9.3 HYDROLOGY

9.3.1 Baseline

9.3.1.1 Introduction

Hydrology includes surface water levels and flows as well as sediment yields and concentrations

This section consists of the hydrology component of the environmental assessment (EA) of the De Beers Canada Inc. (De Beers) Snap Lake Diamond Project. The hydrology component focuses on water and sediment quantity. Specifically, it addresses surface water levels and flows in receiving streams, lakes, and wetlands, which also influence the near-surface water table. It also addresses sediment yields and sediment concentrations in the water in streams, lakes, and wetlands. The quality (*e.g.*, concentrations of constituents such as metals) of the sediment and water is addressed in Section 9.4.

The hydrology component consists of two parts:

- the baseline; and,
- the impact assessment.

The baseline includes the climatic and hydrologic environment prior to development

This baseline section (9.3.1) describes the existing climatic and hydrologic environment prior to the development of the Snap Lake Diamond Project. Climate is included in this section because precipitation, temperature, and evapotranspiration directly affect the natural variability of water levels and flows. Climate, including climate extremes, is very important in describing the environment of the Northwest Territories (NWT). Hence, the quantity and quality of available climate data are described in detail since these determine the level of confidence in predicting future climatic characteristics.

The local and regional study areas are the Snap Lake and Lockhart River drainage areas, respectively

The baseline provides a summary of the hydrology of the regional study area (RSA) and the local study area (LSA). The RSA for hydrology is the Lockhart River system drainage area. The LSA for hydrology is the Snap Lake drainage area. The LSA will receive the direct impacts of the Snap Lake Diamond Project on water quantity and sediment yield. The RSA and LSA are shown in Figures 9.1-1 and 9.1-2.

9.3.1.2 General Setting

9.3.1.2.1 Regional Drainage

Snap Lake occurs in the sub-arctic Precambrian Shield hydrologic region

The Snap Lake Diamond Project is located in the sub-arctic Precambrian Shield hydrologic region. The region extends in a narrow band across the northeastern end of Great Slave Lake trending northwest to and including Great Bear Lake. Rugged landscapes consisting of frequent rock outcrops, glacial features, and lakes characterize this hydrologic region. The extent and depth of soil is limited, and forest and tundra vegetation coverage is sparse.

Snap Lake is the headwater lake in the Lockhart River system

The Snap Lake Diamond Project is located in the Lockhart River system (Figure 9.3-1). The project site is located within the Snap Lake drainage (Figure 9.3-2). Snap Lake is a headwater lake in the Lockhart River system. The outflow from Snap Lake travels over a distance of approximately 38 kilometres (km) through a series of small lakes, prior to discharging to MacKay Lake. Over this distance, inflows from several drainages combine and drain an area of 1,367 square kilometres (km^2) to MacKay Lake.

The Lockhart River drainage contains many waterbodies of varying size

MacKay Lake is part of the Lockhart River system that flows east and then southwest before discharging to Great Slave Lake, which is part of the Mackenzie River drainage area. In total, the Lockhart River drains an area of approximately 27,000 km^2 (Figure 9.3-1). The area includes many waterbodies ranging from small ponds to large lakes, such as MacKay Lake, Aylmer Lake, Clinton-Colden Lake, and Artillery Lake which are, respectively 1,061 km^2, 847 km^2, 737 km^2, and 551 km^2 in size.

Regional surface water flows are characterized by data from long-term hydrometric stations

Regional flow patterns and summary statistics for rivers and streams in south central NWT that are monitored by Environment Canada are provided in Appendix IX.4, Table IX.4-1. Table IX.4-1 contains streamflow data from 19 regional streams that occur between the Arctic circle and the southern Northwest Territories border and between 100° and 116° longitude. Trail Valley Creek, near Inuvik is included because its watershed size, climate, and tundra conditions are similar to Snap Lake. The drainage areas of monitored streams vary greatly in size ranging from 68.3 km^2 to 65,600 km^2 (Appendix IX.4, Table IX.4-1). Unit area runoff values are also variable. Unit area runoff is the mean annual discharge divided by the watershed surface area, and is usually expressed as cubic metres per second per kilometre squared ($m^3/s/km^2$).

Snap Lake likely has lower than average regional runoff

In general, unit area runoff decreases from the northeast section to the southwestern section of the region (Wedel 1990). Greater areas of continuous permafrost, which reduce soil water infiltration, lake evaporation, and evapotranspiration rates, likely contribute to the greater unit area runoff noted for the northeast section of the region. The Snap Lake drainage is located near the southwestern section and, consequently, is likely to have lower than average regional runoff when compared to data presented in Appendix IX.4, Table IX.4-1.

Figure 9.3-1 Lockhart River Drainage

Figure 9.3-2 Snap Lake Watershed and Sub-watersheds

Large lakes within watersheds tend to attenuate flows, reducing spring peak flows but maintaining higher flows during the remainder of the year

For a number of streams in the region, mean monthly flows peak between May and September. In some cases, streams pass most of the snowmelt in a relatively short period of time, while in others, flows are attenuated in large lakes that drain over the summer. The Lockhart River, for example, shows little variation over the summer. Even during April, the lowest flow month, the river flow rate is nearly 53 percent (%) of the rate in September, the maximum flow month. For 10 of the 17 streams evaluated, peak flow volumes occur in June. Other streams exhibit peak flow volumes in May, July, August, and September. Appendix IX.4, Table IX.4-1 also presents the ratio of the mean monthly peak flows to the mean annual flow. The ratio indicates which streams tend to pass peak flow volumes quickly (flashy), and which streams tend to attenuate flows within the watershed.

9.3.1.2.2 Local Drainage

Snap Lake occurs in a headwater drainage and receives only local runoff

Snap Lake is a headwater lake with a drainage area of 67.5 km^2. Numerous small streams ranging from less than 100 metres (m) to several km in length provide local drainage to Snap Lake. Figure 9.3-2 indicates the boundaries and the size of internal sub-basins. Outflow from Snap Lake exits the east arm of the lake through two sub-parallel channels. These channels flow for approximately 300 m prior to discharging to a small lake. Flow characteristics are described in the following sections.

Drainages are not well defined with runoff often passing downslope through a series of muskegs and ponded areas

Within the Snap Lake drainage, the terrain type consists of lakes (35%), wetlands (4%), and uplands (61%). The maximum elevation within the watershed is 475.5 metres above sea level (masl), while the lowest point is the Snap Lake surface elevation is 444.1 masl. The largest sub-basin contributing flows to Snap Lake is approximately 700 hectares (ha) while the smallest sub-basins drain several hectares. In general, drainage paths are not well defined. Runoff from upland areas tends to collect in small ponds and muskeg areas, passing downslope when accumulations exceed the capacity of the ponded area.

9.3.1.3 Climate

Regional climate is described here, local meteorology is in Section 7.2

The regional climate was studied to determine the long-term characteristics of precipitation and the climate patterns to incorporate them into the hydrologic component of this assessment. Long-term data from regional Meteorological Service of Canada (MSC) climate stations were analyzed to provide a basis for determining the precipitation characteristics of the study area. Regional data were required because there is no long-term climate record at the Snap Lake Diamond Project site. A discussion of the local meteorology, from data collected during a short-term on-site monitoring program, is included in Air Quality (Section 7.2) of this assessment.

9.3.1.3.1 Data Sources

Published Data

Regional climate data from Environment Canada were examined

The relevant baseline climatic data required for this study include precipitation, air temperature, wind, evaporation, and solar radiation. The MSC maintains a network of long-term climate monitoring stations in the NWT, which have systematically collected some of the required data. A climatic data inventory was prepared in this assessment and it incorporates recent site data, regional data at the MSC stations in the NWT, south of 70° latitude, north and west of 95° longitude, and data from climate stations adjacent to the project site.

Climate stations at Contwoyto and Lupin are closest to the Snap Lake Diamond Project, but Yellowknife has the longest period of record

Figure 9.3-3 shows the locations of the regional MSC stations examined during this assessment. This figure also shows the locations of the short-term climate stations near the Snap Lake Diamond Project site. Table 9.3-1 provides location and monitoring details for each of the regional MSC climate stations. Six long-term MSC stations are located within a 300 km radius of Snap Lake. The two closest stations are Contwoyto Lake and Lupin. The MSC station at Contwoyto Lake was discontinued in 1982, while the station at Lupin has been in operation since 1981. The combined period of record from these two stations is 45 years. The MSC station at Yellowknife, located approximately 240 km southwest of the project area, has the longest period of historic record (59 years) in the area. The Fort Reliance and Yellowknife hydro stations have periods of record comparable to that of the Yellowknife station. The MSC station at Snare Rapids collected precipitation data before it was discontinued.

Local Data

Short-term climate data from Snap Lake and nearby mine sites located at BHP, Diavik, Salmita, Lower Carp Lake, and Daring Lake were examined

At the Snap Lake Diamond Project site, a weather station collects hourly precipitation, wind, and air temperature data. This station was installed in 1998 and provides local, short-term information. The Department of Indian and Northern Affairs Canada (INAC) and other mine operators have recently installed a network of climate stations near the project site which also provide more local short-term climatic records. Table 9.3-2 lists the short-term climate stations, maintained by INAC and NWT mine operators, that have available climate data and are located within 300 km of the Snap Lake Diamond Project site. These stations are also shown on Figure 9.3-3. Most of these short-term stations have missing data since the stations commenced recording (Table 9.3-2).

Figure 9.3-3 Locations of Regional Climate Stations

Table 9.3-1 Data Available from Environment Canada Weather Stations

Station Name	MSC Station Number	Station Location		Period of Record				
		Latitude North	Longitude West	Air Temperature	Precipitation	Lake Evaporation	Solar Radiation	Wind
Baker Lake	2300500	64° 18'	96° 05'	1946 to 2001	1946 to 2001	-	1970 to 1981	1946 to
Byron Bay Airport	2500595	68° 45'	109° 04'	1955 to 2001	1955 to 2001	-	-	1976 to 2001
Cambridge Bay	2500600	69° 06'	105° 07'	1929 to 2001	1929 to 2001	-	1972 to 1990	1929 to 2001
Cape Young Airport	2200690	68° 56'	116° 55'	1957 to 2001	1957 to 2001	-	-	1974 to 2001
Clinton Point	2200750	69° 35'	120° 48'	1957 to 2001	1957 to 2001	-	-	1973 to 2001
Contwoyto Lake	2200850	65° 29'	110° 22'	1959 to 1981	1956 to 1981	-	-	1956 to 1981
Coppermine/Kugluktuk	2200900[(a)]	67° 50'	115° 07'	1930 to 2001	1930 to 2001	-	-	-
Fort Good Hope Airport	2201400	66° 16'	128° 37'	1944 to 2001	1944 to 2001	-	-	1963 to 1978
Fort Reliance	2201900	62° 43'	109° 10'	1948 to 2001	1948 to 2001	-	-	1948 to 2001
Fort Resolution Airport	2202000	61° 11'	113° 41'	1930 to 2001	1930 to 2001	-	-	1963 to 2001
Fort Simpson Airport	2202101	61° 45'	121° 14'	1922 to 2001	1922 to 2001	-	-	1963 to 2001
Fort Smith Airport	2202200	60° 01'	111° 57'	1943 to 2001	1943 to 2001	1966 to 1978	-	1943 to 2001
Gladman Point Airport	2402340	68° 40'	97° 48'	1955 to 2001	1955 to 2001	-	-	1976 to 2001
Hay River Airport	2202400	60° 50'	115° 47'	1943 to 2001	1943 to 2001	-	-	1943 to 2001
Hay River Paradise Gardens	2202405	60° 39'	116° 00'	1962 to 2001	1962 to 2001	-	-	-
Inuvik Airport	2202570	68° 18'	133° 29'	1957 to 2001	1957 to 2001	-	1961 to 1972	1957 to 2001
Jenny Lind Island Airport	2302650	68° 39'	101° 44'	1957 to 2001	1957 to 2001	-	-	1973 to 2001
Lady Franklin Point Airport	2202680	68° 30'	113° 13'	1957 to 2001	1957 to 2001	-	-	1974 to 1988
Lupin	22026HN[(b)]	65° 46'	114° 14'	1981 to 2001	1981 to 2001	-	-	1981 to 2001
Nicholson Peninsula	2202750	69° 56'	128° 58'	1957 to 2001	1957 to 2001	-	-	1974 to 2001
Norman Wells Airport	2202800	65° 17'	126° 48'	1943 to 2001	1943 to 2001	1964 to 1984	1968 to 1984	1943 to 2001
Snare Rapids	2203700	63° 31'	116° 00'	-	1947 to 1966	-	-	-
Tuktoyaktuk	2203910	69° 27'	133° 00'	1957 to 2001	1957 to 2001	-	-	-
Tuktoyaktuk Airport	2203912	69° 26'	133° 02'	1970 to 2001	1970 to 2001	-	-	1970 to 1985
Tungsten	2203922	61° 57'	128° 15'	1966 to 2001	1966 to 2001	-	-	1975 to 2001
Wrigley Airport	2204000	63° 13'	123° 26'	1943 to 2001	1943 to 2001	-	-	1963 to 1978
Yellowknife Airport	2204100	62° 28'	114° 27'	1942 to 2001	1942 to 2001	1966 to 2001	-	1942 to 2001
Yellowknife Hydro	2204200	62° 40'	114° 15'	1943 to 2001	1943 to 2001	-	-	-

[(a)] Station number changed to 2300902.
[(b)] Station number changed to 23026HN.
MSC = Meteorological Service of Canada.

Table 9.3-2 Short Term Climate Stations with Available Data within 300 km of the Snap Lake Diamond Project

Station Name	Station Location		Available Climate Data	Available Period of Record	Approximate Distance (km) and Direction from the Project Site
	Latitude N	Longitude W			
Snap Lake (De Beers)	63° 35'	110° 51'	Air temperature, relative humidity, wind speed and direction, solar radiation and flux, precipitation, vapour pressure	Feb 2, 1998 to present (some missing data)	–
Royal Oak Mine (Colomac)	64° 23'	115° 03'	Air temperature, relative humidity, wind speed and direction, precipitation	Jun 27, 1995 – Mar 15, 1997 (missing data Jul 2, 1996 – Sep 12, 1996)	224 NW
Snare Hydro (National Water Research Institute)	63° 57'	115° 26'	Air temperature, relative humidity, wind speed and direction, solar radiation, precipitation	Jan 18, 1993 – Sep 19, 1996 (missing data Feb 23 – Oct 6, 1993) currently operating	230 WNW
Salmita Mine	64° 03'	111° 11'	Air temperature, relative humidity, wind speed and direction, precipitation	Aug 6 – Oct 21, 1992 May 12 – Oct 5, 1993 Jun 10 – Sep 28, 1994 Jun 16 – Oct 6, 1995 Jun 19 – Oct 2; Oct 12 – Dec 31, 1996 Jan 1 – Jun 14; Jun 26 – Dec 31, 1997 Jan 1 – Dec 31, 1998 Jan 1 – Sep 28, 1999 currently operating	55 NNW
Lower Carp Lake	63° 37'	113° 51'	Air temperature, relative humidity, wind speed and direction, precipitation	Jun 18, 1997 – Jun 14, 1999 Jul 20, 1999 – Sep 28, 1999	149 W
Daring Lake	64° 52'	111° 35'	Air temperature, relative humidity, wind speed and direction, precipitation	Jun 24, 1996 – Sep 28, 1999 (missing Sep 28 – Nov 22, 1997) currently operating	147 NNW
Pocket Lake	62° 30'	114° 24'	Air temperature, relative humidity, wind speed and direction, precipitation	Jul 8, 1993 – Oct 4, 1999 currently operating	216 SW
Koala (BHP)	64° 48'	110° 56'	Air temperature, relative humidity, wind speed and direction, solar radiation, precipitation	Jan 1, 1994 - Sep 30, 1996 currently operating	114 N
Lac de Gras (Diavik)	64° 30'	114° 24'	Air temperature, relative humidity, wind speed and direction, evaporation, precipitation, dew point	October 1994 to present (some missing data) currently operating	104 NNE

9.3.1.3.2 Air Temperature

Seven MSC stations were selected for analysis of long-term temperature data

Air temperature affects basin snowmelt, lake ice, and water temperature regimes. There are a total of 27 continuing and discontinued MSC stations that recorded daily air temperature data. Table 9.3-1 lists the station names and numbers, the station coordinates, and the available periods of record. Data from seven of the most relevant stations (Table 9.3-3) were used for a regional analysis of temperatures. Those recorded data were used to identify the regional temperature variations. Figure 9.3-4 shows the distributions of the mean monthly minimum, mean, and maximum recorded air temperature based on the available periods of record.

Table 9.3-3 Long Term Climate Stations Selected for Regional Analysis of Temperature

Station Name	Station Number	Location			Period of Record	Years of Record
		Latitude North	Longitude West	Elevation (m)		
Baker Lake	2300500	64° 18'	96° 05'	18	1946 to 2001	55
Contwoyto Lake	2200850	65° 29'	110° 22'	451	1959 to 1981	22
Coppermine/Kugluktuk	2200900[a]	67° 50'	115° 07'	12.5	1930 to 2001	71
Fort Simpson Airport	2202101	61° 45'	121° 14'	168	1922 to 2001	79
Lupin	22026HN[b]	65° 46'	114° 14'	451	1981 to 2001	20
Norman Wells Airport	2202800	65° 17'	126° 48'	67	1943 to 2001	58
Yellowknife Airport	2204100	62° 28'	114° 27'	204	1942 to 2001	59

[a] Station number changed to 2300902.

[b] Station number changed to 23026HN.

Lupin and Contwoyto data were combined to create a longer period of record

The variations of minimum, mean, and maximum monthly recorded air temperatures at Contwoyto (1959 to 1981) and Lupin (1982 to 2001) have similar distributions (Figure 9.3-5). This is to be expected because the two stations are located close to each other and at the same elevation (451 masl). Therefore, the recorded air temperature data at these two stations were combined to create a longer period of record (1959 to 2001). The combined station is named "Lupin Extended" for ease of reference in the remainder of this assessment.

Mean daily temperatures at Snap Lake are midway between those at Lupin and Yellowknife

Figure 9.3-5 presents a comparison of daily air temperatures recorded at the project site and the closest MSC stations (Lupin and Yellowknife Airport [A]) over the concurrent periods of record from January 1998 to June 2001. This figure shows that the mean daily temperature at Snap Lake averages 3°C warmer than Lupin and 3°C colder than Yellowknife A.

Figure 9.3-4 Recorded Monthly Air Temperatures at Regional Climate Stations

Figure 9.3-5 Comparison of Daily Mean Air Temperatures Recorded at Snap Lake, Lupin and Yellowknife

Snap Lake temperatures are similar to those at Salmita

The recorded monthly air temperatures at Snap Lake and the nearby climate station at Salmita are compared with those at Lupin and Yellowknife A for the period from 1997 to 2001. The comparisons are shown on Figure 9.3-6. This figure shows that the temperature at Snap Lake is similar to that at Salmita, and roughly midway between those at Lupin and Yellowknife A. Therefore, the long-term daily air temperature record at Yellowknife A and Lupin Extended were averaged to represent the air temperatures at the project site.

Air temperature statistics were derived for the project site

Table 9.3-4 summarizes the statistics of daily and monthly air temperature derived for the project site based on the available combined period of record for Lupin Extended and Yellowknife A (1942 to 2001). Figure 9.3-7 shows the distributions of the minimum, mean, and maximum monthly air temperature derived for Snap Lake.

