Road salt deicers and riverine salinity in the North Saskatchewan River around Edmonton

J. Patrick Laceby
Watershed Sciences
Resource Stewardship Division
Environment and Protected Areas

Alberta

Introduction

Introduction

QUARTZ

CONSEQUENCES

Rock salt keeps roads safe in winter—at a serious environmental cost

By Jamie Summers & Robin Valleau • January 31, 2019

AP PHOTO/CHUCK BURTON

Rock salt is widely used to deice roads around the world.

Summers, Jamie & Valleau, Robin in Quartz, **January 31, 2019**

Introduction

news For the good of the planet, can we curb our addiction to road salt?

The slippery slope of road salt

(Robert F. Bukaty/AP)

We're all afraid of slipping and falling, especially in winter, so it's not uncommon to see carpets of salt on Canadian sidewalks and roads this time of year.

Mortillaro, Nicole. CBCs What on Earth Series - **January 18, 2019**

Introduction

ensia CATEGORIES SECTIONS EDGE E-News About Co

WE'RE POURING MILLIONS OF TONS OF SALT ON ROADS EACH WINTER. HERE'S WHY THAT'S A PROBLEM.

The use of salt to de-ice roads and parking lots has skyrocketed in recent years. As environmental consequences emerge, scientists propose creative solutions.

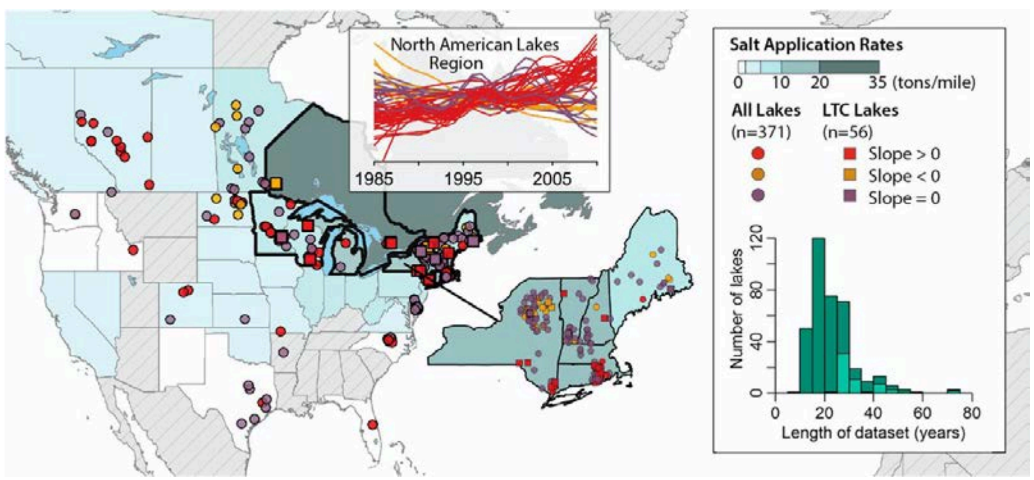
Breining, Greg. "We're Pouring….." Ensia. **November 6, 2017**, (https://ensia.com/features/road-salt/)

Introduction

Salting our freshwater lakes

Hilary A. Dugan[a,b,1], Sarah L. Bartlett[c], Samantha M. Burke[d], Jonathan P. Doubek[e], Flora E. Krivak-Tetley[f], Nicholas K. Skaff[g], Jamie C. Summers[h], Kaitlin J. Farrell[i], Ian M. McCullough[j], Ana M. Morales-Williams[k,2], Derek C. Roberts[l,m], Zutao Ouyang[n], Facundo Scordo[o], Paul C. Hanson[a], and Kathleen C. Weathers[b]

[a]Center for Limnology, University of Wisconsin–Madison, Madison, WI 53706; [b]Cary Institute of Ecosystem Studies, Millbrook, NY 12545; [c]School of Freshwater Sciences, University of Wisconsin–Milwaukee, Milwaukee, WI 53204; [d]Department of Biology, University of Waterloo, Waterloo, ON, N2L 3G1, Canada; [e]Department of Biological Sciences, Virginia Tech, Blacksburg, VA 24061; [f]Department of Biological Sciences, Dartmouth College, Hanover, NH 03755; [g]Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824; [h]Department of Biology, Queen's University, Kingston, ON, K7L 3N6, Canada; [i]Odum School of Ecology, University of Georgia, Athens, GA 30602; [j]Bren School of Environmental Science and Management, University of California, Santa Barbara, CA 93106; [k]Department of Ecology, Evolution and Organismal Biology, Iowa State University, Ames, IA 50011; [l]Department of Civil & Environmental Engineering, University of California, Davis, CA 95616; [m]UC Davis Tahoe Environmental Research Center, Incline Village, NV 89451; [n]Center for Global Change and Earth Observations, Michigan State University, East Lansing, MI 48823; and [o]Instituto Argentino de Oceanografía, Universidad Nacional del Sur–CONICET, Bahia Blanca Bs As, B8000BFW, Argentina



Dugan, Hilary A., et al. "Salting our freshwater lakes." *Proceedings of the National Academy of Sciences* 114.17 (**2017**): 4453-4458.

Introduction

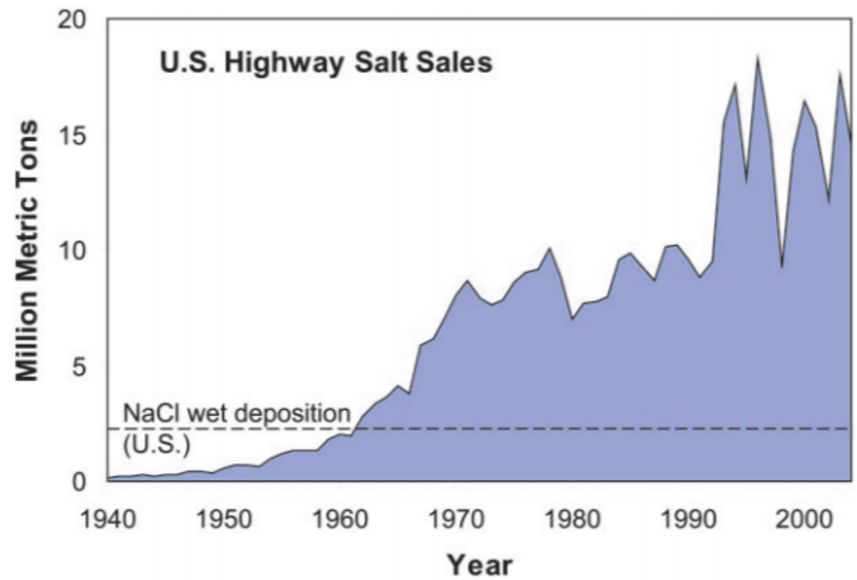
PNAS

From icy roads to salty streams

Robert B. Jackson*† and Esteban G. Jobbágy*‡

Department of Biology, Nicholas School of the Environment and Earth Sciences and Center on Global Change, Duke University, Durham, NC 27708-1000; and ‡Grupo de Estudios Ambientales–Instituto de Matemática Aplicada San Luis, Universidad Nacional de San Luis and Consejo Nacional de Investigaciones Científicas y Técnicas de Argentina, 5700 San Luis, Argentina

For most of human history, salt was a precious commodity. People prized it for flavoring and preserving food and for use in religious ceremonies and burials. The Roman occupation of Britain peppered the English language with a legacy of salt. We retain those Latin links in words such as "salary" and "salami" and in place names like Greenwich and Sandwich, their suffix denoting a saltworks. Today salt is no longer precious. The U.S. mines ≈36 million metric tons [1 metric ton = 1 megagram (Mg)] of rock salt a year (1). Eighteen million Mg is spread on paved surfaces for deicing, making winter roads safer for people and vehicles (2). However, once the salt dissolves, it washes into streams or soil and is forgotten. A new article by Kaushal *et al.* (3) in a recent issue of



Jackson, Robert B., and Esteban G. Jobbagy. "From icy roads to salty streams." *Proceedings of the National Academy of Sciences* 102.41 (2005): 14487-14488.

Introduction

NATIONAL POST

NEWS · FULL COMMENT · SPORTS · CULTURE · LIFE · MORE · DRIVING · CLASSIFIEDS · JOBS · SUBSCRIBE · FINANCIA

How Canada's addiction to road salt is ruining everything

Bringing down bridges, melting cars, poisoning rivers; it's hard to think of something salt isn't ruining

Hopper, Tristen. “How Canada’s addiction to road salt is ruining everything." *National Post* ***January 22, 2018***.

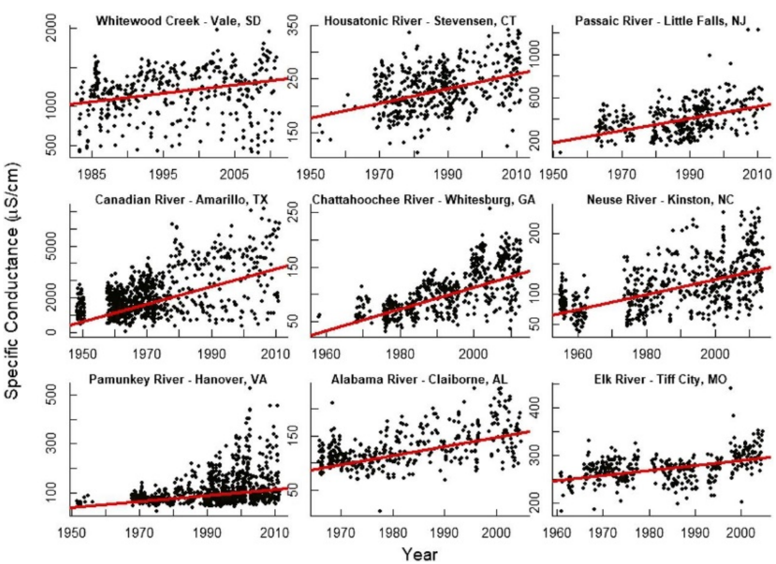
Introduction

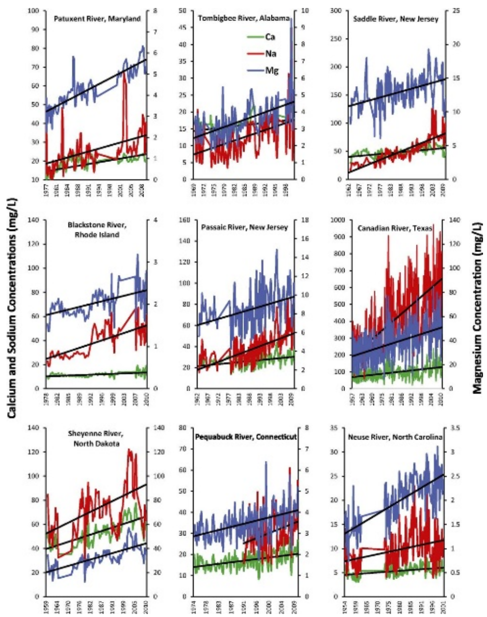
Freshwater salinization syndrome on a continental scale

