BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

FEASIBILITY STUDY

MAY 1976

HYDROELECTRIC DESIGN DIVISION

REPORT NO. 796

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PEACE RIVER SITES C AND E

FEASIBILITY STUDY

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SYNOPSIS

The Peace River falls 260 feet from Site 1 to the British Columbia/Alberta Border. It would be feasible to develop nearly all of this head with either two low dams or a single high dam. However, the two low dam development would be more economic and less disruptive to existing development along the Peace River.

Development with two low dams would consist of:

1. A Site C project with a normal reservoir level of El. 1515 located at an axis just downstream of the Moberly River developing up to 166 feet of head. This project would require a 235-foot high concrete gravity intake and spillway dam with earthfill wing dams.

2. A Site E project with a normal reservoir level between about El. 1342 and El. 1352* located at an axis 1/2 mile downstream of the Alces River developing up to 93 feet of head. This project would consist of a 162-to 172-foot high concrete intake and spillway to the right of the river channel with an earthfill dam closing the major part of the channel.

Alternative development with a single high dam would consist of:

A Site E project with a normal reservoir level of El. 1510 located at an axis 1/2 mile downstream of the Alces river developing

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* Selection of the final reservoir level for the low Site E project can be made only after more exhaustive studies of reservoir impact in the Taylor area. El. 1352 represents the optimum reservoir normal operating level taking into account only engineering and land acquisition costs. Selection of El. 1342 for the reservoir level would minimize relocation problems and reduce the flooding of agricultural land at Taylor, but, depending on how much tailrace improvement is economic at Site C, 4 to 7 1/2 feet of head would be left undeveloped.

251 feet of head. This project would require a 330-foot high concrete gravity intake and spillway dam to the right of the river channel with earthfill dams across the major part of the channel and the low terrace on the right abutment.

Energy and cost data for development with two low dams or a single high dam would be as follows:

Project		Two Low Dams: Site C (1515)	Two Low Dams: Site E (1342) or (Site E (1352))	Two Low Dams: Site C (1515) + Site E (1342) or (Site C (1515) + Site E (1352))	One High Dam: Site E (1510)
Total Capital Cost (mid-1975 price levels)	$ x 10^6	544	452 (483)	996 (1027)	1170
Attributable Plant Capacity	MW	965	597 (665)	1562 (1630)	1790
Capital Cost of Capacity	$/kW	564	757 (726)	638 (630)	654
Total Annual Cost*	$ x 10^6	64.0	53.5 (57.1)	117.5 (121.1)	137.4
Attributable Average Energy (before McGregor Div.)	GWh/yr	4450	2830 (3120)	7280 (7570)	8500
Energy Cost (before McGregor Div.)	mills/kWh	14.4	18.9 (18.3)	16.1 (16.0)	16.2
Attributable Average Energy (after McGregor Div.)	GWh/yr	5245	3145 (3445)	8390 (8690)	9530
Energy Cost (after McGregor Div.)	mills/kWh	12.2	17.0 (16.6)	14.0 13.9	14.4

* Based on a long term interest rate of 10 percent per annum.

The Site C (1515) plus the Site E (1342) or (1352) development as opposed to the single dam Site E (1510) development, would present less complex problems of design and construction associated with the relatively poor foundation conditions. The two low dams would also require far less extensive relocations, flood a little over one-third of the land area which includes some agricultural land, and considerably reduce the greater bank stability problems associated with the alternative single high dam.

Although sedimentation of the reservoirs would occur, the life of the Site C (1515) reservoir is estimated at over 700 years. The Site E (1342) or (1352) reservoir may fill with sediment in as little as 50 years, but the project would be designed to operate with sediment being passed through the dam after the reservoir is substantially filled.

Tight scheduling would permit the first units of the Site C (1515) project to be in service approximately 6 years from issue of the first tender. The Site E (1342) or (1352) project would require an additional year. Preliminary design would add 1 1/2 to 2 years to the above periods. Possible additional time requirements for environmental impact studies and licensing proceedures may lengthen the lead time that would be necessary for the projects. Both the Site C (1510) and the Site E (1342) or (1352) projects would require further and more detailed investigations of the foundation characteristics and of reservoir bank stability before final design of any of the projects.

It is recommended that no further consideration be given to the Site E (1510) project.

SECTION 1.0 - INTRODUCTION

1.1 ASSIGNMENT

The report "Peace River Area - Power Development Studies Between Site 1 and Alberta Border" was prepared by IPEC for B.C. Hydro in July 1972. This study report considered developments at a dam axis upstream of the Moberly River for Site C (Axis C-1) and an axis about 1 mile upstream of the B.C./Alberta border for Site E (Axis E-3). It found that "*... as the foundations at both sites are marginally acceptable, further site investigations and testing would be required to determine the best alternative before proceeding with preliminary design*".

As set out in the memo of 6 August 1973 from H.E. Howe to Dr. H.M. Ellis under Assignment No. 473-068, engineering services were required to investigate the possibility of more favourable project axes at Sites C and E and to assess the reservoir bank stability (particularly in the Taylor area). In October 1973, work commenced on seismic surveys to investigate alternative axes prior to foundation drilling, planned during 1974. On the basis of the seismic surveys and geological appraisals, more favourable axes were selected at which foundation drilling would be concentrated. At Site C, the selected axis was downstream of the Moberly River (Axis C-3), and at Site E about 2 miles upstream of the Alberta border (Axis E-6). Some additional drilling was also planned at the earlier axis (Axis E-3). Based on system energy studies under way at that time, the development of the Lower Peace was not visualized until well into the 1990s, and therefore, the proposed drilling program for 1974 was cancelled.

During late 1974, discussions were held between the governments of British Columbia and Alberta where it was agreed that, while each province would study development of the Peace River separately on its side of the provincial border, studies would also be made of the possible

1.1 <u>ASSIGNMENT</u> - (Cont'd)

benefits of joint development. As a result the Hydroelectric Design Division under Engineering Assignment No. 473-068 Revision 3, dated 14 April 1975 was commissioned to provide engineering services as required to carry out foundation investigations (including seismic surveys and drilling), as well as bank stability studies for the entire shoreline of the reservoir areas.

More specifically the proposed studies included the following:

1. Foundation investigation and project arrangement studies.

2. Spillway design flood studies and diversion flood studies.

3. Reservoir bank stability and relocation investigations.

4. Exploration of gravel deposits and mineral potential assessment.

5. River regime and discharge studies.

1.2 <u>SCOPE</u>

The principal objectives of the studies covered by this report and associated reports referred to herein were as follows:

1. To determine whether more favourable dam axes exist than those selected in previous studies.

2. To confirm or disprove the engineering feasibility of each of the alternative developments (at least one dam axis in each case).

3. To obtain engineering information to assist in deciding between developments with a single "high" Site E dam or two lower dams at Site C and Site E.

1.2 <u>SCOPE</u> - (Cont'd)

4. To make feasibility studies, including cost estimates, of developments entirely within British Columbia on a basis comparable to that used for Alberta's studies of the Dunvegan sites, as required for a decision on possible joint B.C./Alberta development of the Peace River.

5. To obtain data and make studies of an engineering nature required for the Environmental Impact Report.

The main items of work carried out for this assignment, in approximately chronological order, were as follows:

1. Geological appraisal of possible alternative dam axes.

2. Seismic investigations of the possible alternative dam axes.

3. Preliminary reservoir bank stability investigations along the main Peace River Valley for the proposed alternative developments.

4. Preparation of an Interim Report on Site E (1510) compared with Site C (1510) plus Site E (1355). (Issued April 1975.)

5. Extension of existing dam site topographic mapping to include the proposed new axes.

6. Foundation drilling investigations at three alternative dam axes.

7. Laboratory testing of core samples obtained from foundation drilling.

8. Hydrographic, topographic and control surveys of river cross-sections between Site 1 and the Alberta border including re-survey of cross-sections originally measured prior to the impoundment of Williston Lake.

1.2 SCOPE - (Cont'd)

9. Backwater studies to established tailwater rating curves and stage-discharge curves at critical points on the reservoir for alternative reservoir levels.

10. Tentative evaluation of optimum reservoir normal operating levels.

11. Collection of field data on suspended sediment, bed material, river profiles, etc. for river regime and morphology studies which include assessments of the sedimentation filling periods of the proposed reservoirs.

12. Assessment of potential ice problems that could result from the proposed projects.

13. Assessment of probable maximum floods and construction diversion floods from hydrometeorological studies using the U.B.C. Watershed Budget and Flow Models.

14. Further geological and geotechnical investigation of reservoir bank stability for a shoreline assessment of the Lower Peace River and tributaries.

15. Preliminary assessment of transportation and transmission routes affected at the alternative reservoir full pool levels and relocation of facilities required.

16. Investigation, including an exploratory drilling program, of available and potential gravel resources in the Peace River area.

17. Assessment of mineral resources within the proposed reservoir areas.

1.2 SCOPE - (Cont'd)

18. Preliminary assessment of the geotechnical parameters of the foundation bedrock and studies to determine an economic method of obtaining foundation stability.

19. Preparation of preliminary layouts for the alternative projects including arrangements for diversion during construction.

20. Power studies of the capacity and energy potential of the alternative developments.

21. Coordination of B.C. Hydro studies with engineering studies being carried out by Montreal Engineering Company for the Province of Alberta of a possible hydroelectric development at the Dunvegan site downstream in Alberta.

22. Preparation of preliminary cost estimates and construction schedules.

23. Preparation of an engineering feasibility report.

1.3 PREVIOUS REPORTS

Reports on development of the Peace River in British Columbia prepared prior to this assignment are as follows:

1. "Report on Rocky Mountain Trench Area Hydroelectric Investigation, Stage I", September 1958, prepared by B.C. Engineering Co. Ltd. for the British Thomson-Houston Co. Ltd.

2. "Peace River Development, Sites A - E, Summary of Field Observations" by R. Eastman, 17 May 1967 (IPEC internal report).

1.3 PREVIOUS REPORTS - (Cont'd)

3. "Peace River Project - Portage Mountain Development - Energy and Power Studies", May 1967, prepared by IPEC for British Columbia Hydro and Power Authority.

4. "Peace River Project, Site 1-700 Mw Development, Investigation and Preliminary Design", October 1970, prepared by IPEC for British Columbia Hydro and Power Authority.

5. "Peace River Area - Power Development Studies Between Site 1 and Alberta Border", July 1972, prepared by IPEC for British Columbia Hydro and Power Authority.

1.4 REPORTS PREPARED DURING 1974, 1975 AND 1976

Reports on development of the Lower Peace River prepared during the course of the present studies and supplementing this feasibility report are as follows:

1. "Lower Peace River Shoreline Study", March 1974, prepared by Thurber Consultants for B.C. Hydro.

2. "Peace River Power Development Studies, Interim Report on Site E (1510) compared with Site C plus Site E (1355)", April 1975, by Hydroelectric Design Division of B.C. Hydro.

3. "Peace River Development, Site 1 to B.C./Alberta Border, Memorandum on Gravel Deposit Investigations - 1975", prepared by the Hydroelectric Design Division of B.C. Hydro.

4. "Sites C & E Reservoir Area, Notes on Mineral Potential", October 1975, prepared by the Hydroelectric Design Division of B.C. Hydro.

1.4 <u>REPORTS PREPARED DURING 1974, 1975 AND 1976</u> - (Cont'd)

5. "Sites C & E - Lower Peace River and Tributaries Shoreline Assessment", January 1976, prepared by Thurber Consultants for B.C. Hydro.

6. "Peace River Sites C & E - River Regime and Morphology", January 1976, prepared by the Hydroelectric Design Division of B.C. Hydro.

7. "Lower Peace River - Hudson Hope to B.C./Alberta Border, Preliminary Study of Transportation Routes Affected by Proposed Reservoirs", February 1976, prepared by the Hydroelectric Design Division of B.C. Hydro.

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SECTION 2.0 - PROJECT AREA

2.1 AREA DESCRIPTION, LOCATION AND ACCESS

The Peace River originates at the confluence of the Finlay River which flows south in the Rocky Mountain Trench, and the Parsnip River which flows north in the Trench. From this confluence, the Peace River flows eastward through the Rocky Mountains to Alberta. After entering Alberta, it follows a north-easterly course, eventually discharging into the Arctic Ocean via the Slave and MacKenzie Rivers.

The W.A.C. Bennett Dam is located at the head of the Peace River Canyon where the river flows out of the Rocky Mountains. The dam creates the Williston Lake reservoir which extends 70 miles up the Peace River to the former confluence of the Finlay and Parsnip rivers, and 80 miles north and 70 miles south of this point. The Site 1 development now under construction is located 14 miles downstream from the W.A.C. Bennett Dam at the lower end of the Peace River Canyon.

The reservoirs formed by the Sites C and E projects would cover a reach about 90 miles long from Site 1 almost to the Alberta border. In this reach, the river falls 260 feet from El. 1515 at the Site 1 tailwater to about El. 1255 at the border. Major tributaries joining the Peace in this area are the Halfway, Moberly, Pine, Beatton, Kiskatinaw and Alces rivers (Plate 2-1).

At Site C, the two alternative dam axes which have been studied are Axis C-3 located about 0.5 miles downstream from the confluence of the Moberly River and 38.5 miles upstream of the British Columbia/Alberta border, and Axis C-1 located 3 miles upstream of the Moberly River and 42 miles upstream of the border.

2.1 AREA DESCRIPTION, LOCATION AND ACCESS - (Cont'd)

At Site E, the two most favourable dam axes are Axis E-3 located about 0.8 miles upstream of the British Columbia/Alberta border and Axis E-6 located 2.0 miles upstream of the border.

Access to the region can be achieved either by an all-weather surfaced road via Highways 1 and 97 from Vancouver and Prince George or via Alberta Highways 43 and 2 from Edmonton (Plate 2-1). Highway 97 (the Alaska Highway) crosses the Peace River at Taylor 63 miles downstream of Site 1 and 27 miles upstream of the Alberta border; Highway 29 between Chetwynd and Hudson Hope crosses the river about 0.5 miles downstream of Site 1. An unsurfaced road leads north from Dawson Creek to a ferry on the river near Clayhurst, 2.5 miles upstream of the British Columbia/Alberta border.

The British Columbia Railway, which links Chetwynd, Dawson Creek and Fort St. John with the port of North Vancouver, crosses the Peace River 3.5 miles upstream of the Highway 97 road bridge at Taylor.

2.2 HYDROELECTRIC DEVELOPMENT OF THE PEACE RIVER

(a) Existing or Under Construction

(i) Portage Mountain Development

The Portage Mountain Development consists of the 600-foot high W.A.C. Bennett Dam, forming the Williston Lake reservoir, and the G.M. Shrum Generating Station. Williston Lake, with 34 million acre-feet of active storage between the maximum normal level El. 2205 and the minimum operating level El. 2100 provides substantial multi-year regulation for the Peace River.

The dam, located 18 miles upstream of Hudson Hope, is a zoned earthfill embankment with a crest level at El. 2230. The spillway and spillway sluices, together with the four low level outlets in the diversion tunnels, have sufficient capacity to discharge the regulated Probable Maximum Flood (PMF) of 363,000 cfs with Williston Lake at the maximum flood level of El. 2215.

The underground powerplant has been constructed to accommodate ten units; nine units have been installed at the present time (May 1976). The maximum continuous capacity of the powerplant at the ten-unit stage will be:

Units 1 to 5 (261 Mw each at reservoir levels above El. 2150)	1,305 Mw
Units 6 to 8 (275 Mw each at reservoir levels above El. 2170)	825 Mw
Units 9 & 10 (300 Mw each at reservoir levels above El. 2195)	600 Mw
Total	2,730 Mw

At reservoir levels above the elevations listed, the generator capacity limits the unit output, and at lower levels the turbine limits reduce the unit outputs.

(ii) Site 1 Development

The Site 1 Development, located 14 miles downstream of the W.A.C. Bennett Dam, is currently under construction with the first unit scheduled to be in service in September 1979. The project will consist of a 165-foot high concrete gravity dam containing power intake works, a four-unit powerplant, a six-bay gated overflow spillway in the river channel, and an earthfill dam across the saddle on the right bank. With the Site 1 reservoir at a maximum flood level of El. 1656, the spillway will have sufficient capacity to discharge the regulated Probable Maximum Flood (PMF) of 363,000 cfs from the W.A.C. Bennett Dam upstream.

With the normal reservoir level of El. 1650, full gate discharge of the four turbines will be 70,500 cfs, and the tailwater prior to encroachment by a reservoir for Site C will be at about El. 1515. Under a net head of 130 feet, each turbine will produce 240,000 hp and the four generators will each be capable of a maximum continuous output of 175 Mw, yielding a plant capacity of 700 Mw.

(b) Potential Future Development

(i) Development Entirely Within British Columbia

Two alternative developments confined entirely within British Columbia have been considered for the remaining 260-foot fall of the river upstream of the British Columbia/Alberta border:- development with a single high dam at Site E near the British Columbia/Alberta border, or alternatively two lower dams at Site C upstream of Taylor and Site E near the British Columbia/Alberta border. The comparative engineering and economic feasibility of these two alternative developments is the subject of this report.

Diversion of the McGregor River into the Peace River basin is presently under consideration. This diversion would increase power flows for both existing and potential downstream Peace River developments. At the Portage Mountain Development and at Site 1 there would be an increase of up to about 8000 cfs or 21 percent* in the average discharge in the river. At the potential downstream projects the increase in discharge would be proportionately less due to local inflow from tributary streams.

(ii) Joint Development with Alberta

Four alternative developments could be considered in conjunction with the Province of Alberta for the total 360-foot fall of the Peace River from Site 1 to a potential damsite at Dunvegan, about 80 miles downstream of the British Columbia/Alberta border. (Plate 2-2 shows schematic river profiles of these alternative developments.) These are as follows:

1. and 2. Development with a low dam at Dunvegan (gross head about 100 feet) would flood back to Site E and have only a very minor influence on any development within British Columbia. Either of the two options confined within British Columbia could then be developed independently of Alberta.

3. Development with an intermediate height dam at Dunvegan (gross head 178 feet) would flood back to Site C (Axis C-3). This would preclude

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* Fish water releases at McGregor might reduce this figure.

construction of a low Site E project, but would not significantly affect the proposed Site C project.

4. Development with a high dam at Dunvegan (gross head 370 feet) would flood back to Site 1 and eliminate construction of any further projects within British Columbia.

The low and intermediate height dams at Dunvegan as well as the low Site E dam are being investigated under the terms of reference of the joint British Columbia/Alberta studies. A high dam at Dunvegan is also being investigated by Alberta, but is outside the terms of the joint British Columbia/Alberta studies. All the above Dunvegan alternatives are the subject of the report being prepared by Montreal Engineering Co. for the Province of Alberta, scheduled for issue about mid 1976.

2.3 REGIONAL GEOLOGY

The proposed project sites and reservoir areas are located at the western edge of the Interior Plains. The region from Site 1 to the British Columbia/Alberta border is a relatively flat to slightly rolling plain (Alberta Plateau) in which the Peace River has carved a valley a few miles wide and 600 to 750 feet deep.

With valley erosion, the Peace River has cut through a thick sequence of glacial, glacial-fluvial and glacial-lacustrine deposits and into shales of the Shaftesbury Formation, which are of the Lower Cretaceous Period.

2.3 REGIONAL GEOLOGY - (Cont'd)

Bedrock of the underlying Gates Formation and the overlying Dunvegan Formation are the only other formations located in the project area, and these are only exposed respectively at the extreme upper end of the proposed reservoirs near Site 1 and the lower end near the British Columbia/Alberta border (Plate 2-3).

The Gates Formation consists of a series of sandstones, mudstones and thin coal layers.

The Shaftesbury Formation is a sequence of dark grey, flaky to fissile shales. Some sandy siltstone and fine grained sandstone occur in the upper part of the formation. The shales weather readily to clay. Gypsum crystals are commonly found in the shales but no coal has been reported. Analyses of samples from Sites C and E have revealed the presence of some montmorillonite in the shales.

The Dunvegan Formation is a succession of sandstone and interbedded shale which lies conformably on the Shaftesbury shales. The sandstones are fine to coarse-grained, commonly crossbedded, laminated and weather brown. The interbedded mudstones are carbonaceous in part, and contain some thin coal seams.

The valley slopes are continually undergoing adjustment, and landslides are common. Most of these slides are confined to overburden but some slides have been in the shales forming the valley slopes.

There are indications that several pre-glacial river channels, infilled with unconsolidated deposits, exist in the region.* The base of these channels is generally above present river level.

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* "Lower Peace River - Shoreline Study, March 1974" and "Sites C & E - Lower Peace River and Tributaries - Shoreline Assessment, January 1976", by Thurber Consultants.

2.4 SELECTION OF POTENTIAL DAM AXES

(a) Site C

Foundation investigations for development at Site C carried out by IPEC in 1971 were concentrated at Axis C-1 located about 3 miles upstream of the Moberly River.

Subsurface investigation of the axis determined that moderate depths of overburden and slide material covered bedrock on the left slope and under the river, and that deep overburden covered bedrock on the right abutment. Further geological reconnaissance of this axis indicated that the left slope was potentially unstable and that this unstable area extended high above the dam. Also the right bank is subject to considerable slumping.

As part of the investigations for this report, geological reconnaissance and seismic methods were used to select a Site C axis which would be geologically more favourable and, being further downstream, would tend to reduce interference with existing structures at Taylor by allowing a reduction of the operating level of the downstream Site E reservoir. Two potential alternatives to Axis C-1 were considered.

Axis C-2 is located immediately upstream of the Moberly River. At this axis, which would result in a longer dam crest length than Axis C-1, there is a considerable amount of slumped material on the right slope. Slopes on both sides of the Peace River could produce some large slides, both from in-situ material and slumped material. A buried channel of the Peace River exists less than 2 miles southwest of Axis C-2 joining the Peace River upstream with the valley of the Moberly River which enters the Peace River downstream of the axis.

Axis C-3 is located about 0.5 miles downstream of the Moberly River. At this axis, which would result in about the same dam crest length as Axis C-2, bedrock is exposed on the left bank up to the dam crest elevation, and only shallow overburden overlies bedrock under the river and on the right bank. The left bank has some potential for overburden slides above the dam; however, there are terraces on the slope which would limit the size of the largest possible slides and would provide protection from small slides. The right bank appears stable but is also protected by terraces from any slides originating above the crest of the proposed dam.

The principal geological factors considered to make Axis C-3 preferable to the alternative Axes C-1 and C-2 were:

1. Overburden is less on the abutments than for Axes C-1 and C-2.

2. The abutments at Axis C-3 appear stable, whereas the left abutment at Axis C-1 and both abutments at Axis C-2 are unstable.

3. Both abutments at Axis C-3 are protected by terraces from potential slides originating above the crest of the proposed dam.

These geological factors, together with the reduction of potential flooding and interference with existing structures at Taylor from the corresponding lower Site E reservoir, resulted in the selection of Axis C-3 for foundation investigations carried out at Site C during 1975.

Subsequently, as a result of studies made during 1975, other factors found to favour Axis C-3 over the previously studied Axis C-1 were:

2.4 SELECTION OF POTENTIAL DAM AXES - (Cont'd)

1. The greater width of the river channel would allow the location of a six-unit powerhouse and a 10-bay, 615,000 cfs spillway structure in the river channel without significant excavation into the abutments. The greater channel width and the existence of a favourably placed island in the river channel would also facilitate diversion of the river during construction (the spillway design flood has increased significantly since the 1972 studies.)

2. Location of the project axis downstream of the Moberly would provide slightly greater power flows at Site C and avoid the problem of deposition of significant quantities of gravel from the Moberly River in the tailrace channel.

Factors found to be less favourable at Axis C-3 than at Axis C-1 would be:

1. The greater width of the river valley at dam crest level would require substantially larger embankment wing dams.

2. Reservoir slope studies conducted by Thurber Consultants Ltd. indicate that the reservoir from a dam at Axis C-3 which would flood up the Moberly River, could cause some slides in the inundated banks of the Moberly River arm of the reservoir. Because of the possibility of slides just upstream of the dam, special precautions may be required to ensure that slide generated waves would not cause any damage to the dam or other structures.

The factors which make the downstream Axis C-3 more favourable for the development considerably outweigh those more favourable to the upstream Axis C-1. Accordingly, Axis C-3 downstream of the Moberly River was selected as the project site for this feasibility study.

(b) Site E

At Site E, foundation investigations carried out by IPEC in 1971 were concentrated at Axis E-3 located about 0.8 miles upstream of the British Columbia/Alberta border.

Subsurface investigations at this axis revealed considerable depths of overburden in the riverbed with a recorded depth of 153 feet in the centre of the river channel. The left abutment at Axis E-3 is an area of slumped material, the extent of which was not clearly defined by the 1971 drilling program.

On the right bank, talus deposits up to 30 feet thick were found at river level (El. 1250). Higher on the right bank, shale bedrock is exposed in a steep slope leading up to a terrace at approximately El. 1400 overlain by shallow overburden. The width of the terrace rapidly decreases immediately downstream of Axis E-3.

As part of the investigations for this report, geological mapping and seismic surveys were used to select an alternative axis having less overburden.

Three alternative axes upstream of Axis E-3 (Plate 3-3) were considered. Axes downstream were rejected as being in slide areas and as being too close to the British Columbia/Alberta border.

Axis E-4 is located about 0.4 miles upstream of Axis E-3. At this axis the left abutment was still found to be in an area of slumped material. Being close to Axis E-3, it was thought that there would not be any significant reduction in the depth of overburden in the river.

Axis E-5 is located above the confluence of the Alces River, about 2.5 miles upstream of Axis E-3. Although seismic survey indicated that shallower overburden might exist at this axis the considerably greater width of the river channel combined with the loss of head due to higher tailwater level eliminated Axis E-5 from further consideration.

Axis E-6 is located below the confluence of the Alces River, about 1.2 miles upstream of Axis E-3. The left abutment appears stable and is located between an area of colluvium about 35 feet thick upstream and an area of slide debris downstream. Weathered shale bedrock crops out at river level (El. 1255) for a few hundred feet on either side of the axis, and is overlain by resistant sandstone forming the base of the Dunvegan formation. The surface slope above this sandstone is only 12^{o} for a distance of 500 feet. This sloping terrace would provide protection from slides which may originate in the steep slopes above this terrace.

The right bank at Axis E-6 is similar to that at Axes E-3 and E-4 downstream. The terrace at El. 1400 which is wider at this point is underlain by about 12 feet of dirty gravel, 18 feet of sandstone (Dunvegan) and then shale (Shaftesbury). The sandstone is flaggy, except for the bottom few feet which is massive. The shale is weathered to a clay near the surface and is closely jointed. Vertical joints in the sandstone and shale strike parallel to the river. The bedding dips slightly into the slope. Ground water seepage was observed near the top of a gully at the shale-sandstone contact.

Axis E-6 was considered to be geologically superior to Axis E-4 as the left abutment does not consist of slide debris; consequently, drilling investigation of Axis E-6 was carried out during 1975. Some additional drilling was also done at Axis E-3 to confirm bedrock levels on the left bank and further investigate the presence of any clay seams in the shale on the right bank.

As a result of these site investigations and subsequent layout studies made during 1975, Axis E-6 was found to be more favourable than Axis E-3 for the following reasons:

1. The absence of slide debris or deep colluvium at Axis E-6 would provide better geological conditions in the left abutment.

2. Greater protection from potential slides originating from the steeper slopes above the damsite would be provided by the sloping terrace on the left bank.

3. Since the terrace on the right bank at Axis E-6 is wider, less excavation would be required to locate the powerplant and spillway on the right side of the river channel where bedrock is not excessively deep.

4. The upstream Axis E-6 would be well clear of the Ecological Reserve on the left bank in which Axis E-3 is partially located.

Factors found to be less favourable to Axis E-6 would be:

1. A reduction of about 2.5 feet in available head.

2. A longer dam crest length for the higher Site E (1510) dam which would require larger earthfill dams.

2.4 SELECTION OF POTENTIAL DAM AXES - (Cont'd)

The factors which make the upstream Axis E-6 more favourable outweigh those more favourable to Axis E-3 for all the dam crest elevations investigated. As a result Axis E-6 was selected as the project site for all the Site E developments in this feasibility study.

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SECTION 3.0 - GEOTECHNICAL INVESTIGATIONS AND GEOLOGY

3.1 GEOTECHNICAL INVESTIGATIONS

(a) General

Geotechnical investigations were previously carried out at various axes in the Sites C and E areas in 1971, and results of this work are provided in Appendix A.

From October to November 1973 and April to May 1974 seismic surveys were carried out to obtain profiles of the overburden/bedrock contact below the river. In May 1974, geological sections were prepared for two axes at Site C and two axes at Site E at a scale of 1 inch = 200 feet. From July 1975 to December 1975 exploratory drilling and geologic mapping were conducted at both Sites C and E. The results of this work are summarized below and detailed in Appendix A.

In 1973-74 and again in 1975-76, Thurber Consultants carried out reservoir bank stability studies.

(b) Site C Investigations

Seismic refraction surveys, totalling 9600 feet of traverse, were obtained on three lines across the river located at Axis C-1 (1971 axis), Axis C-2 just upstream of the Moberly River, and Axis C-3 (the selected axis).

Information from geologic investigations and from geologic mapping completed in 1975 was used to prepare a geological plan and section at a scale of 1 inch = 200 feet (Plates 3-1 and 3-2).

Seven boreholes were drilled on Axis C-3, totalling 1458 feet. Two boreholes were drilled on the left bank, one hole from a gravel bar near the left bank, two holes in the river from a barge and two holes on the right bank. Triconing and sampling methods were used in overburden drilling and NQ triple tube coring equipment was used to drill in bedrock. Core recovery in bedrock was excellent. Bedrock in all drill holes was water pressure tested using double mechanical packers and a test interval of 20 feet.

Core samples were selected from the various holes for laboratory testing. Laboratory tests included uniaxial compression, double shear, sliding friction and direct shear tests (Appendix A).

(c) Site E Investigations

Seismic refraction surveys, totalling 9000 feet of traverse, were obtained on four lines across the river located on Axis E-3 (1971 axis), Axis E-4 (0.4 miles upstream of E-3), Axis E-5 (2.5 miles upstream of E-3) and Axis E-6 (1.2 miles upstream of E-3). See inset key plan on Plate 3-3.

Information from geological mapping and investigations carried out during 1975, were used to prepare geological plans (Plates 3-3 and 3-5) and sections (Plates 3-4 and 3-6) at a scale of 1 inch = 200 feet respectively at Axis E-3 and Axis E-6.

Five boreholes totalling 1216 feet were drilled on Axis E-6 and three holes totalling 696 feet were drilled on Axis E-3.

Sampling, coring, water testing and laboratory tests as described above for Site C were carried out for Site E.

3.1 GEOTECHNICAL INVESTIGATIONS - (Cont'd)

(d) Reservoir Shoreline Investigations

A preliminary assessment of reservoir bank stability was made for B.C. Hydro and Power Authority in late 1973 by Thurber Consultants. Ref. "Lower Peace River - Shoreline Study, March 1974".

In 1975 and early 1976, more comprehensive studies of reservoir bank stability of the Peace River channel and the main tributaries were carried out by Thurber Consultants. Ref. "Sites C & E - Lower Peace River and Tributaries Shoreline Assessment, January 1976" and "Shoreline Assessment - Moberly River, B.C., April 1976".

In these studies the principal aspects considered were:

1. Existing and potential shoreline bank stability.

2. Preliminary assessment of safelines.

3. Effect upon the Taylor Petroleum Facilities.

Air photo interpretation, helicopter reconnaissance and geological mapping, combined with stability analyses were used to carry out this study.

The existing and potential reservoir shoreline slopes were classified; the former as to the potential types of ground movement which can occur, the latter as to the potential types of ground movement and the probability of that movement occurring.

Reservoir bank slope stability analyses were carried out for the alternative proposed reservoir levels using the Morgenstern Price, and the Bishop Methods. As no drilling, sampling or laboratory testing of the slope soils was carried out, assumptions were made and various conditions of topography, rock and soil strength, groundwater and failure mechanisms were considered to apply. Findings of these analyses included information on the potential of reactivating existing slide and slump material, activating first-time slides in silt, clay and till deposits, stable slope angles for circular-arc and block failures, and the influence of reservoir drawdown on stability of the banks.

A preliminary safeline was drawn along the perimeter of the proposed reservoirs. Safeline criteria were determined by considering geological and geotechnical aspects of the effects of the reservoir on the valley slopes. The criteria were based upon the potential reservoir shoreline stability classifications combined with the stability analyses.

To prevent dissruptions to the Taylor petroleum operations, with a reservoir normal operating level at El. 1510 for the Site E project, it would be necessary to relocate those facilities which would be affected. Assessment of facilities that could be affected and a cost estimate for their relocation was undertaken, together with an assessment of the maximum reservoir level which would have only minimal affect on these facilities.

3.2 DAMSITE GEOLOGY

(a) Site C Geology

(i) General

At Axis C-3 the Peace River has eroded a broad, flat bottomed valley approximately 750 feet deep. The valley is approximately 2 miles wide at the rim, with a river channel width of 1300 feet. Valley slopes are steep sided but are interrupted by a series of river cut terraces (Plate 3-1). On the left side, fluvial and glacial deposits cover bedrock above El. 1505. Below El. 1505, some slide debris and colluvium covers the slopes, although bedrock is generally exposed. On the right bank, a series of river cut shale terraces are mantled by a few feet of gravel and organic silt (Plate 3-2).

Bedrock at Site C consists of flat-lying Shaftesbury shale with interbeds of siltstone. The shale is black to dark grey, soft, weakly bonded and thinly laminated. The shale weathers strongly and has a tendency to exfoliate upon unloading, becoming friable when dried and soft when wetted. Silty shale and siltstone interbeds are less friable and have higher strength and hardness than the shale. Siltstone is generally poorly bedded to massive.

Clay seams commonly occur in shale parallel to laminations in the rock. These seams are generally about 1/4 inch thick but are up to 4 inches thick underlying the river channel and up to 2 feet thick in the left abutment. Clay in these seams is generally dark grey, moist, highly plastic and soft. These seams may represent shale which has reverted to clay by swelling or simply local non-consolidation of the original clay or mud material. No slickensides are seen on rock bounding the clay seams, which suggests that the seams do not result from shearing action.

3.2 DAMSITE GEOLOGY - (Cont'd)

(ii) River Channel - Axis C-3

In the river channel, up to 30 feet of fluvial sand and gravels with some cobbles and boulders overlie a weathered bedrock surface. Bedrock under the river channel is shale and siltstone which has been weathered to a depth of about 10 feet.

Permeability of the riverbed rock is less than 10^{-4} cm/sec.

(iii) Left Bank - Axis C-3

On the left bank of the river, there is an extensive terrace at El. 1900 which extends for 800 feet upstream and for 3000 feet downstream of the axis. Below El. 1900, the valley slopes average about 30^{o} and have much smaller terraces at El. 1650 and El. 1360. Below El. 1505, bedrock crops out continuously along the left bank for 1000 feet upstream and 2000 feet downstream of the axis, except where covered by colluvium or slide debris. The sequence of overburden on the left bank is well graded, well rounded gravel above El. 1860, silt and clay with discontinuous lenses of well rounded gravel to El. 1570, and sand, gravel, cobbles and boulders grading into uniform medium sand directly above bedrock at El. 1505.

Bedrock on the left bank is a sequence of interbedded shale and silty shale. Indications are that the surface rock is weathered up to 30 feet deep. Steeply dipping joints striking parallel to the river channel are common. These joints are the result of stress relief during valley formation.

Several small slumps and mudflows of overburden occur on the steep slopes above the El. 1650 terrace, and the gravel deposits overlying bedrock are subject to surface ravelling. Approximately 300 feet downstream from the axis, a slide has occurred in the surface shale and the overburden. Debris from this slide and colluvial material mantle the lower bedrock slopes near the axis.

(iv) Right Bank - Axis C-3

The right valley slope at Axis C-3 is a series of river cut shale terraces, overlain by a few feet of gravel and organic silt. Well defined terraces occur at El. 1650 upstream and at El. 1520 downstream of the axis. The valley slopes and terraces are forested and are not subject to surface ravelling except in the area from 500 feet downstream of the dam axis where many shallow slides have occurred in overburden and weathered shale.

(b) Site E Geology

(i) General

The Peace River valley at Site E is about 2 miles wide and up to 700 feet deep. Valley slopes are terraced and are covered with overburden, except on the steep sides of some terraces where sandstone crops out. The river flows along the right side of a flat, alluvium filled channel which is 1800 feet wide at Axis E-3, and 2200 feet wide at Axis E-6.

Bedrock at Site E consists of flat-lying Shaftesbury shales conformably overlain at approximately El. 1380 by sandstone and siltstones of the Dunvegan Formation. The Shaftesbury shale at this Site is similar to, though of lower strength than, the shale at Site C. The shale tends to exfoliate upon unloading and slakes when exposed to air or water. Clay seams in the shale are found in the abutments and under the river channel.

The Dunvegan Formation consists of sandstone, siltstone and shale. The sandstone is generally pale yellowish brown, medium to fine grained, hard, slightly calcareous and cross bedded. The surface of the sandstone is rusty where it is exposed to weathering.

Results of geological mapping and drilling are shown at Axis E-3 in Plates 3-3 and 3-4 and at Axis E-6 in Plates 3-5 and 3-6.

(ii) River Channel - Axis E-3

Material overlying shale bedrock in the river channel is well rounded, coarse sand, gravel, cobbles and boulders. The depth of this material varies from about 70 feet across most of the channel to 150 feet near the middle of the channel. Clay seams are most frequent and thickest near the top of the bedrock, but are still encountered more than 100 feet below the bedrock surface. Bedrock permeability could not be tested in the top 80 feet because of difficulties in sealing the packer. Below this depth the permeability is less than 10^{-4} cm/sec.

(iii) Left Bank - Axis E-3

There is a bedrock controlled terrace on the left bank at approximately El. 1500. Silt and clay up to 50 feet thick covers this terrace and forms a thin mantle over bedrock on the slope above the terrace. This slope is covered by bushes and grass and shows no sign of sliding except for some small mudflows. Two thick sandstone beds with siltstone interbeds crop out near the top of the steep slope below the terrace and only a few feet of silt overlie the shale below these outcrops down to El. 1325. Below this elevation the slopes are covered by talus and colluvial material overlying slide debris of rock and overburden up to 80 feet thick. This deposit of slide debris forms an irregular terrace like feature which extends along the base of the valley slope for 4000 feet upstream and for 1000 feet downstream from the axis. Water pressure testing of drill holes on the banks indicates that the permeability is near 10^{-3} cm/sec in the upper 100 feet of the rock and is less than 5 x 10^{-4} cm/sec at greater depths.

(iv) Right Bank - Axis E-3

There is a broad terrace on the right bank at Axis E-3 above El. 1400. The bedrock surface underlying this terrace is nearly horizontal at El. 1400 and is covered by clay and silt. At the edge of the terrace, the riverbank slopes steeply to the river and is covered by a few feet of colluvium.

Permeability testing indicated the bedrock has a permeability of about 5 x 10^{-4} cm/sec.

(v) River Channel - Axis E-6

In the river channel, there is gravel and sand with some cobbles and boulders. The maximum depth of this material, occurring at the centre of the river channel, is 150 feet.

3.2 DAMSITE GEOLOGY - (Cont'd)

Bedrock under the river channel is shale which has been weathered to a depth of about 10 feet. Clay seams in shale underlying the riverbed are predominately near the bedrock surface but were encountered to a depth of more than 100 feet. Water pressure testing indicates the bedrock permeability is near 10^{-4} cm/sec.

(vi) Left Bank - Axis E-6

Above El. 1400, there is an overburden covered, 500-foot wide terrace. Below the terrace there is a few feet of overburden covering the steep shale slope. At the base of this slope, weathered shale crops out for a few hundred feet on either side of the axis. Upstream of this outcrop, there is a deposit of colluvium about 35 feet thick and downstream of the outcrop there is an area of slide debris. Mapping and drilling indicate there are many steeply dipping joints striking parallel to the river in the left bank. Clay seams and zones of poorly bonded shale are common in the top 100 feet of bedrock. In the abutment drill hole, the packer could not be sealed for permeability tests taken in the top 120 feet of bedrock. Below this depth, permeabilities were generally near 10^{-4} cm/sec.

(vii) Right Bank - Axis E-6

The right bank above El. 1400 is a broad, gently sloping terrace. There is a steep bedrock slope covered with a few feet of colluvium below this terrace to the river. The bedrock surface underlying this terrace is nearly horizontal at El. 1400 and is overlain by silt and clay, with a cover of about 12 feet of dirty gravel. At the axis, about 18 feet of flaggy sandstone

3.2 DAMSITE GEOLOGY - (Cont'd)

(Dunvegan) overlies shale (Shaftesbury). Vertical joints in the sandstone and shale strike parallel to the river. Bedding dips slightly into the slope.

Drilling indicates that clay seams are prevalent in the upper part of the bank. Water pressure tests indicated the bedrock permeability was about 10^{-4} cm/sec.

3.3 RESERVOIR SHORELINE ASSESSMENT

Existing bank conditions along the proposed reservoir shorelines show evidence of much sloughing and sliding. There are about 200 identified landslides along the river banks between Site 1 and the British Columbia/Alberta border. Most of these are small and all but 1 percent involve overburden consisting of glacio-lacustrine deposits of silt and clay. Up to 75 percent of the valley banks are covered with sloughed material which, under reservoir operating conditions, could possibly be subject to further sloughing.

The banks of the Peace River and its tributaries would not be affected as much by the low Site E (1342) or (1352) plus Site C (1515) reservoirs than by the high Site E (1510) reservoir. Any reservoir development, as compared with existing conditions, would increase the activity of bank movement within the reservoir area.

Detailed studies of the Moberly River banks just upstream from Site C indicate that the Site C reservoir would flood shale and overlying deposits of undisturbed, free draining gravel. The reservoir would eliminate bank erosion by the river that now occurs. Such erosion at the toe of the slope has caused many slides along the Moberly River near its confluence with the Peace River. However, there is a possibility that loss of strength in some slope material due to the reservoir could

3.3 RESERVOIR SHORELINE ASSESSMENT - (Cont'd)

cause a relatively large volume of material to slide into the reservoir. This problem of slides and the possible effects in the reservoir would be studied prior to final design, and the projects designed so that slides along either the Peace River or its tributaries would not be a risk to the proposed developments.

If a high Site E (1510) dam were constructed, it would be necessary to relocate some transportation and industrial facilities due to the effect of the reservoir on slope stability, bearing capacity and ground water table. To avoid the extensive relocation of the compressor station of the Taylor Petroleum facilities, and minimize the effects on the other petroleum facilities, it would be necessary to keep the reservoir normal operating level at or below El. 1490.

3.4 GEOTECHNICAL FACTORS AFFECTING DESIGN

The geological setting of the Peace River valley at Sites C and E is essentially the same, and the geotechnical factors affecting design for both sites would be very similar. Where specific differences exist, these have been identified.

(a) Surface Rock Conditions

The Shaftesbury shales weather strongly as compared with the shales at Site 1 or Portage Mountain. The shale is considered to have some slaking properties (slaking is the tendency of rock to disintegrate upon wetting or drying when exposed), and has some tendency to exfoliate upon unloading, although more tests are required to confirm these properties.

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3.4 GEOTECHNICAL FACTORS AFFECTING DESIGN - (Cont'd)

Shale exposed during excavation is expected to be soft to medium hard, the hardness being dependent on the siltstone content. It is possible that some of the shale could be excavated by ripping. However, for cost estimating purposes in this study, it was assumed that excavation would have to be carried out by conventional blasting methods.

Exposed rock faces adjacent to completed structures, or faces exposed for some time within the construction area, would require treatment, such as shotcreting, to prevent sloughing or erosion by water.

(b) Resistance of Rocks to Shear and Sliding

An important geotechnical factor that was uncovered in exploration at both sites is the presence of clay seams within the shale. Based on a few laboratory tests, these seams have an angle of internal friction of about 10^{o}. However, drilling for the feasibility study was not extensive enough to establish the origin and continuity of the seams.

The seams may represent shale which has reverted to clay by swelling or simply local non-consolidation of the original clay or mud material. The seams may be discontinuous and the in situ strength of the shale (and resistance to sliding) may be higher than the laboratory test results indicate. Therefore, prior to any further design work being done, the rock formations at these sites would have to be carefully investigated to determine the character and extent of the clay seams.

(c) Permeability

Shale below the riverbed at both sites has a very low permeability whereas the abutment rocks (mainly shale at Site C and shale and sandstone at Site E) are cut by steeply dipping fractures, making the rock slightly more permeable.

Subject to further testing, it appears that remedial grouting and drainage would be required, together with a drainage scheme for the riverbed area beneath the concrete structures.

(d) Rock Slopes

The shales at Sites C and E are less well indurated than the Site 1 rocks as indicated by the respective unconfined compressive strengths. Compared to strengths of 5000 to 15,000 psi at Site 1, the shales at Site C have strengths of 1100 to 3900 psi and at Site E from 240 to 1900 psi. The sandstone at Site E was not tested, but it is a relatively competent rock and is expected to have strengths in excess of 5000 psi.

The strength and weathering characteristics of the shale at Sites C and E indicate that cut slopes in excavations would not stand vertically, but would have to be flattened to at least 1H:1V. Overburden slopes of 2H:1V have been assumed for project layouts.

(e) Earthquakes

From the Seismic Zoning Map of Canada (1970), Sites C and E and the proposed reservoir(s) fall into Zone 1, having peak ground acceleration values between 0.01 g and 0.03 g. From mapping of surface exposures throughout the region, there is no evidence to indicate any earthquakes have occurred for thousands of years.

3.4 GEOTECHNICAL FACTORS AFFECTING DESIGN - (Cont'd)

Although the likelihood of a damaging earthquake is considered negligible, earthquake accelerations of 0.10 g have been used to check the design of the proposed structures.

SECTION 4.0 - HYDRAULIC AND POWER STUDIES

4.1 FLOODS

(a) Introduction

A comprehensive report on the spillway design flood and diversion flood studies made for the Sites C and E projects is being prepared and will be issued as a separate report. This section provides a summary of the flood studies and presents the principal results used in the project feasibility studies.

Probable maximum floods were derived from hydrometeorological studies of storm rainfall, winter snow accumulation and sequences of critically high temperatures that would produce maximum rates of snowmelt.

These studies were applied to the Peace River basin upstream of Site E, including the McGregor River basin upstream of the proposed diversion site (Plate 4-1). The whole basin can be divided into two regions with different flood producing characteristics. The basin upstream of Bennett Dam is mostly west of the Rocky Mountains and major floods on that part of the basin are caused by rapid melting of large snowpacks. However, rainfall during snowmelt can increase flows considerably. East of the Rocky Mountains the snowpacks are smaller and melt earlier, but summer storms can produce extreme amounts of rain that are the major cause of flood peaks. Thus the timing of snowmelt and rain from these two regions is critical to the production of maximum flows at Sites C and E.

(b) Critical Meteorological Conditions for Maximum Flows

The critical meteorological conditions that could produce maximum flows at Sites C and E are a maximum snow accumulation during the winter, a cool spring, followed by a sequence of critically high temperatures and a heavy rainstorm over the basin downstream of Bennett Dam at the time of the peak outflow from Bennett Dam.

The maximum snow accumulation over the basin was estimated from frequency analyses of winter precipitation at several meteorological stations in the area. The upper 95 percent confidence limit of the 1000-year return period value was used to define maximum winter precipitation at each station.

Maximum temperature sequences of 10, 15, 20 and 30 days duration were estimated for periods ending on different dates, from May 15 to July 15. Maximum temperatures were taken as the 1000-year return period values at several stations.

Extreme rainfall amounts that fall on the tributaries between the W.A.C. Bennett Dam and Site E were studied by the Atmospheric Environment Service (AES) of Environment Canada.* From the analyses of storms and data from meteorological stations, the probable maximum rainfall amounts were estimated for separate storms on the Pine, Halfway, Beatton and Kiskatinaw River basins, and also for a storm over all three basins. There is a gradual increase in the probable maximum rainfall amounts as the season progresses because of the increasing amounts of precipitable water in the atmosphere. The highest probable maximum rainfall occurs at the end of July.

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* "Critical Meteorological Conditions for Maximum Flows on the Pine, Beatton and Halfway Rivers in British Columbia with an Estimate of Associated Conditions for the Peace River above the W.A.C. Bennett Dam", by D.M. Pollock and T.F. Gigliotti, Atmospheric Environment Service, Environment Canada, May 1975.

4.1 FLOODS - (Cont'd)

The AES also estimated the maximum rainfall on the basin upstream of the W.A.C. Bennett Dam associated with the probable maximum rainfall on the downstream basin.

It is important to note that the storms that produce maximum rainfall amounts on the west of the Rocky Mountains do not generally produce maximum rain on the east side, and vice versa. For this study, maximum rain on the east side of the Rocky Mountains is important, so that the associated rain on the west side would be less than the probable maximum rainfall for the basin upstream of the W.A.C. Bennett Dam.

(c) Spillway Design Flood

A mathematical model - the U.B.C. Watershed Budget Model - has been used to estimate the probable maximum flood inflows at Sites C and E. The whole basin upstream of Site E was divided into 13 sub-basins (as shown on Plate 4-1) and the U.B.C. Watershed Budget Model was calibrated for each sub-basin using meteorological and flow data for the period April 1963 to August 1964. This period includes the maximum flood of record on most of the gauged sub-basins. Data from several other shorter periods, which included high intensity rainfalls, were also used to check the simulation.

The U.B.C. Flow Model was used to combine the contributions from the sub-basins as a check on recorded flows at Hudson Hope.

For the simulation of the probable maximum floods, the maximized snowpacks on each sub-basin were subjected to the various sequences of maximum temperatures. Using the U.B.C. Flow Model, the inflows to Williston Lake, including the McGregor River diverted

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4.1 FLOODS - (Cont'd)

flows, were routed through Williston Lake storage according to the procedures laid down in the report of May 1973.* The routed outflows from W.A.C. Bennett Dam were combined with the flows from the downstream sub-basins to produce flows at Sites C and E.

Regulated outflows from the W.A.C. Bennett Dam were characterized by rapidly increasing flows from the beginning of the maximum temperature sequence to a peak flow of about 320,000 cfs that was maintained for 15 to 20 days. The outflow then dropped off rapidly. Because rainstorms on the sub-basins downstream of the W.A.C. Bennett Dam are higher later in the season, prolonged high outflows can significantly increase the combined flows at Sites C and E.

It was found that a critical temperature sequence from June 16 to 30 followed by the probable maximum precipitation on the Pine, Halfway, Beatton and Kiskatinaw basins in early July produce the highest flows at Sites C and E.

The probable maximum floods for Sites C and E, derived** from simulations using the U.B.C. Watershed Budget Model are summarized in the table below and the hydrographs shown on Plate 4-2. The floods include the diverted flows of the McGregor River.

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* "Portage Mountain Development, Proposed Procedures for the Regulation of Flood Flows", IPEC, May 1973.

** The spillway crest and reservoir normal operating levels presented in this report differ slightly from those used in the hydraulic simulations.

4.1 FLOODS - (Cont'd)

Spillway Design Floods (including McGregor Diversion)

Project	Normal Operating Level feet	Peak Inflow cfs	Peak Outflow cfs	Maximum Reservoir Level feet
Site C (1515)	1515	643,000	610,000	1520
Site E (1342)*	1342	937,000	900,000	1347
Site E (1352)*	1352	937,000	900,000	1357
Site E (1510)**	1510	952,000	860,000	1515

* Assuming operation of Site C (1515)

** Assuming no Site C (1515).

In routing these flows through Sites C and E reservoirs, it was assumed that the reservoirs were held at their normal operating levels as long as possible, and that increasing flows were passed by opening the spillway gates until the gates were fully open. When inflows exceeded the spillway capacity at the normal operating levels, the reservoir rose above these levels.

(d) Diversion Floods During Construction

Diversion floods at Sites C and E were estimated with and without the McGregor River Diversion. The construction diversion facilities would be designed for a flood with a 30-year return period. If they were used for 3 years, the probability that the design capacity of these facilities would be exceeded during the construction period would be about 10 percent. A diversion flood with a probability of about once in 30 years was selected for this feasibility study as studies for other projects have indicated this to be economic.

4.1 FLOODS - (Cont'd)

However, since flows on the Peace River at Sites C and E would be regulated by Williston Lake, it is not possible to derive meaningful relationships between the flood magnitude at Sites C and E and the probability of exceedance, or return period. Therefore, it was assumed that the diversion design floods at Site C and Site E would be equal to the combination of:

1. Flood flows from a rain event, with a return period of about 30 years, centered on the Lower Peace River basin.

2. A regulated outflow from the W.A.C. Bennett Dam during the period of peak rainfall runoff on the downstream basin of 50,000 cfs without the McGregor Diversion, or 70,000 cfs with the McGregor Diversion.

These assumptions would produce floods at Sites C and E suitable for the preliminary design of the diversion facilities, with return periods of the order of 30 years.

Peak flows for the proposed diversion design floods during construction are shown in the table below.

For comparison the floods regulated by Williston Lake that would have been recorded at Sites C and E during the 1964 flood of record at the W.A.C. Bennet Dam (during which downstream rainfall was low) are also shown in parenthesis.

For Site E (1342) and Site E (1352), it was assumed that the Site C (1515) project would be operating and would regulate flows slightly.

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4.1 FLOODS - (Cont'd)

Diversion Floods

Project	Peak Flow Without McGregor Diversion cfs		Peak Flow With McGregor Diversion cfs	
Site C (1515)	134,000	(100,000)	158,000	(145,000)
Site E (1342) Site E (1352)	220,000	(152,000)	246,000	(200,000)
Site E (1510)	244,000	(152,000)	264,000	(200,000)

These diversion floods have been derived assuming operating procedures for Williston Lake prepared in May 1973, and it is probable that they will be reviewed and revised before construction of Sites C and E. A change in these procedures could have a considerable effect on the flows at Sites C and E, and for this reason it is recommended that the design floods for the diversion facilities be reviewed as part of the preliminary design.

4.2 RIVER FLOW PROFILE AND RESERVOIR LEVEL STUDIES

(a) Introduction

Flow profiles along the 90-mile section of the Peace River from Site 1 to the British Columbia/Alberta border were computed for a range of discharges and reservoir water surface elevations. The purpose of these studies was to provide the hydraulic data required to select appropriate reservoir levels with consideration for the relocation of existing communities and facilities, and the effect of tailwater encroachment on upstream powerplants. Preliminary studies to assess the merit of channel improvement downstream of Site C were also conducted.

Backwater calculations were made with the aid of a computer program using field data from river cross-section surveys and simultaneous stage-discharge measurements obtained during the spring of 1975.

Appendix B presents a more detailed description of the field surveys and subsequent backwater computations.

(b) Results

With the stage-discharge data from these backwater computations, a preliminary assessment was made of the optimum reservoir normal operating and flood levels for each of the alternative developments.

For Site C, a reservoir normal operating level El. 1515 would result in a Site 1 tailwater level El. 1517.2 for the Site 1 effective* discharge of 50,000 cfs (including McGregor Diversion). On the basis of preliminary project costs and energy values, El. 1515 appeared to be the most economic Site C reservoir level and was selected for this feasibility study.

For the low Site E development, a reservoir normal operating level El. 1352 would result in a Site C tailwater level El. 1353.2 for the Site C effective discharge of 55,000 cfs (including McGregor Diversion). On the basis of preliminary project costs and energy values, El. 1352 would provide the most economic reservoir level and was selected as one alternate level for this study. However, the corresponding reservoir elevations at

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* The effective discharge is the "weighted average discharge" which would result in the same long term energy output with the given tailrace stage-discharge curve as the sum of all instantaneous discharges would give with that tailrace stage-discharge curve.

4.2 RIVER FLOW PROFILE AND RESERVOIR LEVEL STUDIES - (Cont'd)

the B.C. Railway Bridge and the Taylor Highway 97 bridge during passage of a flood with a 100-year return period (200,000 and 300,000 cfs approximately) would be about El. 1353. Thus, this reservoir level would probably require the raising of one end of the Taylor highway bridge and protection of the B.C. Railway alignment. A reservoir normal operating level 10 feet lower, at El. 1342, would result in a Site C tailwater level El. 1349.3 for the effective discharge. The reservoir would then be lower than the most economic level, but corresponding reservoir elevations at the B.C. Railway Bridge and the B.C. Highway Bridge for a flood with a 100-year return period would be El. 1347 and El. 1344, respectively. This reservoir level would eliminate most of the relocation work associated with the higher reservoir level and thus was also selected as an alternate level for the feasibility study.

For the high Site E development, a reservoir El. 1510 would result in a tailwater level at Site 1 at El. 1512.6 for the Site 1 effective discharge of 50,000 cfs (including McGregor Diversion). A reservoir normal operating level, El. 1510 was selected for the feasibility study to keep the reservoir below the lower terrace level at Taylor Flats for all discharges but those approaching the Probable Maximum Flood.

4.3 RIVER REGIME AND MORPHOLOGY

(a) General

The River Regime and Morphology Studies were carried out for the purpose of assessing the effects on the sediment and ice regimes of the main Peace River and tributary valleys between Site 1 and the British Columbia/Alberta border of the proposed Sites C and E reservoirs. These studies are described fully in the hydrology report "Peace River Sites C and E - River Regime and Morphology Studies", January 1976, by the Hydroelectric Design Division. A summary is given below.

4.3 RIVER REGIME AND MORPHOLOGY - (Cont'd)

(b) Sediment Regime

The main tributaries of the Peace River, the Halfway and Pine rivers, although they have relatively large basins, carry moderate suspended-loads and small bed-loads. The Moberly River by comparison carries a large gravel bed-load and a moderate suspended-load. The Beatton and Kiskatinaw rivers carry large suspended-loads and small bed-loads.

The Peace River is at present experiencing aggradation downstream from the mouths of its tributaries as a result of accelerated bed and bank erosion in the tributaries and because of large landslides into the main river channel. The channel capacity of the Peace River is being reduced by the encroachment of vegetation on gravel bars in the river.

The tributary bed degradation and bank erosion processes would be halted by the ponding of flows in the Sites C and E reservoirs. These processes may in fact be slowly terminating due to progressive aggradation of the bed of the Peace River and could come to a halt within a few years even if no reservoirs were developed.

The proposed reservoirs created by dams at Sites C and E on the Peace River would be reduced in volume by deposition of suspended-sediment and the build-up of deltas at the mouths of tributaries.

From field measurements made between May and August 1975 of suspended- and bed-materials, river slopes, cross-sections and discharges, and by application of standard methods for estimating suspended- and bed-loads, estimates of sediment yield and bed-load transport were made for both the Peace River and its five major tributaries. Separate estimates were computed for the field season and for the long-term mean conditions as defined by flow-duration curves.

From these calculations, estimates were made of the rates at which bed-load deltas would be built up at the heads of the tributary reservoir arms, of the rate at which the tributary reservoir arms and the main reservoirs would fill up with suspended-sediment, and the expected aggradation in the beds of the Peace River and its tributaries at the upstream ends of the proposed reservoirs.

Bed-load movement in the tributaries would create gravel deltas at the heads of the reservoir arms in each tributary. This phenomenon would create a problem only in the case of the possible obstruction of the tailrace for Site C (1515) by the build-up of a gravel delta by the Moberly River if the project were to be located upstream of the Moberly River, rather than at the proposed site just downstream of the Moberly.

Suspended-loads deposited in the reservoirs would have the effect of first filling the tributary arms and then gradually reducing the volume of the main reservoirs.

For the Site C (1515) reservoir, it is estimated that the 7-mile long Halfway River arm would be filled in less than 50 years and the 7-mile long Moberly River arm would require 300 to 400 years. The life of the main Site C (1515) reservoir is estimated to be over 700 years, based on a long-term sediment yield assessment obtained from the 1975 investigations.

4.3 <u>RIVER REGIME AND MORPHOLOGY</u> - (Cont'd)

For the Site E (1352) or Site E (1342) reservoirs, rates of sedimentation would be higher than for any of the other alternatives because of the heavy contributions from the Beatton and Kiskatinaw rivers and because of the small reservoir volume. It is estimated that the 2 1/2-mile long Pine River arm would fill in less than 1 year, the 10-mile long Beatton arm in 6 years and the 6-mile long Kiskatinaw arm in 14 years. The life of the main Site E (1352) reservoir is estimated at about 50 years, based on a long-term suspended-sediment yield assessment obtained from the 1975 investigations. However, reservoir storage is not required for regulation at Site E and the project can be designed to continue to operate after the reservoir has substantially filled by passing sediment through the dam, either through the turbines or special outlets.

For the Site E (1510) reservoir, it is estimated that the 7-mile long Moberly River arm would require over 300 years to fill, the 30-mile long Pine River arm over 200 years, the 29-mile Beatton River and the 10-mile long Kiskatinaw River arms each about 60 years. The entire high Site E reservoir could have a life of up to 1000 years, although allowance should be made for the possibility of higher long-term suspended-sediment yields than those obtained from the 1975 investigations.

Aggradation of the bed at the upstream ends of the reservoirs caused by the accumulation of deposited suspended- and bed-loads in the reservoirs could possibly be of concern at the head of the Beatton River arm of Site E (1510) reservoir where it may amount to as much as 14 feet after about 50 years. It might also be of concern at the head of the Site E (1352) reservoir, where an estimated 12 to 17 feet of bed aggradation would eventually occur. However, as most of the sediment would be brought in by tributaries in the lower part of the reservoir, it appears unlikely that this material would move into the upstream part of the reservoir. After filling the downstream portion of the reservoir, most of the sediment would be passed through the dam and the time scale for seriously raising the tailwater at Site C could extend to many centuries.

