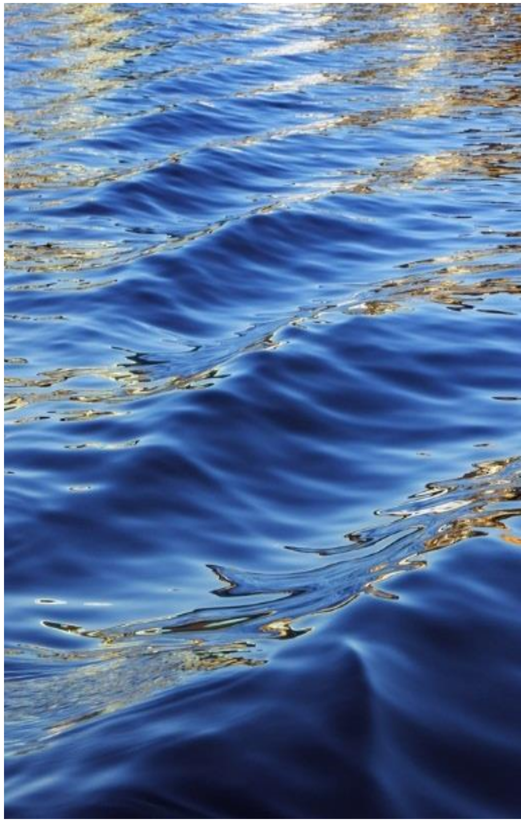
Climate Change: Current and Future Impacts on Erosive Rainfall in Calgary Alberta

My Climate Change Story



Masters Of Science Graduate

Erosion Control Technician – City of Calgary

Royal Roads University

Dr. David Bernard

Calgary, Alberta

Why Is This Happening?

A=R*K*LS*C*P

A= Average Annual Soil Loss

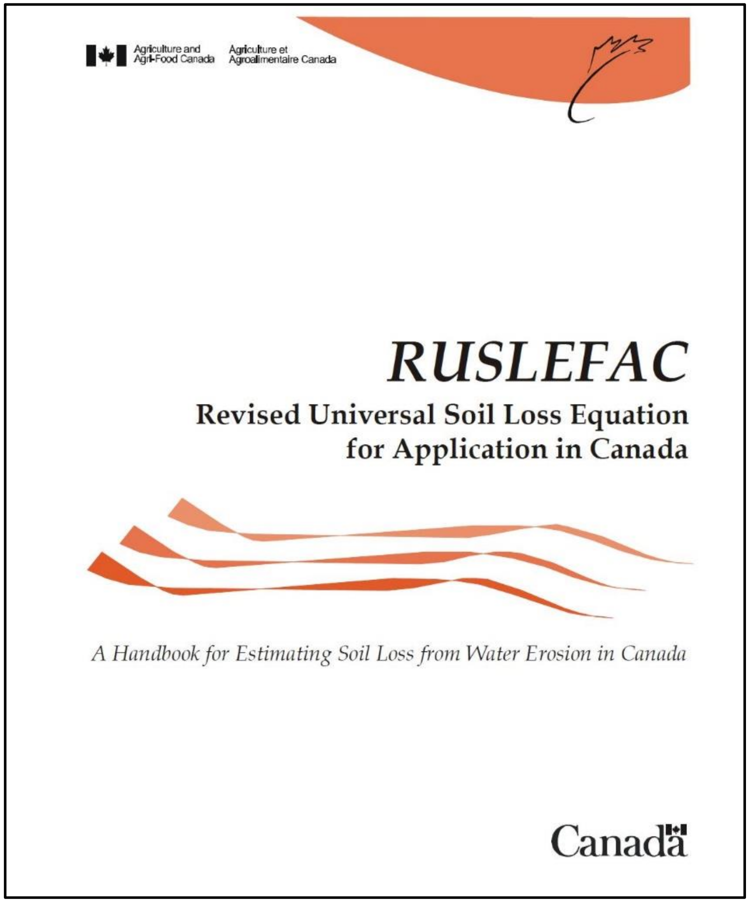
R= Rainfall factor (Constant?)

K= Soil Erodibility (Measured on site)

LS= Length Slope (measures on site)

C= Cover factor (based on practices)

P= Protection factor (based on practices)



Why This Matters? – Impacts To Rivers

Why This Matters? – Impacts To Storm ponds and Pipes

Why This Matters? – Impacts To Storm ponds and Pipes

Why This Matters – Drinking Water

Why This Matters – Recreation and Fish Health

Research and Literature Review

Journal of Hydrology 548 (2017) 251–262

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Research papers

Towards estimates of future rainfall erosivity in Europe based on [...] and WorldClim datasets

Panos Panagos [a,*], Cristiano Ballabio [a], Katrin Meusburger [b], Jonathan Spinoni [a], Chris[...] Pasquale Borrelli [a,b]

[a] European Commission, Joint Research Centre, Directorate for Sustainable Resources, Via E. Fermi 2749, I-21027 Ispra (VA), Italy
[b] Environmental Geosciences, University of Basel, Switzerland

A R T I C L E   I N F O

Article history:
Received 4 November 2016
Received in revised form 23 January 2017
Accepted 4 March 2017
Available online 6 March 2017
This manuscript was handled by K. Georgakakos, Editor-in-Chief, with the assistance of Jennifer Guohong Duan, Associate Editor

Keywords:
R-factor
Climate change
Rainfall intensification
Storminess
RCP4.5
Erosion scenario

A B S T R A C T

1. Introduction

Soil erosion is one of the main European environmental threats, particularly in Southern Europe (Panagos et al., 2015a). Its prevention and mitigation is a key ecosystem service to monitor and access spatially and temporally (Guerra et al., 2016). Accelerated soil erosion may lead to a decrease of ecosystem stability, land productivity, land degradation in general and a loss of income for farmers (Salvati and Carlucci, 2013). Soil erosion and more generally land degradation is driven by unsustainable land management due to increasing human pressure enhanced by climate change (Helldén and Tottrup, 2008). The extent, frequency and magnitude of soil erosion in Europe is expected to increase due to a general increase of extreme rain fall events caused by climate change (Pruski and Nearing, 2002; Deelstra et al., 2011).

