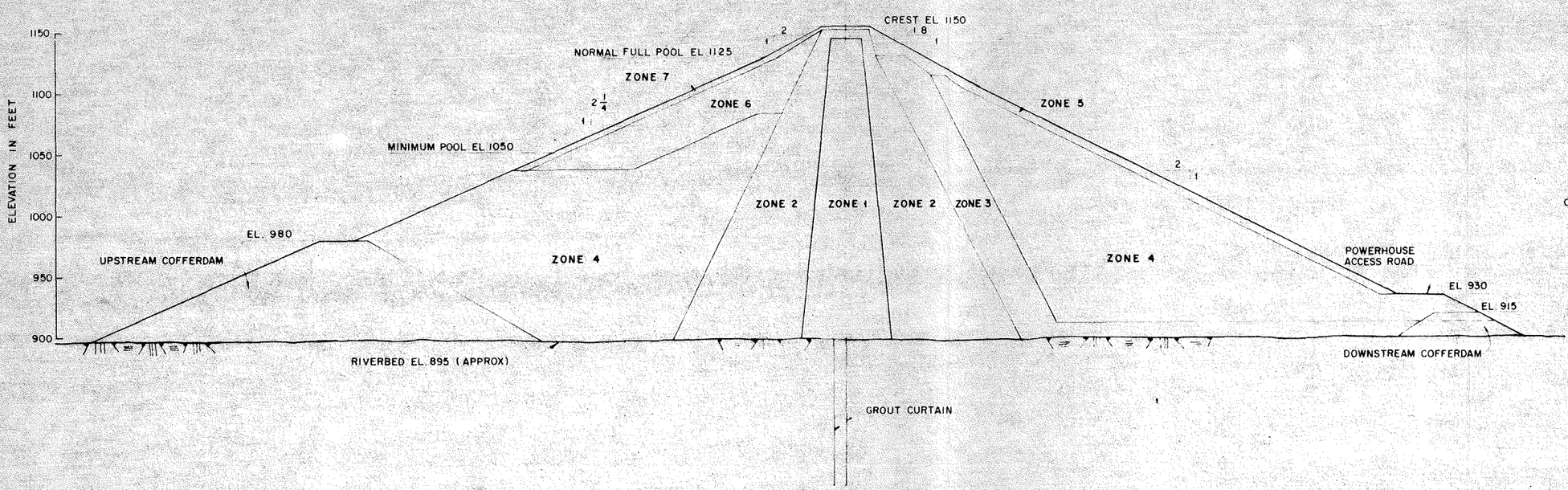
ALBERTA DEPARTMENT OF ENVIRONMENT

ATHABASCA RIVER POWER DEVELOPMENT

CROOKED RAPIDS STUDY
MEDIUM-HEAD PROJECT
GENERAL ARRANGEMENT

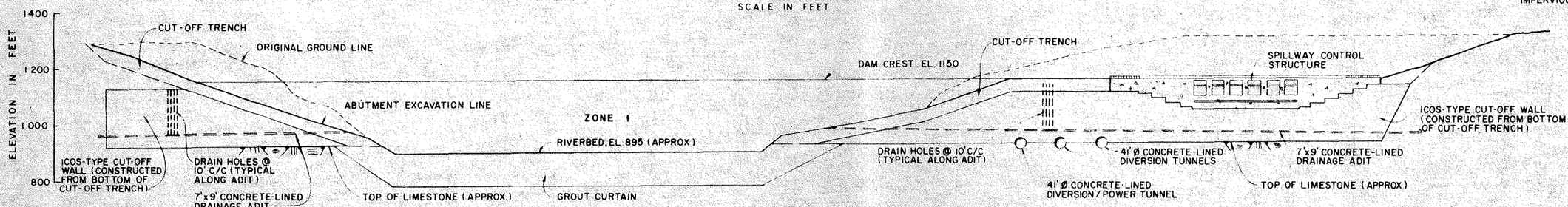
DATE : JAN. 1975

FIG. 6



DAM CROSS-SECTION AT MAXIMUM HEIGHT

50 0 50 100 150
SCALE IN FEET



SECTION ALONG DAM AXIS

200 0 200 400 600
SCALE IN FEET

LEGEND

ZONE	MATERIAL
1	RICH TAR SANDS
2	QUARRIED LIMESTONE FINES, OR SANDY MATERIAL FROM REQUIRED EXCAVATIONS
3	CLEAN FILTER AND DRAIN GRAVEL
4	QUARRY-RUN LIMESTONE (COARSER MATERIAL TOWARDS OUTSIDE SLOPES)
5	CLEAN QUARRIED LARGE-SIZED LIMESTONE
6	CLEAN QUARRIED MEDIUM-SIZED LIMESTONE
7	RIPRAP
COFFERDAMS	MAINLY ROCK-ZONING TO BE DECIDED ON BASIS OF DIVERSION SCHEME

NOTES

1. FOR LOCATION OF SECTIONS SEE FIGURE 6
2. FOR SECTIONS ALONG TUNNELS AND SPILLWAY SEE FIGURE 8
3. SLOPES AND DIMENSIONS OF FILL ZONES MAY VARY SOMEWHAT FROM THOSE SHOWN. QUANTITIES BASED ON SLOPES & DIMENSIONS SHOWN
4. ZONE 3 TO BE CARRIED UP ABUTMENT UNDER DOWNSTREAM SHELL
5. ALL FILL MATERIALS, EXCEPT RIPRAP & OTHER LARGE ROCK NEAR EXTERIOR SLOPES, AND PARTS OF COFFERDAMS, TO BE PLACED IN LIFTS AND COMPACTED
6. DRAINAGE ADITS AND DRAIN HOLES PROJECTED ON TO SECTION
7. CUT-OFF TRENCH TO BE BACKFILLED WITH IMPERVIOUS MATERIAL

DRAWING BASED ON WORK CARRIED OUT BY CRIPPEN ENGINEERING LTD.

