Mackenzie Valley Land and Water Board
7th Floor - 4910 50th Avenue • P.O. Box 2130
YELLOWKNIFE, NT X1A 2P6
Phone (867) 669-0506 • FAX (867) 873-6610

March 24, 2005

File: MV2001L2-0003

Mr. David Harpley
Environmental Coordinator
Canadian Zinc Corporation
Suite 1202-700 West Pender Street
VANCOUVER, BC V6C 1G8

Fax: (604) 594-3855

Dear Mr. Harpley:

Board Approval – Probable Maximum Flood Calculations

The Mackenzie Valley Land and Water Board (the Board) has reviewed the aforementioned calculations required under Part D, Item 1 of Water Licence MV2001L2-0003. The Board hereby approves the Probable Maximum Flood Calculations as presented in the Probable Maximum Flood Profile Report dated March 19, 2004.

The related geotechnical engineer's report evaluating the current flood protection work at the Prairie Creek Mine site that is also required under Part D, Item 1 will be deliberated on by the Board at a later date.

If you have any questions, contact Sarah Baines, Regulatory Officer, at (867) 766-7457 or email sbaines@mvlwb.com.

Sincerely,

Todd Burlingame
Chair

Copied to: Alan Taylor, Canadian Zinc Corporation (Fax: 604-688-2043)
Distribution List

Copy of 00000001.max

March 24, 2005

WL MV2001L2-0003

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ABORIGINAL ORGANIZATIONS

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GOVERNMENT

Ed Hornby	South Mackenzie District Office	669-2720
Kathleen Racher	DIAND – Water Resources	669-2716
Mineral Development Advisor	Mineral Development Division	669-2705
Tom Andrews	GNWT - Prince of Wales Heritage Museum	873-0205
Mark Davy	GNWT - MACA	920-6343
Duane Fleming	GNWT - Health	873-0122
Jason McNeil	GNWT - RWED	873-4021
Michael Brown	GNWT - DOT	920-2565
Mike Fournier	Environment Canada	873-8185

If there is an error in our contact, please notify our office.

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STAFF REPORT

Company: Canadian Zinc Corporation (CZN)	
Location: Prairie Creek Mine Site	**Application:** MV2001L2-0003
Date Prepared: March 16, 2005	**Meeting Date:** March 23, 2005
Subject: Probable Maximum Flood Profile Report (PMFP Report)	

1. Purpose/Report Summary

The Probable Maximum Flood Profile Report (PMFP Report) and related Probable Maximum Flood Profile Report Follow-up (PMFP Report Follow-up) submitted by Canadian Zinc Corporation (CZN) were presented to the Board on November 15, 2004, and March 9, 2005. A decision on the PMFP Report and PMFP Report Follow-up was deferred until further discussions with legal counsel and with Water Resources Division, DIAND, took place.

The purpose of this staff report is to present the results of those discussions to the Board along with the PMFP Report and PMFP Report Follow-up for review and approval.

Probable maximum flood levels are calculated to determine the most severe flood that a specific region will experience. Factors that affect the probable maximum flood level include the climatological, hydrological, and physiographic characteristics of a region.

Predicted flood levels in the PMFP Report will be used to determine if the flood protection work (dykes and tailings dams) at the Prairie Creek Mine site will withstand flood events of various magnitudes.

2. Background

In 1980, Ker Priestman and Associates, a consulting firm from British Columbia, used empirical methods to determine the maximum possible flood that the Prairie Creek Mine site area could experience (Ker Priestman Report). The Ker Priestman Report was submitted to the MVEIRB during the 2001-2003 Environmental Assessment for the pilot plant and underground decline

development at the Prairie Creek Mine. In the Report of Environmental Assessment, the Minister recommended that CZN provide updated probable maximum flood calculations.

In response to this Ministerial recommendation, the Board incorporated a condition, part D, item 1, in Water License MV2001L2-0003 (Type B) that required CZN to submit updated probable maximum flood calculations for the Prairie Creek Mine site area. Part D, item 1 reads as follows:

> Section 1
> *The Licensee shall submit to the Board for approval within six (6) months of the issuance of this license updated probable maximum flood calculations for flood elevations using at least the data available from 1975 to 1990, including data from the weather station at Virginia Falls hydrometric gauge.*
>
> Section 2
> *In addition to these calculations, a description of the adequacy of the current flood protection work shall be submitted with recommendations from a qualified Geotechnical Engineer for any improvements or modifications to be implemented upon approval by the Board.*

Canadian Zinc Corporation has addressed the two sections of this condition in two different documents because determining the adequacy of the flood protection work at the site is entirely dependent on the results of the probable maximum flood calculations. The document dealing with section 2 of the Condition will be finalized once the Board approves the PMFP Report.

The purpose of flood calculations is to determine for particular watercourses the flood magnitude of various return periods such as the 100 year, 500 year, 1,000 year, or probable maximum flood. The probable maximum flood is the most severe flood for a particular location. Engineers use flood calculations when designing dams, dykes and other containment structures to ensure that the elevation and strength structures can withstand specific floods.

Canadian Zinc Corporation contracted Hay and Company Consultants Inc. (HAYCO) to calculate the probable maximum flood for the Prairie Creek Mine site and to determine the most appropriate flood magnitude against which the flood protection at the site will be evaluate.

Chronology

March 19, 2004: Probable Maximum Flood Profile Report (PMFP Report) received. This report was produced by HAYCO (HAYCO) on behalf of CZN.

March 22, 2004: PMFP Report distributed for review. Comments were due May 7, 2004.

June 8, 2004: Request for further information sent to CZN by Board staff. The deadline for the company's response was August 13, 2004.

July 22, 2004: Company response received. The document is titled Probable Maximum Flood Profile Report Follow-up (PMFP Report Follow-up) and was written by HAYCO.

August 4, 2004: The PMFP Report Follow-up distributed for review. Comments were due August 31, 2004.

August 20, 2004: Parks Canada indicates that they have a copy of the Ker Priestman Report. Board staff requested a copy of the report for the Public Registry.

Sept. 27, 2004: Board staff distributed a letter to CZN and to the reviewers that the review process would be stopped until the Ker Priestman Report was received.

Oct. 15, 2004: The Ker Priestman Report was received. It is a very large document with a number of maps and drawings so it took a long time to copy and have it delivered to the MVLWB office.

