WMC INTERNATIONAL LTD.
MELIADINE WEST GOLD PROJECT
WATER BALANCE STUDY
1999 DATA REPORT

Submitted To:

WMC International Ltd.

Nepean, Ontario

Submitted By:

AGRA Earth & Environmental Limited

Calgary, Alberta

December 1999

CW1525.1

T:\Jenn\1999 report\Report\Text File\R_bh121099.wpd

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS (cont'd)

PAGE

TABLE OF CONTENTS (cont'd)

PAGE

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS (cont'd)

PAGE

APPENDICES

ACKNOWLEDGEMENTS

The writer would like to acknowledge the contributions and assistance of the following individuals towards the collection, interpretation and analysis of the data and the preparation of this report:

C Mr. Ben Hubert, WMC's environmental consultant coordinator, for advice and guidance in the planning of the field program and the reporting of the results.

C Mr. Alan Sexton and the other WMC camp staff who provided and coordinated transportation and logistics to facilitate timely execution of the field program.

C Mr. Kelly Owlijoot, the student field staff hired by WMC, for his effort, and Mr. Dustin Fredlund for his willingness to assist on short notice in the field data collection program.

C Mr. Murray Jones and Mr. Wade Hanna of the Water Survey of Canada for their assistance in the practical and technical details of the field data collection program.

EXECUTIVE SUMMARY

Introduction

AGRA Earth & Environmental Limited (AEE) was retained by WMC International Limited (WMC) early in 1997 to conduct a two year water balance study for the Meliadine West Gold Project. The study was extended to a third year in early 1999. The purpose of the water balance study is to provide measurements and estimates of the water balance components of snow melt, rainfall, evaporation, evapotranspiration and runoff in the Meliadine River Basin and selected sub-basins, with the intention of providing a tool to plan for and monitor mine operations and closure.

This document reports the results of work carried out during the 1999 field season. The data collected in 1997 and 1998 were presented in two previous Data Reports.

The project area is located within the basin of Meliadine Lake about 30 km northwest of Rankin Inlet on the western edge of Hudson Bay. The Meliadine Basin is within the zone of continuous permafrost. The terrain is dominated by glacial landforms consisting of drumlins of glacial till, eskers consisting of gravels and sands and numerous shallow lakes and ponds. Meliadine Lake discharges into the Meliadine River which discharges into Hudson Bay just north of Rankin Inlet. A secondary outlet allows some discharge from Meliadine Lake into the adjacent Diana River Basin to the west. The area where mine development is considered most likely is located on a peninsula jutting into Meliadine Lake.

The 1999 work program included measurement of discharges from Meliadine Lake, the Meliadine River and the adjacent Diana River; measuring discharges from lakes in the sub-basins of the peninsula area expected to be affected by gold mine development; monitoring lake levels; measuring evaporation and evaluating the relative magnitudes of the principal basin inputs, losses and yields within the context of regional and historical climate and runoff data. Rainfall, temperature and other climate data for the project area were collected and provided by WMC.

Hydrometric monitoring was conducted in 1999 at the following stations:

The four main river discharge monitoring stations established in 1997 and monitored in 1997 and 1998 were reactivated:

- Meliadine River at the outlet of Meliadine Lake.
- West outlet of Meliadine Lake (discharging into the Diana River basin).
- Meliadine River near the mouth.
- Diana River near Rankin Inlet.

In addition, three of the four lake level monitoring stations established on the main lakes in 1997 were also re-established:

- Meliadine Lake near Rankin Inlet (automated station)
- Diana Lake (staff gauge/direct water level survey)
- Peter Lake (staff gauge/direct water level survey)

Three of the seven lake outlet stations operated in 1998 in the Meliadine Lake peninsula area were continued; four of the 1998 stations were discontinued in 1999.

Regional Climate and Runoff

The available climate data for the region (Rankin Inlet) indicates that the 1999 hydrologic year (October '99 through September '99) was almost equal to the wettest year in the eighteen years of record. The observed total precipitation of 385 mm was 27 percent above the mean and 46 mm higher than the total 1997-1998 precipitation of 334 mm.

The historical runoff data for the Diana River parallels the historical climate data, but with an over-year lag effect. The measured yield for 1999 for the Diana (unadjusted for inflows from the Meliadine Basin) was 306 mm, which, at 106 mm above the 10 year annual mean of 200 mm, was the highest on record and 50 percent higher than the 1998 runoff. The ratio of 1999 runoff to precipitation (Rankin Inlet AES station) is 0.79, well above the average of 0.67, due to the lag effect of the preceding moderately wet year.

Meliadine and Diana Basins

The total 1999 runoff for the Meliadine Lake basin is estimated to be 239 mm over the catchment area of 569 km^2. This includes an estimated 25 mm of runoff which is expected to discharge from Meliadine Lake over the December 1999 to June 2000 winter period. This winter discharge is expected to freeze as surface icing in the immediately downstream area. About 60 mm or 25 percent of the total 1999 Meliadine Lake runoff was discharged through the west outlet into the Diana River basin via Peter Lake. The remaining 179 mm was discharged into the Meliadine River.

The Meliadine River near the mouth discharged a nominal 189 mm of runoff in 1999 based on the total catchment area of 796 km^2. In effect however, when the drainage area is reduced in proportion to the amount of runoff diverted through the west outlet, the runoff becomes 231 mm, which agrees closely with that found for Meliadine Lake.

The Diana River 1999 yield of 306 mm becomes 284 mm when the diversion in from Meliadine Lake is deducted. The latter value is about 17 percent higher than the yields for the Meliadine Lake and River basins. Diana River yields are expected to be higher than Meliadine Basin yields because greater proportional evaporative loss occurs in the latter, as a direct consequence of the fact that Meliadine Lake represents 20 percent of the total catchment, while Diana and Peter Lakes together constitute only 15 percent of the Diana catchment. In addition, higher precipitation appears to have occurred in the Diana Basin in 1999.

For the 1999 hydrologic year the ratio to precipitation (Rankin Inlet) for the Meliadine River basin was 0.62, which is considerably higher than the 1998 and 1997 ratios of 0.43 and 0.45.

Peninsula Basins

The main components of the water balance for three peninsula basins were measured for the 1999 season. The runoff yields for the two larger Lake A1 and Lake B2 basins were relatively consistent at 204 mm and 189 mm, respectively. The yield for Lake B7 was about 20 percent lower, at 159 mm. The 1998 yield for Lake B7 was also lower than that for the other two. A review of possible factors strongly suggests that the drainage area as delineated and used for the B7 basin is too high, and should be investigated in the field. The Lake A1 and Lake B2 1999 yields were about 20 percent lower than that for Meliadine Lake.

Basin storage over the May through September season increased for all basins. The weighted average increase for Basins A and B equals 64 mm. The principal mechanism for basin storage is the retention capacity of basin lakes and ponds.

The weighted average 1999 ratio of runoff to total precipitation (defined as the spring snow water equivalent plus the season's rainfall observed at the Meliadine Camp station) equals 0.52, which is very similar to the 1998 reported average of 0.54.

In 1999, snowmelt contributed about 36 percent and rainfall 64 percent of the total precipitation input. Basin outflows averaged 52 percent of the total precipitation input. Some 23 percent of precipitation was lost by evaporation and 8 percent by evapotranspiration. An average of 17 percent went into basin storage. In terms of the precipitation components, it is estimated that about 90 percent of the snowmelt and 30 percent of the rainfall went to runoff, 25 percent of the rainfall went into basin storage, and the rest was lost to evaporation and evapotranspiration.

Recommendations

Recommendations are made in the report for some further improvements in methodology, if monitoring is to be continued in future years. A recommendation is also made to revise the complete three year data set on the basis of several improvements in the methods and assumptions used for the data processing and analysis.

1.0 INTRODUCTION

1.1 BACKGROUND

WMC International Limited has been conducting a gold exploration program near Meliadine Lake in Nunavut since 1995. The quality of the results indicated that development of a gold mine could become feasible and that environmental baseline studies should commence. AGRA Earth & Environmental Limited (AEE) was retained by WMC early in 1997 to conduct a two year water balance study for the Meliadine West Gold Project. The study was extended to cover a third year, in early 1999. The project area is located about 30 km northwest of Rankin Inlet on the western edge of Hudson Bay (see Figure 1.1).

The results of the 1997 and 1998 data collection programs are reported in previous documents by AEE entitled "WMC International Ltd., Meliadine West Gold Project, Water Balance Study, 1997 Data Report", April 1998, and "WMC International Ltd., Meliadine West Gold Project, Water Balance Study, 1998 Data Report", December 1998. The 1997 and 1998 Data Reports provide background information and describe the project area. The present document reports the results of the 1999 data collection program, and repeats only a limited amount of the background and descriptive information. The present report should be read in conjunction with the 1997 and 1998 Data Reports.

1.2 SCOPE OF 1999 PROGRAM

The main work components and activities planned and carried out by AEE for the 1999 program are summarized as follows in Table 1.1.

Figure 1.1

TABLE 1.1
1999 Water Balance
Component and Activity Summary

Component	Office Activities	Field Activities
Flow Monitoring	C Compile and analyze data	C Decommission 4 existing stations C Place Aquadams C Startup 6 existing stations C Operate stations C Make discharge measurements C Retrieve data C Shut down 6 stations
Lake Level Monitoring	C Compile and analyze data	C Obtain winter ice levels C Survey water levels
Precipitation	C Obtain and compile precipitation data	C Monitor manual rain gauges
Evaporation	C Compile and analyze data	C Install evaporation pan C Operate pan C Shut down pan
Evapotranspiration	C Obtain climate station data C Estimate evapotranspiration	

WMC operated a climate station to monitor precipitation, temperature, relative humidity, net radiation, soil temperature and wind data. These data provided essential inputs to the water balance study.

A parallel fisheries and water quality program was carried out by RL&L Environmental Services Ltd. of Edmonton.

2.0 1999 WORK PROGRAM

2.1 DETAILED WORK PLAN

The detailed work plan for the 1999 season was developed on the basis of continuing the monitoring work started in 1997, but with a reduced level of effort due to budget limitations. Nevertheless, the 1999 work plan was designed to provide continuity for the principal monitoring stations and maintain the integrity of the hydrologic database. Monitoring was carried out in both main lakes and rivers and in the smaller lake basins located in the Meliadine Lake peninsula where the majority of the exploration work is occurring. Monitoring of the peninsula basins was focussed in Basins A and B, as those basins are considered the likely area of future development. The work carried out is summarized in the following sections.