The prediction of soil erosion changes in the future are mainly dependent on modeling future rainfall erosivity, land use changes and impacts of policies on soil loss. The most commonly used erosion models are the the various types of the Universal Soil Loss

* Corresponding author.
E-mail address: panos.panagos@ec.europa.eu (P. Panagos).

http://dx.doi.org/10.1016/j.jhydrol.2017.03.006
0022-1694/© 2017 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

Potential changes in rainfall erosivity in the U.S. with climate change during the 21st century

M.A. Nearing

ABSTRACT: The erosive power of rainfall can be expected to change as climate changes. Such erosive changes are likely to have significant impacts on local and national soil conservation strategies. This study uses results of climate change scenarios from two coupled Atmosphere-Ocean Global Climate Models to investigate the possible levels and patterns of change that might be expected over the 21st century. Results of this study suggest the potential for changes in rainfall erosivity across much of the continental United States during the coming century. The magnitude of change (positive or negative) across the country over an 80 year period averaged between 16–58%, depending upon the method used to make the predictions. Some areas of the country showed increases and others showed decreases in erosivity. Spatial distributions of calculated erosivity changes indicated areas of both consistency and inconsistency between the two climate models.

Keywords: Atmosphere-ocean global climate models, precipitation, RUSLE, soil erosion

Soil erosion rates may change in response to changes in climate for a variety of reasons, including climatic effects on plant biomass production, plant residue decomposition rates, soil microbial activity, evapotranspiration rates, soil surface sealing and crusting, and shifts in land use necessary to accommodate a new climatic regime (Williams et al. 1996). However, the most consequential effect of climate change on water erosion will be in changes of erosive power, or erosivity, of rainfall.

Studies using erosion simulation models (Nearing et al. 1989; Flanagan and Nearing 1995) indicate that erosion response is much more sensitive to the rainfall amount and intensity than to other environmental variables (Nearing et al. 1990). Warmer atmospheric temperatures associated with greenhouse warming are expected to lead to a more vigorous hydrological cycle, including more extreme rainfall events (IPCC 1995). Such a process may already be taking place in the United States. Historical weather records analyzed by Karl et al. (1996) indicate that since 1910 there has been a steady increase in area of the United States affected by extreme precipitation events (> 50.8mm in a 24 hr period), and there is less than one chance in a thousand that this observed trend could occur in a quasi-stationary climate. Karl et al. (1996) also observed an increase in proportion of the country experiencing a greater than normal number of wet days.

Mark A. Nearing is a scientist with the U.S. Department of Agriculture, Agricultural Research Service with the National Soil Erosion Research Laboratory at Purdue University in West Lafayette, Indiana.

© 2001 Journal of Soil and Water Conservation, Volume 56, Number 3. Reprinted by permission of the Soil and Water Conservation Society.

Atmosphere-Ocean Global Climate models also indicate potential changes in rainfall patterns, with changes in both the number of wet days and percentage of precipitation coming in intense convective storms as opposed to longer duration, less intense storms (McFarlane et al. 1992; Johns et al. 1997).

Rainfall erosivity is strongly correlated to the product of total rainstorm energy and maximum 30 minute rainfall intensity during a storm (Wischmeier and Smith 1978). The relationship first derived by Wischmeier and Smith has proved to be robust and is still used today in the Revised Universal Soil Loss Equation (RUSLE) (Renard et al. 1997), which is the current technology applied in the United States for conservation planning and compliance. Studies using a physically-based, continuous simulation model of erosion have also substantiated the geographic trends of published R factors for several parts of the United States (Baffaut et al. 1996).

A direct computation of the rainfall erosivity factor, R, for the RUSLE model requires long term data for rainfall amounts and intensities. Current global circulation models do not provide details requisite for a direct computation of R factors (McFarlane et al. 1992; Johns et al. 1997). However, the models do provide scenarios of monthly and annual changes in total precipitation around the world.

Renard and Freimund (1994) evaluated erosivity at 155 locations within the continental United States, and developed statistical relationships between the R factor and both total annual precipitation at the location and a modified Fournier coefficient (Fournier 1960; Arnoldus 1977), F, calculated from monthly rainfall amounts as

$$F = \frac{\sum_{i=1}^{12} p_i^2}{P} \quad (1)$$

where p_i (mm) is the average monthly precipitation and P (mm) is the average annual precipitation.

Derived relationships between R factor and P developed by Renard and Freimund (1994) were

$$\text{R factor} = 0.04830P^{1.610} \quad (r^2 = 0.81) \quad (2)^1$$

and

$$\text{R factor} = 587.8 - 1.219P + 0.004105P^2 \quad (r^2 = 0.73) \quad (3)$$

and the relationships between R factor and F were

$$\text{R factor} = 0.7397F^{1.847} \quad (r^2 = 0.81) \quad (4)^2$$

and

$$\text{R factor} = 95.77 - 6.081 + 0.04770F^2 \quad (r^2 = 0.75) \quad (5)$$

where the R factor is in units of (MJ mm ha^{-1} yr^{-1}).

Equations 2 and 4 provided a better fit on the lower end of the data range, and equations 3 and 5 fit better on the upper end; therefore, Renard and Freimund (1994) recommended using equation 2 when P was < 850 mm and equation 3 when P was > 850 mm. Likewise, they recommended using equation 4 when F was < 55 mm and equation 5 when F was > 55 mm.

The objective of this study was to estimate potential changes in rainfall erosivity in the United States during the 21st century under global climate change scenarios generated from two coupled Atmosphere-Ocean Global Climate models.

