REVIEW OF FLOOD STAGE FREQUENCY ESTIMATES FOR THE CITY OF FORT McMURRAY FINAL REPORT

Submitted To:

TECHNICAL COMMITTEE
CANADA-ALBERTA FLOOD DAMAGE REDUCTION PROGRAM

Submitted By:

TECHNICAL SERVICES & MONITORING DIVISION
WATER RESOURCES SERVICES
ALBERTA ENVIRONMENTAL PROTECTION

NOVEMBER, 1993

EXECUTIVE SUMMARY

This study was undertaken for the Technical Committee, Canada-Alberta Flood Damage Reduction Program in response to concerns raised by the City of Fort McMurray over the validity of the elevation established in previous studies as representing the 1 in 100 year design flood level. The specific objectives were first, to examine the historic data and assess it reliability and second, to update the flood frequency analysis, incorporating additional data collected in recent years.

The main conclusions arising from the study are:

a) In spite of some limitations, the information available on the 1875 ice jam event and most other historic events is considered to be sufficiently reliable for inclusion in the flood frequency analysis,

b) the 1 in 100 year break-up stage at Fort McMurray based on the updated frequency analysis is 250.0 m, and

c) The estimated return period for the 1875 event is in the order of 350 years and corresponds to a flood stage 2.0 m above the 1 in 100 year stage.

Designation of flood risk areas based on an historical flood that has exceeded the 1 in 100 year event is an option under the Flood Damage Reduction Program. However, given the extreme magnitude of the maximum historic event at Fort McMurray, it is felt to be unreasonable and inappropriate to designate to such a level. Instead, it is recommended that the updated 1 in 100 year breakup stage of 250.0 m be adopted as the design flood level for designation under the Flood Damage Reduction Program.

ACKNOWLEDGEMENTS

This study was conducted by Terry Winhold [1] and Ron Bothe [2] of the Technical Services & Monitoring Division, Alberta Environmental Protection.

Valuable information and data obtained from numerous sources referenced throughout the report is hereby acknowledged.

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1 River Engineer, River Engineering Branch
Co-ordinator, Hydraulic Studies,
Canada-Alberta Flood Damage Reduction Program

2 Senior Hydrologist, Hydrology Branch
Member, Technical Committee
Canada-Alberta Flood Damage Reduction Program

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1.0 INTRODUCTION

1.1 Flood Damage Reduction Program

The Canada-Alberta Flood Damage Reduction Program (FDRP) was initiated subsequent to "An Agreement Respecting Flood Damage Reduction and Flood Risk Mapping in Alberta" signed by the federal and provincial governments in April, 1989. This program supports a non-structural method of flood damage reduction by identifying urban areas subject to flood damages and by encouraging measures such as land use planning, zoning, flood proofing and flood preparedness.

The FDRP includes the following components:

1. Identify, map and designate flood risk areas in urban communities across the province;
2. Increase awareness of flood risk among the general public, industry and government agencies, through a public information program;
3. Regulate new development in flood risk areas using new federal and provincial government policies;
4. Encourage municipalities to develop bylaws recognizing the designated flood risk areas.

1.2 Flood Potential in Fort McMurray

Portions of the City of Fort McMurray (Figure 1) and Waterways situated along the Clearwater River have been subject to periodic flooding dating as far back as the 1870's when the area was first settled. Although the phenomenon is not entirely understood, it is a well documented fact that the severest flooding is associated with the occurrence of ice jams on the Athabasca River during the annual spring breakup. These jams typically form in the reach below the Clearwater River confluence causing water and ice to back up the Clearwater channel (Figure 2).

When a serious ice jam occurs, the flooding process can be dramatic, not only with respect to the depth and extent of flooding, but also in terms of the time lapse between initial jam formation and the reaching of maximum water levels. The latter can be only a matter of one or two hours, thus affording little time to implement emergency measures.

Following the last significant flood which occurred in 1977, Alberta Environment and the City of Fort McMurray have worked together to develop a breakup monitoring program, which with recent improvements can provide some advance warning of breakup on the Athabasca River. However, at the present time and for the foreseeable future, there is no reliable means of predicting or preventing the occurrence of a serious ice jam. Thus the importance of practising proper floodplain management in reducing the potential for future flood damages in Fort McMurray cannot be over stated.

1.3 Study Objective

On April 26, 1990, members of the Steering and Technical Committee's for the Canada-Alberta FDRP met with officials from the City of Fort McMurray to explore the possibility of designating flood risk areas in that community. One of the issues identified by the City Administration at that meeting concerned the validity of the elevation established in previous studies as the 1 in 100 year design flood level. This elevation (252 m) corresponds to what is generally accepted to be the maximum historic ice jam flood level reported to have occurred in 1875.

It was agreed at the April 26, 1990 meeting that the FDRP Technical Committee would undertake a review of the basis for the 1 in 100 year design flood elevation. Thus, the objective of this study is twofold; first to examine the historic data and assess its accuracy and reliability and second to update the flood frequency analysis to incorporate additional data collected in recent years. Based on the results of this investigation, a recommendation will be made with respect to the 1:100 year flood level to be adopted by the FDRP.

2.0 PREVIOUS STUDIES

2.1 Blench Report (1964)

The first serious attempt to quantify ice jam flood levels at Fort McMurray was made by T. Blench (1964) as part of an investigation into alternative flood protection measures for the city. Blench documented the history of flooding at the Fort by researching a number of sources dating back to the establishment of the first Hudson's Bay Company Post in 1870 and by carrying out interviews with long time residents of the area. From the information gathered, Blench conducted a rather crude flood stage frequency analysis by fitting the set of historic ice jam related flood levels listed in Table 2.1 to a log-normal probability distribution. This was based on the assumption that the record could be associated with the entire period dating back to 1870. A curve was fitted through the plotted points and from this the 1 in 100 year ice jam flood level was found to approximate the level of the historic 1875 event as reported by H.J. Moberly, the official in charge of the Hudson's Bay Company Post at that time.

The Blench report recommended that a dyke be constructed to close off what is known as "The Snye" (Figure 2). This recommendation was based on the theory that ice jams on the Athabasca River at Fort McMurray typically initiated or "keyed in" near the mouth of the Snye mainly due to the sudden widening and flattening of the river at this location. It was further theorized that if the Snye Channel were closed off, the "key" location would be shifted approximately 1.5 kilometres downstream to the mouth of the Clearwater River, thus resulting in a potential reduction of flood levels in the Lower Townsite by about one metre. This closure was subsequently implemented in 1966 with the construction of a dyke at the location shown in Figure 2.