(c) Ice Regime

Observations of ice in the Peace River area made by B.C. Hydro during the past 3 years, have shown that the Peace River in the reach upstream from Site C is generally ice-free even in the coldest winters because of relatively warm outflows from Williston Lake through G.M. Shrum turbines, but tributaries are ice-covered. In the reach from Site C to Site E the Peace River is ice-covered in cold winters and bordered with shore ice with the main channel ice-free in mild winters. The process of ice formation usually starts with the generation of frazil ice during cold spells and the gradual accumulation, proceeding in an upstream direction, of frazil pancake formations. The ice sheet thus formed is fractured and irregular as a result of the daily fluctuations of outflow from the G.M. Shrum powerplant. Tributaries are ice-covered even in mild winters.

The Peace River is usually subject to a minor increase in stage on freeze-up because of the increased friction caused by the rough ice cover, but may occasionally experience high stages during the freeze-up period as a result of accumulations of frazil ice at shallow or narrow constrictions.

The ice regime in the Peace River and its tributaries during construction and after completion of the Sites C and E projects can be predicted from these observations of ice conditions in the Peace River under present conditions, and from information published about similar cascades of power stations and reservoirs in the United States and Northern Europe.

Although frazil ice is frequently generated in large quantities in the Peace River in the vicinity of Sites C and E projects during cold spells when the river channel is ice-free, it would be possible by proper hydraulic design of the diversion channels and structures, or by the use of ice booms, to avoid clogging of the channels and temporary openings by frazil ice accumulations during the diversion period.

After completion of Sites C and E dams, the reservoirs ponded behind the dams would probably be ice-free downstream from Sites 1 and C projects respectively for distances which would vary somewhat in extent depending on the prevailing air temperatures. The greater part of the two reservoirs would however, remain ice-covered throughout the winter, although the ice sheets would be fractured by the stresses induced by reservoir fluctuations, which would also produce localized flooding and freezing along the shores of the reservoirs.

Upstream from the power intakes at Sites C and E, there would be openings in the ice sheets caused by the increased velocity of flow, as is visible in Williston Lake every winter in the power intake area. The tributary arms of the Sites C and E reservoirs would also be ice-covered throughout the winter as happens with the present rivers.

4.4 FLOWS AVAILABLE FOR POWER

(a) General

Discharges that would be available for generation of power at Sites C and E are the combination of natural discharges at Portage Mountain (with or without McGregor diversion) which are subjected to regulation by Williston Lake, and local tributary inflow downstream of Portage Mountain.

4.4 FLOWS AVAILABLE FOR POWER - (Cont'd)

Discharges that have been used for power studies in this report are for the period 1928-1968.

(b) Natural Flows at Portage Mountain

Available data on the natural river flows at Portage Mountain are based on flows previously estimated for the Peace River at Portage Mountain* for the period 1912-1965. These data were based on recorded flows at Hudson Hope for the periods from 1917 to 1922 and from 1949 to 1965. The records were extended to cover the missing periods by correlations with the Peace River near Taylor, the Skeena River at Usk, the Peace River at Peace River and the Fraser River at Hope. Net inflows to Williston Lake were calculated by adjusting for reservoir evaporation, seepage through the dam and for the difference in drainage area between the Hudson Hope gauge and the damsite. The above correlations were made on an annual basis. Flows were distributed by months in the same pattern as the flows at the gauging station upon which the correlation was based.

For the following period, 1965 to 1968, net inflows at Portage Mountain for 1965 to 1967 were calculated from the observed flows at Hudson Hope. After closure of W.A.C. Bennett Dam in December 1967, the net inflows were calculated from the reservoir level changes and the outflows through the turbines and the low level outlets (no significant spilling occurred until 1972).

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* IPEC "Peace River Project - Portage Mountain Development, Energy and Power Studies", May 1967.

4.4 FLOWS AVAILABLE FOR POWER - (Cont'd)

The average flows at Portage Mountain for the 40-year period, 1928 to 1968, are 36,400 cfs which is 3 to 4 percent higher than for the 30-year period 1928 to 1958 used in earlier studies of development of the Lower Peace River.

(c) Flows from McGregor Diversion

Flows from the McGregor River, proposed for diversion into the Peace River basin, have been derived from a gauge which has been in service at the McGregor diversion damsite since 1960. Records were extended by monthly correlations with the gauges McGregor River at Upper Canyon, Fraser River at Shelley, Cariboo River below Kangaroo Creek and a hypothetical station produced by subtracting the Thompson flows from the Fraser flow at Hope.

From these extended records, the 40-year (1928-68) average flow was 8000 cfs. For these studies, the flow diverted into the Peace River basin has been assumed to be the full flow, less seepage losses through the McGregor dam. However, any fish release requirements would reduce this average flow.

(d) Local Inflow Between Portage Mountain and Site C

Estimates of the local inflow were made using a mathematical model (the U.B.C. Watershed Budget Model) that simulates the runoff processes in a basin based on the available meteorological and streamflow data in the area.*

For Site C (proposed Axis C-3 downstream of the Moberly River) these local inflows were the sum of the simulated flows for the Halfway River and the ungauged areas which include the Moberly

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* Peace River Area - Flow Studies, Recorded and Estimated Monthly Flows, 1928-72, Hydroelectric Design Division, March 1976.

4.4 FLOWS AVAILABLE FOR POWER - (Cont'd)

River whose flows were simulated using parameter values from the Pine River basin. From June 1962, recorded flows on the Halfway were substituted for the simulated flows.

For this area between Portage Mountain and Site C, the 40-year (1928-68) average inflow was 4700 cfs.

(e) Local Inflow Between Site C and Site E

Estimates of the local inflow again were made using the U.B.C. Watershed Budget Model. Local inflows were mostly simulated except when recorded flows were available on the Pine, Beatton and Kiskatinaw rivers generally from 1961 onwards. The 40-year (1928-68) average inflow was 9900 cfs.

(f) Summary

The average flows for the period July 1928 to June 1968 at the proposed sites estimated as described above and used in power studies for the Site C and Site E projects are summarized below. Also listed in parentheses are comparable flows obtained using the U.B.C. Watershed Budget Model to simulate all flows including Portage Mountain and McGregor diversion flows. Derivation of these flows is documented fully in the report "Peace River Area - Flow Studies, Recorded and Estimated Monthly Flows 1928-72", Hydroelectric Design Division, March 1976. These flows have not been used for the present studies as they are still under review.

	Without McGregor Diversion (cfs)	With McGregor Diversion (cfs)
At Portage Mountain	36,400 (35,900)	44,300 (44,200)
At Site C	41,100 (40,200)	49,000 (48,500)
At Site E	51,000 (49,900)	58,900 (58,200)

4.5 GENERATING CAPACITIES

As the reservoir operation proposed for any of the developments would provide little regulation of flows, the generating capacities of the projects were selected to give capacity factors similar to those of the G.M. Shrum Generating Station and the Site 1 powerplant upstream. The plants would, thus, be in approximate hydraulic balance. The selected generating capacities yielded the following capacity factors based on the maximum generating capacity and the plant average energy produced at each site:

	Peace Flows Only			Peace plus McGregor Flows	
	Maximum Capacity	Plant Average Energy	Capacity Factor	Plant Average Energy	Capacity Factor
	MW	av MW	%	av MW	%
G.M. Shrum G.S.	2,730	1,465	54	1,700	62
Site 1	700	374	53	441	63
Site C (1515)	975	525	54	615	63
Site E (1352)	675	366	54	412	61
Site E (1342)	600	327	55	368	61
Site E (1510)	1,800	978	54	1,111	62

4.6 POWER STUDIES

Power studies were conducted to determine the energy generation and capacity attributable to each of the alternative developments. These were determined by considering the total output from the plants which are expected to comprise the B.C. Hydro Integrated System at the date the first of the Lower Peace River projects would be brought into service (October 1983). The attributable energy and capacity would be the difference between the output from the system with and without the projects.

The power studies were conducted using the computer program SHRUMO with run-of-river operation for each of the projects, as earlier studies for the 1972 report had indicated that any drawdown of the reservoirs would result in a net loss of energy. The studies were based on the sequence of historical and correlated streamflows for the period from 1928-1968.

Since required power flow releases to the Peace river from the W.A.C. Bennett dam are highly dependent on the generation from the Columbia River plants, it was assumed that the Columbia River flow releases would be made in accordance with the latest (1980/81) Columbia River Treaty, Assured Operating Plan discharges.

As the diversion of the McGregor River to the Peace basin would significantly increase the energy from projects on the Peace River, the studies were made both with and without the McGregor diversion. The 40-year average flow diverted to the Peace River basin was assumed to be 7870 cfs, 130 cfs less than the average flow at the damsite. The 130 cfs was considered to be the maximum seepage losses that could occur at the dam on the McGregor River.

For each powerplant, the maximum plant capacity, attributable capacity, attributable firm energy, plant average energy and attributable average energy would be as follows:

4.6 POWER STUDIES - (Cont'd)

Without McGregor diversion:

	Maximum Plant Capacity MW	Attributable Plant Capacity MW	Attributable Firm Energy av MW	Plant Average Energy av MW	Attributable Average Energy av MW
Site C (1515)	975	965	500	525	508
Site E (1352)	675	665	335	366	356
Site C (1515) plus Site E (1352)	1650	1630	835	891	864
Site E (1342)	600	597	308 2700 GW.h	327 2865 GW.h	323 2829 GW.h
Site C (1515) plus Site E (1342)	1575	1562	808	852	831
Site E (1510)	1800	1790	910	978	970

With McGregor diversion:

	Maximum Plant Capacity MW	Attributable Plant Capacity MW	Attributable Firm Energy av MW	Plant Average Energy av MW	Attributable Average Energy av MW
Site C (1515)	975	965	574	615	599
Site E (1352)	675	665	374	412	393
Site C (1515) plus Site E (1352)	1650	1630	948	1027	992
Site E (1342)	600	597	348	368	359
Site C (1515) plus Site E (1342)	1575	1562	922	983	958
Site E (1510)	1800	1790	1032	1111	1088

It can be seen that the attributable capacity of the projects is always less than the installed capacity. This is due to the reduction in capacity at the respective upstream plant as a result of increased tailwater levels imposed by the project reservoir.

4.6 POWER STUDIES - (Cont'd)

Similarly the attributable average energy is less than the plant average energy, due primarily to reduced generation at the upstream powerplant as a result of backwater encroachment from the project reservoir, and also to variations in the output of G.M. Shrum and Site 1 powerplants due to changes in the drawdown pattern of Williston Lake.

4.7 NITROGEN SUPERSATURATION

In general during spillway releases, deep submergence of the water jet in a downstream plunge pool or stilling basin causes entrained air to be forced into solution. The greater the depth of submergence, the larger the amount of gas forced in solution and the higher the resulting percentage supersaturation relative to surface conditions. In their normal respiratory process, fish extract dissolved gases from the water. If the water contains supersaturated gases, the gases tend to come out of solution forming small gas bubbles in the blood stream or body tissue causing injury or death.

The spillways of both the proposed Site C and Site E projects will require deep stilling basins to effectively dissipate the energy of the spillway discharge and prevent extensive scouring of the downstream river channel during large spillway discharges. Without remedial measures the spillway discharge would be subjected to a high degree of submergence and high supersaturation levels would probably result.

The U.S. Corps of Engineers have developed a spillway deflector, located on the downstream spillway face, to direct low to moderate spillway flows along the surface of the water in the stilling basin. Deflectors have been installed at two hydroelectric projects on the lower Columbia River with encouraging results. Prototype tests have shown a substantial decrease in supersaturation levels with spillway deflectors installed.

4.7 NITROGEN SUPERSATURATION - (Cont'd)

To date spillway deflectors have been employed only on hydroelectric projects where the difference between forebay and tailrace water levels is less than 100 feet. Although the deflectors should also be effective on spillways with higher heads, the resulting higher flow velocities on the spillway face would subject the deflector to possible severe cavitation damage. For the low Site E scheme with a gross head of approximately 90 feet and the Site C scheme with a gross head of approximately 160 feet, the use of deflectors on the spillway face should effectively abate gas supersaturation for low and moderate spillway discharges. During infrequent high flood years (return periods in excess of 50 to 100 years) the spillway flow would override the deflector and plunge to the bottom of the stilling basin, resulting in high supersaturation levels. For the alternative higher Site E (1510) development, however, because of the high head (approximately 260 feet) it is doubtful that a suitable deflector design could be developed to withstand the high velocity flows and still effectively prevent gas supersaturation.

It is estimated that, over the long-term, spillway discharge at both Sites C and E should only account for up to a maximum of 5 percent of the total discharge (with McGregor diversion). Most of this spill would occur during a few years of very high tributary runoff and be concentrated in the period June to August. Very occasionally, spill could occur earlier in the year due to prespill requirements at Williston Lake. The provision of spillway deflectors would be investigated more thoroughly for the low dam developments during preliminary and final design.

SECTION 5.0 - SITE C (1515) DEVELOPMENT

5.1 SITE DESCRIPTION

The proposed project site is about 0.5 miles downstream of the confluence of the Moberly and Peace Rivers, 38.5 miles upstream of the British Columbia/Alberta border, and 11 miles upstream of Taylor.

At the selected Axis C-3, the present river channel is about 1300 feet wide. The left bank rises steeply to about El. 1600 and consists of shale bedrock overlain by sand and gravel. These deposits are in turn overlain by glacio-lacustrine deposits of silt and clay which rise gradually to about El. 1900. The right bank rises more gradually in a series of river cut shale terraces mantled by a few feet of gravel and organic silt. In the river channel, bedrock consists of flat lying shale with interbeds of siltstone and is overlain by 30 to 50 feet of granular alluvium.

Clay seams commonly occur in the shale between laminations in the bedrock and range between 1/4 inch and 4 inches thick under the river channel and up to 2 feet thick high in the left abutment. The presence of these seams, which present major problems in ensuring the stability of the concrete dam structures, has been taken into account in the design of the project.

More complete details of site geology are given in Section 3 and in Appendix A.

5.2 FACTORS AFFECTING SELECTION OF THE PROJECT ARRANGEMENT

The moderate to poor shale bedrock found at Site C imposes certain restrictions on the project arrangements that can be considered at this location. An earthfill type dam across the river would minimize foundation stresses and stability problems, however, the relatively poor

5.2 FACTORS AFFECTING SELECTION OF THE PROJECT ARRANGEMENT - (Cont'd)

rock in the abutment, the presence of some thick clay seams, and the steepness and loose nature of the overlying glacial deposits would make uneconomic the construction of diversion and power conduits through the abutment. Alternatively, the conduits could be located through the base of the dam within the river channel. Such an arrangement was not selected at this stage because of the high cost of the diversion facilities.

Weathering of the bedrock is less extensive under the existing river channel and, as excavation of overburden would also be minimized, it would be advantageous to locate as much as possible of the main concrete structures in the river channel provided adequate foundation conditions for these structures can be assured. Selection of earthfill wing dams would provide the optimum arrangement for the remaining sections of the dam as it would minimize excavation of overburden and provide the most satisfactory contact with the shale in the abutments.

An important geotechnical factor affecting the design and feasibility of the project is the presence of clay seams in the foundation bedrock. Although the existence of clay seams was recognized during the 1971-72 studies, their extent was not fully evaluated. At Site C, clayey material was encountered only at or above the foundation level of the concrete gravity structures and it was assumed that excavation for these structures would extend below the clay seams. The most significant factor affecting the design of the structures considered at that time was the need for immediate protection of the exposed rock surfaces against rapid exfoliation.

The 1975 exploration program suggested the extent of the clay seams to be much greater than identified during the 1971-72 explorations. The relatively low values of cohesion and sliding friction of the shale foundations and the presence of clay seams would make it necessary to key the concrete structures relatively deeply into the bedrock. Bedrock anchors were considered for this purpose, but clay seams would make the feasibility of placing anchors that could develop sufficient resistance to movement questionable, and resulted in the proposal of keys formed out of rolled concrete. Rolled concrete was chosen because of its lower cost relative to normally placed concrete. With this arrangment, the capacity of the bedrock to resist the horizontal loading as transmitted by the key depends on the cohesion and friction coefficient of the rock along any potential failure plane. To allow for the possibility of complete deterioration of the rock downstream of the key, the sliding stability was also analysed assuming that the rock downstream of the key is equivalent to a passive wedge of well-compacted rock fill.

Consideration was given to providing a powerplant with four 244 MW units. The mechanical, electrical and powerhouse costs with such units would be less than with six 162.5 MW units. However, the large 244 MW units would prevent close coupling of the intakes and powerhouse, as they would not allow the penstock to be located in the middle of each concrete block to eliminate undesirable differential bearing pressures unless a horizontal offset were provided between the intake and the powerhouse. Also as the units would also be very large (slightly larger than Site 1 units) and transportation problems are envisaged, six smaller 162.5 MW units were selected for this feasibility study.

5.3 SELECTED ARRANGEMENT

The feasibility study arrangement selected for the Site C (1515) project, shown in Plates 5-1 and 5-2, consists of a concrete gravity dam containing power intakes and powerhouse combined in an integral structure on the right side of the river channel, an eight-bay gated overflow spillway located in the middle of the river channel, and earthfill wing dams on both abutments. The dam would have an overall crest length of about 3900 feet, a crest level at El. 1535, and a maximum height of about 235 feet above unweathered bedrock in the foundation.

The power intakes and powerhouse would be constructed as an integral structure to act as a single unit against sliding, and a six-unit powerhouse selected to minimize the stresses developed in the powerhouse as a result of this combined arrangement. The upstream end of the penstock would be located on the centreline of each concrete block to maintain an almost symmetrical bearing stress distribution about the centreline of each block. A key constructed out of rolled concrete would be provided to assist in transmitting horizontal forces from the intake-powerhouse structure into the bedrock.

The overflow spillway controlled by eight 50-foot wide by 50-foot high radial gates would discharge into a 245-foot long stilling basin. The spillway would have a capacity of 615,000 cfs with the reservoir at El. 1520, the maximum flood level. A rolled concrete key to increase the sliding stability of the spillway structure would also provide additional weight to resist the uplift forces on the stilling basin floor.

The spillway would be provided with six 19-foot wide by 36-foot high sluices capable of passing a diversion design flood of 158,000 cfs during construction of the earthfill dams.

Earthfill wing dams would be constructed on each abutment and would wrap around transition concrete gravity sections adjacent to the spillway structure on the left abutment, and the intake-powerhouse structure on the right abutment. The earthfill dams would have shells of granular fill and would be founded on the granular alluvium in the riverbed and on the shales which form the abutments. The impervious central core would extend down to sound bedrock through a trench excavated in the alluvial material in the riverbed and banks.

The six power intakes contained in the intake-powerhouse structure would each be controlled by 19-foot wide by 31-foot high

5.3 SELECTED ARRANGEMENT - (Cont'd)

vertical lift gates designed to close under full flow conditions. Two bulkhead type service gates, interchangeable between the six units and operable only under balanced head conditions, would be provided. Each intake would be connected to a turbine by a 26-foot diameter penstock, steel-lined in the lower portion. The six-unit powerhouse would accommodate Francis turbines each with an output of 222,000 horsepower at a net head of 165 feet. The generators would each be capable of a continuous output of 162.5 MW providing a full plant capacity of 975 MW.

5.4 RESERVOIR AND RELOCATIONS

The surface area of the reservoir for the Site C (1515) project (axis downstream of the Moberly River) at the proposed normal operating level El. 1515 would be about 24,000 acres. The land area flooded (excluding the river channel area) would be 11,500 acres.

The inundated area would consist largely of unimproved valley slopes, but would include some valley bottom land. Much of this bottom land has been developed for agriculture and about 1,000 acres of cultivated land would be flooded by the reservoir. The principal developed agricultural areas that would be affected by the proposed reservoir are near Attachie (mouth of Halfway River) and the lower parts of Bear Flats.

Apart from some residential and agricultural properties at Farrell Creek, Attachie, Lynx Creek and Bear Flats which would be inundated, the only significant development that would be affected would be Highway 29 from Hudson Hope to Fort St. John, and associated river crossing structures. The reservoir would inundate parts of the highway and may effect other parts by initiating local sloughing or slides. Three alternative proposals have been considered for relocation of this highway, ranging from complete relocation onto the high plateau to the minimum relocation required to maintain the existing highway standards. Details of these alternatives are presented in Preliminary Report "Peace River Sites C and E, Relocation of Major Transportation and Transmission

5.4 RESERVOIR AND RELOCATIONS - (Cont'd)

Facilities", April 1976 by B.C. Hydro-Hydroelectric Design Division. The minimum highway relocation would require construction of 10 miles of new highway plus bridges and associated approaches over Lynx Creek, Farrel Creek, the Halfway River and Cache Creek.

At present, the banks of the Peace River and the Halfway and Moberly tributaries show signs of sloughing and sliding in a number of areas. Impounding the Site C reservoir could precipitate or reactivate some potential slides, earlier than they might otherwise have occurred. Although the reservoir would be impounded at a higher level than under natural flood flows in the river, the erosive effect of flowing water along the banks would be removed and in some areas this might decrease bank sloughing. The areas most likely to involve large slides would be along the Peace River on the left bank 2 to 5 miles downstream of Attachie, and downstream of Bear Creek on both banks 11 to 2 miles above the proposed dam axis, and along the Moberly River on both banks 5 to 2 miles above the dam axis. The Site C (1515) project would incorporate measures to avoid any significant risk of damage from slide-generated waves both to the structures or to downstream development.

Details concerning the stability of the reservoir banks are presented in the reports, "Sites C and E, Lower Peace River and Tributaries - Shoreline Assessment" January 1976, and "Shoreline Assessment - Moberly River, B.C.", April 1976, by Thurber Consultants Ltd.

5.5 CONSTRUCTION SCHEDULE

The construction schedule for development of the Site C (1515) project is given on Plate 5-3. A total of 5 3/4 years would be required from issue of the first tender to the in-service date of the first two units. It is assumed that preliminary design and further site investigations and testing would be undertaken in Year A and B and final design in the 6 months prior to issue of the first tender at the start of Year 1.

In constructing the project, the river would first be diverted to the left half of the channel until the lower portion of the spillway and powerplant were completed. It would then be diverted through temporary openings in the spillway until all the structures were essentially completed. The schedule does not include any unusual construction procedures and assumes that there would be a shutdown of concreting and placement of fill during the coldest winter months. It is based on having a separate civil contract for excavation to enlarge the existing river channel for diversion, and for construction of the first stage cofferdam to permit an early construction start.

For construction materials, it has been assumed that suitable materials for the earthfill dams would be obtained close to the proposed structure and to a large extent from the riverbed and excavations for the structures. For the concrete structures, granular materials would be obtained from the riverbed or local river terraces.

5.6 COSTS

The estimate of total capital cost for the Site C (1515) development is $544 million. A breakdown of these costs is given in Table 8-1. Costs are based on mid-1975 price levels. Contingency allowances are as follows: 7 1/2 percent of equipment costs, and 20 percent of all other direct cost items. Engineering, investigations and supervision costs were estimated at 9 percent of the direct costs plus contingencies. Corporate overheads were estimated at 40 percent of Engineering costs. Interest during construction was computed at 10 percent compounded annually. Transmission and escalation costs are not included.

Capital expenditures by fiscal years are shown in Table 8-2.

SECTION 6.0 - SITE E (1342) OR (1352) DEVELOPMENTS

6.1 SITE DESCRIPTION

The proposed project site is located at an axis about 2.0 miles upstream of the British Columbia/Alberta border and 0.5 miles downstream of the Clayhurst Ferry crossing.

At the selected Axis E-6, the present river channel is about 2200 feet wide. An extensive island gravel bar occupies the left half of the river channel. The left bank rises moderately steeply to about El. 1400 and consists of weathered shale and siltstone bedrock overlain by resistant sandstone at the base of the Dunvegan formation. Above El. 1400 the surface slope rises only gradually for a distance of 500 feet. On the right bank shale up to El. 1360, overlain by a thin mantle of sandstone, is exposed in a steep slope leading up to a broad nearly flat terrace at El. 1400. Bedrock is overlain by shallow overburden which allows the terrace to be cultivated. In the river channel deposits of granular alluvium up to a maximum depth of 150 feet near the centre of the channel overlie shale or siltstone bedrock. Towards the right bank the alluvium shallows over a ledge of bedrock which extends out from the right bank.

Clay seams occur in the shale under the river bed and in both abutments. On the right bank clay seams were not observed below a few thick seams recorded within a band of poorly bonded shale which lies between about El. 1170 and El. 1205. However, for this feasibility study, clay seams which present major problems in ensuring the stability of the concrete dam structures have been assumed to exist throughout the foundation area.

More complete details of site geology are given in Section 3 and in Appendix A.

6.2 FACTORS AFFECTING SELECTION OF THE PROJECT ARRANGEMENT

The poor bedrock and the relatively great depth of granular overburden under much of the riverbed impose severe restrictions on project arrangements that could otherwise be considered feasible at this location. An earthfill type dam founded on the alluvium would be most economic in the left and centre of the river channel where up to 150 feet of overburden exists above bedrock.

Concrete structures would be economically feasible only on the higher bedrock ledge in the river channel close to the right bank. However, the width of this bedrock ledge would be insufficient to accommodate both the large spillway and powerhouse structures positioned across the river channel. Substantial excavation into the right bank terrace for powerplant forebay and tailrace channels would be necessary to position the powerhouse adjacent to the spillway which would itself be located within the existing river channel. Alternatively both structures could be positioned along the river bank essentially parallel to the river channel with a combined forebay and spillway channel excavated through the right bank terrace (as adopted in the 1972 Feasibility Study Selected Arrangement.)

As at Site C the presence of clay seams in the foundation is a most important geotechnical factor affecting the design and feasibility of the project. Clay seams were not observed during the 1971-72 studies on the right bank where the main concrete control structures were located, though they were found elsewhere at Axis E-3.

The 1975 exploration program suggested that the extent of the clay seams was much greater than identified during 1971-72 explorations and that seams were also present on the right bank of the river. Despite the low head of this project, the relatively low values of cohesion and sliding friction of the shale foundation, and the presence of clay seams, would make it necessary to key the concrete structures into the bedrock. As at Site C, bedrock anchors could achieve this purpose, but the unknown vertical extent of the clay seams would make

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the feasibility of placing anchors that could develop sufficient resistance to movement questionable. Keys formed out of rolled concrete have been selected as a better alternative.

As with the Site C arrangement, the capacity of the bedrock to resist the horizontal loading as transmitted by the key depends on the cohesion and friction coefficient of the rock along any potential failure plane. To allow for the possibility of complete deterioration of the rock downstream of the key, the sliding stability was also analysed assuming that the rock downstream of the key is equivalent to a passive wedge of well-compacted rock fill. In order to provide adequate safety against sliding, the bedrock surface elevation should not decrease immediately downstream of the key. This ruled out arrangements with the concrete control structures essentially parallel to the river.

Provision of a feasible diversion arrangement for the river during construction posed a major design problem for the Site E (1342) project. In the selected arrangement for the 1972 Feasibility Study, a spillway-powerhouse forebay channel separate from the main river channel was utilized for diversion. However, with the main control structures relocated across the main river channel, this separate excavated channel would not ultimately be utilized for the powerhouse forebay and spillway channel, and would be very uneconomic if utilized only for diversion purposes.

Consideration was given to passing diversion floods through the deep right centre section of the river. This location would provide ample hydraulic capacity and result in low flow velocities, but would require very deep cellular and rockfill cofferdams and would provide considerable seepage potential under the cofferdams. The proposed location of the diversion channel on the extreme left of the river channel would utilize the existing island in the river to provide a much longer seepage path under the cofferdams. This arrangement would result

6.2 <u>FACTORS AFFECTING SELECTION OF THE PROJECT ARRANGEMENT</u> - (Cont'd)

in a relatively confined diversion channel with a high bed level. The resulting potentially low hydraulic capacity could result in some scouring of the bed-material in the diversion channel. Some pre-excavation for this channel would be required.

6.3 SELECTED ARRANGEMENT

The arrangement selected for the Site E (1342) project is shown in Plates 6-1 and 6-2. The selected arrangement for Site E (1352) would be substantially the same with all crest elevations raised 10 feet.

The project would consist of an 1850-foot long earthfill dam extending from the left abutment across the major part of the existing river channel, a ten-bay gated overflow spillway located in the vicinity of the right bank of the existing river channel, and an integral power intake and powerhouse structure located in a bay excavated into the right abutment.

The dam would have an overall crest length of about 3600 feet, a crest level of El. 1362, and a maximum height of about 162 feet above unweathered bedrock in the foundation of the concrete gravity structures.

The power intakes and powerhouse would be combined in an integral structure. A key, constructed out of rolled concrete, would be provided to assist in transmitting horizontal forces from the intake-powerhouse structure into the bedrock.

The overflow spillway, controlled by ten 54-foot wide by 53-foot high radial gates, would discharge into a 240-foot long stilling basin. The spillway would have a capacity of 900,000 cfs with the reservoir at El. 1347, the maximum flood level. A rolled concrete key to increase the sliding stability of the spillway structure would also provide additional weight to resist the uplift forces on the stilling basin floor.

The spillway would be provided with fourteen 19-foot wide by 28-foot high sluices capable of passing a diversion design flood of 246,000 cfs during construction of the earthfill dams.

The earthfill dams would have shells of granular fill and would be founded on the granular alluvium in the river bed and on the shale which forms the left abutments. The impervious central core would extend 10 feet into a trench excavated in the alluvial material in the river bed. A cut-off between the impervious core and bedrock would be provided by a drilled concrete (ICOS type) cut-off wall which would be about 1500 feet long and reach a maximum depth of about 140 feet.

The six power intakes, contained in the intake-powerhouse structure would each be controlled by three 22-foot wide by 38-foot high vertical lift gates designed to close under full flow conditions. Two sets of bulkhead type service gates interchangeable between the six units and operable only under balanced head conditions would be provided. Each intake would be coupled direetly to the concrete spiral case of the turbine.

For the Site E (1342) project, the powerhouse would house six fixed blade propeller-type turbines each with an output of 136,000 horsepower at a net head of 78 feet. The generators would each be capable of a continuous output of 100 MW providing a full plant capacity of 600 MW.

For the Site E (1352) project, similar turbine units would each have an output of 153,000 horsepower at a net head of 88 feet. The generators would then each be capable of a continuous output of 112.5 MW providing a full plant capacity of 675 MW.

6.4 RESERVOIR AND RELOCATIONS

The surface area of the reservoirs for the Site E (1342) project at the proposed normal operating level El. 1342 would be about 19,500 acres. The land area flooded (excluding the river channel area) would be 7,000 acres. For the alternative Site E (1352) project, the water surface and land areas would be respectively 20,500 acres and 8,000 acres.

The inundated area for the Site E (1342) project would consist mainly of valley slopes and old river terraces. The valley slopes are generally unimproved, the areas with flatter slopes consisting basically of slide material. On the right bank, these slopes are partially forest covered. The terrace lands affected are the relatively flat areas situated at about the proposed reservoir normal operating level. These terraces, comprising about 500 acres of cultivated land, would be partially inundated by the Site (1342) project reservoir.

Apart from residential and other properties oriented around agriculture, located almost entirely in the Taylor area, the only significant developments that would be affected by the reservoir would be the north approach to the B.C. Railway crossing of the Peace River which would require replacement of the trestle and possibly some additional slope protection of the "Peace Hill". The secondary road bridge across the Alces River would also require replacement. Some additional stabilization of the north approach to the Highway 97 bridge (Alaska Highway) may also be necessary.

With the Site E (1352) project, the lowest terrace areas comprising a little over 800 acres of cultivated land would be completely inundated. Stabilization of the B.C. Railway and Highway 97 approaches would be more extensive, and also, the south end of the Highway 97 bridge over the Peace River would have to be raised a few feet so that the steel structure would be clear of all reasonable floods (return period up to 200 years) and ice blockages.

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6.4 RESERVOIR AND RELOCATION - (Cont'd)

At present, the banks of the Peace River and the Pine, Beatton, Kiskatinaw and Alces tributaries show signs of sloughing and sliding in a number of areas. Impounding of the low Site E reservoir at either alternative normal operating level could precipitate or reactivate some potential slides earlier than they would otherwise have occurred. The areas with greatest potential for large slides would be between Mile 18 and 17 just upstream of the Beatton River; between Mile 14 and 9 downstream of the Beatton River; and to a lesser extent, between Mile 24 and 23 downstream of Taylor. There would also be a moderate to high probability of isolated smaller slides along the Beatton River, especially at Mile 3 upstream of its confluence with the Peace River. The proposed Site E project would be designed to avoid risk of damage from slide-generated waves both to the dam structure and to any downstream development.

As for Site C, details concerning the stability of the reservoir banks are presented in the report, "Sites C and E, Lower Peace River and Tributaries - Shoreline Assessment" January 1976 by Thurber Consultants.

6.5 CONSTRUCTION SCHEDULE

The construction schedule for development of either the Site E (1342) or the Site E (1352) project is shown in Plate 6-3. A total of 6 3/4 years would be required from issue of the first tender to the in-service date of the first two units. As with Site C, it is assumed that preliminary design and further site investigations and testing would be undertaken in Years A and B and final design in the 6 months prior to the issue of the first tender at the start of Year 1.

The first stage of construction would consist of excavation of the diversion channel in the left half of the riverbed concurrent with the excavation of the forebay channel on the right bank, behind a rock plug. The second stage would be the construction of the cofferdam

6.5 CONSTRUCTION SCHEDULE - (Cont'd)

halfway out into the river from the right bank and the construction of the lower portions of the spillway and powerplant. The river would then be diverted through temporary openings in the spillway until all the structures were essentially completed. The schedule also allows time during construction for the sinking of a deep cut-off wall under the earthfill dam and assumes that there would be a shutdown of concreting and fill placement during the winter months. The schedule is based on having a separate civil contract for the excavation of the diversion channel and forebay, and construction of the cofferdam, to permit a construction start at an early stage in final design.

It has been assumed that suitable construction materials for the cofferdams and the earthfill dam would be obtained from the riverbed and excavations for the structures, and granular materials for the concrete structures from the riverbed.

6.6 COSTS

The estimates of total capital costs for the Site E (1342) development is $452 million and for the Site E (1352) development $483 million. A break down of these costs for the two alternatives is given in Table 8-1. Costs are based on mid-1975 price levels. Contingency allowances are as follows: 7 1/2 percent of equipment costs, and 20 percent of all other direct cost items. Engineering investigations and supervision costs were estimated at 9 percent of the direct costs plus contingencies. Corporate overheads were estimated at 40 percent of Engineering costs. Interest during construction was computed at 10 percent compounded annually. Transmission and escalation costs are not included.

Capital expenditures by fiscal years are shown in Table 8-2.

SECTION 7.0 - SITE E (1510) DEVELOPMENT

7.1 SITE DESCRIPTION

The proposed Site E (1510) development would be located about 2.0 miles upstream of the British Columbia/Alberta border at the same axis as selected for the lower Site E (1342) or (1352) developments.

The topography and geology of the Site are as described for the lower Site E dams (Ref. Section 6.1). However, on the left abutment the dam would extend above the terrace to the steeper slopes which rise well above the proposed dam crest level El. 1530. This steeper upper slope comprising sandstone, siltstone and shale bedrock of the Dunvegan Formation is blanketed by surficial silt deposits. On the right abutment, the dam would extend across the wide alluvium-covered terrace above the essentially horizontal bedrock. The alluvium consists of silt and clay overlying gravel, which deepens progressively away from the river to beyond the point where the ground level rises above the proposed dam crest level.

7.2 FACTORS AFFECTING SELECTION OF THE PROJECT ARRANGEMENT

The problems encountered in determining a feasible arrangement for the Site E (1510) project were similar to those for the lower Site E (1342) and (1352) developments (Ref. Section 6.2), but were considerably increased in magnitude due to the greater head of the impounded reservoir and the higher structures required.

The greater head for the Site E (1510) project would require much more massive keys formed of rolled concrete under the power intake, spillway and gravity dams to assist in transmitting horizontal forces into the bedrock and to ensure stability against sliding. Although the

7.2 FACTORS AFFECTING SELECTION OF THE PROJECT ARRANGEMENT - (Cont'd)

project would utilize Francis turbines as adopted for the Site C (1515) project, it was not considered economic to have close coupling of the power intakes and powerhouse. This was due in part to the size of the units and the stresses that such an arrangement would develop in the powerhouse; in addition the benefits of close coupling would be outweighed by added costs due to complications in construction. A larger number of smaller units would not be as economic due to the greatly increased powerplant costs and the restricted space available where bedrock is located at a high enough level for economic powerhouse and spillway foundations.

7.3 SELECTED ARRANGEMENT

The arrangement selected for the Site E (1510) project is shown in Plates 7-1 and 7-2. The project would consist of an 2100-foot long earthfill dam extending from the left abutment across the major part of the existing river channel, an eight-bay gated overflow spillway located in the vicinity of the right bank of the present river channel, concrete gravity power intake and powerhouse structures located in a bay excavated into the right abutment, and earthfill wing dam on the right bank river terrace. The dam would have an overall crest length of 5900 feet, a crest level at El. 1530, and a maximum height of about 325 feet above unweathered bedrock in the foundation of the concrete gravity dam structures.

The power intakes and powerhouse would be separate structures as integral construction would be unacceptable. A key, constructed out of rolled concrete, would be provided to assist in transmitting horizontal forces from the intake structure into the bedrock.

The overflow spillway controlled by eight 50-foot wide by 64-foot high radial gates would discharge into a 300-foot long stilling basin. The spillway would have a capacity of 865,000 cfs with the reservoir at El. 1515, the maximum flood level. A rolled concrete key to increase the sliding stability of the spillway structure would provide additional weight to resist the uplift forces on the stilling basin floor.

The spillway would be provided with ten 19-foot wide by 36-foot high sluices capable of passing a diversion design flood of 264,000 cfs during construction of the earthfill dams.

The main earthfill dam with a crest length of 2100 feet would have shells of granular fill and would be founded on the granular alluvium in the riverbed and on the shales which form the left abutment. The impervious central core would extend down 10 feet into a trench excavated in the alluvial material in the riverbed. A cutoff between the impervious core and bedrock would be provided by a drilled concrete (I.C.O.S. type) cutoff wall which would be about 1500 feet long and reach a maximum depth of about 140 feet.

The 1500-foot long earthfill wing dam on the right bank would also have shells comprising granular fill and be founded on the alluvium overlying the bedrock terrace which forms the right abutment. The impervious central core would extend 10 feet into a trench excavated in the alluvial material. A cutoff between the impervious core and bedrock would be provided by a drilled concrete (I.C.O.S. type) cutoff wall or by a slurry trench which would be about 1700 feet long and reach a maximum depth of about 80 feet.

The six power intakes would each be controlled by 22-foot wide by 40-foot high vertical lift gates designed to close under full flow conditions. Two bulkhead type service gates interchangeable between the six units and operable only under balanced head conditions would be provided. Each intake would be connected to a turbine by a 28-foot diameter steel-lined penstock. The six-unit powerhouse would house Francis turbines each with an output of 408,000 horsepower at a net

7.3 SELECTED ARRANGEMENT - (Cont'd)

head of 253 feet. The generators would each be capable of a continuous output of 300 MW providing a full plant capacity of 1800 MW.

7.4 RESERVOIR AND RELOCATIONS

The surface area of the reservoir for the Site E (1510) project at the proposed normal operating level El. 1510 would be about 68,000 acres. The land area flooded (excluding river channel area) would be about 42,000 acres.

The inundated area would consist of some valley bottom land, valley slopes and some higher terrace land. The valley slopes are forest-covered in places, but generally are undeveloped as they are either fairly steep or highly undulating where they consist of slide materials. The bottom lands and terraces have been developed for agriculture and a little over 5,000 acres of cultivated land would be flooded. The principal areas affected by the proposed reservoir would be near Attachie, the lower parts of Bear Flats, the low and intermediate terrace lands upstream of the B.C. Railway bridge and in the vicinity of Taylor, the lower edge of Taylor Flats, and the high terrace on the north bank opposite the mouth of the Kiskatinaw River. The terrace on the south bank near the damsite would be inundated only partially due to selection of an upstream location for the dam at axis E-6. The downstream location previously selected at axis E-3 would have resulted in inundation of the whole terrace.

Apart from the residential and other properties oriented around agriculture, developments that would be affected consist of several sections of highways together with associated river crossings, the main highway and railway bridge crossings of the Peace River at Taylor, and parts of the Taylor petroleum facilities.

Relocation of Highway 29 between Hudson Hope and Fort St. John would be the same as for the Site C (1515) project. Relocation of the Highway 97 (Alaska Highway) bridge and approaches would require construction of a new higher level bridge and approach fill close to the existing bridge. Relocation of the secondary highway crossings would include a new bridge across the Beatton River and a high level crossing of the Alces River. The Clayhurst Ferry would be replaced by a road across the dam.

The B.C. Railway relocation would include the section of track which runs along the north bank of the Pine River and a new high level bridge crossing the Peace River probably at a location about 2 miles upstream of the present bridge. Relocations for the petroleum facilities would principally entail reconstruction of the gas compressor station and corresponding services, the disposal ponds and the employee housing compound.

Details of necessary relocations are presented in the preliminary report, "Peace River Sites C and E, Relocation of Major Transportation and Transmission Facilities", April 1976 by B.C. Hydro-Hydroelectric Design Division, and for the Taylor petroleum facilities in the report "Sites C and E, Lower Peace River and Tributaries - Shoreline Assessment", January 1976, by Thurber Consultants Ltd.

At present, the banks of the Peace River and its tributaries show signs of sloughing and sliding in a number of areas. Major ground movements could occur between Site C and Site E with a high Site E (1510) dam. In the upstream reach of the reservoir the areas with the greatest potential for large slides would be similar to those for the Site C (1515) project. In the downstream reach the probability ratings for slides would be much higher than for the Site E (1342) reservoir and also the length of shoreline that may be affected by large slides would be much greater (2 1/2 times). Some areas of sidehill movement such as the "Peace Hill" between Mile 34 and 29, the left bank between Mile 39

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7.4 <u>RESERVOIR AND RELOCATIONS</u> - (Cont'd)

and 37 (just downstream of the Site C-3 dam axis) on the Peace River, and the left bank of the Pine River 7 to 4 miles upstream of the confluence with the Peace River would be affected only by the higher Site E (1510) reservoir.

The proposed Site E (1510) project would be designed to avoid any significant risk of damage from slide-generated waves both to the structures or to downstream development.

Details concerning the stability of the reservoir banks are presented in the reports, "Sites C and E, Lower Peace River and Tributaries - Shoreline Assessment" January 1976, and "Shoreline Assessment - Moberly River, B.C." April 1976 by Thurber Consultants.

7.5 CONSTRUCTION SCHEDULE

The construction schedule for development of the Site E (1515) project is given on Plate 7-3. A total of 7 3/4 years would be required from issue of the first tender to the in-service date of the first two units. As for the other alternatives, it is assumed that preliminary design and further site investigations and testing would be undertaken in Years A and B and final design in the 6 months prior to issue of the first tender at the start of Year 1.

In constructing the project, the construction sequence would be essentially the same as for the Site E (1342) and (1352) alternatives. The schedule, as for the lower project, would include the extended initial period for excavation of the diversion channel and excavations for the spillway and powerhouse, and the later period for construction of the deep cut-off wall. For the high dam, more time would be necessary for the considerably larger concrete and earthfill dam structures.

7.6 COSTS

The estimate of total capital cost for the Site E (1510) development is $1170 million. A breakdown of these costs is given in Table 8-1. Costs are based on mid-1975 price levels. Contingency allowances are as follows: 7 1/2 percent of equipment costs, and 20 percent of all other direct cost items. Engineering, investigations and supervision costs were estimated at 8 percent of the direct costs plus contingencies. Corporate overheads were estimated at 40 percent of Engineering costs. Interest during construction was computed at 10 percent compounded annually. Transmission and escalation costs are not included.

Capital expenditures by fiscal years are shown in Table 8-2.

Approximately 19 percent of the direct cost of this high Site E (1510) development is for flowage, comprising mainly relocation of the major highway and railway crossings of the Peace River near Taylor, and major relocations and protection works to the Westcoast Transmission gas compressor station and corresponding services associated with the Taylor petroleum facilities. Considerable cost would also be incurred in providing the deep rolled concrete foundations keys into the river bedrock and the extensive rock excavation required for the tailrace channel in the right bank.

SECTION 8.0 - COMPARISON OF ALTERNATIVE DEVELOPMENTS

8.1 ENERGY AND COSTS

The capital costs of developing the head on the Peace River between Site 1 and the B.C.-Alberta border with the two dams of the Site C (1515) plus Site E (1342) or Site E (1352) projects, or with a single dam Site E (1510) project, are shown in Table 8-1. Corresponding capital expenditures by fiscal years for each of the projects are shown in Table 8-2.

The estimated annual costs of each development, based on a long-term interest rate of 10 percent per annum and a 70-year average project life and including school and water taxes, are shown in Table 8-3.

The total capital cost, maximum plant capacity, unit cost of attributable plant capacity and annual costs of alternative developments which could be located entirely within British Columbia are summarized below:

	Maximum Plant Capacity	Total Capital Cost	Attributable Plant Capacity	Cost per kW	Total Annual Cost
	MW	$\$x10^6$	MW	$	$\$x10^6$
Site C (1515)	975	544	965	564	64.01
Site E (1352)	675	483	665	726	57.06
Site C (1515) plus Site E (1352)	1650	1027	1630	630	121.07
Site E (1342)	600	452	597	757	53.46
Site C (1515) plus Site E (1342)	1575	996	1562	638	117.47
Site E (1510)	1800	1170	1790	654	137.40

8.1 ENERGY AND COSTS - (Cont'd)

For the Peace River flows only (without McGregor diversion), the attributable average and firm energy for each project and the respective unit costs of the energy would be as tabulated below:

	Attributable Firm Energy GWh/year	Cost per Firm kWh Mills	Attributable Average Energy GWh/year	Cost per Average kWh Mills
Site C (1515)	4380	14.6	4450	14.4
Site E (1352)	2935	19.5	3120	18.3
Site C (1515) plus Site E (1352)	7315	16.6	7570	16.0
Site E (1342)	2700	19.8	2830	18.9
Site C (1515) plus Site E (1342)	7080	16.6	7280	16.1
Site E (1510)	7970	17.2	8500	16.2

For Peace River flows plus diverted McGregor River flows, the attributable firm and average energy for each project and the respective unit costs of the energy would be as tabulated below:

	Attributable Firm Energy Gwh/year	Cost per Firm kWh Mills	Attributable Average Energy GWh/year	Cost per Average kWh Mills
Site C (1515)	5030	12.7	5245	12.2
Site E (1352)	3275	17.4	3445	16.6
Site C (1515) plus Site E (1352)	8305	14.6	8690	13.9
Site E (1342)	3050	17.5	3145	17.0
Site C (1515) plus Site E (1342)	8080	14.5	8390	14.0
Site E (1510)	9040	15.2	9530	14.4

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8.1 ENERGY AND COSTS - (Cont'd)

Based on the project annual costs which include all engineering, operation and financing costs of the project and necessary relocations, development of the Peace River downstream of Site 1 would be more economic with the two dams of the Site C (1515) plus Site E (1342) or (1352) projects than with a single high dam Site E (1510) project. Assuming that the McGregor River will be diverted into the Peace River, the combined average cost per kilowatt-hour of firm energy for the two-dam development despite the 10 percent lower energy output would be about 5 percent below that for the higher single-dam development.

8.2 FLOODING AND RELOCATIONS

The extent of flooding and relocations required for development with the two dams of the Site C (1515) plus Site E (1342) or Site E (1352) projects, or with a single dam Site E (1510) project, are summarized below:

	Site C (1515) plus Site E (1342) or (1352)	Site E (1510)
Land area inundated	18,500 acres 19,500 acres for Site E (1352).	42,000 acres
Cultivated land inundated	1,500 acres 1,800 acres for Site E (1352).	5,000 acres
Relocations required	10 miles of Highway 29 including river crossing structures.	10 miles of Highway 29 including river crossing structures.
	B.C. Railway tressle and slope protection of "Peace Hill".	New high level B.C. Railway crossing of the Peace River.
	Secondary road crossing of the Alces River.	3.5 miles of B.C. Railway alignment along north bank of the Pine River.

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8.2 FLOODING AND RELOCATIONS - (Cont'd)

	Site C (1515) plus Site E (1342) or (1352)	Site E (1510)
Relocations required (Cont'd)	Stabilization of the north approach to the Highway 97 crossing of the Peace River	New high level Highway 97 bridge crossing of the Peace River and approaches.
	For Site E (1352) raising the south end of the Highway 97 bridge crossing of the Peace River and more extensive stabilization of the north approach.	Secondary road crossings of the Beatton and Alces Rivers.
		Gas compressor station and services of the Taylor petroleum facilities.

8.3 RESERVOIR BANKS

The natural slope conditions of the existing river banks in the area of the proposed reservoirs show evidence of many slides. Comparison of the potential shoreline conditions of the reservoir banks of the Site C (1515) plus Site E (1342) or Site (1352) projects, with those for the alternative Site E (1510) project are summarized as follows:

	Site C (1515) plus Site E (1342) or (1352)	Site E (1510)
Reservoir shoreline with potential for major slides*	80 miles out of 252 miles.	135 miles out of 367 miles.
Reservoir shoreline with higher probability of sliding**	10 miles	36 miles

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* Thurber Consultants potential reservoir shoreline stability type classifications C or D.

** Thurber Consultants potential reservoir shoreline stability probability of occurrence classifications 3, 4 or 5.

8.3 RESERVOIR BANKS - (Cont'd)

	Site C (1515) plus Site E (1342) or (1352)	Site E (1510)
Extent of inundation into glacio-lacustrine silt, clay and till overlying shale bedrock, with potential for causing first time slides.	Inundation only marginal and mainly along the Moberly River reservoir arm.	Inundation significantly more extensive.

8.4 RESERVOIR SEDIMENTATION

The proposed reservoirs created by dams at Site C and Site E on the Peace River would be reduced in volume by deposition of suspended sediment and by the buildup of deltas at the mouths of the tributaries. A comparison of the main reservoir sedimentation factors with each of the development alternatives is as follows:

	Site C (1515) plus Site E (1342) or (1352)	Site E (1510)
Sedimentation time of the reservoir	Site C - 700 years Site E - 50 years*	Site E - 1000 years
Ultimate** bed aggradation at upstream end of of main reservoir arm.	Site C (1515) - not significant within possible life of project.	Site E (1510) - not significant within possible life of project.

* Reservoir storage is not required for regulation at Site E and the project could be designed to operate after the reservoir has substantially filled, by passing sediment through the turbines or special outlets.

** Possibily after several centuries.

8.4 RESERVOIR SEDIMENTATION - (Cont'd)

	Site C (1515) plus Site E (1342) or (1352)	Site E (1510)
Ultimate** bed aggradation at upstream end of main reservoir arm (Cont'd)	Site E (1342) - Site C effective tailwater level would ultimately rise from about El. 1349 to between El. 1354 and El. 1359	
	Site E (1352) - Site C effective tailwater level would ultimately rise from about El. 1353 to between El. 1364 and El. 1369	

8.5 SCHEDULING AND IN-SERVICE DATA

The projects comprising the alternative two dam Site C (1515) plus Site E (1342) or (1352) development and the single dam Site E (1510) development require different periods for preliminary and final design and for construction as follows:

	Site C (1515) plus Site E (1342) or (1352)	Site E (1510)
Preliminary and final design prior to issue of first tender.	Site C - 1 1/2 years* Site E - 2 years	Site E - 2 years
Construction from issue of first tender to in-service date of first two units.	Site C - 5 3/4 years Site E - 6 3/4 years	Site E - 7 3/4 years

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* Possible additional time requirements for environmental impact studies and licensing procedures may lengthen the lead time that would be required.

** Possibly after several centuries.

SECTION 9.0 - CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

1. It would be feasible to construct a 235-foot high dam for the Site C (1515) project at an axis just about 0.5 miles downstream of the Moberly River (Axis C-3) to develop up to 166 feet of head back to the Site 1 tailrace at an estimated cost of $544 million.

   The average energy available from this project would be 4450 Gwh/year at a cost of 14.4 mills/kWh* if built before the McGregor diversion or 5245 Gwh/year at a cost of 12.2 mills/kWh* if built after the McGregor diversion.

2. It would be feasible to construct a 162 to 172-foot high dam for the Site E (1342) or (1352) project at an axis about 0.5 miles downstream of the Alces River (Axis E-6) to develop about 83 to 93 feet of head back to the Site C tailrace at an estimated capital cost of $452 to $483 million.

   The average energy available from this project would be from 2830 to 3120 Gwh/year at a cost of 18.9 to 18.3 mills/kWh* before the McGregor diversion or 3145 to 3445 Gwh/year at a cost of 17.0 to 16.6 mills/kWh* after the McGregor diversion.

3. It would be feasible to construct a 330-foot high dam for the Site E (1510) project at an axis about 0.5 miles downstream of the Alces River (Axis E-6) to develop about 251 feet of head back to the Site 1 tailrace. However, severe engineering problems associated with the poor foundation conditions and extensive relocations would result in the relatively high capital cost of $1170 million.

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* Based on a long term interest rate of 10 percent per annum.

9.1 CONCLUSIONS - (Cont'd)

The average energy available from this project would be 8500 Gwh/year at a cost of 16.2 mills/kWh* if built before the McGregor diversion or 9530 Gwh/year at a cost of 14.4 mills/kWh* after McGregor diversion.

4. Development of the head on the Peace River between Site 1 and the British Columbia/Alberta border for hydroelectric power with the two low dams of the Site C (1515) plus Site E (1342) or (1352) projects would be marginally more economic and environmentally far less disruptive than with the single high dam Site E (1510) project.

5. The two lower dams of the Site C (1515) and Site E (1342) or (1352) projects would present complex problems of design and construction due to the relatively poor foundation conditions but not as complex as for the higher dam of the Site E (1510) project.

6. The Site C (1515) plus Site E (1342) development would minimize adverse effects due to reservoirs on existing development along the lower Peace River. Development with two low dams would require only minor to moderate relocations of transportation and transmission facilities in the area and would not significantly affect the Taylor petroleum facilities, which would be adversely affected by the Site E (1510) project.

7. The Site C (1515) plus Site E (1342) reservoirs would inundate about 18,500 acres of land (not including the area of the existing river channel) compared with 42,000 acres for the Site E (1510) reservoir.

8. The Site C (1515) plus Site E (1342) or (1352) reservoirs would cause some sloughing and sliding of the reservoir banks, but this would be considerably less extensive and severe than with the Site E (1510) reservoir.

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* Based on a long term interest rate of 10 percent per annum.

9.1 CONCLUSIONS - (Cont'd)

9. The schedule for final design and construction would permit the first units of the Site C (1515) project to be in service approximately 6 years from issue of the first tender. The Site E (1342) project would require at least one more year, and the Site E (1510) project two more years. Preliminary design would add 1 1/2 to 2 years to the above periods. Possible additional time requirements for environmental impact studies and licensing procedures may lengthen the lead time that would be necessary for the projects.

10. Sedimentation of the reservoir for the Site C (1515) project would proceed very slowly (reservoir life is estimated as over 700 years). In the Site E (1342) or (1352) reservoir, sediment build-up in the lower reaches, particularly below the Beatton River, would be rapid (reservoir life estimated at about 50 years), but the project could be designed to operate with sediment being passed through the turbines or special outlets in the dam after the reservoir had been substantially filled. Eventually (possibly after several centuries) the build up of sediment within the Site E (1352) reservoir would cause a 12 to 17 foot loss of head upstream at Site C by raising the tailwater. However, with the El. 1342 reservoir level the loss of head would be relatively small. With the Site E (1510) project, sediment build up in the main body of the reservoir would also proceed very slowly (reservoir life would be about 1000 years), but some sediment build up would occur at the head of the tributary arms, principally in the Beatton River arm.

12. Comparison of the Site E (1352) project with the Site E (1342) project shows that the project with the higher reservoir level would be only marginally more economic. Selection of El. 1342 for the reservoir level would minimize the relocation problems and flooding of agricultural land at Taylor, but depending on how much tailrace improvement is economic at Site C, from 4 to 7 1/2 feet of head would be left undeveloped.

9.2 RECOMMENDATIONS

1. Future studies, as indicated below, should be concentrated on the most economic Site C (1515) project, and less urgently on the Site E project with reservoir about El. 1342. The Site E (1510) project should not be studied further.

2. More detailed investigations of the dam site foundations should be made. These should include investigations to determine the extent and continuity of the clay seams, in-situ testing of the bedrock to check assumed rock strength characteristics required to select appropriate final design criteria, studies of the slaking characteristics of the shale bedrock, permeability tests of the material in the riverbed, and investigations of the suitability and availability of construction materials.

3. For the Site C (1515) and Site E (1342) reservoirs, more detailed shoreline investigations should be made to determine the reservoir safeline in the developed areas. Detailed investigation and study should also be carried out in areas where potential slides may require special measures for safe development of the projects.

4. More detailed field investigations and studies should be made of developed (settled) and agricultural areas which would be inundated by the reservoirs or adversely affected by a raised watertable to more accurately define the results of reservoir development.

TABLE 8-1

PEACE RIVER SITES C AND E

FEASIBILITY STUDY

ESTIMATES OF CAPITAL COST
($ Millions)

	Item	Site C (1515)	Site E (1342)	Site E (1352)	Site E (1510)
1.	Flowage	24.2	11.6	13.6	121.2
2.	Construction services	5.0	4.0	4.0	9.7
3.	Access	8.7	1.4	1.4	1.4
4.	Site clearing	0.3	0.3	0.3	0.4
5.	Diversion and cofferdams	7.8	10.3	10.3	11.8
6.	Earthfill dams	17.5	14.5	15.5	54.3
7.	Concrete gravity dams	32.0	10.8	11.6	45.6
8.	Spillway	58.9	46.6	48.5	96.0
9.	Intakes and penstocks	42.3	38.5	38.8	94.1
10.	Powerhouse and switchyard				
	- civil	44.2	50.0	60.6	89.6
	- mechanical	48.8	43.0	43.0	53.1
	- electrical	53.8	41.7	41.7	78.6
	TOTAL DIRECT COST	343.5	272.7	289.3	655.8
11.	Contingencies*	53.0	41.4	45.6	112.5
12.	Engineering, investigations and supervision**	35.5	28.1	30.1	61.3
13.	Corporate overheads***	14.2	11.2	12.1	24.4
	SUBTOTAL	446.2	353.4	377.1	854.0
14.	Interest during construction****	97.8	98.6	105.9	316.0
	TOTAL CAPITAL COST	544.0	452.0	483.0	1170.0

* Contingencies - 7 1/2% on equipment costs
- 20% on all other direct cost items.

** Engineering - 9% on total direct cost plus contingencies
- 8% for Site E (1510).

*** Corporate overheads - 40% on Engineering.

**** Interest during construction - 10% per annum.

TABLE 8-2

PEACE RIVER SITES C AND E

FEASIBILITY STUDY

RATE OF CAPITAL EXPENDITURES BY FISCAL YEARS
($ Millions)

	Site C (1515)			Site E (1342)			Site E (1352)			Site E (1510)		
Fiscal Years	Capital Cost without I.D.C.	Interest during Construction	Total Capital Expenditure	Capital Cost without I.D.C.	Interest during Construction	Total Capital Expenditure	Capital Cost without I.D.C.	Interest during Construction	Total Capital Expenditure	Capital Cost without I.D.C.	Interest during Construction	Total Capital Expenditure
A/B	1.4	0.0	1.4	2.5	0.1	2.6	2.7	0.1	2.8	6.1	0.3	6.4
B/1	2.7	0.1	2.8	4.6	0.5	5.1	4.9	0.5	5.4	7.1	1.0	8.1
1/2	23.4	1.6	25.0	20.0	1.7	21.7	21.4	0.2	21.6	56.7	4.3	61.0
2/3	44.2	5.1	49.3	29.6	4.5	34.1	31.7	4.7	36.4	88.0	11.9	99.9
3/4	93.1	12.5	105.6	43.3	8.5	51.8	45.7	9.1	54.8	81.2	21.6	102.8
4/5	92.3	23.2	115.5	55.0	12.2	67.2	58.6	15.6	74.2	104.9	33.1	138.0
5/6	95.5	31.3	126.8	60.4	21.4	81.8	64.9	22.8	87.7	126.7	47.9	174.6
6/7	47.5	22.8	70.3	64.4	29.8	94.2	68.9	31.7	100.6	137.6	59.8	197.4
7/8	22.6	0.6	23.2	39.8	19.0	58.8	42.4	20.3	62.7	109.2	83.9	193.1
8/9	23.5	0.6	24.1	21.7	0.6	22.3	23.5	0.6	24.1	72.3	50.6	122.9
9/10	-	-	-	12.1	0.3	12.4	12.4	0.3	12.7	32.4	0.8	33.2
10/11	-	-	-	-	-	-	-	-	-	31.8	0.8	32.6
TOTALS	446.2	97.8	544.0	353.4	98.6	452.0	377.1	105.9	483.0	854.0	316.0	1170.0

Notes:

1. Expenditures based on Capital Cost Estimates (Table 8-1) and Construction Schedules (Plates 5-3, 6-3 and 7-3).

2. Fiscal Year: 1 April to 31 March.

3. The Operating plant is capitalized according to the following unit in-service schedule:

   Units 1 and 2 - October Year 6 - Site C (1515), Year 7 - Site E (1342 and 1352), Year 8 - Site E (1510)
   Units 3, 4, 5 and 6 - at 6 month intervals following Units 1 and 2.

