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## 7.0 HYDROLOGY

### 7.1 Introduction

Surface water hydrology describes the movement of water over land, into and through surface waterbodies such as wetlands, lakes and watercourses. Hydrology involves the interactions between precipitation, surface storage, evaporation, evapotranspiration, infiltration, surface runoff and groundwater. Surface runoff is the primary mechanism for transporting sediment from land into watercourses and surface waterbodies. Surface water hydrology is directly linked with other aquatic resources, such as fisheries and water quality, and with groundwater systems.

The potential impacts of the Expansion Project on hydrology were assessed based on:

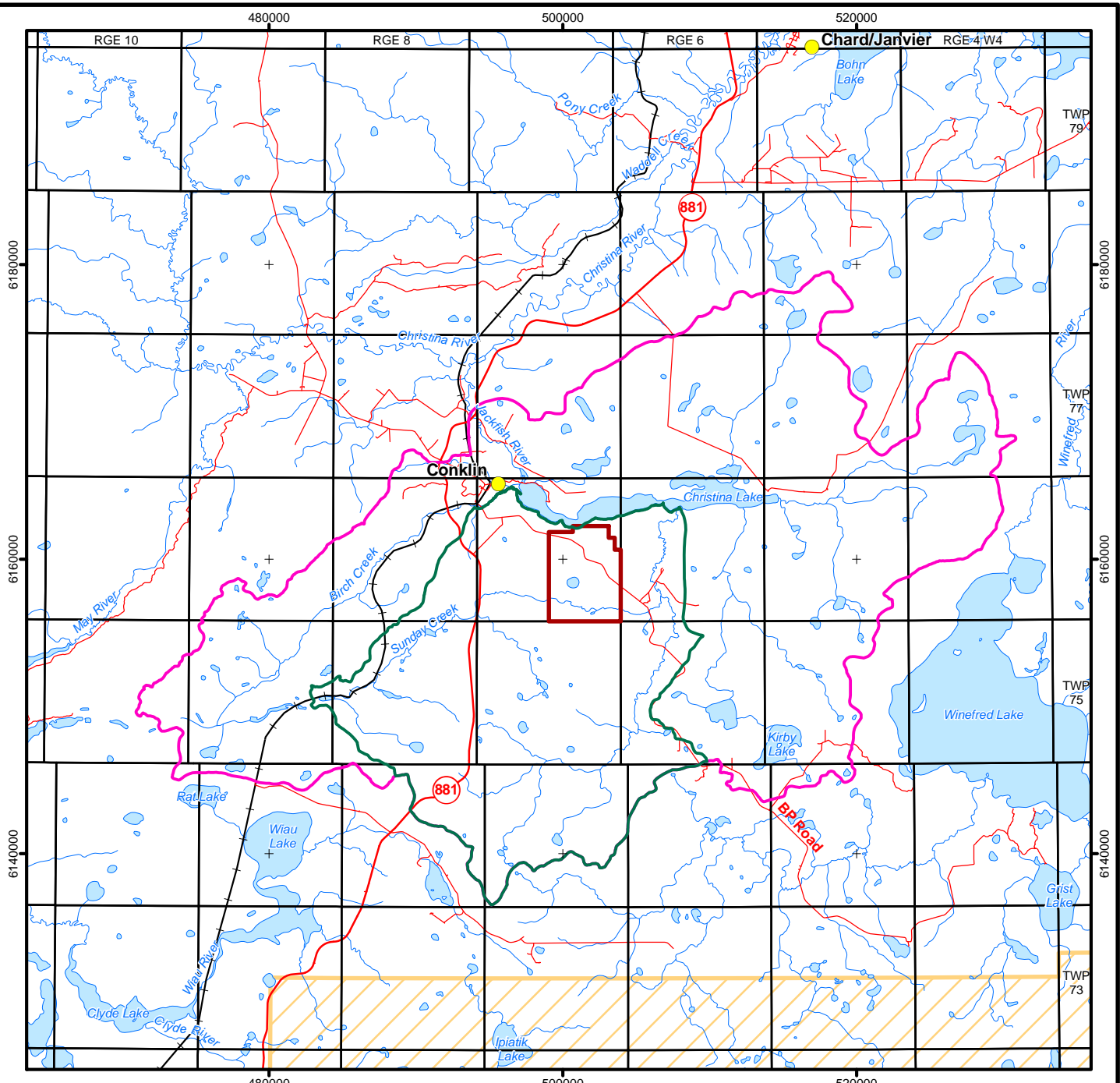
- regional climate data published by Environment Canada (Environment Canada 2009);
- regional historical stream discharge data published by Environment Canada (WSC 2009);
- local hydrological data gathered in 2005 and 2006 (Newmont 2006);
- local hydrological data gathered in 2009 (KNOC);
- hydrological data and baseline assessments prepared by AMEC for the project and other local projects (Devon 2003, 2006, 2008); and
- the proposed footprint of the project development provided by Korea National Oil Corporation (KNOC).

### 7.2 Study Area

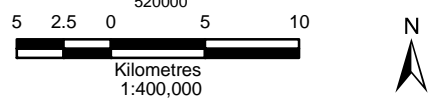
The KNOC BlackGold lease is located south of Christina Lake and approximately 10 km southeast of the town of Conklin, Alberta. The project area is located mainly within the watersheds of Sunday Creek and Birch Creek, which in turn drain into Christina Lake. A small portion of the project is located within the Christina Lake watershed.

Common local and regional study areas ([Figure 7.2-1](#)) were defined for the aquatics disciplines (hydrology, surface water quality, and fisheries and aquatics resources). The Aquatics Local Study Area (ALSA) was defined to assess the geographic extent of project environmental impacts on surface water resources. The boundaries of the ALSA are based on watershed boundaries that primarily encompass the basin of Sunday Creek, tributaries to Birch Creek and channels draining directly to Christina Lake. The Aquatic Regional Study Area (ARSA) includes the Christina Lake watershed and a portion of the Jackfish River catchment downstream of the Christina Lake outlet.

There is little topographical relief within the project area as elevations range from 625 m at the southwest corner of the project area to 550 m at the north boundary. Much of the project area is classified as wetlands, including bogs, fens, marshes and open water areas. Channels are frequently bordered on both banks by wide, flat floodplains vegetated with grasses, shrubs and trees.



- Legend**
- Aquatics Regional Study Area
  - Aquatics Local Study Area
  - Project Area
  - Cold Lake Air Weapons Range
  - Open Water
  - Watercourse



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**Aquatics Local and Regional Study Areas**

DATE: December 2009	<b>Figure 7.2-1</b>
PROJECT: CE03745/410	Fig07.02-01 Aquatic Study Areas 09-11-11
ANALYST: TM    KW    MW    DR	DRAWN BY: AMEC
PROJECTION/DATUM: UTM Zone 12 NAD83	PREPARED BY: AMEC

Beaver activity (dams) and low channel gradients result in generally high water levels (near bankfull). Winter baseflows are sustained by groundwater discharge and muskeg interflow.

The south portion of the project area is crossed by Sunday Creek, which drains east and then north to Christina Lake (Figure 7.2-1). Two unnamed watercourses drain north to Christina Lake from the central portion of the project area. A tributary of Birch Creek drains from the project area west to Birch Creek, which flows north to Christina Lake. A small area located in the central part of the project area drains southwest to a small lake, Lake L1 (Newmont 2006). Three separate areas along the northern edge of the project area drain directly to Christina Lake.

### 7.3 Issues and Assessment Criteria

Construction and operation of the pads, linear developments (pipelines, roads, utilities, rights-of-way [ROW]) and associated project facilities could affect the following aspects of surface water resources:

- magnitude and timing of overland flow and instream discharges;
- channel depths and flow velocities;
- lake water levels and volumes;
- drainage patterns;
- sediment yield and instream sediment transport capacity; and
- water quality.

The measurable parameters for hydrology are annual total flow volumes (or runoff), peak discharges, drought discharges and channel geomorphological characteristics of the watercourses crossed by the ROW (i.e., channel geometry, water levels, velocities, suspended sediment loads and late winter ice thicknesses).

