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CONCURRENT LOW FLOWS
IN THE
ATHABASCA RIVER BASIN

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EXECUTIVE SUMMARY

A hydrologic parameter that has become synonymous with water quality evaluations of rivers is the term "7Q10". This term represents the annual minimum 7-day discharge at a particular location along a river, below which flows would be expected to occur in only 10% of the years. The complement to this definition is that there is a 90% chance in any year that the average 7-day flow would never be less than the 7Q10 value.

Areal variability in climatic and physiographic parameters throughout the Athabasca River basin produces a number of possible low flow scenarios. The question is then: what is the likely flow at one location if the flow at another is known to be the 7Q10 flow? The statistical analysis that answers this question is called conditional probability. It is an approach whereby the distribution of flow at one location is mathematically related to flow at another.

Scenarios of expected concurrent flow along the Athabasca River are developed on the assumption that a 7Q10 event occurs at either Hinton, Whitecourt, Athabasca, or Fort McMurray. While expected flows represent the most probable situations, it is possible that a 7Q10 event can occur from a totally different flow pattern than expected. The likelihood of these other scenarios is outlined where appropriate. Both annual and open water scenarios are provided.

A number of interesting flow patterns are evident. The premise that low flow events throughout the Athabasca River basin cannot be treated as independent events is confirmed. In the annual flow case, concurrent 7Q10 flows can span the reach from the Lesser Slave River to Lake Athabasca. In the open water case, there is a reasonable chance that concurrent low flows could extend from Whitecourt to Athabasca or from Athabasca to Fort McMurray. All scenarios point to the value in basin-wide assessments of low flow.

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1.0 GENERAL INFORMATION

1.1 Introduction

A hydrologic parameter that has become synonymous with water quality evaluations of rivers is the term "7Q10". This term represents the annual minimum 7-day discharge at a particular location along a river, below which flows would be expected to occur in only 10% of the years. The complement to this definition is that there is a 90% chance in any year that the average 7-day flow would never be less than the 7Q10 value.

1.2 Purpose and Objectives

The purpose of this hydrologic study is to develop a series of low flow events that reflect concurrent basin-wide conditions along the Athabasca River.

Specifically, the objectives of the study are as follows:

1. To determine historical annual and open water 7-day low flow values at streamflow stations along the Athabasca River and its major tributaries,
2. To assess the frequency of occurrence of the 7-day low flows,
3. To develop scenarios of expected concurrent low flows along the Athabasca River, assuming a 7Q10 flow occurs at a particular point of interest, and
4. To examine the possibility of other scenarios occurring where the departure from the pattern of flow in the expected scenario is pronounced.

1.3 Scope

The low flow analysis presented in this report is limited to the portion of the Athabasca River downstream of the Town of Hinton to where it enters Lake Athabasca. Lake Athabasca and the associated outflow channels are not considered. In addition, streamflow records at gauging stations on tributaries to the Athabasca River are only analyzed if the station represents the most downstream annual gauging location on the tributary. The McLeod River near Cadomin, the McLeod River above Embarras River, the Pembina River below Paddy Creek, the Pembina River near Entwistle, and the Clearwater River above Christina River are not analyzed.

Two time frames are used to analyze 7Q10 values. One is a water year spanning the period July 1 to June 30. This annual period is selected to ensure over-winter low flow sequences are not split into two different years. The other time frame covers the period May 1 to November 30 and is representative of open water conditions.

Scenarios of basin-wide low flows are developed around four points of interest: Hinton, Whitecourt, Athabasca, and Fort McMurray.

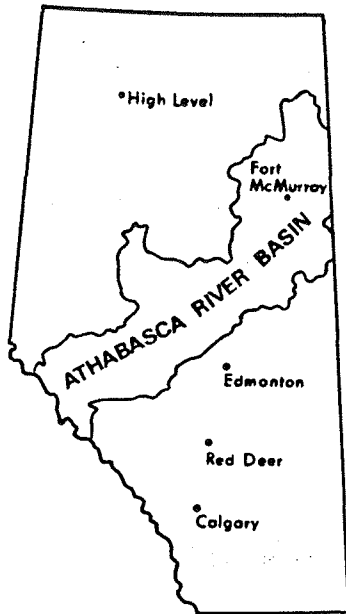
1.4 Prior Studies

A report entitled, "Athabasca River Basin Low FLOW Analysis" was prepared by the Hydrology Branch in 1984. Historical annual and open water low flow sequences and associated frequencies were provided for 13 stations in the Athabasca River basin. Nine of these stations are analyzed in this report and the 7Q10 values contained herein supercede those found in the 1984 report. The 7Q10 values for the Athabasca River above Embarras River, the Pembina River near Entwistle, and the Clearwater River above Christina River have not been updated.

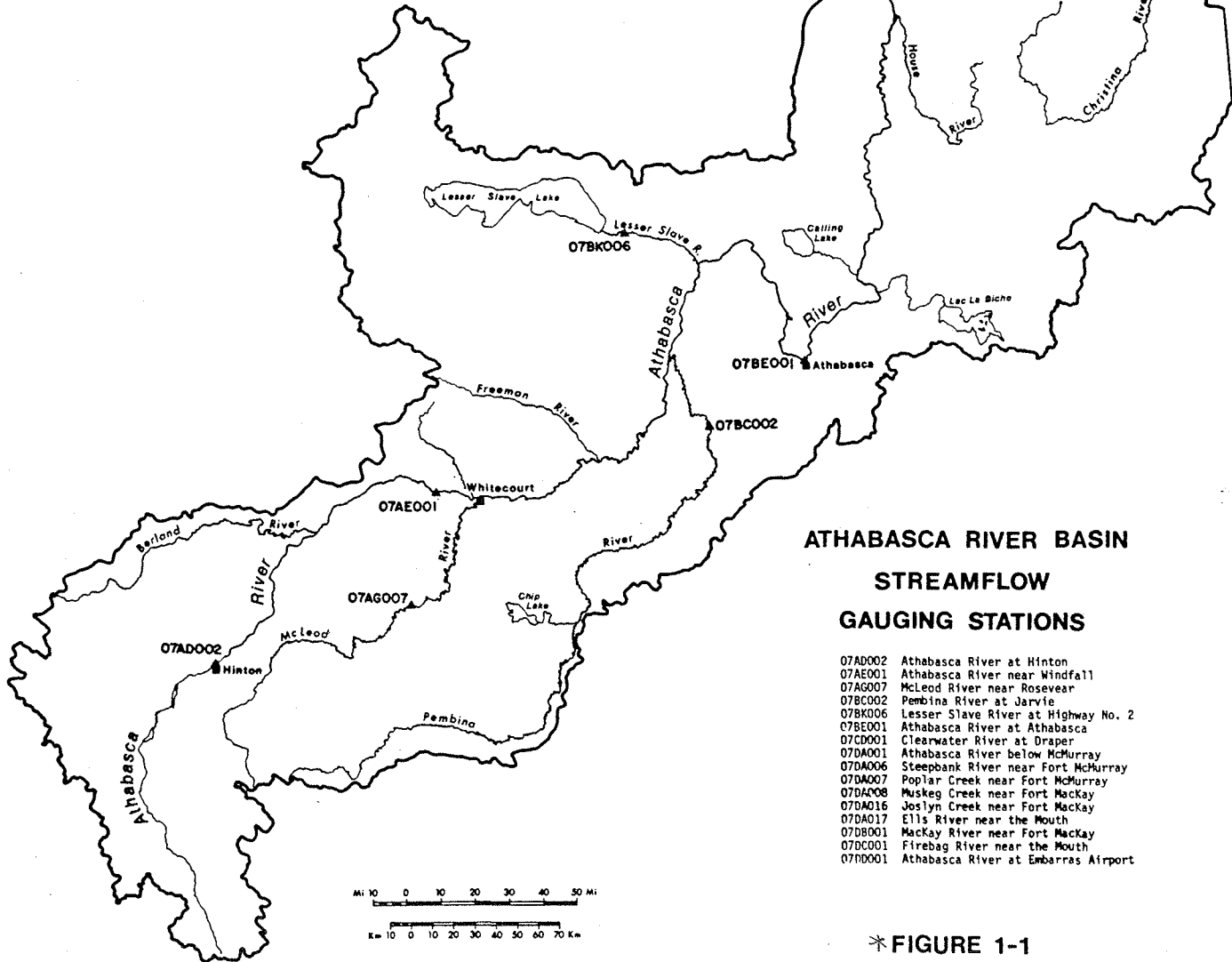
1.5 Study Area

The Athabasca River basin is shown in Figure 1-1. Streamflow gauging stations that are used in the study are identified along with the points of interest along the Athabasca River. The station numbers which are provided for each station are used extensively throughout Appendix A and Appendix B of this report. Pertinent drainage areas are provided in Table 1-1.

Recorded streamflow along the Athabasca River is for all practical purposes representative of natural flow. Although land use changes brought about by agriculture, forestry, and urbanization can produce dramatic changes to the natural runoff from an area, their effects are not significant when compared to the magnitude of the flows in the Athabasca River. The same can be said of lake regulation throughout the basin, with the weir on the outlet of Lesser Slave Lake being the one exception. An examination of the impact of this structure on 7Q10 flows on the Lesser Slave River, however proved to be inconclusive. Fortunately the deviation in predictions is small, ranging from a 7% decrease in the Lesser Slave River 7Q10 flow to a 9% increase. This uncertainty will have little bearing on the evaluation of the Athabasca River, but may prove to be important to the Lesser Slave River itself.

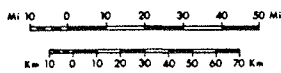


KEY MAP



**ATHABASCA RIVER BASIN
STREAMFLOW
GAUGING STATIONS**

- 07AD002 Athabasca River at Hinton
- 07AE001 Athabasca River near Windfall
- 07AG007 McLeod River near Rosevear
- 07BC002 Pembina River at Jarvie
- 07BK006 Lesser Slave River at Highway No. 2
- 07BE001 Athabasca River at Athabasca
- 07CD001 Clearwater River at Draper
- 07DA001 Athabasca River below McMurray
- 07DA006 Steepbank River near Fort McMurray
- 07DA007 Poplar Creek near Fort McMurray
- 07DA008 Muskeg Creek near Fort McKay
- 07DA016 Joslyn Creek near Fort McKay
- 07DA017 Ellis River near the Mouth
- 07DB001 Mackay River near Fort McKay
- 07DC001 Firebag River near the Mouth
- 07DD001 Athabasca River at Embarras Airport



* FIGURE 1-1

LOCATION PLAN

TABLE 1-1
Drainage Areas (square kilometers)

	Local	Total
Athabasca at Hinton	9784	9784
Hinton Local to Berland	2030	11814
Berland River	4740	16554
Sakwatamau River	1139	17693
Athabasca below Whitecourt	4410	22103
McLeod at Whitecourt	9100	31203
Athabasca below Whitecourt		31203
Freeman - McLeod Local	1863	33066
Freeman River	1662	34728
Pembina - Freeman Local	3034	37762
Pembina River	13101	50863
Lesser Slave - Pembina Local	6747	57610
Lesser Slave River	14400	72010
Athabasca at Athabasca - Lesser Slave Lake Local	2610	74620
Athabasca at Athabasca House - Athabasca at Athabasca Local	19036	93656
House River	764	94420
Athabasca McMurray - House Local	7395	101815
Clearwater River	30793	132608
Athabasca below McMurray		132608
Poplar - Athabasca below McMurray	275	132883
Poplar Creek	151	133034
Steepbank - Poplar Local	181	133215
Steepbank River	1320	134535
Muskeg - Steep Local	653	135188
Muskeg River	1458	136646
MacKay - Muskeg Local	70	136716
MacKay River	5571	142287
Ells - MacKay Local	121	142408
Ells River	2709	145117
Firebag - Ells Local	2360	147477
Firebag River	5988	153465
Athabasca at Embarras - Firebag Local	1682	155147
Athabasca at Embarras		155147

2.0 SITE-SPECIFIC 7Q10 ANALYSIS

2.1 Annual Analysis

The annual 7Q10 analysis is based on a water year from July 1 to June 30. This ensures that all low flow sequences remain intact. June and July are generally a period of high flow along the Athabasca River and it is unlikely that a minimum flow sequence would ever be interrupted by applying this time frame.

The historical 7-day annual minimum flows are provided in Appendix A, Tables A-1 and A-2. Minimum flows are not identified for years of incomplete data unless it is obvious that the minimum flow sequence would not occur during the period of missing records.

Frequency curves of the 7-day minimum flows are developed using a modified Pearson III distribution. Complete frequency summations are provided in Appendix A, Table A-3, while a summary of the 7Q10 values for the stations analyzed is presented in Table 2-1. Plots of the frequency curves for the points of interest are provided in Figure A-1.

2.2 Open Water Analysis

The open water 7Q10 analysis is based on the period May 1 through November 30. Analytical procedures are similar to the annual case. The historical 7-day minimum open water flows and associated frequency curves are provided in Appendix A, Tables A-4, A-5, and A-6, while the open water 7Q10 values are presented in Table 2-1. Plots of the frequency curves for the points of interest are provided in Figure A-2.

TABLE 2-1
7Q10 Flows At Selected Gauging Stations

Gauging Station	Open Water ¹ 7Q10 Flow (cms)	Annual ² 7Q10 Flow (cms)
Athabasca River at Hinton	29.6	15.8
Athabasca River near Windfall	40.3	29.0
McLeod River near Rosevear	4.26	1.59
Athabasca River at Whitecourt ³	47.1	33.3
Pembina River at Jarvie	3.09	1.43
Lesser Slave River at Hwy. No. 2A	15.3	11.6
Athabasca River at Athabasca	84.4	53.3
Clearwater River at Draper	45.3	35.2
Athabasca River below McMurray	145	114
Poplar Creek near Fort McMurray	0.02	0.00
Steepbank River near Fort McMurray	0.23	0.12
Muskeg River near Fort MacKay	0.16	0.10
MacKay River near Fort MacKay	0.24	0.09
Ells River near the Mouth ⁴	0.80	0.19
Firebag River near the Mouth	8.64	6.10

1 May 1 to November 30

2 July 1 to June 30

3 Synthetic site produced by combining Athabasca River near Windfall with McLeod River near Rosevear

4 Includes Joslyn Creek near Fort MacKay

3.0 BASIN 7Q10 ANALYSIS

3.1 Methodology

3.1.1 General Approach

It is unlikely that 7Q10 flows would ever occur concurrently throughout the entire Athabasca River basin. Areal variability in climatic parameters, notably precipitation and temperature; and physiographic parameters, such as elevation, vegetation, and soil properties; produces a number of possible flow scenarios. The question is then: what is the likely flow at one location if the flow at another is known or assumed to be known? The statistical analysis that answers this question is called conditional probability. It is an approach whereby the distribution of flow at one location is mathematically related to flow at another.

The first step in a conditional probability analysis is to select a point of interest along the Athabasca River. Four points of interest, also called primary stations, are used in the study: Hinton, Whitecourt, Athabasca, and Fort McMurray. Once the point of interest is selected, mathematical relationships are developed to relate the flow at other locations along the Athabasca River to the point of interest. These other locations are called secondary stations and, in addition to the four previously mentioned locations, include the Athabasca River near Windfall and the Athabasca River at Embarras Airport. After the relationships are established it is a straightforward procedure to calculate the expected flow at each secondary station that corresponds to a 7Q10 flow at the point of interest.

To better distribute the flow originating in the area between stations along the Athabasca River, relationships are established that relate gauged tributary flow to the appropriate local area flow. For example, the Clearwater River flow is related to the difference in flow between the Fort McMurray and Athabasca stations.

3.1.2 Analytical Details

All conditional probability relationships are formulated using recorded historical weekly flows. To ensure these relationships are representative of low flow conditions, high flows are screened out of the analysis. The criterion adopted to accomplish this is to exclude any data where the primary station flow is greater than the largest recorded 7Q10 flow at the primary station. For local area relationships, data are excluded if the local area flow exceeds the difference between the largest recorded 7Q10 flow at the downstream station and the average 7Q10 flow at the upstream station.

To account for travel time along the Athabasca River, secondary station flows are appropriately lagged before relationships are developed. This ensures that the same event is analysed throughout the basin. Travel times are initially computed on a daily basis, but are subsequently converted to weekly values to correspond to the format of the data. The assessment of annual travel time is presented in Table 3-1, while the weekly lags used in developing the conditional

TABLE 3-1

Travel Time Along The Athabasca River

River Reach	Channel Distance (km)	Velocity (and Weight) for Annual 7Q10 Flow		Average Travel Time (days)
		Upstream Node (m/s)	Downstream Node (m/s)	
Hinton to Windfall	171.7	0.18 (50%)	0.49 (50%)	5.9
Windfall to Whitecourt	31.9	0.49 (100%)		0.8
Whitecourt to Athabasca	342.3	0.49 (75%)	0.35 (25%)	9.5
Athabasca to Fort McMurray	403.0	0.35 (75%)	0.40 (25%)	12.9
Fort McMurray to Embarras Airport	181.2	0.40 (100%)		5.3

probability relationships are provided in Table 3-2. These weekly-averaged lags are appropriate for both the annual and open water analyses, with one exception. When Fort McMurray is the primary station, more conservative relationships are produced for the open water case if the lag between Athabasca and McMurray is considered to be one week instead of two. The actual travel time is somewhere inbetween: 12.9 days for flows representative of annual 7Q10 values; 8.5 days for open water values. The anomaly occurs because of the weekly time-step used in developing the relationships.

TABLE 3-2

Travel Time Used In Developing Conditional
Probability Relationships

River Reach	Average Travel Time
Hinton to Whitecourt	1 week
Whitecourt to Athabasca	1 week
Athabasca to Fort McMurray	2 weeks ¹
Fort McMurray to Embarras Airport	1 week

1 except where noted in Appendix B.

3.1.3 Conditional Probability Relationships

Details on the conditional probability relationships are provided in Appendix B. The primary/secondary station relationships for annual expected flow conditions are presented in Table B-1. Plots of these relationships are displayed in Figures B-1 through B-5. The annual relationship for the Athabasca River at Athabasca (station 07BE001) relative to the Athabasca River at Hinton (station 07AD002), shown in Figure 3-1, is representative these plots. The 50%, 75%, and 95% lines represent the probability of the secondary station flow being greater than or equal to the value on the line, given the appropriate flow at the primary station. For example, given the 7Q10 flow at Hinton (07AD002) of 15.8 cms, there is a 95% chance that the concurrent flow at Athabasca (07BE001) would be greater than 40 cms, a 75% chance that it

07BE001 RELATIVE TO 07AD002

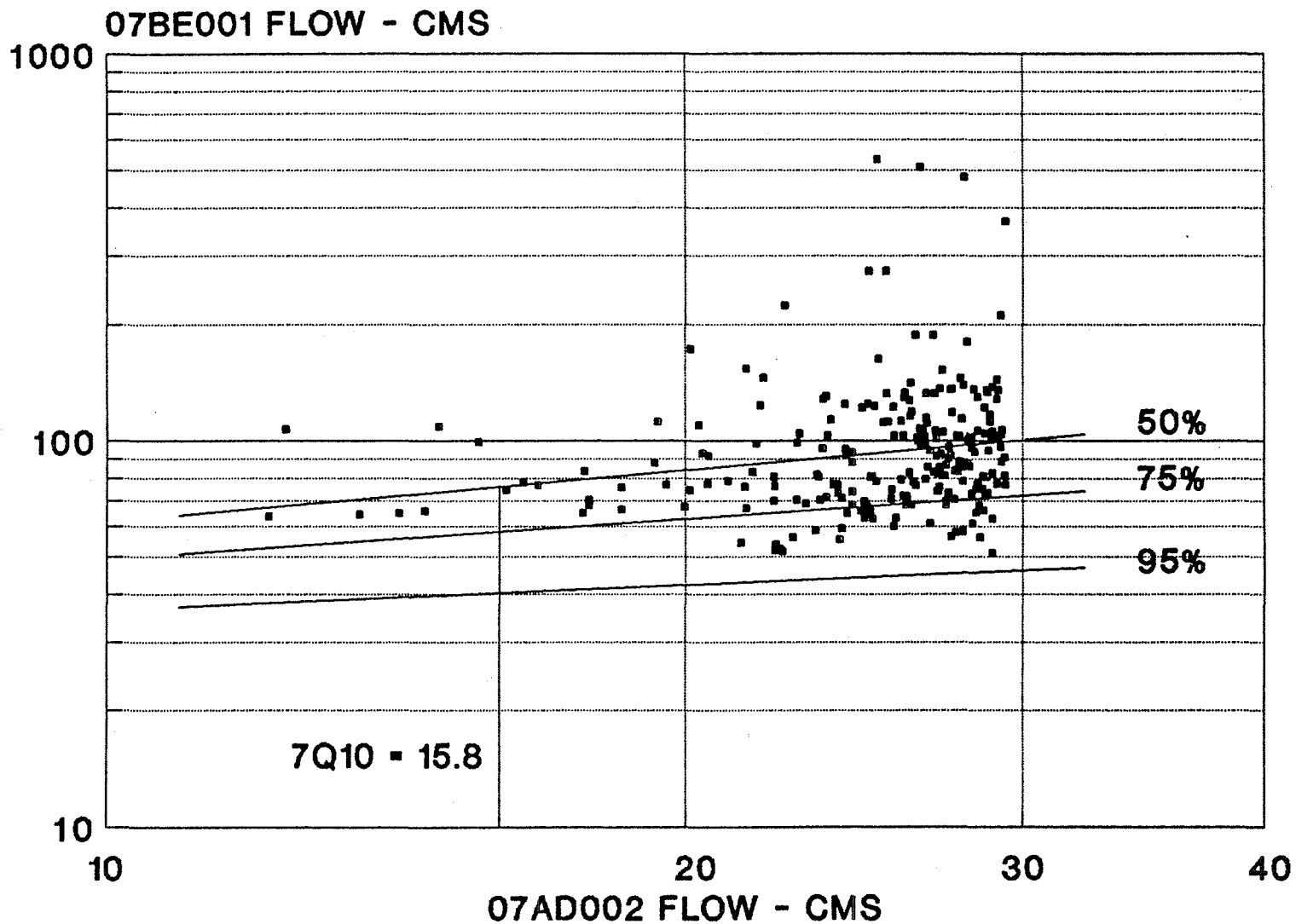


Figure 3-1: Example of Primary / Secondary Annual Relationship

would be greater than 58 cms and a 50% chance that it would be greater than 74.6 cms. The 50% line is the most probable flow and it is the component used in all relationships to develop concurrent flow scenarios for the entire basin. Other information contained in the plot includes the 7Q10 flow at the primary station along with the data points used to develop the relationships. Not all points used in the analysis are shown in all plots due to limitations of the graphical display program.

