INTERNATIONAL RAINY LAKE BOARD OF CONTROL
IRLBC

STATUS REPORT

REVIEW OF THE IJC ORDER
FOR
RAINY AND NAMAKAN LAKES

ADDENDUM 1

IMPACTS ON RAINY RIVER LEVELS

December 8, 1998

1. Introduction

In response to a proposal to alter the current regulation rules for Rainy and Namakan lakes, a study was initiated to assess the impacts of the existing and proposed regulation schemes. Modelling results are presented in Section 3.1.1 of the Status Report, but these focus only on lake levels and outflows. It was left for those with an interest in the Rainy River to deduce how the river regime might be impacted (by the various regulation schemes) by noting the changes in volume and timing of the outflows from Rainy Lake. However, several respondents with an interest in the river requested information on how the differing outflows with each regulation scheme would affect river levels. The purpose of this Addendum is to provide some limited river level information based on the modelled Rainy Lake outflows already presented in Section 3.1.1.

Four regulation schemes were modelled and then presented in the Status Report. The "base" case model runs with these different schemes were F1-IJC (using the existing 1970 International Joint Commission rule curves), F1-SC (using the rule curves proposed by the Rainy-Namakan Water Level International Steering Committee), C1 (using a combination of the IJC curves on Rainy Lake with the SC curves on Namakan Lake), and M1 (using curves modified from the C1 curves). Rainy River levels resulting from these Rainy-Namakan regulation schemes are addressed herein, but reference should be made to Section 3.1.1 of the Status Report before continuing with this Addendum in order to understand the terminology, the data used and how the modelling was done.

2. Rainy River Level Sites

Unlike the basically horizontal water level of a lake, the water level of a river declines with a varying slope as one moves downstream. The water level slope or rate of decline is dependent on factors such as the volume of flow and the channel geometry. Thus, while a single modelled water level applies to a whole lake shoreline, modelling a river's water surface profile is challenging and requires a significant amount of channel data. Such data is not available for the Rainy River. However, water levels have been recorded at three sites along the river, and it is possible to establish a relationship between river flow and level at these sites. These sites are at the dam tailwater (downstream side of dam) at Fort Frances - International Falls, at Manitou Rapids, and at the Town

of Rainy River. The relationships between level and flow can be used in conjunction with the modelled Rainy Lake outflows to estimate levels at these sites under the various regulation schemes, but these levels are only applicable close to these sites. In addition, our climate provides a further constraint on reliably modelling river levels in that ice effects cause the river flow versus level relationship to be highly variable. Thus our relationships can only be reasonably developed and used for the open water period of the year.

3. Level versus Flow Relationships

Fort Frances Tailwater

At the Fort Frances tailwater, the Rainy River level is a function not only of the Rainy Lake outflow, but also of flow in the Big and Little Fork Rivers, which are tributaries to the Rainy River downstream of Fort Frances. The inflow to the Rainy River from these tributaries causes a backwater effect up to the tailrace, which increases the tailwater level as the tributary inflow increases. An approximate relationship for open water conditions, developed by Acres International Ltd. from historic data, uses the Rainy Lake outflow and the total Fork Rivers flow to estimate the tailwater level. The Rainy Lake outflows produced by the model under the four regulation schemes for the modelled inflow years of 1958-1996 were used in this relationship along with historic Fork Rivers flows (for the same years) in order to estimate the tailwater levels.

Manitou Rapids

Because of the flow control provided by the rapids, a high quality unique relationship between river flow and level exists at this site. It was developed by the United States Geologic Survey (USGS) and is used in conjunction with data from their level gauge there to compute river flows at the rapids. The flows at this site are the sum of the Rainy Lake outflows plus the Fork Rivers flows plus other tributary flow and local runoff down to this point on the river. To determine the river levels at this site under the four modelled regulation schemes, the historic Rainy Lake outflows were first subtracted from the historic Manitou Rapids flows for the modelled years (1958-1996), and then the modelled Rainy Lake outflows were added back, in their place, for each of the four regulation schemes. These resultant total flows were then used in the level-flow relationship to determine the river levels to be expected under each scheme.

Town of Rainy River

At the Town, the river level is a function not only of the river flow but is also greatly influenced by the level of Lake of the Woods. The river flow at the Town can be reasonably expected to be little different from the flow at Manitou Rapids since there are no major tributaries between the two sites. As to level data, the Lake of the Woods Control Board has had a temporary level gauge installed on the Town dock for a few years, and lake levels are also collected at several sites on Lake of the Woods. An approximate relationship was derived, using historic data from these sources, to compute river levels as a function of Manitou Rapids flow and Lake of the Woods mean level. To determine the river levels at the Town resulting from the four Rainy-Namakan regulation schemes, the same Manitou Rapids flows as used in the previous relationship were again employed. To obtain the second variable required, advantage was taken of the modelling already done by the Lake of the Woods Control Board. This Board had modelled the impacts on Lake of the Woods levels of the four Rainy-Namakan regulation schemes by using the same modelled outflows from Rainy Lake. Thus modelled lake levels for the same years (1958-1996) were available for input as the second variable in the Townsite relationship, and the river levels were computed.

4. River Level Results

Rainy River level model results at the three sites are summarized on a table and on a number of graphs, as noted below. While the first two graphs for each river site provide statistical summaries of levels, the remaining four plots for each site provide modelled levels for selected individual years. All results are based on 39 years of simulation (1958-1996). All levels used are three-day means centred on the reporting date.

Table 1 - provides a statistical summary of river levels at the three sites, for spring and summer month-end dates, resulting from the four modelled Rainy-Namakan regulation schemes.

Fort Frances Tailwater

Graph 1 - compares the Fort Frances tailwater percentile levels, obtained with regulation on Rainy-Namakan in accordance with the existing 1970 IJC rule curves, with those obtained when regulation is by the proposed SC rule curves. The percentile levels are plotted every quarter month for the nominal open water season (April through November). For example, at the end of June, the 75^{th} %ile level with IJC rule curve operation is 329.99 m, meaning that 75% of time the river surface at the end of June would be at or below this level with IJC operation, and would be above this level 25% of time. In contrast, the 75^{th} %ile level at the end of June with SC operation is 330.41 m, or about 0.4 m (1.3 ft) higher than for the IJC operation case. Table 1 presents some of this same data in tabular form, for specific dates only, but also provides mean levels and results for the C1 and M1 regulation schemes as well. In general, the river levels at the Fort Frances tailrace can be seen to be lower with SC operation than with IJC operation from April through early to late May, but then higher with SC operation than with IJC operation through to September or early October. Because of this switchover, the river level tends to rise more with SC operation than with IJC operation. For example, the median level (the level that is not reached 50% of time and is reached or exceeded 50% of time) rises about 1.15 m (3.8 ft) from the first of May to its high point at the end of the first week in June with SC operation, whereas it rises only slightly and varies over about a 0.25 m (0.8 ft) range with IJC operation. Results with C1 and M1 regulation generally fall between those of IJC and SC, as can be seen for certain dates on Table 1.

Graph 2 - provides Fort Frances tailwater level-duration plots under the four regulation schemes for each of the open water months. It is important to note, though, that these plots are not based on the set of 39 average monthly levels for each regulation scheme for each of these months. Instead, they are based on combining the 4 sets of 39 levels (one at each of the 1/4-month points) that fall in each month for each regulation scheme. To help explain these plots, the plot for June will be used as an example. This plot actually covers the period from the end of the first quarter of June (roughly the end of the first week) through to the end of the fourth quarter of June, since these are the timings of the data points used. Over this period, and with all regulation schemes, the level is never below about 327.1 m (the level is at or below 327.1 m 0% of time), and is never above about 332.7 m (the level is at or below 332.7 m 100% of time). Similarly, with IJC regulation, the level is at or below about 329.1 m 50% of time during this period and, with SC regulation, is at or below about 329.7 m 50% of time during this period. Overall,

these plots show that the largest differences in Fort Frances tailwater levels due to the differing regulation schemes occur in April and in June, with smaller differences occurring in July, August and September, and only minor differences in the other open water months. (This is not to say that you may not still get significant differences between regulation schemes in some other months for individual years, but that on average over many years the biggest differences will be found in those months noted.) Also, as with the previous graph and table, the largest differences are between the levels resulting from IJC and SC operation, while the levels resulting from C1 and M1 operation generally lie between those of IJC and SC. As per the above example, these plots may be used to determine, for each month and for each regulation scheme, how often (what percent of time) river levels should be expected to be at or below certain target levels.

Graph 3 - the upper and lower plots compare, for 1968 and 1974 respectively, the Fort Frances tailwater levels for the open water months for the four Rainy-Namakan regulation schemes that were modelled. Again, the data is plotted on a 1/4-month basis. As noted previously, there is a tendency for SC levels to be lower than IJC levels for April and perhaps into May, but then to be higher through September. Often, the differences in levels do not appear to be significant. However, for those river interests who may be concerned with relatively small differences, be sure to note that the grid scale on the plots is 0.5 m (1.6 ft) and that, in areas where the plot lines are rising or falling steeply, the vertical difference between respective curves is greater than it appears at first glance.

Graph 4 - same as Graph 3, but for 1981 and 1985 inflows

Graph 5 - same as Graph 3, but for 1986 and 1987 inflows

Graph 6 - same as Graph 3, but for 1992 and 1996 inflows

Manitou Rapids

Graphs 7-12 - same as Graphs 1-6, but for the Manitou Rapids site

Town of Rainy River

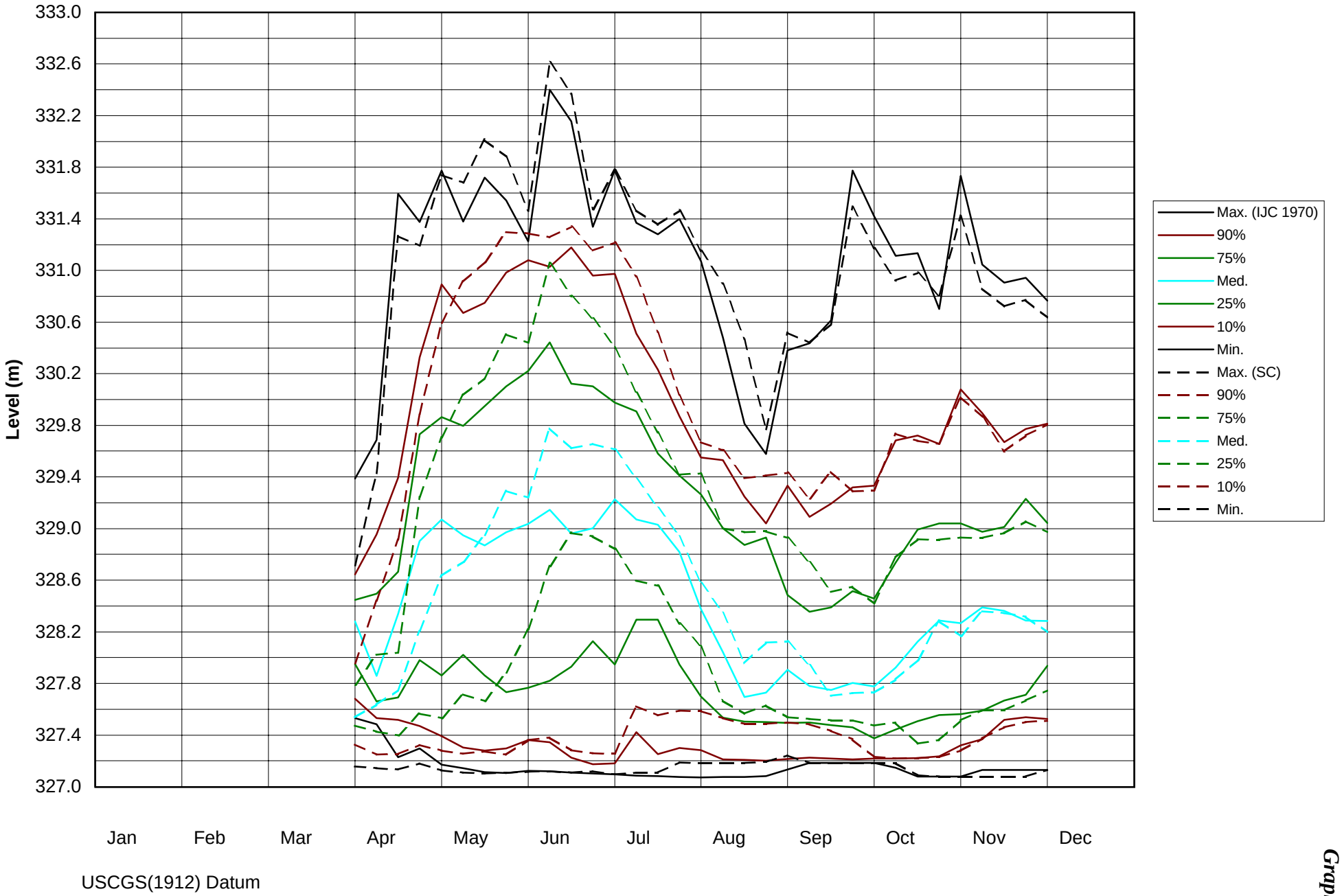
Graphs 13-18 - same as Graphs 1-6, but for the Town of Rainy River site

TABLE 1 - RAINY RIVER LEVEL RESULTS - 39 YEAR RUNS (1958-96)

SCENARIO RUNS		FORT FRANCES TAILWATER				MANITOU RAPIDS				TOWN OF RAINY RIVER			
		F1-IJC	F1-SC	C1	M1	F1-IJC	F1-SC	C1	M1	F1-IJC	F1-SC	C1	M1
Mar 31	Mean Level	328.25	327.63	328.18	328.05	325.54	325.03	325.48	325.38	322.41	322.39	322.41	322.40
	Max Level/Year	329.39/1966	328.71/1966	329.35/1966	329.11/1966	326.57/1966	326.00/1966	326.54/1966	326.32/1966	322.57/1966	322.51/1966	322.56/1966	322.55/1966
	75 %ile Level	328.46	327.79	328.39	328.26	325.74	325.16	325.69	325.56	322.43	322.40	322.43	322.42
	50 %ile Level	328.28	327.54	328.20	328.04	325.53	324.94	325.51	325.37	322.41	322.39	322.41	322.39
	25 %ile Level	327.95	327.47	327.87	327.78	325.31	324.84	325.26	325.18	322.39	322.36	322.38	322.37
	Min Level/Year	327.53/1977	327.16/1988	327.50/1977	327.18/1977	324.82/1977	324.41/1977	324.78/1977	324.41/1977	322.34/1977	322.32/1964	322.32/1977	322.32/1977
Apr 30	Mean Level	329.08	328.84	329.06	329.09	326.62	326.42	326.59	326.62	322.77	322.73	322.77	322.77
	Max Level/Year	331.78/1975	331.74/1975	331.92/1975	331.89/1975	329.52/1975	329.50/1975	329.61/1975	329.60/1975	323.93/1975	323.98/1979	323.96/1975	323.96/1975
	75 %ile Level	329.87	329.78	329.88	329.92	327.40	327.30	327.41	327.43	322.93	322.88	322.93	322.93
	50 %ile Level	329.08	328.64	329.06	329.06	326.43	326.27	326.37	326.38	322.64	322.56	322.63	322.63
	25 %ile Level	328.01	327.56	327.89	328.06	325.61	325.27	325.52	325.64	322.45	322.41	322.43	322.44
	Min Level/Year	327.17/1977	327.13/1977	327.16/1977	327.16/1977	324.49/1977	324.43/1977	324.48/1977	324.47/1977	322.32/1987	322.32/1958	322.32/1987	322.32/1987
										35946.00	35946.00	35946.00	35946.00
May 31	Mean Level	329.09	329.31	329.18	329.16	326.37	326.55	326.45	326.43	322.89	322.93	322.91	322.91
	Max Level/Year	331.23/1966	331.46/1962	331.33/1996	331.33/1996	328.51/1962	328.70/1962	328.58/1962	328.56/1962	323.85/1962	323.97/1962	323.89/1962	323.88/1966
	75 %ile Level	330.26	330.49	330.42	330.34	327.45	327.61	327.48	327.48	323.15	323.21	323.18	323.16
	50 %ile Level	329.05	329.25	329.11	329.07	326.24	326.46	326.32	326.30	322.76	322.83	322.79	322.79
	25 %ile Level	327.91	328.31	328.02	327.98	325.62	325.79	325.68	325.65	322.54	322.53	322.54	322.54
	Min Level/Year	327.12/1980	327.12/1980	327.12/1980	327.13/1977	324.39/1958	324.39/1958	324.39/1958	324.39/1958	322.30/1958	322.27/1958	322.29/1958	322.30/1958
Jun 30	Mean Level	329.16	329.53	329.26	329.26	326.38	326.70	326.47	326.47	323.02	323.11	323.06	323.06
	Max Level/Year	331.78/1985	331.78/1985	331.80/1985	331.80/1985	329.37/1985	329.37/1985	329.38/1985	329.38/1985	324.23/1985	324.30/1985	324.29/1985	324.29/1985
	75 %ile Level	329.99	330.41	330.09	330.07	327.27	327.54	327.28	327.26	323.24	323.35	323.29	323.29
	50 %ile Level	329.39	329.62	329.39	329.39	326.50	326.86	326.57	326.58	322.97	323.04	323.00	323.00
	25 %ile Level	328.18	328.93	328.35	328.35	325.55	326.06	325.68	325.70	322.68	322.78	322.74	322.74
	Min Level/Year	327.09/1980	327.09/1980	327.09/1980	327.09/1980	324.35/1958	324.41/1980	324.35/1958	324.35/1958	322.33/1958	322.31/1958	322.32/1958	322.33/1958
Jul 31	Mean Level	328.53	328.71	328.57	328.66	325.78	325.94	325.83	325.90	322.90	322.95	322.92	322.94
	Max Level/Year	331.07/1968	331.15/1968	331.12/1968	331.12/1968	327.92/1968	328.00/1993	327.95/1968	328.03/1993	323.63/1968	323.69/1968	323.67/1968	323.68/1968
	75 %ile Level	329.29	329.44	329.37	329.44	326.41	326.57	326.44	326.53	323.08	323.11	323.10	323.12
	50 %ile Level	328.41	328.60	328.47	328.59	325.63	325.84	325.69	325.87	322.93	322.93	322.93	322.95
	25 %ile Level	327.77	328.12	327.84	328.03	325.17	325.40	325.16	325.32	322.75	322.83	322.80	322.81
	Min Level/Year	327.07/1988	327.18/1988	327.08/1980	327.08/1980	324.32/1988	324.47/1988	324.37/1980	324.37/1980	322.36/1980	322.36/1980	322.36/1980	322.36/1980
		USCGS(1912) Datum				GSC(1929) Datum				GSC(1979) Datum			