2.2 SNOW SURVEYS

Snow surveys were not carried out in 1999. An estimate of the spring snowpack water equivalent was made based on Rankin Inlet snowfall data and relationships between those data and the 1998 snow survey results.

2.3 HYDROMETRIC MONITORING

2.3.1 General

AEE subcontracted with the Water Survey of Canada (WSC), Yellowknife, to provide services for the selection, procurement and installation of the hydrometric equipment, to assist with operation and shut down of the stations, and associated tasks. All WSC services were carried out under the supervision of Murray Jones, Supervisor, Nunavut Area, WSC, Yellowknife. All equipment and instrumentation used and the methods and procedures used for data collection and data handling, generally conformed to WSC standards.

The principal activities involved in the hydrometric monitoring program and the associated schedule, were as follows:

Pre-Season Ice Levels	May 13 - 14
Station Startup	June 4 - 17
Station Operation	Periodic throughout June - September
Seasonal Shut-Down	September 20 - 22
Data Compilation and Analysis	October through November

2.3.2 Main River Flow Monitoring

The four main river flow monitoring stations established in 1997 were continued:

- Diana River near Rankin Inlet.
- Meliadine River at the outlet of Meliadine Lake.

- Meliadine River near the mouth.
- West outlet of Meliadine Lake (discharging into the Diana River basin).

The locations of the main river monitoring stations are shown on Figure 2.1.

2.3.3 Main Lake Level Monitoring

Five of the six lake level monitoring stations established on the main lakes in 1997 were continued:

- Meliadine Lake near Rankin Inlet (automated station)
- Meliadine Lake at main outlet (staff gauge/direct water level survey)
- Meliadine Lake at west outlet (staff gauge/direct water level survey)
- Diana Lake (staff gauge/direct water level survey)
- Peter Lake (staff gauge/direct water level survey)

The Meliadine Lake at Meliadine Camp station (direct water level survey) was discontinued as it was concluded that the data collected at this station in previous years provided little useful information additional to that provided by the other Meliadine Lake stations. The two Meliadine Lake outlet stations however that correspond to the flow monitoring stations at the same locations, were maintained.

Staff gauges were not used in 1999 to obtain lake water level readings. Instead, direct water levels (DWL) were obtained by level survey from the local benchmarks. This procedure was found to provide more accurate results for practically the same effort.

The automated station on Meliadine Lake provided a continuous record of water levels, which were used as part of the data required to calculate outflows from the two Meliadine Lake outlets.

The locations of the lake level monitoring stations are shown on Figure 2.1.

2.3.4 Peninsula Basin Monitoring

Three of the seven monitoring stations operated in the Meliadine Lake peninsula basins in 1998 were continued in 1999, and four were discontinued. Two of the three continued stations are located in Basin B, at the outlets of Lakes B7 and B2. The third station is located at the outlet of Lake A1 in Basin A. The locations of both the continued and the discontinued stations are shown in Figure 2.2.

Figure 2.1

Figure 2.2

2.4 DRAINAGE AREAS

There was no reason to re-examine drainage areas in 1999, and the values reported in the 1998 Data Report are considered valid. The tables of drainage areas are repeated below for convenience, in Tables 2.1 and 2.2.

TABLE 2.1
Main River Basin and Lake Areas (km^2)

Basin Station	Land Surface	Directly Connected Lake Surface	Other Lake Surface (Estimated)	Total Lake Surface	Total Area
Meliadine River at Meliadine Lake Outlet	334	114	121	235	569
Meliadine River Tributary Basin	157	17	53	70	227
Meliadine River at Mouth	491	131	174	305	796
Diana River near Rankin Inlet	948	217	315	532	1480

TABLE 2.2
Peninsula Monitored Basin and Lake Areas

Monitoring Station	Basin	Land Surface (ha)	Monitored Lake Surface (ha)	Other Lakes		Total Lake Surface (ha)	Total Area (ha)	Ratio of Lake to Total Area
				Surface (ha)	Number			
Lake A6	Sub-Basin	457.64	54.54	137.08	49	191.62	649.26	0.295
	Upstream Basin	457.64				137.08	594.72	0.23
Lake A1	Sub-basin	250.43	16.29	23.15	35	39.44	289.87	0.136
	Total Basin	708.07	16.29	214.77	85	231.06	939.13	0.246
	Upstream Basin	708.07				214.77	922.84	0.233
Lake B7	Sub-Basin	197.55	58.10	7.03	25	65.13	262.68	0.248
	Upstream Basin	197.55				7.03	204.58	0.034
Lake B5	Sub-basin	155.11	55.94	18.34	7	74.28	229.39	0.324
	Total Basin	352.66	55.94	83.47	33	139.41	492.07	0.283
	Upstream Basin	352.66				83.47	436.13	0.191
Lake B4	Sub-basin	1149.57	85.74	309.52	167	395.26	1544.83	0.256
	Total Basin	1502.23	85.74	448.93	201	534.67	2036.9	0.262
	Upstream Basin	1502.23				448.93	1951.16	0.23
Lake B2	Sub-basin	150.60	48.95	18.71	13	67.66	218.26	0.31
	Total Basin	1652.83	48.95	553.38	215	602.33	2255.16	0.267
	Upstream Basin	1652.83				553.38	2206.21	0.251
Lake D5	Sub-Basin	238.35	7.02	123.14	18	130.16	368.51	0.353
	Upstream Basin	238.35				123.14	361.49	0.341

Table 2.2 includes the following breakdown of areas for each of the continued and

discontinued monitoring site:

- land surface area
- surface area of the monitored lake
- surface area and number of other lakes upstream of the monitored lake
- total area of lake surfaces
- total area of sub-basin
- ratio of lake area to total area

The table lists the values for each of the above area categories for the monitored sub-basin, for the total basin including all other upstream monitoring sites if any, and for the total basin upstream of the monitored lake itself. Note that the areas for the sub-basins listed above represent the incremental areas for the sub-basin, not the total areas, which are obtained by adding in the areas of all the upstream sub-basins.

2.5 EVAPORATION

The Class A evaporation pan previously operated in 1997 and 1998 was re-established by AEE at the WMC Camp at Meliadine Lake in early June and operated to the end of September. The pan data were used to estimate lake evaporation losses from the basins.

2.6 EVAPOTRANSPIRATION

Direct measurement of evapotranspiration (ET) was not considered feasible and was not attempted. The value of ET for the 1999 season was estimated from the 1998 value on the basis of comparison of the pan evaporation data for the two years.

3.0 METEOROLOGICAL DATA

3.1 REGIONAL HISTORICAL PRECIPITATION

The Atmospheric Environment Service (AES) and its contractors have collected meteorological data at the Rankin Inlet airport since 1981, including rainfall, snowfall and total precipitation. These data have been rearranged on the basis of a hydrologic year. A hydrologic year is defined so as to include essentially all precipitation that contributes to the annual runoff. For the study area, most precipitation occurring after September 30 will fall as snow and accumulate over the winter to contribute to the next calendar year's runoff. Any precipitation falling as rain after September 30 would be expected to freeze into the already fallen snow or into the active layer. The hydrologic year was thus defined to extend from October 1 of the previous year to September 30 of the current year.

The total 1998-99 annual observed precipitation, on an hydrologic year basis, is 385.4 mm. This value is 27 percent above the 18-year annual average total precipitation of 304.1 mm. The value for each year of record, the mean, and the ratio of the annual value to the mean are listed in Table 3.1. The data listed in Table 3.1 are shown graphically in Figure 3.1.

The 1998-99 total precipitation of 385.4 mm is close to the 387.3 mm recorded in 1990-91, which is the highest year on record. The 1998-99 total of 385.4 mm consisted of 259.6 mm of rainfall and 127.8 mm of snowfall, representing 41 percent higher and 6 percent higher amounts, respectively, than the 18-year rainfall and snowfall averages.

Updated tabulations of observed monthly and annual rainfall, snowfall, and total precipitation for Rankin Inlet, on both a calendar year and a hydrologic year basis for the period of record, are provided in Appendix B.1.

Figure 3.1

TABLE 3.1
Rankin Inlet Observed Annual Precipitation
by Hydrologic Year (Oct. - Sept.)

Hydrologic Year	Total	Total/Average
81 - 82	271.7	0.89
82 - 83	357.6	1.18
83 - 84	278.4	0.92
84 - 85	369.0	1.21
85 - 86	371.9	1.22
86 - 87	334.7	1.10
87 - 88	216.2	0.71
88 - 89	250.7	0.82
89 - 90	359.8	1.18
90 - 91	387.3	1.27
91 - 92	288.5	0.95
92 - 93	316.1	1.04
93 - 94	207.2	0.68
94 - 95	285.9	0.94
95 - 96	281.8	0.93
96 - 97	172.0	0.57
97 - 98	338.8	1.11
98 - 99	385.4	1.27
Average	304.1	

3.2 PROJECT SITE CLIMATE DATA

3.2.1 Data Observations

The automated climate station installed in 1997 at the Meliadine Camp by Hubert and Associates Ltd. for WMC International continued in operation. The data collected over the 1998-99 season were downloaded at the beginning of October 1999. Station observations included air temperature, soil temperature, humidity, wind speed and direction, rainfall (tipping bucket plus manual gauge), and net radiation. Radiation data were not collected over the winter period.

An evaporation pan was installed at the camp by AEE on June 10, 1999, and observations were made to October 6, when it was decommissioned for the season. Rainfall was observed at the pan as part of the evaporation data collection.

3.2.2 Rainfall Data

Rainfall data for the 1999 season were collected by the Meliadine Camp station, using an automated tipping-bucket rain gauge. Daily manual rain gauge observations were also made at this station, as well as at the pan evaporation station located at the Meliadine Camp. In addition, manual rain gauge observations were made at the WMC Peter Lake Camp located about 30 km west of the Meliadine Camp (see Figure 2.1). The AES Rankin Inlet station provided a fifth set of rainfall data. The five sets of data, for the common period of record, are given in Table B.2.1, in Appendix B.2. Note that the manual gauges were not always read each day; however, rainfall for days without readings were generally accumulated until the next reading was taken, as indicated in the table. The readings are thus assumed to provide correct values for the total rainfall.