#### 7.3.1 Temporal Boundaries

Project-related environmental impacts have been assessed for three scenarios:

- peak construction, as changes in vegetative cover and ground disturbance may be expected to alter surface drainage patterns and flows;
- peak operations, as ongoing site access and vegetation management could alter surface drainage patterns and flows; and
- decommissioning, as reclamation activities would include the restoration of surface drainage patterns and natural vegetative cover. This scenario assumes that the pipelines, including buried watercourse crossings, are abandoned in place and that surface facilities (i.e., well pads, above ground pipeline sections) are removed and the sites reclaimed to a stable vegetative cover. The assessment also assumes that all potential hydrological and geomorphological changes due to construction and operations have stabilized by the time of project decommissioning.

### 7.3.2 Definition of Environmental Impacts

The environmental impacts of the project on surface flow patterns are the same as the general attributes described in [Volume 2, Section 3.0](#) with the following modifications:

- **Magnitude** – This category describes the severity of the environmental impact and is characterized as low, moderate or high. Computed changes in measurable parameters such as mean annual total flow volume or peak discharge are expressed as a percent change from baseline conditions and are assigned a corresponding rating. Computed impacts that are lower than the level of measurement accuracy (about 5% for discharge measurements) are rated as having a low environmental impact. Computed impacts ranging between 5 and 10% change are rated as moderate, and impacts resulting in a greater than 10% change are rated as high;
- **Duration** – This category refers to the period between the onset of the impact and the measurable parameter returning to baseline conditions. Durations are assigned a quantitative rating of short term for durations up to 1 year, medium term for durations of 1 to 5 years, long term for durations of more than 5 years but not greater than 30 years after decommissioning, and permanent for durations of more than 30 years after decommissioning; and
- **Geographic Extent** – This is the area within which the impact can be observed. Geographic extents are described as site-specific where impacts are confined to the project area; local for impacts confined to the ALSA and regional where impacts are projected to extend to the boundaries of the ARSA.

## 7.4 Methods

### 7.4.1 Analytical Techniques

Changes in total flow volumes (runoff) and peak discharges resulting from project activities were quantitatively assessed based on the area to be disturbed by the project and associated runoff coefficients for disturbed areas, relative to undisturbed areas. Sediment yield from disturbances were estimated based on disturbed area and suitable sediment export coefficients.

Areas of disturbance within watersheds resulting from project activities were determined quantitatively based on 1:20 000 scale topographic mapping. Hydrological baseline conditions encompassing all existing and future Initial Project disturbances have been established for the Expansion Project and impacts are predicted based on the updated baseline.

#### 7.4.1.1 Mean Annual Total Flow Volume, Peak Discharges and Drought Discharges

Most impacts on hydrology will occur because of clearing and surficial disturbance and may include changes in runoff conditions, changes in sediment yield and disturbances to flow patterns. To quantitatively assess these environmental impacts, existing and proposed disturbance areas were examined in relation to the host watershed.

Mean annual total flow volumes were determined for assessment nodes within the ALSA from regional runoff correlations. Runoff coefficients were calibrated for the watersheds upstream of the assessment nodes using mean annual rainfall amounts estimated from regional recorded climate data. Project-related changes to mean annual total flow volumes were computed by adjusting the calibrated runoff coefficients to reflect the amount and type of project activity in the watershed upstream of the assessment node.

Peak discharges were computed for assessment nodes within the ALSA using regional relationships. Baseline curve numbers were calibrated for each watershed using the US Army Corps of Engineers' HEC-HMS hydrology model (Version 3.3). To assess project-related impacts, curve numbers were adjusted to reflect the amount and type of project-related activity in the watershed, and the HEC-HMS model with the revised curve numbers was used to compute the project-affected peak discharges.

Drought discharges were evaluated for assessment nodes within the ALSA using regional low-flow relationships. For drought discharges, environmental impacts of the project on low flows of varying durations were assessed.

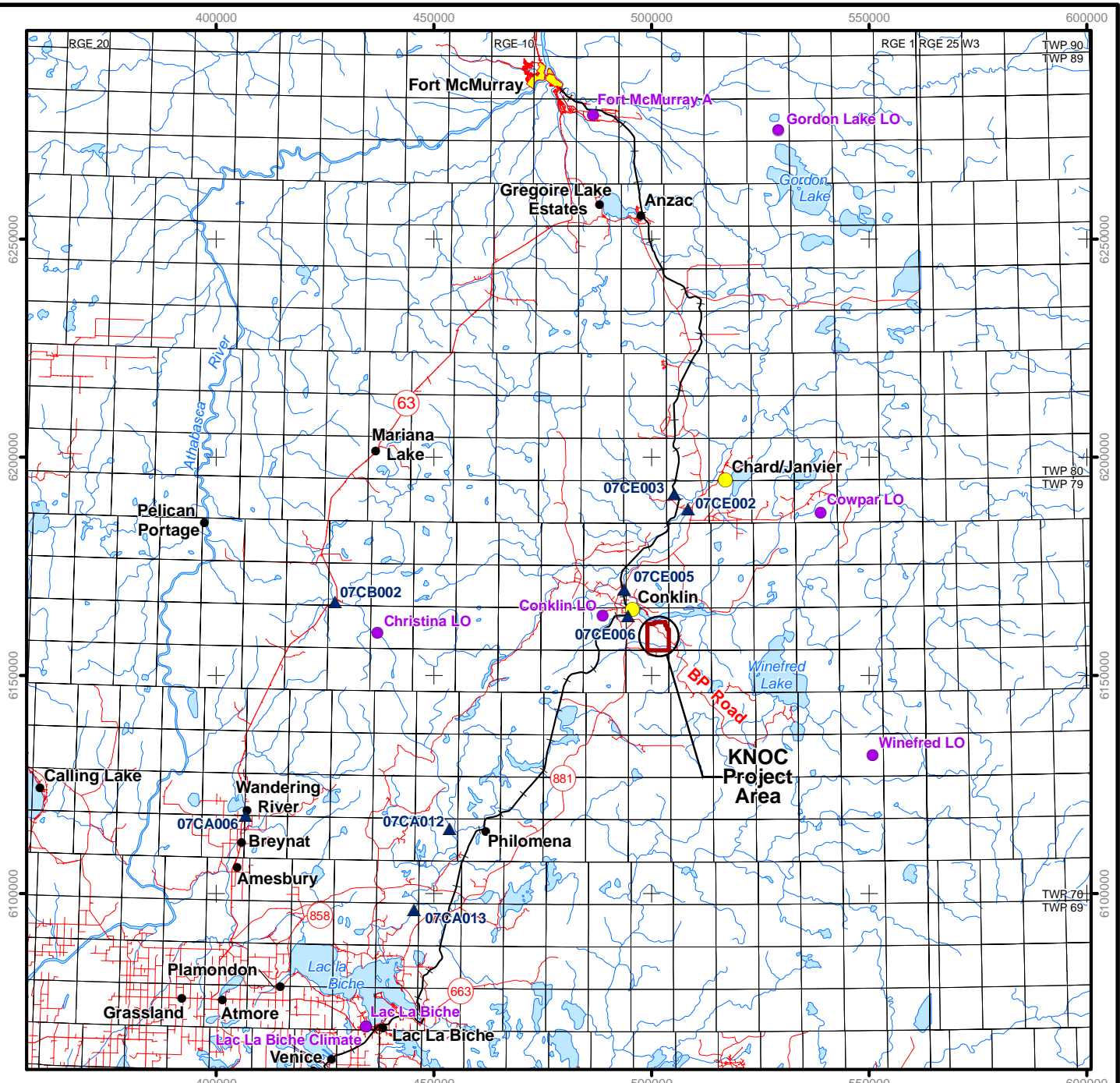
#### **7.4.1.2 Channel Geomorphology**

Channel geomorphology can be affected by changes in streamflow regime, which are manifested as changes in velocity and depth of flow. Channel geomorphology can also be affected by changes to the watercourse sediment loading, which might result from increased surficial erosion from project-affected areas. Destabilization of channel banks because of disturbance during construction could also affect channel geomorphology. The environmental impacts of the project on channel geomorphology were qualitatively assessed based on the predicted environmental impacts of the project on streamflows, sediment loading and bank destabilization. The effectiveness of mitigation measures were incorporated into the environmental impacts assessment.