Similar relationships and plots for open water expected flow conditions are presented in Table B-3 and Figures B-9 through B-13.

Details on relationships for tributary streams and corresponding local areas are also provided in Appendix B. Annual and open water relationships are presented in Tables B-2 and B-4, respectively, while associated plots are presented in Figures B-6 through B-8 and Figures B-14 through B-16. The 50%, 75%, and 95% lines are again shown on the plot. As is the case for the primary/secondary relationships, the 50% line is used to develop the concurrent flow scenarios.

3.1.4 Other Basin Scenarios

The expected concurrent flow scenarios developed using the 50% relationships represent the most probable situations. However, it must be remembered that a 7Q10 event, particularly at the more downstream points of interest, can occur from some combination other than the 50% value. The likelihood of these flow scenarios occurring is examined at each point of interest. Details are provided for any situations where the departure from the expected flow scenario is pronounced and the chance of occurrence of such a pattern is at least 25%.

3.2 Annual Primary/Secondary Station Scenarios

The expected concurrent annual low flows at the primary and secondary stations corresponding to a 7Q10 flow at each of the four points of interest along the Athabasca River are presented in Table 3-3. The 7Q10 values at each location in Table 3-3 are circled to differentiate them from other values. A number of interesting patterns are evident throughout the basin, details of which are presented in the following sections.

3.2.1 Annual 7Q10 Flow at Hinton

The occurrence of an annual 7Q10 flow of 15.8 cms at Hinton reflects a low flow event originating in the mountainous headwaters of the Athabasca River. The event is fairly local since expected flows at the other stations along the Athabasca River are well above their respective 7Q10 values. This independence to the rest of the basin makes physical sense; climatic and physiographic conditions in the watershed upstream of Hinton are quite different from other parts of the basin. One notable flow increase occurs between Hinton and Windfall, where the local area flow contribution amounts to 31.3 cms. This raises the expected flow at Windfall to 47.1 cms. Recent streamflow measurements along this reach during the winter of 1987/1988 confirm the potential for such a local contribution. Variability in this local flow during a Hinton 7Q10 is large, ranging from 20 cms to over 43 cms. These flows have been lower but not during a Hinton 7Q10 event.

When a 7Q10 event occurs at a location other than Hinton, the expected flows at Hinton are almost double the 7Q10 flows. Values range from 25.1 cms to 31.4 cms. The good stability in these flows is typical of base flows from mountain areas.

TABLE 3-3

Initial Estimates of Concurrent 7-Day Annual Low Flows (cms) at Primary/Secondary Stations

Primary/Secondary Station	Point of Interest Where 7Q10 Flow Occurs			
	Hinton	Whitecourt	Athabasca	Fort McMurray
Athabasca River at Hinton	15.8	25.1	27.1	31.4
Athabasca River near Windfall	47.2	29.5	40.9	46.1
Athabasca River below Whitecourt	52.2	33.3	43.2	54.3
Athabasca River at Athabasca	74.6	82.0	53.3	66.3
Athabasca River below McMurray	163	207	109	114
Athabasca River at Embarras Airport	293	244	121	125

Note: Annual 7Q10 flows for each point of interest are circled.

The relationship between Embarras Airport and Hinton produces a concurrent flow of 293 cms at Embarras Airport, given a 7Q10 flow at Hinton. This flow is 130 cms above the Fort McMurray value and is not representative of the local area between the two stations. The cause of this is the poor relationship between Embarras Airport and Hinton. No values have been recorded at Embarras Airport during periods of very low flow at Hinton. Extending the relationship outside of the range of recorded data has produced the poor estimate. Consequently, the flows at Embarras Airport are adjusted to more realistic values, based on analyses at other points of interest, and are presented in Section 3.4 - Annual Basin Scenarios.

3.2.2 Annual 7Q10 Flow at Whitecourt

The occurrence of an annual 7Q10 flow of 33.3 cms at Whitecourt reflects a low flow event originating in the foothill region of the basin between Hinton and Windfall. Expected flow from this local area amounts to only 3.9 cms, one-tenth of the expected flow for the case of a 7Q10 event occurring at Hinton. Flow at Hinton accounts for 75% of the Whitecourt 7Q10 flow; the local area between Hinton and Windfall provides 12% while the remaining 13% comes from the McLeod River.

For an annual 7Q10 flow at Whitecourt, the flow at Athabasca is expected to be 71.0 cms. Expected local area flows between Whitecourt and Athabasca amount to 37.7 cms which is about the average January through March flow. This indicates that the flows originating from the portion of the Athabasca River basin downstream of Whitecourt are independent of the occurrence of a 7Q10 event at Whitecourt.

TABLE 3-4
Average January Through March Flow
at Selected Gauging Stations

Location	Flow at Location (cms)	Local Area Flow Between Locations Indicated (cms)
Athabasca River at Hinton	31	20
Athabasca River near Windfall	51	
McLeod River near Rosevear	5	43
Pembina River at Jarvie	6	
Lesser Slave River at Highway No. 2A	30	
Athabasca River at Athabasca	94	82
Clearwater River at Draper	54	
Athabasca River below McMurray	176	
Firebag River near the mouth	9	

When a 7Q10 event occurs at a location other than Whitecourt, the expected flow for the Athabasca River at Whitecourt ranges from 43.2 cms to 54.3 cms. As the January through March flow at Whitecourt averages 51 cms, this also indicates that the occurrence of an annual 7Q10 flow at Whitecourt is not associated with 7Q10 events elsewhere in the basin.

Once again the relationship for Embarras Airport is poor; revisions are incorporated in Section 3.4.

3.2.3 Annual 7Q10 Flow at Athabasca

The occurrence of an annual 7Q10 flow of 53.3 cms at Athabasca reflects a low flow event primarily originating in the Lesser Slave Lake basin. Expected flows from the local area between Whitecourt and Athabasca total 10.1 cms, only 25% of the normal January through March

flow of 40 cms. Lesser Slave River flows are normally 30 cms during this period. Its expected flow of 7.55 cms is less than 7Q10 event of 11.6 cms. Flow at Whitecourt accounts for 81% of the Athabasca 7Q10 flow; the Pembina River provides 3%; the Lesser Slave River provides 14%, while the remaining 2% comes from the rest of the local area. The concurrent flows at both Hinton and Windfall are 80% of their average January through March flows.

Looking downstream, the expected flow at Fort McMurray is 109 cms, slightly less than the 7Q10 flow of 114 cms at this site. The local area between Athabasca and Fort McMurray provides 55.7 cms or 68% of the normal January through March flow of 82 cms. The bulk of this local area contribution originates in the Clearwater River basin. The concurrent Clearwater River flow is 45.0 cms, about 83% of its winter normal flow. Thus, the remaining local area downstream of Athabasca is in a low flow pattern similar to the Lesser Slave River. The area provides only 38% of its normal winter flow.

The concurrent flow at Embarras Airport is 121 cms. The corresponding local area flow arising between Fort McMurray and Embarras Airport is therefore 12.0 cms. The greatest portion of this flow originates in the Firebag River basin, which contributes 6.1 cms.

3.2.4 Annual 7Q10 Flow at Fort McMurray

In the previous section it is shown that a 7Q10 event at Athabasca can produce a similar concurrent event at Fort McMurray. However, it is not the normal pattern for a Fort McMurray 7Q10 event. The occurrence of an annual 7Q10 flow of 114 cms at Fort McMurray normally reflects below average flows in the Clearwater River basin in conjunction with below average flows along the Athabasca River. Expected flows from the local area between Athabasca and Fort McMurray total 47.7 cms or 58% of the normal January through March flow of 82 cms. Clearwater River flows are normally 54 cms during this period. Its expected concurrent flow is 40.6 cms. Flow at Athabasca accounts for 58% of the Fort

McMurray 7Q10 flow; the Clearwater River provides 36%, while the remaining local area contributes 6%. Note that when a 7Q10 event occurs at Athabasca (that produces a 7Q10 at Fort McMurray), the forementioned contributions to the Fort McMurray flow are different, being 49%, 41%, and 10%, respectively. In the former case, the flows at Athabasca are 70% of normal winter flows, while the Clearwater flows are 75% of normal. This is the expected pattern, the one with a 50% chance of occurring. In the latter case, the flows at Athabasca are 57% of normal, while the Clearwater flows are 83% of normal. Given a 7Q10 event at Fort McMurray, this pattern has a 25% chance of occurring.

The concurrent flow at Embarras Airport is 125 cms. The local area flow arising between Fort McMurray and Embarras Airport is therefore 11.0 cms. Once again, the greatest portion of this flow originates in the Firebag River basin, which contributes 5.0 cms.

3.3 Open Water Primary / Secondary Station Scenarios

The expected concurrent open water low flows at the primary and secondary stations corresponding to a 7Q10 flow at each of the four point of interest along the Athabasca River are presented in Table 3-5. The 7Q10 values at each point of interest are circled to differentiate them from other values. The open water 7Q10 flows predominantly occur in late November and generally reflect the fall recession throughout the watershed. The mechanisms for producing an open water 7Q10 event at the various points of interest are similar to those of the annual 7Q10 events.

TABLE 3-5

Initial Estimates of Concurrent 7-Day Open Water Low Flows (cms) at Primary / Secondary Stations

Primary/Secondary Station	Point of Interest Where 7Q10 Flow Occurs			
	Hinton	Whitecourt	Athabasca	Fort McMurray
Athabasca River at Hinton	29.6	32.2	35.1	32.6
Athabasca River near Windfall	55.7	41.9	54.4	54.9
Athabasca River below Whitecourt	64.2	47.1	65.7	60.8
Athabasca River at Athabasca	120	87.4	84.4	87.8
Athabasca River below McMurray	226	166	164	145
Athabasca River at Embarras Airport	411	162	154	142

Note: Open water 7Q10 flows for each point of interest are circled.

3.3.1 Open Water 7Q10 Flow at Hinton

The occurrence of an open water 7Q10 flow of 29.6 cms at Hinton reflects a low flow event originating in the mountainous headwaters of the Athabasca River. As in the annual case, the event is very localized since expected flows from local areas downstream of Hinton are near the average values that occur during the end of November. Table 3-6 provides the average weekly flows for week 48 at various locations along the Athabasca River. Week 48 is comprised of the last four or five days in November along with the first two or three days in December.

TABLE 3-6

Average Weekly Flow for Week 48 at Selected Locations

Location	Flow at Location (cms)	Local Area Flow Between Locations Indicated (cms)
Athabasca River at Hinton	46.2	22.7
Athabasca River near Windfall	68.9	
McLeod River near Rosevear	10.4	12.1
Athabasca River at Whitecourt	81.0	
Pembina River at Jarvie	8.8	61.0
Lesser Slave River at Highway No. 2A	35.1	
Athabasca River at Athabasca	142	98.0
Clearwater River at Draper	73.1	
Athabasca River below McMurray	240	31.0
Firebag River near the mouth	12.7	
Athabasca River at Embarras Airport	271	

The local area flows between Hinton, Windfall, Whitecourt, Athabasca, and Fort McMurray, given an open water 7Q10 event at Hinton, are 26.1 cms, 8.5 cms, 55.8 cms, and 106 cms, respectively. All these values are close to the average week 48 flows presented in Table 3-6.

When an open water 7Q10 event occurs at a location other than Hinton, the expected flow for the Athabasca River at Hinton ranges from 32.2 cms to 35.1 cms, representing 70 to 75% of the normal week 48 flow. These values are just slightly above the Hinton open water 7Q10 flow of 29.6 cms. It is apparent that when an open water 7Q10 event occurs anywhere along the Athabasca River, the expected flow for the Athabasca River at Hinton is virtually the 7Q10 flow.

Once again the relationship between Embarras Airport and Hinton is poor. Since the flows from the areas downstream of Hinton are at or near the average flows for week 48, the flows in this period are used to produce expected flows downstream of Fort McMurray. The values are presented in Section 3.5 - Open Water Basin Scenarios.

3.3.2 Open Water 7Q10 Flow at Whitecourt

The occurrence of an open water 7Q10 flow of 47.1 cms at Whitecourt reflects a low flow event originating in the foothill region of the basin between Hinton and Whitecourt. The expected flow from the local area between Hinton and Windfall is only 9.7 cms, 43% of the average week 48 flow. The contribution from the McLeod River is similarly low. Flow for the Athabasca River at Hinton is 70% of its normal week 48 flow and accounts for 68% of the Whitecourt 7Q10 flow. The local area between Hinton and Windfall provides 21%, while the remaining 11% comes from the McLeod River. This distribution of flow approximates the annual case, with only the proportion provided by the local area between Hinton and Windfall being noticeably higher in the open water 7Q10 event.

Looking downstream, the concurrent expected flow from the local

area between Whitecourt and Athabasca is 40.3 cms or 66% of the normal week 48 flow. The expected flow for the Athabasca River at Athabasca is 87.4 cms, very close to its open water 7Q10 flow of 84.4 cms. Expected contributions between Athabasca and Fort McMurray amount to 78.6 cms or 80% of the average week 48 flow from this area. The expected flow for the Athabasca River at Fort McMurray is 166 cms, about 69% of its average week 48 flow.

When an open water 7Q10 event occurs at a location other than Whitecourt, the expected flow for the Athabasca River at Whitecourt ranges from 60.8 cms to 65.7 cms, or 75% to 80% of normal week 48 flow. The stability in these values reflect the stability of the concurrent flows originating from the Athabasca River upstream of Hinton, as well as, the foothill region. The fact that the flows are about 20% to 25% below the expected value during this period indicates that flows at Whitecourt have some bearing on open water 7Q10 events elsewhere in the basin. This is a departure from the annual 7Q10 flow scenarios where low flows at Whitecourt are not associated with 7Q10 events elsewhere in the basin.

3.3.3 Open Water 7Q10 Flow at Athabasca

The occurrence of an open water 7Q10 flow of 84.4 cms at Athabasca can arise from two district low flow events. The most probable scenario involves low flow events primarily originating in the Lesser Slave Lake basin. The expected flow from Lesser Slave Lake is only 11.3 cms, less than its 7Q10 flow of 15.3 cms. Flow at Whitecourt accounts for 78% of the Athabasca River at Athabasca 7Q10 flow; the Pembina River provides 6%; the Lesser Slave River provides 13% with the remaining 3% coming from the rest of the local area.

The other scenario that approximates an open water 7Q10 event at Athabasca corresponds to a 7Q10 flow occurring at Whitecourt. For this scenario, about 54% of the Athabasca River at Athabasca 7Q10 flow

originates upstream of Whitecourt; 9% is provided by the Pembina River; 25% is provided by the Lesser Slave River with the remaining 12% from the rest of the local area. Given the occurrence of a 7Q10 event at Athabasca, this scenario has a 25% chance of occurring. Although this is less than the expected scenario which involves substantially lower flows on the Lesser Slave River, it is still significant enough to warrant examination in any water quality modelling of this portion of the Athabasca River.

Looking downstream, the expected flow at Fort McMurray is 164 cms. The contribution from the local area between Athabasca and Fort McMurray is 79.6 cms or 81% of the normal week 48 flow from this area.

When an open water 7Q10 event occurs at a location other than Athabasca, the expected flow for the Athabasca River at Athabasca ranges from 87.4 cms to 120 cms. This range implies good variability of flows at Athabasca, which is deceiving. Only in the case of a Hinton 7Q10 event does the expected flow at Athabasca depart significant from its 7Q10 value of 84.4 cms. Open water 7Q10 events in the basin either influence the flows at Athabasca or are influenced by the flows at Athabasca.

3.3.4 Open Water 7Q10 Flow at Fort McMurray

The occurrence of an open water 7Q10 flow of 145 cms at Fort McMurray reflects simultaneous low flow events on both the Clearwater River and the Athabasca River. The expected flow on the Clearwater River is 46.5 cms, basically equal to its open water 7Q10 flow of 45.3 cms. The expected flow for the Athabasca River at Athabasca is 87.8 cms, also basically equal to its 7Q10 flow of 84.4 cms. Contributions upstream of Athabasca represent 61% of the Fort McMurray open water 7Q10 flow; the Clearwater contributes 32% while the rest of the local area between Athabasca and Fort McMurray provides the remaining 7%.

When an open water 7Q10 event occurs at a location other than Fort McMurray, the expected flow for the Athabasca River at Fort McMurray

ranges from 164 cms to 226 cms. Setting aside the 226 cms flow, which corresponds to an independent headwater 7Q10 event at Hinton, it is apparent that for a 7Q10 event in the basin, a flow of 165 cms can be expected at Fort McMurray, unless the Clearwater experiences below average streamflow recessions in the fall. This then produces the 7Q10 event at Fort McMurray.

3.4 Annual Basin Scenarios

The expected concurrent annual low flows at locations along the Athabasca River corresponding to a 7Q10 flow at each of the four points of interest are presented in Table 3-7. These scenarios represent the most likely flow conditions throughout the basin. Table 3-8 provides a second scenario for Fort McMurray where the flow at Athabasca is closer to its annual 7Q10 flow. This scenario has a 25% chance of occurring, given an annual 7Q10 event at Fort McMurray.

