GROUNDWATER – SURFACE WATER INTERACTIONS IN THE
AQUATIC LOCAL STUDY AREA
ASPEN PROJECT
093 & 094-07 W4M AND 093-06 W4M

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Alexander Haluszka, M.Sc., P.Geol.
Hydrogeologist

Gordon MacMillan, P.Geol.
Principal Hydrogeologist

Amanda McKay, B.Eng.
Water Resources

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TABLE OF CONTENTS

1 INTRODUCTION .......................................................................................................................... 1
2 PHYSICAL SETTING ..................................................................................................................... 1
  2.1 Physiography .......................................................................................................................... 1
  2.2 Hydrology ................................................................................................................................ 1
  2.3 Hydrogeology .......................................................................................................................... 2
     2.3.1 Shallow Hydrostratigraphy .......................................................................................... 3
     2.3.2 Deep Hydrostratigraphy .............................................................................................. 4
     2.3.3 Aquifer Connectivity and Conceptual Hydrogeologic Model ..................................... 5
3 SUMMARY OF GROUNDWATER - SURFACE WATER INTERACTION ............................................ 6
4 REFERENCES ................................................................................................................................. 6

LIST OF TABLES

TABLE 1 Unit Streamflow from RAMP Hydrometric Monitoring Stations ........................................ 2
TABLE 2 Quaternary Well Summary .............................................................................................. 4
TABLE 3 Cretaceous Well Summary ............................................................................................... 5

FIGURES

FIGURE 1 Study Area and Summary Map
FIGURE 2 Cross-section 13-27-093-07W4M (QT-2)
FIGURE 3 Local Aquifer Pressures vs. Elevation
INTRODUCTION

This document describes the physical and hydrologic setting at Imperial Oil Limited’s proposed Aspen Project in northeast Alberta. The physiography, soils, hydrology, vegetation, and hydrogeology data discussed in this report is sourced from the Project’s environmental impact assessment (EIA; Imperial 2013) and recent investigation completed by Imperial.

PHYSICAL SETTING

2.1 Physiography

The relative topographic high of Muskeg Mountain (> 650 m above sea level [asl]) is located to the east of the aquatics local study area (LSA) and regional topography declines radially away from this feature toward the southwest, west, and northwest (Figure 1). Major water bodies within the aquatics LSA include the North Steepbank River, which flows south through the aquatics LSA to converge with the Steepbank River and onto the Athabasca River. The North Steepbank River is not located in a major valley and is incised to only several metres depth below the adjacent topography. Other watercourses within the aquatics LSA include Jackpine Creek, East Jackpine Creek, and several tributaries to Muskeg River that all flow northwest to Muskeg River and on to Athabasca River. There are also eight unnamed water bodies within the aquatics LSA, five of which are located at the headwaters of North Steepbank River and its tributaries, and three located near the headwaters of Muskeg River (Figure 1). Watersheds divide the aquatics LSA into four main drainage areas, the North Steepbank, East Jackpine Creek, Jackpine Creek, and Green Stockings Creek shown on Figure 7.2-1 of the EIA report (Volume 2, Section 7; Imperial 2013).

Approximately 77% of the Project lease area is covered by wetlands (Volume 2, Section 11, Figure 11.5-2 and Table 11.5-3 of the EIA report; Imperial 2013, ). Of these wetlands, 67% are interpreted to comprise fens with the remainder being swamps and marshes. The remainder of the lease area is mapped as upland areas or existing disturbances (Imperial 2013).

2.2 Hydrology

Surface water within and surrounding the Project lease has been characterized in Volume 2, Section 7 of the EIA report (Imperial 2013) and includes descriptions of local climate, high and low flows, and runoff volumes. Key aspects of the aquatics LSA surface water balance reported in the EIA report (Imperial 2013) include:

- average annual precipitation within the aquatics LSA is estimated at 511 mm (Volume 2, Section 7, Table 7.5-4)
- runoff approximated at 105 mm or 21% of precipitation (Volume 2, Section 7.5, page 364)
evaporation and potential evapotranspiration estimates of 300 mm and 811 mm, respectively (Volume 2, Section 7, Figure 7-9)

Based on a review of publically available data, two Regional Aquatics Monitoring Program (RAMP) Stations were identified that could provide some insight on streamflows in the aquatics LSA. Station S37 is located in the East Jackpine Creek watershed (near the 400 m asl contour) close to the western boundary of the aquatics LSA and collects open water (May to October) data. RAMP Station S02 is located on Jackpine Creek (at East Athabasca Highway) approximately 22 km northwest of the aquatics LSA and collects year-round hydrometric data. Streamflow estimates from both were reviewed to gain insight on the streamflow in the aquatics LSA. Because of its proximity to the aquatics LSA, the 6 months of data collected from Station S37 was compared to the year-round data collected at Station S02. To facilitate the comparison, the data was normalized based on the drainage areas. The two RAMP monitoring stations had similar unit streamflows; however, the average streamflow at S37 was slightly higher than S02.

