SURFACE WATER HYDROLOGY

Fort McKay Specific Assessment

Fort McKay
Industry Relations Corporation

March 2010

Contents

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4.0 Surface Water Hydrology

4.1 Fort McKay's Key Concerns Related to Surface Water

The lower Athabasca River and its many tributaries are within Fort McKay's traditional lands. These rivers are important to Fort McKay for traditional uses and the maintenance of their culture. It is equally important to Fort McKay that the ecological integrity of the rivers be protected and sustained for future generations of their people. This includes protection of the water, the fish and the overall aquatic ecosystem. A strong connection to nature has developed an appreciation in the Community of the importance of the linkages between land and water. This holistic approach was understood long before conventional watershed planning techniques began to relate land-based activities to water resources.

Fort McKay's expectation is that rivers will be maintained as close to natural flow conditions as possible. This means both spatially throughout a watershed and temporally throughout the various seasons. Maintaining variability from year-to-year is equally important. Fort McKay also expects that runoff from pristine areas of a watershed will be used to help sustain the river in the downstream portion of the watershed that is undergoing change, as opposed to being used to achieve mine reclamation goals.

Fort McKay believes that one key to protecting surface water is to develop appropriate watershed management plans. Such plans set protection levels up front that provide direction for subsequent development. Watershed monitoring programs provide feedback on whether environmental effects are within predicted values and information necessary for alterations to the management plan.

4.2 Fort McKay Specific Assessment Approach – Surface Water

4.2.1 Introduction

In many EIAs, effects on surface water quantity are not assessed and classified separately, using impact criteria based on such parameters as magnitude, geographic extent, duration, reversibility and frequency of the predicted effect. Rather, potential changes to surface water are determined for use in other environmental areas (e.g., fish habitat, water quality).

Fort McKay's perspective is that there are surface water parameters that can be assessed on their own standing to identify at a high level, the need for management action. Spatial and temporal changes in surface water quantity are factors that can point to the need for a water management plan. Deviations in natural flow patterns or changes to runoff volumes are two specific parameters that can be assessed to assist in this. Cumulative land disturbance in a watershed is another parameter that can be used to determine the potential for impacts to surface water.

4.2.2 Potential Impacts on Surface Water

Many project-specific activities have potential linkages to surface water. These include initial muskeg drainage, overburden dewatering and basal aquifer depressurizing, changes to natural drainage patterns, close-circuit operations during mining, closure drainage systems and pit lakes at the reclamation stage, and water withdrawals from the Athabasca River. Such disturbances have the potential to affect flows and water levels in receiving streams, water levels in lakes, sediment transport and channel stability. Such changes themselves have the potential to impact other areas, for example fish habitat.

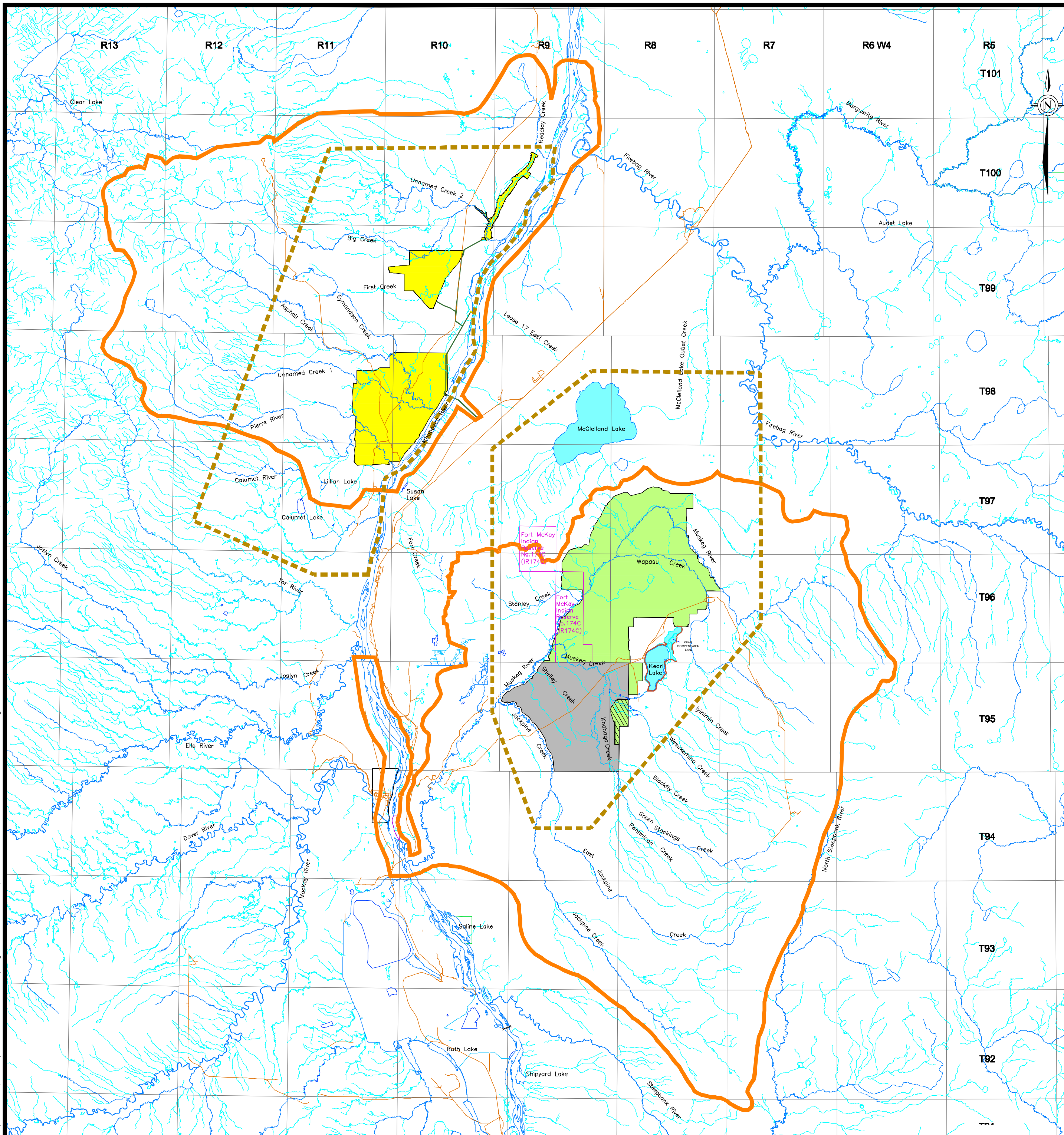
Shell provides a thorough linkage analysis for surface water hydrology in Section 6.4.2.6 of their Surface Water Hydrology Assessment (Volume 4A, Shell, 2007). Connections to other topic areas are identified in their Figure 6.4-3 (Volume 4A, Shell, 2007). These include water quality, fish and fish habitat, and terrestrial vegetation, wetlands and forest resources.