Table 9.3-4 Statistics of Derived Extreme Hourly and Average Monthly Air Temperature at Snap Lake

Month	Extreme Air Temperatures for Month (°C)		Average Air Temperatures for Month (°C)		
	Hourly Min	Hourly Max	Daily Min	Mean	Daily Max
January	-50.1	0.5	-33.0	-29.2	-25.3
February	-52.6	0.6	-31.3	-27.0	-22.7
March	-48.3	4.9	-27.2	-22.0	-16.9
April	-41.1	13.2	-16.9	-11.6	-6.3
May	-28.4	21.8	-5.0	-0.4	4.1
June	-11.2	28.9	4.3	9.2	13.9
July	-0.8	31.8	8.7	13.4	18.1
August	-3.6	29.2	7.6	11.5	15.4
September	-10.8	23.6	1.5	4.5	7.4
October	-31.7	21.3	-7.4	-4.8	-2.1
November	-43.5	3.9	-20.9	-17.3	-13.5
December	-47.5	-0.9	-29.0	-25.4	-21.6

Period of record 1942 to 2001.

Air temperatures at the site are coldest in January and warmest in July

For the available period of record (1942 to 2001), the highest hourly air temperature of 31.8°C occurred in July, and the lowest hourly air temperature of –52.6°C occurred in February. Air temperatures can drop below 0°C in any month of the year. January is the coldest month of the year with an average air temperature of –29.2°C. The average monthly air temperature is below 0°C from October to May. The air temperature peaks in July with an average value of 13.4°C. June to September have average air temperatures above 0°C.

Figure 9.3-6 Comparisons of Mean Monthly Temperatures Recorded at Snap Lake, Salmita, Lupin, and Yellowknife

Figure 9.3-7 Derived Monthly Air Temperature Statistics for Snap Lake

9.3.1.3.3 Precipitation

Twenty-seven regional MSC stations have available precipitation data

Precipitation determines basin moisture input. There are a total of 27 continuing and discontinued MSC stations with available precipitation data including rainfall and snowfall, within the region of the NWT shown on Figure 9.3-3. Table 9.3-1 lists the station names and numbers, the station coordinates, and the available periods of record.

Monthly and Annual Precipitation

Measured precipitation characteristics are similar at Lupin and Contwoyto

Table 9.3-5 lists the selected climate stations for the regional precipitation analysis. The project site is located approximately 200 km from the MSC stations at Contwoyto Lake and Lupin (to the north) and approximately 240 km from the MSC station at Yellowknife A (to the southwest). Figure 9.3-8 shows that the monthly occurrence and distribution of recorded precipitation are similar at Lupin and Contwoyto Lake. The values are almost identical except for the months of July and August, when rainfall at Lupin exceeds rainfall at Contwoyto Lake.

Table 9.3-5 Long-term Climate Stations Selected for the Regional Analysis of Precipitation

Station Name	Location		Elevation (m)	Period of Record	Years of Record
	Latitude North	Longitude West			
Baker Lake	64° 18 '	96° 05 '	18	1946 to 2001	55
Contwoyto Lake	65° 29 '	110° 22 '	451	1959 to 1981	22
Coppermine/Kugluktuk	67° 50 '	115° 07 '	12.5	1930 to 2001	71
Fort Simpson Airport	61° 45 '	121° 14 '	168	1922 to 2001	79
Lupin	65° 46 '	114° 14 '	451	1981 to 2001	20
Norman Wells	65° 17 '	126° 48 '	67	1943 to 2001	58
Yellowknife Airport	62° 28 '	114° 27 '	204	1942 to 2001	59

Lupin and Contwoyto Lake data were combined to create a longer period of record

The mean annual rainfall and total precipitation at Contwoyto Lake are 130 millimetres (mm) and 252 mm, respectively. This compares to a mean annual rainfall and precipitation at Lupin of 161 mm and 301 mm, respectively. Therefore, the recorded precipitation data at Contwoyto Lake for the period from 1959 to 1981 and at Lupin for the period from 1982 to 2001 were combined to form a long period of record from 1959 to 2001. The combined station is referred to “Lupin Extended” as in the case of air temperature.

Figure 9.3-8 Mean Monthly Precipitation Recorded at Contwoyto Lake and Lupin

Annual Mean Precipitation

Precipitation data from long-term stations were used to create regional isographs

Table 9.3-6 presents the recorded mean annual rainfall, snowfall, and total precipitation at the stations listed in Table 9.3-5. The areal variations of the recorded mean annual rainfall and total precipitation are shown on Figures 9.3-9 and 9.3-10, respectively. The figures present estimated isolines (lines joining points that have the same value) based on the data in Table 9.3-6. The snow water equivalent is the difference between the total precipitation and the rainfall amount as reported by MSC.

Table 9.3-6 Recorded Mean Annual Rainfall, Snowfall, and Total Precipitation

Station Name	Rainfall [(a)] (mm)	Water Equivalent Snowfall [(a)] (mm)	Total Precipitation [(a)] (mm)
Lupin Extended	144	130	274
Yellowknife A	153	113	266
Coppermine	121	113	234
Baker Lake	143	100	243
Norman Wells	180	131	312
Fort Simpson	208	133	341

[(a)] Estimated mean annual values based on the recorded data.

Regional isographs were used to predict precipitation at the project site

These isographs show a general trend of precipitation increase from east to west, and from north to south. The recorded mean annual rainfall ranges from about 120 mm to about 210 mm in the study region. The recorded mean annual water equivalent snowfall, without undercatch correction, ranges from about 100 mm to about 135 mm. The recorded mean annual precipitation without undercatch correction ranges from about 210 mm to about 340 mm. The following estimates for the Snap Lake Diamond Project area were made based on the isographs and an interpolation between the values at Yellowknife A and Lupin Extended.

A snowfall undercatch factor was derived and applied to measured data

A snowfall undercatch correction factor of 1.7 was applied to the recorded snowfall to estimate the actual snowfall onto the ground (Table 9.3-7). Derivation of this correction factor is presented in Section 9.3.1.3.4.

Table 9.3-7 Derived Long-term Mean Annual Rainfall, Snowfall, and Precipitation at Snap Lake

Precipitation Parameter	Estimated Annual Values (mm)	
	No Correction to Snowfall Undercatch	With Correction to Snowfall Undercatch
Rainfall	149	149
Snowfall	122	207
Precipitation	271	356

Figure 9.3-9 Recorded Mean Annual Rainfall Isograph

Figure 9.3-10 Recorded Mean Annual Precipitation Isograph (Without Snowfall Undercatch Correction)

Monthly Precipitation

Regional variation of measured monthly precipitation was examined

Figure 9.3-11 shows the regional variation of mean monthly precipitation based on the records at the selected long-term MSC climate stations (Coppermine, Yellowknife A, Lupin Extended, Fort Simpson, Norman Wells, and Baker Lake). This comparison illustrates the similarity of rainfall and snowfall distributions, particularly at the nearby stations of Yellowknife A and Lupin Extended.

A long-term daily precipitation series was derived for Snap Lake

No usable precipitation data were available from the Snap Lake Diamond Project site. Therefore, the daily, monthly, and annual precipitation series for Snap Lake were derived by adjusting the same data series from Yellowknife A. The methodology to adjust the Yellowknife data is as follows:

- the recorded rainfall and snowfall series at Yellowknife were decreased by a factor of 0.97 to account for areal variation as illustrated on Figures 9.3-9 to 9.3-10;
- the adjusted snowfall data series was further increased by a factor of 1.7 to account for snowfall undercatch; and,
- the precipitation series was modified by combining the adjusted rainfall and snowfall series.

Mean monthly rainfall, snowfall, and precipitation series were derived for Snap Lake

Tables 9.3-8 to 9.3-10 list the monthly rainfall, snowfall, and precipitation series estimated for Snap Lake. Figure 9.3-12 shows the distributions of mean monthly rainfall and snowfall at Snap Lake. Based on the derived precipitation data series for Snap Lake, 67% of precipitation occurs as snowfall and 33% as rainfall in an average year. The recorded data at the reference climate stations show that snow may fall in any month of the year. Monthly snowfalls from September to May, nine months of the year, would have water-equivalent depths of approximately 15 to 50 mm. Mean monthly snowfall peaks in November. Precipitation could occur as rainfall from April to October, seven months of the year. Monthly rainfall peaks in August. Mean monthly rainfalls in July and August are about 34 mm and 38 mm, respectively.

Derived precipitation compares favorably to precipitation measured at a nearby mine site

The Koala station, about 114 km to the north, had recorded annual precipitation of 307 mm and 487 mm for 1994 and 1995, respectively (Table 9.3-11). The estimated annual precipitation for the Snap Lake Diamond Project based on the regional analysis ranges from 208 to 541 mm. Therefore, the recorded annual precipitation measured at Koala was within the range of variation in annual precipitation derived for the project site.

Figure 9.3-11 Mean Monthly Precipitation Recorded at Regional Climate Stations

Table 9.3-8 Derived Monthly and Annual Rainfall (mm) at Snap Lake, 1942 - 2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1942							21.4	26.6	28.1	17.0	0.0	0.0	
1943	0.0	0.0	0.0	2.4	25.4	8.3	41.1	20.0	10.4	21.0	0.0	0.0	128.6
1944	0.0	0.0	0.0	0.0	21.9	42.9	12.8	37.9	5.6	21.7	0.0	0.0	142.9
1945	0.0	0.0	0.0	0.0	4.0	11.8	46.9	6.2	27.5	29.1	0.0	0.0	125.5
1946	0.0	0.0	0.0	9.9	20.5	0.5	15.0	22.7	4.9	0.0	0.0	0.0	73.5
1947	0.0	0.0	0.0	0.0	3.2	2.9	13.6	23.7	21.4	13.6	0.0	0.0	78.4
1948	0.0	0.0	0.0	0.0	3.5	17.9	85.5	41.4	48.3	4.9	0.0	0.0	201.6
1949	0.0	0.0	0.0	0.0	10.6	20.5	5.6	18.2	19.5	19.0	0.0	0.0	93.4
1950	0.0	0.0	0.0	2.2	1.0	32.5	19.2	29.3	25.6	3.7	0.0	0.0	113.5
1951	0.0	0.0	0.0	2.4	12.3	31.8	21.4	24.2	29.6	11.8	0.0	0.0	133.6
1952	0.0	0.0	0.0	8.8	25.6	9.6	33.0	48.5	41.4	8.1	0.0	0.0	175.1
1953	0.0	0.0	0.0	1.0	5.6	9.9	22.9	71.7	20.2	19.5	1.3	0.0	152.0
1954	0.0	0.0	0.0	0.0	4.2	10.4	60.3	26.9	35.7	4.2	7.9	0.0	149.5
1955	0.0	0.0	0.0	0.0	3.2	12.6	42.9	8.3	13.1	7.7	0.0	0.0	87.8
1956	0.0	0.0	0.0	0.0	16.3	11.3	25.4	36.7	15.0	1.7	0.0	0.0	106.5
1957	0.0	0.0	0.0	3.2	53.9	44.6	69.7	12.3	35.2	1.7	0.0	0.0	220.8
1958	0.0	0.0	0.5	3.7	24.6	0.8	23.9	116.5	47.8	2.9	1.0	0.3	221.9
1959	0.0	0.0	0.0	1.7	4.7	3.5	61.6	37.2	44.3	4.7	1.7	0.0	159.5
1960	0.0	0.0	0.0	0.0	21.0	13.3	40.9	40.2	32.5	12.3	0.0	0.0	160.1
1961	0.0	0.0	0.0	1.7	0.5	3.2	56.9	18.2	18.7	10.9	1.0	0.0	111.2
1962	0.0	0.0	0.0	0.0	0.0	27.8	30.3	48.3	3.5	10.4	0.5	0.3	121.1
1963	0.0	0.0	0.0	2.9	2.9	27.4	52.0	39.9	20.5	5.9	4.2	1.5	157.0
1964	0.0	0.0	0.0	0.0	11.3	4.9	4.0	9.6	42.1	12.6	0.0	0.0	84.6
1965	0.0	0.0	0.0	0.0	0.3	34.0	35.7	14.6	1.9	5.1	0.3	0.0	92.0
1966	0.0	0.0	0.0	0.3	13.8	31.3	14.6	5.1	20.2	15.0	0.0	0.0	100.3
1967	0.0	0.0	0.0	0.0	1.9	16.8	15.5	4.7	11.3	51.2	0.3	0.0	101.8
1968	0.0	0.0	0.0	0.0	4.2	13.3	11.5	15.2	58.9	10.9	1.3	0.0	115.2
1969	0.0	0.0	0.0	4.0	17.0	10.4	16.3	137.3	11.3	4.7	4.0	0.5	205.3
1970	0.0	0.0	0.0	0.3	3.7	7.7	34.2	82.1	23.7	10.4	1.9	0.0	163.9
1971	0.0	0.0	0.0	0.5	16.8	12.0	11.1	59.4	20.0	24.9	0.0	0.0	144.6
1972	0.0	0.0	0.3	0.0	4.0	15.2	36.2	30.3	22.7	6.2	0.5	0.0	115.3
1973	0.0	0.0	0.0	0.0	9.6	13.6	24.2	123.5	15.8	29.1	0.3	0.0	216.0
1974	0.0	0.0	0.0	0.0	23.2	34.2	72.9	57.4	36.5	8.3	0.0	0.0	232.6
1975	0.0	0.0	0.0	5.4	9.6	2.2	10.1	82.5	18.7	10.4	0.0	0.0	139.0
1976	0.0	0.0	0.0	6.4	16.3	37.4	24.3	37.2	43.4	5.6	1.0	0.0	171.7
1977	0.3	0.2	0.0	0.0	31.9	7.8	22.8	16.9	15.2	19.0	0.0	0.0	114.1

Table 9.3-8 Derived Monthly and Annual Rainfall (mm) at Snap Lake, 1942 - 2001 (continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1978	0.0	0.0	0.0	5.4	3.4	20.5	75.0	5.9	35.0	17.2	0.0	0.0	162.4
1979	0.0	0.0	0.2	0.0	7.8	2.9	22.9	41.0	15.0	16.2	0.0	0.0	106.0
1980	0.0	0.0	0.0	3.1	46.9	13.0	10.4	29.9	24.3	22.3	0.0	0.0	149.8
1981	0.2	0.2	0.0	0.2	2.1	35.1	23.6	35.7	41.4	34.0	0.4	0.0	172.9
1982	0.0	0.0	0.0	1.9	28.8	12.1	10.8	6.6	60.6	8.1	0.2	0.0	129.2
1983	0.0	0.0	0.2	0.2	17.5	11.8	46.6	30.3	9.7	8.7	1.2	0.0	126.1
1984	0.0	0.0	0.2	1.0	5.8	68.5	59.8	27.4	11.8	8.5	0.0	0.0	182.9
1985	0.0	0.0	0.0	0.8	17.7	7.8	55.5	43.8	18.3	6.3	0.0	4.3	154.4
1986	0.0	0.0	0.0	0.0	15.5	45.2	21.1	71.6	9.7	13.8	0.0	0.0	176.9
1987	0.0	0.0	0.0	4.5	4.7	48.2	9.5	27.3	46.0	5.5	0.0	0.0	145.6
1988	0.0	0.0	0.0	1.7	18.0	69.5	104.2	14.9	33.3	13.4	0.0	0.0	255.1
1989	0.0	0.0	0.0	0.0	18.3	27.6	44.4	9.9	16.9	18.8	0.0	0.0	136.0
1990	0.0	0.0	0.2	5.6	2.1	7.6	68.1	82.8	14.4	12.2	0.0	0.0	193.0
1991	0.0	0.8	0.0	0.0	30.1	60.8	16.4	61.0	32.8	23.5	0.0	0.4	225.7
1992	0.0	0.0	0.0	1.2	5.4	33.0	24.8	9.5	27.0	13.0	0.4	0.0	114.3
1993	0.0	0.0	3.3	0.0	31.6	2.1	65.4	14.9	40.4	0.6	0.0	0.0	158.4
1994	0.0	0.0	0.0	0.0	11.3	19.9	27.2	3.9	20.2	15.8	0.7	0.0	98.8
1995	0.0	0.0	0.0	0.0	4.5	12.3	27.2	13.4	32.9	18.2	0.0	0.0	108.4
1996	0.0	0.0	0.0	14.0	4.5	34.5	13.4	46.2	56.6	5.9	0.0	0.0	175.1
1997	0.4	0.0	0.0	0.0	18.0	34.0	21.0	28.6	40.9	10.1	0.8	0.0	153.7
1998	0.0	0.0	0.0	10.3	0.0	41.6	11.4	53.7	43.7	28.4	0.0	0.0	189.2
1999	0.0	0.0	0.2	0.0	15.4		17.8	38.1	34.0	2.9	1.6	0.2	
2000	0.0	0.0	0.2	8.5	1.9	41.1	40.3	85.3	20.9	6.8	0.2	0.0	205.2
2001	0.0	0.0	0.0	4.3	26.7	4.9	58.8	68.8					
Mean	0.0	0.0	0.1	2.0	13.0	21.4	33.7	38.2	26.7	12.7	0.6	0.1	147.9
Maximum	0.4	0.8	3.3	14.0	53.9	69.5	104.2	137.3	60.6	51.2	7.9	4.3	255.1
Minimum	0.0	0.0	0.0	0.0	0.0	0.5	4.0	3.9	1.9	0.0	0.0	0.0	73.5
Std. Dev.	0.1	0.1	0.4	3.1	11.6	17.1	22.4	29.9	14.4	9.4	1.3	0.6	43.3

Note: blank cells indicate months where no data were recorded.