Oct. 15-Nov. 7, 2004: Board staff reviewed the Ker Priestman Report and researched how to calculate probable maximum floods and how the calculations are used.

November 15, 2005: The PMFP Report and the PMFP Report Follow-up were presented to the Board. The Board deferred their decision on the reports until Board staff held further discussions with legal counsel regarding the similarities and differences between the issues raised in the staff report and the circumstances that led to judicial review over the use of the tailings pond.

March 9, 2005: The results of the discussions between Board staff and legal counsel were presented to the Board along with the PMFP Report and the PMFP Report Follow-up. The Board deferred their decision until the Executive Director could follow up on a comment made by Water Resources Division, DIAND. Water Resources Division stated that CZN would be out of compliance with their WL if they did not produce true probable maximum flood calculations despite the company's arguments explaining that the true probable maximum flood cannot be calculated.

3. Discussion

The reviewers are mainly concerned that the PMFP Report does not satisfy the requirements of Part D, Item 1 because the PMFP Report does not represent a true calculation of the probable maximum flood. The reviewers questioned why Ker Priestman could calculate the Probable Maximum Flood in 1980 but HAYCO could not do the same at the present time. HAYCO responded to these concerns in a report titled, PMFP Report Follow-up.

In the PMFP Report Follow-up, HAYCO states that the estimates provided in the Ker Priestman report are actually not true probable maximum flood calculations. This conclusion was reached by HAYCO because Ker Priestman only used

18 years of data in his calculations, which is suitable for the derivation of the 40-50 year flood but not the probable maximum flood. Further support for this conclusion is provided by a statement in the Ker Priestman report itself: "It must be remembered that the estimation of flood flows by statistical methods, from data with a period of record, is uncertain at best" (page 66).

In the HAYCO PMFP Report, the 10,000 year flood is used to approximate the probable maximum flood for two reasons:

a) It is standard practice. Research conducted by Board staff indicated that a number of countries such as the United Kingdom, Australia and the United States construct major dams to withstand the 10,000 year flood.

b) The data to calculate the true probable maximum flood for the area is not available; the magnitude of large flood events cannot be predicted very accurately with only the short data record that is available. For example, a data record of 50 years will predict the magnitude of a 100 year flood with a 25% error margin. This error margin will increase substantially as the magnitude of larger flood events than the 100 year flood is predicted.

4. Comments

Legal Counsel Analysis

The Board did include the Minister's approved recommendations from the Environmental Assessment into the License. The issue in this staff report relates to a difference in opinion over how completely the licensee complied with the License requirement. This seems to be a technical issue, not a legal issue.

These circumstances are quite different from those that led to judicial review over the use of the tailings pond. In the judicial review case, the Board varied from the recommendation approved by the Minister to impose a more stringent condition. In this case, the Board included exactly what the Minister approved but made the report subject to Board approval. The question of whether the CZN engineering analysis satisfies the Board's condition in the License is a matter of fact, not law. Legal counsel suggests that the Board go ahead and exercise its judgement based on the analysis submitted by staff.

Executive Director's Discussion with Water Resources Division

Will be delivered to the Board members at a later date but prior to March 23, 2005.

5. Review Comments

- The DCFN, Parks Canada, and CPAWS are concerned that the HAYCO PMFP Report does not satisfy the requirements of part D, item 1.
- The DCFN and CPAWS recommend that the Board apply the Precautionary Principle and require that CZN evaluate the flood protection work on site using the most conservative standards.
- Environment Canada finds the approach taken in the PMFP Report reasonable and does not have any concerns with the conclusions. Roger Pilling, a Hydrometric Supervisor with Environment Canada, was asked by

Board staff to comment on the issue outside of the standard reviewer comment process. His comments are as follows:

> *"...it would be difficult to complete an estimated flow on Prairie Creek using South Nahanni River at Virginia Falls data due to the different flow regimes of the two basins. The South Nahanni is a much larger basin that has a rather large glacier melt component through the open water season, especially during the warmer months of June to August. The peak flows on the South Nahanni River are often (but not always) heavily influenced by glacial melt. On the other hand, Prairie Creek is significantly affected by summer rainfall events, with no glaciers feeding the basin. Prairie Creek is a much flashier basin with rapid changes over a short period of time, which is common in smaller basin scenarios."*

- Please see the comment summary table for further details on the issues raised in the Discussion section of this staff report.

6. Security

Not applicable.

7. Conclusion

The data that is available does not permit the calculation of the true probable maximum flood but only an estimation of the magnitude of the 10,000 year flood. The data is not appropriate for calculating the true probable maximum flood because the data record is too short and because the data from Virginia Falls is not applicable to the Prairie Creek Valley (see Environment Canada's comments).

Dr. Adrian Chantler is a professional engineer who signed the report stating that the 10,000 year flood is an event comparable to the probable maximum flood. By signing this report, he has accepted professional and legal liability for the contents of that report and the validity of that statement.

8. Recommendation

I recommend that the PMFP Report and PMFP Report Follow-up be approved and that the requirements of section 1 (as defined in the Background section of the staff report) of License condition part D, item 1 be considered fulfilled.

9. Attachments

- Comment Summary Table for the Prairie Creek Probable Maximum Flood Profile Report
- Comment Summary Table for the Prairie Creek Probable Maximum Flood Profile Report Follow-up
- Prairie Creek Probable Maximum Flood Profile Report
- Prairie Creek Probable Maximum Flood Profile Report Follow-up

- Excerpt from the 1980 Ker Priestman Report that deals with maximum possible flood levels at the Prairie Creek Mine site

Respectfully submitted,

for

Sarah Baines
Regulatory Officer

Comment Summary Table
Canadian Zinc Corporation -Probable Maximum Flood Profile Report