Comparison of the five data sets is provided in Figure 3.2 as cumulative total rainfall over the period of common record. The comparison shows that the Meliadine Camp tipping bucket gauge and the AES Rankin Inlet station results are in reasonable agreement, showing season totals (June 1 to September 30) of 237.4 mm and 222.6 mm, respectively. The two manual rain gauges report somewhat lower totals than the tipping bucket gauge. However, since the manual gauges were not observed consistently throughout the season, and different observers were used, it is considered that the likelihood of errors in the manual gauge data is higher than that for the tipping bucket gauge, and that therefore the latter should be accepted. The Peter Lake data deviate strongly from the other station data, showing a considerably higher rainfall total for the season.

Based on the above results, it is concluded that the Camp tipping bucket data, should be used for the Meliadine West Gold Project water balance for the 1999 season. That data set is given in Table 3.2. The total rainfall for the June 1 to September 30 period is therefore 237.4 mm. That amount is 70 percent higher than the 1998 rainfall of 139.9 mm over the same period.

TABLE 3.2
Meliadine West Gold Project
1999 Tipping Bucket Rainfall in mm

Date	June	July	August	September
1		0.0	0.0	0.1
2		0.0	0.6	0.0
3		0.0	0.0	11.3
4		0.0	0.0	0.0
5	0.0	0.0	0.1	0.1
6	0.0	0.0	0.2	0.0
7	0.0	0.0	7.8	0.0
8	0.0	0.8	0.0	0.0
9	0.0	0.0	0.0	0.0
10	0.8	2.1	1.0	0.0
11	0.0	5.1	8.8	0.0
12	0.1	0.0	0.0	0.0
13	0.0	7.3	0.0	2.0
14	0.0	4.9	0.1	0.2
15	0.0	0.0	0.0	10.2
16	0.0	0.2	2.5	0.0
17	0.0	0.0	0.0	0.0
18	0.0	0.0	4.6	0.0
19	0.0	0.3	4.3	0.0
20	0.1	0.1	1.2	6.1
21	0.0	0.0	0.0	10.4
22	0.8	0.0	0.0	0.0
23	56.1	0.0	1.1	0.0
24	1.3	0.0	5.7	2.8
25	0.0	3.3	0.0	5.0
26	0.0	23.8	31.4	0.0
27	0.7	1.6	1.3	0.0
28	0.0	0.6	0.0	0.3
29	0.0	0.1	1.3	0.7
30	0.0	0.0	0.0	0.0
31		0.0	6.1	
Total	59.9	50.2	78.1	49.2
Season Total				237.4

Figure 3.2

The daily rainfall as well as the daily snowfall and daily total precipitation for the Rankin Inlet AES station for 1998-99 hydrologic years are provided in Appendix B.3. Those data show that 29.2 mm of rain fell in May. However, since the mean air temperature did not rise consistently above freezing until the beginning of June (see Figure 3.4 below), that rainfall would have been absorbed and frozen into the snow pack.

3.2.3 Other Data

Besides rainfall, other data recorded at the camp climate station include air temperature, soil temperature, net radiation, humidity and wind speed and direction. Daily values recorded for the 1998-99 season for each of these parameters are shown on Figures 3.3 through 3.7. Net radiation was recorded only for the June - September field season. An expanded plot of maximum and mean daily wind speed is provided for the June - September field season, in Figure 3.8. Monthly mean values are summarized in Table 3.3.

TABLE 3.3
Meliadine Camp Climate Station
Monthly Data Summary 1998-99

Month (98-99)	Air Temperature					Mean Soil Temperature (/C)	Mean Net Radiation (MJ/m²/day)	Mean Humidity (%)	Wind Speed	
	Extreme Day		Average*		Mean (/C)				Mean (km/h)	Average Max.* (km/h)
	Max (/C)	Min (/C)	Max (/C)	Min (/C)						
Oct.	6.2	-12.8	0.4	-4.7	-2.2	0.3	NR	94.5	21.5	44.4
Nov.	-1	-27.8	-7.2	-14.1	-10.6	-4.7	NR	95.4	15.1	30.4
Dec.	-7.1	-39.6	-21.6	-29.5	-25.5	-14.8	NR	83.6	19.9	37.1
Jan.	-13.5	-40.4	-26.4	-33.7	-30.1	-24	NR	78.3	18.9	36.9
Feb.	-10.8	-37.2	-19.8	-28.9	-24.4	-20.3	NR	83.9	14.2	30.5
Mar.	2.1	-42	-16	-25.5	-20.7	-16.9	NR	84.3	16.7	34.7
Apr.	3.3	-32.2	-5.7	-15.3	-10.5	-12.6	NR	91.2	21	42.2
May	4.8	-17.2	-0.5	-7.1	-3.8	-6.9	NR	93.1	19.7	38.1
Jun.	21.6	-5.2	9	0.4	4.7	1.6	14.3	84.8	17	36
Jul.	22.1	2.1	15.4	7.2	11.3	7.1	11	81.2	19.4	40.2
Aug.	20.2	1.9	13.5	6.7	10.1	7.3	7.4	85.7	19.3	42
Sep.	14.5	-3.6	6.9	2	4.4	3.6	3.9	89.3	17.2	37.5

* Represents the average of the daily extremes for the month.
NR = Not recorded

Note that in the 1998 Data Report, the "Mean Wind Speed" column in Table 3.3 was accidentally dropped, and the column "Average Maximum Wind Speed" was mis-labelled as "Mean Wind Speed".

Figure 3.3

Figure 3.4

Figure 3.5

Figure 3.6

Figure 3.7

Figure 3.8

3.2.4 Evaporation

3.2.4.1 Evaporation Measurements

The evaporation pan used for the previous seasons was stored over winter at the camp and re-installed on June 10, 1999 allowing observations to start on June 11. Observations continued through the season to October 6, 1999 when the pan was decommissioned for the season. Monitoring instructions provided to the operator are attached in Appendix A. The pan evaporation observational data are summarized in Table B.4.1 in Appendix B.4. The cumulative (gross) pan evaporation is shown in Figure 3.9.

The data reported in Table B.4.1 include both the raw observational data and the adjusted data. The raw data included a number of cumulative readings representing periods of several days, some readings with obvious errors such as misplaced decimals, some readings affected by high winds blowing water out of the pan, and days with missing data. The periods for which cumulative data were available were adjusted by distributing the end of period reading evenly over the days which had been accumulated, the obvious decimal place errors were corrected, and the missing and wind affected data were estimated by taking an average of preceding and following days.

The evaporation for the period prior to June 11 was estimated by assuming that the daily evaporation rate increased linearly from zero on June 3, to 3.0 mm/day on June 10. June 3 is the estimated date on which ice cover on the lakes started to diminish and open water started to appear. The evaporation rate of 3.0 mm/day is the average evaporation rate measured for the first 5 days of observations starting June 11. The total evaporation for the period June 3 to 10 is thus estimated to be 12.0 mm.

The total gross evaporation loss for the 1999 season was thus 397.0 mm, with a monthly distribution as shown on Figure 3.10. The largest monthly evaporation occurred in July, when 133.9 mm or 34 percent of the annual total occurred. The evaporation pattern and total for the season were very similar to those obtained for the 1998 season.

The data show that several days of negative evaporation occurred in mid-September. Negative evaporation is actually condensation of water vapour. The observer's comments for those days indicate the presence of fog, confirming that condensation was occurring.

Figure 3.9

Figure 3.10

3.2.4.2 Net Pan Evaporation

The net pan evaporation for the 1999 season is obtained by subtracting the total precipitation during the season from the gross pan evaporation of 397.0 mm. The precipitation for the period June 1 to September 30, as recorded by the Meliadine Camp tipping bucket gauge, equals 237.4 mm. The net pan evaporation calculated for the 1999 season thus equals 159.6 mm.

3.2.4.3 Lake Evaporation

Lake evaporation was estimated from the evaporation pan data using the method adopted by AES (Kohler, Nordenson, and Fox, 1955). That method computes lake evaporation as a function of the pan water temperature, the air temperature, the daily wind run (wind run = wind speed x duration), and the pan evaporation.

The available data allowed computations to be completed for 30 days over the open-water season. The computational method and results are given in Appendix B.5. The pan coefficient found for the period equals 0.82. That value is identical to that found for the 1998 season.

The value of 0.82 applied to the complete season provides a total gross lake evaporation of 325.5 mm. Subtracting the total seasonal rainfall of 237.4 mm results in a net lake evaporation of 88.1 mm.

3.2.5 Evapotranspiration

The applicability of using the "GD Relationship" proposed by Granger and Gray (1989) for estimation of the evapotranspiration (ET) for the project area, as was done for the 1997 Data Report, was reassessed. Review of a similar model developed by Morton revealed that the Morton model is not applicable to sites influenced by a nearby large water body which supplies large quantities of moisture to the atmosphere. Morton stated that his model "...cannot be used near sharp environmental discontinuities such as a high latitude coastline...because of advection of heat and water vapour..."(Morton, 1983). It was therefore concluded that the GD Model may not be applicable to the project area, due to the strong influence of Hudson Bay on atmospheric conditions, which the GD Model uses to estimate ET.

Based on the strong similarity in pan evaporation results for 1999 and 1998, it is concluded that ET values for 1999 should be similar to the 1998 ET value, or 38 mm.

4.0 SNOWPACK WATER EQUIVALENT

4.1 ESTIMATE OF SWE

Snow surveys to determine the spring snowpack snow water equivalents (SWE) in the peninsula basins were not carried out in 1999 due to budget limitations. However, it is possible to estimate 1999 SWE values by analyzing the 1998 snow survey and climatological data. The 1997 snow survey determination of SWE was not considered accurate enough for analysis, due to terrain mapping limitations (see 1998 Data Report).

The analysis involves comparing the 1998 SWE as found for the end of May, immediately preceding the start of snowmelt (reported in the 1998 Data Report), with the accumulated precipitation recorded at the Rankin Inlet AES station over the period October 1, 1997 to May 31, 1998, and establishing a ratio between the two. That ratio can then be applied to the 1999 AES station data to estimate the 1999 pre-melt SWE of the snowpack. The analysis and its application are summarized in Table 4.1.

