Renewal Application for Water Licence S03L1-001
Natural Seeps
(Section 5 of 20)

Submitted to the Sahtu Land and Water Board by Imperial Oil Resources N.W.T. Limited

August 2013
## Table of Contents

5.0 Natural Seeps................................................................. 1
5.1 Introduction................................................................. 1
5.2 Historical Identification of Seeps.................................. 1
5.3 Location of Historically Identified Seeps....................... 5
5.4 IOR Identification of and Response to Seeps.................. 8
5.5 Estimates of Seep Productivity...................................... 12
  5.5.1 Natural vs. Anthropogenic Seeps......................... 13
  5.5.2 Reservoir Pressure and Natural Seeps.................... 15
References........................................................................... 17
Figures

Figure A: Delta of Oil Creek (Norman Wells Area) 3
Figure B: Cross-Section of Oil Creek Sheet (Norman Wells Area) 4
Figure C: Location of Seeps (Norman Wells Area) 4
Figure D: Location of Natural Seeps in Sahtu Settlement Region 7
Figure E: Location of Historical Natural Seeps in Norman Wells Area 8
Figure F: Location of Recently Observed Natural Seeps in Norman Wells Area 14
Figure G: Chromatograph of Hydrocarbons from a Natural Seep 15
Figure H: Geophysical Cross-Section from the Area of a Natural Seep 15

Tables

Table A: Location of Natural Seeps in the Lower Mackenzie Valley 6
Table B: Summary of IOR Investigation into Seeps in the Norman Wells Area 9

Photos

Photo A: Natural Seepage Zone on the Mackenzie River Bank South the F-28X Well Site 10
Photo B: Seepage Oil Globules Visible on the Mackenzie River 10
Photo C: Natural Oil Seepage Zone on the Mackenzie River Bank to the East of the Former Refinery Site 11
Photo D: Hydrocarbon Sheen and Gas Seep on a Natural Wetland Near Seepage Lake 11
5.0 Natural Seeps

5.1 Introduction
The presence of natural seeps in the Sahtu Settlement Area, especially around the Town of Norman Wells, is known to predate Imperial Oil Resources N.W.T. Limited (IOR) Norman Wells Operations (NWO). Traditional knowledge indicates seeps are regularly seen around Norman Wells particularly in the vicinity of the docks and above the town water supply, and that oil is seen when sediments are stirred up by barges (Amec 2013). Many natural oil and gas seeps have been documented in the lower Mackenzie River Valley (see Section 9 Maps & Figures). In addition, several studies have been conducted to further investigate the nature and productivity of these seeps.

A review of information regarding the history, location and productivity of the seeps is presented below. The review is based on:

- historical records relating to natural seeps;
- previous attempts to calculate the productivity of the seeps; and
- environmental investigations of several seeps within the NWO.

5.2 Historical Identification of Seeps
The earliest documented account of natural seeps observed along the Mackenzie River is attributed to Alexander Mackenzie, who claimed to have found traces of oil during his exploration of the River between 1789 and 1793 (Hume and Link 1945). In 1889, R.G. McConnell noted the presence of bituminous limestone at Bear Rock, near the confluence of the Bear and Mackenzie Rivers (GNWT 2013).

Early geological reports mention the presence of oil saturated dark shale along the banks of the Mackenzie River near Fort Good Hope. These reports are supported by records kept at trading posts documenting the trade in tar. In particular, a large oil seep at Rond Lake in the Fort Good Hope area is mentioned as a source of tar that was scooped into kegs for trade (GNWT 2013).

Seeps in the present day location of Norman Wells were confirmed in 1911 by Cornwall (Hume and Link 1945). The interest in oil exploration during the period of 1913-1914 prompted a geological expedition to the area, led by Dr T.O. Bosworth. Bosworth staked
several areas around the delta of a creek, then known as “Oil Creek” (now known as Bosworth Creek), for a consortium of Calgary investors.