Table 1

RAINY RIVER AT FORT FRANCES TAILWATER: LEVEL PERCENTILES
RUN F1 - IJC vs. SC

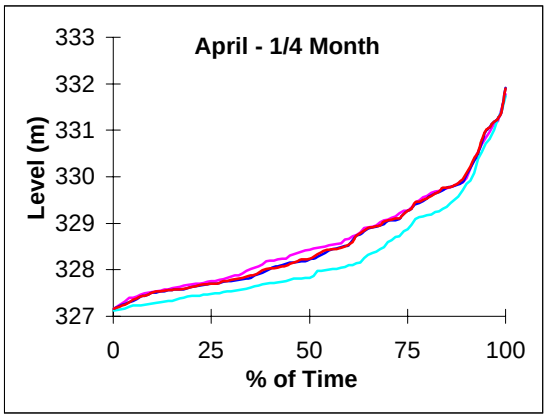


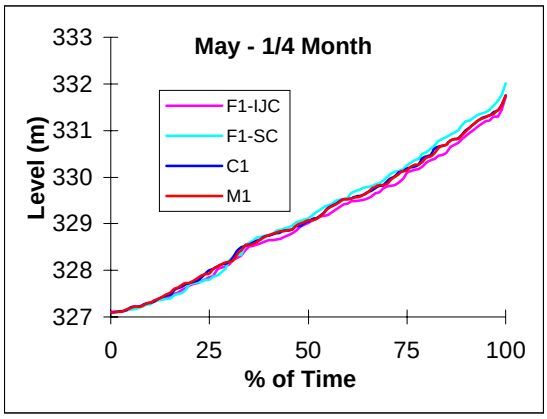
USCGS(1912) Datum

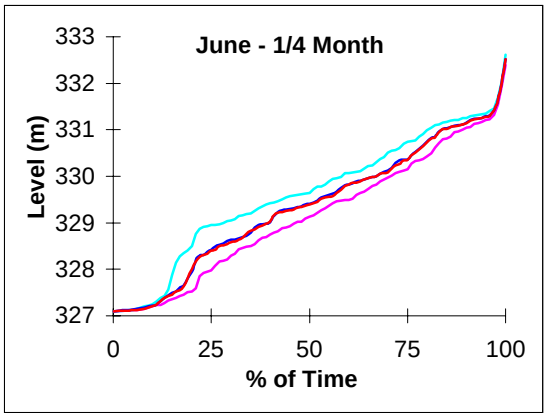
Graph 1

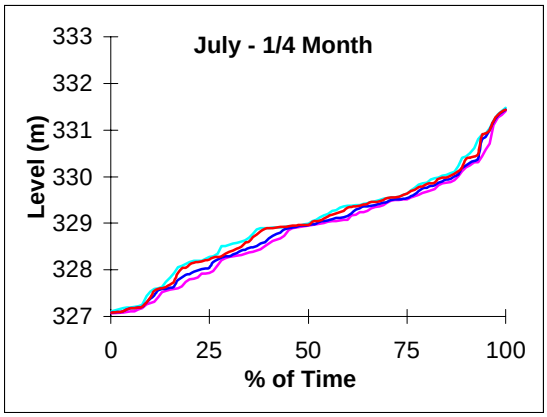
Rainy River at Fort Frances Tailwater

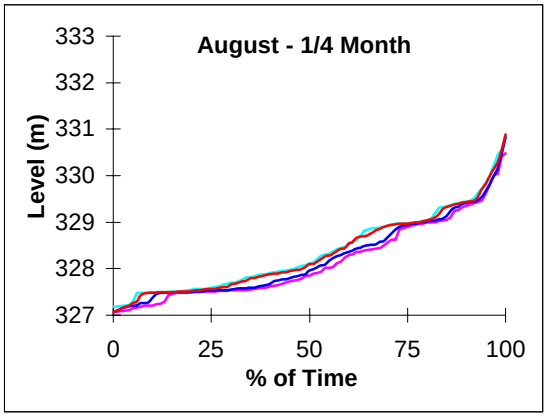
IJC-SC-C1-M1 - Level Duration Curves

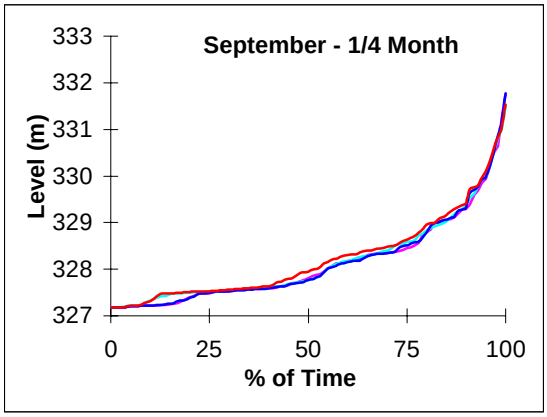


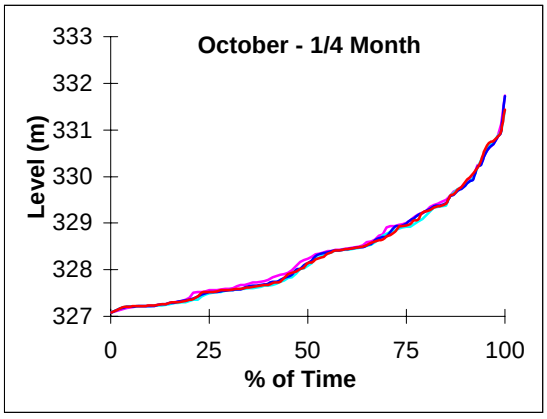


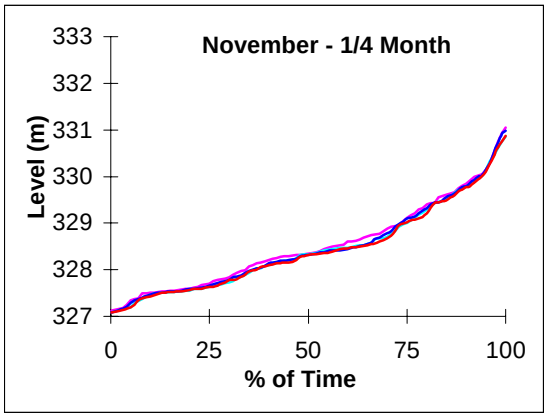






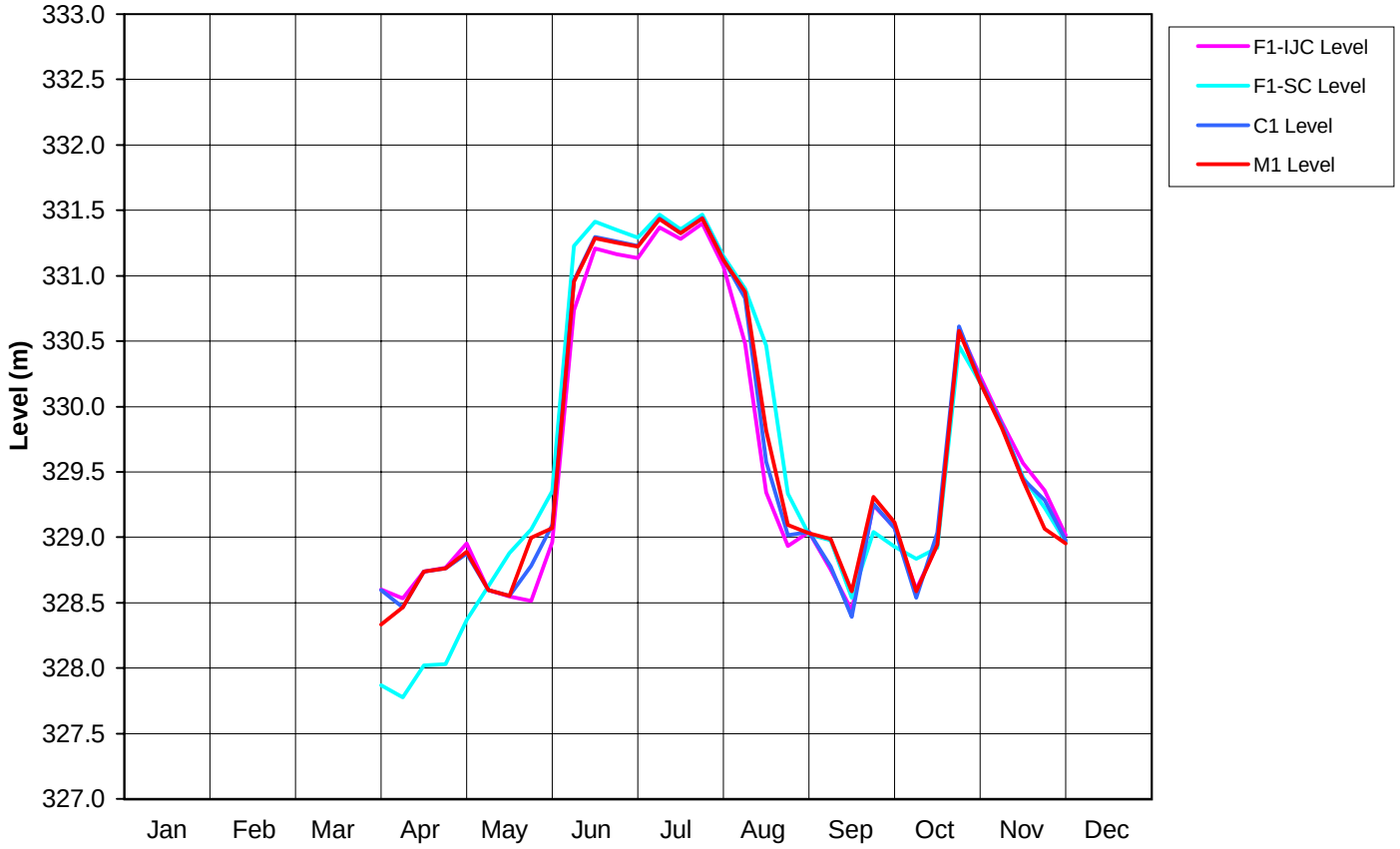




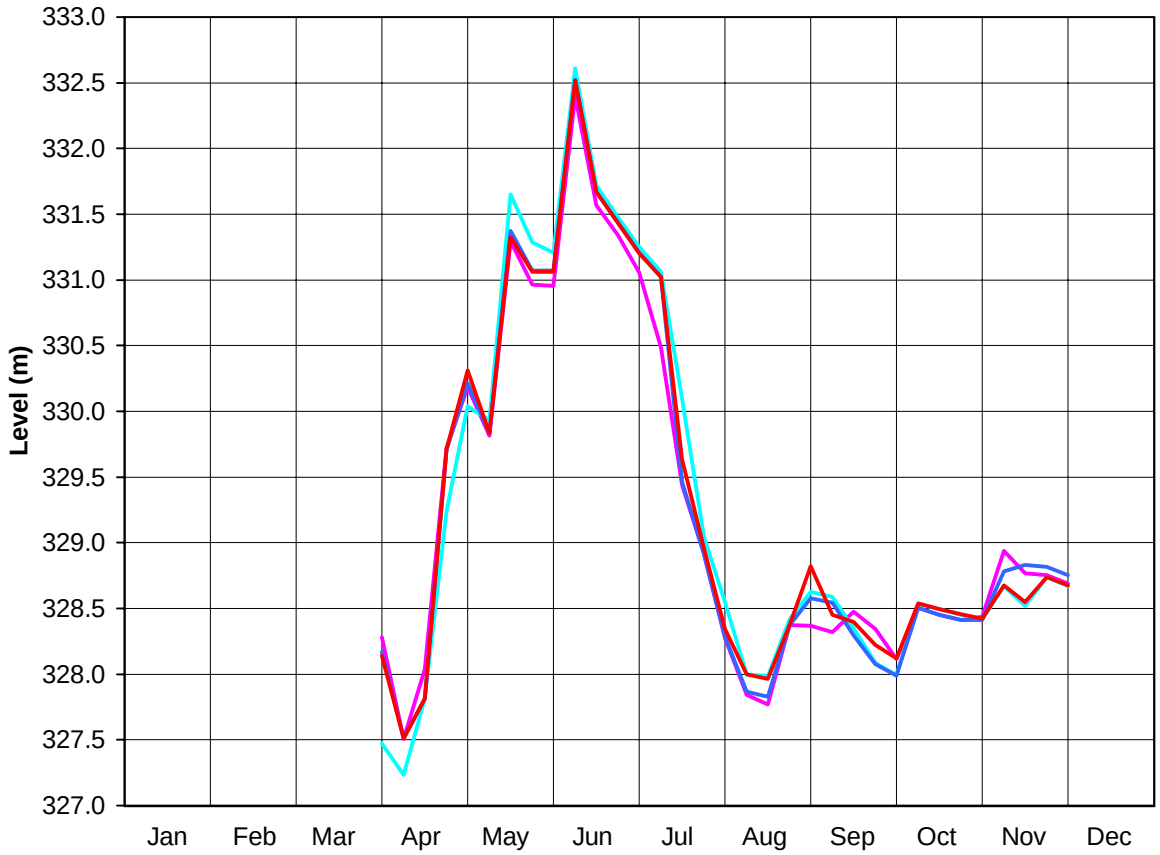