TABLE 4.1
Estimation of 1999 SWE Values Based on 1998 Relationships

Peninsula Basin	May 31 SWE	May Rain	Oct. 1 - May 31			Oct. 6 - May 31			Snowpack to Station Data Relationship		Estimated May 31 SWE	
			AES Snow	AES Rain	AES Total	AES Snow	AES Rain	AES Total	SWE/ AES Total Less May Rain	SWE/ AES Total Full Season	Adjusted for May Rain	Full Season
1998 Data												
Lake A1	135.6	32.4	108.3	78.9	185.8	108.3	55.2	162.1	0.80	**0.84**		
Lake B2	134.5	32.4	108.3	78.9	185.8	108.3	55.2	162.1	0.79	**0.83**		
Lake B7	130.6	32.4	108.3	78.9	185.8	108.3	55.2	162.1	0.76	**0.81**		
1999 Data												
Lake A1		29.2	126.6	37.0	161.6	126.6	35.0	159.6	0.80	**0.84**	133.0	**133.5**
Lake B2		29.2	126.6	37.0	161.6	126.6	35.0	159.6	0.79	**0.83**	131.9	**132.4**
Lake B7		29.2	126.6	37.0	161.6	126.6	35.0	159.6	0.76	**0.81**	127.9	**128.6**

Two complications in connection with the analysis required resolution: the influence of rainfall in early October, and the influence of rainfall in May.

For most purposes, any rain that falls on or after October 1 can be considered to accumulate as part of the following season's snowpack. However, in 1997, a relatively large depth of rain, in the amount of 23.7 mm, fell in the first five days of October, when the air temperature remained above freezing. That rain was therefore considered to run off and not be retained in the basin as part of the following season snowpack. Consequently, it was necessary to adjust the precipitation accumulation period to start on October 6, 1997. Table 4.1 thus reports the AES station values for both the October 1 to May 31 period (for information) and for the adjusted period starting on October 6, 1997 (for use in the analysis). The same period was applied to the 1998-99 hydrologic year. Note that 1998 October 1 to 5 rainfall amounted to only 2.0 mm.

May rainfall can generally be assumed to accumulate in the snowpack and be retained until the start of snowmelt. May rainfall occurring after the 1998 snow survey was therefore added to the SWE values measured in early May in order to obtain pre-melt SWE values. However it was conjectured that the relative amount of May rain compared to the amount of the season's total snow accumulation could affect the value of the ratio between the basin snowpack SWE and the AES data. To test the significance of May rainfall, two sets of ratios were calculated, one for the data adjusted by subtracting the May rainfall, and one for the data with the May rainfall. The results in Table 4.1 indicate that, at least for 1998, the May rainfall has almost no effect on the value of the estimated May 31 SWE. It was therefore decided to use the simpler approach, based on inclusion of May rainfall. The resulting ratio values are bolded in the table.

Application of the selected ratios for the three monitored peninsula basins yields estimates for the basin pre-melt snowpack SWE as reported in the last column of Table 4.1. It is evident that the estimated 1999 SWE values are very close to the measured 1998 values. That is consistent with the close similarity in the AES total precipitation values for the adjusted period for both years.

4.2 ESTIMATE OF SUBLIMATION

The 1998 data can also be used to estimate the amount of sublimation loss experienced by the 1997-98 snowfall. Sublimation mainly occurs when snow particles are blown by the wind. The estimate is made as follows. First, it is known that, due to the "undercatch" effect common to northern weather stations, the SWE accumulated on the ground at Rankin Inlet due to snowfall is on average equal to 1.76 times the weather station snowfall total for the season. Similarly the average undercatch correction factor for rainfall at Rankin Inlet equals 1.05 (see 1997 Data Report, Section 4.1).

Secondly, Table 4.1 shows that the adjusted 1997-98 winter season (October 6 - May 31) snowfall amount of 108.3 mm represents 67 percent of the total precipitation of 162.1 mm over that period, the rest having fallen as rain. The weighted correction factor for undercatch for the 1998 period is therefore estimated to equal (1.76) x (0.67) + (1.05) x (0.33) = 1.53. The total May 31 SWE, before losses, should therefore equal (162.1) x (1.53) = 248.0 mm.

Thirdly, the Lake A1 and Lake B2 basin average 1998 May 31 SWE was measured to be equal to 135.0 mm. Assuming that there was no net loss or gain of snow due to wind transport (i.e. snow blown into basin equals snow blown out of basin), the total loss of SWE over the season is the sublimation loss and is estimated to equal (248.0) - (135.0) = 113.0 mm, or 46 percent.

The estimated sublimation loss of 46 percent is considered realistic for Arctic tundra areas.

Pomeroy and Gray state that "*Blowing snow in open areas can remove up to three-fourths of annual snowfall. If fetches are large, most of this snow sublimates in transit*", and "*Sublimation losses equal to 74% of annual snowfall occur from a 4000 m fetch of fallow at Regina, whereas Prince Albert experiences only a 44% loss for this land use and fetch distance*" and "*...similar high sublimation rates are found in both the southern prairies and in the Arctic*" (J. W. Pomeroy and D. M. Gray, Snowcover: Accumulation, Relocation and Management, 1995, pp. 120, 93 and 120 respectively).

Application of the 1998 sublimation estimate to 1999 is not considered appropriate, since sublimation is sensitive to wind speed, especially to maxima. The wind speed data plot for 1998-99 (Figure 3.7) shows that peak wind speeds were higher than in 1997-98 (1998 Data Report Figure 3.6). It is therefore supposed that the sublimation loss amount was higher in 1999 than 1998.

5.0 HYDROMETRIC MONITORING RESULTS

5.1 OVERVIEW

Hydrometric data collection consisted of monitoring lake levels, lake outflows and river discharges. Monitoring was conducted of the following:

Meliadine River Basin

- Meliadine Lake levels
- Meliadine Lake discharge to Meliadine River
- Meliadine Lake west discharge to Diana River Basin
- Meliadine River discharge at the mouth

Diana River Basin

- Diana River discharge near Rankin Inlet
- Peter Lake levels
- Diana Lake levels

Meliadine Lake Peninsula Basins

- Three peninsula basin lakes - levels and discharges

The station locations and descriptions are provided on standard WSC station description forms, in Appendix C.

Identification of the equipment and methods used, and presentation and discussion of the 1999 monitoring results are given in the following sections. Photos of monitoring locations and monitoring activities are provided in the photo section at the end of this report.

5.2 EQUIPMENT AND METHODS

5.2.1 General

Water level and discharge monitoring were carried out using the same equipment, methods and procedures as in 1997 and 1998, and are described in the previous Data Reports.

The planned schedule of hydrometric monitoring activities, a detailed monitoring checklist, and data recording and communication instructions were provided for the field staff at the start of the monitoring season. Copies of those documents are provided in Appendix A.

5.2.2 Water Level Observations

Water levels at manual stations were measured in 1999 by direct water level (DWL) observations by survey from the local benchmarks. Staff gauges were not used, as the experience gained in 1997 and 1998 demonstrated that DWL surveys provided more accurate data for little additional effort.

5.2.3 Discharge Measurements

Discharge measurements were conducted at seven stations during 1998: two Meliadine Lake outlet stations, one Meliadine River station, one Diana River station, and three peninsula basin stations (see Section 2.4). The discharge at each station was measured from five to seven times during the 1999 season, except for the Diana River station where only three measurements were done as the rating curve for the Diana station is relatively stable.

5.2.4 Pre-Season Lake Levels and Conditions

The ice levels for all of the lakes monitored in 1998 were surveyed relative to local benchmarks in early May prior to the 1999 runoff season, except for Diana Lake, where the bench marks were covered by deep snow drifts. Ice thicknesses were also measured, but were not obtained for all the lakes due to damage to the ice auger sustained by inadvertently striking lake bottom in several shallow locations. Ice thicknesses varied from 1.2 to 1.3 metres. Water levels were not measured as planned due to communication problems.

The Meliadine River at the outlet of Meliadine Lake was observed to be ice covered in early May. A discharge measurement was not attempted due to safety concerns related to the unknown competence of the ice cover, lack of an operational ice auger, and difficulty in locating the channel.

5.2.5 Vertical Control

Vertical control at the stations was maintained for the 1999 program by typically conducting four level circuits (i.e., survey tie-ins) of the local benchmarks during the season, to track the shifting of the benchmarks due to the thawing and freezing of the active layer.

5.2.6 Aquadams for Control of Bypass Flows

Aquadams were placed to confine overbank flows to the main channel at the monitoring locations at the Lake B7 and Lake B2 outlets, on June 5, 1999 within 2 days of the start of runoff. Aquadams were not required at the Lake A1 outlet. The Aquadams were removed prior to July 12, 1999.

5.3 1999 MONITORING RESULTS

5.3.1 1999 Data Set

Complete data sets were obtained for all monitoring stations. There were no data gaps, although water level observations at Diana and Peter Lakes were not made as often as planned. Detailed presentation and discussion of the 1999 runoff results are provided in Section 6.3.3 below.

A summary of the data collected at each of the monitoring stations is provided in Appendix D and generally includes the items listed as follows.

Site Inspection Summary

The site inspection summary includes information on when the station was visited and inspected, the discharge measurements made for the season, the zero outflow elevation of the outlet, the surveyed direct water levels (DWL) and the datalogger water levels, and the adjustments to be made to the datalogger record.

Rating Curve

The rating curve is a plot of the discharge versus water level elevation relationship (rating curve) and the observed data points on which the curve is based. The data points and rating curves used in previous years are included where applicable.

Water Level Plot

The water level plot is a graph of daily mean water level versus time. The plotted water level values are those listed in the Water Level Table (see below). Superimposed on the plot are the DWL survey observations made during the season. For the peninsula stations, the zero flow elevation is identified which defines the point below which there would be no surface outflow from the lake.

Discharge Plot

The discharge plot is a graph of daily discharges versus time. The plotted discharges are those listed in the Discharge Table (see below). Superimposed on the plot are the discharge measurements made during the season. In addition, the observed daily rainfalls for the area are plotted on the figure to show how the station discharge responded to the rainfall inputs.

Water Level Table

The water level table is a table of daily mean water levels for the period of observations. The tabulated values are those obtained from the datalogger record adjusted by linear interpolation between the adjustment points listed in the Site Inspection Summary. Supplementary water levels obtained by DWL Survey, if included, are shown in italics.

Discharge Table

The discharge table is a table of daily mean discharges for the period of observation. The discharge for each day is obtained from the adjusted daily water level and the rating curve. The daily water levels are those recorded by the datalogger, adjusted by linear interpolation between adjustment points determined by comparing the discharge measurements to the rating curve. The table also reports maximum, mean and minimum values of discharge, and the total volume of water discharged.

Discharge measurement data for the period prior to the start of the datalogger record, as well as the last day (if known) of zero discharge prior to runoff, are included in the table and are shown in italics. The maximum, mean and minimum discharges listed in the table are extracted from the datalogger record only; the total volume is derived from all the discharge data.

Gauge History

The gauge history is a history of the vertical control surveys at the station including descriptions and elevations of the benchmarks.