Table 9.3-9 Derived Monthly and Annual Snowfall (cm) at Snap Lake, 1942 - 2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1942							0.0	0.0	0.0	8.7	71.6	18.5	
1943	44.9	36.9	38.1	38.6	0.0	0.0	0.0	0.0	1.3	12.5	18.8	25.6	216.7
1944	20.1	7.1	1.3	1.6	0.0	0.0	0.0	0.0	0.0	9.6	25.1		
1945	10.6	20.9	36.4	15.5	0.0	0.0	0.0	0.0	0.0	7.6	4.1	54.1	149.2
1946	48.6	18.0	20.9	0.5	3.0	0.0	0.0	0.0	4.1	57.4	26.9	40.6	220.0
1947	36.9	27.2	8.4	5.9	0.8	0.0	0.0	0.0	0.0	2.1	28.9	19.6	129.9
1948	14.2	16.0	3.3	0.0	0.0	0.0	0.0	0.0	1.6	0.5	36.4	19.3	91.4
1949	16.8	6.8	20.9	24.7	0.0	0.0	0.0	0.0	0.0	26.4	51.4	7.1	154.2
1950	7.1	24.7	2.1	5.4	12.2	0.0	0.0	0.0	0.8	30.5	10.1	48.6	141.6
1951	7.9	10.1	9.2	3.0	11.7	0.0	0.0	0.0	0.0	16.3	21.4	30.5	110.2
1952	9.6	25.1	20.4	11.7	0.0	0.0	0.0	0.0	18.8	15.5	25.9	31.8	158.8
1953	11.7	16.0	4.6	1.3	2.5	0.0	0.0	0.0	1.6	3.3	30.5	37.8	109.3
1954	13.9	12.5	31.0	4.1	0.0	0.0	0.0	0.0	2.5	12.2	53.6	39.7	169.5
1955	18.0	15.5	9.6	32.3	1.6	0.0	0.0	0.0	0.0	1.6	37.3	21.4	137.4
1956	24.2	25.6	12.5	6.3	0.0	0.0	0.0	0.0	31.5	42.4	40.6	31.8	214.9
1957	24.7	26.4	19.6	11.4	7.6	0.8	0.0	0.0	1.3	18.0	49.8	53.3	212.9
1958	40.6	24.2	27.7	32.7	0.8	0.0	0.0	0.0	0.0	69.6	41.1	82.1	318.8
1959	10.1	20.1	79.2	35.9	4.9	0.0	0.0	0.0	1.3	99.8	59.0	57.4	367.7
1960	16.3	33.5	34.8	5.4	5.4	0.0	0.0	0.0	0.0	87.6	77.8	30.2	291.0
1961	65.0	36.9	38.1	14.7	1.3	0.0	0.0	0.0	28.5	74.2	59.0	38.1	355.9
1962	47.3	20.9	12.2	3.3	7.9	0.0	0.0	0.0	0.0	7.9	70.4	39.4	209.4
1963	46.5	31.0	18.0	5.9	0.0	0.0	0.0	0.0	0.0	6.8	52.4	11.7	172.3
1964	22.3	28.0	12.2	16.8	0.0	0.0	0.0	0.0	11.4	16.0	33.5	11.4	151.5
1965	13.0	12.5	6.8	21.8	0.0	0.0	0.0	0.0	3.0	101.7	88.7	26.9	274.4
1966	15.0	6.8	39.7	34.0	1.6	0.0	0.0	0.0	4.9	38.6	48.2	41.1	229.9
1967	13.9	31.0	25.1	4.6	8.7	5.4	0.0	0.0	0.0	74.2	48.6	23.9	235.5
1968	44.9	23.9	11.4	23.9	15.5	0.0	0.0	0.0	0.0	19.6	54.4	17.6	211.2
1969	16.8	16.0	18.0	34.8	7.9	0.0	0.0	0.0	4.6	5.9	38.9	30.2	173.1
1970	22.6	38.6	30.5	18.5	21.4	4.9	0.0	0.0	1.3	22.6	16.8	41.1	218.3
1971	38.9	20.1	30.5	19.6	4.6	0.0	0.0	0.0	3.0	22.3	74.5	22.6	236.1
1972	13.4	25.9	38.6	39.7	0.5	0.0	0.0	0.0	18.5	69.1	44.9	28.9	279.3
1973	25.6	21.8	46.0	15.5	0.0	0.0	0.0	0.0	0.0	27.7	92.5	42.7	271.8
1974	35.6	19.3	28.5	7.9	8.4	0.0	0.0	0.0	18.0	73.7	50.6	100.1	342.2
1975	24.2	20.1	16.3	8.4	4.9	0.0	0.0	0.0	7.1	68.8	44.0	50.3	244.2
1976	35.6	27.7	24.7	3.8	0.0	0.0	0.0	0.0	0.0	11.4	21.4	20.4	145.1
1977	29.8	31.8	11.7	10.1	5.3	0.0	0.0	0.0	0.0	19.8	64.5	30.3	203.3

Table 9.3-9 Derived Monthly and Annual Snowfall (cm) at Snap Lake, 1942 - 2001 (continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1978	12.5	7.9	24.6	29.2	6.3	0.0	0.0	0.0	0.0	41.7	43.7	52.3	218.2
1979	14.5	3.6	27.7	24.7	35.0	0.0	0.0	0.0	1.0	58.5	44.2	27.0	236.3
1980	52.8	15.5	4.0	1.6	18.1	0.0	0.0	0.0	19.1	15.5	56.4	17.8	200.8
1981	26.7	31.7	15.8	32.3	0.7	0.0	0.0	0.0	1.0	32.3	46.7	19.0	206.1
1982	0.0	59.2	6.9	3.6	22.1	1.8	0.0	2.3	0.0	20.6	43.0	48.3	207.9
1983	50.1	15.7	30.3	10.6	16.5	0.0	0.0	0.0	28.7	29.0	54.1	11.5	246.5
1984	31.8	62.3	27.0	11.5	2.3	0.0	0.0	0.0	4.3	52.4	51.1	20.8	263.7
1985	24.4	73.9	18.5	46.8	10.9	0.0	0.0	0.0	9.6	67.6	74.4	25.7	351.7
1986	30.3	26.7	39.2	12.5	4.3	0.0	0.0	0.0	1.3	18.1	20.4	45.8	198.9
1987	40.9	74.2	17.1	9.9	0.3	0.0	0.0	0.0	0.0	49.6	89.2	42.0	323.4
1988	35.1	30.0	12.2	38.3	1.3	0.0	0.0	0.0	0.7	17.1	97.8	24.4	256.9
1989	56.1	8.4	26.2	2.3	2.6	0.0	0.0	0.0	7.9	21.1	88.1	42.0	254.8
1990	41.6	20.1	17.0	12.5	3.6	0.0	0.0	0.0	0.0	54.1	38.9	60.5	248.3
1991	49.8	31.3	39.6	26.7	2.3	0.0	0.0	0.0	0.0	46.8	68.9	29.0	294.5
1992	62.0	31.0	50.1	26.4	12.2	0.0	0.0	0.0	7.6	30.0	54.7	21.4	295.5
1993	12.5	44.9	24.7	9.9	13.2	0.0	0.0	0.0	0.7	32.3	39.2	72.6	250.0
1994	22.4	16.0	52.1	7.6	4.3	0.0	0.0	0.0	0.0	23.1	76.5	41.9	243.9
1995	29.7	31.0	84.1	18.5	0.0	0.0	0.0	0.0	0.0	2.6	37.4	69.4	272.7
1996	13.7	35.0	33.6	21.4	3.3	0.0	0.0	0.0	0.0	24.1	44.2	38.3	213.5
1997	38.6	9.6	49.8	5.9		0.0	0.0	0.0	8.2	44.9	62.7	35.0	
1998	38.6	28.0	5.9	23.1	0.0	0.0	0.0	0.0	0.0	38.8	34.0	29.2	197.6
1999	33.1	33.0	31.7	20.8	9.9		0.0	0.0	7.3	43.2	45.0	48.0	
2000	7.6	18.8	18.3	0.0	12.5	0.0	0.0	0.0	6.9	77.0	73.9	17.1	232.2
2001	39.2	14.8	50.6	2.3	15.8	0.0	0.0	10.9					
Mean	28.0	25.5	25.4	15.6	5.8	0.2	0.0	0.2	4.6	34.7	48.7	35.9	224.7
Maximum	65.0	74.2	84.1	46.8	35.0	5.4	0.0	10.9	31.5	101.7	97.8	100.1	367.7
Minimum	0.0	3.6	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	4.1	7.1	91.4
Std. Dev.	15.5	14.7	17.1	12.4	7.1	1.0	0.0	1.4	7.7	26.3	21.3	18.0	64.4

Note: blank cells indicate months where no data were recorded.

Table 9.3-10 Derived Monthly and Annual Precipitation (mm) at Snap Lake, 1942 - 2001

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1942							21.4	26.6	28.1	25.9	71.6	18.5	
1943	44.9	36.9	38.1	41.0	25.4	8.3	41.1	20.0	11.5	33.5	18.8	25.6	345.1
1944	20.1	7.1	1.3	1.6	21.9	42.9	12.8	37.9	5.6	31.3	25.1		
1945	10.6	20.9	36.4	15.5	4.0	11.8	46.9	6.2	27.5	36.5	4.1	54.1	274.6
1946	48.6	18.0	20.9	10.2	23.4	0.5	15.0	22.7	9.1	57.4	26.9	40.6	293.3
1947	36.9	27.2	8.4	5.9	4.0	2.9	13.6	23.7	21.4	15.6	28.9	19.6	208.2
1948	14.2	16.0	3.3	0.0	3.5	17.9	85.5	41.4	50.0	5.3	36.4	19.3	292.8
1949	16.8	6.8	20.9	24.7	10.6	20.5	5.6	18.2	19.5	45.4	51.4	7.1	247.6
1950	7.1	24.7	2.1	7.7	13.2	32.5	19.2	29.3	26.4	34.4	10.1	48.6	255.3
1951	7.9	10.1	9.2	5.4	24.0	31.8	21.4	24.2	29.6	28.2	21.4	30.5	243.7
1952	9.6	25.1	20.4	20.7	25.6	9.6	33.0	48.5	60.2	23.6	25.9	31.8	334.0
1953	11.7	16.0	4.6	2.3	8.3	9.9	22.9	71.7	21.8	22.8	31.8	37.8	261.5
1954	13.9	12.5	31.0	4.1	4.2	10.4	60.3	26.9	38.3	16.4	61.4	39.7	319.2
1955	18.0	15.5	9.6	32.3	4.9	12.6	42.9	8.3	13.1	9.3	37.3	21.4	225.1
1956	24.2	25.6	12.5	6.3	16.3	11.3	25.4	36.7	46.4	44.0	40.6	31.8	321.0
1957	24.7	26.4	19.6	14.6	61.5	45.4	69.7	12.3	36.5	19.7	49.8	53.3	433.7
1958	40.6	24.2	28.2	36.3	25.5	0.8	23.9	116.5	47.8	72.5	42.0	82.2	540.5
1959	10.1	20.1	79.2	37.7	9.8	3.5	61.6	37.2	45.6	104.4	60.8	57.4	527.4
1960	16.3	33.5	34.8	5.4	26.4	13.3	40.9	40.2	32.5	99.9	77.8	30.2	451.2
1961	65.0	36.9	38.1	16.4	1.8	3.2	56.9	18.2	47.2	84.9	60.0	38.1	466.9
1962	47.3	20.9	10.9	2.5	6.3	27.8	30.3	48.3	3.5	18.6	47.5	21.2	285.1
1963	33.5	21.4	11.7	8.5	2.9	27.4	52.0	39.9	20.5	13.8	55.8	12.3	299.7
1964	18.5	24.2	10.1	12.5	11.3	4.9	4.0	9.6	57.6	33.1	29.7	9.2	224.7
1965	12.2	12.2	5.9	23.4	0.3	34.0	35.7	14.6	4.1	106.6	47.1	14.7	310.8
1966	14.2	3.0	29.4	36.2	18.1	31.3	14.6	5.1	26.4	58.2	34.8	28.5	299.8
1967	9.6	24.2	21.4	3.8	12.5	22.2	15.5	4.7	11.3	117.5	34.6	17.1	294.5
1968	36.9	15.5	9.6	19.6	18.8	13.3	11.5	15.2	58.9	29.3	45.1	13.9	287.7
1969	10.9	12.2	11.4	28.7	23.2	10.4	16.3	137.3	16.0	10.6	33.2	20.1	330.2
1970	13.9	22.3	15.0	13.2	18.9	12.6	34.2	82.1	25.3	27.5	11.2	28.5	304.6
1971	31.8	16.0	22.6	12.2	21.4	12.0	11.1	59.4	30.0	43.2	36.9	18.8	315.5
1972	8.4	19.6	27.0	25.1	4.3	15.2	36.2	30.3	45.3	54.7	34.0	18.5	318.5
1973	18.8	12.5	34.8	14.7	9.6	13.6	24.2	123.5	15.8	53.3	44.2	26.9	391.8
1974	26.4	13.9	21.8	7.1	31.6	34.2	72.9	57.4	53.6	67.9	42.4	75.4	504.5
1975	18.8	13.4	11.7	13.3	14.7	2.2	10.1	82.5	26.6	57.7	23.9	28.9	303.9
1976	30.5	27.7	23.1	10.2	16.3	37.4	24.3	37.2	43.4	15.4	20.3	19.6	305.4

Table 9.3-10 Derived Monthly and Annual Precipitation (mm) at Snap Lake, 1942 - 2001 (continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1977	26.3	28.1	10.2	9.4	37.2	7.8	22.8	16.9	15.2	44.4	40.6	23.9	282.8
1978	10.1	7.4	23.4	31.2	9.7	20.5	75.0	5.9	35.0	56.3	35.0	32.5	341.8
1979	6.8	2.6	20.1	17.5	44.0	2.9	22.9	41.0	16.0	68.6	29.4	21.1	293.0
1980	43.0	10.6	3.5	4.8	64.7	13.0	10.4	29.9	45.0	42.8	39.9	13.9	321.3
1981	20.6	18.7	12.9	24.4	2.5	35.1	23.6	35.7	42.4	63.6	30.6	12.9	322.9
1982	0.0	43.0	4.0	3.8	49.6	13.9	10.8	8.9	60.6	25.6	27.1	29.5	276.8
1983	35.3	6.4	21.6	9.8	35.6	11.8	46.6	30.3	52.2	39.4	43.4	8.2	340.6
1984	31.8	44.5	24.6	9.2	9.8	68.5	59.8	27.4	15.8	70.2	35.3	17.1	414.0
1985	21.1	52.4	16.2	37.7	34.5	7.8	55.5	43.8	27.9	66.3	51.6	16.1	431.0
1986	18.8	17.8	31.0	12.2	20.1	45.2	21.1	71.6	10.7	30.3	12.5	29.0	320.4
1987	22.6	43.0	10.2	14.5	5.0	48.2	9.5	27.3	46.0	57.6	75.0	27.2	386.2
1988	28.9	27.7	8.6	34.4	20.4	69.5	104.2	14.9	24.0	26.4	54.1	11.5	424.6
1989	35.6	6.6	15.5	2.0	20.6	27.6	44.4	9.9	25.5	38.6	56.6	29.8	312.8
1990	34.1	17.1	15.0	16.5	5.1	7.6	68.1	82.8	14.4	65.3	34.0	52.3	412.3
1991	37.4	22.7	34.1	17.1	33.7	60.8	16.4	61.0	32.8	60.9	31.0	23.5	431.5
1992	46.5	22.6	42.5	25.6	17.6	33.0	24.8	9.5	34.1	39.9	37.8	12.2	346.1
1993	9.9	35.0	21.4	9.4	44.8	2.1	65.4	14.9	41.1		25.6	45.5	
1994	12.2	13.9	33.6	5.3	15.5	19.9	27.2	3.9	20.2	36.6	64.3	30.3	282.9
1995	16.0	23.9	66.5	18.5	4.5	12.3	27.2	13.4	32.9	20.5	13.5	45.8	294.9
1996	9.6	21.8	23.9	30.5	7.1	34.5	13.4	46.2	56.6	21.1	25.6	18.3	308.5
1997	26.6	2.6	30.3			34.0	20.3	28.6	9.6				
1998	38.6	25.4	5.3	32.4	0.0	41.6	11.4	53.7	43.7	29.7	34.0	29.2	345.0
1999	20.4	26.5	25.6	22.4	21.4		17.8	38.1	41.3	29.8	37.7	31.0	
2000	5.4	11.5	15.5	8.5	13.5	41.1	40.3	85.3	27.8	67.1	44.4	17.1	377.6
2001	39.2	7.8	50.6	6.6	39.5	4.9	58.8	79.7					
Mean	23.2	20.4	21.2	15.9	18.6	21.6	33.7	38.4	31.0	44.5	37.4	28.6	334.9
Maximum	65.0	52.4	79.2	41.0	64.7	69.5	104.2	137.3	60.6	117.5	77.8	82.2	540.5
Minimum	0.0	2.6	1.3	0.0	0.0	0.5	4.0	3.9	3.5	5.3	4.1	7.1	208.2
Std. Dev.	13.6	10.8	14.9	11.2	14.8	17.1	22.4	30.1	15.7	25.7	16.0	15.6	75.0

Note: blank cells indicate months where no data were recorded.

Table 9.3-11 Recorded Precipitation at Nearby Short-term Climate Stations

Station Name	Year	Available Period of Record	Recorded Rainfall (mm)	Recorded Snowfall (Snow Water Equivalent) (mm)	Recorded Annual Precipitation (mm)
Royal Oak Mine (Colomac)	1995	Jun 27 - Dec 31	83	–	> 83
	1996	Jan 1 - Jul 2; Sep 12 - Dec 31	100	–	>100
	1997	Jan 1 - Aug 14	95	–	>95
Salmita Mine	1993	May 13 – Oct 4	78	–	>78
	1994	–	–	–	-
	1995	Jun 17 – Oct 5	87	–	>91
	1996	Jun 19 – Dec 31	147	–	>147
	1997	Jan 1 – Jun 6; Jun 26 – Dec 31	151	–	>151
	1998	Jan 1 – Dec 31	196	–	>196
	1999	Jan 1 – Sep 28	180	–	>180
Lower Carp Lake	1997	Jun 18 – Dec 31	104	–	>104
	1998	Jan 1 – Dec 31	220	–	>220
	1999	Jan 1 – Jun 14; Jul 20 – Sep 28	123	–	>123
Daring Lake	1996	Jun 24 – Oct 3	206	50	>256
	1997	Jan 1 – Oct 27; Nov 23 – Dec 31	95	86	>181
	1998	Jan 1 – Dec 31	213	111	324
	1999	Jan 1 – Sep 28	220	65	>285
Pocket Lake	1993	Jul 9 – Dec 31	99	–	>99
	1994	Jan 1 – Dec 31	56	–	>56
	1995	Jan 1 – Dec 31	126	–	>126
	1996	Jan 1 – Dec 31	211	–	>211
	1997	Jan 1 – Dec 31	175	–	>175
	1998	Jan 1 – Dec 31	145	–	>145
	1999	Jan 1 – Oct 4	123	–	>123
Snap Lake	1998	Mar 3 – Dec 31	195	–	>195
	1999	Jun 19 – Dec 31	138	–	>138
Koala (BHP)	1994	Jan 1 – Dec 31	–	–	307
	1995	Jan 1 – Dec 31	–	–	487
	1996	Jan 1 – Sep 30	–	–	>414
Lac de Gras	1995	Jan 1 – Dec 31 (with missing data)	–	–	>245
	1996	Jan 1 – Dec 31 (with missing data)	–	–	>308

– No data were available.

Figure 9.3-12 Precipitation Statistics Derived for Snap Lake

Derived rainfall compares favorably to precipitation measured at a nearby mine site

The Salmita and Daring Lake stations are about 75 km to the southwest of the Snap Lake Diamond Project and 72 km to the northwest, respectively. The available annual rainfall data, from these stations for the period from 1993 to 1999, ranged from 78 to 220 mm. This compares with the range of annual rainfall from 74 mm to 255 mm derived for the project site for the period from 1943 to 2001.

Short term local precipitation data compare favorably to the derived precipitation series for the project site

In this assessment, representative precipitation statistics at the Snap Lake Diamond Project were derived based on a regional analysis of long-term records. They were derived because climatic trend can only be reliably identified based on long-term mean values, and because areal variation of climatic variables (precipitation, wind, *etc*.) may be different from the long-term trend and may vary considerably from year to year. The comparisons with the short-term precipitation data at the nearby climate stations show that the short-term precipitation data are within the range of derived precipitation statistics. This provides a verification of the applicability of the derived precipitation statistics to the project site.

Extreme Monthly, Seasonal, and Annual Precipitation

Wet and dry monthly, seasonal, and annual precipitation data were derived for the project site

Monthly, seasonal, and annual precipitation series for Snap Lake were calculated based on the daily precipitation series derived for Snap Lake. A frequency analysis of the data series was conducted to derive the wet and dry monthly precipitation, seasonal rainfall, seasonal snowfall, and annual precipitation of various return periods. The methodology for the frequency analysis is summarized below:

- For each data series (*e.g.*, the annual precipitation series listed in Table 9.3-11), the data points (*e.g.*, annual precipitation) were ranked in descending order and their probability of occurrences or return periods were calculated.
- Various theoretical frequency distributions were used to fit the ranked data series using the consolidated frequency analysis (CFA) program developed by Environment Canada. The best-fit distribution was selected to estimate the recurrence intervals or return periods.

Extreme precipitation was estimated

Table 9.3-12 lists the extreme monthly precipitation estimates for 10-year and 100-year return periods. Table 9.3-13 lists the extreme seasonal and annual precipitation estimates for 10 year and 100 year return periods. Since extreme values for annual rainfall, annual snowfall and annual precipitation are determined individually, they are not necessarily coincident in the same year. Thus, extreme rainfall and snowfall are not summed to equal precipitation in Table 9.3-13).