USCGS(1912) Datum

RAINY RIVER AT FORT FRANCES TAILWATER: MODELLED LEVELS 1968



RAINY RIVER AT FORT FRANCES TAILWATER: MODELLED LEVELS 1974



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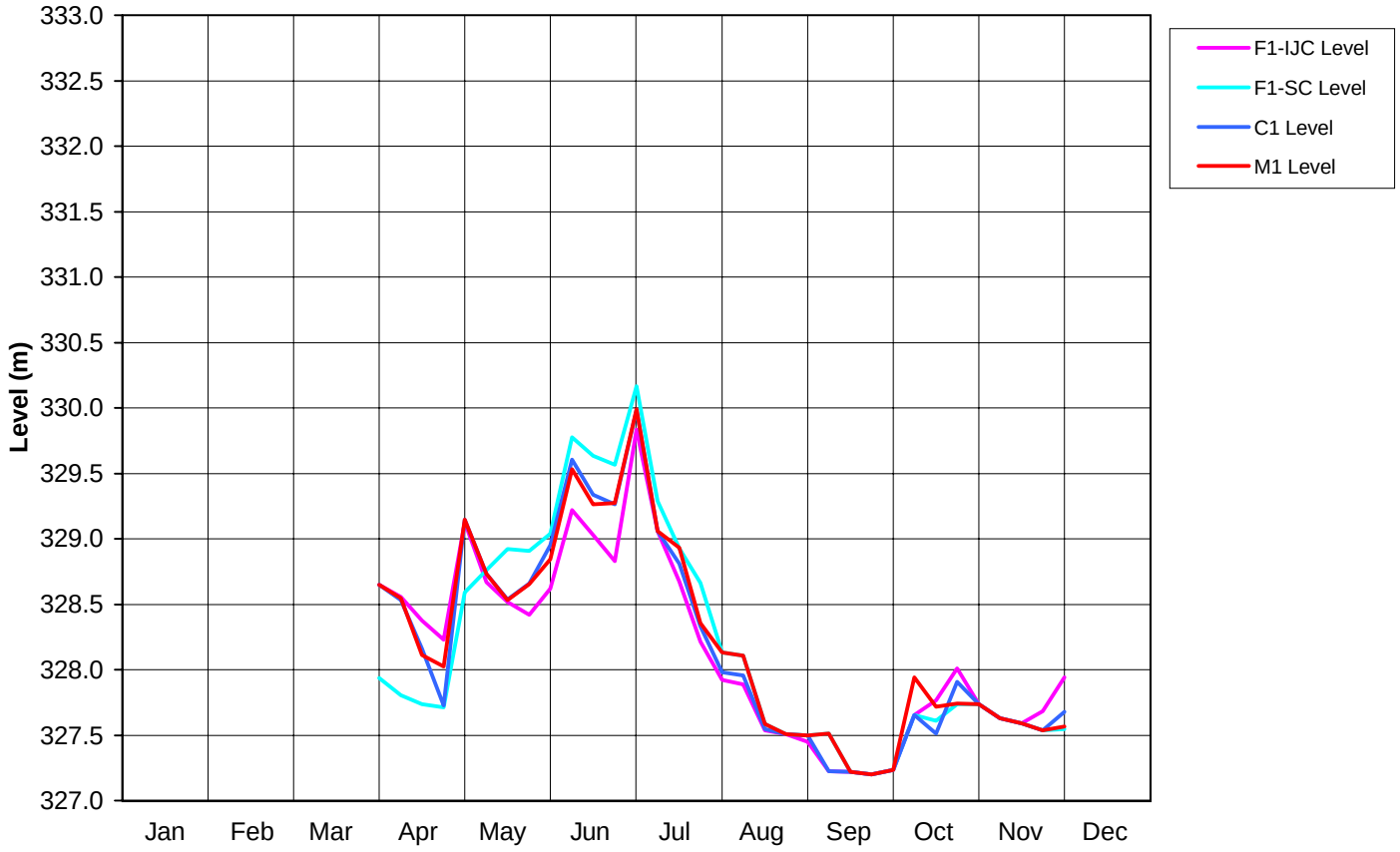
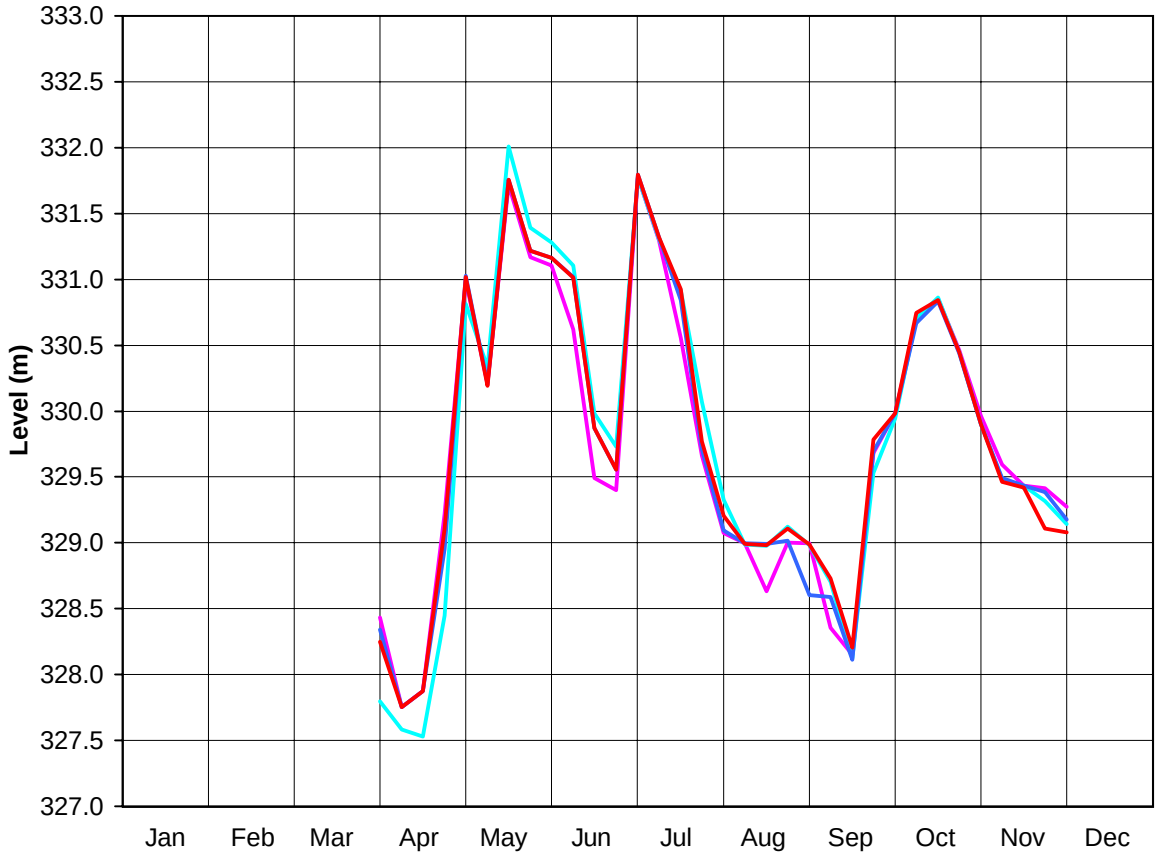
RAINY RIVER AT FORT FRANCES TAILWATER: MODELLED LEVELS 1981



RAINY RIVER AT FORT FRANCES TAILWATER: MODELLED LEVELS 1985



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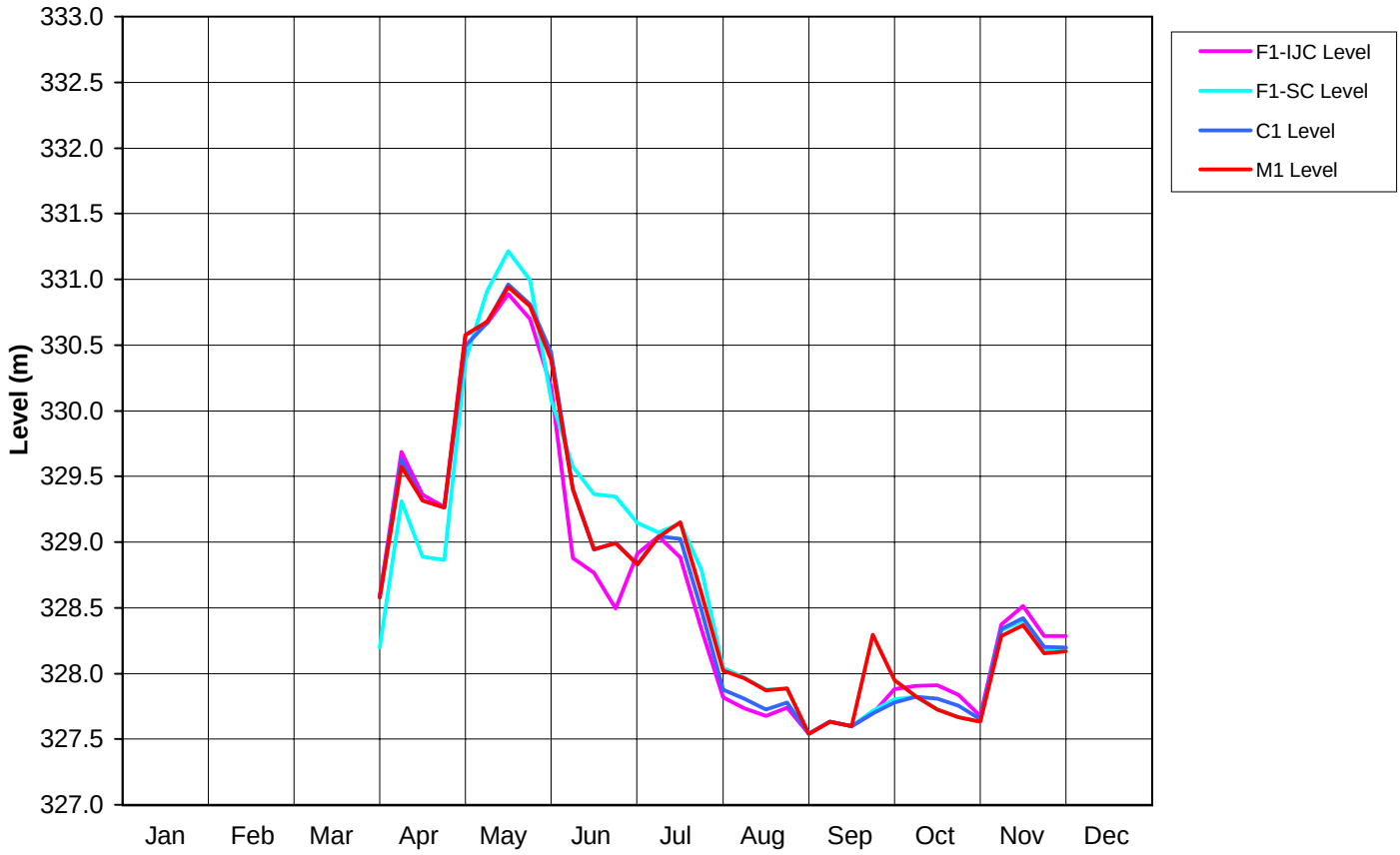
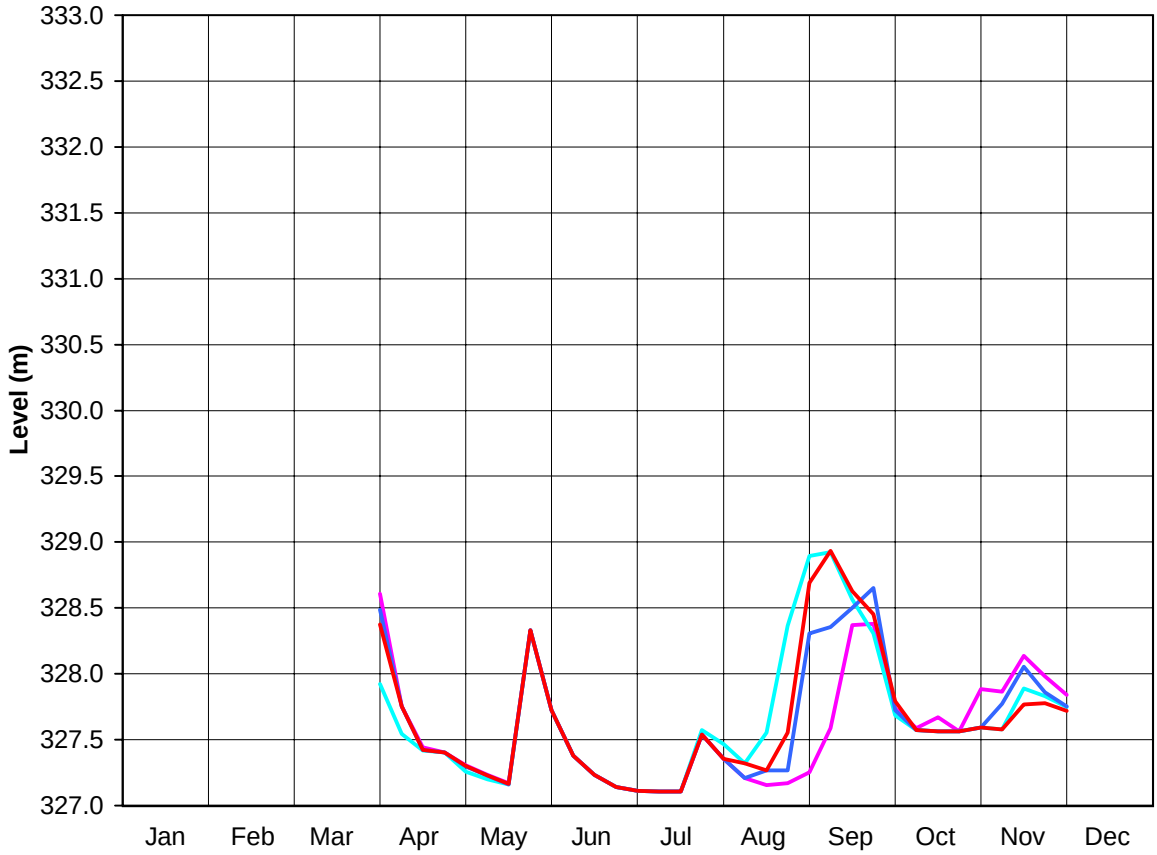
RAINY RIVER AT FORT FRANCES TAILWATER: MODELLED LEVELS 1986