TABLE 2.1

Summary of Historic Ice Jam Flood Levels At Fort McMurray

Year	Elevation [1] (m)	Location of Measurements [2]	Original Information Source
1875	251.5 - 253.0	Hudson's Bay Co. Post right bank of Athabasca River near entrance to Snye Channel	1. Hudson's Bay Co. Archives 2. Moberly H.J. and Cameron, W.R. "When Fur Was King", J.M. Dent and Sons Ltd., Toronto, 1929
1881	Undermined (less than 250)	Water levels over -topped the banks along Snye Channel- general description only.	Hudson's Bay Co. Archives
1885	249.0	Hudson's Bay Co. Post	Hudson's Bay Co. Archives
1925	247.4	Waterway's	Northern Alberta Railways Co.
1928	248.6	Waterway's	Northern Alberta Railways Co.
1936	250.1	Waterway's	Northern Alberta Railways Co.
1962	246.2	Not known-assumed to be highwater mark in Lower Townsite	Department of Northern Affairs and Natural Resources
1963	247.5	Not known-assumed to be highwater mark in Lower Townsite	Department of Northern Affairs and Natural Resources

1 Information extracted from Blench (1964)

2 See Figure 2

2.2 Alberta Research Council (1977)

This document presents a first hand account of a major ice jam flood which occurred at Fort McMurray in April of 1977. Detailed observations provided valuable information on ice jam formation and decay, making it possible to either substantiate or question some of the theories put forth by Blench (1964). First, it appears that the primary location for jam initiation is in the wide, multichanneled reach of the Athabasca River downstream of the Clearwater River confluence. This differs somewhat from the Blench argument that jams would typically "key in" near the Clearwater River confluence following construction of the Snye Dyke. On the other hand, longitudinal water surface profiles surveyed through the 1977 jam do indicate about a one metre drop in levels between the MacEwan Bridge located just above the Snye and the Clearwater River confluence. This later observation, therefore, tends to substantiate the second argument put forth by Blench that closure of the Snye Channel potentially results in a lowering of water levels in town by about one metre, a measure accomplished by effectively shifting control of flood levels from the entrance to the Snye to the mouth of the Clearwater River.

Figure 2 shows a profile of flood levels along the Clearwater River caused by the 1977 ice jam on the Athabasca River.

2.3 Northwest Hydraulic Consultants Report (1979)

A study of flood levels and the impact of proposed dykes along the Clearwater River at Fort McMurray was conducted for Alberta Environment by Northwest Hydraulic Consultants Ltd. (NHCL) in 1979. As with the Blench report, NHCL recommended once again that the historic 1875 event be adopted as the 1 in 100 year ice jam flood level at Fort McMurray. The consultant used a valid analytical approach to determine the statistical distribution of ice jam flood levels, however, it was felt that the results were generally inconclusive due mainly to the shortness and uncertainty of the data base. As an alternative, NHCL decided to simply accept the principle that because a given elevation had not been exceeded in over 100 years it could then be assumed to approximate the 1 in 100 year event.

The flood levels presented in Table 2.2 were used in the NHCL report as the basis for assigning return periods for various flood events. Note that all levels have been adjusted to the mouth of the Clearwater River and therefore vary in some cases from those recorded in Table 2.1. This is to account for the apparent shifting of flood level control from the Snye Channel to the Clearwater confluence as discussed in Sections 2.1 and 2.2. In other words, NHCL's analysis accepted the argument that were the historic ice jam events of 1875, 1881, and 1885 to occur today, the maximum water level reached at the site of the former Hudson's Bay Company Post (Figure 2) would be lowered by approximately one metre due to the Snye Dyke construction in 1966.

TABLE 2.2

Ice Jam Elevations and Corresponding Return Periods Determined by NHCL[1]

Year	Elevation [2] (m)	Approximate Return Period (Years)
1875	252.0	100
1836	250.2	50
1881	249.0	
1928	248.7	
1885	248.1	
1977	247.9	
1963	247.6	
1925	247.5	
1978	247.5	
1962	246.2	10
1972	244.3	

1 Table reproduced from Northwest Hydraulic Consultant Ltd. Report (1979)

2 Adjusted to mouth of Clearwater River

3.0 BREAKUP STAGE DATA REVIEW

3.1 General

As stated in section 1.3 the objectives of this study are:

1. To examine the historic ice jam flood data and assess its reliability and accuracy.
2. Update the flood frequency analysis to incorporate additional data collected in recent years.

The first objective is addressed in Section 3.2 below. The data collected in recent years is presented in Section 3.3.

3.2 Historical Data

Blench (1964) established the largest flood on record as having occurred in 1875, just five years after the establishment of a Hudson's Bay Company post at the location shown on Figure 2. This site was located on the right bank of the Athabasca River near the westend of the present day Franklin Avenue by a long time resident of the area, Mr. Joseph Shott. From a written description of the flood given by H.J. Moberly, who was the officer in charge of the Hudson's Bay Company Post in 1875, the maximum flood level was estimated to be between elevations 825 feet and 830 feet (251.5 metres and 253.0 metres).

There appears to be little doubt that the location of the former trading post site was properly identified by Mr. Shott. Hudson's Bay Company records acquired by Blench (1964) suggest the trading post existed at its original site on the right bank of the Athabasca River above the confluence with the Clearwater River from 1870 to 1899 when it was apparently closed. Mr. Shott, who's father worked for H.J. Moberly, was born in 1886, would have been 13 years old in 1899 when the post shut down and is therefore considered a reliable source of information. Furthermore the descriptions of the site found in excerpts from the Hudson's Bay Company Journals compare well with the location identified by Mr. Shott.

The probable upper limit maximum flood elevation of 830.0 feet or 253.0 metres suggested by Blench (1964) for the 1875 event (see Table 2.1) appears to be more reasonable than the probable lower limit elevation of 825.0 feet or 251.5 metres, given the natural ground elevation* at the presumed location of the original trading post and the description of the flood provided by H. J. Moberly (excerpts from various references containing Moberly's account of this flood are contained in Appendix A). Considering the amount of detail given in these accounts, there appears to be no reason to doubt their authenticity or, indeed, Moberly's credibility. The only notable discrepancy is found in references to the water having risen "about 60 feet" during the flood. It can only be assumed that this estimate was made without benefit of a survey instrument since the maximum rise in river levels based on Blench's determinations is more in the order of 40 feet.

In spite of its limitations, the information gathered on the 1875 event is still considered to be sufficiently reliable to be included in the flood frequency analysis (Section 4). Moreover, the value of including a rare event in the computations far outweighs the inaccuracy of establishing the exact stage.

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* The natural ground elevation reported by Blench (1984) was 823.0 feet (850.0 metres). The existing ground elevation at this site has since been altered by construction of the Snye Dyke in 1966.

Hudson's Bay Company records suggest another serious flood occurred in 1881, however, the description provided does not allow the maximum elevation to be determined with a reasonable degree of confidence. Indications are that the flood waters did not reach the level of the ground (approximately 850.0 metres) at the former trading post site but, perhaps came within a few feet. Because of the uncertainty of this description it is was decided that this particular event would not be included in the updated flood frequency analysis (Section 4.2).

The flood elevations quoted for the remaining historic ice jam events listed in Table 2.1 have been thoroughly reviewed and although the precise accuracy of these levels cannot be verified, the information sources in each case are considered sufficiently reliable to justify inclusion of the data in the flood frequency analysis.