Table 9.3-12 Derived Mean and Extreme Monthly Precipitation at Snap Lake

Month	Monthly Precipitation[1] (mm)				
	100 Year Dry Condition	10 Year Dry Condition	Mean	10 Year Wet Condition	100 Year Wet Condition
January	0.0	9.0	28.2	50.7	90.0
February	6.4	11.2	25.8	44.8	75.1
March	3.1	7.1	25.1	47.8	84.5
April	0.0	2.6	17.9	35.5	46.9
May	0.0	2.7	18.6	38.4	65.3
June	0.0	2.6	21.5	45.2	70.9
July	1.7	8.2	33.0	62.7	112.0
August	3.2	7.8	36.7	74.8	141.0
September	0.0	11.4	31.3	52.3	60.9
October	5.3	15.5	46.5	81.7	126.0
November	7.4	22.3	49.3	77.2	99.5
December	12.3	16.8	36.1	59.7	96.9

(1) A snowfall undercatch correction factor of 1.7 was used to derive these estimates.

Table 9.3-13 Derived Mean and Extreme Annual Rainfall, Snowfall, and Precipitation at Snap Lake

Precipitation Parameter	Annual Value[1] (mm)				
	100 Year Dry Condition	10 Year Dry Condition	Mean	10 Year Wet Condition	100 Year Wet Condition
Annual rainfall	68	89	147	204	266
Annual snowfall	89	148	225	310	373
Annual precipitation	201	274	372	483	585

(1) A snowfall undercatch correction factor of 1.7 was used to derive these estimates.

Long-duration Extreme Rainfall

Extreme long-duration rainfall depths were derived for the project site

To estimate extreme rainfall, a frequency analysis of the annual maximum rainfall series for durations of 1 to 60 days was based on the recorded rainfall data at Lupin Extended (1959 to 1996) and Yellowknife A (1943 to 1996) climate stations. An interpolation, using the following relationship, was made to derive the frequency estimates for Snap Lake by accounting for the areal variation of regional rainfall shown on Figure 9.3-9:

$$R_P = 0.5R_L + 0.5\,R_Y$$

where: R_P - long-duration rainfall depth at Snap Lake (mm)

R_L - long-duration rainfall depth at Lupin Extended (mm)

R_Y - long-duration rainfall depth at Yellowknife A (mm)

Table 9.3-14 summarizes the resulting frequency estimates for Snap Lake.

Table 9.3-14 Frequencies of Long-duration Extreme Rainfall at Snap Lake

Return Period (Year)	Extreme Rainfall Depth for Various Durations (mm)					
	1-day	3-day	5-day	10-day	30-day	60-day
2	20.2	27.5	31.4	37.3	61.1	90.0
5	29.6	38.9	43.6	52.5	82.1	118.8
10	36.5	46.5	51.9	63.6	95.6	137.1
20	43.9	54.0	60.0	75.2	108.8	155.4
50	54.6	64.1	71.5	91.9	126.5	178.5
100	63.8	72.2	80.5	105.9	140.3	196.2

Short-duration Extreme Rainfall

Extreme short-duration rainfall depths were derived for the project site

Derivation of rainfall intensity-duration-frequency (IDF) curves for short-durations ranging from 5 minutes to 24 hours requires a record of rainfall in 5-minute intervals. The climate station at Yellowknife is the closest station that has such short-duration rainfall records. The short-duration rainfall IDF curves for the Yellowknife station were obtained from MSC data. These curves were then adjusted for the areal variation of regional rainfall (Figure 9.3-9) to derive short-duration IDF curves for the Snap Lake Diamond Project. For each return period, the adjustment factor is equal to the ratio between the 1-day duration rainfall at the project site and the same duration rainfall at Yellowknife. Table 9.3-15 lists the resulting short-duration rainfall IDF data derived for the project site.

Table 9.3-15 Frequencies of Short-duration Extreme Rainfall at Snap Lake

Return Period (Year)	Extreme Rainfall Intensity for Various Durations (mm/hr)						
	5-minute	10-minute	30-minute	1-hour	2-hour	12-hour	24-hour
2	42.9	30.5	15.5	9.4	6.1	1.9	1.1
5	65.4	46.2	23.1	13.8	8.8	2.8	1.7
10	78.7	55.4	27.6	16.4	10.4	3.3	2.0
20	94.2	66.2	32.9	19.5	12.2	3.9	2.4
50	102.7	72.1	35.7	21.1	13.3	4.3	2.6
100	111.2	78.1	38.7	22.8	14.3	4.6	2.9

Local Snow Data from Snap Lake

Snow data are provided later

Snow accumulation data for various terrain types at the Snap Lake Diamond Project were obtained in 1999, 2000, and 2001. These data are presented and discussed in Section 9.3.1.4.

9.3.1.3.4 Evaporation and Evapotranspiration

Limited regional evaporation data are available

The MSC provides calculated lake evaporation data for only three stations in the NWT (Table 9.3-1).

Approach

Lake evaporation can be predicted based on analytical models

There are no direct measurements of evaporation at the Snap Lake Diamond Project and the nearby climate stations. Several analytical models are available for estimating lake evaporation and basin evapotranspiration. Some of these models, such as the Priestley-Taylor model, have been proven under Arctic conditions, but such models require input of climate data, such as net radiation, which are not available for the project site. Other models, such as Morton's method, have been reported to over-estimate evaporation and evapotranspiration in the Arctic (Marsh and Bigras 1988; Gibson *et al*. 1996).

Lake evaporation was estimated based on local studies and a regional water balance

The approach used in this assessment to estimate of lake evaporation and evapotranspiration of various terrain types is summarized below:

- estimate lake evaporation based on a local study at Lupin and compare the estimate with other regional studies; and,
- conduct a basin water balance analysis based on available climate and streamflow data for the gauged Waldron River to derive the evapotranspiration rates for various terrain types and to determine the snowfall undercatch correction factor. The Waldron River station was selected on the basis of proximity, period of record, and catchment size. Its headwaters are adjacent to the Snap Lake watershed, it has a sixteen-year period of record, and it is among the smallest gauged watersheds in the region.

Lake Evaporation

Mean Annual Lake Evaporation

Mean annual lake evaporation rate of 300 mm will be used

A mean annual lake evaporation rate of 300 mm was adopted for Snap Lake and other smaller lakes in the region. The derivation of this value is discussed below.

An evaporation study at Lupin estimated a mean annual lake evaporation of 275 mm

Gibson *et al*. (1996) conducted a study of evaporation at small lakes near the Lupin area, approximately 220 km from the Snap Lake Diamond Project. Estimates from this study were based on two years of field measurements of variables necessary to calculate evaporation using the methods of mass balance, the energy balance, the Priestley-Taylor model, and aerodynamic profiling. Measured pan evaporation can be multiplied by a pan correction factor to estimate open-water lake evaporation. Gibson *et al*. (1996) undertook pan and lake measurements in 1992 and 1993 to derive a site-specific pan correction factor of 0.81. This factor was applied to pan evaporation measurements undertaken at the Lupin Airport in 1983 and 1984 to extend the data set. Table 9.3-16 summarizes the lake evaporation estimates made in that study. The results show that the annual evaporation ranged from 220 mm to 320 mm and the mean annual lake evaporation over the four-year period was 275 mm.

Table 9.3-16 Lake Evaporation Estimates

Year	Annual Evaporation for Small Lakes (mm)		
	Lupin Station Based on Study by Gibson *et al.* (1996)	**Salmita Station Based on Study by Reid (1999)**	**Koala Station Based on Study by Rescan (1996)**
1983	260[1]		
1984	320[1]		
1992	300		
1993	220		
1994		336	270[2]
1995		261	340[2]
1996		283	356[2]
1997		242	
1998		348	
1999		295	
Average	275	294	322

1 These estimates were based on the pan evaporation measurements at Lupin and a correction factor of 0.81.

2 These estimates were based on the pan evaporation measurements and a site-specific correction factor of 0.75.

Evaporation studies at Salmita and Koala measured mean annual lake evaporations of 294 mm and 322 mm, respectively

Table 9.3-16 also lists the evaporation estimates by Reid (1999) based on the climate data at Salmita, which is about 55 km north-northwest of the Snap Lake Diamond Project. The annual lake evaporation estimates, based on the Penman method, varied from 261 to 348 mm with an average value of 294 mm for the six-year period. The annual lake evaporation estimates for the Koala station, which is about 114 km north of the project site, ranged from 270 to 356 mm with an average value of 322 mm for the three-year period (Rescan 1996). Table 9.3-16 shows that the averages for the Koala and Salmita stations are 17% to 25% higher than that at Lupin. The weighted average annual lake evaporation is 315 mm, based on the seven years of available estimates, which is about 15% higher than the average estimate of 275 mm at Lupin.

Measured lake evaporation compares favorably to other regional studies

The mean annual evaporation estimates for small lakes in Table 9.3-16 compare favourably to other evaporation studies done in the Arctic and sub-arctic regions (Roulet and Woo 1986). The published values cannot be directly compared because of the varying lengths of study periods and the different estimation methods, ranging from simple water-balance analyses, to pan evaporation techniques, and to physically-based models.

Small lakes have different evaporation characteristics than large lakes

The evaporation estimates presented in Table 9.3-16 are for small lakes. The evaporation regime of large, deep lakes differs from that of small, shallow lakes. Small lakes have less thermal inertia than large lakes and, hence, heat up and cool down faster than large lakes. Small lakes are also subject to advective influences from the surrounding landscape. The relative proportion of evaporation in the beginning of the open-water season in relation to total seasonal evaporation will be greater for small lakes than for large lakes. The reverse is true in the later part of the open-water season.

300 mm mean annual lake evaporation is estimated at the project site

The recommended annual lake evaporation for the study area is 300 mm, regardless of lake size, because of the short period of available evaporation data for small lakes and inadequate data for quantifying the effects of lake size. The recommended value (300 mm) is slightly smaller than the weighted average annual evaporation for small lakes (315 mm), but the recommended value is more appropriate for application to Snap Lake, which is a large lake.

Mean Monthly Lake Evaporation

Monthly distributions of lake evaporation were estimated based on air temperature

Gibson *et al.* (1996) did not report monthly evaporation estimates. Table 9.3-17 presents the calculated monthly distribution of lake evaporation at the Yellowknife MSC station based on the climate data recorded (Environment Canada 1994). Table 9.3-17 also lists the monthly distribution of mean air temperature for the project site, which is one of the important variables affecting lake evaporation. The recommended distribution of mean monthly lake evaporation is listed in Table 9.3-17 by taking account of the evaporation distribution reported for Yellowknife and the air temperature distribution at the Snap Lake Diamond Project.

Basin Evapotranspiration and Snowfall Undercatch Correction Factor

Evapotranspiration and snowfall undercatch parameters were derived

A water balance analysis and literature review were undertaken to derive basin evapotranspiration rates and snowfall undercatch. The adopted mean annual water balance parameters, including evapotranspiration and snowfall undercatch, are summarized below (Table 9.3-18).

Table 9.3-17 Monthly Lake Evaporation Estimates for the Local Study Area

Month	Percent of Annual Evaporation at Yellowknife (%)	Monthly Air Temperature at Snap Lake (°C)	Recommended Percent of Annual Evaporation at Local Study Area (%)	Estimated Monthly Lake Evaporation for Local Study Area (mm)
January	0	-29.2	0	0
February	0	-27.0	0	0
March	0	-22.0	0	0
April	0	-11.6	0	0
May	0	-0.4	0	0
June	33	9.2	15	45
July	33	13.4	40	120
August	23	11.5	30	90
September	11	4.5	10	30
October	0	-4.8	5	15
November	0	-17.3	0	0
December	0	-20.9	0	0
Total	**100**	**-8.5**	**100**	**300**

Table 9.3-18 Mean Annual Water Balance Parameters

Water Balance Parameters	Adopted Value (mm)
Precipitation	
- rainfall	148
- snowfall based on a 1.7 adjustment for undercatch	187
- total precipitation	335
Water loss	
- lake evaporation	300
- upland evapotranspiration	150
- wetland evapotranspiration	240
Total evapotranspiration upstream of Snap Lake	156
Total evapotranspiration at Snap Lake outlet	192

Details of the derivation of evapotranspiration runoff yield and snowfall undercatch adjustment are discussed below.

Data from the Waldron River were used in the water balance analysis

The Waldron River watershed is located immediately south of the Snap Lake watershed. Flows in the Waldron River were monitored over the period 1979-1994. The gauged drainage basin area is 1,830 km^2. The mean annual discharge is 6.4 cubic metres per second (m^3/s), which corresponded to a gross average annual basin runoff of 111 mm. The long-term average recorded annual rainfall and snowfall derived for the project site were used to represent the moisture input to the gauged Waldron River basin (Environment Canada 1998). Table 9.3-19 presents the estimates of mean annual evapotranspiration for the Waldron River basin by assuming a range of snowfall undercatch correction factors of 1 to 2. The resulting basin evapotranspiration estimates range from 147 mm to 257 mm.

Table 9.3-19 Annual Water Balance Analysis for the Waldron River Basin

Annual Water Balance Component	Snowfall Undercatch Correction Factor			
	1.0 (No Correction)	1.5	1.7	2.0
Rainfall (mm)	148	148)	148	148
Snowfall (mm)	110	165	187	220
Precipitation (mm)	258	313	335	368
Basin runoff (mm)	111	111	111	111
Basin evapotranspiration (mm)	147	202	224	257

Land classification information from the Snap Lake area was used in the water balance analysis

The evapotranspiration for the gauged Lockhart River basin includes the net effect of upland and wetland evapotranspiration and evaporation from large lakes and small lakes. Land classification information was not available for the large, gauged Lockhart River basin, but was available for a representative area within a radius of 31 km, centred on the project site (the regional study area for terrestrial resources). The land classification information for the large basin was estimated by assuming that the proportions of lakes, uplands, and wetlands were the same in the large and small basins.

Basin evapotranspiration was assumed to relate to lake evaporation as follows:

$$E = E_L \frac{(b_W \cdot A_W) + (b_U \cdot A_U) + A_L}{A}$$

where:

- E - basin evapotranspiration
- E_L - lake evaporation
- A_W - wetland area
- A_U - upland area
- A_L - lake surface area

A	-	total basin area
b_W	-	correction factor from lake evaporation to wetland evaporation (0.8 to 0.9)
b_U	-	correction factor from lake evaporation to upland evapotranspiration (0.5 to 0.6)

Evapotranspiration estimates were derived for wetland and upland areas

Table 9.3-20 presents estimates of evapotranspiration for the gauged Lockhart River basin. The estimates were based on the adopted mean annual lake evaporation of 300 mm, reasonable ranges of correction factors for wetland evaporation and upland evapotranspiration, and the land classification information.

Table 9.3-20 Basin Evapotranspiration Analysis Based on Land Classification Information for the Terrestrial Regional Study Area

Terrain Type	Percent of Total Basin Area	Contribution to Total Basin Evapotranspiration (mm)	
		Assuming b_W=0.9 and b_U=0.6	Assuming b_W=0.8 and b_U=0.5
Lake	35	105	105
Wetland	4	11	10
Upland	61	110	92
Total	100	226	207

Evapotranspiration and snowfall undercatch derivations are consistent

The results show that the upper bound estimates for wetland evaporation and upland evapotranspiration (b_W=0.9 and b_U=0.6) resulted in an annual basin evapotranspiration estimate of 226 mm. This is similar to the basin evapotranspiration estimate obtained in Table 9.3-18, which assumed a snowfall correction factor of 1.7.

A snowfall undercatch factor of 1.7 was derived

The average wind speed at the Snap Lake Diamond Project was estimated to be about 13 kilometres per hour (km/h). The average snowfall undercatch correction factor (without accounting for trace events) corresponding to this wind speed is about 1.3 for the shielded Canadian Nipher gauges, based on the empirical relationships reported by Metcalfe *et al.* (1994) and by Larson and Peck (1974). The actual snowfall undercatch corrections factor should be higher than 1.3. This is because the effect of a large number of trace events in the Arctic should also be taken into account. The derived mean annual precipitation for the project site is 335 mm based on a snowfall undercatch correction factor of 1.7. This compares with 280 mm annual precipitation derived directly from the recorded data by MSC. The corrected precipitation (335 mm) is believed to be more representative of the basin moisture input than the recorded value (280 mm).

The derived snowfall undercatch factor is conservative

In this study, the correction of precipitation undercatch was conducted based on a water balance procedure. This practical approach may introduce some errors because of the error associated with the basin runoff measurements in the Arctic rivers and the estimation of basin evapotranspiration. To remedy this, a conservative (or high) snowfall undercatch correction factor (1.7) is recommended for the derivation of precipitation at the project site. This degree of conservatism is appropriate for the EA.

The derived annual precipitation correction factor is consistent with published regional values

Environment Canada (Metcalfe *et al.* 1994) is developing a corrected historical precipitation archive for selected NWT stations in recognition of substantial snowfall undercatch in the Arctic using a rigorous approach for the snowfall undercatch correction by accounting for the effects of winds and trace events. Metcalfe *et al.* (1994) reported the following correction factors for the annual precipitation recorded at three stations in the NWT:

- Resolute Bay: 1.5 to 2.0;
- Yellowknife: 1.26; and,
- Norman Wells: 1.19.

The correction factor for precipitation is comparable

The effective correction factor for the annual precipitation recommended for the project site is 1.30, which is comparable to the above-mentioned values derived for the climate stations in the NWT.

Evapotranspiration estimates for various terrain types were derived

Table 9.3-21 presents the resulting evapotranspiration estimates for various terrain types in the terrestrial regional study area. No available data can be directly used for determining the monthly distribution of basin evapotranspiration. However, the evapotranspiration distribution can be roughly estimated using the same distribution for monthly lake evaporation presented in Table 9.3-17.

Table 9.3-21 Evapotranspiration Estimates for Various Terrain Types in the Terrestrial Regional Study Area [(a)]

Terrain Type	Estimated Mean Annual Evapotranspiration (mm)
Wetlands	240
Upland	150
Basin area tributary to Snap Lake	156
Total Snap Lake basin including lake	192

(a) Terrain types are available for the regional study area used in Terrestrial Resources (Section 10). This regional study area is the area within a 31 km radius of the centre of the Snap Lake Diamond Project site.

9.3.1.3.5 Solar Radiation

Solar radiation is addressed in the air quality section

Incoming solar radiation affects basin snowmelt, lake ice, and water temperature regimes. An analysis of local solar radiation data is included in Air Quality (Section 7.2 of this document).

9.3.1.3.6 Wind

Wind is addressed in the air quality section

Wind affects lake circulation patterns, lake currents, wave heights, wave runup, wind setup, and potential lake shore ice ride-up and pile-up. Wind also affects sensible heat transfer between the air and the earth surface. This in turn affects lake evaporation, basin evapotranspiration, snowmelt rate, lake ice freeze-up and break-up, and lake water temperature. An analysis of local wind data is included in Air Quality (Section 7.2).

9.3.1.4 Hydrology

9.3.1.4.1 Surface Hydrology Monitoring Program

Introduction

The hydrology field program included collection of snowcourse, stream flow, and water level data

The surface hydrology monitoring program was designed to collect snowcourse, streamflow, and water level data in the Snap Lake watershed as part of the aquatic baseline data collection program. These data were used to characterize baseline hydrology in the project area and to provide a basis for establishing the relationship between local short-term streamflow data and long-term regional flow data. Long-term local data can be synthesized for purposes of estimating unit area runoff, flood magnitude and frequency, and flow duration curves. The following sections used data collected as part of the hydrology monitoring program and developed estimates of expected hydrological conditions for the Snap Lake site.