4.2.3 Data Sources and Limitations

Fort McKay's surface water assessment is based on data provided by Shell. Shell has identified sources of data for climate, stream flow, channel surveys and water allocations in Section 6.4.2.7 of the Surface Water Hydrology Assessment (Volume 4A, Shell, 2007). Stream flow records at the Water Survey of Canada hydrometric station Athabasca River below McMurray form the basis for the Athabasca River assessment. The historical record provides an acceptable base for analyses. Historical data in the Jackpine River Mine and Pierre River Mine local areas is not as extensive. The Hydrologic Simulation Program – Fortran (HSPF) Model is used in these locations to derive a set of flows that depict runoff from natural, disturbed and reclaimed areas for different time periods. The accuracy of the HSPF model is highly dependent on representative stream flow and climate data with which to base the model calibrations on.

4.2.4 Surface Water Study Areas

There are three surface water study areas associated with the Jackpine Mine Expansion and the Pierre River Mine. These are: the main stem of the lower Athabasca River; the Jackpine Mine Expansion local area that includes the Muskeg River and Wapasu Creek among others; and the Pierre River Mine local area that includes Pierre River, Asphalt Creek, Eymundson Creek, First Creek, and Big Creek among others. These local study areas are consistent with Shell's assessment (See Figure 4-1 and Figure 4-2, which are the same as Figures 6.2-3 and 6.2-4, Volume 4A, Shell, 2007).



LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- JACKPINE MINE – PHASE 1
- LEASE SWAPPED TO SYNCRUDE
- LAKE PERIMETER LEVEE

LOCAL STUDY AREA

- HYDROLOGY, WATER QUALITY, FISH AND FISH HABITAT
- HYDROGEOLOGY

10 0 10
SCALE KILOMETRES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.) USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

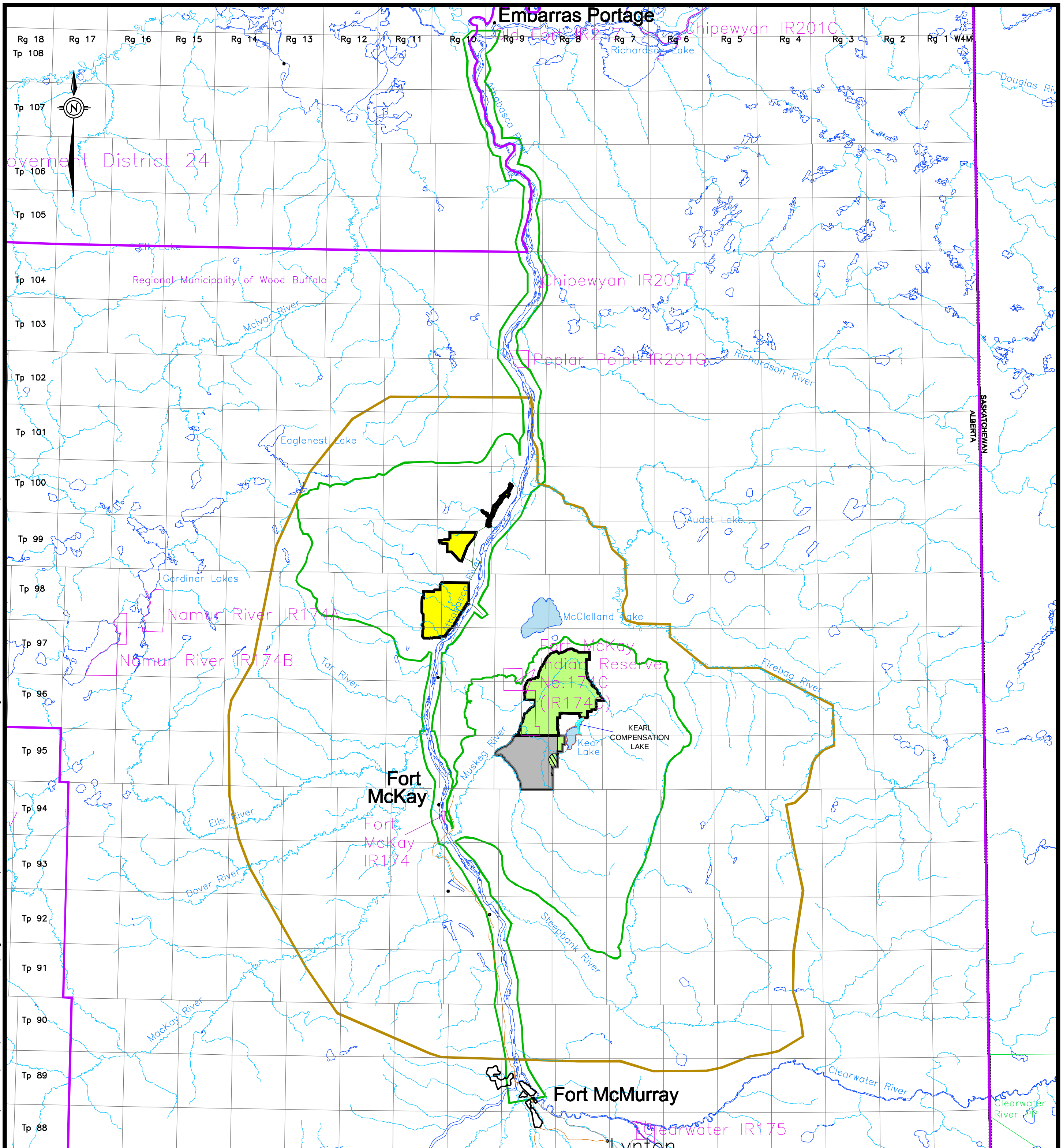
PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

