WMC INTERNATIONAL LTD.
MELIADINE WEST GOLD PROJECT
WATER BALANCE STUDY
1997 DATA REPORT

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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 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. 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 purpose of the water balance study is to provide a measurement of the water balance in the Meliadine River Basin, with the intention of providing a tool to plan for and monitor mine operations and closure.

The 1997 work program included measurement of streamflows on the Meliadine River and adjacent Diana River; measuring outflows from the lakes in the immediate area expected to be affected by gold mine development activities; measuring pre-melt snowpack water equivalent, measuring evaporation and evaluating the relative magnitudes of the principal basin inputs, losses and yields within the context of available regional and historical climate and runoff data.

Hydrometric monitoring stations were established at the following locations:

- Diana River near Rankin Inlet (WSC Sta. No. 06OA001);
- Meliadine River at the outlet of Meliadine Lake;
- Meliadine River near the mouth;
- west outlet of Meliadine Lake discharging into the Diana River basin;
- Diana Lake (staff gauge);
- Peter Lake (staff gauge); and
- at five lake outlets in the smaller basins located in the peninsula area.

Regional Climate and Runoff

The available climate data for the region (Rankin Inlet) indicates that the 1996-97 hydrologic year (October through September) was the driest year since 1981, when records began. The observed total precipitation of 172 mm was just 57 percent of the 16 year average of 297 mm.

The historical runoff data for the Diana River parallels the historical climate data. The measured yield for 1997 for the Diana is 134 mm, which was 69 percent of the preceding seven year mean of 194 mm, and the lowest in the eight years of record. Regional comparison with the Ferguson and Lorillard rivers suggests that the 1997 runoff may have been the lowest since 1980.

The Diana River runoff averages about 0.65 of the observed Rankin Inlet precipitation. When the observed precipitation is corrected for undercatch, the runoff to precipitation ratio becomes 0.48.

Meliadine and Diana Basins

The total 1997 runoff for the Meliadine Lake basin is estimated to be 78 mm over the catchment area of 569 km^2. This includes about 14 mm of runoff estimated to have occurred through the winter prior to the spring snowmelt. About 11 mm or 15 percent of the runoff was discharged through the west outlet of Meliadine Lake into the Diana River basin via Peter Lake. The remaining 67 mm was discharged into the Meliadine River.

The Meliadine River near the mouth discharged 57 mm of runoff based on the total catchment area of 796 km^2, or 63 mm when the drainage area is reduced in proportion to the amount of runoff diverted through the west outlet. In the absence of data, no allowance has been made for possible discharges during winter, which would have increased the runoff depth.

The Diana River yield of 134 mm becomes 130 mm when the diversion in from Meliadine Lake is deducted. The later value is about 70 percent higher than the yield of 78 mm for the Meliadine Lake basin. Part of the difference is due to the greater evaporative loss in the Meliadine basin, because Meliadine Lake represents 20 percent of the total catchment area, while Diana and Peter Lakes together constitute only 15 percent of the Diana catchment area.

A more important difference between the Diana and the Meliadine basins is the different outlet discharge characteristics. The Meliadine outlets are considerably wider than that of the Diana, and inflows to Meliadine Lake are passed through the outlets relatively quickly, resulting in limited if any over-year storage during years of higher runoff, compared to the Diana. Higher runoff years are also expected to result in a higher proportion of the outflows being diverted through the west outlet. It is therefore anticipated that Meliadine basin yields will always be less than those of the Diana. For 1997 the runoff ratio for the Meliadine River basin (using precipitation corrected for undercatch) was 0.27 while for the Diana it was 0.56 (based on 130 mm of yield).

Peninsula Basins

The main components of the water balance for the five monitored peninsula basins were measured for the 1997 season. Based on direct measurements of surface outflows over the season, annual yields for two of the basins (Peg Lake and Nevvy Lake) were quite similar, at about 60 mm. A third basin (Lake D5 downstream of Wolf Lake) had an annual yield of 80 mm. The lowest yield was 30 mm, for Control Lake, and the highest was 114 mm for Lake A1 (i.e., Basin A as a whole).

Estimates of subsurface outflows from the five basins were made by calculating the residual in the daily water balance for each monitored lake. This procedure indicated that subsurface outflows were significant for Peg Lake, Nevvy Lake and Control Lake, but not for Lake A1 and Lake D5. Addition of the estimated subsurface outflow to the measured surface outflow volumes caused the basin yields to converge, with values ranging from 72 to 87 mm for four of the basins. The yield for Lake A1 increased slightly to 117 mm. The Lake A1 sub-basin was calculated to have a yield of about 180 mm, or twice that of the other basins. The ratio of runoff to precipitation for the Lake A1 sub-basin is 0.80, while that for the other basins is in the range of 0.38 to 0.45. The mean runoff ratio of 0.44 for the peninsula basins is very similar to the Diana River historical mean value of 0.48.

The snowmelt contributed about 100 mm or just above 50 percent of the season's moisture input, while rainfall accounted for 94 mm or just under 50 percent. Evaporative losses removed about 112 mm of moisture from the basins, which thus consumed all of the rainfall input and about 15 percent of the snowmelt input. Some 85 percent of the snowmelt therefore resulted in basin runoff or yield.

About 20 mm of the basin yield appears to have been drawn from basin storage for the Peg Lake, Lake A1 and Lake D5 basins. Water balance computations indicate that the Nevvy Lake and Control Lake basins appear to have increased their basin storages; however, that result is thought to be an artifact of measurement errors and inaccuracies.

The peninsula basins all stopped discharging surface outflows sometime during the open water season. The smaller lakes (Control Lake and Lake D5) reached their zero outflow levels by the middle of July. Peg Lake stopped outflows near the end of July, followed by the downstream Lake A1 a few days later. Nevvy Lake, the largest of the five monitored lakes and having the largest of the basins, continued to discharge surface flows until the middle of September. By the end of September the smaller lakes had dropped 0.15 metres below their outlets.

Reliability of Results

Accuracy of the 1997 monitoring data was affected by undesirable characteristics at most of the basin lake outlets. In general the outlet channel was not well defined, additional secondary channels were present, and higher flows tended to spread out beyond the banks where measurement was not feasible. Additional problems were caused by the movement of benchmarks at the monitoring sites which affected the accuracy of water level observations.

Recommendations

Recommendations are made in the report for additional monitoring as well as improvements in methodology for the 1998 program, based on the experience gained in 1997.

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 have 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.

1.2 PROJECT AREA

The project area is located about 30 km northwest of Rankin Inlet on the western edge of Hudson Bay (see Figure 1.1). The project is within the basin of Meliadine Lake, which has its geographic center at about 63/05'N and 92/20'W. The mean annual temperature in the region, based on climate normals for Chesterfield Inlet located 80 km to the north, is about -12/C. Monthly mean temperatures above freezing occur only in the four month June through September period. Lakes are ice-covered from about mid-October to late June.

The Meliadine Basin is within the zone of continuous permafrost and is located well north of the tree line near Churchill 400 km to the south. The terrain is dominated by glacial landforms consisting of drumlins of glacial till, eskers consisting of gravels and sands and numerous shallow lakes.

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.

1.3 PURPOSE OF STUDY

The purpose of the water balance study is to provide a description and reliable measurement of the water balance in the Meliadine River Basin, with the intention of providing a tool to plan for and monitor mine operations and closure.

Achievement of the above involves measurement of streamflows on the Meliadine River and adjacent Diana River; measuring outflows from the lakes in the immediate area expected to be affected by gold mine development activities; measuring pre-melt snowpack water equivalent, measuring evaporation and evaluating the relative magnitudes of the principal basin inputs, losses and yields within the context of available regional and historical climate and runoff data.

Figure 1.1

1.4 SCOPE OF STUDY

The main work components and activities planned and carried out by AEE for the 1997 water balance study are summarized as follows in Table 1.1.

TABLE 1.1
1997 Water Balance
Component and Activity Summary

Component	Office Activities	Field Activities
Snow Water Equivalent	C Prepare snow distribution map, select transects C Calculate snow water equivalents	C Conduct snow surveys
Precipitation	C Obtain and compile precipitation data	
Flow Monitoring	C Specify and order equipment C Compile and analyze data	C Select sites C Install stations C Operate stations C Retrieve data C Make discharge measurements C Shut down stations
Lake Level Monitoring	C Compile and analyze data	C Select locations C Install staff gauges C Monitor staff gauges
Evaporation	C Specify and order equipment C Compile and analyze data	C Install evaporation pan C Operate pan C Shut down pan
Evapotranspiration (ET)	C Obtain climate station data C Calculate ET	

WMC installed and 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 study was carried out by RL&L Environmental Services Ltd. of Edmonton.

2.0 MELIADINE BASIN

The Meliadine Basin in which the project is located measures approximately 60 km long by 20 km wide and extends from near Rankin Inlet towards the northwest, as shown on Figure 2.1.

An area of 455 km^2 drains into the lake, of which about 4 km^2 are islands. Meliadine Lake itself has a surface area of 114 km^2, thus the total drainage area for the Meliadine Lake basin is 569 km^2. Meliadine Lake discharges into the Meliadine River at the location shown on Figure 2.1. The Meliadine River downstream of the lake outlet drains an additional 227 km^2 before discharging into Hudson Bay just north of Rankin Inlet. The total drainage area of the Meliadine River is thus 796 km^2. Meliadine Lake constitutes 20 percent of the Meliadine Lake drainage area and 14.3 percent of the area of the Meliadine River basin at the mouth.

A secondary outlet, labelled the "west outlet" was discovered by the AEE team during the June 1997 field reconnaissance of the project area. This west outlet, located as shown on Figure 2.1, drains into the adjacent Diana River basin. The Diana River drains a total area of 1480 km^2, which is 85 percent larger than the Meliadine River basin. The Diana River basin is similar to the Meliadine in that the river drains a large lake area of 217 km^2 made up of Diana Lake (40 km^2) and the connected Peter Lake (177 km^2). The combined Diana Lake and Peter Lake area constitutes 14.7 percent of the total Diana River drainage area which is almost identical to that of the Meliadine Basin. Given the further similarity between the two basins in watershed shape and orientation and their proximity to one another, it would be expected that the two basins would have similar hydrologic regimes.

The area of exploration activity, and the focus of much of the water balance study is the peninsula area which juts out into Meliadine Lake from the southeast. The terrain in this area (as in the Meliadine Basin and the region generally) is dominated by glacial landforms oriented approximately northwest-southeast at an azimuth of about 135 degrees. The topography consists of drumlins of glacial till, eskers consisting of gravels and sands and numerous shallow lakes. Lakes are interconnected by ephemeral streams, many with poorly defined channels. Some of the smaller ponds appear to have no regular outlet; however, it is assumed that they overflow in years of heavy runoff.

Other than the esker sands and gravels, the surficial material in the area consists almost entirely of glacial till, with scattered small bedrock outcrops. The tills consist of a 5 to 10 metre thick (up to 20 metres on drumlins) conglomerate with a matrix of clayey silt to fine sand containing small pebbles to large boulders. Some deposits of a very thin silt veneer and some minor wave cut platforms are evidence of a minor marine transgression associated with retreat of the last ice sheet.

Figure 2.1

The region is within the zone of continuous permafrost. The seasonal active zone is thought to range from less than one metre to about two metres. Soil formation since the ice sheet retreat has been very minor; there has been some development of a patchy mat of organic material about 4 to 5 cm thick derived from tundra vegetation. Post glacial fluvial deposition appears to be minimal. Frost boils, thought to be due to the expulsion of water upward as the active zone freezes down in the fall toward the permafrost surface, are common. The extent of post glacial lacustrine sedimentation is uncertain.

3.0 1997 WORK PROGRAM

3.1 DETAILED WORK PLAN

A detailed work plan for the 1997 season was prepared and submitted to WMC before the field work began (AEE, 1997). The work plan included a monitoring plan which identified the locations of flow monitoring and water level monitoring sites. These locations were revised on the basis of field reconnaissance. The monitoring plan included establishment of flow monitoring stations on the Meliadine River and the Diana River, lake level monitoring of Meliadine, Peter and Diana Lakes, and flow and level monitoring in the smaller lake basins located in the Meliadine Lake peninsula where the majority of the exploration work is occurring. Snow surveys in the peninsula basins was also included in the 1997 prograr

3.2 SNOW SURVEYS

Snow surveys were carried out in the peninsula basins in the period May 12 to May 18, 1997. Snow depth and density were sampled along 12 transects over a total distance of 8300 metres. Snow distribution terrain units were identified and the snow survey data were used to calculate the total water equivalent for the snowpack in each study basin.

3.3 HYDROMETRIC MONITORING

3.3.1 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 as well as all methods and procedures used for data collection and data handling, conformed to WSC standards.

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

Reconnaissance and Site Selection	June 9 - 13
Installation and Startup	June 18 - 30
Operation - Inspection	Weekly throughout July - September
Operation - Discharge Measurement	Monthly throughout July - September
Seasonal Shut-Down	September 22 - 26
Data Retrieval and Handling	June through September
Data Compilation and Analysis	October through December

3.3.2 Main River Flow Monitoring

Four main river flow monitoring stations were established:

- The WSC station on the Diana River, previously discontinued in 1996 (Sta. No. 06OA001).
- A new station on the Meliadine River at the outlet of Meliadine Lake.
- A new station on the Meliadine River near the mouth.
- A new station on the west outlet of Meliadine Lake discharging into the Diana River basin.

The Diana River station was established to permit correlation of Meliadine River discharges with the longer data record of the Diana River.

The locations of the main river monitoring stations are shown on Figure 3.1. A full-size copy of Figure 3.2 is attached at the end of this report. Photographs of the stations are provided in the photo section following the text of the report (Photos 1 through 7).

3.3.3 Main Lake Level Monitoring

Six lake level monitoring stations were established on the main lakes, as follows:

- Meliadine Lake near Rankin Inlet (automated station)
- Meliadine Lake at Meliadine Camp (staff gauge)
- Meliadine Lake at main outlet (staff gauge)
- Meliadine Lake at west outlet (staff gauge)
- Diana Lake (staff gauge)
- Peter Lake (staff gauge)

The staff gauges at the two Meliadine Lake outlets correspond to the flow monitoring stations at the same locations.

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 staff gauges were read at intervals as permitted by the work schedule, and were used to provide local water level readings at the flow monitoring sites and to attempt to detect possible water level differences due to wind effects.

The Diana Lake and Peter Lake water level stations were intended to permit regional comparisons for Meliadine Lake water levels.

The locations of the lake level monitoring stations are shown on Figure 3.1.

Figure 3.1

3.3.4 Peninsula Basins Monitoring

Five flow and level monitoring stations were selected for the basins in the Meliadine Lake peninsula area. Five stations were considered to be adequate to provide a reasonable coverage of the various basin and sub-basin areas.

The location and delineation of the Meliadine Lake peninsula basins in the study area are shown on Figure 3.2 attached in the drawing pocket at the end of this report. A reduced copy of Figure 3.2 is provided on the following page. The peninsula basins have been identified by an arbitrarily assigned letter. Four basins were selected for inclusion in the water balance study: Basins A, B, D and G. Basins A, B, and D include the areas where exploration has indicated that gold mine development could take place. Basin G is expected not to be affected by any future gold mine development and as such was selected as a control basin.