3.3 Recent Systematic Record

Systematic records of maximum breakup stage at Fort McMurray are available from 1977 on with the exception of the years 1980 and 1981. This information was compiled from various sources, including; the City of Fort McMurray, the Alberta Research Council and Alberta Environmental Protection, River Engineering Branch. The data are presented in Table 3.1

The stage elevations shown in Table 3.1 were all measured at or near the mouth of the Clearwater River in order to provide a standardized data set. Water levels produced at this location as a result of a "normal" ice run * or a significant ice jam on the Athabasca River below the Clearwater confluence are, in either case, assumed to act as the control for flood levels along the lower Clearwater River and in the Lower Townsite

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* Breakup stages less than about 246.0 are generally the result of a "normal" (uneventful) ice run on the Athabasca with only minor jamming occurring.

and Waterways areas of Fort McMurray. The exception to this would be the case where local ice movement, due to partial or complete breakup of the Clearwater River resulted in higher water levels being produced in these areas than caused by the actual breakup of the Athabasca River in a particular year. The latter scenario has been documented, for example in 1983 and in 1991 when the Clearwater River broke up ahead of the Athabasca River. However, water levels associated with these events have not resulted in any significant flooding.

TABLE 3.1

Recorded Maximum Breakup Stage at the Clearwater River Confluence from 1977 to 1990

Year	Breakup Stage (m)	Source
1977	247.9	Alberta Research Council (1977)
1978	242.0	Alberta Research Council (1978)
1979	246.5	Alberta Research Council (1979)
1980	Not Available[1]	
1981	Not Available[1]	
1982	242.2	Alberta Environment (1982)
1983	242.3	Alberta Research Council (1984)
1984	243.5	Alberta Research Council (1985)
1985	243.5	Alberta Research Council (1985)
1986	244.0	Alberta Research Council (1988)
1987	245.1	Alberta Environment (1988)
1988	244.5	City of Fort McMurray [2]
1989	243.1	City of Fort McMurray
1990	243.0	City of Fort McMurray

1 "normal" ice run occurred with no significant jamming
2 City Engineering Department - Breakup Monitoring Records

4.0 FREQUENCY ANALYSIS

4.1 Re-Analysis of NHCL Data Set

A re-analysis of the NHCL data set (Table 2.2) places the 1 in 100 year breakup level (based strictly on the frequency curve) at 251.0 metres as shown in Figure 3(a). This suggests that a return period of about 1 in 500 years would have been established for the 1875 event.

Because of its magnitude, the 1875 event has a significant influence on the frequency analysis. As shown in Figure 3(a) (dotted line), removal of this event from the data set lowers the estimate of the 1 in 100 year event by about 1.0 metres. However, as stated previously the value of including a rare event in the computations far outweighs any question concerning the exact stage.

The conditional frequency curve for the NHCL data set is also plotted on Figure 3(a) for comparison. The conditional curve indicates the probability of occurrence of a certain water level given the occurrence of an ice jam.

4.2 Updated Flood Frequency Analysis

The updated breakup stage data set for Fort McMurray is listed in Table 4.1. Several significant changes have occurred to the data set (Table 2.2) which was used in the previous study by NHCL (1979). These are:

1. The 1881 stage of 249.0, which was established by NHCL, is not considered quantifiable and is therefore dropped from the data set.
2. The 1978 stage of 247.5 has been revised to 242.0 metres based on documented observations published by Alberta Research Council (1978).
3. An ice jam event with a breakup stage of 246.5 metres was recorded in April, 1979.

4. Systematic records of "normal" breakup stages for the period 1982 to 1990 have been included in the data set.

TABLE 4.1

Updated Breakup Stage Data Set for Fort McMurray

Year	Stage [1] (m)
1875	252.0
1885	248.0
1925	247.4
1928	248.6
1936	250.1
1962	246.2
1963	247.5
1972	244.3
1977	247.9
1978	242.0
1979	246.5
1982	242.2
1983	242.3
1984	243.5
1985	243.5
1986	244.0
1987	245.1
1988	244.5
1989	243.1
1990	243.0

[1] All levels have been measured near or were adjusted to the mouth of the Clearwater River.

Because of the additional data provided by the systematic record, the approach used to develop the updated frequency analysis differs from the NHCL approach. In the update analysis, the systematic data is used to define "typical" breakup stages while events above 246.0 metres* (lowest significant ice jam event) are adjusted to reflect their relative magnitude in the historical period 1871 to 1990. The results of this frequency analysis, which assumes a Pearson III distribution, are presented in Figure 3(b). Once again the conditional frequency curve is shown for comparison, as is the annual curve with the 1875 event removed from the data set.

The annual frequency curve in Figure 3(b) indicates a 1 in 100 year breakup level of 250.0 metres, whereas the 1875 event would have a return period of about 1 in 350 years. Excluding the 1875 event from the data set lowers the estimate of the 1 in 100 year event by approximately 1.0 m.

4.3 Perception Stage Method

Gerard and Karpuk (1979) have proposed an alternative method of determining the probability distribution of floods utilizing both the available historical data and the more recent systematic record. This method, which is referred to as the "perception stage" method, tends to remove the discontinuity in the probability distribution which is often found when analyzing the combined data set by conventional methods (i.e, a discontinuity often appears in the frequency curve caused by the sudden change in the number of years of record associated with the historical period and the systematic period). The problem is overcome by first establishing a stage above which a particular

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* Approximate flood threshold. Above this level flooding begins to occur along the left bank of the Clearwater River and begins to affect low lying areas in the Lower Townsite and Waterways.

source is likely to have provided information on the flood peak in any given year and then assigning an appropriate rank and record length to each reported flood peak. This procedure is illustrated in Figure 4 which shows a summary diagram of annual maximum breakup stages at Fort McMurray.

The perception stage method has been used to carry out a frequency analysis on the updated breakup stage data set listed in Table 4.1. The resulting frequency curve shown on Figure 5 places the 1 in 100 year break up stage at 250.5 metres, whereas the 1875 event is estimated to have a return period of about 250 years. Appendix B provides a further explanation of the perception stage method and documents how it was applied in this case.

4.4 Comparison of Conventional and Perception Stage Methods

Table 4.2 compares the results obtained using the "conventional" and "perception stage" methods for the updated frequency analysis.

TABLE 4.2

Comparison of Updated Flood Frequency Estimates

	Conventional Frequency Analysis	Perception Stage Method
Return Period-1875 Event	350 years	250 years
1 in 100 year Flood Stage	250.0 m	250.5 m
1 in 50 year Flood Stage	248.9 m	249.2 m
1 in 20 year Flood Stage	247.2 m	247.5 m
1 in 10 year Flood Stage	246.0 m	246.2 m
1 in 5 year Flood Stage	244.8 m	245.0 m

As can be seen from Table 4.2, the results obtained from the conventional frequency analysis and from the perception stage method are quite similar, the latter approach giving a slightly more conservative estimate of the 1 in 100 year event. Although both are considered valid methods, it is recommended that the results of the conventional frequency analysis be accepted to be consistent with the analytical approach used in other hydrologic studies conducted under the Flood Damage Reduction Program.