Methods and Materials

Two coupled Atmosphere-Ocean Global Climate models from which results were used were developed by the

VOLUME 56 NUMBER 3 2001 229

International Soil and Water Conservation Research 4 (2016) 186–194

Contents lists available at ScienceDirect

[...]ernational Soil and Water Conservation Research

journal homepage: www.elsevier.com/locate/iswcr

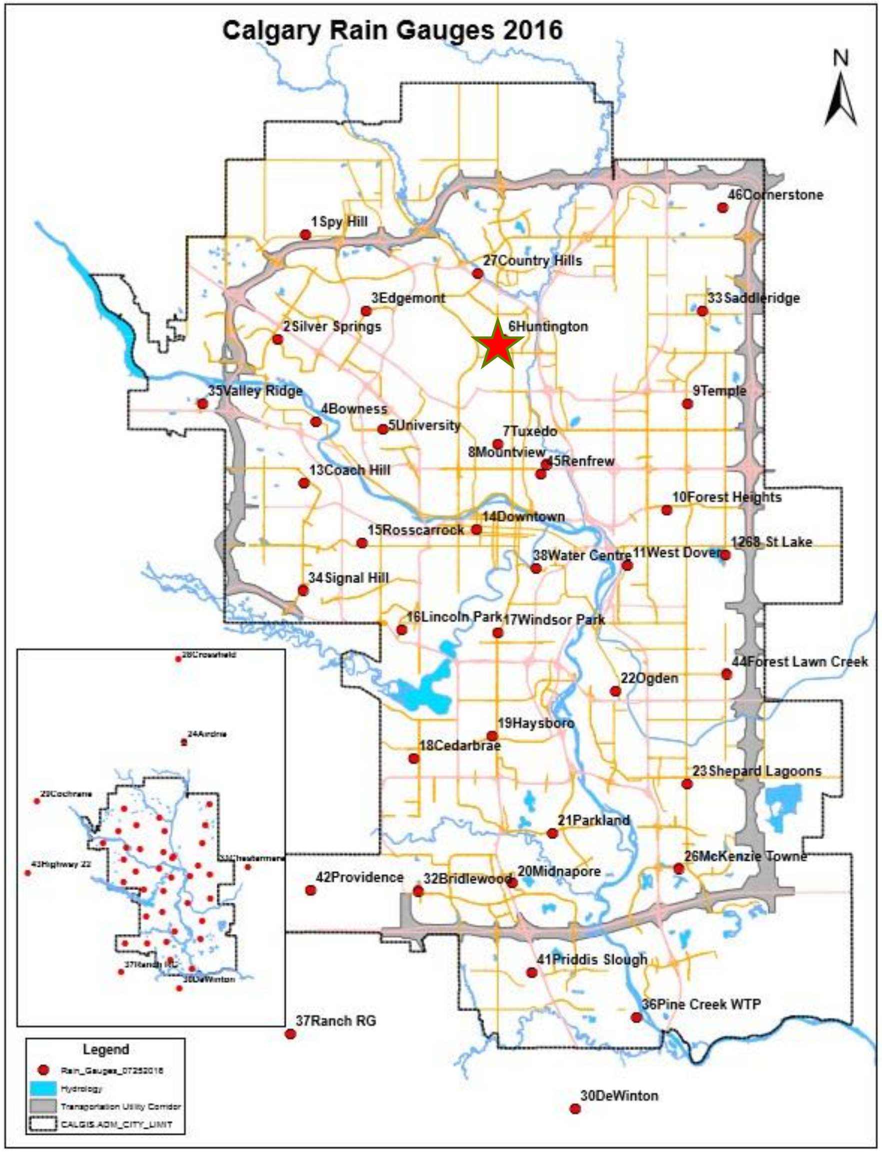
[...]l erosivity in the past and future due to climate [...]ntral part of India

[...]k Khare, Sananda Kundu

A B S T R A C T

Temporal change in rainfall erosivity varies due to the rainfall characteristic (amount, intensity, frequency, duration), which affects the conservation of soil and water. This study illustrates the variation of rainfall erosivity due to changing rainfall in the past and the future. The projected rainfall is generated by SDSM (Statistical DownScaling Model) after calibration and validation using two GCMs (general circulation model) data of HadCM3 (A2 and B2 scenario) and CGCM3 (A1B and A2 scenario). The selected study area is mainly a cultivable area with an agricultural based economy. This economy depends on rainfall and is located in a part of the Narmada river basin in central India. Nine rainfall locations are selected that are distributed throughout the study area and surrounding. The results indicate gradually increasing projected rainfall while the past rainfall has shown a declined pattern by Mann-Kendall test with statistical 95% confidence level. Rainfall erosivity has increased due to the projected increase in the future rainfall (2080 s) in comparison to the past. Rainfall erosivity varies from −32.91% to 24.12% in the 2020s, −18.82 to 75.48% in 2050 s and 20.95–202.40% in 2080s. The outputs of this paper can be helpful for the decision makers to manage the soil water conservation in this study area.
© 2016 International Research and Training Center on Erosion and Sedimentation and China Water and Power Press. Production and Hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Rain gauges – Huntington Hills station