Hydrometric stations were selected in the peninsula basins at locations where monitoring was considered to be most useful for hydrologic characterization of the area. Monitoring at the preferred locations could often not be implemented due to unsuitable site conditions with poorly defined channels and diffuse and spreading flow. The final station locations are shown on Figure 3.2. Photos of the peninsula basin stations are provided in the photo section (Photos 8 through 29). These photos also show some of the other lake outlets which were considered unsuitable for the 1997 program.

The lakes within each basin are identified on Figure 3.2 using a numbering scheme devised by RL&L Environmental Services Ltd. as part of their 1997 fisheries and water quality study for the Meliadine project. That scheme is based on assigning a number in sequence starting at the basin outlet and proceeding up the main stem, thereafter proceeding around the basin starting at the tributary most directly north of the main stem. Local lake names where known, are also indicated on Figure 3.2.

Peninsula lakes are thought to be relatively shallow, generally no more than 3 to 4 metres deep, except for occasional deeper areas of up to 5 to 6 metres in the larger lakes.

3.3.5 Drainage Areas

Main River Basins and Lakes

Drainage areas for the main river flow monitoring stations are summarized in Table 3.1. The table includes identification of the directly connected main lake area upstream of the monitoring station, as well as an estimate of the area of the other lakes in the basin. That area is estimated at 25 percent of the total basin area after deducting the area of the directly connected main lake area. The value of 25 percent was obtained from detailed lake and land surface area measurements of the peninsula basins. The purpose of identifying lake are to facilitate hydrologic comparison of the basins as well as to permit assessment of the effect of lake evaporation on the basin yield and water balance.

Figure 3.2

TABLE 3.1
Main River Basin and Lake Areas in 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	487	131	174	305	796
Diana River at WSC Station	948	217	315	532	1480

Peninsula Basins and Lakes

Areas of peninsula basins and lakes were measured using the EMXS digital terrain model (DTM), and are reported in Table 3.2. The table includes the following breakdown of basin areas:

- total basin area
- total area of sub-basins upstream and downstream of hydrometric stations
- surface area of directly connected, monitored lakes
- areas of land and lake surfaces within each basin and sub-basin
- ratio of lake area to total area

The breakdown of basin areas facilitates hydrologic comparison between basins and permits assessment of the effect of lake evaporation on the basin yield and water balance.

TABLE 3.2
Peninsula Basin and Lake Areas

Watershed	Land Surface (ha)	Monitored Lake Surface (ha)	Other Lake Surface (ha)	Total Lake Surface (ha)	Total Area (ha)	Ratio of Lake to Total Area
Basin A	652.79	N/A	N/A	209.76	862.55	0.243
Peg Lake Sub-	410.04	50.57	126.01	176.58	586.62	0.301
Lake A1 Sub-Basin	242.75	14.85	18.33	33.18	275.93	0.12
Basin B	1527	N/A	N/A	530.66	2057.66	0.258
Newy Lake Sub-	1334.1	84.31	364.63	448.95	1783.06	0.252
Outlet Sub-Basin	192.89	N/A	N/A	81.71	274.6	0.298
Basin D	555.09	N/A	N/A	219.92	775.01	0.284
Lake D5 Sub-Basin	236.12	6.26	115.49	121.75	357.87	0.34
Outlet Sub-Basin	318.97	N/A	N/A	98.17	417.14	0.235
Basin G	105.15	N/A	N/A	17.07	122.22	0.14
Control Lake Sub-	35.51	11.94	0.27	12.21	47.72	0.256
Outlet Sub-Basin	69.64	N/A	N/A	4.86	74.5	0.065
Basins Total	2840	N/A	N/A	977	3817	0.256

Table 3.2 indicates that for the peninsula basins, lakes occupy about 25 percent of the total

area, on average.

3.4 EVAPORATION

A Class A evaporation pan was established at the WMC Camp on Meliadine Lake in mid-June and operated to the end of September. The pan data were used to estimate lake evaporation losses from the basins.

3.5 EVAPOTRANSPIRATION

Direct measurement of evapotranspiration (ET) was not considered feasible and was not attempted. Instead, the potential ET was calculated using climate data from the climate station at the WMC Camp, and then factored to estimate the actual ET losses in the study basins.

4.0 METEOROLOGICAL DATA

4.1 REGIONAL HISTORICAL PRECIPITATION

The Atmospheric Environment Service (AES) has collected meteorological data at the Rankin Inlet station since 1981, including rainfall, snowfall and total precipitation. Precipitation observations in the Arctic are known to under-represent the actual precipitation by a significant factor which varies from station to station and from year to year (Prowse and Ommanney, 1990). The main reason is the large number of trace snowfall events (T) which occur in the Arctic. Such events do not add snow depth amounts to the record, but in reality do contribute a small amount of precipitation each and the cumulative effect can be significant. The observed (or "archived") data up to 1992 have been corrected for undercatch by the AES (Metcalfe and Ishida, 1994). The available observed and corrected data and the associated correction factors are summarized in Table 4.1.

TABLE 4.1
Rankin Inlet Annual Precipitation

Year	Observed Data			Corrected Data			Correction Factor		
	Rain (mm)	Snow (cm)	Total Precip. (mm)	Rain (mm)	Snow (mm)	Total Precip. (mm)	Rain (mm)	Snow (mm)	Precip. (mm)
1981	199.0	110.2	306.9	208.2	184.5	392.7	1.05	1.67	1.28
1982	171.0	108.7	277.3	181.1	190.6	371.7	1.06	1.75	1.34
1983	233.9	97.2	323.4	243.6	171.9	415.5	1.04	1.77	1.28
1984	174.9	102.5	262.2	183.1	171	354.1	1.05	1.67	1.35
1985	255.7	209.5	449.2	264.5	339.5	604.0	1.03	1.62	1.34
1986	168.8	103.5	270.1	176.6	187.7	364.3	1.05	1.81	1.35
1987	161.4	189.4	352.5	168.8	329.5	498.3	1.05	1.74	1.41
1988	110.3	117.4	221.4	117.6	199	316.6	1.07	1.7	1.43
1989	133.4	68.5	198.1	139.7	143.5	283.2	1.05	2.09	1.43
1990	253.4	162.6	399.9	264.0	277.9	541.9	1.04	1.71	1.36
1991	228.6	165.8	387.8	237.9	285.1	523.0	1.04	1.72	1.35
1992	139.8	113.7	253.2	146.8	214.4	361.2	1.05	1.89	1.43
1993	191.4	121.8	312.8						
1994	120.0	111.1	231.5						
1995	197.8	73.6	271.2						
1996	159.2	108.8	265.2						
1997	140.1	100.9	240.8						
Mean	178.7	121.5	295.5	194.3	224.6	418.9	1.05	1.76	1.36

The data in Table 4.1 show that corrected rainfall amounts to about 5 percent more than observed rainfall, whereas corrected snowfall is on average 76 percent greater (in terms of snow water equivalent) than observed snowfall (which is presumed to have a density equal to 10 percent of water). The annual total precipitation as observed needs to be corrected on average by a factor of 1.36 to represent the actual annual precipitation.
A plot of the observed data in Table 4.1 is provided on Figure 4.1, showing the annual variation of rainfall, snowfall and total precipitation, plus the corrected total precipitation on

a calendar year basis. The data indicate that 1997 was a relatively dry year, although 1988, 1989 and 1994 were drier.

A more meaningful evaluation of annual precipitation is to use the "hydrologic year" instead of a calendar year. A hydrologic year is defined so as to include most if not all precipitation that contributes to the annual runoff. For the study area, most precipitation occurring after October 1 will fall as snow and accumulate over the winter to contribute to the next year's runoff. The hydrologic year is thus defined to extend from October 1 of the previous year to September 30 of the current year.

A re-tabulation of the Rankin Inlet observed annual total precipitation based on a hydrologic year is given in Table 4.2 and shown graphically on Figure 4.2. The reorganized data show that 1997 was the driest year on record, with a total observed precipitation of only 172 mm or 58 percent of the mean, with the next driest being 1994 with 207 mm or 70 percent of the mean.

A complete tabulation of observed monthly and annual rainfall, snowfall, and total precipitation for Rankin Inlet, on both a calendar year and a hydrologic year basis, is provided in Appendix B.1.

TABLE 4.2
Rankin Inlet Observed Annual Precipitation
by Hydrologic Year (Oct. - Sept.)

Hydrologic Year	Total	Total/Average
81-82	271.7	0.92
82-83	357.6	1.20
83-84	278.4	0.94
84-85	369.0	1.24
85-86	371.9	1.25
86-87	334.7	1.13
87-88	216.2	0.73
88-89	250.7	0.84
89-90	359.8	1.21
90-91	387.3	1.30
91-92	288.5	0.97
92-93	316.1	1.07
93-94	207.2	0.70
94-95	285.9	0.96
95-96	281.8	0.95
96-97	172.0	0.58
Average	296.8	

Figure 4.1

Figure 4.2

4.2 PROJECT SITE CLIMATE DATA

4.2.1 Data Observations

Climate data at the project site were collected during the 1997 work seasonal by Hubert and Associates Ltd. for WMC International. An automated climate station was installed at the Meliadine Camp in mid-April to log temperature, humidity and wind data. At the beginning of June, rainfall, radiation and soil temperature were added. Observations were continued to the end of October. Data for a 32 day period (August 29 to September 29 inclusive) were lost due to an improper keypad sequence entered during an attempt to obtain current station readings.

An evaporation pan was installed at the camp by AEE on June 23, 1997. Daily observations were made to September 21. The pan was decommissioned for the season on September 30. Daily rainfall was observed at the pan as part of the evaporation data.

4.2.2 Rainfall Data

Rainfall data for the 1997 season were collected by the Meliadine Camp station, using an automated tipping-bucket rain gauge, and at the pan evaporation station using daily manual observations. Evaluation of the two data sets indicated inconsistencies in the tipping-bucket data. Further comparison with the AES Rankin Inlet rainfall data confirmed that the tipping-bucket data were incorrect. The tipping-bucket rainfall data were therefore not used in the present report and the Rankin Inlet data were used instead. The daily rainfall as well as the daily snowfall and total precipitation for Rankin Inlet for 1997 are provided in Appendix B.3.

The tables in Appendix B.3 show that in 1997 the first rain fell in mid-April and the last rainfall occurred on November 1. Such early and late rainfalls, however, would not result in immediate runoff. The early rainfalls would have frozen into the snowpack (where it was measured as part of the snow survey) for release during the spring melt. The late rainfalls would likewise have frozen either into early snow accumulations or in the near surface active layer zone, for subsequent release next year. The time period within which rainfall can be considered to contribute to 1997 rainfall runoff can be estimated by noting when the mean daily air temperature remains above the freezing point. Reference to a plot of the 1997 air temperature data (Figure 4.3) indicates that the above freezing time period extends from about mid-May to the end of September. The total rainfall which occurred in 1997 during this period, as obtained from Table B.3.1, amounts to 94 mm. There were no snowfall events recorded within this period.

4.2.3 Other Data

Besides rainfall, other data recorded at the camp climate station include temperature, net radiation, soil temperature, humidity and wind speed. Daily values of each of these parameters are shown on Figures 4.3 through 4.7. Monthly mean values are summarized in Table 4.3.

Figure 4.3

Figure 4.4

Figure 4.5

Figure 4.6

Figure 4.7

TABLE 4.3
Meliadine Camp Climate Station
Monthly Data Summary

Month	Temperature (°C)			Mean Net Radiation (MJ/day/m²)	Mean Soil Temperature (°C)	Mean Humidity (%)	Mean Wind Speed (km/h)
	Maximum[1]	Minimum[1]	Mean				
April (17-30)	-3.4	-9.6	-6.5	---[2]	---[2]	88.5	---
May	-0.4	-8.2	-4.3	---[2]	---[2]	85.7	---
June	11.4	2.2	6.8	13.5	2.6	80.1	15.3
July	19	8.5	13.8	12.1	8.2	74.2	18.9
August	16	6.5	11.2	8.6	7	81	17.4
September	---[2]	---[2]	---[2]	---[2]	---[2]	---[2]	---
October (1-	-3.1	-7	-5.1	0.1	-0.5	93.5	---

Notes:

1. Maximum (and minimum) temperatures reported here are the monthly average of the daily maximum (or minimum) temperatures.
2. Lost or unrecorded data.

4.2.4 Evaporation

4.2.4.1 Equipment and Methods

Evaporation at the site was measured during the open-water season using a standard Class A evaporation pan. The pan is 1.22 metres (4 feet) in diameter and 254 mm (10 inches) deep. It is constructed of galvanized steel and water is maintained at a precise level within 7 cm of the top. It is set on timbers to permit air circulation below the pan. Evaporation is determined from the records of water added to the pan each day, corrected for the amount of water added by rainfall. The equipment consists of the following items:

- Class A Evaporation Pan.
- Stilling well with a fixed point to allow precise filling to the same level each day.
- Metric Graduate Cylinder to measure the water added (or removed) each day.
- Minimum/Maximum Thermometer to measure changes in pan water temperature.
- Accumulating Rain Gauge which stores the rainfall accumulated from one reading to the next.

4.2.4.2 Evaporation Measurements

The pan was installed at the Meliadine Camp on June 23 (Photo 30) and decommissioned for the season on September 30. Monitoring instructions provided to the operator are attached in Appendix A, and the daily readings are provided in Appendix B.4.

The data set is relatively complete except for a 14 day period from July 30 to August 12 when no observations were taken. Cumulative evaporation and rainfall depths are shown on Figure 4.8. A review of the graph indicates that the evaporation pan was probably filled on August 12 without the filling being recorded. As a result, the evaporation which occurred during the July 30 to August 12 period was not measured. However, an estimate of the evaporation which occurred during that period may be obtained by extrapolating cumulative evaporation as shown by the dotted line on Figure 4.8. The estimated gross evaporation rate during the missing period was 5.35 mm/day, compared to an average measured gross evaporation rate of 6.66 mm/day in July and 4.17 mm/day in the last half of August.

Missing records during the remainder of the season appear to have been handled correctly, with the evaporation recorded for the day after a missing observation reflecting the total evaporation since the last reading. Daily totals in these cases are not correct, but the cumulative evaporation is correct. Evaporation readings were not made after September 21 but evaporation after that date is estimated to have been negligibly small, and has been assumed equal to zero.

The evaporation for the period prior to June 23 was estimated by assuming that the daily evaporation rate increased linearly from zero on June 1, to 3.7 mm/day on June 22. June 1 is the estimated date on which ice cover on the lakes started to break up and open water started to appear. The rate of 3.7 mm/day is the weekly average evaporation rate measured for the first week of observations starting June 23. The total evaporation for the period June 1 to 22 is thus estimated to be 41 mm.

The gross evaporation depth during the season was thus 468 mm, with a monthly distribution as shown on Figure 4.9. The largest monthly evaporation occurred in July, when 203 mm or 43 percent of the annual total occurred.

4.2.4.3 Net Pan Evaporation

The net pan evaporation for the 1997 season is estimated by subtracting the total precipitation during the season from the gross pan evaporation of 468 mm. The AES Rankin Inlet data are used for this because of incompleteness of the rainfall data at the pan station. The Rankin Inlet precipitation for the period June 1 to September 21 over which the evaporation amount was measured or estimated, equals 80 mm (Appendix B.3). The net pan evaporation for 1997 therefore equals 388 mm.

Figure 4.8

Figure 4.9

4.2.4.4 Lake Evaporation

An attempt was made to estimate lake evaporation 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. However, the necessary data was only available for a few days of the total record. Wind run was based on incomplete Rankin Inlet data, air temperature was based on incomplete site data, and the pan water temperature data appears to be of poor quality. For the days when the data was complete and apparently correct, the ratio of computed lake evaporation to measured pan evaporation averaged about 0.70. This ratio is defined as the "pan coefficient". The value of 0.70 is consistent with values reported in the technical literature (Gray, 1970, p. 3.29).