Reviewing Agency, Date Comments Received	Comments	Mitigation Measure
Deh Gah Got'ie Dene Council, April 23, 2004	1. During the April 15, 2004 Council meeting it was agreed by to support the First Nations of Nahanni Butte and Ft. Simpson. This support is for any concerns they may have in relation to the report and their endeavour to have them addressed.	1. Presented to the Board.
Environmental Protection Branch, Environment Canada, May 4, 2004	1. The Regional Hydrologist reviewed the PMFP Report and finds that the approach is reasonable. 2. EC has no concerns with the conclusions reached.	1. Presented to the Board. 2. Presented to the Board.
Deh Cho First Nations (DCFN), May 7, 2004	1. DCFN requires clarification on several statements within the report produced by HAYCO & Company Consultants Inc.: • "very rough analysis...using limited data that are available" • "strictly speaking this is not a Probable Maximum Flood analysis, as such an analysis requires a lot of detailed data and some weeks of work" • "it has not been possible to review the earlier calculations of the PMF and the corresponding flood profile, as these have not been made available" 2. It is inconsequential that a true Probable Maximum Flood analysis may take some weeks of work given that CZN has had 6 months to produce the report. 3. It is unclear why the consulting firm (HAYCO) had a lack of data from which to draw more significant conclusions. DCFN requests clarification on why the consulting firm is noting a lack of available data with which to produce a more accurate Probable Maximum Flood analysis.	1. In the PMFP Report Follow-up, HAYCO clarifies each of these points. Please see the Discussion section of the staff report for further detail. 2. True PMF calculations cannot be done as not all of the required data is available. 3. It is not that the data was not provided to HAYCO but rather that all the data needed does not exist. See the Discussion section of the staff report for further details.
Parks Canada, May 7, 2004	1. The report does not fulfill the requirements of Part D, Item 1 of Water License MV2001L2-0003.	1. Presented to the Board.

	2. Considering that the mine is within a floodplain, the submission of a "rough analysis...using the limited data that are available" is inadequate. Parks Canada has expressed its concerns about the water quality of the South Nahanni River and possible contamination from several aspects of the Prairie Creek Mine, including the tailings pond, the fuel storage facilities and the chemical storage area. Inadequate or poor information on probable maximum flood levels will not enable the Board to provide recommendations on the required improvements or modifications needed at the site to ensure adequate flood protection.	2. HAYCO clarifies why true probable maximum flood calculations were not carried out in the PMFP Report Follow-up. See the discussion section of the staff report for further details.
	3. This analysis does not include recent data; the Rainfall Atlas used to calculate Probable Maximum Precipitation dates back to 1985, and therefore, the analysis does not factor in the possible changes to precipitation as a result of global climate change.	3. Data from the Virginia Falls hydrometric gauge as well as three other gauges were used in conjunction with the Rainfall Atlas.

Comment Summary Table
Canadian Zinc Corporation -Probable Maximum Flood Profile Report Follow-up

Reviewing Agency, Date Comments Received	Comments	Mitigation Measure
Deh Cho First Nations (DCFN), September 10, 2004	1. Given the location of the Prairie Creek Mine site within an active floodplain and an area of seismic activity, DCFN must stress that the highest possible standards should apply to ensure that the flood protection structures are structurally sound along their entire length, and designed to deal with a worst case scenario. Given the continued level of uncertainty regarding the flood history of the site, DCFN can only conclude that the Board must adopt the Precautionary Principle with regards to all earthworks, structures, floodworks and associated infrastructure at the Prairie Creek Mine. 2. The DCFN recommend that in the absence of additional data, that a precautionary approach to risk management would be more appropriate in these circumstances, and that CZN be required to undertake measures to ensure that the dyke and riprap can withstand the more conservative calculations provided in the HAYCO report.	1. Presented to the Board. See the Discussion section of the staff report for further details. 2. Presented to the Board. See the Discussion section of the staff report for further details.
CPAWS-NWT, September 10, 2004	1. Given that HAYCO did not submit a PMF and is of the opinion that a PMF can not be completed, CPAWS-NWT recommends that the Board consult and work with the MVEIRB on this issue to obtain a clear indication of why it was included in the Report of Environmental Assessment and how to evaluate the applicability of the reports submitted.	1. Presented to the Board.
Water Resources Division, October 21, 2004	1. Despite the arguments and reasoning presented in the report, the Company is in non-compliance with the terms of their WL if a PMF Flood calculation is not submitted. 2. If the 200 year flood calculations are adopted as the standard, more conservative freeboard limits than 0.5 m should be required.	1. Presented to the Board. 2. Presented to the Board.

CANADIAN ZINC CORPORATION

July 22, 2004

Via fax/mail: 867-873-6610

Mackenzie Valley Land & Water Board
File
JUL 22 2004
MV2001C0023
Application # MV2001L2-0003
Copied To SB/PUH/BW/Reg.

Sarah Baines
Regulatory Officer
Mackenzie Valley Land & Water Board
7th Floor, 4910-50th Avenue,
Yellowknife, NT
X1A 2P6

Dear Sarah:

Re: MV2001C0023, MV2001L2-0003, Prairie Creek Probable Maximum Flood Profile Report Follow-up

Please find enclosed 2 duplicate reports from Hay & Company Consultants Inc. dated July 6, 2004, regarding Prairie Creek Mine Flood Calculations on behalf of Canadian Zinc Corporation. This report represents a requested follow-up with reference to your letter of June 8, 2004 for your review and consideration.

A follow-up report regarding your additional requests on the A & R Plan Requirements referencing your letters of June 8 and June 30, 2004, will be forthcoming shortly.

Yours truly,

Alan B. Taylor
VP Exploration

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HAY & COMPANY
CONSULTANTS INC.
One West 7th Avenue, Vancouver, B.C., Canada V5Y 1L4
Tel: (604) 875-6391 Fax: (604) 875-6383
E-mail: hayco@hayco.com Web Site: http://www.hayco.com/

2004 July 6

FILE: EBA.012

Canadian Zinc Corporation
Suite 1202 – 700 West Pender Street
Vancouver, BC V6C 1G8

Attention: Mr. Alan B. Taylor, P.Geo.

Dear Alan:

Re: Flood Calculations

Thank you for the opportunity to discuss the flood calculations at the Prairie Creek Mine on June 17. This letter provides some background to the flood calculations and addresses the comments we have received from the water licence application reviewers regarding our letter of March 10, 2004.

BACKGROUND

Previous work done on the site by Ker Priestman (1980) refers to a "Maximum Possible Flood" in Prairie Creek, which was used to estimate flood levels and the corresponding required dyke elevations. For the extracts of this report provided, it appears that this flood was derived from an analysis of hydrometric data for "Prairie Creek at Cadillac Mine", for which there were six years of record available at the time, and "South Nahanni River above Virginia Falls", for which there were 18 years available. It is not clear what KPA meant by a "Maximum Possible Flood" or how it was derived. Eighteen years is a relatively short period of record to use for derivation of anything beyond about a 40- or 50-year flood, which would be a much smaller event. Clearly some extrapolation was involved, which is the only practicable approach in such situations, but it must always be accompanied by a word of caution regarding the accuracy. It should be understood that Ker Priestman did not estimate a Probable Maximum Flood (PMF). UMA (the company which acquired Ker Priestman) have confirmed that the calculations done by KPA in 1980 are no longer available.