TABLE 1  Unit Streamflow from RAMP Hydrometric Monitoring Stations

<table>
<thead>
<tr>
<th>Month</th>
<th>S02 Unit Streamflow (L/s/km²)</th>
<th>S37 Unit Streamflow (L/s/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>0.21</td>
<td>-</td>
</tr>
<tr>
<td>Feb</td>
<td>0.13</td>
<td>-</td>
</tr>
<tr>
<td>Mar</td>
<td>0.19</td>
<td>-</td>
</tr>
<tr>
<td>Apr</td>
<td>2.99</td>
<td>-</td>
</tr>
<tr>
<td>May</td>
<td>12.15</td>
<td>9.06</td>
</tr>
<tr>
<td>Jun</td>
<td>8.46</td>
<td>10.21</td>
</tr>
<tr>
<td>Jul</td>
<td>5.85</td>
<td>7.88</td>
</tr>
<tr>
<td>Aug</td>
<td>2.31</td>
<td>2.31</td>
</tr>
<tr>
<td>Sep</td>
<td>4.49</td>
<td>4.43</td>
</tr>
<tr>
<td>Oct</td>
<td>4.15</td>
<td>5.34</td>
</tr>
<tr>
<td>Nov</td>
<td>2.10</td>
<td>-</td>
</tr>
<tr>
<td>Dec</td>
<td>0.52</td>
<td>-</td>
</tr>
<tr>
<td>Open-Water Average</td>
<td>6.23</td>
<td>6.54</td>
</tr>
</tbody>
</table>

Notes:
Not available

Using the scaled S37 streamflow data and the winter data from S02, it is anticipated that there would be some baseflow in East Jackpine Creek including the winter months; however, due to the paucity of available streamflow data, detailed characterization of winter baseflow is limited.

2.3 Hydrogeology

The degree of aquifer interaction with surface water is dependent on the hydraulic connections between those features. A qualitative description of the degree of connections and the locations of potential connections can be developed by understanding the near surface geology. This section
provides a discussion of the geologic framework in the aquatics LSA, with an emphasis on the near surface geology, and separates the geologic units into a hydrostratigraphic framework.

### 2.3.1 Shallow Hydrostratigraphy

For the purposes of this assessment, the near surface geology is considered to include Holocene soil horizons, and surficial and subsurface Quaternary deposits. Four key sources of geologic data provide valuable information about the shallow hydrostratigraphy:

- surficial geology maps produced by Imperial and included in the EIA report (Volume 2, Section 10, Figure 10.5-1; Imperial 2013,)
- four shallow (less than 20 m) groundwater monitoring wells installed at the proposed central processing facility (CPF) location in 2015
- three deep (109 to 114 m) Quaternary boreholes installed on the aquatics LSA between 2013 and 2015
- downhole wireline geophysical logs from oil and gas industry wells completed in the vicinity of the aquatics LSA

Surficial geologic mapping of the Project lease area indicates that the bulk of these surficial deposits comprise organic material associated with wetlands (Volume 2, Section 10, Figure 10.5-1 of the EIA report; Imperial 2013,). Some areas are mapped to comprise morainal or glaciofluvial deposits. Organic soils can have variable hydraulic conductivity dependant the degree of decomposition of the soils (Boelter 1969). Upland areas with morainal deposits may comprise more clay rich, low permeability surficial material. Glaciofluvial deposits, which cover a relatively small portion of the lease area, may comprise higher permeability sand and gravel units. The current planned location for the CPF is mapped as organic soil (Imperial 2013).