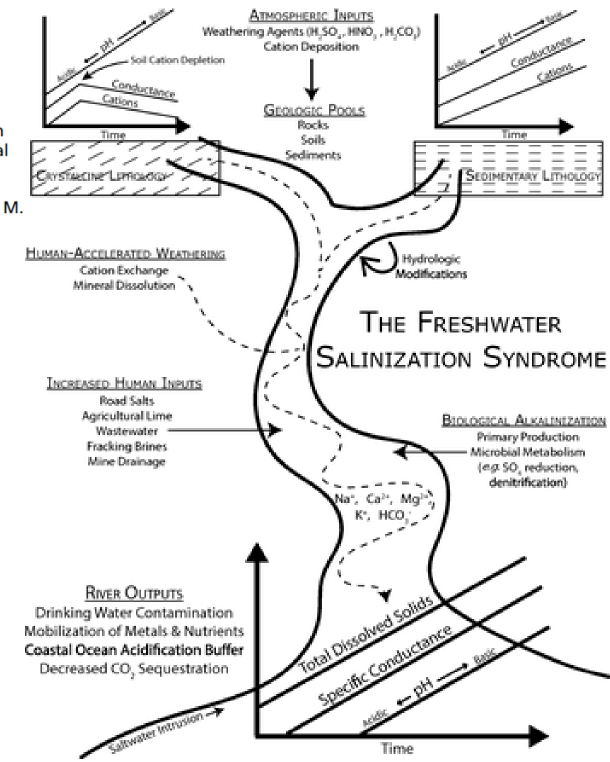
Sujay S. Kaushal[a,1], Gene E. Likens[b,c,1], Michael L. Pace[d], Ryan M. Utz[e], Shahan Haq[a], Julia Gorman[a], and Melissa Grese[a]

[a]Department of Geology and Earth System Science Interdisciplinary Center, University of Maryland, College Park, MD 20740; [b]Cary Institute of Ecosystem Studies, Millbrook, NY 12545; [c]Department of Ecology and Evolutionary Biology, University of Connecticut, Storrs, CT 06269; [d]Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22904; and [e]Falk School of Sustainability, Chatham University, Gibsonia, PA 15044

Contributed by Gene E. Likens, November 30, 2017 (sent for review June 28, 2017; reviewed by Jacqueline A. Aitkenhead-Peterson, W. Berry Lyons, Diane M. McKnight, and Matthew Miller)







Kaushal, Sujay S., et al. "Freshwater salinization syndrome on a continental scale." Proceedings of the National Academy of Sciences (**2018**): 201711234.

Introduction

Environmental Science & Technology

Viewpoint

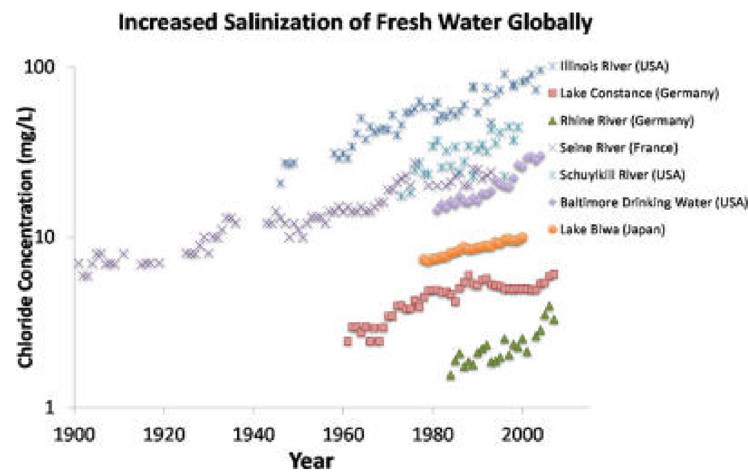
pubs.acs.org/est

Increased Salinization Decreases Safe Drinking Water

Sujay S. Kaushal*

Department of Geology & Earth System Science Interdisciplinary Center, University of Maryland, College Park Maryland 20740, United States

*"<u>**Increased salinization**</u> of fresh water can <u>contribute</u> to **leaching of metals** from aging water infrastructure and sediments in pipes….. <u>Leaching of metals</u> from water infrastructure and sediments has **contributed** to recent well-publicized incidents of **increased <u>lead</u> concentrations in drinking water in <u>Flint, Michigan</u>**." (pg. 2766)*



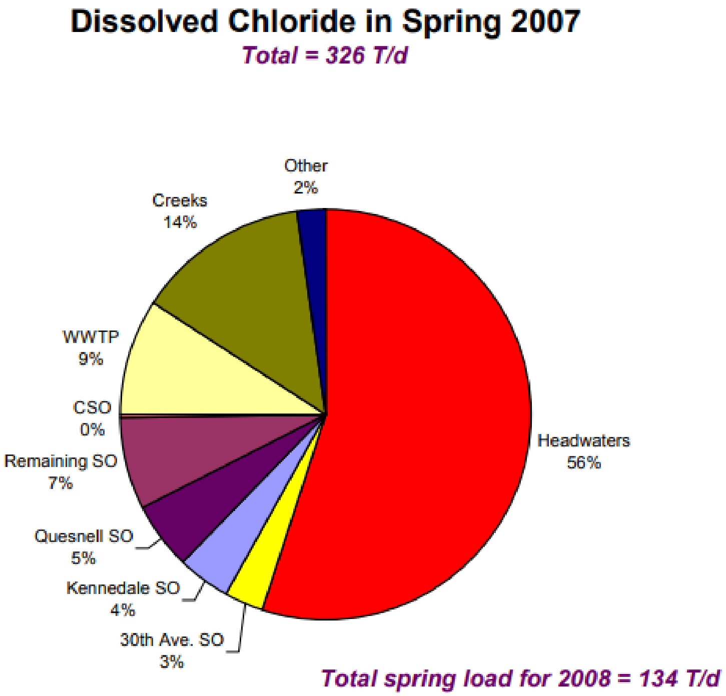
Kaushal, Sujay S. "Increased salinization decreases safe drinking water." Environ. Sci. Technol. **2016**, 50, 2765−2766.

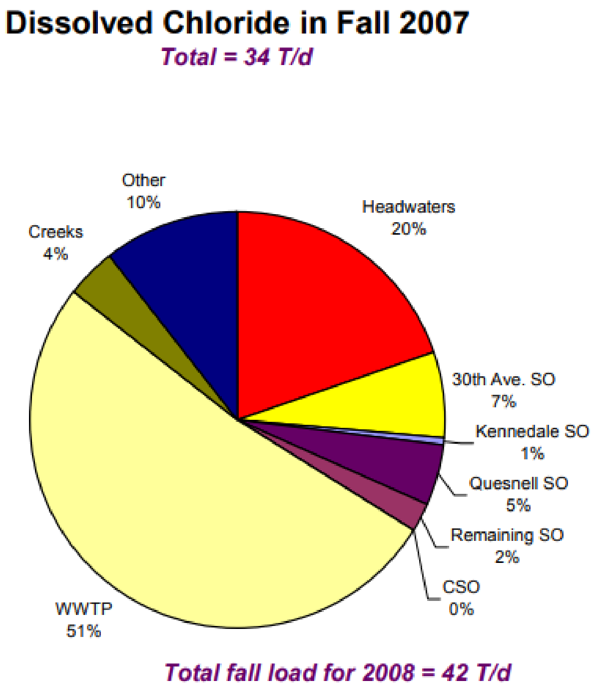
Introduction

- Majority of research is from out East
- Very few studies from colder, northern environments
  - Rock Salt (NaCl) becomes ineffective below -10°C

Introduction

- What about Edmonton?





AECOM and Anderson, A.M., 2011.

Introduction

- What about Edmonton?

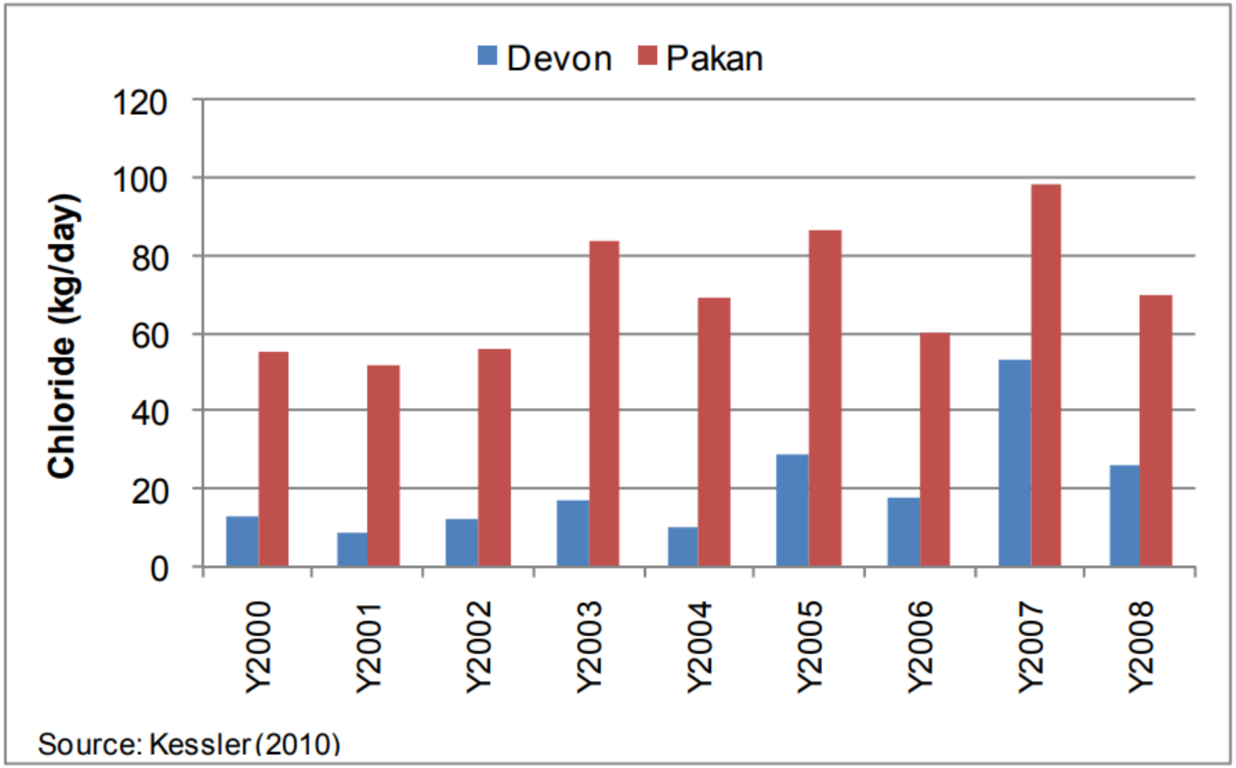


Figure 3-6. Estimated Annual In-River Loads of Chloride

AECOM and Anderson, A.M., 2011.