There is now more flow data available at the hydrometric stations mentioned above than there was in 1980, and this was utilized in Hayco's recent analysis.

PROBABLE MAXIMUM FLOOD

The definition of Probable Maximum Flood (PMF) adopted by the US Committee of the International Commission on Large Dams is as follows:

> *The Probable Maximum Flood identifies estimates of hypothetical flood characteristics (peak discharge, volume and hydrograph shape) that are considered to be the most severe "reasonably possible" at a particular location, based on relatively comprehensive hydrometeorological analysis of critical runoff-producing precipitation (snowmelt if pertinent) and hydrologic factors favourable for maximum flood runoff.*

For watercourses such as Prairie Creek, for which the annual maximum flood is snowmelt-dominated, PMF estimation would involve developing a maximized snowpack and a critical temperature sequence. These are then modelled in combination with a rare, but not extreme, rainfall even, such as a 100-year storm. All additional factors, such as soil moisture and base flow in the creek would be set at conservatively higher than normal values. Other combinations of events are usually investigated, such as the Probable Maximum Precipitation (PMP) occurring on a 100-year snowpack and a "pre-storm" plus the PMP on the 100-year snowpack. The PMP is either determined by meteorologists from a consideration of dew points, maximum precipitable moisture and other factors, or from statistical relationships with precipitation of known return periods. The Hershfield method is an example of the latter technique. It is unlikely that the necessary data exist to calculate a PMF.

FLOOD PROTECTION STANDARDS

The Probable Maximum Flood is typically used in the design of spillways for major dams, in the Very High consequence category (Canadian Dam Association, 1995). This is defined as a situation that would cause a large increase in loss of life (over what would have occurred without the structure) or excessive increase in social, economic and/or environmental losses. BC Hydro is an organization that carries out PMF studies for its major dams. Typically these studies require a vast amount of data on rainstorms, temperatures, snowpack and water equivalent, dew points etc., which is not available in many areas of the country. A PMF study takes several months to complete and costs in the order of $100,000. The accuracy of the result is probably ±30%.

The PMF is not considered applicable to the issue of flood control in Prairie Creek. For river flood control works, the design criterion in British Columbia is the 200-year flood plus a freeboard allowance of up to 0.6 m. In Alberta the standard is the 100-year flood. The Probable Maximum Flood is only used for dams associated with a high hazard (National Research Council Canada, 1989).

FLOOD ESTIMATES BY HAY & COMPANY

We were initially asked to provide an estimate of a Probable Maximum Flood for the purposes of assessing the adequacy of the existing Prairie Creek dyke. In our response, we were careful to say that what we could produce was not a true Probable Maximum Flood, as defined above, but was an extreme flood with a return period in the order of 10,000 years. This is considered to be an event of comparable magnitude to a PMF. As outlined in our letter of March 10, 2004, two approaches were adopted: one using a regional analysis of hydrometric data; and, the other using an estimate of Probable Maximum Precipitation and a catchment runoff model. The two approaches yielded similar flows of about 500 m^3/s. The resulting flood water surface profile was below the crest of the dyke at all but one of the cross sections (Chainage 126+00 ft), where the crest elevation is about 0.3 m too low. However, we consider this design standard to be extremely conservative by Canadian standards and it would be more appropriate to consider assessing the dyke adequacy for a lower design flood.

The hydrometric records for the four regional stations referred to in our letter of March 10, 2004 were analyzed to determine the 200-year flood flow in Prairie Creek using the relationship between the 200-year flood flow and drainage area (see Figure 1). The 200-year flood in Prairie Creek at the minesite is estimated to be 250 m^3/s.

The HEC-RAS program was then applied to establish the water levels in Prairie Creek during a 200-year flood. The results are presented in Table 1 below. Freeboard is the vertical height between the flood elevation and dyke crest elevation.

Table 1: 200-Year Water Surface Profile

Chainage (ft)	200-Year Water Level (ft)	200-Year Water Level (m)	Dyke Crest Elevation (m)	Freeboard (m)
102+20	2851.4	869.1	870.5	1.4
114+00	2845.1	867.2	868.1	0.9
120+00	2840.1	865.7	868.1	2.4
126+00	2836.9	864.7	865.6	0.9
131+00	2832.3	863.3	864.7	1.4
153+60	2814.2	857.8	858.3	0.5

It can be seen from Table 1 that there is at least 0.5 m freeboard at all points along the dyke.
In addition to the above, if very large flood were to occur at present, equipment and manpower is available to undertake sand-bagging and/or fill placement on the lower sections of the dyke, should this be necessary.

WATER LICENCE APPLICATION REVIEW COMMENTS

In response to the specific comments we make the following observations:

- Mackenzie Valley Land and Water Board, June 8, 2004
  "CZN is required to submit the following "Probable maximum flood calculations for flood elevations using at least the data from 1975 to 1990, including data from the weather station (sic) at the Virginia Falls hydrometric gauge."
  Data from this gauge was used, along with data from three other stations.

- Deh Cho First Nations, undated
  "very rough analysis... using limited data that are available"; "strictly speaking this is not a PMF analysis" etc. (Hay & Company). "CZN has had 6 months to complete this report"; "DCFN requests clarification on why the consulting firm is noting a lack of available data with which to produce a more accurate PMF analysis."
  The comments in the foregoing pages of this letter address these issues. The data required to do a true PMF study for Prairie Creek, probably do not exist. This, and the appropriateness of the PMF are the main issues, rather than the time required.

- Parks Canada, May 6, 2004
  "This is not a Probable Maximum Flood analysis etc"; "very rough analysis... using the limited data that are available" (Hay & Company)
  These comments have been explained in the earlier part of this letter.
  This analysis does not include recent data; the Rainfall Frequency Atlas used to calculate the PMP dates back to 1985 and therefore does not factor in the possible changes to precipitation as a result of global climate change.
  The comment regarding the Rainfall Atlas is correct, but it remains a useful and convenient indicator of precipitation quantities of various durations and return periods. It is likely that updated data would lead to a result well within the accuracy of the current estimate.