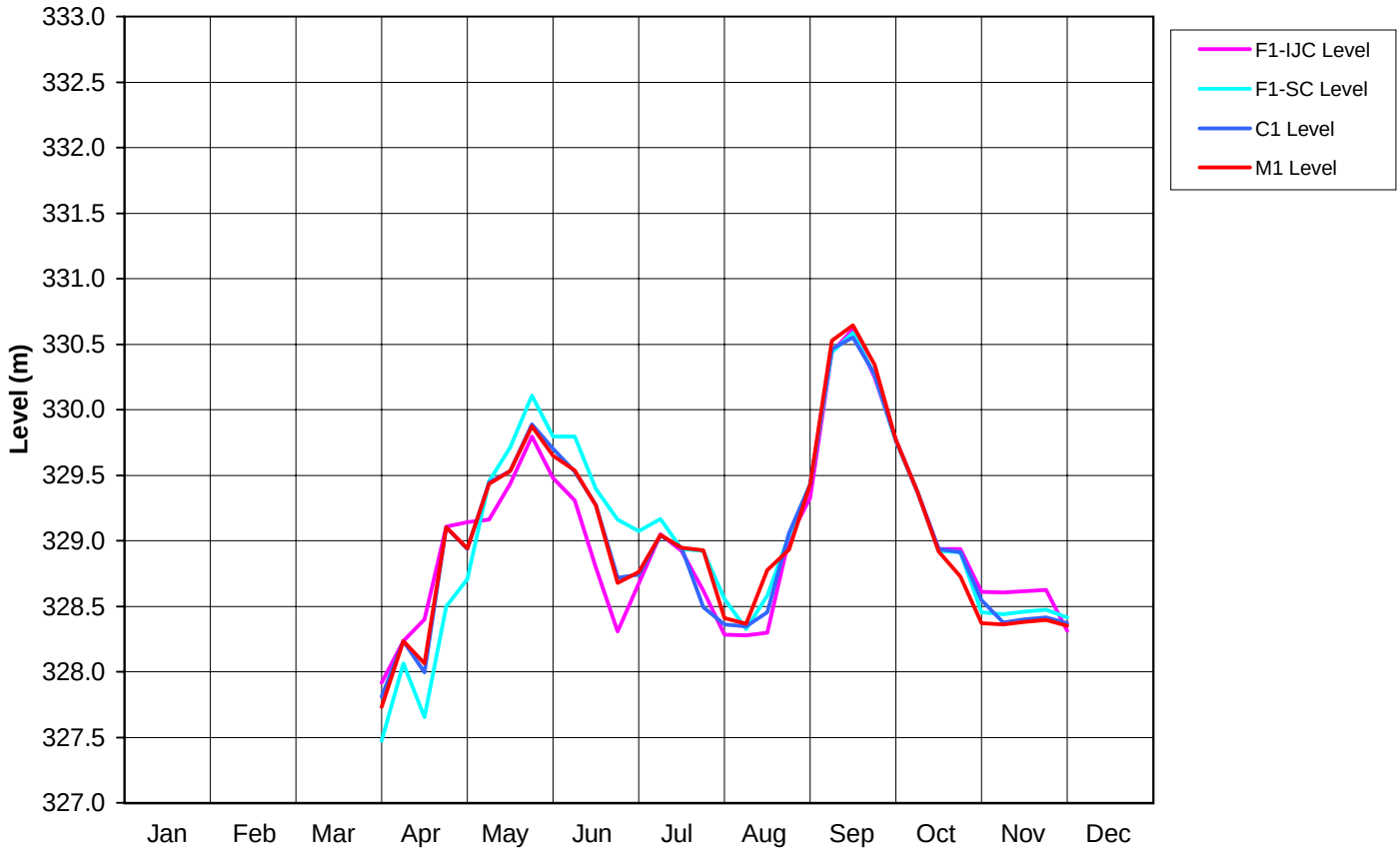


RAINY RIVER AT FORT FRANCES TAILWATER: MODELLED LEVELS 1987

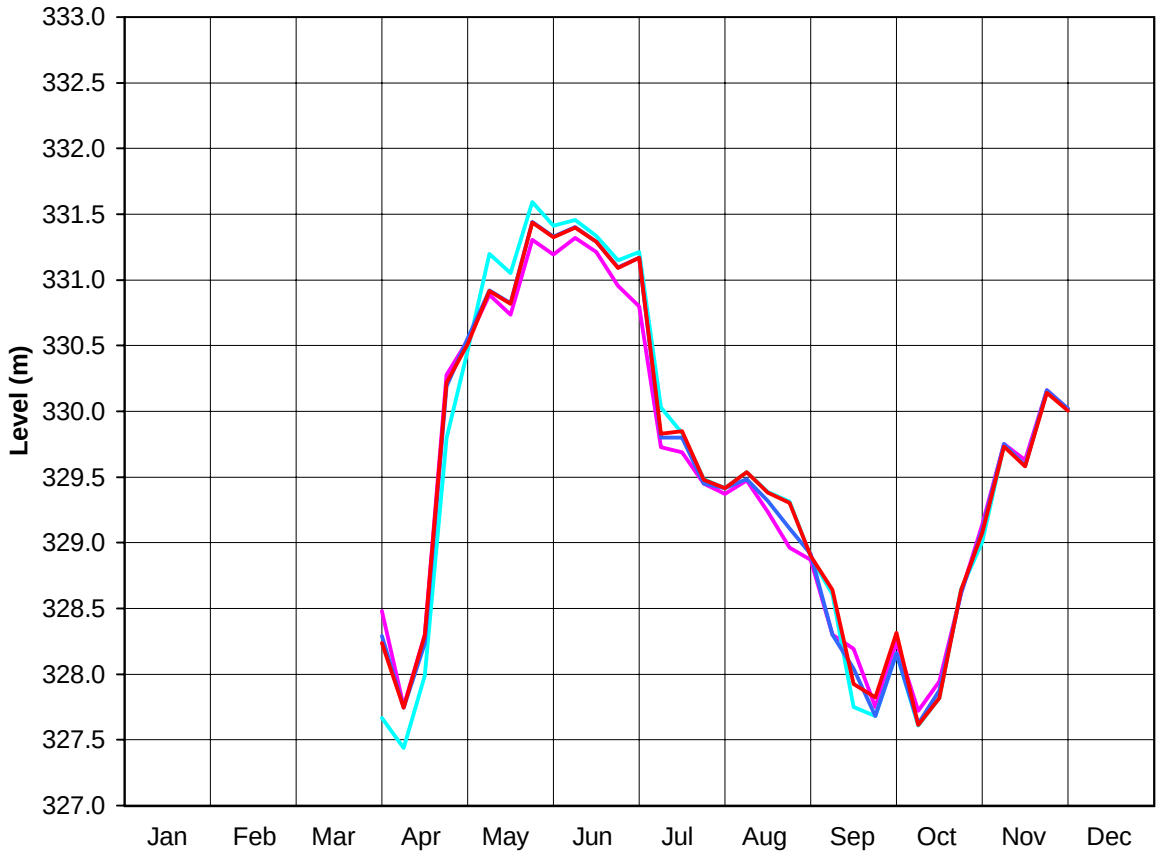


USCGS(1912) Datum

RAINY RIVER AT FORT FRANCES TAILWATER: MODELLED LEVELS 1992



RAINY RIVER AT FORT FRANCES TAILWATER: MODELLED LEVELS 1996



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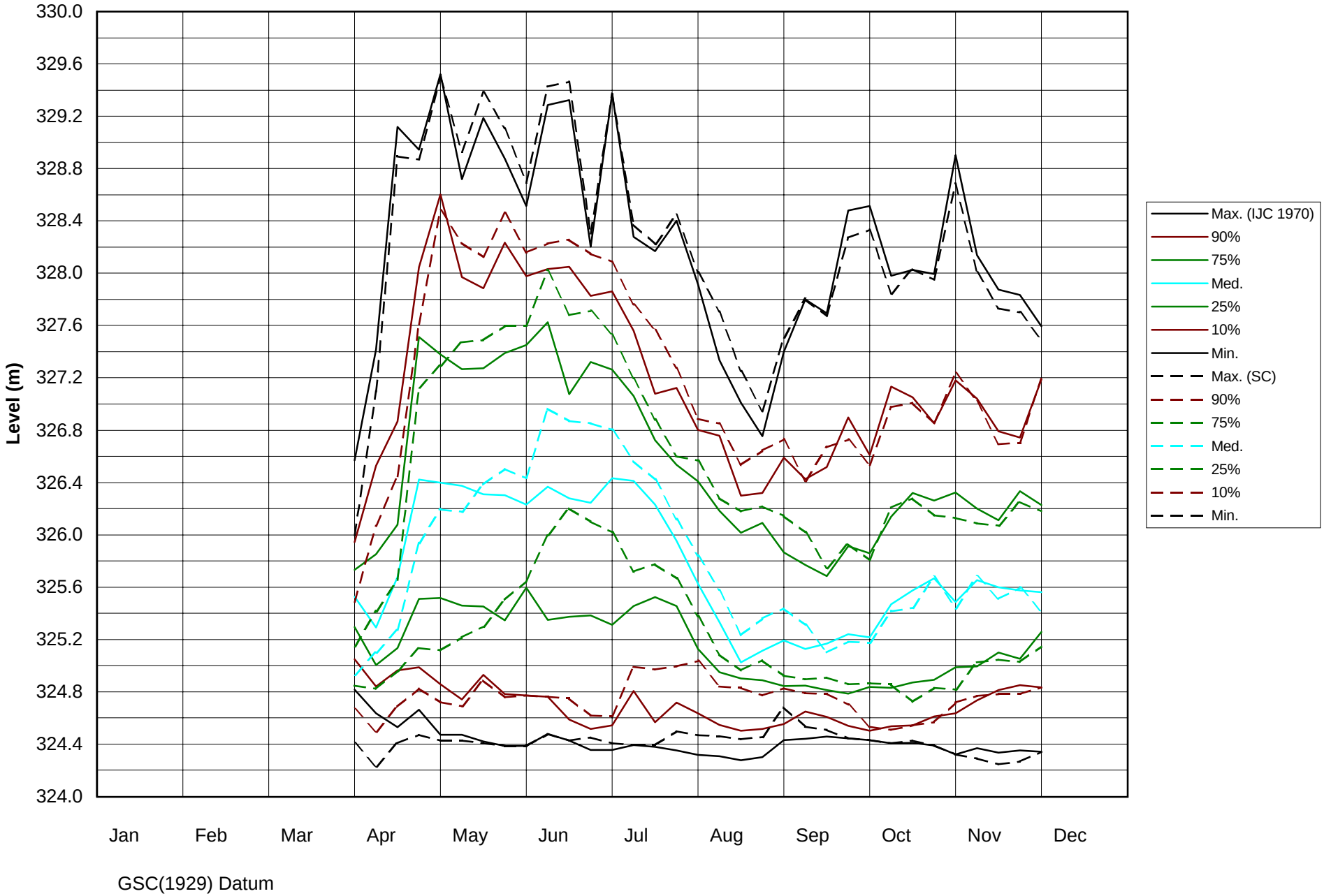
RAINY RIVER AT MANITOU RAPIDS: LEVEL PERCENTILES
RUN F1 - IJC vs. SC