ALBERTA DEPARTMENT OF ENVIRONMENT

ATHABASCA RIVER POWER DEVELOPMENT

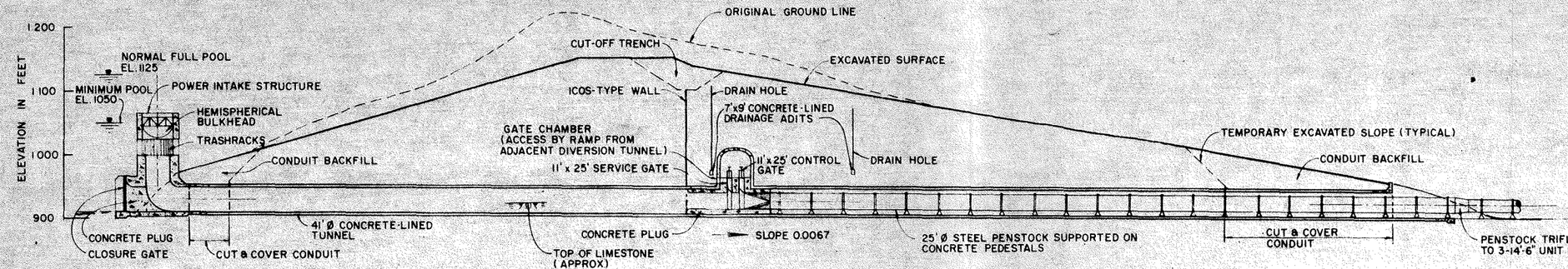
CROOKED RAPIDS STUDY

MEDIUM-HEAD PROJECT

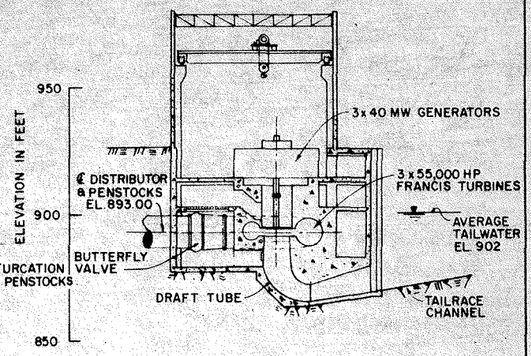
DAM SECTIONS

DATE : JAN. 1975

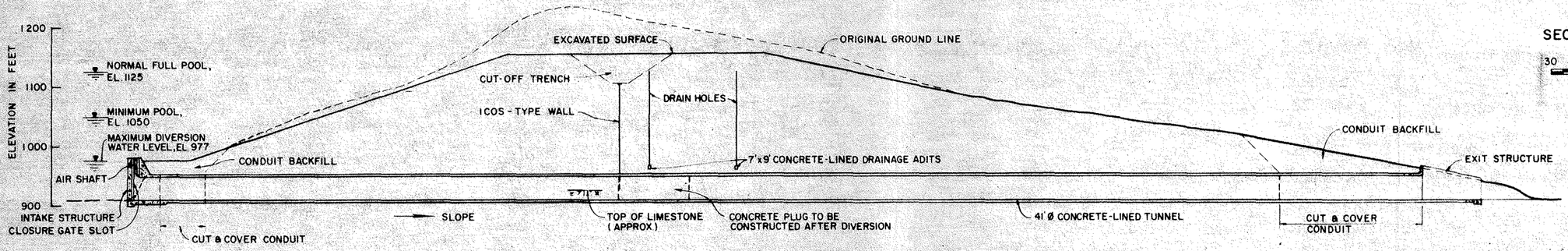
FIG. 7



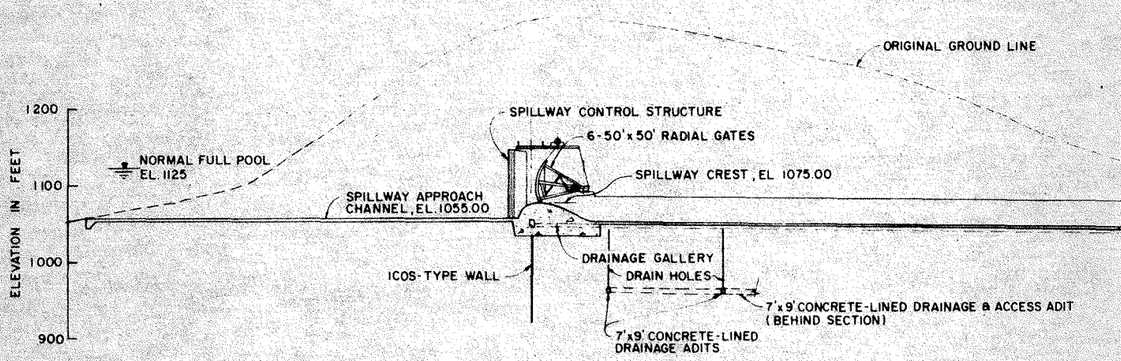
SECTION THROUGH DIVERSION / POWER TUNNEL



SECTION THROUGH POWERHOUSE



SECTION THROUGH DIVERSION TUNNELS
(TYPICAL FOR TWO TUNNELS)



SECTION THROUGH SPILLWAY

100 0 100 200 300 400
SCALE IN FEET

30 0 30 60 90
SCALE IN FEET

NOTES

1. FOR LOCATION OF SECTIONS SEE FIGURE 6
2. FOR CLARITY, ACCESS RAMP AND AIR VENT SYSTEM TO GATE CHAMBER NOT SHOWN
3. CUT-OFF TRENCH TO BE BACKFILLED WITH IMPERVIOUS MATERIAL
4. SPILLWAY APPROACH CHANNEL & CHUTE TO BE LINED

ALBERTA DEPARTMENT OF ENVIRONMENT

ATHABASCA RIVER POWER DEVELOPMENT

CROOKED RAPIDS STUDY
MEDIUM-HEAD PROJECT
SECTIONS THROUGH TUNNELS & SPILLWAY

DRAWING BASED ON WORK CARRIED OUT BY CRIPPEN ENGINEERING LTD.