TABLE 3-7

Athabasca River Basin Annual 7Q10 Flows (cms)

	Point of Interest							
	Hinton		Whitecourt		Athabasca		Fort McMurray	
	Local	Total	Local	Total	Local	Total	Local	Total
Athabasca at Hinton		15.8		25.1		27.1		31.4
Hinton to Berland Local	5.2	21.0	0.7	25.8	2.3	29.4	2.4	33.8
Berland River	12.0	33.0	1.7	27.5	5.2	34.6	5.6	39.4
Sakwatamau River	2.9	35.9	0.4	27.9	1.3	35.9	1.4	40.8
Berland to Windfall Local	11.3	47.2	1.6	29.5	5.0	40.9	5.3	46.1
Athabasca near Windfall		47.2		29.5		40.9		46.1
McLeod at Whitecourt	5.0	52.2	3.8	33.3	2.3	43.2	8.2	54.3
Athabasca at Whitecourt		52.2		33.3		43.2		54.3
McLeod to Freeman Local	0.4	52.6	1.4	34.7	0.1	43.3	0.1	54.4
Freeman River	0.4	53.0	1.2	35.9	0.1	43.4	0.1	54.5
Freeman to Pembina Local	0.7	53.7	2.3	38.2	0.2	43.6	0.2	54.7
Pembina River	3.1	56.8	5.5	43.7	1.8	45.4	2.0	56.7
Pembina to Lesser Slave Local	1.6	58.4	5.0	48.7	0.3	45.7	0.5	57.2
Lesser Slave River	15.6	74.0	31.3	80.0	7.5	53.2	8.9	66.1
Lesser Slave to Athabasca Local	0.6	74.6	2.0	82.0	0.1	53.3	0.2	66.3
Athabasca at Athabasca		74.6		82.0		53.3		66.3
Athabasca to House Local	19.3	93.9	34.1	116.1	7.5	60.8	5.0	71.3
House River	0.8	94.7	1.4	117.5	0.3	61.1	0.2	71.5
House to Fort McMurray Local	7.5	102.2	13.2	130.7	2.9	64.0	1.9	73.4
Clearwater River	61.0	163.2	76.5	207.2	44.9	108.9	40.6	114.0
Athabasca below McMurray		163.2		207.2		108.9		114.0
Athabasca below McMurray to Poplar Local	0.1	163.3	0.1	207.3	0.1	109.0	0.1	114.1
Poplar Creek	0.0	163.3	0.0	207.3	0.1	109.1	0.1	114.2
Poplar to Steepbank Local	0.1	163.4	0.1	207.4	0.1	109.2	0.1	114.3
Steepbank River	0.4	163.8	0.4	207.8	0.5	109.7	0.5	114.7
Steepbank to Muskeg Local	0.2	164.0	0.2	208.0	0.3	110.0	0.3	115.1
Muskeg River	0.3	164.3	0.3	208.3	0.4	110.4	0.4	115.5
Muskeg to MacKay Local	0.0	164.3	0.0	208.3	0.0	110.4	0.0	115.5
MacKay River	0.5	164.8	0.5	208.8	0.5	110.9	0.4	115.9
MacKay to Ells Local	0.0	164.8	0.0	208.8	0.1	111.0	0.0	115.9
Ells River	1.0	165.8	1.0	209.8	1.5	112.5	1.4	117.3
Ells to Firebag Local	0.7	166.5	0.7	210.5	1.0	113.5	0.9	118.2
Firebag River	9.1	175.6	9.1	219.6	6.6	120.1	6.2	124.4
Firebag to Embarras Airport Local	0.5	176.1	0.5	220.1	0.7	120.8	0.7	125.1
Athabasca at Embarras Airport		176.1		220.1		120.8		125.1

TABLE 3-8

Alternate Annual Flow Scenario For Fort McMurray
As The Point of Interest

	Local	Total
Athabasca at Hinton		27.5
Hinton to Berland Local	2.3	29.8
Berland River	5.4	35.2
Sakwatamau River	1.3	36.5
Berland to Windfall Local	5.0	41.5
Athabasca near Windfall		41.5
McLeod at Whitecourt	2.5	44.0
Athabasca at Whitecourt		44.0
McLeod to Freeman Local	0.1	44.1
Freeman River	0.1	44.2
Freeman to Pembina Local	0.2	44.4
Pembina River	1.9	46.3
Pembina to Lesser Slave Local	0.4	46.7
Lesser Slave River	8.2	54.9
Lesser Slave to Athabasca Local	0.2	55.1
Athabasca at Athabasca		55.1
Athabasca to House Local	5.0	60.1
House River	0.3	60.4
House to Fort McMurray Local	3.3	63.7
Clearwater River	46.7	110.4
Athabasca below McMurray		110.4
Athabasca below McMurray to Poplar Local	0.2	110.6
Poplar Creek	0.1	110.7
Poplar to Steepbank Local	0.1	110.8
Steepbank River	0.5	111.3
Steepbank to Muskeg Local	0.3	111.6
Muskeg River	0.4	112.0
Muskeg to MacKay Local	0.0	112.0
MacKay River	0.4	112.4
MacKay to Ells Local	0.0	112.4
Ells River	1.4	113.8
Ells to Firebag Local	0.9	114.7
Firebag River	6.2	120.9
Firebag to Embarras Airport Local	0.7	121.6
Athabasca at Embarras Airport		121.6

3.5 Open Water Basin Scenario

The expected concurrent open water low flows at locations along the Athabasca River corresponding to a 7Q10 flow at each of the four points of interest are presented in Table 3-9. As in the annual case, these scenarios represent the most likely flow conditions throughout the basin. Table 3-10 provides a second flow scenario for Athabasca where the flow at Whitecourt is closer to its open water 7Q10 value. This scenario has a 25% chance of occurring given an open water 7Q10 event at Athabasca.

TABLE 3-9

Athabasca River Basin Open Water 7Q10 Flows (cms)

	Hinton		Point of Interest				Fort McMurray	
			Whitecourt		Athabasca			
	Local	Total	Local	Total	Local	Total	Local	Total
Athabasca at Hinton		29.6		32.2		35.1		32.6
Hinton to Berland Local	4.3	33.9	1.6	33.8	3.2	38.3	3.7	36.3
Berland River	10.1	44.0	3.7	37.5	7.4	45.7	8.5	44.8
Sakwatamau River	2.4	46.4	0.9	38.4	1.8	47.5	2.1	46.9
Berland to Windfall Local	9.3	55.7	3.5	41.9	6.9	54.4	8.0	54.9
Athabasca near Windfall		55.7		41.9		54.4		54.9
McLeod at Whitecourt	8.5	64.2	5.2	47.1	11.3	65.7	5.9	60.8
Athabasca at Whitecourt		64.2		47.1		65.7		60.8
McLeod to Freeman Local	2.1	66.3	1.3	48.4	0.3	66.0	0.6	61.4
Freeman River	1.9	68.2	1.1	49.5	0.2	66.2	0.5	61.9
Freeman to Pembina Local	3.4	71.6	2.0	51.5	0.4	66.6	1.0	62.9
Pembina River	10.1	81.7	8.2	59.7	5.0	71.6	6.4	69.3
Pembina to Lesser Slave Local	7.5	89.2	4.5	64.2	1.0	72.6	2.2	71.5
Lesser Slave River	28.1	117.3	21.4	85.6	11.4	84.0	15.4	86.9
Lesser Slave to Athabasca Local	2.9	120.2	1.8	87.4	0.4	84.4	0.9	87.8
Athabasca at Athabasca		120.2		87.4		84.4		87.8
Athabasca to House Local	23.0	143.2	13.8	101.2	14.3	98.7	7.6	95.4
House River	0.9	144.1	0.6	101.8	0.6	99.3	0.3	95.7
House to Fort McMurray Local	8.9	153.0	5.4	107.2	5.6	104.9	2.9	98.6
Clearwater River	72.9	225.9	58.4	165.6	59.2	164.1	46.4	145.0
Athabasca below McMurray		225.9		165.6		164.1		145.0
Athabasca below McMurray to Poplar Local	0.6	226.5	0.6	166.2	0.6	164.7	0.4	145.4
Poplar Creek	0.2	226.7	0.2	166.4	0.2	164.9	0.3	145.7
Poplar to Steepbank Local	0.4	227.1	0.4	166.8	0.4	165.3	0.3	146.0
Steepbank River	1.1	228.2	1.1	167.9	1.1	166.4	1.8	147.8
Steepbank to Muskeg Local	1.3	229.5	1.3	169.2	1.3	167.7	0.9	148.7
Muskeg River	0.9	230.4	0.9	170.1	0.9	168.6	1.2	149.9
Muskeg to MacKay Local	0.1	230.5	0.1	170.2	0.1	168.7	0.1	150.0
MacKay River	1.6	232.1	1.6	171.8	1.6	170.3	4.2	154.2
MacKay to Ells Local	0.2	232.3	0.2	172.0	0.2	170.5	0.2	154.4
Ells River	3.5	235.8	3.5	175.5	3.5	174.0	3.2	157.6
Ells to Firebag Local	4.7	240.5	4.7	180.2	4.7	178.7	3.4	161.0
Firebag River	12.7	253.2	12.7	192.9	12.7	191.4	17.0	178.0
Firebag to Embarras Airport Local	3.4	256.6	3.4	196.3	3.4	194.8	2.4	180.4
Athabasca at Embarras Airport		256.6		196.3		194.8		180.4

TABLE 3-10

Alternate Open Water Flow Scenario For Athabasca
As The Point of Interest

	Local	Total
Athabasca at Hinton		29.7
Hinton to Berland Local	1.9	31.6
Berland River	4.3	35.9
Sakwatamau River	1.0	36.9
Berland to Windfall Local	4.0	40.9
Athabasca near Windfall		40.9
McLeod at Whitecourt	5.1	46.0
Athabasca at Whitecourt		46.0
McLeod to Freeman Local	1.2	47.2
Freeman River	1.0	48.2
Freeman to Pembina Local	1.9	50.1
Pembina River	8.0	58.1
Pembina to Lesser Slave Local	4.2	62.3
Lesser Slave River	20.6	82.9
Lesser Slave to Athabasca Local	1.6	84.5
Athabasca at Athabasca		84.5
Athabasca to House Local	14.3	98.8
House River	0.6	99.4
House to Fort McMurray Local	5.6	105.0
Clearwater River	59.2	164.2
Athabasca below McMurray		164.2
Athabasca below McMurray to Poplar Local	0.6	164.8
Poplar Creek	0.2	165.0
Poplar to Steepbank Local	0.4	165.4
Steepbank River	1.1	166.5
Steepbank to Muskeg Local	1.3	167.8
Muskeg River	0.9	168.7
Muskeg to MacKay Local	0.1	168.8
MacKay River	1.6	170.4
MacKay to Ells Local	0.2	170.6
Ells River	3.5	174.1
Ells to Firebag Local	4.7	178.8
Firebag River	12.7	191.5
Firebag to Embarras Airport Local	3.4	194.9
Athabasca at Embarras Airport		194.9

4.0 SUMMARY OF FINDINGS

The following statements provide a brief summary of the effects of a 7Q10 event along the Athabasca River.

1. An annual 7Q10 event at Hinton reflects a low flow event originating in the mountains that is independent of the rest of the Athabasca River basin.
2. An annual 7Q10 event at Whitecourt reflects a low flow event originating in the foothill region of the basin. The Athabasca River at Hinton accounts for 75% of the Whitecourt flow. The occurrence of an annual 7Q10 event at Whitecourt is independent of the rest of the basin.
3. An annual 7Q10 event at Athabasca reflects a low flow event primarily originating in the Lesser Slave Lake basin. Flow at Whitecourt accounts for 81% of the flow at Athabasca. Given a 7Q10 flow at Athabasca, the expected concurrent flow at Fort McMurray is basically its 7Q10 value.
4. An annual 7Q10 event at Fort McMurray normally reflects below average flows in the Clearwater River basin coupled with below average flows at Athabasca. The portion contributed by each area varies. In the expected or 50% scenario, flows at Fort McMurray are comprised of 58% upstream of Athabasca, 36% from the Clearwater River and 6% local. There is a 25% chance that this distribution is 49%, 41% and 10%, respectively. This latter case reflects a concurrent 7Q10 event at Athabasca.
5. An open water 7Q10 event at Hinton reflects a low flow event originating in the mountains that is independent of the rest of the basin. However, when an open water 7Q10 flow event occurs elsewhere in the basin, the flow at Hinton is just marginally above its 7Q10 flow.

6. An open water 7Q10 event at Whitecourt reflects a low flow event originating in the foothill region of the basin. The expected concurrent flow at Athabasca is basically its 7Q10 open water flow. Flows at Whitecourt have some bearing on open water 7Q10 events at downstream locations.
7. An open water 7Q10 event at Athabasca normally reflects a low flow event primarily originating in the Lesser Slave Lake basin. For this scenario, flow at Whitecourt accounts for 78% of the flow at Athabasca. There is a 25% chance that this area contributes only 54% of the flow at Athabasca. This latter scenario reflects a concurrent 7Q10 event at Whitecourt.
8. An open water 7Q10 event at Fort McMurray reflects simultaneous low flow events on both the Athabasca River and Clearwater River. The expected concurrent flows at both Athabasca and on the Clearwater River approximate their 7Q10 values.

5.0 REFERENCES

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APPENDIX A
Site-Specific 7Q10 Data and Frequencies

TABLE A-1
 Historical Annual 7Q10 Flows (cms) at Major Streamflow Stations

Water Year	Athabasca River at Hinton	Athabasca River near Windfall	McLeod River near Rosevear	Athabasca River at Whitecourt	Pembina River at Jarvie	Lesser Slave River at Hwy 2A	Athabasca River at Athabasca	Clearwater River at Draper	Athabasca River below McMurray
1914-15			2.33				79.7		
1915-16	23.1		1.75			15.8	64.8		
1916-17	24.1		2.21			15.4	57.5		
1917-18	29.0		5.16			15.3	77.5		
1918-19	27.3		2.00			16.7	52.9		
1919-20	22.0		3.56			24.5	72.9		
1920-21	26.3		2.15			39.2	88.2		
1921-22			0.60			27.8	68.6		
1922-23			0.10			16.5	48.3		
1923-24	25.7					12.0	53.9		
1924-25	21.4					18.2	49.5		
1925-26	29.4					22.6	117.6		
1926-27	23.7					17.1	103.0		
1927-28	21.5					35.2	95.4		
1928-29	20.9					19.8	74.7		
1929-30	24.6					19.2	56.2		
1930-31	21.5					20.5			
1931-32	20.1								
1932-33	18.6								
1933-34	21.5								
1934-35	23.8								
1935-36	8.9					50.1			
1936-37	10.7					46.0			
1937-38	17.0					30.0			
1938-39	17.6					18.9			

TABLE A-1
 Historical Annual 7Q10 Flows (cms) at Major Streamflow Stations

Water Year	Athabasca River at Hinton	Athabasca River near Windfall	McLeod River near Rosevear	Athabasca River at Whitecourt	Pembina River at Jarvie	Lesser Slave River at Hwy 2A	Athabasca River at Athabasca	Clearwater River at Draper	Athabasca River below McMurray
1939-40						12.7			
1940-41									
1941-42									
1942-43									
1943-44									
1944-45									
1945-46									
1946-47									
1947-48									
1948-49									
1949-50									
1950-51									
1951-52							68.7		
1952-53							48.5		
1953-54							65.7		
1954-55							57.1		
1955-56	23.8						64.7		
1956-57	23.6						46.9		
1957-58	21.5		8.59				117.4	46.3	163.6
1958-59	17.4		2.49				62.8	45.9	108.1
1959-60	28.6		4.02				58.7	59.1	138.7
1960-61	12.8	44.8	3.64	51.3		9.58	62.7	66.5	166.7
1961-62	12.0	34.5	4.41	40.3	.840	7.80	63.3	33.0	118.7
1962-63	12.1	33.4	2.39	36.2	2.49		93.0	56.0	184.0
1963-64	18.8	24.6	2.50	27.9	1.04		67.6	41.9	

TABLE A-1
Historical Annual 7Q10 Flows (cms) at Major Streamflow Stations

Water Year	Athabasca River at Hinton	Athabasca River near Windfall	McLeod River near Rosevear	Athabasca River at Whitecourt	Pembina River at Jarvie	Lesser Slave River at Hwy 2A	Athabasca River at Athabasca	Clearwater River at Draper	Athabasca River below McMurray
1964-65	21.7	32.4	4.31	37.6	3.83	36.8	101.3	41.4	143.6
1965-66	18.6	43.3	5.26	48.6	4.38	43.7	82.7	40.2	183.7
1966-67	29.0	30.8	4.98	37.2	3.85	26.0	93.0	53.3	143.3
1967-68	27.1	30.2	2.23	32.4	.590	6.82	52.3	30.9	111.1
1968-69	28.6	32.1		49.1	1.58	8.73	55.3	51.2	110.3
1969-70	24.9	37.9		51.1	4.15	14.1	73.6	37.7	139.6
1970-71	20.7	33.1	3.40	37.3	1.53	17.4	69.7	54.1	115.6
1971-72	27.7	38.1	5.41	44.5	4.08	29.7	86.6	34.6	155.5
1972-73	29.4	49.9	8.02	61.5	3.98	29.3	95.6	46.6	157.1
1973-74	27.0	42.5	5.50	48.8	3.34	31.2	101.0	55.5	183.4
1974-75	28.4	39.6	3.59	43.2	3.48	42.9	97.9	59.5	186.9
1975-76	24.0	42.2	3.92	46.2	3.11	32.1	89.9	52.9	171.9
1976-77	26.2	45.8	3.43	50.1	3.06	39.3	93.4	40.4	131.5
1977-78	21.5	32.8	4.29	38.6	5.86	43.2	95.5	55.9	146.2
1978-79	24.9		2.99		3.55	30.9	93.4	52.9	149.1
1979-80	18.6		4.18		3.44	38.5	87.3	50.0	178.0
1980-81	24.4		3.94		7.50	20.7	95.0	44.1	157.7
1981-82	18.2		2.10		.850	13.2	58.6	26.5	95.1
1982-83	28.3		5.44		5.50	16.1	84.0	42.0	152.6
1983-84	27.6		3.36		4.24	30.3	106.1	51.0	164.3
1984-85	19.5		5.85		4.44	23.7	90.0	51.2	164.3
1985-86	22.6		7.67		5.75	23.3	100.0	45.8	166.0
1986-87	26.1		7.05		6.20	29.0	113.0	52.4	167.0
1987-88	23.2		3.88		1.03	12.6	55.4	32.9	90.8

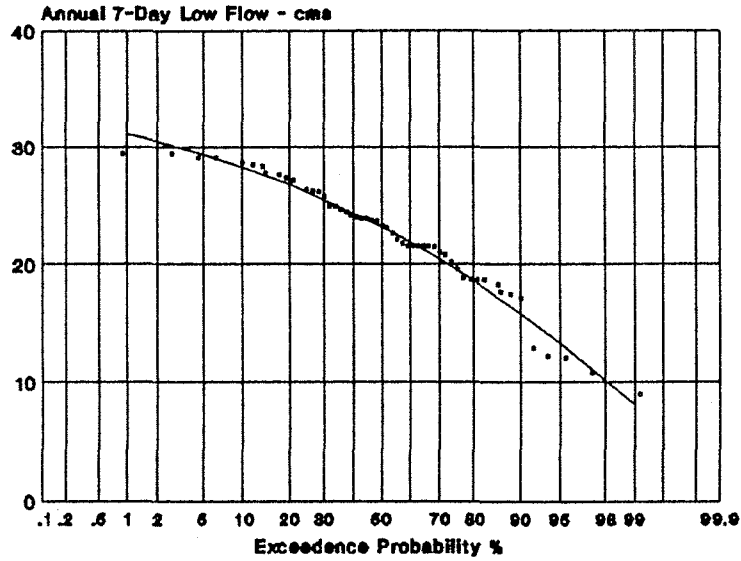
TABLE A-2
 Historical Annual 7Q10 Flows (cms) at Other Streamflow Stations

Water Year	Poplar Creek near Fort McMurray	Steepbank River near Fort McMurray	Muskeg River near Fort MacKay	MacKay River near Fort MacKay	Ells River near the mouth	Firebag River near the mouth
1969-70						
1970-71						
1971-72						7.08
1972-73	.01			.03		5.56
1973-74	.01	.52	.21	.44		8.92
1974-75	0.0	.40	.34	.44		9.17
1975-76	0.0	.40	.43	.44	1.39	8.52
1976-77	0.0	.34	.14	.22	.40	8.48
1977-78	0.0	.26	.23	.30	.85	6.98
1978-79	0.0	.32	.46	.42	1.60	7.74
1979-80	0.0	.17	.20	.25	.98	7.30
1980-81	0.0	.27	.29	.39	.76	8.05
1981-82	0.0	.05	.11	.11	.04	5.44
1982-83	0.0	.30	.21	.39	.64	9.09
1983-84	0.0	.08	.04	.12	1.20	7.00
1984-85	0.0	.35	.21	.48	.64	7.32
1985-86	0.0	.21	.26	.11	.30	7.70
1986-87		.39	.34			11.9
1987-88						

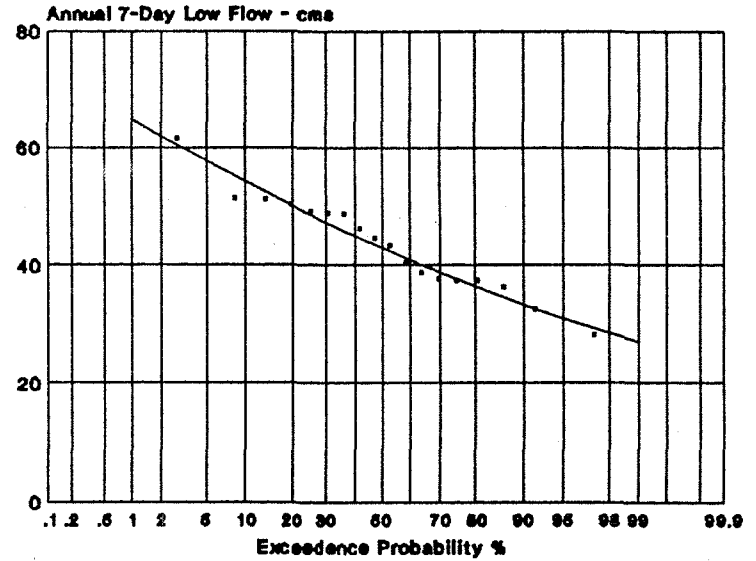
TABLE A-3
Annual 7Q10 Frequency Distributions