RECOMMENDATIONS

Our recommendation is to suggest to the Water Board that, in terms of the design criterion for flood protection at the minesite, consideration be given to bringing it into line with common practice in North America and elsewhere. A 200-year flood would be an appropriate level of protection, meaning that there is a 0.5% chance of failure in any year. This flood flow (and hence water level) has been calculated with a reasonable degree of accuracy using the hydrometric data and creek cross sections

available. The resulting water surface profile shows that the there would be at least 0.5 m of freeboard along the dyke in a 200-year event.

As you are aware, we are working with Don Hayley, P.Eng., the Project Geotechnical Engineer to evaluate the adequacy of the riprap, which is a further condition of the water licence.

Yours very truly,

HAY & COMPANY CONSULTANTS INC.

A.C. Chantler

Dr. Adrian Chantler, P.Eng.
President
AGC/jk

cc: Mr. Rick Hoos, EBA Vancouver
Mr. Don Hayley, EBA, Kelowna

REFERENCES

Ker Priestman & Associates, October 1980
Environmental Evaluation for Cadillac Explorations Limited Prairie Creek Project, NWT

Candian Dam Safety Asssociation, January 1995
Dam Safety Guidelines

National Research Council Canada, 1989
Hydrology of Floods in Canada – A Guide to Planning and Design

HAY & COMPANY
CONSULTANTS INC.

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2004 March 10

FILE: EBA-012

EBA Engineering Consultants Inc.
500-110 Melville Street
Vancouver, BC V6E 4A6

Attn: Mr. Rick Hoos

Dear Rick

Re: Prairie Creek Mine Probable Maximum Flood Profile

Hayco has carried out a very rough analysis of the flood flows in Prairie Creek, using the limited data that are available. Strictly speaking this is not a Probable Maximum Flood analysis, as such an analysis requires a lot of detailed data and some weeks of work.

Hayco adopted two approaches:

- A frequency analysis of the regional hydrometric data available; and
- An estimate of the probable maximum precipitation and a simple catchment model

Note that it has not been possible to review the earlier calculations of the PMF and the corresponding flood profile, as these have not been made available.

1. Regional Frequency Analysis

There are flow data available for the following hydrometric stations:

Table 1: Hydrometric Stations

No.	Station Name	Years	Drainage Area (sq km)
10EC002	Prairie Creek at Cadillac Mine	14	495
10EA003	Flat River near the Mouth	33	8560
10EB001	S. Nahanni R above Victoria Falls	34	14600
10EC001	S. Nahanni R above Clausen Ck	24	31100

The annual maximum instantaneous flows were analyzed using Environment Canada's Consolidated Frequency Analysis program. A generalized extreme value distribution was fitted to each set of data and the results were extrapolated to 10,000 years to be indicative of the order of magnitude of a Probable Maximum Flood. It must be stressed that there is limited accuracy associated with this approach. One cannot reliably estimate the flood of a return period longer than about twice the record length. However, this does provide an order of magnitude estimate. The results for all four hydrometric stations are given in Figure 1. Combining the results and applying the regression equation gives an estimate of the 10,000-year maximum instantaneous flow for Prairie Creek at the minesite of about **473 m^3/s**.

Note that this event uses actual hydrometric data, so could be a snowmelt or rainfall event.

2. Probable Maximum Precipitation and Catchment Model

Hershfield's method (NRC, 1989) was used to establish the Probable Maximum Precipitation using data published in the Rainfall Frequency Atlas (Hogg and Carr, 1985). This method is also very approximate due to the paucity of data and relatively short record periods, particularly when the atlas was published, however data from the (then) Cadillac Mine should be incorporated. A mean annual 24-hour maximum rainfall of 30 mm was determined from the Rainfall Atlas, along with a standard deviation of 12.5 mm. Hershfield's frequency factor K_{24} is a function of the mean annual 24-hour maximum rainfall, P_{24} and was determined to be 17.77 from the equation:

$$K_{24} = 19\ (10)^{-0.000965 * P_{24}}$$

Substituting this value of K_{24} into the standard prediction equation gives:

$$PMP_{24} = P_{24} + K_{24} * 12.5 = 252 \text{ mm}$$

This is a point rainfall value and can be reduced to a mean value over the whole catchment using curves developed by Pugsley (1981). The probable maximum average catchment rainfall over the 495 square km of drainage area is estimated to be 227 mm in 24 hours.

This rainfall was then used in a simple catchment model (HEC-HMS) to estimate the peak flow that would result from such a storm. The lag time for the catchment was estimated at 25 hours and a curve number (CN) of 65 was assumed. The resulting peak discharge was **549 m^3/s**, which is comparable to the value determined by frequency analysis, given the approximate nature of both approaches.

3. Flood Profile Computation

A flood profile in Prairie Creek in the vicinity of the mine was computed using a discharge of 549 m^3/s (the larger of the two values determined above) and creek cross sections given in a Figure 18 by Ker Priestman & Associates, probably dating from the 1980s. The results of this analysis are presented in the table below, with the corresponding water surface profile elevations given by Ker Priestman in their Figure 18, for comparison.

Table 2: Probable Maximum Water Surface Profiles

Chainage (ft)	KPA Water Level (ft)	Updated Water Level (ft)	KPA Water Level (m)	Updated Water Level (m)
102+20	2858	2854	871.1	869.9
114+00	2850	2848	868.7	868.1
120+00	2848	2843	868.1	866.5
126+00	2843	2841	866.5	865.9
131+00	2841	2836	865.9	864.4
153+60	2818	2816	858.9	858.3

It can be seen that the elevations calculated in this study are consistently lower than those calculated by KPA by between 0.6 and 1.6 m.

We hope this brief study meets your requirements. Please call if you have any questions.

Yours very truly,

HAY & COMPANY CONSULTANTS INC.

