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Portions of the "Alberta - B.C. Joint Task Force on Peace River Ice - Report" prepared by Alberta Environment

PEACE RIVER

1981/82 ICE OBSERVATION REPORT

November 1982

SUMMARY

This report contains the first draft of the sections of the 'Alberta - B.C. Joint Task Force on Peace River Ice' Report which were the responsibility of Alberta Environment. Other sections, written by the B.C. Ministry of the Environment and by B.C. Hydro and Power Authority, complete the report to the respective Ministers of the Environment for the two Provinces.

The report summarizes the events which occurred at freeze-up at Peace River Town in January of 1982. A presentation is made of the basement flooding problem which occurred in the West Peace River subdivision. An outline of the breakup preparation undertaken, including ice weakening efforts, is made. The observations of River Engineering Branch field staff of the breakup of the Heart, Smoky and Peace River are presented.

Finally, a proposal for a controlled mode of operation of B.C. Hydro's G.M. Shrum generating station at the WAC Bennett Dam during freeze-up at Peace River Town is included.

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2.0 PEACE RIVER FREEZE-UP

2.1 General

The Peace River at Peace River Town froze up, in the 1981/82 season, in an unusual manner for the river. The initial ice cover formed normally in early January, however, five days after the initial cover formation the river experienced a second staging due to consolidation of the ice pack. This second staging was in the order of 3.5 m, and brought the ice level to within 1.66 m of the top of the dikes in Peace River Town*. A complete record of hourly water levels at Peace River, and flow releases, uncorrected for travel time, from B.C. Hydro and Power Authority's (BCHPA) G.M. Shrum (GMS) generating station, for the period 24 December 1981 to 30 April 1982, is shown in Figure(s) 1.

2.2 Sequence of Events

The sequence of events which occurred at Peace River Town during the 1981/82 freeze-up period has been previously summarized by Northwest Hydraulic Consultants Ltd (NHCL) (1)**, based on preliminary data and verbal reports collected by Alberta Environment, Acres Consulting Engineering Ltd. and others. Copies of this report were distributed to BCHPA, the B.C. Ministry of Environment and Alberta

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Note: * All reference to dike levels is made with respect to the dike across the river from the Water Survey of Canada gauging station.

** Numbers in parentheses refer to numbered references cited following the text of this report.

Environment. The following is a slight change to that reported sequence of events, based on an increased data base.

In its analysis NHCL presented the freeze-up events in terms of BCHPA's releases from GMS, lagged three days to allow for flow through time to Peace River Town. Figure 2 shows open water flow travel times from Hudson Hope to Taylor, and from Taylor to Peace River, based on data provided by the Alberta River Forecast Centre. Figure 3 shows these times consolidated for flow from Hudson Hope to Peace River. BCHPA's mean daily releases during the period 24 December 1981 to 7 January 1982 varied from a minimum of 800 m^3 s^{-1} to a maximum of 1777 m^3s^{-1}, and had an average of 1347 m^3s^{-1}. Flow through times from Figure 3 would thus be 86, 46 and 41.5 hours for the minimum, average and maximum releases respectively. For this reason the mean daily GMS releases have been plotted on Figure 4, for the period 25 December to 8 January, lagged 48 hours (instead of the 72 hours used by NHCL). Shown also are the Peace River gauge heights, based on hourly data, and Water Survey of Canada's (WSC) preliminary mean daily flows for the gauge 07HA001, Peace River at Peace River. Figure 4 should be consulted while reading the following sequence of events:

a. 25 to 28 December 1981

The river stage at Peace River generally decreased due to decreased releases from the GMS plant in response to lesser power demand over the Christmas holiday. It was originally reported that the upstream progressing ice accumulation had passed through the Town of Peace River on 28 December. The absence of a significant rise in water level on this date indicates that the river was still operating in an open water mode. The slight rise at approximately 0300 hours of 28 December could be due to a brief stationary period in the general ice flow, brought on by the reduction in surface area corresponding to the decrease in flow at Peace River from 1500 to 913 m^3s^- between 26 and 28 December. The preliminary WSC records for December of 1981 show 'ice conditions' for the period 16 to 20 December, and 27 and 28 December, but show normal, or open water, conditions for the remaining time. The disappearance of ice conditions reflected in the WSC records can be explained in terms of a warm period between 19 and 22 December, as shown in the leveling-off of accumulated degree-days of freezing shown in Figure 5.

b. 28 December 1981 to 1 January 1982

The water level at Peace River rose gradually by 0.8 m until approximately 1700 hours on 1 January, in response to increased power generation releases following the Christmas break. Air temperatures, which had been at a mean daily value of -3°C on 21 December, dropped to a mean of -37°C on 1 January, with nightly lows in the order of -40 to -41°C. This caused a dramatic increase in the accumulation of degree-days of freezing, and initiated rapid ice production in the open river.

c. 1 to 2 January 1982

Water levels rose 2.63 m at Peace River while the discharge in the river was in the order of 2060 to 2170 m^3s^{-1}. Most of this increase corresponds to the normal experience of 'staging' at freeze-up, as the open water rating curve indicates a change of 0.06 m between the two discharges. This staging almost certainly indicates the formation of an ice cover on the river, with the corresponding increase in hydraulic resistance.

d. 3 to 4 January 1982

Water levels at Peace River dropped 1.22 m from the staging peak on 2 January. Power releases at GMS had dropped from 1777 m^3s^{-1} on 30 December to 1724 m^3s^- on 31 December, and further to 798 m^3s^{-1} on 1 January as the load demand decreased for the New Year's holiday. W.S.C. records show the discharge at Peace River dropped from 2170 m^3s^{-1} on 2 January to 1010 m^3s^{-1} on 4 January, which would have caused a stage reduction of 0.81 m under open water conditions. The remaining 0.41 m of stage decrease can probably be attributed to smoothening out of the roughness of the under side of the ice cover as the roughness projections were melted off by the slightly warmer fluid flow beneath the ice.

e. 4 to 7 January 1982

Increasing GMS releases, from 798 m^3s^{-1} on 1 January to 1695 m^3s^{-1} on 5 January, reflecting increased load demand following New Year's Day, caused an increase in water level at Peace River of 1.03 m by 2100 hours on 7 January. This brought the stage at Peace River to within 0.2 m of the peak stage attained during ice cover formation on 2 January, though the mean daily discharge at Peace River on 7 January was 160 m^3s^{-1} less than it had been on the 2nd when the ice first packed in. The mean daily discharge continued to increase into 8 January.

f. 7 to 8 January 1982

The WSC recorder chart for Peace River at Peace River shows an increase in water level of 0.60 m between 2100 and 2200 hours on 7 January. A report from a Peace River resident indicated that at approximately 2230 hours on 7 January the ice cover on the river cracked and the ice began to move downstream. The water level rose sharply a total of 3.54 m from 2100 hours on 7 January to 0100 hours on 8 January, a rate of 0.89 m hr^{-1}. The water level reached a stage of 13.35 m (Elevation 318.15 m Geodetic), which was 1.66 m below the top of dike across from the WSC gauge (top of dike Elevation is 319.81 m Geodetic).

A couple of hours before the ice cover ruptured at Peace River, as reported by Messers R. Carson, P. Eng. and K. Baillergeon of Acres Consulting Services Ltd., who were monitoring the Peace River freeze-up in the vicinity of Dunvegan, a resident in the Dunvegan area telephoned Mr. Carson to tell him the ice was moving at Dunvegan. Mr. Carson reported this to the local RCMP, and went out to investigate. Later evidence showed that the lengthening ice cover had progressed upstream of Dunvegan by 7 January, reportedly between 'a few' and 50 km upstream. It was not known at this time whether the whole of the ice cover at, and upstream of, Dunvegan was in motion, through this eventually proved to be the case.

According to observations by Mr. Carson, and verified later by Alberta Environment, the moving ice formed an ice jam at the downstream end of Verte Island, some 14 km downstream of Dunvegan, between 1700 and 1900 hours on 7 January. The jam attained a height of approximately 9 m, and was only in place for a few hours before it released. The available evidence indicates that the ice jam released prior to the ice movement at the Town of Peace River.

Following its rapid rise to peak at 0100 hours on 8 January, the water level at Peace River receded through the rest of the day, dropping 1.34 m by midnight. As the mean daily discharge on 8 January was 120 m^3s^{-1} higher than that of 7 January, according to the WSC preliminary records, the decrease in water level must be attributed to the smoothening of the underside of the ice cover.

g. 9 to 20 January 1982

Because of the potential for serious flooding of the Town of Peace River if the new ice accumulation re-ruptured and reconsolidated, BCHPA was requested to regulate their releases from GMS to a constant value, in order to let the ice accumulation gain strength by freezing. Accordingly, as can be seen on Sheet 2 of Figure 1, BCHPA regulated their releases to an average of 1691 m^3s^{-1} over the period of 9 to 20 January. In this same period the recorded discharges at Peace River had a mean of 1941 m^3s^{-1}, while the Smoky River had a mean discharge of 22 m^3s^{-1}, yielding a local inflow between GMS and Peace River of 228 m^3s^{-1}.

The water level at Peace River dropped a further 0.41 m on 9 January before it levelled off, with minor fluctuations, until the middle of February, when a decrease in releases caused the water level to drop a further 1.33 m (see discussion of West Peace River groundwater levels).

3.0 COMMITTEE ACTIVITIES

3.1 West Peace River Groundwater Flooding

When the water levels in the Peace River rose on the night of 7/8 January, the groundwater table in the river's floodplain responded by rising as well. Unfortunately, no data was taken during January. Groundwater levels in West Peace River were recorded at a private well by Mr. Barry Ellis, a Town employee, from 5 February, and were subsequently tied into Geodetic Bench by the Town of Peace River. The groundwater level data has been added to Figure(s) 1 in terms of corresponding gauge heights. No correction was included for river slope to transfer the levels as elevations to the WSC gauge, however, the data serves to indicate relative effects.

When the river level rose and stabilized by 9/10 January, at a gauge height between 11.5 and 12 m, the groundwater table in West Peace River came up and caused flooding in a number of basements. The groundwater response to the change in river levels was reported to be relatively moderate, as it was a matter of some twelve days before the Town started to receive flooding complaints. As BCHPA had a fairly high power demand, and the various authorities were trying to maintain the river level while the ice cover gained strength through freezing, the releases from GMS had to be held constant. Hence, little could be done at that time to alleviate the basement flooding problem in West Peace River.

The releases from GMS were held nearly constant for the period 8 to 20 January in order to let the ice accumulation at Peace River gain strength by freezing (Figure 1, sheets 2 and 3). Following this, the GMS generating station resumed its normal operations. However, the groundwater problem in West Peace River continued, as the attenuated releases from GMS did not cause a substantial river level change at Peace River Town.

In February the basement flooding problem was still acute. From the reported depths of basement flooding it was judged that if the river level could be drawn down in the order of a metre, the flooding problem would abate, hence BCHPA was requested to reduce its releases. BCHPA complied with the request and began stepping down its GMS releases on 16 February. The releases were stepped down from a mean discharge of 1615 m^3s^{-1}, for the first half of February, to an average of 1030 m^3s^{-1} for the second half. Sheet 5 of Figure 1 shows the resulting decrease of 1.27 m in stage at Peace River over the period 19 to 25 February. In the same period the groundwater table in West Peace River dropped 0.42 m; and continued to drop a further 0.48 m by mid March. During this period the basement flooding problem in West Peace River appears to have abated, though one or two homes may still have experienced some minor flooding.

An increase in releases from GMS on 16 March caused the river level to again increase, with a corresponding increase in groundwater levels. The data shows that the increase in flows from GMS, initiated at 0600 hours on 16 March, caused the river levels at Peace River to increase 0.39 m starting at 2100 hours on 18 March. This indicates an ice-covered flow travel time, for the ice conditions which existed, of 63 hours for a discharge of approximately 1250 m^3s^{-1}; an increase in travel time of 15.5 hours over the open water travel time (Figure 3).

The groundwater level increase, over the period 18 to 31 March, which resulted from the 0.39 m increase in river level, was measured to be 0.34 m. This increase in groundwater level was sufficient to reinstate basement flooding in five or six homes in West Peace River. The flooding persisted until the river levels decreased following the 'break-up' of the Peace River in late April.

The data indicates that (as an initial attempt) if future occurrences of basement flooding in West Peace River are to be avoided, the ice-covered river stage at Peace River should not be allowed to increase above 11.0 m (Elevation 315.80 m, or 1036.09 ft GSC). Additional data would be required to confirm or alter this value. In this respect it is recommended that basement elevations in West Peace River be established by the Town for all of the homes in the subdivision. Additionally, in order to obtain better records of groundwater levels to determine the maximum river level that would not cause basement flooding, Alberta Environment has established three groundwater level recording wells in West Peace, and will record the levels daily throughout the ice-covered period.

3.2 Breakup Preparations

Because of the unusually high level at freeze-up and the perceived thickness of the ice accumulation in the reach through Peace River Town, it was thought that the thick ice would prove a barrier or blockage to the passage of the normal spring break-up front. As well, snowpacks in the river basins tributary to the Peace River above the Town were gauged as being above normal, which could result in above normal spring runoff. The combination of a possible blockage to the passage of the break-up front and possible high spring runoff gave every indication that an ice jam, if one occurred at Peace River, could result in serious flooding of the Town. For this reason preparations for break-up were commenced in February of 1982.

The Town of Peace River reviewed and updated its contingency plan for flooding situations in the Town. On March 3rd, a coordinating meeting was held in Peace River of most agencies, Government, Police and the like, which could be involved in providing assistance to the Town in case of spring flooding. Following this meeting, and at the recommendation of the River Engineering Branch, Alberta Environment, the Town of Peace River undertook to plow a single lane on the surface of the ice in preparation for other possible break-up mitigative measures. This aspect is discussed in more detail in the next section.

A meeting was held between the members of the Alberta - B.C. Joint Task Force on Peace River Ice, in Peace River on 25 March. At that time Alberta Environment submitted a draft report to the other members of the Committee, entitled 'Status Report and Proposed Ice Jam Mitigation

Plans, Peace River at Peace River Town'(2). The report summarized preparations by the Town and others towards the anticipated breakup flooding, outlined a breakup observation plan, provided a summary of mitigative measures conducted in the past at Peace River, and made aseries of recommendations regarding what should be attempted to this end in 1982. After due consideration and discussion the members of the Committee agreed to the adoption of most of the recommendations, which led to the implementation of a program of pre-break-up mitigative measures.

3.3 Ice Weakening Effort

Ice weakening measures, in advance of breakup, were conducted as approved by the Committee. These included lane clearing and dusting, plus preblasting in specific areas identified in previous studies as being ice jam prone.