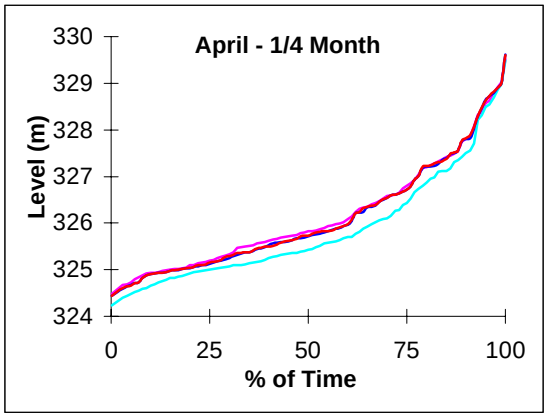


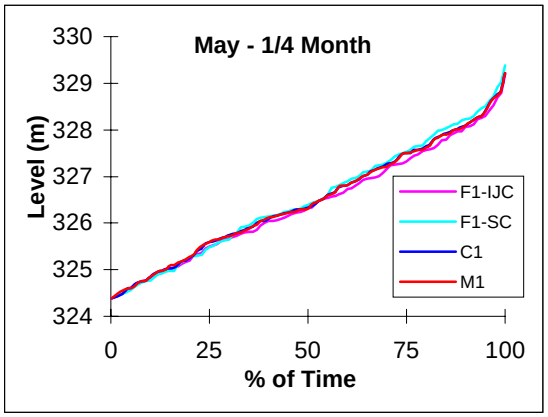
GSC(1929) Datum

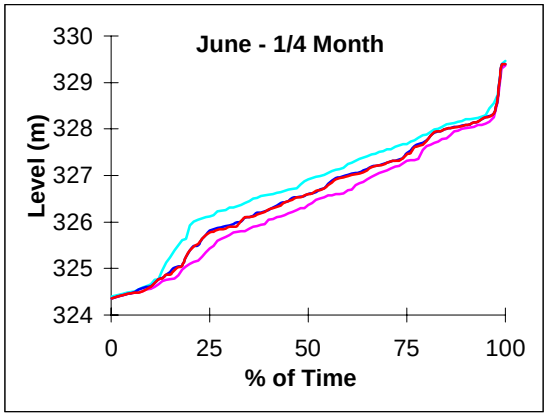
Graph 7

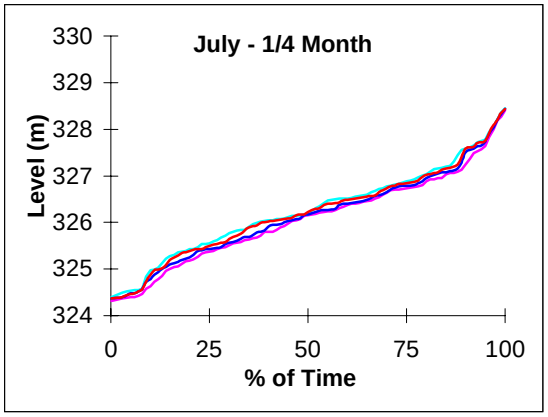
Rainy River at Manitou Rapids

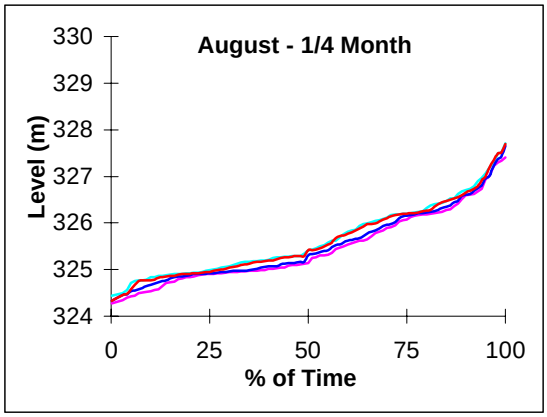
IJC-SC-C1-M1 - Level Duration Curves

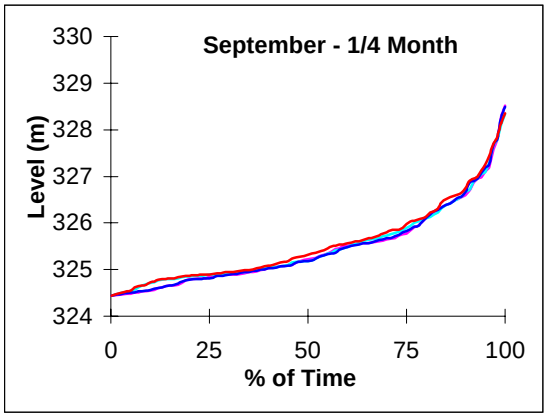


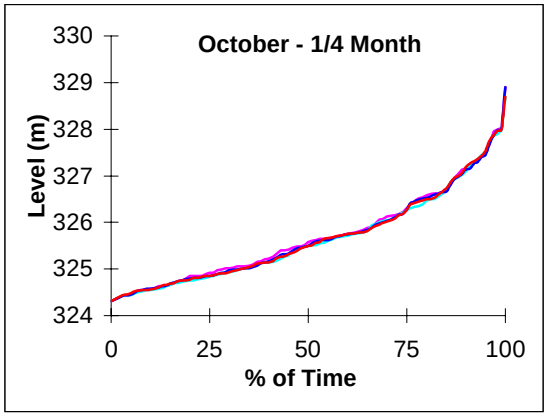


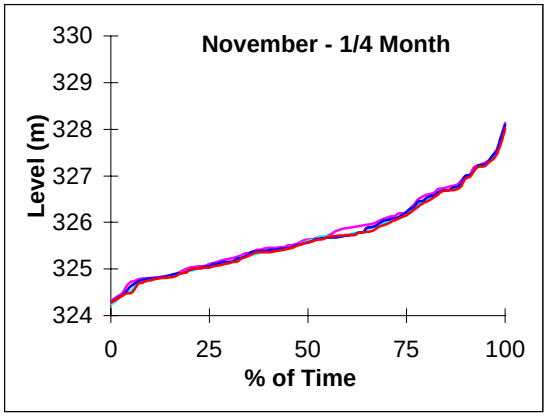






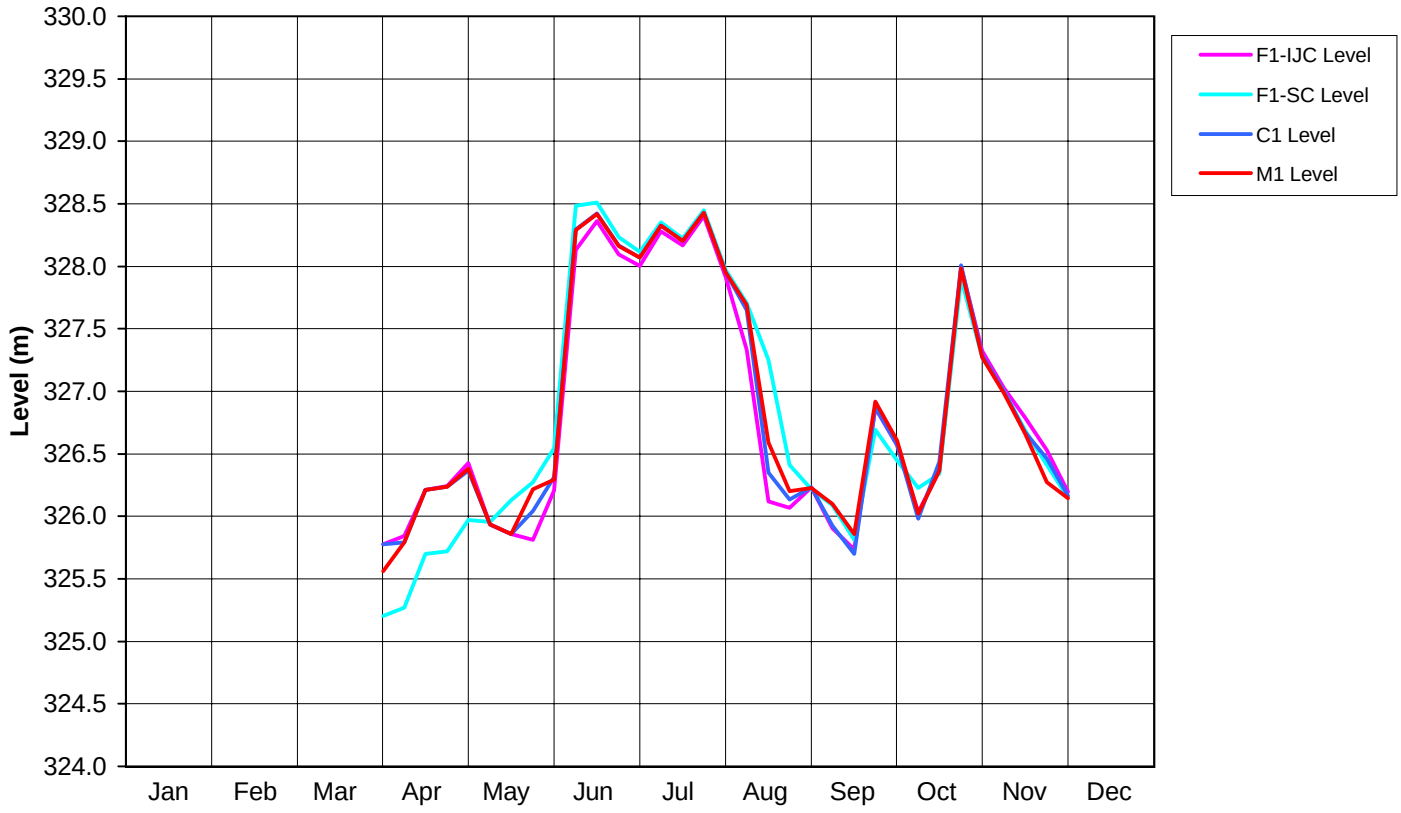




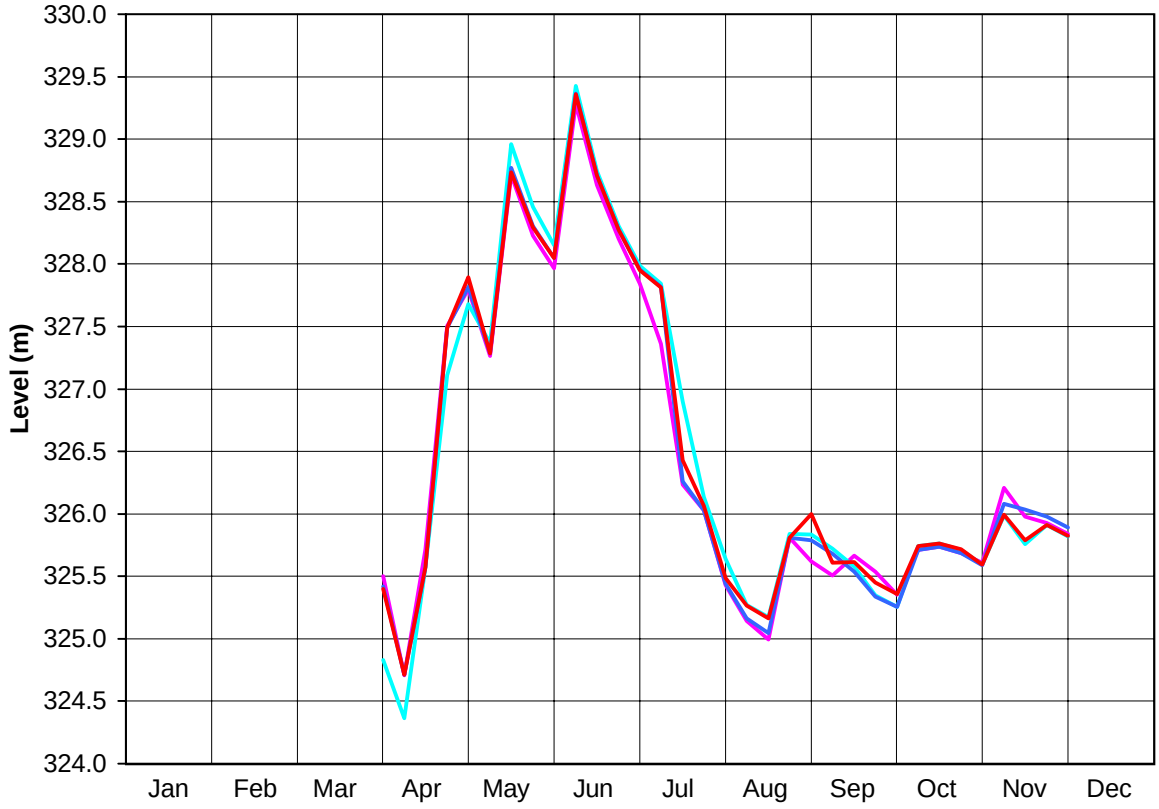


GSC(1929) Datum

RAINY RIVER AT MANITOU RAPIDS: MODELLED LEVELS 1968

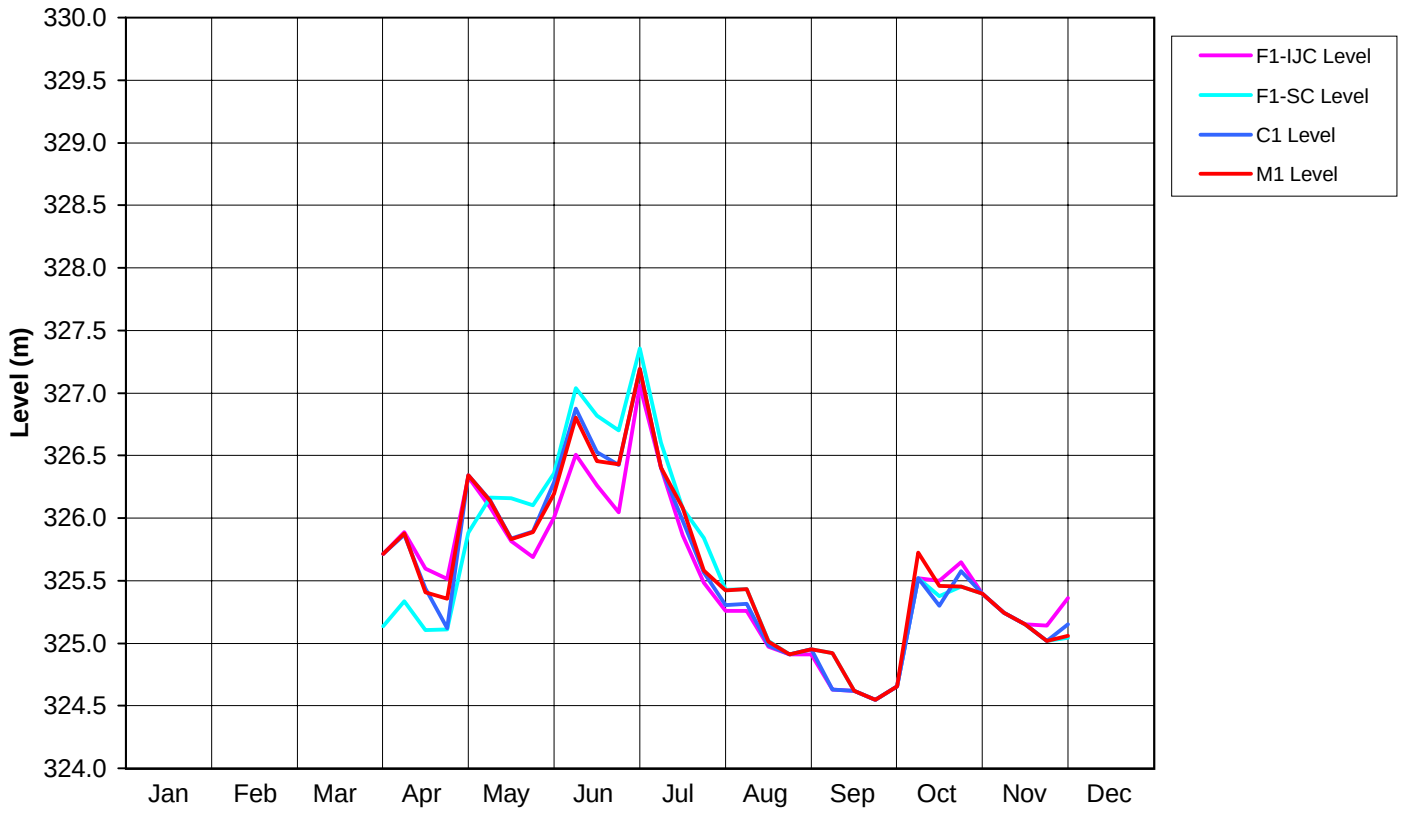


RAINY RIVER AT MANITOU RAPIDS: MODELLED LEVELS 1974

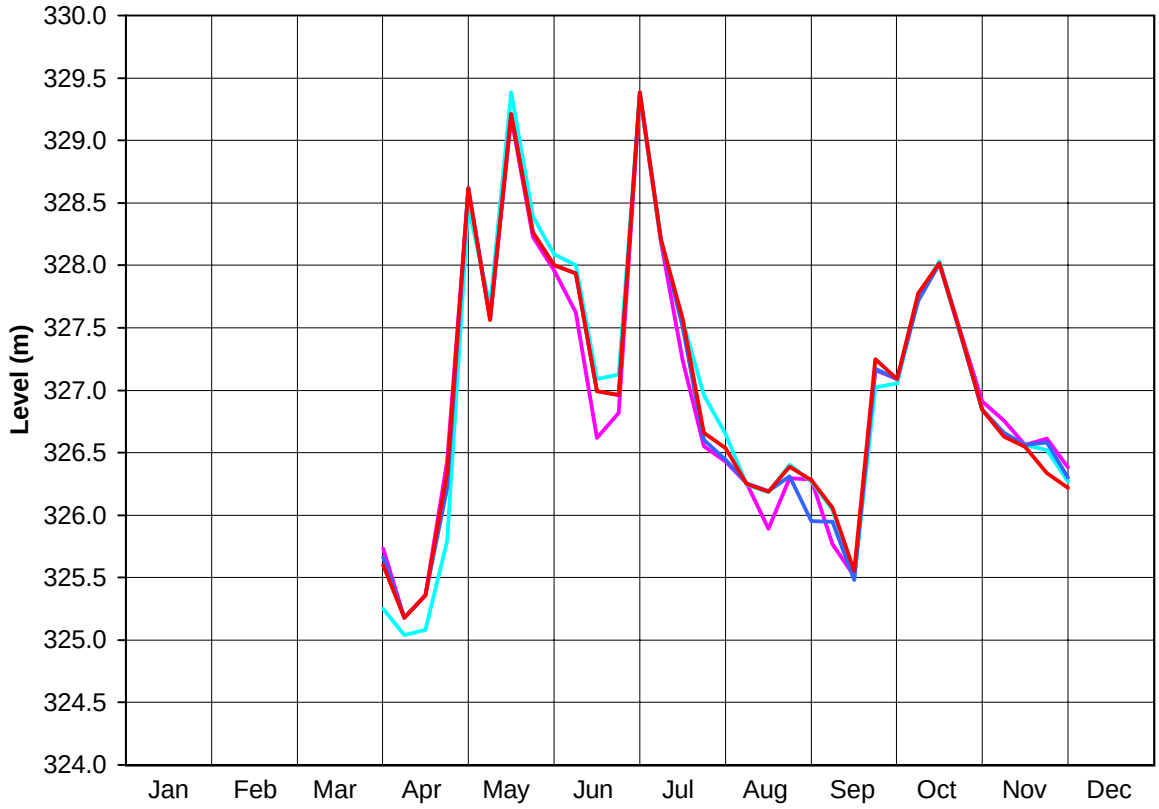


GSC(1929) Datum

RAINY RIVER AT MANITOU RAPIDS: MODELLED LEVELS 1981



RAINY RIVER AT MANITOU RAPIDS: MODELLED LEVELS 1985



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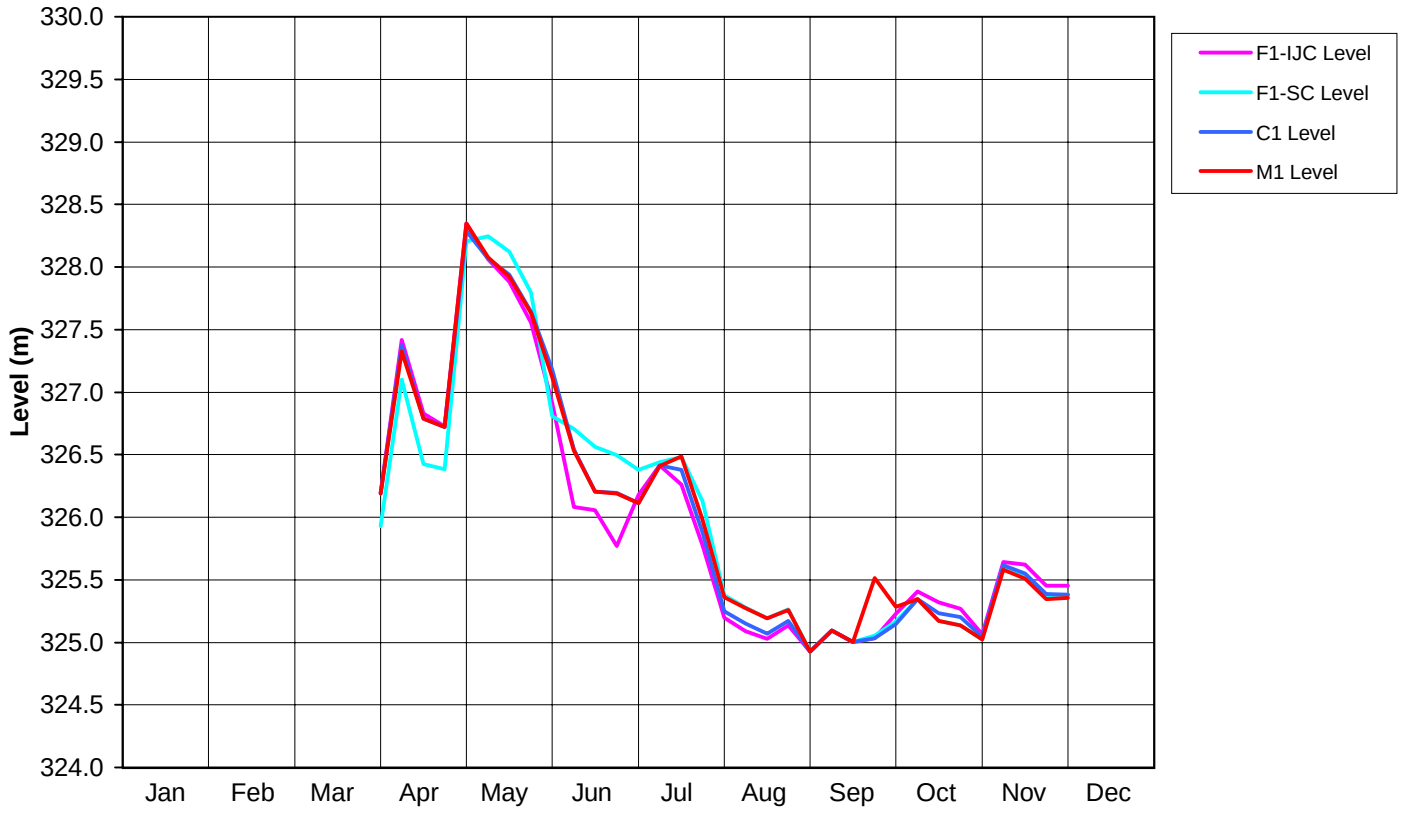
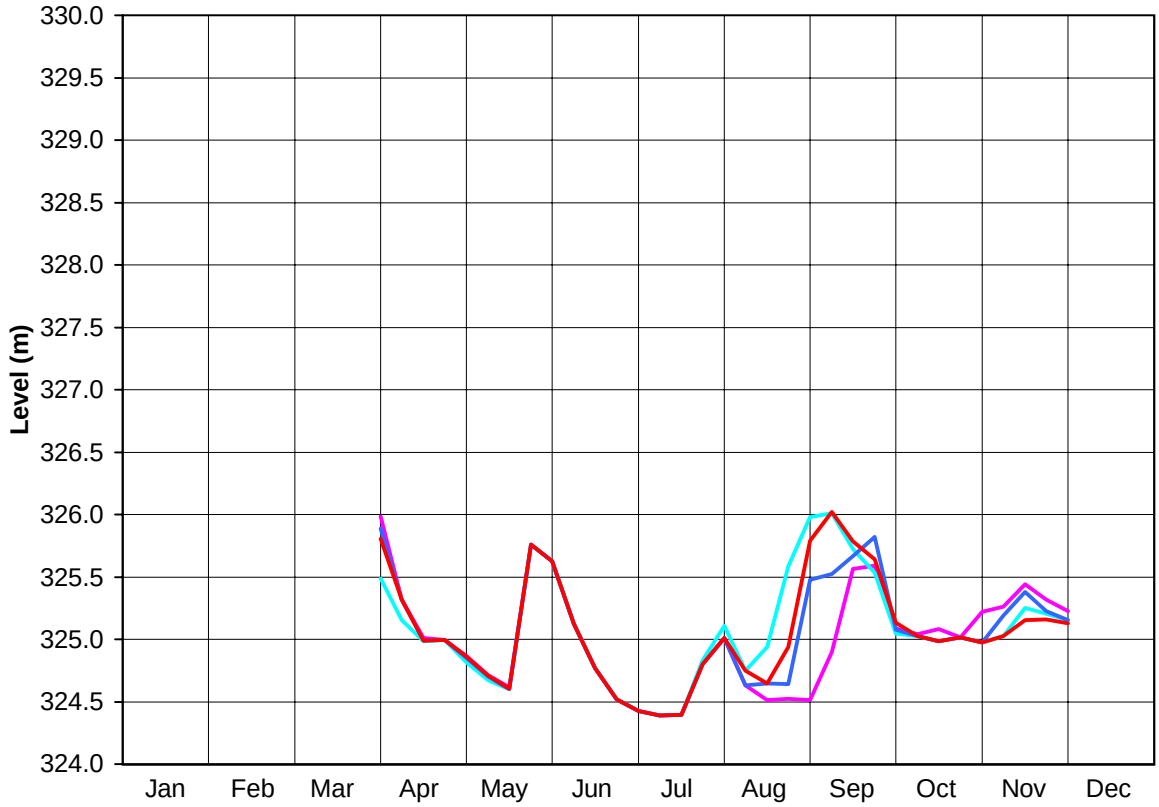
RAINY RIVER AT MANITOU RAPIDS: MODELLED LEVELS 1986