Four groundwater monitoring wells were installed at the CPF in early 2015. These wells indicate approximately 0.5 m of organic material, several metres of silty to sandy clay, and in some cases encounter sand layers within the upper 10 to 20 m of stratigraphy. Sand aquifers at this depth will be described as “Quaternary Sand 1” for the purposes of this assessment. Three water supply test wells were drilled in 2015 within the Pemmican Valley (Figure 1), a buried valley first mapped by Andriashek and Atkinson (2007). Drilling observations indicate that the lithologic fill of the channel is heterogeneous, containing local aquifer lenses and a possible connection to regionally extensive aquifers. The local cross-section presented on Figure 2 illustrates the currently understood relationship between these Quaternary aquifers and the more regional Cretaceous bedrock units. Consistent with the shallow geotechnical investigations, local water supply well drilling and associated investigations encountered shallow sand and gravel deposits in the upper 20 m (Quaternary Sand 1). Other sand and gravel deposits that may or may not be continuous occur between 25 and 50 m (Quaternary Sand 2) as well as basal sand and gravels within the Pemmican Valley (Quaternary Sand 3).
A summary of geologic and hydrogeologic information from the wells intersecting Quaternary units is presented in Table 2. The location of these wells is illustrated on Figure 1.

### TABLE 2 Quaternary Well Summary

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Easting (N83)</th>
<th>Northing (N83)</th>
<th>Ground Elevation (m asl)</th>
<th>Mid-Point of Completion Interval (mGL)</th>
<th>Groundwater Elevation (m asl)</th>
<th>Interpreted Hydrostratigraphic Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH17-15</td>
<td>498585.5</td>
<td>6330258.2</td>
<td>526.9</td>
<td>12.5</td>
<td>524.7</td>
<td>Quaternary Sand 1</td>
</tr>
<tr>
<td>BH31-15</td>
<td>498838.4</td>
<td>6330317.3</td>
<td>528.6</td>
<td>12.8</td>
<td>526.3</td>
<td>Quaternary Sand 1</td>
</tr>
<tr>
<td>TH09-15</td>
<td>499031.8</td>
<td>6330455.9</td>
<td>528.8</td>
<td>7.5</td>
<td>526.8</td>
<td>Quaternary Sand 1</td>
</tr>
<tr>
<td>TH10-15</td>
<td>498946.6</td>
<td>6330090.0</td>
<td>527.4</td>
<td>8.5</td>
<td>525.6</td>
<td>Quaternary Sand 1</td>
</tr>
<tr>
<td>QT-2</td>
<td>497193.0</td>
<td>6328841.0</td>
<td>513.5</td>
<td>37.1</td>
<td>509.6</td>
<td>Quaternary Sand 2</td>
</tr>
<tr>
<td>QT-1</td>
<td>496060.0</td>
<td>6327050.0</td>
<td>503.5</td>
<td>70.0</td>
<td>507.5</td>
<td>Quaternary Sand 3</td>
</tr>
</tbody>
</table>

### 2.3.2 Deep Hydrostratigraphy

For the purposes of this assessment, deep hydrostratigraphy is considered to be the units below Quaternary deposits typically described as “bedrock” units, including Cretaceous deposits down to the top of Devonian formations. Recent drilling in the Project lease area since 2013 has focused on Cretaceous and Devonian investigations for water supply and disposal potential.

Sandstone aquifers in the Cretaceous bedrock have been mapped in the aquatics LSA using wireline logs and are interpreted to comprise laterally continuous marine-deposited sandstone units within the Grand Rapids Formation, consisting of the Lower- and Middle Grand Rapids aquifers. The Middle and Lower Grand Rapids aquifers are interpreted to outcrop in topographically lower areas around Muskeg Mountain. The anticipated subcrop area for the Lower Grand Rapids Aquifer is illustrated on Figure 1, including both areas where it is interpreted to be intersected by the Pemmican Valley as well as the more regional subcrop based on bedrock topography. The Basal McMurray Aquifer consists of locally water saturated parts of the McMurray Formation that are present within local structural lows on the Pre-Cretaceous Unconformity within the lease area (Basal McMurray Aquifer; Imperial 2013).

A summary of geologic and hydrogeologic information from Cretaceous Water Supply test wells is presented in Table 3. The location of these wells is illustrated on Figure 1.
### TABLE 3  
Cretaceous Well Summary