When the secondary staging occurred on 7/8 January the ice surface ended up as a jagged mass. The ice cover thickness, as measured by the Alberta Research Council in late January, was reported to be in the order of 1 m of solid ice, with up to 3 m of loose floes and accumulated slush ice beneath. The jagged surface made access and movement on the ice, for ice jam mitigation purposes, virtually impossible. It was decided to plow lanes on the ice surface, which would require the use of bulldozers, from the mouth of the Heart River to a point downstream of the Town. This would provide dual benefits in that a passable lane would exist which could be used to access the river for other mitigative measures; and the lanes themselves could be dusted with some dark granular material to promote absorption of solar radiation and hence speed up the ice melting process from the upper surface. This need had been recognized earlier, with the result that a lane had already been started by the Town of Peace River as mentioned above.

Alberta Environment and the Town of Peace River cooperated in the plowing of the lanes. This had to be accomplished through the use of small bulldozers in order to plane the jagged surface of the ice down into something which was passable by foot or vehicle. The location of the single lane begun by the Town in February had been selected to follow the same route as Nuttall(3) had had plowed in 1974. The single lane was eventually matched with other lanes on either side of it. The lanes themselves were in the order of 7.6 m wide, and were spaced something like 38 m apart.

As a safety measure, a crew was put ahead of the working bulldozers to measure the ice thickness. Where it was judged that the ice was not thick enough to support the weight of the bulldozer (0.61 m was used as the criterion), the lane was jogged over one way or the other, with the result that in a few places the lane ended up being over from its intended location. It should be noted at this time that the ice thickness was not a constant, in the order of 4 m as indicated earlier, but was of varying thickness. This stemmed from the manner in which the individual ice floes came to rest during the consolidation movement of 7/8 January. In places the ice was still over 2 - 3 m thick, while in others it was less than a metre.

The centre lane extended from the mouth of the Heart River, along the right side of Bewely Island, and was to have extended all the way down to a small island just past the head of a bedrock outcrop on the right side of the river known as Six Mile Point. The lane did not end up being this long, due to a problem in identifying the island from groundlevel. The flanking lanes started at the Highway 2 Bridge, and followed the centre lane, ending at a point about halfway between Bewely Island and the end of the centre lane.

To decrease the albedo of the plowed lanes, and hence increase their solar energy absorption ratio, the Town sanded the lanes using standard road sanding equipment. Based upon the Russian experience with ice 'dusting' (Sinotin, 1973)[4], Alberta Environment had recommended a light coating of sand between 0.1 and 0.5 mm in diameter; with a 'coat' consisting of a thin layer approximately one grain diameter thick. The sand used by the Town had a D_{50} of approximately 0.3 mm, but was extremely heavy in the coarser fractions, with grain sizes in the order of 25 mm present. The Town foreman indicated that the applied sand had a salt content of 118.6 kg m^{-3} (200 lb/yd^3). This served to depress the melting point of the ice, while not adding excessive salt concentrations to the river. The thickness of the applied layer of sand was also in excess of what was recommended, in some places being in the order of 50 to 75 mm. Where the applied layer of sand was excessively thick, the sand may have served to insulate the surface of the plowed lanes rather than inducing accelerated melt. If lane clearing and sanding is ever considered for future use, the thickness of the sand layer, and the gradation of the sand, must be more strictly controlled.

Preblasting of the ice surface was carried out at three locations. The blasting was not carried out with a view towards the creation of a continuous open lead, but rather with an eye toward general weakening of the ice cover, in specific areas, caused by the intersection of circumferential and radial cracks which emanate from the crater produced via an underwater explosion as described by Fonstad (1981)[5].

In a previous study, Andres (1975, Figure 6)[6] had identified two areas which were prone to the initial keying of ice jams. These were:

a. at the start of the bend just downstream of Six Mile Point, and

b. in the maze of small islands just downstream of Bewley and Lee Islands (the latter of which contains the Town's sewage treatment lagoons).

As well, there was an area identified, for this particular year, which would also require some preblasting, being at the mouth of the Heart River. While the ice had packed in during its consolidation of 7/8 January, a very large shear zone had been created around the outside of the bend in the Peace River where the Heart River joins it. The shear zone was a minimum of 1000 m in length, and extended approximately 60 m from the river bank, with more than three shear lines apparent. The ice which accumulated in this shear zone had piled up to a maximum of 3 m above the mean ice level in the Peace River, which, because of the buoyancy of ice, indicated that there was at least this amount below the mean ice level. If the ice were floating freely, static equilibrium calculations based on the density of ice indicated that there could be as much as 27 m of ice accumulated below the mean ice level. As this amount of ice was not practicable, due to the depth of the Peace River channel, it was assumed that the ice in the shear zone was fast to the river bed, thereby blocking the incoming discharge from the Heart River.

As flooding of the downtown core of Peace River Town had occurred in the past due to ice jams forming on the Heart River, keyed in because of the thicker ice on the Peace River, it was recommended that an area of the shear zone be blasted in order to weaken the ice and perhaps provide a flow area through the shear zone for the Heart River discharges.

To facilitate this blasting, the Town of Peace River was requested to use its equipment, which was clearing lanes on the ice, to clear away the ice accumulated in the shear zone above the mean river ice level. Accordingly, a path of about the same width as the Heart River at its mouth, or approximately 40 m, was cut through the accumulated ice to the mean ice level. That there was a significant amount of ice beneath the mean ice level became apparent between the time the path was cut and the time the blasting was carried out, as the once-level ice surface in the cut had bowed upwards, due to its buoyancy, in the order of 0.75 m.

Ice thicknesses between 1.68 and greater than 2.44 m (maximum length of measuring rod) were recorded along the main shear line. These decreased to between 0.76 and 2.13 m as the river bank was approached, and further to between 0.61 and 1.37 m in the mouth of the Heart River proper. Optimum charge weights (maximum crater size for minimum explosives for the given ice thickness) were calculated, but the resulting charges of 19 to 45 kg were considered far too large to use in close proximity to the downtown core. Accordingly a larger number of smaller charges were computed, though consumption of explosives was not optimal.

Three lines of 1 kg charges were used through the path cleared in the shear zone. The outer two lines were extended into the lanes plowed on the Peace River to the mouth of the Heart, as well as into the mouth of the Heart itself. 5 kg charges were used on the river side of the shear zone, 1 kg charges (with closer spacing) through the shear zone, and 0.5 kg charges in the mouth of the Heart River. The charges were detonated in small groups to minimize the blast shock in the vicinity of the downtown area.

Following the detonations the 'cratered' area was measured. The width of the cratered area varied from 10 to 16 m, and was in the order of 140 m in length. Overbreak, i.e., ice fractured outside the true crater, was measured to extend between 3 and 11 m from the true crater. Most of the ice lifted by the detonation fell back into the crater, as has been well documented in the literature(5). The mean level of the fractured ice in the cratered area appeared to have risen about another 0.5 m above the 'bowed' level before the detonations. With the fracturing of the ice, plus the lift obtained from both the removal of the overburden and the increase noted following the detonation, it was considered that any major Heart River flow would be able to force its way through the fractured ice shear zone.

The other two areas which were preblasted were those identified by Andres(6) as previously mentioned. Ice thicknesses at the Six Mile

Point site varied from 0.46 to 1.83 m, with an average of 1.2 m. A total of sixteen charges were set along a line which approximated the river's thalweg. Each charge had a mass of 19 kg. The craters which resulted from the detonation had an average diameter of 8.9 m, and were centred approximately 30 m apart. In the area just below Bewley and Lee Islands a larger number of charges were set as the islands and shoals present would increase the chance of ice jams forming in this location. A total of 32 charges were set in two lines, each line being placed in the outside plowed lanes. Ice thicknesses measured varied from 0.69 to greater than 2.44 m, with an average of 1.4 m. The charges, again 19 kg each, created craters with an average diameter of 9.4 m.

A previous study(7) had shown that the system of circumferential cracks which accompanied crater formation extended approximately 3.3 crater radii from the centre of the crater, and radial cracking extended approximately 12 crater radii from the centre of the crater. The designed charge spacing of 30 m should thus have caused the zones of circumferential cracking between two adjacent charges to just touch, and should have caused the complete intersection of zones of radial cracking.

The resulting average crater sizes of 8.9 and 9.4 m were slightly smaller than calculations had shown they would be, though this is entirely attributable to the variation in ice thickness. The charges had been calculated for an ice thickness of 0.91 m, based upon average ice thickness measurements taken while the lanes were being plowed, however, the above data indicates that actual ice thicknesses were as much as 2.7 times the thickness used in the calculation. Thus, while the zones of circumferential cracking might not have touched (as desired), the combination of true crater size, zones of circumferential cracking and intersecting zones of radial cracking; would have left a much weaker ice cover in the areas which had been blasted. The nature of the ice cover rendered impossible any attempt to verify the actual extent of ice cracking associated with the blasting.

4.0 BREAKUP OBSERVATIONS

4.1 Heart River

Breakup of the Heart River was uneventful this year. Few observations, if any, were carried out prior to April 16. Alberta Environment carried out aerial inspections of the Heart River from Nampa to Peace River every second day from 16 April to 23 april, and daily thereafter until breakup occurred in the Peace River at Peace River Town on 26 April.

All observations showed the ice in the Heart River to be virtually melting in place. By 19 April the river was virtually free of ice between Nampa and the mouth of the river. There were three exceptions.

The lowest kilometre of the river, between its mouth and the NAR railway bridge which crosses the Heart River just above the '12 Foot Davis' Ballpark retained ice. This reach still contained both solid and fragmented ice. The ice, however, was deteriorating (candling and melting) rapidly due to solar radiation and thermal erosion due to the river flow. Sediments carried in the flow were, at times, being deposited on top of the ice, which would have accelerated the thermal deterioration processes.

The other two reaches where a complete ice cover existed were in areas where bank slides (one major, one minor) had constricted the Heart River. The minor slide had constricted the channel width by about 50%, and held the river ice upstream of the constriction. The ice in this area basically melted out in place. The major slide completely blocked the Heart River channel, and acted like a dam on the river. The ice which had formed above the constriction, as well as some fragmented ice which had arrived from upstream was also melting in place.

The impoundment behind the major constriction caused some consternation to the Town Officials in Peace River, as the Heart River was actively downcutting through the materials in the toe of the slide. The Town Officials visualized a 'dam-break' situation occurring in the river, which could cause flooding problems in downtown Peace River, if the released flood wave caused ice jamming in the Heart River below the ball park, keyed onto the extremely high ice level in the shear ridge of Peace River ice across the mouth of the Heart. A set of calculations of normal depth under established equilibrium conditions for an ice jam in the lower reach of the Heart River were conducted; using a discharge of 75 m^3s^{-1} (forecasted as maximum for the river by the Alberta River Forecast Centre) and using four Peace River levels (which corresponded to the 'States of Flooding Alert' established by the Town of Peace River) as initial keying levels in the mouth of the Heart. The calculations showed that ice jam flooding from this source should not be a problem.

Downcutting through the toe of the large slide was not complete by the time the Heart River broke up at the mouth.

Breakup of the Peace River occurred on 26 April at the Town, but saw ice still in the reach of the Heart River between its mouth and the first bend upstream (at the entrance to the ball park). This ice stayed in place until 28 April, when it moved down and was turned downstream to occupy the space between the ice in the shear ridge across the mouth and the right bank of the Peace River. The ice in the gap plowed and blasted in the shear ridge across the mouth of the Heart did not go out at this time, however, it was evident that most of the Heart River discharge was finding its way through the gap and into the Peace River.

The final dislodgement and run of the ice in the lower reach of the Heart River resulted in a stage decrease, possibly due more to the lowering of the Peace River levels following its breakup, of approximately 1.5 m.

4.2 Smoky River

Few known observations of the ice conditions on the Smoky River between its confluence with the Peace River and the WSC Gauge 'Smoky River at Watino' were carried out prior to 16 April 1982. From 16 to 23 April Alberta Environment carried out aerial observations every second day, and daily observations from 23 to 26 April when the ice on the Peace River went out. Additional minor observations were taken on 27 and 28 April, when the Smoky River was finally clear of ice.

More detailed observations were made for the Smoky River than for the Heart. The following is a summary of the observations made by Alberta Environment staff over the period 16 to 28 April.

a. 16 April

- Ice on the Smoky River generally darker than on the Peace River.

- The ice was noticeably darker along the river's thalweg, some small open leads had formed.

- In the reach below the Hanging Dam there were a few places where the river was up to 30% open.

- Generally not much water on top of the ice to indicate significant melting.

- Snowpack on the prairie level outside the river valley is complete, though probably condensing.

b. 19 April

- Smoky ice darker than before.

- Prominent dark lines along thalweg have been replaced by two dark lines paralleling the river banks, probably adjacent to bed or shorefast ice.

- Open leads slightly larger than before.

- No evidence of runoff commencement yet (flow in ravines in river valley), snowpack still continuous on prairie level, but starting to show the ground in the fields of the valley near Watino.

c. 21 April

- Starting to see meltwater sitting in fields in the valley near Watino, prairie level snowpacks just starting to show ground beneath.

- Ice along river banks starting to melt, much darker than before.

- Little other changes.

- Gauge Height 1.580 m at Watino.

d. 23 April

- Had telephone report that river was breaking up at Watino, proved false. Some minor ice adjustments had prompted telephone call.

- Gauge Height 1.581 m at 0900 hours at Watino.

- Small ice floes breaking off of edges of a few of the open leads, not general though.

- Lots of meltwater sitting in ditches and open fields near Watino, but sill 70 - 80% snow cover on prairie level away from the valley.

e. 24 April

- Inspected Smoky and Little Smoky above Watino, not much different from the remainder of the observation reach.

- Still not much happening.

- Gauge Height 1.866 m at Watino.

- Still 70 - 80% snowpack on prairie level southeast of Watino.

f. 25 April

- Helicopter down today with fuel pump problems.

- Smoky River reported to be breaking up again at Watino, so drove out.

- Gauge Height 2.836 m at 1135 hours MST.

- Ice had moved at the gauge, but had jammed at the bend approximately 1.5 km downstream. The ice in the bend and downstream to the NAR bridge was still intact. Below the NAR bridge the river had opened for a distance of about 5 km, and had formed a small jam at a location as far down as wheeled transport would allow inspection.

- Gauge Height 2.784 m at 1225 hours MST.

g. 26 April

- Heavily hummocked ice between the islands at the confluence of the Smoky River with the Peace was holding back a 4 - 6 km jam of little consequence at the mouth of the Smoky, though the Peace River was open along its left side.

- Small ice floes moving in the river, though no jamming between mouth and Hanging Dam.

- Upon arrival at the Hanging Dam an ice jam of 8 - 10 km length was keyed onto the Hanging Dam. The Dam itself had broken into 5 or 6 large fragments in its downstream half, but was still complete in the upstream half. As we hovered over the dam a large flow of well-fragmented ice started to boil up between two of the chunks of the Hanging Dam. The fragments of ice boiling up were not larger than about 0.35

m, and appeared to be being forced between the chunks of the ice dam as the latter stayed virtually motionless. At first we could not tell where the fragmented ice was coming from, but after waiting for 15 - 20 minutes, it became apparent that the ice was being entrained into the river flow about 30 - 40 m upstream of the toe of the jam held by the Dam. The ice was apparently being 'simply' entrained, i.e., little to no vorticity associated with the entrainment, and passed beneath the toe of the jam and upstream half of the dam, and was re-emerging in the fragmented downstream half.