#### **7.4.2 Data Sources and Fieldwork**

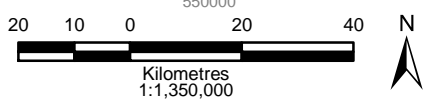
Climate data were obtained from the Meteorological Service of Canada (MSC) for stations located within 130 km of the ALSA. The locations of the selected stations are shown on [Figure 7.4-1](#). Data included mean daily temperature and daily, monthly and annual rainfall, snowfall, and total precipitation.

Streamflow data for stations located within 100 km of the ALSA were obtained from the Water Survey of Canada (WSC). Data from the stations shown on [Figure 7.4-1](#) were used to develop regional hydrological parameters.



**Legend**

- Project Area
- Open Water
- Watercourse
- Climate Station
- Airport
- Lookout
- Water Survey of Canada (WSC) Streamflow Monitoring Station



Sources: ESRI, GeoBase®, KNOC, Spatial Data Warehouse Ltd.

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**Regional Climate and  
Streamflow Monitoring  
Stations**

DATE: December 2009	<b>Figure 7.4-1</b>
PROJECT: CE03745/310	Fig07.04-01 Climate Streamflow Sites 09-11-12
ANALYST: TM KW MW DR	DRAWN BY: AMEC
PROJECTION/DATUM: UTM Zone 12 NAD83	PREPARED BY: AMEC

## 7.5 Existing Conditions

### 7.5.1 Climate

The hydrologic regime of the project area is closely linked to climatic conditions, principally precipitation. There are no climate data available specifically for the project area. However, long-term seasonal and continuously operating climate stations are operated by Environment Canada in the region of the proposed development, including those stations listed in [Table 7.5-1](#) and previously shown on [Figure 7.4-1](#).

**Table 7.5-1: Regional Climate Monitoring Stations**

Station Number	Station Name	Period of Record	Seasonal/Year Round Data	Elevation (m)
3061800	Conklin Lookout	1954 to present	Seasonal	671
3061930	Cowpar Lookout	1957 to present	Seasonal	563
3061580	Christina Lookout	1966 to 2002	Seasonal	823
3062889	Gordon Lake Lookout	1964 to present	Seasonal	488
3067590	Winefred Lookout	1957 to present	Seasonal	744
3063685	Lac La Biche	1958 to 2003	Year-round	567
3063686	Lac La Biche Climate	2003 to present	Year-round	567
3062693	Fort McMurray	1944 to present	Year-round	541

Data from the regional fire lookout stations comprise daily mean temperature and daily total precipitation, generally for the period of May to August each year. Year-round data are available only for the continuously operated climate stations located in Lac La Biche and Fort McMurray.

#### 7.5.1.1 Temperature

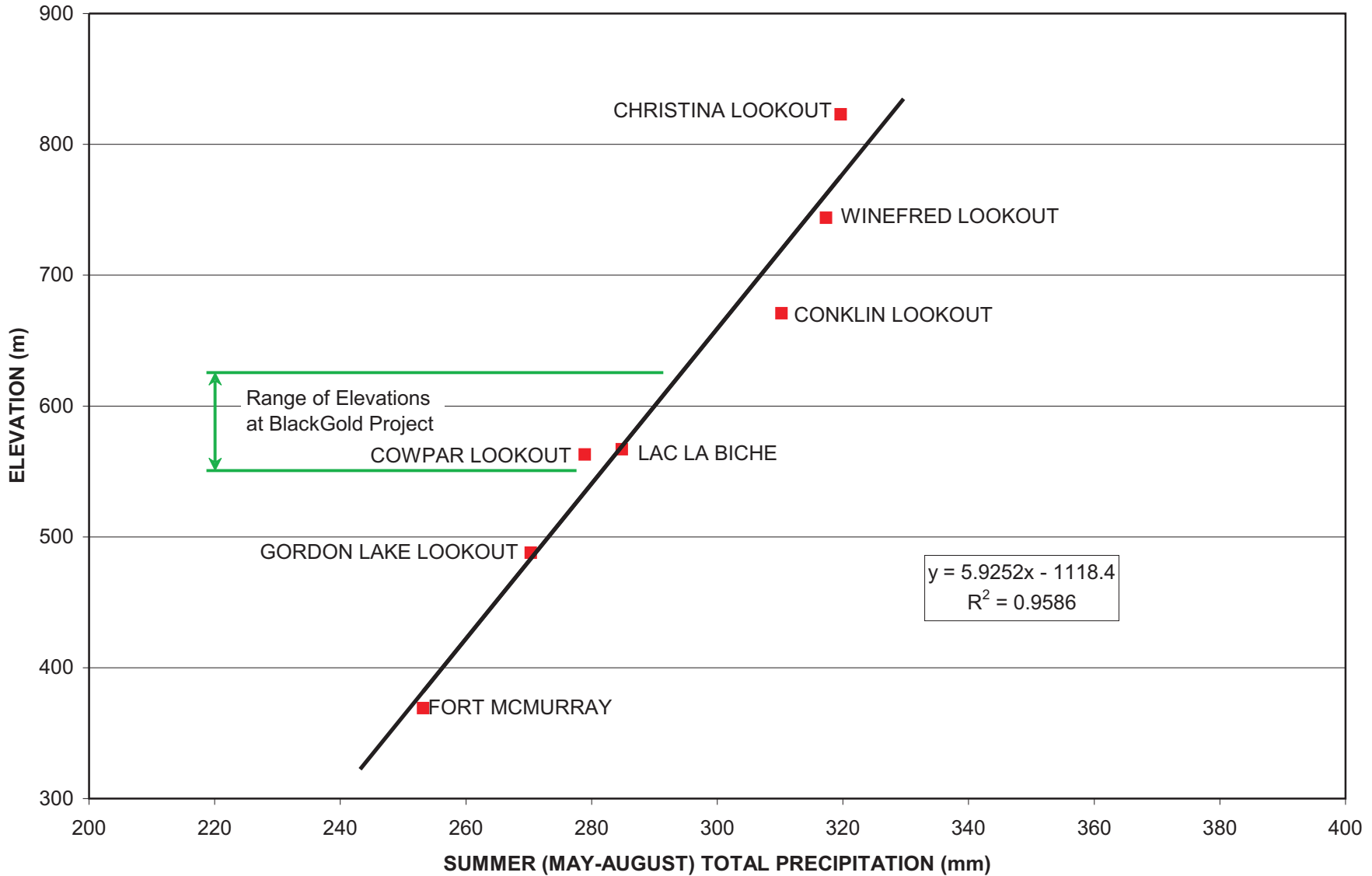
Mean monthly temperatures were compared between the Fort McMurray climate station and Conklin Lookout, which is the closest station to the project area. Monthly mean temperatures over comparable periods of record were found to compare closely between the two stations.

#### 7.5.1.2 Precipitation

A good correlation between seasonal (May to August) total precipitation and station elevation was found for the regional climate stations ([Figure 7.5-1](#)). This elevation-precipitation relationship was used to estimate seasonal precipitation within the project area.

Mean monthly and mean annual precipitation amounts for the project area were pro-rated from the estimated seasonal total precipitation using ratios of seasonal to annual precipitation and monthly to annual precipitation at the Lac La Biche climate monitoring station. Similarly, monthly snowfall and rainfall amounts were estimated using observed proportions from the Lac La Biche and Fort McMurray monitoring stations. Estimated monthly, seasonal, and annual precipitation values for the project area are summarized in [Table 7.5-2](#) and shown on [Figure 7.5-2](#).