Updating R values

- e=0.119 + 0.0873 log10 *I*

- E=$\sum_{k}^{p} e_k \Delta V_k$

- R=EI

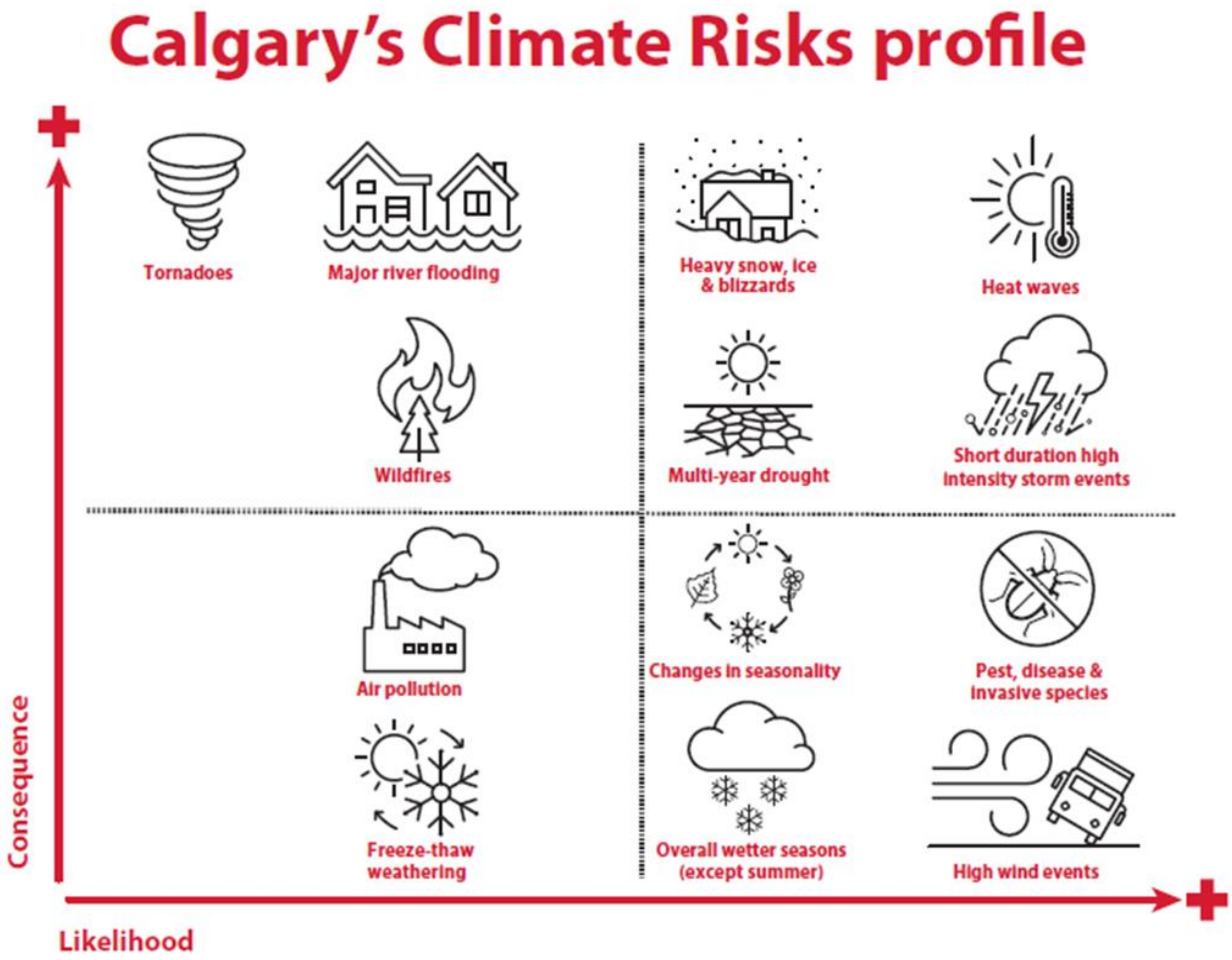
* Units for the R-value are (MJ*mm/Ha*H*Y) and were intentionally left out of both the presentation and paper for readability. This is typical for similar papers

Running the Data

1	CHANNEL # 6					
2	LOCATION : "HUNTINGTON "					
3	SUMMARY OF RECORDED RAINFALL					
4	Date	Time	Volume (mm)	6 h volume	Storm Event	15 Min Volume
5	4/21/2006	18:55	0			0
6	4/21/2006	19:00	0			0
7	4/21/2006	19:05	0			0
8	4/21/2006	19:10	0			0
9	4/21/2006	19:15	0			0
10	4/21/2006	19:20	0			0
11	4/21/2006	19:25	0			0
57354	11/6/2006	22:00	0	0		0
57355	11/6/2006	22:05	0	0		0
57356	11/6/2006	22:10	0	0		0
57357	11/6/2006	22:15	0	0		0
57358	11/6/2006	22:20	0	0		0
57359	11/6/2006	22:25	0	0		0
57360	11/6/2006	22:30	0	0		0
57361	11/6/2006	22:35	0	0		0
57362	11/6/2006	22:40	0	0		0
57363	11/6/2006	22:45	0	0		0
57364	11/6/2006	22:50	0	0		0
57365	11/6/2006	22:55	0	0		0
57366	11/6/2006	23:00	0	0		0
57367	11/6/2006	23:05	0	0		0
57368	11/6/2006	23:10	0	0		0
57369	11/6/2006	23:15	0	0		0
57370	11/6/2006	23:20	0	0		0
57371	11/6/2006	23:25	0	0		0
57372	11/6/2006	23:30	0	0		0
57373	11/6/2006	23:35	0	0		0
57374	11/6/2006	23:40	0	0		0
57375	11/6/2006	23:45	0	0		0
57376	11/6/2006	23:50	0	0		0
57377	11/6/2006	23:55	0	0		0
57378	11/7/2006	0:00	0	0		0
57379						
57380						