Baseline conditions of small basins and Snap Lake were required to evaluate project impacts

The baseline conditions of small basin runoff and Snap Lake water balance were characterized to provide a basis for evaluation of the impacts of the Snap Lake Diamond Project on surface water hydrology. The snowcourse data were used to assess local snowfall amount. The snow and streamflow data were used to calibrate a snowmelt simulation model for deriving small basin runoff characteristics. The lake inflow, water level, and outflow data were used to calibrate a water balance model needed to characterize the baseline lake water balance and assess future project impacts.

Methods

Field Program Design

Snowcourse Surveys

Snow accumulation depends on topography (open, upland, and lowland areas) and vegetation

Snow accumulation depends on terrain type, which is a function of both topography and vegetation. In the Snap Lake watershed, topography is the dominant feature dictating the terrain classification. The following main terrain types were identified:

- open areas, including lake and land;
- upland areas - elevated areas generally exposed to wind; and,
- lowland areas - low areas generally sheltered from wind, including wetlands.

Snowcourse surveys were conducted in early spring 1999, 2000, and 2001 over representative terrain types

Snowcourse surveys were performed in 1999, 2000, and 2001 at several sites representative of each terrain type. Twelve sites were sampled in 1999, nine sites in 2000, and fifteen sites in 2001. Fewer sites were sampled in 2000 because of a broken sampling device. A greater number of sites was sampled in 2001 because more sites were required to provide data for a snow quality study. The surveys were performed in early spring to measure the maximum snow accumulation before the start of snowmelt. In 1999, the survey was undertaken on March 22 and 23, and in 2000, the survey was undertaken on April 1. Measurements of snow depth and density were undertaken at each site as described under data collection methods. The locations of the sampling sites are provided in Table 9.3-22 and Figure 9.3-13.

Stream Discharges

Continuous stream discharge monitoring was undertaken in 1999, 2000, and 2001 at one lake inflow channel and on the two outlet channels from Snap Lake. The lake inflow location is labelled as H4, and the lake outlets are labelled as H1 and H2 on Figure 9.3-13. The inflow stream was chosen to be representative of a typical catchment draining to Snap Lake. It is located close to the project site and is the largest catchment draining to Snap Lake. Stream discharge monitoring was undertaken during open water periods, from May 28 to October 6, 1999 and from June 8 to October 10, 2000. In 2001, streamflow monitoring was initiated on May 29 and ended in October 2001. Data from 2001 has not yet been tabulated and will not be included in the EA.

Lake Levels

Lake levels were monitored in 1999, 2000, and 2001

Continuous lake level monitoring was undertaken in 1999, 2000, and 2001 at the location shown as H3 on Figure 9.3-13. This site was selected because it is close to the project site and to Station H4. Water level measurements were gathered from May 28 to October 6, 1999 and from June 8 to October 10, 2000. In 2001, lake level monitoring was initiated on May 29 and was completed in October.

Figure 9.3-13 Locations of Hydrology Monitoring Stations

Table 9.3-22 Snow Survey Sampling Site Locations, 1999 to 2001

Terrain Type	1999 Snow Survey		2000 Snow Survey		2001 Snow Survey	
	Sample Plot	UTM Coordinates	Sample Plot	UTM Coordinates	Sample Plot	UTM Coordinates
Upland area	SUP-99-1	7053678 N 506147 E	SUP-00-1	7049570 N 505771 E	SUP-01-1	7056940 N 497880 E
	SUP-99-2	7050656 N 507810 E	SUP-00-2	7053654 N 509781 E	SUP-01-2	7054411 N 499674 E
	SUP-99-3	7052551 N 510846 E	SUP-00-3	7053640 N 506593 E	SUP-01-3	7055407 N 511247 E
	SUP-99-4	7054485 N 510100 E			SUP-01-4	7052326 N 506299 E
					SUP-01-5	7053378 N 506873 E
Lowland area	SLL-99-1	7054021 N 506715 E	SLL-00-1	7050298 N 506408 E	SLL-01-1	7056772 N 498008 E
	SLL-99-2	7050029 N 507530 E	SLL-00-2	7054742 N 509614 E	SLL-01-2	7054636 N 499732 E
	SLL-99-3	7051047 N 509334 E	SLL-00-3	7053460 N 505884 E	SLL-01-3	7055221 N 511242 E
	SLL-99-4	7053905 N 512202 E			SLL-01-4	7052177 N 506491 E
					SLL-01-5	7053426 N 506782 E
Open area	SOL-99-1	7053460 N 506006 E	SOL-00-1	7050238 N 506463 E	SOL-01-1	7055960 N 498458 E
	SOL-99-2	7053021 N 507405 E	SOL-00-2	7054147 N 509614 E	SOL-01-2	7054590 N 499740 E
	SOL-99-3	7050668 N 508150 E	SOL-00-3	7053499 N 506649 E	SOL-01-3	7054780 N 510967 E
	SOL-99-4	7053921 N 511912 E			SOL-01-4	7051981 N 506930 E
					SOL-01-5	7053256 N 507283 E

UTM = universal transverse mercator.

Data Collection Methods

Snow Surveys

Snow depth was measured at 30 random locations within each sample station

At each snow survey sampling location, snow depths and densities were measured. Thirty depth measurements were taken at random locations over a traverse distance of 100 to 200 m. The surveyor walked a large circle with approximately ten steps between each measurement to ensure that locations were randomly chosen. If the point measured was over a fallen log, a rock, or a bare spot of land, it was considered a valid measurement because it was equally representative of the terrain. Depth measurements were taken by inserting a piece of rebar into the snow, marking the top of the snow on the rebar, and measuring the rebar from the end that touched the ground to the mark with a tape measure.

Snow density was measured with the use of a corer

Three density measurements were taken at each sampling location, using an Atmospheric Environment Service snow density sampler. The sampler was inserted slowly to guard against sudden compaction of the snow. If sudden compaction occurred, the measurement was repeated elsewhere. Snow depth was read on the tube when the corer reached the substrate surface. The corer was then inserted further while twisting to get a “plug” of soil to prevent the granular snow at the bottom of the sample from falling out. If it was not possible to plug the end of the corer, the surveyor dug around the corer with a shovel, slid the blade of the shovel under the corer, and lifted out the corer with the blade against it to prevent the snow from falling out. The corer tube was then held horizontally and the weight measured using a spring scale. The units on the spring scale read directly in centimetres of snow water equivalent. The tare (empty weight) of the spring scale was read at the beginning of the day and periodically throughout the day by weighing the empty tube.

Records and notes were standardized

Snow density and depth measurements were recorded according to standard procedures to ensure a complete data set. Additional notes were taken on cover type, colour of the snow surface, and consistency of snow in case these were required to interpret the field data.

Stream Discharges

Continuous stream depth was measured using a pressure transducer

Stream water levels were measured continuously with data logging equipment and stream discharges were measured periodically during site visits. The monitoring equipment used for continuous stream depth measurement consisted of a solid state pressure transducer connected to an electronic data logger. The data loggers were set up to record water depths every hour. The battery operated data logger is able to record several months of data and can be downloaded directly to a computer for data processing.

Manual discharge measurements establish the relationship between stream water level and discharge

Each monitoring site (H1, H2, and H4) was visited several times over the course of the field program (on May 28, June 6, June 25, July 7, September 10, and October 6, 1999; June 8, September 13, and October 10, 2000; and May 29 and October 25, 2001) and manual discharge measurements were performed using a Marsh-McBirney FloMate 2000 flow meter. More visits were required in the first year to establish a stage-discharge rating curve. To establish the rating curve, the water velocity was measured at several representative points across the stream channel and each velocity was multiplied by the flow area represented by the measurement to calculate discharges for a section of the channel. By summing the discharges for each section across the channel, a total channel discharge was determined.

GPS was used to record position

A global positioning system (GPS) tied the stream water surface elevation at the pressure transducer to a geodetic datum.

Lake Levels

Stream and lake level monitoring equipment was identical

The single lake level monitoring station also used a pressure transducer with a data logger. A GPS system tied the lake water surface elevation to a geodetic datum.

Data Analysis

Snow Surveys

Mean snow water equivalent was calculated from mean snow density and depth

Field data from each sampling location was processed by calculating the mean snow density from the three measurements and calculating the mean snow depth from the thirty measurements. The mean snow density and snow depth were then used to calculate the snow water equivalent at the sampling site. This is equal to the depth of water that would result from melting the snow accumulated in a given area.

Stream Discharges

A continuous record of discharge was calculated

Measured water depths were converted into geodetic elevations by adding the measured water depth to the geodetic datum.

A stage-discharge rating curve was applied to water levels to determine discharge

Manual measurements of stream discharge at each monitoring site were paired with water levels measured at the same time and location, and the resulting data set was used to prepare a stage-discharge rating curve that related water surface elevation to stream discharge over a range of water levels and discharges. The stage-discharge rating curve was then applied to the continuous record of water levels to produce a continuous record of discharges.

Lake Levels

Water levels were determined

Lake water surface elevations were determined by adding the continuous record of lake water depths to the geodetic datum.

Results

Snow Surveys

Snow survey results shown

Results from the 1999, 2000, and 2001 snowcourse surveys are shown in Figure 9.3-14 and Table 9.3-23.

Stream Discharges

Discharge results are in the following tables

A summary of results from the 1999 and 2000 stream discharge monitoring is shown in Table 9.3-24. Details of manual discharge measurements are shown in Table 9.3-25 and the continuous records of discharges are shown in Appendix IX.4, Tables IX.4-2 to IX.4-7 and Figures IX.4-1 to IX.4-6.

Figure 9.3-14 Snowcourse Survey Results, 1999 - 2001

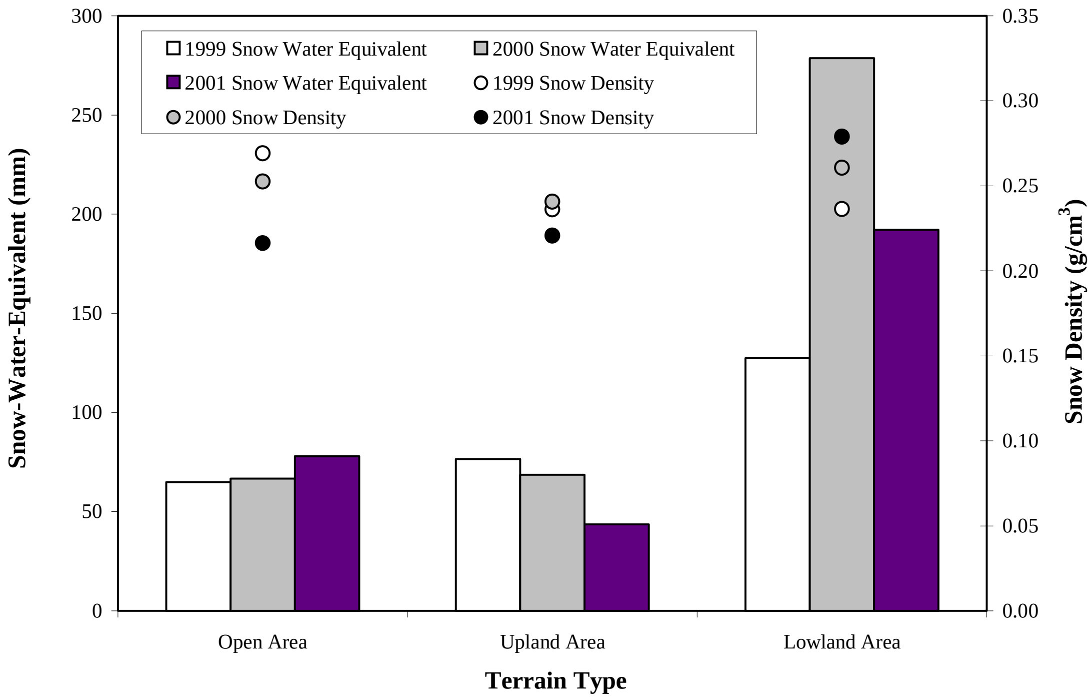


Table 9.3-23 Snowcourse Survey Results, 1999 - 2001

Terrain Type	1999 Snowcourse Survey				2000 Snowcourse Survey				2001 Snowcourse Survey			
	Survey Plot No	Snow Density (g/cm^3)	Snow Depth (cm)	Snow Water Equivalent (mm)	Survey Plot No	Snow Density (g/cm^3)	Snow Depth (cm)	Snow Water Equivalent (mm)	Survey Plot No	Snow Density (g/cm^3)	Snow Depth (cm)	Snow Water Equivalent (mm)
Lowland area	SLL-99-1	0.201	67.4	135.7	SLL-00-1	0.204	114.6	234.2	SLL-01-1	0.244	92.4	225.3
	SLL-99-2	0.250	67.7	169.3	SLL-00-2	0.285	103.3	294.3	SLL-01-2	0.150	88.7	133.3
	SLL-99-3	0.280	53.2	149.1	SLL-00-3	0.292	105.2	307.3	SLL-01-3	0.213	84.8	180.5
	SLL-99-4	0.214	25.9	55.4					SLL-01-4	0.235	83.4	195.8
									SLL-01-5	0.239	94.4	225.2
	MEAN	**0.236**	**53.6**	**127.4**	**MEAN**	**0.261**	**107.7**	**278.6**	**MEAN**	**0.216**	**88.7**	**192.0**
Open lake area	SOL-99-1	0.228	23.6	53.9	SOL-00-1	0.224	22.0	49.3	SOL-01-1	0.362	24.9	90.1
	SOL-99-2	0.461	24.4	112.6	SOL-00-2	0.304	38.5	116.9	SOL-01-2	0.278	31.1	86.5
	SOL-99-3	0.285	27.9	79.4	SOL-00-3	0.230	14.7	33.9	SOL-01-3	0.231	26.0	60.3
	SOL-99-4	0.254	19.9	50.3					SOL-01-4	0.284	30.7	87.1
									SOL-01-5	0.239	27.6	65.8
	MEAN	**0.269**	**23.9**	**64.9**	**MEAN**	**0.253**	**25.1**	**66.7**	MEAN	0.279	28.1	78.0
Upland area	SUP-99-1	0.196	30.7	60.0	SUP-00-1	0.236	34.7	81.7	SUP-01-1	0.136	21.2	28.9
	SUP-99-2	0.214	39.8	85.1	SUP-00-2	0.203	26.9	54.6	SUP-01-2	0.216	20.9	45.1
	SUP-99-3	0.374	27.6	103.0	SUP-00-3	0.284	24.5	69.5	SUP-01-3	0.263	16.9	44.6
	SUP-99-4	0.160	36.2	58.1					SUP-01-4	0.209	19.4	40.6
									SUP-01-5	0.279	21.1	58.9
	MEAN	**0.236**	**33.5**	**76.5**	**MEAN**	**0.241**	**28.7**	**68.6**	**MEAN**	**0.221**	**19.9**	**43.6**

Table 9.3-24 Stream Discharge Monitoring Results, 1999 and 2000

Parameter Measured	Station H1 North Lake Outlet	Station H2 South Lake Outlet	Station H4 Representative Lake Inlet
May 28 to October 6, 1999			
Maximum discharge	0.439 m^3/s	1.969 m^3/s	0.624 m^3/s
Mean discharge	0.170 m^3/s	0.491 m^3/s	0.119 m^3/s
Minimum discharge	0.065 m^3/s	0.110 m^3/s	0.000 m^3/s
Cumulative runoff volume	1,909,000 m^3	5,515,000 m^3	1,337,000 m^3
June 8 to October 10, 2000[1]			
Maximum discharge	0.173 m^3/s	0.313 m^3/s	0.099 m^3/s
Mean discharge	0.043 m^3/s	0.109 m^3/s	0.021 m^3/s
Minimum discharge	0.002 m^3/s	0.036 m^3/s	0.004 m^3/s
Cumulative runoff volume	477,000 m^3	1,296,000 m^3	287,000 m^3

[1] Stations were installed after the flood peak in 2000, so maximum recorded discharges are not representative of the flood peak (freshet).

Table 9.3-25 Manual Discharge Measurements, 1999 and 2000

Date	H1 – North Outlet		H2 - South Outlet		H4 - Main Inlet	
	Q (m^3/s)	Time (hh:mm)	Q (m^3/s)	Time (hh:mm)	Q (m^3/s)	Time (hh:mm)
23-Mar-99	-	-	0.053	10:45	-	-
28-May-99	0.120	15:30	0.292	14:30	0.370	9:00
6-Jun-99	0.304	-	1.667	14:00	0.456	-
25-Jun-99	0.279	-	0.845	14:00	0.048	-
7-Jul-99	0.207	10:00	0.389	10:00	0.029	11:45
10-Sep-99	0.118	14:20	0.225	16:00	0.046	15:15
6-Oct-99	0.104	12:35	0.182	11:45	0.055	15:00
8-Jun-00	-	-	-	-	0.091	20:30
9-Jun-00	0.041	10:00	0.197	8:45	0.094	11:30
13-Sep-00	0.000	19:30	0.052	18:00	0.031	14:30
9-Oct-00	-	-	-	-	0.021	15:00
10-Oct-00	0.030	9:00	0.078	10:30	-	-
29-May-01	0.185	11:00	0.413	10:30	0.514	9:00

Note: Q = discharge.

Lake Levels

Lake level results shown

A summary of results from the 1999 and 2000 lake level monitoring is shown in Table 9.3-26. Details of lake level monitoring are shown in Appendix IX.4, Tables IX.4-8 and IX.4-9 and Figures IX.4-7 and IX.4-8.

Table 9.3-26 Lake Level Monitoring Results, 1999 and 2000

	Station H3 Lake Levels May 18 to October 6, 1999 (m)	Station H3 Lake Levels[1] July 9 to October 10, 2000 (m)
Maximum lake level	444.167	443.879
Mean lake level	443.964	443.717
Minimum lake level	443.829	443.662

[1] Station H3 was installed after the flood peak in 2000 so maximum recorded lake level is not representative of the flood peak.

9.3.1.4.2 Streamflow Modelling

The short-term flow record for Snap Lake outlet can be extended by comparing the local data with long-term regional flow data

Streamflow monitoring at the Snap Lake outlet has provided valuable information with regard to the flow characteristics. However, data collection has only recently begun (*i.e.*, last two years) and does not include stream discharges for the winter months. Where streamflow records are relatively short and intermittent, it is necessary to extend the flow record over a continuous period of sufficient duration so that estimates of stream discharge can be determined under a wide range of climatic conditions. The flow record should be of sufficient length that average to rare low and high flow events would be included.

Continuous discharge data needed

In order to predict flood and low flow magnitudes and frequencies for streams in the Snap Lake Diamond Project area, it is necessary to synthesize continuous discharge data, based on daily discharges collected at other streams in the region.

Streamflow can be synthesized from other hydrometric stations

In a given hydrologic region, factors that influence runoff conditions are normally similar. It is possible to estimate streamflow characteristics that may have occurred where only sparse flow records are available by relating flows documented at another hydrometric station that has a longer flow record. By comparing the time-series flow data common to both stations and determining a mathematical relationship best fitting the data, an estimate of long-term flow can be determined for the location with only a short record. Regression analysis is used to synthesize data for streams where continuous data are absent.

It is important to select regional streams whose flow regime is similar to Snap Lake outlet

The climatic, geomorphological, vegetation, and other factors which influence runoff rates are considered in selecting a station whose flow data are to be used to generate data for missing periods, or to extend the short-term record to the length of the long-term station.