The geological report prepared by Bosworth in 1914 noted that the principal seepage of oil occurred along approximately 75 miles of the Mackenzie River, between Fort Norman (now known as Tulita) and Oil Creek (Bosworth Creek). This section of the River was known as the “Long Reach”. The Fort Creek Shale (now included in the Canol Formation) outcrop along the River’s edge for most of this section. IOR purchased the claims from the Calgary based consortium, and began development of the Norman Wells area in 1919.

Additional mapping of the area by Link in 1919 and 1920 lead to the identification of oil and gas seeps at Oil Creek (Bosworth Creek), Seepage Lake, and Joe Creek (Golder 2007). In addition to these locations, Link also observed that oil could be seen rising to the surface of the Mackenzie River in the summer and would pool under the ice in the winter (Golder 2007).

Link also produced a series of detailed maps and cross-sections documenting his findings. Figures A, B, and C present a selection of Link’s early work to document seeps in the Norman Wells area.
Figure A: Delta of Oil Creek (Norman Wells Area)

Source: Link, N.D.
**Figure B: Cross-Section of Oil Creek Sheet (Norman Wells Area)**

![Figure B](image)

Source: Link, N.D.

**Figure C: Location of Seeps (Norman Wells Area)**

![Figure C](image)

Source: Link, N.D.

*Seeps denoted by red x*
In addition to the oil and gas seeps identified in the Mackenzie River, at Oil Creek (Bosworth Creek), Seepage Lake, and Joe Creek, Link also identified sulphur rich springs at Bear Rock, Bluefish Creek, and Vermillion Creek.

Following the mapping expedition in 1919, a second program in 1920 involved drilling a well at the location of the seeps at Oil Creek. Link describes the results of the drilling of the Discovery Well No.1 in his second report (Link 1920). The well was located approximately 100 metres (m) inland from the bank of the Mackenzie River, and approximately 10 m above the river level. The lithological log recorded by Debuc and Patrick indicates that oil was first encountered at a depth of 83 feet (25 m) within the lower Norman Sandstone (now included in the Imperial Formation). The Hope Shale (now referred to as the Canol Shale) was intercepted at a depth of 255 feet (78 m), and a major oil strike occurred at a depth of 783 feet (239 m). The main Kee Scarp reservoir was penetrated and identified in subsequent wells in the 1920s and 1930s.

Following the success of the Discovery Well No. 1, the field was expanded slowly over the next 10 years. A major expansion of the Norman Wells field occurred in the 1940s and coincided with the construction of the CANOL pipeline. More extensive mapping of the area was undertaken as part of the CANOL project. Additional oil seeps were mapped at Bluefish Creek and Bear Rock (Link 1943, and Stelek et al 1944). During a second period of oil exploration in the 1970s, other occurrences of oil and gas seeps in the Mackenzie River Valley were noted.

5.3 Location of Historically Identified Seeps

The historically documented seeps are presented in Table A and Figures D and E below. Larger reproductions of these Figures are available in the Maps and Figures Section of the Licence Renewal (see Section 9).
## Table A: Location of Natural Seeps in the Lower Mackenzie Valley