4. Costs are based on mid-1975 prices.

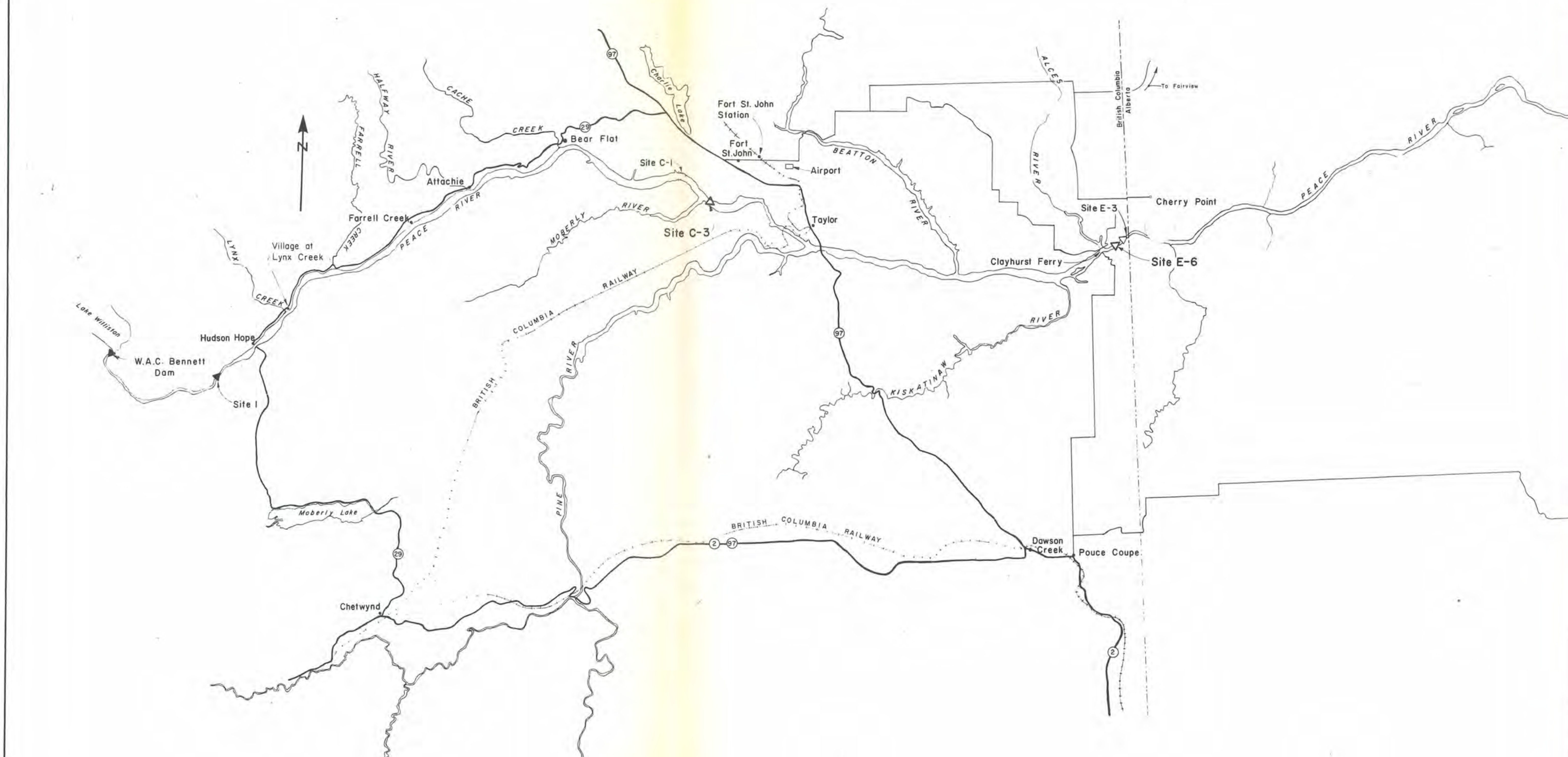
TABLE 8-3

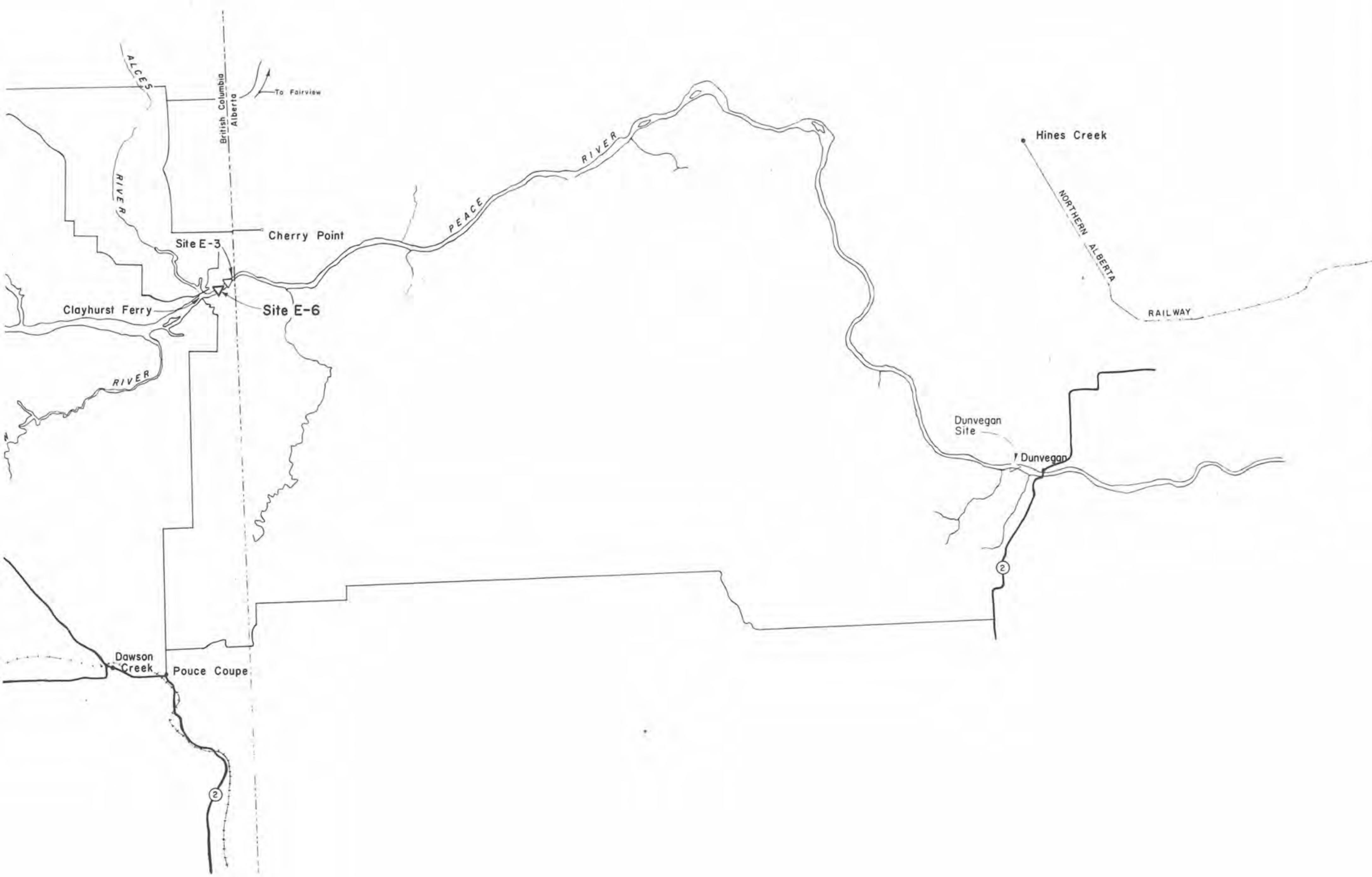
PEACE RIVER SITES C AND E

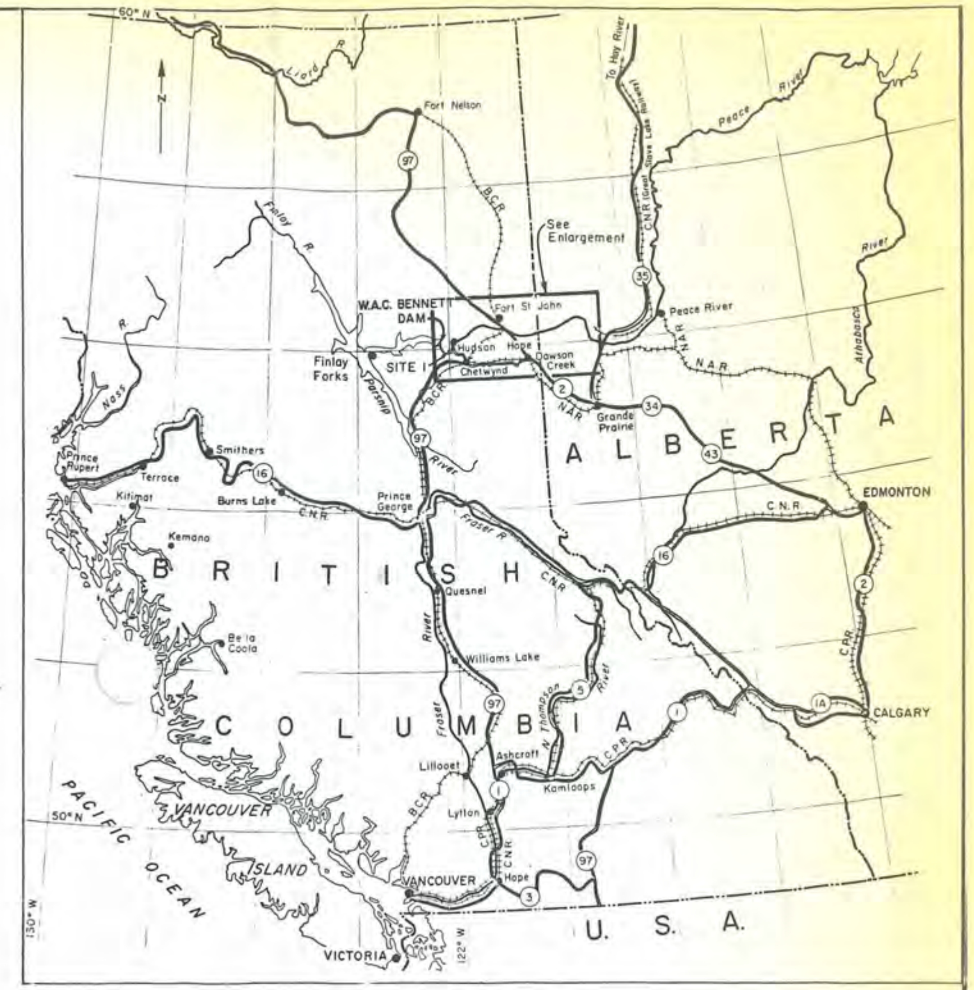
FEASIBILITY STUDY

ESTIMATES OF ANNUAL COSTS
($ Millions)

Item	Site C (1515)	Site E (1342)	Site E (1352)	Site E (1510)
Interest at 10 percent of capital cost	54.40	45.20	48.30	117.00
Amortization over 70 years (sinking fund at 10 percent)	0.07	0.06	0.06	0.16
Operation and maintenance	0.89	1.02	1.02	1.64
Administration and general expense at 0.04 percent of capital cost	0.22	0.18	0.19	0.47
Interim replacements at 0.20 percent of capital cost	1.09	0.90	0.97	2.34
Insurance at 0.10 percent of capital cost	0.54	0.45	0.48	1.17
School and water taxes at 1.25 percent of capital cost	6.80	5.65	6.04	14.62
TOTAL ANNUAL COST	64.01	53.46	57.06	137.40


N
Lake Williston
W.A.C. Bennett Dam
Site I
Hudson Hope
LYNX CREEK
Village at Lynx Creek
Farrell Creek
FARRELL CREEK
HALFWAY RIVER
CACHE CREEK
Attachie
Bear Flat
PEACE RIVER
29
97
Charlie Lake
Fort St. John Station
Fort St. John
Airport
Site C-1
Site C-3
MOBERLY RIVER
Taylor
BEATTON RIVER
ALCES RIVER
British Columbia
Alberta
To Fairview
Cherry Point
Site E-3
Site E-6
Clayhurst Ferry
PEACE RIVER
KISKATINAW RIVER
BRITISH COLUMBIA RAILWAY
PINE RIVER
Moberly Lake
Chetwynd
2
BRITISH COLUMBIA RAILWAY
Dawson Creek
Pouce Coupe





KEY PLAN

LEGEND

- ▽ *Proposed Dam*
- ▼ *Existing Dam*
- *Railway*
- 97 *Highway*
- *Secondary Road*
- *Territorial Boundaries*
- • *City, Town or Village*

Scale: 100 0 100 200 Miles (Approx.) *Key Plan*

Scale: 4 0 4 8 12 Miles *Enlargement*

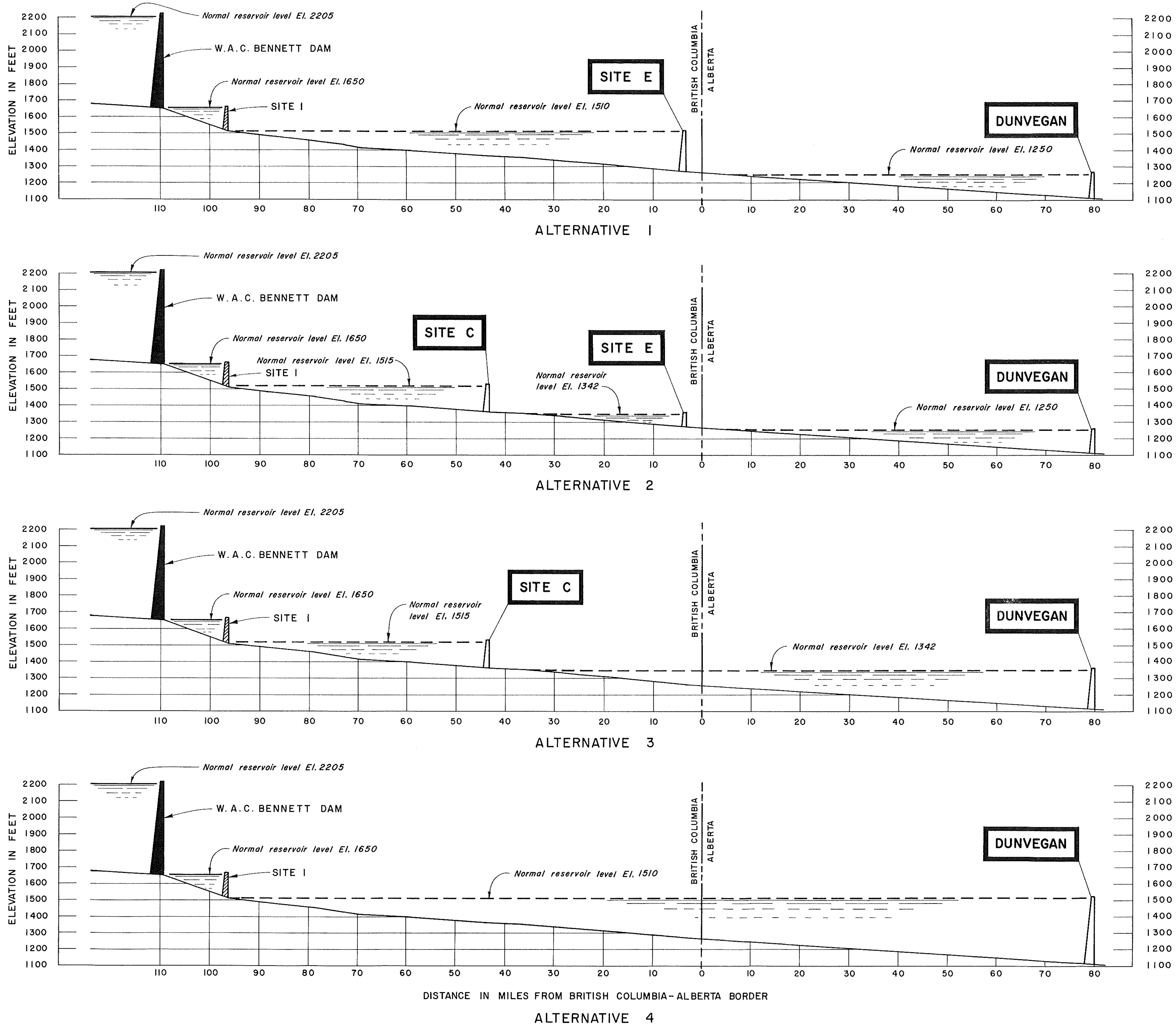
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

PROJECT AREA AND LOCATION MAP

DATE MAY 1976	PLATE 2-1	R
DWN CA	DWG No. 1016-C14-X102	

REPORT No. 796



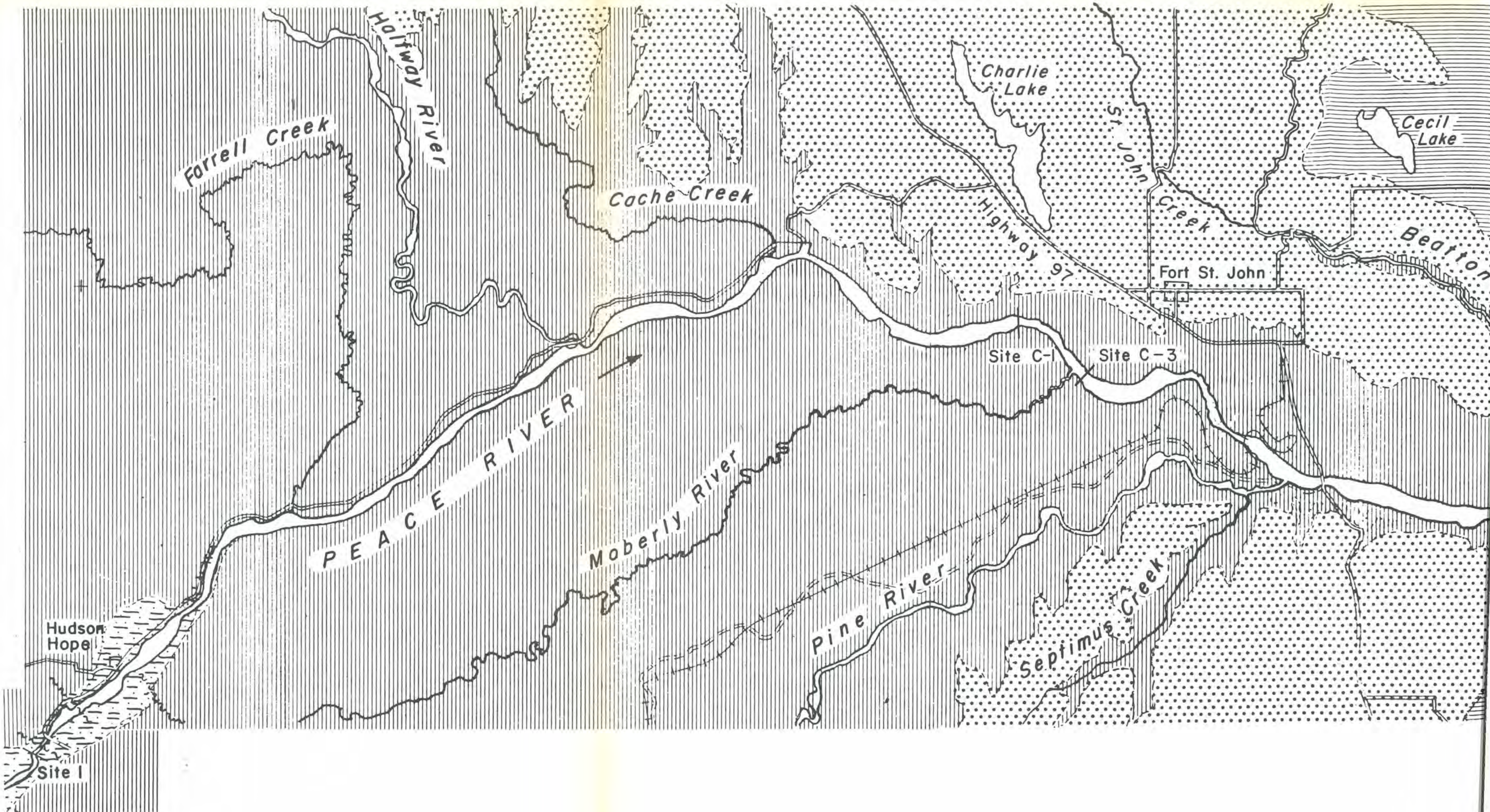
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

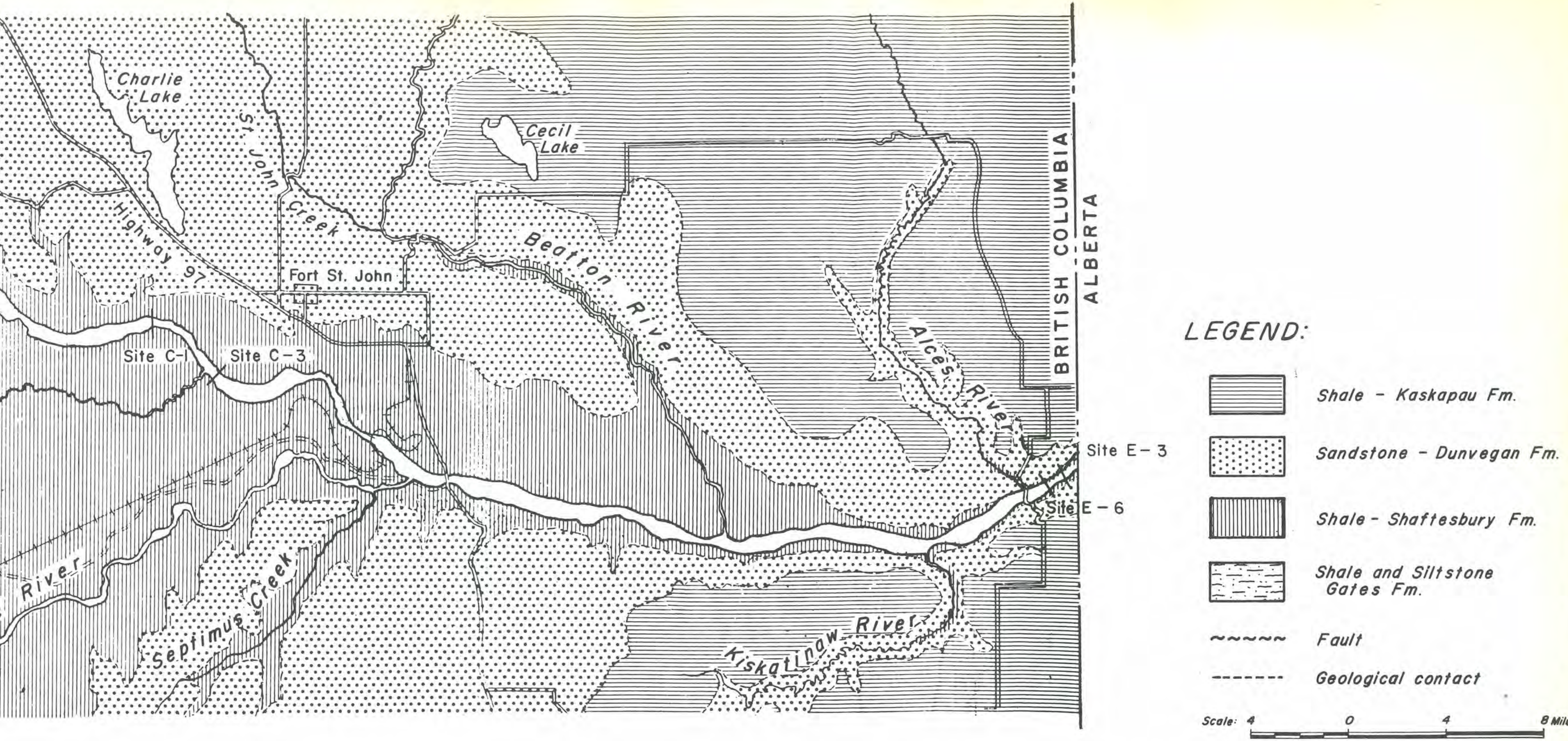
RIVER PROFILES FOR ALTERNATIVE DEVELOPMENTS

DATE MAY, 1976	PLATE 2-2	R
DWN T. L. C.	DWG No.	

REPORT No. 796



Halfway River
Farrell Creek
Cache Creek
Charlie Lake
St. John Creek
Highway 97
Cecil Lake
Beatton
Fort St. John
Site C-1
Site C-3
PEACE RIVER
Moberly River
Pine River
Septimus Creek
Hudson Hope
Site I



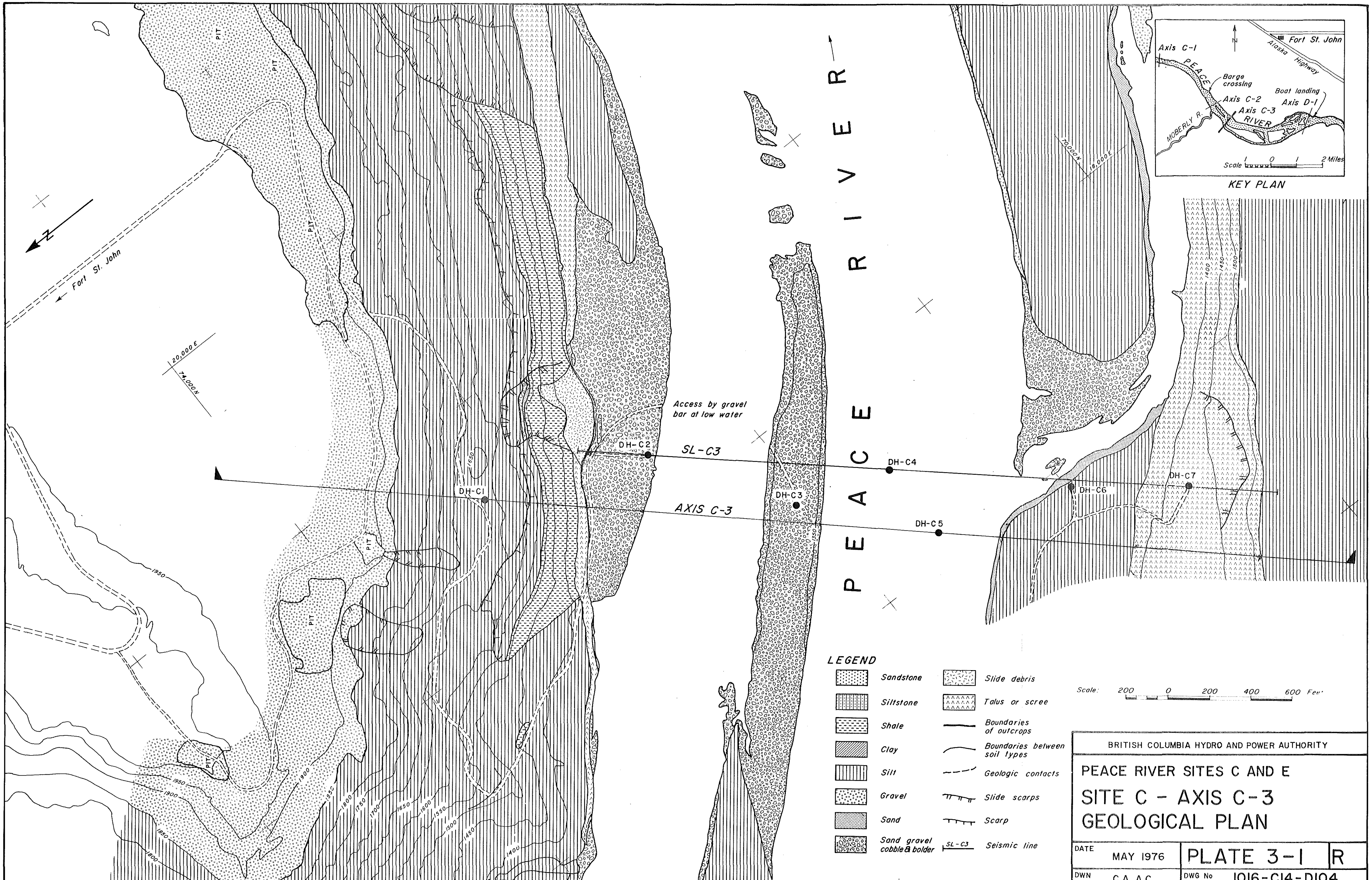
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

REGIONAL GEOLOGY

DATE MAY 1976	PLATE 2-3	R
DWN	DWG No 1016-C14-D103	

REPORT No. 796



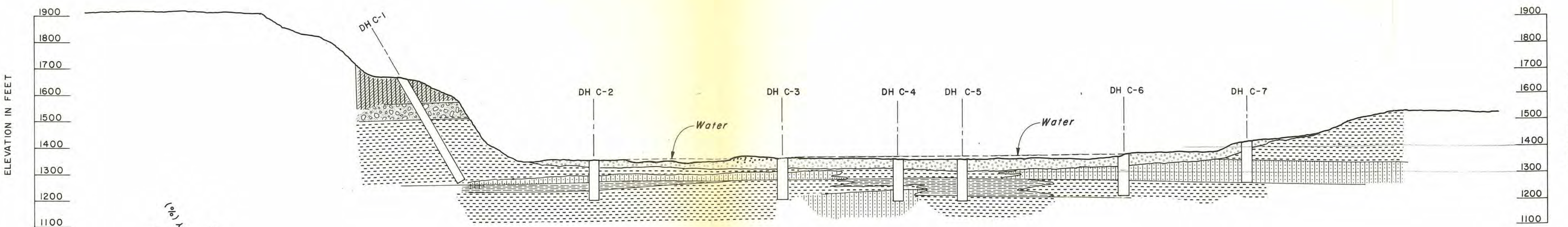
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

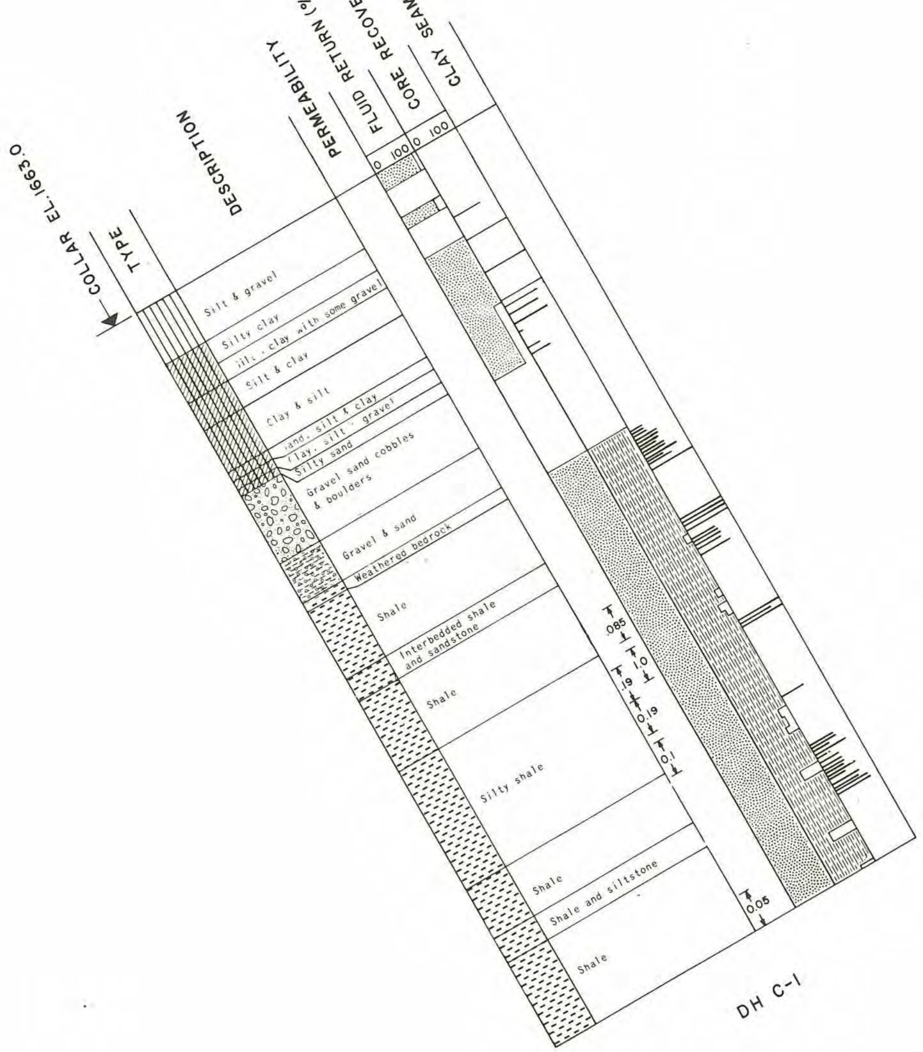
SITE C - AXIS C-3 GEOLOGICAL PLAN

DATE MAY 1976	PLATE 3-1	R
DWN C.A., A.C.	DWG No 1016-C14-D104	

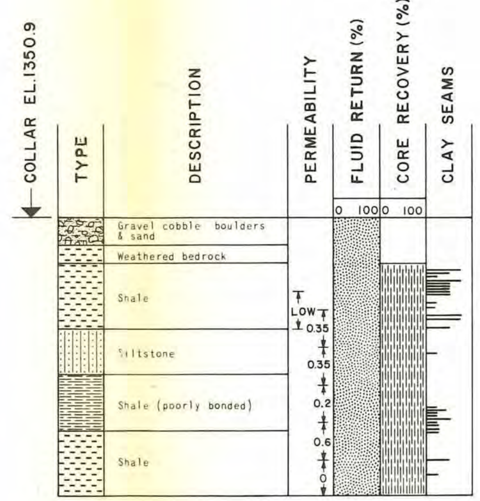
REPORT No. 796



SITE C, AXIS C-3



DH C-1



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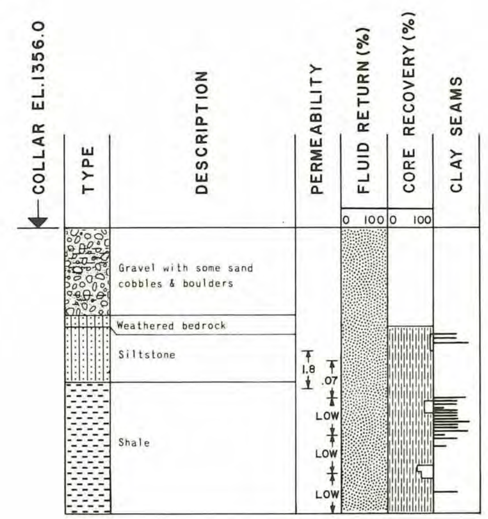

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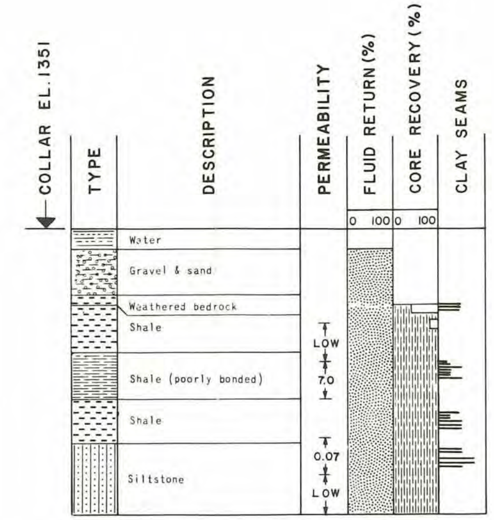

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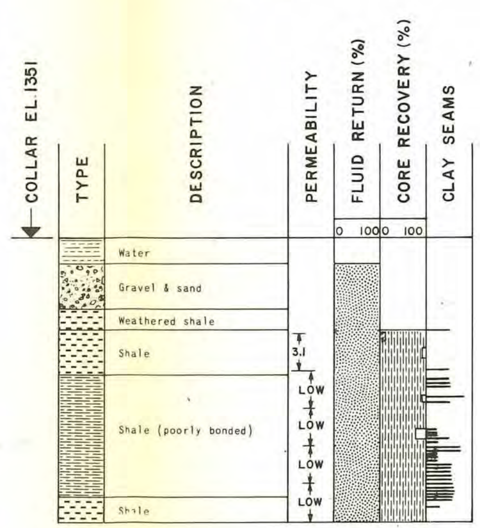

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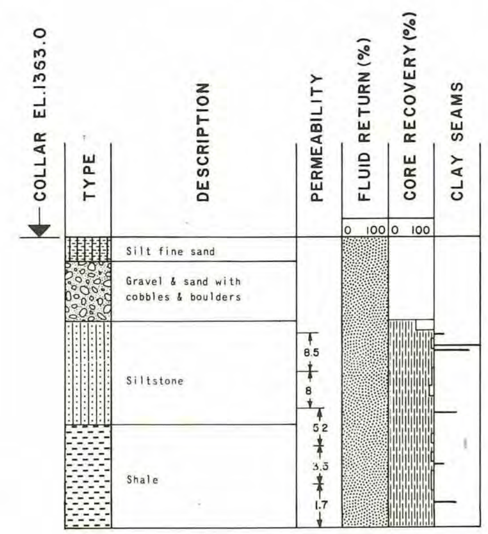
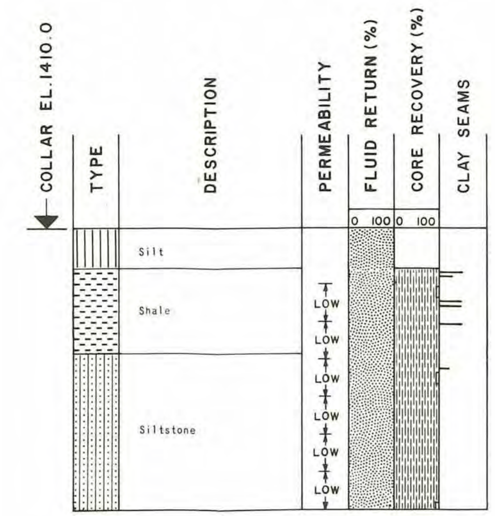


DH C-S



DH C-7

Section
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Graphic
Scale:

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PEAC

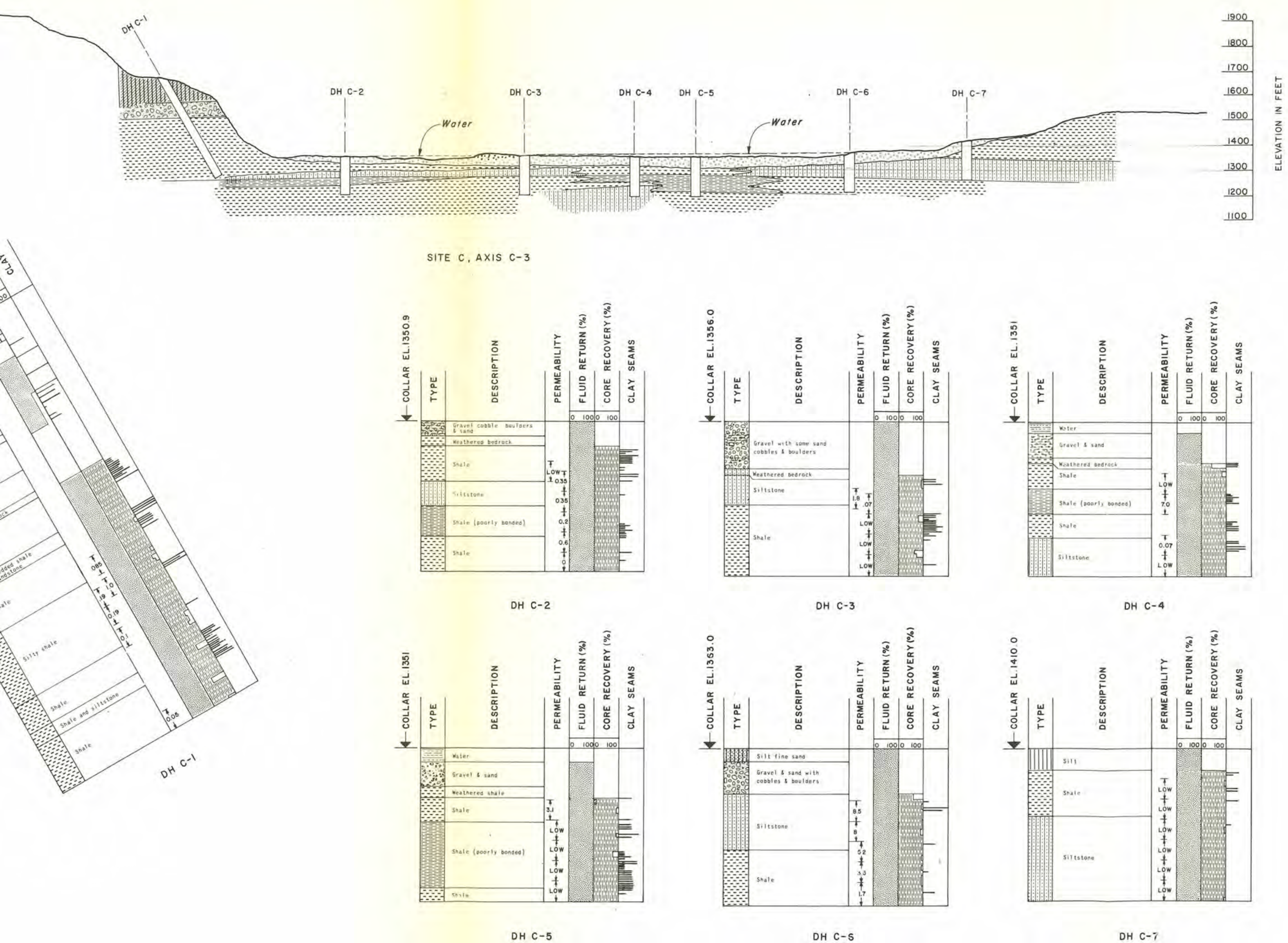
SITE

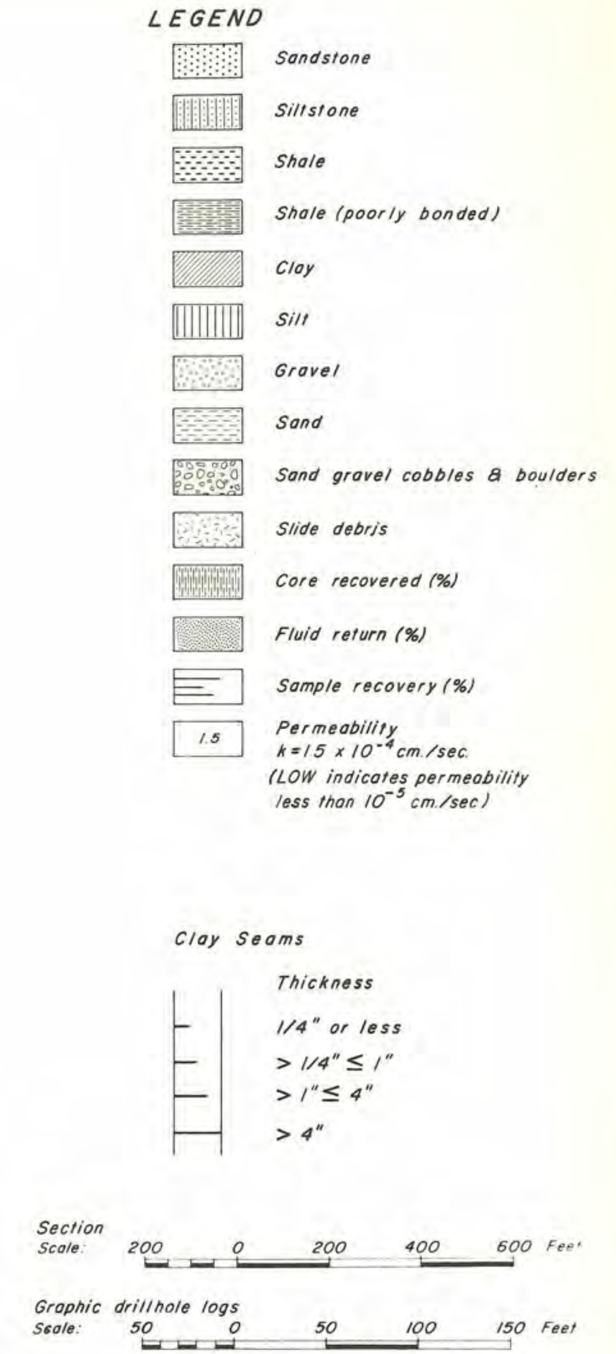
SECT

DATE AP

DWN AC

REPORT N





BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

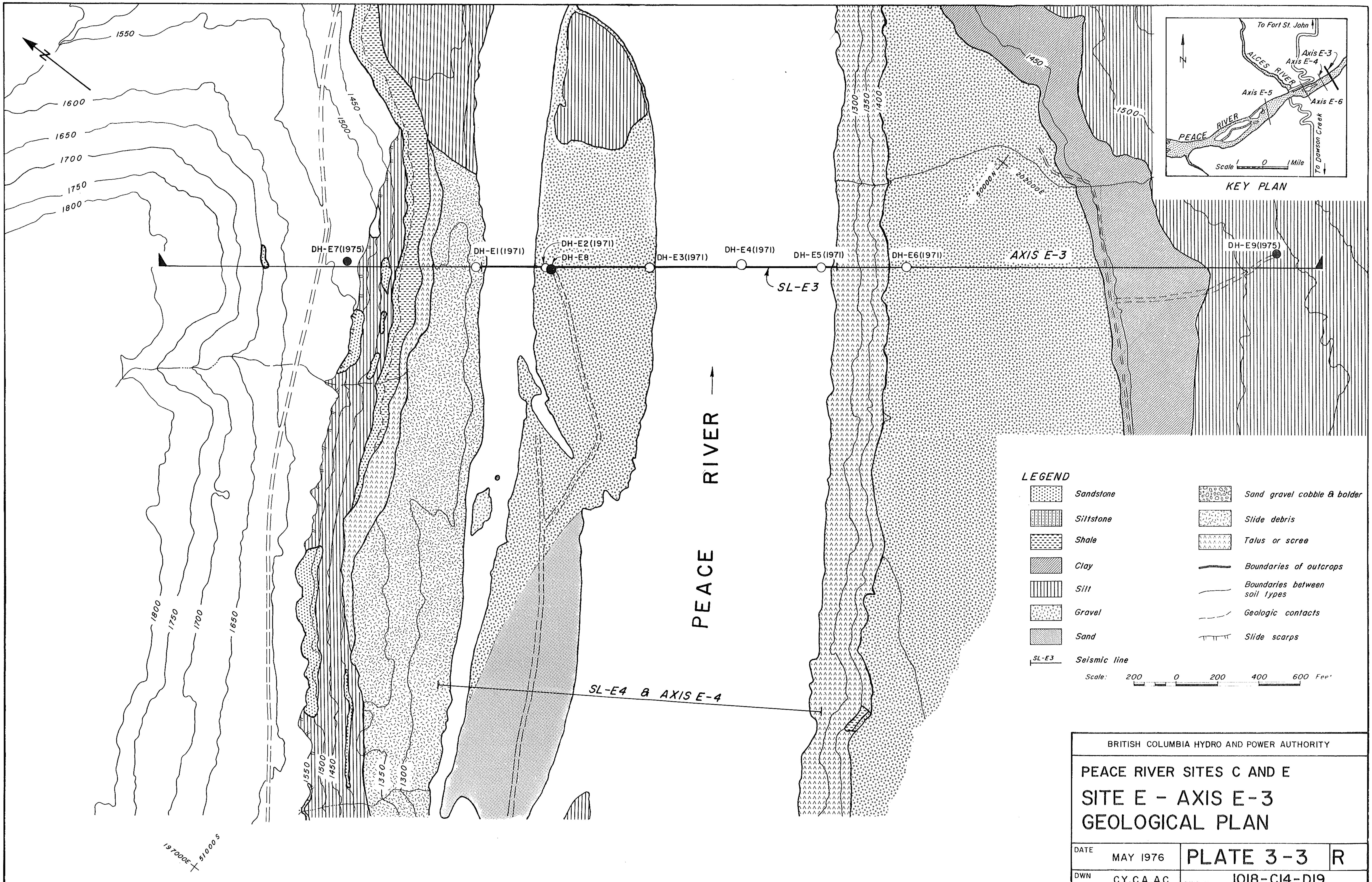
PEACE RIVER SITES C AND E

SITE C-AXIS C-3
SECTIONS & GRAPHIC DRILLHOLE LOGS

DATE APRIL 1976 | PLATE 3-2 | R

DWN AC CA | DWG No. 1016-C14-U105

REPORT No. 796



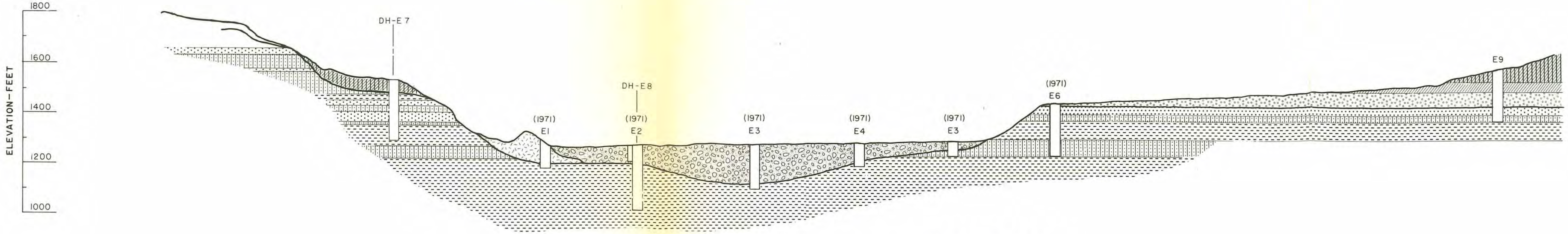
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

SITE E - AXIS E-3 GEOLOGICAL PLAN

DATE	MAY 1976	PLATE 3-3	R
DWN	C.Y., C.A., A.C.	DWG No. 1018-C14-D19	

REPORT No. 796



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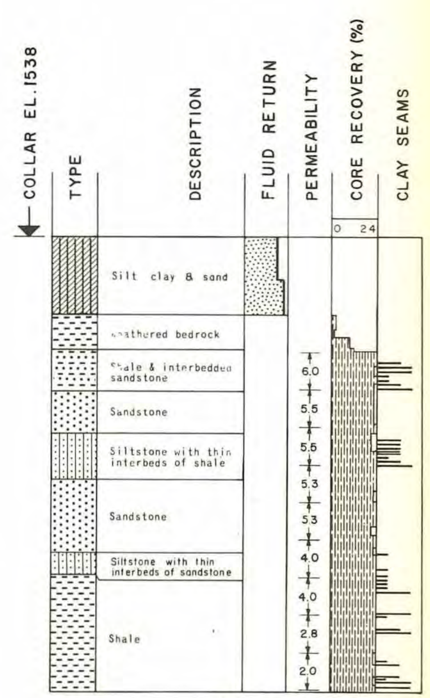

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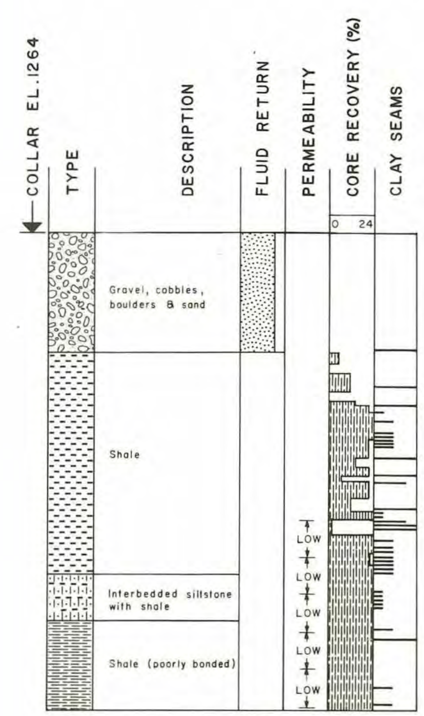

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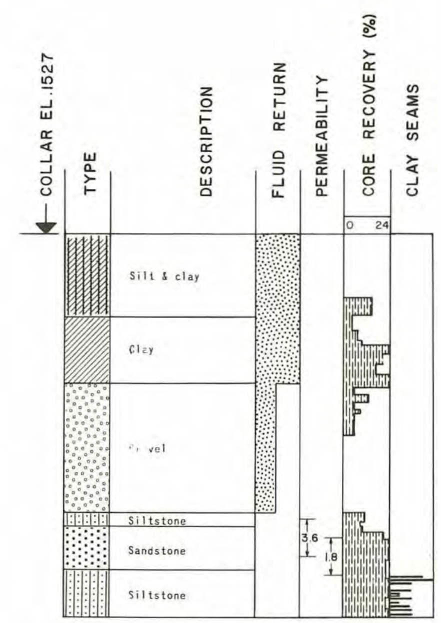


DH E-9

Section
Scale: 2

Graphic dr
Scale: 5

BRI

PEACE

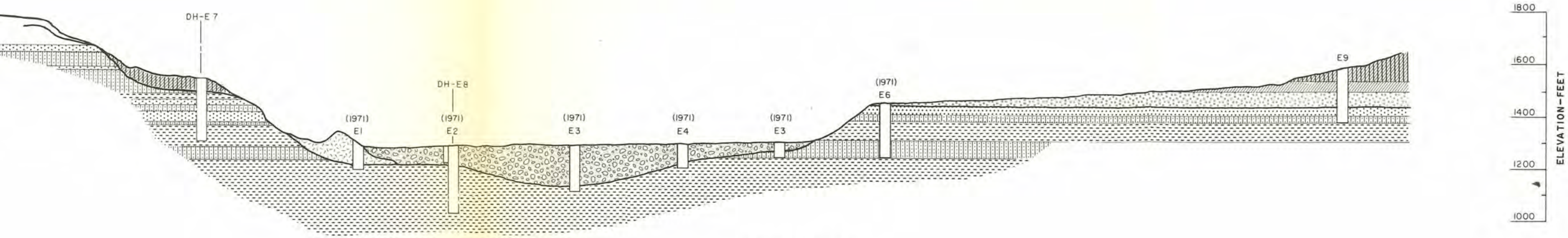
SITE

SECT

DATE APR

DWN C.A.

REPORT No



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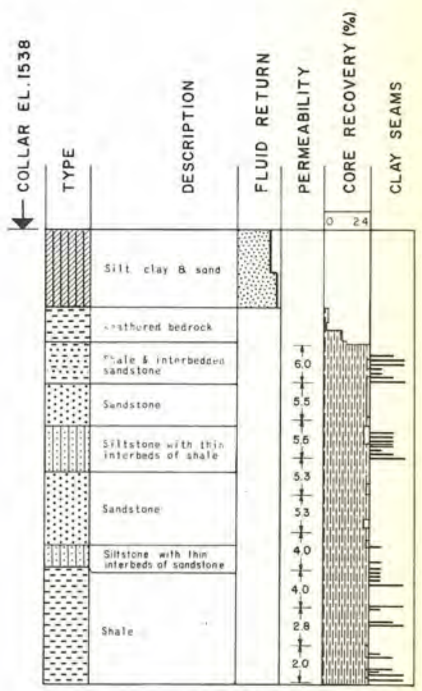

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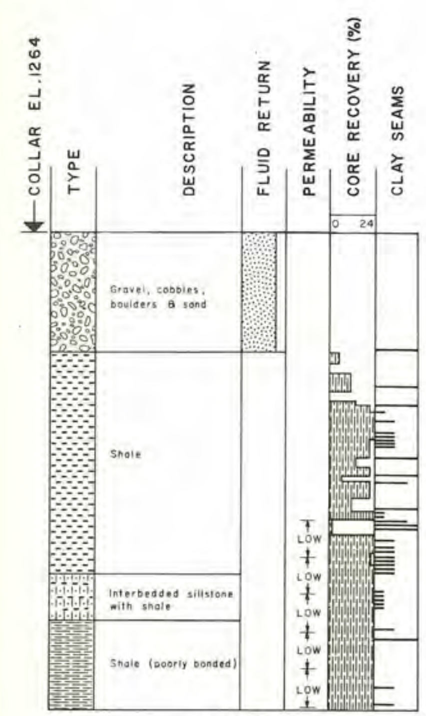

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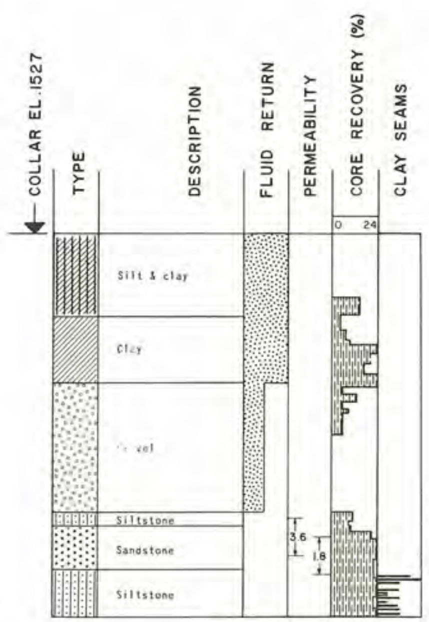


DH E-9

NOTES:

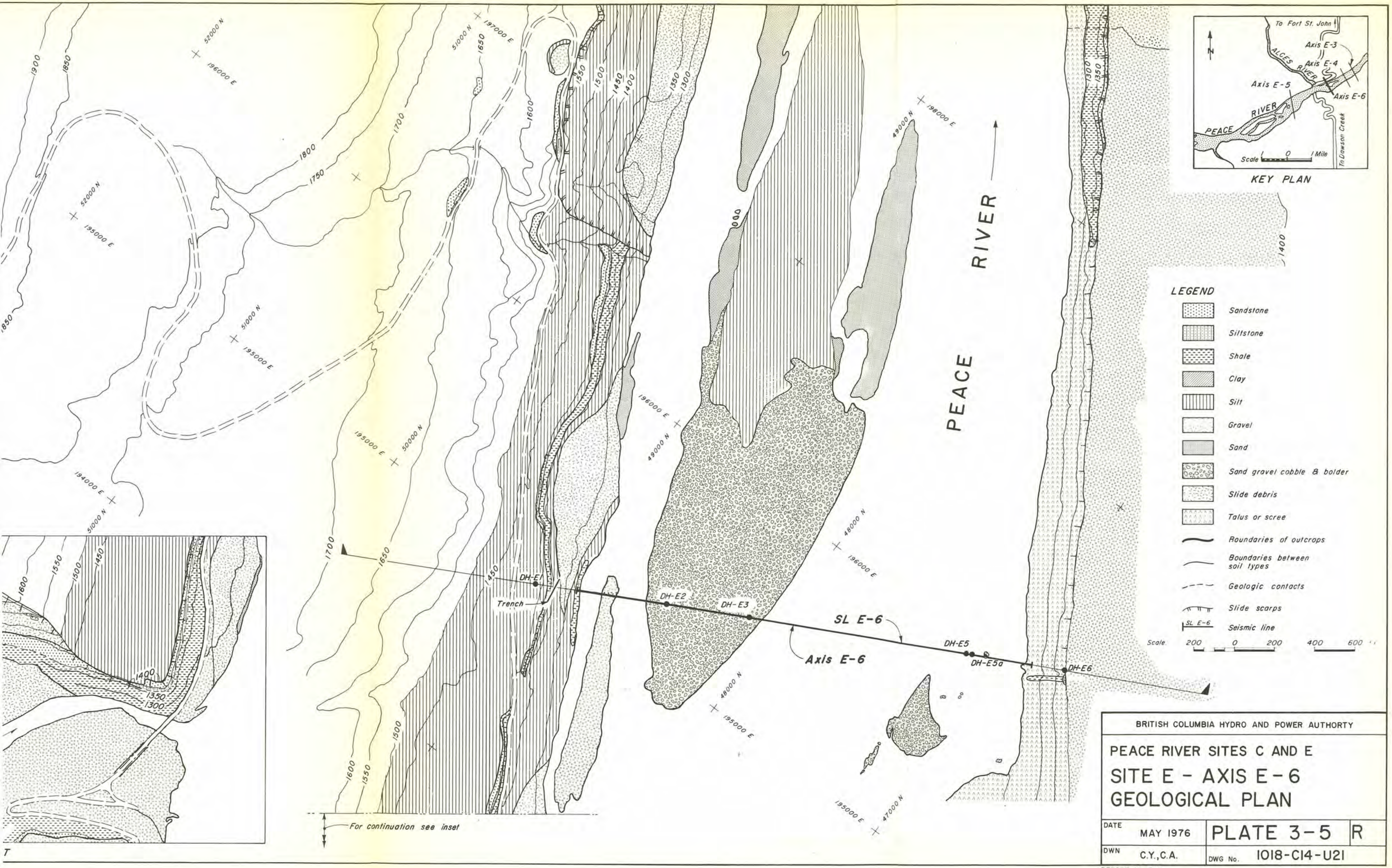
1. DRILL LOGS OF 1971 DRILLHOLES CAN BE FOUND IN "PEACE RIVER AREA - POWER DEVELOPMENT STUDIES BETWEEN SITE 1 AND ALBERTA BORDER." FEASIBILITY STUDY I.P.E.C., 1972.