Location	Exceedence Probability (%)											
	5	10	20	30	40	50	60	70	80	90	95	99
Athabasca River at Hinton	29.4	28.3	26.8	25.5	24.3	23.2	21.9	20.4	18.6	15.8	13.3	8.07
Athabasca River near Windfall	48.7	45.8	42.5	40.2	38.4	36.7	35.0	33.4	31.5	29.0	27.0	23.7
McLeod River near Rosevear	7.31	6.45	5.46	4.79	4.24	3.75	3.29	2.81	2.27	1.59	1.06	0.17
Athabasca River at Whitecourt	57.8	54.3	50.1	47.3	45.0	42.9	40.9	38.8	36.4	33.3	30.9	26.8
Pembina River at Jarvie	6.86	5.89	4.84	4.16	3.63	3.17	2.76	2.35	1.93	1.43	1.09	0.60
Lesser Slave River at Hwy. No. 2A	45.4	39.5	33.1	28.9	25.7	22.8	20.2	17.6	14.9	11.6	9.29	5.84
Athabasca River at Athabasca	113	104	93.6	86.6	80.9	75.9	71.0	66.0	60.5	53.3	47.9	38.7
Clearwater River at Draper	63.3	59.2	54.5	51.3	48.6	46.2	43.9	41.5	38.8	35.2	32.5	27.7
Athabasca River below McMurray	196	184	171	161	153	146	140	133	125	115	107	92.6
Poplar Creek near Fort McMurray	.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Steepbank River near Fort McMurray	.49	.45	.40	.36	.33	.30	.27	.23	.18	.12	.06	0.0
Muskeg River near Fort MacKay	.45	.40	.34	.31	.27	.24	.21	.18	.15	.10	.07	0.0
MacKay River near Fort MacKay	.53	.48	.43	.38	.34	.31	.27	.22	.17	.09	.03	0.0
Ells River near the Mouth	2.24	1.88	1.49	1.24	1.04	.88	.73	.59	.43	.19	0.0	0.0
Firebag River near the Mouth	10.7	9.94	9.09	8.52	8.08	7.69	7.32	6.96	6.58	6.10	5.76	5.23

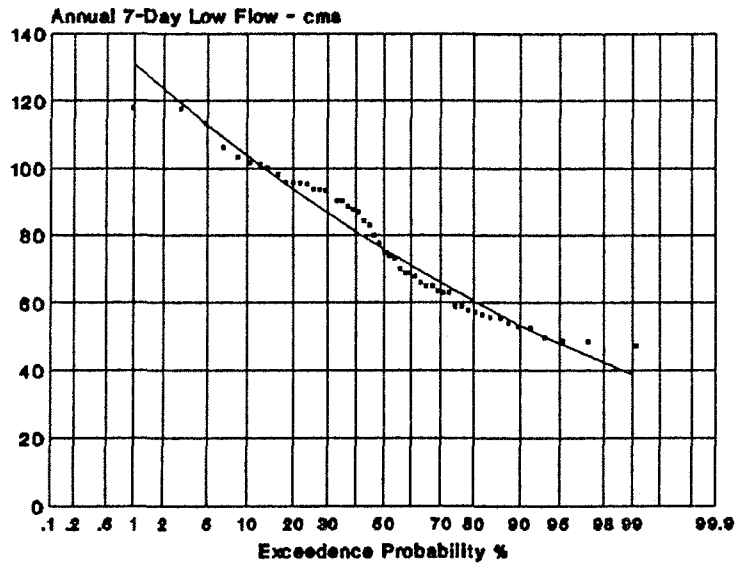
Athabasca River At Hinton



Athabasca River At Whitecourt



Athabasca River At Athabasca



Athabasca River Below McMurray

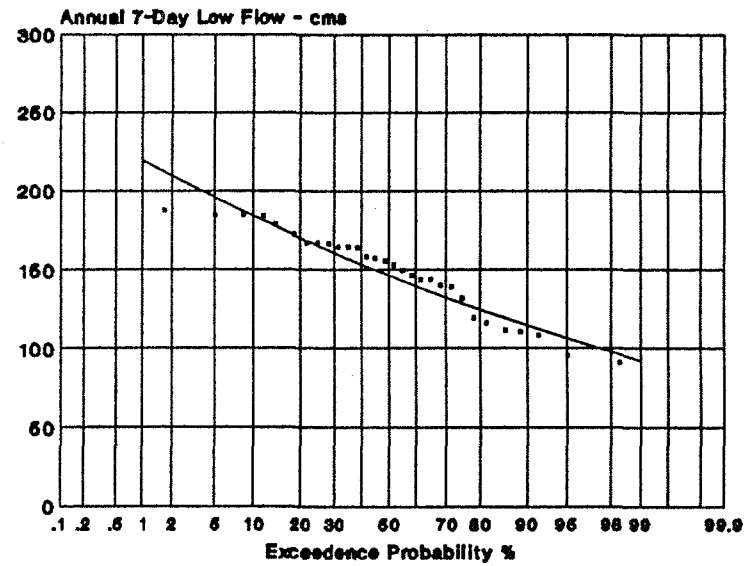


Figure A-1: Annual 7-Day Low Flow Frequency Curves for Points of Interest

TABLE A-4
 Historical Open Water 7Q10 Flows (cms) at Major Streamflow Stations

Water Year	Athabasca River at Hinton	Athabasca River near Windfall	McLeod River near Rosevear	Athabasca River at Whitecourt	Pembina River at Jarvie	Lesser Slave River at Hwy 2A	Athabasca River at Athabasca	Clearwater River at Draper	Athabasca River below McMurray
1914			7.16				113.0		
1915	56.6		10.4				120.0		
1916	46.7		11.6			21.0	96.5		
1917	50.8		12.2			27.2	120.0		
1918	31.7		4.57			19.9	103.0		
1919	39.9		8.23			22.6	140.0		
1920	42.7		8.84			32.1	138.0		
1921	55.0		3.37			33.5	126.0		
1922			3.73			23.6	102.0		
1923	47.7		10.5			22.7	215.0		
1924	38.3					19.4	173.0		
1925	36.3					27.2	163.0		
1926	37.0					29.1	185.0		
1927	28.5					35.3	149.0		
1928	36.7					30.0	134.0		
1929	53.5					30.9	121.0		
1930	50.4		10.2			44.2	190.0		
1931	40.8								
1932	30.4								
1933	71.9								
1934	59.7								
1935	38.8								
1936	49.0					74.3			
1937	41.2					41.6			
1938	55.8					23.2			
1939	52.7					19.6			

TABLE A-4
 Historical Open Water 7Q10 Flows (cms) at Major Streamflow Stations

Water Year	Athabasca River at Hinton	Athabasca River near Windfall	McLeod River near Rosevear	Athabasca River at Whitecourt	Pembina River at Jarvie	Lesser Slave River at Hwy 2A	Athabasca River at Athabasca	Clearwater River at Draper	Athabasca River below McMurray
1940									
1941									
1942									
1943									
1944									
1945									
1946									
1947									
1948									
1949									
1950									
1951							87.9		
1952							99.8		
1953							124.0		
1954							200.0		
1955	34.0						64.7		
1956	37.3						77.3		
1957	43.0				12.3		213.0		
1958	48.9		2.93		5.82		66.0	65.6	141
1959	38.8		11.2		11.2		68.7	90.4	216
1960	45.3	44.9	5.59	51.3	6.98		89.6	92.7	304
1961	38.4	95.9	11.5	118.0	2.58	7.79	115.0	45.8	172
1962	36.2	94.3	16.2	110.0	11.4		121.0	101.0	298
1963	43.9	73.5	6.35	79.9	1.04		93.9	66.9	185
1964	53.9	64.2	14.7	78.8	10.6	47.4	173.0	60.0	158

TABLE A-4
 Historical Open Water 7Q10 Flows (cms) at Major Streamflow Stations

Water Year	Athabasca River at Hinton	Athabasca River near Windfall	McLeod River near Rosevear	Athabasca River at Whitecourt	Pembina River at Jarvie	Lesser Slave River at Hwy 2A	Athabasca River at Athabasca	Clearwater River at Draper	Athabasca River below McMurray
1965	70.2	93.2	10.8	112.0	18.1	64.0	181.0	78.3	256
1966	49.2	103	8.16	131.0	8.86	32.6	177.0	70.0	262
1967	31.4	80.3	4.16	84.4	2.47	8.29	107.0	65.7	189
1968	39.6	56.0	9.55	66.3	3.90	8.73	88.4	74.8	227
1969	48.4	37.9		136.0	9.23	17.3	150.0	58.8	
1970	20.2	39.1	4.52	43.6	1.83	22.1	71.0	54.1	115
1971	38.0	71.4	14.3	85.7	12.6	37.7	172.0	49.7	249
1972	29.7	51.2	12.1	63.3	8.39	38.1	153.0	59.8	168
1973	33.7	51.3	9.63	66.5	8.37	42.3	119.0	116.0	294
1974	44.8	67.1	6.11	74.7	8.96	50.1	130.0	73.0	219
1975	42.3	57.4	4.03	61.5	5.10	48.5	155.0	106.0	242
1976	38.1	68.0	5.23	74.5	5.41	60.3	112.0	41.9	135
1977	21.5	32.8	5.63	38.6	6.63	63.1	167.0	57.0	147
1978	46.1		9.25		15.00	50.8	114.0	74.1	330
1979	25.5		4.64		4.59	64.9	117.0	99.1	257
1980	29.1		8.60		13.7	44.5	166.0	70.4	383
1981	32.4		8.49		4.69	27.1	88.5	35.1	178
1982	41.6		15.7		10.5	20.1	129.0	50.7	220
1983	41.0		6.17		6.13	28.7	168.0	61.2	412
1984	42.9		7.89		4.84	30.3	212.0	76.7	281
1985	34.3		11.5		8.51	27.7	115.0	55.8	251
1986	44.3		21.2		4.07	35.3	179.0	77.0	266
1987	43.3		7.98		388	17.1	104.0	44.9	176

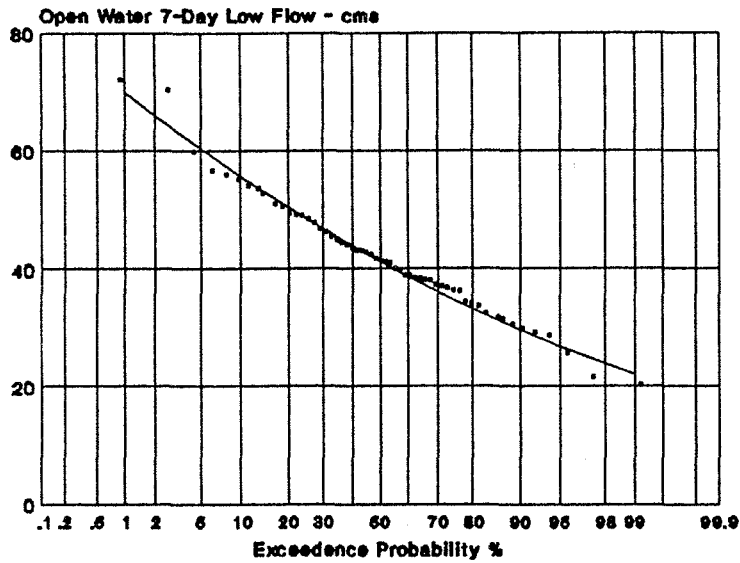
TABLE A-5
 Historical Open Water 7Q10 Flows (cms) at Other Streamflow Stations

Water Year	Poplar Creek near Fort McMurray	Steepbank River near Fort McMurray	Muskeg River near Fort MacKay	MacKay River near Fort MacKay	Ells River near the mouth	Firebag River near the mouth
1972				.42		13.6
1973	.10			2.80		17.4
1974	.06	1.12	.72	1.56		18.0
1975	.09	1.22	1.55	3.72	4.59	16.3
1976	.04	.88	.50	.81	1.51	11.9
1977	.09	.54	.72	.79	2.77	9.84
1978	.12	1.27	.72	1.09	3.60	14.3
1979	.08	1.48	.96	.76	2.43	12.1
1980	.01	.27	.26	.50	1.28	9.86
1981	.01	.05	.11	.11	.48	6.27
1982	.15	.52	.27	.58	.95	11.5
1983	.02	.63	.31	1.56	2.16	10.9
1984	.19	.82	.30	2.55	5.03	13.0
1985	.04	.36	.26	.36	1.09	10.7
1986	.06	.94	.75	1.03	1.36	12.8
1987						

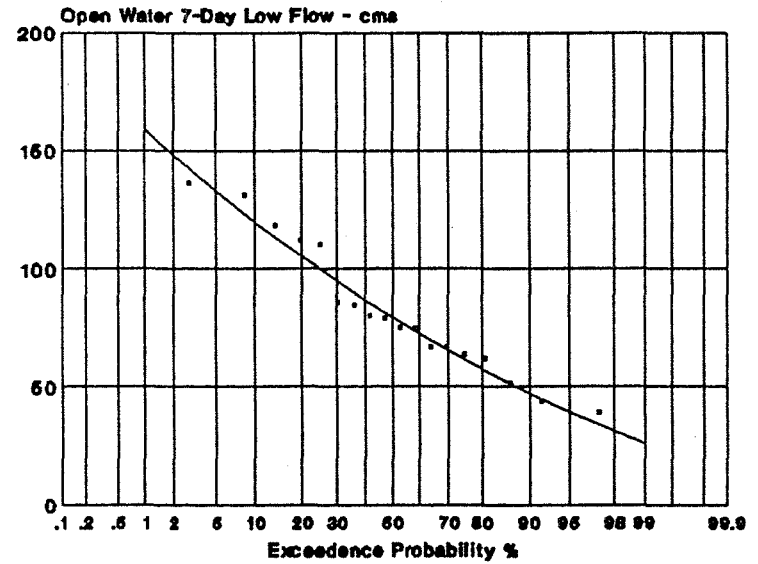
TABLE A-6
Open Water 7Q10 Frequency Distributions

Location	Exceedence Probability (%)											
	5	10	20	30	40	50	60	70	80	90	95	99
Athabasca River at Hinton	60.4	55.7	50.4	46.8	43.9	41.2	38.7	36.1	33.3	29.6	26.7	22.0
Athabasca River near Windfall	105	94.1	82.5	74.8	68.6	63.1	58.0	52.9	47.3	40.3	35.2	27.0
McLeod River near Rosevear	16.3	14.3	12.0	10.5	9.29	8.28	7.34	6.41	5.44	4.26	3.43	2.20
Athabasca River at Whitecourt	133	120	105	95.2	87.0	79.6	72.6	65.4	57.4	47.1	39.2	25.9
Pembina River at Jarvie	15.5	13.2	10.8	9.17	7.96	6.92	5.99	5.09	4.16	3.09	2.37	1.39
Lesser Slave River at Hwy. No. 2A	62.8	54.6	45.6	39.7	35.1	31.1	27.4	23.8	20.0	15.3	12.1	7.22
Athabasca River at Athabasca	205	186	165	150	139	129	119	109	98.2	84.4	74.1	57.1
Clearwater River at Draper	105	95.5	85.0	77.9	72.2	67.1	62.3	57.4	52.1	45.3	40.2	31.8
Athabasca River below McMurray	362	328	290	264	243	225	207	190	170	145	126	96
Poplar Creek near Fort McMurray	.18	.15	.11	.09	.08	.06	.05	.04	.03	.02	.01	.01
Steepbank River near Fort McMurray	1.48	1.32	1.14	1.00	.88	.78	.67	.55	.42	.23	.07	0.0
Muskeg River near Fort MacKay	1.33	1.10	.85	.69	.58	.48	.40	.32	.24	.16	.11	.05
MacKay River near Fort MacKay	3.28	2.61	1.92	1.51	1.21	.97	.76	.58	.41	.24	.15	.07
Ells River near the Mouth	6.08	5.04	3.95	3.26	2.74	2.31	1.92	1.56	1.20	.80	.55	.23
Firebag River near the Mouth	17.7	16.6	15.2	14.2	13.3	12.5	11.7	10.9	9.95	8.64	7.57	5.61

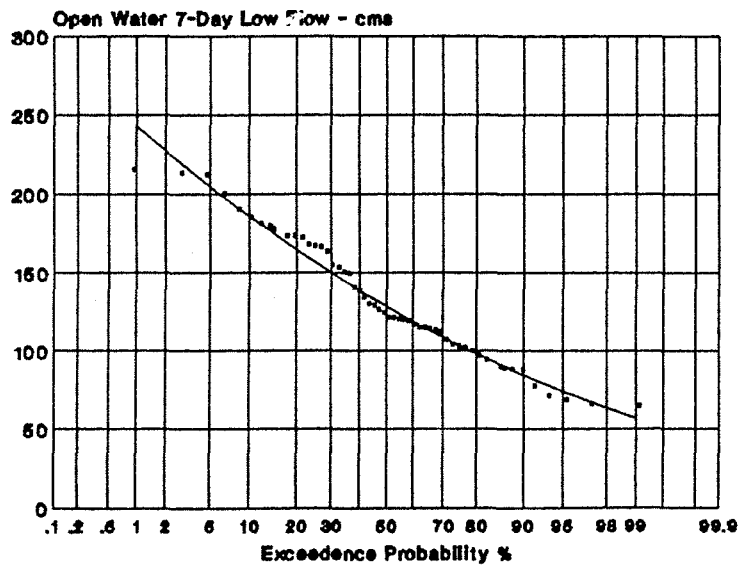
Athabasca River At Hinton



Athabasca River At Whitecourt



Athabasca River At Athabasca



Athabasca River Below McMurray

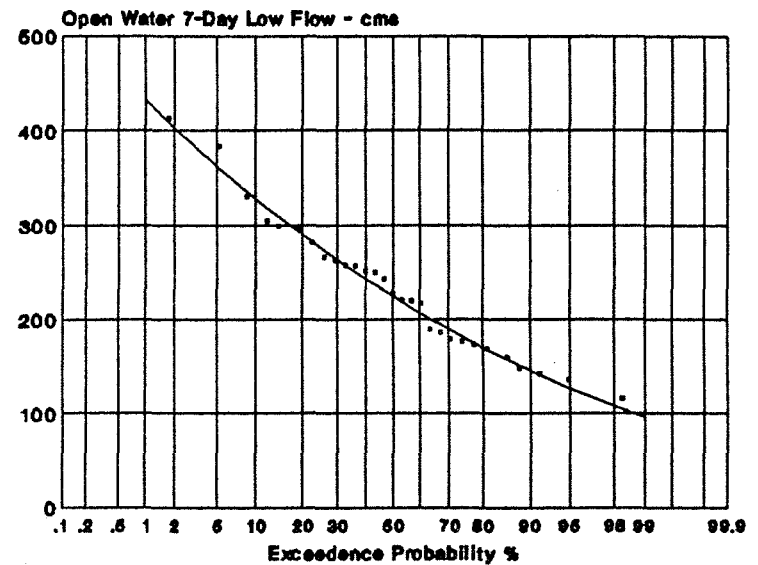


Figure A-2: Open Water 7-Day Low Flow Frequency Curves for Points of Interest

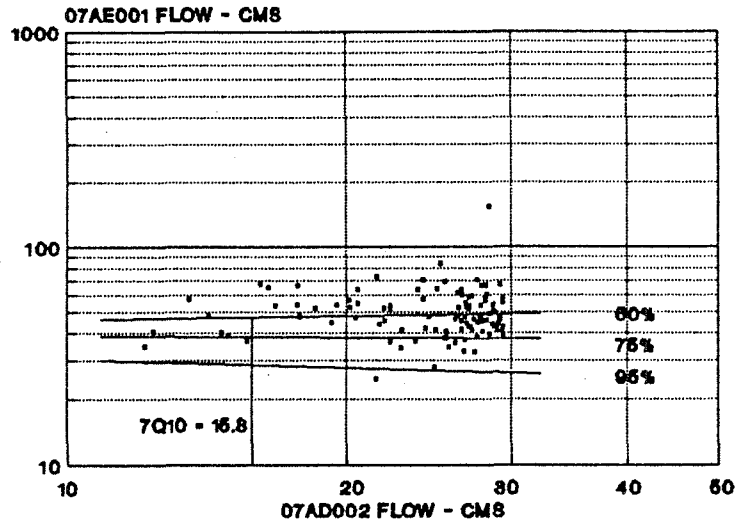
APPENDIX B
Conditional Probability Relationships