The value of 0.70 was adopted for the preliminary water balance calculation and applied to the complete season of measurements to estimate a seasonal gross lake evaporation of 328 mm. Subtracting the measured rainfall of 80 mm during the same period (June 1 to Sept. 21) results in a net lake evaporation of 248 mm.

4.2.5 Evapotranspiration

Evapotranspiration (ET) for the project area has been estimated using the "GD Relationship" proposed by Granger and Gray (1989). The relationship is defined in terms of the general evapotranspiration equation for non-saturated surfaces which is given as:

$$ET = [\Delta G\,(R_n - Q_g) + \gamma\, GE_a]/(\Delta G + \gamma)$$

where, **)** is the slope of the saturation vapour pressure versus temperature curve; G, the relative evaporation, is a dimensionless parameter; R_n is the net radiation; Q_g is the soil heat flux; **(** is the psychrometric constant; and E_a is the drying power of the air. The detailed application of the GD Relationship is provided in Appendix B.5.

The resulting values for ET are shown on Figure 4.10 in cumulative form for the 1997 season. The values for the September period have been estimated by extrapolation due to the lack of September climate station data. The total cumulative ET for 1997 estimated using the above procedure is 225 mm. This represents the total possible ET for 1997 climatic conditions, based on moisture being continuously available for evapotranspiration at the ground surface.

In reality, the ET actually produced would have been strongly limited because of the following factors (Prowse and Ommanney, 1990, p. 19):

C Portions of the terrestrial surface are not vegetated (e.g., eskers) or are sparsely vegetated (e.g., ridges, hilltops).

Figure 4.10

C A proportion of the vegetative cover consists of mosses and lichens which do not transpire or of vegetation which transpires at relatively low rates.

C Progressive loss of soil moisture after snowmelt (and after rainfall events) leads to a gradual reduction and finally a cessation of ET.

The actual amount of ET produced (ET_a) can be represented by:

$$ET_a = \% ET$$

where % is a coefficient which integrates the limiting factors. Values for % reported for Arctic tundra sites range down to 0.16 for a lichen crested hummock (Marsh, Quinton and Pomeroy, 1994 and as low as almost 0 for dry and bare mineral soil surfaces (Prowse and Ommanney, 1990, p. 198). A value of % = 0.09 was obtained in a previous water balance study in the Rankin Inlet area (Stanley, 1996). A value of % = 0.15 was selected for the present stuc

Therefore the value of ET_a for 1997 is estimated at 0.15 (225 mm) = 33.8 mm.

5.0 SNOWPACK WATER EQUIVALENT

5.1 SELECTION OF METHOD

The objective of obtaining snow data was to determine the snow water equivalent of the snowpack in each basin prior to the spring runoff. Although snowfall in the Arctic generally accumulates throughout the winter period without significant melt prior to the spring runoff, meteorological station snowfall gauge data are not useful in determining the amount of runoff because of the undercatch typical for such gauges in the Arctic and the significant ablation and redistribution of snow by wind.

The method found to be best suited to the Arctic environment has been termed the "stratified method" (Pomeroy and Gray, 1995). In this method the basin is mapped according to landscape types (strata) or terrain units which are characterized as typical for various accumulations of snow. After these terrain units have been determined and the basin map delineated accordingly, snow surveys are carried out just before spring melt to obtain representative snow depth and density measurements for each terrain unit. Those values are then applied to the total area of each type of terrain unit in the basin to obtain the total snow water equivalent.

The principal variables affecting snow accumulation are topography, vegetation and human development of the land. For the Meliadine study area, the land is in its natural state. The vegetation is uniform, consisting of low grasses and low tundra shrubs less than 200 mm tall. The dominant variable affecting snow accumulation in the study area is topography.

The best topographic mapping available for the study area is the 1:50 000 scale NTS mapping. The study area straddles two NTS map sheets. The northern sheet (55N/01) has a contour interval of 10 metres whereas the southern sheet (55K/16) is in imperial units and has a contour interval of 25 feet. The applicable sections of these map sheets were digitized and the contours interpolated to metric. The resulting mapping was used as the base plan for the study area, as shown on Figure 3.3. As indicated on that figure, the NTS map data defines the relief rather coarsely, there being generally no more than two (or, along the perimeter of the peninsula, three) 10 metre contour intervals available to define terrain slopes.

5.2 TRANSECT LOCATIONS

Pomeroy found for a snow distribution study in the Inuvik region of the western Arctic that snow drift accumulation occurred mainly on slopes greater than 9 degrees and along stream channels with presumably similar bank or valley side slopes (Pomeroy *et al.*, in press). The digitized map of the Meliadine peninsula area was manipulated using the EMXS DTM to identify areas with slopes greater than 9 degrees. It was found that the area contains almost no identifiable areas with slopes of 9 degrees or steeper. Photo 31 is indicative of the terrain. Further analysis indicated that most of the area (89 percent) consists of slopes of 3 degrees or less, that slopes of between 3 degrees and 6 degrees are found in only 10 percent of the area, and that only a very limited area (1 percent) has slopes of between 6 degrees and 9 degrees. These areas are shown on Figure 5.1.

The percentages of each slope category in each basin are summarized in Table 5.1.

TABLE 5.1
Terrain Slope Category Distributions by Basin

Terrain Slope Category	Percent of Basin Area (%)				Mean
	Basin A	Basin B	Basin D	Basin G	
0 - 3%	90.6	87.5	93.8	79.1	89.2
3 - 6%	8.8	10.8	5.6	20.9	9.6
6 - 9%	0.6	1.5	0.6	0	1.1
9 - 12%	0	0.2	0	0	0.1
>12%	0	0	0	0	0

Aerial photographs available for the study area consist of one flight carried out in August 1954 at a scale of 1:60,000. Enlargements of those photos at a factor of 4X suggested the existence of relief features, such as steeper slopes significant for snow accumulation, which do not show up on the NTS mapping. It was therefore decided to locate snow survey transects at locations where various slopes could be expected, such as along a sequence of topographic lows and highs and across watershed boundaries.

The prevailing wind direction during winter was also considered in selecting transect locations. The prevailing wind direction in the region is from the northwest, parallel to the orientation of the ridges and valleys. Transects were therefore selected both across this direction and parallel to it.

Transects were located according to the above procedure and marked on the area plan. The coordinates of the end points were then scaled from the plan UTM grid derived from the NTS map grid (NAD 1927). The transects were adjusted, deleted and added to in the field as snow survey information was obtained and reviewed. Twelve transects were ultimately located in the field and surveyed. The transect locations are shown on Figure 5.2. The total length of transect surveyed was 8300 metres. Individual transect lengths varied from 300 metres to 1500 metres.

Figure 5.1

Figure 5.2

5.3 FIELD PROCEDURES AND EQUIPMENT

Horizontal control on the ground was obtained using hand held GPS units referenced to the NAD 1927 UTM coordinates. The GPS unit was capable of defining a location to within about 100 metres. The starting point of each transect was located using approximate visual orientation followed by GPS location according to the scaled UTM grid coordinates. GPS readings of location were taken about halfway along each transect and at each end. The GPS determined coordinates are listed in Table 5.2. The locations of the transects as shown on Figure 5.2 are based on the end point coordinates listed in the table.

Transect alignment was maintained by line of sight using range poles, as compass traverse was not feasible due to significant temporal magnetic drift and the presence of strong local anomalies. Transect stationing was controlled by using a 300 metre kevlar tagline marked every 5 metres.

The snow depth was measured along each transect at 10 metre intervals and recorded in a field book. Depths were recorded at 5 metres intervals over the 1500 metres length of the first transect but evaluation of the data indicated that no loss of accuracy would occur if the depth intervals were increased to 10 metres. Depths were measured using an aluminum probe marked in inches. Inch units were used in order to correspond to the units of the snow density sampling equipment.

Snow density was measured at intervals of 25 metres for all transects using a “Utah Snow Kit” and recorded on WSC snow survey forms. The Utah Snow Kit is the standard kit used by WSC for measuring snow density. A basic description of the Utah Snow Kit, taken from the WSC Hydrometric Equipment Handbook, is provided in Appendix C. Two Utah Snow Kits were rented from WSC. One kit was used for all measurements; the second kit was a spare kit and was not used. The kit used in the field was calibrated both before and after field use. The calibration sheets are included in Appendix C.

Where snow depths were less than about 250 mm, a bulk sampling procedure was used in which samples were accumulated in a plastic bag and weighed when enough snow had been collected to give a significant scale reading. The resulting density was then assigned to all of the points used to make up the bulk sample.

In addition to the depth and density measurements, the slope of the ground being traversed was measured using a clinometer, to the nearest 1 degree, and basic topographic features noted such as the crests of ridges, valley flats and the edges of lakes.

TABLE 5.2
Snow Survey Transect Locations

Transect	Station (m)	UTM Coordinates	
		Easting (m)	Northing (m)
1	0	538750	6987900
	1200	539291	6988980
	1500	539472	6989336
3	0	539168	6987770
	700	539475	6988410
	1500	539834	6989151
4	0	537991	6989524
	200	538014	6989684
	500	538164	6989970
5	0	536612	6988940
	800	537153	6989562
	1090	537280	6989760
6	0	538303	6989160
	300	538536	6988961
7A	0	539166	6988661
	300	539189	6988425
	500	539262	6988201
8A	0	538946	6988274
	200	539062	6988107
	400	539145	6987929
9A	0	538880	6988005
	200	539003	6987796
	400	539150	6987683
11	0	537332	6988056
	300	537550	6987827
	600	537692	6987511
12	0	538839	6987603
	300	539153	6987550
15	0	542792	6985600
	300	542952	6985404
	700	543220	6985092
16	0	542758	6985190
	300	542952	6985404
	600	543220	6985621

The snow depth and density and related data collected for each transect are summarized in graphical form on Figures 5.3 through 5.14. A complete tabulation of the data is provided in Appendix C. All density measurements are reported as a percentage of the density of water.

5.4 TERRAIN UNITS AND SNOW DISTRIBUTION

Terrain units were selected on the basis of the snow survey results and the available mapping. The snow survey data were evaluated to identify distinctive snow depth and density values characteristics in relation to slope orientation, steepness and location relative to topographic boundaries. It was found that slope steepness by itself was not a useful characteristic because of the almost complete lack of slopes steeper than about 6 degrees and because of the lack of slope resolution on the available mapping. It was however noted that the one short segment of steeper slope (Transect 1, station 900 - 1000 metres, slope 9 degrees,(see Figure 5.3) showed a notably deeper snowpack than at any other location on all the transects, which agrees with the slope criterion used by Pomeroy as discussed above.

The review of the snow survey data yielded six terrain units with distinctive snow depth and density characteristics which could be identified and delineated on the mapping. These terrain units are listed in Table 5.3, along with the sections of transects which characterize them and the associated values of snow depth, density for each and snow water equivalent (SWE). The mean and standard deviations of the sample data for each are also listed.

Figure 5.3

Figure 5.4

Figure 5.5

Figure 5.6

Figure 5.7

Figure 5.8

Figure 5.9

Figure 5.10

Figure 5.11

Figure 5.12

Figure 5.13

Figure 5.14

TABLE 5.3
Terrain Units and Representative Snow Depths, Densities and SWE

Terrain Unit No.	Terrain Unit Description	Snow Course Transect	Start Station	End Station	Depth (inches) Mean	Depth (inches) SD	Density (%) Mean	Density (%) SD	SWE (mm)
1	Flat Areas	1	1365	1500	10.4	4.4	32.7	1.0	
		3	1270	1500	7.4	3.3	32.1	2.2	
		4	130	500	6.7	6.0	28.1	3.6	
		11	0	600	9.8	9.3	31.3	4.7	
		Combined			**8.8**	**7.1**	**31.8**	**3.6**	**71**
2	SW Slopes	1	all +ve slopes		21.9	18.8	34.7	5.1	
		3	all +ve slopes		10.5	13.2	32.4	5.9	
		5	all +ve slopes		17.6	13.8	33.5	6.1	
		8A	0	400	26.7	9.2	38.0	1.6	
		9A	0	400	33.8	17.2	37.8	3.0	
		Combined			**21.9**	**17.5**	**35.3**	**5.0**	**197**
3	NE Slopes	1	all -ve slopes		9.5	7.1	27.8	6.4	
		3	all -ve slopes		11.8	7.8	30.8	5.2	
		5	all -ve slopes		6.3	9.6	33.9	3.8	
		Combined			**9.3**	**8.2**	**29.9**	**6.0**	**71**
4	NW Slopes	12	0	300	21.8	9.0	34.0	N/A	
		15	210	700	9.9	7.2	30.8	2.9	
		16	0	600	9.5	7.9	28.9	3.7	
		Combined			**12.4**	**9.7**	**30.7**	**3.5**	**96**
5	Lake Edges	4	80	120	21.5	12.8	31.0	N/A	
		5	60	100	11.8	7.2	34.0	N/A	
		5	990	1030	16.8	18.3	42.0	N/A	
		15	160	200	18.7	3.5	40.0	N/A	
		Combined			**17.2**	**11.5**	**36.0**	**N/A**	**157**
6	Lake	6	0	300	**3.7**	**2.9**	**36.0**	**N/A**	**34**

Note: SD = standard deviation of sample data
N/A= not applicable due to use of bulk sampling method

All of the snow survey data were used to develop the characteristic snow depths and densities for the terrain units, except for Transect 7A. Transect 7A was not used as it had been poorly located at an angle across several different terrain units, which, given the horizontal accuracy limits of the GPS (+/- 100 metres) made interpretation of the data problematic.

5.5 SNOWMELT VOLUME AND SNOW WATER EQUIVALENT

The areas of the flow-monitored sub-basins within Basins A, D and G were divided into the six terrain units, and the units were delineated and the areas measured. Delineation of the terrain units required a certain amount of subjective interpretation of the limited topography on the available mapping. The topography over significant portions of Basin B is particularly ill-defined, therefore delineation of terrain units in Basin B was not attempted. Instead, the snow water equivalent for Basin B was estimated by comparison of the basin's measured runoff with that of the other monitored basins, as described below.

The delineated sub-basins are shown on Figure 5.15. The mean snow depth and density characteristic of each terrain unit as reported in Table 5.3 was applied to the area of each unit within each sub-basin to obtain an estimate of the total snow water equivalent in the sub-basin. The results are summarized in Table 5.4.

TABLE 5.4
Sub-Basin Terrain Unit Areas and Snow Water Equivalents (SWE)

Terrain Unit	SWE (mm)	Peg Lake Sub-Basin		Lake A1 Sub-Basin		Basin A		Lake D5 Sub-Basin		Control Lake Sub-Basin	
		Area (ha)	SWE (dam^3)	Area (ha)	SWE (dam^3)	Area (ha)	SWE (dam^3)	Area (ha)	SWE (dam^3)	Area (ha)	SWE (dam^3)
1	71	175.16	124	---	---	175.16	124	58.73	42	---	---
2	197	95.3	188	105.51	208	200.81	396	79.49	157	14.32	28
3	71	101.96	72	37.49	27	139.45	99	64.18	46	21.31	15
4	96	37.72	36	99.86	96	137.58	132	34.22	33	---	---
5	157	76.83	121	25.04	39	101.87	160	53.74	84	8.56	13
6	34	99.66	34	8.02	3	107.68	37	67.52	23	3.53	1
Total		586.68	575	275.93	372	862.55	948	357.87	384	47.72	58
Mean SWE (mm			98		135		110		107		121

The snow water equivalents listed in Table 5.4 represent the volumes of water released by the melting of the snowpack within each sub-basin in the spring of 1997.