5.3.2 Uncertainties and Sources of Error

The uncertainties and sources of error considered applicable to the 1999 program are discussed below.

Vertical Control

No significant errors are considered to have been introduced into the data due to vertical control problems in 1999.

Field Staff Human Error

Field staff human error continued to be a factor in 1999 as in previous years. Resignation of the lead field staff midway through the season led to some errors and omissions. Careful review and checking of the field data were required to validate the data. Most of the identified errors could be corrected, and omissions filled in with, if necessary, a "best guess" estimate. The residual effect of these errors and omissions is not considered to be serious, and does not compromise the overall reliability of the 1999 data.

Wind Effects

The Meliadine Lake water level datalogger station is located a considerable distance from the two lake outlets. Wind-induced set up of the lake surface can cause a difference in water level between the datalogger location and the outlets, causing actual outflows to be slightly higher or lower than indicated by the observed level.

Rating Curve Error

The data points of measured discharge versus water level generally do not describe a smooth line relationship, due in part to the factors listed above, but also due to inherent limits in equipment and measurement accuracy plus physical characteristics such as the presence of rocks or vegetative growth on the bed of the channel which can strongly distort local flow patterns.

Most of the rating curves were modified on the basis of the additional discharge measurements obtained in 1999. The modifications included adjustment of the curves as well as extensions to higher values. The assessment of the 1999 rating curve quality and accuracy is given in Table 5.1.

The addition of the 1999 data points resulted in some additional data point scatter for the "Meliadine River at the Outlet of Meliadine Lake" and "Outlet of Lake A1" rating curves. Consequently these were downgraded from "good" to "mediocre". For the Meliadine Lake outlet station, a review of channel conditions indicated that measurement accuracy is significantly degraded due to large boulders on the channel bed which cause distortions in the local flow patterns. However, the existing measurement location is considered the best available.

TABLE 5.1
1999 Rating Curve Accuracy Assessment

Rating Curve Assessment	Estimated Accuracy of Computed Discharges	Station
Excellent	±5%	Diana River Meliadine River near the Mouth
Good	±10%	Outlet of Lake B2
Mediocre	±20%	Meliadine River at Outlet Meliadine Lake West Outlet of Meliadine Lake Outlet of Lake A1 Outlet of Lake B7

Estimation of Runoff for Pre-Record and Post-Record Periods

Runoff from the peninsula basins is characterized by a very rapid rise to maximum discharge rates followed by a rapid fall to lower discharges. It was not possible to capture the first few days of runoff, meaning that some of the annual runoff volume was not measured directly and had to be estimated. Similarly, shutdown of the stations before freeze-up required that subsequent runoff had to be estimated.

5.4 PRE-SEASON CONDITIONS

5.4.1 Lake Water Levels

Observed Ice and Water Levels

The ice levels for all of the lakes monitored in 1998 were surveyed relative to local benchmarks on May 13 and 14 prior to the 1999 runoff season, except for Diana Lake, where the bench marks were covered by deep snow drifts. Ice thicknesses were also measured, but were not obtained for all the lakes due to damage to the ice auger sustained by inadvertently striking lake bottom in several shallow locations. The results are summarized in Table 5.2, together with a comparison of the change from the levels observed at the end of September 1998.

Water levels were not measured as planned due to communication problems, but have been estimated based on the ice levels. The water levels are considered to be accurate only to within about ±100 mm. That is because the water level generally does not coincide with the ice level, typically being somewhat below the ice, depending on ice thickness and the ice cover snow load (see 1998 Data Report Table 5.2). In addition, the 1999 survey relied on secondary benchmarks for which the true elevation at the time of the survey was not precisely determined. The information presented in Table 5.2 should therefore be used with caution, and only as a guide.

Note that peninsula lake storage changes are not expressed in terms of the basin yield in Table 5.2, as the value of that term depends on the area of the basin relative to the area of the monitored lake, and thus varies considerably among the monitored basins.

TABLE 5.2
Lake Ice and Water Levels - May 1999

May 1999 Conditions					Comparison of Change September 1998 - May 1999					
Lake	Snow Thickness (m)	Ice Thickness (m)	Ice Level (m)	Estimated Water Level (m)	September 1998 Water Level (m)	Water Level Change (m)	Lake Area (km^2)	Volume Change		Basin Area (km^2)
								Lake (dam^3)	Basin (mm)	
Meliadine	0.80	n.m.	3.12	3.12	3.36	-0.24	114	-27246	-48	569
Peter	0.30	n.m.	7.27	7.27	7.26	0.01	177	2478	2	1480
Lake A1	0.30	n.m.	9.25	9.25	9.39	-0.15	0.1629	-24	N.A.	N.A.
Lake A6	0.25	n.m.	9.32	9.32	9.28	0.04	0.5454	23	N.A.	N.A.
Lake B7	0.45	1.2	8.00	8.00	7.97	0.03	0.581	19	N.A.	N.A.
Lake B5	0.30	1.3	8.54	8.54	8.55	-0.01	0.5594	-7	N.A.	N.A.
Lake B4	0.14	1.3	8.01	7.91[2]	7.98	-0.07	0.8574	-57	N.A.	N.A.
Lake B2	0.15	1.3	7.46	7.36	7.53	-0.18	0.4895	-86	N.A.	N.A.
Lake D5	0.25	1.3	8.39	8.29[2]	8.09	0.20	0.0702	14	N.A.	N.A.

Notes: 1. n.m. = not measured
2. Lake frozen to bottom; equivalent water level assumed = ice level - 0.08 ice thickness
3. N.A. = not applicable

Main Lake Levels and Storage Changes

Table 5.2 shows that the level of Meliadine Lake fell by 240 mm over the September 1998 to May 1999 winter season, equivalent to a lake storage volume of 27 246 dam^3 or 48 mm of basin yield. Assuming negligible inflow into the lake, this lake storage volume reduction represents the total outflow from the lake over the winter period. The post-record outflow from Meliadine Lake for the period September 23 to November 30, 1998 was estimated in the 1998 Data Report (Table 5.4) to equal 12 959 dam^3, suggesting that 14 287 dam^3 discharged over the period December 1, 1998 to May 14, 1999. The corresponding average discharge rate over that period equals 1.00 m^3/s.

Note that the above winter discharge rate is an estimate which is quite sensitive to the May water level, which was also estimated. The accuracy of the estimated water level is in the order of ±100 mm, which for Meliadine Lake corresponds to a variation in the estimated winter discharge rate of ±0.5 m^3/s. Unfortunately, a May 1999 discharge measurement could not be conducted as planned.

The level of Peter Lake remained practically constant.

Peninsula Lake Levels and Storage Changes

The levels of the seven peninsula lakes changed over the winter season by amounts ranging from +200 mm to -180 mm. The balance of inflow less outflow volumes from the lakes over the 1998 post-record discharge period, assumed to extend from September 23/24 to the end of October, is considered to adequately explain those level differences.

5.4.2 Main Basin Station Discharges

The main basin stations were not individually investigated in 1999 to determine the preseason conditions, but these were assumed to be similar to the May 1998 conditions.

The average winter discharge from the main outlet of Meliadine Lake was inferred, to an accuracy of ±50 percent, to equal 1.00 m^3/s, based on the observations noted in the preceding section. That estimate appears reasonable when compared to a measured discharge of 0.309 m^3/s on May 7, 1998 and 0.600 m^3/s on May 19, 1997.

The west outlet of Meliadine Lake, the Meliadine River near the mouth, and the Diana River were assumed to be frozen to the bottom with zero discharge through the period begin December 1998 to end May 1999.

5.5 DISCHARGE HYDROGRAPHS

The plots of daily discharge versus time (hydrograph) as obtained from the daily water levels and the rating curve for each station, are given on Figures 5.1 through 5.4 for the three Meliadine basin stations and the Diana River station (the four main basin stations) and on Figures 5.5 through 5.7 for the three peninsula basin stations. Each plot includes the discharge measurements made at the station during the season.

Based on field notes of observations made in the week preceding the start of runoff, it is estimated that the snowmelt runoff at the main basin stations started on June 1. Using that date and discharge measurements made prior to station datalogger startup, the initial days of the runoff hydrograph were estimated by interpolation. The estimated portions are so identified on the plots. Of the four main basin stations, only the Diana River station actually captured the snowmelt peak, on June 13.

A similar approach was used for the three peninsula basins. For those stations, snowmelt runoff started on June 3. The inferred date of the snowmelt peak was June 5 for Lakes A1 and B2, and June 6 for Lake B7.

Each hydrograph also includes a plot of the daily rainfall amounts (hyetographs) recorded by the WMC Camp climate station tipping bucket gauge. Inspection of the combined plots shows that there were three significant rainfall events during the season which produced a response in the hydrographs: a 58 mm rainfall centered on June 23, a 29 mm event centered on July 26, and a 33 mm event centered on August 26. The large June rainfall produced a pronounced discharge peak at all stations which was higher than the snowmelt peak except

Figure 5.1

Figure 5.2

Figure 5.3

Figure 5.4

Figure 5.5

Figure 5.6

Figure 5.7

at Lakes A1 and B2. The other two rainfall events produced somewhat variable responses in the hydrographs at the stations.

A common plot of the main basin station hydrographs is shown on Figure 5.8. The two Meliadine Lake outlet hydrographs are very similar because they are derived from a single water level record; the differences are derived from the differences in the respective rating curves. The Meliadine River near the mouth shows a snowmelt peak much earlier than the other three main basin stations, and steeper and sharper rainfall peaks. These characteristics indicate the runoff hydrograph for the Meliadine River near the mouth is strongly influenced by the tributary basin downstream of Meliadine Lake.

The effect of wind is noticeable on all four hydrographs near the end of August. The Diana River and the Meliadine River near the mouth show a slight dip and recovery, while the two Meliadine Lake outlets both show a slight rise and fall over the same period. The exact opposite effect corresponding to an opposite wind direction, is shown in the common plot for these stations for 1998, in late August and in mid September (Figure 5.12, 1998 Data Report).

A common plot of the three peninsula basin station hydrographs is shown on Figure 5.9. A similar pattern is evident for all three stations: a very rapid rise to peak at the beginning of June, followed by a rapid decline over two weeks, followed by the late June rainstorm peak and another two to three week recession period to summer low flows, with subsequent responses to later rainstorm events.

5.6. ANNUAL DISCHARGE VOLUME

In order to obtain the total annual discharge for each of the monitoring stations, an estimate needs to be made of the runoff which occurred prior to the start of monitoring (June 6 to 17) and runoff which occurred after monitoring ceased (September 16 to 22).

