Saskatchewan’s Industry Adapting to our Changing Climate: Case Study of Qu’Appelle River Watershed and the Potash Industry

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13 March 2014

Invited Presentation to the Ministry of Environment, Saskatchewan

SRC Publication # 13687-1D14
First section

– brief overview of the physical science behind climate change
– A look back at the Canadian prairie climate
– A look forward at what may be in store for us

Second section

– how extreme climatic events can impact industry in Saskatchewan.
– Case study of the potash industry in the Qu’Appelle River Watershed
Warming of the climate system is Unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia.
Radiative Forcing Estimates in 2011

<table>
<thead>
<tr>
<th>Emitted compound</th>
<th>Resulting atmospheric drivers</th>
<th>Radiative forcing by emissions and drivers</th>
<th>Level of confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>CO₂</td>
<td>1.68 [1.33 to 2.03]</td>
<td>VH</td>
</tr>
<tr>
<td>CH₄</td>
<td>CO₂ H₂O² O₃ CH₄</td>
<td>0.97 [0.74 to 1.20]</td>
<td>H</td>
</tr>
<tr>
<td>Halo-carbons</td>
<td>O₃ CFCs HCFCs</td>
<td>0.18 [0.01 to 0.35]</td>
<td>H</td>
</tr>
<tr>
<td>N₂O</td>
<td>N₂O</td>
<td>0.17 [0.13 to 0.21]</td>
<td>VH</td>
</tr>
<tr>
<td>CO</td>
<td>CO₂ CH₄ O₃</td>
<td>0.23 [0.16 to 0.30]</td>
<td>M</td>
</tr>
<tr>
<td>NMVOC</td>
<td>CO₂ CH₄ O₃</td>
<td>0.10 [0.05 to 0.15]</td>
<td>M</td>
</tr>
<tr>
<td>NO₂</td>
<td>Nitrate CH₄ O₅</td>
<td>-0.15 [-0.34 to 0.03]</td>
<td>M</td>
</tr>
<tr>
<td>Aerosols and precursors</td>
<td>Mineral dust Sulfate Nitrate Organic carbon Black carbon</td>
<td>-0.27 [-0.77 to 0.23]</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>Cloud adjustments due to aerosols</td>
<td>-0.55 [-1.33 to -0.06]</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>Albedo change due to land use</td>
<td>-0.15 [-0.25 to -0.05]</td>
<td>M</td>
</tr>
<tr>
<td>Natural</td>
<td>Changes in solar irradiance</td>
<td>0.05 [0.00 to 0.10]</td>
<td>M</td>
</tr>
</tbody>
</table>

Total anthropogenic RF relative to 1750

- 2011: 2.29 [1.13 to 3.33] (H)
- 1980: 1.25 [0.64 to 1.86] (H)
- 1950: 0.57 [0.29 to 0.85] (M)

Radiative forcing relative to 1750 (W m⁻²)
**CO₂ Atmospheric Concentrations**

For 650,000 years, atmospheric CO₂ has never been above this line ... until now.

**Years before today (0 = 1950)**

- 400,000
- 350,000
- 300,000
- 250,000
- 200,000
- 150,000
- 100,000
- 50,000
- 0

**CO₂ parts per million**

- 440
- 420
- 400
- 380
- 360
- 340
- 320
- 300
- 280
- 260
- 240
- 220
- 200
- 180
- 160

**Current CO₂ level**

1950

Top: NASA 2013
Right: IPCC 2013
For the world this means....

In the Northern Hemisphere, 1983-2012, was *likely* the warmest 30-year period of the last 1400 years (*medium confidence*)
Large portions of land are already in the 1.75 to 2.5°C temperature increase
What is happening on the Canadian Prairies and especially Saskatchewan?
Annual Temperature Departures for Prairies and Northwestern Forest (1948-2013)

Data: Environment Canada 2014
Annual Precipitation Departures (Prairies) (1948-2013)

Data: Environment Canada 2014
Extreme Events - Worldwide

Loss Events Worldwide 1980 – 2013

Number of events

Source: Munich Re 2014
Extreme Events – North America

Natural catastrophes in North America 1980-2011: Number of events

- Geophysical events
- Meteorological events
- Hydrological events
- Climatological events

Source: Munich Re, NatCatSERVICE

Source: Kuczinski and Irvin 2012
Extreme Events – Saskatchewan and Prairie Provinces

Data: Public Safety Canada 2013
Many events documented by Public Safety Canada (PSC) do not have costs associated with them e.g., Drought of 2001-2002. Wheaton et al. 2008 estimated the reduction in GDP to be $5.8M.
Drought Severity

Major North American Droughts

Source: Wheaton et al. 2008
Severity of Extreme Events - Costs

Most expensive event
17 June 2010 Flood
(affected S. Alberta and
Saskatchewan) $956M
(PSC 2013)

Does not include the
June 2013 flooding in
Alberta and parts of
Saskatchewan

Photo: SWA 19 June 2010
SSR Natural and Recorded Flow Volumes at Alberta/Saskatchewan (1912-2006)

[Bar chart showing historical and naturalized flow volumes from 1912 to 2006.]