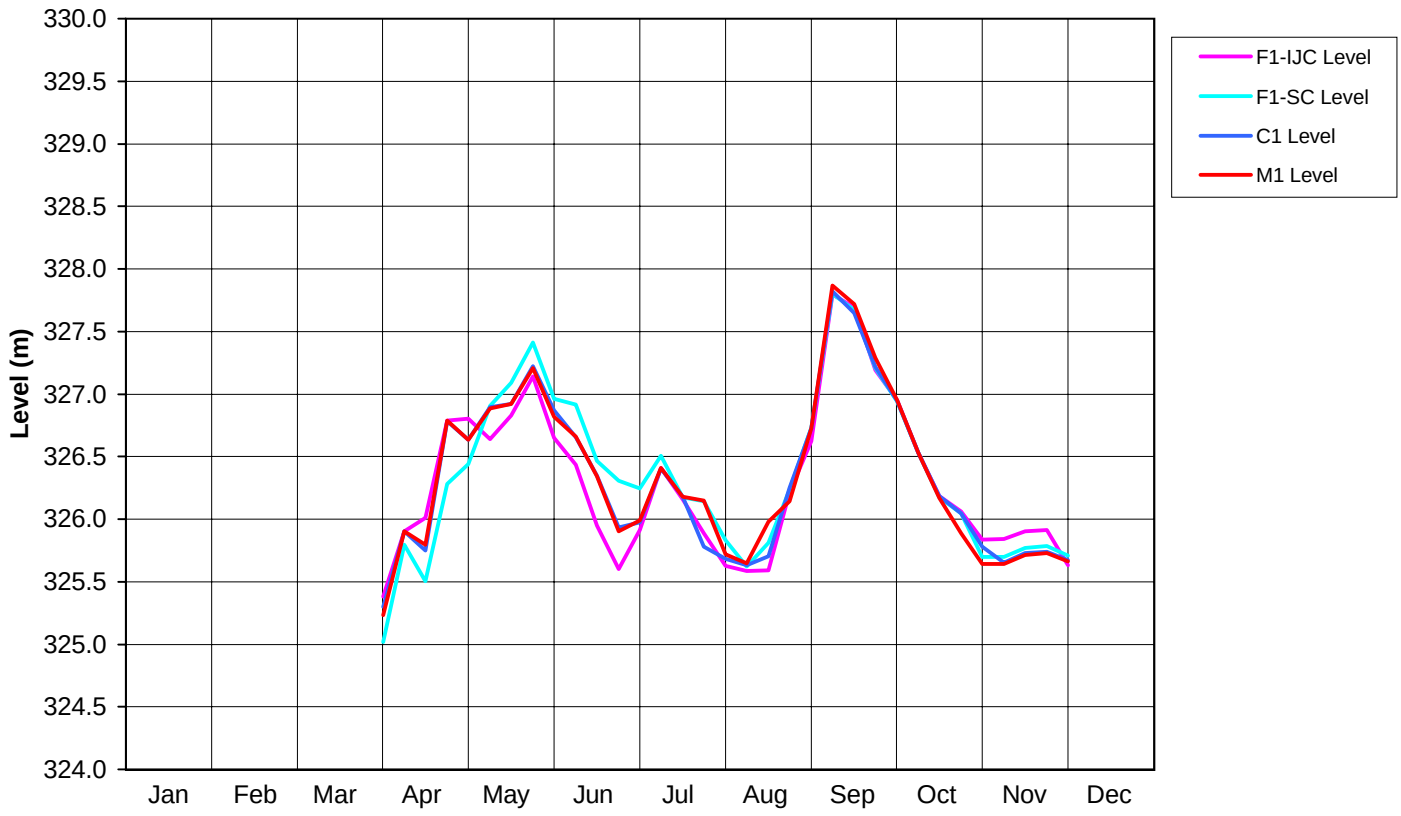


RAINY RIVER AT MANITOU RAPIDS: MODELLED LEVELS 1987

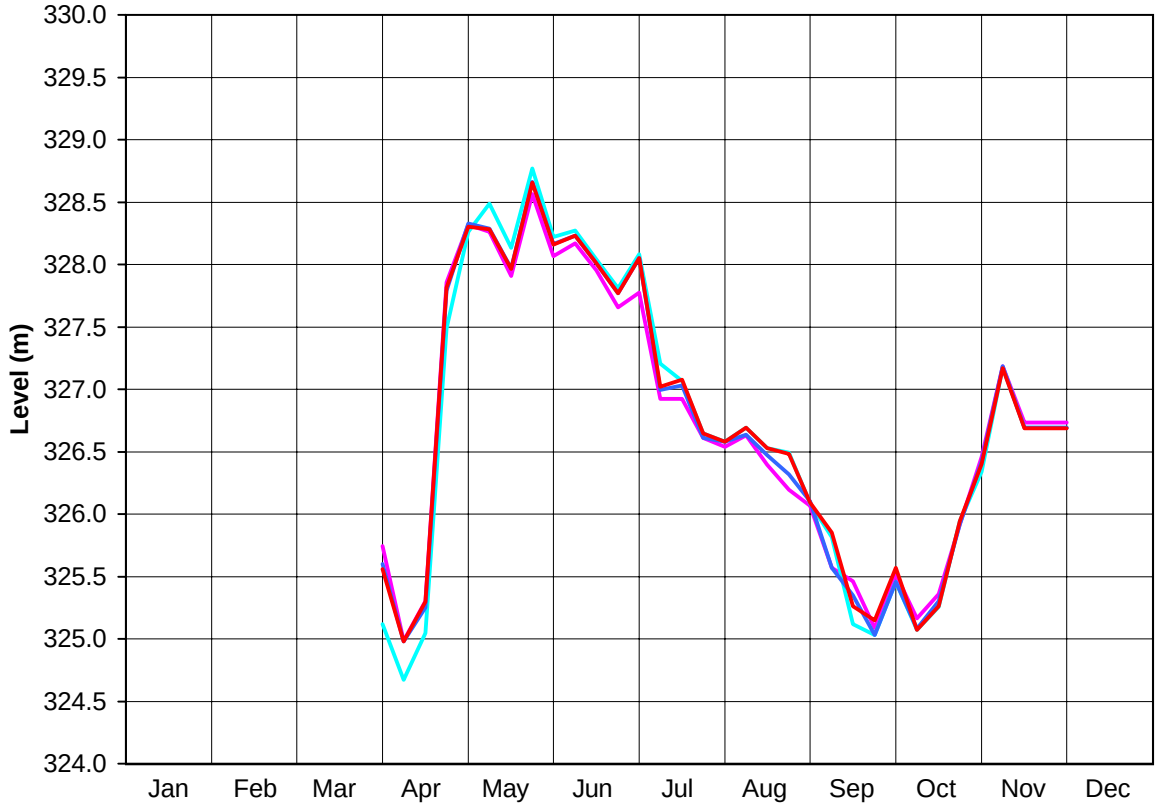


GSC(1929) Datum

RAINY RIVER AT MANITOU RAPIDS: MODELLED LEVELS 1992

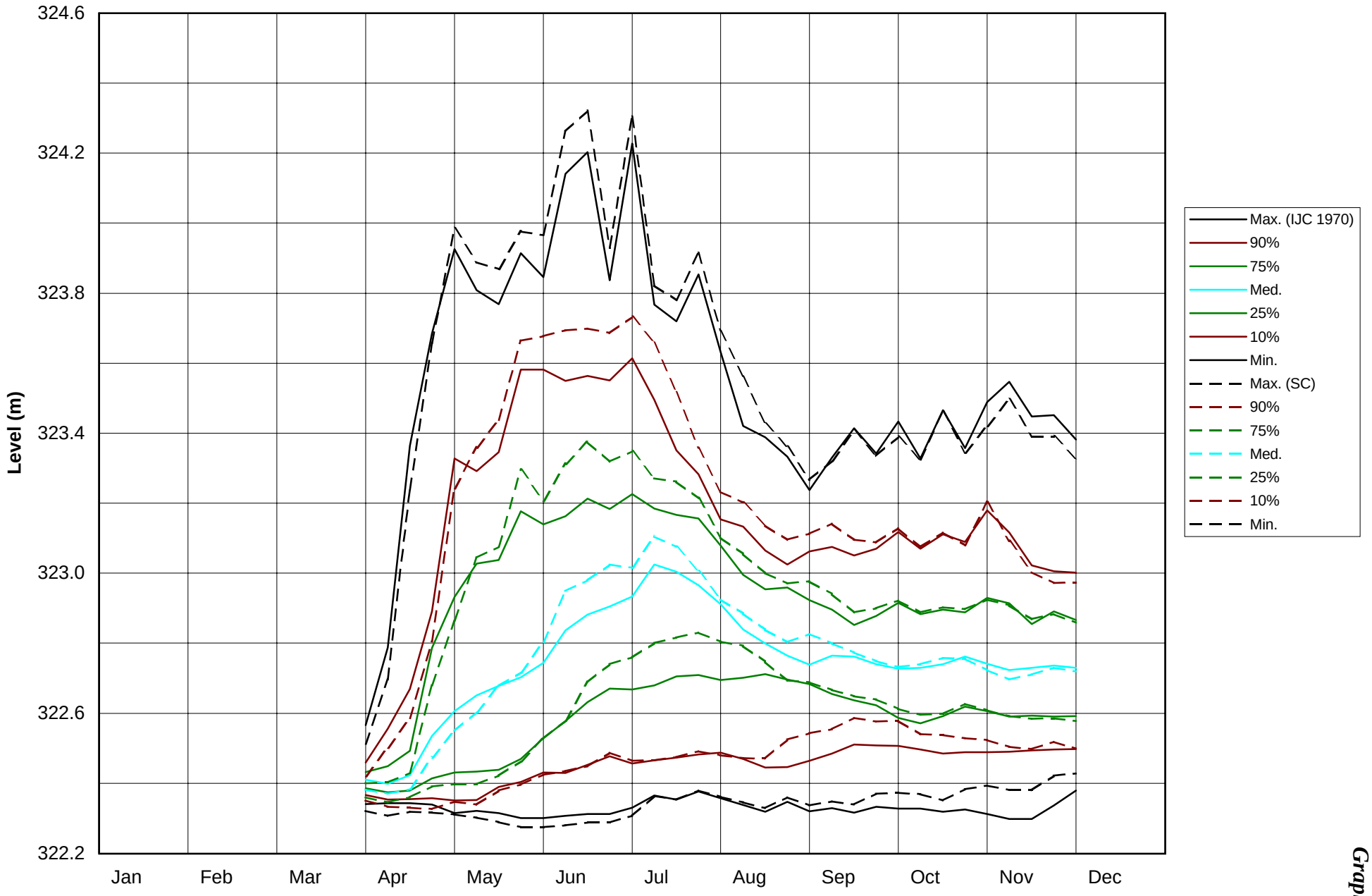


RAINY RIVER AT MANITOU RAPIDS: MODELLED LEVELS 1996



GSC(1929) Datum

RAINY RIVER AT TOWN OF RAINY RIVER: LEVEL PERCENTILES
RUN F1 - IJC vs. SC

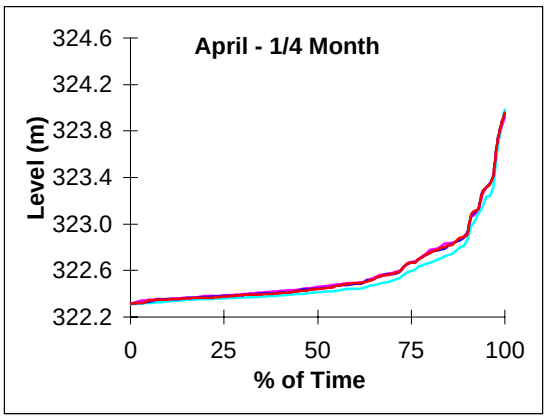


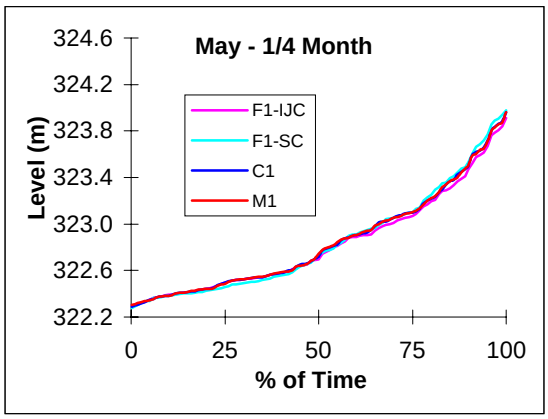
GSC(1979) Datum

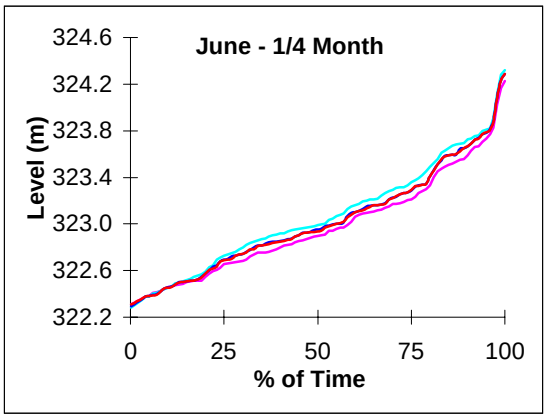
Graph 13

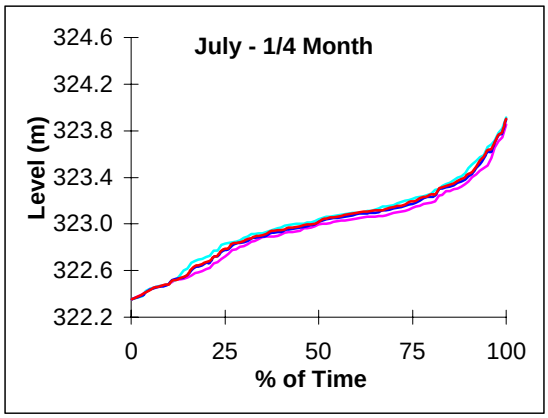