S:\Gis\Projects\CE\KNOC\_BlackGold\CE03745\_EIA\Draw\Section 07 - Surface Water Quantity\Fig07.05-01 Seasonal Precip.cdr



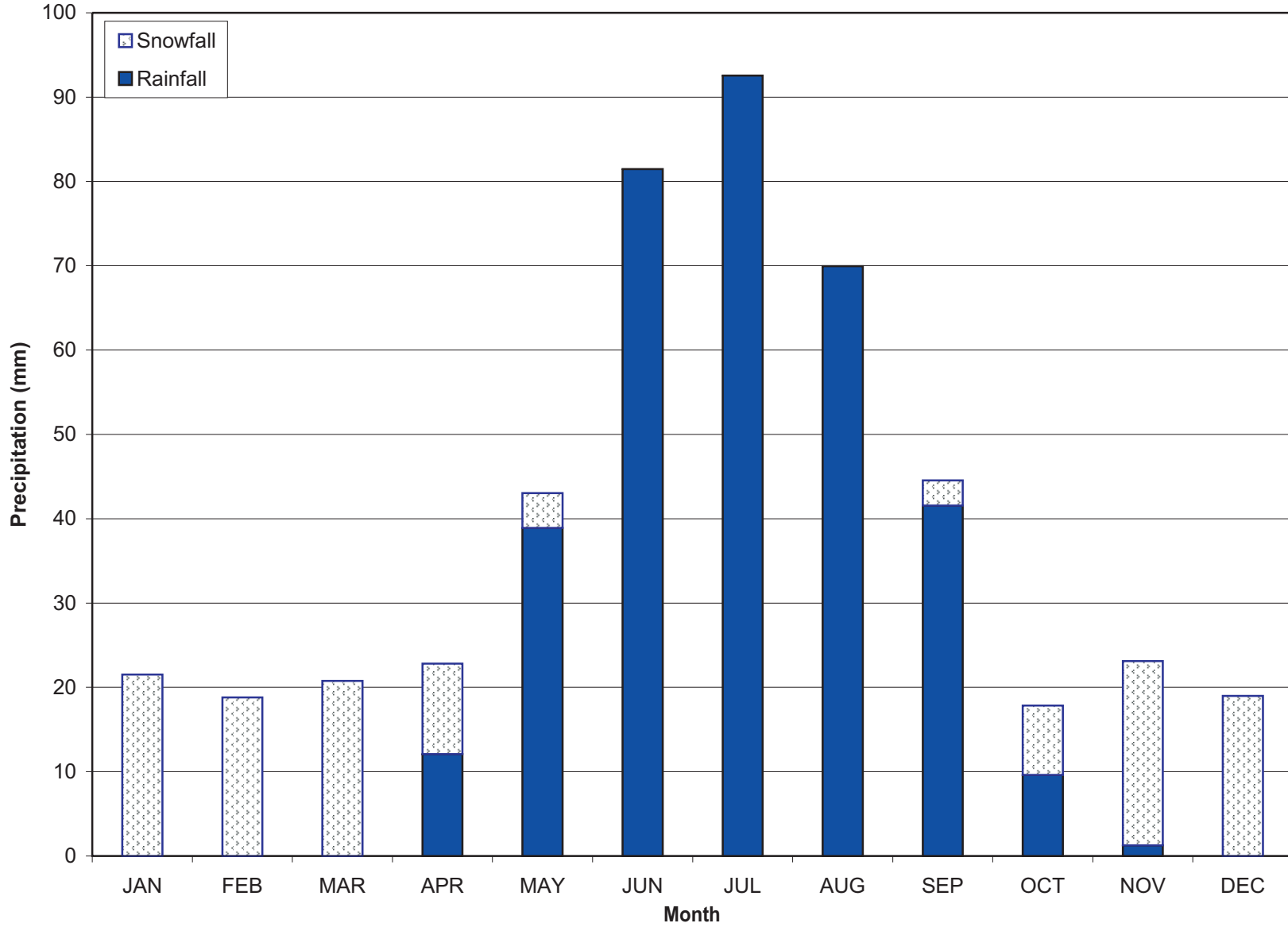
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Regional Seasonal Precipitation Correlation

DATE: December 2009		Fig07.05-01 Seasonal Precip 09-11-25	
PROJECT: CE03745/310		DRAWN BY: AMEC	
ANALYST: CP	QA/QC: KW MW DR	PREPARED BY: AMEC	

**Figure 7.5-1**

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**Estimated Monthly Precipitation at the BlackGold Expansion Project Site**

DATE: December 2009		Fig07.05-02 Monthly Precip 09-11-25	
PROJECT: CE03745/310		DRAWN BY: AMEC	
ANALYST: CP	QA/QC: KW MW DR	PREPARED BY: AMEC	

**Figure 7.5-2**

**Table 7.5-2: Estimated Precipitation at the Project Site**

Month	Rainfall (mm)	Snowfall <sup>1</sup> (mm)	Total Precipitation (mm)
January	0.0	21.5	21.5
February	0.0	18.8	18.8
March	0.0	20.8	20.8
April	12.1	10.7	22.8
May	38.9	4.1	43.0
June	81.5	0.0	81.5
July	92.5	0.0	92.5
August	69.9	0.0	69.9
September	41.6	3.0	44.5
October	9.6	8.2	17.8
November	1.3	21.9	23.1
December	0.0	19.0	19.0
Seasonal (May-Aug)	282.9	4.1	287.0
<b>Annual Total</b>	<b>347.4</b>	<b>128.0</b>	<b>475.4</b>

<sup>1</sup> mm water equivalent.

Based on year-round records from the Lac La Biche and Fort McMurray climate stations, approximately 73% of the annual total precipitation at the project site is expected to occur as rain and the remaining 27% as snow. Annually, there is a 30% probability that snowfall will occur at least once during the summer months of June to August.

## 7.5.2 Hydrology

Long-term or continuous streamflow data are not available for the project area. However, there are several hydrometeorological monitoring sites found regionally from which data were obtained to provide the basis for characterizing the hydrological characteristics of the ALSA. These stations are operated by the WSC. The locations of the WSC stations listed in [Table 7.5-3](#) are shown on [Figure 7.4-1](#).

**Table 7.5-3: Regional Streamflow Monitoring Stations**

Station Name	Station Number	Drainage Area (km <sup>2</sup> )	Period of Record	Comments
Logan River near the Mouth	07CA012	425	1984-2007	Seasonal (Mar-Oct)
Owl River below Piche River	07CA013	3 080	1984-2006	Seasonal (Mar-Oct)
Christina River near Chard	07CE002	4 860	1982-2006	Seasonal (Mar-Oct)
Pony Creek near Chard	07CE003	278	1982-2006	Seasonal (Mar-Oct)
Jackfish River below Christina Lake	07CE005	1 290	1982-1995	Seasonal (Mar-Oct)
Birch Creek near Conklin	07CE006	232	1984-1995	Seasonal (Mar-Oct)
Wandering River near Wandering River	07CA006	1 110	1971-2006	Continuous (1971-1996) Seasonal (1997-2006)
House River at Highway No. 63	07CB002	764	1982-2006	Seasonal (Mar-Oct)