x30

The Risk to Calgary and where this study fits



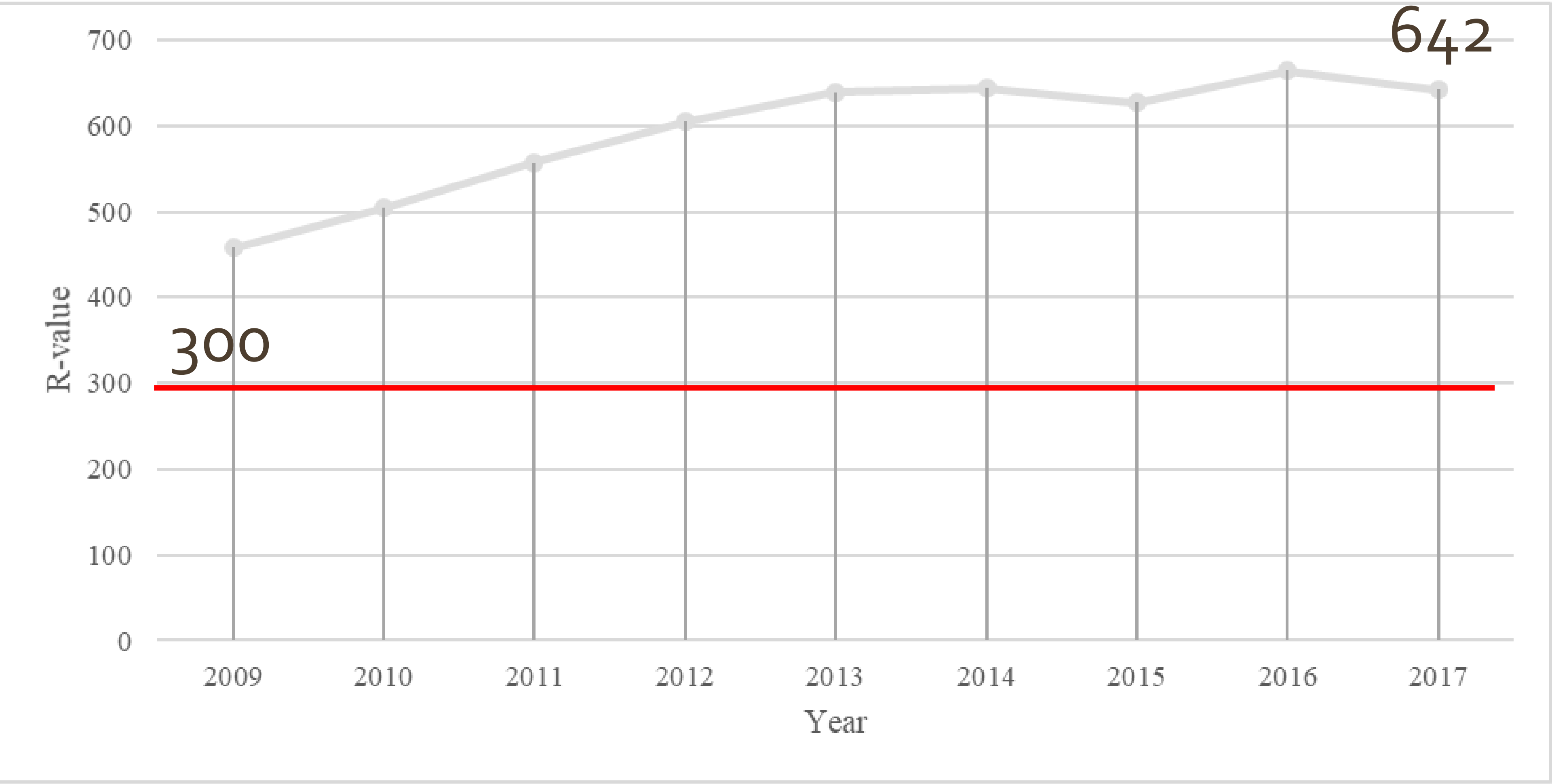
Climate change

- $F = (\sum_{i=1}^{12} pi^2)/P$

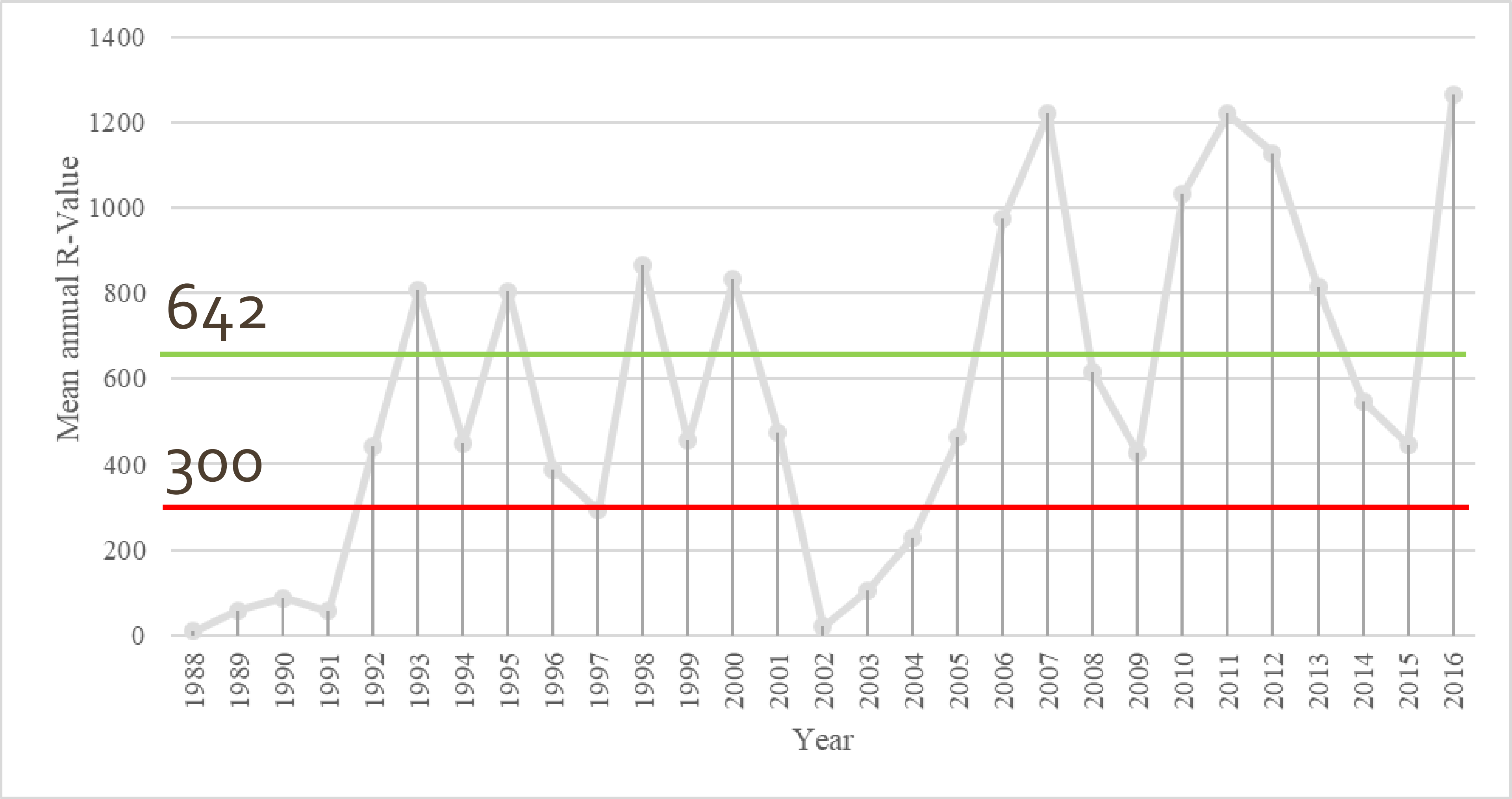
- R-value = $0.7397F^{1.847}$

- R-value = $95.77 - 6.081 + 0.04770F^2$

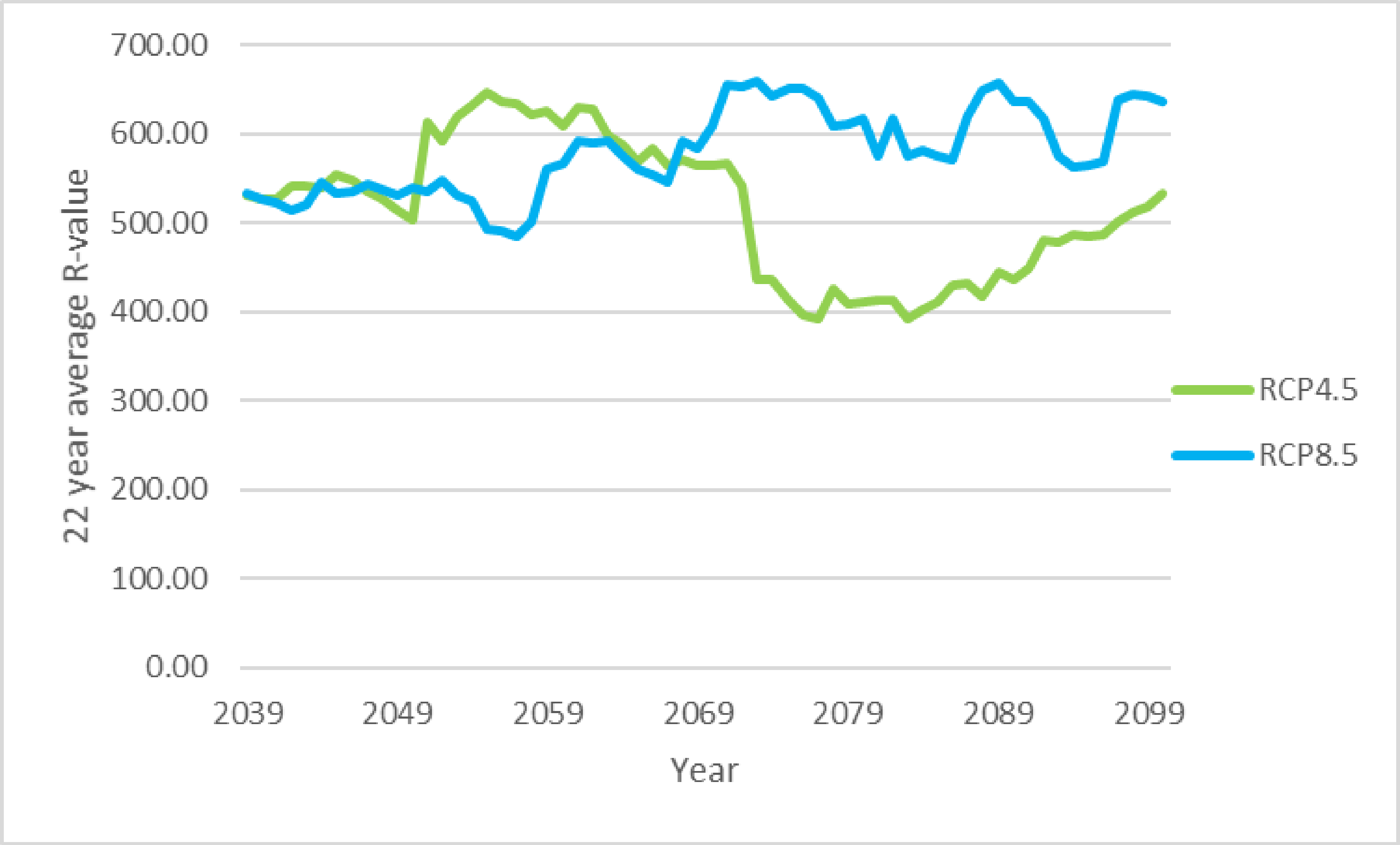
Findings - R-value has increased 2.14 times



Findings – Large Year Over Year Fluctuations in R value



Comparative 22 year average 4.5 to 8.5



Short Duration High Intensity Rainfall

- most erosive rainstorms contributed an average of 43% of erosive rainfall for the year
- second most erosive storm contributed an average of 19%

Short Duration High Intensity Rainfall

- The statistical relationship used to predict erosive rainfall in the future may not be applicable in Calgary
- Only moderately successful when tested; tended to underrepresent R-value

What This Means – Moving Forward

What This Means – Estimates May Be Incorrect

Table 2

Sites approved in 2017 that meet the City of Calgary approval limit (2 tonnes/hectare/year) under accepted (300) and calculated (642) R-values

	R-Value	
Variable	Accepted (300)	Calculated (642)
Total Number of sites	181	181
Number of sites that pass	170	113
Percent of total that pass	94%	62%