Estimate of Pre-Monitoring Runoff

The snowmelt runoff is estimated to have started at the peninsula basins on June 3, since zero flow conditions were observed on June 2 and the first discharge measurement, for increasing flow conditions, was made on June 4 at Lake A1. For the main basin stations, runoff was estimated to have started on June 1.

Data recording at the stations started from June 6 (at Diana River) to June 17 (Meliadine River near the mouth). The hydrographs for the period between the start of runoff and the start of data recording were estimated by interpolation between discharge measurements made during that period. The interpolation points were added to the data logger records and the pre-monitoring or pre-record discharge volumes were thus calculated as part of the total season

Figure 5.8

Figure 5.9

volume calculation. A separate estimate or calculation of pre-record runoff volume was therefore not required.

Estimate of Post-Monitoring Runoff

It was estimated that the peninsula basins, as well as the West Outlet of Meliadine Lake, continued to discharge to the end of October. The three other main basin stations were assumed to discharge until the end of November. The runoff volume during the period from the last monitoring day to the cessation of runoff was thus estimated by assuming a linear decrease in discharges, over the period, to zero.

One exception to the above is the Meliadine River at the outlet of Meliadine Lake, which based on previous observations, is assumed to continue discharging throughout the winter. The volume so discharged cannot be known until May 2000. However, an estimate of this volume can be made by assuming it will be similar to the 1998-99 winter (December 1 - May 31) discharge volume, which is estimated to be 14 300 dam^3 (see Section 5.4.1 above). This discharge is believed to freeze and be stored as ice in the immediate downstream area.

Total Runoff

The recorded runoff volumes and the estimated volumes for the pre- and post-monitoring runoff periods are summarized in Table 5.3.

TABLE 5.3
1999 Runoff Summary

Station Name	Catchment Area (km^2)	Period of Record	Measured Volume (dam^3)	Estimated Volume		Total Volume	
				Post-Record (dam^3)	Winter (dam^3)	(dam^3)	(mm)
MAIN BASIN STATIONS							
Meliadine River at Meliadine Lake Outlet	569	June 16-Sept 20	75684	11612	14300	101596	179
West Outlet of Meliadine Lake	569	June 16-Sept 20	32740	1371		34111	60
Meliadine Lake Both Outlets	569	June 6-Sept 22	108424	12983	14300	135707	239
Meliadine River near the Mouth - Nominal	796	June 17-Sept 22	127799	22946		150745	189
Meliadine River near the Mouth - Effective	653	June 17-Sept 22	127799	22946		150745	231
Diana River near Rankin Inlet - Nominal	1480	June 6-Sept 16	366693	86430		453123	306
Diana River near Rankin Inlet - Adjusted	1480	June 6-Sept 16	333953	86430		420383	284
PENINSULA STATIONS							
Outlet of Lake A1	9.3913	June 14-Sept 20	1777	135		1912	204
Outlet of Lake B7	2.6268	June 14-Sept 20	391	27		418	159
Outlet of Lake B2	22.5516	June 14-Sept 20	4076	188		4264	189

The total volume is reported both in cubic decametres (dam^3) and in mm of depth over the catchment area. Note that 1 dam^3 of runoff volume is equivalent to a yield of 1 mm of runoff depth from a catchment area of 1 km^2. The runoff volumes for 1999 expressed as basin yields are also shown graphically on Figure 5.10.

In Table 5.3 and Figure 5.10, there are two entries for the Meliadine River near the mouth. The first entry (189 mm) gives the "nominal" yield, the second entry (242 mm) gives the "effective" yield. The nominal yield is that obtained by using the full catchment area of 796 km^2 as measured from the mapping. The effective yield is that obtained by using the effective catchment area, i.e., the measured area reduced in proportion to the diversion of Meliadine Lake outflows through the west outlet. The west outlet in 1999 diverted 25 percent of the annual total Meliadine Lake basin runoff, thus representing the runoff from 143 km^2 of that basin. Therefore, the effective catchment area for the Meliadine River near the mouth for 1999 is 796 - 143 = 653 km^2. The resulting effective yield of 231 mm for the Meliadine River near the mouth is close to the yield of 239 mm obtained for Meliadine Lake (both outlets).

Table 5.3 and Figure 5.10 also contain two entries for the Diana River. The first entry gives the "nominal" yield of 306 mm, as measured. The second entry is an "adjusted" yield based on deducting the volume diverted in from the Meliadine basin through the Meliadine Lake west outlet. The adjusted yield for the Diana River is 284 mm or 7 percent less than the nominal yield. The adjusted yield is about 17 percent higher than the yield of the Meliadine Lake or the Meliadine River basins. It is possible that the higher yield is a result of higher precipitation in the Diana Basin, as suggested by the observations at the Peter Lake rain gauge (see Section 3.2.2 above). An additional contributing factor could be the fact that the Meliadine Lake surface area represents a larger proportion of its basin than do Peter and Diana Lakes, leading to a proportionally higher evaporation loss.

The runoff volumes and yields of the two larger of the three peninsula basins (204 mm for Lake A1 and 189 mm for Lake B2) agree to within about 10 percent of each other. This difference is consistent with the level of accuracy expected. Both those yields however are about 20 percent less than the yields of the Meliadine Lake and River basins. That difference may be explained in part by higher rainfalls experienced west of the peninsula basins, as indicated by the Peter Lake rain gauge data.

Lake B7 Basin Runoff

The Lake B7 station recorded the lowest yield, 159 mm, or about 20 percent less than the other two peninsula basins. That is consistent with the 1998 results, and suggests that some systematic discrepancy may be involved. A comparison of the hydrographs for the three peninsula stations suggests that the Lake B7 basin snowmelt runoff was significantly smaller

Figure 5.10

than for the other two basins. That is partially supported by the 1998 snow survey results which indicated that the B7 basin SWE was about 5 percent less than the SWE for the other two.

A second factor may be that the drainage area as delineated on the basin map (Figure 2.2) may be larger than the actual drainage area. A review of the delineated area indicates that the topographic flat area located in the vicinity of the bulge along the northwestern edge may in fact drain away from Lake B7 and, if so, should be excluded from the basin. An approximate measurement indicates that this would reduce the drainage area by 0.27 km^2 or 10 percent. If that area should be excluded, it would explain much of the observed differences in the results between the Lake B7 basin and the other peninsula basins.

5.7 LAKE WATER LEVELS AND STORAGE

5.7.1 Main Lakes

Meliadine Lake levels recorded in 1999 at the datalogger station and the DWL survey observations at the station plus at the two lake outlets are shown on Figure 5.11. The levels were adjusted to a common datum by fitting the staff gauge and DWL survey observations to the adjusted datalogger record. The levels show generally good correlation, with some minor discrepancies due mostly to the differing effects of wind at the different observation locations.

The effect of wind can be detected by comparing the water level fluctuations with periods of strong winds as indicated by the plot of daily mean wind speeds on the alternate axis of Figure 5.11, although the effect is somewhat obscured by the effect of runoff from rainfall which tends to accompany high winds. Wind effects can be noted by the slight dip and recovery of water levels near the beginning and at the end of August.

A comparison of the 1999 water levels of Meliadine Lake with those recorded on Peter Lake and Diana Lake is shown on Figure 5.12. The levels for Peter and Diana Lakes have been adjusted to an arbitrary datum to facilitate comparison. It is apparent that the rainfall peak on Peter and Diana Lakes was not recorded. However the overall pattern tend to be similar

The changes in lake levels over the year since September 1998, including the changes in lake storage, expressed as an equivalent depth in millimetres over the total basin area, are summarized in Table 5.4.

Figure 5.11

Figure 5.12

TABLE 5.4
Main Lake Levels and Storage Changes 1998 - 1999

Lake	Lake Area (km^2)	Basin Area (km^2)	Water Levels (m)					Lake Storage Changes (mm)			
			September 1998	May 1999	Peak 1999	September 1999	Change 98 - 99	Winter Change	Gain to Peak	Summer Loss	Annual Change
Meliadine Lake	114	569	3.357	3.120	3.719	3.385	0.028	-47	120	-67	6
Peter Lake	177	1480	7.259	7.270	n.m.	7.399	0.140	1	---	---	17
Diana Lake	40	1480	6.252	n.m.	n.m.	6.433	0.181	---	---	---	5
Diana Basin	217	1480						1	---	---	22

Note: n.m. = not measured

Table 5.4 shows that the Meliadine Lake level fell by 0.239 m over the winter, equivalent to 47 mm of basin storage. That is consistent with the assumption of continuous winter discharge. There was a small annual net gain in level from September 1998 to September 1999. Peter Lake and Diana Lake also gained in level over the same period. The net gain is consistent with the fact that the precipitation for the 1998 - 99 year was unusually high. Meliadine Lake gained less in both water level and storage as an equivalent basin depth than did the Diana Basin lakes.

An estimate of the total seasonal (June 1 to September 16-20, 1999) inflow to each main lake system can be made by summing the "gain to peak" plus "summer loss" storage changes from Table 5.4, the seasonal outflow (the measured volumes from Table 5.3) and the net lake evaporation of 88.1 mm over the lake surface area. The results are given in Table 5.5. The "upstream basin yield" in the table represents the runoff for the season up to the end of monitoring (September 16-20), from the lake tributary basin (i.e., the total basin area less the main lake surface area). The outflow value used for the Diana Basin is the adjusted value with the inflows from Meliadine Lake deducted.

TABLE 5.5
Main Lakes
Lake Inflow Volume 1999

Lake	Lake Area (km^2)	Basin Area (km^2)	Seasonal Change			Inflow Volume		Outflow as % of Inflow
			Outflow to Sept. 20 (dam^3)	Storage Gain (dam^3)	Net Evaporation (dam^3)	Volume (dam^3)	Upstream Basin Yield (mm)	
Meliadine Lake	114	569	108424	30210	10043.4	148677.4	327	73
Diana Basin	217	1480	333953	22833	19117.7	375903.7	298	89

The upstream basin yields for the two basins differ by only 10 percent. Meliadine Lake discharged 73 percent of that inflow, while the two Diana Basin lakes discharged 89 percent.

5.7.2 Peninsula Basin Lakes

Water levels at the three monitored lakes on the peninsula are compared on Figure 5.13. The levels are shown relative to the zero outflow elevation for each lake. Water levels followed a very similar pattern for all three lakes including the response to precipitation.