Streams with different characteristics were eliminated

With the exception of those streams where streamflow gauges are no longer in operation, data from all streams presented in Appendix IX.4, Table IX.4-1 were initially considered for extending flows in the Snap Lake area. Streams with relatively flat hydrographs (a graph showing discharge over time) were eliminated as well as those with very large watersheds or watersheds which were far enough away from the Snap Lake area to be influenced by different climatic conditions. Vegetation cover was also considered.

The Indin and Waldron rivers were considered

Following the evaluation, two streams were considered suitable for flow extensions at Snap Lake. These are the Indin River and the Waldron River, which drain areas of 1,520 km^2 and 1,830 km^2, respectively. The Indin River monitoring station (WSC 07SA004) is located about 200 km northwest of Snap Lake, although its drainage basin extends eastward to within 90 km of Snap Lake. The Waldron River monitoring station (WSC 07SC002) is the closest stream to the Snap Lake outlet that has recorded data. It is located approximately 65 km south of Snap Lake with its northern watershed boundary less than 5 km from the Snap Lake watershed southern boundary.

The Indin River was selected for generating long-term data for Snap Lake

The flow record for the Indin River extends from 1978 to present while the Waldron River record covers the period 1979 to 1994, when flow monitoring at that location was discontinued. Since the current assessment requires coincident data from the long-term and short-term monitoring station to establish the statistical relationship between flows, the Waldron River is not a candidate for flow extension.

Climatic conditions in the Indin River watershed are very similar to Snap Lake

The Indin River drainage shares many hydrological characteristics with the Snap Lake area. Prowse (1990) provides mapped isolines depicting mean annual total precipitation, mean annual total rainfall and snowfall, dates of formation and loss of snowcover, mean maximum depth of snowcover, mean lake evaporation, and mean derived evapotranspiration. All indications are that the Snap Lake area and the Indin River watershed are similarly situated with respect to isolines approximating the above climatic influences. In addition, mean ice thickness is consistent between areas. While the above climatic evaluations are coarse, the information provided above including the nature of the hydrograph does support the use of Indin River flow data to infill and extend the Snap Lake outlet flow record.

Both rivers had similar characteristics

To demonstrate the similarity in the timing of peak events between the Indin River and Waldron River, the daily hydrograph is presented in Appendix IX.4, Figure IX.4-9. Appendix IX.4, Figure IX.4-9 illustrates that in most years there is little difference between the rivers in terms of the timing of peak flows and the receding limb of the hydrograph. Hydrographs from both stations indicate that these streams respond rapidly and are dominated by snowmelt flows. Discharges from both streams are extremely low during the winter months. Snap Lake outflow is also strongly dominated by snowmelt runoff. Winter outflow from Snap Lake has not been evaluated though it is likely that some flow or seepage continues in winter.

9.3.1.4.3 Synthesized Flow Data for the Snap Lake Outlet

Regression and correlation analysis was completed using same time series data from the Indin River and the Snap Lake outflow

Daily discharge data, collected over the periods May 28 to October 6, 1999 and June 23 to October 10, 2000 from the outlet of Snap Lake were compared with the equivalent time series data collected at the Indin River station. A total of 242 data values were used. Several types of curves were fitted to the data; the linear curve proved to best fit the data. Regression analysis was conducted and the results are presented in Appendix IX.4, Figure IX.4-10. The following linear regression equation was derived:

$$y = 0.0276x - 0.0036$$
$$r = 0.937$$

where: y is the station to be extended (Snap Lake outlet), and x is the station record to be used for the extension (Indin River).

While statistical imperfections exist in the regression model, the synthesized flow record is considered to reasonably represent the outflow regime form Snap Lake, and the model will be improved over time

From Appendix IX.4, Figure IX.4-10 it can be seen that several points along the curve occur well below the curve. This is a result of flows not increasing as quickly at the Snap Lake outflow during the first few days of 1999 relative to Indin River flows, due to some attenuation from Snap Lake. However, both streams reached peak flow over the same two-day period. While some assumptions about residuals have been violated, it is appropriate to use regression techniques despite these violations though the resulting regression equation should be applied over the range of data used to develop the curve (Gordon *et al*. 1993). Since the actual streamflow data used to develop the regression are from both a high flow year (1999) and a low flow year (2000), the predicted values are considered reasonable. The data and results are preliminary and will be further refined as more data become available.

A strong flow correlation was found under both high and low flow conditions

The regression equation was used to generate daily flows for the Snap Lake outlet over a 22-year period (1978-2000). The correlation coefficient indicates a strong relationship between measured flows. Actual data collected at the Snap Lake outlet in 1999 and 2000 were substituted for synthesized data in the flow record. Synthesized and actual daily data over the long-term have been used to estimate flood magnitude and frequency, flow duration, and summary statistics for stream discharges at the Snap Lake outlet. Over time, more actual data will replace synthesized data in the flow record.

Long-term flow estimates indicate a mean annual discharge from Snap Lake of 0.215 m^3/s

Appendix IX.4, Table IX.4-10 provides a summary of estimated monthly and annual mean discharges, and extreme values for the Snap Lake outlet. June is typically the month of highest stream discharge while flows are usually lowest in February, March, and April (Appendix IX.4, Table IX.4-10). The estimated mean discharge for the Snap Lake outlet over the period of record is 0.215 m^3/s. Based on the mean discharge and the drainage area of Snap Lake (67.5 km^2), the unit area runoff value is 0.0032 $m^3/s/km^2$. This is comparable with many monitored streams in the region (see Appendix IX.4, Table IX.4-1) and is similar to the Waldron River (0.0035 $m^3/s/km^2$) which is the nearest stream with recorded flow data. Though the Waldron River watershed does have more forest cover, tundra conditions occur over approximately 90% of its watershed. The Snap Lake watershed is primarily tundra with occasional small patches of black spruce in low lying areas. Given the similarity in groundcover, close proximity, similar climate and hydrography (large proportion of lakes and wetlands), and comparable runoff, the synthesized values for Snap Lake outflow appear reasonable.

Measured flows from Snap Lake outlet were among historical high flows for the region

Appendix IX.4, Table IX.4-10 shows that 1999 was a relatively wet year. Mean annual discharges higher than 1999 discharges occurred only in 1984 and 1996 over the 22-year period. Conversely, 2000 was a relatively dry year. Only six years had lower mean annual flows than 2000. The highest daily discharge value from Appendix IX.4, Table IX.4-10 is an actual discharge from June 10, 1999 (2.32 m^3/s). An examination of records from the Lockhart River and the Indin River tend to support this extreme flow. From the Indin River, the peak discharge from 1999 has only been slightly exceeded on two other occasions. At the Lockhart River, the mean discharge for the month of September 1999 has only been exceeded over a four-month period in 1991. All other monthly mean values over the 45-year period of record are lower than the September 1999 value. Flood frequency analysis was carried out for the Lockhart River and Indin River using the annual peak daily discharge values (Table 9.3-27). Peak discharges in 1999 were 239 m^3/s for the Lockhart River and 73.7 m^3/s for the Indin River. In both cases, these values are very close to the 1:10 peak estimates generated from the flood frequency assessment. This further supports the conclusion that measured peak discharge for the Snap Lake outlet flow in 1999 (2.32 m^3/s) was approximately the 1:10 year peak flow.

Table 9.3-27 Flood Frequency Analysis for the Lockhart and Indin Rivers

Return Period (Years)	Lockhart River Peak Daily Discharge (m^3/s)	Indin River Peak Daily Discharge (m^3/s)
1.11	126.0	21.3
1.25	138.6	27.4
2	168.2	41.8
5	208.0	61.2
10	234.4	74.0
20	259.7	86.3

Data from the Thonokied River were reviewed

Data from the Thonokied River, located approximately 120 km northeast of Snap Lake were also reviewed for comparative purposes. The Thonokied River (WSC 07RC001) is a tributary of the Lockhart River; it drains 1,780 km^2 of area located northwest of Aylmer Lake. Streamflow monitoring was initiated by Water Survey of Canada (WSC) on the Thonokied River in 1981 and was discontinued in 1990. Mean discharge over this period was 14.6 m^3/s. Mean annual unit area runoff was substantially higher than any other monitored stream in the region (Appendix IX.4, Table IX.4-1). Peak discharges for the Thonokied River also appear substantially higher than for other streams in the region. WSC records indicate that in 1983 and 1990, peak daily discharges were 161 m^3/s and 168 m^3/s, respectively. On a unit area yield basis, an average of these flows would translate to peak discharges of 6.23 m^3/s for the Snap Lake outlet. This value is approximately three times the measured peak for 1999, which is considered near the 1:10 year peak flow based on other streams in the region. Therefore, Thonokied River flow runoff values do not appear appropriate for Snap Lake outlet estimates.

Winter flows in Snap Lake outlet are estimated to be very low

Although actual measured flow data are not available to verify the following conclusion, it is likely that flows in the Snap Lake outlet may be reduced to a few litres per second or less in winter. Late winter flows in the Waldron and Indin rivers are commonly below the 0.5-0.7 m^3/s range although their drainage areas are substantially larger than that of the Snap Lake outlet (Appendix IX.4, Table IX.4-1). From Appendix IX.4, Table IX.4-10, low winter flows (April) in the Snap Lake outlet may be reduced to 0.0118 m^3/s.

9.3.1.4.4 Historical Water Elevations for Snap Lake

Measured water elevations were compared with same day outflow discharge to define the relationship

Water elevations at Snap Lake were monitored in 1999 and 2000. As expected, outflow discharge is a function of lake elevation. Regression analysis was used to define this relationship. Coincident daily discharge and lake elevation data, collected over the period May 28 to October 6, 1999 and July 9 to October 10, 2000 were compared. The resulting logarithmic regression curve is provided in Appendix IX.4, Figure IX.4-11. The long-term discharge record generated for the Snap Lake outlet discharges was used to generate historic water elevations for Snap Lake. These data are provided in Appendix IX.4, Table IX.4-11.

Lake elevations during the winter are estimated

At present, measured data relating winter water elevation to outflow are not available. Winter elevations are estimated by adjusting the outflow rating curve for the ice-cover condition by reducing the rated discharge for the open-water condition by a factor of 0.62. This factor was determined by the procedures discussed by Watt *et al*. (1989). The winter rating curve is provided in Appendix IX.4 Figure IX.4-12.

Data summaries are provided

Appendix IX.4, Table IX.4-11 provides a summary of estimated annual and monthly mean lake elevations, along with maximum and minimum values on a monthly and daily basis. Summary data from daily values over the open water period are also included in Appendix IX.4, Table IX.4-11.

In a typical year, the difference in maximum and minimum water elevations is estimated at 55 cm

Data from Appendix IX.4, Table IX.4-11 indicate that the mean water elevation is 443.74 masl. On a monthly basis, the average range in lake elevation is estimated at 0.548 m. The mean maximum estimated value over the period of record is 444.03 masl while the minimum estimated water elevation is 443.484 masl.

9.3.1.4.5 Flood Magnitude and Frequency

Both measured and estimated flow data were used to estimate flood magnitude and frequency

Flood magnitude and frequency estimates for the outlet of Snap Lake were obtained by using the annual maximum daily discharges observed in the synthesized data, which were generated by regression analysis using the actual data collected in 1999 and 2000.

Average recurrence intervals of floods were predicted

A probability distribution, log Pearson III, was fitted to a sample of floods that were observed in the data. The estimated parameters were then used to predict average recurrence intervals of floods of selected magnitudes or magnitudes of floods over some period of time.

Flood magnitude and frequency analysis indicates that Snap Lake outflow in 1999 was uncommonly high

Results of the flood frequency analysis are presented in Table 9.3-28. This table describes the exceedance probability, the average recurrence interval, and the flood magnitude. The average recurrence interval is the average length of time between two floods of a given size or larger. The exceedance probability describes the likelihood of a flood of a given magnitude being equalled or exceeded in any given year. For example, a flood event with a magnitude of 2.49 m^3/s may occur, on average, once every 20 years. The probability of a flood of this magnitude occurring in any given year is 5%. Based on the results of this analysis, the peak flow in 1999 (2.32 m^3/s) would have a return period of about 15 years.

Table 9.3-28 Estimate of Flood Magnitude and Frequency for the Outlet of Snap Lake

Exceedance Probability	Average Recurrence Interval (years)	Flood Magnitude (m^3/s)
0.99	1.01	0.25
0.95	1.05	0.42
0.90	1.11	0.54
0.80	1.25	0.72
0.50	2	1.16
0.20	5	1.77
0.10	10	2.14
0.05	20	2.49
0.02	50	2.9
0.01	100	3.19

9.3.1.4.6 Flow Duration Analysis

The proportion of time which flows are expected to exceed a particular level was estimated

The flow duration analysis is another method of representing the historical streamflow record and characterizing streamflow patterns. Flow duration curves are used to describe the relationship between streamflow and the percentage of time in which a specific flow level is exceeded. The flow-duration curve incorporates all of the daily discharge data over the period of record, not just the annual maximum or minimum flows, as is the case with flood or low-flow frequency analysis. In the case of the Snap Lake outlet, 8,401 daily discharge values (1978-2000) were used for the flow duration analysis.

Flows in Snap Lake outlet would exceed 0.1 m^3/s about 50% of the time

The results of the flow duration analysis are presented in Table 9.3-29. This table describes the percentage of time that a given flow volume will be exceeded on a daily basis.

Table 9.3-29 Flow Duration Analysis for Snap Lake Outlet

Duration (%)	Discharge (m^3/s)
1	1.620
2	1.366
5	0.926
10	0.532
20	0.301
30	0.197
40	0.139
50	0.093
60	0.069
70	0.046
80	0.023
90	0.012
95	0.012
98	0.012
99	0.012

9.3.1.4.7 Lake Flushing Rates

Snap Lake has a retention time of about 13 years

Annual stream discharge volumes and lake water volumes were used to calculate theoretical flushing rates for Snap Lake. The estimates for mean annual total discharge were determined through regression analysis as described in the previous sections. Based on the mean annual discharge (0.215 m^3/s) and the volume of Snap Lake (87,021,961 m^3), the total volume would be replaced approximately once every 13 years. As a headwater lake, inflows are derived from local drainage only. The limited amount of inflow available to a headwater lake causes the long retention time.

9.3.1.4.8 Peak Flows from Small Watersheds

Small watersheds tend to generate more runoff from snowmelt or storms and have higher peak flows on a per unit area basis

On a per unit area basis, small watersheds tend to generate more runoff and peak sooner than do larger watersheds in response to a precipitation event or snowmelt. This is partly because the average intensity of a storm event decreases over a larger area. With a small drainage, all portions of the watershed may be contributing runoff at the outlet at the same time. In addition, larger drainage areas may contain lakes and muskeg areas that can attenuate flows and dampen peak discharges. On an annual basis, mean annual flow tends to be a function of drainage basin size.

Measured flows between Snap Lake outflow and its largest tributary were compared

A comparison of unit area runoff values for the Snap Lake outflow and the H4 tributary is provided in Table 9.3-30. Daily data collected over the same time period at both locations are used in the assessment. Streamflow monitoring did not begin until mid-June in 2000, so it is possible that the peak flow period was missed by a few days. Streamflow in 2000 was lower than average for 2000 while 1999 flows were approximately 1 in 10 year peak discharges.

Table 9.3-30 Comparison of Runoff between Snap Lake Outflow and the H4 Tributary

Year	Snap Lake Outflow		Stream H4	
	1999	2000	1999	2000
Drainage area (km$^{2)}$	67.5		7.04	
Mean discharge UAR ($m^3/s/km^2$)	0.0098	0.0022	0.0169	0.0029
Maximum discharge UAR ($m^3/s/km^2$)	0.0343	0.0047	0.0825	0.0051
Minimum discharge UAR ($m^3/s/km^2$)	0.0031	0.0009	0.0018	0.0006

UAR = unit area runoff.

For small basins, peak flows are higher but pass quickly; peaks are dampened but higher flows persist longer in large basins

As can be seen from Table 9.3-30, the H4 drainage area is approximately one tenth the size of the Snap Lake drainage. As expected, on a per unit area basis, maximum runoff in 1999 at H4 is more than double the peak runoff at the Snap Lake outlet, while mean runoff is about 1.7 times greater. Mean and maximum unit area runoff values are comparable between streams in 2000. Snap Lake outflow minimum flows are substantially higher than at H4 in both years. On an annual basis it is likely that total flow volumes are similar as Snap Lake outflow likely persists over the winter, while flows from H4 are expected to freeze off.

Peak flows for the watersheds on the northwest peninsula could be underestimated

The application of flood magnitude and frequency, previously generated for the Snap Lake outlet, would likely underestimate peak flows for small watersheds. Most of the watersheds on the northwest peninsula where mining facilities will be constructed are smaller than 1 km^2, and many are only several hectares in size.

Runoff was not measured because stream channels were undefined

Given the difficulty in measuring runoff from small watersheds, particularly when stream channels are not well defined, no site-specific data are available for watersheds in the 1 to 100 ha size range. Due to this uncertainty, a conservative approach is used for estimating runoff.

Peak flood magnitude and frequency for small basins were estimated conservatively

For small basins in the Snap Lake area, peak flood magnitude and frequency data have been estimated (Table 9.3-31). The estimates were generated using a snowmelt model based on the degree day method. The model was calibrated by matching the simulated flood peak discharges and snowmelt runoff volumes with the measured flood peak discharges and snowmelt runoff volumes of seven small watersheds near the Diavik Diamond Mine, located approximately 115 km north of Snap Lake (Golder 1998). The model results do not account for overland and channel routing and assume that concentration times are less than one day. In addition, it does not account for storage of meltwater in the snowpack, soils, or in small lakes.

Table 9.3-31 Runoff From Natural Surfaces at the Snap Lake Diamond Project Site

Parameter	Value[1]
Small basin 2 year wet water yield	273 mm
Small basin 10 year wet water yield	353 mm
Small basin 100 year wet water yield	458 mm
Small basin 2 year flood	$Q = 1.60\ A^{0.537}$ (Q in m^3/s; A in km^2)
Small basin 10 year flood	$Q = 2.85\ A^{0.537}$ (Q in m^3/s; A in km^2)
Small basin 100 year flood	$Q = 3.20\ A^{0.537}$ (Q in m^3/s; A in km^2)

[1] – Based on runoff analysis.

Model results are unlikely to underestimate runoff

Despite these limitations, the modelled results are considered appropriate for purposes of site design as they are unlikely to underestimate flows even for watersheds which exhibit optimum high snowmelt runoff conditions. Annual runoff for wet years under various return periods and surface types are also provided (Table 9.3-32).

Table 9.3-32 Runoff From Various Types of Disturbed and Reclaimed Surfaces at the Snap Lake Diamond Project Site

Surface	Annual Water Yield	Rational Method Runoff Coefficient[3]
Mine and plant site[1] Roads[1] Rock and paste stockpiles[1]	2 year: 324 mm 10 year: 419 mm 100 year: 543 mm	0.95
Reclaimed surface[2]	2 year: 273 mm 10 year: 353 mm 100 year: 458 mm	Use small basin equations from Table 9.3-31

[1] – Based on conservative estimate.
[2] – Based on Diavik runoff analysis.
[3] – For use with rainfall intensities from Table 9.3-14.

9.3.1.4.9 Lake Ice

Snap Lake ice regime was modelled with models used for Diavik

Snap Lake is covered by ice for approximately eight months of the year. The ice regime of Snap Lake is composed of the lake freeze-up, ice cover thickness, ice cover duration, and ice break-up. To estimate these parameters for Snap Lake, a series of models which were used to estimate conditions at the Diavik Diamond Mine were applied using site specific temperature data for the Snap Lake area (Golder 1997a).