- The inspection was carried on up to Watino and back, with no ice except that grounded on the banks being present.

- Upon arrival back at the Hanging Dam the river was virtually clear of ice. Only about 0.75 km of the original jam remained, as well as grounded ice along the river banks in what were the jam's shear walls. Ice continued to be forced through the Hanging Dam.

- The ice which had flowed through the dam was small, and well dispersed, with no indication of reforming another jam.

h. 27 April

- The jam at the mouth of the river was still in place, though was 2 - 3 km longer. No flood threat was perceived.

- The river was clear of ice to Watino, except for this jam, the Hanging Dam fragments and grounded ice along the banks.

- Gauge Height was 1.911 m at 0900 hours MST at Watino.

i. 29 April

- The ice jam at the mouth of the Smoky had pushed through the most right-hand distributary channel (between the islands and the right bank of the Peace River) last night, leaving the heavily hummocked ice between the remaining islands and shoals intact.

- Smoky River clear of ice except for Hanging Dam and grounded ice along the banks.

The Smoky River breakup was therefore an uneventful occurrence, and was basically thermal (semi-static) in nature. No flooding was experienced; and the event which usually causes problems for the Town of

Peace River, that is the Smoky River ice running out before the Peace River is clear of ice, did not occur. That the ice went out in a thermal (melt) mode was attributed to the marked lack of inflow from snowmelt, as witnessed by the gauge heights recorded at Watino.

The only event of interest was the manner in which the ice, jammed on the Hanging Dam, went out.

4.3 Peace River

Observation of the location of the Peace River Breakup front was conducted by BCHPA from 17 March 1982, and was taken over (by agreement) by Alberta Environment when the breakup front reached the Dunvegan Bridge, or April 16th in this case. The breakup front position and associated information is given in the following Table 1.

The breakup 'front' could be classified as a thermal (semi-static) phenomenon, as opposed to the more dynamic breakup events characterized by the fracturing and movement of a still fairly substantial ice cover under the influence of a flood wave or general rising stage due to an increase in discharge with the commencement of the spring runoff. The thermal front was characterized by the following (moving from upstream to downstream):

a. An open lead in the ice cover, varying in width from an eighth to a quarter of the width of the river. Within this open lead were small ice floes broken off of the edges of the upstream ice still attached to the banks, and a small amount of debris such as timber deadfall. The ice floes and debris covered the open lead to less than ten percent of its area.

b. At the downstream limit of the open lead was a small accumulation of jammed ice and debris, occupying a width roughly equal to the width of the open lead upstream, and varied in length from 30 to 100 m (±). This small debris jam did not appear to create a significant backwater behind it.

c. Ahead of the 'debris front' the ice cover was mostly intact, or more properly had not moved yet. A long, narrow area of very dark ice, indicating rapid deterioration, preceded the debris front, and basically followed the river's thalweg. More often than not, this 'finger' of dark ice contained a number of small areas where the ice had melted out in place, and small floes had been detached by melt.

TABLE 1
Peace River Breakup
Breakup Front Position/Timing

Date	Time	Front[1] at Mile	Progression Rate (miles/day)	Comments
17 Mar		88.	4.5	1 mile above Clayhurst Ferry
23 Mar		115.	2.5	
25 Mar		120.	2.5	
29 Mar		130.	1.5	
31 Mar		133.	1.5	112 mi upstream of Peace River Town
2 Apr		136.	0.0	
5 Apr		136.	3.3	
8 Apr		146.	4.8	
13 Apr		170.	2.5	75 mi upstream of Peace River Town
16 Apr	0900	177.5	6.53	
19 Apr	0840	197.1	5.55	
21 Apr	0830	208.2	6.35	
23 Apr	0845	220.9	7.00	
24 Apr	0820	227.9	8.90	
25 Apr	0800	236.8	6.70	
26 Apr	0600	243.5	6.12	
26 Apr	1600	246.1	5.16	At Bridges in Peace River
27 Apr	0830	249.6	4.06	
27 Apr	1500	250.7	9.33	
28 Apr	0830	257.5	16.00	
3 May	0940	337.5	58.10[2]	
7 May	1035	570.0		

<u>Notes</u>: See next Page.

Notes: To Table 1 on previous page.

1. Breakup front locations are given as 'River Miles below G.M. Shrum Generating Station'. Some notable mileages are:
   Mile 0 - G.M. Shrum Generating Station
   Mile 104 - BC/Alberta border
   Mile 130 - BCHPA's last observer
   Mile 180 - Dunvegan Bridge
   Mile 245 - Mouth of Heart River at Peace River Town
   Mile 517 - Ft. Vermilion Settlement

2. RCMP Detachment at Ft. Vermilion reported the river clear of ice at mile 517 on 4 May. This must have been a second melt front initiated somewhere between Peace River Town and Ft Vermilion, with an ice cover still intact between, as reported on 3 May. The rate of advance between 3 and 7 May then probably reflects the accumulated rate of the two fronts working in parallel.

Sometimes the amount of melt, ahead of the debris front, within the eighth- to quarter-channel width finger, was of such extent that it was difficult to judge what exactly would represent the breakup front proper. For this reason the most downstream edge of the debris jam was considered as the breakup front, as it was the most consistent feature of the entire configuration.

The following is a summary of the field notes (augmented by memory) by Alberta Environment staff while observing the breakup over the period 16 to 28 April.

a. 16 April

- Ice front at Mile 177.5 at 0900 hours, or 2.5 miles upstream Dunvegan Bridge.
- Lead open above a small debris jam, with a small amount of ice floes floating in the lead.
- Ice rotting out in a long 'finger' ahead of the debris jam.

- The finger appears to follow the river's thalweg, and extends almost all the way down to Dunvegan Bridge. Some small areas of open water occur in the finger, where the ice has melted out in place already.

- No evidence of major stage change ahead of or behind the breakup front.

b. 19 April

- Ice front at Mile 197.1 at 0840 hours, or 17.1 miles downstream of Dunvegan Bridge.

- Melting finger ahead of the most upstream debris jam extends almost all the way down to the mouth of the Saddle (Burnt) River at Mile 202.8, a distance of 5.7 miles, again following the river's thalweg.

- Melting lead, or finger, is wider than last Friday, and contains a second debris jam approximately 0.8 km in length, formed of small to large ice floes detached from the sides of the finger. Still used the upstream debris jam to mark the breakup front.

- Two large open water areas had formed at the mouth of the Saddle River, and were ahead of the discernible tip of the melting finger.

c. 21 April

- Ice front at Mile 202.8 at 0830 hours, between Long and Camp Islands.

- The lead/debris jam configuration was slightly different than in the previous observations. The debris jam, the head of which was again used to mark the breakup front, was approximately 2.1 km long, though narrower than before, and was 'hung-up' along Long Island, slowly moving downstream. Ahead of the debris jam was an open lead for approximately 0.75 km, to the upstream end of Camp Island. There were no small ice floes in this forward lead, however, there was a smaller debris accumulation at the head of it. Again, the melting finger extended a few kilometres ahead of the lead.

- It seemed as if the melting and advancing process at the breakup front had continued as previously, except the majority of the debris jam was confined by the narrow lead adjacent to Long Island. The debris was slowly working its way downstream, and would eventually free itself from Long Island.

- In general, the ice cover appeared darker than it had before, indicating more advanced rot of the ice cover as a whole.

d. 23 April

- Ice front at Mile 220.9 at 0845 hours.

- The melt finger ahead of the front extended to Mile 223.3

- Little change in manner or rate of breakup.

e. 24 April

- Ice front at Mile 227.9 at 0820 hours.

- The breakup front had to pass through an area of heavy, hummocky ice accumulation in the reach Mile 224.5 to 225.5 (approximately), which had been noted in a February reconnaissance to be an area where one of the many 'jams', formed by consolidation or 'telescoping' of the ice, had occurred at freeze-up.

- That the ice in this reach was generally thicker than on most of the river was noted by the presence of large shear walls along the sides of the hummocky ice, as well as the manner in which the breakup front passed through the accumulation.

- When the melting finger reached the heavy ice accumulation it seemed to have disappeared, there was no sign of the dark streak through the accumulation that had characterized where the river would open up next in other reaches. When the advancing debris front reached the upstream end of the heavy ice accumulation, its advance was halted completely.

- The finger began to reappear below what was the toe of the freeze-up shove front before it started to show through the hummocky ice. The melt re-established itself as an open lead with its own small debris jam, and carried on down the river.

- After considerable time the heavy ice was finally melted through by the flow, and the debris which was held up by the accumulation flowed downstream to add to the small jam at the head of the usual breakup front.

f. 25 April

- Helicopter not operational today.

- Had time change last night from MDT to MST.

- Drove out and found the ice front approximately 0.5 km below the Peace River Correctional Institute, ie at Mile 236.8 at 0800 hours.

- Checked the Alberta Environment recorder in the wet well of the pump house for the Institute. Showed a recent stage increase of approximately 0.5 m. Gauge height at 0810 hours was 7.245 m.

- There appeared to be much more ice flowing in the open lead behind the debris jam than in previous observations, as well as more ice in the debris jam itself. This could be due to the different perspective of the observation.

- The melting finger extended off into the distance, but could not tell for sure where it ended.

- River level started dropping as the front progressed downstream. By 1130 hours the gauge height at the Alberta Environment recorder was 6.900 m.

- At 1530 the WSC Gauge at Peace River reached a peak stage of 11.103 m.

- At 1650 hours the gauge height at the Alberta Environment recorder was 6.380 m.

- By 1800 hours the breakup front has progressed to just short of Mile 240, and was approximately 1.5 km upstream of the confluence of the Smoky River.

- The melting lead was still following the thalweg, and was immediately adjacent to the left bank of the Peace River. Immediately below the last distributary channel of the Smoky River confluence, the melting finger crossed over to the right side of the Peace. The finger carried on down the channel to the right side of the second island upstream of West Peace River, and ended just below the island.

g. 26 April

- Between midnight and 0550 hours could not see the front, but could hear the ice moving and grinding out in the river. Most of the noise came from the area above West Peace River.

- At 0600 could discern the head of the front at Mile 243.5, which was approximately the location of the end of the finger last night.

- There were now two separate breakup 'fronts', working down both sides of the river. The front had apparently 'hung-up' on the second island upstream of West Peace River, and had alternately pushed its way down both sides of the island. The melt fingers for each front extended down to near the mouth of the Heart River.

- Throughout the morning each front alternately progressed downstream. At about noon the ice between the opened leads started moving, thereby creating one large breakup front that was about a third of the river's width wide.

- By 1325 hours the front was adjacent to the Town Yards, or just downstream of the mouth of Pat's Creek.

- At 1605 hours the breakup front passed beneath the Highway 2 bridge (Mile 246.05).

- The melting finger extended past the WSC Gauge and into the left channel around Bewley Island, which caused a little concern since the pre-blasting operations had been conducted at the lower end of the right channel around Bewley Island. A local resident stated, however, that it was usual for the initial breakup front to pass to the left of Bewley, and that it would eventually get halted at the lower end of the left channel and would start to work its way into the right channel, eventually clearing that channel first. Such proved to be the case.

- At about 2300 hours the ice could be heard to be moving in the vicinity of 71 Avenue, though the front could not be seen.

h. 27 April

- The ice front, from the right channel around Bewley Island, had progressed to Mile 249.6 by 0830 hours.

- All of the ice and debris which entered the left channel around Bewley had grounded out on the small islands and shoals which cross the lower end of that channel.

- The river stage at the WSC Gauge had dropped 1.833 m to a gauge height of 9.270 m at 0900 hours.

- The breakup front continued its slow advance, reaching Mile 250.7 by 1500 hours.

i. 28 April

- Ice front at Mile 257.5 at 0830 hours, an area known as '12 - Mile Flats'.
- The front had passed through all known areas of ice jam initiation.

4.4 General Observations

The 1982 ice breakup on the Peace River was nowhere near as disastrous as mid-winter data indicators pointed out that it could be. That the breakup went quietly and smoothly can be attributed, by priority, to the following:

a. A cool spring which held off the snowmelt runoff until the breakup was through Peace River Town.

b. A reportedly dry late summer and fall, such there was little moisture in the ground at freeze-up. Most of the local snowmelt in spring appeared to be absorbed into the ground.

c. Controlled releases from GMS. And,

d. In some small measure, to the ice weakening efforts carried out before the arrival of the breakup front.

The first two points are natural phenomena, and hence cannot be controlled for purposes of ice jam mitigation. These two alone, however, probably contributed as much as 70 percent of the effective mitigative circumstances which led to the uneventful breakup.

The controlled releases from GMS by BCHPA likely added another 20 percent to the total effective mitigative effort. The constant, or very gradually varied flow releases within operating limits, prevented major stage changes in the river which could have precipitated a more dynamic breakup. One contingency allowance that was made, but never invoked, was to have the GMS releases cut back as snowmelt runoff increased, in order to maintain a fairly constant flow through Peace River Town. It is the constancy of discharge at Peace River Town which is desirable, both at breakup and at freeze-up.

The remaining 10 percent of the effective mitigative measures goes to the ice weakening effort. Some comments should be made concerning the efficacy of these efforts due to the costs involved.

a. to Alberta Environment -	$ 21,751.14 (less wages etc.)
b. to Peace River Town -	$150,385.24
c. to BCHPA -	
TOTAL	$

Ice thickness measurements made during the preblasting operations showed an average decrease in ice thickness along the plowed lanes of 0.62 m (2.04 ft) from the measurements made while the lanes were being plowed, with a maximum decrease of 1.05 m. Even with this reduction, some ice thickness measurements carried out for the preblasting operation, in the period of 16 to 21 April, were in excess of 2.44 m.

The plowed lanes served a second purpose, being drainage of the surface melt of the ice cover. When the winter jam (which created the ice cover) formed in January there was a certain amount of silt deposited on the ice from the flow, as well as a certain amount of debris in the form of deadfall timber. As the sun angle increased into the spring, the exposed faces of the hummocked ice surface began to melt, aided by radiation absorption due to the deposited silts and debris. The melt, however, was only of the exposed ice hummocks, above the mean ice surface, and did not contribute toward general ice weakening. Some of the meltwater found its way into the plowed lanes, and began to flow downstream. As well, in the numerous holes that were augered through the ice to test its thickness prior to plowing the lanes, river flow exchanged with the meltwater flow. Dependent upon the location of the lane surface with respect to the river's hydraulic grade line i.e., raised above or depressed below, the ice lane flow would drop down through the auger holes, or river flow would boil up through them respectively. The flow through the holes caused enlargement through thermal erosion, many holes becoming large enough for a man to drop through, and in one or two instances large enough to drop a vehicle through. With fluid flow on top of the lanes as well as beneath them, thermal erosion would occur from both sides.