Rainy River at Town of Rainy River

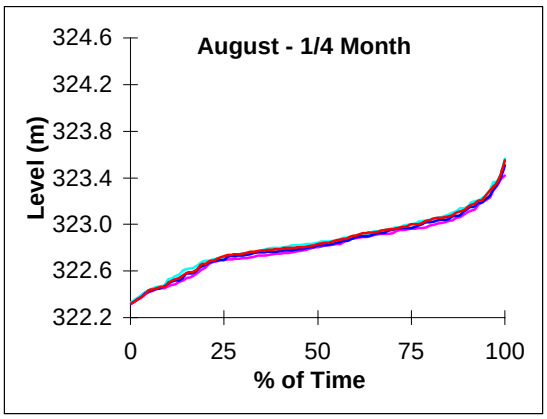
IJC-SC-C1-M1 - Level Duration Curves

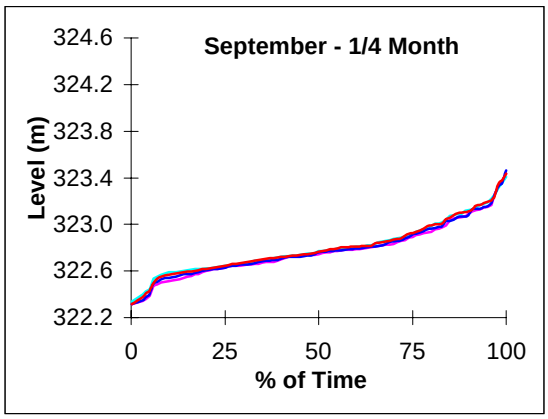


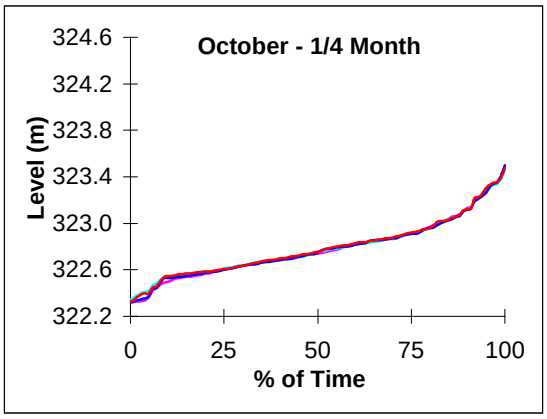


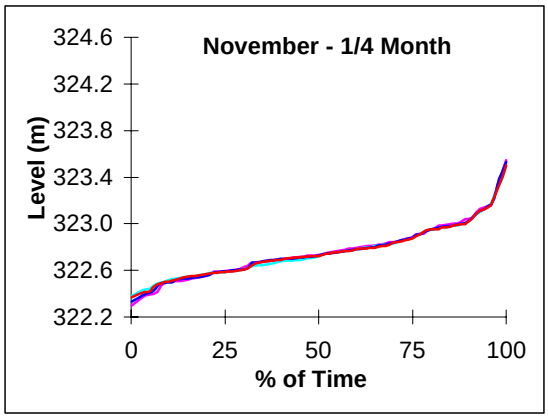






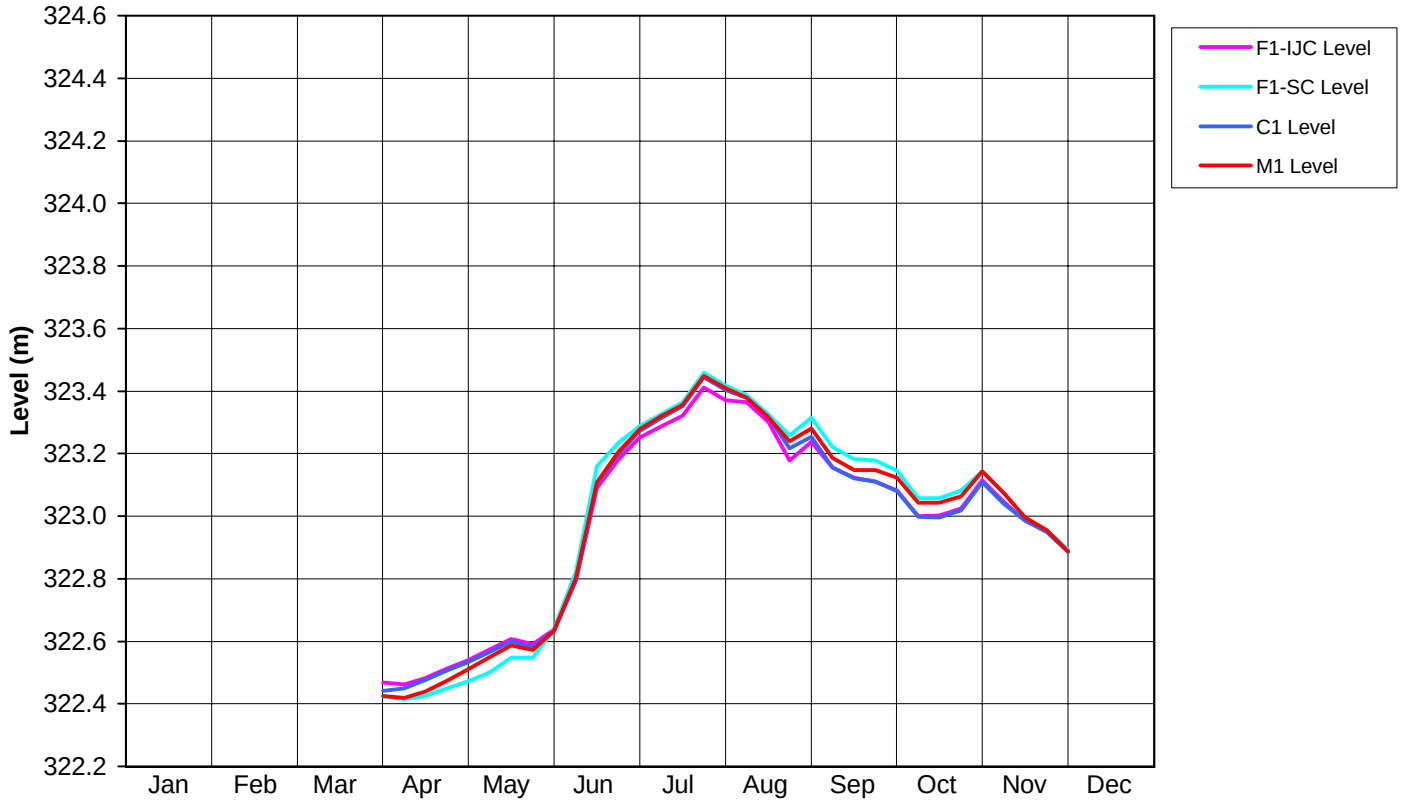




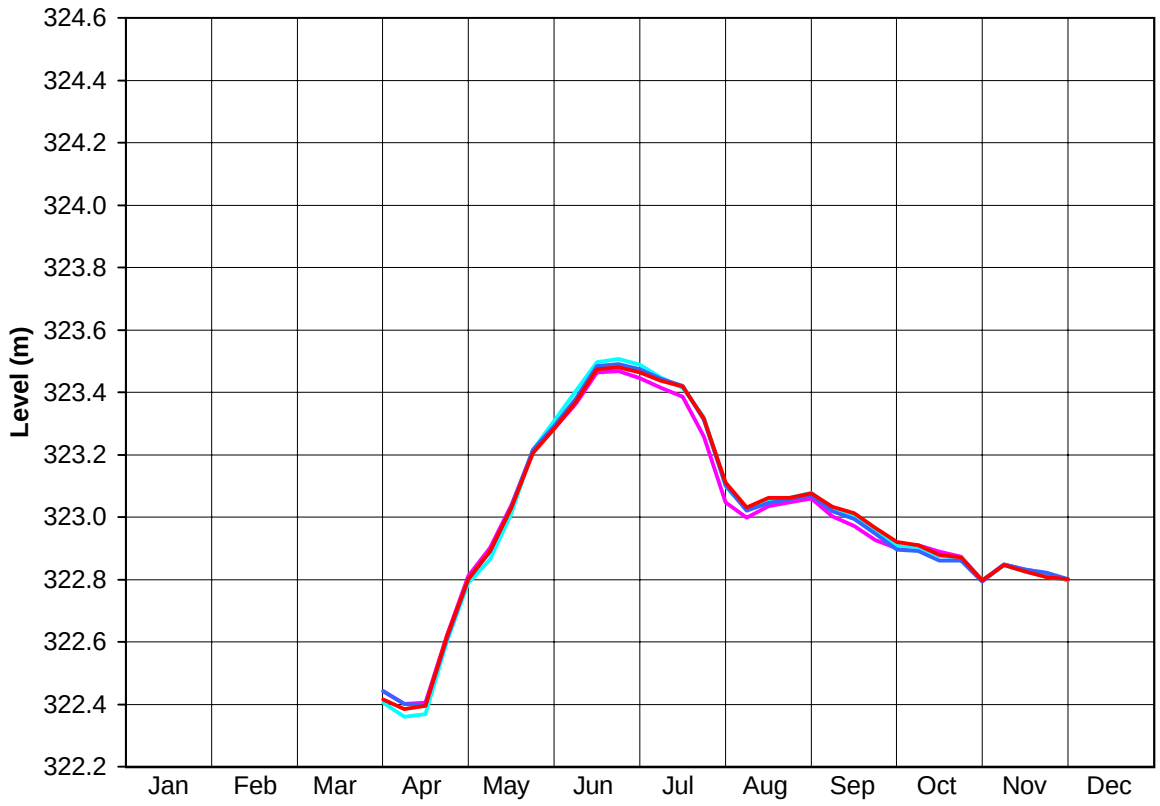


GSC(1979) Datum

RAINY RIVER AT TOWN OF RAINY RIVER: MODELLED LEVELS 1968

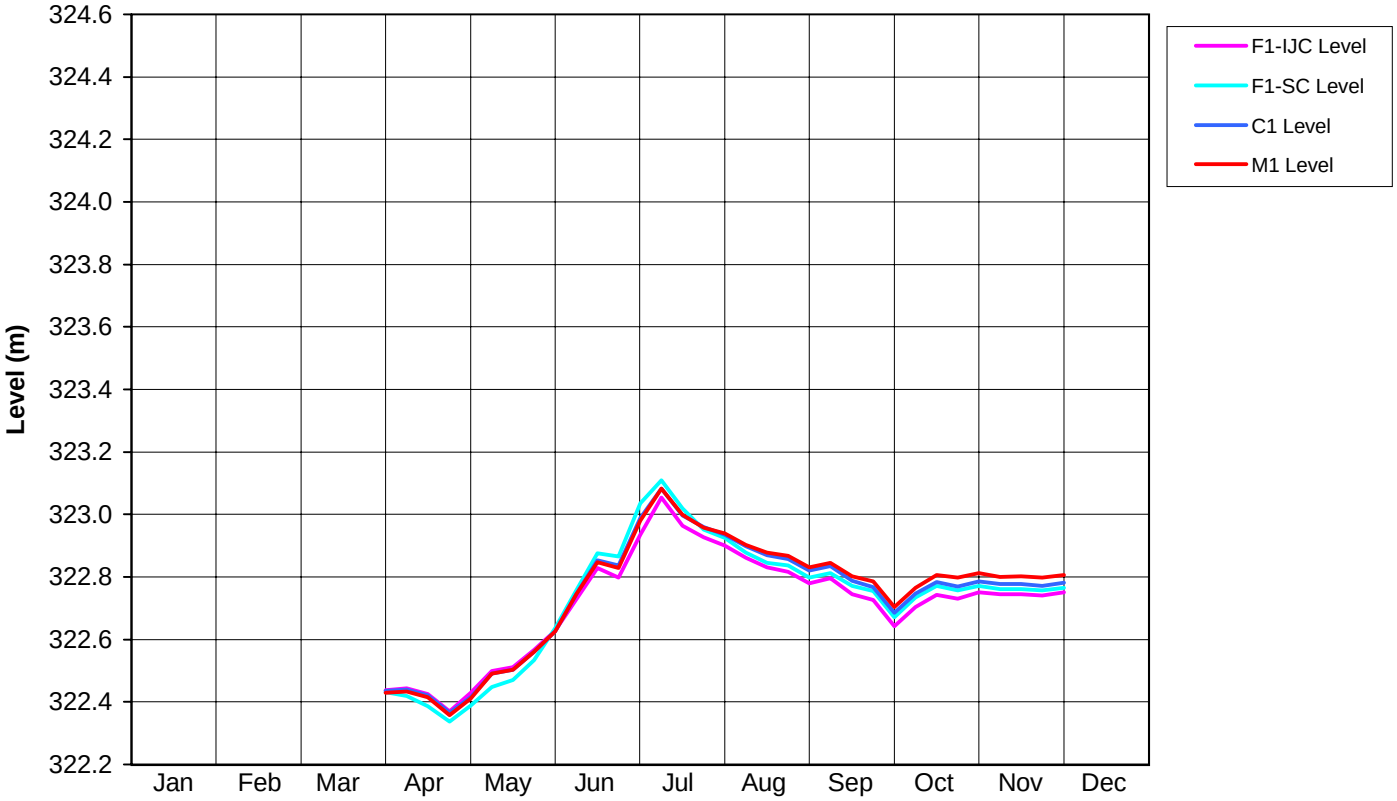


RAINY RIVER AT TOWN OF RAINY RIVER: MODELLED LEVELS 1974

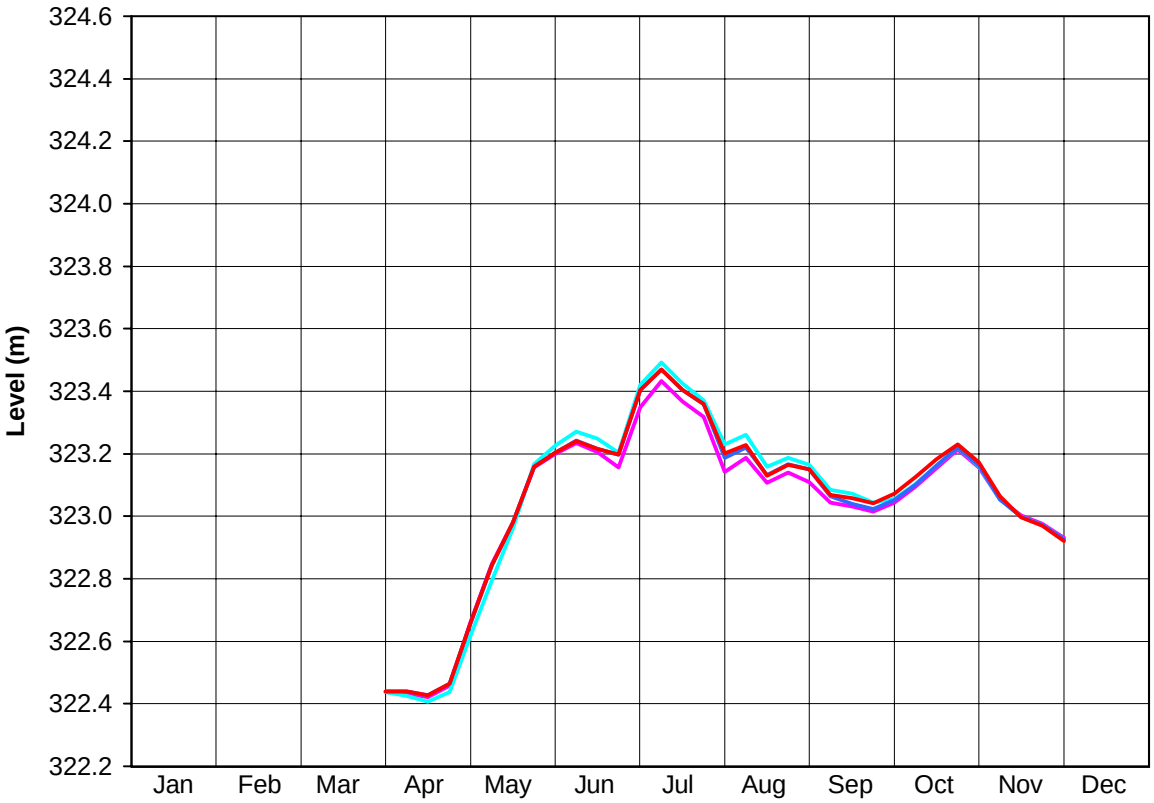


GSC(1979) Datum

RAINY RIVER AT TOWN OF RAINY RIVER: MODELLED LEVELS 1981