A.G. Chantler

Dr. Adrian Chantler, P.Eng.
President
/agc

REFERENCES

Hogg W.D., and D.A. Carr, 1985
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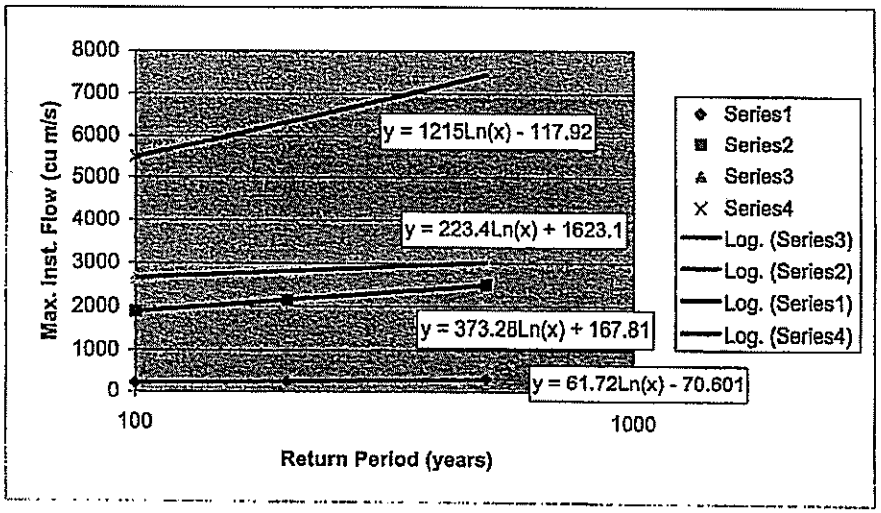
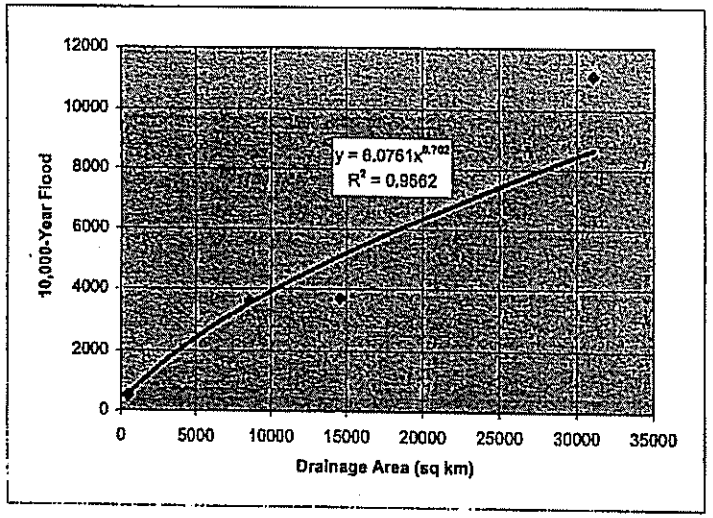
Prairie Creek Flood Analysis

Station No.	Station Name	Years	Drainage km^2	Q_{100} m^3/s 100	Q_{200} m^3/s 200	Q_{500} m^3/s 500	Q_{10000}
10EC002	Prairie Creek at Cadillac Mine	14	495	215	254	314	498
10EA003	Flat River near the Mouth	33	8560	1890	2140	2490	3606
10EB001	S. Nahanni R above Victoria Falls	34	14600	2650	2810	3010	3681
10EC001	S. Nahanni R above Clausen Ck	24	31100	5500	6280	7450	11073





Based on the correlation of 10,000-year flood and drainage area, the 10,000 year flood at the mineslte would be 473 m^3/s

FIGURE 1

5.1.4 Evaporation

There were no changes in the available data for mean monthly and annual evaporation. Therefore the evaporation rates given in the P.E.E., which were taken from Climatic Mapping, are also reproduced in Table 4.

5.1.5 Snow Cover

Snow cover data is available for Watson Lake, Norman Wells and Fort Nelson from 1962 to date, and for Tungsten for the two winters ending in 1977 and 1978. The average accumulations at the three longer te: regate average is 25 inches. gsten, the mean snow cover the: 40 inches annually.

Excerpt from the Ker Priestman Report, 1980.

The h at the minesite over the nches, which does not compare w tations. Consequently, ood estimates of snow cove ions from these other locations

5.1.6 Streamflows and Probable Maximum Flood calculations.

The n programme at the minesite rainfalls. The Atmospher provide a rate of rainfall necessary to estab- lish a Cl te which will complement the two stream crest gauges installed at the site in July, 1980.

5.2 Hydrology

5.2.1 General

Runoff shows a marked peak in June, decreasing through the fall and winter to a low in February and March. Groundwater storage would be low in winter due to frozen ground, hence extremely low winter flows occur. For Prairie Creek, the ratio of the June: March average flows is 73:1. The index hydrograph, Figure 15, for flows on Prairie Creek illustrates this seasonal fluctuation.

Periods of ice cover are indicated. Smaller creeks will have a more extreme variation and larger creeks, less extreme. Annual peak flows on the larger drainage basins such as Prairie Creek are usually due to spring snowmelt, but may also be due to widespread rain, whereas the smaller creeks will produce flash floods as a result of localized thundershower activity.

5.2.2 Records

Published runoff data is available from the Water Survey of Canada. Additional data is being collected by the Water Resources Division of the Department of Indian & Northern Affairs, but no reference index is available at this time.

The relevant stream gauging stations are listed in Table 5 with their locations shown on Figure 13.

Data from Station 10EC002 (Prairie Creek at Cadillac Mine), and Station 10EC001 (South Nahanni River near Hot Springs) is considered to be the most pertinent to this study.

Because of a shortage of data having a reasonable period of record for small basins (i.e. less than 50 sq. miles), runoff characteristics for small catchments are not known.

5.2.3 Mean Flows

Based on the Prairie Creek and South Nahanni River gauges, the long term water yield for the Study Area is 1.1 cfs per square mile. Mean annual flow in the South Nahanni River is 14900 cfs with a minimum monthly average of 2000 cfs and a maximum monthly average of 50500 cfs. The catchment area above this gauge is 12900 sq. miles.

Mean annual flow in Prairie Creek is 204 cfs,with a minimum monthly average of 10 cfs and a maximum monthly average of 696 cfs, respectively. The catchment area above the Prairie Creek gauge is 191 sq. miles.

The mean annual yield ratio is defined as equivalent volume of annual runoff divided by volume of total annual precipitation. For the Study Area it is equal to 0.7. (Yield ratio is not the same as runoff coefficient (C) which relates rates of runoff and precipitation).

5.2.4 Peak Flows

Streamflow and Rational Method Analysis

Information presented in this section is based on streamflow records, discussions with J. N. Jasper (Hydrologist for Water Resources Division, Dept. of Indian & Northern Affairs, Yellowknife), and use of empirical calculations such as the Rational Method. The estimation of peak flows for small basins is very uncertain due to the unavailablity of reliable data.