Section Scale: 200 0 200 400 600 Feet

Graphic drillhole logs Scale: 50 0 50 100 150 Feet

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY	
PEACE RIVER SITES C AND E	
SITE E-AXIS E-3 SECTION & GRAPHIC DRILLHOLE LOGS	
DATE APRIL 1976	PLATE 3-4 R
DWN C.A., A.C.	DWG No. 1018 - C14 - U20

REPORT No 796



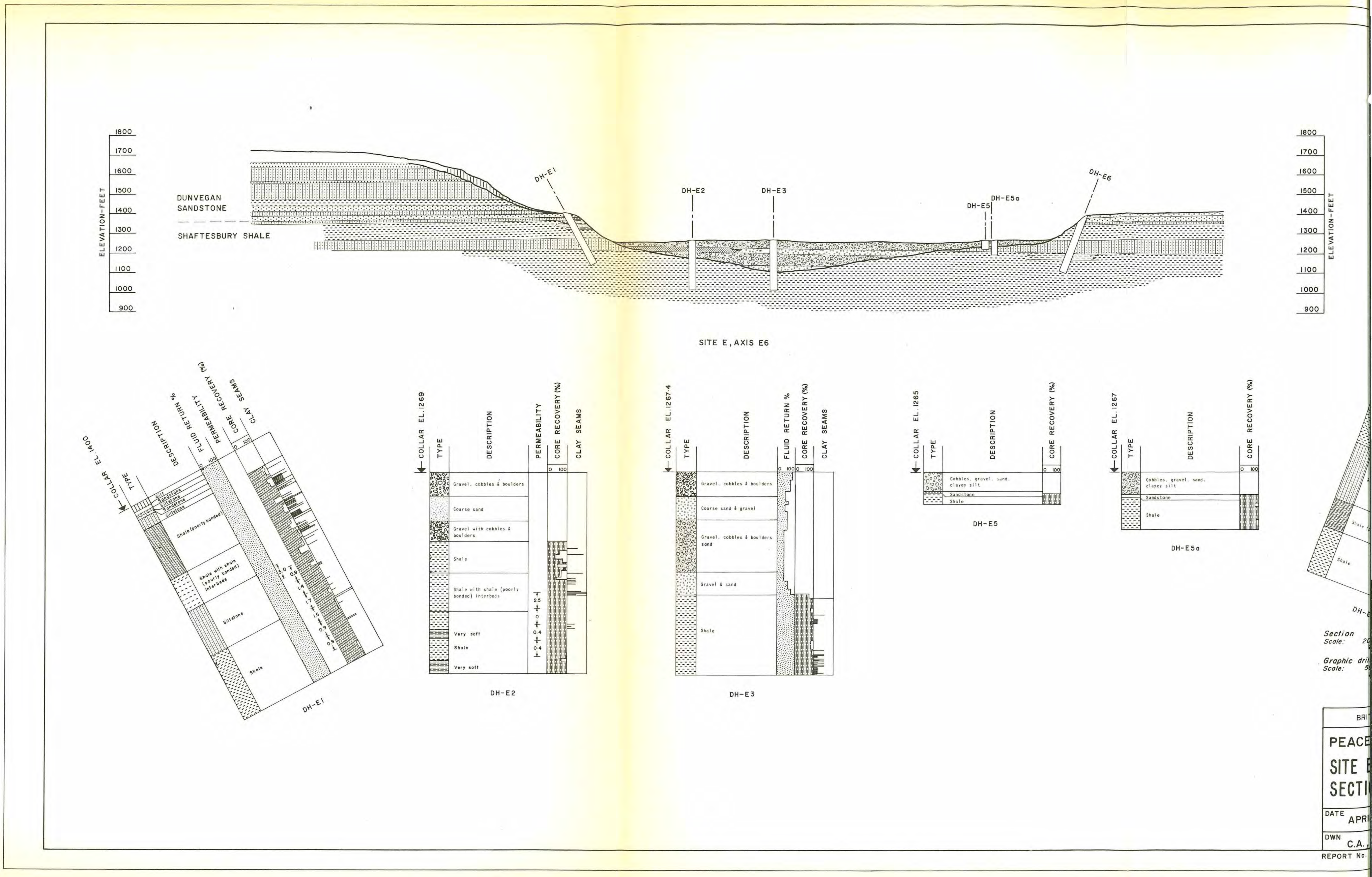
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

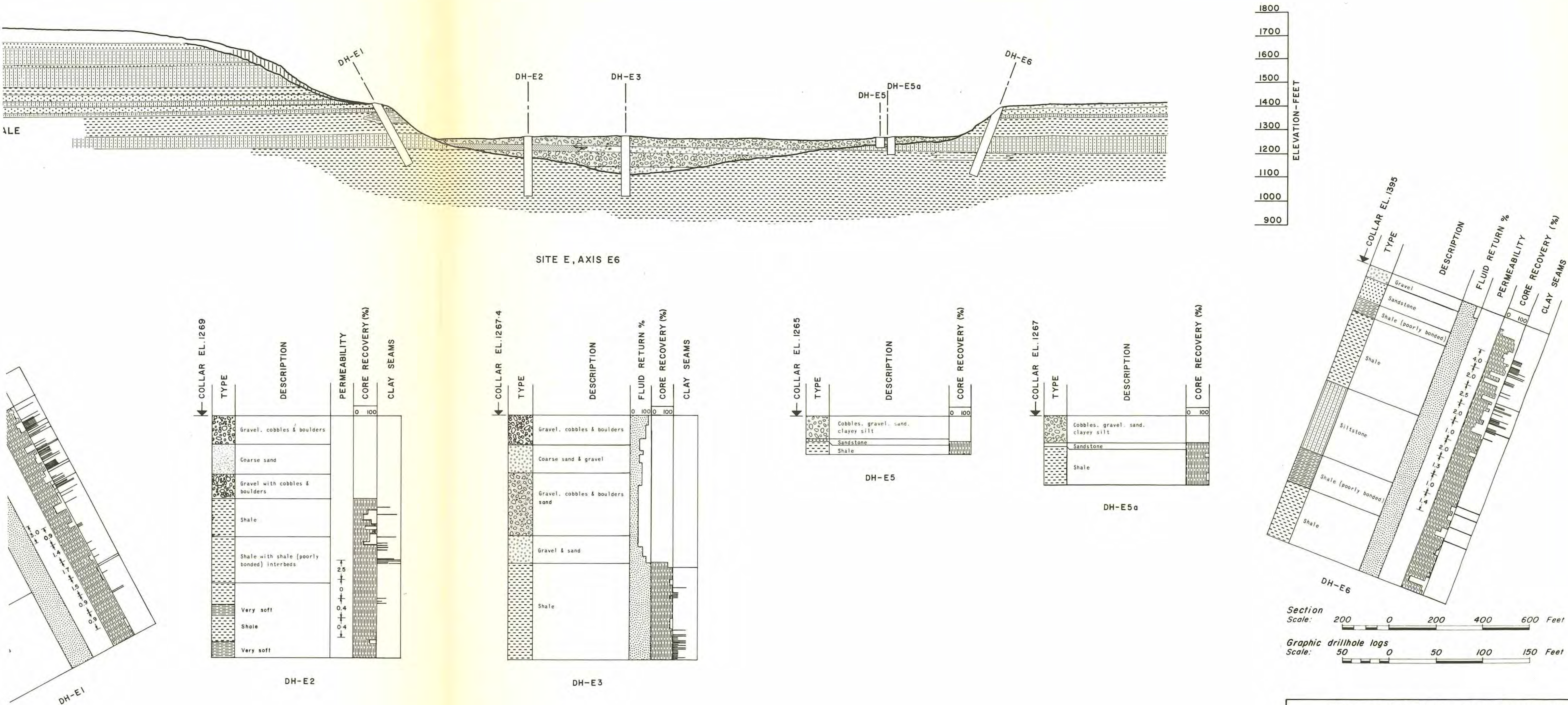
SITE E - AXIS E-6 GEOLOGICAL PLAN

DATE MAY 1976	PLATE 3-5	R
DWN C.Y., C.A.	DWG No. 1018-C14-U21	

REPORT No. 796



ELEVATION-FEET
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
DUNVEGAN SANDSTONE
SHAFTESBURY SHALE
DH-E1
DH-E2
DH-E3
DH-E5
DH-E5a
DH-E6
SITE E, AXIS E6
COLLAR EL. 1400
TYPE
DESCRIPTION
FLUID RETURN %
PERMEABILITY (%)
CORE RECOVERY
CLAY SEAMS
Silt
Sandstone
Siltstone
Sandstone
Siltstone
Shale (poorly bonded)
Shale with shale (poorly bonded) interbeds
Siltstone
Shale
DH-E1
COLLAR EL. 1269
TYPE
DESCRIPTION
PERMEABILITY
CORE RECOVERY (%)
CLAY SEAMS
Gravel, cobbles & boulders
Coarse sand
Gravel with cobbles & boulders
Shale
Shale with shale (poorly bonded) interbeds
Very soft
Shale
Very soft
DH-E2
COLLAR EL. 1267.4
TYPE
DESCRIPTION
FLUID RETURN %
CORE RECOVERY (%)
CLAY SEAMS
Gravel, cobbles & boulders
Coarse sand & gravel
Gravel, cobbles & boulders sand
Gravel & sand
Shale
DH-E3
COLLAR EL. 1265
TYPE
DESCRIPTION
CORE RECOVERY (%)
Cobbles, gravel, sand, clayey silt
Sandstone
Shale
DH-E5
COLLAR EL. 1267
TYPE
DESCRIPTION
CORE RECOVERY (%)
Cobbles, gravel, sand, clayey silt
Sandstone
Shale
DH-E5a
Section
Scale:
Graphic dril
Scale:
BRIT
PEACE
SITE
SECTI
DATE
APRI
DWN
C.A.
REPORT No.



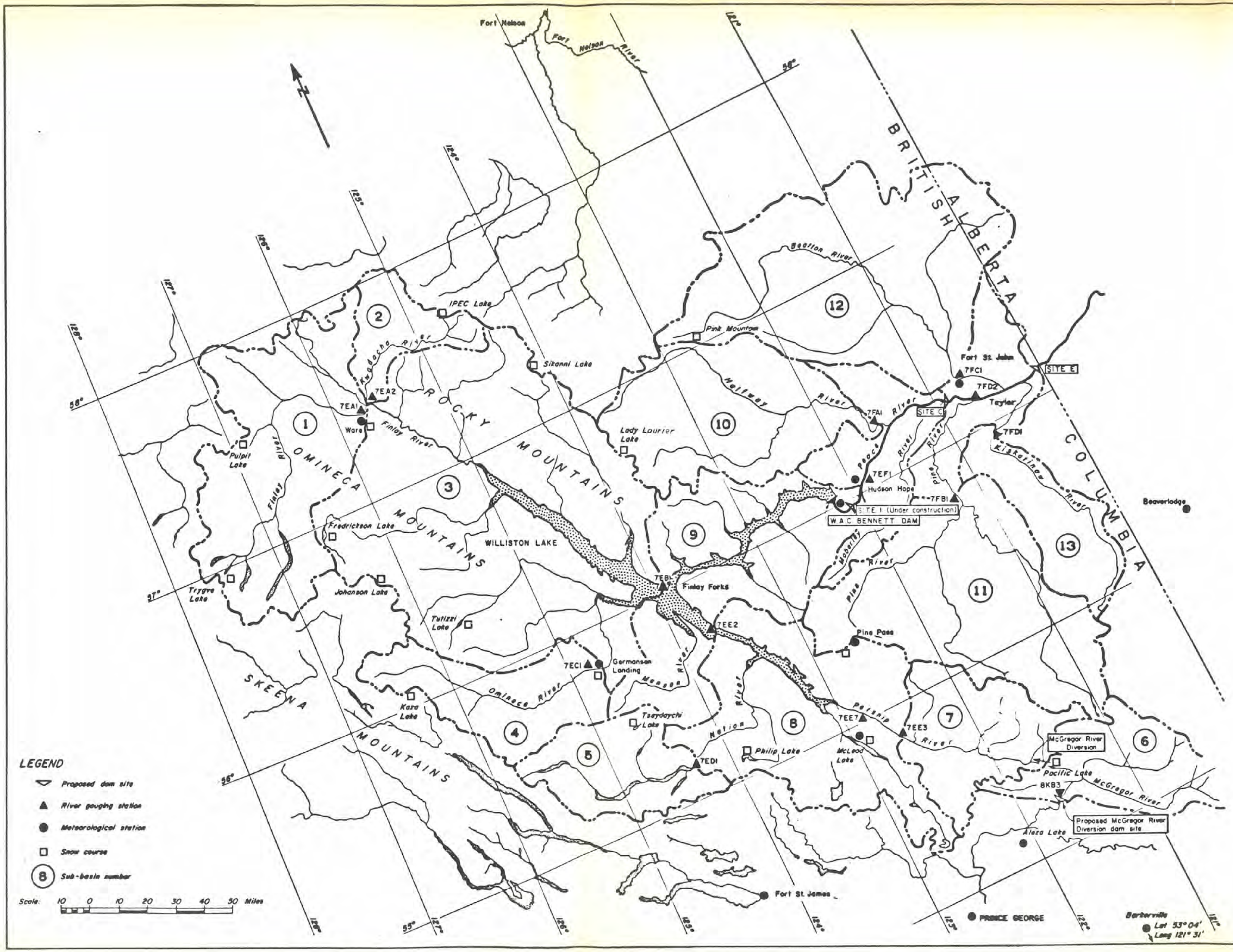
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

SITE E-AXIS E-6
SECTIONS & GRAPHIC DRILLHOLE LOGS

DATE APRIL 1976	PLATE 3-6 R
DWN C.A., A.C.	DWG No. 1018 - C14 - U22

REPORT No. 796



SELECTED GAUGING STATI

STATION	W.S.C. No.
Finlay River at Ware	7EA1
Kwadacha at Ware	7EA2
Finlay River at Finlay Forks	7EB1
Omineca River at Germansen Landing	7EC1
Nation River near Ft St. James	7ED1
Parsnip River at PGE Bridge	7EE3
Parsnip River above Misinchinka	7EE7
Parsnip River near Finlay Forks	7EE2
Peace River at Hudson Hope	7EF1
Halfway River near Farrell Creek	7FA1
Pine River near East Pine	7FB1
Kiskatinaw River near Farmington	7FD1
Beatton River near Ft. St John	7FC1
McGregor River at Lower Canyon	8KB3
Peace River near Taylor	7FD2

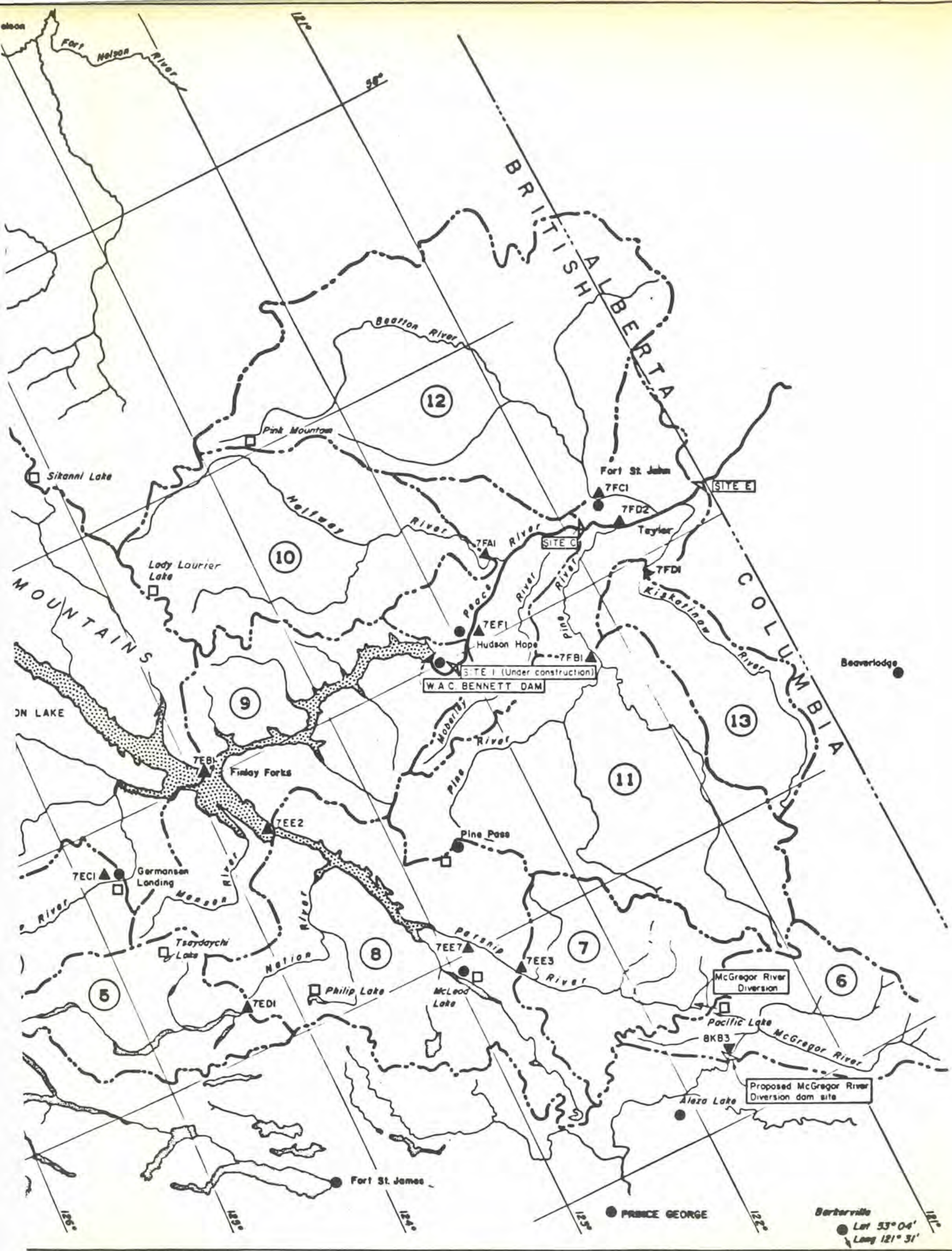
SELECTED METEOROLOGICAL

STATION		ELEV IN FEET
Aleza Lake	T, P	2050
Prince George	T, P	2218
Barkerville	T, P	4180
Hudson Hope	T, P	1552/1606
Hudson Hope PMD	T, P	2260
Germansen Landing	T, P	2450
Ware	T, P	2550
Pine Pass	T, P	3060
McLeod Lake	T, P	2310
Fort St. John	T, P	2210/2275
Fort St. James	T, P	2280
Beaverlodge	E	2500

SELECTED SNOW COURSES *

STATION	No.	ELEV IN FEET
McLeod Lake	110	3200
Pine Pass	117	4700
Upper Ware	118	5150
Lower Ware	119	3200
Upper Germansen Landing	120	4930
Lower Germansen Landing	188	2450
Pacific Lake	131	2540
Tutizzi Lake	132	3500
Johansen Lake	133	5050
Sikanni Lake	134	4600
Lady Laurier Lake	135	4800
IPEC Lake	136	4300
Pulpit Lake	137	4300
Frederickson Lake	138	4300
Trygve Lake	139	4600
Kaza Lake	140	3900
Tsaydaychi Lake	141	3800
Philip Lake	142	3200
Pink Mountain	146	3850

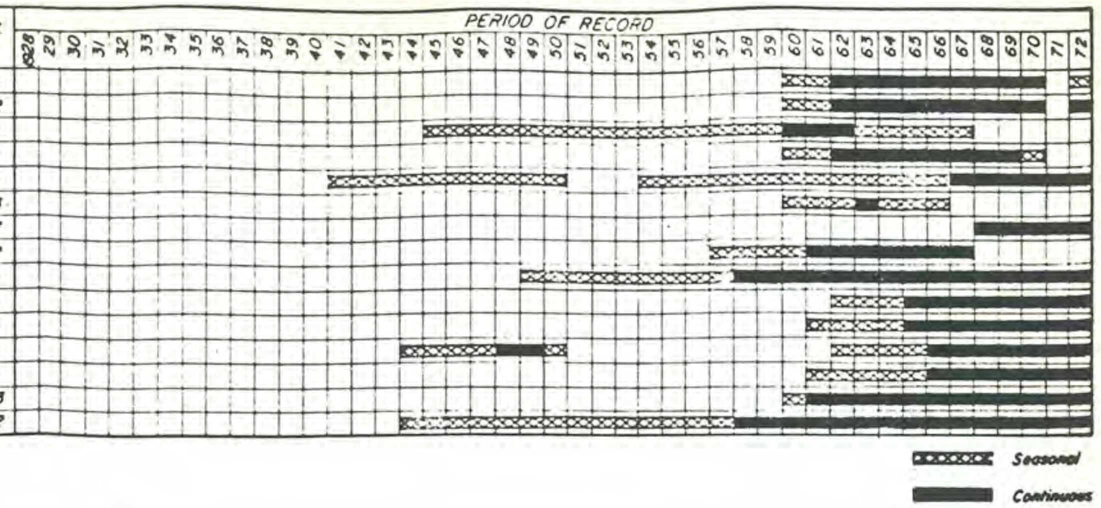
* NOTE 7 Courses in Lower Peace Basin were establi
However these records were not utilized in the
study.



SELECTED GAUGING STATIONS ON PEACE RIVER SYSTEM

STATION	W.S.C. No.
Finlay River at Ware	7EA1
Kwadacha at Ware	7EA2
Finlay River at Finlay Forks	7EB1
Omineca River at Germansen Landing	7EC1
Nation River near Ft. St. James	7ED1
Parsnip River at PGE Bridge	7EE3
Parsnip River above Misinchinka	7EE7
Parsnip River near Finlay Forks	7EE2
Peace River at Hudson Hope	7EF1
Halfway River near Farrell Creek	7FA1
Pine River near East Pine	7FB1
Kiskatinaw River near Farmington	7FD1
Beatton River near Ft. St. John	7FC1
McGregor River at Lower Canyon	8KB3
Peace River near Taylor	7FD2

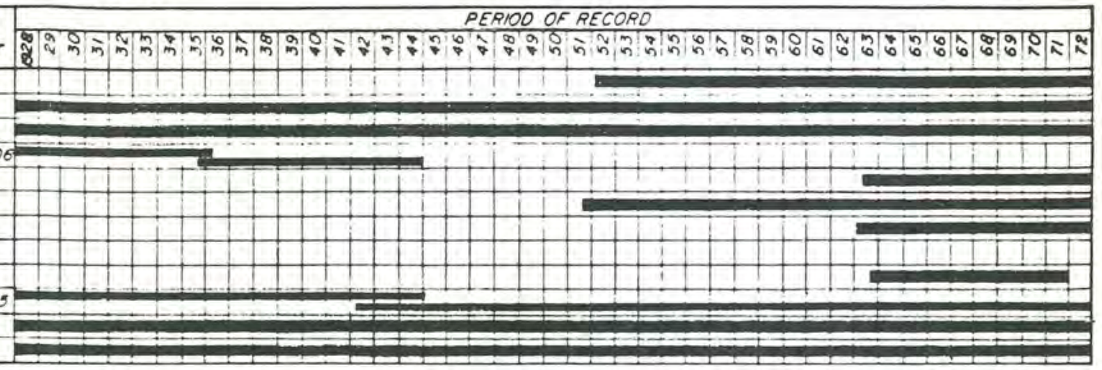
PERIOD OF RECORD



SELECTED METEOROLOGICAL STATIONS

STATION		ELEV IN FEET
Aleza Lake	T, P	2050
Prince George	T, P	2218
Barkerville	T, P	4180
Hudson Hope	T, P	1552/1606
Hudson Hope PMD	T, P	2260
Germansen Landing	T, P	2450
Ware	T, P	2550
Pine Pass	T, P	3060
McLeod Lake	T, P	2310
Fort St. John	T, P	2210/2275
Fort St. James	T, P	2280
Beaverlodge	E	2500

PERIOD OF RECORD



T - Temperature
P - Precipitation
E - Evaporation

SELECTED SNOW COURSES *

STATION	No.	ELEV IN FEET
McLeod Lake	110	3200
Pine Pass	117	4700
Upper Ware	118	5150
Lower Ware	119	3200
Upper Germansen Landing	120	4930
Lower Germansen Landing	188	2450
Pacific Lake	131	2540
Tutizzi Lake	132	3500
Johansen Lake	133	5050
Sikanni Lake	134	4600
Lady Laurier Lake	135	4800
IPEC Lake	136	4300
Pulpit Lake	137	4300
Frederickson Lake	138	4300
Trygve Lake	139	4600
Kaza Lake	140	3900
Tsaydaychi Lake	141	3800
Philip Lake	142	3200
Pink Mountain	146	3850

PERIOD OF RECORD

* NOTE 7 Courses in Lower Peace Basin were established in 1973 However these records were not utilized in the current study.

SUB-BASIN NUMBERS

SUB-BASIN	NUMBER	SUB-BASIN	NUMBER
Finlay. Ware	1	Parsnip. PGE	7
Kwadacha	2	Parsnip. Local	8
Finlay. Local	3	Peace. Local	9
Omineca	4	Halfway	10
Nation	5	Pine	11
McGregor	6	Beatton	12
		Kiskatinaw	13

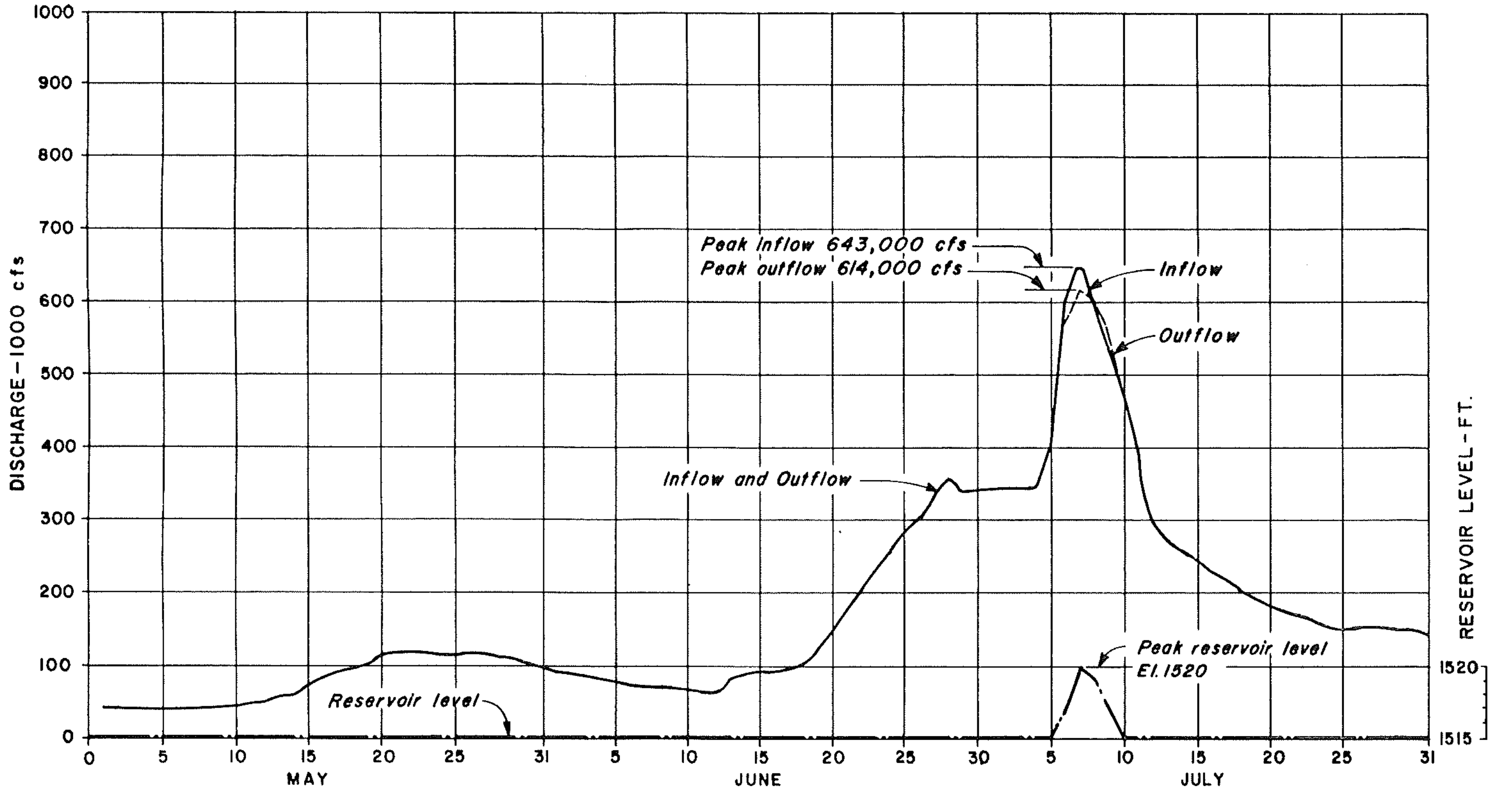
NOTE: The ungauged areas between Peace River at Hudson Hope and Site C, and between Site C and Site E were sub-divided into areas north and south of the Peace River

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

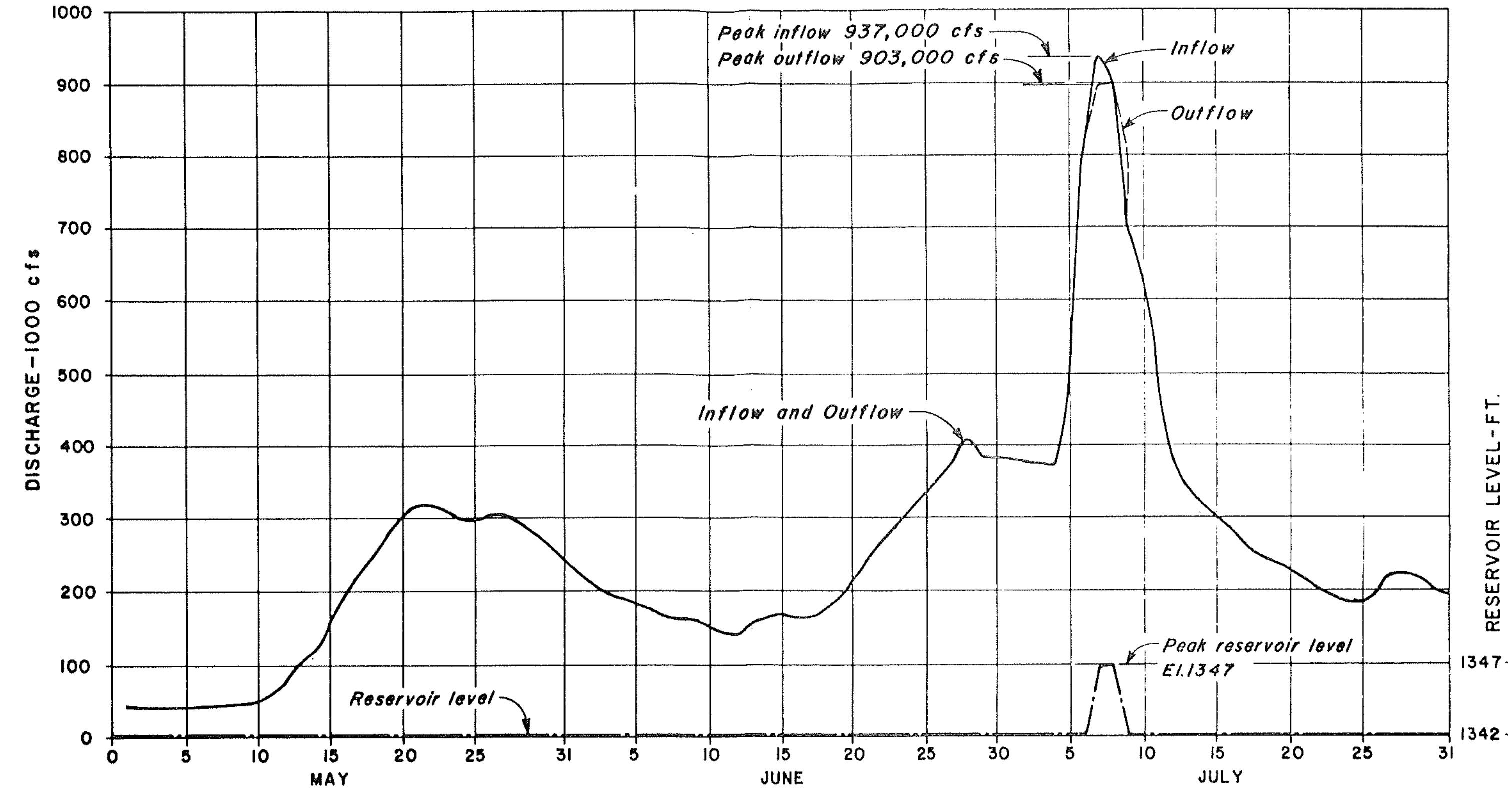
PEACE RIVER SITES C AND E
LOCATION MAP FOR SUB-BASINS, STREAMFLOW STATIONS, METEOROLOGICAL STATIONS & SNOW COURSES

DATE MAY 1976 | PLATE 4-1
DWN D.B.G. | DWG No 1016-C14-C106

REPORT No 796



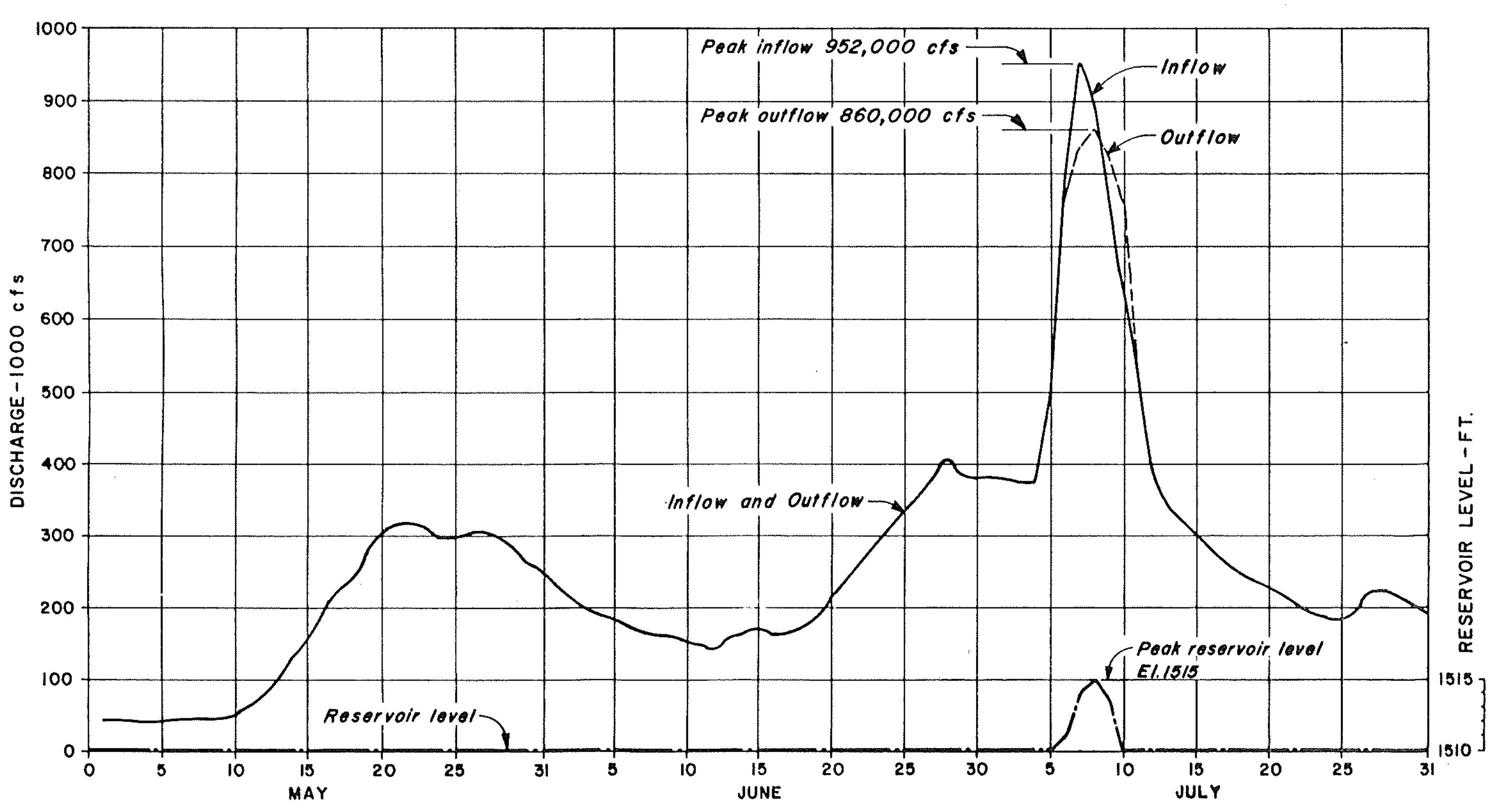
SITE C (1515)



SITE E (1342)

NOTE:

FOR SITE E (1352) INFLOWS AND OUTFLOWS WOULD BE THE SAME AS FOR SITE E (1342) AND RESERVOIR LEVELS WOULD BE TEN FEET HIGHER.



SITE E (1510)

NOTE:

HYDROGRAPHS OF INFLOWS AND OUTFLOWS SHOWN HERE WERE TAKEN FROM COMPUTER FLOOD ROUTING OUTPUT. HOWEVER, THE RESERVOIR LEVELS SHOWN WERE ADJUSTED FROM THE FLOOD ROUTING RESULTS IN ACCORDANCE WITH CHANGES MADE TO SPILLWAY CREST LEVELS AND SPILLWAY RATING CURVES SUBSEQUENT TO THE FLOOD ROUTING.

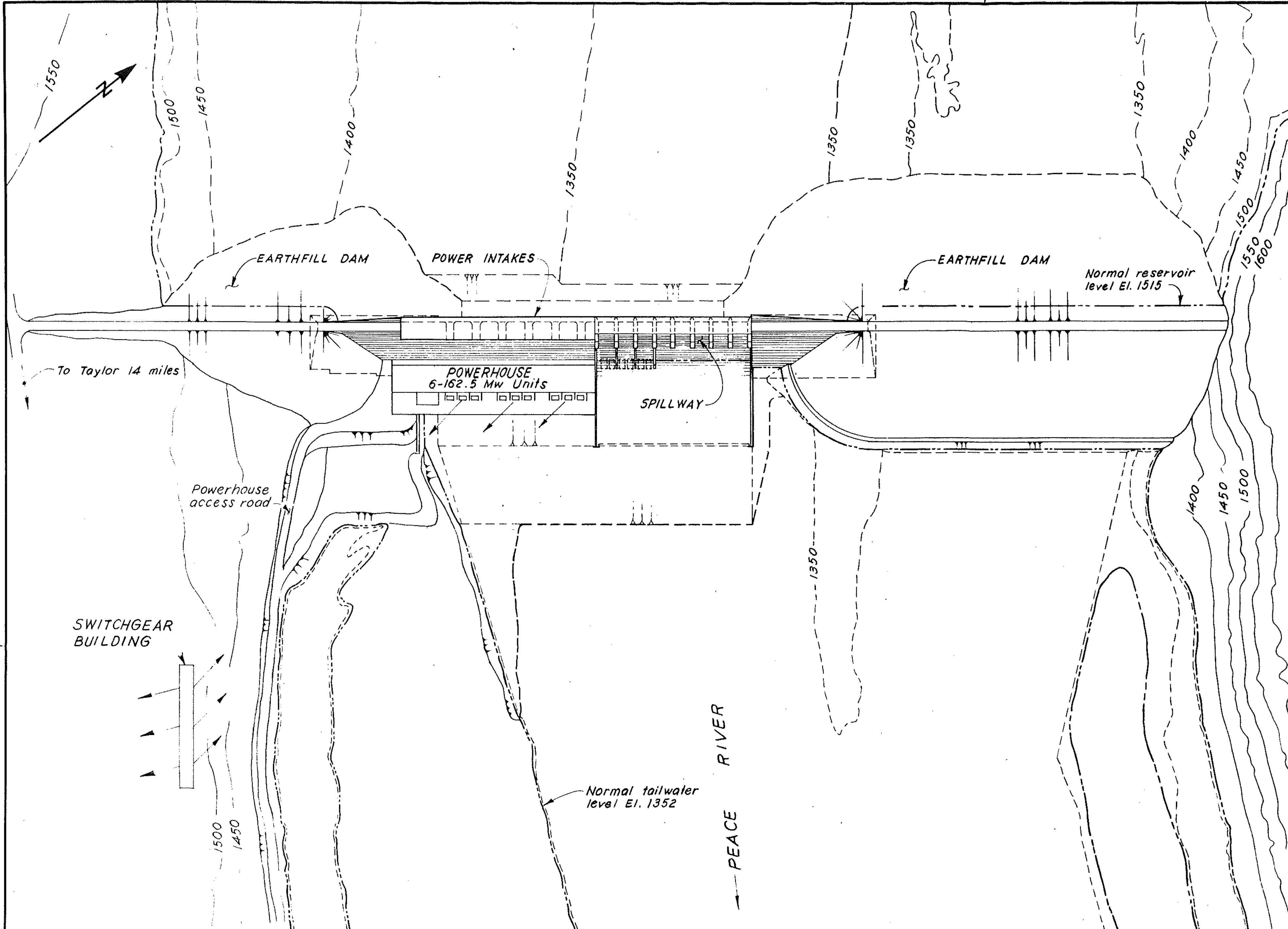
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

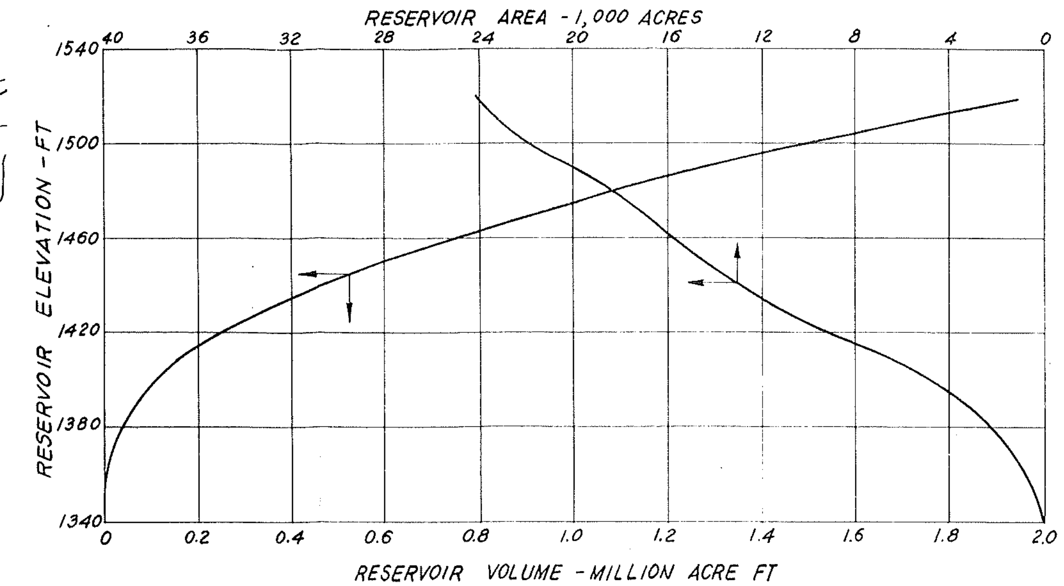
PEACE RIVER SITES C AND E

PROBABLE MAXIMUM FLOOD HYDROGRAPHS FOR SITES C AND E WITH McGREGOR RIVER DIVERSION

DATE MAY 1976	PLATE 4-2 R
DWN A.C.	DWG No. 1016-C14-D107

REPORT No. 796

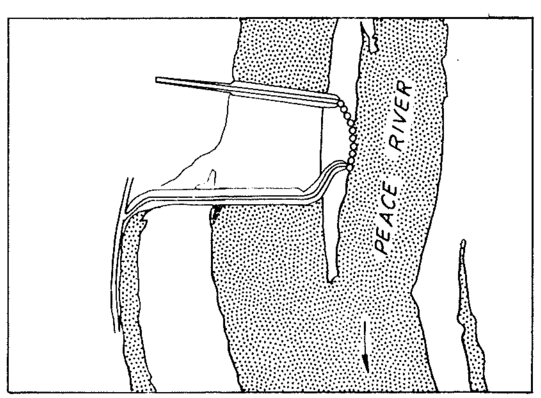




RESERVOIR AREA & VOLUME VS ELEVATION - SITE C3

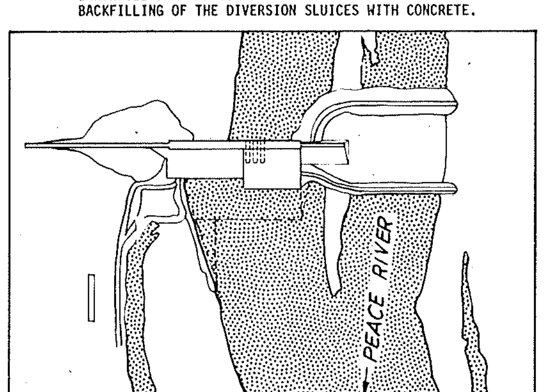
1ST STAGE

CONSTRUCTION OF 1ST STAGE COFFERDAMS. CONSTRUCTION OF THE SPILLWAY, POWERHOUSE, GRAVITY WALLS AND RIGHT EARTHFILL DAM (AT LEAST UP TO ELEVATION 1394).



2ND STAGE

REMOVAL OF 1ST STAGE COFFERDAMS AND CONSTRUCTION OF THE 2ND STAGE COFFERDAMS. CONSTRUCTION OF THE LEFT EARTHFILL DAM AND COMPLETION OF THE OTHER WORKS. BACKFILLING OF THE DIVERSION SLUICES WITH CONCRETE.



Scale: 200 0 200 400 600 Feet

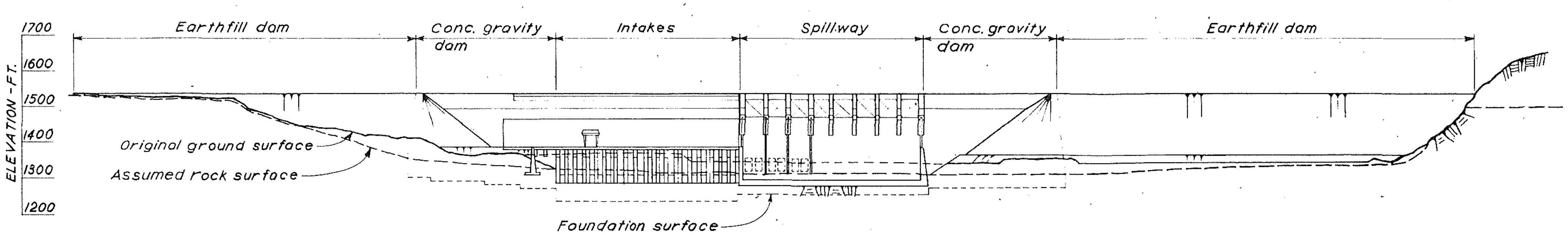
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

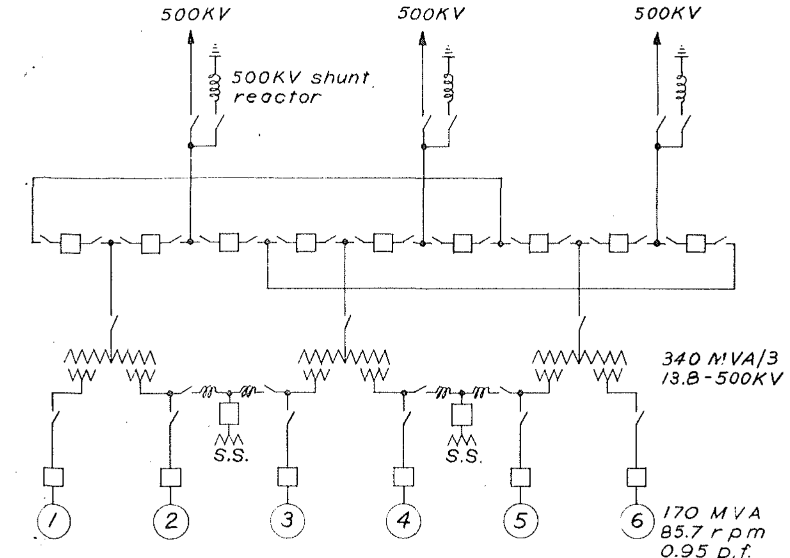
SITE C (1515) PROJECT PLAN

DATE MAY 1976	PLATE 5-1	R
DWN C.Y.	DWG No. 1016-C14-D109	

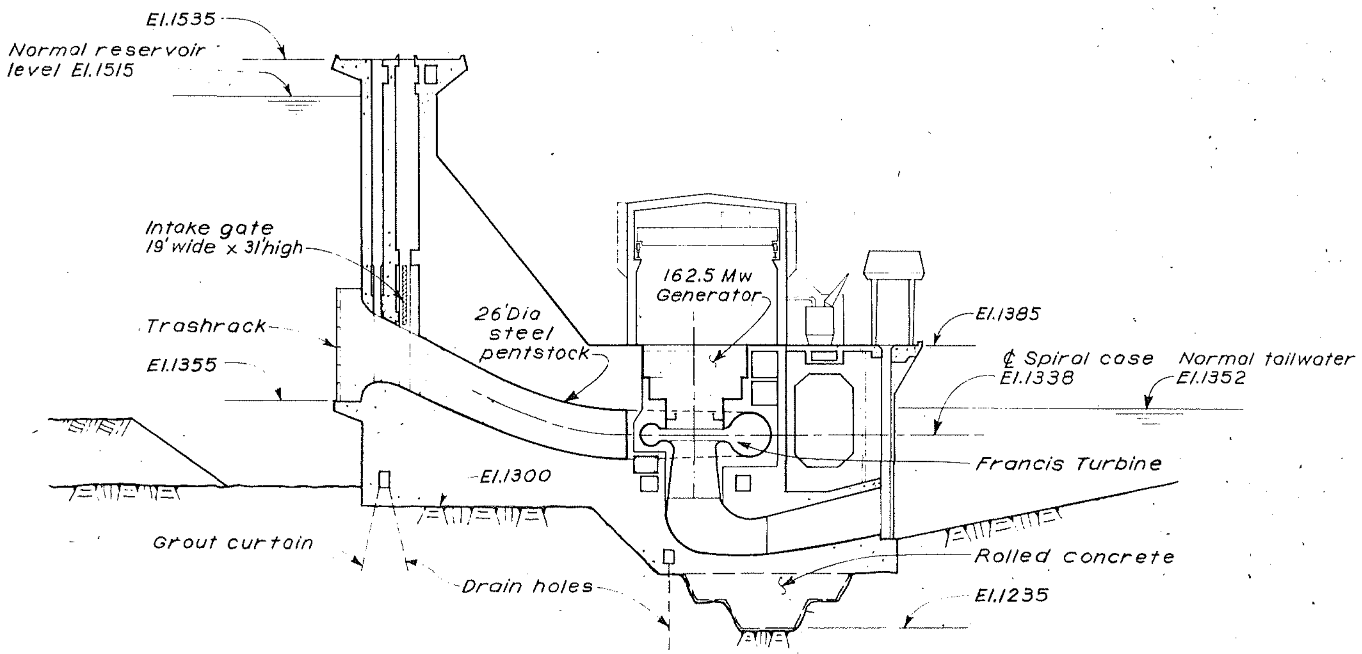
REPORT No. 796



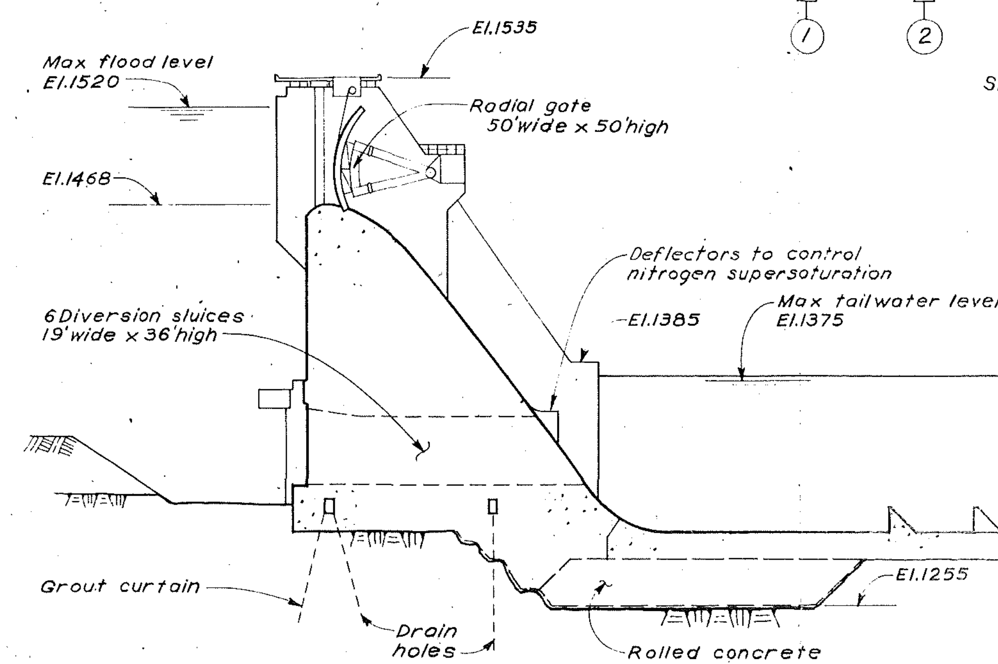
DOWNSTREAM ELEVATION
Scale A



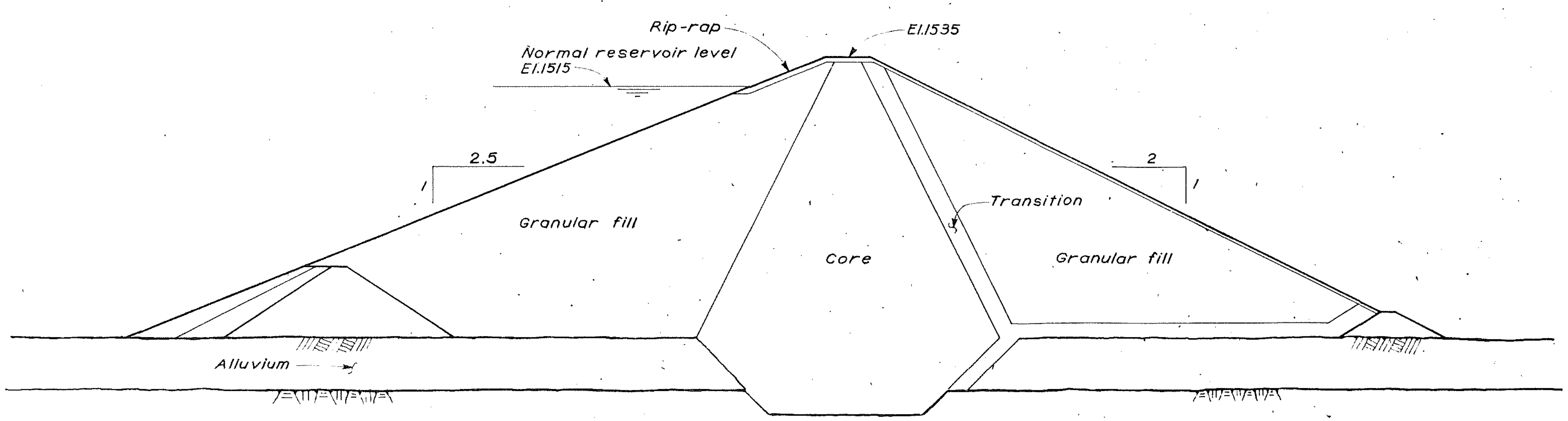
SINGLE LINE DIAGRAM



SECTION THROUGH INTAKE, PENSTOCK & POWERHOUSE
Scale B



SECTION THROUGH SPILLWAY
Scale B



SECTION THROUGH EARTHFILL DAM
Scale B

Scale A 200 0 200 400 600 Feet

Scale B 50 0 50 100 150 Feet

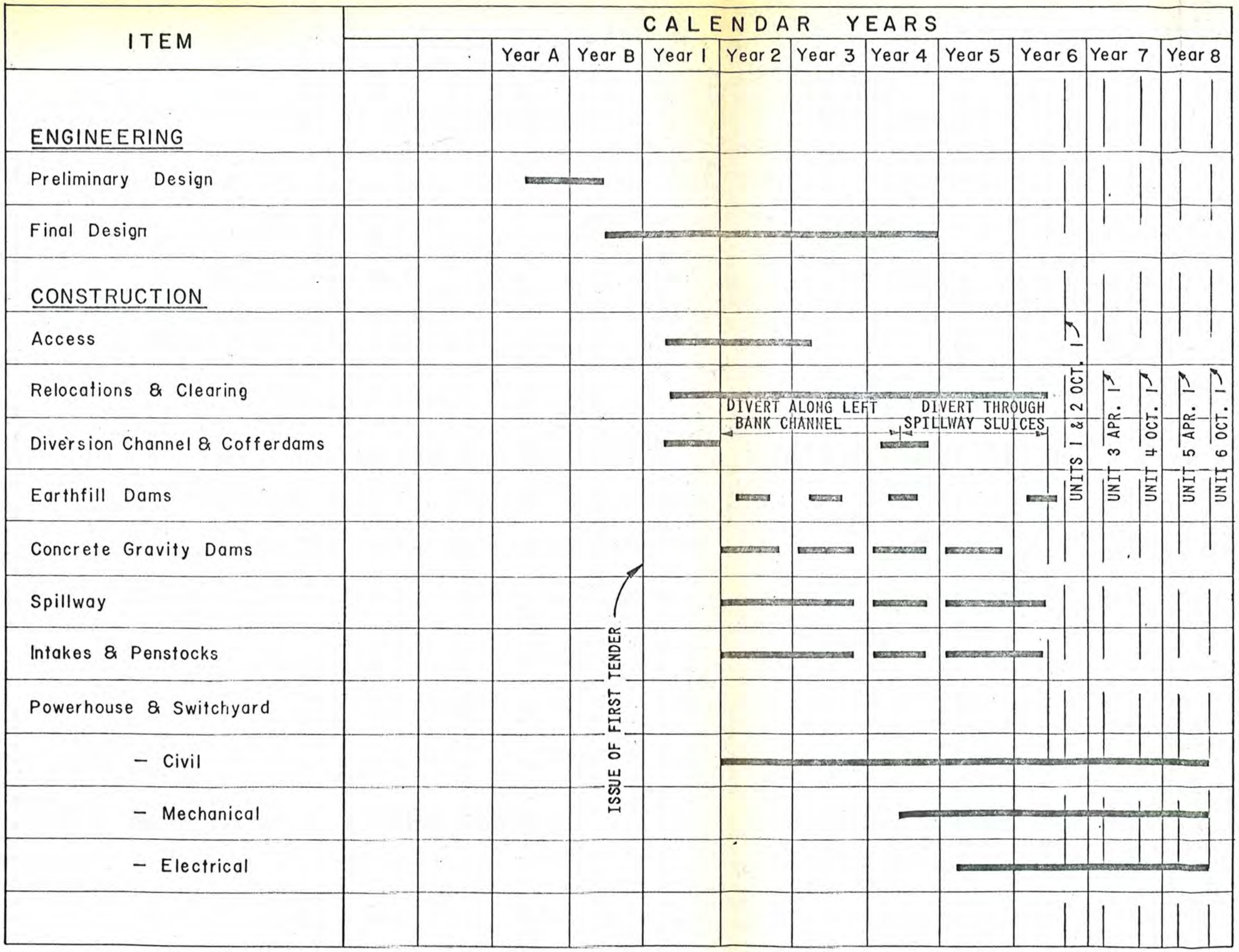
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

SITE C (1515) PROJECT
ELEVATIONS & SECTIONS

DATE MAY 1976	PLATE 5-2 R
DWN A. C.	DWG No. 1016-C14-D110

REPORT No. 796



NOTE:

POSSIBLE ADDITIONAL TIME REQUIREMENTS FOR ENVIRONMENTAL IMPACT STUDIES AND LICENSING PROCEDURES MAY LENGTHEN THE LEAD TIME THAT WOULD BE REQUIRED DURING YEARS A AND B.