Introduction

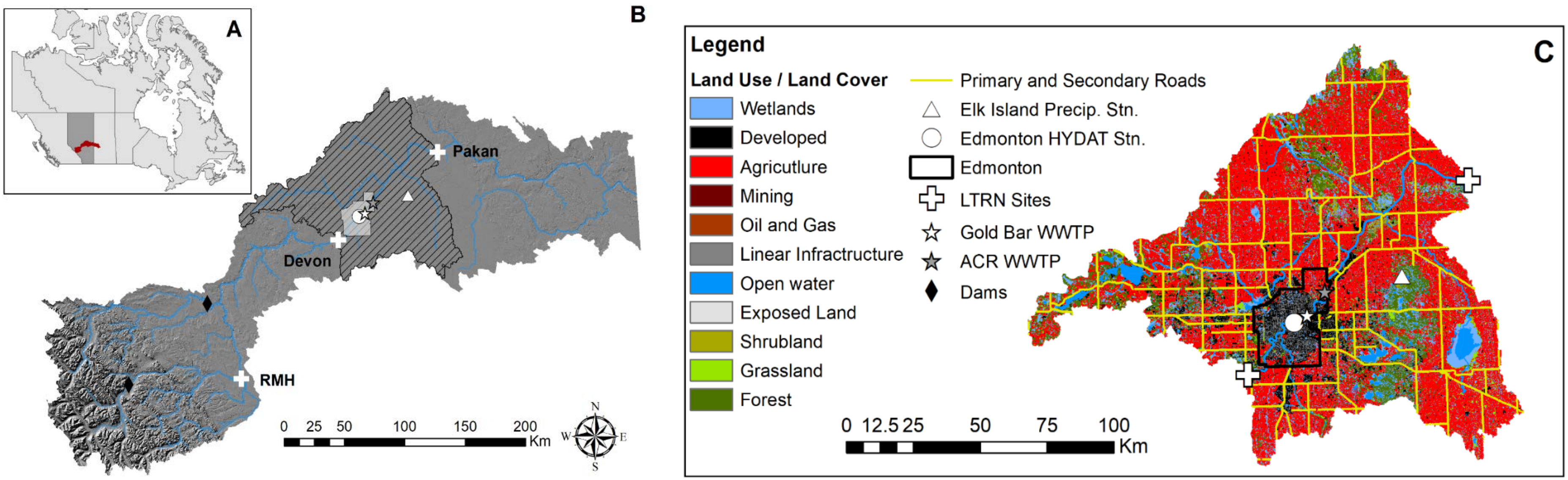
Research Questions:

- What are the spatial and temporal dynamics of major salt chemistry in the North Saskatchewan River (NSR)?
- What are the main sources (and their *relative contributions*) of ***chloride*** in the sub-basin NSR between Devon and Pakan?

Material and Methods

Materials and Methods

- Studying the sub-basin between Devon and Pakan



Materials and Methods

- Essentially focussing on the impact of Edmonton

Materials and Methods

- LTRN water quality samples from 1987-2017
- Focus on major Anions and Cations
  - Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, SO_4^{2-},Cl^{-}, CO_3^{2-}, HCO_3^{-}
- Examine spatial and temporal trends in milliequivalents (meq/L)
  - Change ratios for spatial trends
  - Seasonal Kendall tests for temporal trends
- Develop a chloride mass balance
  - 2010-2017 (hydrological years - e.g. Oct. 1 – Sept. 31)

Materials and Methods

- Chloride Mass Balance
  - Cl loads at Devon (inflow) and Pakan (outflow) (Hydat & LTRN data)
  - Point Sources
    - WWTP inputs: Gold Bar & Alberta Capital Region (ACR) (Epcor/Approvals)
    - Industrial Effluent for all major facilities discharging into the NSR (Approvals database, AEP monitoring data)
  - Diffuse Sources
    - Deicer Applications
      - Edmonton Roads (City of Edmonton)
      - Provincial Roads (Ministry of Transportation, GIS)
      - Private Residence (Canadian Census and literature, GIS)
      - Parking Lots (GIS, Literature, Provincial application rates)
    - Agriculture (livestock and fertilizer) (Canadian Agricultural Survey and literature)
    - Water Softeners (Canadian Census and literature)
    - Precipitation (Air monitoring data)

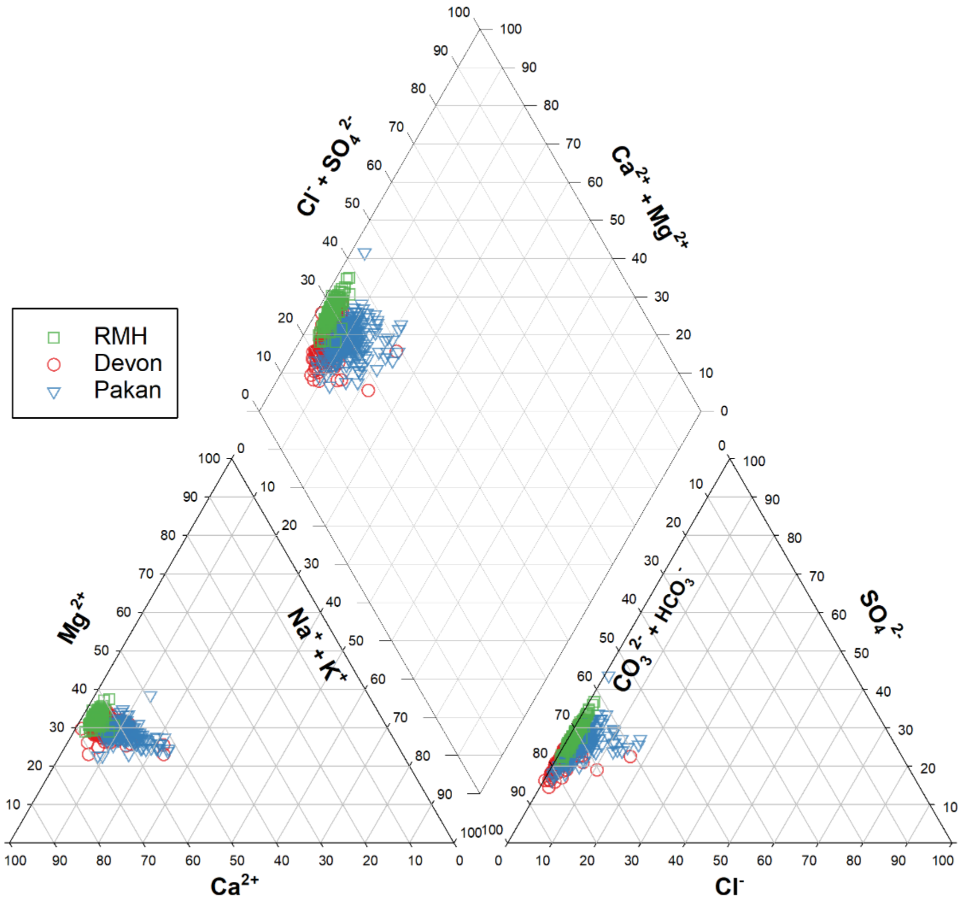
For more info: J.P. Laceby, et al., 2019 Chloride inputs to the North Saskatchewan River watershed: the role of road salts as a potential driver of salinization downstream of North America's northern most major city (Edmonton, Canada), Science of The Total Environment, Volume 688 (https://doi.org/10.1016/j.scitotenv.2019.06.208)

Results

Results

NSR Major Ion chemistry

- Characterized by the dominance of Ca carbonates, and to a lesser extent, Mg carbonates.
- 60-85% of the anion charge was attributed to HCO_3^-
- 50-70% of the cation charge was associated with Ca^{2+}

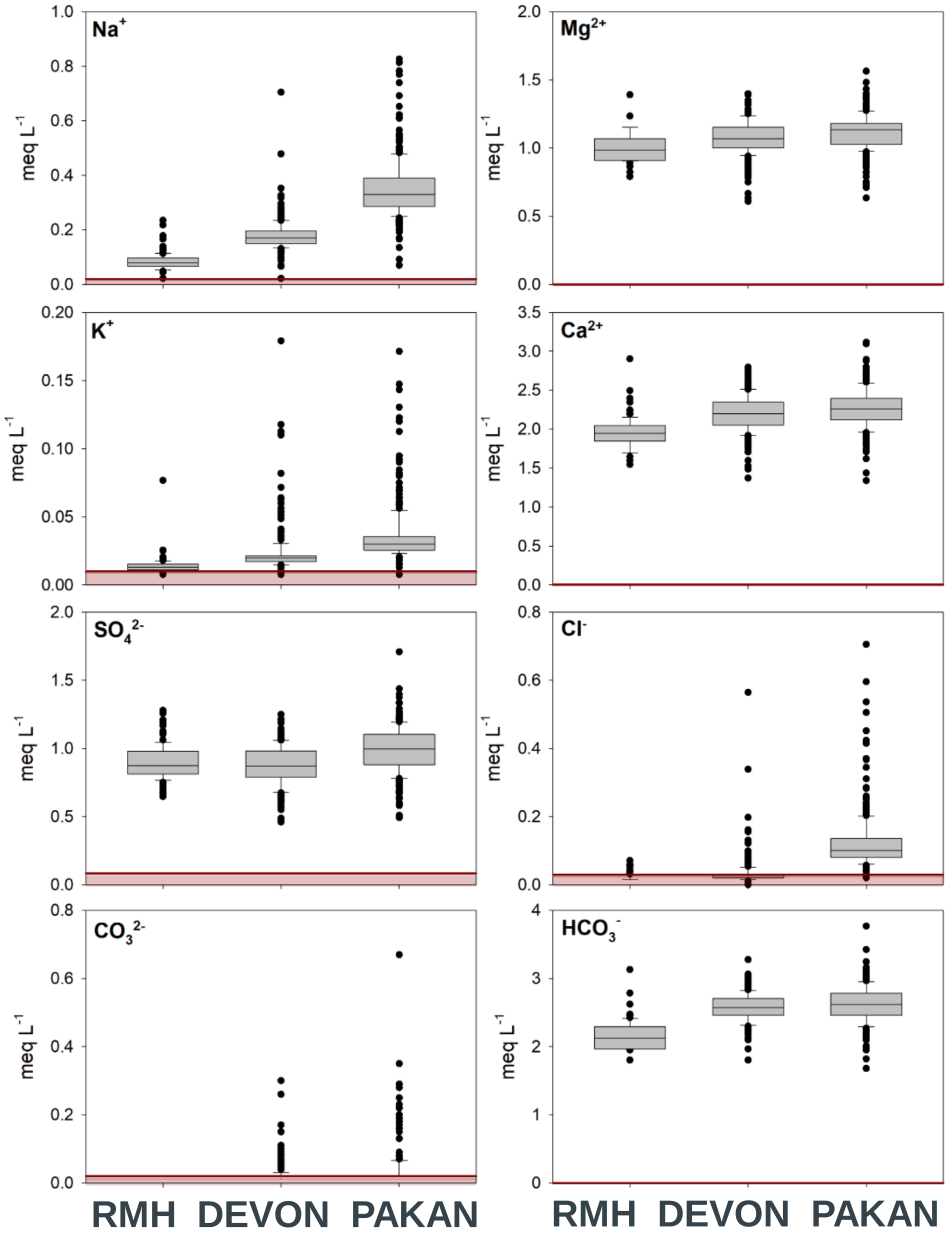


Results

Longitudinal Trends

Between Devon and Pakan:

- Major increases in Na and Cl
- Minor increases in K and SO_4

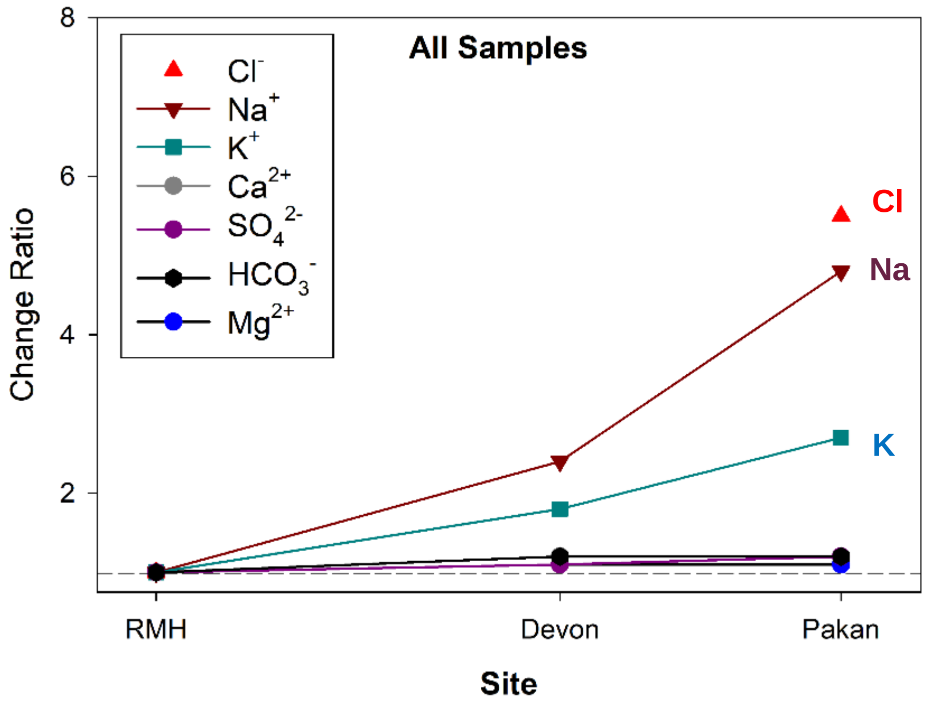


Results

Change Ratios

(proportional increase relative to U/S RMH)

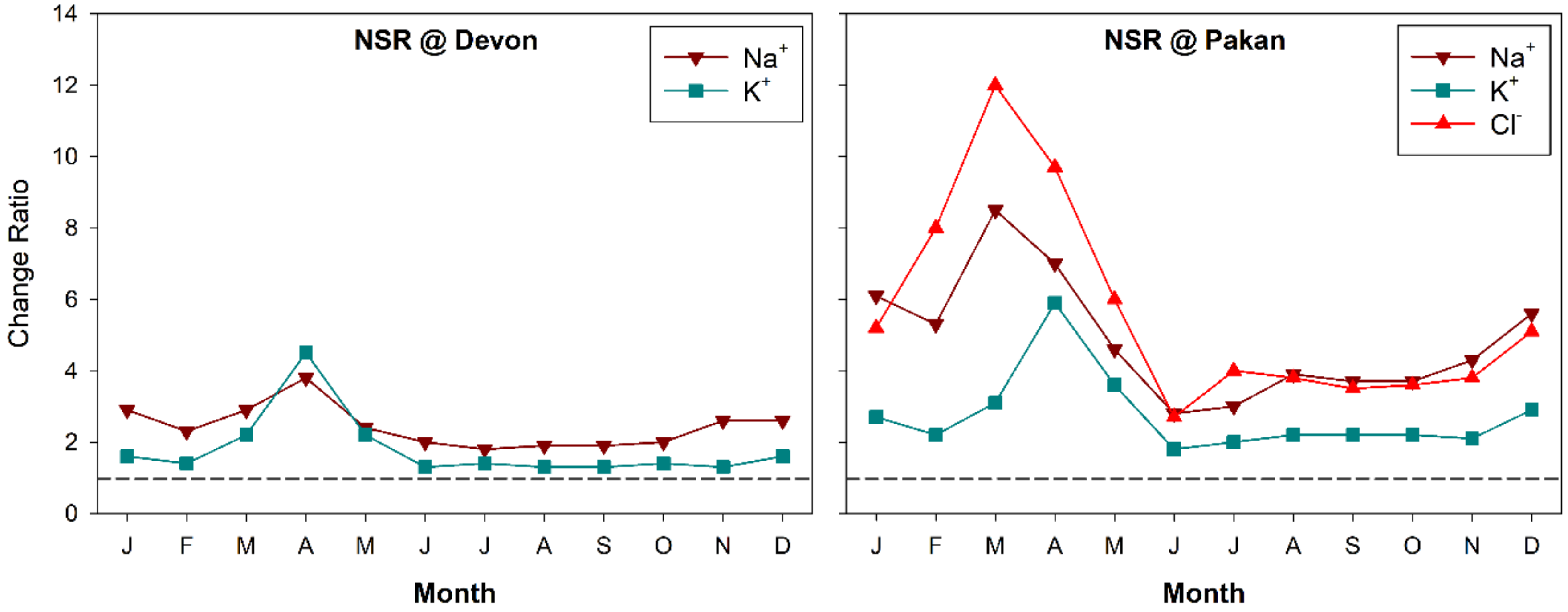
- *Cl increases by 5.7 times*
- *Na increases by 4.8 times*
- *K increases by 2.7 times*



A change ratio of 5 means that a value is 5 times or 500% more than the RMH value

Results

Change Ratios

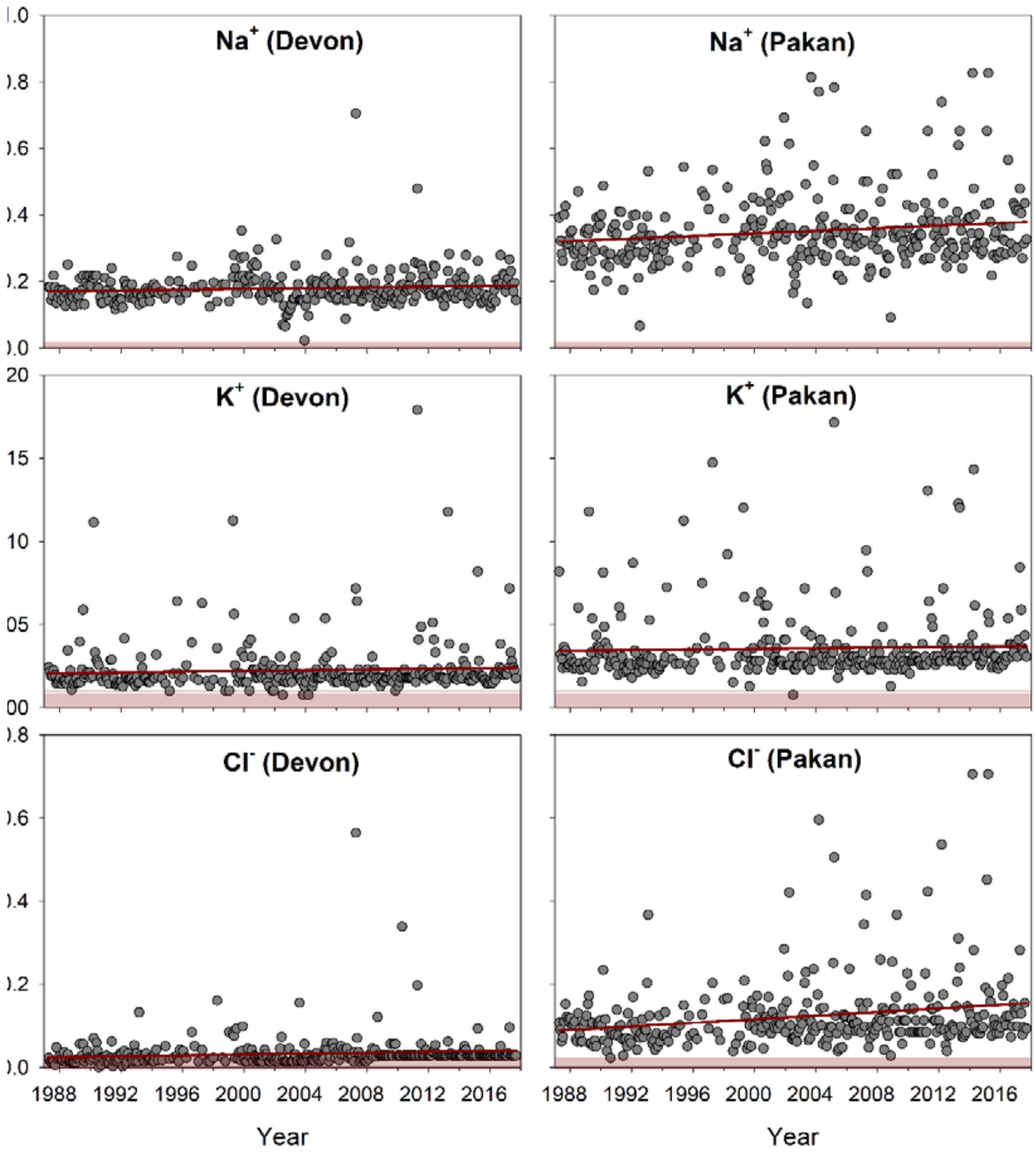


A change ratio of 12 means that a value is 12 times or 1200% more than the RMH value

Results

Temporal Trends:

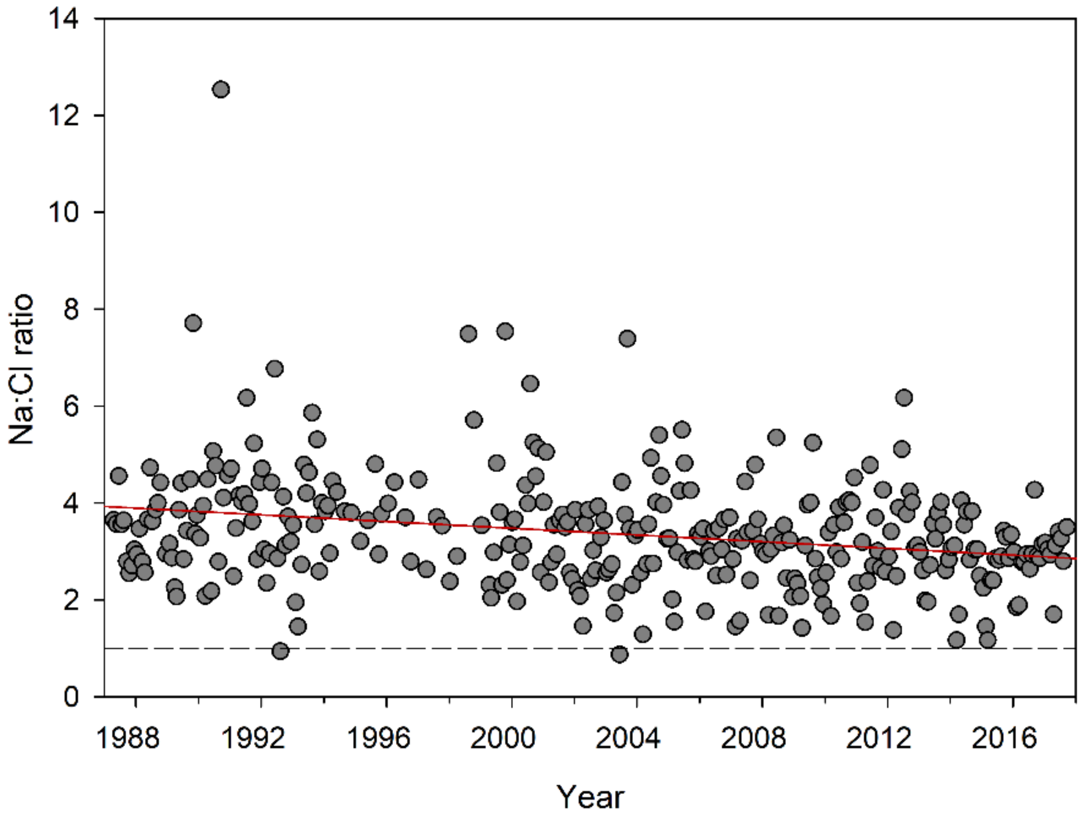
- Upstream of Edmonton, no significant changes in Na, K, or Cl at Devon.
- Downstream of Edmonton Na, K, and Cl are increasing significantly over time at Pakan.
- Rate of Change for Cl at Pakan is **~2-6 times** the other ions