AQUATIC RESOURCES LOCAL STUDY AREAS

PROJECT 06-1346-022.6500			FILE No. LSA	
DESIGN	AT	28/09/07	SCALE AS SHOWN	REV. 0
CADD	TY	27/11/07		
CHECK	AT	29/10/07	FIGURE: 6.2-3	
REVIEW	WES	05/12/07		



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LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- JACKPINE MINE – PHASE 1
- LEASE SWAPPED TO SYNCRUDE

REGIONAL STUDY AREAS

- HYDROLOGY, WATER QUALITY, FISH AND FISH HABITAT
- HYDROGEOLOGY

20 0 20

SCALE METRES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.) USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

AQUATICS RESOURCES REGIONAL STUDY AREAS

PROJECT 06-1346-022.6500			FILE No. RSA
DESIGN	AT	28/09/07	SCALE AS SHOWN REV. 0
CADD	TY	27/11/07	**FIGURE: 6.2-4**
CHECK	AT	16/10/07	
REVIEW	WES	04/12/07	

4.2.5 Surface Water Key Indicators

Two key indicators are used to assess implications of changes to surface water hydrology. The first indicator is the change in the magnitude and frequency of seasonal flows. The second indicator is the percentage of watershed area undergoing change due to development and related land-use activity.

Together the key indicators provide a first order overview of the state of surface water in a given watershed. This qualitative assessment points more to the need for water management planning than the potential state of a particular component. Indicators for other connected topic areas, such as fish and water quality, can add further detail to this state of a watershed.

4.2.6 Fort McKay Surface Water Assessment Criteria

The following criteria were developed by Fort McKay as part of the Healing the Earth Strategy to provide a first order overview of the state of surface water in a watershed. The criteria are based on observed changes in surface water runoff that occurred in the Spring Creek and Tri Creeks research watersheds in Alberta (DeBoer unpublished data, Jablonski 1978).

The degree of change in a watershed forms the basis for this state of the watershed index. The index points to the relative need for water management planning to be undertaken in a watershed. From a regulatory perspective, it identifies the need for a shift from case-by-case approvals to a comprehensive plan for a watershed.

- **Sustainable** – less than 10% change in stream flow in any given season and/or less than 20% of the watershed area affected by development and related land-use changes. No water management plan is needed at this time.
- **Threatened** – more than 10% change but less than 25% change in stream flow in any season, and/or between 20% and 40% of the watershed area affected by development and related land-use changes. A water management plan should be developed to establish impact limits and provide direction to development.
- **Endangered** – more than 25% change in stream flow in any given season and/or more than 40% of the watershed area affected by development and related land-use changes. A water management plan is urgently needed to establish impact limits and provide direction to development.

A state of the watershed index of either threatened (**yellow** situation) or endangered (**red** situation) is considered a significant effect.

4.2.7 Fort McKay's Healing the Earth Strategy

Fort McKay's Healing the Earth Strategy (HTES; Fort McKay IRC 2010) has four strategies (***retain***, ***reclaim***, ***improve*** and ***offset***) that the Community supports with regard to addressing environmental issues. Of the four tenets of Fort McKay's Healing the Earth Strategy, the surface water hydrology component emphasizes ***retain*** and ***reclaim***. Retaining both the undisturbed watershed area at 80% or greater and seasonal stream flows at 90% of natural flows or greater would ensure a sustainable watershed. Reclaiming disturbed areas in a timely fashion would restore such areas to a state similar to undisturbed.

4.3 Athabasca River Impact Assessment

4.3.1 Stressors on the Athabasca River

Water withdrawals are the main stressors on the Athabasca River. These withdrawals can be either direct from the river or indirect through activities such as close-circuit operations during mining or changes in the basal aquifer. Shell predicts the maximum average net water withdrawal to be 701,424 dam^3. This assessment of future water withdrawals is reasonable. Oil sands accounts for 512,801 dam^3 or 73% of this maximum.

4.3.2 Pre-Development Scenario

Pre-Development Scenario flows for the Athabasca River were computed by Shell by adding the licensed water requirement for each year to the recorded flows at Water Survey of Canada Station 07DA001 - Athabasca River below McMurray. Seasonal pre-development values are summarized in Table 4-1.

4.3.3 Current Scenario

The year 2008 is selected to represent the Current Scenario for the Athabasca River since oil sands water-use reports are available for that year. Table 4-2 shows the 2008 oil sands water use from the Athabasca River. The total water use by oil sands projects from the Athabasca River was about 118,268 dam^3 in 2008. The total 2008 net water use, which is defined as water withdrawal minus return flow, was about 114,318 dam^3. This is equivalent to an average annual rate of 3.63 m^3/s. Note that the peak instantaneous licensed allocation for these oil sands operators during this period was 14.39 m^3/s, which reflects the total intake capacity of these projects rather than day-to-day need.