A Gumbel (extremal probability paper) plot was prepared from the recorded peak flows in Prairie Creek and the South Nahanni River (Fig. 16). These curves, extrapolated to a 100-year return period, provided estimates of peak flows as follows:

$Q_5 = 0.8\ Q_{10}$ where Q_5 = flood flow with 5 year return period

$Q_{25} = 1.3\ Q_{10}$

$Q_{50} = 1.5\ Q_{10}$ where Q_{10} = flood flow with 10 year return period

$Q_{100} = 1.7\ Q_{10}$

The unit peak flows (cfs/mi^2) for the two recording stations were plotted for the 10year return period (Fig. 17). Instantaneous flows for typical small basins of 1 and 10 square mile catchment areas, calculated by the Rational Method, were also plotted on this graph.

The Rational Method gives estimates of peak flows by a formula relating rainfall intensity, runoff coefficient and drainage area. Rainfall intensity was determined from the Fort Nelson IDF curves for a 10-year return period, assuming a 50-minute time of concentration for the 1 mi^2 basin and 90-minute time of concentration for the 10 mi^2 basin:

1 mi^2 basin - rainfall intensity 30 mm/hr. (1.2 in./hr.)
10 mi^2 basin - rainfall intensity 20 mm/hr. (0.8 in./hr.)

These times of concentration and corresponding rainfall intensities were based on estimates of overland and creek flow velocities at times of peak flow for typical basins in the Study Area.

Runoff coefficient (C) values of 0.3 to 0.5 were considered to be representative of ground conditions during peak rainfalls in the summer. The Suggested Design Curve (Fig. 17) has been drawn through C=0.3 because a C-value greater than this would likely only result from an infrequent combination of events (i.e. less frequently than once in 10 years).

Comparisons were also made with work done previously by others, including the Department of Indian & Northern Affairs (1979) for the Tungsten, N.W.T. area. Generally the Design Curve for the Cadillac Study Area (Fig. 17) gives higher flood values than those for the Tungsten area.

Streamflow Data Extensions

An isolated analysis of the short period of record on Prairie Creek is not sufficient to make confident predictions of the magnitude of major events. Therefore, an extension of the record was attempted by correlation with longer term records at both stations on the South Nahanni River. Because there was a poor correlation between the recorded peaks on Prairie Creek and those on South Nahanni River no further attempt was made to extend Prairie Creek flow data.

Application of Liard Highway Hydrology Regression Formula

In a report by M. M. Dillon Ltd., the hydrology studies of four other consultants were reviewed and a new hydrological design method was developed for creek and river crossings along the Liard Highway.

The hydrological design method developed in the report uses a regression formula and this was applied to the Prairie Creek and Harrison Creek basins. The 10 and 100 year return period flows obtained for Prairie Creek were 10,500 cfs and 15,800 cfs, respectively; for Harrison Creek they were 780 cfs and 1,180 cfs, respectively. These values compare fairly well with flows obtained from the Design Curve on Figure 17.

The regression formula is very sensitive to the precipitation and mean daily temperature and variations of 2 inches in the mean annual precipitation or of 2^{o} F in the mean daily temperature entered in the formula result in peak flow differing by 25% to 50%. However, the Dillon formula gives good confirmation of the stream-flow and rational method analysis performed initially.

Kinematic Wave Flood Analysis

The Water Resources Division of the Department of Indian and Northern Affairs in Whitehorse has developed a computer model based on the kinematic wave theory of flood runoff routing and on data collected by Water Resources and Water Survey of Canada on smaller streams in the Yukon Territory.

Use of this model by government personnel gave the 10 and 100 year return period flows for Prairie Creek as 2970 cfs and 5010 cfs, respectively; for Harrison Creek flows were 128 cfs and 213 cfs, respectively. These results are not at all in agreement with other stronger and better corroborated evidence. It is felt that they are either in error or that the computer model has been poorly calibrated in the MacKenzie Mountain area. Therefore, the kinematic wave flood analysis has been disregarded.

Summary and Recommended Design Method

After reviewing many of the approaches available for hydrologic design in the area, it is believed the peak flows should be derived from the Design Curve shown on Figure 17. Design flows for Prairie and Harrison Creeks are therefore as follows:

	10 Year Flow (cfs)	100 Year Flow (cfs)
Prairie Creek	11,000	18,000
Harrison Creek	510	870

It must be remembered that the estimation of flood flows by statistical methods, from data with a short period of record, is uncertain at best. Usually flood estimates are not reliable to any great extent beyond the period of record. For example, if there are 15 years of record (as for the South Nahanni River), the 10 year flood can be estimated with confidence and the 15 and 30 year floods with somewhat lesser confidence. Confidence in estimates of the 100 year return period flood is poor. It would be safe to say that the 100 year flood on Prairie Creek at the mine-site would fall in the range of 10,000 cfs to 22,000 cfs. Similar ranges would apply to the other small drainage areas.

5.2.5 Maximum Possible Flood (MPF) $C_P = C_N$ 0.028

From Chow (1964) and Fawkes, the maximum possible flood is the largest flood for which there is any reasonable expectancy in this climatic era. It is used in design where failure could lead to great damage and loss of life. The MPF is rigorously determined through detailed study of storm patterns and/or snowmelt patterns, transposition of the storms to a position that will give maximum runoff and calculation of the flood by unit hydrograph or computerized routing methods. It is assumed that the MPF will not result from a catastrophe such as the failure of an ice dam or similar failure of an earth obstruction.

In this study empirical methods have been utilized to calculate the MPF.

The first of 2 methods which were investigated is an extension of a calculation developed by D. M. Herschfield (1977) for probable maximum precipitation. The basic equation is:

MPF = (mean of recorded annual peaks) + k(standard deviation of the recorded peaks)

A value for k in the Study Area would be between 15 and 20 (Fawkes, pers.com.). This gives an instantaneous MPF of about 38,000 cfs on Prairie Creek. The period of record is extremely short for this type of analysis.

The second method utilizes the results of studies of MPF carried out on the Columbia and Peace Rivers and utilized by SIGMA Resource Consultants Ltd. (1974) in The Development of Power in the Yukon. For the purposes of this work the MPF can be taken as 2.5 times the 25 year return period flood. The calculation gives 34,000 cfs.