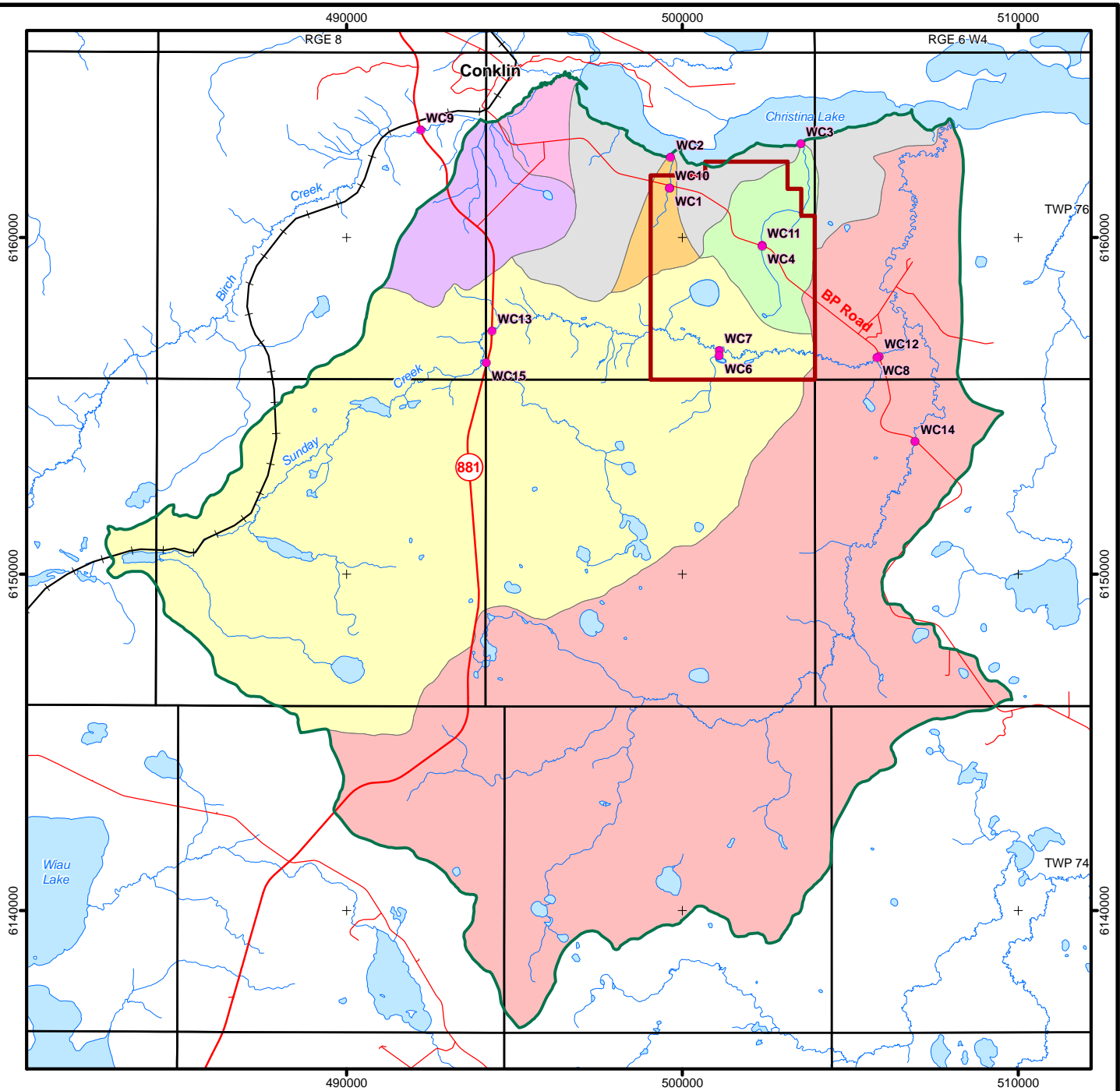
Regional streamflow data, including mean daily streamflows and annual extreme high and low flows were obtained from WSC for the stations listed in [Table 7.5-3](#). Birch Creek is the closest regional streamflow station to the project area with a watershed area of less than 300 km<sup>2</sup> and has similar hydrological characteristics to Sunday Creek. Data from the WSC Birch Creek station, supplemented with information from the other regional stations, was used as the basis for characterizing the hydrologic characteristics of Sunday Creek and the unnamed creeks in the ALSA.

In addition to the WSC data, spot discharge measurements were undertaken at several locations near the project area in 2005 (Newmont 2006) under both open water and ice-covered conditions. A water level monitoring station was also operated continuously at Site WC8 from July to September 2005. In addition to the data from the 2005 monitoring program, spot discharge measurements were undertaken by KNOC at Birch Creek, Sunday Creek and several additional locations in the project area in 2009. The 2005/2006 and 2009 data are summarized in [Table 7.5-4](#). The sampling locations are shown on [Figure 7.5-3](#).

**Table 7.5-4: Summary of Discharge Measurements  
by Newmont (2006)<sup>1</sup> and KNOC (2009)**

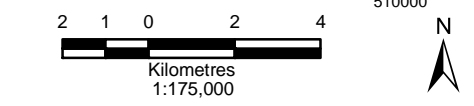
Site	Drainage Area (km <sup>2</sup> )	Measured Discharge (m <sup>3</sup> /s) and Measurement Date			
		Spring	Summer	Fall	Winter
WC1/WC10	3.9	No Data	0.08 11 Aug 2005	0.20 30 Sep 2005 0.0027 23 Sept 2009	0.10 11 Feb 2006
WC2	4.3	No Data	0.09 13 Aug 2005	0.20 30 Sep 2005	No Data
WC3	11.3	No Data	0.06 13 Aug 2005	No Data	No Data
WC4/WC11	4	No Data	0.08 11 Aug 2005	0.003 23 Sep 2009	No Data
WC6	3.2	No Data	0.05 10 Aug 2005	No Data	No Data
WC7	141.4	No Data	0.65 10 Aug 2005	No Data	0.02 11 Feb 2006
WC8	174.6	No Data	1.13 3 Aug 2005 0.96 12 Aug 2005	0.79 27 Sep 2005 0.42 3 Oct 2005	0.22 11 Feb 2006
WC9	210.3	No Data	No Data	0.26 23 Sep 2009	No Data
WC 12	180.7	No Data	No Data	0.11 23 Sep 2009	No Data
WC 13	89.1	No Data	No Data	0.13 23 Sep 2009	No Data
WC 14	167.3	No Data	No Data	0.06 23 Sep 2009	No Data
WC 15	38.5	No Data	No Data	0.1 23 Sept 2009	No Data

<sup>1</sup> Source: Newmont 2006.



**Legend**

- Aquatics Local Study Area
  - Project Area
  - Open Water
  - Watercourse
- Drainage Basin**
- Basin A - Sunday Creek Upstream of Project Area
  - Basin B - Sunday Creek Downstream of Project Area
  - Basin C - East Unnamed Creek
  - Basin D - West Unnamed Creek
  - Basin E - Birch Creek Tributaries
  - Basin F - Birch Creek Downstream of Project Area
  - Direct Drainage to Christina Lake
  - Hydrology Sampling Location



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**Hydrology Sampling Locations**

DATE: December 2009	<b>Figure 7.5-3</b>
PROJECT: CE03745/310	Fig07.05-03 Hydro Sample Sites 09-11-11
ANALYST: TM    KW    AJ    DR	DRAWN BY: AMEC
PROJECTION/DATUM: UTM Zone 12 NAD83	PREPARED BY: AMEC

### 7.5.2.1 Surface Drainage Patterns

The project area was divided into sub-catchments within the Birch Creek, Sunday Creek and Christina Lake watersheds (Figure 7.5-3). The drainage boundaries between the sub-catchments were derived based on available 1:20 000 scale mapping. The average ground surface gradient within the project area is much less than 1%. There is sufficient topographical relief in the project area to define the catchment boundaries, although extensive muskeg and wetlands areas frequently cross catchment boundaries.

The assessment nodes in Table 7.5-5 and on Figure 7.5-4 were located at the outlets of potentially affected sub-basins. Baseline conditions and project impacts were computed for the site of each assessment node.

**Table 7.5-5: Catchment Areas for Channels in the Project Area**

Catchment Name/Sub-catchment Identifier	Assessment Node	Total Drainage Area (km <sup>2</sup> )
Sunday Creek at the Eastern Boundary of the Project Area (A)	SC1	166
Sunday Creek at the Mouth (B)	SC2	378
East Unnamed Creek (C)	UC1	11.9
West Unnamed Creek (D)	UC2	4.3
Birch Creek Tributaries (E and F)	BC1	16.2
Direct Drainage to Christina Lake	–	24.1