TABLE B-1
Primary / Secondary Station Annual 7Q10 Expected Flow Relationships

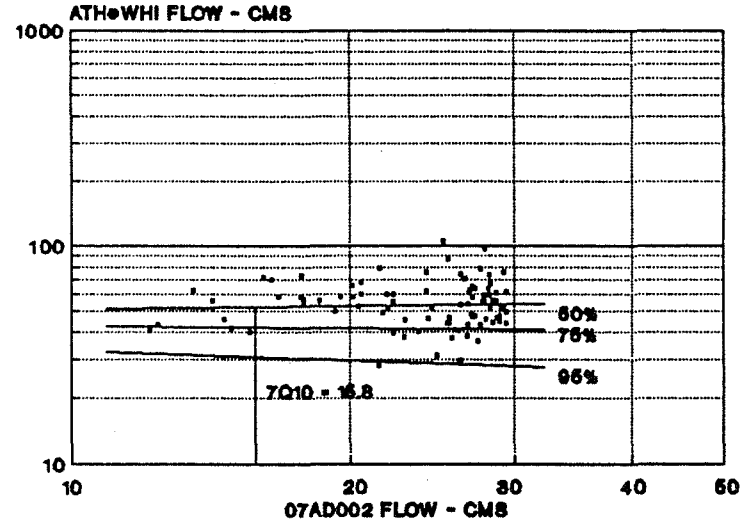
Equation Format: $\log (\text{Secondary Station Flow}) = A + B \log (\text{Primary Station Flow})$

Primary Station	Secondary Station	A	B	Remarks
Hinton	Windfall	1.606	.05647	
	Whitecourt	1.659	.04872	
	Athabasca	1.333	.45300	
	Fort McMurray	1.345	.72390	
	Embarras Airport	1.862	.50400	Not used.
Whitecourt	Hinton	.723	.44395	
	Windfall	-.078	1.01695	
	Athabasca	1.136	.51098	Used data points to fit curve for low flows.
	Fort McMurray	2.030	.18814	Used average of lowest 8 points.
	Embarras Airport	1.890	.32653	Not used.
Athabasca	Hinton	.706	.42132	
	Windfall	.932	.39354	
	Whitecourt	.800	.48386	
	Fort McMurray	.383	.95814	
	Embarras Airport	.347	1.00476	
Fort McMurray	Hinton	.571	.45001	
	Windfall	.620	.50743	
	Whitecourt	.973	.37052	
	Athabasca	-.438	1.09855	
	Embarras Airport	-.179	1.10671	

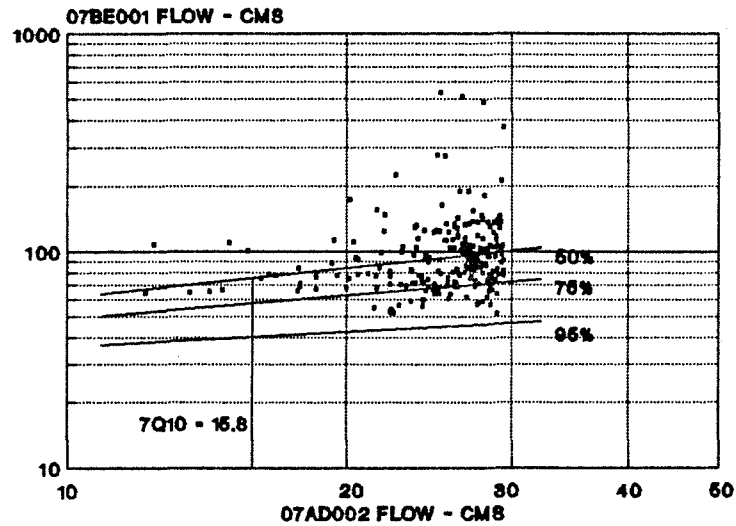
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ATH@WHI RELATIVE TO 07AD002



07BE001 RELATIVE TO 07AD002



07DA001 RELATIVE TO 07AD002

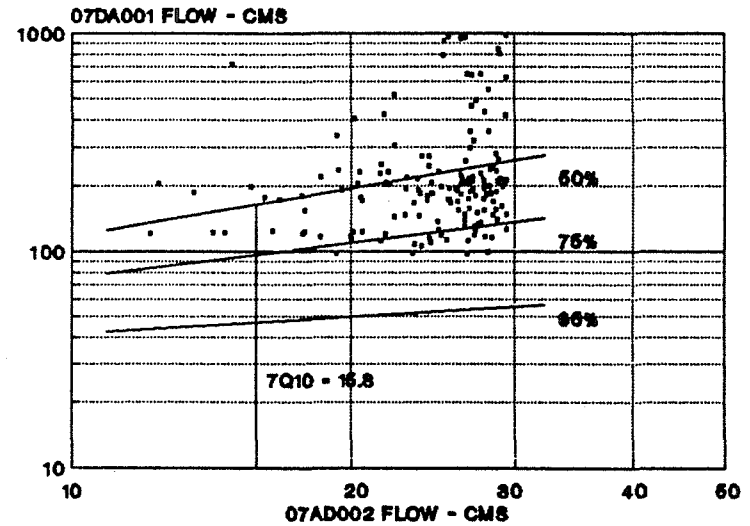
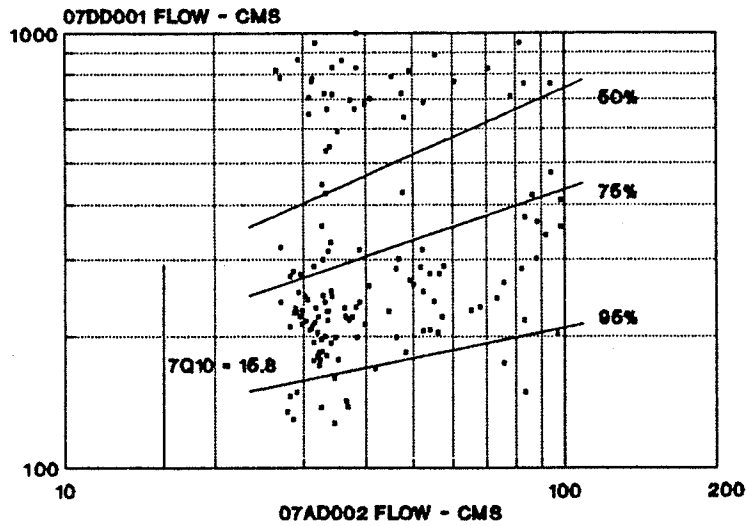
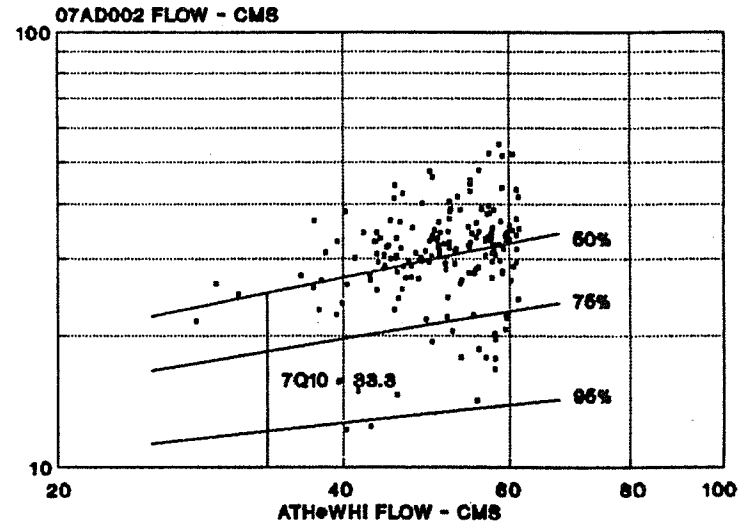


Figure B-1: Primary / Secondary Annual Relationships - Hinton

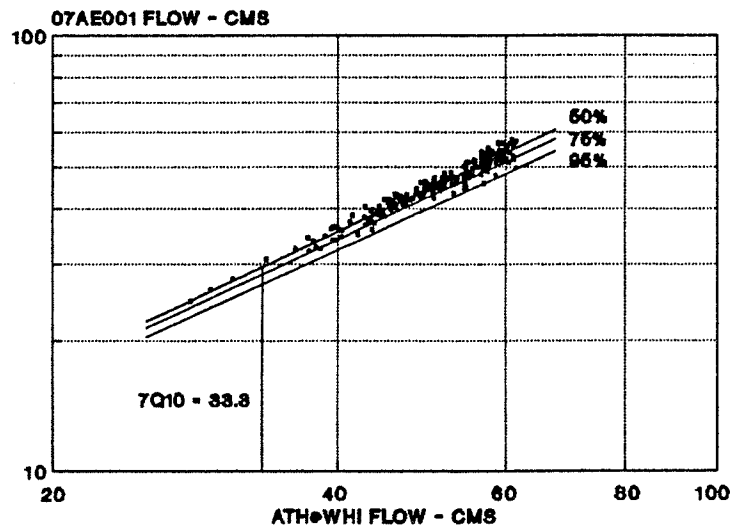
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07AD002 RELATIVE TO ATH@WHI



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07BE001 RELATIVE TO ATH@WHI

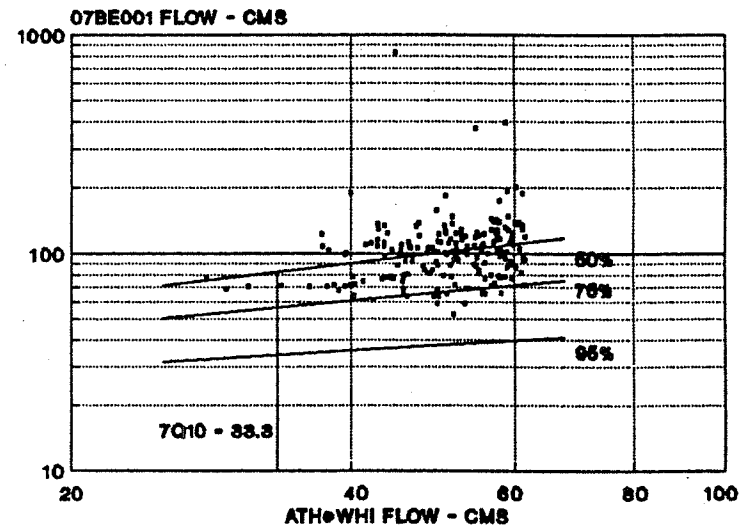
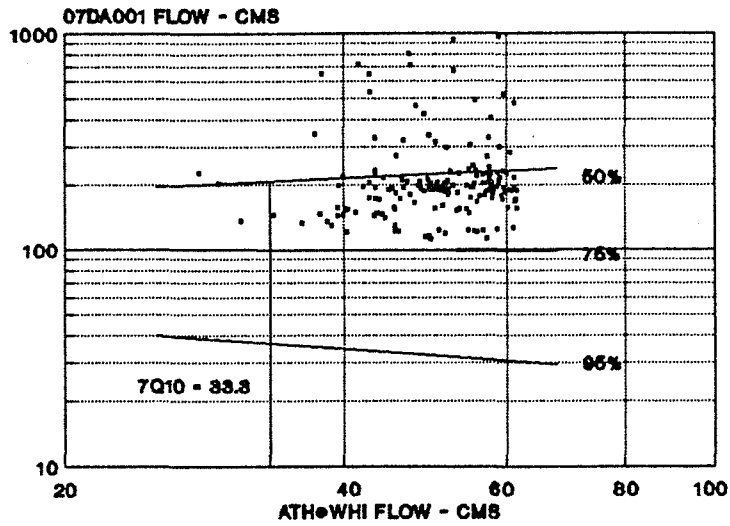
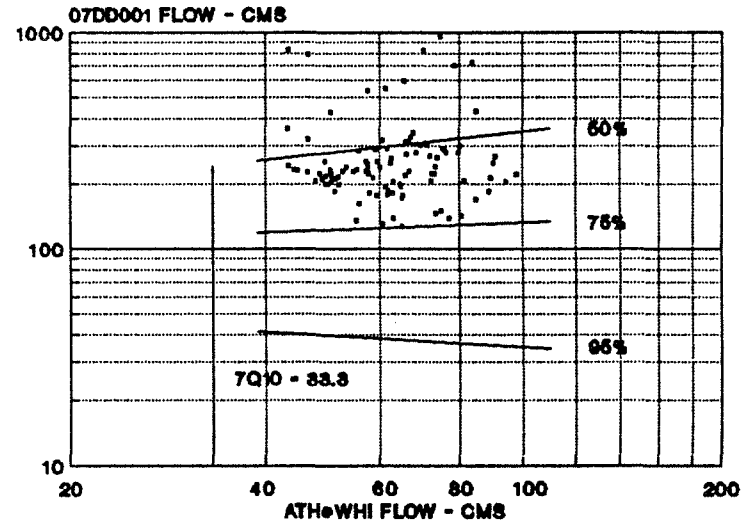


Figure B-2: Primary / Secondary Annual Relationships - Hinton and Whitecourt

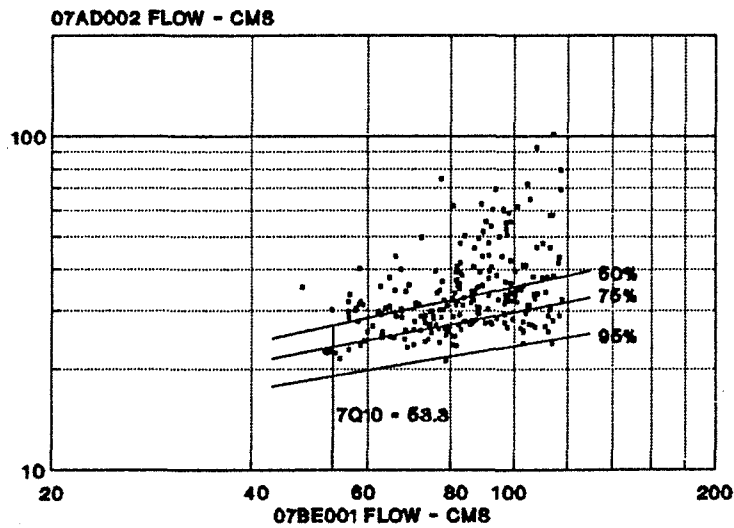
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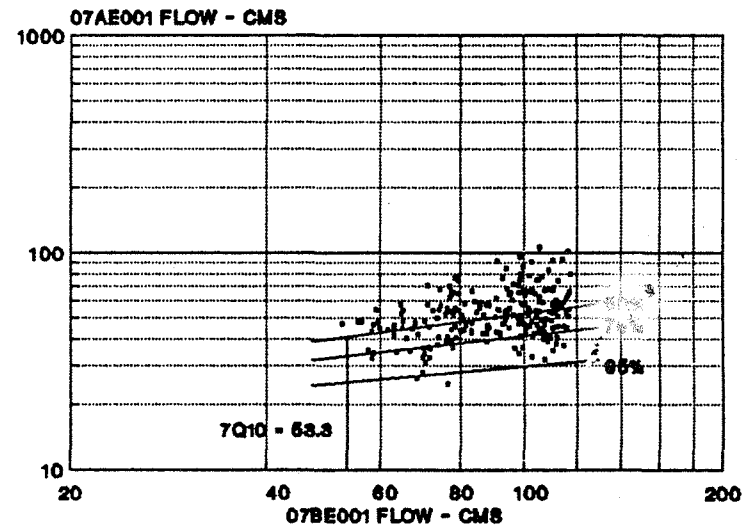
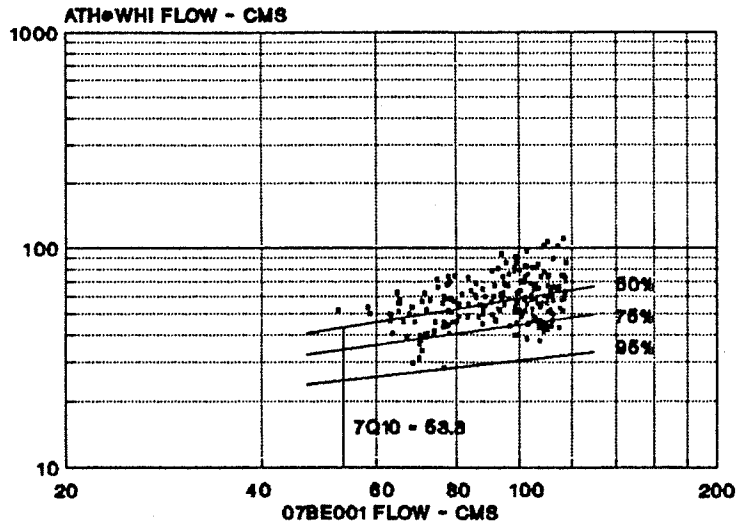
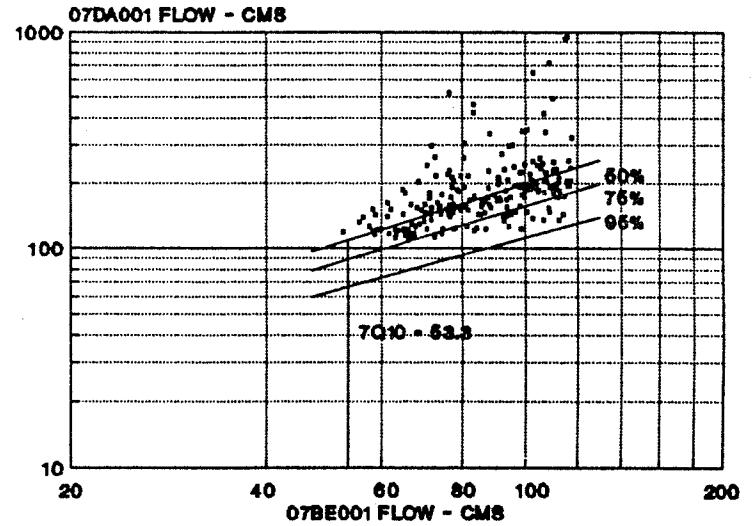