The two results are reasonably consistent. However, in order to be conservative, the instantaneous MPF for Prairie Creek is taken as 38,000 cfs.

5.2.6 Flood Elevations and River Dyking

General

MPF and 100-year flood elevations on Prairie Creek and Harrison Creek in the vicinity of the mine have been estimated on the basis of the creek profile and cross sections which were surveyed in August, 1980.

Manning's equation has been used to develop the flood profiles and an estimation of Manning's "n" is from a lengthy discussion in Chow 1959. The value selected is 0.04. At the Prairie Creek gauge site, Water Survey of Canada estimated flows on the basis of the Slope-area Method which involves an estimation of "n". They selected a value of 0.032 for the improved reach immediately upstream from the gauge. However, there is no evidence to support an "n" value as low as 0.032 for design purposes. Manning's formula calculations are based on the assumption of uniform flow since the channel cross-section does not change abruptly. The flow is normally subcritical, hence the calculated flood profiles have been inspected for possible backwater effects and adjusted accordingly.

The design flood velocities are in the range of 7 to 13 feet per second for the 100-year return period flood and 9 to 16 feet per second for the MPF depending on the particular slope and cross section. These velocities are sufficiently high that some form of bank and dyke protection (i.e. riprap) will be necessary to prevent erosion and possible river breakthrough. As there appears to be few fines in the bank and dyke material, downstream siltation, as a

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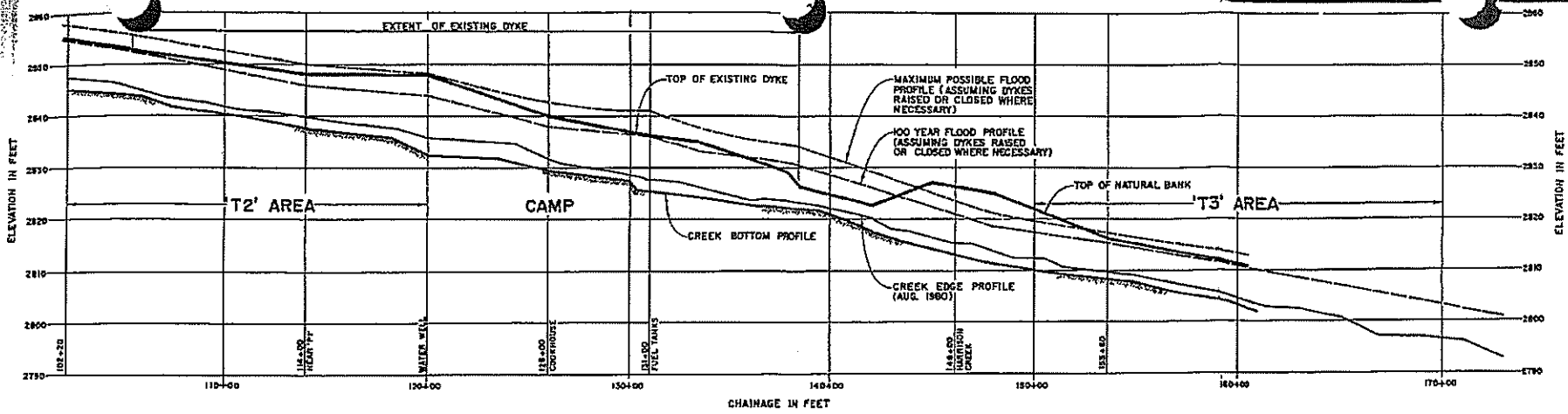
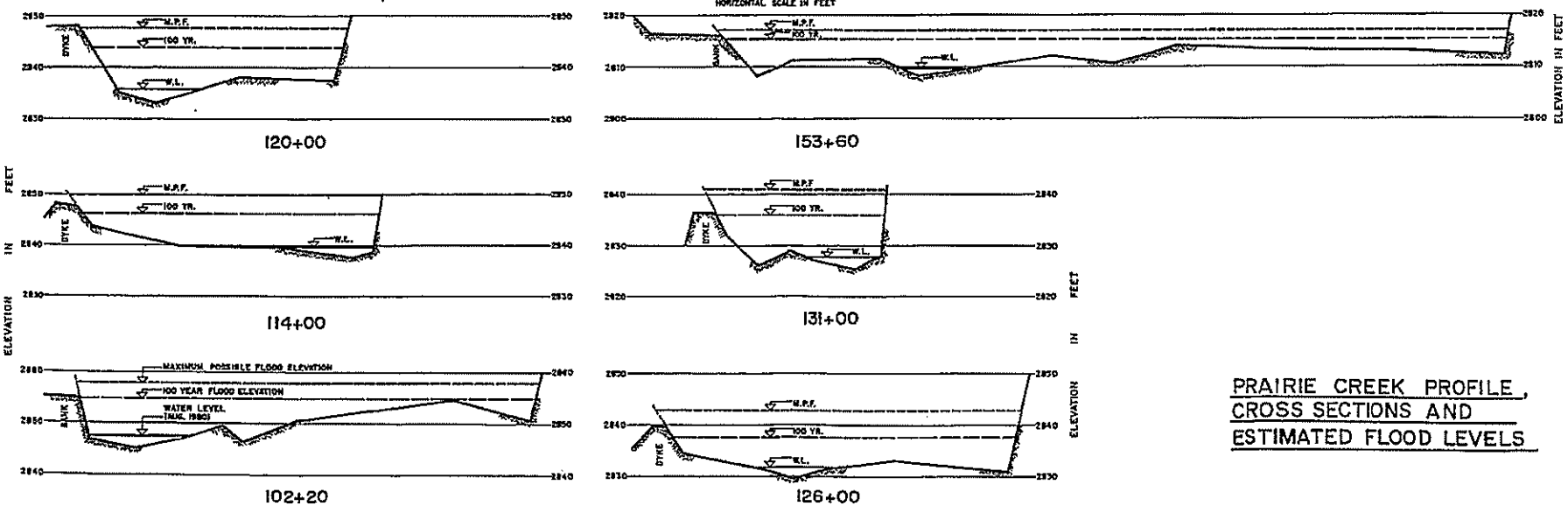


PROFILE - PRAIRIE CREEK

HORIZONTAL SCALE IN FEET



CROSS SECTIONS

HORIZONTAL SCALE IN FEET

PRAIRIE CREEK PROFILE, CROSS SECTIONS AND ESTIMATED FLOOD LEVELS

FIGURE 18

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