Notes: only sites with the area information were included in the totals

What This Means – Estimates May Be Incorrect

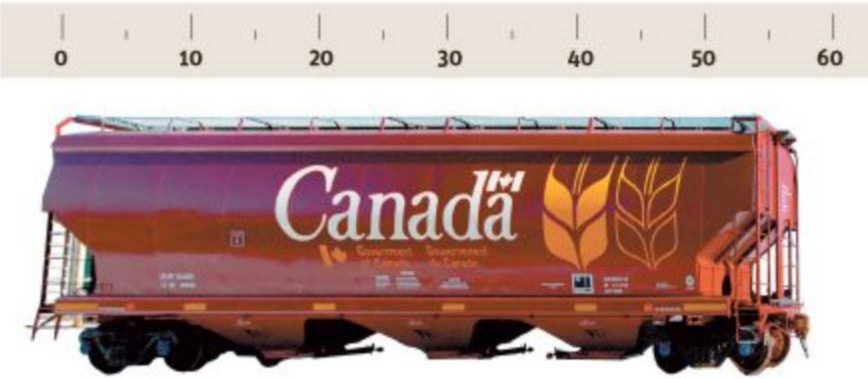
Table 3

Difference in estimated sediment approved to enter the storm system based on accepted (300) and calculates (642) R-values

	R-value		
Variable	Accepted (300)	Calculated (642)	Difference
Yield with controls	1646	3521	1876
Yield without controls	30575	65431	34856
Estimated sediment kept out by controls	29091	62254	33163

Notes: only sites with years where average annual site soil loss has been calculated