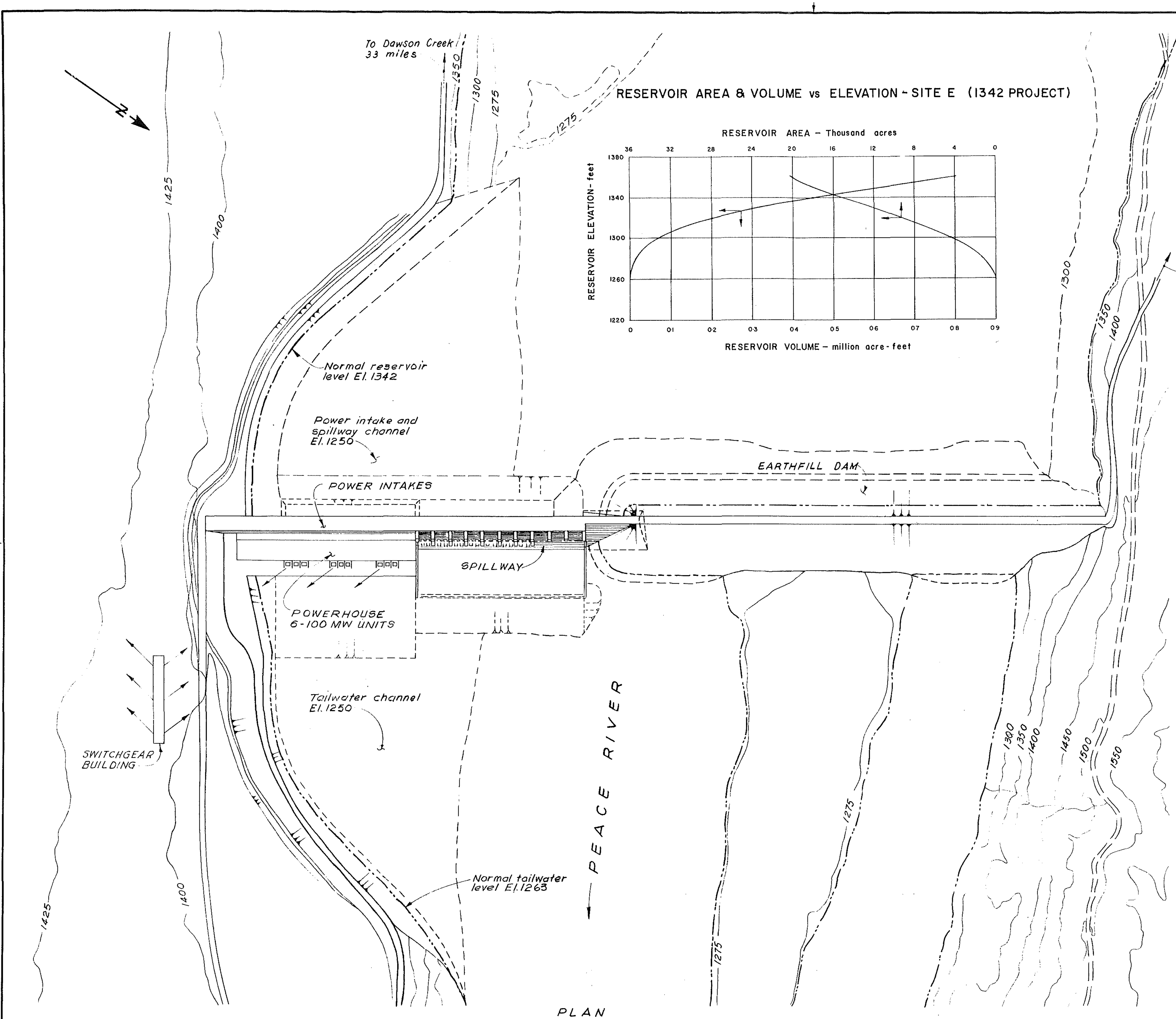
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

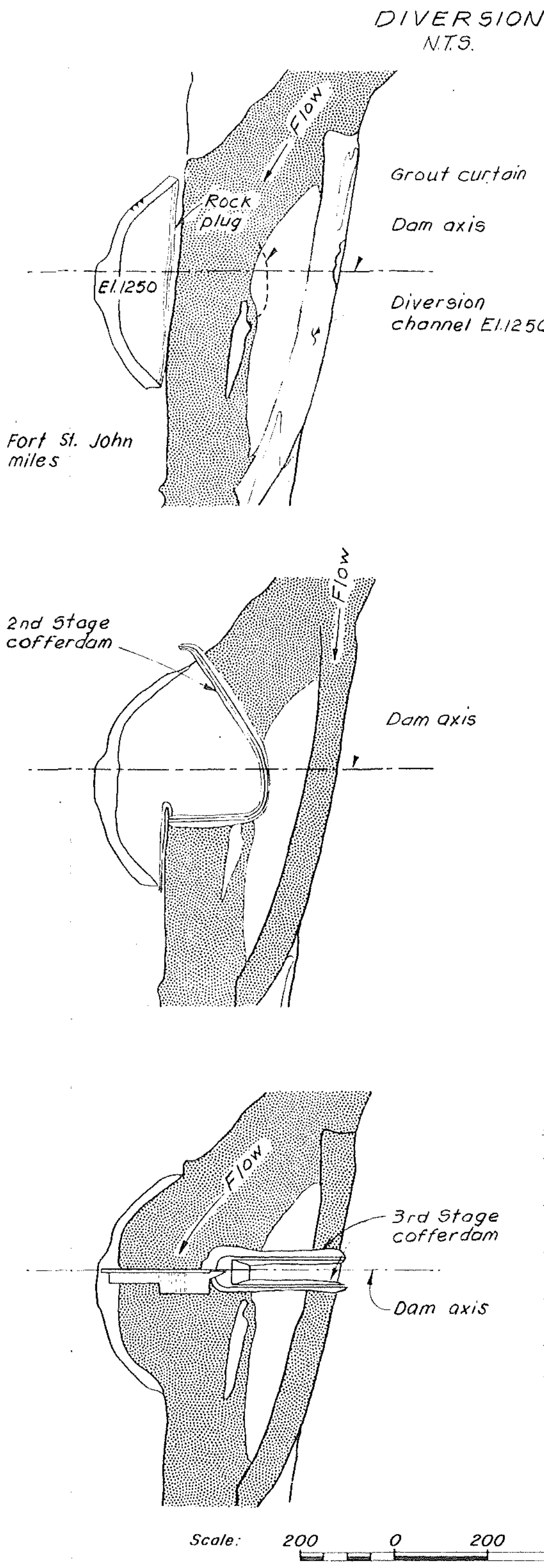
PEACE RIVER SITES C & E

SITE C (1515) PROJECT CONSTRUCTION SCHEDULE

DATE MAY 5/76	PLATE 5-3		R
DWN CA	DWG No. 1016-C14-B111		

REPORT NO 796





1ST STAGE

- powerhouse, forebay and tail-race channel excavation, behind left in place rock plug.
- excavation of diversion channel.
- construction of grout curtain.

2ND STAGE

- construction of 2nd stage cofferdam.
- removal of part of rock plug and spillway excavation.
- construction of powerhouse, spillway, gravity transition block and part of earthfill dam to El. 1304 (min.).

3RD STAGE

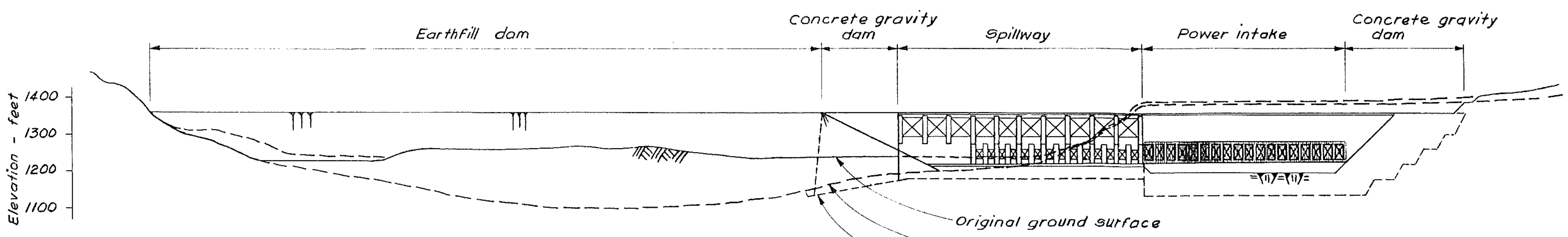
- continue powerhouse and spill-way construction.
- removal of 2nd stage cofferdam and rock plug.
- construction of 3rd stage cofferdams.
- tailrace improvement if necessary.
- construction of cut off wall.
- construction of earthfill dam.

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

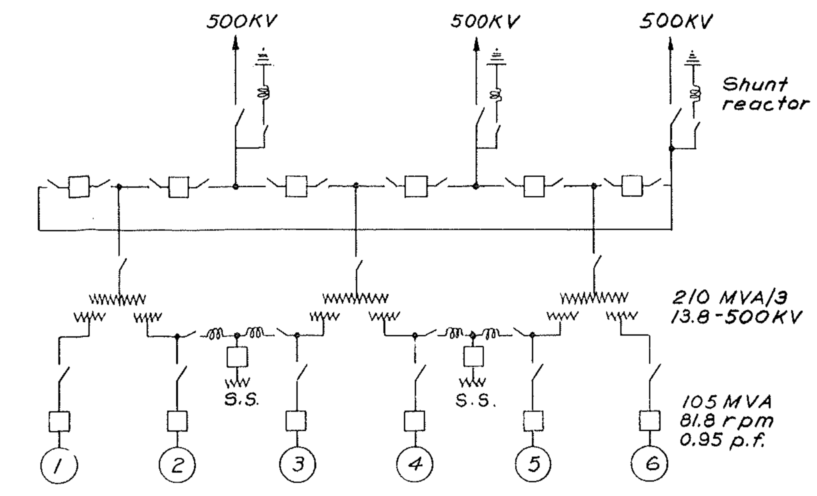
PEACE RIVER SITES C AND E

SITE E (1342) PROJECT PLAN

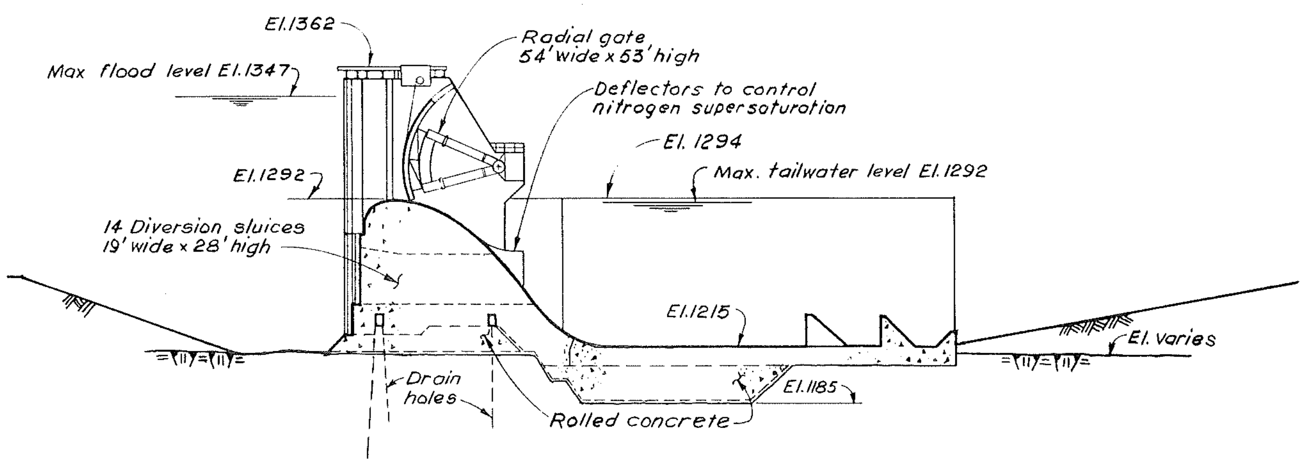
DATE MAY 1976	PLATE 6 - 1		R
DWN CY CA	DWG No. 1018-C14-D24		



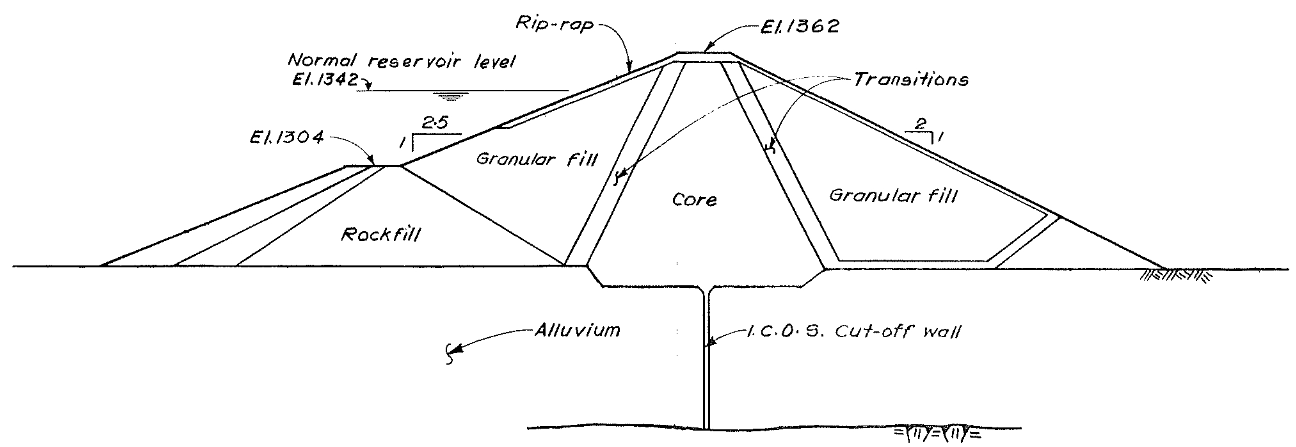
UPSTREAM ELEVATION
Scale: A



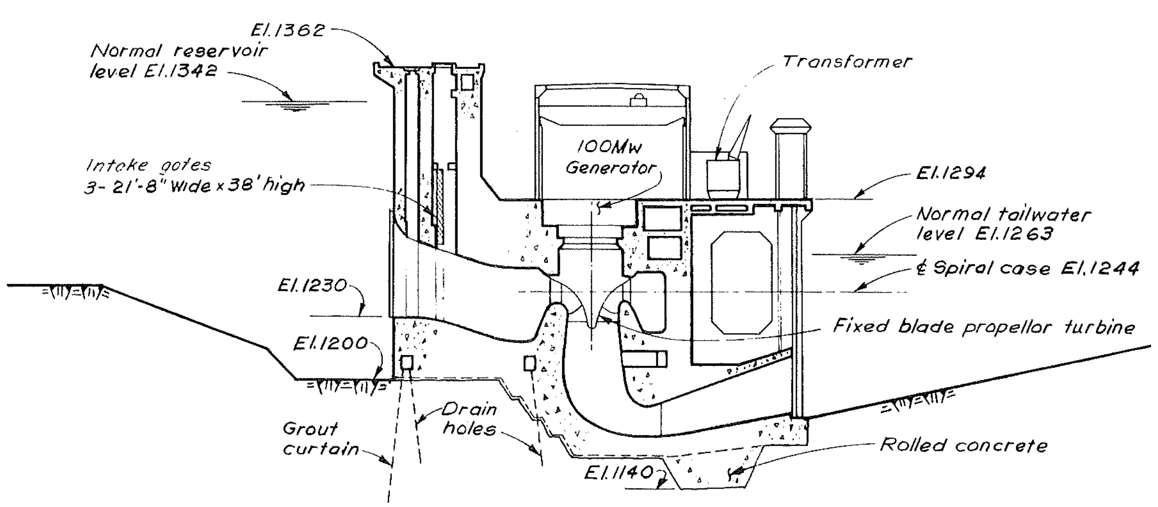
SINGLE LINE DIAGRAM



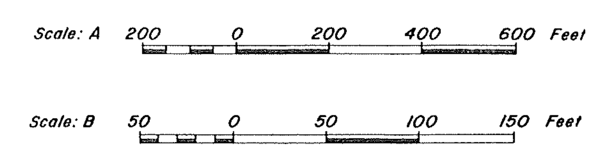
SECTION THROUGH SPILLWAY
Scale: B



SECTION THROUGH EARTHFILL DAM
Scale B



SECTION THROUGH POWER INTAKE & POWERHOUSE
Scale: B



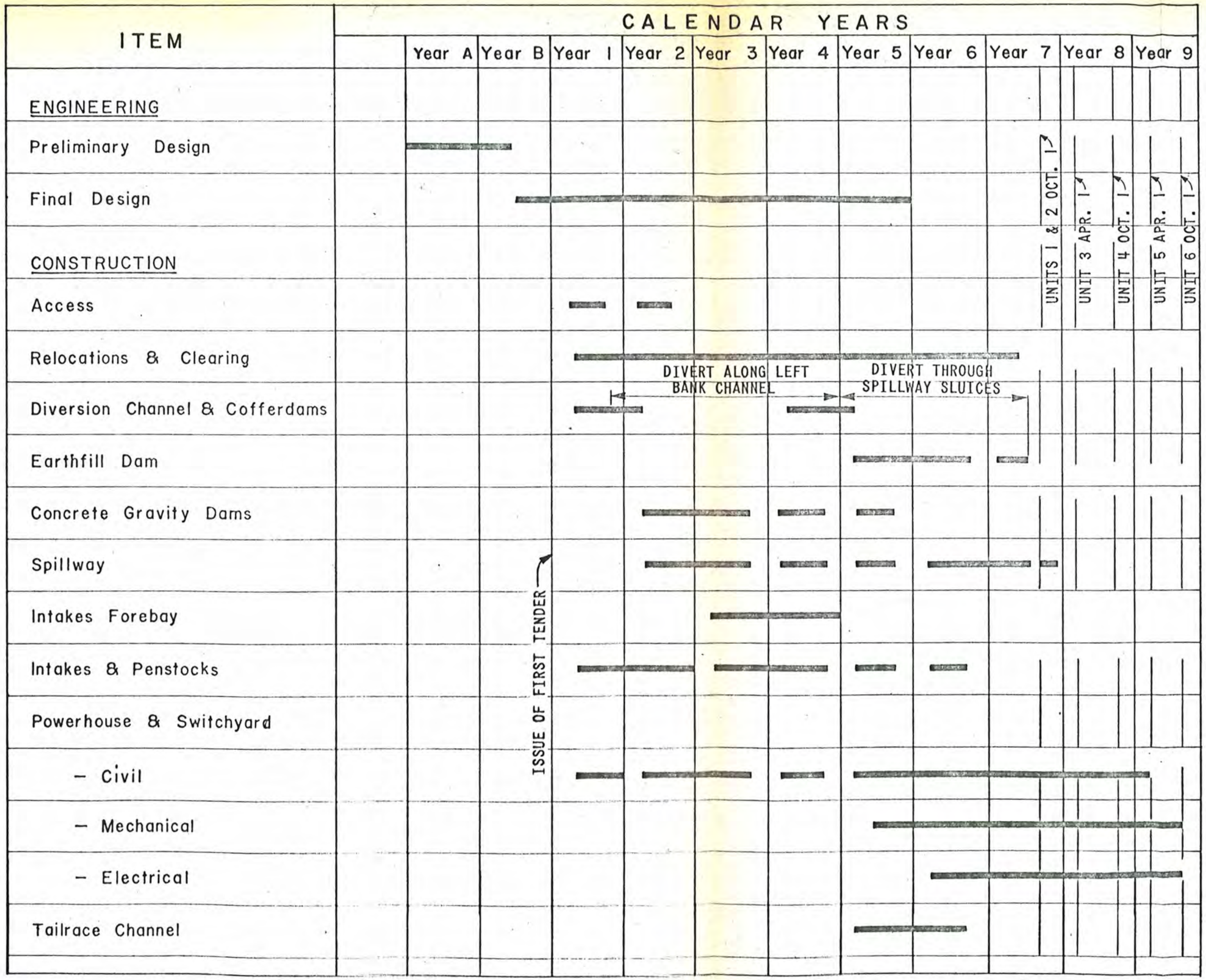
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

SITE E (1342) PROJECT
ELEVATIONS & SECTIONS

DATE MAY 1976	PLATE 6-2	R
DWN C.A., A.C.	DWG No. 1018-C14-D25	

REPORT No. 796



NOTE:

POSSIBLE ADDITIONAL TIME REQUIREMENTS FOR ENVIRONMENTAL IMPACT STUDIES AND LICENSING PROCEDURES MAY LENGTHEN THE LEAD TIME THAT WOULD BE REQUIRED DURING YEARS A AND B.

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

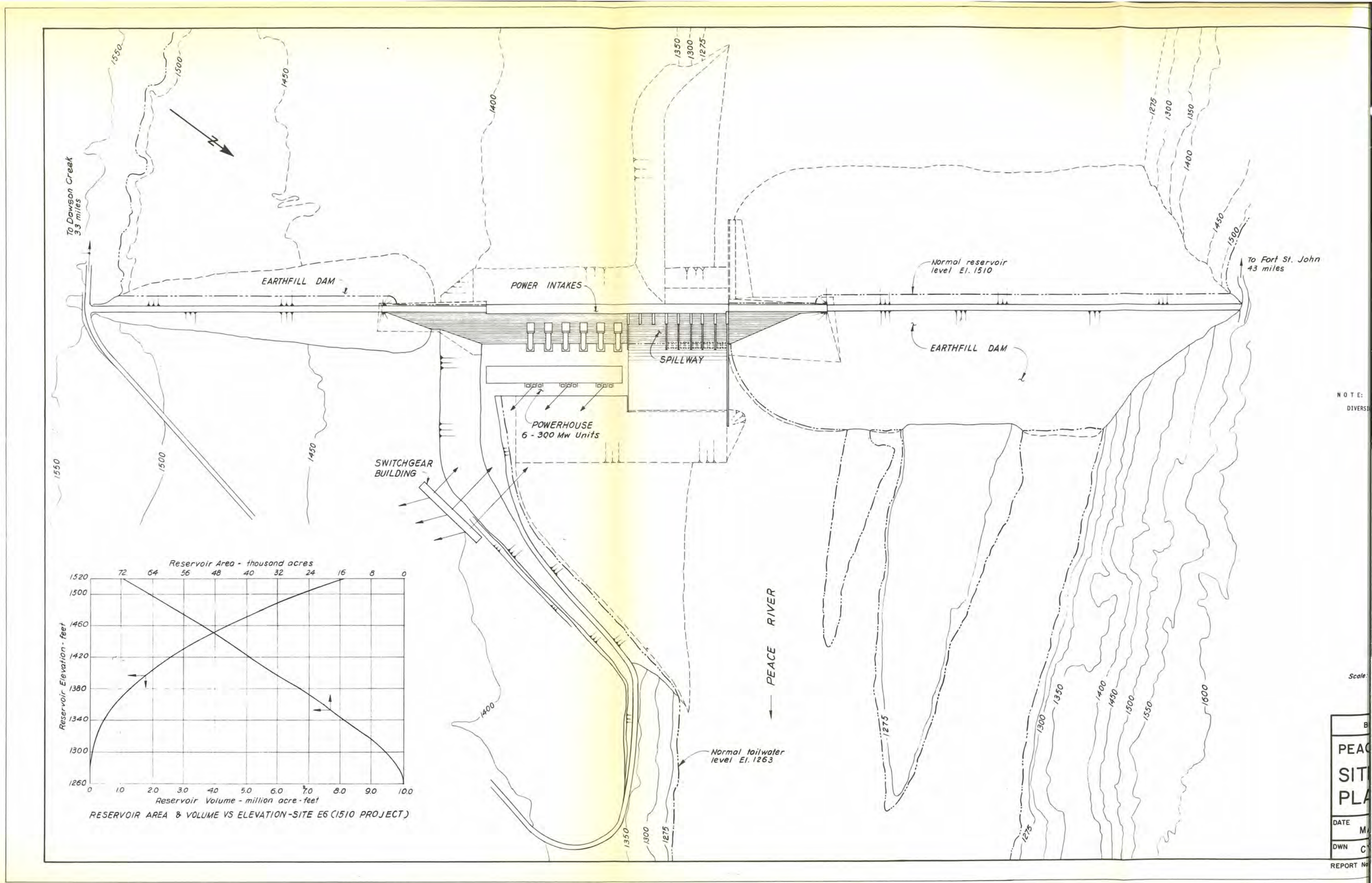
PEACE RIVER - SITES C & E

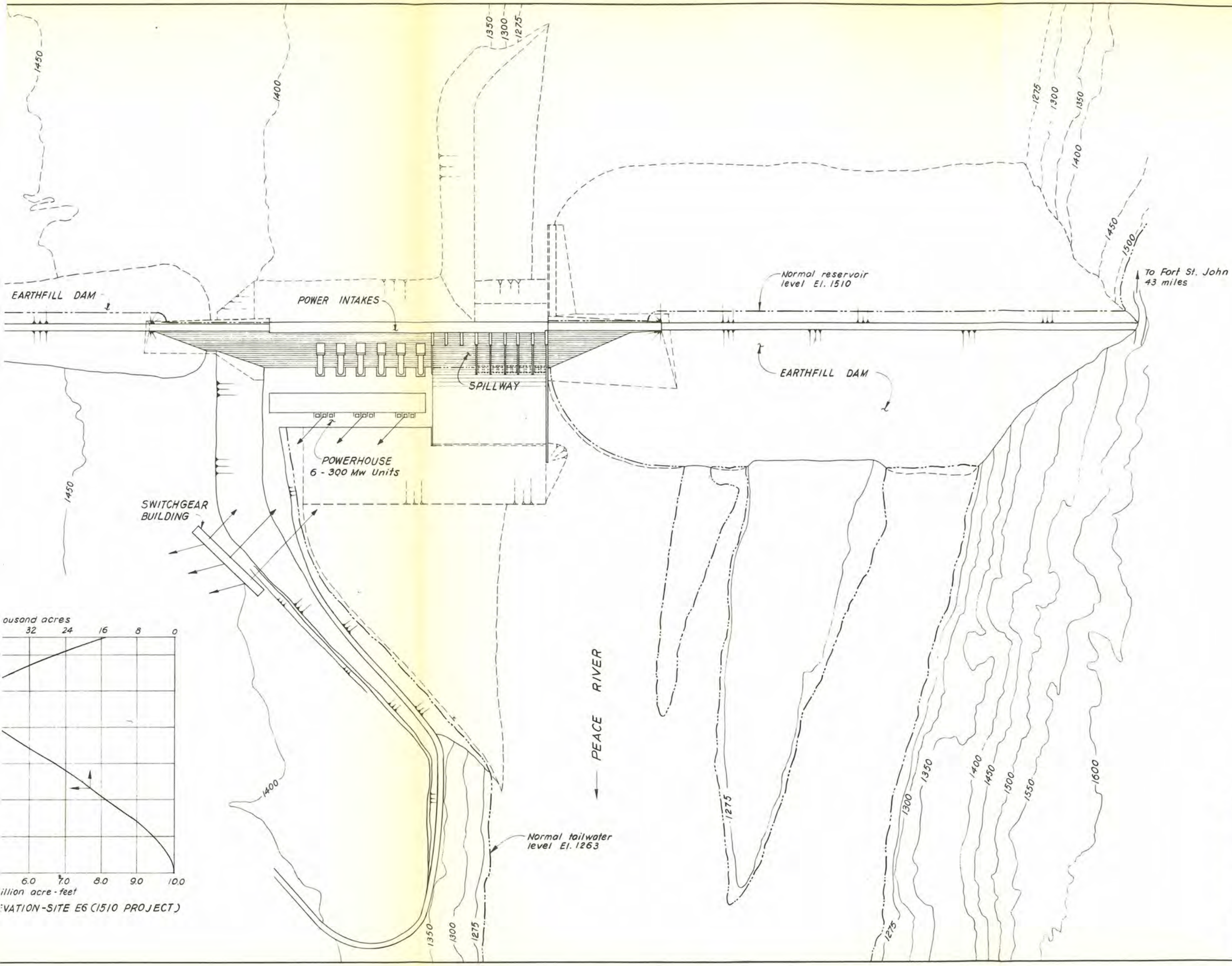
SITE E (1342) OR (1352) PROJECT CONSTRUCTION SCHEDULE

DATE MAY 7/76 | PLATE 6-3 | R

DWN CA | DWG No. 1016-C14-B26

REPORT No. 796


To Dawson Creek 33 miles
To Fort St. John 43 miles
EARTHFILL DAM
POWER INTAKES
Normal reservoir level El. 1510
SPILLWAY
EARTHFILL DAM
POWERHOUSE
6 - 300 Mw Units
SWITCHGEAR BUILDING
PEACE RIVER
Normal tailwater level El. 1263
Reservoir Area - thousand acres
Reservoir Elevation - feet
Reservoir Volume - million acre-feet
RESERVOIR AREA & VOLUME VS ELEVATION-SITE E6 (1510 PROJECT)
NOTE:
DIVERSI
Scale:
PEA
SIT
PL
DATE
DWN
REPORT No



NOTE:

DIVERSION SCHEME SIMILAR TO SITE E (1342) PROJECT.

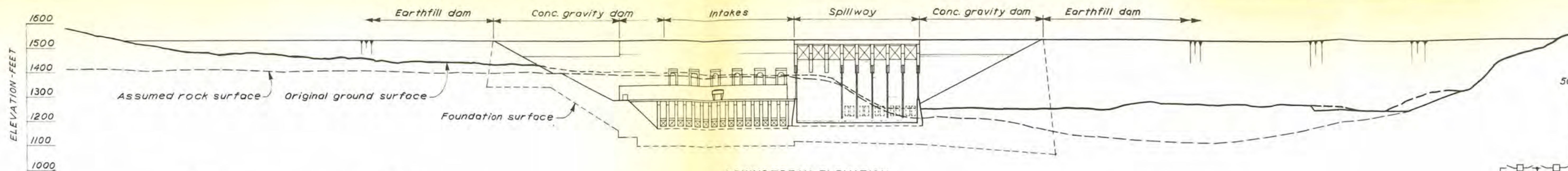
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

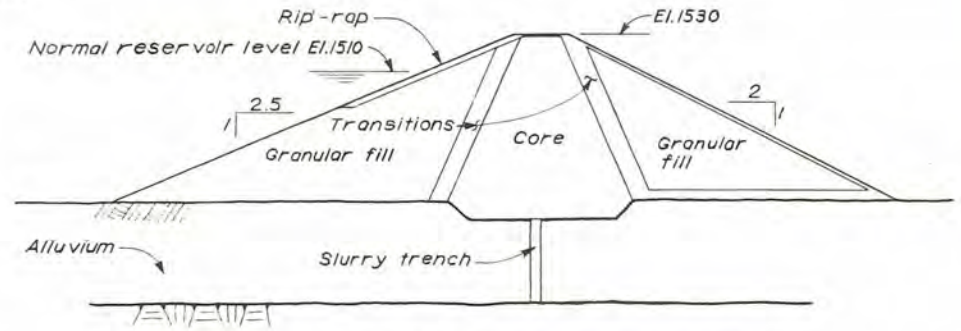
SITE E (1510) PROJECT PLAN

DATE MAY 1976	PLATE 7-1	R
DWN CY	DWG No. 1018-C14-U27	

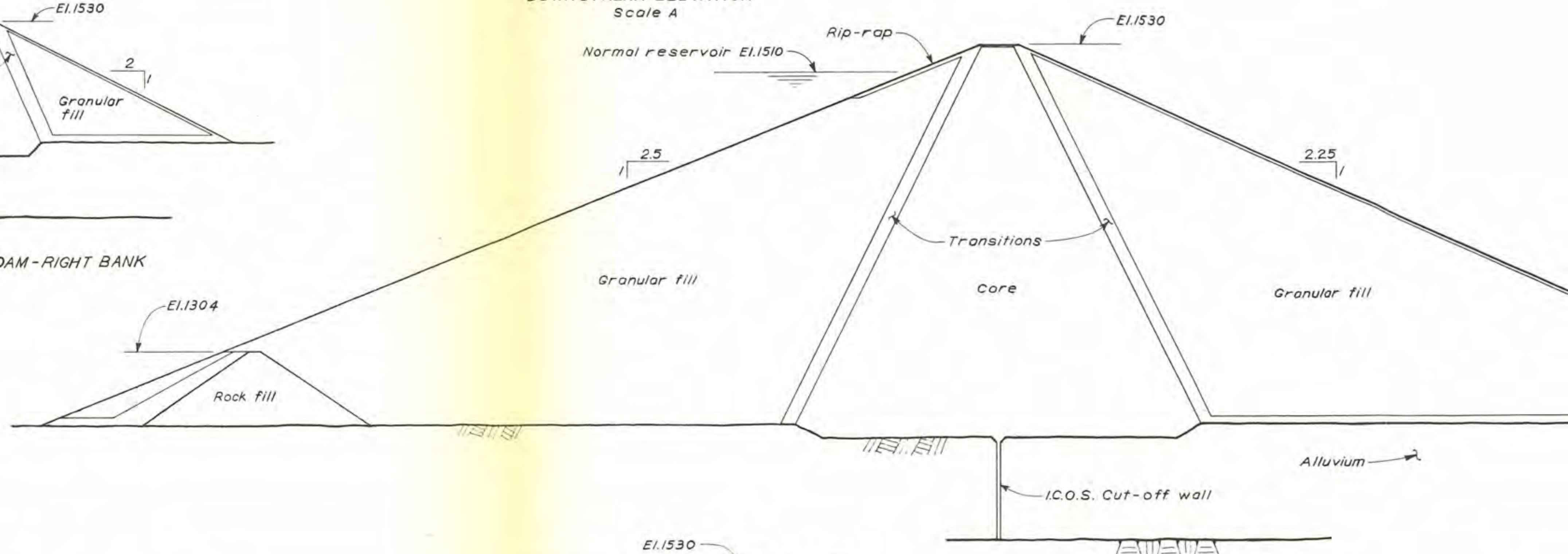
REPORT No. 796



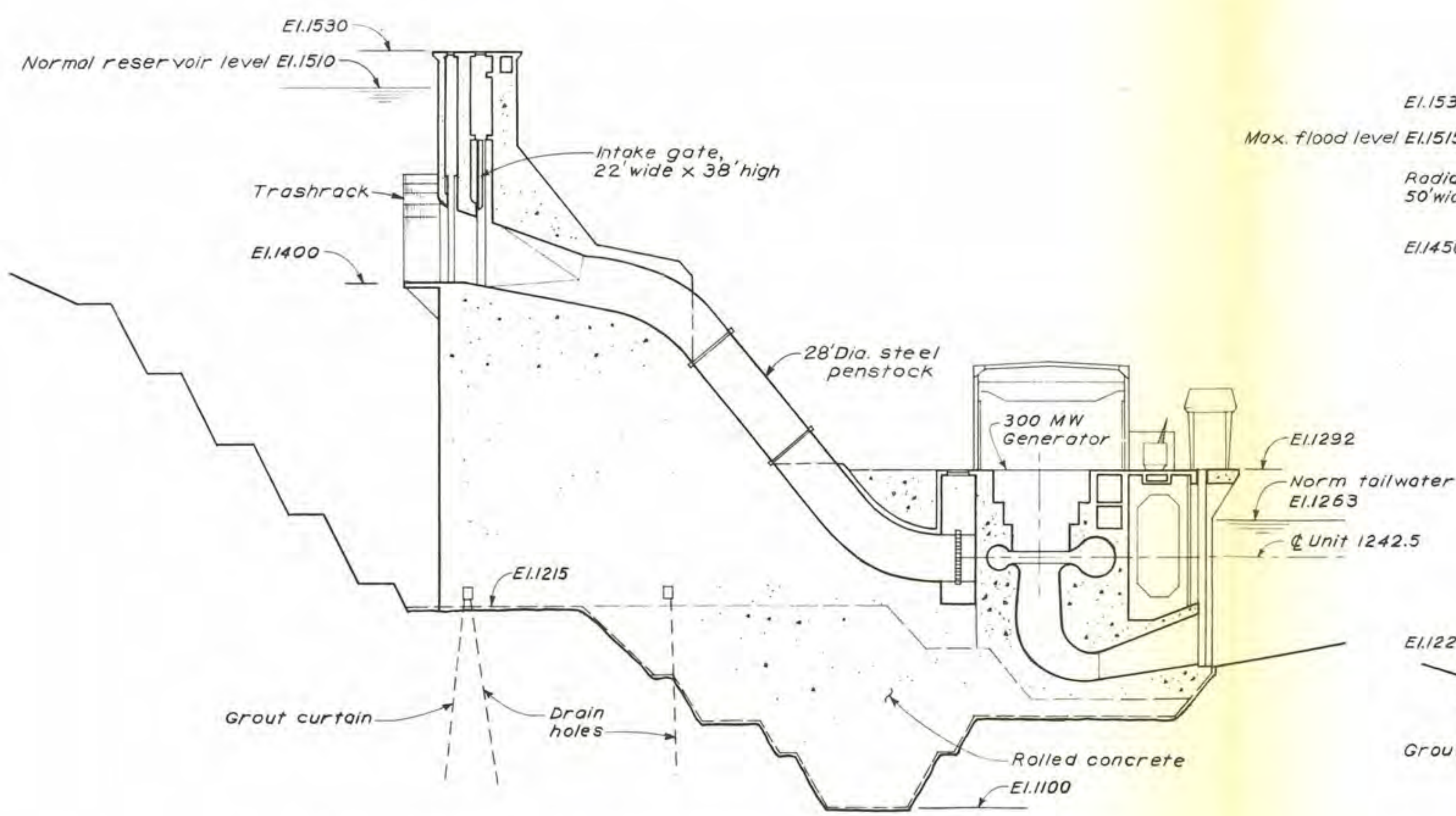
DOWNSTREAM ELEVATION
Scale A



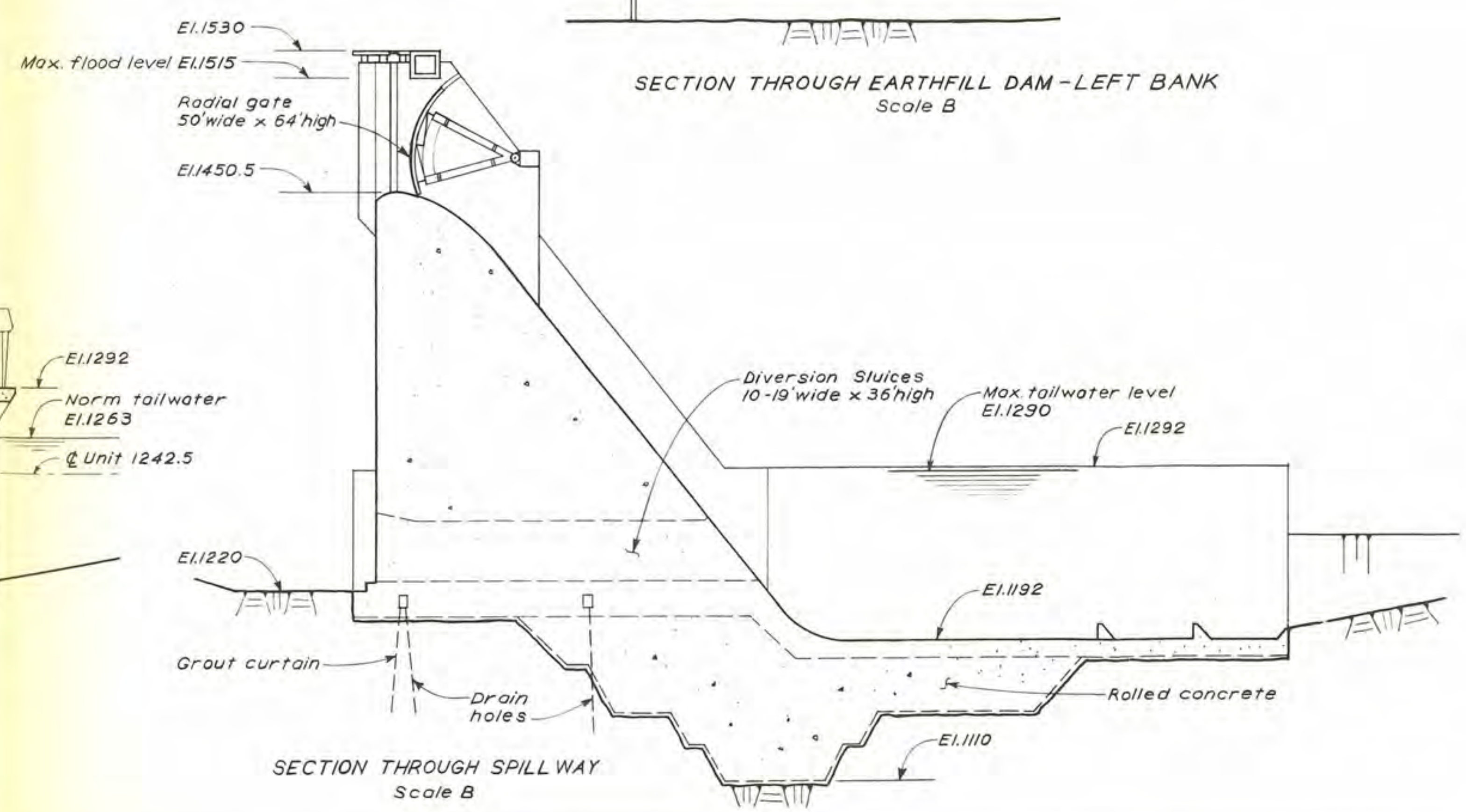
SECTION THROUGH EARTHFILL DAM - RIGHT BANK
Scale B



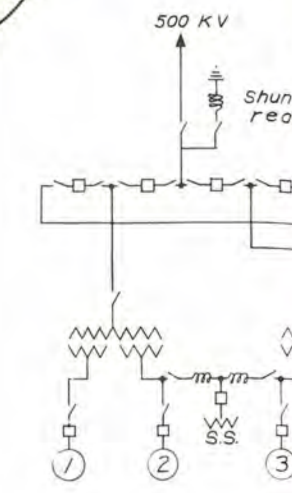
SECTION THROUGH EARTHFILL DAM - LEFT BANK
Scale B



SECTION THROUGH INTAKE, PENSTOCK & POWERHOUSE
Scale B



SECTION THROUGH SPILLWAY
Scale B



SING

Scale: A 200

Scale: B 50

BRIT

PEACE

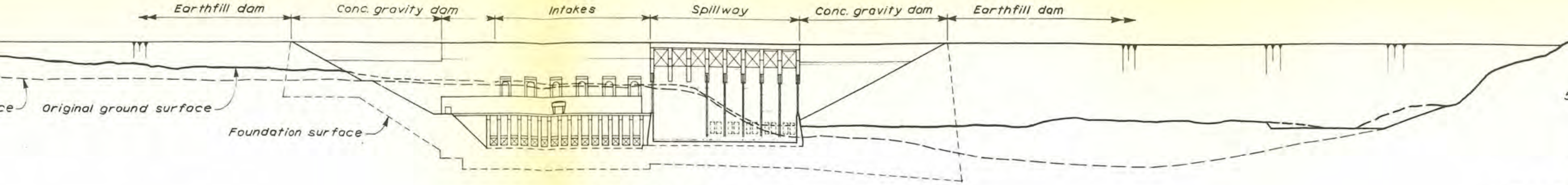
SITE

ELE

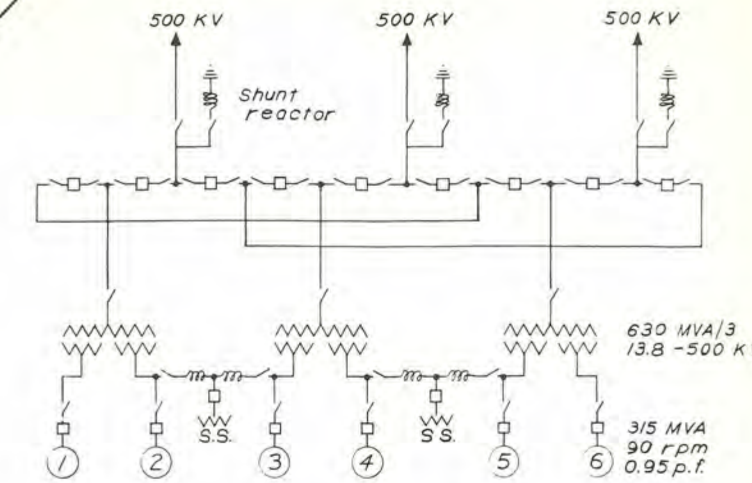
DATE M

DWN A

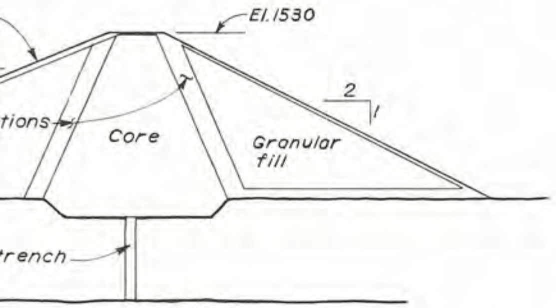
REPORT No.



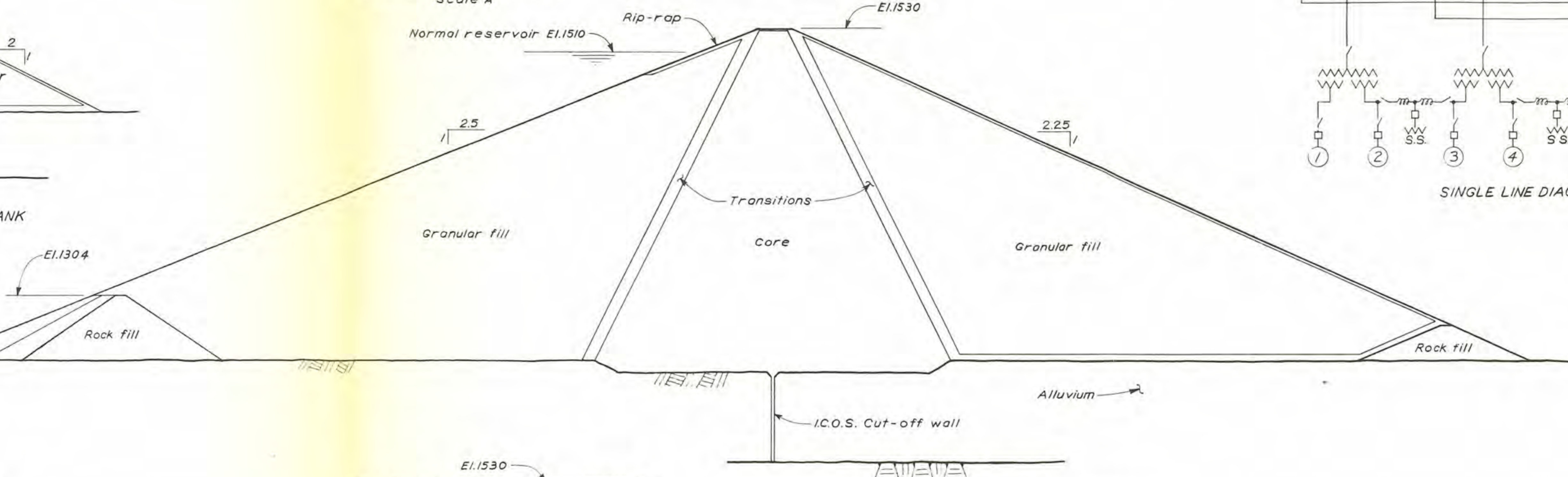
DOWNSTREAM ELEVATION
Scale A



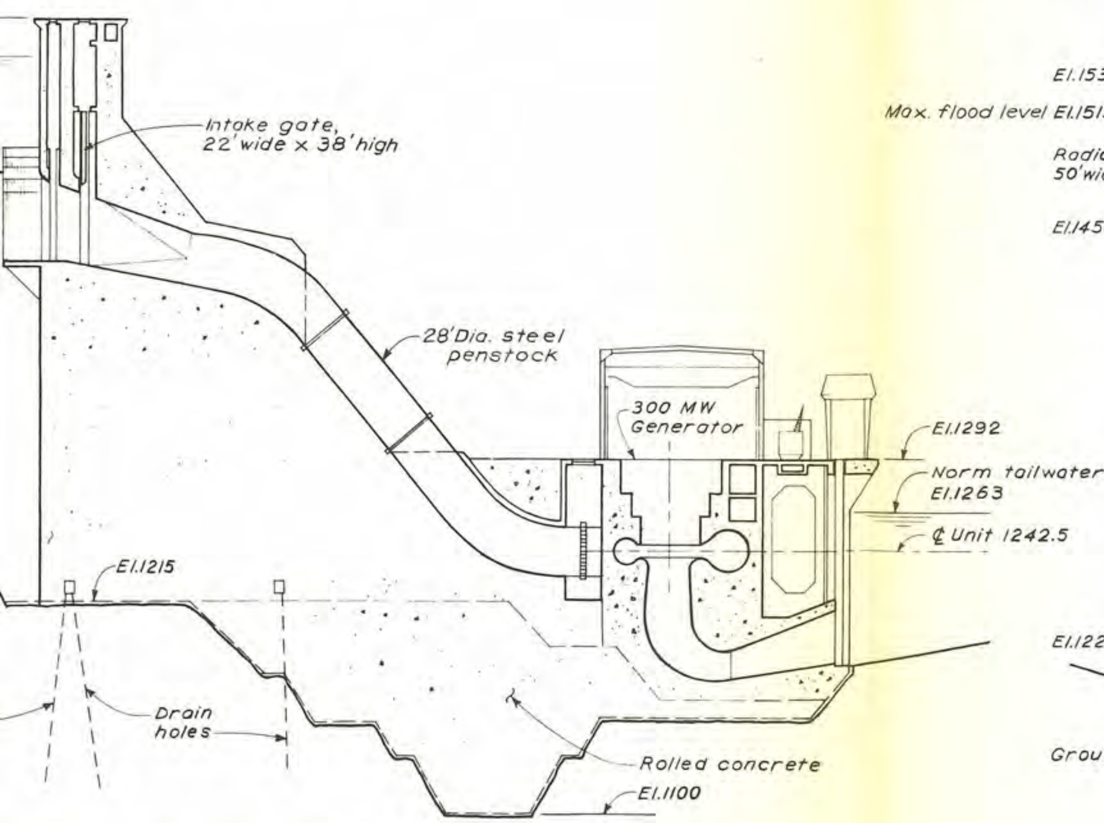
SINGLE LINE DIAGRAM



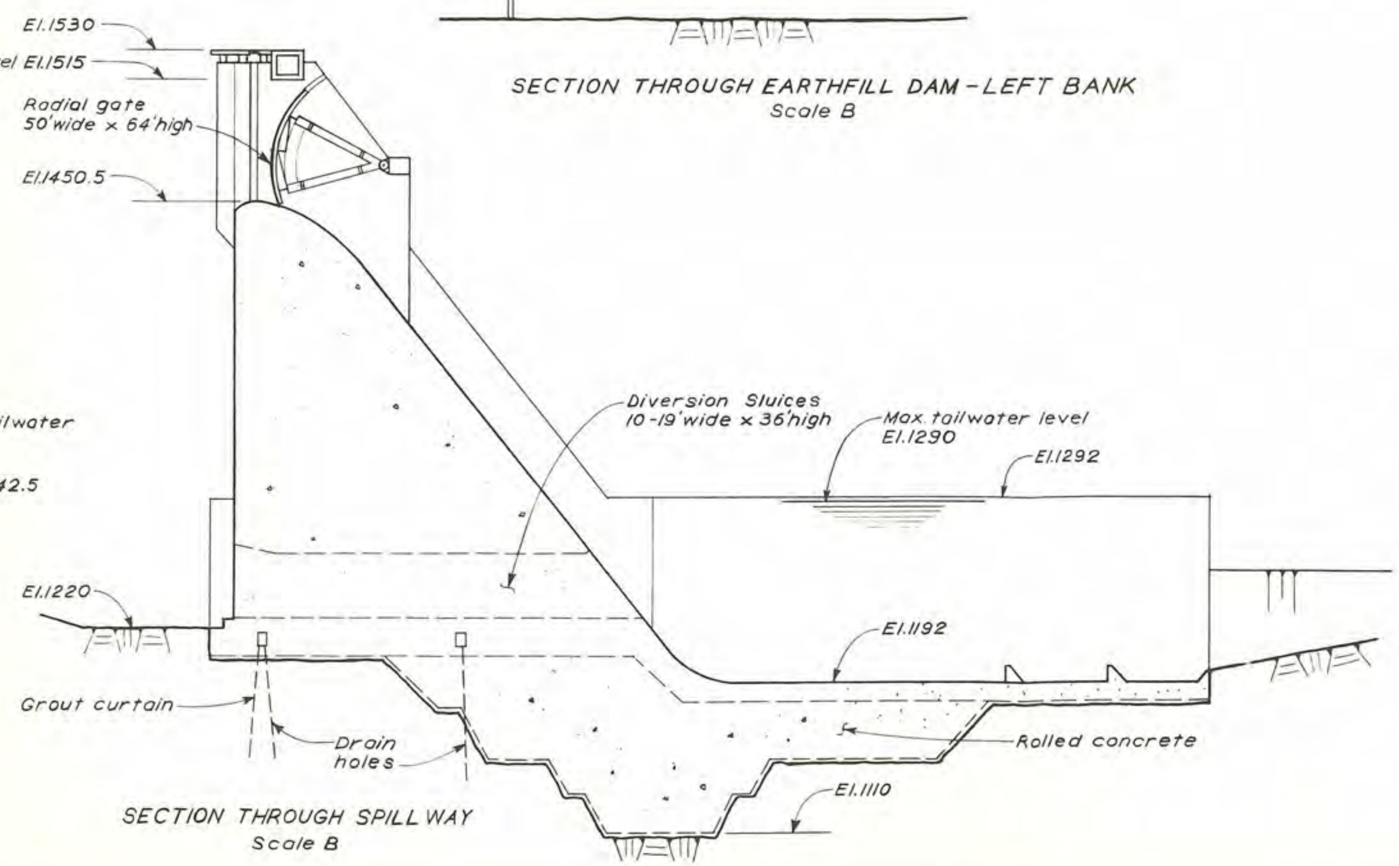
H EARTHFILL DAM-RIGHT BANK
Scale B



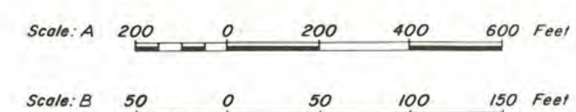
SECTION THROUGH EARTHFILL DAM-LEFT BANK
Scale B



THROUGH INTAKE, PENSTOCK & POWERHOUSE
Scale B



SECTION THROUGH SPILLWAY
Scale B



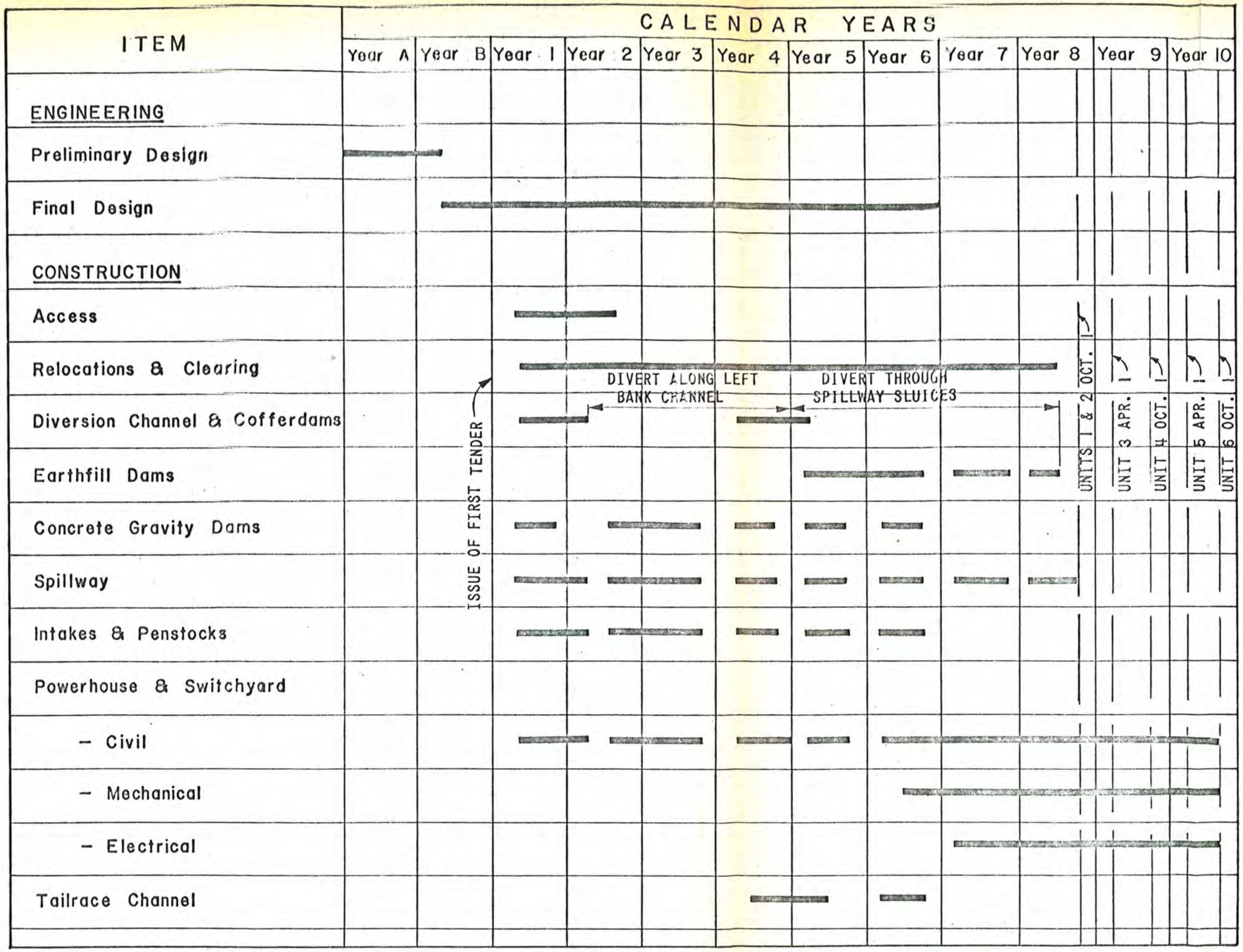
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

SITE E (1510) PROJECT
ELEVATIONS & SECTIONS

DATE MAY 1976	PLATE 7–2	R
DWN A.C.	DWG No. 1018-C14-U28	

REPORT No. 796



NOTE:

POSSIBLE ADDITIONAL TIME REQUIREMENTS FOR ENVIRONMENTAL IMPACT STUDIES AND LICENSING PROCEDURES MAY LENGTHEN THE LEAD TIME THAT WOULD BE REQUIRED DURING YEARS A AND B.

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER - SITES C & E

SITE E (1510) PROJECT CONSTRUCTION SCHEDULE

DATE MAY 10/76

PLATE 7-3 R

DWN CA

DWG No. 1018-C14-B29

REPORT No. 796

PEACE RIVER SITES C AND E

FEASIBILITY STUDY

APPENDIX A

GEOTECHNICAL INVESTIGATIONS

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SUMMARY

Geotechnical investigations for the hydroelectric development of the Peace River between Site 1 and the Alberta border were carried out in 1971 and 1975. Investigations at the sites consisted of drilling, seismic refraction surveying, laboratory testing and geologic mapping. Geologic mapping of the reservoir shoreline was carried out to assess the reservoir bank stability.

In 1975, subsurface exploration was carried out at Axis C-3 at Site C and at axes E-3 and E-6 at Site E. The exploration at Site E was principally of Axis E-6 and was intended to investigate for a dam with a proposed crest at about El. 1355 at this axis. Investigations of Axis E-3 were planned to complete 1971 investigations of this axis for a dam with a proposed crest at El. 1510.

At Site C (Axis C-3) the river channel has about 30 feet of gravel and sand overlying bedrock. On the left slope overburden to a depth of over 200 feet exists on the upper terraces. The lower slopes on the left side are shale bedrock. The right valley slope is a series of river cut shale terraces which are overlain by a few feet of overburden. Both the right and left abutments at Axis C-3 are sound and are considered to be satisfactory as abutments for the proposed dam.

At Site E the river flows along the right side of a wide channel which is filled with deep alluvium. Above the dam crest of both sites, the left bank consists of overburden terraces. Lower slopes on the left side are bedrock except where covered by colluvium or slide debris. The right bank at Site E is a broad, bedrock terrace covered by silt and clay. At Axis E-6 the valley slopes are stable and are protected by terraces from small slides above the crest of the proposed low Site E dam.

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TABLES

ANNEX

The assessment of proposed reservoir bank conditions indicates that both reservoir alternatives, as compared with existing conditions, would increase the potential for landslides to occur. However, the potential for reservoir related landslides is much less for the lower reservoir level than for the higher level. Also, the Peace River tributaries would have significantly fewer potential slides or sloughs under the low Site E and Site C alternative than under the high Site E alternative.

A.1 INTRODUCTION - (Cont'd)

5. Geologic mapping of the reservoir shoreline to assess the reservoir bank stability.

Seismic profiling was used to define the depth to bedrock along each of the axes studied. The geologic conditions of the valley walls near the axes were evaluated by a geologic reconnaissance. Based on these studies the C-3 axis at Site C, and the E-3 and E-6 axes at Site E were selected for further study and exploration.

This Appendix reviews previous geotechnical investigations and provides detailed information about the explorations conducted in 1974 and 1975.

A.2 REGIONAL GEOLOGY

The proposed project sites and reservoir area(s) are located at the western edge of the interior plains. The region from Site 1 to the Alberta border is a relatively flat to slightly rolling plain (Alberta plateau) in which the Peace River has carved a broad valley, averaging 700 feet deep and 2 miles from rim to rim. The river itself is from 1/4 to 1/2 mile from bank to bank and the floodplain averages 3/4 of a mile wide. The walls of the river channel rise sharply at angles close to 35 degrees where the banks are cut in rock, or at angles as low as 10 degrees where unconsolidated sediments have slumped down to a terrace.

The Peace River valley follows a wide, preglacial bedrock valley that is infilled by a sequence of unconsolidated fluvial, lacustrine and glacial deposits (Table A-1). The present river has downcut through this infilling material and about 100 to 150 feet into the bedrock floor of the preglacial valley. Except for a few local areas where new channels have been cut through bedrock outside the preglacial valley limits, the present river is confined within the infilled preglacial valley.

Bedrock formations exposed in this region are the Dunvegan, Shaftesbury and Gates (Plate 2-3). Structurally, these bedrock formations are flat lying to very gently dipping to the east.

The Dunvegan Formation is a succession of sandstone and interbedded shale which lies conformably on the Shaftesbury shales. The sandstones are fine to coarse-grained, commonly crossbedded, laminated and weather brown. The interbedded mudstones are carbonaceous in part, and contain some thin coal seams.

Valley slopes in interbedded sandstone and shale of this formation are commonly steep and local thick beds of sandstone form scarps with a line of outcrops at the crests.

The Shaftesbury Formation is the most abundant rock formation in the area and consists of a sequence of dark grey, flaky to fissile shales which weather rusty. Some sandy siltstone and fine-grained sandstone occur in the upper part of the formation. The shales weather readily to clay. Gypsum crystals are commonly found in the shales but no coal has been reported. Analyses of samples from Sites C and E have revealed the presence of some montmorillonite in the shales. The shale is a "low" slaking material (slaking is the tendency of a rock to disintegrate upon alternate wetting and drying). Particles of shale talus seldom exceed 1 inch in diameter and break easily under finger pressure.

The valley slopes are continually undergoing adjustment and landslides are common. Most of these slides are confined to overburden but some slides have occurred in the shales forming the valley slopes.

A.3 EXPLORATION PROGRAM

(a) Pre-1974 Exploration

In 1958, B.C. Engineering Co. Ltd., in their preliminary report on the Rocky Mountain Trench area for the British Thompson - Houston Co. Ltd., described four potential damsites in the area between Site 1 and Taylor (Sites A, B, C and D). Subsequent investigations indentified Site E near the Alberta border. These studies indicated that the available head could best be developed by either a single high dam at Site E or two low dams, one near the border at Site E and the other between Site 1 and the border at either Site A, B, C or D. In 1967, a surface geological reconnaissance of these potential sites indicated that Site C was preferable to the other sites on the river for development.

Based on these studies axes at Sites C and E were selected for preliminary subsurface exploration. In 1971, exploration of Axis C-1 at Site C and Axis E-3 at Site E was conducted to determine the depth and nature of overburden, the type and characteristics of bedrock and the sources of construction materials. Drilling at the sites consisted of seven holes totalling 720 feet at Axis C-1 and six holes totalling 660 feet at Axis E-3. Geologic maps of the sites were prepared at a scale of 1 inch = 400 feet.[1]

These investigations indicated that the bedrock underlying both sites is soft shale. The Site C drilling program indicated that a buried channel of the old Peace River, which extends into the Moberly River valley, exists on the right side of Axis C-1. Drilling at Site E indicated that although the bedrock is of very low strength and deep overburden overlays bedrock near the center of the river channel, the site was considered to be adequate for a high dam, providing design of such a dam was carefully carried out.