5.0 CONCLUSIONS AND RECOMMENDATION

Based on a review of the historical ice jam data at Fort McMurray the following conclusions are made:

1. In spite of its limitations, the information available on the 1875 ice jam event (highest known to have occurred) is still considered to be sufficiently reliable to be included in the flood frequency analysis.
2. With the exception of the 1881 event, all of the historic ice jam events documented by Blench (1964) and listed in Table 2.1 are believed to be quantified with sufficient accuracy to be included in the flood frequency analysis.
3. The 1 in 100 year break up stage at Fort McMurray based on the updated frequency analysis is 250.0 metres.
4. The estimated return period for the 1875 event based on the updated frequency analysis is in the order of 350 years.

Recommendation:

Updated frequency estimates place the 1875 event at Fort McMurray as a 1 in 350 year event, corresponding to a flood stage 2.0 metres above the 1 in 100 year stage. Designating flood risk areas to an historical flood that has exceeded the 1 in 100 year event is an option under the Flood Damage Reduction Program, however, given the extreme magnitude of this event, it is not considered reasonable or appropriate to designate to this level. It is therefore recommended that the updated 1 in 100 year breakup stage of 250.0 m be adopted as the design flood level for designation under the Flood Damage Reduction Program.

REFERENCES

1. Blench, T. & Associates Ltd., "Flood Protection Proposals for Fort McMurray", (Prepared for Alberta Provincial Planning Board) Edmonton, May, 1964.

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11. Winhold, T.H., "Fort McMurray Ice Studies 1987 Breakup Observation Report", Alberta Environment, River Engineering Branch, Edmonton, January, 1988.

FIGURES

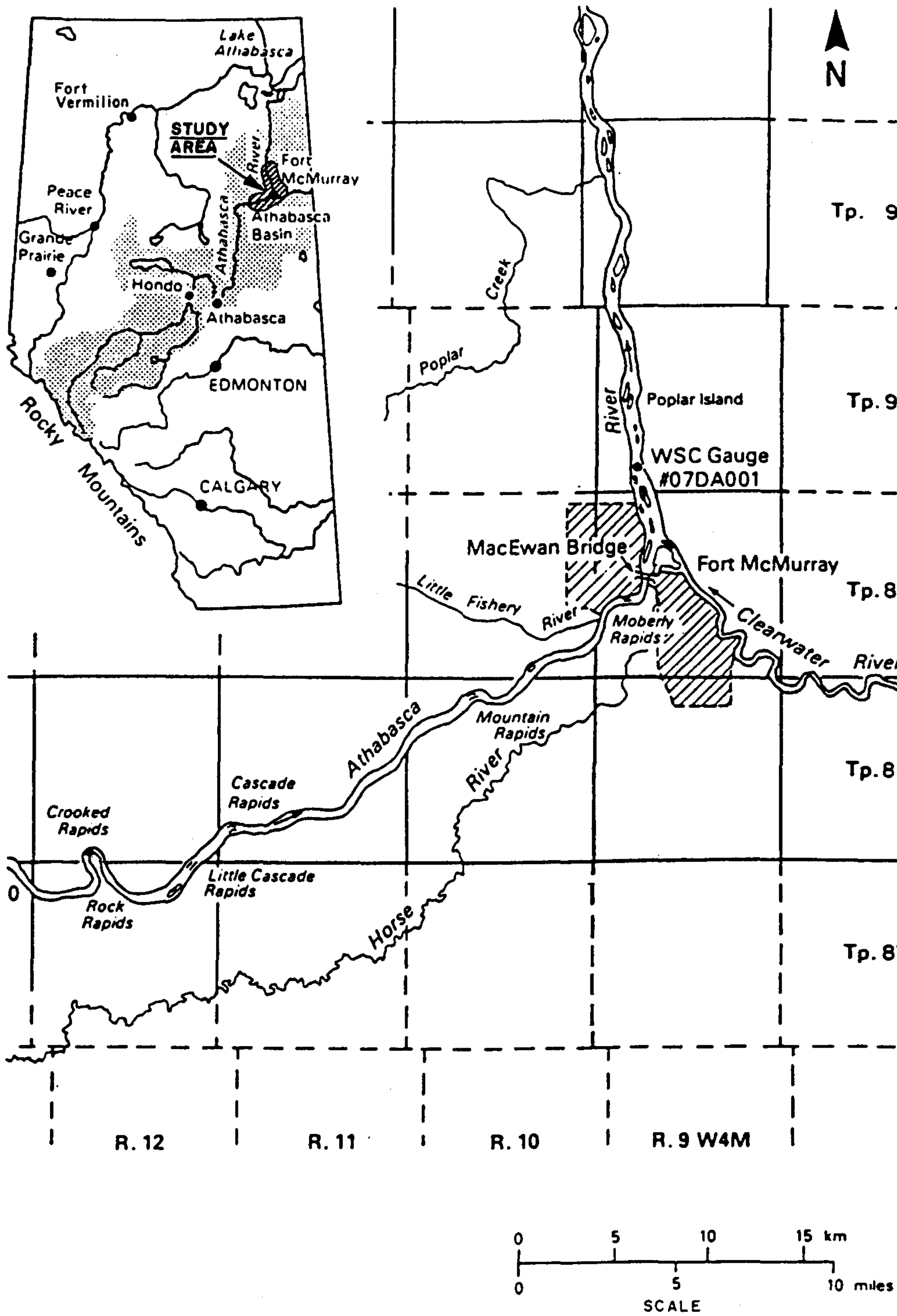
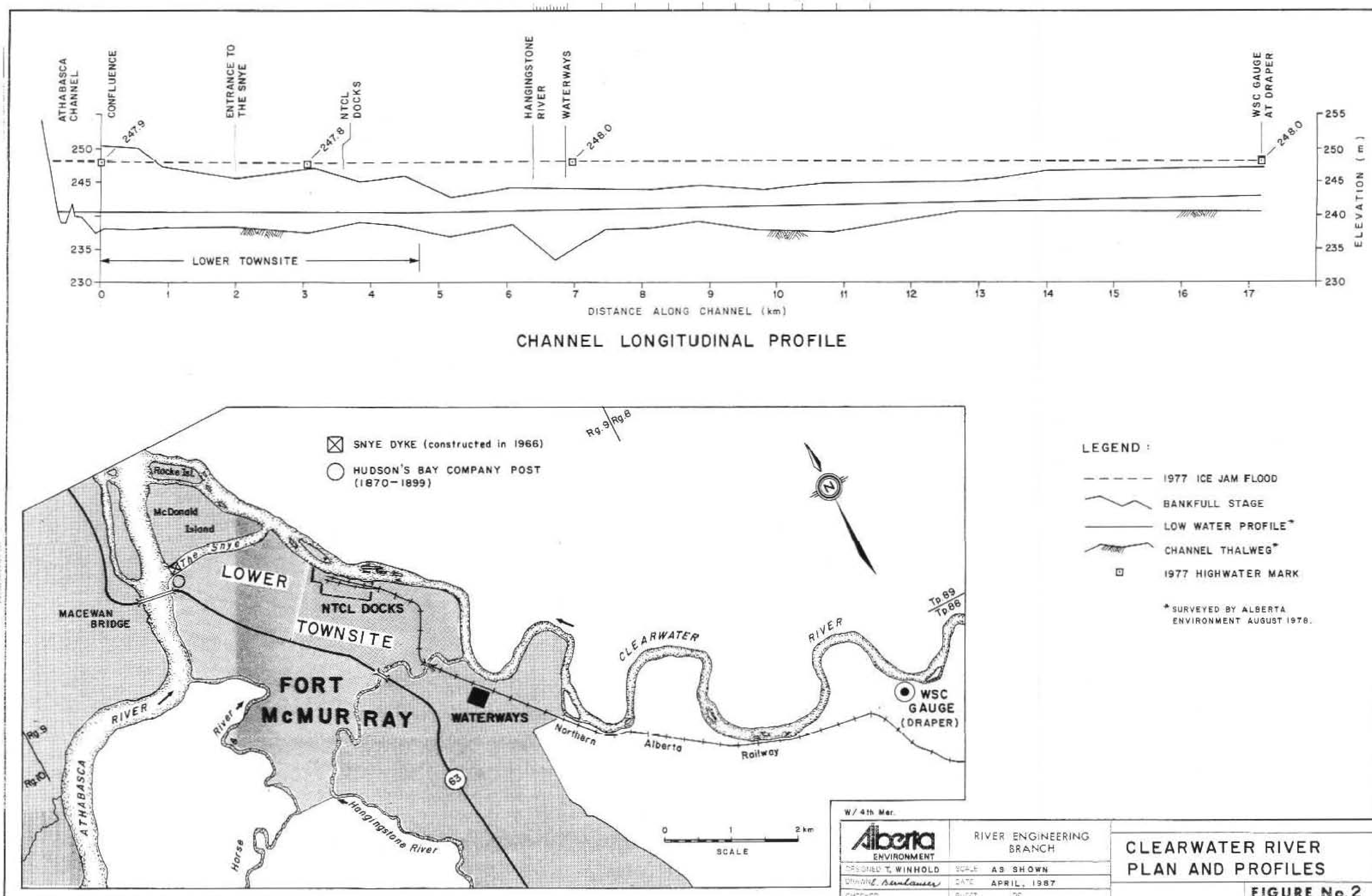