Table 4-1: Athabasca River Flows in Reach 4 for Development Cases Compared to Pre-Development

Hydrologic Condition	Season	Pre-Development	Current Scenario			Base Case				Application Case				Planned Development Case		
		Stream Flow Discharge	Stream Flow Discharge	Change Due to Current Scenario	Change From Pre-Development (%)	Stream Flow Discharge	Change Due to Base Case	Change From Pre-Development	Change from Pre-Development	Stream Flow Discharge	Change Due to the Project	Change From Pre-Development	Change From Pre-Development	Change Due to Planned Development	Change From Pre-Development	Change From Pre-Development
		[m³/s]	[m³/s]	[m³/s]	[%]	[m³/s]	[m³/s]	[m³/s]	[%]	[m³/s]	[m³/s]	[m³/s]	[%]	[m³/s]	[m³/s]	[%]
average year	winter	186	176	-9.61	**-5.5**	163	-13	-22.6	**-7.0**	160	-3.6	-26.2	**-14.1**	-1.74	-28.0	**-15.0**
	spring	541	531	-9.61	**-1.8**	519	-12	-21.6	**-2.2**	515	-3.7	-25.3	**-4.7**	-1.74	-27.1	**-5.0**
	summer	1239	1229	-9.61	**-0.8**	1,217	-12	-21.6	**-1.0**	1,213	-4.2	-25.8	**-2.1**	-1.74	-27.6	**-2.2**
	fall	578	568	-9.61	**-1.7**	556	-12	-21.6	**-2.1**	552	-4.2	-25.8	**-4.5**	-1.74	-27.6	**-4.8**
10-year dry	winter	128	118	-9.61	**-8.1**	114	-4	-13.6	**-3.1**	113	-0.2	-13.8	**-10.8**	-1.74	-15.6	**-12.1**
	spring	261	251	-9.61	**-3.8**	243	-8	-17.6	**-3.1**	242	-1.2	-18.8	**-7.2**	-1.74	-20.6	**-7.9**
	summer	1028	1018	-9.61	**-0.9**	1,006	-12	-21.6	**-1.2**	1,002	-4.2	-25.8	**-2.5**	-1.74	-27.6	**-2.7**
	fall	439	429	-9.61	**-2.2**	417	-12	-21.6	**-2.7**	413	-3.6	-25.2	**-5.7**	-1.74	-27.0	**-6.1**
10-year wet	winter	195	185	-9.61	**-5.2**	174	-11	-20.6	**-5.6**	172	-2	-22.6	**-11.6**	-1.74	-24.4	**-12.5**
	spring	575	565	-9.61	**-1.7**	554	-11	-20.6	**-1.9**	551	-2.6	-23.2	**-4.0**	-1.74	-25.0	**-4.3**
	summer	1720	1710	-9.61	**-0.6**	1,698	-12	-21.6	**-0.7**	1,694	-4.2	-25.8	**-1.5**	-1.74	-27.6	**-1.6**
	fall	790	780	-9.61	**-1.2**	767	-13	-22.6	**-1.6**	763	-4.2	-26.8	**-3.4**	-1.74	-28.6	**-3.6**

Table 4-2: 2008 Oil Sands Water Use from the Athabasca River

	Water Withdrawal (dam^3)	Return Flow (dam^3)	Net Water Use (dam^3)
Suncor	45,939	3,950	41,989
Syncrude	41,233	0	41,233
Shell	13,505	0	13,505
CNRL	17,591	0	17,591
2008 Total	**118,268**	**3,950**	**114,318**

Shell summarized the non-oil sands water allocations from the Athabasca River in Table 6.4-26 of the Surface Water Hydrology Assessment (Volume 4A, Shell, 2007). The total annual net water requirement for the non-oil sands users was determined to be 188,723 dam^3, equivalent to 5.98 m^3/s as an average annual rate. Assuming this rate to be constant in 2008, the total net water use from the Athabasca River for the Current Scenario is 9.61 m^3/s. This represents a 1.5% reduction in the mean annual Athabasca River at Fort McMurray flow of 630 m^3/s. Table 4-1 shows a comparison between Pre-Development Scenario flows and the Current Scenario in the Athabasca River in Reach 4.

An ***Interim Framework: Instream Flow Needs and Water Management System for the Lower Athabasca River*** (also known as the Phase 1 Water Management Framework) is currently in place (AENV and Fisheries and Oceans Canada (DFO) 2007). The Phase 1 Water Management Framework sets maximum withdrawal rates for each week of the year. These limits are prescribed for three water management zones (green, yellow and red) and are based on the flow in the river. The lowest rate specified in the Phase 1 Framework is 8 m^3/s during a red condition during week 6 through week 11 of the year (week 1 is from January 1 to January 7, week 2 is from January 8 to January 14, etc). While this red condition would limit peak instantaneous diversions for oil sands, the current average annual daily oil sands requirement of 3.63 m^3/s is well below the 8 m^3/s limit. Accordingly, there are currently no restrictions beyond existing water license limits on either annual or seasonal oil sands water allocations.

The largest change in the Current Scenario from Pre-Development occurs in winter when flows in the river are the lowest. For a 10-year dry hydrologic condition, approximately a yellow condition, there is a -8.1% change from pre-development flows (Table 4-1).

Fort McKay's surface water assessment criteria (see Section 4.2.6) set the state of the lower Athabasca River watershed for the Current Scenario as sustainable (a **green** situation) since the net change in stream flow in any given season is < 10% and the change in watershed area is < 20%.

4.3.4 Base Case

Shell identifies the annual water allocations for the Base Case in Section 6.4.7.1 of the Surface Water Hydrology Assessment (Volume 4A, Shell, 2007). The net water allocation for the watershed is 615,000 dam^3, equivalent to an average annual rate of 19.5 m^3/s. Of this, oil sands operations account for 425,801 dam^3, or 13.5 m^3/s.

The Phase 1 Water Management Framework would limit a portion of these oil sands water diversions during some winter yellow flow conditions and most winter red flow conditions. For a 10-year dry hydrologic condition, approximately a yellow condition, there is a -10.9% change from Pre-Development flows (Table 4-1). For an average year hydrologic condition, there is a -12.4% change from Pre-Development flows (Table 4-1).

The Fort McKay surface water assessment criteria set the state of the lower Athabasca River watershed for the Base Case as threatened (a **yellow** situation) since the change in stream flow is >10% but <25% in any given season and the change in watershed area is <20%.

4.3.5 Application Case

4.3.5.1 Application Case Assessment

Shell identifies the annual water allocations for the Application Case in Section 6.4.7.2 of the Surface Water Hydrology Assessment (Volume 4A, Shell, 2007). Water allocations from the Athabasca River increase annual withdrawal by 55,000 dam^3 for the Pierre River Mine, equivalent to an average annual rate of 1.74 m^3/s. An additional 18,000 dam^3 will be added for the Jackpine Expansion.