In order to select the most appropriate value of snow water equivalent for the monitored area in Basin B (the Newy Lake Sub-Basin), the outflow measured for this basin was compared to that of the other monitored basins on a depth of runoff or yield basis (see Table 7.3). That comparison showed that the Newy Lake Sub-Basin was most comparable to the Peg Lake Sub-Basin. The latter's mean 1997 snow water equivalent of 98 mm was therefore selected as representative of the Newy Lake Sub-Basin.

Figure 5.15

5.6 SUBLIMATION LOSSES

Sublimation is the conversion of snow directly to water vapour. Significant sublimation losses can occur from snow during transport by wind throughout the winter season. Losses of 20 percent to 30 percent of the total snow water equivalent of the winter snowfall have been estimated for Arctic tundra areas (Pomeroy *et al.*, in press).

Assuming that the average snowfall undercatch adjustment factor of 1.76 applies to the 1996-97 hydrologic year annual snowfall of 76 mm, a total SWE input accumulation over the winter of 134 mm is obtained. Allowing sublimation of 20 percent due to wind transport through the winter results in an estimated 107 mm of SWE remaining in the spring snowpack, on average. That value is very close to the weighted mean value of 109 mm estimated from the snow survey data for the Peg Lake, Lake A1 and Lake D5 basins as shown in Table 5.4.

Sublimation losses from the spring snowpack prior to and during the melt process however, are estimated to be minor, as most incoming energy is used to melt the snow (Marsh and Woo, 1979), and it requires 8.5 times as much energy to sublimate snow than to melt it (Gray, 1970). For situations where the humidity of the overlying air is high, which is the case in the vicinity of the project site (see Figure 4.6), condensation of vapour onto the snowpack can occur. Arctic water balance studies typically ignore sublimation losses from (and condensation gains to) the melting snowpack (e.g., Marsh and Woo, 1979; Marsh, Quinton and Pomeroy, 1994).

6.0 HYDROMETRIC MONITORING RESULTS

6.1 OVERVIEW

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

- Meliadine Lake levels
- Meliadine Lake outflow to Meliadine River
- Meliadine Lake west outflow to Diana River Basin
- Meliadine River at the mouth
- Diana River at WSC Station 06N001
- Peter Lake levels
- Diana Lake levels
- Five peninsula basin lakes - levels and outflows

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

A description of the equipment and methods used, and a presentation and discussion of the monitoring results, are given in the following sections.

6.2 EQUIPMENT AND METHODS

6.2.1 Water Level Monitoring

Two types of water level monitoring stations were installed, continuous monitoring stations which were automated and collected a continuous data sequence using dataloggers, and staff gauges which were read manually at intervals.

The continuous stations consisted of equipment which met WSC standards and consisted of the following components:

- Shelter (Regina)
- Datalogger (Sutron 8210)
- Nitrogen tank complete with regulator
- Accubar
- Safe Purge
- Orifice line complete with block, cables, etc.
- Battery (GNB Sunlyte)
- Solar panel complete with regulator (Siemens/Sunsaver)

A typical shelter with equipment installed is shown in Photos 32 and 33.

Each station was assembled and tested at the WSC shop in Yellowknife before shipment to the field.

Water levels at each station were recorded using a nitrogen bubbler system in which compressed gas is released slowly through a tube with its open end at the bottom of the stream or lake. The pressure required to discharge the gas is measured and converted to an equivalent depth of water by the datalogger. The datalogger was set to read water levels at 5 minute intervals and log the average of three consecutive readings (i.e., 15 minute averages).

A total of eight continuous water level monitoring stations were installed (see Section 3.3). In addition, two staff gauges were installed, three on Meliadine Lake and one each on Peter Lake and Diana Lake.

Each staff gauge consists of a standard WSC gauge plate mounted on a timber and/or steel post driven into the lake bed near the shore.

6.2.2 Discharge Monitoring

Monitoring of discharge (or lake outflows) was accomplished using the standard WSC method which consisted of the following steps:

(1) Measuring the cross-sectional area and water flow velocity of the stream channel at each monitoring location, and calculating a discharge rate, for a range of discharges and water levels over the monitoring season.

(2) Developing a rating curve to define a continuous relationship between water level and discharge, using the measured points.

(3) Using the rating curve to convert the continuous record of water levels to discharges.

Discharge measurements were carried out using velocity meters, survey equipment and accessory equipment rented from WSC Yellowknife. All discharge measurements were carried out by wading except for the Meliadine River at the mouth and the Diana River for which an inflatable boat and motor (also rented from WSC) were used.

Discharge measurements were conducted at nine stations (see Section 3.3). The discharge at each station was measured from six to eight times during the 1997 season, except for the Diana River station which only four measurements were done as a rating curve already existed for the Diana station. The rating curve for all the hydrometric stations are provided in Appendix E.

6.2.3 Zero Outflow Levels

During discharge measurements at each station, the water level at which outflow would cease was determined by locating and measuring the deepest flow depth at the control section in the outflow channel. These zero outflow levels are reported in the discussion of lake levels and storage changes in Section 6.6.

6.2.4 Vertical Control

Vertical control (elevation) for water level measurements was obtained at each station by a set of three local benchmarks established at the beginning of the season. The benchmarks generally consist of red paint marks on nearby bedrock outcrops or the largest available rocks in the vicinity. The benchmark locations and descriptions and their relative elevations are given on each of the station descriptions provided in Appendix D.

A potential problem associated with the use of benchmarks on rocks is the likelihood that there will be some movement of the rocks during the season because of thawing of the active layer. The use of three benchmarks (which is standard WSC practice) is designed to provide enough cross-checks so that any relative benchmark movement can be determined. Alternative methods such as driving or drilling steel rods into the ground has generally not been successful in the type of terrain common to the study area.

6.2.5 Site Inspections

Each station was inspected on a regular schedule to record general conditions at the site, to check station operation, and to resolve any problems. A checklist was prepared for this purpose and is attached in Appendix A. Discharge measurements were generally scheduled to coincide with these site inspections. A summary of the site inspections made during the season is also provided in Appendix A.

6.2.6 Data Summaries

A summary of all the data collected at each of the monitoring stations is provided in Appendix E. The data set for each station includes the following:

Site Inspection Summary

A summary of when the station was inspected, the measured discharge, the zero outflow elevation of the outlet, the water levels as reported by the datalogger and/or staff gauge and as surveyed from the benchmarks, and a reconciliation of vertical control.

Gauge History

A history of the vertical control at the station including descriptions and elevations of the benchmarks.

Rating Curve Plot

A plot of the discharge versus water level elevation relationship (rating curve) and the observed data points on which the curve is based.

Water Level Plot

A plot of daily mean water level versus time. The zero flow elevation is identified which defines the point below which there was no surface outflow from the lake.

Water Level Table

A table of daily mean water levels for the period of observations. This table is the basis for the plot of water levels.

Discharge Table

A table of daily mean discharges for the period of observation. The discharge for each day is obtained from the daily water level and the rating curve. The table also reports maximum, mean and minimum values of discharge, and the monthly and total volume of water discharged.

6.3 UNCERTAINTIES AND SOURCES OF ERROR

Uncertainties and sources of error were involved in the monitoring program, which affected the accuracy of the data and the resulting water balance calculations. The most important factors include the following:

Vertical Control

The three benchmarks at most stations appear to have moved appreciably due to thawing ground over the course of the monitoring season. The vertical movement of the benchmarks relative to Benchmark 1 at each station is reported in Table 6.1. Relative staff gauge movement is also reported for stations with a staff gauge.

TABLE 6.1
Monitoring Station Benchmarks and Staff Gauges
1997 Season Relative Movement in mm

Station	BM2	BM3	Staff
Meliadine Lake near Rankin Inlet	—(1)	—(1)	—(1)
Meliadine Lake at Meliadine Camp	-33	-52	3
Meliadine Lake at Main Outlet	-10	-18	25
Meliadine Lake at West Outlet	-15	-3	-65
Peter Lake	—(2)	—(2)	-24
Diana Lake	0	—(3)	-15
Diana River at WSC Station	1	90	
Outlet of Lake A1	-11	-41	
Outlet of Peg Lake	—(4)	-12	
Outlet of Newy Lake	-3	-3	
Outlet of Lake D5	-36	-35	
Outlet of Control Lake	-20	-20	

Notes:(1) BM's were only surveyed once.
(2) BM2 and BM3 not tied into second survey.
(3) Only 2 BM's installed.
(4) BM1 was destroyed; BM2 used as reference.

In some cases, it was possible to determine with reasonable certainty which benchmarks had moved. In other cases, it was not possible to be certain, and reconciliation of the observed vertical movement was done by subjective interpretation.

Field Staff Human Error

The field staff recruited and trained to conduct the monitoring did not always accurately record and check all required observations. Such human errors required later subjective interpretation to complete the data records and the calculation of the levels and flows.

Wind Effects

At some of the stations, the lake water level is measured some distance from the lake outlet (due to the need to locate the bubbler orifice in deeper water). In such cases, wind-induced set up of the lake surface could cause a difference in water level between the orifice location and the outlet, causing actual outflows to be slightly higher or lower than indicated by the observed level.

Rating Curve Data Scatter

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 and the variation in other factors such as vegetative growth in the outlet channel which can alter the discharge characteristics.

A subjective assessment of the rating curves obtained for 1997 is given in Table 6.2. The estimated accuracies of discharges computed from the rating curves are also provided.

TABLE 6.2
Rating Curve Accuracy Assessment

Rating Curve Assessment	Estimated Accuracy of Computed Discharges	Station
Excellent	±5%	C Diana River C Meliadine River near the Mouth
Good	±10%	C Meliadine River at Outlet Meliadine Lake C Outlet of Peg Lake C Outlet of Newy Lake
Mediocre	±20%	C West Outlet of Meliadine Lake C Outlet of Lake A1 C Outlet of Lake D5
Poor	±50%	C Outlet of Control Lake

Flow Bypassing the Monitoring Station

In addition to the sources of error noted above, which have been integrated into the accuracy assessment of the rating curves as listed in Table 6.2, the five peninsula stations had an additional source of error caused by some surface outflows bypassing the monitoring stations. The peninsula monitoring sites are characterized by channels with poorly defined banks and shallow depths of flow such that higher flows can exceed the channel depth, causing some flow to pass over the ground surface adjacent to the channel, or through small secondary channels and depressions. Some bypass flow is estimated to have occurred at all five peninsula stations. The amount of bypass flow is estimated to have been less than 10 percent of the measured outflows at all stations except for the Newy Lake station, at which it is estimated that bypass flows may have been as high as 20 percent of the measured surface outflow (see Photos 19 and 20).

6.4 DISCHARGE HYDROGRAPHS

The plot of daily discharge versus time (hydrograph) as obtained from the daily water levels and the rating curve for each station, is given on Figures 6.1 through 6.9 for the five peninsula basin stations, the three Meliadine basin stations, and the Diana River station.

Each plot shows the discharge measurements made during the season. The discharge measurement points do not necessarily plot precisely on the hydrograph because the latter is based on the rating curve.

Each hydrograph plot also shows the daily rainfall amounts as recorded at the AES Rankin Inlet station, to permit assessment of the flow response to rainfall events. Inspection of the hydrographs indicates that rainfall events during the post snowmelt runoff were small and did not generate a runoff response, except for about one week of rain totalling 22.2 mm at the end of June, which caused a rise in the hydrograph of all the peninsula basin stations except the Newy Lake outlet station. The Lake A1 outlet showed a much larger response, proportionally, than the other peninsula basin stations.

A common plot of the five peninsula basin station hydrographs is shown on Figure 6.10. The plot emphasizes the distinctive response of the Lake A1 basin. The plot suggests that the Lake A1 basin responds much faster and converts a much higher proportion of precipitation (or snowmelt) to runoff than do the other peninsula basins.

A common plot of the main basin station hydrographs is shown on Figure 6.11.

6.5 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 11 to 13) and runoff which may have occurred after monitoring ceased (September 24 to 25).

For the early runoff, it is estimated that runoff started about two weeks prior to the start of monitoring. Runoff volumes for that period were therefore estimated by assuming zero flow two weeks before the first measurement, and increasing linearly over that time. This procedure was applied to all the stations, except for the Meliadine River at the outlet of Meliadine Lake, which was reported by locals to have been flowing for much of the winter, and was measured on May 19 to be discharging at a rate of 0.600 m^3/s. An additional runoff volume of 7830 cubic decametres for this station was therefore estimated by assuming a constant outflow of 0.600 m^3/s from January 1 to the end of May, when the snowmelt runoff was assumed to have started. It is not known if the Meliadine River near the mouth also discharged during the January to May period. In the absence of information it is assumed that there was zero discharge during this period.

Figure 6.1

Figure 6.2

Figure 6.3

Figure 6.4

Figure 6.5

Figure 6.6

Figure 6.7

Figure 6.8

Figure 6.9

Figure 6.10

Figure 6.11

At the end of September, when monitoring ceased, surface outflows had ceased from all the peninsula basins, and from the west outlet of Meliadine Lake. The other three main basin stations were still discharging, and it was assumed that, based on a review of the winter flow data for the Diana River, discharge continued in a linearly decreasing manner, reaching zero discharge by about the end of November.

The measured and estimated discharge volumes for each of the stations is summarized in Table 6.3. 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.

TABLE 6.3
1997 Runoff Summary

Station Name and Number	Catchment Area (km^2)	Period of Continuous Record 1997	Measured Volume (dam^3)	Estimated Volume		Total Volume	
				Pre-Record Volume (dam^3)	Post-Record Volume (dam^3)	(dam^3)	(mm)
PENINSULA STATIONS							
Outlet of Peg Lake	5.87	June 11 - Sept 25	210	134	0	344	59
Outlet of Lake A1	8.63	June 11 - Sept 25	759	225	0	984	114
Outlet of Newy Lake	17.8	June 11 - Sept 25	668	345	0	1013	57
Outlet of Lake D5	3.58	June 11 - Sept 25	234	61	0	295	82
Outlet of Control Lake	0.477	June 12 - Sept 24	9.26	4.33	0	13.5	28
MAIN BASIN STATIONS							
Meliadine River at Meliadine Lake Outlet	569	June 12 - Sept 25	25400	11 700	1140	38 240	67
West Outlet of Meliadine Lake	569	June 12 - Sept 25	5200	930	0	6130	11
Meliadine Lake Both Outlets	569	June 12 - Sept 25	30 600	12 630	1140	44 370	78
Meliadine River near the Mouth - Nominal	796	June 13 - Sept 25	35800	7260	2000	45 060	57
Meliadine River near the Mouth - Effective	711	June 13 - Sept 25	35 800	7260	2000	45 060	63
Diana River near Rankin Inlet - Nominal	1480	June 7 - Sept 24	174 267	9160	14 800	198 227	134
Diana River near Rankin Inlet - Adjusted	1480	June 7 - Sept 24	169 067	8230	14 800	192 097	130

The total outflow volumes for the peninsula basin stations varies considerably, from 28 mm for Control Lake to 114 mm for Lake A1. The Peg Lake and Newy Lake basins show very similar runoff results, at 59 mm and 57 mm, respectively, with the Lake D5 basin about 40 percent higher, at 82 mm.