A.3 EXPLORATION PROGRAM - (Cont'd)

(b) General

Geotechnical investigations carried out for this feasibility study consisted of seismic refraction surveys, geologic reconnaissance, rotary drilling, geologic mapping of the sites and geologic investigations related to reservoir bank stability.

Based upon the 1971 drilling at Axis C-1 and upon seismic investigations and geologic reconnaissance of axes C-1 and C-3, Axis C-3 was considered preferable to Axis C-1 for further studies. The abutments at C-3 appear stable and have less overburden cover than the C-1 axis. Moreover the left abutment at C-1 is considered to be unsuitable for a dam abutment. Investigations in 1975 were carried out to further explore Axis C-3.

In 1974 and 1975 geologic investigations were conducted by Thurber Consultants Ltd. to assess the reservoir bank conditions. These studies indicated that the reservoirs would likely have some effect on the slopes and that the single high dam at Site E would have a much more severe effect than the two lower dams. Geologic reconnaissance at Site E indicated that Axis E-6 was a reasonable location for a low dam. Investigations at Site E were to determine the feasibility of a high dam at Axis E-3 or a low dam at Axis E-6.

(c) Site C Exploration

(i) Seismic Surveys

In October - November 1973 and April - May 1974 Geotronics Surveys Ltd. of Vancouver carried out seismic surveys to obtain profiles of the overburden/bedrock contact below the river.

Data was recorded using a SIE Dresser 12-channel refraction/reflection seismograph amplifier system with a photo-recording oscillograph and 8-cycle per second

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geophones. For land work a 12-geophone 550-foot spread with shots at each end and at the center of the spread was used. Over the river seismic data was obtained by planting geophones on either bank and detonating shots at 50-foot intervals across the river. Data was analyzed using an intercept-delay time technique.

At Site C, seismic traverses totalling 9600 feet were carried out along axes C-1, C-2 and C-3.

On Axis C-1 the interpretation of seismic results was correlated with the drilling done in 1971. Correlation between the seismic and drilling is generally good except near the right bank where seismic data overestimated the depth of overburden by 50 feet. Bedrock in this area may have relatively numerous clay seams and fractures. Seismic results suggest that overburden is about 50 feet deep on the left slope and under the river. On the right slope overburden is 50 feet deep at the river bank and apparently increases in depth to approximately 150 feet deep at El. 1500 on the slope.

At Axis C-2 no drilling was available for correlating seismic data. Seismic results suggest that overburden on the left slope is about 80 feet deep. Under the river overburden is approximately 20 feet deep near the left bank and increases to approximately 80 feet deep near the right bank.

At Axis C-3 overburden is about 30 feet deep. Seismic results were incorrect and showed overburden to be approximately 60 feet deep near the left bank, 50 feet deep near the middle of the channel and 100 feet deep near the right bank.

A.3 EXPLORATION PROGRAM - (Cont'd)

(ii) Geological Reconnaissance

A geological reconnaissance of axes C-1 and C-3 was made during May 6 - 9, 1974 and geologic cross sections at 1 inch = 200 feet were prepared along the axes. This study indicated that Axis C-3 is geologically superior to Axis C-1 for the following reasons:

1. Bedrock is nearer the surface on the abutments.

2. Stable overburden slopes exist at C-3 whereas the left abutment at C-1 shows evidence of previous slides.

3. Both abutments at Axis C-3 have terraces above the dam crest, which flatten the valley slope.

4. The right slope at Axis C-1 has been subject to considerable slumping.

(iii) Drilling

In 1974 and 1975 seven boreholes, totalling 1458 feet, were drilled on Axis C-3 (Plate 3-1). Two boreholes were drilled on the left bank, one hole from a gravel bar near the left bank, two holes in the river from a barge and two holes on the right bank. Triconing and sampling methods were used in overburden and NQ triple tube coring equipment was used in bedrock. Core recovery in bedrock was about 95 percent. Bedrock in all drill holes was water-pressure tested using double mechanical packers and a test interval of 20 feet.

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Drilling of holes C-1 to C-5 was carried out by the B.C. Department of Highways. Drilling of holes C-6 and C-7 was done by the B.C. Hydro Construction Department.

All core has been stored in the area except for the samples taken for laboratory testing. Laboratory tests included uniaxial compression, double shear, sliding friction and direct shear tests.

(iv) Geological Mapping

Geologic mapping at Site C was carried out concurrently with the Site C drilling using provincial government topographic mapping at 1 inch = 200 feet and chain and compass or altimeter for control. Results of geological mapping at Site C are shown on Plate 3-1.

(d) Site E Exploration

(i) Seismic Surveys

At Site E, seismic traverses totalling 9000 feet were conducted along axes E-3, E-4, E-5 and E-6. In general, seismic results at Site E were poor, probably because overburden was deep.

At Axis E-3, seismic data was correlated with the drilling done in 1971. The seismic results agree with the drill holes but show many bedrock irregularities between drill holes.

At Axis E-4, seismic results show overburden is deepest near the right side of the channel where it is 80 feet deep.

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Seismic results at Axis E-5 show overburden as being about 30 feet deep. At Axis E-6, up to 150 feet of overburden overlies bedrock, however, seismic results showed only about 30 feet of overburden.

(ii) Geological Reconnaissance

Geological reconnaissance of axes E-4 and E-6 was made during May 10 - 11, 1974. Geological cross sections were drawn of these axes at 1 inch = 200 feet. This reconnaissance indicates Axis E-6 is geologically preferred since there is slide debris on the left side of Axis E-4 which is not present at Axis E-6.

(iii) Drilling

In 1975, using B.C. Hydro drill crews and equipment (Boyles 35A rig), five boreholes, totalling 1216 feet, were drilled on Axis E-6 (Plate 3-5), and three holes, totalling 696 feet, were drilled on Axis E-3 (Plate 3-3). Drilling at Site E was used to investigate the foundation conditions for a possible low dam at Axis E-6 and to complete information gathered from the 1971 drilling at Axis E-3 for a possible high dam.

Sampling, coring, water testing and laboratory test methods described for Site C were used in all drill holes except E-5. (Drill hole E-5 was drilled by Becker Drilling Ltd. using a reverse circulation drill.) No water pressure tests could be taken in drill hole E-3 because the hole was partly caved in. Water pressure tests were attempted at 20-foot intervals in all other drill holes but it was often impossible to seal the packers in the top 20 to 80 feet of bedrock.

A.3 EXPLORATION PROGRAM - (Cont'd)

(iv) Geological Mapping

Geological mapping at Site E was carried out using provincial government topographic mapping at 1 inch = 200 feet and chain and compass or altimeter for control (Plates 3-3 and 3-5).

(e) Reservoir Shoreline Investigations

A preliminary assessment of reservoir bank conditions was made for B.C. Hydro in late 1973 by Thurber Consultants.[5]

In 1975 and early 1976 more comprehensive studies of reservoir bank conditions of the Peace River channel and the main tributaries were carried out.[6,7]

In these studies the principal aspects considered were:

1. Existing and potential shoreline slides or ground movement areas.

2. Preliminary assessment of shoreline safelines.

3. Affect of reservoirs upon the petroleum facilities at Taylor, B.C.

Air photo interpretation, geological mapping and helicopter reconnaissance, combined with stability analyses, were used to carry out the study.

The existing and potential reservoir shoreline slopes were classified: the former as to the potential types of ground movement which can occur; the latter as to the potential types of ground movement and the probability of that movement occurring.

A.3 EXPLORATION PROGRAM - (Cont'd)

Slope stability under the proposed reservoir levels was analyzed using the Morgenstern and Price, and Bishop Methods as programmed for the electronic computer. No drilling, sampling or laboratory testing was carried out, therefore assumptions were made and various conditions of topography, rock and soil strength, groundwater and failure mechanisms were considered in the analyses. Findings of these analyses include information on the potential of reactivating existing slide and slump material, activating first-time slides in silt, clay and till deposits, slope angles for circular-arc and block failures, and the influence of drawdown on the reservoir slopes.

A preliminary safeline was drawn around the perimeter of the proposed reservoirs. Safeline criteria were determined by considering geological and geotechnical engineering aspects of this study. The criteria were based upon the potential reservoir shoreline stability classifications combined with the stability analyses.

To keep the Taylor petroleum facilities operational with a reservoir full supply level at El. 1510 for the Site E project, it would be necessary to relocate some facilities which would be affected. Assessment of the facilities that could be affected, and a cost estimate for their relocation was undertaken. The reservoir level which would substantially eliminate any effect on these facilities was also assessed.

A.4 SITE GEOLOGY

(a) Site C

(i) General

At Site C the Peace River has eroded a broad, flat bottomed valley approximately 750 feet deep. Measured along Axis C-3 the valley is approximately 2 miles wide with a river channel about 2300 feet wide. Valley slopes are steep sided but are interrupted by a series of river cut terraces. On the left side, fluvial and glacial deposits cover bedrock above El. 1505. Some slide debris and colluvium covers slopes below El. 1505 although bedrock is generally exposed. On the right bank a series of river cut shale terraces are mantled by a few feet of gravel and organic silt.

Bedrock at the site is flat-lying Shaftesbury shale with interbeds of siltstone (Table A-1). Shale is predominant at the site and occurs throughout the abutments. Shale and siltstone underlie the riverbed. Zones of poorly bonded shale occur near the left abutment and in the middle of the river channel at about the elevation of the channel bottom.

Clayey silt seams commonly occur in the shale parallel to laminations in the rock. These seams are generally about 1/4 inch thick but are up to 2 feet thick in the left abutment. The clayey silt in these seams is generally dark grey, moist and soft. Atterberg limits tests on the seams indicate that they are inorganic clay of medium plasticity with medium to high swelling potential. These seams could be the result of swelling of the shale resulting from stress release or could be the result of local nonconsolidation of the original clay or mud materials.

No slickensides are seen on rock bounding the clay seams, which suggests that the seams do not result from shearing action.

A.4 SITE GEOLOGY - (Cont'd)

(ii) River Channel

In the river channel up to 30 feet of fluvial sands and gravels with some cobbles and boulders overlie a weathered bedrock surface. These deposits are predominantly composed of well rounded quartzite and sandstones. A terrace of silt and fine sand approximately 12 feet thick overlies the river gravels near the left bank.

Bedrock under the river channel is shale and siltstone which has been weathered to a depth of about 10 feet. Clay seams occur in the shale predominantly on the left side of the river channel and near the bedrock surface although the clay seams do extend to below the bottoms of drill holes.

Measured permeabilities of riverbed rock are from 10^{-3} to 10^{-4} cm/sec in the top 40 feet of bedrock and less than 10^{-4} cm/sec at greater depths. Permeabilities of the rock are probably less than the measured value because of the difficulty of sealing the packer in the hole. The high permeabilities in drill hole C-6 resulted from leakage around the packers.

(iii) Left Bank

On the left bank of the river there is an extensive terrace at El. 1900 which extends for 800 feet upstream and for 3000 feet downstream of the axis. Below El. 1900 the valley slopes average about 30 degrees and have much smaller terraces at El. 1650 and El. 1360.

The sequence of overburden on the left bank is well graded, well rounded gravel above El. 1860; silt and clay with discontinuous lenses of well rounded gravel to

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A.4 SITE GEOLOGY - (Cont'd)

El. 1570; and sand, gravel, cobbles and boulders grading into uniform medium sand directly above bedrock at El. 1505 (Plate 3-2).

The bedrock surface underlying overburden on the left slope is controlled by the base level of the preglacial Peace River channel and probably has a gently rolling topography at about El. 1500. Weathering of this bedrock surface is apparently from 5 to 20 feet deep.

Bedrock in the slope is a sequence of shale with some silty shale interbeds. Many clayey silt seams (up to 2 feet thick) occur in the shale parallel to the bedding.

Steeply dipping (70 - 90 degrees) fractures striking parallel to the river, cut the shale. These fractures are fresh, smooth, planar and are common in outcrop, but are seldom continuous for more than 10 feet. These fractures are probably caused by relaxation of stress during downcutting of the river, and are likely to be less numerous with distance away from the edge of the valley.

Below El. 1505 bedrock outcrops continuously occur along the left bank for 1000 feet upstream and 2000 feet downstream of the axis except where covered by colluvium or slide debris. Approximately 300 feet downstream of the axis a shallow slide has occurred in the surface shale and the overburden above it. Debris from this slide and colluvial material mantle the lower bedrock slopes near the axis.

(iv) Right Bank

The right valley slope at Axis C-3 is a series of river cut shale terraces which are overlain by a few feet of gravel and organic silt. Well defined terraces occur at El. 1650 upstream and at El. 1520 downstream of the axis.

An arc shaped depression which extends for 500 feet downstream of the dam axis and from approximately El. 1500 to El. 1450 is the scarp of a shale slump block. The topography of the scarp suggests that the block may have slid about 20 feet. The depth of the slump block is not known. More than 500 feet downstream of the axis, numerous small slides have occurred in overburden and weathered shale on the slope below El. 1520.

(b) Site E

(i) General

The Peace River valley at Site E is almost 3 miles wide and is up to 700 feet deep. Valley slopes are terraced and are covered with overburden, except on the steep sides of some terraces where sandstone outcrops. The river flows along the right side of a flat, alluvium filled channel which is 1800 feet wide at Axis E-3, and 2200 feet wide at Axis E-6.

Bedrock at the site consists of flat-lying Shaftesbury shales conformably overlain at approximately El. 1380 by sandstone and siltstones of the Dunvegan Formation. The Shaftesbury shale at this site is similar to, though of lower strength than, the shale at Site C. The shale tends to exfoliate upon unloading and slakes when exposed to air or water. X-ray diffraction of a sample of shale at Site E indicated there is some montmorillonite present in the clay fraction of the shale. Clay seams in the shale are found in the banks and under the river channel.

The Dunvegan Formation consists of sandstone, siltstone and shale. The sandstone is generally pale yellowish brown, medium to fine grained, hard, slightly calcareous and crossbedded. The surface of the sandstone is rusty where it is exposed to weathering.

(ii) Riverbed - Axis E-3

Results of geological mapping and drilling at Axis E-3 are shown in Plates 3-3 and 3-4.

Material overlying shale bedrock in the river channel is well rounded coarse sand, gravel, cobbles and boulders. The depth of this material varies from about 70 feet across most of the channel to 150 feet near the middle of the channel. Clay seams are most frequent and thickest near the top of bedrock, but were still encountered more than 100 feet below the bedrock surface. Bedrock permeability could not be tested in the top 80 feet because of difficulties in sealing the packer. Below this depth the permeability was less than 10^{-4} cm/sec.

(iii) Left Bank - Axis E-3

There is a bedrock terrace on the left bank at about El. 1500. Silt and clay up to 50 feet thick, covers this terrace and forms a thin mantle over bedrock on the slope above the terrace. This slope is covered by

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bushes and grass and shows no sign of sliding except for some small mudflows. Two thick sandstone beds with siltstone interbeds crop out near the top of the steep slope below the terrace and only a few feet of silt overlie the shale below these outcrops down to El. 1325. Below this elevation, slopes are covered by talus and colluvial material overlying slide debris of rock and overburden up to 80 feet thick. This deposit of slide debris forms an irregular terrace-like feature which extends along the base of the valley slope for 4000 feet upstream and for 1000 feet downstream from the axis. Water pressure testing of drill holes on the banks indicates that the permeability is near 10^{-3} cm/sec in the upper 100 feet of the rock and is less than 5 by 10^{-4} cm/sec at greater depths.

(iv) Right Bank - Axis E-3

There is a broad terrace on the right bank at Axis E-3 above El. 1400. The bedrock surface underlying this terrace is nearly horizontal at El. 1400 and is covered by clay and silt. Below the terrace the riverbank slopes steeply to the river and is covered by shallow colluvium.

Permeability testing indicated the bedrock permeability is about 5 by 10^{-4} cm/sec.

(v) River Channel - Axis E-6

Results of geological mapping, drilling and seismic at Axis E-6 are shown on Plates 3-5 and 3-6.

A.4 SITE GEOLOGY - (Cont'd)

In the river channel there is gravel and sand with some cobbles and boulders. The maximum depth of this material, which occurs at the center of the river channel, is 150 feet.

Bedrock under the river channel is shale which has been weathered to a depth of about 10 feet. Water pressure testing indicates the bedrock permeability is approximately 10^{-4} cm/sec.

(vi) Left Bank - Axis E-6

Above El. 1400 there is an overburden covered, 500-foot wide terrace. Below the terrace there is a few feet of overburden covering the steep shale slope. At the base of this slope weathered shale crops out for a few hundred feet on either side of the axis. Upstream of this outcrop there is a deposit of colluvium about 35 feet thick and downstream of the outcrop there is an area of slide debris. Mapping and drilling indicate there are many steeply dipping joints striking parallel to the river in the left bank. Clay seams and zones of poorly bonded shale are common in the top 100 feet of bedrock. In the abutment drill hole the packer could not be sealed for permeability tests taken in the top 120 feet of bedrock. Below this depth permeabilities were generally near 10^{-4} cm/sec.

(vii) Right Bank - Axis E-6

The right bank above El. 1400 is a broad, gently sloping terrace. There is a steep bedrock slope covered with a few feet of colluvium below this terrace to the river. The bedrock surface underlying this terrace is nearly horizontal at El. 1400 and is overlain by silt and clay, with a cover of about 12 feet of dirty gravel. At the axis, about 18 feet of flaggy sandstone (Dunvegan) overlies shale (Shaftesbury). Vertical joints in the sandstone and shale strike parallel to the river. Bedding dips slightly into the slope.

Drilling indicates that clay seams are prevalent in the upper part of the bank. Water pressure tests indicated the bedrock permeability is about 10^{-4} cm/sec.

(c) Reservoir Shoreline Investigation Results

Existing bank conditions along the Peace River shorelines show evidence of much sloughing and sliding. There are about 200 identified landslides along the river banks between Site 1 and the border. Most of these are small and all but 1 percent involved overburden, which usually occurred in glaciolacustrine deposits of silt and clay. Up to 75 percent of the lower valley banks are covered with sloughed material which, under reservoir operating conditions would not be continually eroded as the river now does, but could probably be subject to further downslope movement into the reservoir. Such movement would be inconsequential to the reservoir banks.

The Peace River and its tributaries would have significantly fewer problems with sloughing and sliding under the low Site E and Site C alternative than under the high Site E alternative. It is also apparent that both reservoir alternatives, as compared with existing conditions, would decrease the erosive effects of the Peace River, but would increase the potential for slides or slumps along the reservoir shoreline, especially where the slopes presently have a factor of safety near unity.

A.4 SITE GEOLOGY - (Cont'd)

Detailed studies of the Moberly River banks, just upstream from Site C, indicate that the Site C reservoir (El. 1510) would flood the shale and the overlying deposit of undisturbed, free draining gravel. Reservoir flooding could affect the slopes where silts and clays exist. However, the reservoir will eliminate the bank erosion along the Moberly River that now occurs. Such erosion at the toe of the slopes has caused many slides in the past along the Moberly River near its confluence with the Peace River. According to Thurber Consultants,[7] there is a remote possibility that loss of strength in some slope material due to the reservoir could cause a relatively large volume of material to slide into the reservoir, to the extent that it may even fill the valley. However such a slide would not affect any development or private land or reservoir operation. Any possible waves from such a slide will be studied to determine its affect on the banks of the reservoir in the Peace River valley and on the project itself.

If a high dam were constructed at Site E it would be necessary to relocate some petroleum facilities at Taylor as well as most of the transportation access routes.

If a high Site E (1510) dam were constructed, it would be necessary to relocate some transportation and industrial facilities due to the effect of the reservoir on its banks. To avoid the extensive relocation of the compressor station of the Taylor petroleum facilities, and minimize the effects on the other petroleum facilities, it would be necessary to keep the reservoir normal operating level at or below El. 1490. Lowering of the reservoir level would be required in order not to jeopardize the compressor station area with regard to slope stability, bearing capacity and a higher ground water table.

A.5 LABORATORY TESTING

(a) Rock Tests

Samples (NQ core) of shale, siltstone and clay seams obtained at Sites C and E were selected for a laboratory testing program consisting of:

1. Unconfined compression tests.
2. Sliding friction tests.
3. Double shear tests.
4. Multistage reversal direct shear tests.

All testing on rock samples was conducted by Thurber Consultants Ltd. and the detailed test procedure and results are given in their report.[8] Test results are summarized on Tables A-3 through A-6.

(i) Unconfined Compression Tests

The results of ten unconfined compression tests are shown on Table A-3. For all compression tests the bedding of samples was perpendicular to the applied load.

At Site C three tests were carried out on shale and the average compressive strength of the shale was 2150 psi. The tangent modulus of elasticity for shale averaged 2.9 by 10^5 psi. Only one sample of shale (poorly bonded) and one sample of siltstone were tested. Measured unconfined compressive strengths were 260 psi and 2200 psi respectively.

At Site E two samples of shale were tested and the average compressive strength of these samples was 1400 psi. Only one sample of shale (poorly bonded) and one sample of siltstone were tested which indicated unconfined compressive strengths of 240 psi and 1448 psi respectively.

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(ii) Sliding Friction Tests

At Site C three samples of shale were tested and indicated an average friction coefficient of 0.57 (friction angle of 29 degrees). One sample of poorly bonded shale and one of siltstone were tested which indicated a friction angle of 26 and 39 degrees respectively.

Tests on two samples of shale from Site E indicated an average friction angle of 33 degrees. The sample of poorly bonded shale had a coefficient of sliding friction of 0.524 (friction angle of 28 degrees).

(iii) Double Shear Tests

The direction of shearing for all test samples was parallel to the bedding. Results of double shear tests are shown in Table A-5.

One double shear test was carried out on a sample of shale from Site E and indicated the shear strength was only 7 psi. This test result may be lower than the real shear strength because slight drying of the sample caused it to crack before it was tested.

Because of the small number and the distribution of double shear tests on siltstone, the shear strengths for siltstone are averaged for samples from both sites. Tests made on three samples from Site C and one sample from Site E indicate an overall average shear strength of 88 psi.

Two samples of clay seams from Site E, tested by double shearing, indicated an average shear strength of 10.5 psi.

A.5 LABORATORY TESTING - (Cont'd)

(iv) Multistage Reversal Direct Shear Tests

Four samples of clay, two from each site, were tested to obtain their gradation curves, water contents, Atterberg limits, coefficients of consolidation and residual shear strengths (Table A-6). Gradation test results indicate that the samples have a predominant fraction of silt with a clay fraction ranging from 40 to 49 percent and averaging 44 percent. Atterberg limits tests on the clay-silt samples indicate average values for: liquid limit = 45 percent; plastic limit = 20 percent; and plasticity index = 25 percent. These limit values are indicative of an inorganic clay of medium plasticity and having medium to high swelling potential. The coefficients of consolidation calculated for these samples ranged from 0.0051 to 0.026 square inch per minute and averaged 0.0137 square inch per minute.

Direct shear tests were carried out on the four samples over the 50 to 200 psi normal stress range. The residual friction angle ϕ averaged about 10 degrees and showed a slight tendency to decrease with increasing normal stress (from 10 to 9.5 degrees). The tests indicated there was no effective residual cohesion.

(b) Soil Tests

Laboratory testing was carried out on four samples of clay obtained from drill hole C-1 to determine their gradations, water contents, Atterberg limits and unconfined shear strengths (Table A-7). The water contents of these samples were fairly high and for two samples the water content exceeded the plastic limit. The unconfined shear strengths determined for this sample and for one other sample were 4 psi and 55 psi respectively.

A.5 LABORATORY TESTING - (Cont'd)

Soil tests were carried out by Thurber Consultants Ltd. and the detailed procedure and results are given in their report.[9]

A.6 GEOTECHNICAL FACTORS AFFECTING DESIGN

(a) Surface Rock Conditions

The Shaftesbury shales weather stongly as compared to shales at Site 1 or W.A.C. Bennett Dam. The shale has some tendency to slake when exposed to air or water and tends to exfoliate upon unloading. The shale may have some swelling potential. More testing of the shale is required to assess these properties.

Shale exposed during excavation is expected to be soft to medium hard, the hardness being dependent on the siltstone content. It is possible that some of the shale could be excavated by ripping. However, for the feasibility study, it was assumed that excavation would have to be carried out by conventional blasting methods.

Exposed rock faces adjacent to completed structures or faces exposed for some time within the construction area will require treatment, such as shotcreting and reinforcement, to prevent sloughing or erosion by water. Rock reinforcement should be restricted to bars set in holes filled with grout. Rock bolts would be difficult to anchor in the shale.

(b) Permeability

Shale below the riverbed at both sites has a very low permeability whereas the abutment rocks (mainly shale at Site C and shale and sandstone at Site E) are cut by steeply dipping fractures which make the rock slightly more permeable.

Subject to further testing, it appears that remedial grouting and drainage will be required, together with a drainage scheme for the riverbed area beneath the concrete structures to prevent large uplift forces.

(c) Rock Slopes

The shales at Sites C and E are less well indurated than the Site 1 rocks as indicated by the respective unconfined compressive strengths. Compared to strengths of 5000 to 15,000 psi at Site 1, the shales at Site C have strengths of 1100 to 3900 psi and at Site E from 240 to 1900 psi (based on only a few tests). The sandstone at Site E was not tested but it is a relatively competent rock and is expected to have strengths in excess of 5000 psi.

The strength and weathering characteristics of the shale at Sites C and E indicate that high cut slopes in excavations will not stand vertically but will have to be flattened to at least 1H:1V.

(d) Resistance of Rocks to Shear and Sliding

An important geotechnical factor determined during exploration at both sites is the presence of clay seams within the shale. Based on direct shear tests these seams have an internal friction angle of about 10 degrees and consequently will substantially reduce the resistance of the rock to counteract the forces applied to it. The continuity and origin of these seams was not determined by the drilling for the feasibility study. However, the seams probably represent strata of the shale which have reverted to clay by swelling during stress relief from valley erosion. The properties and continuity of these clay seams will be carefully investigated before further design work on the rock formations at these sites is done.

A.6 GEOTECHNICAL FACTORS AFFECTING DESIGN - (Cont'd)

(e) Earthquakes

From the Seismic Zoning Map of Canada (1970), Sites C and E and the proposed reservoir(s) fall into Zone 1 for which the peak ground acceleration values are between 1 percent g and 3 percent g. From mapping of surface exposures throughout the region there is no evidence to indicate any earthquakes have occurred for thousands of years.

Although the likelihood of a damaging earthquake is considered negligible, earthquake accelerations of 10 percent g have been used in the design.

A.7 CONCLUSIONS

Hydroelectric development of the Peace River from Site 1 to the Alberta border is feasible and can economically be accomplished by construction of two dams, one near the border at Site E and the other near Fort St. John at Site C. Axis E-6 at Site E and Axis C-3 at Site C are the preferred locations for these dams.

The advantages of constructing two low dams rather than a single high dam became apparent from the reservoir shoreline study which indicated that:

1. The Peace River and its tributaries would have significantly fewer shoreline problems under the low Site E and Site C alternative than under the high Site E alternative.

2. Both reservoir alternatives, as compared with existing conditions, would increase the potential of activating many landslides in the reservoir area.

A.7 CONCLUSIONS - (Cont'd)

3. An area of potential sliding for Site C development is near the mouth of the Moberly River, upstream from Axis C-3. This area will be thoroughly investigated during design of this project.

Investigations conducted at the sites determined the critical geotechnical factors affecting the design of the dams. The conclusions regarding these factors are:

1. The shale and siltstone in the foundation and abutments of the proposed dams have very low strengths. The presence of clay seams within the shale further reduces the foundation's resistance to sliding.

2. Dams at axes C-3 and E-6 can be abutted against sound bedrock slopes. Terraces on these slopes will protect the dams from any sliding or sloughing material coming from the slope above the terraces.

3. The depth of overburden in the river channel at Axis C-3 is shallow compared to other axes at Site C. Deep overburden overlies bedrock in the river channel Axis E-6 but it is unlikely that any other axes at Site E would have substantially less overburden.

A.8 RECOMMENDATIONS

The following further investigations are recommended for exploration of Site C:

1. Obtain additional data on the in situ strength and characteristics of the bedrock by driving an exploratory adit into the left abutment at Axis C-3. Quantitative measurements of swelling and deformation

*

characteristics of the rock can be monitored at intervals along this adit. Several large scale shear and plate-loading tests should be carried out within the adit.

2. Drill a large diameter borehole in the foundation at Site C to allow inspection of the rock underlying the proposed dam. This borehole would allow in situ examination of the distribution of clay seams with depth, the depth and intensity of weathering of the shale and the deformation characteristics of the rock.

3. Drill about 3000 feet of rock core holes to provide information about the foundation underlying the project area. Rock testing of cores from these drill holes should be carried out and the results of these tests should be correlated with the results of in situ tests. Slaking and swelling tests of the shale should be made of several core samples. Gradation and X-ray diffraction tests of core samples are required to correlate the engineering properties of the rock with the rock types.

The following investigations are recommended for further exploration at Site E:

1. Obtain additional data on the in situ strength and characteristics of the bedrock. To expose fresh rock, a test adit or a large open cut into one of the abutments is required. Some large scale shear and plate-loading tests should be made of the fresh rock.

2. An exploration program of about 3000 feet of drilling, primarily in overburden, should be carried out to provide information for preliminary design. This investigation would be principally directed toward establishing the type and permeability of overburden which infills the river channel.

A.8 RECOMMENDATIONS - (Cont'd)

Studies of the reservoir banks should be continued to locate potential slides into the reservoir, determine the nature and size of these potential slides and assess the consequences of sliding into the reservoir. The results of reservoir bank studies could affect the design of a dam at Axis C-3 and consequently should be carried out in conjunction with preliminary design investigations.

A.9 REFERENCES

1. "Peace River Area - Power Development Studies between Site 1 and Alberta Border", IPEC for B.C. Hydro and Power Authority, 1972.

2. "Geotechnical Implications of Valley Rebound", D.S. Matheson, Ph.D. Thesis, University of Alberta, 1972.

3. "Quaternary Stratigraphy and Geomorphology of the Fort St. John Area Northeastern British Columbia", W.H. Mathews, 1963.

4. "Peace River Power Development, Dunvegan Damsite", Monenco Consultants Ltd. for Calgary Power Ltd., 1976.

5. "Lower Peace River - Shoreline Study", Thurber Consultants Ltd. for B.C. Hydro and Power Authority, 1974.

6. "Sites C and E - Lower Peace River and Tributaries Shoreline Assessment", Thurber Consultants Ltd., January 1976.

7. "Shoreline Assessment - Moberly River, B.C.", Thurber Consultants for B.C. Hydro and Power Authority, April 1976.

8. "Laboratory Testing of Rock Samples from Lower Peace River", Thurber Consultants Ltd. for B.C. Hydro and Power Authority, March 1974.

9. "Sites C and E Foundation Materials Testing", Thurber Consultants Ltd. for B.C. Hydro and Power Authority, March 1976.

TABLE A-1

SUMMARY OF GEOLOGICAL FORMATIONS

PERIOD	EPOCH	DESCRIPTION
QUATERNARY	RECENT	Slide debris, slope wash
		Alluvial deposits (fans, floodplains, etc.)
	PLEISTOCENE	Glaciolacustrine silt and clay
		Glacial till (Wisconsin)
		Interglacial silt and clay
		Glacial till (Laurentide)
? TERTIARY	?	Interglacial or preglacial basal fluvial sands and gravels
CRETACEOUS	UPPER	Kaskapau Formation: shale
		Dunvegan Formation: sandstone
	LOWER	Shaftesbury Formation: Fort St. John shale
		Gates Formation: sandstone and shale

*

*

TABLE A-2

Rock Name	Composition	Description
Shale	50% clay size 50% silt size	Black to dark grey, soft, weakly bonded and thinly laminated.
	(Composition of clay fraction) 40 - 20% illite 0 - 20% montmorillonite 0 - 20% vermiculite 0 - 20% chlorite 0 - 40% quartz, limonite, calcite	The shale has a tendency to spall upon unloading. The shale also has some tendency to slake and becomes friable when dried and soft when wetted. Drying of a sample of shale core causes parting, principally parallel to bedding, (also slight cracking perpendicular to bedding) which results in breakdown of the shale into pieces about 1/4 inch thick. Immersion of a sample of shale core in water for about an hour softens the shale and will cause it to break into chips and form a clayey silt film on exposed surfaces. Shale in outcrop breaks down quickly with wetting and drying but is not as susceptible to breakdown as shale core.
Shale (poorly bonded)	50% clay size 50% silt size	Same as shale described above, however, it is more susceptible to breakdown.
Siltstone	50% silt size 30 - 50% clay size 0 - 20% sand size	Siltstone and silty shale are less friable and have higher strength and hardness than shale. Siltstone is generally weakly bedded to massive.
	Not present at Site C	
Sandstone	20 -100% sand size 0 - 20% silt size	Pale yellowish brown, medium to fine grained, hard, slightly calcareous and crossbedded. The surface of the sandstone is rusty where it is exposed to weathering. In outcrop the sandstone is generally blocky to flaggy.

*

TABLE A-3

UNCONFINED COMPRESSION TESTS

	Sample No.	Rock Type	Ultimate Compressive Strength (psi)	Tangent Modulus of Elasticity x 10^3 (psi)
Site C	C-U-1	Shale	1376	99
	C-U-4	Shale	3890	612
	C-U-5	Shale	1176	165
	C-U-3	Shale (poorly bonded)	263	15
	C-U-2	Siltstone	2232	304
Site E	E-U-3	Shale	893	26
	E-U-5	Shale	1902	275
	E-U-6	Shale (poorly bonded)	240	16
	E-U-7	Siltstone	1448	77

*

TABLE A-4

SLIDING FRICTION TESTS

	Sample No.	Rock Type	Maximum Shearing Stress (psi)	Normal Stress at Maximum Shearing Stress (psi)	Friction Angle (Degrees)
Site C	C-S-1	Shale	379	1000	21
	C-S-2	Shale	671	1000	34
	C-S-4	Shale	650	1000	33
	C-S-3	Shale (poorly bonded)	443	1000	24
	C-S-5	Siltstone	814*	1005	39
Site E	E-S-2	Shale	545	1000	29
	E-S-3	Shale	747	1000	37
	E-S-1	Shale (poorly bonded)	524	1000	28

* Shear stress was limited by maximum allowable horizontal machine load.

*

TABLE A-5

DOUBLE SHEAR TESTS

	Sample No.	Rock Type	Shear Strength
Site C	C-D-1	Siltstone	145
	C-D-3	Siltstone	137
	C-D-4	Siltstone	21
Site E	E-D-3	Shale	7
	E-D-4	Siltstone	50
	E-D-1	Clay Seam	10
	E-D-2	Clay Seam	11

*

TABLE A-6

MULTISTAGE REVERSAL DIRECT SHEAR TESTS

WATER CONTENTS, ATTERBERG LIMITS AND COEFFICIENTS OF CONSOLIDATION

	Sample No.	Material	In situ Water Content	Liquid Limit	Plastic Limit	Plasticity Index	Coefficient of Consolidation sq in/min
Site C	C-DS-1	Clay Seam	11.3	47	21	26	.026
	C-DS-2	Clay Seam	10.1	43	22	21	.0051
Site E	E-DS-1	Clay Seam	7.3	44	19	25	.0077
	E-DS-2	Clay Seam	19.2	46	21	25	.0159

*

TABLE A-7

SOIL TESTING

Sample depth (feet)	38.5 - 40.5	52.5 - 53.5	72.5 - 74.0	91.5 - 92.5
Water content (%)	17	26	27	22
Liquid limit	35	32	51	52
Plastic limit	18	20	25	26
Plasticity index	17	12	26	26
Unconfined shear strength (psf)	-	557	-	7985

B. C. HYDRO — EXPLORATORY DRILLING — SOILS LOG

D74-1018

Project: Lower Peace River — Co-ords: 73203 N, 18569 E — Bearing: S 41° W

Location: Site C - Axis C3 — Ref. Elev.: 1663 — Angle From Horiz.: -60°

Contractor: Highways Dept. — Hole Size: 5 1/2" — In. Total Length: 450 Ft.

Depth of Overburden: 0 — Depth of Bedrock: 179 — Length of Casing: H-82, N-182

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	(%) Fluid Return & Color	Sample Description	Soil Log Datum Ground 0
	0–8	No sample taken	drilling 5 1/2" tung.bit	0.0%	Mostly smooth slow 150 200psi	brown 90% to 4.0' Total Loss at 4.0'	Silt: dark brown, slightly clayey, medium dense minor amts coarse & fine Gravel (GM) (ML)	0.0' - 32' Silt & gravel
	13–20	No sample taken	drilling 5 1/2" tung. bit		Fairly Rough to Smooth 150 250psi	0.0%	15.0' - 25.5' mostly dense gravel, minor silt. (ML) (GM)	
	26–33	No sample taken	drilling 5 1/2" tung. bit		Fairly Rough 200 to 300psi	0.0%		

Inspection: J. Roberts — Checked By: L. Cornish

Date: Aug. 20/76 — Hole No.: C1 — Page 1 of 6

B. C. HYDRO — EXPLORATORY DRILLING — SOILS LOG

D74-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	(%) Fluid Return & Color	Sample Description	Soil Log Datum Ground 0
	33–35	No sample taken	Tricone 3 7/8"	Nil	Smooth to Fairly Rough 250 psi	light brown 27.0' to 33.5' 70% to 90%	Silt, Gravel mixture (GW-ML)	
	35–38	#1	NQ Core	Not Measurable	Fairly Rough 200 to 250 psi	Lost mud at 34.0	#1: Silt, dark brown, slightly clayey Gravel, coarse rounded (ML)	
	39–41	#2	2" TO 24"	15" / 24"	30 psi		#2: Silt clay mixture 65% silt; 35% clay. Silt is dark brown, slightly clayey, medium dense, dilatancy slow. Fine gravel occurs in the clay. Clay: light grey with fine laminations (MH-CL)	32' - 45' Silt Clay
	43–51	No sample taken	Tricone 3 7/8"	Nil	Fairly smooth 150 psi	0.0%		
	52–53	#3	3" TO 12"	12" / 12"	200 psi		Silt, clayey, minor rounded Gravel (ML) (CL) (GM)	
	55–60						#3: Silt with clay dark brown to grey, stiff, medium dense, some inclusions coarse gravel. Clay has fine laminations (MH-CL)	45' - 55' Silt & Clay with some Gravel

Inspector: J. Roberts — Checked By: L. Cornish

Date: Aug. 20/75 — Hole No.: C1 — Page 2 of 6

B.C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

074-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	Fluid (%) Return & color	Sample Description	Soil Log Datum Ground 0
								55' - 72'
								Silt & Clay
					Smooth 150 200 psi slow	80 to 90% medium brown		
				Nil				
	65	No sample taken	Triconing 3 7/8"					
	70							
		#4	3" TO	18"/18"	100psi		#4;Silty Clay, grey brown	72' - 98'
	75						color, stiff, medium dry	Clay & Silt
							strength, dilatancy slow (CL)	
	80			Nil				
					Smooth to Fairly Rough 150 200psi Slow	90% brown to grey		
	85	No sample taken	Triconing 3 7/8"					
	90							

Inspector J. Roberts Checked By L. Cornish

Date Aug. 20/75 Hole No. C1 Page 3 of 6

B.C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

074-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	Fluid (%) Return & Color	Sample Description	Soil Log Datum Ground 0
	90						#5:	
		#5	3" TO	12"/12"	300 psi Fairly Slow		Clay with some silt, dark grey	
							color, hard, dense, medium	
	95	#6	NQ Core	4.1'/5.0'	Smooth 150 psi		dry strength. (CL)	
						80% Grey brown	#6: Clay, slightly silty,	
	100			3.5'/4.8'			dark grey, stiff, dense,	
		#7	NQ Core		Fairly Slow Smooth 150 psi		moist, slightly stratified.	
							Thin layers brown silt	
							at 93.2', 93.6' & 98.2' (CL)	
	105	#8	NQ Core	4.0'/5.0'	Slow Smooth 150 to 180 psi	80% grey brown	#7: 98.2' - 98.6' Clay,	98' - 103'
							slightly silty, dark grey,	Sand, silt clay
							stiff, dense, moist.	
		#9	NQ Core	0.2'/4.0'	Slow smooth 100 to 150 psi		98.6' - 103.0' Silty fine	
	110						sand, slightly clayey, grey to	
							to rusty brown, very dense,	
							firm, moist. Intervals well	
							cemented (ferrous) Last 0.2'	
							laminated (CL) (SM)	
						80% grey brown	#8: Clay & Silt, dark grey	103' - 108'
							stiff, moist, uniform, dense	Clay & Silt with
							Rusty intervals 107.8 - 108.0	Gravel
							Rusty fine Sand slightly	
							silty. Inclusions of coarse &	
							fine gravel, rounded (CL) (SP)	
						70%-80% brown	#9: Medium Sand, silty,	108.0' - 112.0'
							brown color, med. dense,	Silty sand
							soft, angular to subangular	
							(SP)	

Inspector J. Roberts Checked By L. Cornish

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LOWER PEACE RIVER

DRILL HOLE C1

B.C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	Fluid (%) Return & Color	Sample Description	Soil Log Datum Ground 0
	110							
		#10	NQ Core	0.2'/4.9'	Fairly slow smooth to Fairly smooth 100 to 150 psi	70% to 80%	#10: Coarse gravel rounded (Angular & Subangular) Sand.medium, small amt fine sand, slightly silty Sand & silt washed out shows in return mud. (GP)	
	115							
		#11	NQ Core	1.3'/5.0'	Slow Fairly Rough to Rough 150 to 250 psi		#11: Coarse Gravel rounded pieces broken gravel 10" boulder. Sand washed out.(GP)	
	120							
		#12	NQ Core	1.0/2.1		80% lgt br.		
	125	No sample	Tricone 3 7/8"	Nil	Slow Fairly rough to Rough 150 to 300 psi	Lost mud at 123.0'	#12 Coarse Gravel rounded 4" cobble. Sand washed out. (GP)	112' - 150' Sand, gravel, cobbles & boulders.
	130					0.0%	No sample: Gravel, Cobbles Sand. (From drill action)(GP)	
				Nil			No sample: Gravel, boulders Sand (From drill action) (GP)	
	135	No sample	Triconing 3 7/8"					
	140							
	145	No sample	Triconing 3 7/8"		Smooth 300Psi Slow	0.0%		
	150							

Inspector J. Roberts — Checked By L. Cornish

Date Aug. 20/75 — Hole No. C1 — Page 5 of 6

B.C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	Fluid (%) Return & Color	Sample Description	Soil Log
	150							
		13	No Care	0.5'/1.5'	Smooth to Fairly Rough 200 psi	0.0%	#13 Gravel, coarse, sand washed out (GP)	150' - 179'
	155	Triconing 3-7/8"	No Sample Taken	Nil	Smooth to Fairly Rough 100 to 150 psi	0.0%	Gravel, coarse to fine & Sand (From drill action.)	Gravel & Sand
	160							
	165				Smooth to Fairly Rough 100 to 150 psi	0.0%	Gravel, & Sand, possibly some silt (From drill action)	
	170	Triconing 3-7/8"	No Sample Taken	Nil				
	175							
	180	Tricone 3-7/8"	No Sample	Nil	Smooth 100 to 150 psi	0.0%	Back pressure on pump. Tricone was mudded in.	
								179' - 183.4' Weathered bedrock.
	185						When Tricone was examined it was covered with dark grey clay	
							183.4'-450' See Bedrock Log.	

Inspector J. Roberts — Checked By L. Cornish

Date Aug. 20/75 — Hole No. C1 — Page 6 of 6

B.C. HYDRO — EXPLORATORY DRILLING – BEDROCK LOG

PROJECT Lower Peace River — CO-ORDS 73,203 N, 18,569 E — BEARING S41° W

LOCATION Site C - Axis C-3 — REF. ELEV. 1663 — BEDROCK ELEV. 1508 — ANGLE FROM HORIZ. -60°

CONTRACTOR B.C. Dept. of Highways — CORE SIZE NQ — TOTAL LENGTH 450 FT

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
0	179	OVERBURDEN	See Soils Log	0	183.4	186.7	100
				0	186.7	187.8	100
179	225.0	SHALE	Black to grey, very fine grained, soft to medium hard, thinly	0	187.8	194.5	100
			bedded, splits easily along bedding planes, swells on exposure,	0	194.5	199.5	100
			contains clay seams to 1 1/2" thick.	0	199.5	204.6	100
			BEDDING 185 80°	0	204.6	209.7	100
			195 80°	0	209.7	214.8	100
			205 75°	0	214.8	219.8	100
			215 75°	0	219.8	224.7	100
				0	224.7	229.5	100
			FRACTURED AND BROKEN ZONES				
			189.3 vertical fracture				
			203.6 - 203.9 tight vertical fracture				
			212 fracture at 50°				
			223.0 - 223.4 vertical fracture				
			223.7 - 224.1 vertical fracture				
			CORE BREAKAGE				
			183.4 - 187 1" - 4" pieces, average 2"				
			187 - 190 2" - 8" pieces, average 6"				
			190 - 202 1" - 4" pieces, average 2"				

DATE September 19, 1975 LOGGED BY L. Cornish CHECKED BY R. McCosh HOLE NO. C-1 PAGE 1 OF 9

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			202 - 214.8 1" - 6" pieces, average 2"				
			214.8 - 219.2 1" - 6" pieces, average 3"				
			CLAY SEAMS				
			191.4 1/4" thick				
			192.4 1/4" thick				
			192.65 1/4" thick				
			192.9 1/4" thick				
			192.9 1/2" thick				
			193.2 3/8" thick				
			195.7 1/2" thick				
			196.1 1/8" thick				
			196.8 1/2" thick				
			197 1/2" thick				
			197.9 1" thick				
			201.7 1 1/2" thick				
			206 1/8" thick				
			206.5 1/2" thick				
			207.3 - 208.5 soft clayey zone with small broken pieces				
			of shale				

HOLE NO. C-1 PAGE 2 OF 9

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
225.0	239.	INTERBEDDED SHALE	SHALE: Black to grey, medium to hard, very fine grained,	0	229.5	234.8	100
		AND SANDSTONE	very thinly bedded, splits easily along bedding.	0	234.8	240	100
			SILTSTONE: Thinly bedded, hard, light grey, fine grained,				
			irregular (turbulent deposition).				
			BEDDING: 225 75°				
			235 75°				
			FRACTURED AND BROKEN ZONES:				
			229.6 - 229.8 vertical fracture				
			238.0 - 238.4 fracture @ 35°				
			CORE BREAKAGE:				
			225 - 239 1" - 12" pieces, average 8"				
239.0	282.0	SHALE	Black, soft to very soft, very fine grained, very thinly bedded,	0	240	244	100
			Much swelling of core on exposure.	0	244	247	100
			BEDDING 245 80°	0	247	248.5	100
			255 85°	0	248.5	253	100
				0	253	257.6	100
				0	257.6	259.6	100
				0	259.6	264	100
				0	264	269	100

Hole No. C-1 Page 3 of 9

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			FRACTURED AND BROKEN ZONES:	0	269	273.6	100
			242.5 - 244.0 Core extremely broken shale and clay,	0	273.6	277	100
			easily broken with fingers.	0	277	282	100
			248.5 open fracture @ 20°				
			249.5 tight fracture @ 10°				
			275.5 fracture @ 70°				
			276.2 fracture @ 45°				
			277.4 - 278.1 core badly broken				
			279.7 - 281.0 core badly broken				
			CORE BREAKAGE:				
			239 - 252 1" - 12" pieces, average 3"				
			252 - 282 1" - 14" pieces, average 5"				
			CLAY SEAMS:				
			240.0 - 242.5 slight swelling, 2" - 3" seams				
			245.6 - 247.8 very soft swelling clay and shale.				
			247.8 - 248.1 clay seam				
			253.5 1/2" thick seam				
			255.5 1" thick seam of clay with pieces of shale				
			258 1/2" thick				
			258.5 1/2" thick				
			259.5 1 1/2" clay with pieces of shale				

Hole No. C-1 Page 4 of 9

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
282	354	SILTY SHALE	Black to grey, weakly bedded, medium hardness to very soft.	40	282	286.5	90
			BEDDING: 285 @ 80°	0	286.5	289.5	100
			295 @ 70°	30	289.5	294.5	80
			310 @ 62°	40	294.5	297.5	90
			320 @ 70°	0	297.5	299.8	100
			330 @ 60°	0	299.8	309.5	100
			340 @ 70°	0	309.5	314.5	100
			350 @ 70°	0	314.5	318.5	100
				0	318.5	323.5	100
			CORE BREAKAGE:	0	323.5	329	100
			Breaks in the core predominantly occur parallel to the bedding	20	329	333.5	100
			but also are common (approx. 30%) on partings which are	20	333.5	338	100
			oriented at 90° to the bedding.	0	338	339.5	100
			282 - 300 0.1' - 0.4' ave. length 0.2'	0	339.5	344.5	100
			300 - 305 0.1' - 0.5' ave. length 0.3'	0	344.5	349.5	100
			305 - 325 0.1' - 0.4' ave. length 0.2'	0	349.5	354	100
			325 - 340 0.1' - 0.8' ave. length 0.3'				
			340 - 345 0.1' - 0.4' ave. length 0.2'				
			345 - 354 0.1' - 0.6' ave. 0.3'				

Hole No. C-1 Page 5 of 9

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			CLAY SEAMS:				
			300 - 305 Very soft rock & clay.				
			4" of soft dark grey clay at 304.5' - 305'				
			349.7 1/2" of soft clay				
354	384	SHALE	Black with light grey bands of SILTSTONE. Shale is moderately	30	354.6	359.6	86
			bedded, friable, medium hard to soft.	30	359.6	364.7	92
				80	364.7	368.6	80
			BEDDING:	100	368.6	369.7	100
			355 86°	30	369.7	374.7	100
			357 66°	30	374.7	379	100
			368 61°	30	379	384	100
			374 72°				
			380 50°				
			381 60°				
			CORE BREAKAGE:				
			354 - 357 0.1' intervals parallel to bedding. Tight				
			cracks also occur within the core.				
			357 - 380 0.2' to 1.2' average length 0.8'. Breaks				
			are all parallel to foliation.				

Hole No. C-1 Page 6 of 9

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			380 - 381.5 >0.1' generally core is broken into small fragments at approximately 5° to the core axis.				
			381.0 - 382.0 1' of intact core.				
			382.0 - 383 Core is in fragments with numerous fractures at 5° to the core axis and partings parallel to foliation.				
			CLAY SEAMS:				
			381 - 384 Seam of dark grey to black clay 1" thick occurs at 382'. Several clay seams parallel to bedding.				
384	398	SHALE & SILTSTONE	Black, well bedded, ribbed, soft to moderately hard.	50	384	389	100
				16	389	394	60
			BEDDING:	16	394	398.6	100
			394 60°				
			CORE BREAKAGE:				
			384 - 390 0.1' - 1.2' average length 0.6'				
			390 - 398 0.1' - 1.0' average length 0.5'				
			CLAY SEAMS:				
			387.5' 1/4" thick seam of black clay at 60° to the core axis crossing the foliation.				

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
398	450	SHALE	Black, medium hard, very fine grained, splits easily on bedding	0	398.6	403	100
			planes and on partings at 70° to the core axis.	0	403	407.5	100
				0	407.5	414.5	100
			BEDDING:	0	414.5	416	100
			Bedding is very weak and is oriented as follows:	0	416	418.5	100
			400 62°	0	418.5	419.7	100
			405 62°	0	419.7	424.7	100
			409 67°	50	424.7	429.6	50
			412 60°	18	429.6	434.7	100
			420 60°	20	434.7	439.7	100
			430 56°	0	439.7	441.6	100
			440 62°	20	441.6	444	100
			450 64°	10	444	448	100
				50	448	450	75
			CORE BREAKAGE:				
			Breaks in the core generally occur parallel to the bedding with the exception of fractures at 0° to the core axis from 421 - 424 and at 10° to the core axis from 398 - 403.				
			398 - 403 Core is broken into fragments of 0.1' length. These breaks are generally parallel to the foliation and cross the core axis at 10°.				
			403 - 409 Core is broken at .03' - .2'. Breaks are parallel to bedding.				

Footage (from ref elev)		Rock Type	Description	RQD	Core Recovery		
From	To			%	From	To	%
			409 - 424 0.1' - 0.4' lengths average length 0.15'.				
			424 - 428 0.1' - 0.6' average length 0.3'				
			428 - 430 <0.1' - 0.2' average length 0.1'				
			430 - 450 0.1' - 0.5' average length 0.3'.				
			CLAY SEAMS:				
			398.6 - 403 Traces of clay occur on core fragments but				
			most clay has probably been washed away.				
			398 1" thick interval of firm black clay,				
			parallel to bedding.				
			399.6 - 398.2 1/2" thick clay seam.				
			398.3 1/4" clay seam.				
			398.5 1 1/4" clay seam.				
			399 1" clay seam.				
			399.1 1/4" clay seam.				
			399.2 1/2" clay seam.				
			399.3 1/2" clay seam.				
			404 1/2" clay seam.				
			404.5 1/2" clay seam.				
			404.6 1/2" clay seam.				
			405 1"clay seam.				
			405.2 3" clay seam.				
			407.2 - 407.5 3" clay seam.				
			End of Hole				

B. C. HYDRO — EXPLORATORY DRILLING — SOILS LOG

D74-1018

Project: Lower Peace River
Co-ords.: 71,611 N, 17,490 E
Bearing: -

Location: Site C - Axis C3
Ref. Elev.: 1351
Angle From Horiz.: -90°

Contractor: Dept. of Highways
Hole Size: NQ
In. Total Length: 152 Ft.

Depth of Overburden: 10'
Depth of Bedrock: 35'
Length of Casing: 40'

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	Fluid Return	Sample Description	Soil Log
			Triconing 4 3/4"					0 - 10' Water
								10' - 35'
								Gravel, sand with
								some cobbles and
								boulders
							35' - 152' See Bedrock Log	

Inspection:
Checked By: L. Cornish

Date: Nov. 7/75
Hole No.: C-4
Page 1 of 1

B.C. HYDRO — EXPLORATORY DRILLING — BEDROCK LOG

PROJECT LOWER PEACE RIVER CO-ORDS 72,477 N 18261.1 E BEARING -

LOCATION SITE C - AXIS C3 REF. ELEV. 1,350.4 BEDROCK ELEV. 1,334 ANGLE FROM HORIZ. -90

CONTRACTOR DEPT. OF HIGHWAYS CORE SIZE NQ TOTAL LENGTH 150 FT

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
0	16	OVERBURDEN	See Soils Log				
16	26.5	WEATHERED BEDROCK					
26.5	61	SHALE	Soft, poorly indurated, weakly cemented, black to grey, very	28	25.5	28.5	100
			fine grained.	0	28.5	33	100
				0	33	38	100
			BEDDING:	20	38	43	100
			Smooth, regular, planar bedding is at 85° to the core axis.	0	43	48	100
			The rock is pitted & ribbed by erosion of unindurated	0	48	52.5	100
			laminae during drilling.	8	52.5	57.5	100
				50	57.5	58.5	100
			CORE BREAKAGE:	70	58.5	63	100
			Core is broken into pieces from 0.1' to 0.4' average length				
			0.2'. Breaks are generally parallel to bedding. Many				
			laminae are unindurated & break with handling.				
			One break not parallel to bedding occurs at 39' at 25°.				

DATE October 8, 1975 LOGGED BY L. Cornish CHECKED BY HOLE NO. C-2 PAGE 1 OF 5

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			CLAY SEAMS:				
			Clay seams are prevalent with average spacing 2.3'. Seams				
			occur parallel to bedding and are from 1/8" to 3" thick.				
			29' 3" hard clay				
			29.7' 1" clay with shale fragments				
			30.5' 1/8" clay				
			30.7' 2, 1/2" thick clay seams				
			31.5' 1/2" clay				
			31.7' 1" clay				
			32.3' 1/2" clay				
			32.6' 1/2" clay				
			41' 1/2" clay				
			42.2' 1/4" clay				
			47' 1/4" clay				
			54.2' 1 1/2" clay and shale				
			55.3' 2" clay and shale				
			61.2' 1" clay				
61	82	SILTSTONE	Argillaceous, black to light grey, moderately cemented.	70	63	68	100
				0	68	73	100
			BEDDING:	55	73	77.5	100
			Moderately bedded to massive at 85° to the core axis.	60	77.5	82.5	100

HOLE NO. C-2 PAGE 2 OF 5

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			CORE BREAKAGE:				
			Core is broken into 0.1' - 0.5' lengths, average length 0.3'.				
			Breaks are generally parallel to the bedding but are often				
			uneven or hackly.				
			Breaks not parallel to the bedding occur at:				
			69' 45°				
			69.5' 45°				
			74.5' 60°				
			75.5' 45°				
			76' 60°				
			78.5' 50°				
			79.5' 50°				
			CLAY SEAMS:				
			74' break with trace clay at 45°.				
82	114	SHALE	Soft, poorly indurated, uncemented, black, very fine grained.	0	82.5	87	100
		(poorly bonded)		0	87	88	100
			BEDDING:	0	88	91	100
			Smooth, planar, regular at 90° to the core axis. The rock	0	91	95	100
			is thin laminated and many laminae are slightly indurated	0	95	98.5	100
			clay. Laminae are ribbed and pitted by drilling. Soft	0	98.5	103.5	100
			very thin clay seams occur at 1/4" intervals.	0	103.5	108	100
				0	108	113	100
				0	113	117.5	100

Hole No. C-2 Page 3 of 5

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			CORE BREAKAGE:				
			Partings occur in unindurated clay. No fractures cross the				
			laminae.				
			CLAY SEAMS:				
			102.5 1/4" clay				
			107 1/2" clay				
			108.4 1/8" clay				
			108.5 1/8" clay				
			108.9 1/2" clay				
			109.2 1/4" clay				
			111.5 1/4" clay				
			112 1/4" clay				
			112.1 1/4" clay				
114	150	SHALE	Black to light grey, soft, very fine grained.	0	117.5	122.5	100
				80	122.5	127	100
			BEDDING:	0	127	131.5	100
			Smooth, planar, regular bedding at 87° to the core axis.	0	131.5	136	100
			Parting occur parallel to lamina.	0	136	140.5	100
				0	140.5	145.5	100
			CORE BREAKAGE:	0	145.5	150	100
			0.1' - 0.4' average length 0.3'. Breaks occur on partings				
			parallel to laminae. Handling greatly increases the number				
			of breaks.				

Hole No. C-2 Page 4 of 5

Footage (From Ref Elev)		Rock Type	Description	RQD	Core Recovery		
From	To			%	From	To	%
			CLAY SEAMS:				
			130 1/2" soft clay				
			139.5 1/4" clay				
			150' END OF HOLE				

Hole No. C-2 Page 5 of 5

B. C. HYDRO — EXPLORATORY DRILLING – SOILS LOG D74-1018

PROJECT LOWER PEACE RIVER   CO-ORDS. 72092.0 N 17651.6 E   BEARING –

LOCATION Site C – Axis C3   REF. ELEV. 1356.0   ANGLE FROM HORIZ. -90°

CONTRACTOR Dept. of Highways   HOLE SIZE NQ IN.   TOTAL LENGTH 150 FT.

DEPTH OF OVERBURDEN 0'   DEPTH OF BEDROCK 45'   LENGTH OF CASING N-51'

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	Fluid Return	Sample Description	Soil Log
			Triconing 4 3/4"	0.0%			Surface material:	0' – 45'
							Gravel with some sand,	Gravel with some
							cobbles and boulders. Grains	sand, cobbles and
							are well rounded, hard,	boulders.
							fresh. (GW)	
							45 – 150 See Bedrock Log	
	45							

INSPECTION ______   CHECKED BY L. Cornish

DATE Sept. 26/75   HOLE NO. C-3   PAGE 1 OF 1

B.C. HYDRO — EXPLORATORY DRILLING — BEDROCK LOG

PROJECT: LOWER PEACE RIVER | CO-ORDS: 72092 17651 | BEARING: -
LOCATION: SITE C - AXIS C3 | REF. ELEV.: 1356.0 | BEDROCK ELEV.: 1311 | ANGLE FROM HORIZ.: -90
CONTRACTOR: Dept. of Highways | CORE SIZE: NQ | TOTAL LENGTH: 151.5 FT

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
0	45	—	See Soils Log	0	51.5	55.5	100
45	81	SILTSTONE	Argillaceous, medium hardness, slightly cemented, black to	0	55.5	60	96
			dark grey with some light grey irregular intervals	40	60	64.5	96
			BEDDING:	70	64.5	68.5	100
			Irregular and weakly bedded with partings parallel to bedding.	90	68.5	73	100
			56' - 90°	75	73	75	100
			65' - 90°	75	75	78	100
			75' - 90°	50	78	83	100
			CORE BREAKAGE:				
			51.5 - 62 0.1' - 0.3' average 0.2'				
			62 - 81 0.2' - 1.0' average 0.8'				
			Breaks generally occur parallel to bedding but are often uneven				
			CLAY SEAMS:				
			58.5 1/2" dark grey clay				
			59 1/2" clay				
			61.6' 1" clay with shale fragments				

DATE: Sept. 26/75 LOGGED BY: L. Cornish CHECKED BY: HOLE NO.: C-3 PAGE 1 OF 3

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
81	151.5	SHALE	Dark grey to black, very soft, fissile. Clay seams occur	0	83	88	100
			commonly and core is often eroded and ribbed by drilling.	0	88	91.5	100
			120 - 123 SILTSTONE interbed.	0	91.5	97.5	82
				0	97.5	101.5	100
			BEDDING:	0	101.5	106	100
			Core is weakly bedded but is laminated. Some laminae are eroded	0	106	111	100
			by drilling. Partings occur parallel to laminae but do not	0	111	115.5	100
			always break the core.	0	115.5	120.5	100
				0	120.5	125	100
			CORE BREAKAGE:	0	125	128	66
			81 - 85 < 0.1'	0	128	132	75
			85 - 94 average 0.1'	0	132	136	100
			94 - 115 .05 to 0.2 average 0.1'. Partings occur within	0	136	140	100
			these intervals of intact core but do not break	0	140	143	100
			the core. Rock is laminated, poorly indurated,	0	143	146.5	100
			with many clay seams.	0	146.5	151.5	100
			115 - 132 0.1' - 0.2' average 0.1'. Rock is bedded at 0.1'				
			average				
			132 - 151.5 0.05 - 0.3 average 0.1'. Rock is laminated.				
			Partings occur within these intervals of intact				
			core but do not always break the core.				