Application Case flow changes from Pre-Development flows in Reach 4 of the Athabasca River are provided in Table 4-1. As in the Base Case, the Phase 1 Water Management Framework would limit a portion of these oil sands water diversions during some winter yellow flow conditions and most winter red flow conditions. For a 10-year dry hydrologic condition, approximately a yellow condition (as described in the Phase 1 Water Management Framework), there is a -11.6% change from Pre-Development flows. For an average year hydrologic condition, there is a -13.9% change from Pre-Development flows.

The Fort McKay surface water assessment criteria set the state of the lower Athabasca River watershed for the Application Case as threatened (a **yellow** situation) since the proposed stream flow changes are >10% but less than 25% in any given season and the change in watershed area is <20%.

4.3.5.2 Shell's Proposed Mitigation and Management Measures

Shell has proposed several mitigation measures for the Athabasca River. These include minimizing raw water withdrawal requirements, staging mine site water-related activities such as drainage and diversion, and following the water withdrawal limits specified by the Phase 1 Water Management Framework. These are all appropriate measures.

Without the final Phase 2 Water Management Framework, which is still under development, it is difficult to discuss details on what steps would be appropriate for Shell to take to meet the Framework conditions. Once a management plan is established, industry will collectively need to adjust their operations to meet the plan. Shell has committed to comply with the Phase 2 Water Management Framework for the lower Athabasca River.

4.3.6 Planned Development Case

Shell identifies the annual water allocations for the Planned Development Case in Section 6.4.7.2 of the Surface Water Hydrology Assessment (Volume 4A, Shell, 2007). The additional 32,000 dam^3 is equivalent to 1.74 m^3/s. This would add another 1% to the change from Pre-Development conditions.

For an average year hydrologic condition, there is a -14.9% change from Pre-Development flows.

The Fort McKay surface water assessment criteria set the state of the lower Athabasca River watershed for the Planned Development Case as threatened (a **yellow** situation) since the existing, approved and planned flow changes are >10% but less than 25% in any given season and the change in watershed area is <20%.

4.3.7 Overall Conclusions Regarding Surface Water in the Lower Athabasca River Watershed

Oil sands water demand during Athabasca River winter flows could exceed 20% in the 10-year low flow winter. For the 7Q10 flow – the seven-day consecutive low flow with a ten-year return period – of 100 m^3/s, this demand could exceed 25%.

Although an interim measure, the Phase 1 Water Management Framework is positioned to limit water withdrawal in the lower Athabasca River. Peak instantaneous oil sands water withdrawals are curtailed during low flow winters, although current projects can meet their average daily water requirement. Oil sands water withdrawals would also be restricted during low flow winters for the Base Case, Application Case and Planned Development Case.

Fort McKay's assessment of the state of surface water in the Lower Athabasca River Watershed is summarized in Table 4-3.

Table 4-3: Summary of the State of Surface Water in the Lower Athabasca River Watershed

	Current Scenario	Base Case	Application Case	Planned Development Case
Maximum change in seasonal stream flow	-8.1%	-11%	-12%	-14%
Watershed area affected by development	<10%	<10%	<10%	<10%
State of surface water in the watershed	Sustainable	Threatened	Threatened	Threatened

4.4 Jackpine Mine Expansion Impact Assessment

4.4.1 Stressors on the Muskeg River

Activities related to mine development are the key stressors on the Muskeg River. These include initial muskeg drainage, overburden dewatering and basal aquifer depressurizing, changes to natural drainage patterns, close-circuit operations during mining, closure drainage systems and pit lakes at the reclamation stage. A complicating factor is the shear number of existing and approved mines in the area. These include Albian Sands Muskeg River Mine and Expansion, Shell Jackpine Mine – Phase 1, Syncrude Aurora North and South mines and Imperial Oil Kearl Project. Timing of various activities in each mine becomes a factor in cumulative effects.

4.4.2 Pre-Development Scenario

Shell provided Fort McKay with Pre-Development Scenario watershed disturbance and flow information for the Muskeg River watershed (Golder 2009). Watershed disturbance due to development in the Pre-Development Scenario is zero (Table 4-4).

Shell used hydrologic parameters similar to those in the EIA to create pre-development flow files for the Muskeg River watershed. Flows are provided for Jackpine Creek at Node J1, and Muskeg River at Node M0, M1, M2 and M3 (Tables 4.2-5 to 4.2-10 in Golder 2009). The Muskeg River at Node M3 is selected for state of the watershed analysis. A rating at Node M3 would be equaled or exceeded at most upstream nodes in the watershed. Pre-development flows in the Muskeg River are shown in Table 4-5.

Table 4-4: Disturbance Areas by Type and Development Case for the Muskeg River Watershed

	Pre-Development Scenario		Current Scenario		Base Case		Application Case		Planned Development Case	
Disturbance Type	Area [ha]	% of Watershed	Area [ha]	% of Watershed	Area [ha]	% of Watershed	Area [ha]	% of Watershed	Area [ha]	% of Watershed
Development	0	0	18,419	12.5	50,690	34.3	63,667	43.1	69,106	46.8
Fire	8,248	6	8,362	5.7	3,613	2.4	685	0.5	412	0.3
Pipeline	0	0	886	0.6	886	0.6	886	0.6	1099	0.7
Road	0	0	75	0.1	75	0.1	58	0	43	0
Seismic/Cutline	0	0	1,073	0.7	1,073	0.7	875	0.6	820	0.6
Wellsite	0	0	550	0.4	463	0.3	362	0.2	327	0.2
Plant	0	0	0	0	0	0	0	0	0	0
Municipal	0	0	0	0	0	0	0	0	0	0
Urban	0	0	0	0	0	0	0	0	0	0
Transmission Line	0	0	0	0	0	0	0	0	0	0
Total	**8,248**	**6**	**29,366**	**19.9**	**56,801**	**38.5**	**66,533**	**45.1**	**71,808**	**48.7**
Total (not including fire)	**0.0**	**0.0**	**21,004**	**14.2**	**53,188**	**36.1**	**65,848**	**44.6**	**71,396**	**48.4**

Note: total area of Muskeg River watershed is 147, 782 ha

Table 4-5: Muskeg River Flows at Node M3 by Development Case Compared to Pre-Development