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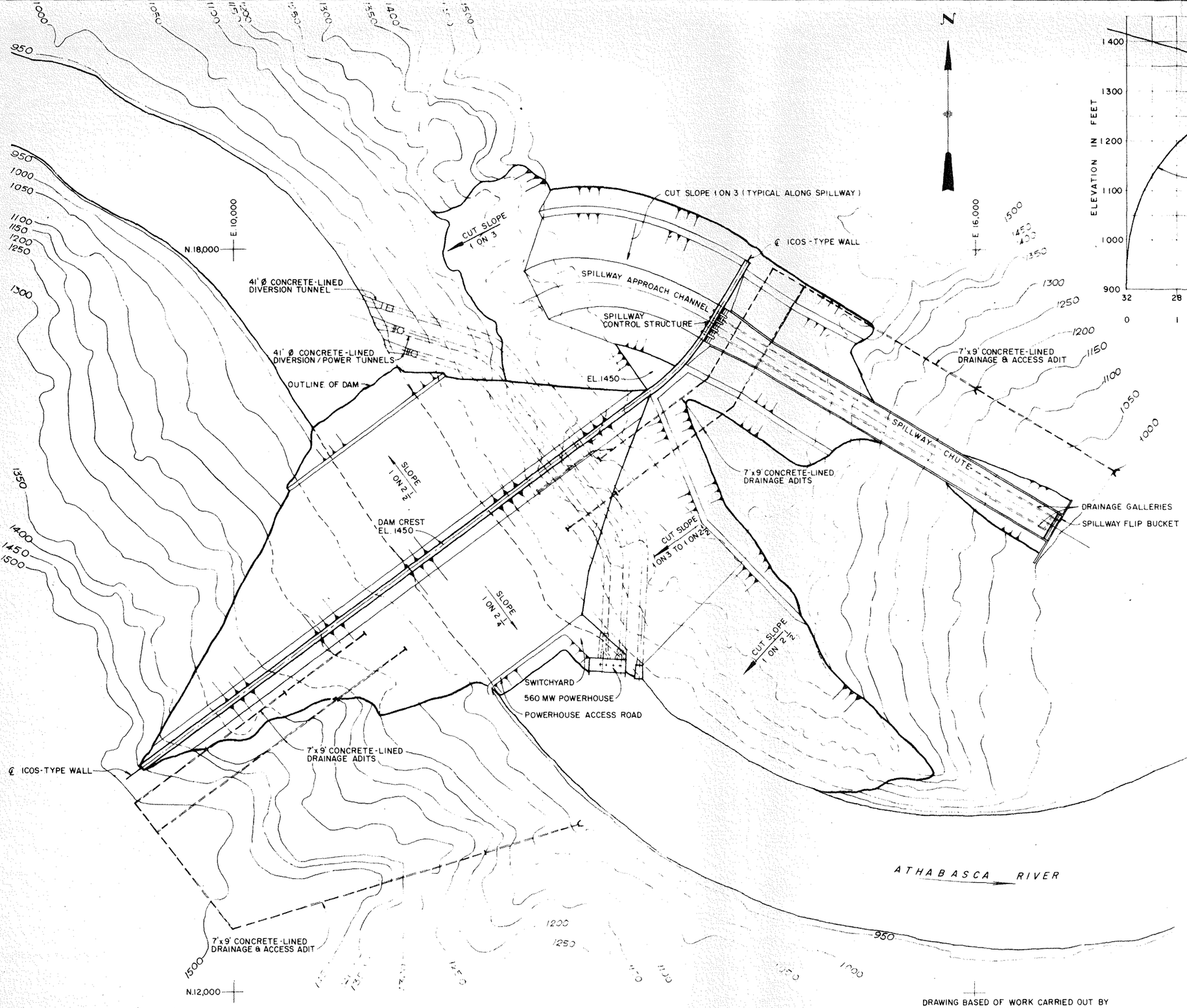
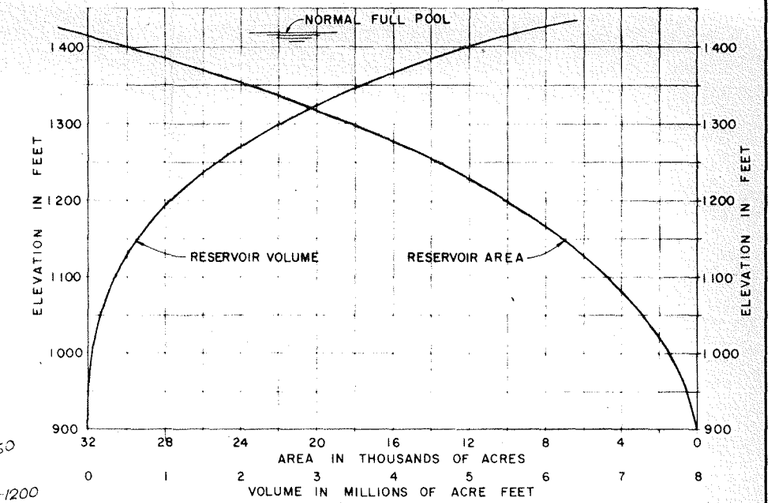
FIG. 8