The effect of wind on the peninsula lakes does not appear to be pronounced. One noticeable effect occurred near the end of August, just prior to the large rainfall event of August 26. The wind caused the water levels at the Lake B2 station to decline, at the Lake B7 station to increase, and did not affect the water levels at the Lake A1 station.

The changes in water level since September 1998 and the corresponding change in storage are summarized in Table 5.6.

TABLE 5.6
Peninsula Lake Levels and Storage Changes 1998 - 1999

Lake	Lake Area (km^2)	Water Levels				Water Level and Storage Changes					
		September 1998 (m)	May 1999 (m)	Peak 1999 (m)	September 1999 (m)	Sept. 98 - May 99		May 99 - Sept. 99		Sept. 98 - Sept. 99	
						Level (m)	Storage (dam^3)	Level (m)	Storage (dam^3)	Level (m)	Storage (dam^3)
Lake A1	0.1629	9.394	9.25	9.73	9.408	-0.144	-23	0.158	26	0.014	2
Lake B7	0.5810	7.984	8.00	8.266	7.982	0.016	9	-0.018	-10	-0.002	-1
Lake B2	0.4895	7.533	7.36	7.899	7.558	-0.173	-85	0.198	97	0.025	12

Table 5.6 does not report changes in storage in terms of equivalent basin depth in millimetres, as the volume storage change in the monitored lake, when distributed over the total basin area, results in very differing depths depending on the ratio of monitored lake area to total basin area, and does not represent a useful index or measure of the changes in the basin.

An estimate of the total seasonal (June 3 - September 20) inflow to each peninsula lake can be made by summing the May - September storage change from Table 5.6, the seasonal outflow (the measured volumes from Table 5.3) and the net lake evaporation of 88.1 mm over the lake surface area. The results are given in Table 5.7. The "upstream basin yield" in the table represents the runoff for the season up to the end of monitoring (September 20), from the lake tributary basin (i.e., the total basin area less the area of the monitored lake).

Figure 5.13

TABLE 5.7
Peninsula Lakes
Lake Inflow Volume 1999

Lake	Lake Area (km^2)	Basin Area (km^2)	Seasonal Change			Inflow Volume		Outflow as % of Inflow
			Outflow to Sept. 20 (dam^3)	Storage Gain (dam^3)	Net Evaporation (dam^3)	Volume (dam^3)	Upstream Basin Yield (mm)	
Lake A1	0.1629	9.3913	1777	25.7	14.4	1817	197	98
Lake B7	0.5810	2.6268	391	-10.5	51.2	432	211	91
Lake B2	0.4895	22.552	4076	96.9	43.1	4216	191	97

The "upstream basin yields" for all three basins agree within about 10 percent. Lake B7 discharged 91 percent of its inflow while Lakes B2 and A1 discharged 98 and 97 percent, respectively.

6.0 BASIN YIELD AND WATER BALANCE

6.1 REGIONAL HISTORICAL YIELDS

Comparison of the annual Diana River runoff (unadjusted) with the Rankin Inlet annual (hydrologic year) precipitation, updated to include the 1999 data, is given in Table 6.1 below. A similar comparison for the available three years of runoff for Meliadine Lake is also included in Table 6.1.

TABLE 6.1
Historical Regional Precipitation and Runoff

Hydrologic Year	Rankin Inlet Precipitation		Diana River Runoff			Meliadine Lake Runoff	
	mm	Fraction of Mean	mm	Fraction of Mean	Runoff Ratio	mm	Runoff Ratio
1989	251	0.84	160	0.80	0.64		
1990	360	1.21	196	0.98	0.54		
1991	387	1.30	263	1.32	0.68		
1992	289	0.97	267	1.34	0.92		
1993	316	1.06	184	0.92	0.58		
1994	207	0.70	135	0.68	0.65		
1995	286	0.96	151	0.76	0.53		
1996	282	0.95					
1997	172	0.58	134	0.67	0.78	78	0.45
1998	339	1.14	203	1.02	0.60	147	0.43
1999	385	1.29	306	1.53	0.79	239	0.62
Mean	298		200		0.67		

The precipitation data represent the annual total inputs of accumulated snow starting from the previous October, up to and including the September precipitation for each year (see Section 3.1). The pattern of high and low years of precipitation is seen to be generally similar to the variation of runoff with a tendency for runoff to reflect the previous year's precipitation. The data show that 1999 was a year of high precipitation at 29 percent above the 11-year mean. The Diana River runoff was very high, at 53 percent above the mean. The ratio of Diana River runoff to precipitation is above the average of 0.67, illustrating the lag effect caused by the preceding wet year. The data given in Table 6.1 are shown graphically on Figure 6.1

Figure 6.1

6.2 1999 BASIN YIELD

6.2.1 Overall Results

The runoff volumes obtained from the 1999 monitoring results as presented in Section 5.6 are summarized in Table 6.2 in terms of the basin yields. The basin yields are based on the measured outflows plus the season's outflows estimated to have occurred after the end of monitoring, from the monitored lakes. The data in Table 6.2 is shown graphically in Figure 6.2.

TABLE 6.2
1999 Basin Yield Summary

Station Name	Basin Area (km^2)	Basin Yield (mm)
MAIN BASIN STATIONS		
Meliadine River at Meliadine Lake Outlet	569	179
West Outlet of Meliadine Lake	569	60
Meliadine Lake Both Outlets	569	239
Meliadine River near the Mouth - Nominal	796	189
Meliadine River near the Mouth - Effective (1)	653	231
Diana River near Rankin Inlet - Nominal	1480	306
Diana River near Rankin Inlet - Adjusted (2)	1480	284
PENINSULA STATIONS		
Outlet of Lake A1	9.3913	204
Outlet of Lake B7	2.6268	159
Outlet of Lake B2	22.5516	189

Notes: 1. Based on "effective" catchment area to account for Meliadine Lake west outflows.
2. Based on adjusted volume by deduction of Meliadine Lake west outflows.

The main points relating to the tabulated basin yield values are discussed below. Some aspects relating to the above results are presented in Section 5.6 above.

6.2.2 Main Basins

The basin yield of Meliadine Lake (from both outlets) of 239 mm was split 75:25 between the main outlet and the west outlet, respectively. The proportion going to the west outlet increased from 15 percent in 1997 and 20 percent in 1998 to 25 percent in 1999, due to the differing discharge characteristics of the two outlets which cause the proportion of the total outflow discharged through the west outlet to increase for higher overall Meliadine Lake levels. The "effective" yield of 231 mm for the Meliadine River near the Mouth is within 3 percent of the yield of the Meliadine Lake basin.

Figure 6.2

The gross yield of the Diana River of 306 mm when adjusted by subtracting the interbasin transfer from the west outlet of Meliadine Lake, reduced by 7 percent to 284 mm. That adjustment is slightly higher than the 1998 adjustment of 6 percent. The adjusted yield is some 17 percent higher than the Meliadine Lake and Meliadine River yields. That difference is much less than the 28 percent difference found in 1998.

The 1999 runoff ratio for Meliadine Lake, using the regional Rankin Inlet precipitation data, was equal to 0.62, considerably higher than the values of 0.43 for the 1998 and 0.45 for the 1997 hydrologic years, but close to the 1999 value of 0.67 for the Diana River basin.

6.2.3 Peninsula Basins

The 1999 basin yields for the Lake A1 and Lake B2 basins are 204 mm and 189 mm, respectively, while that for the Lake B7 basin is 159 mm, or about 20 percent less than the other two. The 1999 yields are higher than the corresponding 1998 yields, due to the higher 1999 precipitation. In 1998 the Lake B7 basin yield was also about 20 percent less than that for the other two basins. Most of this difference may be due to using a drainage area which is too large. This questions requires further investigation (see Section 5.6).

The weighted average Lake A1 and Lake B2 basin yield of 193 mm is about 20 percent less than the Meliadine Lake yield of 239 mm. In 1998, these three yields were lower but did not differ significantly from one another.

6.3 PENINSULA BASINS WATER BALANCE ANALYSIS

6.3.1 Water Balance Equation

A water balance analysis for the monitored peninsula basins has been carried out in order to provide an evaluation of the significance of the main hydrologic inputs to and outputs from each basin and to assess the correctness of the evaluation.

The main components to be considered are as follows:

Snowpack melt input expressed as SWE over the basin	=	SWE
Rainfall input	=	P
Evaporation from lake surfaces	=	E
Evapotranspiration from land surfaces	=	ET
Surface water outflow from the basin	=	O
Basin storage increase	=	B

Basin storage increase B consists of lake storage B_L plus moisture storage in the active layer B_A. The relationship between the water balance components is indicated in the basin schematic shown on Figure 6.3.

Figure 6.3

The water balance is an expression of the conservation of mass for the water entering and leaving the basin. Basically this is expressed as:

Volume In = Volume Out + Change in Storage

In terms of the components identified above, the equation becomes:

$$(SWE)\,(A_{Land} + A_{Lakes}) + P\,(A_{Land}+A_{Lakes}) - ET\,(A_{Land}) - E\,(A_{Lakes}) = O + B$$

Each of the components is discussed below. The evaluation of most of the components is discussed in previous sections of this report.

6.3.2 Water Balance Components

Catchment Areas

The catchment areas and total basin lake areas are reported in Section 2 and elsewhere in this report. The land area (A_{Land}) is the difference between total basin and total lake areas (A_{Lakes}).

Snowpack Melt

The SWE of the snowpack accumulation is based on an estimate of the spring snowpack as reported in Section 4.

Precipitation

The precipitation (P) is the rainfall over the runoff season as recorded at the Meliadine Camp tipping bucket gauge, and equals 237.4 mm for the 1999 season (Section 3.2.2).

Evaporation

Expressed as gross lake evaporation E, this value equals 325.5 mm for the 1999 season (Section 3.2.4).

Evapotranspiration

The estimated value of the 1999 ET equals 38 mm (Section 3.2.5).

Basin Storage

The basin storage term functions as the residual term in the water balance and is determined by subtracting the basin outputs (evaporation, evapotranspiration, and outflow) from the inputs (snowmelt SWE and rainfall).

6.3.3 Water Balance Results

The water balance for the 1999 season for each of the three peninsula basins is summarized in Table 6.3. The weighted mean values for Basins A and B combined are also included. The derivation of the values for the various columns of Table 6.3 is explained in the footnotes to the table.

The values reported in Table 6.3 are reasonably consistent for the Lake A1 and Lake B2 basins. The Lake B7 results differ from the results for the other two basins in a manner similar to that for 1998.