In Table 6.3, there are two entries for the Meliadine River near the mouth. The first entry (57 mm) gives the "nominal" yield, the second entry (63 mm) gives the "effective" yield. The nominal yield is that obtained by using the full catchment area of 796 km^2 as measured. 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 diverts about 15 percent of the total Meliadine Lake basin runoff, representing the runoff from 85 km^2 of that basin. Therefore, the effective catchment area for the Meliadine River near the mouth is 796 - 85 = 711 km^2.

The effective yield of 63 mm for the Meliadine River near the mouth is about 15 mm less than the yield of 78 mm for Meliadine Lake (both outlets) because of the additional 7830 dam^3 of flow estimated for the Meliadine Lake main outlet due to winter outflows. If those flows had also occurred at the mouth of the Meliadine River, the yields at the two locations would have been the same.

Table 6.3 also contains two entries for the Diana River. The first entry gives the "nominal" yield, as measured. The second entry is an "adjusted" yield based on deducting the volume diverted from the Meliadine basin through the Meliadine Lake west outlet. The adjusted yield for the Diana is 130 mm. That yield is about 70 percent higher than the yield of the Meliadine Lake basin, and just over 100 percent higher than the Meliadine River near the mouth.

The 1997 runoff summary is shown graphically on Figure 6.12.

6.6 LAKE WATER LEVELS AND STORAGE

6.6.1 Main Lakes

Meliadine Lake levels recorded in 1997 are shown on Figure 6.13. The levels were adjusted to a common datum by fitting the staff gauge observations to the continuous water levels recorded at the station "Meliadine Lake near Rankin Inlet". The levels show generally good correlation. Some discrepancies between levels recorded at the various stations were expected because of wind effects, but the staff gauge readings were not taken frequently enough to provide conclusive data on wind effects. The discrepancies of 0.15 metres and 0.10 metres observed in late June at the outlet to the Meliadine River and in mid-July at the west outlet, respectively, could have been due to wind effects, but may also have been due, in whole or in part, to human errors in taking readings.

Readings at the outlet to the Meliadine River show a trend of increasing discrepancies through the season. This trend of staff gauge readings giving gradually increasing positive differences (i.e., reading too high a level) suggests that the staff gauge and/or the benchmarks may have been gradually moving down due to thawing of the active layer.

Figure 6.12

Figure 6.13

A comparison of the 1997 water levels of Meliadine Lake with those recorded on Peter Lake and Diana Lake is shown on Figure 6.14. The levels have been arbitrarily set to a common end of season level to facilitate comparison. It is evident that the drop in the level of Meliadine Lake of 0.33 metres is only about half the drop observed for Peter Lake (0.55 metres) and Diana Lake (0.70 metres). The associated changes in lake storage, expressed as a volume in dam^3 and as an equivalent depth in mm over the total basin area, are summarized in Table 6.5.

TABLE 6.5
Main Lake Levels and Storage Changes 1997

Lake	Lake Area (km^2)	Change in Level (m)	Change in Storage	
			Volume (dam^3)	Equivalent Basin Depth (mm)
Meliadine	114	-0.33	-37 600	66
Peter Diana	177 40	-0.55 -0.70	-97 350 -28 000	
Diana Basin	217	---	-125 350	85

The above-noted changes in water levels and storage apply to the period when observations were made, which started in the last half of June. It is not known how much lake levels may have changed (either up or down) due to previous inflows and outflows.

An evaluation of the contribution made by lake storage (Table 6.5) to basin outflow volume (Tables 6.3 and 6.4) can be made by accounting for the lake surface net evaporation loss of 248 mm. This is given in Table 6.6. The values of runoff and storage changes are those applicable to the period of observation, i.e., from about mid-June to the end of Septemb

TABLE 6.6
Main Lakes
Lake Storage Contribution to Measured 1997 Outflow

Basin	Main Lake Area (km^2)	Measured 1997 Outflow (dam^3)	Lake Storage Reduction (dam^3)	Net Lake Evaporation (dam^3)	Storage Contribution to Outflow		
					Volume (dam^3)	% of 1997 Total Outflow	Equivalent Basin Depth (mm)
Meliadine Lake Outflows	114	30 600	37 600	28 300	9300	30	16
Diana River near Rankin Inlet	217	174 300	125 350	53 800	71 500	41	48

Figure 6.14

Table 6.6 shows that 30 percent of the measured 1997 runoff for the Meliadine Lake basin was derived from main lake storage. This corresponds to about 16 mm of the runoff from the basin. For the Diana basin, 41 percent of the measured 1997 runoff or 48 mm was derived from main lake storage, in spite of the fact that Peter and Diana Lakes constitute only about 15 percent of the total catchment area, whereas Meliadine Lake contributes about 20 percent of its catchment. The storage potential of Meliadine Lake thus appears to be considerably less, in proportion to lake surface area, than that for Peter Lake and Diana Lake.

6.6.2 Peninsula Basin Lakes

Water levels at the five monitored lakes on the peninsula are compared on Figure 6.15. The levels are shown relative to the zero outflow elevation for each lake. When a lake level reached the zero outflow elevation, surface outflows ceased, and all subsequent lake level declines would have been due to evaporation and seepage losses.

Water levels in general declined in a gradual and similar pattern for all five lakes. The range of levels for the season was not large. The difference between the levels recorded at the beginning and end of the season ranged from 0.24 metres for Lake D5 to 0.43 metres for Newy Lake. The water level data and the corresponding changes in storage are summarized in Table 6.7.

TABLE 6.7
Peninsula Basin Lake Levels and Storage Changes 1997

Lake	Lake Surface Area (km^2)	Date Outflow Ceased	During Outflow		Post Outflow		Total	
			Change in Level (m)	Change in Storage (dam^3)	Change in Level (m)	Change in Storage (dam^3)	Change in Level (m)	Change in Storage (dam^3)
Peg Lake (A6)	0.506	July 28	0.164	83	0.12	60.7	0.284	144
Lake A1	0.148	Aug. 1	0.278	41.1	0.076	11.2	0.354	52.4
Newy Lake (B4)	0.843	Sept. 15	0.419	353	0.01	6.7	0.427	360
Lake D5	0.0626	July 13	0.065	4.1	0.172	10.8	0.237	14.8
Control Lake (G2)	0.119	July 13	0.043	5.1	0.265	31.5	0.308	36.7

An assessment of the contribution of lake storage to the total 1997 runoff is made in Section 7.0 in terms of overall basin storage, in the context of the evaluation of the water balance for the peninsula basins.

Figure 6.15

7.0 BASIN YIELD AND WATER BALANCE

7.1 REGIONAL HISTORICAL YIELDS

7.1.1 Diana River

The Diana River basin lies immediately adjacent to the Meliadine basin, to the southwest, and is similar in area. It is therefore well suited to provide comparative historical runoff data. The Diana River has been monitored by WSC at Station 06NC001 (drainage area 1480 km^2) from 1985 through 1995, and was recommissioned as part of the current water balance study in June 1997. Data for the years prior to 1989 are incomplete, therefore annual runoff values for only 1989 to 1995 and for 1997 are available. The data range from a low of 134 mm of runoff, which occurred in 1997, to a high of 267 mm which occurred in 1992.

The 1997 Diana River hydrograph is compared to historical discharges on Figure 7.1. Historical data are shown on the graph as the range and mean of daily discharges which occurred during the period 1989 - 95, as measured by the Water Survey of Canada. Based on this information, the 1997 snowmelt peak was lower and earlier than usual. Discharges through most of the summer were approximately equal to the lowest recorded during the 1989 - 95 period, and in September were lower than the previously recorded minimum.

The 1997 results indicate that about 6000 dam^3 of the 1997 runoff was derived from interbasin transfer from Meliadine Lake. This corresponds to a yield of about 4 mm over the Diana basin. The actual basin yield for 1997 was therefore 130 mm. This suggests that more accurate values for annual yields can be obtained by applying a reduction of about 3 percent. However, the reduction factor may vary from year to year, therefore it was not considered desirable to revise the historic data for the purpose of the present review.

7.1.2 Adjacent Basins

The other nearest monitored river basins draining into Hudson Bay are the Ferguson River located about 150 km to the south, and the Lorillard River, located a similar distance to the north. These basins are much larger, with the Ferguson at 12 400 km^2 (WSC Station 06NB002) and the Lorillard at 11 000 km^2 (WSC Station 06OA001). The Ferguson basin appears similar to the Meliadine and Diana basins in that it contains a large amount of lake area including large lakes, whereas the Lorillard basin contains significantly less lake area, and no large lakes (see Figure 1.1). The runoff data for these basins extends back to 1978, and the data have been assembled together with the Diana data on Figure 7.2.

Comparison of the overlapping data for the Diana and the Ferguson indicates considerable similarity, with agreement to within about 15 percent for most years. A review of the Ferguson data shows a variation in runoff from a low of about 150 mm, in 1980, to a hi

Figure 7.1

Figure 7.2

of about 290 mm in 1991. Those results are very similar to the Diana basin range of 130 mm to 270 mm.

The runoff data for the Lorillard basin shows a significantly wider range, from a low of about 140 mm in 1978 to a high of 360 mm in 1983. These results are considered to reflect the lack of lakes in the basin, and the associated reduction in the potential to attenuate extreme lows and highs by lake storage. The Lorillard basin data are thus not considered comparable to the Meliadine basin.

A comparison of the annual yields for the Diana and the Ferguson basins is given in Table 7.1. The table shows that the 1997 Diana runoff of 134 mm was the lowest in the eight years of record, and was equal to about 69 percent of the seven year 1989 to 1995 mean of 194 mm. The second driest year was 1994 when a runoff of 135 mm occurred. The 1989 to 1995 mean for the Ferguson River is 209 mm which is within 8 percent of that for the Diana. The variation of the annual values as a fraction of the mean is similar for both basins, but differences of 10 to 20 percent between the two basins are common. The driest year in the Ferguson basin prior to 1996 occurred in 1980 where the runoff was 70 percent of the mean.

TABLE 7.1
Regional Historical Yield

Calendar Year	Diana River		Ferguson River	
	Runoff (mm)	Fraction of Mean	Runoff (mm)	Fraction of Mean
1980	---	---	147	0.70
1981	---	---	---	---
1982	---	---	---	---
1983	---	---	195	0.94
1984	---	---	---	---
1985	---	---	198	0.95
1986	---	---	225	1.08
1987	---	---	265	1.27
1988	---	---	198	0.95
1989	160	0.83	189	0.90
1990	196	1.01	173	0.83
1991	263	1.36	290	1.39
1992	267	1.38	233	1.12
1993	184	0.95	210	1.01
1994	135	0.70	165	0.79
1995	151	0.78	201	0.96
1996	---	---	---	---
1997	134	0.69	---	---
1989-95 Mean	194		209	

7.1.3 Runoff and Precipitation

Comparison of the annual variation in Diana runoff with the Rankin Inlet annual (hydrologic year) precipitation is shown in Table 7.2.

TABLE 7.2
Historical Precipitation and Runoff

Hydrologic Year	Rankin Inlet Precipitation		Diana River Runoff		Runoff Ratio
	mm	Fraction of Mean	mm	Fraction of Mean	
1989	251	0.84	160	0.83	0.64
1990	360	1.20	196	1.01	0.54
1991	387	1.29	263	1.36	0.68
1992	289	0.96	267	1.38	0.93
1993	316	1.06	184	0.95	0.58
1994	207	0.69	135	0.70	0.65
1995	286	0.96	151	0.78	0.53
1996	282	0.94	---	---	---
1997	172	0.57	134	0.69	0.78
1989-95 Mean	299		194		0.65

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 4.1). The pattern of high and low years of precipitation is seen to be generally similar to the variation of runoff. The data show that 1997 was the year of lowest precipitation as well as the year of lowest runoff, with 1994 being the second lowest for both. Close agreement between the two data sets would not be expected since the Rankin Inlet precipitation would not apply to the entire Diana basin.

The ratio of runoff to precipitation is given in the last column of Table 7.2. The fraction of the total precipitation which runs off varies from 0.53 to 0.78 (except for a single year (1992) for which the ratio is 0.93) and averages around 0.65. It should be understood, however, that this ratio is an apparent ratio, based on "observed" or "archived" precipitation values, and that when values are used which have been corrected for undercatch (for Rankin Inlet, about 1.36 higher than observed, see Section 4.1) the mean runoff ratio reduces to 0.48.

The data given in Table 7.2 are shown graphically on Figure 7.3. Examination of the pattern of high and low precipitation and runoff years suggests that there is a one-year "lag" effect in the runoff pattern. For example, the 1992 runoff is large relative to the precipitation. This

Figure 7.3

is likely due to the effect of "over-year" storage in the basin; larger internal runoff amounts are not able to discharge from the basin in the year they occur, are partly stored over the winter, and contribute to the next year's runoff out of the basin.

7.2 1997 BASIN YIELD

7.2.1 Preliminary Assessment

The runoff volumes (basin yields) obtained from the 1997 monitoring results presented in Section 6.5 are summarized in Table 7.3. The basin yields are based on the measured plus estimated surface outflows from the monitoring lakes at the downstream ends of the basins.

The magnitude of the monitored basin outflows are affected by evaporative losses from the lake at which monitoring took place. Since the magnitude of that evaporative loss varies considerably depending on the lake surface area, it is considered useful to compare the basin results in terms of the "upstream basin" yield. The upstream basin yield is here defined as the basin yield that would occur if the monitoring lake (which is located at the most downstream portion of the basin) were to have its surface area converted to land. The upstream basin yield includes the following components:

- surface flows into the monitoring lake, from the upstream basin
- subsurface flows into the monitoring lake from the upstream basin
- surface runoff plus seepage inflows from the area directly tributary to the monitoring lake

TABLE 7.3
1997 Basin Yield Summary

Basin	Catchment Area km^2	Basin Yield (dam^3)	Basin Yield (mm)	Monitored Lake Area (km^2)	Monitored Lake Net Evaporation (dam^3)	Upstream Basin Yield (mm)
PENINSULA BASINS						
Peg Lake	5.87	344	59	0.506	125	80
Lake A1	8.63	984	114	0.148	37	118
Newy Lake	17.8	1013	57	0.843	209	69
Lake D5	3.58	295	82	0.063	16	87
Control Lake	0.477	13.5	28	0.119	30	91
MAIN BASINS						
Meliadine Lake Main Outlet	569	38 240	67	114	28 272	117
Meliadine Lake Both Outlets	569	44 370	78	114	28 272	128
Meliadine River at the Mouth - Nominal	796	45 060	57	131	32 488	97
Meliadine River at the Mouth - Effective	711(1)	45 060	63(1)	131	32 488	109
Diana River near Rankin Inlet - Nominal	1480	198 227	134	217	53 816	170
Diana River near Rankin Inlet - Adjusted	1480	192 100(2)	130(2)	217	53 816	166

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 basin yields given in Table 7.3 are shown graphically on Figure 7.4.

7.2.2 Main Basins

The nominal (measured) yield for 1997 for the Meliadine River near the mouth was 57 mm. The “effective yield”, based on reducing the catchment area in proportion to the flow split between the main and west outlets of Meliadine Lake, was 63 mm. In other words if the flow which discharged form Meliadine Lake through the west outlet into the Diana River basin had been discharged instead into the Meliadine River, the latter’s yield would have been 63 mm instead of 57 mm. This effective yield of 63 mm was still 15 mm less than the yield of 78 mm for Meliadine Lake, due to the estimated 7830 dam^3 discharged from Meliadine Lake through the main outlet during the pre-snowmelt runoff winter season.