FIGURE 1. LOCATION PLAN



Alberta ENVIRONMENT

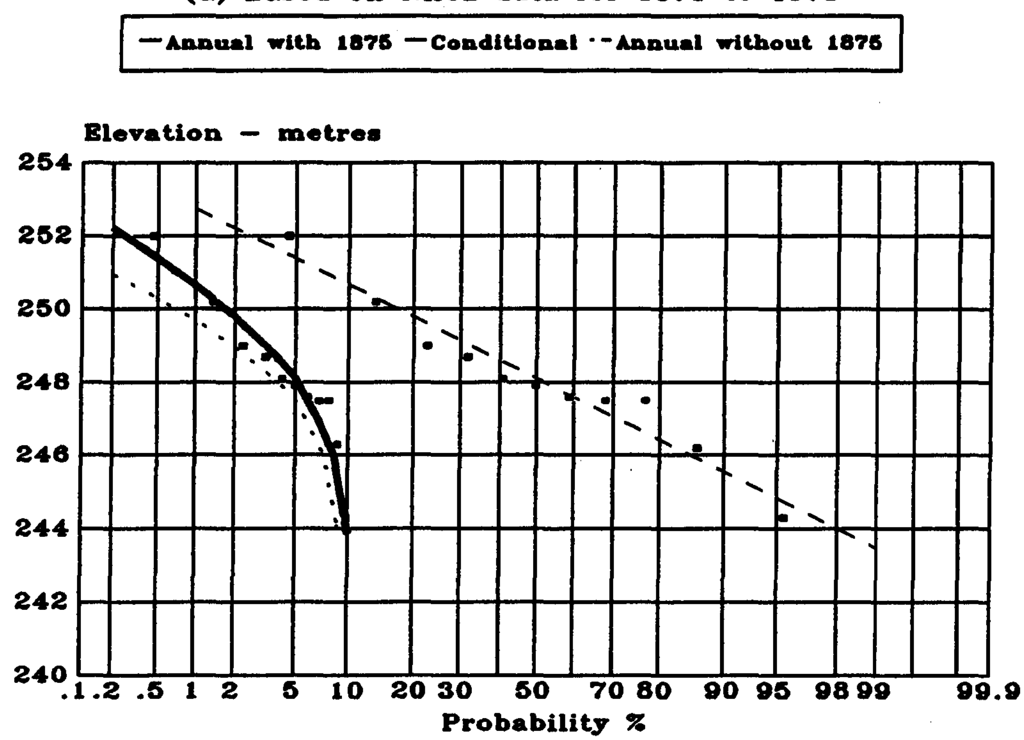
RIVER ENGINEERING BRANCH

DESIGNED T. WINHOLD | SCALE AS SHOWN
DRAWN | DATE APRIL, 1987

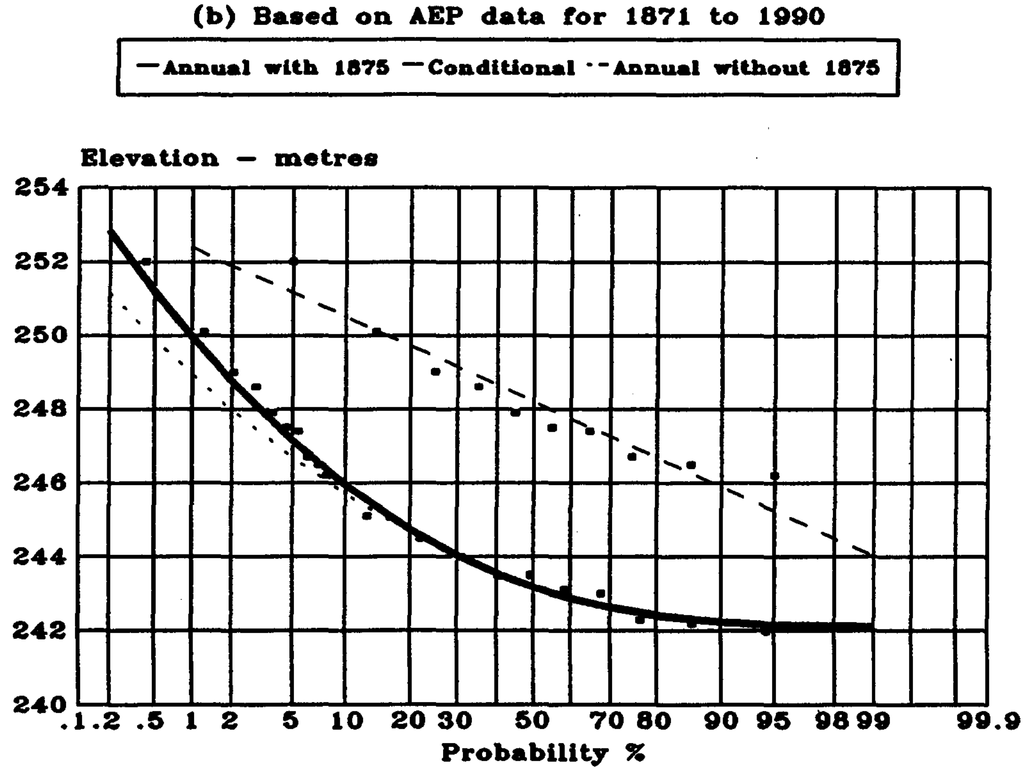
CLEARWATER RIVER PLAN AND PROFILES

FIGURE No. 2

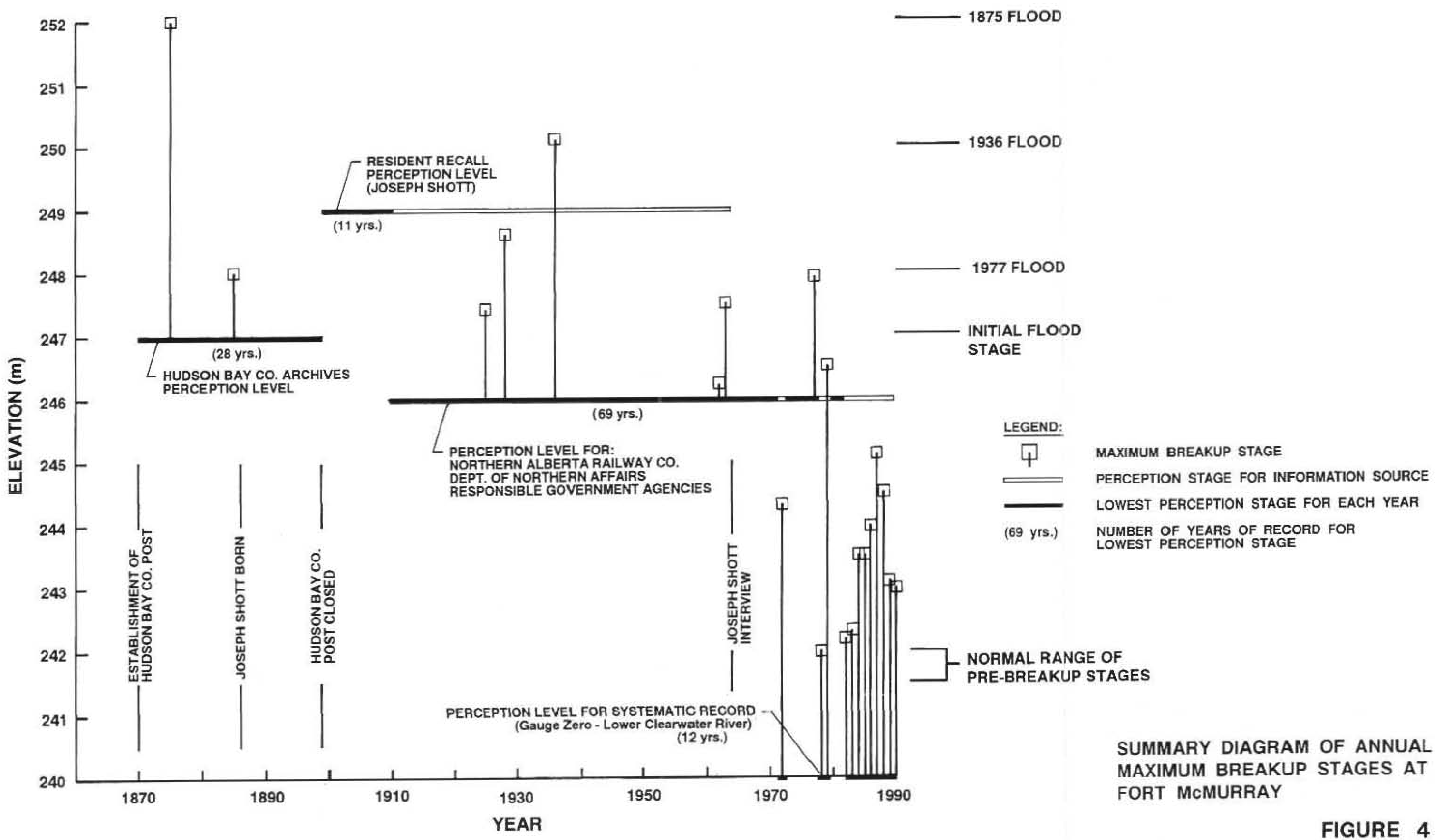
(a) Based on NHCL data for 1871 to 1978



(b) Based on AEP data for 1871 to 1990



Alberta ENVIRONMENT	Technical Services Division HYDROLOGY BRANCH	Frequency of Athabasca River Breakup Stage at Fort McMurray
SUBMITTED R.A. Bothe, P. Eng. DATE October 1990	DESIGNED R.A. Bothe, P. Eng. DATE October 1990	
APPROVED A.M. Mustapha, P. Eng. DATE October 1990	DRAWN CHECKED	SCALE DATE October 1990 — FIGURE No. 3