RAINY RIVER AT TOWN OF RAINY RIVER: MODELLED LEVELS 1985



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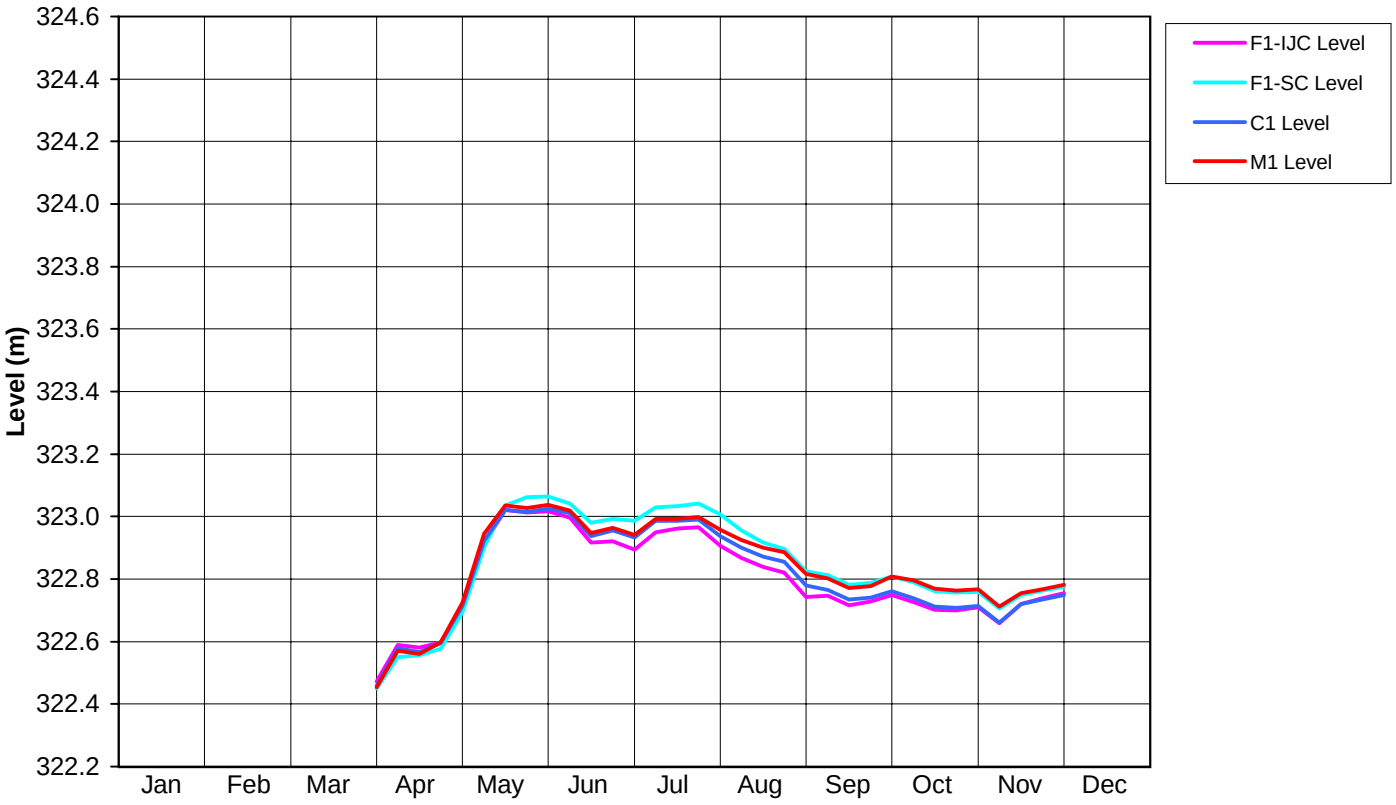
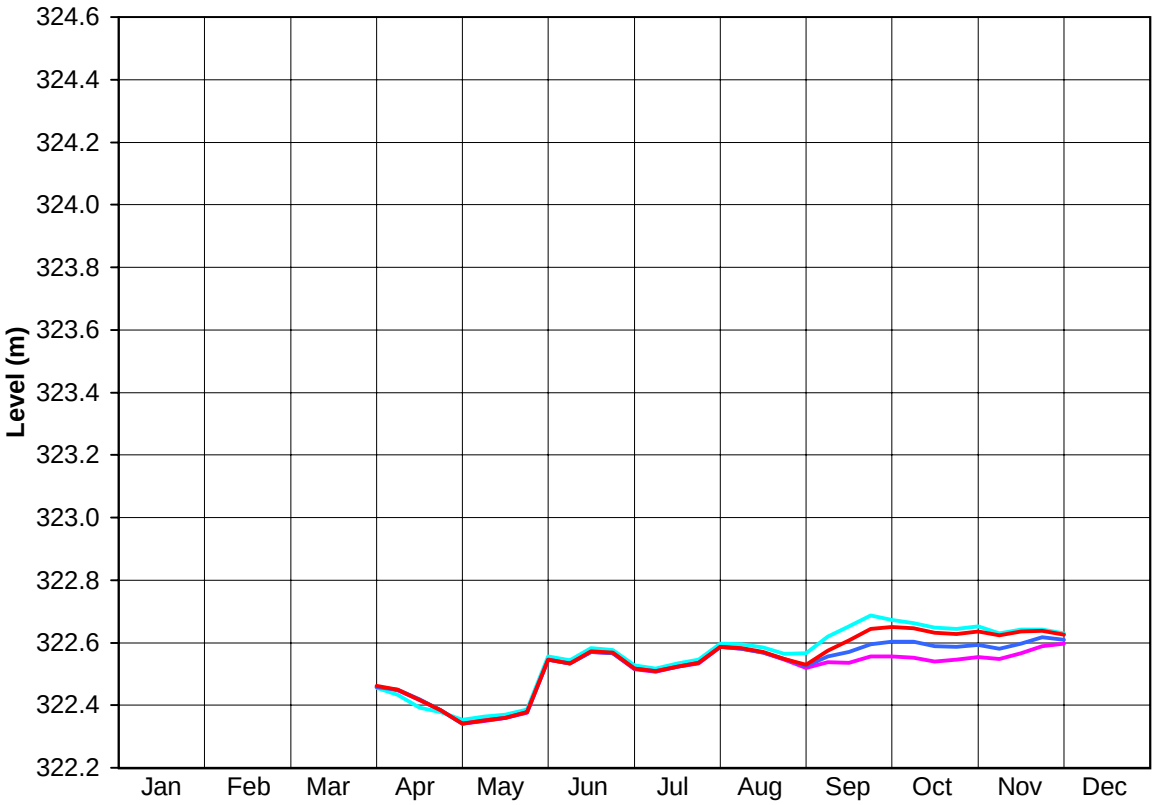
RAINY RIVER AT TOWN OF RAINY RIVER: MODELLED LEVELS 1986

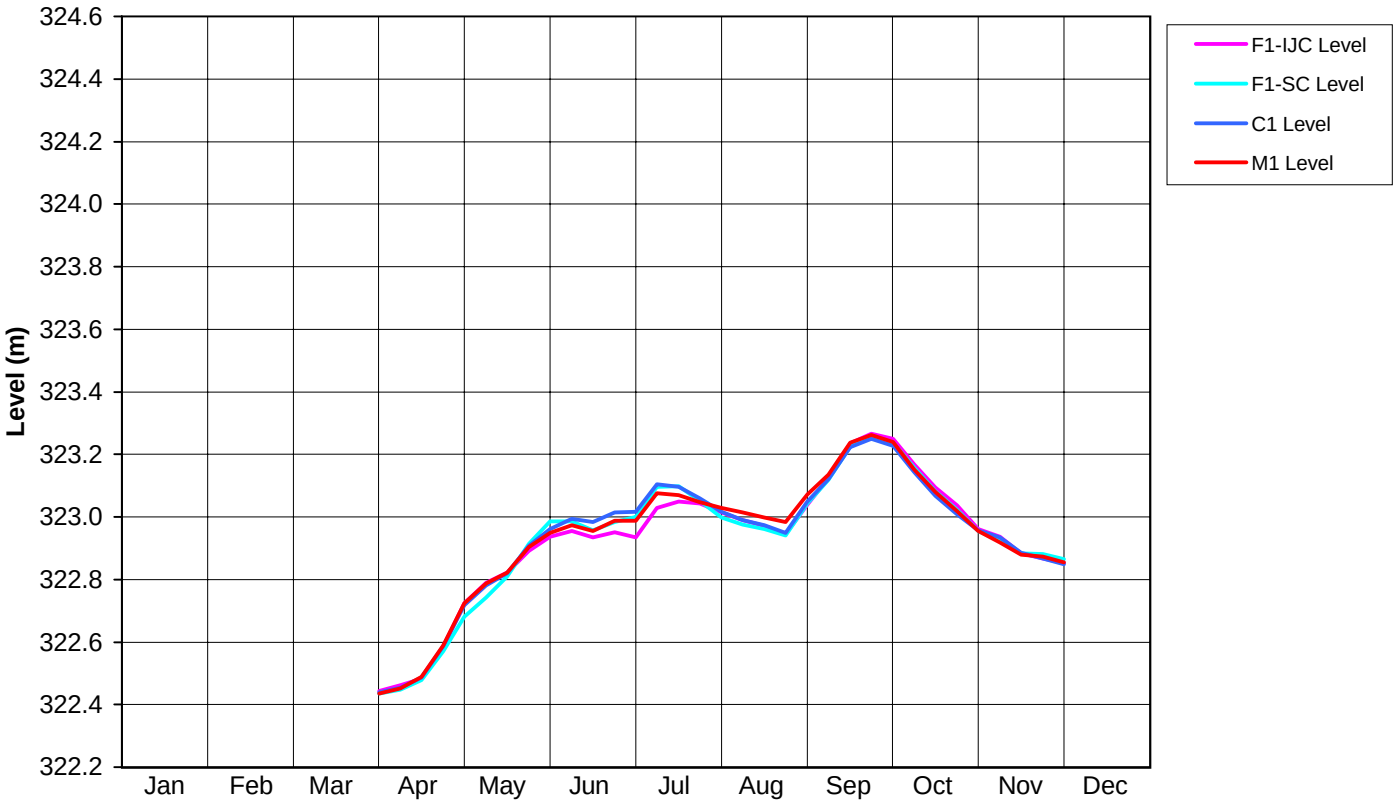


RAINY RIVER AT TOWN OF RAINY RIVER: MODELLED LEVELS 1987

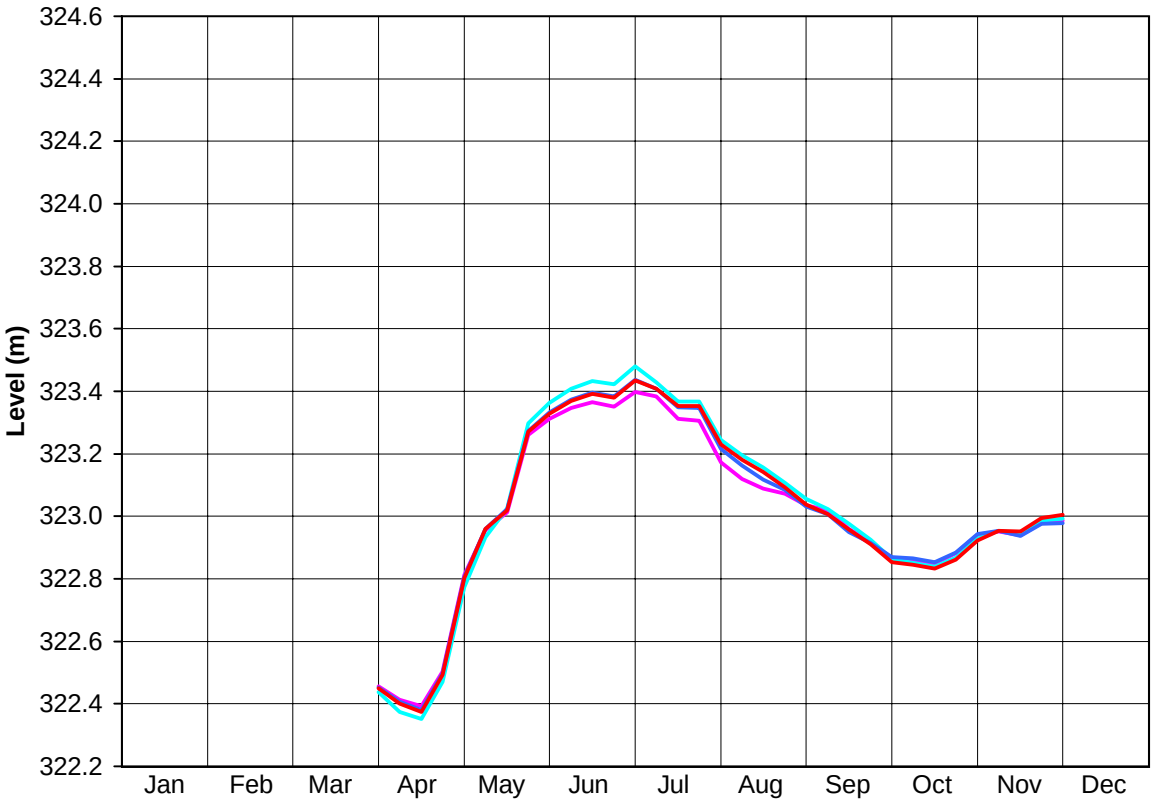


GSC(1979) Datum

RAINY RIVER AT TOWN OF RAINY RIVER: MODELLED LEVELS 1992



RAINY RIVER AT TOWN OF RAINY RIVER: MODELLED LEVELS 1996



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