Figure B-3: Primary / Secondary Annual Relationships - Whitecourt and Athabasca

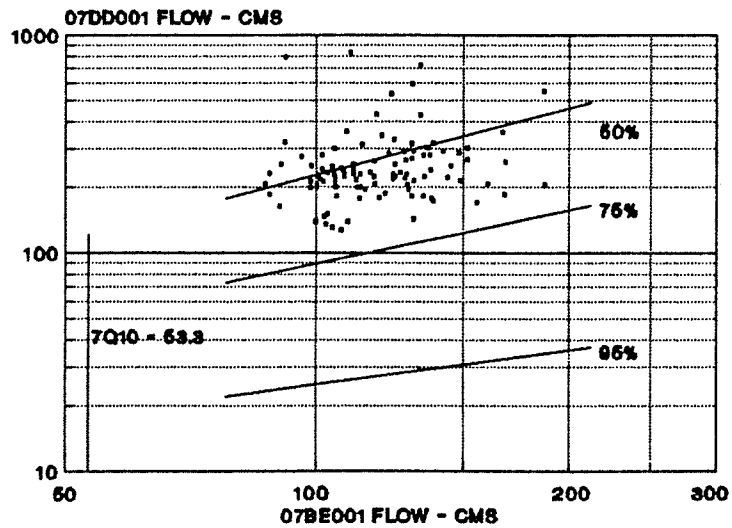
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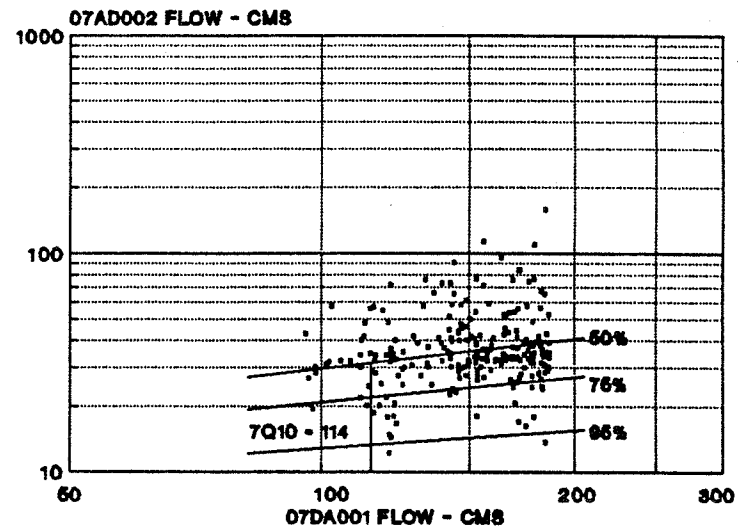
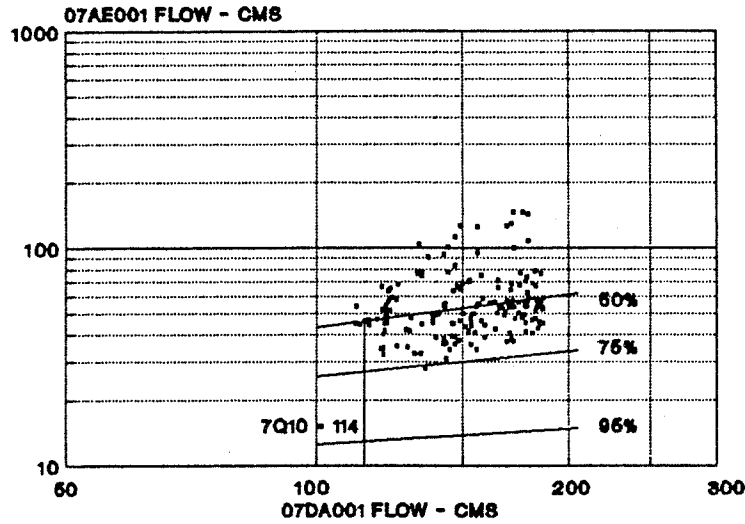
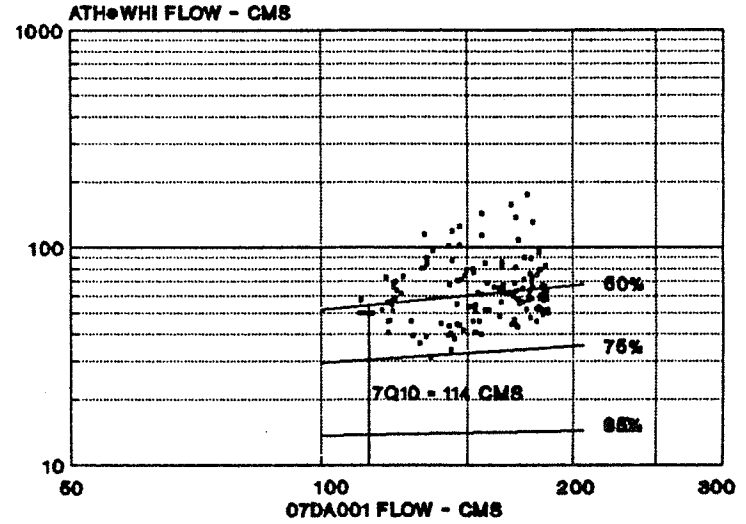


Figure B-4: Primary / Secondary Annual Relationships - Athabasca and Fort McMurray

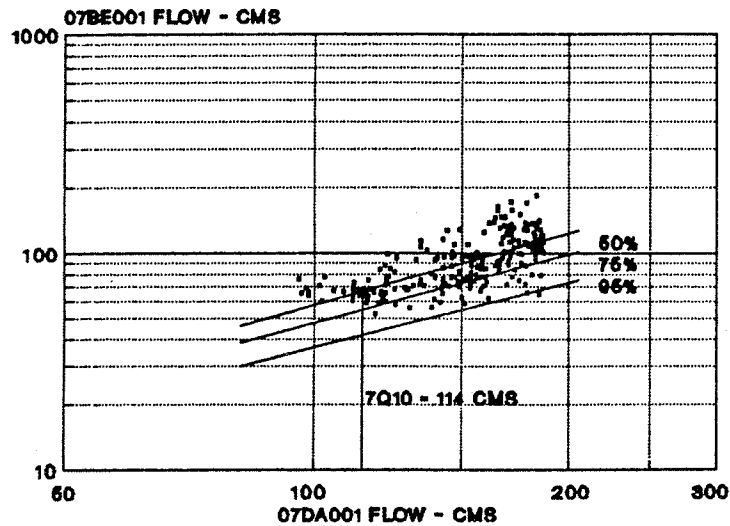
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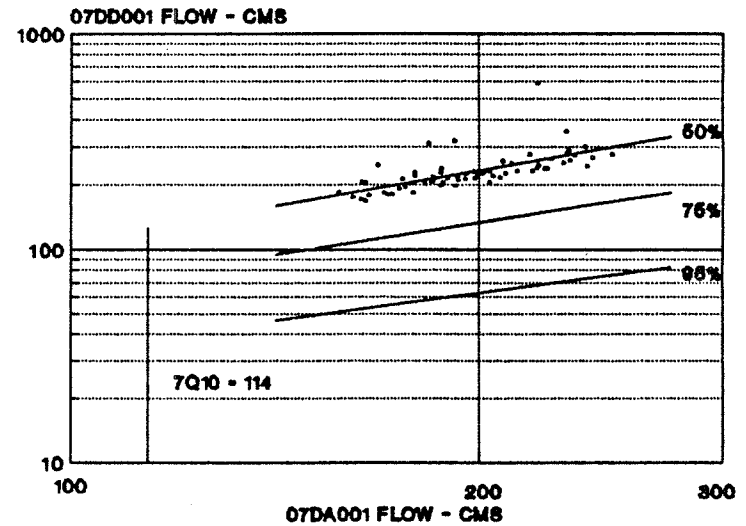


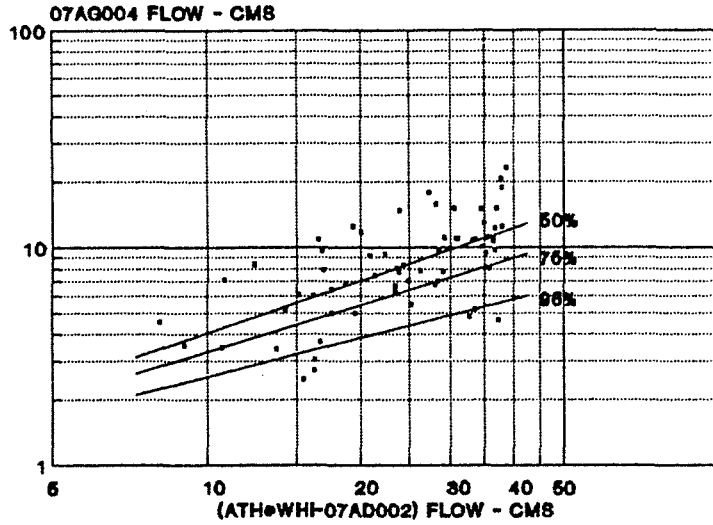
Figure B-5: Primary / Secondary Annual Relationships - Fort McMurray

TABLE B-2
Tributary / Local Area Annual 7Q10 Expected Flow Relationships

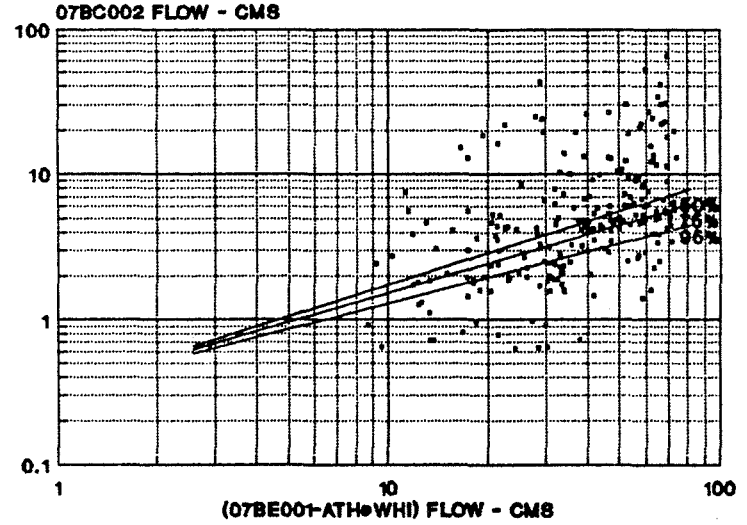
Equation Format: $\log(\text{Tributary Flow}) = A + B \log(\text{Local Area Flow})$

Local Area	Tributary	A	B	Remarks
Hinton to Whitecourt	McLeod River near Rosevear	-.195	.80039	Used only as check
Windfall to Whitecourt	McLeod River near Rosevear	No equation. Local basically equals McLeod River contribution.		
Whitecourt to Athabasca	Pembina River at Jarvie	-.479	.72083	
	Lesser Slave River at Hwy 2A	-.030	.90442	
Athabasca to Fort McMurray	Clearwater River at Draper	.508	.65592	07BE001 lagged 1 week
Fort McMurray to Embarras Airport	Poplar Creek	-.738	-.11213	
	Steepbank River	-.331	.28872	
	Muskeg River	-.458	.30220	
	MacKay River	-1.010	.85383	
	Ells River + Joslyn River	.108	.29901	
	Firebag River	.720	.31807	

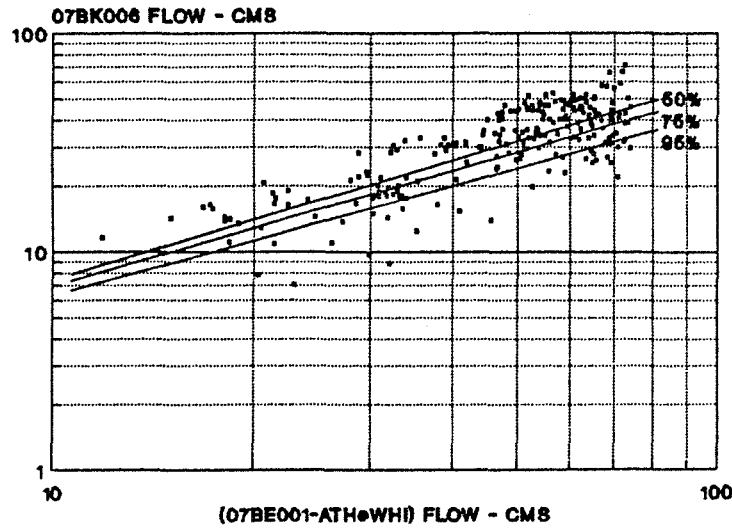
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07BC002 RELATIVE TO (07BE001-ATH-WHI)



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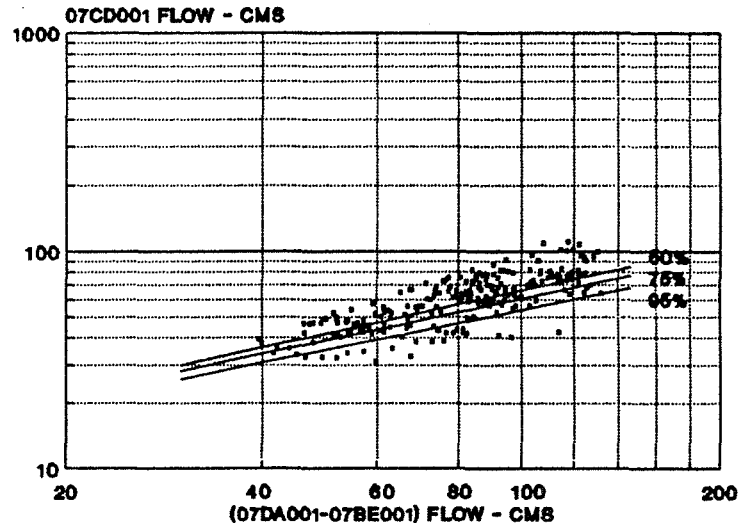


Figure B-6: Tributary / Local Area Annual Relationships - Major Tributaries

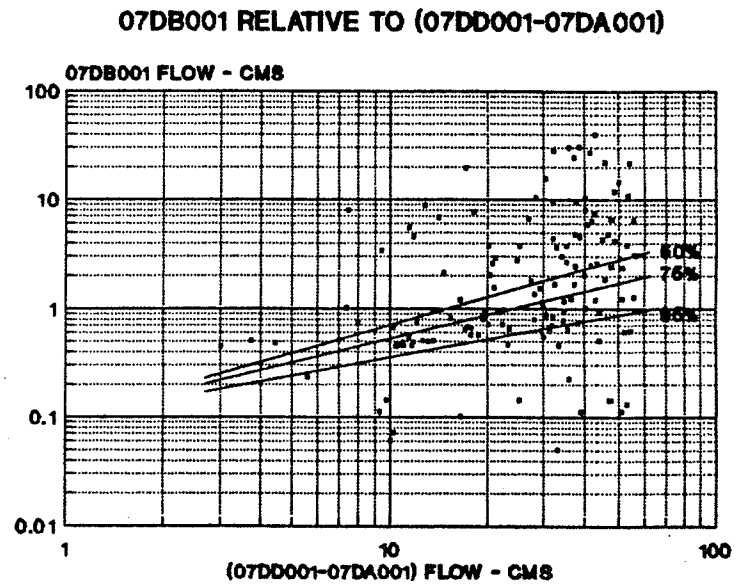
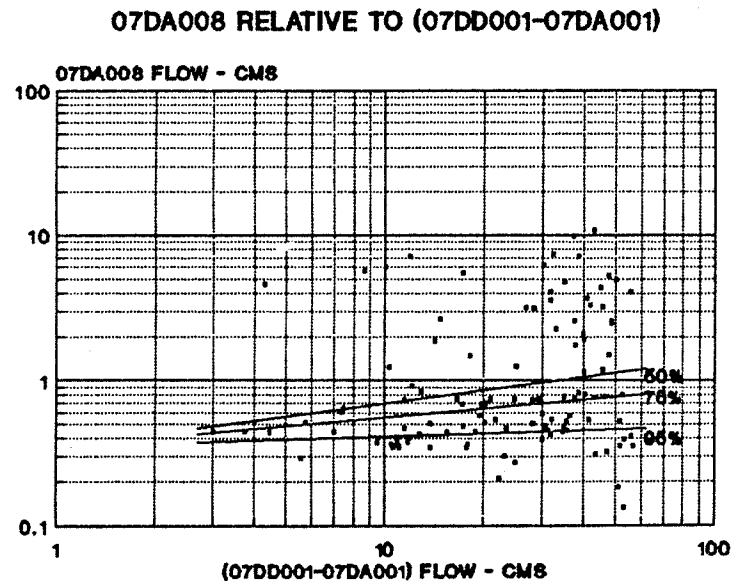
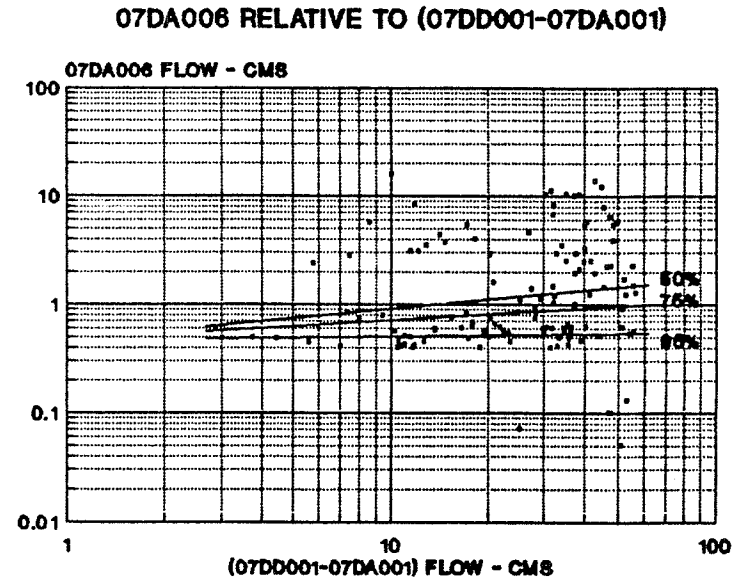
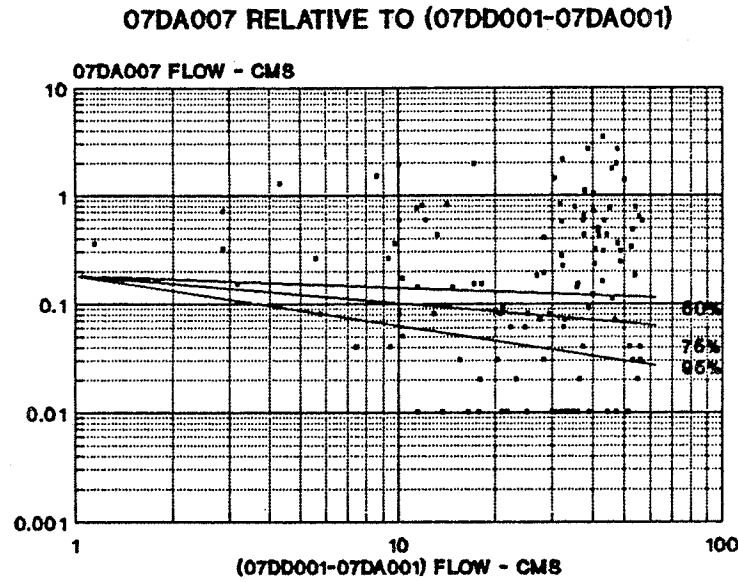
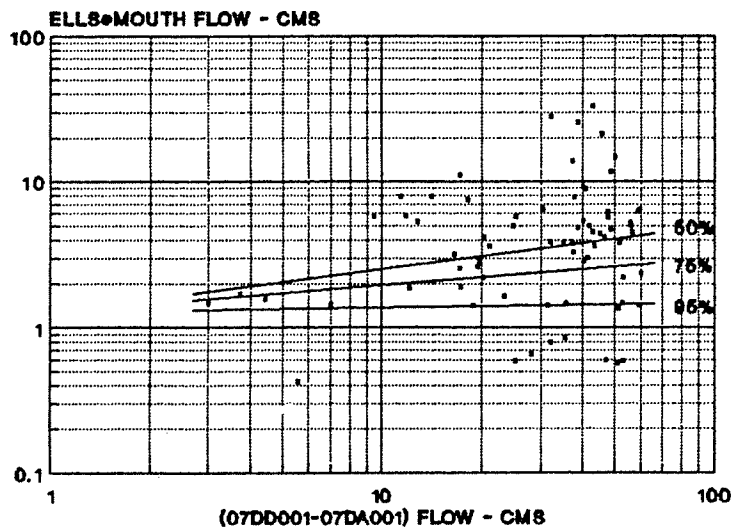


Figure B-7: Tributary / Local Area Annual Relationships - Other Tributaries

ELLSMOUTH RELATIVE TO (07DD001-07DA001)



NOTE : ELLSMOUTH - 07DA016 - 07DA017

07DC001 RELATIVE TO (07DD001-07DA001)

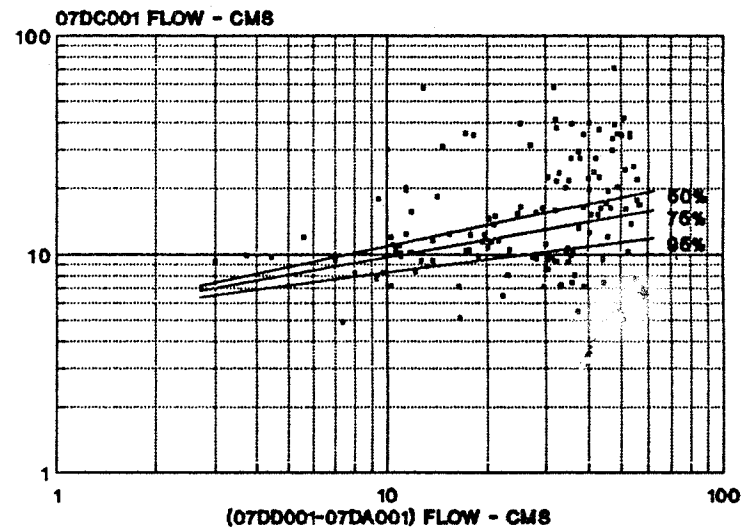
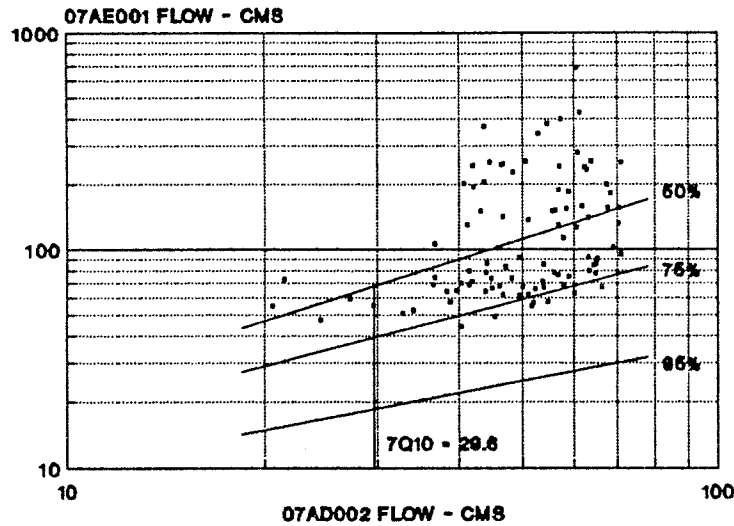