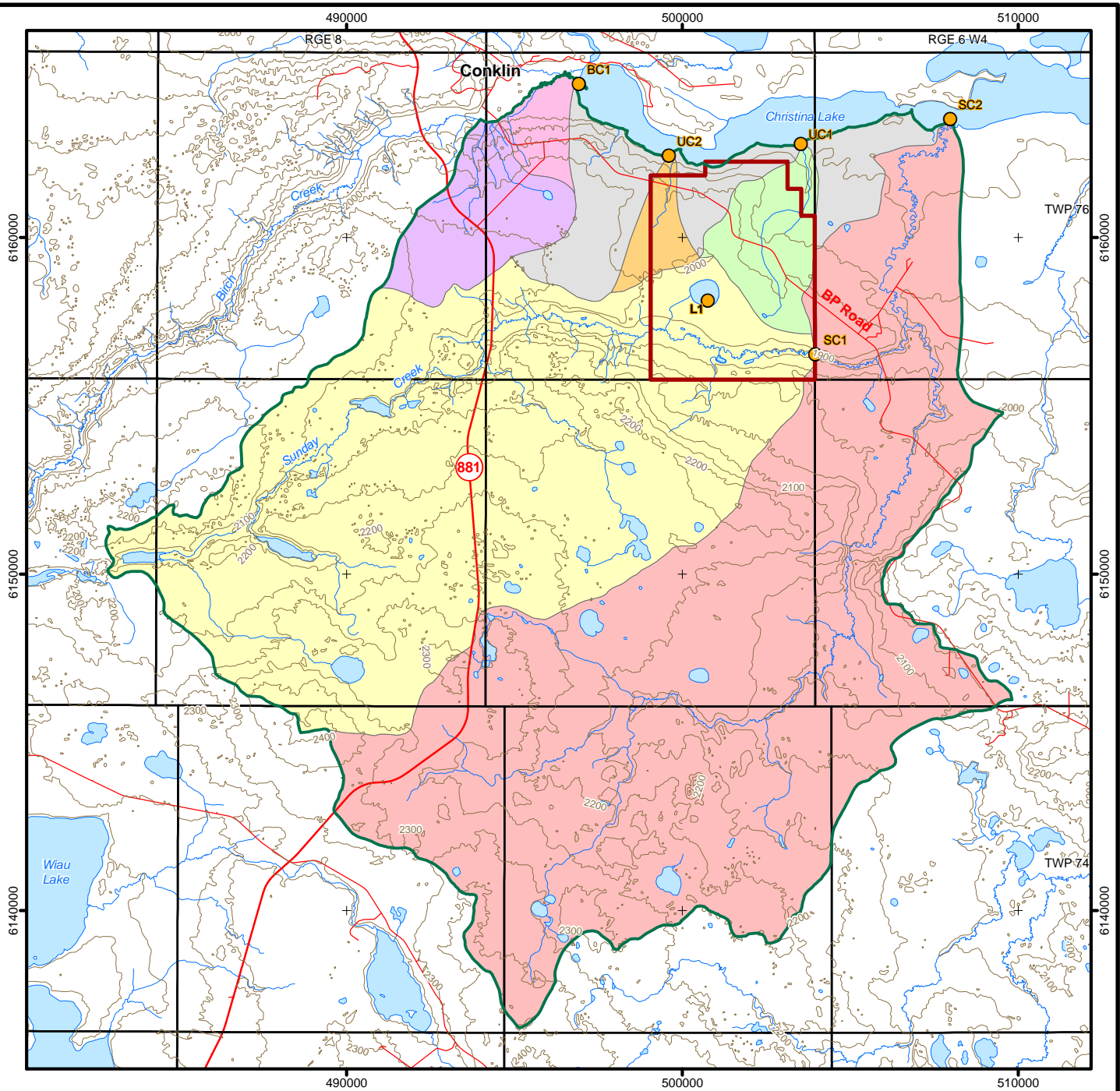
### 7.5.2.2 Seasonal and Annual Runoff

Mean seasonal (March to October) and mean annual runoff from the project area is estimated to be in the order of 85 mm and 90 mm, respectively. Approximately 95% of total mean annual runoff occurs during the March to October period and the remaining 5% of the total mean annual runoff occurs during the winter (November to February) period. For East and West Unnamed Creeks catchments, the proportion of winter discharge may be even lower as watersheds with drainage areas of less than approximately 20 km<sup>2</sup> are expected to have zero flows (Devon 2006).

### 7.5.2.3 Peak Discharges

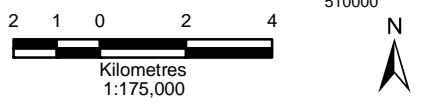
In the regional catchments, annual peak discharges typically occur in May due to snowmelt, with high discharges sustained through July due to basin storage and early summer rains. Peak flows can also occur in late summer (August and September) due to rainfall events.

Equations relating watershed area to snowmelt and rainfall runoff event peak discharges have been developed based on regional data. These relationships were used to estimate peak discharges at the assessment nodes on Figure 7.5-4.



**Legend**

- Aquatics Local Study Area
  - Project Area
  - Open Water
  - Watercourse
- Drainage Basin**
- Basin A - Sunday Creek Upstream of Project Area
  - Basin B - Sunday Creek Downstream of Project Area
  - Basin C - East Unnamed Creek
  - Basin D - West Unnamed Creek
  - Basin E - Birch Creek Tributaries
  - Basin F - Birch Creek Downstream of Project Area
  - Direct Drainage to Christina Lake
  - Contour (Interval - 50 ft)
  - Hydrology Assessment Node



Sources: © Department of Natural Resources Canada. All rights reserved, GeoBase®, KNOC, Spatial Data Warehouse Ltd.

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**BlackGold Expansion Project**

**Drainage Basins and Assessment Node Locations**

DATE: December 2009		<b>Figure 7.5-4</b>	
PROJECT: CE03745/310		Fig07.05-04 ALSA Drainage Basins 09-11-14	
ANALYST: TM	QA/QC: KW MW DR	DRAWN BY: AMEC	
PROJECTION/DATUM: UTM Zone 12 NAD83		PREPARED BY: AMEC	

#### 7.5.2.4 Low Flows

Comparable regional streamflow monitoring stations (Birch Creek and Pony Creek) have operated on a seasonal basis and have no available winter flow data. However, zero flows have been recorded in early spring at both Pony Creek and Birch Creek over the available periods of record in [Table 7.5-6](#).

**Table 7.5-6: Zero Flow Occurrences in Regional Watercourses**

WSC Station Name	Drainage Area (km <sup>2</sup> )	Zero Flow Occurrences		
		Year	Dates <sup>1</sup>	Duration (days)
Birch Creek near Conklin	232	1989	March 1-21	>21
Pony Creek near Chard	278	1989	March 1-19	>19
		1993	March 1-29	>29
		1995	March 1-11 April 4-8	>11 5
		2001	March 26-April 10	17
		2002	March 1-20	>20
		2003	March 1-18	>18

<sup>1</sup> Stations operate seasonally. Data are available only for the period of March 1 to October 31.

Streamflows measurements conducted in February 2005 (Newmont 2006) indicated flow in both Sunday Creek and the West Unnamed Creek. Pony Creek also had continuous flow over the 2005/2006 winter season.

Flow duration curves prepared using mean daily discharge data for Birch Creek and Pony Creek indicate that there is between a 5 to 10% annual probability of zero flow in Sunday Creek for durations of 1 to 14 days. In smaller watersheds, such as the East and West Unnamed Creeks, the annual probability of zero flows is as high as 50% for durations of up to 28 days.

#### 7.5.3 Baseline Hydrological Characteristics at Assessment Nodes

Baseline hydrological characteristics have been computed for the following assessment node locations in the ALSA:

- at the mouth of the West Unnamed Creek (Site UC1);
- at the mouth of the East Unnamed Creek (Site UC2);
- on the main stem of Sunday creek immediately downstream (east) of the project area boundary (Site SC1);
- at the mouth of Sunday Creek (Site SC2); and
- at the mouth of Birch Creek Tributary (Site BC1).

Baseline mean annual runoff, mean total annual flow volumes, and 1:10 year and 1:100 year peak discharges are in [Table 7.5-7](#) for each assessment node.

**Table 7.5-7: Baseline Hydrological Characteristics at Assessment Nodes**

Assessment Node		Drainage Area (km <sup>2</sup> )	Mean Annual Discharge (m <sup>3</sup> /s)	Mean Annual Total Flow Volume <sup>1</sup> (dam <sup>3</sup> )	Mean Annual Runoff (mm)	Peak Discharges for Return Period Event	
						1:10 Year (m <sup>3</sup> /s)	1:100 Year (m <sup>3</sup> /s)
SC1	Sunday Creek Downstream of Project Area	167	0.57	18 000	108	14.1	25.9
SC2	Sunday Creek at the Mouth <sup>2</sup>	378	1.27	39 900	106	22.7	41.5
UC1	East Unnamed Creek at the Mouth	11.9	0.043	1 350	114	2.81	5.22
UC2	West Unnamed Creek at the Mouth	4.6	0.014	446	97	1.35	2.76
BC1	Birch Creek at the Mouth	16.2	0.050	1 570	97	3.81	7.58
Direct	Direct Drainage to Christina Lake	24.1	0.073	2 300	95	5.56	11.2

<sup>1</sup> 1 dam<sup>3</sup> – 1 000 m<sup>3</sup>

<sup>2</sup> Baseline hydrological characteristics for Sunday Creek Downstream of project area (SC1) and Sunday Creek at the Mouth (SC2) taken to be parameters as impacted by the Devon Jackfish and Jackfish 2 projects (Devon 2003; 2006).