The efficacy of the ice blasting downstream of Bewley Island and downstream of Six Mile Point was difficult to judge, as the breakup front passed through both of these areas at night. However, observation of the resulting craters before the arrival of the breakup front had shown that most of the blast debris which had fallen back into the craters had disappeared by the time the breakup front arrived. This can be attributed to ice floe entrainment by the river flow, and possibly to melt to a small degree. The craters allowed sediment laden river flow onto the surface, which in turn created thermal erosion around and between the craters, and possibly some increased heat absorption through the changed surface albedo.

There is a hint in the data contained in Table 1 that the ice front passed through the blasted area slightly quicker than others. See for instance the progression rates between 1500 hours on 27 April and 0830 hours on 28 April, when the front moved through the blasted area below Six Mile Point. That a similar increase is not noticeable between 1600 hours on 26 April and 0830 hours on 27 April, when the front moved through the blasted area below Bewley Island, is thought to be due to the time spent pushing the front down the left channel around Bewley before it jammed and started going down the right channel.

It was noticed that in a couple of locations the plowed lanes were not situated to best advantage for this year's breakup, which indicates that they could likely be better situated for more dynamic breakup events as well. The single lane between the mouth of the Heart River and the bridges was located approximately one quarter of the way across the river from the main townsite, and angled to the left to go between the third and fourth railway bridge piers from the left bank. The breakup front, following the river's thalweg, pushed through at roughly the mid-channel position, angling slightly to the left towards the bridges. The ice front went through the bridges between the second and third railway bridges piers from the left bank.

Because the front went through the bridges just to the left of the single lane, it just caught the upstream ends of the downstream triple lanes before carrying on into the left channel around Bewley Island. This in itself is not all bad, as this year's observations, backed up by local resident reports, showed that this is the normal mode of breakup at the head of Bewley Island. When the right channel began to open up the front followed the second and third lane from the right bank, but left the closest lane to the right bank intact. Thus these lanes should have been located one-lane-spacing (38 m±) further towards Bewley Island. The breakup front continued to follow the second and third lanes all the way down to the end of the lanes near Six Mile Point. In this respect the thinner ice in the lanes appears to have been beneficial.

The area where the most noticeable effects, and possibly the most noticeable success in the overall ice weakening effort was achieved, was the work conducted at the mouth of the Heart River. There is little doubt but that the massive ice accumulation in the shear zone across the mouth of the Heart constituted an obstruction to both fluid and ice flow from the Heart. A good portion of the ice in the shear zone was probably grounded to the bed of the Peace River, allowing flow from the Heart through it by percolation only. Plowing a gap through the shear zone removed the surcharge load on the mean ice cover. The buoyancy of the ice remaining beneath the ice cover caused the ice to lift, most probably through the mechanism of plastic creep. This may have opened a small waterway through the ice in the shear zone. Subsequent blasting of the ice in the gap, with the charges placed at depth, appeared to cause further heave of the upper surface, and likely caused an enlargement of the waterway at the bottom of the ice.

When the little ice which remained in the Heart River (following melt) finally moved out, it was contained against the right bank of the Peace River by the shear ridge. The Heart River flow, however, was observed to be making its way through the gap. The ultimate efficacy of this work was not tested, as the Heart River neither jammed at the mouth, nor increased its discharges appreciably.

As in past years, a summary table of breakup data over the years is included in the following Table 2.

TABLE 2
Breakup Data
Peace River at Peace River Town

Year	Breakup Date	5-Day Pre-breakup Elevation* (m)	Discharge During Breakup Peace River Above Smoky River*2	Smoky River Above Confluence*3	Maximum Ice Jam Elevation (m)	Maximum Stage Increase Above Pre-breakup Elevation (m)
1960	Apr 16	312.88	883.49	365.29	313.21	0.33
1961	Apr 20	311.69	1112.85	104.77	311.81	0.12
1962	Apr 16	312.30	866.50	648.46	313.94	1.64
1963	Apr 19	311.75	3381.03	1093.03	316.14	4.39
1964	Apr 19	312.33	897.64	206.15	312.15	-0.18
1965	Apr 14	311.90	1568.75	481.39	313.61	1.71
1966						
1967	Apr 30	311.90	291.66	1005.25	313.40	1.50
1968						
1969	Apr 15	311.96	475.72	948.61	314.89	2.93
1970						
1971	Apr 19	312.48	1260.10	203.88	313.06	0.58
1972	Apr 20	313.21	1452.65	538.02	314.86	1.65
1973	Apr 12	313.76	2273.84	515.37	318.18	4.42
1974	apr 20	313.36	2288.00	1308.24	317.51	4.15
1975	Apr 17	314.16	2174.73	69.94	314.52	0.36
1976	Apr 11	313.94	1676.36	594.65	314.34	0.40
1977	Mar 12	312.72	767.39	66.83	311.90	-0.82
1978	Apr 15	313.18	1333.72	215.77	313.49	0.31
1979	Apr 30	314.10	2520.20	1589.99	318.61	4.51
1980	Apr 18	311.81	651.29	387.94	313.06	1.25
1981						
1982	Apr 26	315.46	1653.00	247.00	315.94	0.48

Notes: *1 Average elevation of mean daily discharges at Peace River for 5 days prior to breakup, estimated from recorded water levels.

*2 Peace River Discharge = Discharge at Peace River - Smoky River Discharge at Watino

*3 Smoky River at Watino.

5.0 PROPOSED MODE OF OPERATION FOR 1982/83 FREEZE-UP

Cross sections established during the 1981/82 ice season were surveyed following breakup, however they were not available in time to conduct any analysis towards the mode of operation of GMS for the freeze-up period in 1982/83. However, the limited data and observations available from the 1981/82 season suggest a mode of operation which can be considered a first attempt at controlling the freeze-up level.

First, it was noted that for this past freeze-up the rupturing of the initial ice cover was caused by increased releases from GMS in response to an increased load demand following reduction in load over the Christmas to New Year holiday season (See Figure 1, Sheet 2 of 9 or Figure 4). Figure 1, Sheet 2 of 9, shows something like a five-fold increase in releases over the period 1 to 6 January. It is now known that the release of a moderately sized ice jam, in the vicinity of Verte Island, created a slug of flow (released from storage) which contributed to the rupture of the initial cover in Peace River, however, this release was also likely due to the stepped up releases from GMS.

The point to be made here, and in fact to the operation of any hydro generating station when the freeze-up front is passing through sensitive areas for winter flooding, is that the discharge should be held constant, or at least within reasonable limits, until the ice cover has formed and gained some internal strength through freezing. The question remains as to what would constitute the maximum desirable freeze-up level through the Town of Peace River; to allow BCHPA a reasonable amount of freedom of operation in response to load demand, and yet avoid both surface and groundwater flooding in the Town of Peace River? As groundwater flooding occurs in response to increased river levels, at a lower level than that which would cause overbank flooding, and stays for the longest time, this should be the primary consideration for attempting to control the freeze-up level. If this criteria is met, then there should be no occurrences of surface flooding due to dike overtopping from stage increases as the ice cover forms.

The limited groundwater level data available shows that a Peace River ice-covered stage, <u>for the particular cover thickness attained in 1982</u>, of between 11 and 12 m (Elevation 315.8 to 316.8 m; 1036.1 to 1039.4 ft) maintained the basement flooding condition in West Peace River until mid-February. BCHPA's releases during this period were in the order of 1690 m^3s^{-1} (59,689 cfs) over the period 9 to 20 January to provide a constant discharge to let the cover gain strength; and varied from 1930 to 880 m^3s^{-1} (68,160 to 31,080 cfs) until 16 February when the releases were cut to in the order of 1000 m^3s^{-1} (35,320 cfs) in order to lessen the groundwater flooding in West Peace River.

When the GMS releases were reduced following 16 February the groundwater table dropped over a period of 12 days so that it corresponded to a gauge height at the WSC gauge of approximately 11.0 m. The corresponding groundwater level was in the order of 10.4 m (See March 1 levels, Figure 1, Sheet 5 of 9). The basement flooding problem abated with this decrease, with the exception of perhaps five homes. This suggests that the maximum allowable Peace River stage following freeze-up should be in the order of 10.0 to 10.4 m; or Elevation 314.8

to 315.2 m, say 315.0 m (1033.46 ft) is the maximum desirable river elevation. If all the basement elevations in West Peace River were known, it would be a simple matter to determine the maximum allowable river level, but they are not.

The emphasis placed earlier on the particular ice cover thickness for 1982 should be noted. Different cover thicknesses, generated by the manner of freeze-up, for a constant discharge will yield different maximum ice levels. However, as the freeze-up in January of 1982 was so unique, possibly giving an upper bound to ultimate initial cover thickness, use of the 1982 data should prove conservative. Observations from future years, hence different initial ice thicknesses, may refine this rather crude analysis and allow BCHPA a little more flexibility in operations at freeze-up.

An interesting, and rather unique analysis of the Peace River freeze-up levels by Carson and Lavender (1980)[8] of Acres Consulting Services Ltd., gives an indication of the allowable GMS releases, attenuated to Peace River, that would produce the maximum desirable ice covered level of 315.0 m. It should be noted that while their analysis was based upon leading edge stability criteria for initial ice cover formation, the figure they produced described completely (with only minor assumptions) the entire event at Peace River last year, including the secondary staging due to telescoping of the ice cover. From their figure (see Figure 2 of Ref 1) for the above allowable river stage, the maximum value of the parameter $(Q/B)^{2/3}$ should be 2, which corresponds to a discharge at Peace River Town of about 1350 m^3s^{-1} (47,675 cfs). At this point in time it is not known how much the releases from GMS attenuate before reaching Peace River Town, therefore it is suggested that 1345 m^3s^{-1} (47,500 cfs) be the maximum constant discharge released from GMS to arrive at Peace River with the ice front.

Figure 3 shows an open water flow travel time, for a discharge of 1345 m^3s^{-1}, of approximately 42 hours. Therefore the following mode of operation for GMS for the 1982/83 freeze-up period is recommended:

1. Monitor the rate of advance of the freeze-up front towards the Town of Peace River, paying attention to changes in the rate brought on by changes in atmospheric conditions, in order to be able to forecast when the freeze-up front will reach Peace River Town within 48 hours. For this purpose, it is recommended that Mile 255 (Birch Island, just downstream of Six Mile Point) be considered as the 'arrival' location, as the area is ice jam prone and could affect the Town. During this period allow BCHPA to operate GMS as load demand requires.

2. When the ice front is calculated to reach Mile 255 in 48 hours, restrict GMS releases to a maximum of 1345 m^3s^{-1} to allow the discharge releases to arrive at Peace River coincident with the ice front. A smaller release, to conserve winter storage in Williston Lake and for conservatism due to the rough nature of the guidelines through which this estimate was made, would be acceptable, but not less than 1000 m^3s^{-1}. The discharge should preferably be held constant, or at most be allowed to fluctuate 42 m^3s^{-1} (1500 cfs), providing a release of 1345 m^3s^{-1} is not exceeded.

3. Closely monitor the groundwater levels in West Peace River (Alberta Environment has established three recording wells for this purpose), and if basement flooding becomes immanent, reduce the releases from GMS fully realizing that it will take 48 hours to have any effect at Peace River Town.

4. As was initiated in January 1982, the ice cover formation discharge should be held constant for awhile, to allow the ice cover to gain strength by freezing. Twelve days were allowed in January 1982, and it is recommended that a similar time be allowed this year.

5. Following the 12 day ice cover strengthening period, slowly step up base flows and peaking to normal operations in response to load demand. Peaking releases should not exceed base flows by too great an amount, though there is insufficient data to recommend limits at this time. If basement flooding begins to

be a problem, revert back to the operation on the day before the releases which brought on the problem, and consider that the maximum releases until breakup.

The above proposal is not as conservative as it could be, considering this will be a first attempt at setting the ice level and it aims for the maximum allowable level identified at this time. Data taken from this event should be able to refine the analysis, perhaps imposing further restrictions, or perhaps lifting some.

Emergency power generation requirements through the formation and 12 day period should be made up from other sources if possible. The Committee will have to discuss, before the need arises, the advisability of large sustained releases after the 12 day period.

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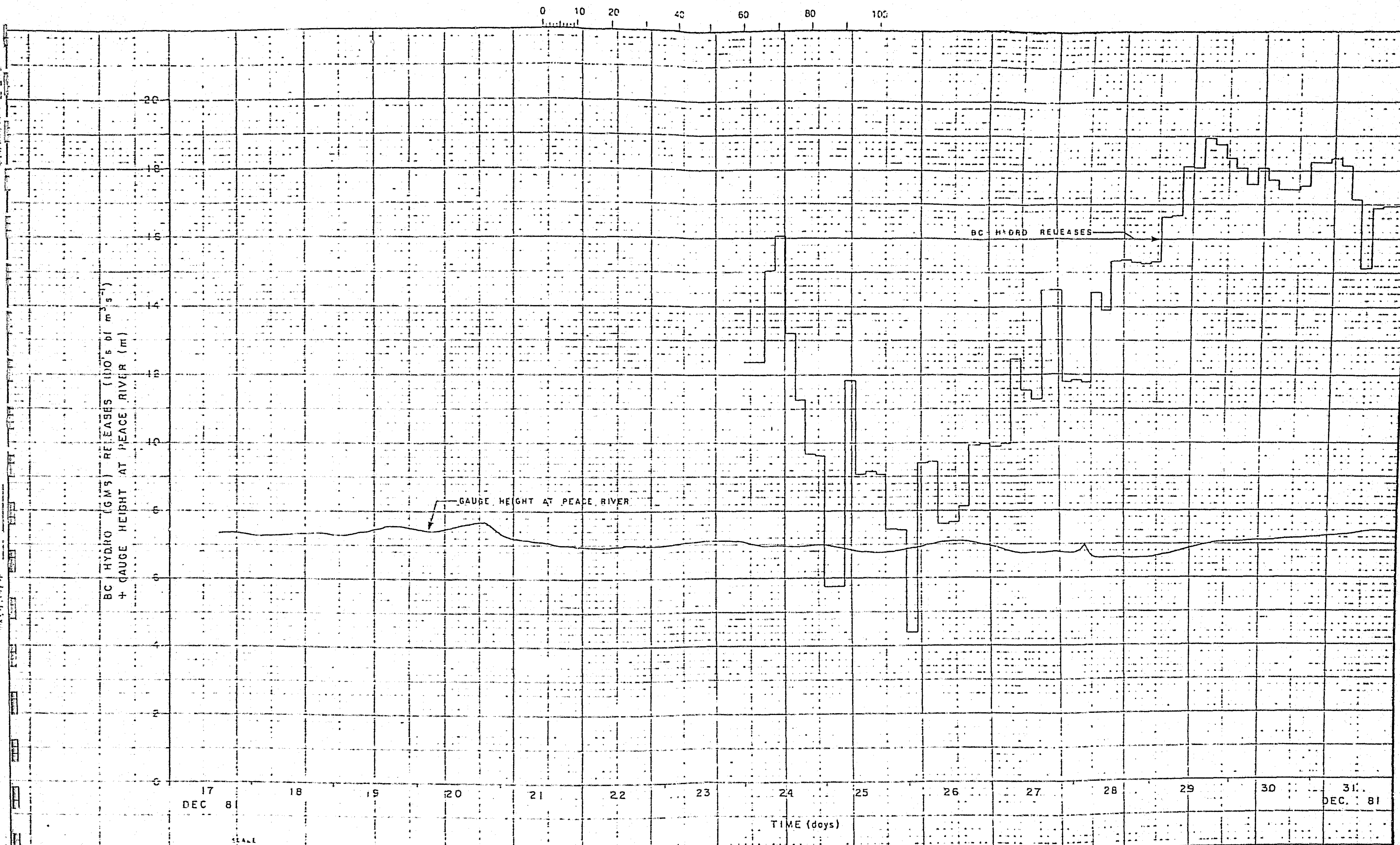