SUMMARY DIAGRAM OF ANNUAL MAXIMUM BREAKUP STAGES AT FORT McMURRAY

FIGURE 4

Breakup Stage Frequency Analysis - Perception Stage Method

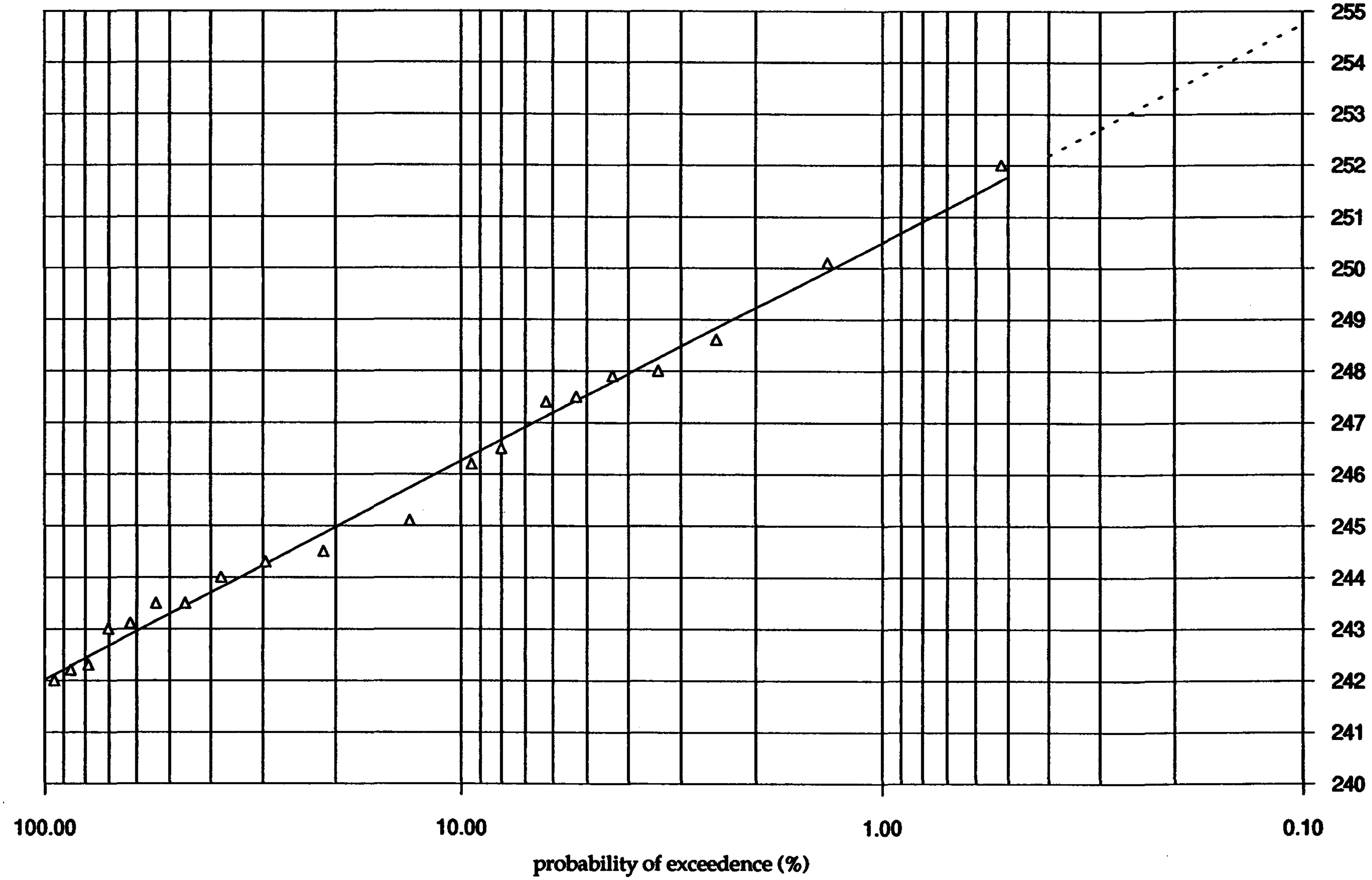


FIGURE 5

APPENDIX A

ACCOUNTS OF THE 1875 ICE JAM FLOOD AT FORT MCMURRAY

ACCOUNTS OF THE 1875 ICE JAM FLOOD AT FORT MCMURRAY

This appendix includes selected exerpts from H.J. Moberly's accounts of the 1875 ice jam flood at Fort McMurray. The exerpts are reproduced from Blench (1964) with the original sources noted as follows.

Exerpts No.	Original Source
1	Moberly H.J. and Cameron, W.B. "When Fur Was King", J.M. Dent and Sons, Ltd., Toronto, 1929, pp. 141-2, pp. 151-2.
2	Hudson's Bay Co. Archives [1]
3	Hudson's Bay Co. Archives [1]

1 A statement of the rules and regulations governing information obtained from the Hudson's Bay Company Archives is included as Attachment No. 1.

ENCLOSURE NO. 1

Extract from copy of letter from Chief Trader Roderick MacFarlane to Chief Commissioner James A. Grahame at Fort Garry, dated 'En Route Clear Water River', 14 June 1875.

"I beg to transmit to you herewith copy of Mr H.J. Moberly's Report to me dated 25 April 1875*...

Fort McMurray is situated on the left bank of the Athabasca River at its confluence with the 'Clear Water' - the buildings are upwards of 50 feet above the winter level of the water. A beautiful Prairie extends for 2 miles to the rear of the post along the clear water river. On the East it is bounded by a hummock of tall pines and poplars and on the South by a high ridge of land. A supply of excellent hay for 60 head of Cattle can be obtained on this Prairie. For the sake of shelter and convenience of watering the Animals during Winter, the Byres were erected in the midst of said timber, also their keeper's house.

On the morning of 20 April last James Daniel (a) the man in charge on becoming aware that the river was breaking up, immediately liberated the Oxen and began to drive them to the highlands beyond the Woods, but before he could get them through, the water rose so suddenly that he barely escaped with his own life and had to leave the poor animals to their fate. Had the Ice, however, not completely surrounded, as it did, the said woods, all of them would have escaped by swimming; but as the water and ice continued high for 5 or 6 days, it was impossible to render them any assistance from the Fort, and the poor brutes after swimming about and making the most strenuous efforts to escape, at length perished one by one, their bodies being since found scattered at intervals in all directions ... The Athabasca broke up very suddenly and quite unexpected while the water rose higher than was ever before known; and after making full and particular enquiries on the spot, I feel satisfied that no blame can justly attach to any one for this unfortunate and much to be regretted occurrence...

A Flood similar to that of 1875 has probably never before happened, and is not likely to occur again so soon; At all events, after this spring's experience, I think I may safely venture to state that with the precautionary measures to be taken in future, no danger need be apprehended that we shall again lose any Animals or property from this cause ...'.

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* See Enclosure No. 2.

EXERPT NO. 1

ENCLOSURE NO. 2

Extract from copy of letter from Henry J. Moberly, clerk in charge of Fort McMurray, to Chief Trader Roderick MacFarlane, officer in charge of Athabasca District at Fort Chipewyan, dated Fort McMurray, 25 April 1875.

'I have now the painful duty to perform of letting you know that we have had a very sudden Inundation here, a few days ago, accompanied by serious loss to the Hudson's Bay Company.

On the 20 Instant about 2 hours after daylight, the river suddenly gave signs of breaking up and in half an hour from that time the water had risen about 60 feet, and the whole place was flooded - the water and ice passing with fearful rapidity and carrying off everything before them. We had just time to escape to the hill, in our immediate vicinity, with the families, bedding and a little Provisions and Ammunition, and to throw up stairs the Furs and most of the valuable property, when the water was already rushing through the Fort. From the time the river first gave signs of starting hardly half an hour elapsed before there was 5 feet of water in the highest building in the Fort, and the Interpreter's house was carried bodily away and dashed to pieces in the Woods; the Workshop and Men's houses have been almost destroyed.

As soon as the river appeared bad, I gave immediate orders to have the Cattle driven to the high lands; and altho' their Keeper James Daniel did all that could be done and even risked his life to save them, still there was no time, as the water rose so suddenly, and I regret to say they all perished ... I had been expecting high water this spring, altho' nothing like what has happened: But the Weather was still very cold - the snow had hardly melted any, and the Ice on the river to all appearance as solid as in Winter - and no one expected the river to break up for 10 days, and then only if the Weather changed and got warm ...

The Ice and Water swept clean over the Prairie up the Clear Water River, which accounts for all the Cattle being drowned as they could not hold against such a torrent ... It may take 2 weeks before the Ice, which is now piled up at least 80 or 100 feet in the Athabasca and Clear Water Rivers, clears off ...'.