<table>
<thead>
<tr>
<th>Map ID</th>
<th>Name</th>
<th>Type</th>
<th>Reference</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bosworth Creek</td>
<td>Sulphur</td>
<td>Link 1919</td>
<td>+65.19.28</td>
<td>-126.52.13</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Oil</td>
<td>Link 1919</td>
<td>+65.16.49</td>
<td>-126.51.24</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Oil</td>
<td>Link 1920</td>
<td>+65.17.00</td>
<td>-126.52.55</td>
</tr>
<tr>
<td>4</td>
<td>Seepage Lake</td>
<td>Oil</td>
<td>Link 1920</td>
<td>+65.17.39</td>
<td>-126.49.31</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Gas</td>
<td>Hume &amp; Link 1945</td>
<td>+65.17.33</td>
<td>-126.50.03</td>
</tr>
<tr>
<td>6</td>
<td>Joe Creek</td>
<td>Gas</td>
<td>Hume &amp; Link 1945</td>
<td>+65.14.55</td>
<td>-126.39.59</td>
</tr>
<tr>
<td>7</td>
<td>Bluefish Creek</td>
<td>Oil</td>
<td>Stelek 1944</td>
<td>+64.55.00</td>
<td>-125.44.33</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>Oil</td>
<td>Link 1919</td>
<td>+64.56.30</td>
<td>-125.46.45</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Sulphur</td>
<td>Link 1919</td>
<td>+64.56.25</td>
<td>-125.46.00</td>
</tr>
<tr>
<td>10</td>
<td>Vermillion Creek</td>
<td>Sulphur</td>
<td>Link 1919, 1920</td>
<td>+65.07.46</td>
<td>-126.04.56</td>
</tr>
<tr>
<td>11</td>
<td>Bear Rock</td>
<td>Sulphur</td>
<td>Stelek 1944</td>
<td>+64.56.25</td>
<td>-125.46.00</td>
</tr>
<tr>
<td>12</td>
<td>Donnelly Ridge</td>
<td>Oil</td>
<td>Murphy 1958</td>
<td>+65.50.00</td>
<td>-128.30.00</td>
</tr>
<tr>
<td>13</td>
<td>Hanna River</td>
<td>Oil</td>
<td>Murphy 1958</td>
<td>+65.43.00</td>
<td>-128.44.00</td>
</tr>
<tr>
<td>14</td>
<td>Rond Lake</td>
<td>Oil</td>
<td>Paterson &amp; Kirker 1958</td>
<td>+67.05.00</td>
<td>-128.20.00</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td>McDonald 1970 Acham 1973</td>
<td>+67.04.00</td>
<td>-128.28.00</td>
</tr>
<tr>
<td>16</td>
<td>Lac a Lacques</td>
<td>Oil</td>
<td>Acham 1973 Lichtenbelt 1961</td>
<td>+66.19.00</td>
<td>-127.54.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Foo 1984</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Lac Belot</td>
<td>Oil</td>
<td>McDonald 1970 Acham 1973</td>
<td>+66.53.00</td>
<td>-126.29.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Foo 1984</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Lac des Bois</td>
<td>Oil sand</td>
<td>Acham 1973 Foo 1984 Smith 1968</td>
<td>+67.47.00</td>
<td>-125.30.00</td>
</tr>
</tbody>
</table>
Figure D: Location of Natural Seeps in Sahtu Settlement Region
5.4  IOR Identification of and Response to Seeps

In addition to the historical identification of seeps, IOR conducts investigations when any sheen or indication of hydrocarbon is reported on the Mackenzie River near its Operations. Operations personnel are dispatched to investigate the area. Facilities within and upstream of the area are checked to confirm integrity. If the sheen is spotted in the vicinity of any of IOR’s flowlines in the river, the live pressure data from the flowlines (which can be viewed in the CPF) is reviewed to ensure there is no significant changes in pressure. Changes in flowline pressure can be caused by a number of reasons such as increasing or decreasing volume of production, but may also be an indicator of a potential leak. If significant changes in pressure are seen while reviewing the data, further investigation is done to confirm the reason for the pressure change. The flowlines are also equipped with high and low pressure switches. This means if the pressure of the flowline is too high or too low, it will automatically be shut and isolated from the rest of the field. The integrity of the line can be confirmed by isolating the flowline at both ends and performing a stand up test.
A summary of IOR’s recent response efforts to investigate reported seeps is presented in Table B below. Some examples of seeps in the Norman Wells are presented in Photos A through D.