PEACE RIVER 1981-82 ICE STUDY

Alberta ENVIRONMENT | RIVER ENGINEERING BRANCH

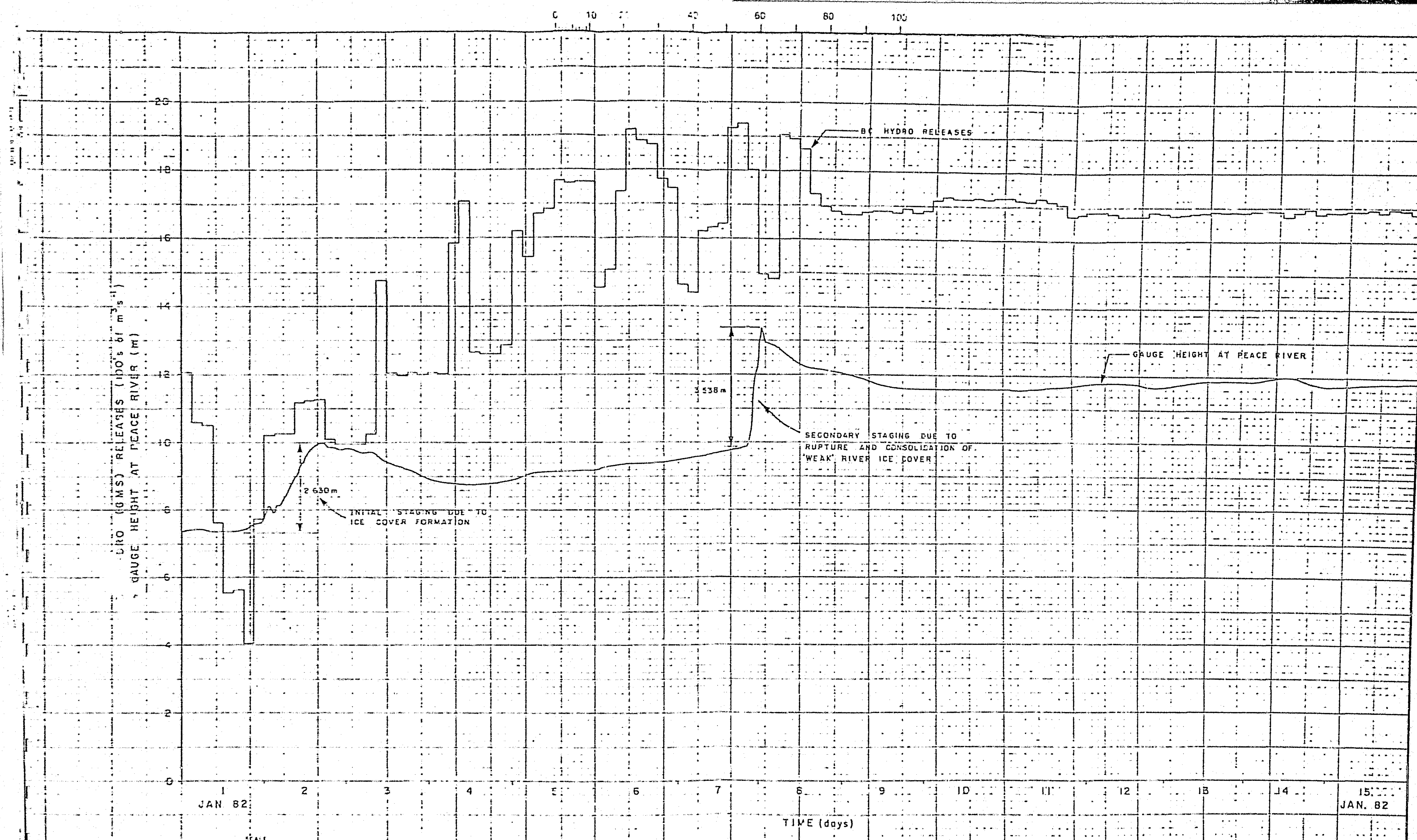
B.C. HYDRO 3-HOURLY FLOW RELEASES AND GAUGE HEIGHT AT PEACE RIVER

SUBMITTED
DATE
APPROVED
DATE

DESIGNED
CHECKED
DRAWN

SCALE AS SHOWN

SHEET 1 OF 9



Alberta ENVIRONMENT

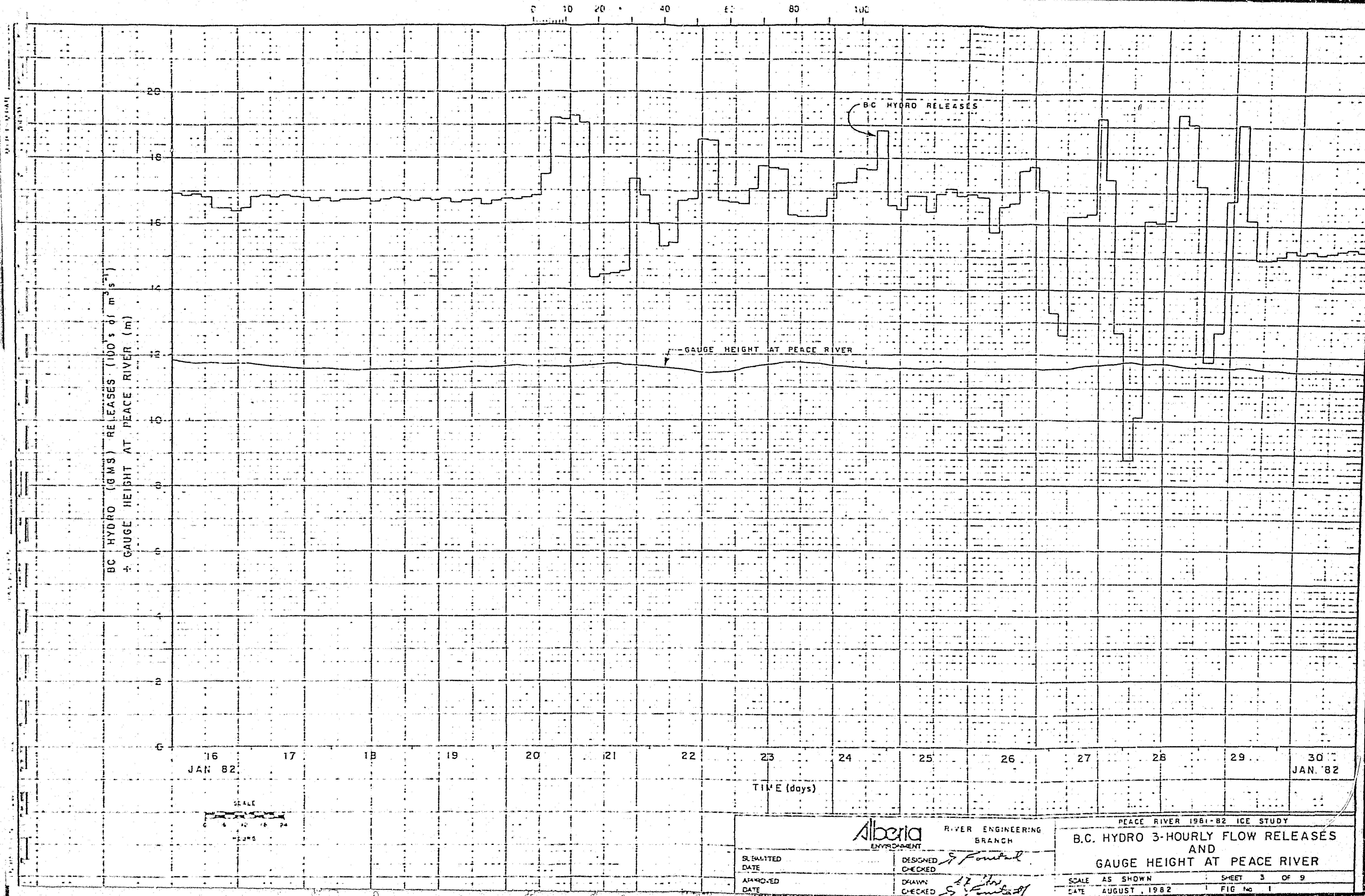
RIVER ENGINEERING BRANCH

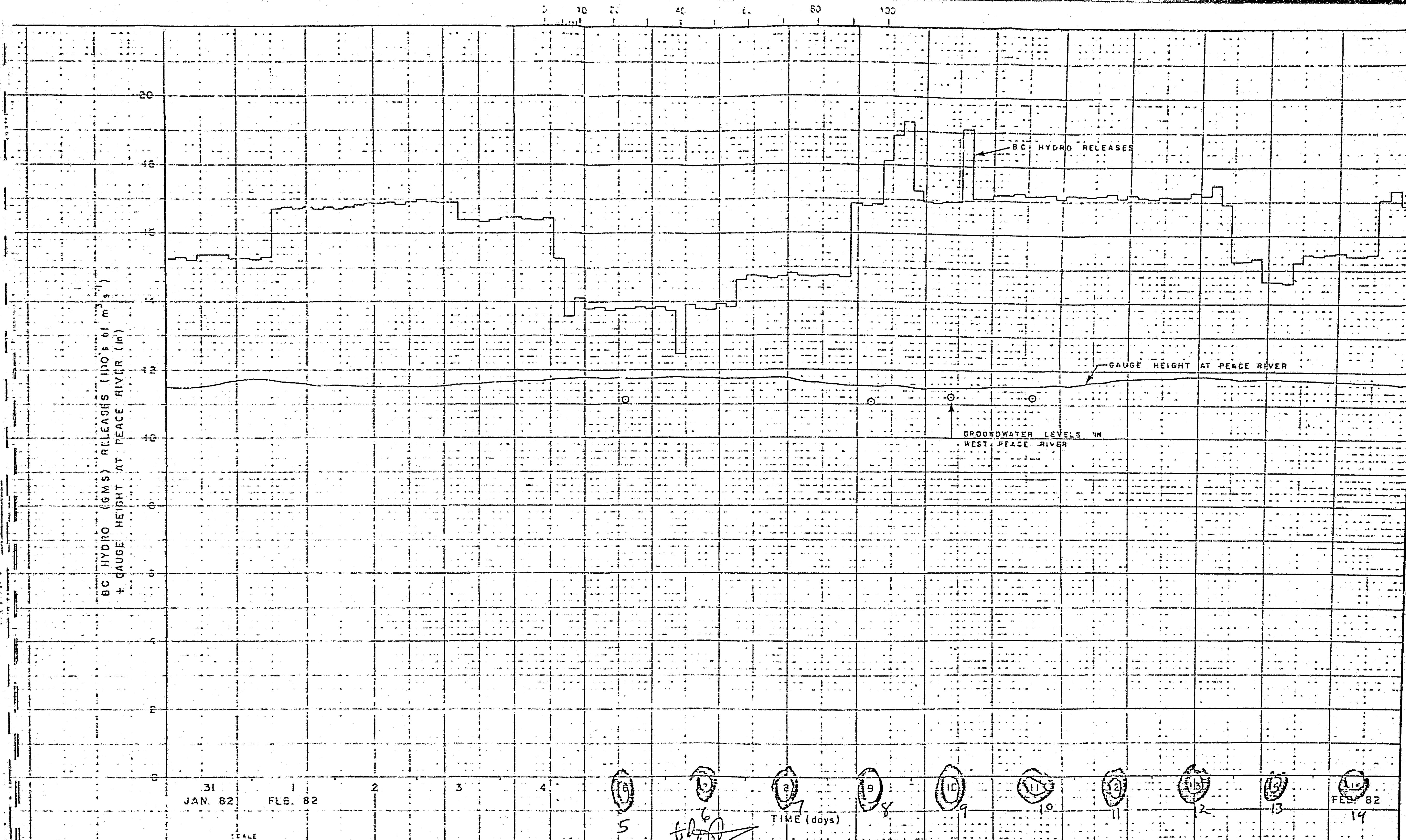
PEACE RIVER 1981-82 ICE STUDY

B.C. HYDRO 3-HOURLY FLOW RELEASES
AND
GAUGE HEIGHT AT PEACE RIVER

SUBMITTED		DESIGNED	G. Fonstad
DATE		CHECKED	
APPROVED		DRAWN	S.P. Tar
DATE		CHECKED	G. Fonstad

SCALE AS SHOWN | SHEET 2 OF 9


BC HYDRO (GMS) RELEASES (100's of m^3s^{-1})
+ GAUGE HEIGHT AT PEACE RIVER (m)
BC HYDRO RELEASES
GAUGE HEIGHT AT PEACE RIVER
0 10 20 40 80 100
20
18
16
14
12
10
8
6
4
2
0
16
JAN 82
17
18
19
20
21
22
23
24
25
26
27
28
29
30
JAN. '82
TIME (days)
SCALE
HOURS
Alberta
ENVIRONMENT
RIVER ENGINEERING BRANCH
SUBMITTED
DATE
APPROVED
DATE
DESIGNED
CHECKED
DRAWN
CHECKED
PEACE RIVER 1981-82 ICE STUDY
B.C. HYDRO 3-HOURLY FLOW RELEASES
AND
GAUGE HEIGHT AT PEACE RIVER
SCALE AS SHOWN
DATE AUGUST, 1982
SHEET 3 OF 9
FIG No 1