(H.B.C. Arch. B.39/c/2)

EXERPT NO. 2

"The winter of 1874-75 was a bitter one, with deep snow and never a thaw until April. On the 2nd or 3rd of that month, however, a further heavy fall of snow was followed by a sudden rise in temperature. The change of weather and weight of the melting snow caused the ice for the eighty-five-mile stretch of rapids above the fort to break up, and it came down the Athabasca with terrific force. On striking the turn in the stream at the post it blocked the river and drove the ice two miles up the Clearwater in piles forty or fifty feet high. In less than an hour the water rose fifty-seven feet, flooding the whole flat and mowing down trees, some three feet in diameter, like grass.

Fortunately, the spur of the hill just above the fort sloped to the river, forming an eddy. The flood caught only one of the houses, but this was at once swept away. When the water had mounted almost to the bank I ordered everyone back to the high ground, but fearing that if the rise reached the house its contents would be damaged, I stayed behind and, shutting the doors, commenced to carry what articles I could to the upper rooms.

Presently I noticed water trickling in under the doors. I was too much occupied, however, to take the time to look out, until a large tree dashed in at the window. I knew now that I was in for a cold bath. After I had with great difficulty got out of the trap a hundred yards of water five to ten feet deep still separated me from dry land. When, at times wading and again swimming, I at length reach it and safety no one with ague ever shook harder than did I after my ducking.

We cleared away the snow and made a comfortable camp, and here we remained for five days before we could re-occupy the houses. Out of thirty-seven oxen for the transport service one only escaped. The rest were drowned".

HUDSON'S BAY COMPANY

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Secretary

Revised 27 September 1962.

APPENDIX B

PERCEPTION STAGE FREQUENCY ANALYSIS

PERCEPTION STAGE FREQUENCY ANALYSIS

General

Since the crux of the problem of analyzing historical data is in the assigning of an appropriate rank and record length to each reported flood peak, Gerard and Karpuk (1979) introduced the concept of "Perception Stage" which they defined as the stage above which it is estimated that a particular source would have provided information on the flood peak in any given year. For instance, the perception stage for a resident is the level below which the maximum stage in a given year is likely to have gone unnoticed, or not be recalled by the resident. Obviously this stage would depend on such factors as how far back from the river the resident lived and the residents memory capability (i.e, the perception stage for a 70 year old resident living 100 metres from the river bank is likely to be lower than for a 90 year old resident living 1.0 kilometres from the river bank). The perception stage for archival sources such as journals and newspapers is the minimum flood level that would have warranted a special comment or report. Because the information is normally recorded immediately after the event, the perception stage for such sources will not require modification for failing recollection as may be the case for a long time resident. For hydrometric records the perception stage would be the minimum gage reading for that station. Similar assessments can be made for other sources, and a perception stage allocated to each source for each year of record.

The perception stage allocated to each source for each year of record provides the means whereby the data can be merged to estimate the probability distribution. The advantage of the perception stage concept over conventional methods "follows from the fact that if the source was in a position to notice and recall if this perception stage was exceeded, but didn't report it, it can be presumed the maximum water level was below the perception stage for that year. This simple property of the perception stage allows for the systematic analysis of historical data and although the determination of these perception stages will generally be quite subjective, it is felt that this subjectivity is more than compensated for by the objective analysis of the historical data it affords".

Procedure Followed

Step 1:

A perception stage was assigned for each information source associated with the updated breakup stage data set (Table 4.1 Main Report). The rational for this selection is given in Table B-1.

TABLE B-1

Determination of Perception Stage

Information Source [1]	Perception Level (m)	Rational
Hudson's Bay Co. Archives	247.0	approximate initial flood stage for "prairie" lands east of trading post site
Joseph Shott	249.0	has no recollection of a significant flood prior to 1936 - it is assumed that he would have some recollection of a flood larger than the 1928 event which reached a peak stage of 248.6 m
Northern Alberta Railway Co.	246.0	railway line is close to being overtopped at Waterways at this level
Department of Northern Affairs/Responsible Government Agencies	246.0	approaching initial flood stage in Fort McMurray
Systematic Record	240.0	assumed gauge zero for Clearwater River above confluence with Athabasca River

[1] Refer to Table 2.1 and 3.1 (Main Report)

Step 2:

The breakup stages from the updated data set were plotted on a summary diagram (Figure 4 Main Report) along with their corresponding perception stages as determined in Step 1. The length of time the information source was able to observe or record breakup stages equal to or higher than the perception stage is indicated by a horizontal bar on the summary diagram. The "lowest" perception stage for each year is denoted by the solid portion of the horizontal bars on the summary diagram.

Step 3:

The number of years of record associated with each breakup stage was determined by summing all of the years having a "lowest" perception level at or below that stage (ie., sum of all years marked with a solid bar on Figure 4 at or below a given stage).

Step 4:

The rank of each breakup stage shown on Figure 4 was determined by ordering (based on magnitude) all of the events in the group having a perception stage equal to or lower than the breakup stage for that event.

Step 5:

Probability estimates for each breakup stage were calculated using the formula

$$(m - 0.375) / (N + 0.250)$$

which defines the plotting positions for the log-normal frequency distribution. These calculations are summarized in Table B-2.

Step 6:

The results of the frequency analysis were than presented graphically on Figure 4 (Main Report). A linear regression was used to produce the "best fit" line through the calculated plotting positions.

Table B2 - Calculations for Breakup Stage Frequency Analysis using Perception Stage Method

frequency analysis of known peak breakup stages

gauge zero = 240 m geodetic

year	breakup stage (m)	elevation (m)	perception stage (m)	years of record	rank	exceedence probability	exceedence probability (%)	return period (years)
1875	12	252	7	120	1	0.0052	0.52	192
1936	10.1	250.1	5	120	2	0.0135	1.35	74
1928	8.6	248.6	5	106	3	0.0247	2.47	40
1885	8	248	7	106	4	0.0341	3.41	29
1977	7.9	247.9	0	106	5	0.0435	4.35	23
1963	7.5	247.5	5	106	6	0.0529	5.29	19
1925	7.4	247.4	5	106	7	0.0624	6.24	16
1979	6.5	246.5	0	70	6	0.0801	8.01	12
1962	6.2	246.2	5	70	7	0.0943	9.43	11
1987	5.1	245.1	0	12	2	0.1327	13.27	7.5
1988	4.5	244.5	0	12	3	0.2143	21.43	4.7
1972	4.3	244.3	0	12	4	0.2959	29.59	3.4
1986	4	244	0	12	5	0.3776	37.76	2.6
1984	3.5	243.5	0	12	6	0.4592	45.92	2.2
1985	3.5	243.5	0	12	7	0.5408	54.08	1.8
1989	3.1	243.1	0	12	8	0.6224	62.24	1.6
1990	3	243	0	12	9	0.7041	70.41	1.4
1983	2.3	242.3	0	12	10	0.7857	78.57	1.3
1982	2.2	242.2	0	12	11	0.8673	86.73	1.2
1978	2	242	0	12	12	0.9490	94.90	1.1