Figure B-8: Tributary / Local Area Annual Relationships - Other Tributaries (continued)

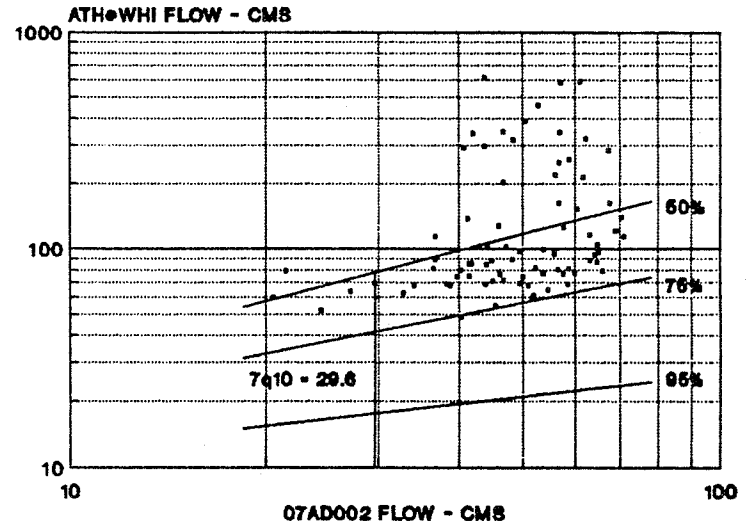
TABLE B-3
Primary / Station Open Waters 7Q10 Expected Flow Relationships

Equation Format: $\log(\text{Secondary Station Flow}) = A + B \log(\text{Primary Station Flow})$				
Primary Station	Secondary Station	A	B	Remarks
Hinton	Windfall	.449	.93988	Used average of lowest 7 points.
	Whitecourt	.747	.77811	Used average of lowest 7 points.
	Athabasca	.857	.83086	
	Fort McMurray	1.398	.64962	
	Embarras Airport	2.078	.36440	Not used.
Whitecourt	Hinton	.026	.88588	
	Windfall	-.01	.97552	
	Athabasca	.550	.83172	
	Fort McMurray	1.196	.61134	
	Embarras Airport	.836	.82084	Not used.
Athabasca	Hinton	.597	.49210	
	Windfall	.717	.52880	
	Whitecourt	.381	.74582	
	Fort McMurray	.744	.76364	
	Embarras Airport	.264	.99917	Not used.
Fort McMurray	Hinton	.393	.51799	Based on 3 week lag.
	Windfall	.597	.52874	Based on 2 week lag.
	Whitecourt	.539	.57602	Based on 2 week lag.
	Athabasca	.388	.71958	Based on 1 week lag.
	Embarras Airport	.232	.93594	Based on no lag.

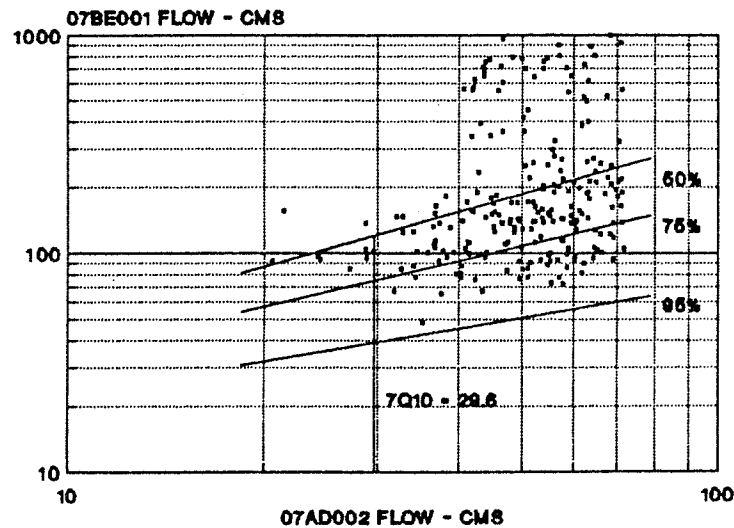
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07BE001 RELATIVE TO 07AD002



07DA001 RELATIVE TO 07AD002

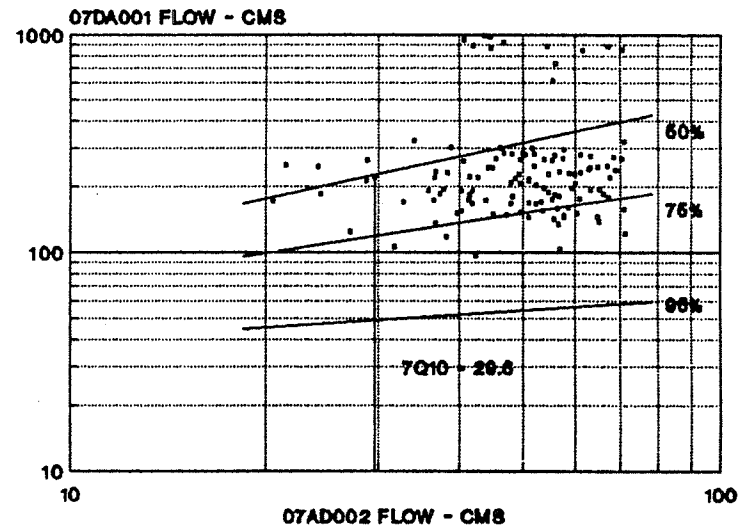
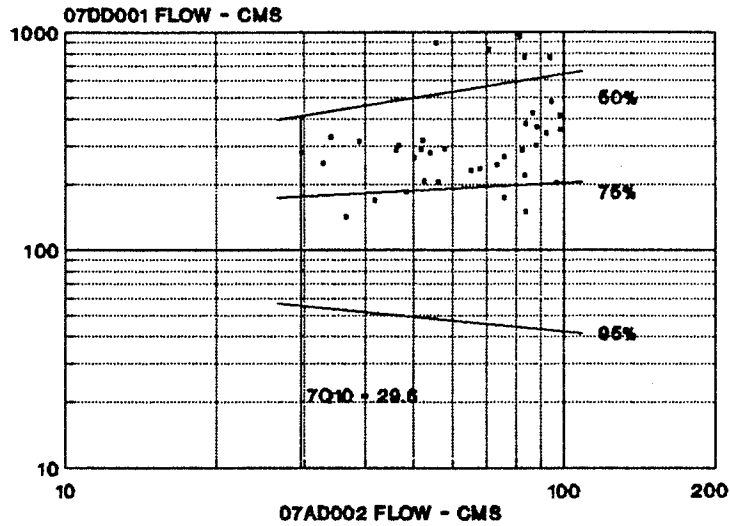
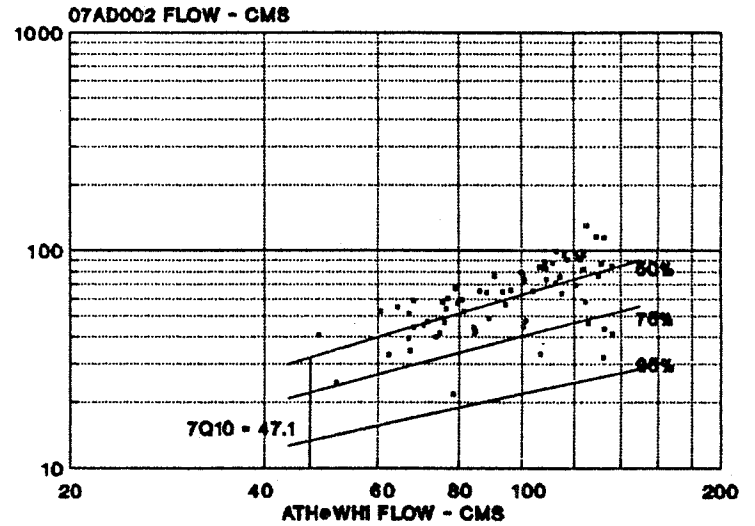


Figure B-9: Primary / Secondary Open Water Relationships - Hinton

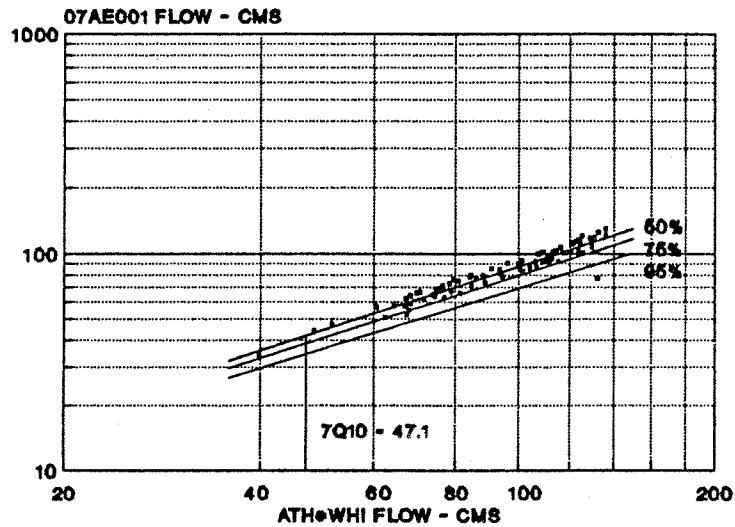
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07AD002 RELATIVE TO ATH@WHI



07AE001 RELATIVE TO ATH@WHI



07BE001 RELATIVE TO ATH@WHI

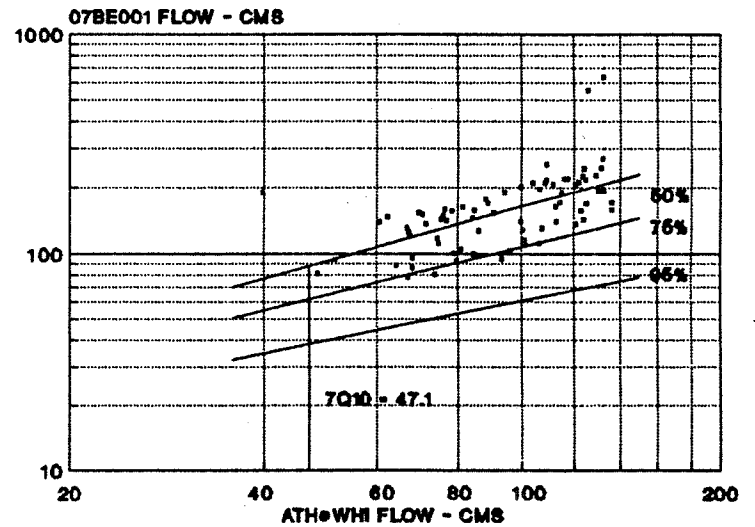
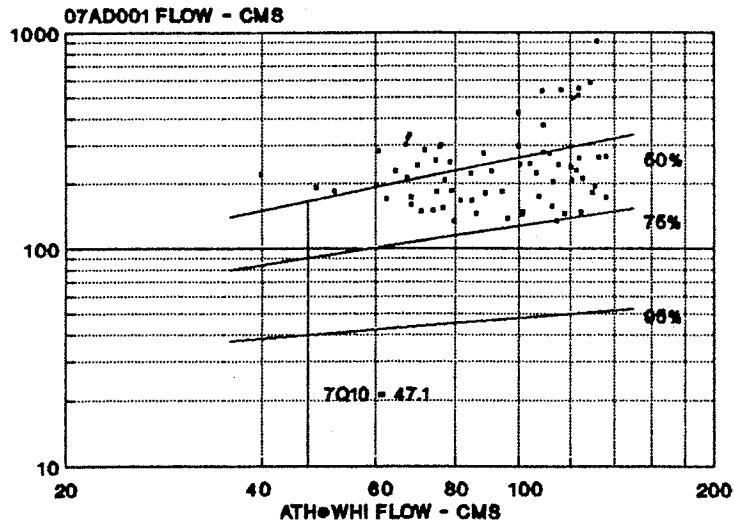
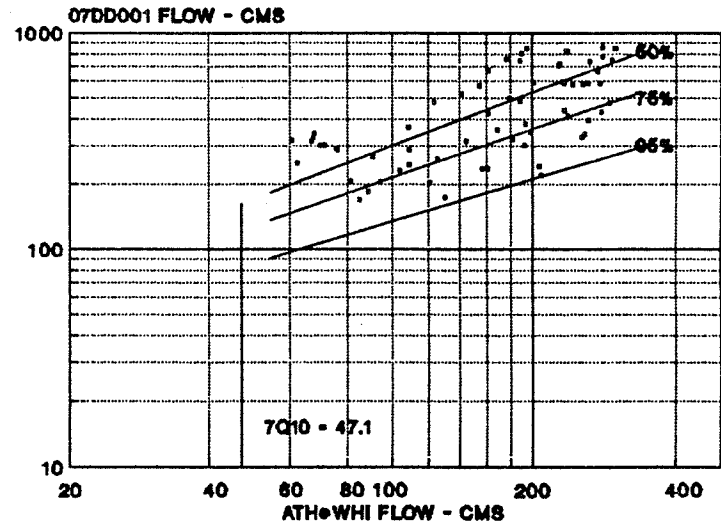


Figure B-10: Primary / Secondary Open Water Relationships - Hinton and Whitecourt

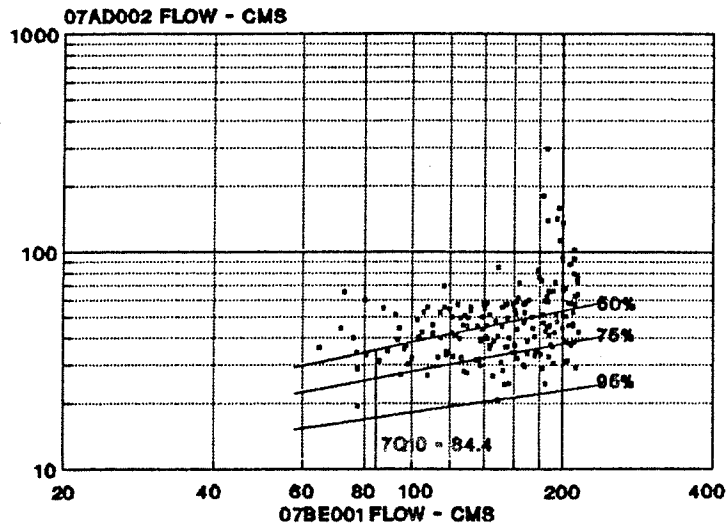
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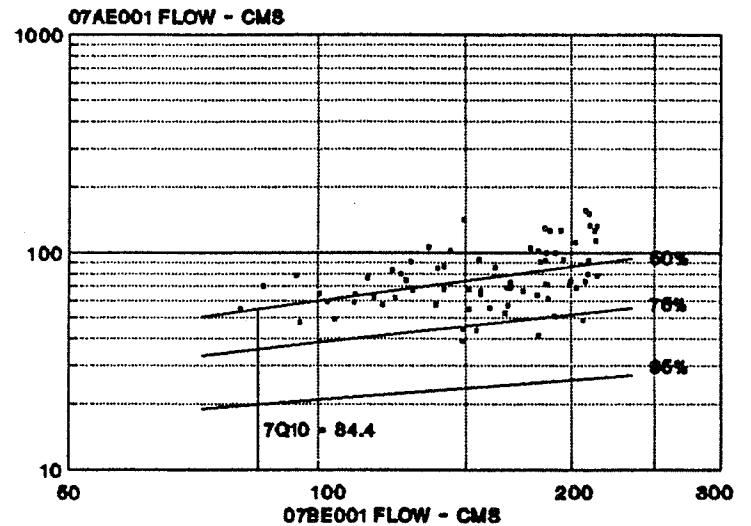


Figure B-11: Primary / Secondary Open Water Relationships - Whitecourt and Athabasca

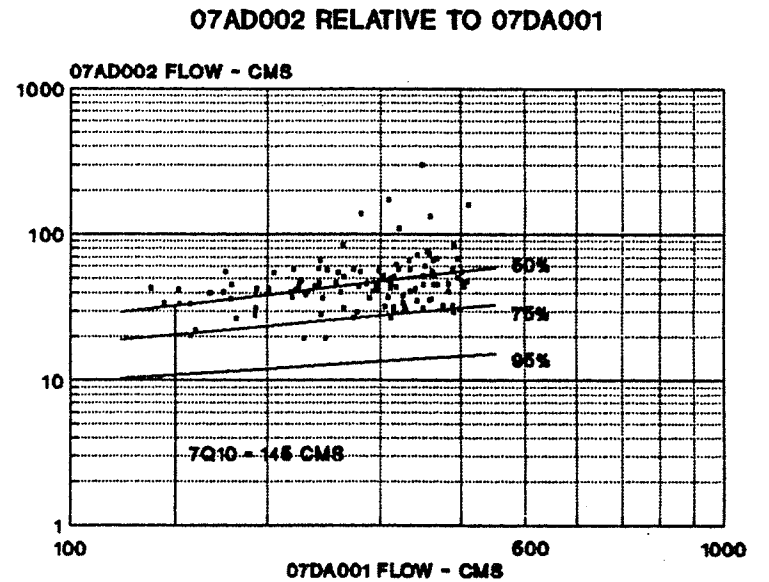
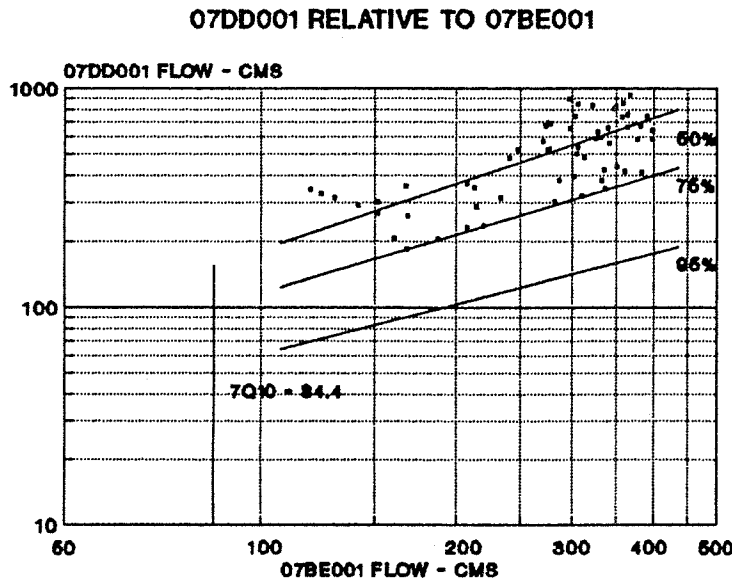
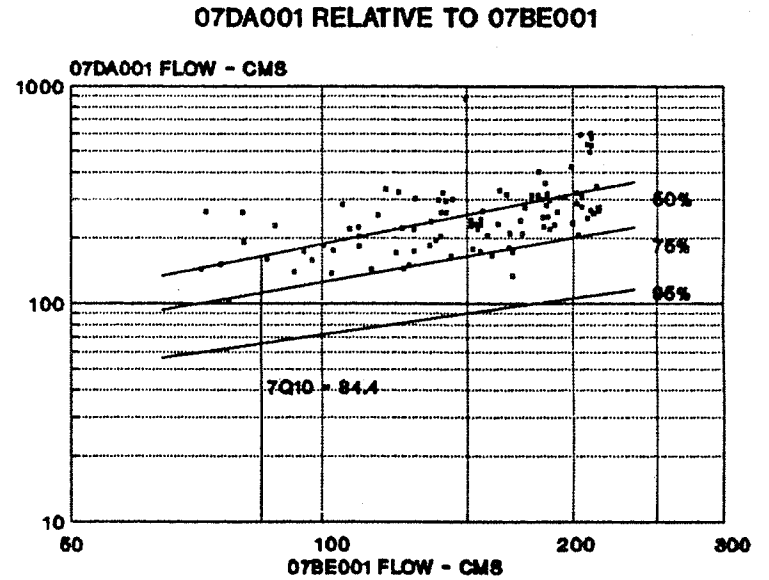
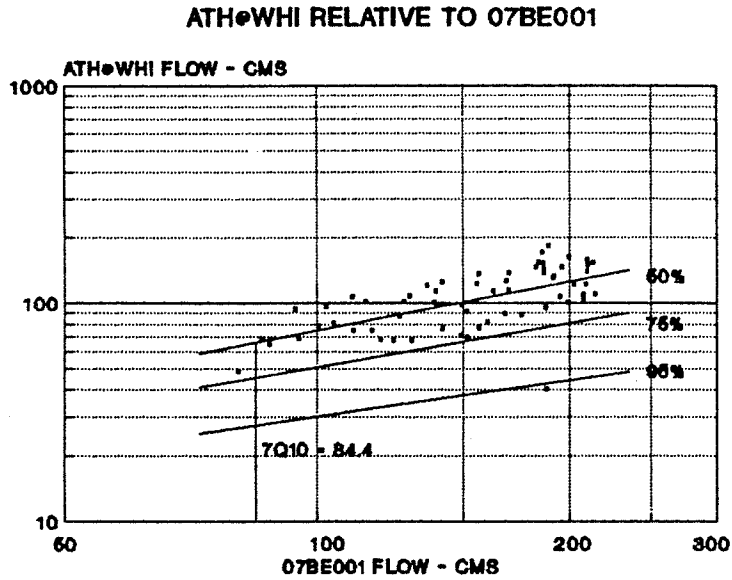
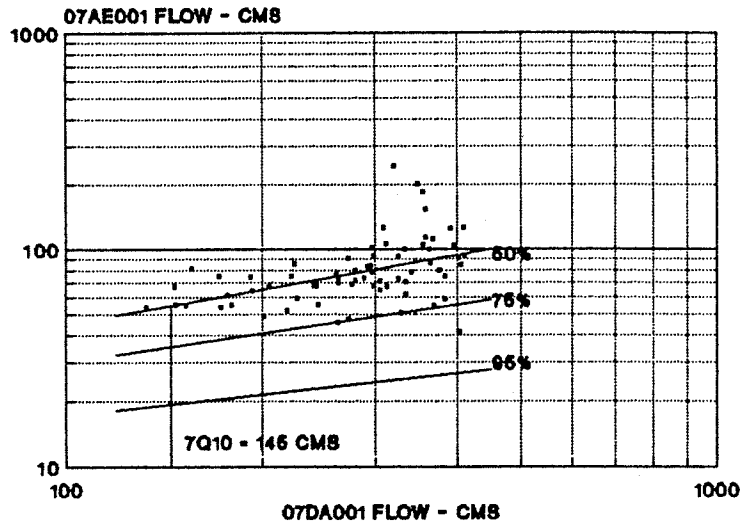
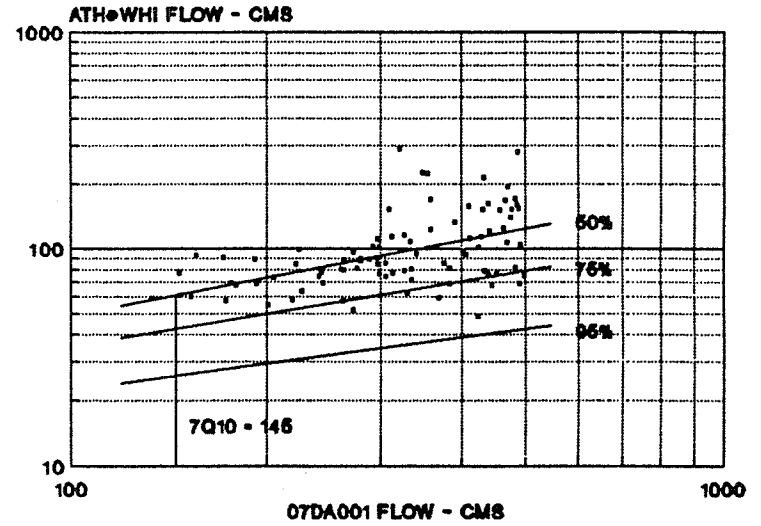