<table>
<thead>
<tr>
<th>Well Name</th>
<th>Easting (N83)</th>
<th>Northing (N83)</th>
<th>Ground Elevation (m asl)</th>
<th>Mid-Point of Completion Interval (mGL)</th>
<th>Groundwater Elevation (m asl)</th>
<th>Interpreted Hydrostratigraphic Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR-1a</td>
<td>498816.0</td>
<td>6330804.0</td>
<td>527.7</td>
<td>92.6</td>
<td>519.9</td>
<td>Lower Grand Rapids Aquifer</td>
</tr>
<tr>
<td>GR-3</td>
<td>498874.6</td>
<td>6330997.4</td>
<td>528.1</td>
<td>100.5</td>
<td>520.7</td>
<td>Lower Grand Rapids Aquifer</td>
</tr>
<tr>
<td>GR-5a</td>
<td>498560.0</td>
<td>6330943.0</td>
<td>525</td>
<td>97.8</td>
<td>519.8</td>
<td>Lower Grand Rapids Aquifer</td>
</tr>
<tr>
<td>GR-6</td>
<td>499523.0</td>
<td>6332083.0</td>
<td>536.6</td>
<td>103.1</td>
<td>524.0</td>
<td>Lower Grand Rapids Aquifer</td>
</tr>
<tr>
<td>DL-1</td>
<td>494561.0</td>
<td>6324455.0</td>
<td>495.1</td>
<td>256.1</td>
<td>319.0</td>
<td>Basal McMurray Aquifer</td>
</tr>
<tr>
<td>BA-4</td>
<td>493254.0</td>
<td>6326218.0</td>
<td>491.6</td>
<td>246.8</td>
<td>320.3</td>
<td>Basal McMurray Aquifer</td>
</tr>
</tbody>
</table>

#### 2.3.3  Aquifer Connectivity and Conceptual Hydrogeologic Model

The cross-section illustrated on Figure 2 suggests a hydrogeologic system in which aquifers between the Lower Grand Rapids and ground surface are fairly well hydraulically connected. There laterally continuous aquifers that in some cases are in direct hydraulic communication with each other (i.e., Quaternary sand 3 and Lower Grand Rapids aquifers) and in other cases are separated by relatively thin aquitards (i.e., Quaternary Sand 1 and 2 aquifers). The Undifferentiated Quaternary Drift Aquifer/Aquitard is likely not a strong aquitard as it is heterogeneous and in some areas may be comprised mostly of coarse-grained sediments.

Aquifer pressure data supports these interpretations. Figure 3 illustrates a pressure versus elevation plot including water level information from the wells presented in Tables 2 and 3. All data points from aquifers shallower than the Basal McMurray Aquifer, plot proximal to a single hydrostatic gradient line, which suggests good hydraulic communication between the units and/or limited vertical flux. Considerable pressure loss between the upper groundwater flow system and the Basal McMurray Aquifer is expected, based on the conceptual model, as the Clearwater-McMurray Aquitard is a thick, regionally-continuous marine shale, and bitumen-saturated sandstone interval. Water levels in the Quaternary Sand 3 Aquifer are similar to the Lower Grand Rapids Aquifer, which is expected based on the interpreted direct connection between the aquifers.

Local artesian conditions were encountered in the Quaternary Sand 3 Aquifer at QT-1 (6 m above ground surface). This may indicate that the Quaternary Sand 3 Aquifer is relatively continuous within the Pemmican Valley and has a relatively high transmissivity. This would result in a relatively flat hydraulic gradient in the aquifer that could exceed ground surface elevation with local topographic variations. The shallowest aquifers, Quaternary Sand 1 and 2, seem to be relatively laterally continuous and well connected, and have limited intervening aquitard material isolating them from the surficial aquifers and
associated surface water features. These units may be the sources of groundwater discharge to fens in the area.

3 SUMMARY OF GROUNDWATER - SURFACE WATER INTERACTION

The descriptions of the physiography, hydrology, and hydrogeology provided in the EIA report (Volume 2; Imperial 2013) and in the previous sections support the following characterization:

- The abundance of wetlands suggests a shallow water table in the area. This has been confirmed through the observation of groundwater levels encountered at four shallow groundwater monitoring wells installed at the proposed CPF.

- Based on mapped Quaternary geology there are three sand aquifers that may be continuous on the scale of the aquatics LSA. Water levels in these aquifers indicate that there is very little vertical hydraulic gradient in the aquatics LSA.

- The headwaters of the East Jackpine Creek occur predominantly at elevations below 500 m asl (Volume 2, Section 6, Figure 6.4-1 of the EIA report; Imperial 2013,) approximately 25 m below the hydraulic head measured in the Quaternary 1 Aquifer (total hydraulic heads of approximately 525 m asl). This suggests that there may be some impedance (perhaps low permeability till) between the aquifer and the headwaters of the creek.

4 REFERENCES


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Local Aquifer Pressures vs. Elevation

Pressure (kPa)

Elevation (masl)

- Quaternary Sand 1
- Quaternary Sand 2
- Quaternary Sand 3
- Lower Grand Rapids
- Basal McMurray
- Hydrostatic Gradient
- Observed Hydraulic Gradient