HOLE NO. C-3 PAGE 2 OF 3

Footage (from ref elev)		Rock Type	Description	RQD	Core Recovery		
From	To			%	From	To	%
			CLAY SEAMS:				
			91.6 1" clay				
			92 1/2"				
			92.2 1/2"				
			95 1/4"				
			95.1 1/4"				
			95.2 1/2"				
			95.3 1/2"				
			95.5 3/4"				
			95.6 1/4"				
			97.2 1/2"				
			100 1"				
			103 1 1/2"				
			103.4 1"				
			103.8 1"				
			104.2 1"				
			105 2"				
			108.5 1/4"				
			109.4 1"				
			118 1/2"				
			142 1"				
			151.5 End of Hole				

Hole No. C-3 Page 3 of 3

B. C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018

Project: Lower Peace River | Co-ords.: 71,611 N, 17,490 E | Bearing: -

Location: Site C - Axis C3 | Ref. Elev.: 1351 | Angle From Horiz.: -90°

Contractor: Dept. of Highways | Hole Size: NQ | In. Total Length: 152 Ft.

Depth of Overburden: 10' | Depth of Bedrock: 35' | Length of Casing: 40'

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	Fluid Return	Sample Description	Soil Log
			Triconing 4 3/4"					0 - 10' Water
								10' - 35'
								Gravel, sand with
								some cobbles and
								boulders
							35' - 152' See Bedrock Log	

Inspection: | Checked By: L. Cornish

Date: Nov. 7/75 | Hole No.: C-4 | Page 1 of 1

LOWER PEACE RIVER

DRILL HOLE C4

B.C. HYDRO	EXPLORATORY DRILLING – BEDROCK LOG

PROJECT Lower Peace River CO-ORDS 71,611 N, 17,490.E BEARING -
LOCATION Site C - Axis C3 REF. ELEV. 1351 BEDROCK ELEV. 1316 ANGLE FROM HORIZ. -90
CONTRACTOR Dept. of Highways CORE SIZE NQ TOTAL LENGTH 152 FT

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			0 - 35 See Soils Log				
35	65	SHALE	Black, poorly indurated, soft, massive, from 58 - 65 the shale	0	40	45	40
			is silty.	0	45	48	100
				0	48	53	82
			BEDDING:	20	53	57.5	100
			Rock is generally massive but with minor interbeds of	40	57.5	63	100
			SILTSTONE approx. 1/4" to 1" thick.	80	63	67.5	100
			CORE BREAKAGE:				
			Breaks are at 90° to the core axis and are generally smooth and				
			planar.				
			40 - 52 breaks occur at 0.1'-0.4' average 0.2'. Partings				
			occur within these intervals of intact core but				
			do not always break the core.				
			52 - 65 0.1' - 0.8' average 0.4' Partings occur within				
			these intervals of intact core but do not always				
			break the core.				

DATE Nov. 8/75 LOGGED BY L. Cornish CHECKED BY HOLE NO. C4 PAGE 1 OF 5

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			CLAY SEAMS:				
			40.5 1"				
			40.8 1"				
			44.7 1"				
65	90	SHALE	Black, very soft with many clay seams. Clay is smeared over the	80	67.5	72.5	100
		(Poorly bonded)	surface of the core by drilling. 65 - 72 shale is silty.	0	72.5	77.5	100
				0	77.5	78.5	100
			BEDDING:	0	78.5	82.5	100
			Rock is massive but has clay seams at 90° to the core axis.	0	82.5	87	100
			Partings occur within the rock at 90°.	0	87	88.5	96
			65 - 77 0.4' - 2.0' average 0.5'	0	88.5	93	92
			Partings occur within these intervals of intact				
			core but do not always break the core.				
			77 - 90 0.1' - 0.3' average 0.2'				
			Partings occur within these intervals of intact				
			core but do not always break the core.				

HOLE NO. C-4 PAGE 2 OF 5

Footage (from ref elev)		Rock Type	Description	RQD	Core Recovery		
From	To			%	From	To	%
			CORE BREAKAGE:				
			72' 1/2"				
			72.8' 1/4"				
			72.9' 1/4"				
			72.95' 1/2"				
			73 1/4"				
			73.1 1/4"				
			73.3 1/4"				
			73.4 1/4"				
			74 1/2"				
			74.1 1/2"				
			81' 1/2"				
			84' 1/2"				
			86' 1/4"				
			87.6' 1/4"				
			87.7' 1/4"				
			88.3' 1/4"				
90	112	SHALE	Black, soft, massive, ribbed.	0	93	96	100
				0	96	98	100
			BEDDING:	0	98	103	100
			Massive but with partings clay seams at 90°.	0	103	108	100
				0	108	113	98

Hole No. C-4 Page 3 of 5

Footage (from ref elev)		Rock Type	Description	RQD	Core Recovery		
From	To			%	From	To	%
			CORE BREAKAGE:				
			90 - 103 0.1' - 0.3' average 0.2'				
			Partings occur in these intervals of intact core				
			but do not always break the core.				
			103' - 113' 0.1' - 0.5' average 0.3'				
			Breaks are smooth and at 90° to core axis.				
			CLAY SEAMS				
			96.3 1/4"				
			96.5 1/4"				
			98.5 1/2"				
			99 1/4"				
			99.5 1/4"				
			100.5 1/2"				
			101.5 - 102 5 clay seams 1/4" thick with average spacing 0.1'				
			102.6 - 103 4 clay seams 1/4" thick				

Hole No. C-4 Page 4 of 5

Footage (from ref elev)		Rock Type	Description	RQD	Core Recovery		
From	To			%	From	To	%
112	152	SILTSTONE	Argillaceous black to dark grey, medium hardness to soft.	70	113	117	100
			SHALE interbed occurs	0	117	118	100
			117 - 125	0	118	123	100
				0	123	125	100
			BEDDING:	60	125	128	100
			Interval has 1 interbed of SHALE which has gradational contacts	20	128	132	98
			with the SILTSTONE. Partings occur at 90° to the core axis.	0	132	136	98
				0	136	138	100
			CORE BREAKAGE:	10	138	143	100
			112 - 117 0.1' - 0.5' average 0.3'	40	143	148	100
			117 - 125 0.1' - 0.5' average 0.2'	25	148	152	100
			Partings.				
			125 - 152 0.1' - 0.4' average 0.2'				
			Slight partings occur				
			CLAY SEAMS:				
			119.5 ' 1/2"				
			121' 1/2"				
			123.6' 3"				
			124.5' 3"				
			125' 1"				
			No clay seams below 125'				
			152' End of Hole				

Hole No. C-4 Page 5 of 5

B. C. HYDRO — EXPLORATORY DRILLING — SOILS LOG

D74-1018

Project: Lower Peace River — Co-ords.: 71,613N 17,112E — Bearing: -

Location: Site C - Axis C3 — Ref. Elev.: 1351 — Angle From Horiz.: -90°

Contractor: Dept. of Highways — Hole Size: NQ — In. Total Length: 150.5 Ft.

Depth of Overburden: 13 — Depth of Bedrock: 38 — Length of Casing:

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	Fluid Return	Sample Description	Soil Log
			Triconing 4 3/4"					0 - 13' Water
								13 - 38' Gravel, sand with some cobbles and boulders
								38 - 48 Weathered Shale
							48 - 150.5 See Bedrock Log	
	38							

Inspection: — Checked By: L. Cornish

Date: Oct. 28/75 — Hole No.: C-5 — Page 1 of 1

LOWER PEACE RIVER — DRILL HOLE C5

B.C. HYDRO	EXPLORATORY DRILLING – BEDROCK LOG

Project: SITE C   Co-ords: 71,613N 17,112E   Bearing: -
Location: Site C - Axis C3   Ref. Elev.: 1351   Bedrock Elev.: 1313   Angle From Horiz.: -90
Contractor: Core Size: NQ   Total Length: 150.5 Ft

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
13	48		See Soils Log	60	48	52	100
48	72	SHALE	Black, silty soft, poorly indurated, massive	0	52	56	100
			BEDDING:	100	56	58	100
			Rock is massive with partings at 90° to the core axis.	8	58	63	96
				68	63	68	100
			CORE BREAKAGE:	68	68	72.5	100
			48 - 63 Core is broken into 0.1' - 0.3' lengths average 0.2'				
			63 - 72 Core is in 0.1' - 1.6' lengths average 0.6'				
			Breaks are approximately 90° but are mainly uneven.				
			CLAY SEAMS:				
			50 1"				
			72 1"				
72	137	SHALE	Black, soft very poorly indurated, massive.	0	72.5	76.5	100
		(Poorly bonded)		0	75.5	78.5	100
			BEDDING:	0	78.5	83	100
			Rock is massive but with partings at 90° to the core axis. Clay	18	83	87	96
			seams are common and the core is ribbed where clay has been	50	87	88	100
			washed away during drilling.	0	88	93	100

Date: Nov. 4/75   Logged By: L. Cornish   Checked By: Hole No.: C5   Page 1 of 4

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			CORE BREAKAGE:	0	93	96.5	100
			72 - 93 0.1' - 0.6' lengths average 0.3'	0	96.5	101.5	100
			Partings occur within these intervals but do not always	0	101.5	106	100
			break the core.	0	106	107	100
			93 - 111 0.1' - 0.4' average 0.2'	0	107	111	100
			111 - 118 0.1' - 0.4' average 0.2'	32	111	117	82
			118 - 132 average 0.1'. Partings occur throughout these	20	117	122	100
			intervals of intact core and clay seams are common.	0	122	127	100
			Breaks not parallel to bedding:	0	127	128	100
			93 45°	0	128	132.5	100
			93.5 45°	0	132.5	137	100
			94 45°				
			94.5 50°				
			96 35°				
			CLAY SEAMS:				
			75 1/2"				
			76 1"				
			78.2 1/2"				
			83 4" interval of clay and rock fragments.				
			85.6 1/2"				
			101 1/4"				
			106 1/4"				
			106.1 1/4"				
			108 1/2"				
			108.4 1/4"				
			108.5 2"				

Hole No. C5   Page 2 of 4

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			110 2"				
			116.5 1/4"				
			118 1/4"				
			118.2 1/4"				
			120 1/4"				
			120.4 1/4"				
			120.5 1/4"				
			120.6 1/4"				
			120.8 1/4"				
			121.4 1/4"				
			121 - 126 Core is soft with 1/4" clay seams at average spacing				
			of 0.2'.				
			127.8 1/4"				
			128 1/2"				
			128.5 1/2"				
			129 1/2"				
			129.2 1/2"				
			129.3 1/2"				
			130 1/2"				
			130.1 1/2"				
			131 1/4"				
			131.2 1/4"				
			132 1/2"				
			132.6 - 136.8 Shale is extremely soft and clay seams occur at an				
			average spacing of 0.1' and are 1/4" thick.				
			137 1/2".				

Hole No. C5 Page 3 of 4

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
137	150.5	SHALE	Black, massive, soft, moderately indurated	0	137	137.5	100
				30	137.5	142.5	100
			BEDDING:	24	142.5	147.5	100
			Rock is massive. Weak partings occur at 90° to the core axis.	18	147.5	150.5	100
			CORE BREAKAGE:				
			Breaks occur at 90° to the core axis and are smooth.				
			127 - 150.5 0.1' - 0.4' average length 0.2'.				
			CLAY SEAMS:				
			138 1/4"				
			142 1"				
			142.3 1/4"				
			150.5 End of hole.				

Hole No. C5 Page 4 of 4

B. C. HYDRO — EXPLORATORY DRILLING — SOILS LOG (D74-1018)

Project: Lower Peace River
Co-ords.: 70,982 N, 16,892 E
Bearing: -
Location: Site C - Axis C3
Ref. Elev.: 1363
Angle From Horiz.: -90
Contractor: B.C. Hydro
Hole Size: NQ
In. Total Length: 153 Ft.
Depth of Overburden: 0
Depth of Bedrock: 44
Length of Casing: N-153

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	Fluid Return	Sample Description	Soil Log
					Rough slow		Surface Sample:	0' - 12'
							0' - 12' exposed in the slope	Silt & fine sand
	5						to the river bank adjacent	
							to the drill hole.	
							Silt & fine sand.	
	10							
	15							
	20							
	25							
	30							
	35							

Inspection: Al Penner
Checked By: L. Cornish
Date: Oct. 28/75
Hole No.: C-6
Page 1 of 2

B. C. HYDRO — EXPLORATORY DRILLING — SOILS LOG (D74-1018A)

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	Fluid Return	Sample Description	Soil Log
	40						42' - 44' Core sample	12' - 44'
							Gravel, cobbles, well	Sand, gravel,
							rounded, generally quartz	cobbles & boulders
							rich.	
	45						44' - 153' See Bedrock Log	

Inspector: Al Penner
Checked By: L. Cornish
Date: Oct. 28/75
Hole No.: C-6
Page 2 of 2

LOWER PEACE RIVER

DRILL HOLE C6

B.C. HYDRO — EXPLORATORY DRILLING — BEDROCK LOG

Project: Lower Peace River — Co-ords: 70,982 N 16,892 E — Bearing: -

Location: Site C - Acis C3 — Ref. Elev. 1363 — Bedrock Elev. 1319 — Angle From Horiz. -90

Contractor: B.C. Hydro — Core Size: NQ — Total Length: 153 Ft

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
0	44	OVERBURDEN	See Soils Log		41	45	0
				0	45	48	60
44	98	SILTSTONE	Argillaceous, massive, black to dark grey	28	48	53	100
				64	53	58	96
			BEDDING:	36	58	63	100
			Rock is massive except for thin lenses of sandy SILTSTONE.	68	63	68	100
			Partings occur at 90° and are smooth.	48	68	73	98
				98	73	78	98
			CORE BREAKAGE:	76	78	83	88
			44 - 45 Fragments of core less than -.1" in diameter.	82	83	88	100
			45 - 48 0.1 - 0.8 average 0.4	20	88	93	100
			No partings occur within these intervals of intact core.	60	93	98	100
			58 - 64 0.1 - 0.9 average 0.6				
			No partings occur				
			64 - 98 0.2 - 1.2 average 0.7				
			No partings.				
			Core is slightly ribbed toward the end of the interval.				
			Breaks not parallel to partings occur at:				
			62.5 60°				
			70 60°				

Date: ____ Logged By: L. Cornish Checked By: ____ Hole No. C6 Page 1 of 3

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			83 45° - 60°				
			86 20°				
			87.5 20°				
			87.6 30° opposite direction of above				
			87.9 30°				
			93 10°				
			96 10°				
			BROKEN ZONES:				
			82.5 - 83 0.1' diameter				
			CLAY SEAMS:				
			52 1/4"				
			58 - 58.6 7"				
			70 2"				
			96 1/2"				
				80	98	103	100
98	153	SHALE	Silty, black, massive, slightly ribbed.	60	103	108	96
				0	108	113	100
			BEDDING:	20	113	118	98
			Core is massive except for minor thin irregular lenses of	0	118	123	100
			SILTSTONE	60	123	128	96
				60	128	133	96
				40	133	138	100
				24	138	143	100

Hole No. C6 Page 2 of 3

Footage (from ref elev)		Rock Type	Description	RQD	Core Recovery		
From	To			%	From	To	%
			CORE BREAKAGE %:	24	143	148	100
			98 - 113 0.1 - 0.3 average 0.2 Partings	50	148	153	100
			113 - 128 0.1 - 0.6 average 0.3 Partings				
			128 - 153 0.1 - 0.6 average 0.2 Partings				
			Breaks are at 90° and are smooth.				
			BROKEN ZONES occur at:				
			110 - 110.5 pieces of 0.1" diameter				
			137 - 139 breaks at 5° to the core axis and core				
			fragments are 0.1' diameter				
			147 - 147.7 breaks at 5° to the core axis and core				
			fragments are 0.1' diameter				
			CLAY SEAMS:				
			122.5 1/4"				
			142.3 1"				
			End of Hole.				

Hole No. C6 Page 3 of 3

B. C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018

Project Lower Peace River — Co-ords. 70,541N 16,558E — Bearing –

Location Site C – Axis C3 — Ref. Elev. 1410 — Angle From Horiz. -90

Contractor B.C. Hydro — Hole Size NQ — In. Total Length 152 Ft.

Depth of Overburden 0 — Depth of Bedrock 21 — Length of Casing

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	Fluid Return	Sample Description	Soil Log
							Surface sample:	0 – 21
							Black, organic silt.	Organic, black
								silt grading into
	5							weathered shale
	10							
	15							
	20						21' – 152' See Bedrock Log	
	25							

Inspection — Checked By L. Cornish

Date Oct. 30/75 Hole No. C-7 Page 1 of 1

LOWER PEACE RIVER DRILL HOLE C7

B.C. HYDRO — EXPLORATORY DRILLING — BEDROCK LOG

Project: Lower Peace River | Co-ords: 70,541N 16,558E | Bearing: -

Location: Site C - Axis C3 | Ref. Elev. 1410 | Bedrock Elev. 1389 | Angle From Horiz. -90

Contractor: B.C. Hydro | Core Size: NQ | Total Length: 152 Ft

Footage From	Footage To	Rock Type	Description	Rqd %	Core Recovery From	Core Recovery To	Core Recovery %
			0 - 21' See Soils Log				
21	67	SHALE	Silty, black, soft, pitted and ribbed by erosion of unindurated	0	21	26	100
			layers during drilling.	0	26	31	100
				30	31	37	94
			BEDDING:	0	37	42	100
			Massive but with partings at 90° to the core axis.	0	42	47	100
				0	47	52	100
			CORE BREAKAGE:	0	52	57	100
			21 - 31 The rock is highly ribbed & broken into pieces	60	57	62	100
			averaging 0.2' long. These breaks are often	26	62	67	100
			(40%) uneven & not at 90°.				
			31 - 67 0.1-0.3' average 0.2'. Partings are present				
			within these intervals of intact core but do not				
			always break the core. Breaks are smooth at 90°.				

Date: Oct. 31/75 | Logged By: L. Cornish | Checked By: | Hole No. C7 | Page 1 of 3

Footage From	Footage To	Rock Type	Description	Rqd %	Core Recovery From	Core Recovery To	Core Recovery %
			CLAY SEAMS:				
			23' 1" Silty Clay				
			25' 1/2" Silty Clay				
			40' 1" Silty Clay				
			41.6' 1/2" Silty Clay				
			52 1" Silty Clay				
67	152	SILTSTONE	Black, argillaceous, moderate hardness, moderately well	0	67	72	100
			cemented and indurated.	0	72	77	100
				40	77	82	100
			BEDDING"	60	82	87	100
			Massive with some partings at 90°.	30	87	92	100
				0	92	97	100
			CORE BREAKAGE:	60	97	102	100
			67 - 80 0.05-0.2 average 0.1'	20	102	107	100
			80 - 92 0.1-0.3 average 0.2'	72	107	112	100
			92 - 122 0.1-0.8 average 0.4'	68	112	117	100
			122 - 142 0.1-0.4 average 0.2'	22	117	122	100
			142 - 152 0.1-0.2 average 0.1'	58	122	127	100
				0	127	132	96
			Breaks are generally at 90° and are even.	16	132	137	100
				32	137	142	100
				0	142	147	100
				0	147	152	92

Hole No. C7 | Page 2 of 3

Footage (from ref elev)		Rock Type	Description	RQD	Core Recovery		
From	To			%	From	To	%
			Breaks not at 90° occur at:				
			77' 30°				
			110' 0°				
			112' 45°				
			138' many breaks occur at 0 - 20° and are probably				
			caused by excessive pressure during drilling.				
			CLAY SEAMS:				
			72' fracture with trace clay				
			75' 1/4" clay				
			152' End of Hole.				

Hole No. C7 Page 3 of 3

B. C. HYDRO — EXPLORATORY DRILLING — SOILS LOG D74-1018

PROJECT Lower Peace River — CO-ORDS. 49,062 N, 191,936 E — BEARING S 38° E

LOCATION Site E - Axis E6 — REF. ELEV. 1400 — ANGLE FROM HORIZ. -60

CONTRACTOR B.C. Hydro — HOLE SIZE NQ IN. — TOTAL LENGTH 303 FT.

DEPTH OF OVERBURDEN 0 — DEPTH OF BEDROCK 9 — LENGTH OF CASING 30

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	Fluid Return	Sample Description	Soil Log
							Information from a trench	0' - 9'
	5						adjacent to the drill hole	Organic silt
							indicates that bedrock is at	
							9' depth.	9' - 19' Sand-
								stone (no recovery
	10						The following succession of	Siltstone
							rock types can be seen in	(no recovery)
							the trench.	
							0' - 9' Organic silt	
	15						9' - 14' Sandstone	
							14' - 18' Siltstone	
							18' - 19' Sandstone	
							19' - 32' Siltstone	
	20							
	25							
	30						30' - 303' See Bedrock Log.	

INSPECTION J. Roberts — CHECKED BY L. Cornish

DATE Oct. 8/75 — HOLE NO. E-1 — PAGE 1 OF 1

B.C. HYDRO — EXPLORATORY DRILLING — BEDROCK LOG

PROJECT Lower Peace River   CO-ORDS 49,062 N, 191,936 E   BEARING S 28° E

LOCATION Site E - Axis E6   REF. ELEV. 1400   BEDROCK ELEV. 1391   ANGLE FROM HORIZ. -60

CONTRACTOR B.C. Hydro   CORE SIZE NQ   TOTAL LENGTH 303 FT

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			0' - 30' See Soils Log				
30	104	SHALE	Soft, uncemented, unindurated, dark grey to light grey.	0	30	35.5	91
		(Poorly bonded)	Very fine grained with considerable intervals of hard	0	35.5	41	95
			clay seam and zones. Core is strongly ribbed and	0	41	46	90
			pitted.	0	46	51	100
				0	51	56	76
			BEDDING:	0	56	61.5	84
			Well defined and regular at 60° to the core axis.	0	61.5	66.5	100
			Core is bedded at approximately 3" intervals with	0	66.5	71.5	100
			light grey slightly cemented SILTSTONE and dark grey,	0	71.5	76.5	100
			uncemented unindurated SHALE, poorly bonded. Laminations occur	0	76.5	81.5	60
			within the beds and partings parallel to laminae	0	81.5	83	60
			are at 1/4" intervals. Clay seams occur predominantly	0	83	88	100
			in the poorly bonded SHALE	0	88	93	84
				0	93	98	80
			CORE BREAKAGE:	0	98	103	100
			Breaks occur parallel to bedding at 0.1' - 0.3' lengths.	0	103	108	100
			Partings occur within these pieces of intact core at				
			1/4" intervals. These partings do not always break the				
			core.				

DATE October 13, 1975   LOGGED BY L. Cornish   CHECKED BY ____   HOLE NO. E1   PAGE 1 OF 6

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			CLAY SEAMS:				
			30 — 6" firm grey clay				
			34.5 — 1 1/2" firm grey clay				
			44 — 1 1/2" firm grey clay				
			49.7 — 1"				
			50.0 — 1 1/2" soft clay				
			51 — 1"				
			51.5 — 1"				
			51.7 — 1/2"				
			53 — 1"				
			55 — 1"				
			55.5 — 6"				
			56.1 — 1"				
			56.5 — 1"				
			61 — 6"				
			63 — 1 1/2"				
			63.5 — 1/2"				
			64 — 2' clay				
			74.5 — 1/2" clay				
			80 — 1" clay				
			80.5 — 1' of clay with shale fragments.				
			81.6 — 1' of soft clay				
			83 - 88 — clay seams occur at 3" intervals and are 1" thick.				
			90 — 1" clay				
			90.5 — 1/2" clay				
			92 — 1 1/2" clay				

HOLE NO. E1   PAGE 2 OF 6

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			94.5 2" clay				
			97.5 1" clay				
			100 1" clay				
			100.1 1"				
			101.5 1"				
			102 1"				
			103 1"				
			103.1 1"				
			103.5 6"				
104	150	SHALE with SHALE	Soft, uncemented, unindurated, dark grey, fine grained.	0	108	113	86
		(Poorly bonded)	Core is strongly ribbed and pitted.	0	113	120	71
		Interbeds		0	120	125	100
			BEDDING:	0	125	130	96
			Moderately strong, regular, planar bedding at 60°	0	130	135	100
			to the core axis. Partings occur parallel to	0	135	140.5	89
			bedding at 1/4" intervals.	0	140.5	145.5	88
				0	145.5	153	51
			CORE BREAKAGE:				
			Breaks occur at 0.1' - 0.4' average 0.2'.				
			Partings occur within these intact pieces but do not				
			always break the core.				

Hole No. E1 Page 3 of 6

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			Breaks not parallel to the bedding occur at:				
			126 30° crossing the bedding				
			126.5 30° in the same direction as bedding				
			127 30° in the same direction as bedding				
			137 35° in the same direction as bedding				
			137.5 25° crossing the bedding				
			145.8 25° crossing the bedding.				
			CLAY SEAMS				
			106 6" soft clay and shale				
			113 1/4" firm clay				
			114 1" dark grey clay				
			117 1" dark grey clay				
			117.5 1/2"				
			120 6" soft clay				
			121.5 1"				
			122 1/2"				
			124.7 3"				
			125 2"				
			132 2"				
			135 1/2"				
			144 1/2"				

Hole No. E1 Page 4 of 6

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
150	213	SILTSTONE	Dark grey to light grey, soft, moderately cemented,	8	153	158	100
			moderately indurated.	40	158	163	100
				80	163	168	94
			BEDDING:	12	168	173	64
			Moderately strong, irregular and uneven at 60° to the	80	173	178	100
			core axis.	90	178	183	100
				96	183	188	100
			CORE BREAKAGE:	94	188	193	94
			150 - 163 0.2' - 0.7' average 0.4'	76	193	198	100
			163 - 194 0.1' - 2.0' average 0.8'	48	198	203	94
			194 - 207 0.1' - 0.6' average 0.3'	24	203	208	100
			Breaks generally occur parallel to the bedding but	0	208	213	80
			are often uneven.				
			Breaks not parallel to bedding occur at:				
			165 0°				
			167 0°				
			175-178 Core is in 0.1' diameter pieces with breaks				
			0°-20° to the core axis.				
			CLAY SEAMS:				
			169 - 171.5 uneven breaks occur at 0.1' intervals with				
			traces of clay on broken surfaces.				
			191 1/4" clay seam at 85°				
			200 1/4" clay seam at 85°				
			207 1/8" clay seam at 90°				

Hole No. E1 Page 5 of 6

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
213	303	SHALE	Black to dark grey, soft, uncemented, moderately indurated.	0	213	218	100
				0	218	223	100
			BEDDING:	0	223	228	96
			BEDDING is strong regular and planar at 60°	18	228	233	94
			212 - 227 core is laminated and is ribbed and pitted	20	233	238	96
			by drilling	0	238	243	100
			227 - 238 moderately well bedded	0	243	249	96
			238 - 243 core is laminated	8	249	253	100
			243 - 263 moderately strong bedding	0	253	258	100
			263 - 303 core is laminated.	0	258	263	96
				0	263	268	100
			CORE BREAKAGE:	0	268	273	100
			Breaks occur parallel to bedding and are smooth and planar.	3	273	278	100
			217 - 227 average 0.1. Partings also occur within	0	278	283	100
			these intervals parallel to laminae, but do	0	283	288	92
			not break the core.	0	288	293	92
			243 - 263 average 0.1'	0	293	298	100
			263 - 303 average 0.1'. Partings occur within these	8	298	303	94
			pieces but do not break the core.				
			CLAY SEAMS:				
			216 - 216.5 1' of clay				
			218 7" of clay				
			226 1/4" of clay				
			248 1" of clay				
			249 1/2" of clay				
303			303' END OF HOLE				

Hole No. E1 Page 6 of 6

B. C. HYDRO — EXPLORATORY DRILLING – SOILS LOG (D74-1018)

Project: Lower Peace River — Co-ords.: 48,474N 192,266E — Bearing: -

Location: Site E - Axis E6 — Ref. Elev.: 1269 — Angle From Horiz.: -90

Contractor: B.C. Hydro — Hole Size: NQ — In. Total Length: 251 Ft.

Depth of Overburden: 0 — Depth of Bedrock: 87 — Length of Casing: N-155'

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	Fluid Return	Sample Description	Soil Log
			Triconing				Surface Soil:	
							Well rounded; gravel	0 - 30
							cobbles & boulders	Gravel, cobbles &
	5							boulders
	10							
	15							
	20							
	25							
	30							
	35							

Inspection: — Checked By: L. Cornish

Date: Sept. 21/75 — Hole No.: E-2 — Page 1 of 2

B. C. HYDRO — EXPLORATORY DRILLING – SOILS LOG (D74-1018A)

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	Fluid Return	Sample Description	Soil Log
			3" DS	24/24			Sample #1 35' -37'	
	40						Sand, coarse, light brown	
							angular to subangular,	30 - 60
							medium dense (SP).	Coarse sand
	45							
	50		3" DS	12/18			Sample #2 50' - 51.5'	
							Sand, coarse, light	
							brown, angular to	
							subangular.	
	55							
	60							60 - 87
								Gravel with
								cobbles & boulders
	65							
	70						87 - 251 See Bedrock Log	
	75							

Inspector: — Checked By: L. Cornish

Date: Sept. 21/75 — Hole No.: E2 — Page 2 of 2

B.C. HYDRO — EXPLORATORY DRILLING — BEDROCK LOG

Project: Lower Peace River — Co-ords: 48,474N 192,266E — Bearing: -
Location: Site E - Axis E6 — Ref. Elev.: 1269 — Bedrock Elev.: 1182 — Angle From Horiz.: -90
Contractor: B.C. Hydro — Core Size: NQ — Total Length: 251 Ft

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
0	87		See Soils Log	0	87	92	120
87	126	SHALE	Soft black to dark grey, clay size grains with some silt.	0	92	96	110
			BEDDING:	0	96	101	60
			Rock is moderately bedded with partings along bedding planes.	0	101	106	40
			Bedding is generally at 87°	0	106	111	76
				0	111	113	100
			CORE BREAKAGE:	0	113	116	50
			Is into 0.05' to 0.2' pieces average length 0.1'. The core has	0	116	121	100
			been slightly dried and cracking of the core has occurred at	0	121	129	67
			approximately 1/4" intervals.				
			CLAY SEAMS:				
			95 1" clay seam.				
			This seam has swelled 0.2" in diameter.				
			102 3" clay seam. Clay has swelled 0.1" in diameter				

Date: Sept. 25, 1975 — Logged By: L. Cornish — Checked By: — Hole No.: E-2 — Page 1 of 4

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
126	174	SHALE with	Black to dark grey very soft, clay size with some silt size	0	129	133	46
		SHALE (poorly bonded)	grains, ribbed. Clay seams are prevalent in poorly bonded SHALE	0	133	138	100
		Interbeds	INTERBEDS. INTERBEDS OF poorly bonded SHALE occur at:	0	138	143	110
			126 - 136	0	143	145	100
			143 - 146	0	145	150	100
			150 - 154	0	150	151	100
				0	151	155	100
			BEDDING:	0	155	157	100
			Is well defined at 90° to the core axis. Partings occur along	0	157	159	100
			weak laminae and are predominant in the poorly bonded SHALE	0	159	162	46
				0	162	167	18
			CORE BREAKAGE:	0	167	171	25
			126 - 136 0.1' - 0.4' average length 0.2'	0	171	173	50
			136 - 143 0.2' - 0.8' average length 0.5'	0	173	174.5	66
			143 - 146 0.1' - 0.3' average length 0.2'				
			146 - 150 0.1' - 0.5' average length 0.3'				
			150 - 174 average length 0.05'				
			CLAY SEAMS:				
			126 3" of soft clay				
			132.5 1/2" of soft clay				
			133.5 1/2" of soft clay				
			134 1/2"				
			135 1"				
			149 2"				
			151 6"				
			152.5 6"				

Hole No. E-2 — Page 2 of 4

Footage (from ref elev)		Rock Type	Description	RQD	Core Recovery		
From	To			%	From	To	%
			153.1 1/2"				
			153.5 5"				
174	251	SHALE	Black, friable, soft, uncemented, poorly indurated. The core	0	174.5	178	100
			is frequently pitted and ribbed where soft unindurated clay	0	178	179	10
			seams have been eroded by drilling.	0	179	183	80
				0	183	188	96
			BEDDING:	0	188	193	100
			Rock is well bedded at 90° to the core axis. Laminations occur	0	193	198	100
			in the bedding and partings occur on weak laminae but do not	0	198	203	96
			always break the core.	0	203	208	100
				0	208	213	100
			CORE BREAKAGE:	0	213	218	100
			174 - 188 average length 0.1. Partings occur at 1/8"	0	218	223	100
			intervals	0	223	228	100
			188 - 198 average 0.1'. Partings at 1/4" intervals.	0	228	233	100
			198 - 210 core is laminated and ribbed with partings	0	233	237	71
			parallel to laminae. Average length 1/8".	0	237	242	100
			210 - 223 core is bedded with partings parallel to	0	242	247	100
			bedding. Average length 0.1'	0	247	251	100
			223 - 237 laminated and ribbed with partings parallel to				
			laminae. Average length 1/8"				
			237 - 251 well bedded and laminated and ribbed in some				
			intervals. Partings occur at 1" intervals.				

Footage (from ref elev)		Rock Type	Description	RQD	Core Recovery		
From	To			%	From	To	%
			CLAY SEAMS:				
			190' 1/2" clay				
			193.5' 1/4" clay				
			194.5' 1/2" clay				
			Zones of very soft, unindurated poorly bonded SHALE				
			198 - 210				
			237 - 251				
			251' End of Hole				

B.C. HYDRO	EXPLORATORY DRILLING – BEDROCK LOG

Project: Lower Peace River | Co-ord.: 48,113 N, 195,462 E | Bearing: –

Location: Site E - Axis E6 | Ref. Elev.: 1267 | Bedrock Elev.: 1114 | Angle From Horiz.: -90

Contractor: B.C. Hydro | Core Size: NQ | Total Length: 253 Ft

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			0' - 153' See Soils Log				
153	253	SHALE	Black, fissile, uncemented poorly indurated, argillaceous with	0	152	157.5	80
			some silt. The rock has very thin seams of clay at average				
			intervals of 0.5'. These clay seams are generally eroded by	0	162.5	165	100
			drilling and give the core a ribbed appearance	0	165	170	100
				0	170	175.5	91
			BEDDING:	0	175.5	180	90
			Laminated at 90° to the core axis with partings parallel to	0	180	185	100
			lamina.	0	185	190	100
				0	190	195	100
			CORE BREAKAGE:	0	195	200	100
			152 - 162 fractures occur parallel to laminations.	0	200	205	100
			Fractures are smooth and planar.	0	205	210	100
			Breakage of the core also occurs to a minor	0	210	215.5	90
			degree perpendicular to bedding probably the	0	215.5	221	90
			result of shrinkage.	0	221	223	100
			162 - 178.5 core is generally laminated with breaks	0	223	228	96
			parallel to laminae. Pieces of intact core	0	228	233	100
			up to 0.1' long occur in the interval.	0	233	238	100
				0	238	243	100
				0	243	248	100

Date: Sept. 28, 1975 Logged By: L. Cornish Checked By: ______ Hole No. E-3 Page 1 of 3

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			178.5 - 188 Core is weakly bedded with partings parallel to bedding. Partings occur at	0	248	253	100
			.01' to 0.3' average 0.1'				
			188 - 196 Core is laminated with partings parallel to				
			laminae.				
			196 - 238 Core is well bedded with partings parallel				
			to bedding maximum length of core is 0.1'				
			238 - 253 Core is laminated with partings parallel				
			to laminae.				
			CLAY SEAMS:				
			157.5 - 158.5 1' seam of black clay with shale fragments.				
			184.8 1" seam of soft black clay				
			190 - 197 Frequent very thin clay seams occur in the				
			core. The core is eroded where these seams				
			are washed away.				
			194.5 - 195 5 seams of black clay each 1/4" thick				
			237.9 1" clay				
			241.8 1/2" black clay				
			242 1/2" black clay				
			242.1 1/4" black clay				
			242.3 1/2" black clay				
			243 1/4" black clay				
			244 1/4" black clay				
			244.1 1/2" black clay				
			244.2 1/2" clay seam				
			244.4 1/2"				

Hole No. E-3 Page 2 of 3

Footage (from ref elev)		Rock Type	Description		RQD	Core Recovery		
From	To				%	From	To	%
			245	1/4"				
			245.3	1/2"				
			245.6	1/4"				
			246.7	1/4"				
			247	1/2"				
			247.3	1/2"				
			247.4	1/4"				
			247.5	1/4"				
			248.2	1/4"				
			250	1/4"				
			250.3	1/4"				
			250.8	1/4"				
			252.4	1/2"				
			252.6	1/4"				
			End of Hole					

Hole No. E-3 Page 3 of 3

B. C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018

Project: Lower Peace River | Co-ords: 48,113 N, 195,462 E | Bearing: –
Location: Site E – Axis E6 | Ref. Elev.: 1267 | Angle From Horiz.: -90°
Contractor: B.C. Hydro | Hole Size: NQ | In. Total Length: 253 Ft.

Depth of Overburden: 0 | Depth of Bedrock: 153 | Length of Casing: H-10', N-142'

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	Fluid Return & Colour	Sample Description	Soil Log
	0.0 – 10	No Sample	4 3/4" Tricone	0.0	Very Rough 150 300psi	80% Med. brown	0.0' – 11.0' Boulders – small amount coarse sand in return	0 – 30 Boulders, cobbles gravel & sand.
	10 – 15	No Sample	4 3/4" Tric.	0.0	Very Rough	60% 80% med. brown	11.0' – 15.0' Boulders, cobbles, coarse gravel, coarse sand (GP)	
	15 – 25	No Sample	4 3/4" Tricone	0.0	Very Rough	60% 80% med. brown	15.0' – 25.0' Boulders – some coarse sand	
	25 – 35	No Sample	4 3/4" Tricone	0.0	Very Rough	0.0% 70.0% med. brown	25.0' – 35.0' Boulders – coarse sand	
	35 – 38	No Sample	4 3/4 Tric.	0.0	Very Rough	70% med brown	35.0' – 38.0' Boulders Coarse Sand	

Inspector: J. Roberts | Checked By: L. Cornsih
Date: Sept. 26/75 | Hole No.: E3 | Page 1 of 5

B.C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	% Fluid Return & Colour	Sample Description	Soil Log
	35 – 50	No Sample	4 3/4" Tricone	0.0	Very Rough to Rough	0.0% 60% med. brown	38.0' – 52.0' Boulders, Cobbles, Coarse Gravel, Coarse Sand (GP)	
	50 – 54	#1	N split spoon	14/24	6"–325 6"–140 6"– 85 6"– 90	10% 70% med. brown	52.0' – 54.0' Coarse Sand – fine Gravel, black-brown White – Angular to Subangular (GP) (SP)	30 – 60 Sand & gravel
	54 – 78	No Sample	4 3/4" Tricone	0.0	Rough to Med. Rough	0.0% 80% med. brown	54.0' – 75.0' Boulders, Cobbles, Coarse Gravel, Coarse Sand – Small Layers fine Gravel (GP (SP)	60.0' – 126 Boulders, Cobbles Gravel, Sand

Inspector: J. A. Roberts | Checked By: L. Cornish
Date: Sept. 27/75 | Hole No.: E3 | Page 2 of 5

LOWER PEACE RIVER DRILL HOLE E3

B.C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	% Fluid Return & Colour	Sample Description	Soil Log
	75						75.0' - 110.0'	
							Boulders, Cobbles,	
							mixture Coarse & fine	
							Gravel, Coarse Sand	
	80						(GP) (SP)	
	85							
		No Sample	4 3/4" Tricone	0.0	Fairly Smooth to Rough	0.0%		
	90					60%		
						Med.		
						brown		
	95							
	100							
	105							
	110							
	115							

Inspector J. A. Roberts — Checked By L. Cornish

Date Sept. 27/75 — Hole No. E3 — Page 3 of 5

B.C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	% Fluid Return & Colour	Sample Description	Soil Log
	110						110.0' - 126.0'	
						0.0%	Cobbles, Coarse & fine	
						70%	Gravel, Coarse Sand	
						med.	(GP) (SP)	
	115					brown		
		No Sample	3 7/8" Tricone	0.0	Fairly smooth to Rough			
	120							
	125							
							126.0' - 142.0'	126' - 153'
							Coarse Gravel &	Gravel - Sand
	130						Coarse Sand (GP) SP)	
				0.0	Fairly smooth	0.0%		
						70%		
						med.		
	135	No Sample	3 7/8" Tricone			brown		
	140							
							142.0' - 149.0'	
						30%	Coarse Gravel	
	145	#2	NQ Core Barrel	1.4 / 7.0	Fairly smooth	80%	Sand Washed out	
						med.	Rounded to Sub	
						brown	Rounded	
	150							

Inspector J. A. Roberts — Checked By L. Cornish

Date Sept. 29/75 — Hole No. E3 — Page 4 of 5

B.C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	% Fluid Return & Colour	Sample Description	Soil Log
	150			1.4/4.0	Fairly smooth	80%	149.0' - 153.0'	
						med.	Coarse Gravel	
						brown	Sand washed out	
							Rounded to Sub	
	155						Rounded. (GP) (SP)	
							NOTE: Drilled into	
							Bedrock (Shale) at	
							approximately 153.0'	
							153' - 253' See Bedrock Log	

Inspector J. A. Roberts — Checked By L. Cornish

Date Sept. 29/75 — Hole No. E3 — Page 5 of 5

B. C. HYDRO — EXPLORATORY DRILLING – SOILS LOG D74-1018

Project: Peace River - Site E
Co-ords.: 47,281 N 195,996 E
Bearing: -
Location: Site E - Axis E-6
Ref. Elev.: 1265'
Angle From Horiz.: -90°
Contractor: Becker Drilling Ltd.
Hole Size: NX
In. Total Length: 40' Ft.

Depth of Overburden: 0
Depth of Bedrock: 24
Length of Casing: 29'

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	Fluid Return	Sample Description	Soil Log
						80%	0.0' - 24.0'	0.0' - 24.0'
						Light	Cobbles, coarse gravel,	Cobbles, gravel,
						Brown	coarse sand, clayey silt.	sand, clayey silt.
	5.0				Rough			
	10.0							
	15.0							
	20.0							
	24.0						24' - 40' See Bedrock Log	

Inspection: A. Penner
Checked By:
Date: Dec. 8/75
Hole No.: E-5
Page 1 of 1

LOWER PEACE RIVER

DRILL HOLE E5

B.C. HYDRO — EXPLORATORY DRILLING — BEDROCK LOG

PROJECT Lower Peace River CO-ORDS 47,281 N 195,996 E BEARING -

LOCATION Site E - Axis E-6 REF. ELEV. 1265' BEDROCK ELEV. 1241 ANGLE FROM HORIZ. -90

CONTRACTOR Becker Drilling Ltd. CORE SIZE NX TOTAL LENGTH 40' FT

FOOTAGE (FROM REF ELEV)		ROCK TYPE	DESCRIPTION	RQD	CORE RECOVERY		
FROM	TO		0 - 24' See Soils Log	%	FROM	TO	%
24	26	SANDSTONE	Massive fine grained sand, light grey, moderately hard.	0	24	29	0
			BEDDING:				
			Very weakly bedded at 90° to core axis.				
			CORE BREAKAGE:				
			Breaks are uneven and at 90° to core axis.				
26	40	SHALE	Silty dark grey to light grey, uncemented, poorly indurated.	0	29	35	100
			The core has a distinct ribbed appearance due to very thin	80	35	40	100
			clay seams which have been eroded due to the drill action.				
			BEDDING:				
			Core is moderately bedded at 90° to core axis with partings				
			occurring along bedding planes.				
			CORE BREAKAGE:				
			Fractures are parallel to bedding.				
			26' - 35' Average interval is 0.1'				
			35' - 40' Average interval is 0.5'				

DATE Dec. 13/75 LOGGED BY A. Penner CHECKED BY ____ HOLE NO. E-5 PAGE 1 OF 1

B. C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

Project: Peace River - Site E Co-ords.: 47,129 N / 196,000 E Bearing: -

Location: Site E - Axis E-6 Ref. Elev.: 1267' Angle From Horiz.: -90°

Contractor: Becker Drilling Ltd. Hole Size: NX In. Total Length: 70' Ft.

Depth of Overburden: 0 Depth of Bedrock: 27' Length of Casing: 30'

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	Fluid Return	Sample Description	Soil Log
		#1 (E-5a 0-10)				80%	0.0' - 27.0'	0.0' - 27.0'
						Light	Cobbles, coarse gravel	Cobbles, gravel
	5.0					Brown	coarse sand, clayey silt.	sand, clayey silt.
					Rough			
	10.0	#2 (E-5a 10-20)						
	15.0							
	20.0	#3 (E-5a 20-30)						
	25.0							
	27.0						27' - 70' See Bedrock Log	

Inspection: A. Penner Checked By:

Date: Dec. 11/75 Hole No.: E-5a Page 1 of 1

B.C. HYDRO	EXPLORATORY DRILLING — BEDROCK LOG

PROJECT Lower Peace River CO-ORDS 47,129 N 196,000 E BEARING -

LOCATION Site E - Axis E-6 REF. ELEV. 1267' BEDROCK ELEV. 1240' ANGLE FROM HORIZ. -90

CONTRACTOR Becker Drilling Ltd. CORE SIZE NX TOTAL LENGTH 70' FT

FOOTAGE (FROM REF ELEV)		ROCK TYPE	DESCRIPTION	RQD	CORE RECOVERY		
FROM	TO		0 - 27' See Soils Log	%	FROM	TO	%
27	29	SANDSTONE	Massive fine grained sand, light grey, moderately hard.				
			BEDDING:				
			Very weakly bedded at 90° to core axis.				
			CORE BREAKAGE:				
			Breaks are uneven at 90° to core axis.				
29	70	SHALE	Dark grey to light grey, uncemented, poorly indurated, generally				
			argillaceous with some silt. Layer of SILTSTONE about 1' thick				
			is present at 65'.				
			BEDDING:				
			Core is moderately bedded at 90° to core axis with partings				
			occurring along bedding planes.				
			CORE BREAKAGE:				
			Fractures are parallel to bedding.				
			70' - End of Hole				

DATE Dec. 14/75 LOGGED BY A. Penner CHECKED BY ______ HOLE NO. E-5 a PAGE 1 OF 1

LOWER PEACE RIVER DRILL HOLE E5a

B. C. HYDRO — EXPLORATORY DRILLING – SOILS LOG — D74-1018

Project	Lower Peace River	Co-ords.	46,725 N, 196,215 E	Bearing	N28°W
Location	Site E - Axis E-6	Ref. Elev.	1395	Angle From Horiz.	-70°
Contractor	B.C. Hydro	Hole Size	NQ	In. Total Length	302.0' Ft.
Depth of Overburden	0	Depth of Bedrock	13.0'	Length of Casing	H-10.0, N-24.0'

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	% Fluid Return & Colour	Sample Description	Soil Log
	0.0	No sample	Triconing 4 3/4 & 3 7/8"	NIL	Rough	80%	0.0' - 13.0'	0.0 - 13.0
						Light	Boulders, cobbles, coarse	boulders, cobbles
	5.0					brown	gravel, coarse sand, clayey	gravel, sand,
							silt	clayey silt
							13' - 302' See Bedrock Log	
	10.0							
	15.0							

Inspection J.A. Roberts — Checked By L. Cornish

Date Oct. 18/75 Hole No. E6 Page 1 of 1

B.C. HYDRO — EXPLORATORY DRILLING — BEDROCK LOG

Project: Lower Peace River — Co-ords: 46,725 N, 196,215 E — Bearing: N28°E
Location: Site E - Axis - E-6 — Ref. Elev. 1395 — Bedrock Elev. 1383 — Angle From Horiz. -70°
Contractor: B.C. Hydro — Core Size: NQ — Total Length: 301.5 Ft

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			0 - 13' See Soils Log				
13	35.4	SANDSTONE	Uniform fine grained sand, light grey, moderately hard.	0	13	17	20
				0	17	18	0
			BEDDING:	0	18	22	75
			Weakly bedded with slight colour changes between beds.	0	22	27	84
				44	27	32	88
			CORE BREAKAGE:	26	32	35	70
			13' - 18' Drill rounded fragments of SANDSTONE of 0.1' diameter.				
			18' - 22' Core is broken at regular intervals into 0.15' lengths. Breaks are at 90° to the core axis.				
			22' - 27' Core is broken into 0.2' lengths. Approx. 30% of the interval is composed of uncemented sand.				
			27' - 35.4' 0.1' - 1.2' lengths with average length 0.5' Breaks are uneven, generally at 90° to the core axis. Cross bedding at 20°.				
			SOFT ZONES:				
			22' - 26.8' Core is poorly cemented SANDSTONE and sand.				

Date: October 22, 1975 — Logged By: L. Cornish — Checked By: — Hole No. E-6 — Page 1 of 6

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
35.4	52	SHALE	Dark grey to black, fine grained, soft, poorly indurated.	0	35	40	56
		(poorly bonded)		0	40	45	66
			BEDDING:	60	45	47	90
			Core is weakly bedded with irregular intervals of SILTSTONE.	0	47	52	84
			Partings occur parallel to bedding.				
			CORE BREAKAGE:				
			45' - 51' Core is broken in lengths of 0.1' - 0.4'. Partings occur parallel to bedding but do not always break the core.				
			CLAY SEAMS: 37' - 1" 48.8' - 1/2"				
			38' - 1" 48.9' - 1/2"				
			39' - 1" 49.0' - 1/2"				
			40' - 1" 49.4' - 2"				
			47' - 1/2" 51' - 1/2"				
			48.5' - 1/2"				
52	128	SHALE	Silty, black to light grey, soft.	8	52	57	90
				0	57	62	30
			BEDDING:	0	62	65	83
			Strong irregular bedding with SILTSTONE at 0.1' intervlas.	0	65	70	16
				0	70	75	80
			CORE BREAKAGE:	0	75	77.5	80
			Breaks occur parallel to bedding at 0.1' - 0.6' intervals.	0	77.5	80	88
			51'-91' Core is broken in lengths of 0.1' - 0.6' with average	0	80	82.5	88
			length 0.4'. Partings occur within these intervals of	0	82.5	87.5	36
			intact core.	0	87.5	90	84
			91'-109' Core is broken in lengths less than 0.1'. Core is very soft and clay seams are abundant.	0	90	95	70

Hole No. E-6 — Page 2 of 6

Footage (From Ref Elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			CLAY SEAMS:	0	95	98	86
				0	98	103	60
				0	103	108	60
				0	108	113	80
				0	113	118	54
				0	118	123	44
				0	123	128	90
			54' - 2"				
			55.2' - 2"				
			63.5' - 1/2"				
			63.9' - 1/2"				
			64.2' - 1/2"				
			75.3' - 1"				
			78.5' - 1"				
			87.5' - 9"				
			91.5' - 1/2"				
			91.3' - 1/2"				
			94' - 2"				
			94.8' - 2"				
			99.2' - 1"				
			106.5' - 4"				

Hole No. E-6 Page 3 of 6

Footage (From Ref Elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			107' - 1"				
			107.5' - 1"				
			107.7' - 1"				
			109' - 4"				
			109.5' - 2"				
			116.9' - 1"				
			118' - 1"				
			118.3' - 6"				
			119.5' - 1"				
			128' - 1"				
128	203	SILTSTONE	Light grey to dark grey, medium hardness, uniform grain size,	16	128	133	100
			slight banding of colour. The grain size gradually grades from	16	133	138	100
			silt size to silt size with fine sand at 150' - 182' and then	80	138	143	100
			back to silt size at 182' - 223'.	20	143	148	68
				70	148	152	100
			BEDDING:	100	152	157	100
			Very weak bedding. From 128' - 150', weak bedding with some	100	157	162	100
			light grey sandy SILTSTONE interbeds. From 150' - 182', massive	87	162	167.5	91
			with orientation of mineral grains, poorly cemented intervals.	92	167.5	172.5	100
			From 182' - 223', weak bedding with some light grey sandy	94	172.5	177.5	100
			SILTSTONE interbeds.	100	177.5	182.5	100
				98	182.5	187.5	100
				92	187.5	192.5	100
				78	192.5	198	100
				52	198	203	100

Hole No. E-6 Page 4 of 6

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			CORE BREAKAGE:				
			128' - 143' Core is broken into 0.1' - 0.6' lengths with				
			average length 0.4'. Partings occur at 0.05'				
			intervals parallel to bedding planar.				
			143' - 153' Core is broken into 0.1' - 0.6' lengths with				
			average length . Partings parallel to				
			bedding and uneven.				
203	241	SHALE	Black, very soft, poorly indurated, pitted and ribbed by drilling,	74	203	208	80
		(poorly bonded)	clay seams are prevalent and the core is coated by clay.	40	208	213	94
				0	213	218	80
			BEDDING:	0	218	223	100
			Massive with strong regular, planar, thin laminations. Partings	22	223	228	100
			occur parallel to these laminae. Unindurated laminae are	0	228	233	76
			eroded by drillings.	0	233	238	54
				0	238	241.5	100
			CORE BREAKAGE:				
			203' - 218' Core is broken at 0.1' - 0.4' with average length				
			0.2'. All breaks occur at 70°. Core is thin				
			laminated and very soft. Partings occur at 0.01'				
			lengths but do not always break the core.				
			218' - 220' Core is broken at 0.1' - 0.4' lengths with				
			average length 0.2' (Silty).				
			220' - 223' Core is broken at 0.1' - 0.4' lengths with				
			average length 0.2' (Shale - poorly bonded)				

Hole No. E-6 Page 5 of 6

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			223' - 240' Core is broken at 0.1' - 0.4' with average				
			length 0.2' (Silty)				
			240' - 241.5' (Clay)				
			CLAY SEAMS:				
			201' - 7" (shale and clay)				
			209' - 3.5' (shale and clay)				
			225' - 2.5' (shale and clay)				
			240' - 1' (clay)				
241	302	SHALE	Silty, moderately indurated, medium hardness, black to light grey.	0	241.5	246.5	100
		(poorly bonded)		0	246.5	252	91
			BEDDING:	0	252	257	82
			Rock is massive but partings occur at regular intervals of	0	257	262	100
			0.1' at 70°.	0	262	267	100
				0	267	272	100
			CORE BREAKAGE:	0	272	277	100
			241.5' - 302' On the average the core is broken into 0.1'	0	277	282	100
			lengths. Partings are regular, planar (Silty).	0	282	287	92
				0	287	292	26
			301.5' END OF HOLE.	0	292	297	90
				0	297	302	96

Hole No. E-6 Page 6 of 6

B. C. HYDRO	EXPLORATORY DRILLING — SOILS LOG
	074-1018

PROJECT Lower Peace River — CO-ORDS. 52,139N, 199,700 E — BEARING -

LOCATION Site E - Axis E3 — REF. ELEV. 1538 — ANGLE FROM HORIZ. -90°

CONTRACTOR B.C. Hydro — HOLE SIZE NQ — IN. TOTAL LENGTH 241 FT.

DEPTH OF OVERBURDEN 0 — DEPTH OF BEDROCK 41 — LENGTH OF CASING N-58'

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	% Fluid Return Colour	Sample Description	Soil Log
	0.0	No samples taken	Triconing 4 3/4"	NIL	150 psi	70%	0.0' - 26.0'	0.0' - 41
						grey	Silt, clay, sand	Silt clay sand
						brown		
	5.0				Smooth slow			
	10.0							
	15.0							
	20.0				Smooth Slow			
	25.0	No sample taken	Triconing 4 3/4" & 3 7/8"	NIL	180 psi	85%		
						grey		
	30.0					brown		
							(Driller reports too hard to take drive sample)	
	35.0						41' - 241' See Bedrock Log	

INSPECTOR J.A. Roberts — CHECKED BY L. Cornish

DATE Oct.12/75 — HOLE NO. E7 — PAGE 1 OF

B.C. HYDRO	EXPLORATORY DRILLING — BEDROCK LOG

PROJECT Lower Peace River CO-ORDS 52,139 N, 199,700 E BEARING -
LOCATION Site E - Axis E3 REF. ELEV. 1538 BEDROCK ELEV. 1497 ANGLE FROM HORIZ. -90
CONTRACTOR B.C. Hydro CORE SIZE NQ TOTAL LENGTH 241 FT

FOOTAGE (FROM REF ELEV)		ROCK TYPE	DESCRIPTION	RQD	CORE RECOVERY		
FROM	TO			%	FROM	TO	%
0	41	OVERBURDEN	See Soils Log				
				0	41	48	10
41	58	WEATHERED BEDROCK	Fragments of rock in a clay matrix, dark grey to light grey	0	48	53	2
			53 - 58' 2' of grey clay.	0	53	58	40
				0	58	59	50
58	81	SHALE & INTERBEDDED	Black to dark grey, very fine grained, very soft, weakly	48	59	64	100
		SANDSTONE	indurated, strongly bedded. SANDSTONE is light grey,	46	64	68	100
			silt and fine sand size grains, moderately cemented, soft	8	68	73	90
			to medium hardness, weakly bedded.	0	73	78	100
			SANDSTONE interbeds occur at:	96	78	83	94
			69 - 69.5 63 - 64				
			78 - 81				
			BEDDING:				
			Shale is strongly bedded and laminated parallel to bedding				
			at 90°.				
			SANDSTONE has weak irregular bedding.				

DATE Oct. 18, 1975 LOGGED BY L. Cornish CHECKED BY ____ HOLE NO. E7 PAGE 1 OF 7

FOOTAGE (FROM REF ELEV)		ROCK TYPE	DESCRIPTION	RQD	CORE RECOVERY		
FROM	TO			%	FROM	TO	%
			CORE BREAKAGE:				
			59 - 63 average 0.1' lengths. Partings also occur				
			parallel to laminae but do not always				
			break the core.				
			63 - 64 average 0.5' breaks are uneven parallel to				
			bedding.				
			64 - 78 average 0.1'. Partings also occur parallel to				
			laminae but do not always break the core.				
			78 - 81 average 0.5', breaks are uneven, parallel to				
			bedding.				
			81 - 81.5 0.1'. Partings also occur parallel to laminae				
			but do not always break the core.				
			CLAY SEAMS:				
			67' 1" clay				
			67.2' 2" clay				
			68.5' 1 1/2"				
			69.3' 1/4"				
			69.5' 1/4"				
			73.2' 1/4"				
			75' 1"				
			76' 1 1/2"				
			78' 1" coal.				

HOLE NO. E7 PAGE 2 OF 7

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
81	103	SANDSTONE	Fine sand size grains, moderately cemented, soft to medium	20	83	88	96
			hardness, weakly bedded, greyish brown to red brown.	82	88	93	96
				78	93	98	96
			BEDDING:	92	98	103	100
			Rock is only very weakly bedded and grades from medium				
			sand at 81.5 to fine silty sand at 103'. Bedding is at 90°				
			CORE BREAKAGE:				
			Core breakage is 0.1' to 1.2' average 0.6'.				
			Breaks are planar, even and regular at 90° to the core axis.				
			CONTACT:				
			The upper and lower contacts are abrupt and parallel to bedding.				
103	128	SILTSTONE with thin	SILTSTONE is light grey, medium hard, moderately cemented,	58	103	108	92
		interbeds of SHALE	well bedded with SHALE at average 0.1' intervals.	65	108	113	88
				40	113	118	100
			SHALE interbeds are distributed throughout the interval.	66	118	123	100
				8	123	128	100
			BEDDING:				
			Core has regular interbeds at 90° of shale with contacts				
			grading average 1/4" thickness.				