## 7.6 Potential Impacts and Mitigative Measures

### 7.6.1 Project Footprint

Activities associated with the project that could potentially affect the hydrology of watercourses within the project area are summarized in [Table 7.6-1](#).

**Table 7.6-1: Project Activities Potentially Affecting Surface Water Hydrology**

Activity	Description	Potential Impact on Hydrology
ROW Development	ROW clearing	<ul style="list-style-type: none"> <li>ROW clearing that removes vegetative ground cover can alter the runoff characteristics of the area and increase runoff.</li> </ul>
	Roadbed construction	<ul style="list-style-type: none"> <li>Placement of fill along roadway alignments can impede overland flows.</li> </ul>
	Watercourse crossings	<ul style="list-style-type: none"> <li>Watercourse crossings can impede flows if they are undersized or improperly placed.</li> </ul>
Pad Development	Pad clearing	<ul style="list-style-type: none"> <li>Clearing that removes vegetative ground cover can alter the runoff characteristics of the area and increase runoff.</li> </ul>
	Pad construction	<ul style="list-style-type: none"> <li>Placement of fill at the pad location can impede overland flows.</li> </ul>
Temporary Construction Laydown Area	Site clearing	<ul style="list-style-type: none"> <li>Clearing that removes vegetative ground cover can alter the runoff characteristics of the area and increase runoff.</li> </ul>
	Site development	<ul style="list-style-type: none"> <li>Fill placement can impede overland flows.</li> <li>Altered ground cover and structures increase site runoff.</li> </ul>
	Site water management	<ul style="list-style-type: none"> <li>Site water management can affect the timing and volume of site runoff.</li> </ul>
Operations	Process, sanitary and potable water requirements	<ul style="list-style-type: none"> <li>Withdrawals and releases of water from/to surface watercourses can affect instream flows.</li> </ul>

The project footprint provided by KNOC was used to estimate the areas of disturbance, by watershed for the project area, as summarized in [Table 7.6-2](#). The basin boundaries are shown on [Figure 7.5-4](#).

**Table 7.6-2: Project Surface Disturbances**

Site	Basin	Basin Area (km <sup>2</sup> )	Existing Disturbance Area <sup>1</sup> (km <sup>2</sup> )	Project Disturbance Area (km <sup>2</sup> )	Total Disturbance Area <sup>1</sup>	
					km <sup>2</sup>	% of Area
SC1	(A) Sunday Creek Downstream of Project Area	167	28.3	0.80	29.1	17%
SC2	(B) Sunday Creek at the Mouth	378	52.7	0.91	53.6	14%
UC1	(C) East Unnamed Creek	11.9	2.38	0.78	3.16	27%
UC2	(D) West Unnamed Creek	4.60	0.38	0.32	0.70	15%
BC1	(E & F) Birch Creek	16.2	1.49	0.00	1.49	9.2%
	Direct Drainage to Christina Lake	24.1	1.37	0.26	1.63	6.8%

<sup>1</sup> Total disturbance area will be less than the total of existing disturbance area plus project disturbance area where elements of the project are placed on existing (baseline) disturbed areas.

The project will occupy less than 0.3% of the Sunday Creek watershed. Disturbed areas will increase from a baseline disturbance of 20% to 27% in the East Unnamed Creek watershed and from 8% in the West Unnamed Creek watershed to 15%. Disturbance within those areas draining directly to Christina Lake will increase from less than 6% for baseline conditions to almost 7%. The lease area occupies the headwaters of a 16.2 km<sup>2</sup> tributary sub-basin of Birch Creek, which comprises 7% of the area draining to Birch Creek at the mouth; however, disturbance within the Birch Creek sub-basin does not increase as a result of the Expansion Project.

## **7.6.2 Hydrologic Impacts**

### **7.6.2.1 Streamflows**

Watershed runoff can be related to precipitation through runoff coefficients and converted to streamflows based on basin drainage area. Baseline runoffs were computed for each assessment node based on regional runoff data and prorated for the level and type of baseline disturbance in the watershed. Impacted runoffs were computed by adjusting the baseline runoff coefficients to account for the project disturbances, i.e., ROW road development and pad construction.

The disturbance areas resulting from project activities are small relative to the area of the Sunday Creek watershed, and the effects of the Expansion Project on Sunday Creek discharges are correspondingly small (less than 0.3% increase). Disturbance areas and hence Expansion Project effects are more substantial when compared to the area of the East and West Unnamed Creek basins. Mean annual streamflows in East Unnamed Creek and West Unnamed Creek are projected to increase by 6.9% and 8.7%, respectively, as a result of the proposed Expansion Project. Although the flow increases in the East and West Unnamed creeks are proportionately large, the estimated magnitudes of the flow increases are 0.003 m<sup>3</sup>/s and 0.001 m<sup>3</sup>/s in East and West Unnamed Creeks, respectively. The Expansion Project will have no effect on flows in the Birch Creek tributaries. Mean annual flows from areas draining directly to Christina Lake will increase by 1.1%.

Process water will be obtained from a deep water well on the lease in SW<sup>1</sup>/<sub>4</sub> Sec 9, Twp 76, Rge 7 W4M. The source aquifer is not hydraulically connected to the local surface water system. Water withdrawal is not expected to impact surface water flow. Potable water will be trucked in from a third party off-site and therefore will have no impact on surface water flows.

### **7.6.2.2 Flow Patterns**

Constraints mapping has been used to ensure that, wherever possible, pads and access roads (other than at watercourse crossings) are located at least 100 m from surface waterbodies.

The proposed development plan will require three watercourse crossings for pipelines. Elevated watercourse crossings are being contemplated for pipelines. A bridge or open bottom culvert will be used to provide vehicle access to Pad 119 at the Sunday Creek crossing. Culverts will be

used to construct vehicle crossings along the Lake L1 outlet channel and East Unnamed Creek. All watercourse crossings (road, pipeline, powerline, etc.) will be designed so as not to impede normal instream flows. Additional methods to mitigate potential obstructions to surface flows are outlined in [Section 7.6.3](#).

### **7.6.2.3 Peak Flows**

Baseline peak flows at the assessment nodes were estimated from regional peak flow data. Hydrologic curve numbers used in peak flow computer modelling were calibrated for baseline conditions in the potentially affected sub-basins. The impacts of the project on peak flows were modelled by prorating the curve numbers for the proposed area and type of disturbance within each sub-basin. The attenuating impacts of stormwater management systems were included in the model.

Peak flows at the mouth of the East Unnamed Creek watershed will increase by 7.5% for the 1:10 year event and 5.1% for the 1:100 year event. In West Unnamed Creek, peak flows will increase by 7.6% for the 1:10 year event and 5.9% for the 1:100 year event. As with annual runoff, peak flows in Sunday Creek immediately downstream of the project area will increase only slightly above baseline values (0.7% for the 1:10 year event and 0.5% for the 1:100 year event). The effects of the Expansion Project on peak flows in Sunday Creek are even lower at the mouth of the creek (0.3% increase for the 1:10 year event and 0.2% increase for the 1:100 year event). Peak flows in Birch Creek are not affected by the Expansion Project. Peak flows from areas draining directly into Christina Lake are projected to increase by 1% for the 1:10 year event and 0.7% for the 1:100 year event.

### **7.6.2.4 Low Flows**

Low flows occur during the winter months, usually as a result of watercourses freezing to the bed and/or depletion of near surface groundwater inflows to the channel. Zero flow has also been observed in both Birch Creek and Pony Creek in early spring.

Flow duration curves prepared using mean daily discharge data for Birch Creek and Pony Creek indicate that, prior to project development, the probability of zero flow in Sunday Creek for durations of 1 to 14 days is between 5% and 10% annually. In smaller watersheds, such as the East and West Unnamed Creeks, the annual probability of zero flows is likely much higher, up to 50% for durations of up to 28 days. The frequency of zero flow in the creeks within the influence of the project area will not be measurably affected by increases in mean annual flow or summer/spring peak flow. The project will not affect the frequency of occurrence or the duration of winter low flow events in West Unnamed Creek, East Unnamed Creek, Sunday Creek or Birch Creek.