Table B: Summary of IOR Investigation into Seeps in the Norman Wells Area

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>IOR Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>04-30-2012</td>
<td>Report of oil on ice road upstream of Island 1</td>
<td>Helicopter surveillance completed on road, location identified; confirmed not a spill. Natural seep in area.</td>
</tr>
<tr>
<td>10-20-2011</td>
<td>Report of sheen on river, mainland side upstream of Island 1 (between Island 1 and Island 2)</td>
<td>Sheen originating from Town dock sheet pile area. Completed stand up test on Island 2 flowline (passed). Not a facility related source.</td>
</tr>
<tr>
<td>09-30-2011</td>
<td>Report of a sheen on river Mainland side of river upstream of Island 1 (between Island 1 and Island 2)</td>
<td>Boat placed in river and sheen followed to source. Appeared to originate from leading edge of Town dock, due to current oil was collecting between Town and refinery dock. Confirmed not associated with production facilities.</td>
</tr>
<tr>
<td>08-15-2010</td>
<td>Report of sheen in river</td>
<td>Response boat put in river, sheen followed to source. NTCL tug at Town dock, props stirring up bottoms at Town dock. Confirmed with NTCL not coming from the vessel bilge.</td>
</tr>
</tbody>
</table>
Photo A: Natural Seepage Zone on the Mackenzie River Bank South the F-28X Well Site

Photo B: Seepage Oil Globules Visible on the Mackenzie River
Photo C: Natural Oil Seepage Zone on the Mackenzie River Bank to the East of the Former Refinery Site

Photo D: Hydrocarbon Sheen and Gas Seep on a Natural Wetland Near Seepage Lake
5.5 Estimates of Seep Productivity

Estimates of the productivity of the natural seeps encountered in the Norman Wells area have been made several times using various methodologies.

In 1919, Link dug four holes along the north bank of Mackenzie River where he collected oil over a three-day period. Measuring the volume of oil recovered in his test holes, Link then calculated the annual production of the seeps along the bank of the River by estimating the total number of spots where oil could been seen along the banks. Using this method, Link estimated between 6.3 barrels (1 m³) and 200 barrels (31.8 m³) of oil was seeping from the north bank of the River now occupied by the Town of Norman Wells (Golder 2007).

In 1954, Hume estimated that several hundred barrels of oil were being produced by the natural seeps along the lower Mackenzie River Area (Golder 2007). However, the method of estimation used by Hume is not provided, and, therefore, it is uncertain how accurate his estimate may be.

In 2001-2002, Komex conducted a field estimation of hydrocarbon volume potentially entering the Mackenzie River from seepage zones. As part of this work, oil globules were counted at three locations around Norman Wells (near well E-32X, Bosworth Creek, and the NTCL Dock). Volume estimates from these locations were then extrapolated to account for smaller seeps not directly measured. Based on these assumptions, it was estimated that between 3.8 m³/yr and 6.7 m³/yr of oil was being produced by the seeps near Norman Wells. This was consistent with the range provided by Link (1 to 31.8 m³/yr).

The previous work done to estimate the hydrocarbon production of the seeps demonstrates the difficulties with providing an accurate estimate. In addition, variations in surface water levels can also have an effect on the seeps. It has been observed that low water levels in the Mackenzie River expose seeps along the banks of Bosworth Creek to air which appear to halt the production of oil and create a rust coloured stain at the ground surface (Golder 2007).
5.5.1 Natural vs. Anthropogenic Seeps

Since 1998, IOR has commissioned a number of field and laboratory investigations of the oil and gas seepage zones around the mainland portion of NWO (Komex 1999, 2001, 2002, 2003; WorleyParsons 2008). Figure F shows the locations of recently identified natural seeps.

The objectives of these investigations were to:

- confirm geographic locations and extent of seepage zones relative to the historic work conducted by Link (1919/1920);
- complete a detailed characterization of the seep environment, to assist in the differentiation of naturally-occurring seepage relative to possible hydrocarbon spillage at surface; and
- confirm the estimate of naturally-occurring hydrocarbons potentially entering the Mackenzie River annually.