Year	Expected Value of Parameter for Snapshot Conditions	Pre-Development	Current Scenario		Base Case					Application Case			
		Streamflow Discharge	Streamflow Discharge	Change From Pre-Development	Change From Pre-Development	Streamflow Discharge	Change Due to Base Case	Change From Pre-Development Condition	Change From Pre-Development	Streamflow Discharge	Change Due to the Project	Change From Pre-Development Condition	Change From Pre-Development Condition
		[m³/s]	[m³/s]	[m³/s]	[m³/s]	[m³/s]	[m³/s]	[m³/s]	[%]	[m³/s]	[m³/s]	[m³/s]	[%]
2012	Mean Annual Discharge	3.75	3.63	-0.12	-3.2	4.18	0.55	0.43	11.5	4.22	0.0384	0.47	12.5
	Mean Open-Water Discharge[(a)]	6.13	5.88	-0.25	-4.1	6.64	0.76	0.51	8.3	6.67	0.0368	0.54	8.8
	Mean Ice-Cover Discharge[(a)]	0.463	0.44	-0.023	-5.0	0.808	0.368	0.345	74.5	0.844	0.0357	0.381	82.3
	7Q10 Low Flow Discharge	0.016	0.016	0	0.0	0.368	0.352	0.352	2200.0	0.373	0.0045	0.357	2231.3
	10 Year Flood Peak Discharge	50.8	49	-1.8	-3.5	45.4	-3.6	-5.4	-10.6	49.1	3.66	-1.7	-3.3

Year	Expected Value of Parameter for Snapshot Conditions	Pre-Development	Current Scenario		Base Case					Application Case			
		Streamflow Discharge	Streamflow Discharge	Change From Pre-Development	Change From Pre-Development	Streamflow Discharge	Change Due to Base Case	Change From Pre-Development Condition	Change From Pre-Development	Streamflow Discharge	Change Due to the Project	Change From Pre-Development Condition	Change From Pre-Development Condition
		[m³/s]	[m³/s]	[m³/s]	[m³/s]	[m³/s]	[m³/s]	[m³/s]	[%]	[m³/s]	[m³/s]	[m³/s]	[%]
2029	Mean Annual Discharge	3.75	3.63	-0.12	-3.2	3.79	0.16	0.04	1.1	3.91	0.1261	0.16	4.3
	Mean Open-Water Discharge[a]	6.13	5.88	-0.25	-4.1	5.78	-0.1	-0.35	-5.7	5.97	0.1902	-0.16	-2.6
	Mean Ice-Cover Discharge[a]	0.463	0.44	-0.023	-5.0	1.046	0.606	0.583	125.9	1.146	0.1005	0.683	147.5
	7Q10 Low Flow Discharge	0.016	0.016	0	0.0	0.63	0.614	0.614	3837.5	0.687	0.0569	0.671	4193.8
	10 Year Flood Peak Discharge	50.8	49	-1.8	-3.5	40.1	-8.9	-10.7	-21.1	36.1	-4.05	-14.7	-28.9

Year	Expected Value of Parameter for Snapshot Conditions	Pre-Development	Current Scenario		Base Case					Application Case			
		Streamflow Discharge	Streamflow Discharge	Change From Pre-Development	Change From Pre-Development	Streamflow Discharge	Change Due to Base Case	Change From Pre-Development Condition	Change From Pre-Development	Streamflow Discharge	Change Due to the Project	Change From Pre-Development Condition	Change From Pre-Development Condition
2049	Mean Annual Discharge	3.75	3.63	-0.12	-3.2	3.24	-0.39	-0.51	-13.6	2.92	-0.3192	-0.83	-22.1
	Mean Open-Water Discharge[(a)]	6.13	5.88	-0.25	-4.1	4.96	-0.92	-1.17	-19.1	4.55	-0.4106	-1.58	-25.8
	Mean Ice-Cover Discharge[(a)]	0.463	0.44	-0.023	-5.0	0.832	0.392	0.369	79.7	0.641	-0.1916	0.178	38.4
	7Q10 Low Flow Discharge	0.016	0.016	0	0.0	0.263	0.247	0.247	1543.8	0.239	-0.0249	0.223	1393.8
	10 Year Flood Peak Discharge	50.8	49	-1.8	-3.5	31.1	-17.9	-19.7	-38.8	23.4	-7.72	-27.4	-53.9

Year	Expected Value of Parameter for Snapshot Conditions	Pre-Development	Current Scenario		Base Case					Application Case			
		Streamflow Discharge	Streamflow Discharge	Change From Pre-Development	Change From Pre-Development	Streamflow Discharge	Change Due to Base Case	Change From Pre-Development Condition	Change From Pre-Development	Streamflow Discharge	Change Due to the Project	Change From Pre-Development Condition	Change From Pre-Development Condition
2065 and Far Future	Mean Annual Discharge	3.75	3.63	-0.12	-3.2	3.96	0.33	0.21	5.6	4.04	0.0746	0.29	7.7
	Mean Open-Water Discharge[a]	6.13	5.88	-0.25	-4.1	5.79	-0.09	-0.34	-5.5	5.63	-0.1603	-0.5	-8.2
	Mean Ice-Cover Discharge[a]	0.463	0.44	-0.023	-5.0	1.381	0.941	0.918	198.3	1.785	0.4042	1.322	285.5
	7Q10 Low Flow Discharge	0.016	0.016	0	0.0	0.301	0.285	0.285	1781.3	0.417	0.1152	0.401	2506.3
	10 Year Flood Peak Discharge	50.8	49	-1.8	-3.5	30.5	-18.5	-20.3	-40.0	27.9	-2.6	-22.9	-45.1

[a] The "open-water" season is the period from mid-April to mid-November; "ice-cover" season is the period from mid-November to mid-April.

4.4.3 Current Scenario

The year 2008 is selected as the Current Scenario for the Muskeg River. The Aurora North Mine and the Muskeg River Mine and Expansion account for the majority of the changes from the Pre-Development Scenario. The watershed area affected by development for the Current Scenario is 14.2% (Table 4-4). Flow changes for the Current Scenario range from -4% for the mean open-water discharge to -5% for the mean ice-covered discharge (Table 4-5).