Results

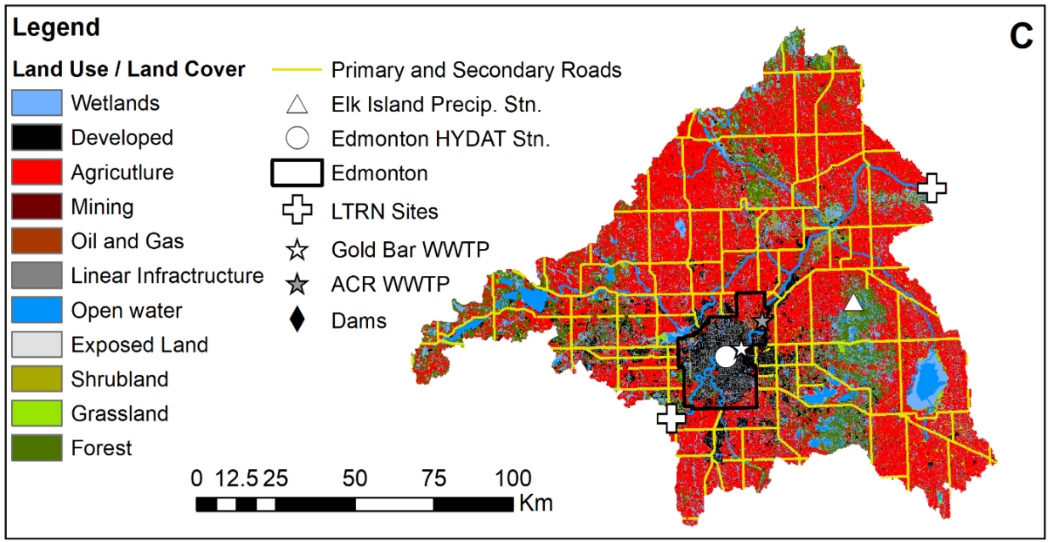
Temporal Trends:

- The Na:Cl ratio has decreased significantly over the study period
- Trending towards a 1:1 Na:Cl ratio which is indicative of halite, the main constituent of road salts (the dashed line).



Results

Chloride Mass Balance
2010-2017 (t yr^{-1})



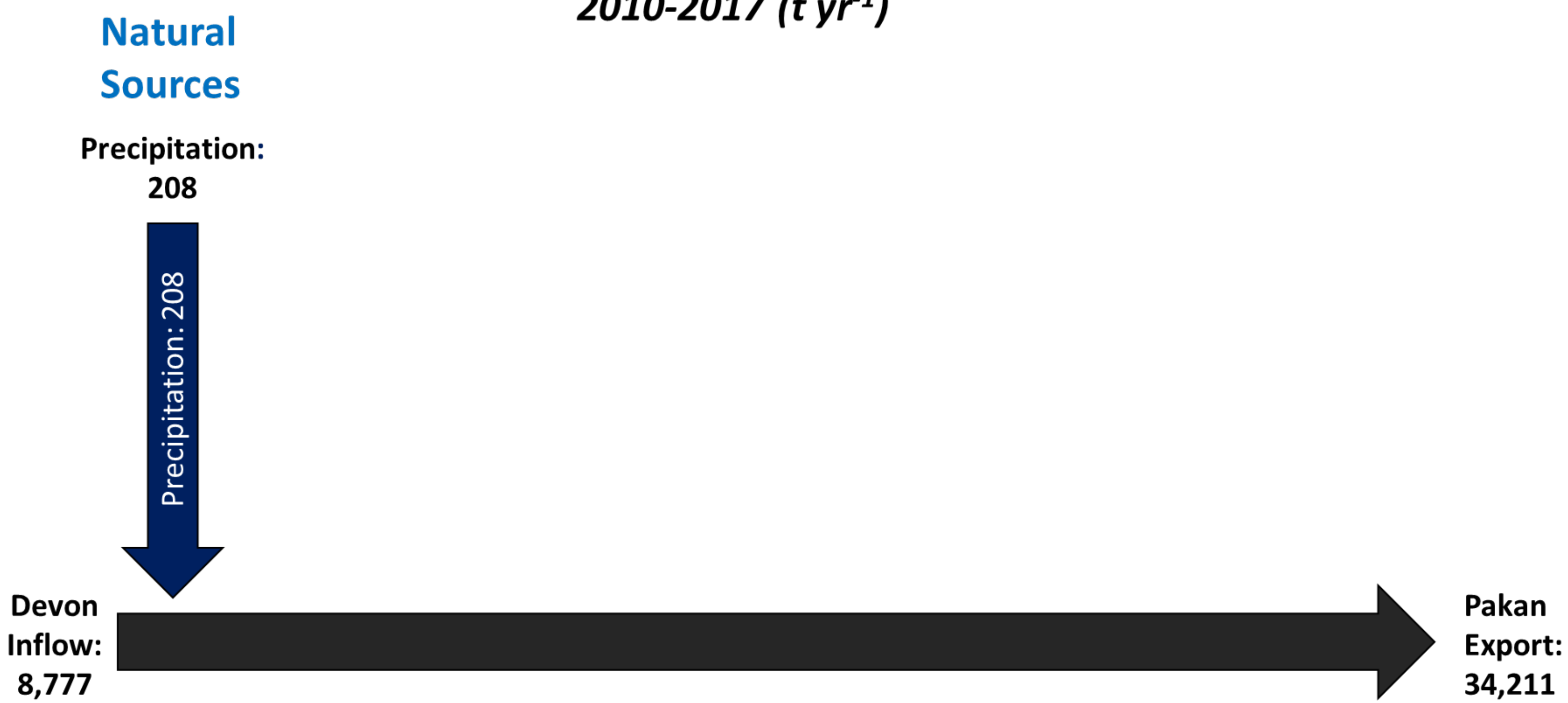
Devon Inflow: 8,777

Pakan Export: 34,211

All values are in metric tonnes

Results

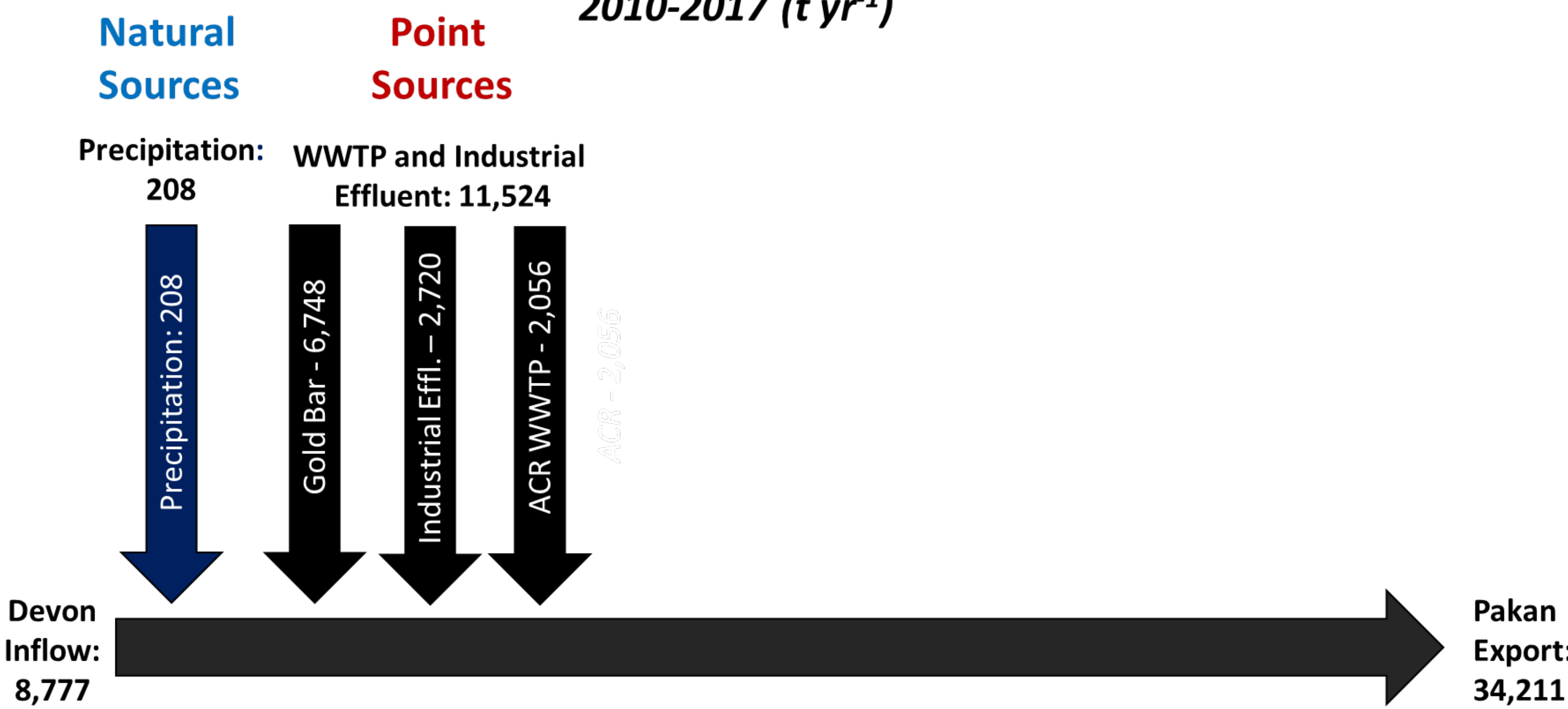
Chloride Mass Balance
2010-2017 (t yr^{-1})