RESERVOIR STORAGE CURVES

NOTES

1. FOR SECTIONS OF DAM SEE FIGURE 10
2. FOR SECTIONS ALONG SPILLWAY AND TUNNELS, AND THROUGH POWERHOUSE SEE FIGURE 11
3. FOR SLOPE OF FILL OVER CUT AND COVER SECTIONS OF TUNNELS SEE FIGURE 11
4. CONTOURS OBTAINED FROM AIR PHOTO MAPPING BY NORTHWEST SURVEY CORPORATION LIMITED, JUNE 1974. ELEVATIONS ARE ABOVE G.S.C. DATUM
5. RESERVOIR VOLUME CURVES OBTAINED FROM ROUGH CONTOUR MAPS SUPPLIED BY CALGARY POWER LTD
6. SPILLWAY APPROACH CHANNEL & CHUTE TO BE LINED
7. NO REQUIRED EXCAVATION SHOWN DOWNSTREAM OF SPILLWAY FLIP BUCKET SINCE AREA IS POTENTIAL QUARRY
8. SITE ROADS NOT SHOWN

400 0 400 800 1200 1600 2000
SCALE IN FEET

DRAWING BASED OF WORK CARRIED OUT BY CRIPPEN ENGINEERING LTD

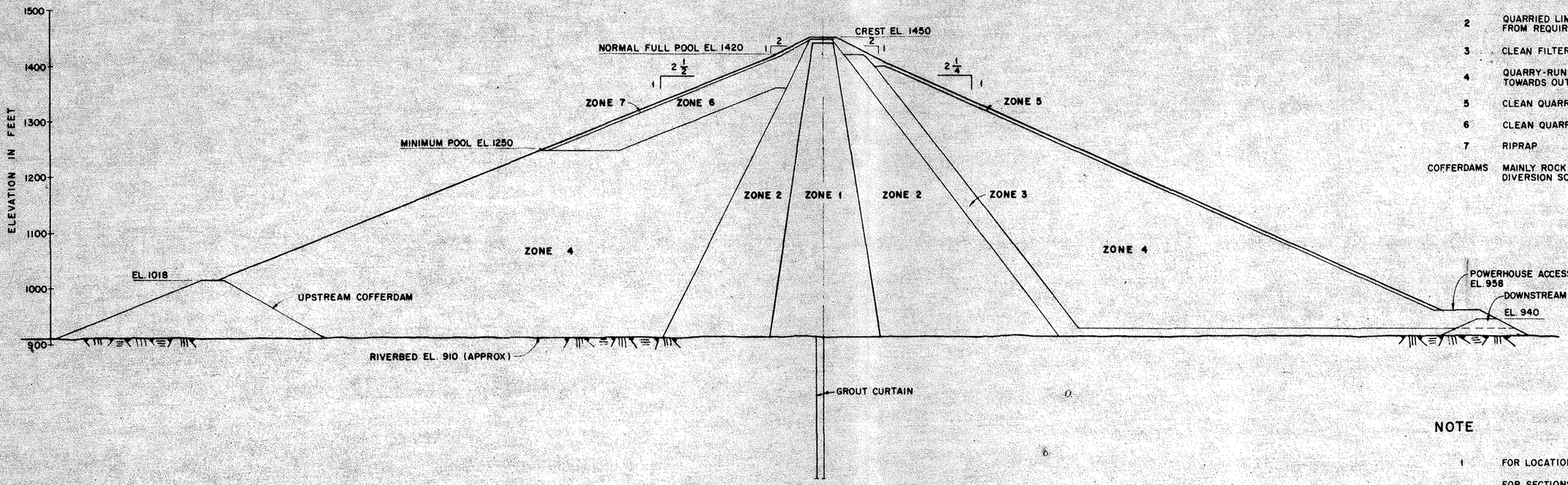
ALBERTA DEPARTMENT OF ENVIRONMENT

ATHABASCA RIVER POWER DEVELOPMENT

CROOKED RAPIDS STUDY
HIGH-HEAD PROJECT
GENERAL ARRANGEMENT

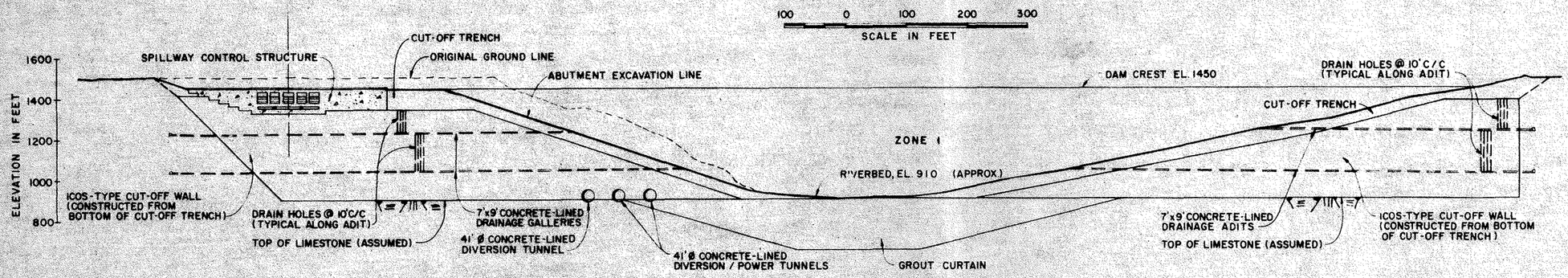
DATE : JAN. 1975

FIG. 9



DAM CROSS-SECTION AT MAXIMUM HEIGHT

100 0 100 200 300
SCALE IN FEET



SECTION ALONG DAM AXIS

300 0 300 600 900
SCALE IN FEET

LEGEND

ZONE	MATERIAL
1	RICH TAR SANDS
2	QUARRIED LIMESTONE FINES, OR SANDY MATERIAL FROM REQUIRED EXCAVATIONS
3	CLEAN FILTER AND DRAIN GRAVEL
4	QUARRY-RUN LIMESTONE (COARSER MATERIAL TOWARDS OUTSIDE SLOPES)
5	CLEAN QUARRIED LARGE-SIZED LIMESTONE
6	CLEAN QUARRIED MEDIUM-SIZED LIMESTONE
7	RIPRAP
COFFERDAMS	MAINLY ROCK-ZONING TO BE DECIDED ON BASIS OF DIVERSION SCHEME.