Fort McKay's surface water assessment criterion assesses the state of the Muskeg River watershed for the Current Scenario as sustainable (a **green** situation).

4.4.4 Base Case

In addition to the Aurora North and Muskeg River Mine and Expansion, the Base Case includes the Aurora South Mine, the Jackpine Mine – Phase 1, and the Kearl Oil Sands Project. The watershed area affected by development for the Base Case is 36.1% (Table 4-5), which gives this a threatened rating based on area.

From a flow perspective, there are significant changes from the Pre-Development Scenario. Depending on the year, future changes in mean open-water discharge range from +8% to -19% (Table 4-5). Change in mean ice-covered discharges range from +75% to +126% during operations, and +198% in the far future. Accordingly, Fort McKay's surface water assessment criteria set the state of the Muskeg River watershed for the Base Case as endangered, a **red** situation.

4.4.5 Application Case

4.4.5.1 Application Case Assessment

The Jackpine Mine Expansion Application Case adds some 9,700 hectares (ha) to the total disturbed area in the Muskeg River watershed. The area of watershed disturbance for the Application Case is 66,533 ha, or 44.6% (Table 4-5). Area disturbed by fire is not included in this total.

4.4.5.2 Shell's Proposed Mitigation and Management Measures

Coordination of mining activities is a key to minimizing the impacts to the Muskeg River. Shell indicates that it held a number of meetings with Syncrude and Imperial Oil to address potential operational and closure issues in the Muskeg River watershed. The surface drainage plans are provided by Shell in Volume 1, Section 10 and Volume 4, Appendix 4-3 (Shell 2007). Given that the timing of mine operations is in a state of flux, this will need to be an ongoing effort.

4.4.5.3 Fort McKay's Impact Ranking

Shell's Jackpine Mine Expansion increases the watershed areas affected by development to 44.6%. This alone gives the state of the watershed index an endangered rating. From a flow perspective, there are still significant changes from the Pre-Development Scenario. Depending on the year, future changes in mean open-water discharge range from +3% to -26%. Change in mean ice-covered discharges range from +38% to +148% during operations, and +286% in the far future. Accordingly, Fort McKay's surface water assessment criteria set the state of the Muskeg River watershed for the Application Case as endangered (**red** situation).

4.4.6 Planned Development Case

4.4.6.1 Planned Development Case Assessment

The Planned Development Case increases the watershed areas affected by development to 48.4%, excluding fire disturbances (Table 4-5).

4.4.6.2 Fort McKay's Impact Ranking

The state of the Muskeg River watershed remains at endangered (**red**) for the Planned Development Case.

4.4.7 Overall Conclusions Regarding Surface Water in the Muskeg River Watershed

The overall conclusions regarding surface water in the Muskeg River watershed are summarized in Table 4-6.

Table 4-6: Summary of the State of Surface Water in the Muskeg River Watershed at Node M3

	Current Scenario	Base Case	Application Case	Planned Development Case
Maximum change in seasonal stream flow	-5%	126%	148%	148%
Watershed area affected by development	14.2%	36.1%	44.6%	48.4%
State of surface water in the watershed	Sustainable	Endangered	Endangered	Endangered

4.5 Pierre River Mine Impact Assessment

4.5.1 Stressors on the Pierre River Mine Area

The Pierre River Mine Area is essentially in its natural state. Mine development and water diversion will be the future main stressors in the area. Specific activities include initial muskeg drainage, overburden dewatering and basal aquifer depressurizing, changes to natural drainage patterns, close-circuit operations during mining, closure drainage systems and pit lakes at the reclamation stage.

4.5.2 Pre-development, Current Scenario, and Base Case Scenarios

Pre-Development, Current Scenario, and Base Case hydrologic conditions for the Pierre River Mine area are the same as natural (a **green** situation).

4.5.3 Application Case

4.5.3.1 Application Case Assessment

Shell indicates that during construction and operation of the Pierre River Mine, a portion of the downstream channels of the Pierre River, Eymundson Creek and Unnamed Creek will be removed because of mining activities. A permanent lake will be constructed as part of the diversion plan that will see Big Creek diverted to the Redclay Compensation Lake.

The projected watershed area affected by development remains less than 10% throughout the Application Case (Table 4-7).

Changes in the mean open-water discharge are all less than -10%. However, changes in the mean ice-covered discharge in several of the watersheds exceed -20%, a notable change in flow volumes.

4.5.3.2 Shell's Proposed Mitigation and Management Measures

During mine operations, only the Pierre River experiences changes to seasonal stream flow greater than 10%. While mean open water discharges change tends to be about -7%, mean ice covered discharges are about -23% towards the end of operations. Far-future projections for mean ice-covered discharges approach -25%. This places the state of the watershed index for the Pierre River as threatened (**yellow**), but on the borderline of endangered (**red**).

Shell mitigation measures specific to the Pierre River Mine Area include allowing surface water from undeveloped areas to continue to flow to nearby streams, releasing site runoff that meet water quality standards, and collecting process affected water within a close-circuit system. These are all acceptable measures.

Table 4-8 is the same as Table 6.4-22 from Shell 2007, Volume 4, Page 6-324.

Table 4-7: Disturbance Areas by Type and Development Case for the Pierre River Watershed

	Pre-Development Scenario		Current Scenario/ Base Case		Application Case	
Disturbance Type	**Area [ha]**	**% of Watershed**	**Area [ha]**	**% of Watershed**	**Area [ha]**	**% of Watershed**
Development	0	0	122	0.9	1,208	9
Fire	0	0	1,513	11.3	1,509	11.2
Pipeline	0	0	0	0	0	0
Road	0	0	0	0	0	0
Seismic/Cutline	0	0	89	0.7	79	0.6
Wellsite	0	0	30	0.2	23	0.2
Plant	0	0	0	0	0	0
Municipal	0	0	0	0	0	0
Urban	0	0	0	0	0	0
Transmission Line	0	0	0	0	0	0
Total	**0**	**0**	**1,754**	**13.1**	**2,819**	**21**
Total (not including fire)	**0**	**0**	**241**	**2**	**1,310**	**10**

Note: Pierre River watershed area is 13,427 ha. No planned development case is shown because currently there are no other planned developments.