### **7.6.2.5 Lake Levels**

The project will increase the total mean annual discharge volume into Christina Lake from the ALSA by 264 dam<sup>3</sup> (1 dam<sup>3</sup> = 1 000 m<sup>3</sup>). However, outflows from the lake will correspondingly increase thus the net effect may be little or no change in lake levels.

### **7.6.2.6 Channel Morphology**

The project will moderately increase mean annual streamflows and peak flows in East and West Unnamed Creeks downstream of the project area. However, the volumetric increases of 1 L/s and 3 L/s in East and West Unnamed Creeks are not expected to have any measurable effect on the morphology of the creek channels.

The proposed changes to streamflows at the mouth of Sunday Creek are well within the range of measurement error ( $\pm 5\%$ ) and hence will not adversely affect the morphology of Sunday Creek. No changes are proposed within the Birch Creek watershed and therefore no changes to morphology are expected.

### **7.6.3 Mitigation**

The project has been designed using constraints mapping, which included hydrological considerations. Thus, the placement of the temporary construction laydown areas, pads, access roads and pipeline corridors has been laid out so as to minimize or mitigate, wherever possible, potential hydrologic impacts. Many of the potential impacts of the project can be effectively mitigated using appropriate planning and water management techniques, particularly with respect to the type, sizing and construction of watercourse crossings. Natural drainage patterns will be maintained to minimize disruptions to surface flows.

#### **7.6.3.1 Overland Drainage**

The most common impact of development is the blockage of existing flow paths. This can be effectively mitigated by providing ditches and culverts at all defined surface channels, at all low points and at regular intervals through wetland areas to provide cross-drainage. Sediments generated can be prevented from entering watercourses by utilizing appropriate sediment control techniques.

#### **7.6.3.2 Well Pads Stormwater Runoff**

Well pads will be bermed and graded to drain towards an internal perimeter ditch to manage stormwater runoff.

Contaminated runoff or runoff not meeting regulatory criteria will be routed into the recycle water system at the CPF.

#### **7.6.3.3 Watercourse Crossings**

Based on the proposed project footprint, all pads and facilities (excluding road and pipeline crossings) will be located 100 m or more from surface watercourses with defined beds and banks. Road crossings and pipeline crossings will be installed per the requirements of Alberta Environment's *Code of Practice for Watercourse Crossings* (AENV 2003a) and *Code of Practice for Pipelines and Telecommunications Lines Crossing a Water Body* (AENV 2003b), respectively.

Crossing locations that are stable and that avoid steep crossing approaches will be selected where possible. Erosion and sediment control techniques will be implemented at the time of construction. These techniques will include bank stabilization and ROW revegetation following construction.

Culvert structures should be long enough to ensure that road grading operations do not result in the deposition of road gravel into the channel. Similarly, bridges should be equipped with side rails high enough to contain road gravel on the surface and prevent it from being graded into the channel.

#### **7.6.4 Monitoring**

Specific aspects of the monitoring program are:

- routine monitoring of road crossings to ensure that culverts are not blocked by ice, sediment, debris or beaver dams. Monitoring will be undertaken each spring during breakup and following high flow events;
- in wetland/muskeg areas, water levels on both sides of the road will be routinely monitored to ensure that ponding, which indicates drainage obstruction, does not occur;
- pipeline crossings will be monitored after spring breakup and after high flow events to ensure that banks are stable and not eroding. Similarly, crossing approach slopes will be monitored each spring after breakup to assess the stability of the slope and revegetation/erosion control measures;
- monitoring of water levels in stormwater ponds and maintenance of a sufficient storage capacity for the design storm event at all times over the spring to fall (April to October) period. Ensure that stormwater ponds are emptied when necessary, and monitor sediment accumulations to ensure that the storage capacity of the ponds is maintained;
- monitoring streamflows at representative locations to document post-development flows in the potentially affected channels; and
- monitoring the stability of the watercourses. Specifically, observe and note areas of increased bed/bank erosion so that channel stabilization measures can be implemented in a timely manner, if required.

#### **7.7 Cumulative Effects**

On a regional basis, i.e., at the outlet of Christina Lake or the downstream limit of the ARSA, the hydrological impacts of the project are predicted to be low.

#### **7.8 Summary**

The project includes access roads, pipeline/utility corridors, a temporary construction laydown area, stockpiles and well pads. The project will increase the proportion of disturbed areas in the Sunday Creek watershed by less than 1% (Tables 7.8-1 and 7.8-2). In the East Unnamed and West Unnamed Creek watersheds, surface disturbances will increase up to 7% of the respective watershed areas.

**Table 7.8-1: Summary of Hydrological Impacts of the Project**

Site	Area			Mean Annual			1:10 Year Flood Event		1:100 Year Flood Event	
	Total (km <sup>2</sup> )	Undisturbed (km <sup>2</sup> )	Disturbed <sup>1</sup> (km <sup>2</sup> )	Volume (dam <sup>3</sup> )	Flow (m <sup>3</sup> /s)	Change (%)	Daily Discharge (m <sup>3</sup> /s)	Change (%)	Daily Discharge (m <sup>3</sup> /s)	Change (%)
<b>Baseline</b>										
SC1	167	138	28	17 956	0.57	24%	14.1	22%	25.9	15%
SC2	378	325	53	39 932	1.27	9.6%	22.7	19%	41.5	13%
UC1	11.9	9.51	2.4	1 351	0.043	28%	2.81	23%	5.22	13%
UC2	4.6	4.21	0.4	446	0.014	9.1%	1.35	6.8%	2.76	5.5%
BC1	16.2	14.7	1.5	1 574	0.050	9.1%	3.81	8.3%	7.58	5.1%
Direct	24.1	22.7	1.4	2 294	0.073	6.9%	5.56	5.5%	11.2	3.3%
<b>Impacts</b>										
SC1	167	138	29	18 056	0.57	0.55%	14.2	0.65%	26.0	0.47%
SC2	378	324	54	40 039	1.27	0.27%	22.8	0.33%	41.6	0.24%
UC1	11.9	8.84	3.0	1 443	0.046	6.9%	3.02	7.5%	5.48	5.1%
UC2	4.6	3.94	0.7	485	0.015	8.7%	1.45	7.6%	2.93	5.9%
BC1	16.2	14.7	1.5	1 574	0.050	0.00%	3.81	0.00%	7.58	0.00%
Direct	24.1	22.5	1.6	2 319	0.074	1.1%	5.62	1.1%	11.2	0.71%

<sup>1</sup> Includes disturbance areas from Devon Jackfish and Jackfish 2 projects (Devon 2003, 2006).

**Table 7.8-2: Summary of Project Impacts on Water Quantity**

<b>Water Quantity Characteristic</b>	<b>Direction</b>	<b>Geographical Extent</b>	<b>Magnitude</b>	<b>Duration</b>	<b>Reversible</b>	<b>Confidence</b>	<b>Final Impact Rating</b>
Mean Annual Flow	Negative	Local	Low to moderate	Long-term	Yes	Good	Moderate
1:10 Year Flood Even	Negative	Local	Low to moderate	Long-term	Yes	Good	Moderate
1:100 Year Flood Event	Negative	Local	Low to moderate	Long-term	Yes	Good	Moderate
Low Flows	Negative	Local	Low to moderate	Long-term	Yes	Good	Moderate

Impacts to streamflows (annual total discharge and peak flows) in the East and West Unnamed Creek watersheds are predicted to be moderate. The effects on flows in the remaining watersheds considered in this assessment are classified as low (i.e., well within the range of measurement error). The impact of the Expansion Project on Christina Lake water levels has also been predicted to be low.

The cumulative effects of the project on surface water flows in the ARSA are summarized in [Table 7.8-3](#).

**Table 7.8-3: Cumulative Effects Assessment**

Attribute	Sunday Creek	Christina Lake
Geographic Extent	Local	Regional
Magnitude	Low	Low
Direction	Neutral	Neutral
Duration	Mid-term	Mid-term
Confidence: Understanding of Impact	Good	Good
Confidence: Understanding of Mitigation	Good	Good
Confidence: Adequacy of Site-Specific Data	Poor	Good

## 7.9 Literature Cited

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