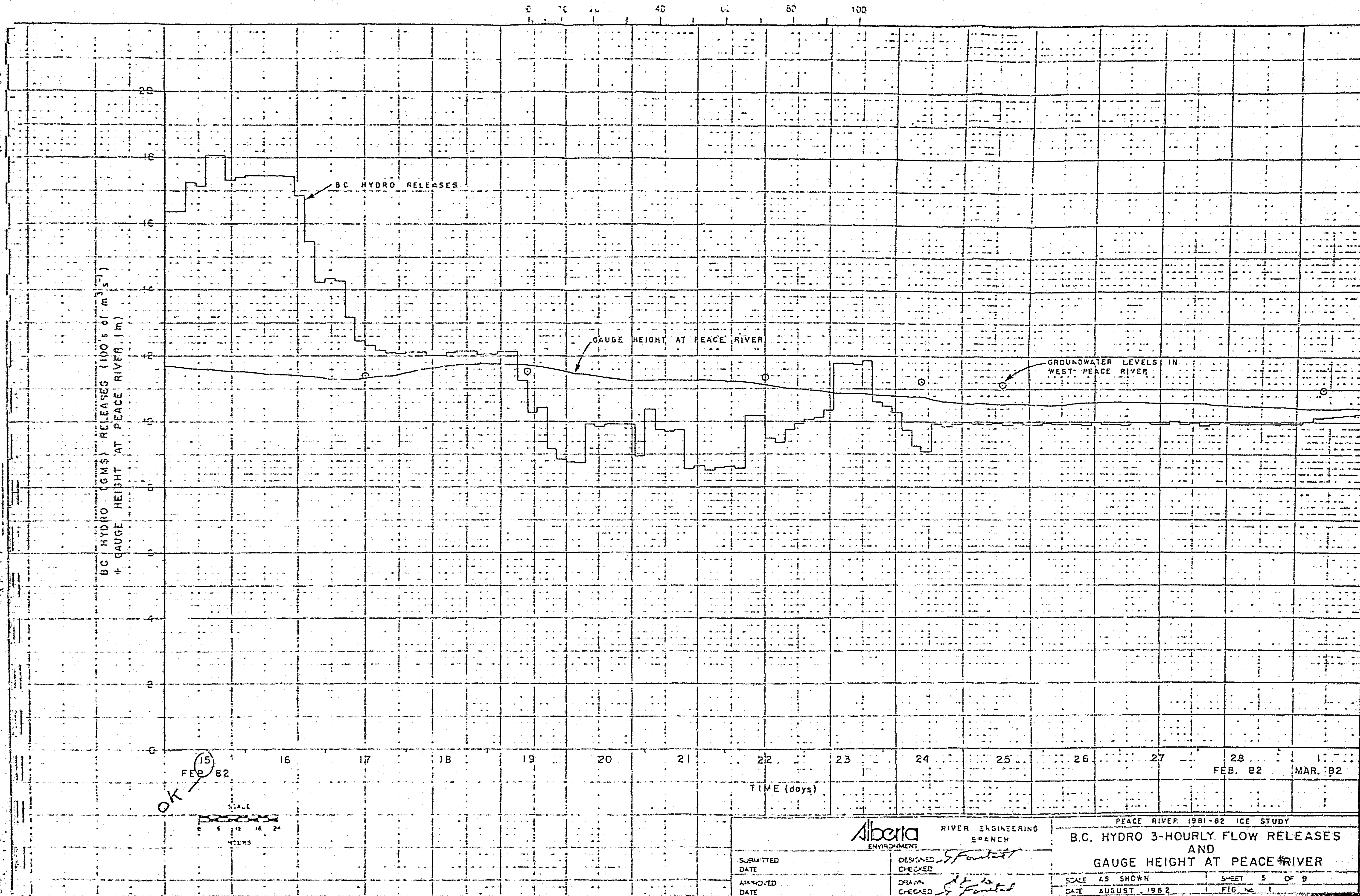


PEACE RIVER 1981-82 ICE STUDY

Alberta ENVIRONMENT — RIVER ENGINEERING BRANCH

B.C. HYDRO 3-HOURLY FLOW RELEASES AND GAUGE HEIGHT AT PEACE RIVER

SUBMITTED	DESIGNED	SCALE AS SHOWN	SHEET 4 OF 9
DATE	CHECKED	DATE AUGUST, 1982	FIG No 1
APPROVED	DRAWN		
DATE	CHECKED		



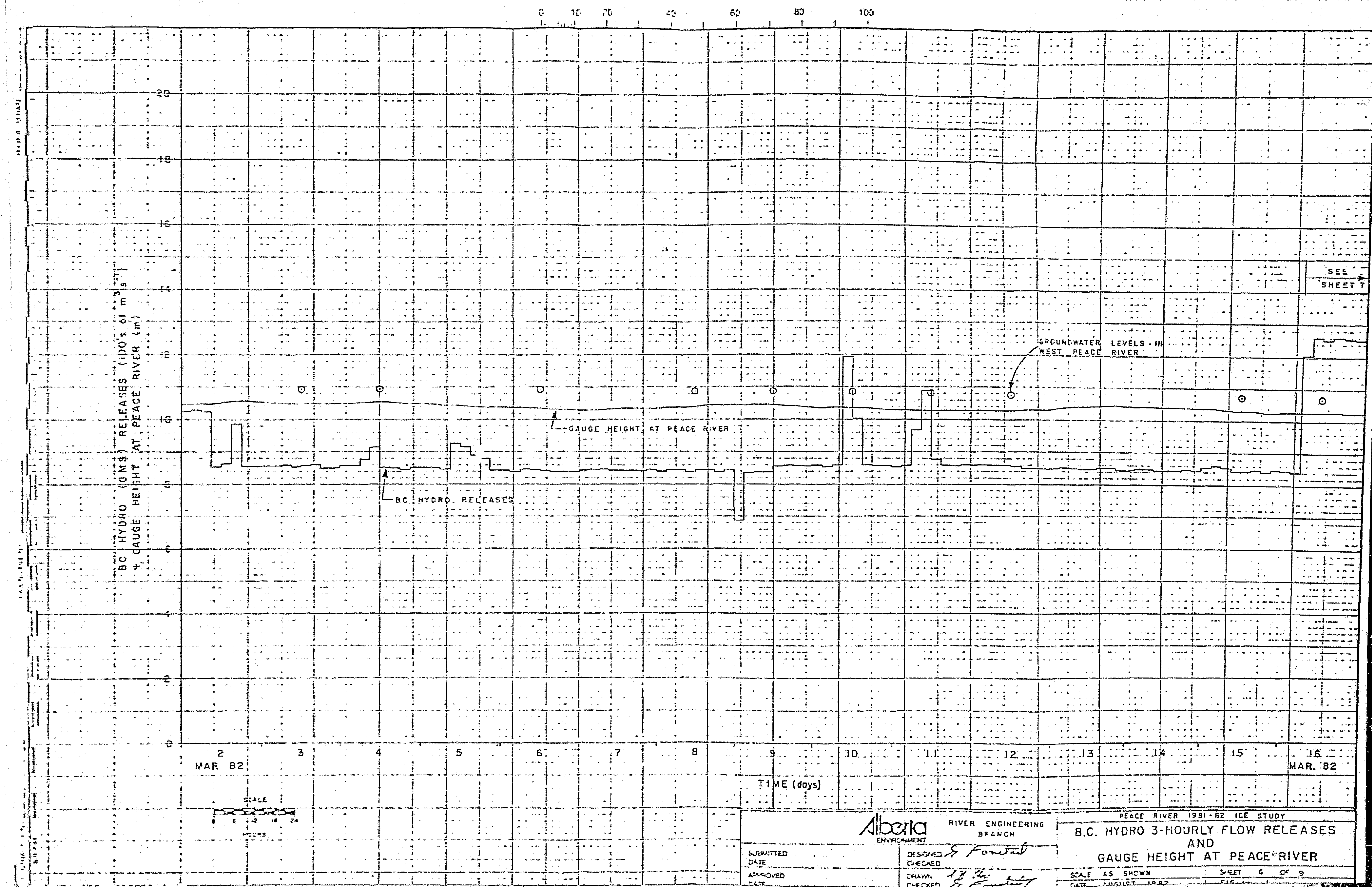
Alberta ENVIRONMENT — RIVER ENGINEERING BRANCH

PEACE RIVER 1981-82 ICE STUDY

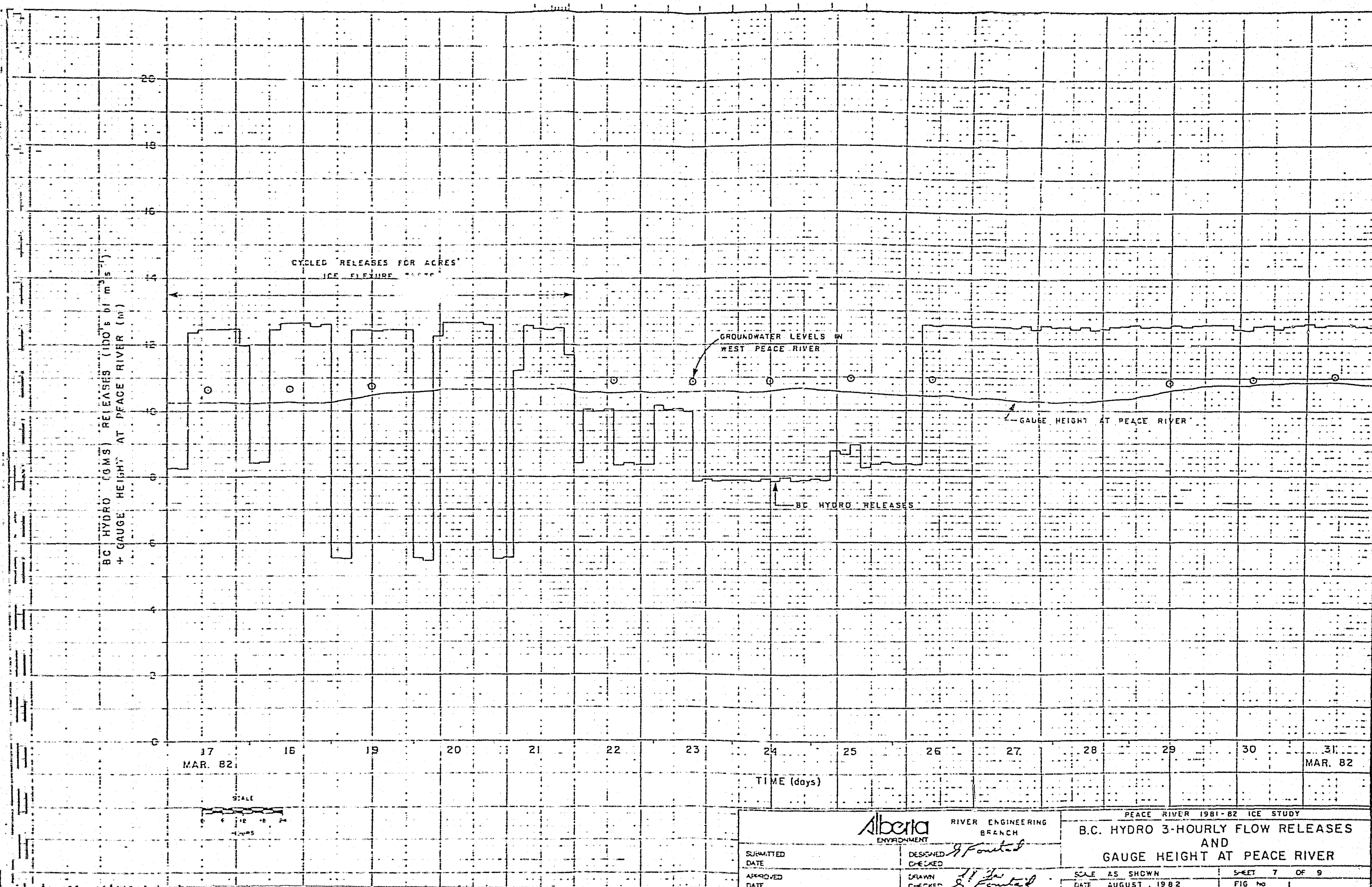
B.C. HYDRO 3-HOURLY FLOW RELEASES AND GAUGE HEIGHT AT PEACE RIVER

SUBMITTED / DATE / APPROVED / DATE
DESIGNED / CHECKED / DRAWN / CHECKED

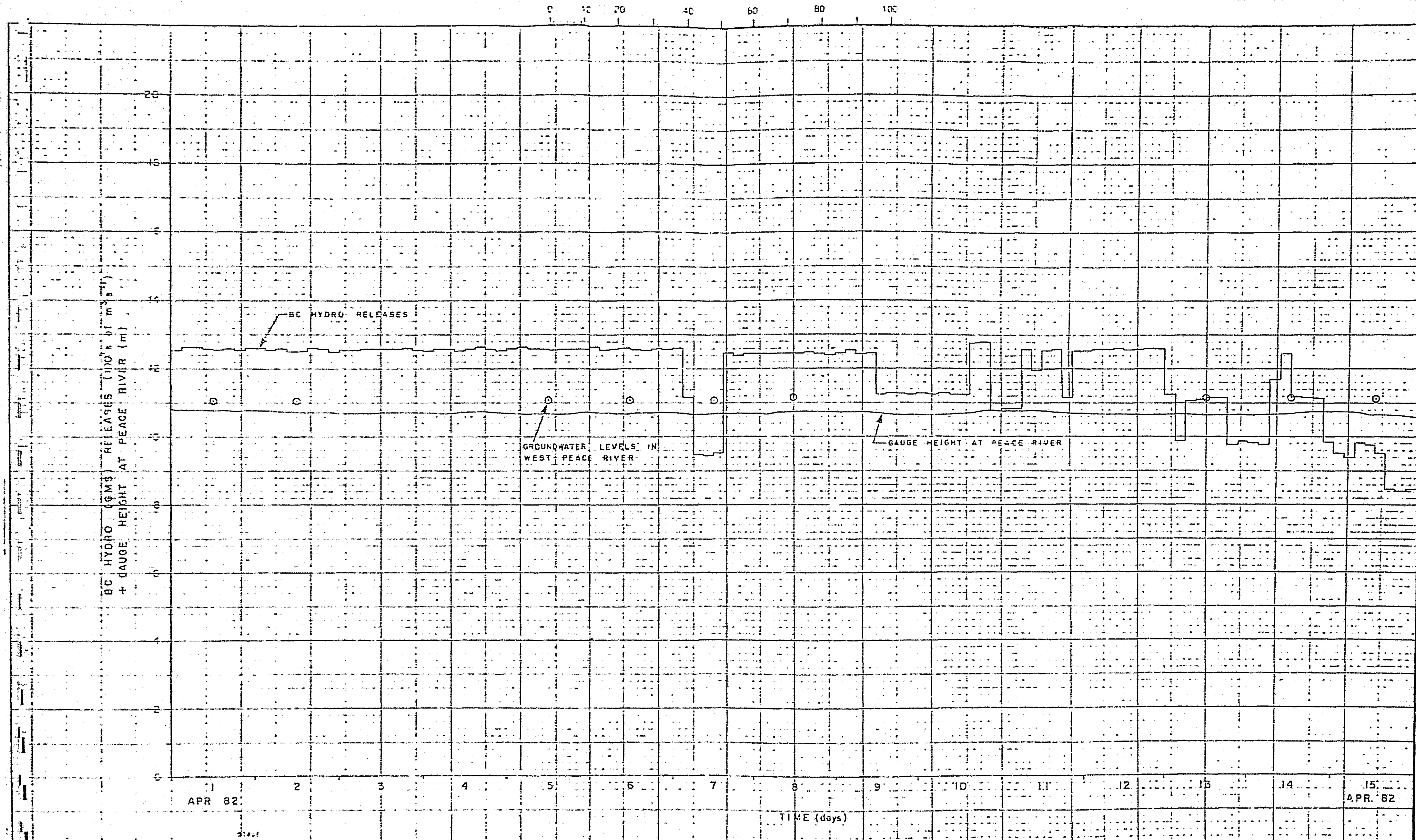
SCALE AS SHOWN — SHEET 5 OF 9
DATE AUGUST, 1982 — FIG. No.