The nominal yield for the Diana River was 134 mm. The yield reduces to 130 mm when the 1997 runoff volume is adjusted to remove the inflows from Meliadine Lake through its west outlet. The adjusted yield of 130 mm for the Diana River is 70 percent and 100 percent higher, respectively, than the yields obtained for Meliadine Lake and the Meliadine River near the mouth. The ratio of runoff to precipitation (using a corrected precipitation value of 234 mm based on the mean undercatch adjustment factor of 1.36 applied to the observed 1996-97 precipitation of 172 mm) for the Meliadine River basin equals 0.27. The runoff ratio for the adjusted Diana yield of 130 mm, equals 0.56.

When the effect of evaporation from the main lakes is taken into account however, as indicated in the “upstream basin yield” column of Table 7.3, the difference between the Meliadine and Diana basins becomes smaller, and the Diana “upstream basin yield” is only 30 percent and 50 percent higher than the two Meliadine values. This indicates that a significant portion of the basin yield difference can be explained as being due to lake evaporation differences. Nevertheless, a significant difference in yields is still indicated. The characteristics of the Meliadine Basin, which may account for the difference in yields are discussed below.

Estimation of the yield for the Meliadine River sub-basin by taking differences between data for the two Meliadine River stations was assessed to be unreliable and potentially misleading, because of uncertainty as to the magnitudes and timing of inflows and outflows for the period before and after monitoring.

7.2.3 Meliadine Basin Characteristics

The differences between the Meliadine and Diana basins are thought to be due to several distinct differences in characteristics between the two basins. Differences are apparent in basin lake evaporation, in outlet discharge characteristics, and associated over-year lake storage.

Figure 7.4

The effect of evaporation from the main, directly-connected lake area is noted above. When the main lake net evaporation is added back into the total 1997 surface outflows for both basins, the difference between the Diana and Meliadine basin yields reduces from about 70 percent to 30 percent.

Another significant difference between the two basins is in the discharge characteristics of the outlets. The Diana River basin is controlled, at the monitoring station location, by an outflow channel about 40 metres wide. The Meliadine Lake basin, however, has two outlets; the main outlet is about 70 metres wide, while the west outlet is about 50 metres wide, for a total width of 120 metres. Consequently, a given rise in water level will result in a significantly higher discharge rate from Meliadine Lake than from Peter and Diana Lakes. This is illustrated by a common plot of the discharge rating curves, as shown on Figure 7.5. In the figure, the zero outflow point for the Diana station has been adjusted to coincide with that of the Meliadine main outlet. The rating curve for the west outlet is plotted correctly relative to that of the main outlet.

For example, as indicated by the rating curves, for a water level at 0.6 metres above the zero flow level of 2.9 metres (i.e., at 3.5 metres, which corresponds to the highest observed level on Meliadine Lake in 1997) the Diana River would discharge at a rate of only about 0.4 m^3/s, while the Meliadine Lake main and west outlets would discharge at rates of 7.5 m^3/s and 2.0 m^3/s, respectively, for a total of 9.5 m^3/s. The Diana would have to rise by an additional 0.8 metres to achieve such a discharge rate.

These discharge characteristics imply that the seasonal water level fluctuates much less in Meliadine Lake than in Peter or Diana Lakes, since inflows to Meliadine Lake are discharged through the outlets relatively quickly. Consequently, little, if any, over-year storage likely occurs on Meliadine Lake to moderate the effects of high and low runoff years, such as appears to occur in the Diana basin (see Figure 7.3).

Another aspect of the Meliadine Lake outlet discharge characteristic is that the flow split between the main and west outlets would be expected to shift with increasing lake levels (i.e., for years of higher runoff), in the direction of increasing the proportion of outflows diverted through the west outlet.

7.2.4 Peninsula Basins

The basin yields for the peninsula basins vary from 28 mm to 114 mm. The range of this variation shrinks considerably when the effect of evaporation from the monitored lake surface is accounted for, as indicated in the "upstream basin yield" column in Table 7.3. The "upstream basin yield" values vary from 69 mm to 118 mm, suggesting that greater hydrologic similarity exists for the peninsula basins than the direct yield values indicate.

Figure 7.5

Estimation of yield values for the Lake A1 sub-basin by taking differences between data for the Peg Lake and Lake A1 stations was considered to be unreliable. For example, if there was significant subsurface outflow from Peg Lake into Lake A1, which discharged from Lake A1 as surface flow, an excessively high yield would be obtained. Further examination of this issue is included in the water balance analysis presented in the following section.

7.3 PENINSULA BASINS WATER BALANCE ANALYSIS

7.3.1 Water Balance Equation

A water balance analysis for the 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
Subsurface outflow from the basin	=	S
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 7.6.

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

$$\text{Volume In} = \text{Volume Out} + \text{Change in Storage}$$

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

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

Rearranging the terms for convenience leads to:

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

Each of the components is discussed below. The evaluation of most of the components is discussed in previous sections of this report.
Figure 7.6

7.3.2 Subsurface Outflows

Subsurface outflows were not measured in 1997. There was no evidence prior to the monitoring that subsurface outflow was a significant factor. Evaluation of the variability in the observed runoff values however suggested that subsurface outflow might be significant, and an analysis of the data was performed.

The analysis to estimate the volume discharging from the basin as subsurface flow was based on the water balance principle as applied to the individual lake being monitored. For each monitoring lake, the water balance equation can be written as:

$$O + S = I - B_L - (E - P)\, A_{Lake}$$

where the terms are as defined above, and I = surface inflow plus subsurface inflow to the lake. Note that B_L represents an increase in lake storage through an increase in lake water level; B_L is negative if the lake level falls. The equation is illustrated schematically on Figure 7.7.

Rearranging the above equation for convenience results in:

$$I - S = O + B_L + (E - P)\, A_{Lake}$$

Since all the components on the right hand side of the equation have been monitored or estimated on the basis of monitoring, the left hand side can be calculated. When the term (I - S) is positive, then total inflows exceed subsurface outflows. When the term (I - S) is negative, then there must be some subsurface outflow occurring, although the magnitude cannot be defined unless the value of I can be estimated.

The term (I - S) has been termed the “net inflow”, for convenience. Net inflows were calculated on a daily basis for each of the five peninsula basin monitored lakes. The results are shown graphically on Figures 7.8 through 7.12.

An estimate of the subsurface outflow rate was made for each monitored lake by identifying the sequence of two to four days with the largest negative (I - S) values. This sequence was found for all the lakes to occur at the end of July to beginning of August period. The subsurface outflow rates as identified were then extrapolated linearly from August 1 back in time to an assumed zero rate on June 21, and forward to an assumed zero rate on September 21. The results are summarized in Table 7.4.

Figure 7.7

Figure 7.8

Figure 7.9

Figure 7.10

Figure 7.11

Figure 7.12

TABLE 7.4
Peninsula Basins Monitored Lakes
Estimated Subsurface Outflows

Lake	Subsurface Outflow			Cumulative (I - S) Aug. 1 - Sept. 21	
	Rate	Volume		dam³	mm
	dam³/day	dam³	% of Surface Outflow Volume		
Peg Lake	3.62	163	47	5	0.9
Lake A1	0.63	28	3	4	0.5
Newy Lake	6.02	271	27	19	1.1
Lake D5	0.36	16	5	3	0.8
Control Lake	0.63	28	200	4	8.3

As shown by the data in Table 7.4, significant subsurface outflows are indicated for Peg Lake and Newy Lake. The subsurface outflows from Lake A1 and from Lake D5 are comparatively low. Subsurface outflows from Control Lake are relatively low in terms of the daily rate, but the volume over the season is very significant because of the low volume of surface outflows measured for this basin.

The cumulative values of (I - S) over the drier portion of the season, from August 1 to September 21, are also listed in Table 7.4. The results indicate that subsurface outflows were generally balanced by inflows to the monitored lakes. It is presumed that, since surface outflows ceased by August 1 for all except Newy Lake, that surface inflows would likely also have ceased by about that date and that inflows would thus have been due mainly if not entirely to subsurface inflows. The proportion of subsurface inflows contributed by seepage around the lake shore from the active layer is not known.

The relative absence of subsurface outflows from Lake A1 and Lake D5 is reflected in the plots of the daily (I - S) net inflow values on Figures 7.7 through 7.11. The plots for Lake A1 and Lake D5 show a consistent trend with little day to day fluctuation, whereas the plots for the other lakes do show such fluctuations. These data are interpreted to mean that Lake A1 and Lake D5, although receiving significant subsurface inflows, do not have significant subsurface outflows, and the surface outflows monitored from those two lakes include most of the subsurface inflows. Consequently, the basin yields for Lake A1 and Lake D5 based on surface outflows as summarized in Table 7.3, are higher than for the others.

7.3.3 Water Balance Components

Catchment Areas

The catchment areas and total basin lake areas are reported in Section 3 and elsewhere. The land area (A_{Land}) is the difference between total catchment and total lake areas (A_{Lakes}).

Snowpack Melt

The SWE of the snowpack accumulations is based on snow surveys of the spring snowpack and measurement of the snow distribution terrain types within the basins, as reported in Section 5.

Precipitation

The precipitation (P) is the rainfall over the runoff season as recorded at the AES Rankin Station, and equals 94 mm for the 1997 season (Section 4.2.2).

Evaporation

Expressed as gross lake evaporation E, this value equals 328 mm for the 1997 season (Section 4.2.4).

Evapotranspiration

The estimated value of the 1997 ET equals 22.5 mm (Section 4.2.5).

Subsurface Outflows

Subsurface outflows are estimated on the basis of analysis of data for the monitored lake in each basin (Section 7.3.2).

Basin Storage

Basin storage changes are assumed to equal zero, as there is no independent data or method of estimating this. However, given that 1997 was considerably drier than 1996, it is expected that in general there would be a reduction in basin storage over the 1997 season.

7.3.4 Water Balance Results

The water balance for each of the five peninsula basins is summarized in Table 7.5. The table includes a listing of the values of all the water balance components, the “measured” surface

TABLE 7.5
Peninsula Basins 1997 Water Balance

Basin	Basin Area		Measured Surface Outflow		Estimated Subsurface Outflow		Estimated Total Outflow		Snowmelt Volume	Rainfall Volume	Evapotrans-piration	Gross Lake Evaporation	Calculated Total Outflow		Basin Storage Change		Outflow as Fraction of Total Precipitation
	Total km^2	Lake km^2	dam^3	mm	dam^3	mm	dam^3	mm	dam^3	dam^3	dam^3	dam^3	dam^3	Calculated/ Estimated	dam^3	mm	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Peg Lake	5.87	1.77	344	59	163	28	507	86	575	552	138	581	408	0.80	-99	-17	0.45
Lake A1	8.63	2.10	984	114	28	3	1012	117	949	811	220	689	851	0.84	-161	-19	0.57
Lake A1 Sub-basin	2.76	0.33	---	---	---	---	505	183	374	259	82	108	443	0.88	-62	-22	0.80
Newy Lake	17.8	4.49	1013	57	271	15	1284	72	1744	1673	449	1473	1495	1.16	211	12	0.38
Lake D5	3.58	1.22	295	82	16	4	311	87	383	337	80	400	240	0.77	-71	-20	0.43
Control Lake	0.48	0.12	14	29	28	59	42	88	58	45	12	40	51	1.21	9	19	0.41
Totals/Means	36.36	9.70	2650	73	506	14	3156	87	3710	3418	900	3182	3046	0.97	-110	-3	0.44

Column 1 = Basin name
Column 2 = Total catchment area of basin
Column 3 = Total lake surface area within basin
Column 4 = Measured plus estimated early season outflow volume
Column 5 = Column 4 divided by Column 2
Column 6 = Subsurface outflow volume estimated from monitored lake data
Column 7 = Column 6 divided by Column 2
Column 8 = Column 4 plus Column 6
Column 9 = Column 8 divided by Column 2
Column 10 = Snowmelt volume obtained from SWE reported in Table 5.4 times Column 2
Column 11 = Total season rainfall of 94 mm times Column 2
Column 12 = Actual ET of 33.8 mm times (Column 2 - Column 3)
Column 13 = Gross lake evaporation of 328 mm times Column 3
Column 14 = Calculated Outflow = Column 10 + Column 11 - Column 12 - Column 13
Column 15 = Column 14 divided by Column 8
Column 16 = Column 14 - Column 8
Column 17 = Column 16 divided by Column 2
Column 18 = Column 8 divided by (Column 10 + Column 11)

outflow (where "measured" includes the estimated pre-monitoring period runoff), the estimated subsurface outflow, the calculated value for surface outflow obtained from the water balance equation, expressed both as a total volume and as a percentage of the "measured" volume and an estimate of the basin storage change based on the difference between the "measured" and calculated values. The derivation of the values for the various columns of Table 7.5 is explained in the footnotes to the table.

Table 7.5 also includes inferred values for the Lake A1 sub-basin, obtained by subtracting the results for the Peg Lake basin from the Lake A1 basin.

The results summarized in Table 7.5 indicate yields ranging from a low of 72 mm for Nevvy Lake basin to a high of 117 mm for the Lake A1 basins, with the other three peninsula basins having values of 86, 87 and 88 mm. The latter three values are remarkably similar and possibly fortuitous, given the level of accuracy involved in the discharge measurements and the estimates made for pre-monitoring and subsurface outflows.

The value of 72 mm for the Nevvy Lake basin is about 17 percent less than the mean of the three basins with yields of 86, 87 and 88 mm. That difference is judged to be within the natural variation to be expected between basins, and the relative accuracy of the results. However, it is suggested that the surface outflows for Nevvy Lake may have been up to 20 percent higher than measured, due to a significant fraction of the discharge occurring as unmeasured overbank flow (see Section 6.3 and Photos 19 and 20). That possibility is supported by the computed basin storage change in the water balance analysis, which indicates that basin storage increased by 12 mm in the Nevvy Lake basin. That is an unlikely result, because it is known that 1997 was a much drier year than 1996, and therefore basin storage should have decreased, rather than increased. Thus, if the surface outflows had in reality been greater by 12 mm, the resulting basin yield would have been calculated at 84 mm, which is very similar to that of the three basins noted above.

The Control Lake basin results are not considered reliable because of the relatively high amount (23 mm) of basin storage increase indicated by the water balance results reported in Table 7.5. As noted above, a basin storage decrease is expected. The poor quality of the discharge rating curve for the Control Lake outlet associated with the relatively low flows and small catchment area for this basin also suggests that the results for Control Lake should be considered as unreliable.

The high value of 117 mm for the Lake A1 basin as a whole is due to the high runoff derived from the Lake A1 sub-basin below the Peg Lake basin. The Lake A1 sub-basin yield of 183 mm is about twice that of the other basins. The last column in Table 7.5 shows that this basin converts 84 percent of precipitation to runoff, whereas the other basins only convert 40 percent to 45 percent to runoff. Part of the reason for this is that the sub-basin has a much smaller proportion of its catchment as lake surface area and therefore basin evaporation losses are less. However, the Lake A1 surface runoff hydrograph shows a much stronger response to significant rainfall than the other lakes, indicating that infiltration and other losses are much smaller in this basin. Lake A1 outflows were measured at the outlet of the basin into Meliadine Lake, whereas all the other basin outflows were measured some distance upstream of Meliadine Lake. It is now known if this is a factor in the high yields for the Lake A1 sub-basin.