Hole No. E-7 Page 3 of 7

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			CORE BREAKAGE:				
			0.05' - 0.6' average 0.3'				
			Breaks are generally smooth, planar and occur parallel to				
			bedding. Some partings also occur in shale interbeds.				
			Breaks not parallel to bedding occur at:				
			107' 25°				
			107.5' 25°				
			CLAY SEAMS:				
			107 1" clay				
			114.5 1" uncemented sand				
			115 1/2" uncemented sand				
			116 1" clay				
			116.6 1" clay				
			117 1/4" clay				
			118 1" clay				
			123.6 2" clay.				
128	167	SANDSTONE	Medium to fine grained uniform sand, moderately cemented,	68	128	133	100
			medium hardness.	70	133	138	98
				100	138	143	100
			BEDDING:	94	143	148	100
			Poorly defined gradational bedding at 90° to the core axis.	94	148	153	100
				76	153	158	82
				80	158	163	100
				84	163	168	96

Hole No. E7 Page 4 of 7

Footage (from ref elev) From	Footage To	Rock Type	Description	RQD %	Core Recovery From	Core Recovery To	Core Recovery %
			CORE BREAKAGE:				
			0.1' - 2.5' average 1.0'				
			Breaks are generally smooth, planar and occur parallel to				
			bedding, however, approximately 30% are parallel to bedding				
			but are uneven.				
167	179	SILTSTONE with thin	SILTSTONE is black, ribbed, moderately laminated, slightly	62	168	173	100
		interbeds of	cemented.	70	173	178	100
		SANDSTONE	Light grey to black, moderately hard, ribbed.	76	178	183	100
			SANDSTONE is moderately cemented, uniform, medium grain				
			size and weakly bedded.				
			BEDDING:				
			is well defined with alternate SANDSTONE and thin SILTSTONE				
			interbeds at 0.1' intervals. Partings occur in the				
			SILTSTONE interbeds.				
			CORE BREAKAGE:				
			0.1' - 0.5' average 0.3'				
			Breaks are parallel to bedding in SILTSTONE interbeds.				
			CLAY SEAMS:				
			167 1/2" clay				
			173.2 1/2"				
			177.5 1/8"				
			179.1 1/8"				
			179.3 1/4"				

Hole No. E7 Page 5 of 7

Footage (from ref elev) From	Footage To	Rock Type	Description	RQD %	Core Recovery From	Core Recovery To	Core Recovery %
179	241	SHALE	Black to dark grey, very fine grained, very soft, weakly	8	183	188	100
			indurated strongly bedded.	32	188	193	100
				0	193	198	100
			BEDDING:	16	198	203	100
			Strong irregular bedded with very thin interbeds of light	16	203	208	100
			grey SILTSTONE at an average spacing of 0.1'.	0	208	212	100
				0	212	217.5	100
			CORE BREAKAGE:	0	217.5	222.5	100
			Breaks in the core are parallel to bedding and are generally	0	222.5	228	97
			smooth and planar	0	228	233	100
			179 - 193 0.05 - 0.2 average 0.1	0	233	238	94
			193 - 212 0.05 - 0.4 average 0.1	0	238	241	[illegible]
			212 0.02 - 0.2 average 0.5				
			CLAY SEAMS:				
			179.2 1/2" 183.7 1"				
			181 1/4" 184.9 1/2"				
			181.1 1/8" 184.0 1/2"				
			182.7 4" of clay 184.2 3"				
			183.3 1/2" 185 1"				
			183.4 1/2" 185.2 1/2"				
			185.7 1/2"				
			186.0 1/2"				
			186.1 1/2"				
			186.2 1/4"				

Hole No. E7 Page 6 of 7

Footage (from ref elev)		Rock Type	Description		RQD	Core Recovery		
From	To				%	From	To	%
			187	1' of thin clay seams throughout the shale.				
				Approximately 40% clay.				
			192.2	1/2"				
			200	1/2"				
			200.1	1/4"				
			200.5	1/4"				
			210.0	1/2"				
			210.6	3"				
			221.5	1/2"				
			227.8	1/4"				
			228.3	1"				
			239.9	1"				
			240	1/4"				
			240.1	2 1/2"				
			240.5	3"				
			241' End of Hole					

Hole No. E7 Page 7 of 7

D74-1018

B. C. HYDRO — EXPLORATORY DRILLING - SOILS LOG

Project: Lower Peace River
Co-ords.: 51,365 N, 200,245 E
Bearing: -
Location: Site E - Axis E3
Ref. Elev.: 1264
Angle From Horiz.: -90°
Contractor: B. C. Hydro
Hole Size: NQ
In. Total Length: 252 Ft.

Depth of Overburden: 0
Depth of Bedrock: 63
Length of Casing: N 63'

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	Fluid Return	Sample Description	Soil Log
	0						0.0' - 10.0' Surface sample	0.0' - 63'
							Boulders Cobbles, Gravel	Boulders, Cobbles
							Sand; well rounded.	Gravel & sand.
	5	No Sample	6 1/4" Tricone	0.0	Very Rough 180 psi	85% lt. brown		
	10	No Sample	6 1/4" Tricone	0.0	Very Rough 200psi	90% Light Brown		
	15	No Sample	Triconing 4 3/4"	0.0	Very Rough 200psi	90% Light Brown		
	20							
	25							
	30	No Sample	Triconing 6 1/4"	0.0	Very Rough to Rough 200psi	90% Light Brown		
	35							

Inspector: J. A. Roberts
Checked By: L. Cornish
Date: Oct. 1/75
Hole No.: E8
Page 1 of 2

D74-1018A

B.C. HYDRO — EXPLORATORY DRILLING - SOILS LOG

Water Level	Depth (Ft.)	Sample No.	Sample Type	% Recovery	Blow Count Drill Action	% Fluid Return & Colour	Sample Description	Soil Log
	35							
	40			0.0	Rough 200 psi	80% Light Brown		
	45							
	50							
	55							
	60	No Sample	Tri cone 4 3/4	0.0	Rough 200psi	80% Light Brown		
	65						63' - 252' See Bedrock Log	
	70							

Inspector: J. A. Roberts
Checked By: L. Cornish
Date: Oct. 3/75
Hole No.: E8
Page 2 of 2

LOWER PEACE RIVER

DRILL HOLE E8

B.C. HYDRO	EXPLORATORY DRILLING – BEDROCK LOG

Project: Lower Peace River — Co-ords: 51,365 N, 200,245 E — Bearing: -

Location: Site E - Axis E3 — Ref. Elev.: 1264 — Bedrock Elev.: 1201 — Angle From Horiz.: -90

Contractor: — Core Size: NQ — Total Length: 252 Ft

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			0 - 63' See Soils Log				
63	181	SHALE	Black, soft, fine grained, uncemented, unindurated	0	63	68	25
				0	68	73	0
			BEDDING	0	73	83	50
			Strong, regular, planar bedding. Laminated at 1/4" intervals	0	83	88	0
			with partings parallel to laminae at 90° to the core axis.	0	88	91	60
				0	91	95	90
			CORE BREAKAGE:	20	95	100	100
			Core is broken into 0.05 - 0.5' lengths, average length	0	100	103	100
			0.2'. Partings occur with these intervals but do not	20	103	108	100
			always break the core.	0	108	113	90
			Breaks not parallel to bedding occur at:	0	113	118	90
			98' 45°	0	118	123	60
			110-114' 0° to core axis	0	123	128	90
			131' 0°	0	128	131	30
			170-170.5' 0°	0	131	136	90
			173-170' 0°	0	136	141	90
				0	141	147	50
				0	147	149	100
				0	149	151.5	100
				0	151.5	157	3

Date: Oct. 7/75 — Logged By: L. Cornish — Checked By: — Hole No.: E-8 — Page 1 of 5

Footage (from ref elev) From	To	Rock Type	Description		RQD %	Core Recovery From	To	%
			CLAY SEAMS:		0	157	160	2.5
			63' - 68'	clay	0	160	165	100
			79' - 83'	1' of clay	0	165	170	100
			88' - 91'	Clay	0	170	176	90
			93'	1/4" clay	0	176	181	100
			99'	1" clay				
			99.5'	1" clay				
			104'	1/2" clay				
			104.2'	1/2" clay				
			104.5'	1/2" clay				
			104.7'	1/2" clay				
			104.8'	1/2" clay				
			105'	1/2" clay				
			109.3'	1" clay				
			118' - 122.5'	clay				
			123.5' - 126'	18" clay				
			131' - 131.25'	3" clay				
			145.8' - 146.8'	1' of clay with shale fragments				
			148'	2, 1/4" clay seams				
			151.7'	1" clay				
			151.9'	5" clay				
			153' - 157'	clay with shale fragments				
			163.5'	1/2" clay				
			163.6'	1/2" clay				
			164'	1/2" clay				
			164.5'	1/2" clay				
			166'	1/2" clay				

Hole No.: E8 — Page 2 of 5

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			167' 1/2" clay				
			167.2' 1/2" clay				
			168.8' 1/2" clay				
			168.9' 1/4" clay				
			170' 1/2" clay				
			177' 1/2" clay				
			177.1' 1/2" clay				
			177.5' 1/2" clay				
			179' 1/2" clay				
			179.1' 1/2" clay				
181	206	INTERBEDDED	SHALE is black fine grained, uncemented weakly indurated	10	181	186	100
		SILTSTONE with	strongly bedded, laminated with partings parallel to	70	186	191	100
		SHALE	laminae.	20	191	196	100
			SILTSTONE is black, weakly bedded with partings parallel	60	196	201.5	100
			to bedding to massive, moderately cemented.	10	201.5	206.5	100
			Interbeds of SILTSTONE occur at:				
			182' - 184'				
			185' - 190'				
			198' - 201'				

Hole No. E8 Page 3 of 5

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			CORE BREAKAGE:				
			Breaks are parallel to bedding.				
			181' - 184' 0.1' - 0.3' lengths				
			184' - 185' 0.1' - 0.3' lengths. Partings also occur				
			but do not break the core.				
			185' - 190' 0.1' - 0.5' average 0.3'				
			190' - 198' 0.1' - 0.2' Partings also occur but do				
			not always break the core				
			198' - 201' 0.1' - 0.6' average 0.3'				
			CLAY SEAMS:				
			192.5' 1/4" clay				
			192.6' 1/4" clay				
			196.5' 1/4" clay				
			197' 1/4" clay				
			197.1' 1/4" clay				
			198' 1/4" clay				

Hole No. E8 Page 4 of 5

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
206	252	CLAY SHALE	Soft, poorly indurated, pitted and ribbed by erosion of	0	206.5	211.5	100
			clay laminae during drilling.	40	211.5	216.5	100
			BEDDING:	0	216.5	222	100
			Moderately bedded, laminated with partings parallel to laminae.	0	222	227	100
				0	227	232	100
			CORE BREAKAGE:	0	232	237	100
			less than 0.2' with partings parallel to laminae at 1/4"	0	237	242	100
			intervals not breaking the core.	0	242	247	100
				0	247	252	100
			CLAY SEAMS:				
			210' 1/2"				
			211' - 216' Approx. 40% of interval is composed of clay				
			244' 1" clay seam				
			251' 1" clay seam				
			Clay seams are abundant throughout the interval but are				
			very thin and are evenly distributed throughout the core.				
			252' End of Hole.				

HOLE NO. E8 PAGE 5 OF 5

B.C. HYDRO	EXPLORATORY DRILLING — BEDROCK LOG

Project: Lower Peace River | Co-ords: 48,690 N, 202,460 E | Bearing: -

Location: Site E - Axis E3 | Ref. Elev.: 1527 | Bedrock Elev.: 1379 | Angle From Horiz.: -90

Contractor: B.C. Hydro | Core Size: NQ | Total Length: 203 Ft

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			0' - 148' See Soils Log				
148	155	SILTSTONE	Dark grey, very soft, unindurated, uncemented.	8	148	153	40
			Some fine sand size.	35	153	158	50
			BEDDING:				
			Moderately bedded with silty SANDSTONE.				
			CORE BREAKAGE:				
			Core will not remain intact when removed from the core box.				
155	178	SANDSTONE	Medium hardness medium-fine sand size grains, light grey,	70	158	163	92
			moderately cemented with silica, slightly banded with light	50	163	168	100
			and dark grey rock.	40	168	173	100
				65	173	178	94
			BEDDING:				
			Massive but with variations in colour.				
			CORE BREAKAGE:				
			0.1' - 1.8' average length 0.8'				
			Breaks are uneven but 50% are at 90°.				

Date: Oct. 28/75 | Logged By: L. Cornish | Checked By: | Hole No.: E9 | Page 1 of 3

Footage (from ref elev) From	To	Rock Type	Description	RQD %	Core Recovery From	To	%
			Breaks not parallel to bedding are:				
			173 60°				
			177 50°				
			177.5 10°				
178	203	SILTSTONE	Dark grey with interbeds of light grey SANDSTONE and black	45	178	183	100
			SHALE. Soft to medium hardness, moderately cemented, slightly	45	183	188	100
			ribbed on some intervals.	50	188	193	100
				40	193	198	94
			BEDDING:	60	198	203	100
			Bedding is strong with a repeated succession of SANDSTONE,				
			SILTSTONE AND SHALE at intervals of .15' on average. The				
			rock grades from predominantly SANDSTONE (60%) with minor				
			SILTSTONE AND SHALE at 180' - 199' to SILTSTONE AND SHALE				
			with very minor SANDSTONE from 199' - 203'.				
			CORE BREAKAGE:				
			Core is generally broken at 0.1 to 0.4' average 0.2'.				
			Breaks are predominantly in SHALE and are parallel to bedding.				
			CLAY SEAMS:				
			184 1 1/2" light brown clay				
			185 4" medium grey				
			187 1/2" clay seam				
			187.7 1/2" clay seam				

Hole No.: E9 | Page 2 of 3

LOWER PEACE RIVER DRILL HOLE E9

Footage (From Ref Elev)		Rock Type	Description	RQD	Core Recovery		
From	To			%	From	To	%
			190.5 1/4" clay seam				
			192.7 1/4" clay seam				
			193 1" clay seam				
			194 1/4" clay seam				
			194.1 1/4" clay seam				
			194.3 1/2" clay seam				
			195 1/4" clay seam				
			195.1 1/4" clay seam				
			198.7 1" clay seam				
			200 1/2" clay seam				
			202 1/2" clay seam				
			203' End of Hole.				

Hole No. E9 Page 3 of 3

B. C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018

Project: Lower Peace River
Co-ords.: 48,690 N, 202,460 E
Bearing: –
Location: Site E – Axis E3
Ref. Elev.: 1527
Angle From Horiz.: 90°
Contractor: B.C. Hydro
Hole Size: NQ
In. Total Length: 203 Ft.

Depth of Overburden: 0
Depth of Bedrock: 148
Length of Casing: N-148'

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill. Action	Fluid Return	Sample Description	Soil Log
								0 – 44
	5						Silt & clay, slightly	Silt & Clay
							sandy, medium brown, soft.	
							(ML)	
	10							
	15			0.0%				
		No Sample Taken	Triconine 4 3/4" Bit					
	20							
	25							
	30							
	35							

Inspection: J.A. Roberts
Checked By: L. Cornish
Date: Oct. 26/75
Hole No.: E9
Page 1 of 5

B. C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	Fluid Return	Sample Description	Soil Log
	35						34 – 38	
				2.6/4.0	smooth/100psi	90-100	Clayey silt slightly	
						Light	sandy med. brown, soft (ML)	
						brown		
	40						38 – 44	
				1.0/6.0	smooth/100psi	100	Clayey silt, slightly sandy	
						Light	med. brown, soft (ML)	
	45					brown		
							44 – 49	44 – 79
				1.0/5.0	smooth/150psi	100	Clay, dark grey, soft,dense	Clay
						dark	highly plastic, 1/8" lenses	
	50					grey	black clay. (CH)	
						100	49 – 54	
				2.0/5.0	smooth/150psi	dark	Clay same as 44 – 49	
						grey		
	55	NQ Core						
				2.1/4.0	smooth/150psi	100	49 – 58	
						dark	Clay – same as 44 – 54	
	60					grey		
				5.0/5.0	smooth/150psi	100	54 – 58	
						dark	Clay – same as 44 – 54	
						grey		
	65							

Inspector: J.A. Roberts
Checked By: L. Cornish
Date: Oct. 26/75
Hole No.: E9
Page 2 of 5

LOWER PEACE RIVER

DRILL HOLE E9

B.C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	Fluid Return	Sample Description	Soil Log
							63 - 79	
							Clay, dark grey, soft	
						100	dense, highly plastic	
	65		NQ Core	4.2/5.0	smooth 150psi	dark	1/8" lenses black clay (CH)	
						grey		
	70					100		
				3.4/5.0	smooth 150psi	dark		
						grey		
	75					100		
			NQ Core	4.8/5.0	smooth 150psi	dark		
						grey	79 - 83	
							Silt, brown soft, gravel	
	80					100	embedded	
				1.2/5.0	smooth 150psi	dark		
						grey	83 - 97	79 - 148
						0-0	Gravel, coarse, rounded	Gravel
	85			0.5/2.5	rough to	80	to Sub-rounded	
			NQ Core	0.5/2.5	fairly rough	Light		
				1.0/1.5	"	brown		
	90			0.5/1.5	"			
			NQ Core	1.5/7.5	"			
	95							
	100							

Inspector J.A. Roberts Checked By L. Cornish

Date Oct. 26/75 Hole No. E9 Page 3 of 5

B.C. HYDRO — EXPLORATORY DRILLING – SOILS LOG

D74-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	Fluid Return	Sample Description	Soil Log
			NQ Core	1.0/5.0	Fairly rough 150 200psi	0.0	97 - 102	
	100					80	Gravel, coarse	
						Light	rounded & subrounded (GP)	
						brown		
	105							
	110	No samples	3 7/8" Triconeing	NIL	Fairly rough 200psi	0.0		
						80		
						Light		
						brown		
	115							
	120							
	125							
	130							
	135							

Inspector J.A. Roberts Checked By L. Cornish

Date Oct. 26/75 Hole No. E9 Page 4 of 5

B.C. HYDRO

EXPLORATORY DRILLING – SOILS LOG

D74-1018A

Water Level	Depth (Ft.)	Sample No.	Sample Type	Recovery	Blow Count Drill Action	Fluid Return	Sample Description	Soil Log
				0.0	Fairly rough	0.0	130 - 135	
						80	Gravel Coarse (GP)	
	135					Light		
						brown		
							148' - 203' See Bedrock Log.	

Inspector J.A. Roberts Checked By L. Cornish

Date Oct. 26/75 Hole No. E9 Page 5 of 5

PEACE RIVER SITES C AND E

FEASIBILITY STUDY

APPENDIX A

GEOTECHNICAL INVESTIGATIONS

ANNEX A

GEOLOGICAL LOGS OF DRILL HOLES

APPENDIX B

RIVER FLOW PROFILE STUDIES

B.1 INTRODUCTION

Flow profiles along the 90-mile section of the Peace River from Site 1 to the Alberta border were calculated with the aid of a computer program for a range of discharges and reservoir water surface elevations. The purpose of these studies was to provide the hydraulic data required to select appropriate reservoir levels with consideration for the relocation of existing communities and facilities, and the effect of tailwater encroachment on upstream powerplants. Preliminary studies to assess the merit of channel improvement downstream of Site C were also conducted.

B.2 RIVER CHARACTERISTICS

From Site 1 downstream to the British Columbia/Alberta border major tributaries which join the main stem of the Peace River are the Halfway, Moberly, Pine, Beatton, Kiskatinaw and Alces rivers (listed in order of their confluence proceeding downstream). The present river channel has been formed by river erosion following the retreat of the glaciers and prior to construction of the W.A.C. Bennett dam was reaching a relatively stable and mature stage in its fluvial development.

Downstream from Site 1, for a distance of 5 miles to Hudson Hope, the Peace River channel is relatively narrow (500-1000 feet) and is well confined by steep sided canyons and river terraces. Bedrock ridges across the riverbed cause riffles at several locations. The river channel alternates between wide and narrow sections with the occasional gravel bar and bedrock islet in the wider sections. The river slope in this reach is approximately 6 feet per mile.

*

PEACE RIVER SITES C AND E

FEASIBILITY STUDY

APPENDIX B

RIVER FLOW PROFILE STUDIES

TABLE OF CONTENTS

PLATES

B.2 RIVER CHARACTERISTICS - (Cont'd)

For 85 miles, from Hudson Hope downstream to the British Columbia /Alberta border the Peace River has formed a stable gravel bed channel. The river channel is confined by high valley sides and has a relatively narrow discontinuous flood plain. The channel width varies from 1000 to 3000 feet and alternates between wide and narrow sections with numerous small islands and gravel bars formed in the wider sections. Bends in the river channel are even and gradual. The river slope varies from approximately 3 feet per mile downstream of Hudson Hope to 2 feet per mile at the British Columbia/Alberta border.

B.3 CHANNEL CROSS-SECTIONS

To determine the hydraulic conveyance of the river channel a number of cross-sections were surveyed during summer of 1975. These were augmented by cross-sections developed from topographic maps.* For this study the Peace River was divided into two reaches: the upstream reach from Site 1 to Site C and the downstream reach from Site C to Site E. The surveyed cross-sections were concentrated at the upstream end of each reach where water levels subsequent to project development would approximate existing water levels. The cross-sections developed from topographic maps were used over the downstream portion of each river reach where post-development water depths would be from 50 to 200 feet and detailed data for the existing river channel are not required. River cross-sections, surveyed in 1968 for the River Regime Study*, were also used to define the river channel.

---

* Peace River Pondage, B.C. Dept. of Lands, Forests and Water Resources Topographic Map Series, Scale: 1 inch equals 1000 feet, Contour Interval: 20 feet.

* IPEC, Portage Mountain Development, Downstream Channel Regime Studies, September 1968.

B.3 CHANNEL CROSS-SECTIONS - (Cont'd)

Cross-sections were located at changes in channel shape with a spacing of approximately one to two times the channel width. The locations of all cross-sections for both the upstream and downstream river reaches are shown in Plates B-1 and B-2, respectively.

B.4 STAGE DISCHARGE DATA

To provide prototype data for calibration of the computer model, several temporary staff gauges were installed along both the upstream and downstream river reaches. Gauge readings were scheduled to obtain as wide a range of river discharges as possible and as far as possible to ensure steady state flow conditions throughout the river reach. Since both the upstream and downstream river reaches would be calibrated independently, the two sets of gauges were read separately.

(a) Upstream Reach

For the upstream reach between Site 1 and Site C, five gauges were installed, located as shown on Plate B-1. These together with the Water Survey of Canada gauge at Hudson Hope (Station 07EF001) which provided both river stage and discharge information, yielded the required stage-discharge data for the upstream reach. Because of the low flood runoff, both on the main Peace River channel and its tributaries during 1975, data for only the lower range of discharges, corresponding to the powerplant discharges from the Portage Mountain Development could be obtained.

Due to the variation in load demand at G.M. Shrum Generating Station, steady state flow conditions throughout the channel reach were impossible to obtain. The travel time required for a change in discharge to affect the river stage at the individual gauges was determined, and using these travel times the discharge corresponding to each gauge reading was estimated from Hudson Hope discharge

*

B.4 STAGE DISCHARGE DATA - (Cont'd)

data. Five sets of readings at each gauge were recorded and the resulting data were used to prepare stage-discharge curves at each gauge. To calibrate the computer model, river stages for steady state flow conditions were obtained from the stage-discharge curves for the following discharges:

13,500 cfs
33,000 cfs
41,300 cfs
49,900 cfs

(b) Downstream Reach

For the downstream reach between Site C and Site E, six gauges were installed, located as shown in Plate B-2. In addition, both water surface levels and river discharges were provided by the Water Survey of Canada recorder gauge at Taylor (Station 07FD002). As for the upstream reach, it was impossible to obtain steady state flow conditions throughout the entire reach and water travel times between the gauges and Taylor were used in a manner similar to that for the upstream reach to determine the discharge at each gauge.

In addition, analysis of the downstream reach was further complicated by the confluence of the Pine River downstream of gauge No. 9. The Peace River discharge as determined from the Taylor gauge record was used directly for the two downstream gauges but for gauges No. 6 to No. 9 the relevant discharge was determined by subtracting the Pine River discharge from the Taylor discharge value. No adjustment of the discharge at gauge No. 6 for the Moberly River discharge was made.

Again, five sets of readings were recorded. Based on these data, stage-discharge curves were prepared for each gauge. To calibrate the computer model, river stages for steady state flow

B.4 STAGE DISCHARGE DATA - (Cont'd)

conditions were obtained from the stage-discharge curves for the following discharges:

Upstream of Pine R.	Downstream of Pine R.
22,000 cfs	28,000 cfs
40,000 cfs	70,000 cfs
55,000 cfs	61,000 cfs

B.5 COMPUTER SIMULATION

(a) Model

The U.S. Corps of Engineers, "Water Surface Profiles", Computer Program, was used to simulate river profiles under various flow conditions. This program is based on the standard step method of flow profile calculation; for a given starting elevation and river discharge, the river stage and flow velocity at each channel cross-section is calculated. Topographic input consists of channel cross-sections and the distance between adjacent cross-sections.

The hydraulic conveyance is calculated for each cross-section. If the computed flow depth for a particular cross-section is less than the critical depth, a discontinuity is assumed in the flow profile at that point and continuation of the upstream flow profile is computed based on the critical depth. Form losses for flow expansion and contraction are determined as a function of the difference in velocity heads assuming K expansion = 0.3 and K contraction = 0.1. Friction losses were based on Manning's equation with Manning's "n" values required as an input parameter.

*

B.5 COMPUTER SIMULATION - (Cont'd)

(b) Calibration

Calibration of the computer model against the measured prototype data was achieved by adjusting the Manning's "n" value for each section of river between gauges. The "n" values were adjusted until agreement between calculated and measured water levels at each gauge was within ±0.1 feet.

B.6 BACKWATER CALCULATIONS

(a) Site C (1515)

Backwater profiles from Site C upstream to the Site 1 tailrace were calculated for Site C forebay levels increasing in 5-foot increments from El. 1500 to El. 1520 for the following flow conditions:

1. For no local inflow (i.e., negligible inflow from the Halfway River which is reasonably representative of average flow conditions) for the following discharges:

Discharge (cfs)
15,000
25,000
50,000
100,000
200,000

2. For maximum local inflow (which is more representative of extreme flood conditions) for the following discharges:

*

B.6 BACKWATER CALCULATIONS - (Cont'd)

Discharge (cfs)	
Upstream of Halfway River	Downstream of Halfway River
120,000	200,000
180,000	300,000
240,000	400,000
300,000	500,000
390,000	650,000

The flow distribution between the Halfway River and the Peace River upstream of the Halfway confluence of 40 percent and 60 percent, respectively, is based on the flow contributions of the individual catchment areas used to determine the spillway design flood hydrograph. The results of these backwater calculations are presented as stage-discharge curves in Plate B-3.

(b) Site E (1352) or (1342)

Backwater profiles from Site E upstream to Site C were calculated for Site E forebay levels increasing in 5-foot increments from El. 1340 to El. 1360 for the following flow conditions:

1. For no local inflow (i.e., negligible inflow from the Pine, Beatton and Kiskatinaw rivers which is reasonably representative of average flow conditions) for the following discharges:

Discharge (cfs)
15,000
25,000
50,000
100,000
200,000

B.6 BACKWATER CALCULATIONS - (Cont'd)

2. For maximum local inflow (which is more representative of extreme flood conditions) for the following discharges:

Discharge (cfs)	
Upstream of Pine River	Downstream of Kiskatinaw River
180,000	300,000
240,000	400,000
300,000	500,000
390,000	650,000
480,000	800,000
570,000	950,000

The flow distribution between the main Peace River channel and its major tributaries the Kiskatinaw, Beatton and the Pine rivers was based on the flow contributions from the various sub-basins used in the determination of the spillway design flood hydrograph. The following percentage flow distributions were used:

Kiskatinaw River	5%
Beatton River	10%
Pine River	25%
Halfway River	25%
Peace River upstream of Halfway	35%

The results of these backwater calculations are presented as stage-discharge curves in Plate B-4.

(c) Site E (1510)

Backwater profiles from Site E upstream to Site 1 were calculated for Site E (1510) forebay levels increasing in 10-foot increments from El. 1500 to El. 1520 for the following flow conditions:

*

B.6 BACKWATER CALCULATIONS - (Cont'd)

1. For no local inflow (i.e., negligible inflow from the Halfway, Moberly, Pine, Beatton and Kiskatinaw rivers which are reasonably representative of average flow conditions) for the following discharges:

Discharge (cfs)
15,000
25,000
50,000
100,000
200,000

2. For maximum local inflow (which is more representative of extreme flood conditions) for the following discharges:

Discharge (cfs)	
Upstream of Halfway River	Downstream of Kiskatinaw River
105,000	300,000
140,000	400,000
175,000	500,000
227,500	650,000
280,000	800,000
332,500	950,000

The same flow distribution between the main Peace River channel and its major tributaries as used for the Low Site E calculations was used in the calculations for the above flow profiles. The resulting stage-discharge data differed only slightly from the results for Site C and the stage-discharge curves presented in Plate B-3 also represent the river stage-discharge relationships for Site E (1510).

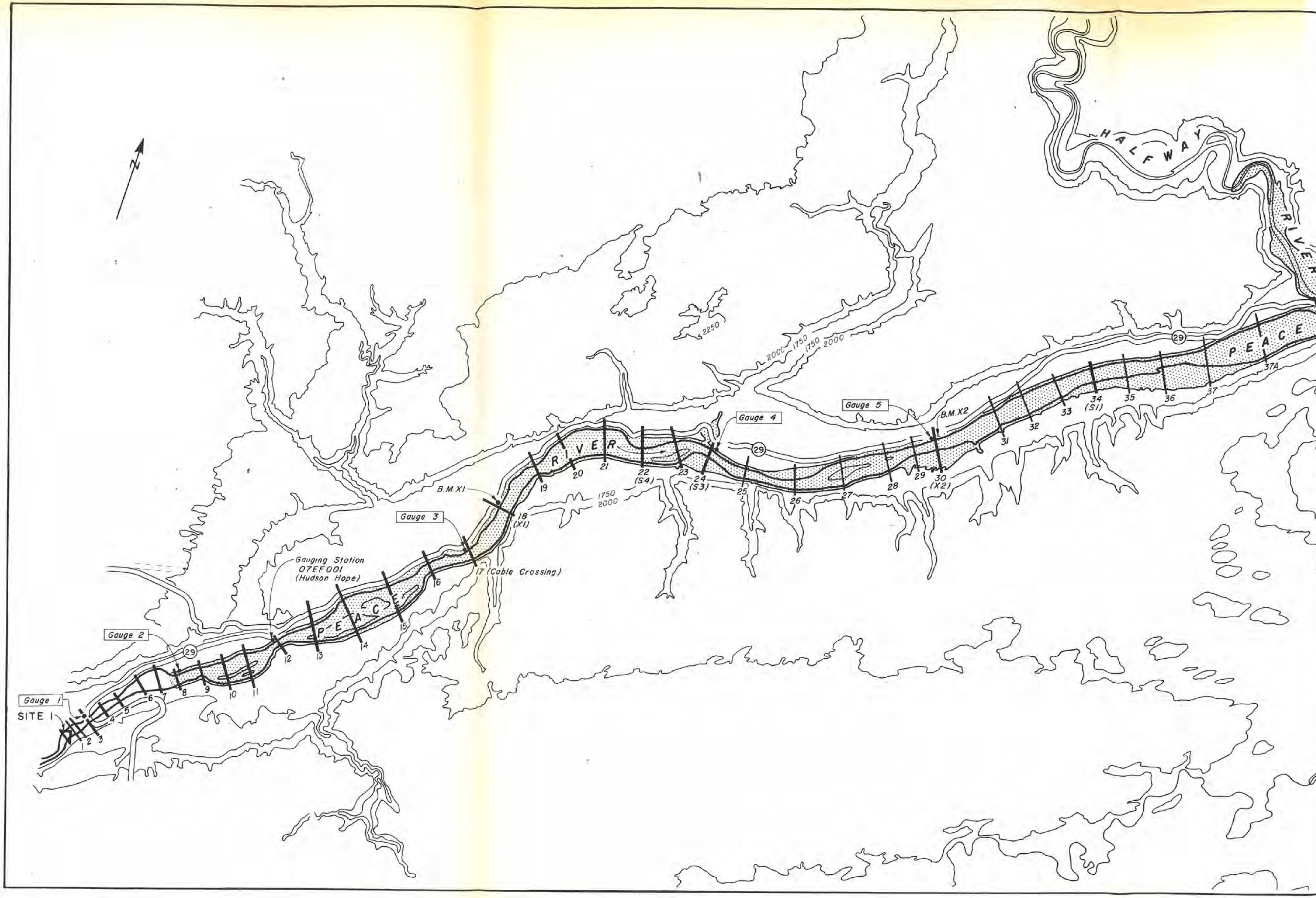
B.7 SITE C TAILRACE IMPROVEMENT

Backwater profiles were also calculated for different extents of channel improvement downstream of Site C. The resulting reduction in Site C tailwater levels for a discharge of 55,000 cfs (estimated effective plant discharge) and a range of Site E forebay levels are tabulated below:

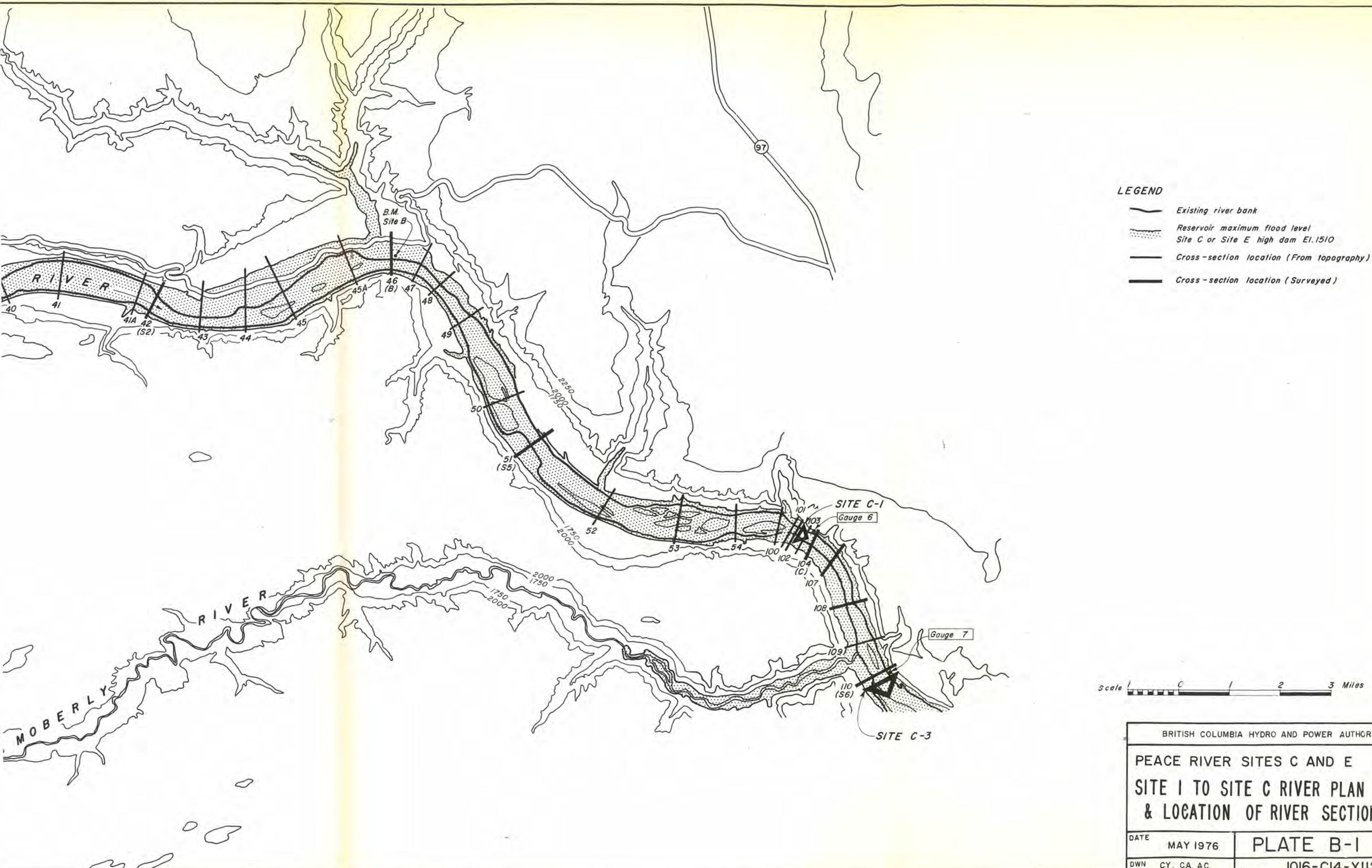
Extent of Dredging	Volume Dredged (10^6 cu yds)	W.S. Elevation (feet) Site E Forebay	Site C Tailrace	Diff.	Head Gained
Natural	0	1340.0	1349.3	9.3	-
		1345.0	1349.7	4.7	-
		1350.0	1351.8	1.8	-
		1355.0	1355.7	0.7	-
		1360.0	1360.4	0.4	-
Sec.110-Sec.112*	2.1	1340.0	1346.5	6.5	2.8
		1345.0	1347.9	2.9	1.8
Sec.110-Sec.113	2.9	1340.0	1346.0	6.0	3.3
		1345.0	1347.6	2.6	2.1
Sec.110-Sec.115	4.4	1340.0	1345.4	5.4	3.9
		1345.0	1347.4	2.4	2.3

* See Plate B-2.

Net benefits from tailrace channel improvement at Site C depend on the reservoir level finally adopted for a Site E or Dunvegan reservoir downstream and the unit cost of dredging. Based on these initial studies a preliminary assessment would be that net benefits of tailrace channel improvement would be marginal, but should be investigated more thoroughly during preliminary design.



N
SITE 1
Gauge 1
Gauge 2
Gauge 3
Gauge 4
Gauge 5
Gauging Station
07EF001
(Hudson Hope)
17 (Cable Crossing)
18
(X1)
22
(S4)
24
(S3)
30
(X2)
34
(S1)
37A
B.M.X1
B.M.X2
PEACE
RIVER
PEACE
RIVER
PEACE
HALFWAY
RIVER
29
1750
2000
2250



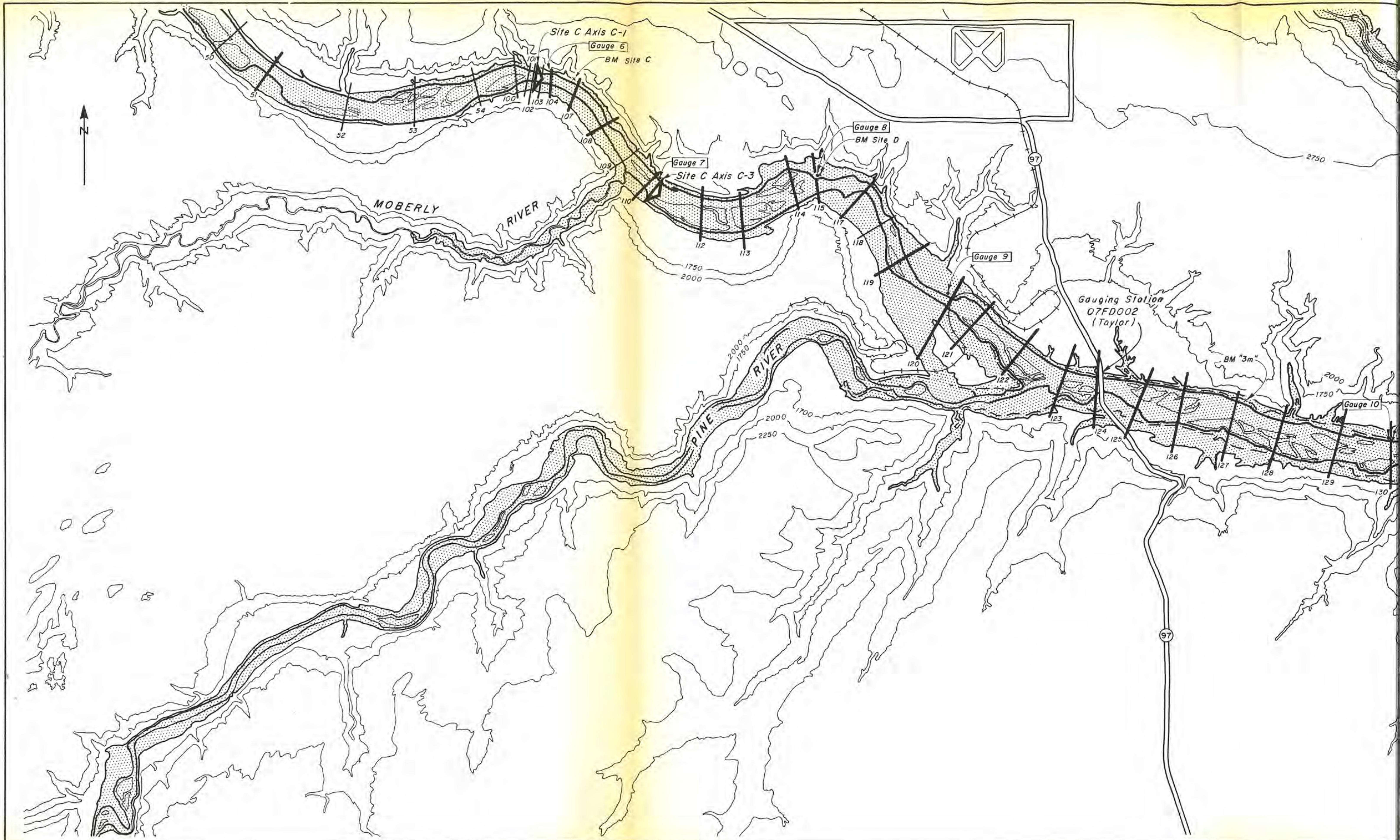
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

SITE I TO SITE C RIVER PLAN & LOCATION OF RIVER SECTIONS

DATE MAY 1976	PLATE B-I	R
DWN CY. CA. AC.	DWG No. 1016-C14-X112	

REPORT No. 796



N
Site C Axis C-1
Gauge 6
BM Site C
Gauge 7
Site C Axis C-3
Gauge 8
BM Site D
Gauge 9
Gauging Station
07FD002
(Taylor)
BM "3m"
Gauge 10
MOBERLY
RIVER
PINE
RIVER
97
2750
2000
1750
1700
2250
50
51
52
53
54
100
101
102
103
104
107
108
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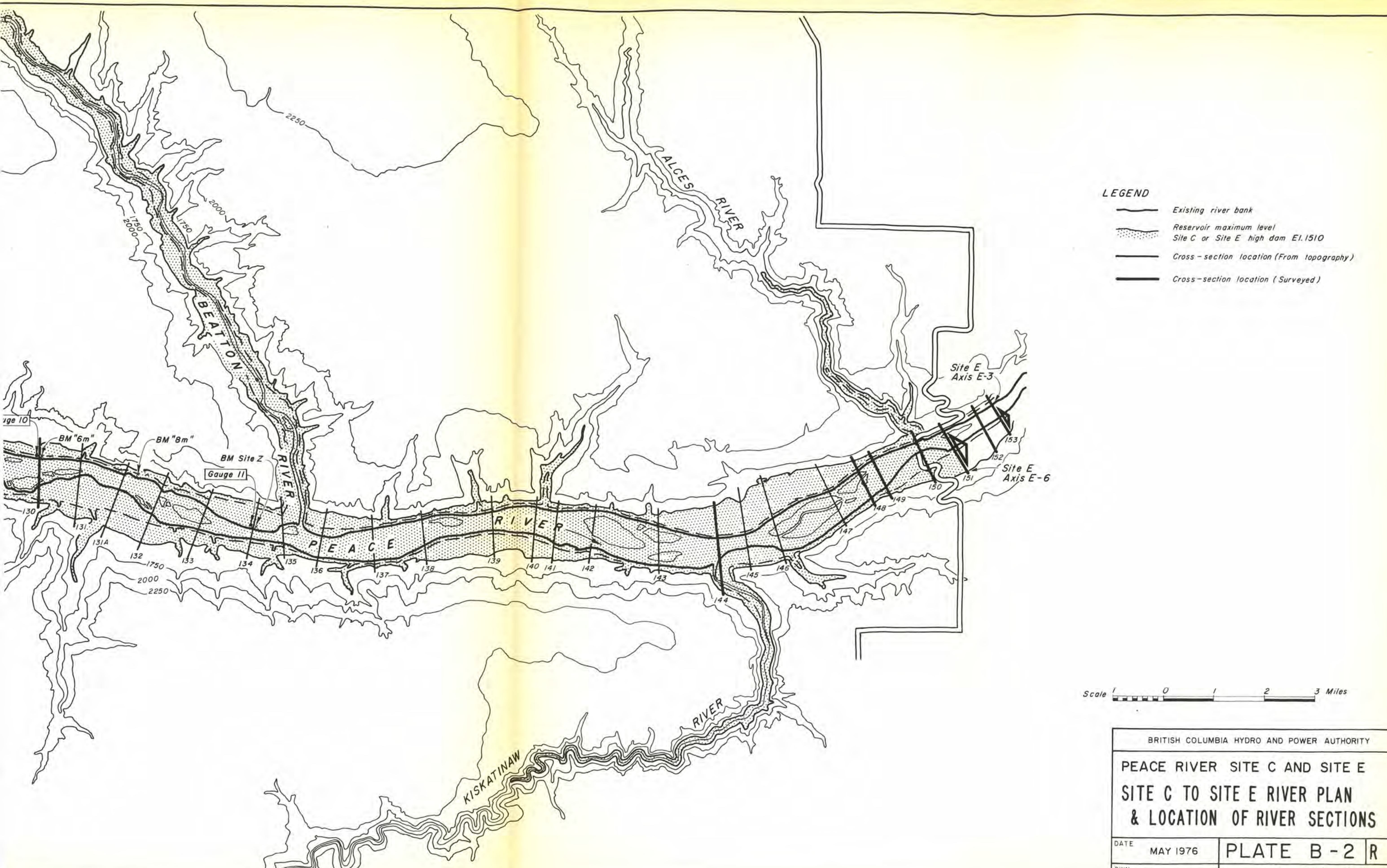
130



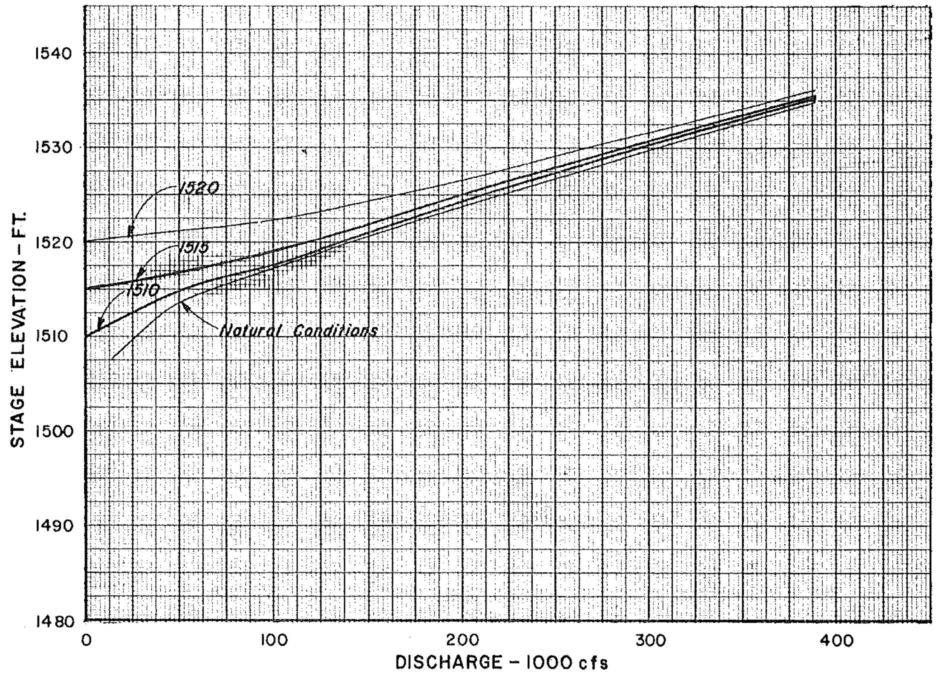
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITE C AND SITE E

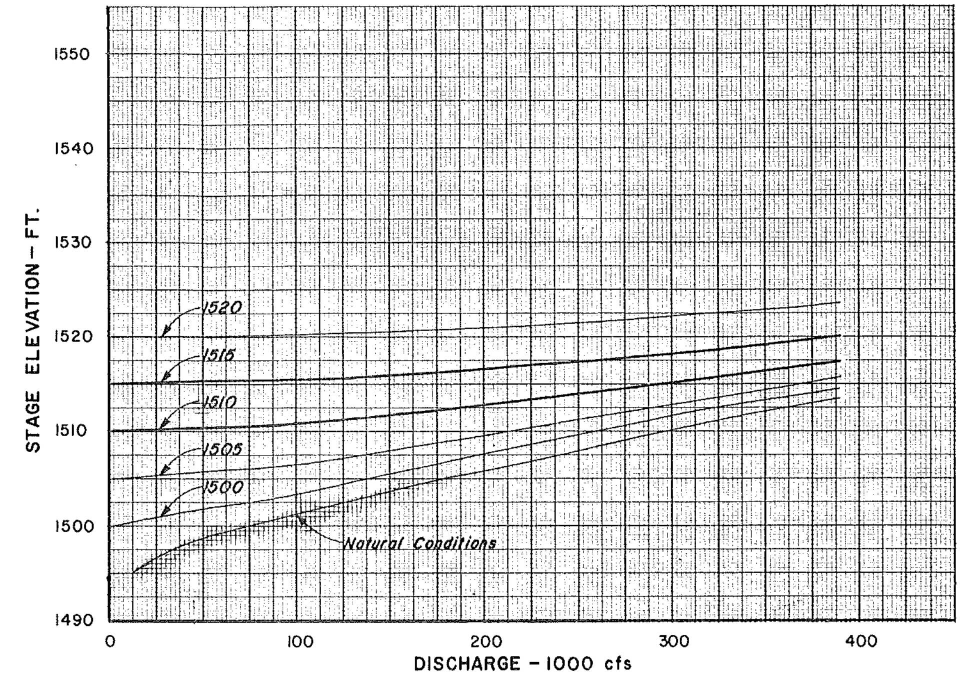
SITE C TO SITE E RIVER PLAN & LOCATION OF RIVER SECTIONS

DATE MAY 1976	PLATE B - 2	R
DWN CY	DWG No. 1016 - C14 - X103	

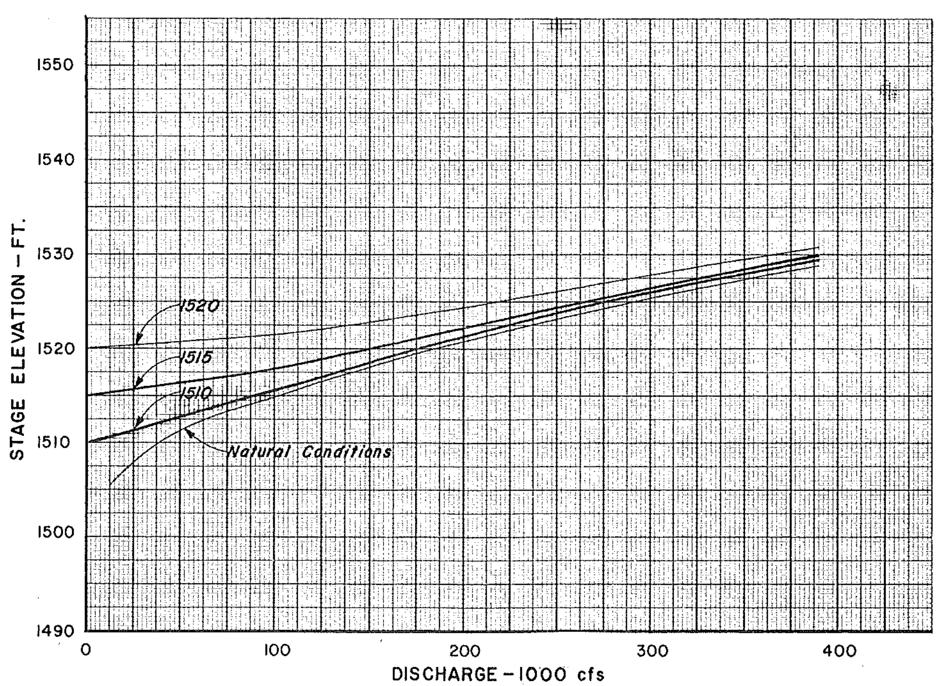
REPORT No. 796



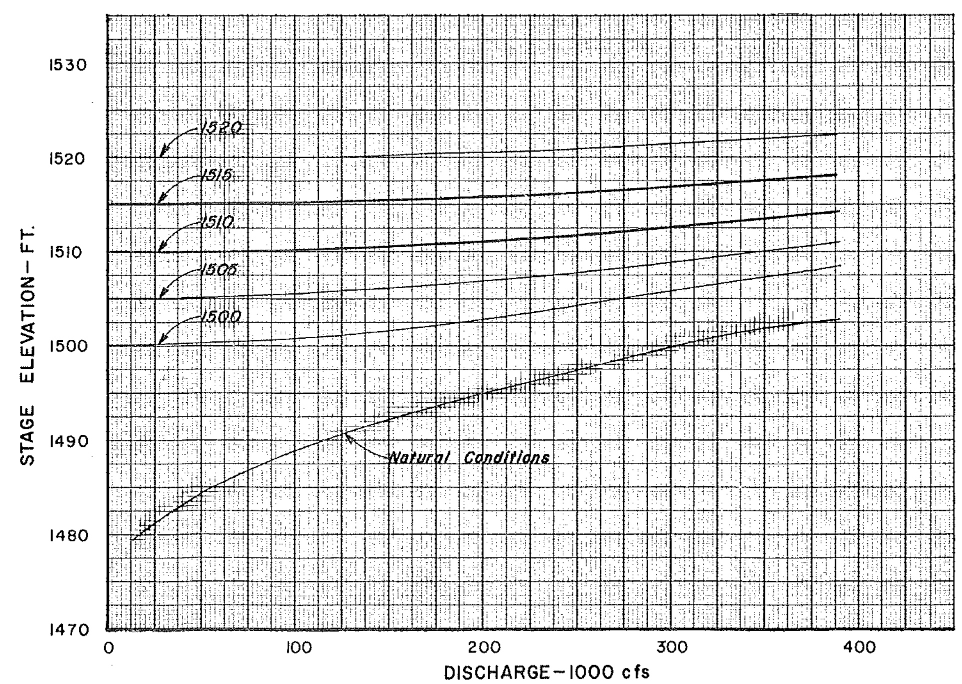
SITE I TAILRACE
Cross-Section No. 1



GAUGE NO. 2
Cross-Section No. 8



GAUGE NO. 1
Cross-Section No. 3



HUDSON HOPE
Cross-Section No. 12

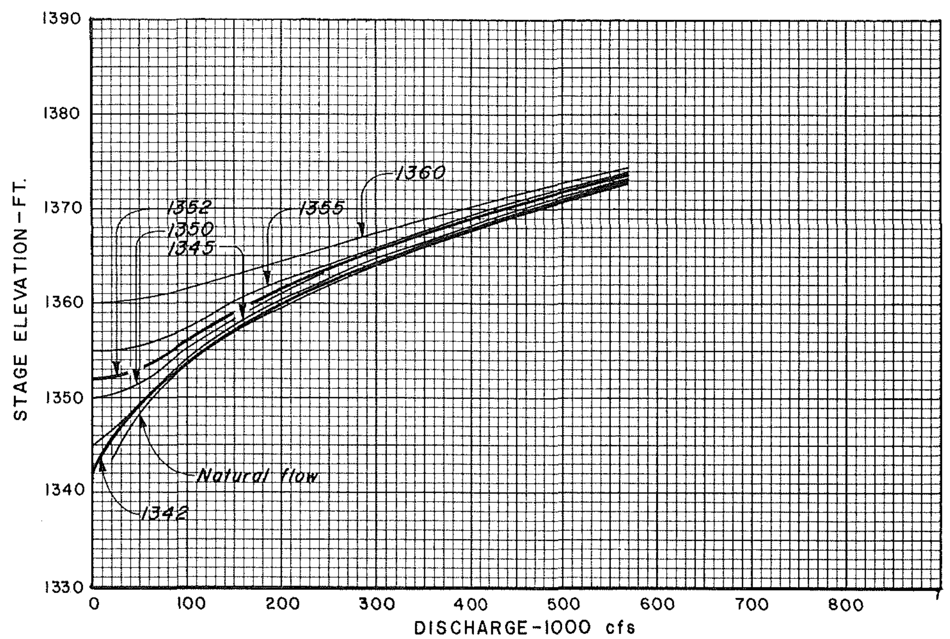
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C AND E

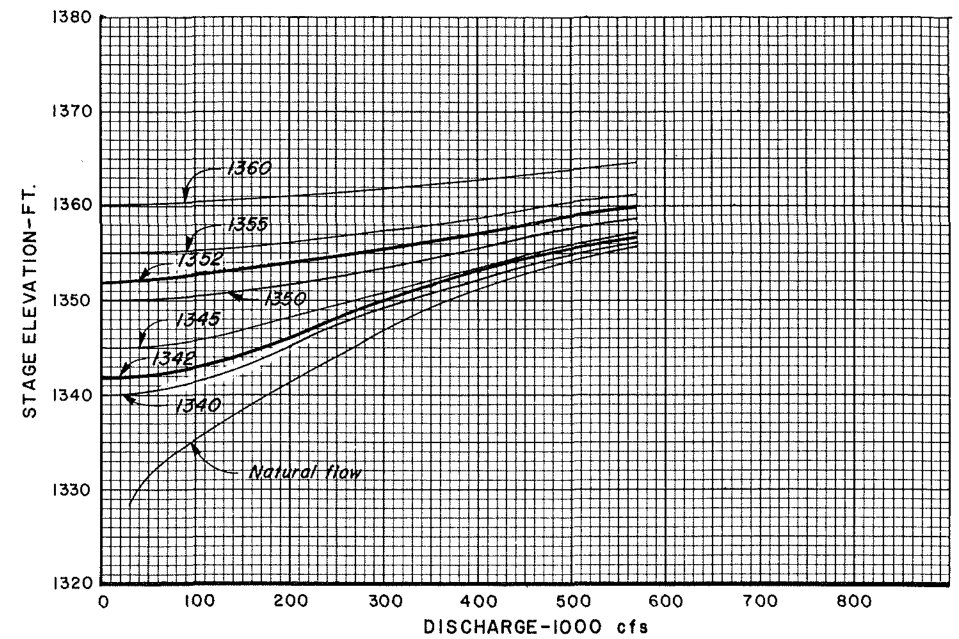
SITE C (1515) & SITE E (1510) PROJECTS STAGE DISCHARGE CURVES

DATE MAY 1976	PLATE B-3	R
DWN CA	DWG No. 1016-C14-D108	

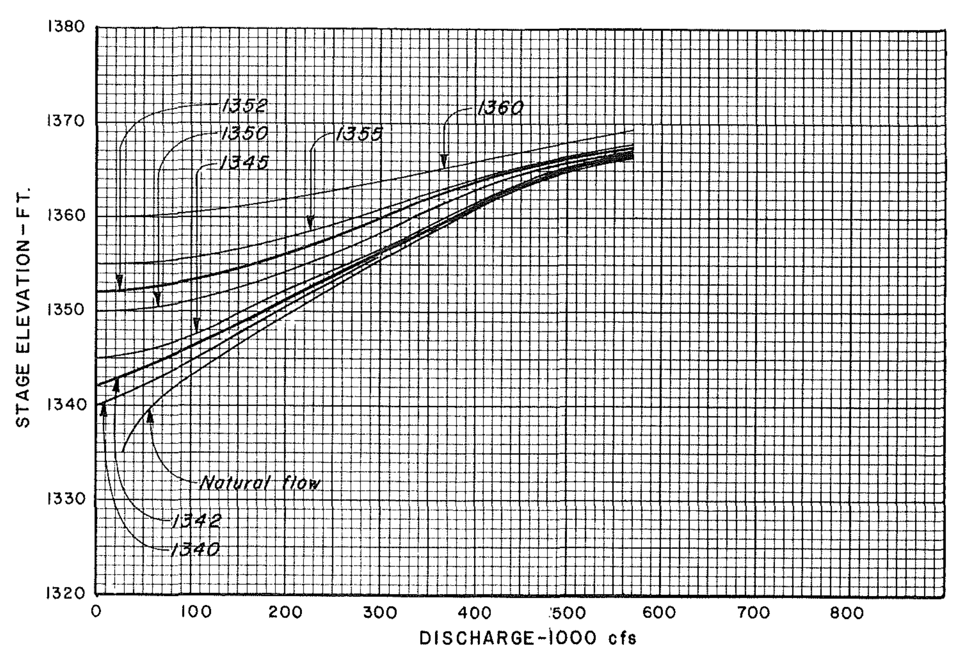
REPORT No. 796



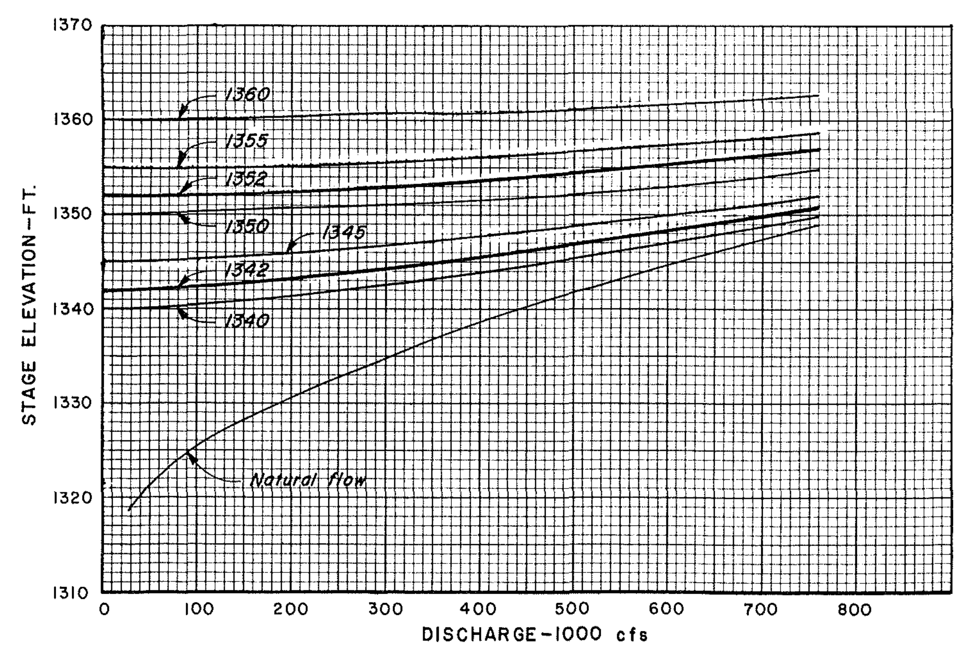
SITE C (AXIS C-3)
Gauge No. 7



B.C. RAILWAY BRIDGE
Gauge No. 9
Section 120



GAUGE No. 8
Section 115



TAYLOR HIGHWAY BRIDGE
Section 124

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

PEACE RIVER SITES C & E

SITE E (1342) & SITE E (1352) PROJECTS

STAGE DISCHARGE CURVES

DATE MAY 1976	PLATE B-4 R
DWN A.C.	DWG No. 1018-C14-D23

REPORT No. 796