NOTE

1. FOR LOCATION OF SECTIONS SEE FIGURE 9
2. FOR SECTIONS ALONG TUNNELS AND SPILLWAY SEE FIGURE 11
3. SLOPES AND DIMENSIONS OF FILL ZONES MAY VARY SOMEWHAT FROM THOSE SHOWN. QUANTITIES BASED ON SLOPES & DIMENSIONS SHOWN
4. ZONE 3 TO BE CARRIED UP ABUTMENT UNDER DOWNSTREAM SHELL
5. ALL FILL MATERIALS, EXCEPT RIPRAP & OTHER LARGE ROCK NEAR EXTERIOR SLOPES, AND PARTS OF COFFERDAMS, TO BE PLACED IN LIFTS AND COMPACTED
6. EXCAVATION ON RIGHT ABUTMENT OF LIMITED EXTENT NOT SHOWN
7. DRAINAGE ADITS AND DRAIN HOLES, PROJECTED ON TO SECTION
8. CUT-OFF TRENCH TO BE BACKFILLED WITH IMPERVIOUS MATERIAL

DRAWING BASED ON WORK CARRIED OUT BY CRIPPEN ENGINEERING LTD.

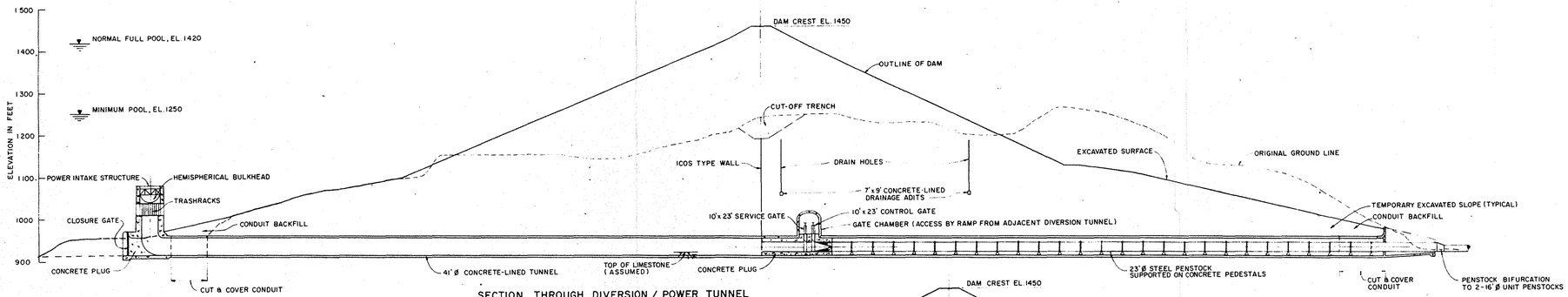
ALBERTA DEPARTMENT OF ENVIRONMENT

ATHABASCA RIVER POWER DEVELOPMENT

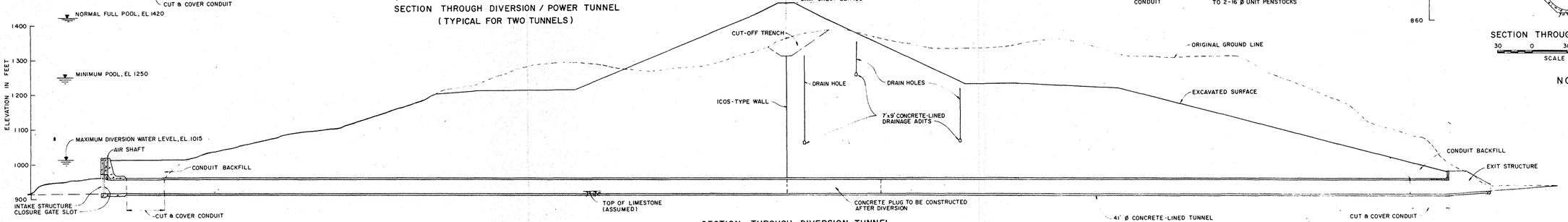