All values are in metric tonnes

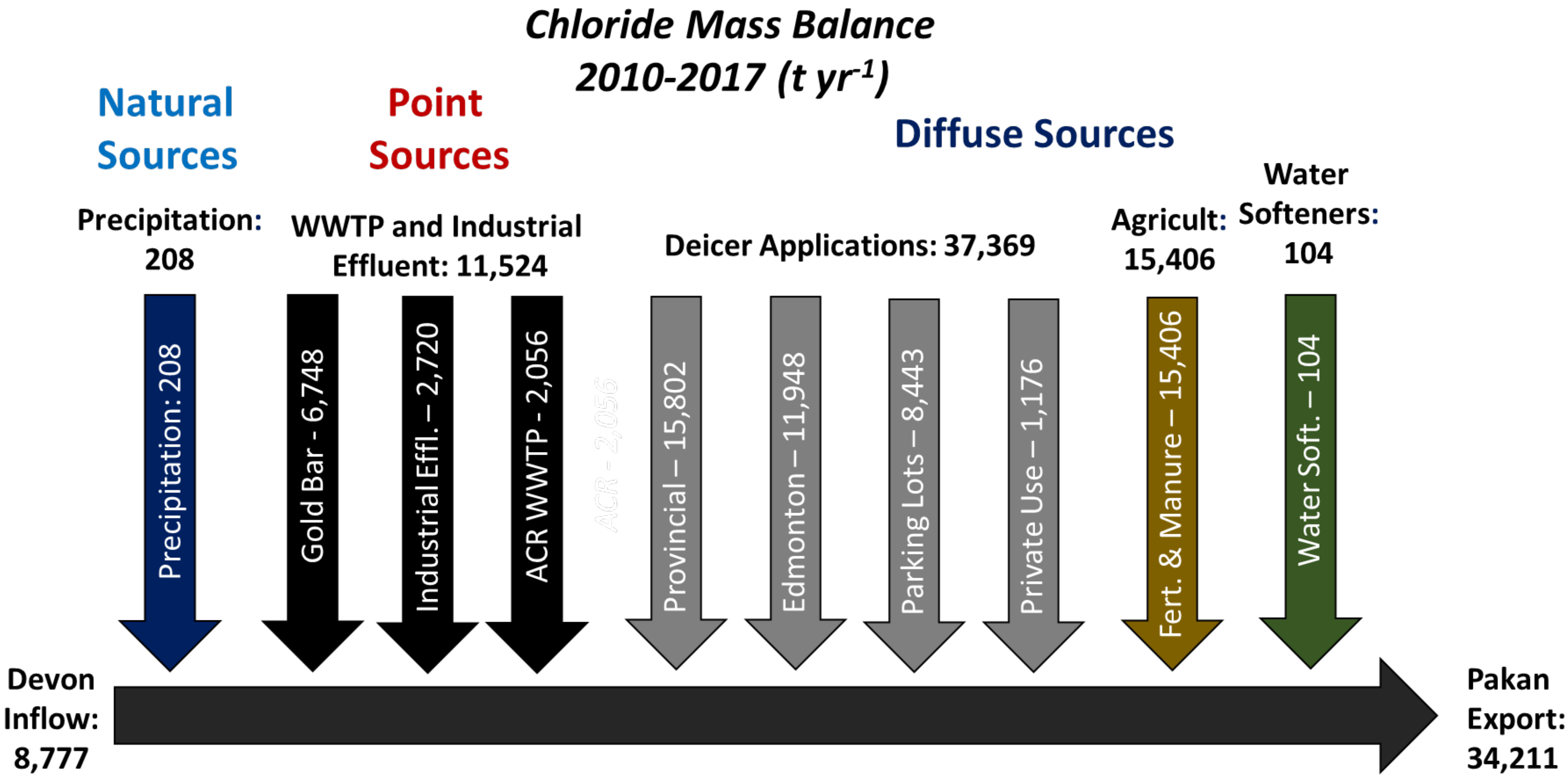
Results

Chloride Mass Balance 2010-2017 (t yr^{-1})



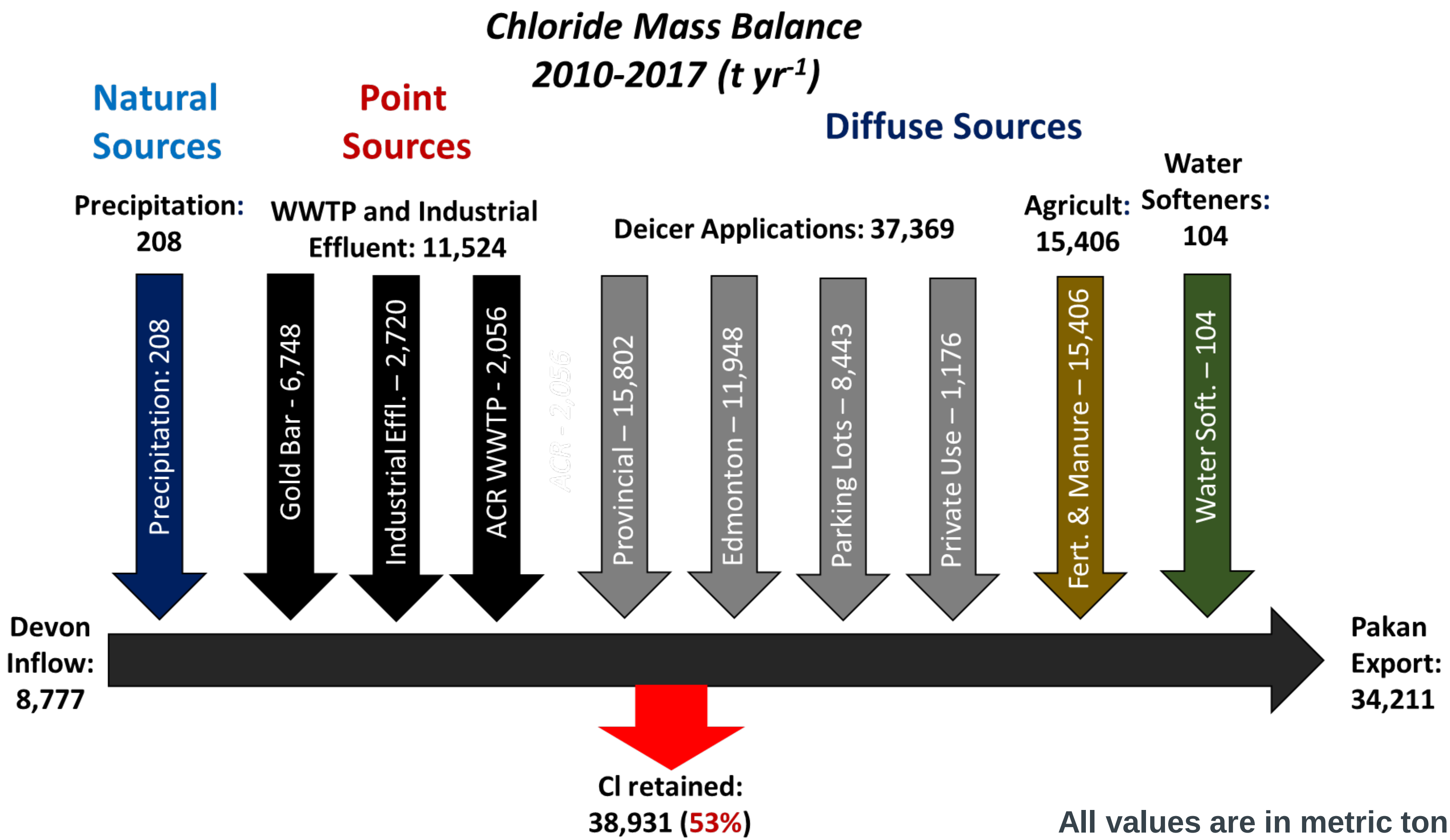
All values are in metric tonnes

Results



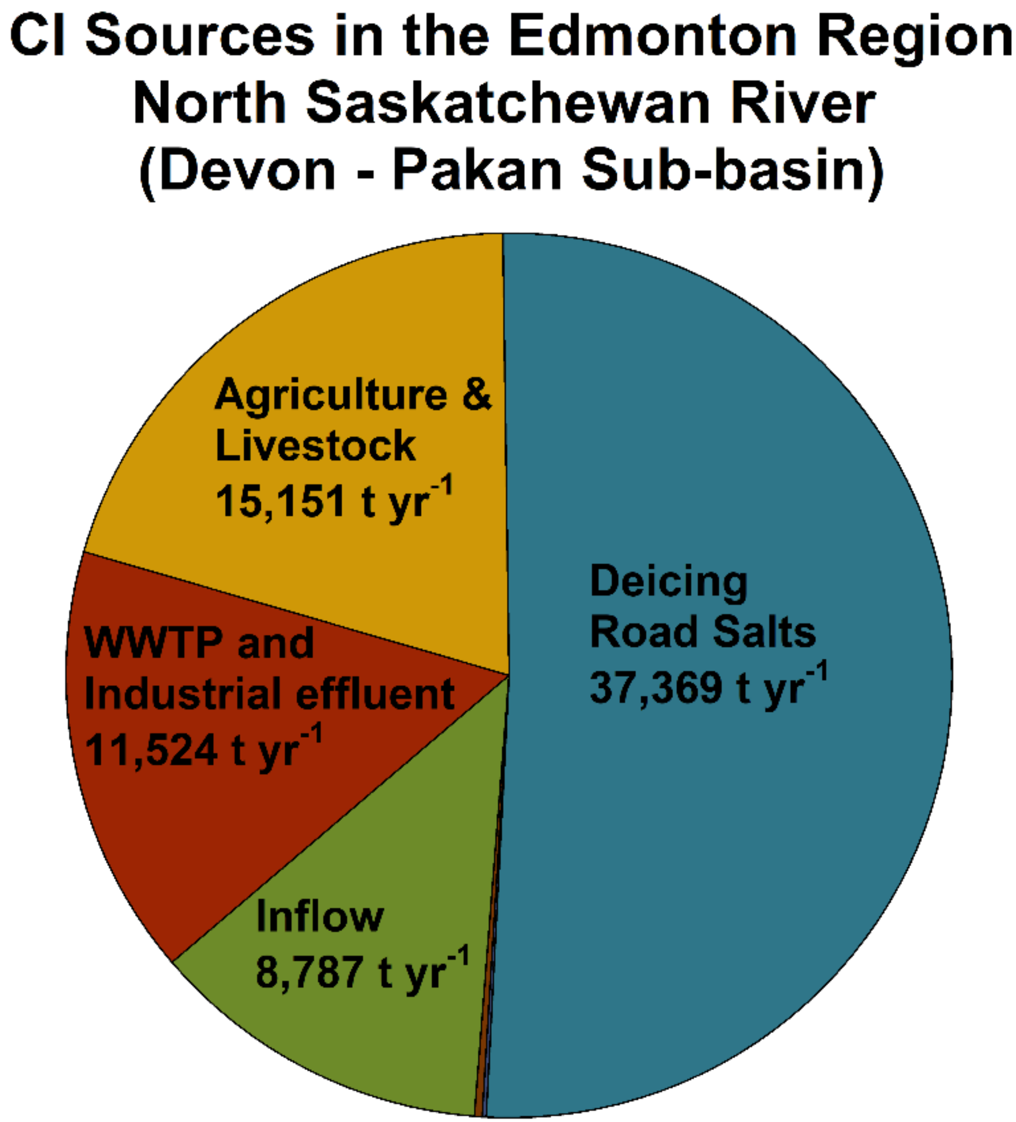
All values are in metric tonnes

Results



All values are in metric tonnes

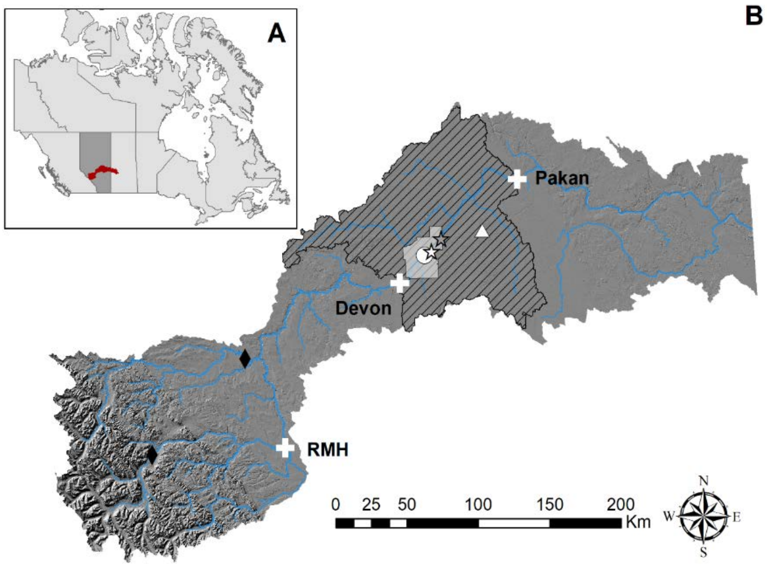
Results


Cl Sources in the Edmonton Region
North Saskatchewan River
(Devon - Pakan Sub-basin)
Agriculture & Livestock 15,151 t yr^{-1}
Deicing Road Salts 37,369 t yr^{-1}
WWTP and Industrial effluent 11,524 t yr^{-1}
Inflow 8,787 t yr^{-1}