BC HYDRO (CMS) RELEASES (100's of m³s⁻¹)
+ GAUGE HEIGHT AT PEACE RIVER (m)
GROUNDWATER LEVELS IN WEST PEACE RIVER
GAUGE HEIGHT AT PEACE RIVER
BC HYDRO RELEASES
SEE SHEET 7
2 MAR. 82
3
4
5
6
7
8
9
10
11
12
13
14
15
16 MAR. 82
TIME (days)
SCALE
HOURS
Alberta ENVIRONMENT
RIVER ENGINEERING BRANCH
SUBMITTED
DATE
APPROVED
DATE
DESIGNED
CHECKED
DRAWN
CHECKED
PEACE RIVER 1981-82 ICE STUDY
B.C. HYDRO 3-HOURLY FLOW RELEASES
AND
GAUGE HEIGHT AT PEACE RIVER
SCALE AS SHOWN
SHEET 6 OF 9



CYCLED RELEASES FOR ACRES ICE FLEXURE TESTS
GROUNDWATER LEVELS IN WEST PEACE RIVER
GAUGE HEIGHT AT PEACE RIVER
BC HYDRO RELEASES
B.C. HYDRO (CMS) RELEASES (100's of m³s⁻¹)
+ GAUGE HEIGHT AT PEACE RIVER (m)
20
18
16
14
12
10
8
6
4
2
0
17
MAR. 82
18
19
20
21
22
23
24
25
26
27
28
29
30
31
MAR. 82
TIME (days)
SCALE
HOURS
Alberta ENVIRONMENT
RIVER ENGINEERING BRANCH
SUBMITTED
DATE
APPROVED
DATE
DESIGNED
CHECKED
DRAWN
CHECKED
PEACE RIVER 1981-82 ICE STUDY
B.C. HYDRO 3-HOURLY FLOW RELEASES
AND
GAUGE HEIGHT AT PEACE RIVER
SCALE AS SHOWN
DATE AUGUST, 1982
SHEET 7 OF 9
FIG No 1



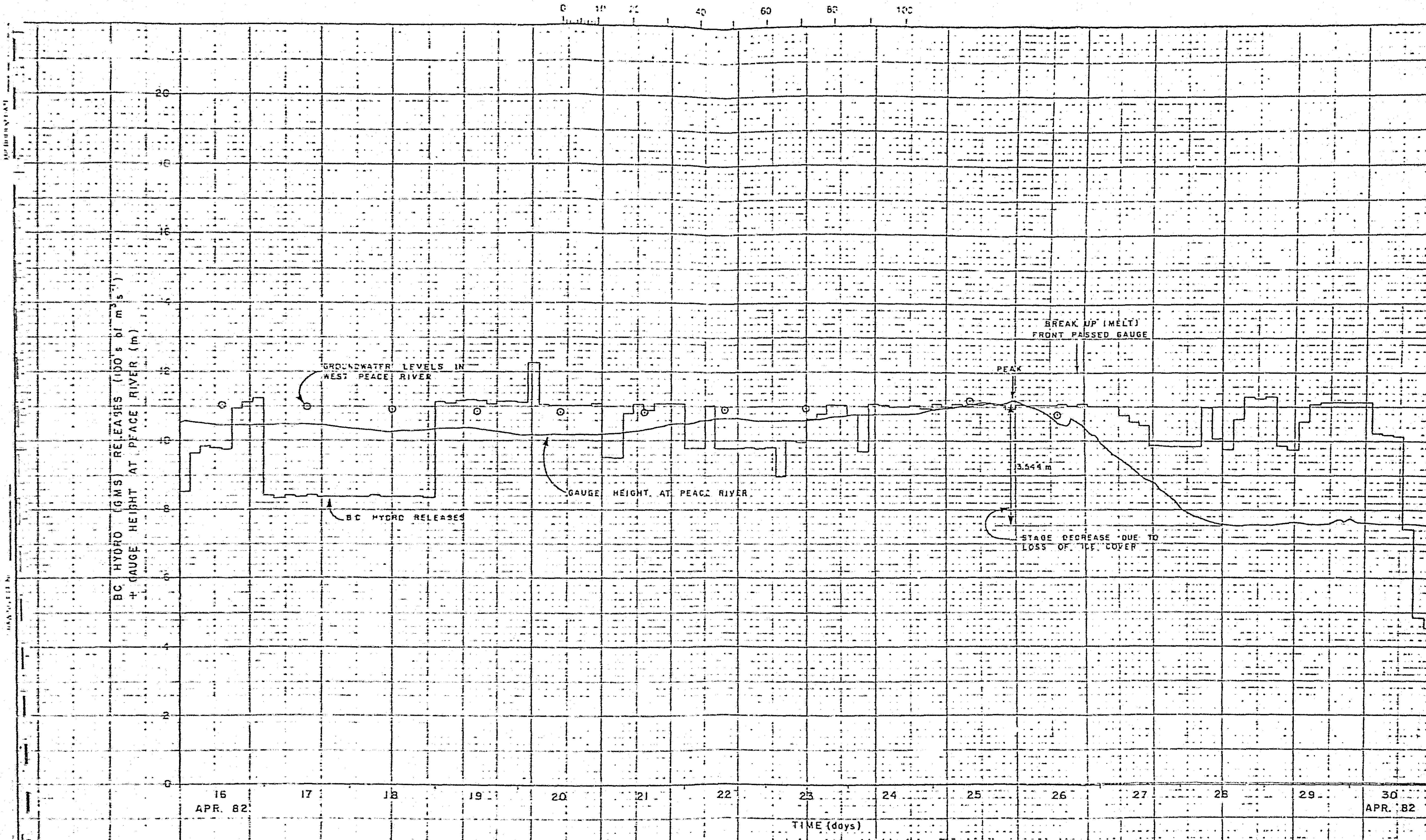
Alberta ENVIRONMENT
RIVER ENGINEERING BRANCH

PEACE RIVER 1981-82 ICE STUDY

B.C. HYDRO 3-HOURLY FLOW RELEASES AND GAUGE HEIGHT AT PEACE RIVER

SUBMITTED
DATE
APPROVED
DATE
DESIGNED G. Fonstad
CHECKED
DRAWN
CHECKED G. Fonstad

SCALE AS SHOWN
DATE AUGUST, 1982
SHEET 8 OF 9
FIG No 1

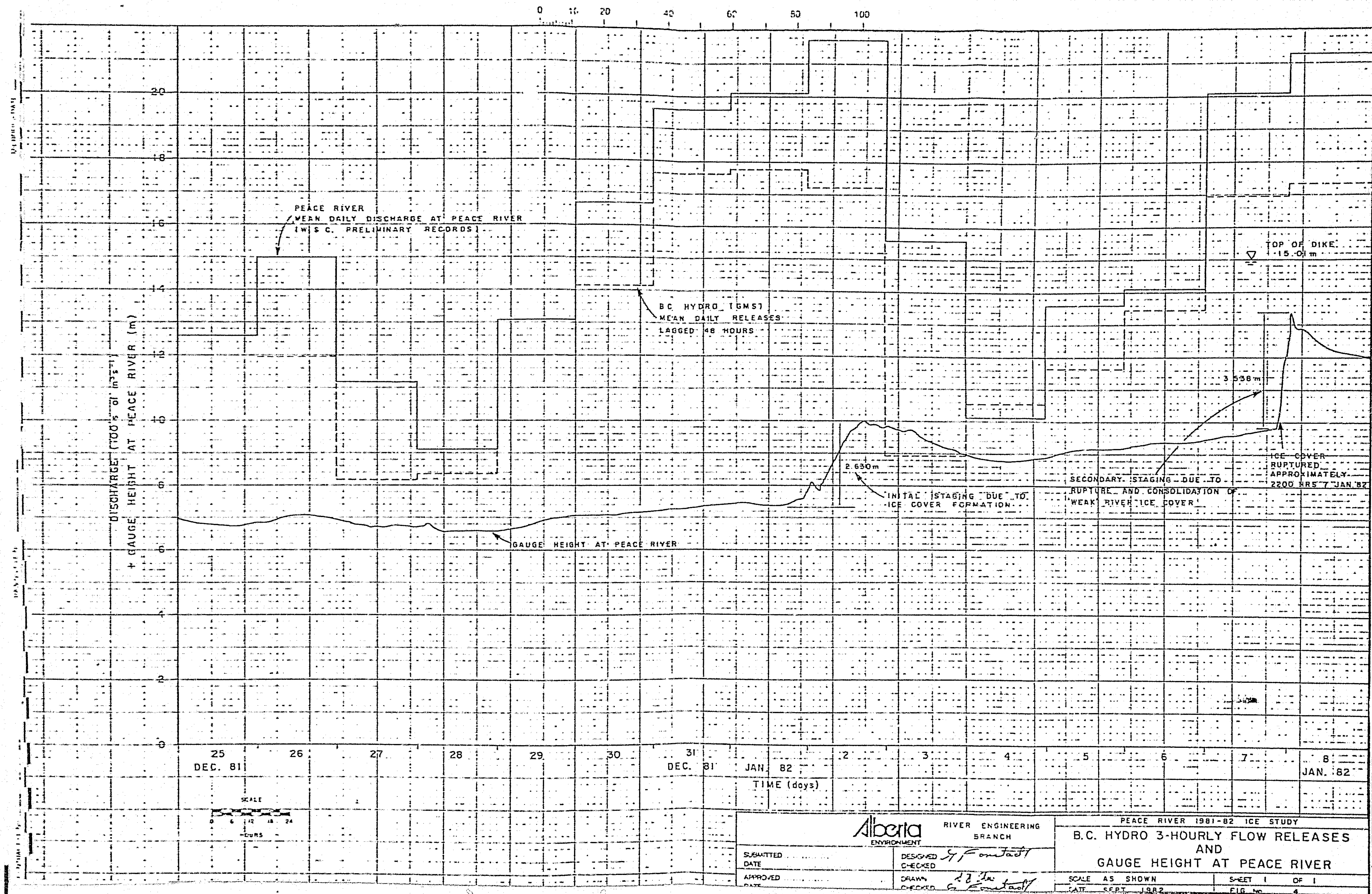


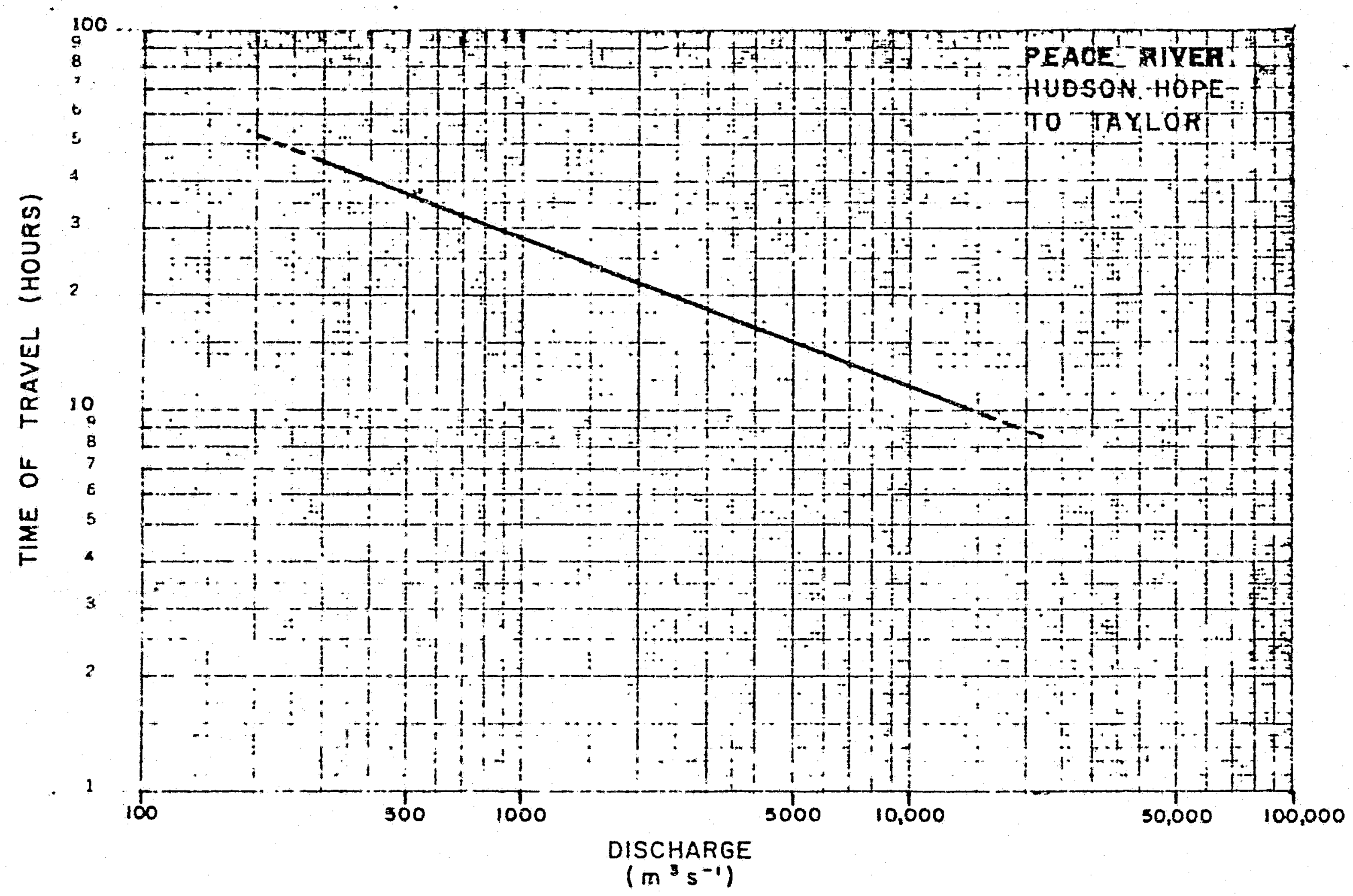
Alberta ENVIRONMENT — RIVER ENGINEERING BRANCH