CROOKED RAPIDS STUDY
HIGH-HEAD PROJECT
DAM SECTIONS

DATE : JAN. 1975

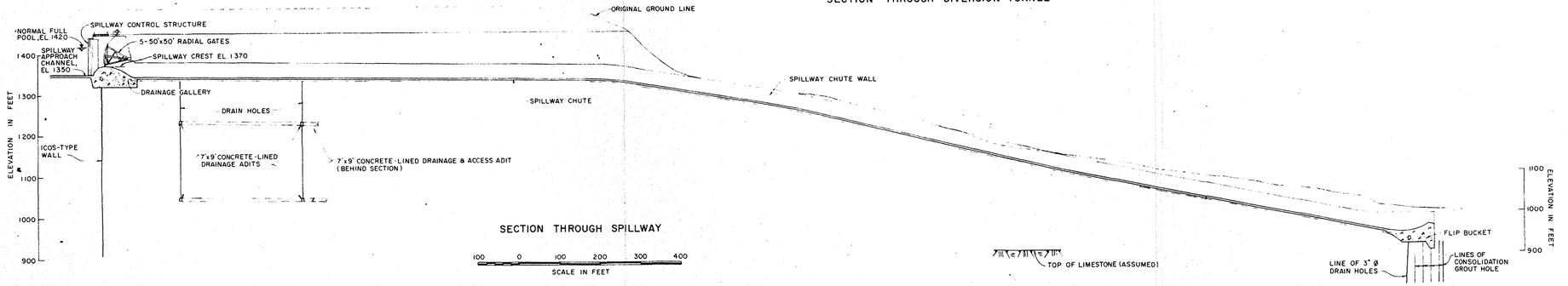
FIG. 10



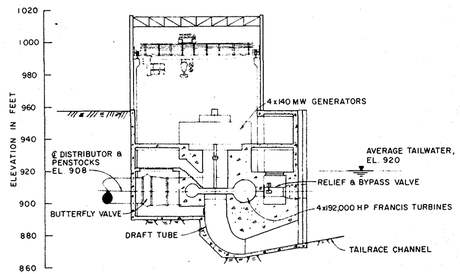
SECTION THROUGH DIVERSION / POWER TUNNEL
(TYPICAL FOR TWO TUNNELS)



SECTION THROUGH DIVERSION TUNNEL



SECTION THROUGH SPILLWAY



SECTION THROUGH POWERHOUSE

30 0 30 60 90
SCALE IN FEET

NOTES

1. FOR LOCATION OF SECTIONS SEE FIGURE 9
2. FOR CLARITY, ACCESS RAMP AND AIR VENT SYSTEM TO GATE CHAMBER NOT SHOWN
3. CUT-OFF TRENCH TO BE BACKFILLED WITH IMPERVIOUS MATERIAL
4. SPILLWAY APPROACH CHANNEL & CHUTE TO BE LINED

ALBERTA DEPARTMENT OF ENVIRONMENT

ATHABASCA RIVER POWER DEVELOPMENT

CROOKED RAPIDS STUDY
HIGH-HEAD PROJECT
SECTIONS THROUGH TUNNELS & SPILLWAY

DRAWING BASED ON WORK CARRIED OUT BY CRIPPEN ENGINEERING LTD

DATE : JAN. 1975

FIG. 11