Results

Devon-Pakan Sub-Basin:

- ~73,000 t yr^{-1} added to the system
- ~5.6 t km^{-2} yr^{-1}



Edmonton City Limits:

- **~36,000 t yr^{-1} added to the system**
- **~52.7 t km^{-2} yr^{-1}**

Discussion

Discussion

ORILLIAMATTERS.com

BEYOND LOCAL: The good, the bad and the salty about what we use to de-ice our roads

Researchers from Queen's University say road salt makes winter driving safer, but may have negative impacts on the environment

Jan 28, 2019 8:00 PM by: Village Media
Updated Jan 29, 2019 11:22 AM

Stock image

Jamie Summers & Robin Valleau in Orillia Matters, **January 28, 2019**

Discussion

THE GOOD: Cl is still well below guidelines (120 mg/L)

At Pakan: the maximum Cl concentration was 25 mg/L and the median over the study period is ~4

Discussion

<u>THE BAD</u>: Cl concentrations exceed guidelines in Edmonton NSR Tributaries during snow melt runoff

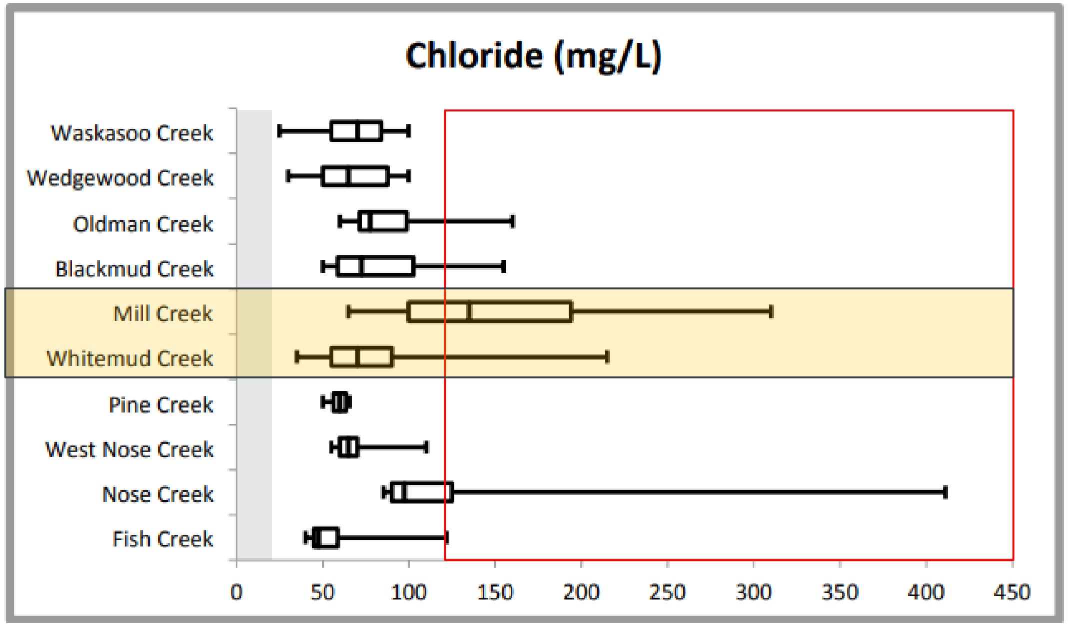


Figure 12 Distribution of data shown in a box-and-whisker plot for chloride

Reed Froklage (2016) Alberta Creek Watch – A report card on urban creek water quality (2016)

Discussion

<u>THE SALTY</u>: Cl yield in Edmonton is one of the higher rates in the literature (outside of the Greater Toronto region)

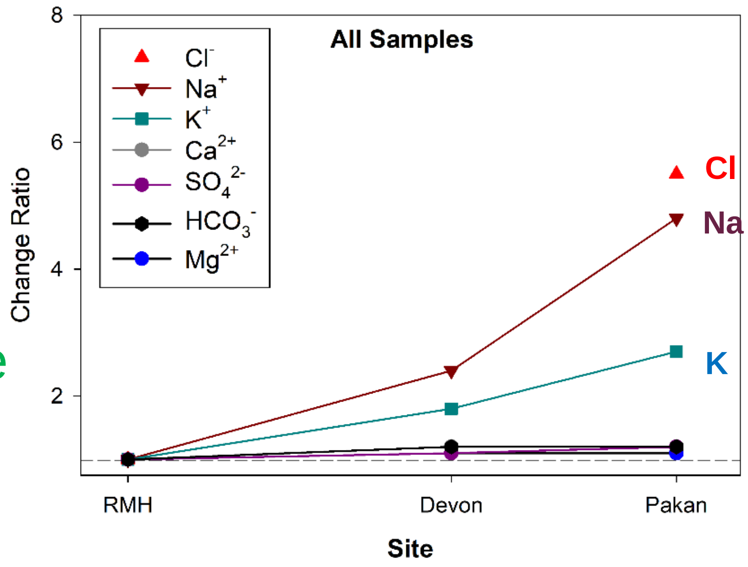
Reference	Region	Area (km^2)	% R	Total Cl t/yr	Total Cl Yld*	DI Road %	DI Com/Ind %	DI Private %	WWTP %	Water Soft. %	Precip. %	Agr. %	Other %
Meriano et al., (2009)	Ontario, Canada	27	48	7649	283	79	20	1	--	--	--	--	--
Perera et al., (2013)	Ontario, Canada	85	40	17241	203	65	35	--	--	--	--	--	--
Howard & Haynes (1993)	Ontario, Canada	104	55	10294	99	87	12	1	--	--	--	--	--
Novotny et al., (2009)	Minnesota, US	4150	51	235020	57	46	15	--	37	1	0	2	--
Edmonton only (this study)	***Alberta, Canada***	***684***	***--***	***36115***	***53***	***47***	***19***	***2***	***24***	***--***	***0.03***	***--***	***8***
Jin et al., (2011)	New York, US	500	--	21511	43	87	--	--	--	12	1	--	--
Kelly et al., (2008)	New York, US	62	--*	1421	23	83	8	--	4	3	1	--	1
Nimiroski & Waldron (2002)	Rhode Island, US	151	--	2322	15	90	--	1	--	4	6	--	--
Kelly et al., (2010)	Illinois, US	78000	--*	765900	10	28	--	--	41	4.7	1	25	--
Müller & Gächter (2012)	Alps, Europe	10919	31	101000	9	52	--	--	23	--	3	11	9
DP Basin (this study)	***Alberta, Canada***	***12971***	***53***	***73142***	***5.6***	***38***	***12***	***2***	***12***	***0.1***	***0.3***	***21***	***16***
Thunqvist (2004)	Vastmanland, Sweden	857	--*	2721	3	59	--	2	2	2	13	14	8

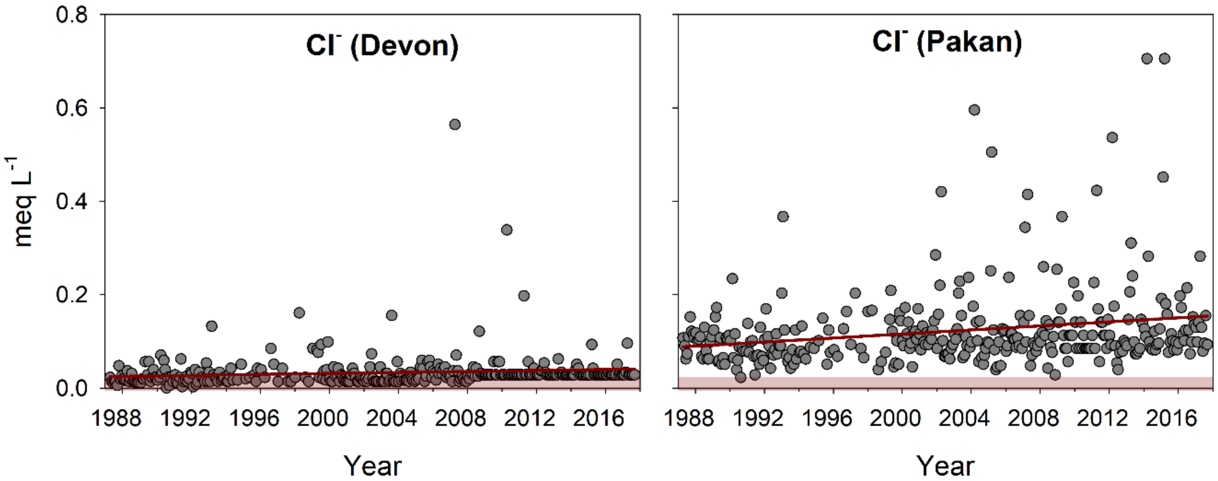
Conclusion

Conclusions

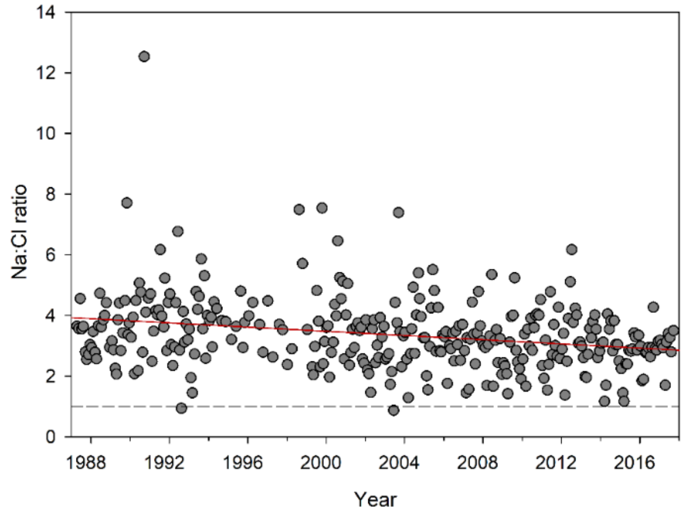
KEY FINDINGS:

- Na & Cl increased ~500% at Pakan (relative to RMH)
- There is a significant temporal increase of both Na and Cl at Pakan and not at Devon





Conclusions

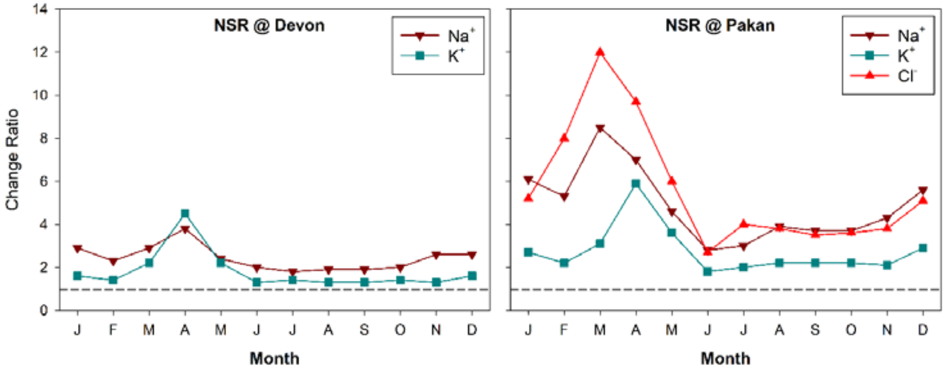


KEY FINDINGS:

- Na & Cl increase in March at Pakan and in April at Devon

- The Na:Cl ratio is decreasing over time

- Road Salts (~50%) the main source of Cl in the Devon-Pakan sub-basin



Conclusions

FUTURE OUTLOOK:

- **Climate change** may reduce the dilution of salts and other contaminants in the NSR
- Important to be cognizant of the salinization risks in the NSR and across Alberta
- Indeed, once you have a Cl problem it is incredibly difficult and expensive to manage

WATER

Saving freshwater from salts

Ion-specific standards are needed to protect biodiversity

By **M. Cañedo-Argüelles,[1,2] C. P. Hawkins,[3] B. J. Kefford,[4] R. B. Schäfer,[5] B. J. Dyack,[4] S. Brucet,[6,1] D. Buchwalter,[7] J. Dunlop,[8] O. Frör,[5] J. Lazorchak,[9] E. Coring,[10] H. R. Fernandez,[11] W. Goodfellow,[12] A. L. González Achem,[11] S. Hatfield-Dodds,[13] B. K. Karimov,[14] P. Mensah,[15] J. R. Olson,[16] C. Piscart,[17] N. Prat,[2] S. Ponsá,[1] C.-J. Schulz,[18] A. J. Timpano[19]**

Many human activities—like agriculture and resource extraction—are increasing the total concentration of dissolved inorganic salts (i.e., salinity) in freshwaters. Increasing salinity can have adverse effects on human health (*1*); increase the costs of water treatment for human consumption; and damage infrastructure [e.g., amounting to $700 million per year in the Border Rivers catchment, Australia (*2*)]. It can also reduce freshwater biodiversity (*3*); alter ecosystem functions (*4*); and affect economic well-being by altering ecosystem goods and services (e.g., fisheries collapse). Yet water-quality legislation and regulations that target salinity typically focus on drinking water and irrigation water, which does not automatically protect biodiversity.

POLICY

For example, specific electrical conductivities (a proxy for salinity) of 2 mS/cm can be acceptable for drinking and irrigation but could extirpate many freshwater insect species (*3*). We argue that salinity standards for specific ions and ion mixtures, not just for total salinity, should be developed and legally enforced to protect freshwater life and ecosystem services. We identify barriers

Canada and the United States are the only countries in the world that identify concentrations of a specific ion (chloride) above which freshwater life will be harmed (*6*, *8*). Globally, concentrations of other ions (e.g., Mg^{2+}, HCO_3^-) remain free from regulation in spite of their potential toxicity (*9*).

The situation will likely worsen in the future, because predicted increase in demand for freshwater will reduce the capacity of surface waters to dilute salts, and increasing resource extraction and other human activities (*10*) will generate additional saline effluents and runoff. Climate change will likely exacerbate salinization by causing seawater intrusion in coastal freshwaters, increasing evaporation, and reducing precipitation in some regions (*11*).

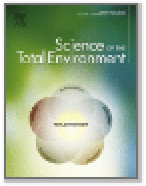
Cañedo-Argüelles, Miguel, et al. "Saving freshwater from salts." Science 351.6276 (2016): 914-916.

For more information on this presentation:

ELSEVIER

Science of The Total Environment

Volume 688, 20 October 2019, Pages 1056-1068



Chloride inputs to the North Saskatchewan River watershed: the role of road salts as a potential driver of salinization downstream of North America's northern most major city (Edmonton, Canada)

J.P. Laceby [a], J.G. Kerr [a], D. Zhu [b], C. Chung [a], Q. Situ [a], S. Abbasi [a], J.F. Orwin [a]

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https://doi.org/10.1016/j.scitotenv.2019.06.208

For more salinization info For Southern Alberta:

LIMNOLOGY and OCEANOGRAPHY

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Multiple land use activities drive riverine salinization in a large, semi-arid river basin in western Canada

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Abstract

Salinization is increasingly recognized as a global issue. However, the relative importance of different drivers across a broad range of ions and ecosystems is not well understood. This study examined spatial and temporal dynamics in riverine salinity (conductivity, Ca^{2+}, Mg^{2+}, Na^+, K^+, SO_4^{2-}, Cl^- and HCO_3^-) in the South Saskatchewan River Basin (SSRB), a semi-arid, mixed land use watershed in Alberta, Canada. A significant temporal increase ($p < 0.05$) in the concentration of one or more ions was observed at all 12 study sites. While all ions exhibited a significant increase in concentration over time, the rate of change was generally highest for Cl^- (≈ 1.4–3.0% yr^{-1}). The observed increase in riverine Cl^- loading downstream of a large urban center (≈ 1700 tonnes yr^{-1}) was attributed to increasing inputs from road salt (≈ 1800 tonnes yr^{-1}) and to a lesser extent municipal wastewater (≈ 400 tonnes yr^{-1}). For most other salts, spatial variation was driven not by urbanization but by the proportion of salt affected soils and/or cropland. A distinct Na_2SO_4 signal was observed at stations draining salt affected soils which strengthened over time at 7/12 sites indicating temporal trends in Na^+ and SO_4^{2-} have been driven largely by soil processes. A strong relationship between cropland and salt chemistry across the basin suggests agricultural activities have also contributed to observed trends. Therefore, in regions with similar climatic and anthropogenic characteristics to the SSRB, multiple stressors are likely to be operating and as such, these systems may be at particular risk from salinization.

Alberta

For provincial scale chloride information:

← Water

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Water indicators – Chloride

Water quality monitoring results for chloride concentrations.

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Chloride in surface waters of Alberta's rivers

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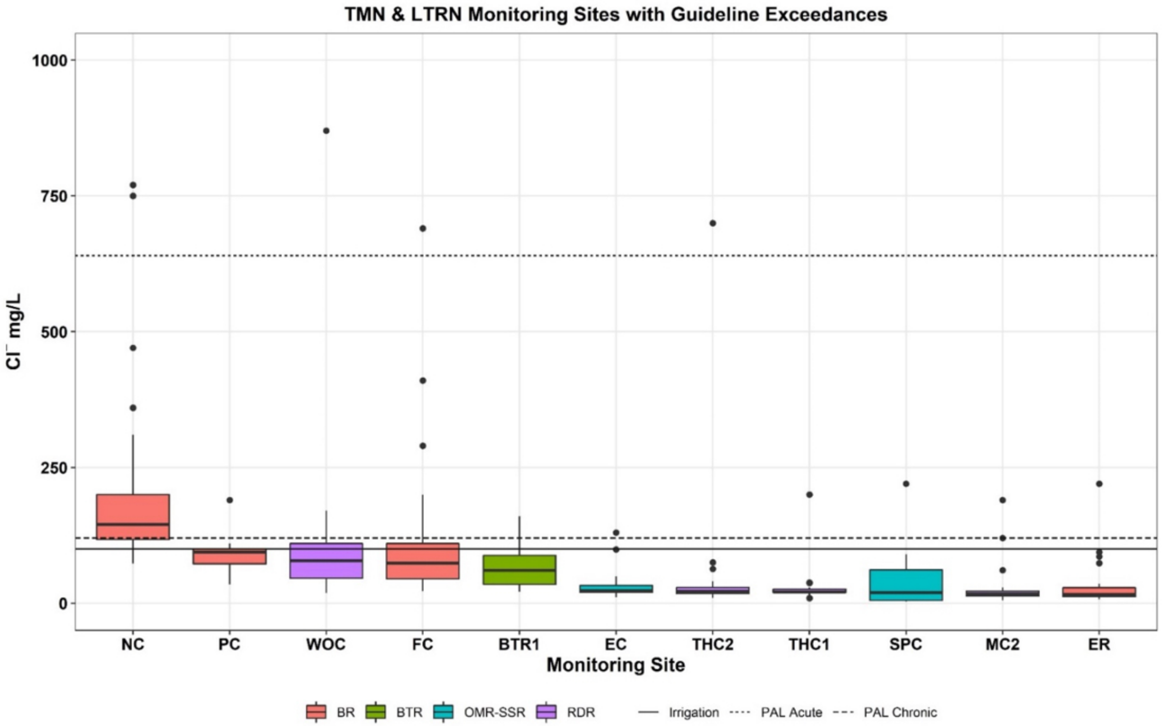

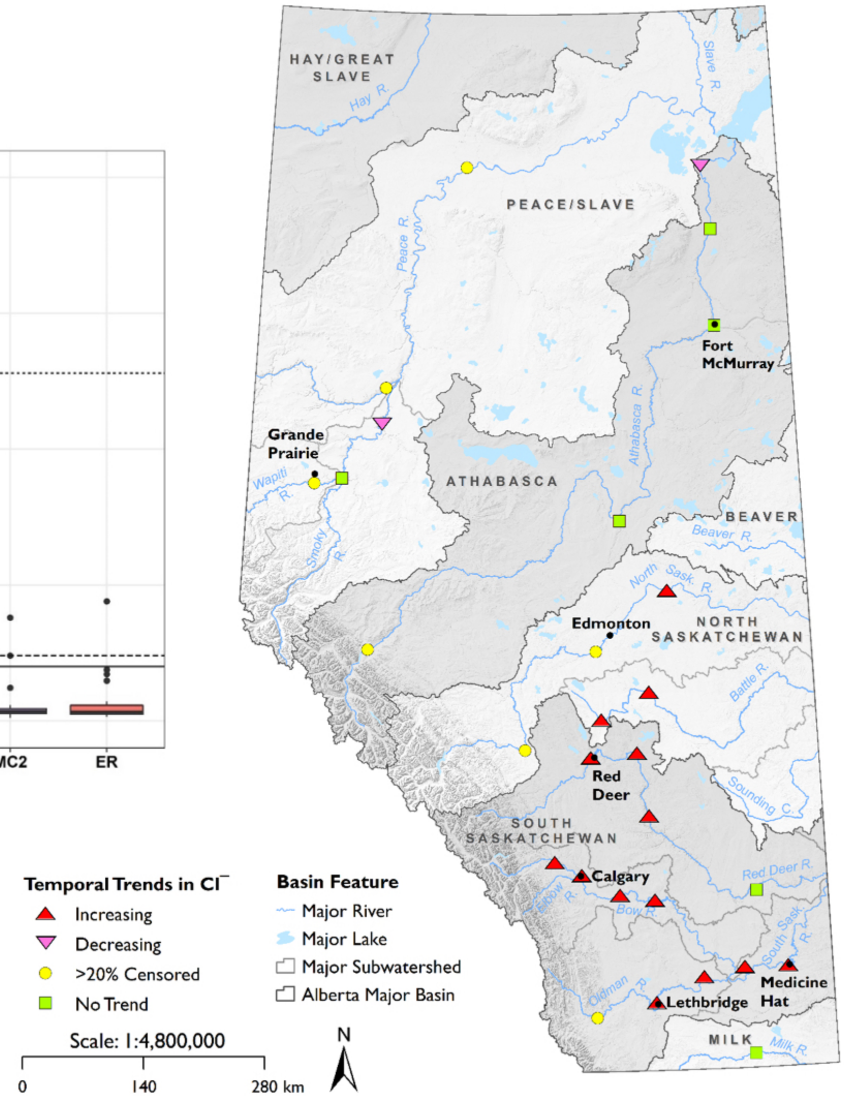

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