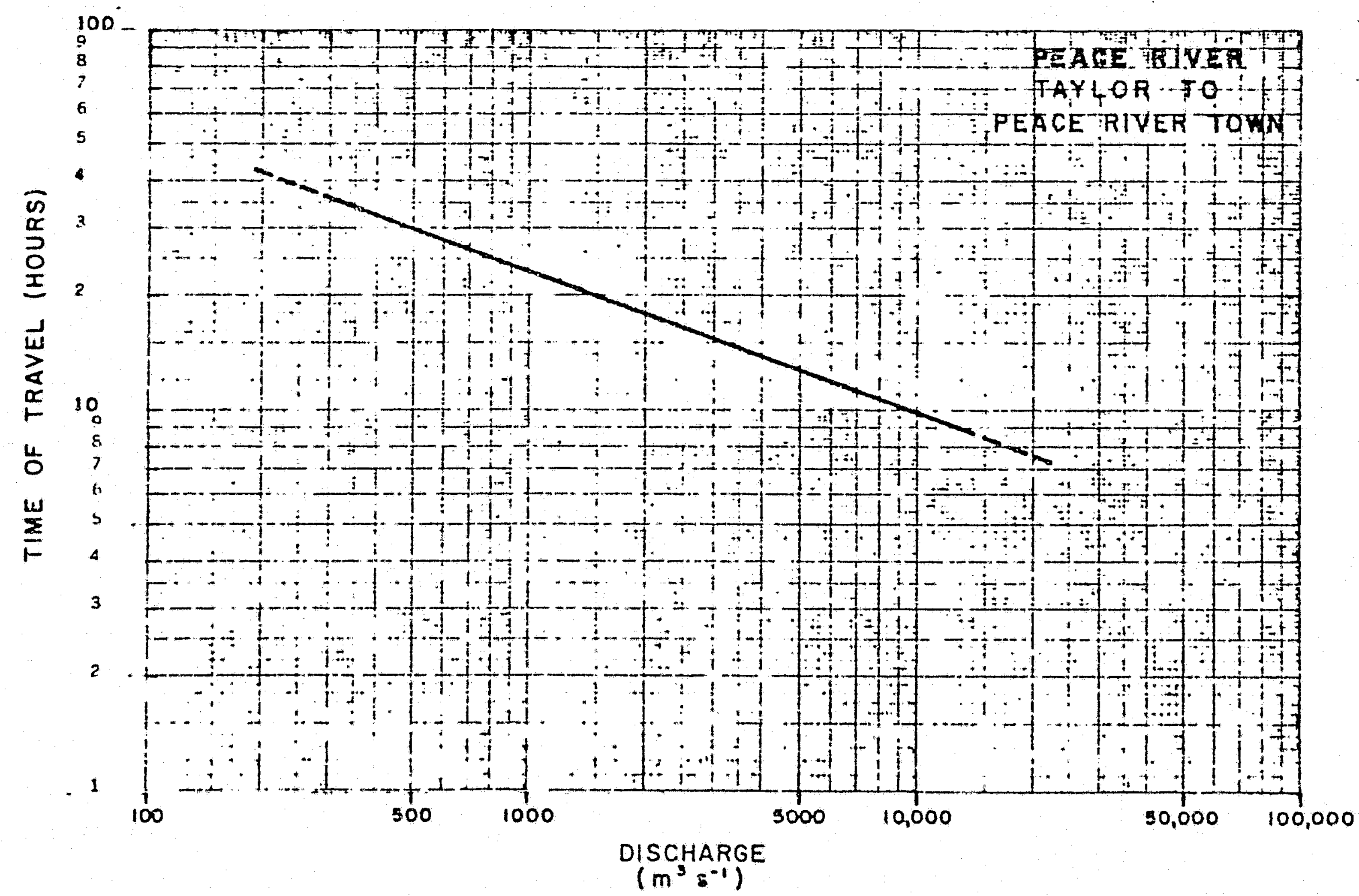
PEACE RIVER 1981-82 ICE STUDY

B.C. HYDRO 3-HOURLY FLOW RELEASES AND GAUGE HEIGHT AT PEACE RIVER

SUBMITTED / DATE	DESIGNED G. Fonstad / CHECKED	SCALE AS SHOWN
APPROVED	DRAWN	SHEET 9 OF 9


PEACE RIVER
MEAN DAILY DISCHARGE AT PEACE RIVER
(W.S.C. PRELIMINARY RECORDS)
B.C. HYDRO (GMS)
MEAN DAILY RELEASES
LAGGED 48 HOURS
GAUGE HEIGHT AT PEACE RIVER
2.630 m
INITIAL STAGING DUE TO ICE COVER FORMATION
SECONDARY STAGING DUE TO RUPTURE AND CONSOLIDATION OF WEAK RIVER ICE COVER
3.538 m
ICE COVER RUPTURED APPROXIMATELY 2200 HRS 7 JAN. 82
TOP OF DIKE 15.01 m
DISCHARGE (100's of m³s⁻¹)
+ GAUGE HEIGHT AT PEACE RIVER (m)
25
DEC. 81
26
27
28
29
30
31
DEC. 81
JAN. 82
2
3
4
5
6
7
8
JAN. 82
TIME (days)
SCALE
HOURS
Alberta ENVIRONMENT
RIVER ENGINEERING BRANCH
PEACE RIVER 1981-82 ICE STUDY
B.C. HYDRO 3-HOURLY FLOW RELEASES AND GAUGE HEIGHT AT PEACE RIVER
SUBMITTED
DATE
APPROVED
DESIGNED
CHECKED
DRAWN
SCALE AS SHOWN
DATE SEPT. 1982
SHEET 1 OF 1
FIG. No. 4





NOTE : FROM DATA PROVIDED BY ALBERTA RIVER FORECAST CENTRE

Alberta ENVIRONMENT

RIVER ENGINEERING BRANCH

PEACE RIVER 1981 - 82 ICE STUDY

PEACE RIVER
OPEN WATER FLOW TRAVEL TIMES
(HUDSON HOPE TO TAYLOR TAYLOR TO PEACE RIVER TOWN)

DESIGNED		SCALE	AS SHOWN
DRAWN	S. Y. C.	DATE	AUGUST , 1982
CHECKED	G. Fonstad	SHEET	OF

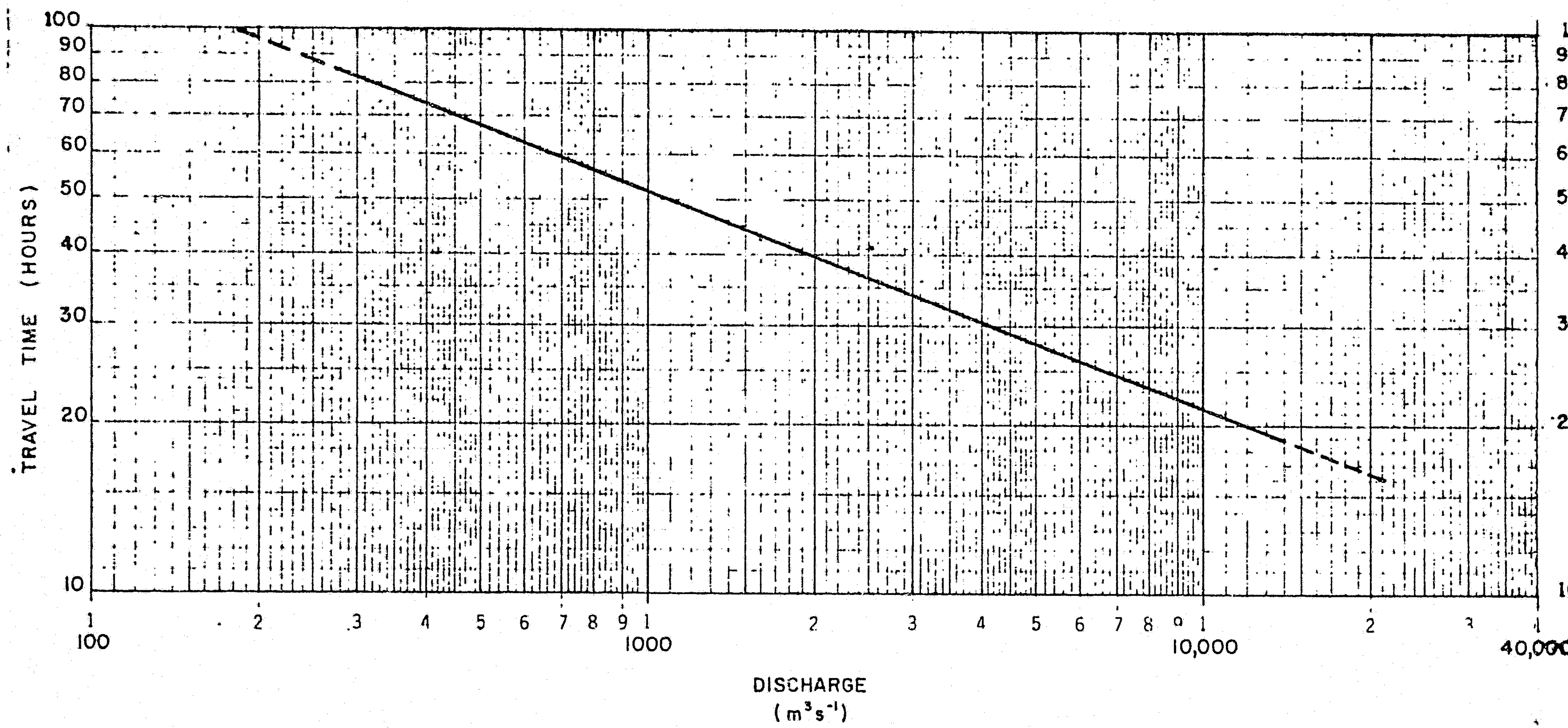
FIGURE No. 2

MICROFILM DATE

DRAWING No

FILE No

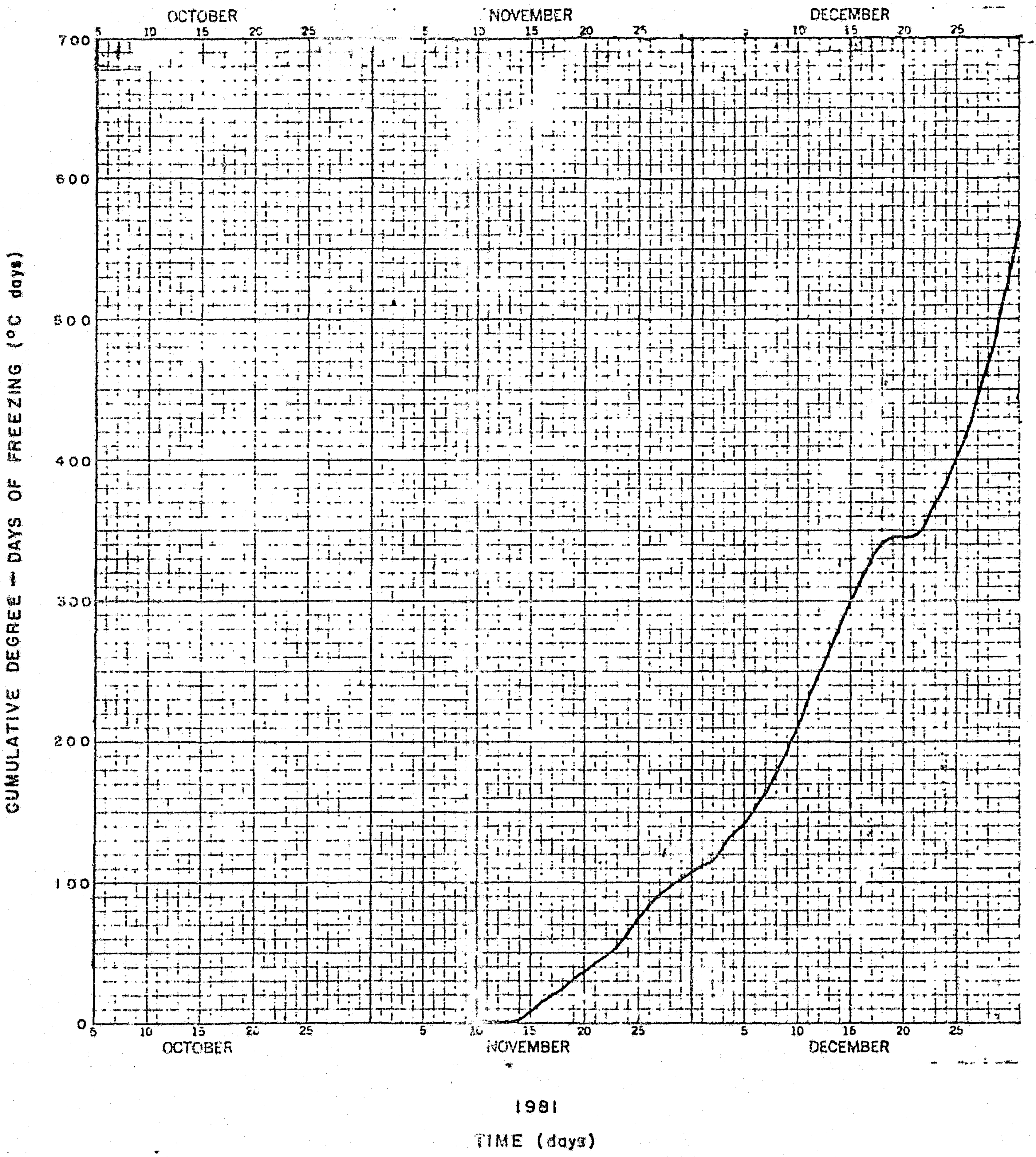
P4-215 x 280



NOTE : FROM DATA PROVIDED BY ALBERTA RIVER FORECAST CENTRE

Alberta ENVIRONMENT	RIVER ENGINEERING BRANCH	PEACE RIVER 1981-82 ICE STUDY PEACE RIVER OPEN WATER FLOW TRAVEL TIME HUDSON HOPE TO PEACE RIVER TOWN
DESIGNED	SCALE AS SHOWN	
DRAWN S. Y. C.	DATE AUGUST, 1982	
CHECKED [illegible]	SHEET OF	FIGURE No. 3

P4 215 × 280



DATA FROM PEACE RIVER AIRPORT

Alberta ENVIRONMENT

RIVER ENGINEERING BRANCH

PEACE RIVER 1981-82 ICE STUDY

DEGREE DAYS OF FREEZING TOWN OF PEACE RIVER TO DECEMBER 31, 1981

DESIGNED G FONSTAD	SCALE AS SHOWN
DRAWN C.F.	DATE SEPT. 1982
CHECKED G Fonstad	SHEET 1 OF 1

FIGURE No. 5