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 all the basins as reported in Table 7.5 are shown graphically in Figures 7.13 through 7.19. In general, snowmelt and rainfall each contributed about 50 percent of the precipitation input. Total outflows averaged 44 percent of the precipitation inputs with 56 percent going to evaporation and evapotranspiration. The 1997 average runoff ratio of 44 percent for the peninsula basins is close to the historical average runoff ratio (based on adjusted precipitation) of 48 percent for the Diana River basin (see Section 7.1.3).

The data collected do not permit partitioning of the snowmelt and rainfall components into basin runoff and evaporative losses. However, based on the shape of the runoff hydrographs, which show only a slight response to most rainfall events, it can be assumed that all of the rainfall input was converted to evaporative loss, which further consumed about 15 percent of the snowmelt.

Subsurface flows constituted 25 percent and 50 percent of the total outflow for the Newy Lake and Peg Lake basins, respectively. The Lake D5 and Lake A1 basins outflows occurred almost entirely as surface flows. The results for Control Lake indicate that subsurface outflows represented 65 percent of the total outflow.

The withdrawal of about 20 mm of moisture from basin storage is indicated for the Peg Lake, Lake A1 and Lake D5 basins. That withdrawal represents about 25 percent of the total outflows. The net moisture inputs to basin storage indicated for Newy Lake and Control Lake are suspected to be due principally to the under-measurement of outflows, and an inaccurate discharge rating curve, respectively.

Figure 7.13

Figure 7.14

Figure 7.15

Figure 7.16

Figure 7.17

Figure 7.18

Figure 7.19

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

Regional Climate and Runoff

The available climate data for the region (Rankin Inlet) indicates that the 1996-97 hydrologic year (October through September) was the driest since 1981, when records began. The observed total precipitation of 172 mm was just 57 percent of the 16 year annual average. The previous hydrologic year (1995-96) had a total precipitation of 282 mm or 94 percent of the average. The second driest year in the period of record was 1993-94, when total precipitation was 69 percent of the average.

The historical runoff data for the Diana River parallels the historical climate data. The measured yield for 1997 for the Diana is 134 mm, which was 69 percent of the preceding seven year annual mean of 194 mm, and the lowest in the eight years of record. Regional comparison with the Ferguson and Lorillard rivers suggests that the 1997 runoff may have been the lowest since 1980.

The Diana River runoff averages about 0.65 of the observed Rankin Inlet precipitation. When the precipitation is corrected for undercatch, the runoff to precipitation ratio becomes 0.48.

Meliadine and Diana Basins

The total 1997 runoff for the Meliadine Lake basin is estimated to be 78 mm over the catchment area of 569 km^2. This includes about 14 mm of runoff estimated to have occurred through the winter prior to the spring snowmelt. About 11 mm or 15 percent of the runoff was discharged through the west outlet of Meliadine Lake into the Diana River basin via Peter Lake. The remaining 67 mm was discharged into the Meliadine River.

The Meliadine River near the mouth discharged 57 mm of runoff based on the total catchment area of 796 km^2, or 63 mm when the drainage area is reduced in proportion to the amount of runoff diverted through the west outlet. In the absence of data, no allowance has been made for possible discharges during winter.

The Diana River yield of 134 mm becomes 130 mm when the diversion in from Meliadine Lake is deducted. The later value is about 70 percent higher than the yield of 78 mm for the Meliadine Lake basin. Part of the difference is due to the greater evaporative loss in the Meliadine basin, because Meliadine Lake represents 20 percent of the total catchment, while Diana and Peter Lakes together constitute only 15 percent of the Diana catchment.

A more important difference between the Diana and the Meliadine basins is the different outlet discharge characteristics. The Meliadine outlets are considerably wider than that of the Diana, and inflows to Meliadine Lake are passed through the outlets relatively quickly, resulting in limited if any over-year storage during years of higher runoff, compared to the Diana. Higher runoff years are also thought to result in a higher proportion of the outflows being diverted through the west outlet. It is therefore anticipated that Meliadine basin yields will always be less than those of the Diana. For 1997 the runoff ratio for the Meliadine River basin (using precipitation corrected for undercatch) was 0.27 while for the Diana it was 0.56 (based on 130 mm of yield).

Peninsula Basins

The main components of the water balance for five peninsula basins were measured for the 1997 season. Based on direct measurements of surface outflows over the season, annual yields for two of the basins (Peg Lake and Newy Lake) were quite similar, at about 60 mm. A third basin (Lake D5 downstream of Wolf Lake) had an annual yield of 80 mm. The lowest yield was 30 mm, for Control Lake, and the highest was 114 mm for Lake A1 (i.e., Basin A as a whole).

Estimates of subsurface outflows from the five basins were made by calculating the residual in the daily water balance for each monitored lake. This procedure indicated that subsurface outflows were significant for Peg Lake, Newy Lake and Control Lake, but not for Lake A1 and Lake D5. Addition of the estimated subsurface outflow to the measured surface outflow volumes caused the basin yields to converge, with values ranging from 72 to 88 mm for four of the basins. The yield for Lake A1 increased slightly to 117 mm. The Lake A1 sub-basin was calculated to have a yield of about 180 mm, or twice that of the other basins. The ratio of runoff to precipitation for the Lake A1 sub-basin is 0.80, while that for the other basins is in the range of 0.38 to 0.45. The mean runoff ratio of 0.44 for the peninsula basins is very similar to the Diana River historical mean value of 0.48.

The snowmelt contributed about 100 mm or just above 50 percent of the season's moisture input, while rainfall accounted for about 94 mm or just under 50 percent. Evaporative losses removed about 112 mm of moisture from the basins, which thus consumed all of the rainfall input and about 15 percent of the snowmelt input. Some 85 percent of the snowmelt therefore resulted in basin runoff or yield.

About 20 mm of the basin yield appears to have been drawn from basin storage for the Peg Lake, Lake A1 and Lake D5 basins. Water balance computations indicate that the Newy Lake and Control Lake basins appear to have increased their basin storages; however, that result is thought to be an artifact of measurement errors and inaccuracies.

The peninsula basins all stopped discharging surface outflows sometime during the open water season. The smaller lakes (Control Lake and Lake D5) reached their zero outflow levels by the middle of July. Peg Lake stopped outflows near the end of July, followed by the downstream Lake A1 a few days later. Newy Lake, the largest of the five monitored lakes and having the largest of the basins, continued to discharge surface flows until the middle of September. By the end of September the smaller lakes had dropped 0.15 metres below their outlets.

1997 Field Program

The main difficulties encountered during the 1997 field program which affected the reliability and accuracy of the data were the following:

- Selection of good monitoring sites for the peninsula basins was difficult because most lake outflow channels are poorly defined and shallow. In many cases there are multiple channels. In addition, the higher flows exceed the channel capacity and overbank flow occurs, which cannot be measured directly. This problem was particularly pronounced at the Newy Lake monitoring site, and less so at the other sites with the exception of the Lake A1 site where this problem did not occur.

- Vertical control at most monitoring sites was problematic, due to apparent relative movement of benchmarks. This caused uncertainty in the interpretation of water level observations and thus in calculating discharges.

- Limited involvement by AEE staff in the field program during most of the season resulted in a limited understanding of hydrologic conditions and made subsequent interpretation of field data less certain.

- The WMC field staff assigned to the water balance program did not collect all required data as instructed. Communication was also not carried out as requested, thus foreclosing the opportunity to provide corrective guidance.

8.2 RECOMMENDATIONS

The following recommendations are made on the basis of the experience gained and the results obtained in 1997, and with the understanding that the focus of mine development is expected to be in Basin B, especially in the Woody Lake and Bud Lake sub-basins, and in Basin A.

General

1. The aerial photos flown in 1997 and associated digital mapping should be made available prior to finalization of the 1998 detailed work plan.

2. The WMC field staff should be fully dedicated to the water balance program. The same staff should be available throughout the season. Communication from the field must be improved and more supervision must be provided.

Snow Surveys

3. The new aerial photos and mapping should be used to reinterpret the terrain with respect to snow distribution.

4. Snow survey transects for the 1998 program should be located entirely within the monitored sub-basins of Basin A and B, using the new mapping to optimize lengths and alignments.

5. The target date for starting the 1998 snow surveys should be May 4. The date can be moved as needed to suit weather trends.

6. Top of ice and water levels should be surveyed for all monitored lakes during the snow survey work, prior to break up, to establish the start of season levels and lake storage. Levels should be tied to the hydrometric station benchmarks, or provision made for tie-in later in the season.

Hydrometric Program

7. The target date for start of the hydrometric program should be June 1.

8. The Control Lake monitoring station should be decommissioned and the instrumentation used at another site.

9. The other four existing hydrometric stations in the peninsula basins should be continued.

9\. Three new hydrometric stations should be established, at the following sites:

   C at the outlet of Woody Lake (B7)
   C at the outlet of Bud Lake (B5)
   C at the outlet of Lake B2

11. Additional monitoring stations if considered desirable during the program can be established using staff gauges, to be read every two or three days

during the main runoff and weekly thereafter.

12. The peninsula basin hydrometric stations should be improved to reduce the amount of flow which bypasses the discharge measurement section. At most stations temporary low dams are required to direct the overbank flow into the measurement section.

13. Greater understanding of subsurface outflow from peninsula basin lakes is desirable. Development of the 1998 Detailed Work Plan should include assessment of the feasibility of measuring subsurface outflows to validate the calculated 1997 results, and of field investigations to identify the presence of taliks and/or subsurface flow paths between lakes.

14. Winter flow monitoring should be considered for the two Meliadine River stations. This could consist of two or three discharge measurements, as winter flows change very gradually. One set of discharge measurements should be conducted during the snow survey program.

15. The possibility of installing new, improved benchmarks should be investigated at all stations at the start of the 1998 season. Benchmarks should be firmly anchored in bedrock or permafrost to avoid movement by frost/thaw action if at all possible. Alternatively, more solid benchmarks should be selected even if at some distance from the station.

16. All benchmarks should be tied to the permanent benchmarks which already exist in the project area. A survey circuit to make these ties should be made at the start and the end of the hydrometric season.

17. A survey circuit of all benchmarks at each monitoring site should be carried out for each and every stream discharge measurement.

18. Observations of inflow and outflow conditions at lakes upstream and downstream of monitoring sites should be routinely carried out in 1998. This was one of the tasks assigned during the 1997 program but not carried out by the WMC field staff.

19. The three staff gauges in Meliadine Lake and the staff gauges in Peter and Diana Lakes should be read weekly. The gauge at camp should be read every day, at the same time of day.

20. The drainage basin of Meliadine Lake should be carefully examined using aerial photo enlargements to confirm the watershed boundary and to check for possible outflows to other basins. Subsequently, an aerial reconnaissance should be carried out to examine any questionable locations.

21. AEE staff should participate in the seasonal start up and shutdown trips. AEE staff should also carry out two field reconnaissance trips, one In July, and one in August, to obtain a better understanding of hydrologic conditions as well as to provide supervision to the field program.

Climate Data

22. The camp climate station functions and programming should be completely reviewed to ensure that data collected will be complete and accurate.

23. The evaporation pan should be setup during the start of the hydrometric program. The setup location should be moved to near the lake directly south of the camp.

Seepage/Slope water

24. Slope water storage or movement need not be measured or accounted for as a separate component of the water balance. However, an understanding of seepage flow paths and rates of flow would be valuable in connection with water quality issues.

Lake Data

25. Bathymetry or shoreline topography of monitored lakes should be determined, at least to the extent of determining the approximate storage-elevation curves up to the high water level.

9.0 CLOSURE

This report contains hydrometric and climate monitoring data collected in 1997 in the Meliadine and Diana River basins, a review of available historical information prior to 1997, analysis and interpretation of the data, conclusions, and recommendations for the 1998 work program.

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

Respectfully submitted,

AGRA Earth & Environmental Limited

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1997 FIELD PROGRAM DETAILS

A.1 1997 Hydrometric Monitoring Activity Summary

A.2 Checklist for Evaporation Pan Operation

A.3 Checklist for Hydrometric Monitoring

APPENDIX A.1

1997 Hydrometric Monitoring Activity Summary

TABLE A.1
Hydrometric Gauging Activity Summary

Date (m/d)	Continuous Water Level and/or Streamflow Measurements[1]								Manual Level Measurements[1]					Personnel[2]
	Peg Creek near the Mouth (A1-ML)	Outlet of Peg Lake (A6-5)	Outlet of Newy Lake (B4-3)	Outlet of Lake D5 (D5-4)	Outlet of Control Lake[3] (G2-1)	Meliadine Lake near Rankin Inlet	Meliadine River near the Mouth (06MC001)	Diana River near Rankin Inlet 06NC001	Meliadine River at the Outlet of Meliadine Lake (ML-MR)	West Outlet of Meliadine Lake (ML-PL)	Peter Lake near Rankin Inlet (PL)	Diana Lake near Rankin Inlet (DL)	Meliadine Lake at Meliadine Camp	
5/19									V					DJF, WMC
6/10								V						DJF, NVG, MKJ
6/11	V	V	V	V										DJF, NVG, MKJ
6/12						V				V				NVG, MKJ
6/12		V			V				V					DJF, NVG, MKJ
6/13							V							DJF, NVG, MKJ
6/19								I						RNP, MKJ
6/20	I	I					I							DJF, RNP, MKJ
6/21		V	I	I	I									DJF, RNP, MKJ
6/22						I			I	I				DJF, RNP, MKJ
6/23						V								RNP, MKJ
6/23											I	I	I	DJF, RNP, MKJ
6/23							V							DJF, WD, MKJ
6/24	V	V	V	V										DJF, MKJ
6/25								V						DJF, WD, MKJ
6/25					V									DJF, MKJ
6/26	V						V		V	V	V	V	V	DJF, MKJ
7/1													V	DJF
7/7	V[4]	V	V											DJF, WMC
7/8				V	V	V					V	V		DJF, WMC
7/9							V		V	V				DJF, WMC
7/10	V	V			V			V						DJF, WMC
7/17											V	V		DJF, WMC
7/21		V												DJF, WMC
7/22										V				DJF, WMC
7/23			V						V					DJF, WMC
7/24	V													DJF, WMC
7/28				V			V							DJF, WMC
7/29						V		V			V	V		DJF, WMC
8/17						V								DJF, WMC
8/19	V				V									DJF, WMC
8/23							V							WMC, DJF
8/24		V							V	V	V	V		WMC, DJF
8/25								V						DJF, WMC
9/24					S			S			S	S		MKJ
9/25	S	S	S	S		S	S						S	MKJ
9/26									V	S				MKJ

Notes:
1. Field activity abbreviations are:
   I - Installed datalogger/transducer and activated gauge, or established staff gauge
   V - Visit
   S - Shut down station or removed staff gauge

2. **Personnel Initial** **Full Name**
   DJF Dustin Fredland (WMC)
   NVG Neil van der Gugten (AEE)
   RNP R. N. Pilling (WSC)
   MKJ Murray Jones (WSC)
   WD Wes Dick (AEE)
   WMC Other WMC staff

3. There is one undated gauge visit in July to outlet of Control Lake

4. Assumed date of visit

APPENDIX A.2

Checklist for Evaporation Pan Operation

APPENDIX A.3

Checklist for Hydrometric Monitoring

APPENDIX B

CLIMATE DATA

B.1 Rankin Inlet Historical Precipitation

B.2 1997 Rainfall Data Analysis

B.3 Rankin Inlet 1997 Daily Rainfall, Snowfall and Total Precipitation

B.4 Meliadine Camp 1997 Evaporation Pan Data

B.5 1997 Evapotranspiration

APPENDIX B.1

Rankin Inlet Historical Precipitation

APPENDIX B.2

1997 Rainfall Data Analysis

RAINFALL DATA ANALYSIS

Rainfall data for the summer of 1997 is available from three sources:

C Data collected by AES at Rankin Inlet
C A tipping-bucket rain gauge, installed as part of the Meliadine Camp climate station;
C A storage rain gauge installed as part of the Meliadine Camp pan evaporation station; and

The data are summarized in Table B.2.1.