Figure B-12: Primary / Secondary Open Water Relationships - Athabasca and Fort McMurray

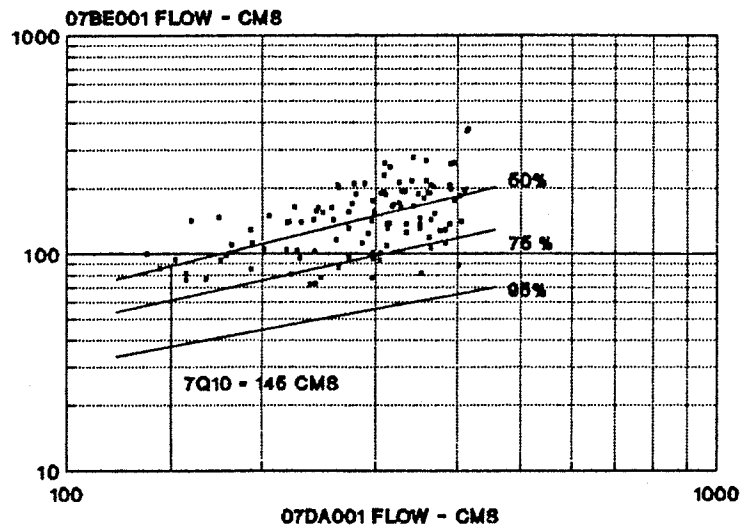
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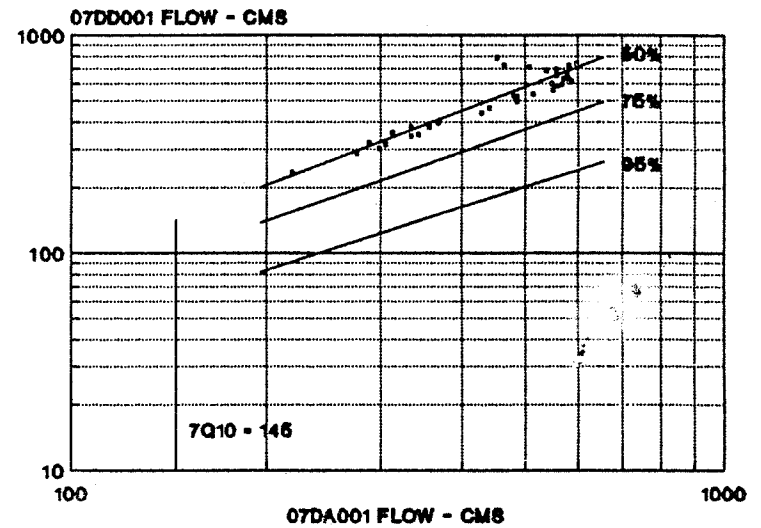
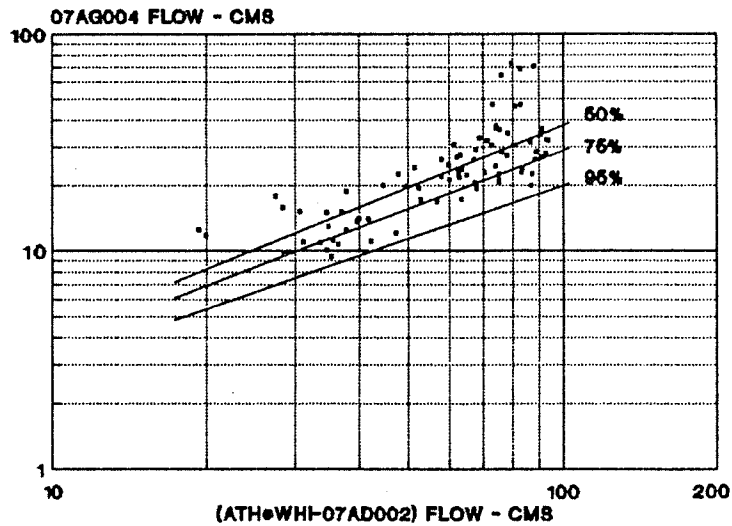


Figure B-13: Primary / Secondary Open Water Relationships - Fort McMurray

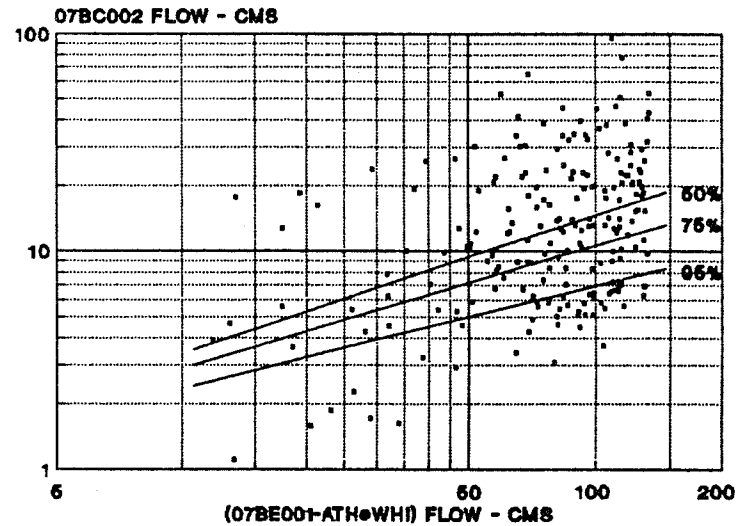
TABLE B-4
Tributary / Local Area Annual 7Q10 Expected Flow Relationships

Equation Format: $\log(\text{Tributary Flow}) = A + B \log(\text{Local Area Flow})$				
Local Area	Tributary	A	B	Remarks
Hinton to Whitecourt	McLeod River near Rosevear	-.317	.94575	Used only as check
Windfall to Whitecourt	McLeod River near Rosevear	No equation. Local basically equals McLeod River contribution.		
Whitecourt to Athabasca	Pembina River at Jarvie	-.104	.63419	
	Lesser Slave River at Hwy 2A	.003	.82710	
Athabasca to Fort McMurray	Clearwater River at Draper	.380	.73241	07BE001 lagged 1 week
Fort McMurray to Embarras Airport	Poplar Creek	-1.114	.46927	
	Steepbank River	-.375	.50956	
	Muskeg River	-.582	.51301	
	MacKay River	.321	.28930	
	Ells River + Joslyn River	.330	.20777	
	Firebag River	.04070	1.315	

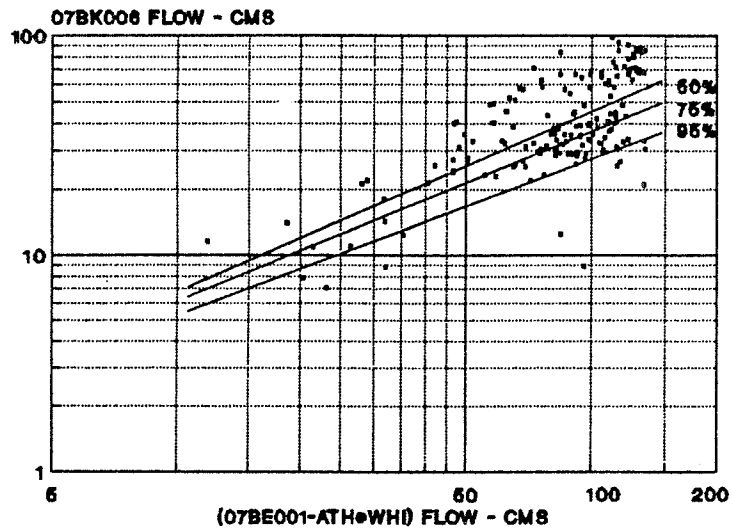
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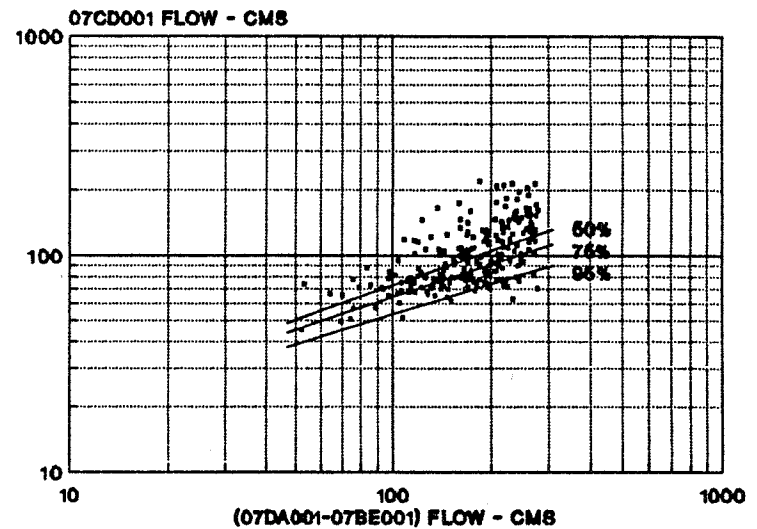
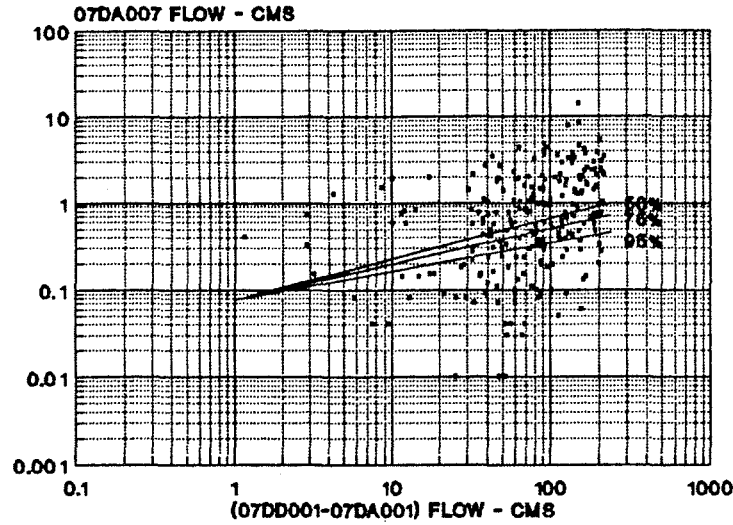
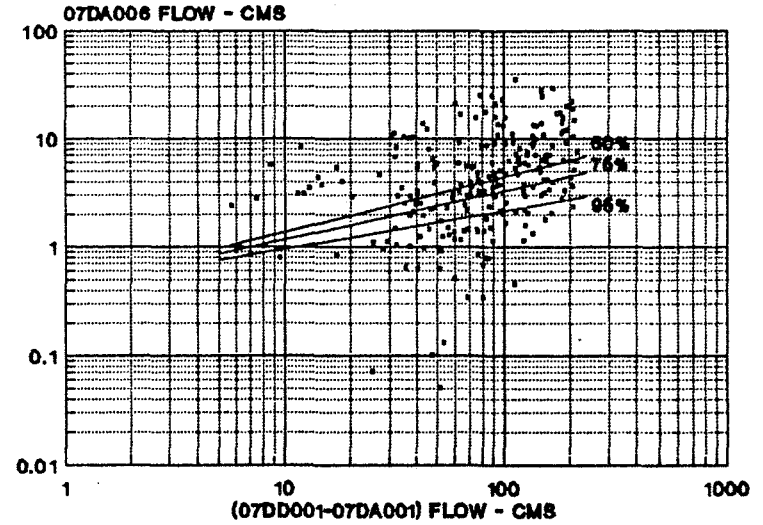


Figure B-14: Tributary / Local Area Open Water Relationships - Major Tributaries

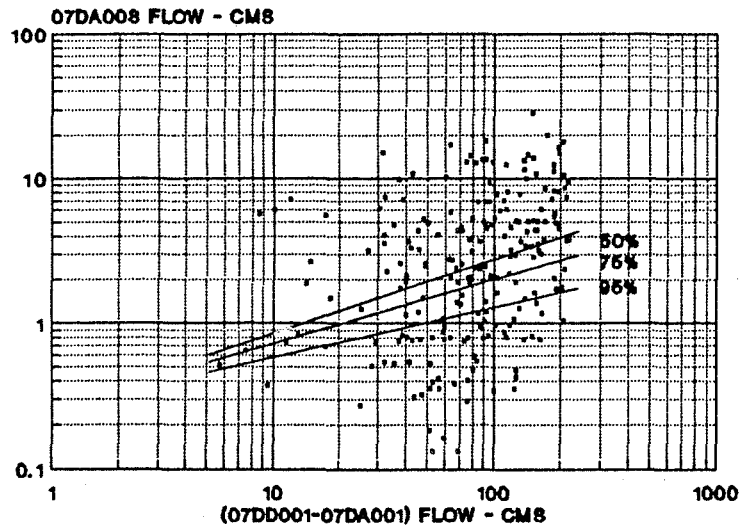
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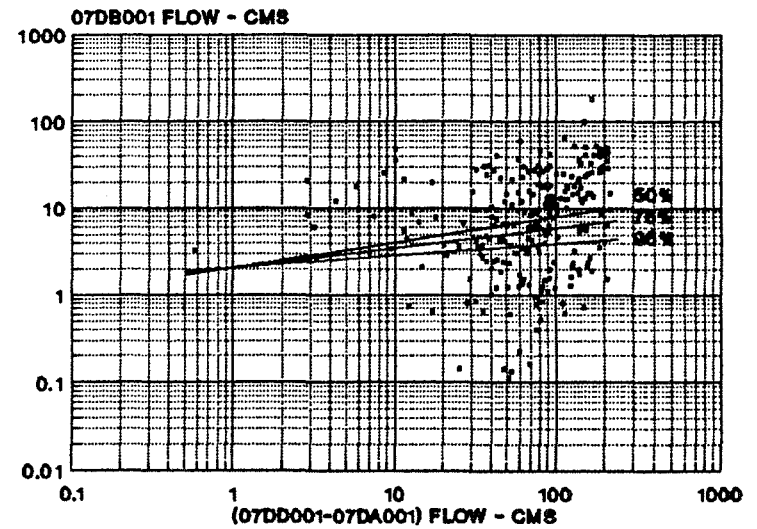
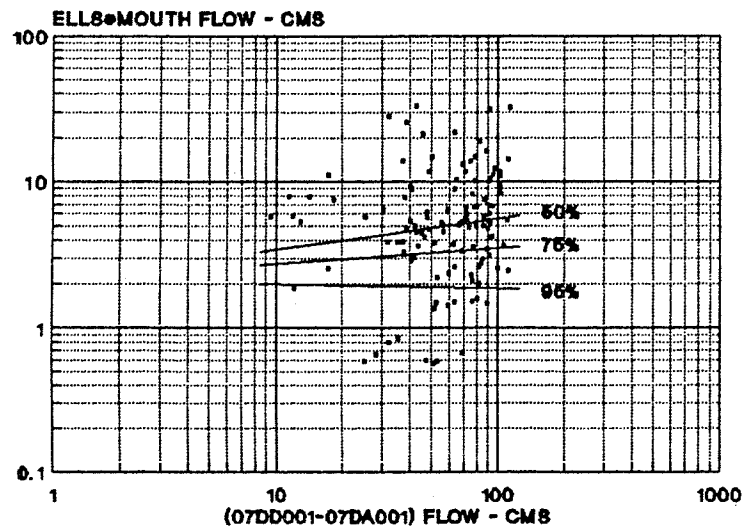


Figure B-15: Tributary / Local Area Open Water Relationships - Other Tributaries

ELLSMOUTH RELATIVE TO (07DD001-07DA001)



ELLSMOUTH - 07DA016 • 07DA017

07DC001 RELATIVE TO (07DD001-07DA001)

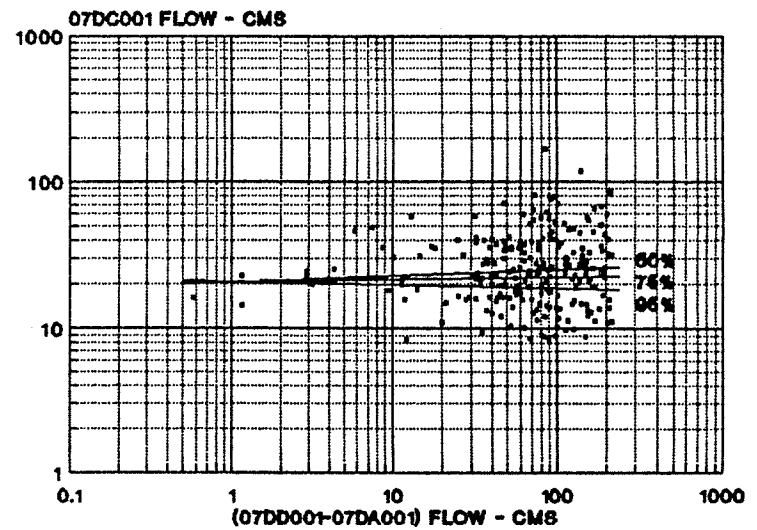


Figure B-16: Tributary / Local Area Open Water Relationships - Other Tributaries (continued)

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