The investigations comprised:

- geophysical investigations to map vertical conductive and resistive zones through the seepage areas;
- hydrogeologic investigations in the seepage zones to confirm geochemistry of fluids and host soil/bedrock, as well as groundwater/hydrocarbon surface elevations;
- detailed hydrocarbon characterization using gas chromatography/mass spectrometer analytical techniques; and
- measurement of the volume of hydrocarbon potentially being released from specific seepage zones by means of seepage meters, test pit fluid recovery rates, and actual counting of hydrocarbon droplets observed releasing on the water surface in the Mackenzie River directly above natural seeps at the Town Dock.

Results to date indicate that it is possible to differentiate between naturally-occurring hydrocarbon seepage zones and hydrocarbon release areas attributable to industrial activities on the basis of the following:

- naturally occurring crude oil has a “flat” pattern to the chromatogram (Figure G);
• geophysical investigations often indicate a general conductive anomaly originating from depth, with a surrounding resistive zone of bedrock, permafrost or both (Figure H);

• the surface expressions of the seepage zones are in close agreement with those mapped by Link in 1919 and 1920;

• natural seepage fluids generally have a sodium signature to the main ion chemistry (Na-HCO₃ ± Cl type water); and

• the natural seepage zones may exhibit either crude oil or crude oil/gas discharge.

The criteria that would support a facility-related seepage zone or comingled natural and facility-related seepage includes the following:

• lack of documented historical seep occurrences in the area;

• a refined ("light end") hydrocarbon signature in the chromatograph;

• associated Ca±Mg – HCO₃ type water;

• shallow “perched” groundwater occurrences; and

• nearby contaminant source identified/documentated.

Figure F: Location of Recently Observed Natural Seeps in Norman Wells Area
5.5.2 Reservoir Pressure and Natural Seeps

NWO has been asked whether increased reservoir pressure associated with water injection causes more oil to seep out into the river. Because there is no known reliable method to measure the rate of natural seeps, and very limited baseline data regarding natural seep rates, it is difficult to know how rates have varied through time. As such, it is uncertain what, if any, impact NWO has had on natural seeps.
The field average pressure has been gradually increasing since the waterflood was started in the early 1980s to enhance oil recovery. Water injection pressure has been targeted at 500 kPa below the fracture pressure (the pressure that must be exerted in order to crack the oil-bearing formation). Since the waterflood was initiated that has not changed. The reservoir pressure varies from this higher pressure close to the injecting wells (injectors) to a pressure much lower than average at the producing wells (producers). In situ stress testing and overburden calculations suggest that any induced fractures from the waterflood would be horizontal rather than the vertical fractures typical of deeper formations. As seeps must find their way through about 250 m of the silty, clay rich shale above the oil producing formation to reach the surface, it is unlikely that such horizontal fractures, should they occur, would create new natural seeps.

When wells are drilled, surface casing is set into the higher (closer to ground surface) formation. Surface casing is a large diameter pipe cemented into place on the outside wall of the hole being drilled. It is put in place to help stabilize the hole and protect groundwater. Surface casing vents may help to de-pressure the sediments through which the seeps must travel to the surface. This may reduce natural seeps to surface.

If the higher reservoir pressure were to increase the flow of hydrocarbons into the seeps from the reservoir, surface casing vents may have the effect of providing a path for hydrocarbons to more directly travel to the surface in a manner which could be controlled and monitored. This may decrease natural seeps.

According to traditional knowledge, natural seeps have been present around Norman Wells for a long time and are part of the natural environment in this area (Amec 2013).
References


Amec, 2013. Imperial Oil Resources Norman Wells Operations Mackenzie River Traditional Knowledge and Use Study. CEO4310.


Link, T.A., 1943. Mid-Season Exploration Progress Report for Imperial Oil Ltd., Canol Project.

Link, T.A., N.D. Figure Reproductions on file with WorleyParsons.


Smith, 1968. Program to evaluate oil sands, Lac Des Bois Area, NWT. NEB Reports 538-3-5-8 and 538-1-6-9.