TABLE B.2.1
1997 Field Season
Rainfall in mm

Day	June			July			August			September		
	Rankin Station	Camp Station	Evap. Station	Rankin Station	Camp Station	Evap. Station	Rankin Station	Camp Station	Evap. Station	Rankin Station	Camp Station	Evap. Station
1	0			0.0	0.0	0.0	0	0.0		0.0		0.0
2	0.0			0	0	0	0	0		0		0
3	2.8	6.4		0.0	0	0.0	0.0	0.0		1.0		0.0
4	1.0	1.0		5.2	8.1	0.0	0.0	0.0		1.0		7.4
5	0.0	0.0		0.6	2.3	4.4	0.8	3.0		0.0		0.0
6	0.0	0.0		0.0	0.0	0.0	0.0	0.5		0.0		0.2
7	14.8	34.0		0.2	9.7	4.0	0.4	1.8		0.0		0.0
8	6.2	23.6		5.6	9.1	1.1	0.0	0.0		0.0		0.0
9	0.0	0.0		1.4	3.3	3.4	0.0	0.3		0.0		0.0
10	0.0	0.0		0	0.0	0.0	1.0	0.0		0.0		0.0
11	0.0	0.0		0.0	0.0	0.0	0.8	0.3		0.0		0.0
12	0.0	0.0		0.0	0.0	0.0	0.0	0.0		1.2		
13	0.0	0.0		0	0.0	0.0	0.0	0.0	0.0	0.0		0.2
14	0.6	0.8		0.2	0.8	0.0	0.0	0.0		0.0		0.1
15	0.0	0.3		0.6	0.3	0.6	0.0	0.0	0.0	0.0		0.0
16	0.0	0.0		0.0	0.3	0.0	0.0	0.0	0.0	0.0		
17	0.0	0.0		0.0	0.0	0.0	0.2	0.0		0.0		
18	0.0	0.0		0.0	0.0	0.0	0.8	0.8		0.0		
19	0.0	0.0		0.0	0.0	0.0	0.2	2.5	1.4	0.0		
20	0.0	0.0		0.4	0.8	0.0	0.0	0.0	0.0	0.0		0.3
21	0.0	0.0		1.4	6.1	0.0	2.4	0.0	0.0	0.0		0.0
22	2.2	0.0		0.2	0.0	2.5	0.0	0.0		0.0		
23	5.4	16.0	0.0	0.0	0.0	0.0	1.6	12.4	5.0	0.0		
24	0.4	0.3	0.3	0.0	0.0	0.0	1.2	0.0		0.8		
25	0.0	0.8	1.4	0.0	0.0	0.0	0.0	0.3		7.8		
26	4.0	10.4	6.2	0.0	0.0	0.0	0.0	0.0		0.4		
27	2.6	8.9	2.8	0.0	0.0	0.0	0.4	2.3		0.0		
28	6.0	10.7	17.4	0.0	0	0.0	0.0	0.0	0.0	0.0		
29	1.6	21.1	0.6	1.6	1.5	0.0	0.0		0.0	0		
30	0	1		0.4	0.3		2		4	0.8	1.0	8.5
31				0	0		0		0			

The three sets of data were compared to assess the quality of the data. The comparison was done using a double-mass curve, in which the cumulative depth of precipitation at one station is plotted against the cumulative depth at another station.

The two stations at the Meliadine Camp are compared on Figure B.2.1 for the period June 23 to August 28. Aside from an initial difference on June 23, the stations agreed reasonably well until July 4, when the climate station began to record significantly more precipitation than the evaporation station. By the end of August, the climate station had recorded over 135 mm of precipitation, compared to just over 50 mm recorded at the evaporation station. The two stations are located within a few hundred metres of each other, and should be expected to produce similar results.

A similar comparison of the Meliadine Camp climate station with the AES Rankin Inlet Station is shown on Figure B.2.2 for the full period of overlapping record which starts on June 2. This comparison shows a similar deviation, with the Meliadine Camp station accumulating over 200 mm of rain while the AES Station shows just about 75 mm for the same period.

The evaporation station is compared to the AES Rankin Inlet Station on Figure B.2.3. The total precipitation measured at Rankin Inlet (for the concurrent period of record) is about 58 mm compared to about 72 mm at the evaporation station. Agreement between these two stations appears reasonable indicating that it is the Meliadine Camp climate station data which are in error.

It is therefore concluded that the Meliadine Camp rainfall data for 1997 are in error and should not be used.

APPENDIX B.3

Rankin Inlet
1997 Daily Rainfall, Snowfall and Total Precipitation

APPENDIX B.4

Meliadine Camp
1997 Evaporation Pan Data

APPENDIX B.5

1997 Evapotranspiration

1997 EVAPOTRANSPIRATION

Evapotranspiration (ET) for the project area for 1997 has been estimated using the "GD Relationship" proposed by Granger and Gray (1989). The relationship is defined in terms of the general evapotranspiration equation for non-saturated surfaces which is given as:

$$ET = [\Delta G\,(R_n - Q_g) + \gamma\, G E_a]/(\Delta G + \gamma) \qquad (1)$$

where, **)** is the slope of the saturation vapour pressure versus temperature curve; G, the relative evaporation, is a dimension less parameter; R_n is the net radiation; Q_g is the soil heat flux; **(** is the psychrometric constant; and E_a is the drying power of the air.

All the fluxes, ET, R_n, Q_g and E_a are in units of mm/d equivalent evaporation. The net radiation and soil heat fluxes can be converted from units of W/m^2 by multiplying by 0.035.

) is derived from the average air temperature using:

$$\Delta = \alpha\beta e*/(T + \beta)^2 \; in\; kPa/^{\circ}C \qquad (2)$$

where T is the air temperature, in C, and
for T$ 0, **"** = 17.27 and **$** = 237.3;
for T< 0, **"** = 21.88 and **$** = 265.5.

e* is the saturation vapour pressure at the temperature, T, and is given as:

$$e* = 0.611\exp[\alpha T/(T + \beta)],\; in\; kPa \qquad (3)$$

The drying power, E_a, is derived using a Dalton-type formulation:

$$E_a = f(u)\,(e* - e_a) \qquad (4)$$

where, e_a is the actual vapour pressure of the air (kPa); and f(u) is a function of windspeed and surface roughness such that:

$$f(u) = a + bu \qquad (5)$$

where the wind speed, u, is given in m/s; and the constants a and b are related to the surface roughness by:

$$a = 8.19 + 0.22z_0 \tag{6a}$$

$$b = 1.16 + 0.08z_0 \tag{6b}$$

The roughness height, z_0, is given in cm. If the roughness height is not available, it can be estimated (Brutsaert, 1982) from the mean height of the vegetation, h, by:

$$z_0 = h/7.6 \tag{7}$$

Brutsaert (1982) also gives examples of the roughness parameter for various surfaces.

The relative evaporation, G, is obtained from a dimension less relationship with the relative drying power:

$$D = E_a/(E_a + R_n - Q_g) \tag{8}$$

$$G = 1/(0.793 + 0.2\ \exp(4.902D)) + 0.006D \tag{9}$$

Evapotranspiration, ET, is then obtained from equation (1).

The data required to calculate ET consist of the following:

Air Temperature	T
Wind Speed	μ
Vapour Pressure	e_a
Net Radiation	R_n
Soil Heat Flux	Q_g

Values of T, μ and R_n were recorded directly at the Meliadine Camp climate station, as was the relative humidity from which vapour pressure can be calculated. However, values of R_n as reported by the climate station were increased by a factor of 70.0 so that the monthly means equalled the monthly normals published for the AES Baker Lake station.

The soil heat flux, Q_g, can be measured directly using a soil heat flux plate, however, this was not available for the 1997 season; instead, soil temperatures were monitored at a depth of 5 cm below the surface. Soil heat flux was therefore calculated using a relationship obtained from Shuttleworth (1992):

$$Q_g = (Cs)\,(D)\left(\frac{T2 - T1}{t}\right) \qquad (10)$$

where: Q_g = ground heat flux (W/m^2)
Cs = soil heat capacity (J/m^3°C)
D = depth to thermistor (m)
T2 = current temperature (°C)
T1 = previous temperature (°C)
t = time interval (sec)

The soil heat capacity, Cs, is found from:

$$Cs = BD\,(Csd + (W)\,(Cw)) \qquad (11)$$

where: BD= bulk density of the soil (kg/m^3)
Csd= specific heat of soil (J/kg°C)
W = soil moisture (as kg/kg)
Cw= specific heat of water (J/kg°C) = 4190 J/kg°C

This equation for Cs is given in the instruction manual for the Campbell Scientific TCAV averaging soil thermocouple probe used at the site.

The soil parameters at the site were estimated using typical values for moss-covered glacial till, as follows:

BD	=	2080 kg/m^3
Csd	=	840 J/kg°C
W	=	30 percent

The resulting values for evapotranspiration calculated for the project area are shown in cumulative form on Figure B.5.1. The cumulative total for the 1997 season up to the end of August is estimated to be 200 mm.

APPENDIX C

SNOW SURVEY DATA 1997

C.1 Utah Snow Survey Kit Description

C.2 Snow Survey Kit Calibrations

C.3 Snow Survey Data

APPENDIX C.1

Utah Snow Survey Kit Description

APPENDIX C.2

Snow Survey Kit Calibrations

APPENDIX C.3

Snow Survey Data

APPENDIX D

HYDROMETRIC STATION DESCRIPTIONS

- Meliadine Lake near Rankin Inlet
- Meliadine River at Outlet Meliadine Lake
- West Outlet Meliadine Lake
- Meliadine River near the Mouth
- Diana River near Rankin Inlet
- Diana Lake near Rankin Inlet
- Peter Lake near Rankin Inlet
- Outlet of Peg Lake
- Outlet of Lake A1 (= Peg Creek near the Mouth)
- Outlet of Newy Lake
- Outlet of Lake D5 (= Inlet to Lake No. 4)
- Outlet of Control Lake

APPENDIX E

HYDROLOGIC MONITORING DATA

- E.1 General Information
- E.2 Outlet of Peg Lake
- E.3 Outlet of Lake A1
- E.4 Outlet of Newy Lake
- E.5 Outlet of Lake D5
- E.6 Outlet of Control Lake
- E.7 Meliadine River at Meliadine Lake Outlet
- E.8 West Outlet of Meliadine Lake
- E.9 Meliadine River Near the Mouth
- E.10 Diana River Near Rankin Inlet
- E.11 Meliadine Lake Near Rankin Inlet
- E.12 Meliadine Lake at Meliadine Camp
- E.13 Peter Lake Near Rankin Inlet
- E.14 Diana Lake Near Rankin Inlet

APPENDIX E.1

General Information

Hydrometric Monitoring Data 1997
General Information

This appendix contains the following information for each station:

- A table listing the site visits made during the year, with water level observations and flow measurements.
- A "Gauge History" page reporting benchmark surveys made at the site.
- The station rating curve of the relationship between water elevation and discharge (for streamflow stations only).
- A graph showing water levels recorded in 1997.
- A table of mean daily water levels (for continuous recording stations only).
- A table of mean daily discharges (for continuous streamflow stations only).

The stations are listed in the order given in Table E.1.1 below. The table provides station names and numbers under several different numbering systems used during the project

TABLE E.1.1
Streamflow and Lake Level Monitoring Stations

Appendix	Name (Alternate Name)	Type[1]	RL&L[2]	WSC[3]	Wall Map[4]	Proposal[5]
E.2	Outlet of Peg Lake	CS	A6-5	06MC004	5	A1
E.3	Outlet of Lake A1 (Peg Creek near the Mouth)	CS	A1-ML	06MC003	4	A2
E.4	Outlet of Newy Lake	CS	B4-3	06MC005	6	B2[6]
E.5	Outlet of Lake D5 (Inlet to Lake No. 4)	CS	D5-4	06MC006	7	D1[6]
E.6	Outlet of Control Lake	CS	G2-1	06MC007	8	
E.7	Meliadine River at Meliadine Lake Outlet	MS	ML-MR	06MC008	9	
E.8	West Outlet of Meliadine Lake	MS	ML-PL or ML-DR	06MC009	10	
E.9	Meliadine River near the Mouth	CS		06MC001	2	
E.10	Diana River near Rankin Inlet	CS		06NC001	1	
E.11	Meliadine Lake near Rankin Inlet	CL		06MC002	3	
E.12	Meliadine Lake at Meliadine Camp (Meliadine Lake at WMC Camp)	ML				
E.13	Peter Lake near Rankin Inlet	ML	PL	06NC003	11	
E.14	Diana Lake near Rankin Inlet	ML	DL	06NC002	12	

1. Type: C = Continuous (datalogger)
   M = Manual (staff gauge)
   S = Streamflow
   L = Water Level only
2. Number system based on RL&L nomenclature.
3. Water Survey of Canada station numbers (unofficial except for Diana River).
4. Number system indicating site locations on the wall map at the Meliadine Camp office.
5. Number system used in AEE's proposal.
6. These stations were installed upstream of the locations shown in the AEE proposal; due to site conditions.

Abbreviations used in this appendix are as follows:

C DWL Direct water level. A water level obtained by surveying from a benchmark.
C DL Datalogger
C E Estimate
C NR Not recorded in the field notes
C NDLR No datalogger records
C WSC Water Survey of Canada

Some general notes explaining the data in this appendix are defined below.

C Elevations shown in the "DWL" column of the Site Visit Record have been adjusted to compensate for movement of the benchmarks during the season.

C Elevations shown in the "Data Log" column of the Site Visit Record are values read from the datalogger's digital display during the field visit. These values are close to instantaneous values and are therefore considered to be less accurate than the values in the "Start" and "End" columns, which are recorded in the digital files and are the result of averaging over several minutes.

C The adjustment in the "Site Visit Record" accounts for systematic differences between the surveyed water levels and those recorded by the datalogger.

C Depths are measured above the "zero flow elevation", which is the water level below which no streamflow will occur.

C For the calculation of seasonal flow volumes, missing discharges are estimated by linear interpolation between measured discharges.

C Discharges are calculated from the recorded 15-minute interval water level readings, then averaged to obtain mean daily values.

APPENDIX E.2

Outlet of Peg Lake

APPENDIX E.3

Outlet of Lake A1

APPENDIX E.4

Outlet of Newy Lake

APPENDIX E.5

Outlet of Lake D5

APPENDIX E.6

Outlet of Control Lake

APPENDIX E.7

Meliadine River at Meliadine Lake Outlet

APPENDIX E.8

West Outlet of Meliadine Lake

APPENDIX E.9

Meliadine River Near the Mouth

APPENDIX E.10

Diana River Near Rankin Inlet

APPENDIX E.11

Meliadine Lake Near Rankin Inlet

APPENDIX E.12

Meliadine Lake at Meliadine Camp

APPENDIX E.13

Peter Lake Near Rankin Inlet

APPENDIX E.14

Diana Lake Near Rankin Inlet