A lake temperature, ice cover formation, and ice cover decay models were used

A lake temperature model was used to equate heat loss from the lake to heat gain from the atmosphere. The daily lake temperature was simulated based on air temperature generated for the project site. Once the lake temperature was reduced to 2ºC, it was assumed that the lake surface temperature would be 0ºC and that ice cover formation would begin. An ice cover formation model which accounts for heat conduction was used to simulate the growth of lake ice cover. The total heat flux through the ice and snow is a summation of the heat flux from the warm water below and the latent heat loss as a result of ice formation. The model was simulated from July 1 to the date of maximum ice cover thickness. The ice cover decay model is a variation of the ice cover formation model and is used after the maximum seasonal ice cover thickness was predicted using the ice cover formation model.

On average, Snap Lake is ice covered for 224 days per year and maximum ice thickness is 1.6 m

The ice cover formation and decay models were used to conduct simulations for the period 1942 to 2000. Summary statistics related to ice cover duration and thickness are provided in Table 9.3-33. In the Snap Lake area, the mean date of freeze over is October 11 and the mean date of ice melt is June 6. The mean number of ice-covered days is 224. Ice thickens gradually over the winter with the mean maximum ice thickness of 1.6 m typically occurring in April.

Ice thickness and freeze over dates for Snap Lake are consistent with regional values from small lakes

The data presented in Table 9.3-33 are consistent with regional values. In late April and early May of 1996, an ice thickness survey was conducted at 54 small lakes in the Diavik area (Golder 1997b). Of these lakes, 28 were frozen to the bottom. Mean, maximum and minimum ice thickness values for the remaining lakes are 1.59 m, 1.82 m, and 1.24 m, respectively (Golder 1997b). Isoline maps depicting maximum ice thickness and mean freeze-over dates are also in close agreement with the values presented in Table 9.3-33 (Prowse 1990).

Table 9.3-33 Estimate of Lake Ice Occurrence, Duration, and Thickness for Snap Lake

Event	Earliest Date	Mean Date	Latest Date
First occurrence of permanent ice	10-Sep	11-Oct	4-Nov
Complete lake freeze over	24-Sep	18-Oct	10-Nov
Beginning of ice-cover season	24-Sep	14-Oct	7-Nov
First occurrence of ice deterioration	15-Apr	14-May	8-Jun
Lake water clear of ice	4-May	6-Jun	30-Jun
End of ice-cover season	24-Apr	26-May	19-Jun
Item	**Minimum**	**Mean**	**Maximum**
Maximum ice cover thickness (m)	1.211	1.569	1.900
Date of occurrence of maximum ice cover thickness	2-Apr	30-Apr	27-May
Duration of ice-cover season (days)	183	224	255
Month	**Monthly Ice Cover Thickness (m)**		
	Minimum	**Mean**	**Maximum**
January	0.77	1.06	1.42
February	0.95	1.29	1.63
March	1.09	1.45	1.79
April	1.19	1.53	1.87
May	0.04	1.22	1.84
June	0.00	0.23	0.97
July	0.00	0.00	0.00
August	0.00	0.00	0.00
September	0.00	0.00	0.10
October	0.00	0.13	0.54
November	0.21	0.45	0.98
December	0.51	0.77	1.19

9.3.2 Impact Assessment

9.3.2.1 Introduction

Two key questions were derived

The impact assessment describes the "impact on water quantity, including changes in timing, volume, and deviation of peak and minimum flows resulting from the developments", as required by the EA Terms of Reference (Table 9.1-1 in Section 9.1) The key questions for assessing the impact of the Snap Lake Diamond Project on surface water hydrology and suspended solids identified from the project description and the Terms of Reference are as follows:

Key Question H1: What impacts will the Snap Lake Diamond Project have on near-surface water tables and flows, and water levels in receiving streams, lakes, and wetlands?

Key Question H-2: What impacts will the Snap Lake Diamond Project have on sediment yields and sediment concentrations in receiving streams, lakes, and wetlands?

These key questions provide a systematic framework to present the impact analysis results and assess the residual impacts.

The impact is assessed using a series of steps

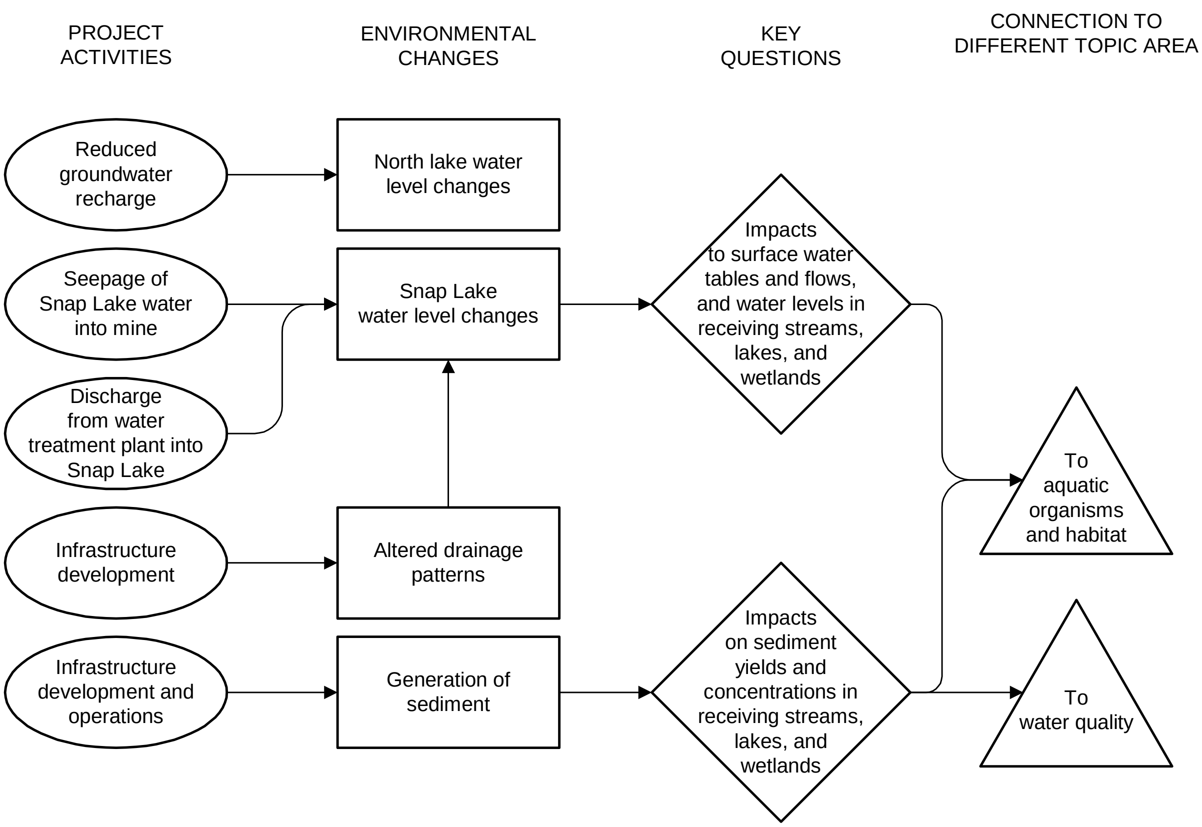
The key questions are addressed by quantifying the incremental impacts of the Snap Lake Diamond Project on the surface water hydrologic conditions using the following methodology:

- identify the linkage of various project activities with the area hydrology and determine if the linkage is valid;
- describe mitigation measures to minimize residual effects on the environment;
- conduct hydrologic analysis to quantify the residual impacts on the surface water hydrology;
- classify the residual impacts; and,
- recommend monitoring, if necessary.

Changes in runoff patterns will occur around mine facilities and storage areas

The development of the Snap Lake Diamond Project will result in some disturbance to the hydrologic systems in the Snap Lake drainage during various phases of the project including construction, operation, and closure. Figure 9.3-15 summarizes the main links and pathways by which surface waters could be impacted by project activities.

Figure 9.3-15 Hydrology Linkage Diagram



9.3.2.2 Key Question H1: What Impacts Will the Snap Lake Diamond Project Have on Near-surface Water Tables and Flows, and Water Levels in Receiving Streams, Lakes, and Wetlands?

9.3.2.2.1 Linkage Analysis

The underground workings and the surface infrastructure will alter the hydrology

Development of both the surface facilities and the underground mine have the potential to affect the near surface water tables and flows and water levels in receiving lakes and streams.

- The operation of the Snap Lake Diamond Project will result in changes to surface water flow patterns on the northwest peninsula in the immediate area of the process plant and the north pile. Natural drainage paths will be disrupted to construct surface facilities. Runoff from these areas will be contained and treated, prior to release to Snap Lake, during the construction, operation, and closure phases.

- Minewater pumped from the underground workings is by far the largest component of releases from the project to Snap Lake. As mining progresses, up to 95% of the water pumped from the underground workings may originate from the lake (Section 9.2). Seepage of Snap Lake water into the mine and discharge of treated mine water into Snap Lake combine to form a recycling process.
- Road and airstrip construction could potentially interrupt or delay drainage.

The linkage is valid

Therefore, the linkage between the Snap Lake Diamond Project development and the key question is considered valid.

9.3.2.2.2 Mitigation

Runoff from the project site, including the north pile will be collected and released to Snap Lake following treatment

Mitigative measures for changes in flows and water levels are inherent in the water management process. Under baseline conditions, runoff from the mine footprint area of the northwest peninsula drains directly to Snap Lake. During the operations period, drainage from the surface facilities, adjacent areas and the north pile will be collected and directed to the water treatment plant prior to release in Snap Lake.

Runoff from the northwest peninsula will be returned to Snap Lake

Drainage from the north pile passes through one or more of three small ponds around the perimeter and several sumps prior to pumping to the water treatment plant. Runoff that reported to Snap Lake from the northwest peninsula under baseline conditions will continue to flow to the lake during operations, although it will flow through an engineered water management system to ensure that water quality objectives will be met.

Most of the treated minewater released to Snap Lake is seepage to the underground workings from Snap Lake

Estimates from the GoldSim model (Appendix IX.1) indicate that as mining progresses, a greater proportion of the water seeping into the mine will originate from Snap Lake, and the connate water contribution will be reduced. Following treatment, mine water will be returned to Snap Lake. Seepage losses from the lake to the mine will be balanced with treated minewater outflows so that consequential changes in water elevation or outflow from Snap Lake will be minimized (refer to Section 3.6.3 for the water balance).

Culverts will be sized correctly

To maintain natural flow patterns and eliminate potential flow impediments due to road and airstrip construction, culverts would be installed to provide cross drainage. Culvert requirements will be identified during detailed engineering. If required, culverts would be installed at all defined drainage paths and low points along road and airstrip profile to ensure that natural drainage directions are maintained. Culverts would be sized appropriately, allowing excess capacity during more common high flow periods. Care would be taken to ensure that channels upstream and downstream of the crossing are stable and not subject to erosion.

Surface runoff from the north pile will be apportioned to supply adjacent waterbodies

To minimize erosion by wind or precipitation from the north pile, a surface cover will be developed for the north pile. Most of the north pile containment area occurs over three small watersheds (H, K, and O). As much as possible, the surface of the cover will be contoured to direct surface runoff such that the approximate size and orientation of the natural drainage areas will be re-established on the north pile surface. The intention is to apportion surface runoff in order to supply sufficient flow to maintain adjacent small lakes and wetlands at the approximate pre-mining water elevations.

9.3.2.2.3 Impact Analysis

Project water balance data are compared with natural lake elevations and outflow

The potential effect on Snap Lake water elevations and outflow discharges is evaluated by comparing predicted water balance parameters with the natural flow regime occurring at the outlet of Snap Lake. Estimates of baseline outflow and corresponding lake elevations are presented in Section 9.3.1.4.

Snap Lake Outflow

The project water balance accounts for incoming and outgoing flows in Snap Lake

The results of the project water balance calculations define the flow rates from the minesite that are planned for release to Snap Lake over the life of the project. Project related inflows to Snap Lake will be balanced against reduced lake volumes due to seepage from Snap Lake to the mine. Some runoff from portions of small watersheds occurring on the mine footprint will be intercepted and transferred to the water treatment plant, thus direct runoff to Snap Lake will be reduced according to the proportion of the sub-basin from which flows are contained. A further consideration is the increased runoff from portions of sub-basins due to land-use changes. Soil compaction for construction purposes in the case of the airstrip and roads will result in higher runoff coefficients than coefficients for natural surfaces. Other water balance parameters such as precipitation and evaporation need not be considered because measured streamflow data include net precipitation.

Water balance information was generated for the representative periods of the project

Water balance data were generated on a monthly basis covering three representative periods of mine development over the life of the project. These periods are: year 1 (construction), year 6 (early operation), and years 17-22 (late operation). Table 9.3-34 provides a summary of water balance parameters under baseline conditions and over the periods indicated. Appendix Tables IX.4-12 to IX.4-14 provide more detailed data on a monthly basis. Appendix Figures IX.4-12 to IX.4-14 compare baseline flows with operational flows in year 1, 6, and 17-22.

Table 9.3-34 Summary of Snap Lake Water Balance Parameters Over Selected Periods

Year	Total Project Flow to Snap Lake (m^3/s)	Minewater Pumping (m^3/s)	Site Runoff Collection Outflow (m^3/s)	Snap Lake Natural Outflow (m^3/s)	Snap Lake Operations Total Outflow (m^3/s)	Loss to Snap Lake via GW Recharge (m^3/s)	Changes in Surface Runoff Rates (m^3/s)	Total Loss at Snap Lake Outflow (m^3/s)	Net Snap Lake Outflow (m^3/s)	Change in Snap Lake Outflow (m^3/s)	Change in Outflow (%)
	Factors that Increase Outflow					Decrease Outflow			Net Changes		
Year 1	0.075	0.072	0.0038	0.215	0.290	0.055	0.0013	0.056	0.234	0.019	8.8
Year 6	0.248	0.243	0.0049	0.215	0.463	0.216	0.0013	0.217	0.245	0.030	14.4
Year 17-22	0.226	0.217	0.0091	0.215	0.441	0.209	0.0013	0.210	0.231	0.016	7.4

Potable water is not included

A description of water balance parameters evaluated in Table 9.3-34 has been broken down into the parameters that result in increased flows to Snap Lake and those that reduce outflow. Withdrawal and release of potable water is not included in the calculation since these volumes are essentially the same and do not result in any net change in Snap Lake.

Factors that increase flow to Snap Lake are defined

Increased flow to Snap Lake from the project and the source of the flow data are identified under the following headings:

- **Total project flow to Snap Lake** – total releases to Snap Lake including treated minewater and site runoff. Data are from the GoldSim model which incorporates the site water balance estimates with the results of groundwater modelling (Appendix IX.1).
- **Minewater pumping rate** – indicates groundwater pumped to surface from the underground workings (GoldSim model).
- **Site runoff collection outflow** – runoff collected from site facilities that are treated and released to Snap Lake (GoldSim model).
- **Snap Lake natural outflow** – estimated long term outflow from Snap Lake under baseline conditions (Appendix Table IX.4-10).
- **Snap Lake operations total outflow** – combined project related releases and natural outflows from Snap Lake before losses are calculated.

Factors that reduce flow from Snap Lake are defined

Factors that result in reductions in outflow from Snap Lake and the source of the flow data are identified under the following headings:

- **Loss to Snap Lake via groundwater recharge** – the rate of loss from Snap Lake due to seepage to the mine underground workings (GoldSim model).
- **Loss of flow from intercepted drainage** – indicates changes in runoff from sub-basins influenced by mine activities on and near the footprint area. Data are provided in Table 9.3-35. The locations of sub-basins are noted on Figure 9.3-16.
- **Total loss at Snap Lake outflow** – combined losses from changes in surface runoff inflow and seepage losses from Snap Lake (GoldSim model).

Figure 9.3-16 Location of Drainage Area Boundaries and Mine Facilities and Storage Areas

Table 9.3-35 Changes to Runoff Rates for Watersheds in the Vicinity of the Snap Lake Mine

Watershed	Total Drainage Area (km^2)	Drainage Area Isolated (km^2)	Net Drainage Area (km^2)	Natural Runoff (L/s)	Operations Runoff (L/s)
A	0.035	0.002	0.033	0.113	0.106
B	0.036	0.000	0.036	0.115	0.115
C	0.120	0.056	0.064	0.383	0.205
D	0.018	0.001	0.017	0.057	0.054
E	0.090	0.066	0.024	0.288	0.078
F	0.064	0.000	0.064	0.206	0.205
G	0.068	0.017	0.052	0.219	0.165
H	0.300	0.200	0.100	0.959	0.319
I	0.347	0.258	.0.89	1.111	0.286
J	0.081	0.033	0.048	0.260	0.155
K	0.118	0.100	0.017	0.376	0.056
L	0.385	0.010	0.375	1.231	1.471
M	0.044	0.005	0.039	0.141	0.125
N	0.121	0.032	0.089	0.386	0.285
O	0.890	0.890	0.000	2.849	0.000
P	0.866	0.048	0.818	2.771	3.040
Q	2.645	0.000	2.645	8.464	9.35
R	0.654	0.000	0.654	2.093	2.280
S	7.045	0.00	7.045	22.543	25.000
Total	**13.927**	**1.72**	**12.0**	**44.57**	**43.29**

See map Figure 9.3.16 for drainage area locations.

Potential changes to Snap Lake outflow are calculated in three ways

Changes to the outflow from Snap Lake after accounting for gains and losses to the system are defined below:

- **Net flow from Snap Lake outlet** – net outflow from Snap Lake during operations. Combines gains and losses with natural flow levels to estimate stream discharge from Snap Lake over the operations period.
- **Change in Snap Lake outflow –** indicates change in flow rate from baseline conditions to the operations period.
- **Change in Snap Lake outflow –** indicates outflow change from baseline conditions on a percentage basis.

There will be a net increase in Snap Lake outflow because of the project

As can be seen from Table 9.3-34, estimates indicate a net increase in outflow for all operations periods as project inflows exceed recharge losses by a small margin.

Snap Lake Water Elevation

Changes to Snap Lake elevation were derived

Lake elevation and outflow are closely related as indicated by the regression model provided in Appendix IX.4, Figure IX.4-11. Changes in Snap Lake water elevation are derived using the regression equation and lake outflow estimates.

Project operations are expected to increase water elevations by a small margin in Snap Lake

Table 9.3-36 provides a summary of estimated changes to lake elevations. A comparison of baseline lake elevation and predicted lake elevations during operations is based on the change in outflow and the statistical relationship, previously established, between outflow and lake elevation. Mean annual lake elevations are expected to increase by a small margin in each of the representative periods. Increases range from 3.3 cm in years 17-22 to 5.3 cm in year 6. The largest monthly increase is expected to occur in April when lake elevations may remain approximately 14 cm higher than mean baseline conditions (Appendix IX.4-14). In June, project related flow increases are so small relative to the high outflow normally occurring during that time of the year, that there would be little change expected from baseline elevations (Appendix IX.4, Tables IX.4-12 to IX.4-14).