- Historical
- Naturalized

Naturalized flow (1912-2001): Alberta Environment
Historical flow (1912-1933; 1935-2006): Water Survey of Canada

Long-Term Average Naturalized Volume: 7,389,000 dam$^3$
Measured Levels of Lake Diefenbaker, 1971-2012

Lake Diefenbaker, Saskatchewan
(1971-2012)

Data: Environment Canada
SSR Flow Trends at Saskatoon (1911-2010)
South Saskatchewan River Basin and SSRB Study Model nodes along with mean and range of change in annual streamflow for individual sub-basins. Changes for the normal period 1961-1990 to future period 2039-2070 as a percentage of naturalized annual flows in normal period (from Al Pietroniro and Bruneau and Toth, 2007).
Historic Lake Winnipeg Mean Levels (1913-2013)

Even with regulation, extended high water and low water events still occur.
Future Possible Change in Seasonal Average Temperature Patterns (2050+)

Winter

Summer
Mean Seasonal Precipitation in the 2050s

(Sauchyn and Kulshreshtha 2008)
Future Possible Droughts?
(Wheaton et al. 2013)

- Increased intensity of dryness, driven by increased evaporation potential
- Droughts at least 6-10 months long increase in frequency by about an additional 4 events by 2050
- Number of droughts of at least five years doubles towards 2099
Future Excessive Moisture Years?
(Wheaton et al. 2013)

- The number of 1 in 20 year maximum precipitation events doubles by 2099
- Extreme rainfall amounts increase by 5 to 20% by the 1950s
- More wet periods similar to worst wet period of the record occur by 2050
- Sequences of large storms more likely and switching from dry to wet events increase.
So how is all this going to impact Industry?

Qu’Appelle River Watershed: Potash Industry
Analyze the risk to the mining industry within the Qu’Appelle River Watershed and determine what adaptation strategies and actions have been undertaken to manage extreme drought and excessive moisture events.
Results based on Five Reports


Potash Mines in Qu’Appelle River Watershed

- Types of mining
  - Conventional (Mosaic Esterhazy K1 and K2 and PCS Rocanville)
  - Solution (Mosaic Belle Plaine)

- Most potash mines in Saskatchewan were established in the late 1960s/early 1970s

SGIC 2013, Esterhazy K1 and K2
Water Allocation (Kulshrestha et al. 2012)

- Water demand estimates for all Saskatchewan Potash mines:
  - surface water - 18,696 dam$^3$, groundwater 3,363 dam$^3$

- Water allocation for Potash Mines in Qu’Appelle
  - PCS Rocanville – groundwater
    - Current 1,300 dam$^3$ expand to 2,800 dam$^3$ in 2020
  - Mosaic Esterhazy K1 and K2 – groundwater and surface water
    - Current 3,500 dam$^3$ expand to 5,450 dam$^3$ in 2020
  - Mosaic Belle Plaine - surface – Buffalo Pound
    - Current 12,000 dam$^3$
All Canadian Potash Mines

Operate as a closed surface hydrologic system - water is allowed to come in (precipitation, brine) but no water is allowed to be released back to downstream surface flow.

Tailings are reduced through:
- evaporation
- injecting water into deep underground caverns
- recycling
Trend analysis of temperature and precipitation (Gridded dataset - EC)

Spatial and Temporal analysis using Climatic Indices

- Palmer Drought Severity Index (-5 to +5)
- Standardized Precipitation Index (-2.5 to +2.5)
- Standardized Precipitation Evapotranspiration Index (-2.5 to +2.5)
SPEI Extreme Maximums and Minimums

Standardized Precipitation Evapotranspiration Index
September to August (1901-2011)

Left (red) column, close to Belle Plaine

Right (blue) column, close to Rocanville, Lanigan
The two most extreme SPEI years (1901-2011)
Left column (red), close to Belle Plaine, center column (green) close to Esterhazy, right column (blue) close to Rocanville
The two most extreme PDSI years
Unfortunately, no precipitation data for the recent wet years.....
Isn’t really thought of as an issue because the mines utilize either ground water or have surface water supplied from the South Saskatchewan River.

Can challenge existing water supply infrastructure.
Impacts of Historic Excessive Moisture

- Historic EIA assessments are based on one time events, not back-to-back events.
- Mine sites are considered to be closed basins (water not allowed to leave site via surface waterways)
- Recent years have resulted in some negative impacts with having too much brine water on site
Future Excessive Moisture Scenarios

- Probable maximum precipitation increases between 5-20% by 2100
- Back-to-back storms more likely (i.e., increase frequency in 1/20 and 1/100 year events)
- Many wet periods similar to the 1970s will occur towards the 2050s
Future Drought Scenarios

- Increased frequency and duration
- Greater spatial extent and intensity
- Interspersed with more powerful super storms that increase the risk of floods
- ‘Surprise’ events as new climate characteristics emerge

Photo: V. Wittrock
Industry Adaptation Strategies to Drought

- Proactive planning
- Water re-use and recycling
- Innovative and alternative water sourcing
- Are these sufficient?

Aquifers in Saskatchewan (Mance ND)

Non-Potable Water Supply System (SaskWater 2014)
Industry Adaptation Strategies to Excessive Moisture

- Develop strategies to reduce excessive amounts of surface water on site
  - More deep water wells to remove excessive surface water
  - Higher berms

- Back-to-back extreme precipitation events both daily and yearly need further investigation (re-assess EIA criteria).
Outside factors (cumulative effects)

- External infrastructure influenced by extreme events
  - Roadways, Rail lines, Electrical lines
- Economics and drought and excessive impacts on the agricultural industry
- Potential water conflicts
- Health issues (e.g. West Nile)

Environment Canada 2013
Lessons learned and where government can help

- Risk management – expect the unexpected, especially with mines extended life span
- Never just one sector impacted – consider cumulative impacts and linked/multi-purpose adaptation strategies
- Importance of collaboration
- More bridging of science and industry
Lessons learned and where government can help

- Enhance research and awareness of increasing changes of extreme climate events and their risks to industry
- Enhance research capacity
- Provide effective communication
Questions?
References

References


• Zwiers, F., and E. Wheaton. 14 Feb 2014. Changing Climate (IPCC AR5) and Implications for the Canadian Prairies. Invited presentation to the School of Environment and Sustainability, University of Saskatchewan