4.5.3.3 Shell's Proposed Mitigation and Management Measures

Shell mitigation measures specific to the Pierre River Mine Area include allowing surface water from undeveloped areas to continue to flow to nearby streams, releasing site runoff that meet water quality standards, and collecting process affected water within a close-circuit system. These are all acceptable measures.

Table 4-8: Pierre River Flows for Application Case compared to Pre-Development

Year	Expected Value of Parameter for Snapshot Conditions	Pre-Development[c]	Application Case		
		Streamflow Discharge	Streamflow Discharge	Change Due to the Project	Change From Pre-Development Condition
		[m³/s]	[m³/s]	[m³/s]	[%]
2015	Mean Annual Discharge	0.29	0.29	0	**0.0**
	Mean Open-Water Discharge[a]	0.47	0.47	0	**0.0**
	Mean Ice-Cover Discharge[a]	0.04	0.04	0	**0.0**
	7Q10 Low Flow Discharge	0	0	0	**0.0**
	10 Year Flood Peak Discharge	7.5	7.5	0	**0.0**
2031	Mean Annual Discharge	0.44	0.41	-0.03	**-6.8**
	Mean Open-Water Discharge[a]	0.721	0.67	-0.051	**-7.1**
	Mean Ice-Cover Discharge[a]	0.052	0.04	-0.012	**-23.1**
	7Q10 Low Flow Discharge	0	0	0	**0.0**
	10 Year Flood Peak Discharge	11.8	11.3	-0.5	**-4.2**
2039[b]	Mean Annual Discharge	0.44	0.41	-0.03	**-6.8**
	Mean Open-Water Discharge[a]	0.721	0.67	-0.051	**-7.1**
	Mean Ice-Cover Discharge[a]	0.052	0.04	-0.012	**-23.1**
	7Q10 Low Flow Discharge	0	0	0	**0.0**
	10 Year Flood Peak Discharge	11.8	11.3	-0.5	**-4.2**
2049 and Far Future	Mean Annual Discharge	0.29	0.25	-0.04	**-13.8**
	Mean Open-Water Discharge[a]	0.47	0.42	-0.05	**-10.6**
	Mean Ice-Cover Discharge[a]	0.04	0.03	-0.01	**-25.0**
	7Q10 Low Flow Discharge	0	0	0	**0.0**
	10 Year Flood Peak Discharge	7.5	7	-0.5	**-6.7**

(a) The "open-water" season is the period from mid-April to mid-November; "ice-cover" season is the period from mid-November to mid-April.

(b) Application Case flow includes diversion of head watershed of Unnamed Creek 1. Hence, the predevelopment flow include pre-development runoff from Unnamed Creek

(c) Base Case and Current Scenario are the same as pre-development

4.5.4 Overall Conclusions Regarding Surface Water in the Pierre River Watershed

The results of the surface water assessment for the Pierre River Watershed are presented in Table 4-9.

Table 4-9: State of Surface Water Summary in the Pierre River Watershed

	Current Scenario	Application Case
Maximum change in seasonal stream flow	0%	-23%
Watershed area affected by development	1.8%	9.8%
State of surface water in the watershed	Sustainable	Threatened

4.6 Overall Conclusions and Recommendations Regarding Surface Water

The need for water management planning is clearly evident in the lower Athabasca River and the Muskeg River watershed.

4.6.1 Lower Athabasca River Watershed

The Fort McKay surface water assessment criteria assess the state of the lower Athabasca River watershed for the Application Case and Planned Development Case as threatened.

4.6.1.1 Project-Specific Recommendations

To protect the lower Athabasca River during winter low flow events, at some point water withdrawals must cease. Such a cutoff would help to ensure that this important ecosystem is retained for future generations. It would be unacceptable to have industrial withdrawals continue no matter what the flow in the river fell to. These low flow events can typically span several months, from late December into early April. It is therefore recommended that:

- Shell either to provide three to four months of water storage to ensure continued operations during these periods or present contingency plans for their operations should such an event arise (project-specific recommendation).

4.6.1.2 Cumulative Effects Recommendations

The Phase 1 Water Management Framework does restrict water withdrawals, but even still, change to surface water is significant. It is important for work on the Phase 2 Water Management Framework for the lower Athabasca River be completed so total impact limits can be set and future development can be directed.

- Fort McKay recommends that a water management plan for the Lower Athabasca River be finalized on an expedited basis) and the regulators ensure that water withdrawal and other impact limits are established for the Lower Athabasca River Watershed.

4.6.2 Muskeg River Watershed

The state of the Muskeg River watershed is assessed as endangered for the Base Case, Application Case and Planned Development Case. It is critical that a water management plan be created for this watershed. This recommendation is related to both project-specific and cumulative effects. Fort McKay recommends:

- The development and implementation of a complete Water Management Plan for the Muskeg River Watershed, in consultation with Fort McKay, to establish impact limits that retain both undisturbed areas and natural seasonal stream flow patterns, and provide direction to the Jackpine Mine Expansion and other developments (project-specific and cumulative effects recommendation).

The opportunity to establish such a plan has not been lost as the state of the Muskeg River in the Current Scenario is still sustainable.

4.6.3 Pierre River Watershed

The Pierre River watershed is assessed as threatened for the Application case, primarily due to changes in seasonal stream flow.

- As only Shell's project is foreseen in this watershed at this time, no watershed management plan is necessary. It is recommended however that Shell take steps to minimize the large negative change in projected stream flow (project-specific recommendation).

4.7 References

Deboer, A., Spring Creek Research Watershed, Alberta Environment, unpublished data and reports.

Fort McKay Industry Relations Corporation. 2010. Healing the Earth Strategy.

Jablonski, D. 1978. The Tri-Creeks Watershed: a study into the effects of logging on the physical, chemical and biotic conditions of three Alberta East-slope streams, Alberta Forestry Research Centre.