Table 9.3-36 Summary of Snap Lake Elevations Over Project Operations

Year	Natural Lake Elevation (masl)	Operations Lake Elevation (masl)	Net Change in Lake Elevation (m)
Year 1	443.770	443.812	0.042
Year 6	443.770	443.823	0.053
Year 17-22	443.770	443.802	0.033

North Lake Water Elevation and Outflow

Inflow losses to lakes outside the Snap Lake watershed are expected to be small

The north lake, located approximately 2.5 km directly north of the west arm of Snap Lake, (Figure 9.2-3) receives approximately 2,700 cubic metres per day (m^3/d) from Snap Lake via groundwater inflows (Section 9.2). Groundwater modelling has indicated that in the worst case, this inflow to the lake may be reduced by 800 m^3/d to 1900 m^3/d in the final years of operation. This is expected to result in a small reduction in the north lake water elevations and outflow, and a similar but smaller change to the northeast lake which occurs about 700 m downstream of the north lake (Figure 9.2-3). While the northeast lake receives about 800 m^3/d via groundwater recharge from Snap Lake, this volume is not expected to be reduced by mining operations. Changes to the northeast lake result from slightly reduced outflow from the north lake. Groundwater modelling predicts that there will be no change in groundwater recharge to other lakes in the LSA.

Changes in the north lake outflow are estimated using a water balance approach

The north lake is a headwater lake in the adjacent drainage area north of the Snap Lake drainage. At present, there are no direct measurements of outflows or water elevation available for the north lake. Consequently, no lake elevation-outflow rating curves are available. However, an assessment of potential changes can be made using a water balance approach to provide an estimate of baseline outflow, and changes due to reduced groundwater inflow. Changes in lake elevation can be approximated by subtracting the annual volume change distributed over the surface area of the lake. Calculations of flow estimates are provided in Appendix Table IX.4-15.

Estimates indicate that changes in mean water elevation for the north lake would be approximately 3 cm

Based on the water balance assessment provided in Appendix Table IX.4-15, mean annual north lake outflow will be reduced by approximately 8% from 3,669,670 m^3 (0.116 m^3/s) to 3,377,670 m^3 (0.107 m^3/s). Groundwater recharge will be reduced by approximately 292,000 m^3 annually. Since 292,000 m^3 is equivalent to 292 cubic decametres (dam^3) and 1 dam^3 covers 1 km to a depth of 1 mm, it follows that 292 dam^3 over the north lake surface area (9.54 km^2) amounts to 30.6 mm. Based on this rationale, the reduction in lake elevation at the north lake would be approximately 3 cm. A similar assessment was conducted for the northeast lake in Appendix IX.4, Table IX.4-15 which indicated that outflow from that lake would be reduced by about 2 %, with a corresponding decrease in lake elevation of approximately 1.6 cm.

Reduced groundwater recharge would likely have the greatest effect on outflow during winter

It is expected that since groundwater recharge is quite static over time, groundwater flows likely contribute a large proportion of inflow to the lake during winter. Thus, reduced groundwater recharge would have the greatest effect on outflow during this season. Groundwater would comprise a relatively small portion of outflow during the spring and early summer high flow period.

Project Site Drainage

Mining activity will disrupt runoff patterns for small sub-basins near mining facilities and storage areas

Construction and mining activity will disrupt natural flow patterns over portions of the northwest peninsula. Figure 9.3-2 depicts the Snap Lake drainage area and indicates the location and size of sub-basins A through AA. The sub-basins are defined as drainage areas with no defined stream channel or point of entry to Snap Lake. As no mining activity or construction is proposed in sub-basins T through Y, little surface disturbance is expected in these areas and changes in runoff are not anticipated. Varying degrees of drainage alteration are expected to occur within sub-basins A through S and are largely a function of the proportion of the sub-basin that has been disturbed to construct surface facilities. In most cases, drainage patterns will be interrupted by intercepting runoff from disturbed areas, and redirecting these flows to the water treatment plant, prior to release to Snap Lake. Runoff from small portions of sub-basins L, P, Q, R, and S will increase by a small margin due to higher runoff from the airstrip, laydown areas, and near the bulk emission plant (Figure 9.3-16).

Culverts will provide cross-drainage at low points along the emulsion plant access road

Runoff from the airstrip, emulsion plant, and the access road to the emulsion plant will not be contained. Cross-drainage structures will be installed at low points in the road profile, if necessary, to ensure that runoff continues along natural drainage paths and that ponding does not occur upstream.

The change in flow volume from small sub-basins is proportional to area of runoff containment

Figure 9.3-16 details the sub-basin boundaries occurring on and adjacent to the northwest peninsula and indicates the location of mine facilities and storage locations within each sub-basin. The degree of disturbance ranges from nearly the entire sub-basin (*i.e.*, sub-basin O) to no disturbance (*i.e.*, sub-basin B). Disturbed portions of other sub-basins on the northwest peninsula range between the two extremes.

The flow of runoff from sub-basins was evaluated

To assess the effect of contained runoff from portions of individual sub-basins on drainage volume, and the impact of this flow interruption on Snap Lake water balance, the following evaluation was undertaken. Total areas of sub-watersheds were determined using 1:17,500 scale contour maps developed for the project. Project facilities and storage areas were superimposed on the drainage map using the computer application AutoCAD to determine the extent of disturbed areas within each sub-basin. The unit area runoff value (0.0032 $m^3/s/km^2$) for the Snap Lake drainage area was used to estimate changes in runoff based on the remaining sub-basin area, once isolated portions were subtracted from the total sub-basin area. In some cases, where local topography directs runoff from undisturbed portions to areas where runoff is contained, the area of intercepted drainage may exceed the actual disturbed area.

An increase in runoff is expected from areas where surfaces have been compacted

Increased runoff from compacted surfaces in sub-basins L, P, Q, R, and S was estimated by applying a precipitation-runoff coefficient of 0.95 to the measured areas occupied by the airstrip, laydown areas, roads, and the bulk emulsion plant. Runoff from the remaining portions of these sub-basins was calculated using the unit area yield value of 0.0032 $m^3/s/km^2$.

Natural runoff rates were compared with predicted flows during the operational period

Table 9.3-35 provides the total drainage area for sub-basins A through S and indicates the area of contained runoff. The change in runoff from baseline conditions to full development by sub-basin is predicted by comparing the estimated natural runoff rate per unit area, with the adjusted runoff rate given that portions of sub-basins are isolated from natural drainage paths. In both cases, runoff is based on the mean annual runoff value (0.0032 $m^3/s/km^2$), previously estimated for the Snap Lake drainage.

Changes in runoff volume and flow direction is substantial for some sub-basins although the overall change is small

From Table 9.3-35, the total area of sub-basins A through S is 13.9 km^2 while the total disturbed area is approximately 1.9 km^2. Though runoff from the airstrip, emulsion plant, and the access road to the emulsion plant is not contained, the remaining disturbed area plus runoff from undisturbed areas that flow to contained areas equals 1.7 km^2. Runoff flow paths over the remaining 12.2 km^2 are not expected to change during project operations, though runoff rates will be increased over portions of sub-basins watersheds L, P, Q, R, and S due to surface compaction. In total, combined runoff from sub-basins A through S may be reduced from 44.6 L/s to 43.3 L/s during operations. While the reduction of flows reporting to Snap Lake may be considerable for some sub-basins, where project infrastructure occupies a large portion of the sub-basin, the overall reduction in runoff (1.3 L/s) is quite small and is more than offset by release of treated runoff collected from the contained areas.

9.3.2.2.4 Residual Impact Classification

Definition of Streamflow Effects Criteria

Changes in mean discharge and water level are the basis of the classification

The parameters used to characterize the hydrological conditions (*i.e.*, water quantity) at Snap Lake and its outflow, as well as other lakes and streams in the LSA, are mean discharge and water level. The predicted future changes to these parameters are compared to estimated baseline values to derive the percent change. This provides a general basis for classifying the magnitude of the effect of the proposed project on water quantity. The criteria for determining the magnitude are provided in Table 9.1-2.

Snap Lake Outflow

Comparisons between baseline and operations period mean annual outflow indicate a low magnitude of change

The predicted changes from baseline flow conditions at the Snap Lake outlet are increases of 8.8%, 14.4% and 7.4% in year 1, year 6 and during years 17-22, respectively. According to the general magnitude classification scheme described in Section 9.1, the changes in year 1 and years 17-22 are considered low in terms of magnitude. Year 6 changes are classified moderate. The magnitude of potential change to stream channels and lake shorelines is likely overstated. While the percentage change in mean annual flow are accurate, they do not consider the natural range in flows within and among years. From Appendix Table IX.4-10, mean annual discharges range from 0.106 m^3/s to 0.405 m^3/s over the period of synthesized data. Within years, mean monthly flows range from 0.018 m^3/s in late winter to 0.937 m^3/s during spring runoff. While project related flow increases are expected to increase mean annual discharge from the baseline value of 0.215 m^3/s to 0.234 m^3/s, 0.245 m^3/s, and 0.231 m^3/s in years 1, 6, and 17-22, respectively, peak flow increases are negligible. Appendix Figures IX.4-12 to IX.4-14 depict the mean annual hydrograph. These figures illustrate that flow increases occur primarily during the winter period when discharges are normally very low.

Negligible increases in peak flow during the spring runoff would not affect channel morphology

Stream channel morphology is typically controlled by relatively common high flow events. The 1:2 year flood flow is statistically related to the bankfull discharge, which forms and maintains the channel and moves most of the sediment over time. During the spring runoff period (June), the percent change is near zero in each of the assessed time periods. The spring runoff period is typically the only time when discharges may be expected to reach bankfull levels and affect channel morphology. Since changes in flow are lowest over the higher range in the hydrograph, with operations flows virtually indistinguishable from baseline conditions, it is highly unlikely that changes in channel morphology would result from the negligible increases predicted for the high flow period. Small increases in flow during low flow periods are insufficient to cause any channel modification. Therefore, the magnitude of increased flows on channel geomorphic conditions is considered negligible. The impact will occur in the LSA. It will occur during operations, but it will be reversible in the short-term. At the completion of mining, baseline flow conditions will return. The environmental consequence will be negligible. Classification of residual impacts is provided in Table 9.3-38.

Snap Lake Water Levels

Snap Lake water elevations are expected to increase by a small margin

On an annual basis, predicted increases in water levels at Snap Lake range from 3.3 cm to 5.3 cm over the operations period (Appendix IX.4, Tables IX.9-12 to Appendix Tables IX.4-14). Similar to outflow, the maximum changes are expected in the winter where a 14.4 cm increase is predicted in the late winter months of year 1. However, as this increase occurs during a month when levels are naturally low, the increase is still well below the mean flow.

Table 9.3-38 Classification of Residual Impacts on Near Surface Water Tables and Flows, and Water Levels in Receiving Streams, Lakes, and Wetlands

Watershed	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Consequence
Snap Lake outflow	negative	negligible	local	medium-term	high	reversible (short-term)	negligible
Snap Lake elevation	negative	negligible	local	medium-term	high	reversible (short-term)	negligible
North lake outflow	negative	low	local	medium-term	high	reversible (short-term)	low
North lake elevation	negative	negligible	local	medium-term	high	reversible (short-term)	negligible
Northeast lake outflow	negative	negligible	local	medium-term	high	reversible (short-term)	negligible
Northeast lake elevation	negative	negligible	local	medium-term	high	reversible (short-term)	negligible
Sub-basins A - S	negative	negligible	local	medium-term	high	reversible (short-term)	negligible

Increases in the mean Snap Lake water elevation is expected to be negligible

As the mean depth of Snap Lake is approximately 5 m, the percent change in mean lake level in year 1, 6, and 17-22 is 0.84%, 1.06%, and 0.66%, respectively. According to the magnitude criteria in Table 9.1-2, the changes are considered negligible. The overall effect of the project on lake elevations is that low water elevations will not be quite as low as under normal conditions, while high water elevations will not change measurably. Thus, the annual range in lake elevations is slightly decreased. The effect will be local, medium-term and reversible in the short-term. The environmental consequence is, therefore, negligible.

North Lake and Northeast Lake

Small changes in water elevation and outflow may occur in the last years of mining at the north and northeast lakes

In the last years of mining, the predicted change in the mean annual outflow is a decrease of approximately 8% for the north lake and 2% for the northeast lake. Thus, the magnitude is considered low for the north lake and negligible for the northeast lake.

The magnitude of change in lake elevation in the north and northeast lakes is considered negligible

While the mean depth is unknown for both the north lake and the northeast lake, they are believed to be substantially shallower than Snap Lake. Assuming a mean depth of 2 m for both lakes, the estimated decrease in mean annual water elevation for the north lake is 3 cm, while decreases in the northeast lake are estimated to be 1.6 cm. The percent change in mean lake elevation is estimated at 1.5% for the north lake and 0.8% for the northeast lake. The magnitude of these changes are considered negligible in both cases. Two small lakes occur along the stream draining the north lake to the northeast lake. These lakes are NL5 and NL6 (Figure 9.2-13). While these lakes would not be affected by changes in groundwater recharge, inflow and water elevations would decrease by a small margin due to reduced inflow (8%) from the north lake. The changes to the north and northeast lakes will occur during operation when groundwater is drawn into the mine workings. This effect on groundwater and, therefore, the lakes to the north is reversible in the short-term when the mine is flooded. The environmental consequences to the north and northeast lakes are negligible, except north lake outflow, which has a low environmental consequence.

Sub-basins A through S

Overall, the change in runoff from watersheds draining the northwest peninsula is expected to be very small

There will be large changes in runoff volumes for some small sub-basins located on the mine footprint area. Runoff from substantial portions of some of these watersheds will be intercepted and treated prior to release in Snap Lake resulting in reduced runoff. This is partly offset by increased runoff due to surface compaction in portions of other sub-basins. While the net change in inflow to Snap Lake from these watersheds is expected to be very small, the flow patterns and runoff volumes will be altered in many of these sub-basins. Overall, intercepted runoff around mine facilities and increased runoff due to land use changes from the combined sub-basin areas A through S will reduce direct inflow to Snap Lake by approximately 1.3 L/s, a change of 2.9%. The magnitude of the change in flow volume from sub-basins occurring on the northwest peninsula is classified as negligible.

Drainage areas and flow direction will be reestablished during decommissioning

At the conclusion of mining, the intention is to contour the disturbed area to reestablish pre-mining drainage areas and flow directions. Based on the magnitude described above and the other criteria shown in Table 9.3-38, the environmental consequence of the impact to flow from these sub-basins is considered to be negligible.

9.3.2.2.5 Monitoring

The current surface hydrology monitoring program will be continued

Currently, stream discharge at the outlet of Snap Lake and lake elevation monitoring are conducted on a continuous basis during the open water season. This monitoring program will be continued over the over the period of operations.

9.3.2.3 Key Question H-2: What Impacts Will the Snap Lake Diamond Project Have on Sediment Yields and Sediment Concentrations in Receiving Streams, Lakes, and Wetlands?

9.3.2.3.1 Linkage Analysis

Some facilities and disturbances are expected to increase sediments

The Snap Lake Diamond Project facilities that have potential to affect sediment yields and sediment concentrations in receiving streams, lakes, ponds, and wetlands are the plant sites, the north pile area, access roads and airstrip, and laydown areas. These linkages are illustrated in Figure 9.3-15. The disturbed, less pervious surfaces adjacent to plant sites and support facilities including the processed kimberlite, WMP, roads, containment area, and the airstrip have the potential to generate elevated levels of suspended solids in surface runoff. In general, the disturbance of streambed and banks during construction of road crossings has the potential to increase sediment loads downstream.

Linkage is valid

Therefore the linkage between the Snap Lake Diamond Project and Key Question H-2 is valid.

9.3.2.3.2 Mitigation

Mitigation is planned

To minimize the potential impacts of elevated suspended solids concentrations in receiving streams, lakes, ponds, and wetlands, the following mitigation is planned and will be implemented as part of the overall project water management plan (Appendix III.4).

Site runoff will be contained and treated prior to release in Snap Lake

Runoff from the core surface facilities, including roads on site, developed areas, and adjacent undeveloped areas will be retained and transferred to the water treatment plant. This will ensure that runoff containing elevated suspended solids is not discharged directly to Snap Lake.

Settling ponds and water treatment will reduce suspended solids levels from the north pile area

During operations, water from the north pile area will be directed to sedimentation ponds to reduce the total suspended solids content before being pumped to the water treatment plant prior to release to Snap Lake. Runoff will pass through one of or all three small waterbodies that occur along the north pile area boundary. These lakes will serve as settling ponds and runoff storage reservoirs. They will be maintained at low water elevations to prevent any flow from leaving the flow circuit prior to reaching the sump that transfers the flow to the water treatment plant.

The access road, airstrip, and laydown areas are located near drainage divides to minimize water volumes contacting disturbed surfaces

There is potential for runoff, which flows in ditches and through culverts, to contain elevated suspended sediment concentrations. Runoff from the access road to the emulsion plant, the airstrip, and laydown areas is not collected and treated. Mitigation for elevated suspended solids from these sources largely relates to road route selection and the site location for the airstrip and laydown areas. The intention is to locate these developments near the top of drainage divides so that little water from upslope will contact the disturbed surfaces. In addition, suspended solids in the runoff from these disturbed surfaces will be deposited near the source since little water is generated near the drainage divide for sediment transport. Sediment traps will be installed along low-lying areas of roads. Water that overflows from the trap will have reduced suspended solids.

Suspended solids concentrations will be reduced as runoff passes through wetlands

While no channelized streams will be crossed by the road nor by the airstrip, both developments pass over low-lying areas which provided a pathway for snowmelt and excess rainfall runoff at several locations. Culverts will be installed, if required, to pass drainage through these areas. While it is expected that flows passing through the culverts will be small and intermittent, they may contain elevated suspended solid concentrations. Flow through these crossings and runoff over much of the area tends to pass through low-lying areas containing wetlands. As flow velocities are substantially reduced in these areas, most suspended materials will be deposited along the flow path prior to reaching Snap Lake or streams.

Natural drainage areas and flow directions will be re-established

At the conclusion of mining, the intention is to restore the baseline drainage regime. In the case of the surface facilities, surface contouring will re-establish natural drainage divides.

9.3.2.3.3 Impact Analysis

Containment and treatment of runoff from disturbed areas will greatly minimize impacts from suspended solids in Snap Lake

The mitigation measures described above will minimize the potential affect of increased suspended solids concentrations in runoff reaching Snap Lake. Discharges from the mine facilities and building area, along with runoff from the north pile containment area, will be contained and treated to reduce suspended solids prior to release to Snap Lake.

Suspected solids will settle in small wetland areas near their source

Any increased suspended solids concentration in runoff from roadways and the airstrip will be dispersed and filtered by adjacent wetlands and small ponded areas in the headwater portions of the drainages. This may result in elevated concentrations of suspended solids in these areas but it is expected that impacts will quickly diminish downstream due to low flows near drainage divides, and due to the numerous ponded areas and wetlands that will settle and filter suspended material. This will minimize impacts from suspended solids to Snap Lake.

9.3.2.3.4 Residual Impact Classification

The environmental consequence is low

The magnitude of residual impact of the Snap Lake Diamond Project on sediment yields and concentrations in receiving streams, lakes, ponds, and wetlands is classified as negligible as concentrations of suspended solids reaching Snap Lake are expected to be within the range of natural background levels. The residual impacts are considered local in geographic extent, long-term in duration, medium in frequency and reversible in the short-term (Table 9.3-39). The overall environmental consequence is considered low.

Table 9.3-39 Classification of Residual Impacts of Surface Disturbances on Sediment Yields and Concentrations in Receiving Streams, Lakes, Ponds, and Wetlands

Watershed	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Environmental Consequence
Snap Lake	negative	negligible	local	long-term	medium	reversible (short-term)	low

Probability of occurrence and level of confidence are both high

The probability of occurrence of the predicted impact is high since construction will cause the changes in compaction, *etc*., that have been described. However, there is a high level of confidence that impacts will not be greater than described due to the mitigation proposed.

9.3.2.3.5 Monitoring

Ongoing monitoring will continue

On-site water quality monitoring will provide ongoing data to evaluate changes in total suspended solids levels (see Section 9.4).