The results indicate that basin storage increased for all three basins in amounts ranging from 59 and 66 mm for Lakes A1 and B2 respectively, to 98 mm for Lake B7. Basin storage increase is consistent with a high precipitation year.

Basin storage in the study area occurs principally by retention of water in lakes and ponds. Since the measured ratio of lake area to total basin areas for the peninsula basins equals about 0.25 (see Table 2.2), the basin water bodies would need to retain four times the basin-averaged storage depth. For the weighted average basin storage increase of 64 mm for the Lake A1 and Lake B2 basins, the increase in water levels in the basin lakes would be expected to be about 256 mm.

The “observed” water level increases for Lakes A1 and B2, from May through September are 158 mm and 198 mm, respectively (Table 5.6). Since those levels are not very accurate, with an error margin of ±100 mm, it is evident that the water balance results can be considered to be in agreement with the “observed” levels. The basin storage increase of 98 mm for Lake B7 is considered to be incorrect, as a result, at least in part, of using too high a drainage area for the B7 basin (see Section 5.6).

The ratio of outflow to total precipitation is similar for the Lakes A1 and B2 basins, at 0.55 and 0.51, respectively. The outflow ratio for Lake B7 was lower, at 0.43. These values are very similar to the 1998 values, which were 0.52, 0.55, and 0.42 for the Lake A1, Lake B2, and Lake B7 basins, respectively.

The magnitudes and relative percentage contributions of the various water balance inputs and outputs for each basin as well as the overall area-weighted mean for Basins A and B as reported in Table 6.3 are shown graphically in Figures 6.4 through 6.7. In 1999, snowmelt contributed about 36 percent, and rainfall about 64 percent of the total precipitation input. Basin outflows averaged 52 percent of the total precipitation input. Some 23 percent of precipitation was lost by evaporation and 8 percent by evapotranspiration. An average of 17 percent of precipitation was retained in basin storage.

TABLE 6.3
Peninsula Basins 1999 Water Balance

Basin	Basin Area		Measured Outflow		SWE (estimated) mm	Snowmelt Volume dam^3	Rainfall dam^3	Gross Lake Evaporation dam^3	Evapo-transpiration dam^3	Snowmelt + Rainfall - Evaporation - ET		Basin Storage Change		Outflow as Fraction of Precipitation
	Total km^2	Lake km^2	dam^3	mm						dam^3	% of Outflow	dam^3	mm	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lake A1	9.3913	2.3106	1912	204	134	1254	2229	752	268	2463	129	551	59	0.55
Lake B7	2.6268	0.6513	418	159	129	338	624	212	75	675	161	257	98	0.43
Lake B2	22.5516	6.0233	4264	189	132	2986	5354	1961	625	5754	135	1490	66	0.51
Basin A + B	31.9429	8.3339	6176	193	133	4240	7583	2713	892	8218	133	2042	64	0.52

Column 1 = Basin name
Column 2 = Total catchment area of basin
Column 3 = Total lake surface area within basin
Column 4 = Measured plus estimated pre- and post-monitoring outflow volume
Column 5 = Column 4 divided by Column 2
Column 6 = Snow water equivalent (SWE) in spring snowpack
Column 7 = Snowmelt volume obtained from SWE (Column 6) times Column 2
Column 8 = Total season rainfall of 237.4 mm times Column 2
Column 9 = Gross lake evaporation of 325.5 mm times Column 3
Column 10 = ET of 38 mm times (Column 2 - Column 3)
Column 11 = Basin inputs less losses = Column 7 + Column 8 - Column 9 - Column 10
Column 12 = Column 11 divided by Column 4
Column 13 = Column 11 - Column 4
Column 14 = Column 13 divided by Column 2
Column 15 = Column 4 divided by (Column 7 + Column 8)

Figure 6.4

Figure 6.5

Figure 6.6

Figure 6.7

It is estimated that about 90 percent of the snowmelt and about 30 percent of the rainfall went to runoff, while all the rest was lost to evaporation and evapotranspiration except for about 25 percent of the rainfall which went into basin storage.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Regional Climate and Runoff

The available climate data for the region (Rankin Inlet) indicates that the 1999 hydrologic year (October '99 through September '99) was almost equal to the wettest year in the eighteen years of record. The observed total precipitation of 385 mm was 27 percent above the mean and 46 mm higher than the total 1997-1998 precipitation of 334 mm.

The historical runoff data for the Diana River parallels the historical climate data, but with an over-year lag effect. The measured yield for 1999 for the Diana (unadjusted for inflows from the Meliadine Basin) was 306 mm, which, at 106 mm above the 10 year annual mean of 200 mm, was the highest on record and 50 percent higher than the 1998 runoff. The ratio of 1999 runoff to precipitation (Rankin Inlet AES station) is 0.79, well above the average of 0.67, and is influenced by the lag effect of the preceding moderately wet year.

Meliadine and Diana Basins

The total 1999 runoff for the Meliadine Lake basin is estimated to be 239 mm over the catchment area of 569 km^2. This includes an estimated 25 mm of runoff which is expected to discharge from Meliadine Lake over the December 1999 to June 2000 winter period. This winter discharge is expected to freeze as surface icing in the immediately downstream area. About 60 mm or 25 percent of the total 1999 Meliadine Lake runoff was discharged through the west outlet into the Diana River basin via Peter Lake. The remaining 179 mm was discharged into the Meliadine River.

The Meliadine River near the mouth discharged a nominal 189 mm of runoff in 1999 based on the total catchment area of 796 km^2. In effect however, when the drainage area is reduced in proportion to the amount of runoff diverted through the west outlet, the runoff becomes 231 mm, which agrees closely with that found for Meliadine Lake.

The Diana River 1999 yield of 306 mm becomes 284 mm when the diversion in from Meliadine Lake is deducted. The latter value is about 17 percent higher than the yields for the Meliadine Lake and River basins. Diana River yields are expected to be higher than Meliadine Basin yields because greater proportional evaporative loss occurs in the latter, as a direct consequence of the fact that Meliadine Lake represents 20 percent of the total catchment, while Diana and Peter Lakes together constitute only 15 percent of the Diana catchment. In addition, higher precipitation appears to have occurred in the Diana Basin in 1999.

For the 1999 hydrologic year the ratio to precipitation (Rankin Inlet) for the Meliadine River basin was 0.62, which is considerably higher than the 1998 and 1997 ratios of 0.43 and 0.45.

Peninsula Basins

The main components of the water balance for three peninsula basins were measured for the 1999 season. The runoff yields for the two larger Lake A1 and Lake B2 basins were relatively consistent at 204 mm and 189 mm, respectively. The yield for Lake B7 was about 20 percent lower, at 159 mm. The 1998 yield for Lake B7 was also lower than that for the other two. A review of possible factors strongly suggests that the drainage area as delineated and used for the B7 basin is too high, and should be investigated in the field. The Lake A1 and Lake B2 1999 yields were about 20 percent lower than that for Meliadine Lake.

Basin storage over the May through September season increased for all basins. The weighted average increase for Basins A and B equals 64 mm. The principal mechanism for basin storage is the retention capacity of basin lakes and ponds.

The weighted average 1999 ratio of runoff to total precipitation (defined as the spring snow water equivalent plus the season's rainfall observed at the Meliadine Camp station) equals 0.52, which is very similar to the 1998 reported average of 0.54.

In 1999, snowmelt contributed about 36 percent and rainfall 64 percent of the total precipitation input. Basin outflows averaged 52 percent of the total precipitation input. Some 23 percent of precipitation was lost by evaporation and 8 percent by evapotranspiration. An average of 17 percent went into basin storage. In terms of the precipitation components, it is estimated that about 90 percent of the snowmelt and 30 percent of the rainfall went to runoff, 25 percent of the rainfall went into basin storage, and the rest was lost to evaporation and evapotranspiration.

7.2 RECOMMENDATIONS

Pre-Season Monitoring

Observation of water levels in May prior to the snowmelt runoff is important for understanding basin storage as a component of the water balance. It is recommended that adequate effort be allocated to determining May 2000 water levels.

Station Start-Up

The importance of starting discharge monitoring as early as possible is again demonstrated by the 1999 runoff hydrographs, as it was in 1998. The discharge peaks very quickly, within a few days of the start of the runoff. It is therefore recommended that sufficient manpower be mobilized at the start of the season for future monitoring work.

It is also recommended that discharge measurements during station start-up be made using a streamlined procedure which relies on fewer measurement points across the channel. In 1998 and 1997, the standard WSC method of dividing the channel into about 20 segments was used. However, it is recommended that in future, for the small peninsula basin outflow channels, ten segments or even less be used. The loss of accuracy should be minimal for small channel widths, and would be a small tradeoff when compared to the extra discharge measurements that could be made. Such extra measurements would be valuable during the initial period before datalogger monitoring commenced.

Lake B7 Basin Drainage Area

Based on discrepancies noted for the Lake B7 basin yield and water balance results, it is considered likely that the drainage area delineated and used for the basin is too high. It is recommended that the drainage area boundaries be investigated in the field at the beginning of the 2000 monitoring season.

Rain Gauges

There are continuing minor differences between the manual rain gauges and the tipping bucket located at the WMC camp. Therefore it is recommended that the camp tipping bucket rainfall gauge be calibrated prior to the start of the next rainfall season (June 2000), and that the datalogger be adjusted to provide rainfall data in units of 0.1 mm.

The manual rain gauge at Peter Lake has identified significant variation in the rainfall pattern over the main lake basin areas in both 1998 and 1999. This gauge should be retained for future years. Efforts should be made to have this gauge read as often as possible and to collect a complete record for the June 1 to September 31 season.

Adjustment of Data Set

Various corrections and adjustments to data collected over the three years of the program to date, are required to obtain the most accurate and consistent data set possible. Corrections include those to be derived from improvements to rating curves, better estimates of snowfall water equivalents, and drainage area corrections. It is therefore recommended that future reporting include correcting the complete data set.

8.0 CLOSURE

This report contains hydrometric and climate monitoring data collected in 1999 in the Meliadine and Diana River basins, analysis and interpretation of the data, and conclusions and recommendations for future work.

This report has been prepared for the exclusive use of WMC International Limited.

Respectfully submitted,

AGRA Earth & Environmental Limited

Reviewed by:

Neil van der Gugten, M.A.Sc., P.Eng.
Senior Hydrotechnical Engineer

Gary R. E. Beckstead, M.Sc., P.Eng.
Reviewer

PHOTOGRAPHS