What This Means – Estimates May Be Incorrect



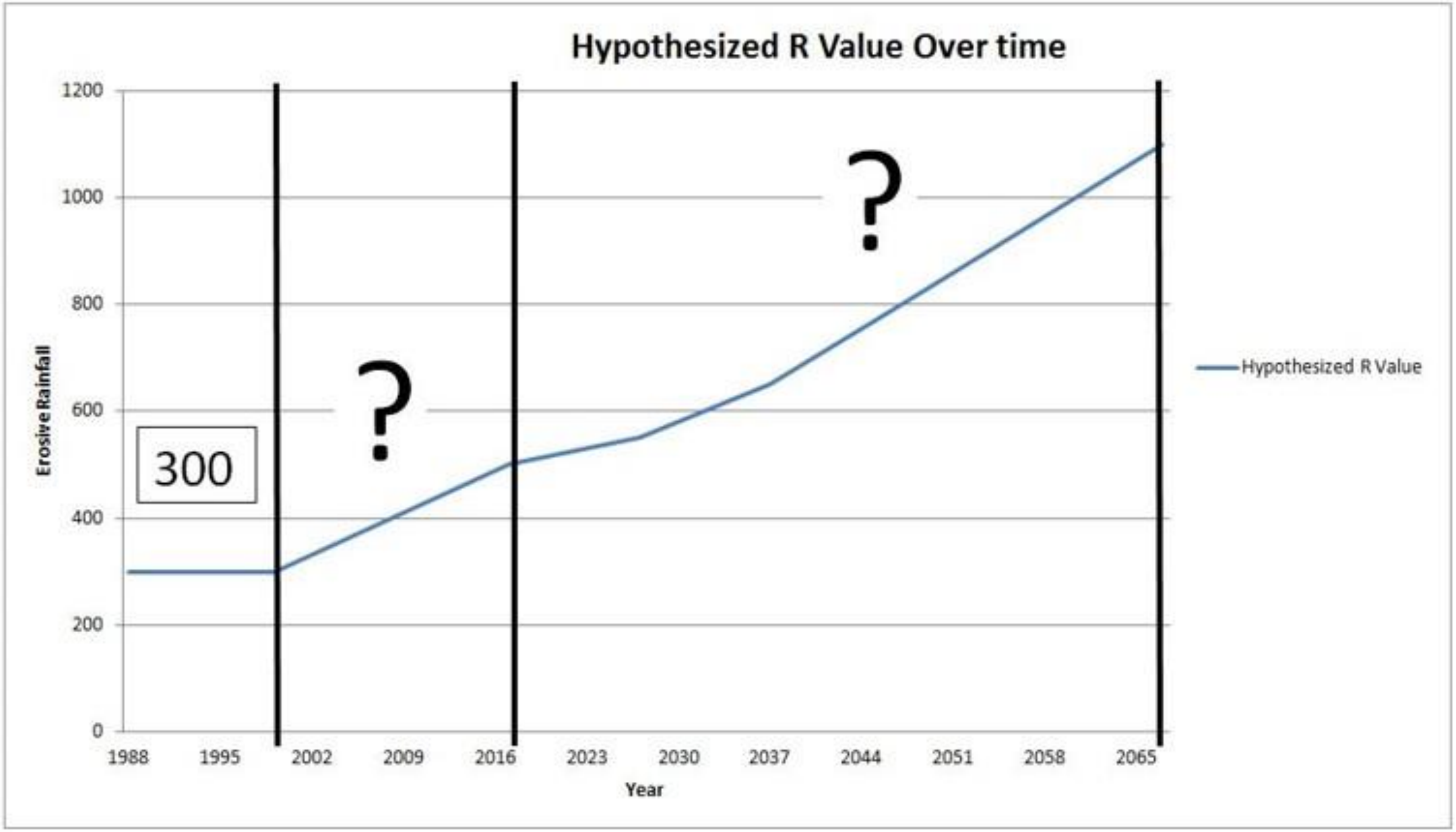
=

X3.3

OR

ONE

What This Means – Future R-values

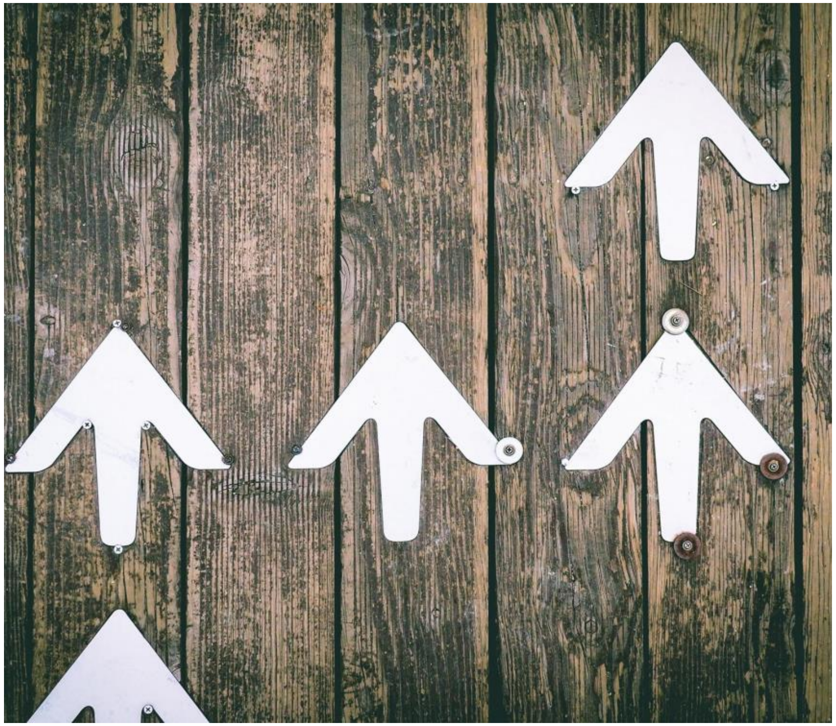


What This Means – Increased Practice Failure

What This Means – Erosive Rainfall Is Likely To Increase

Conclusions

- The erosive rainfall value **increased** from 300 to 642. Or **2.14 times**.
- Potential impact of **increasing** soil loss by **1,800 tns** to nearly **35,000 tns**
- **28%** under a carbon reduced future and **31%** under business as usual.
- **A small proportion of storms contributed a large proportion of erosive rainfall**
- Designing to a 22-year average r value may be setting a site up for annual failures.



My Ask of The City of Calgary

- These findings are relevant for the Huntington Hills station.
- The City of Calgary should consider carefully implementing these findings
- Care should be taken prior to implementing these findings

My Ask of ESC Stakeholders

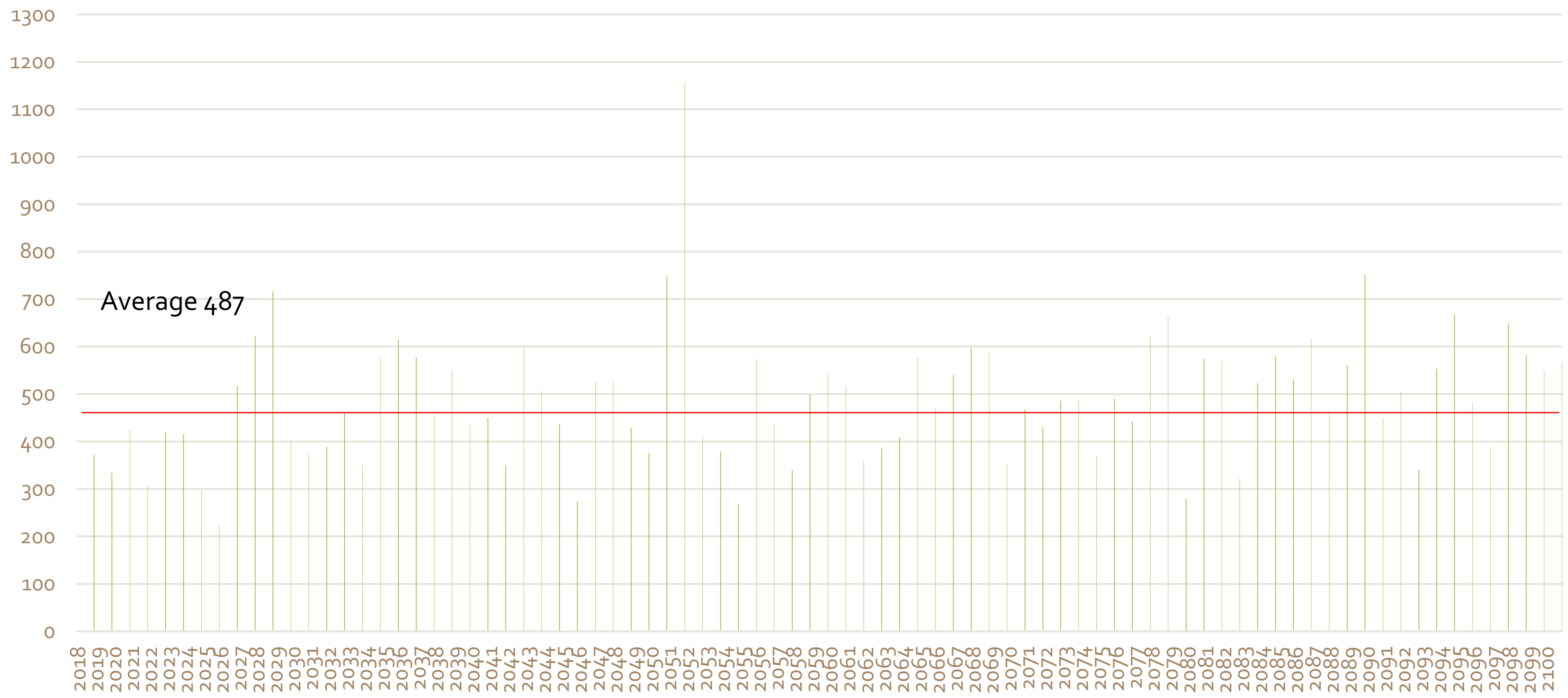
- Keep an open mind
- Remember what it is we are all protecting

Questions?

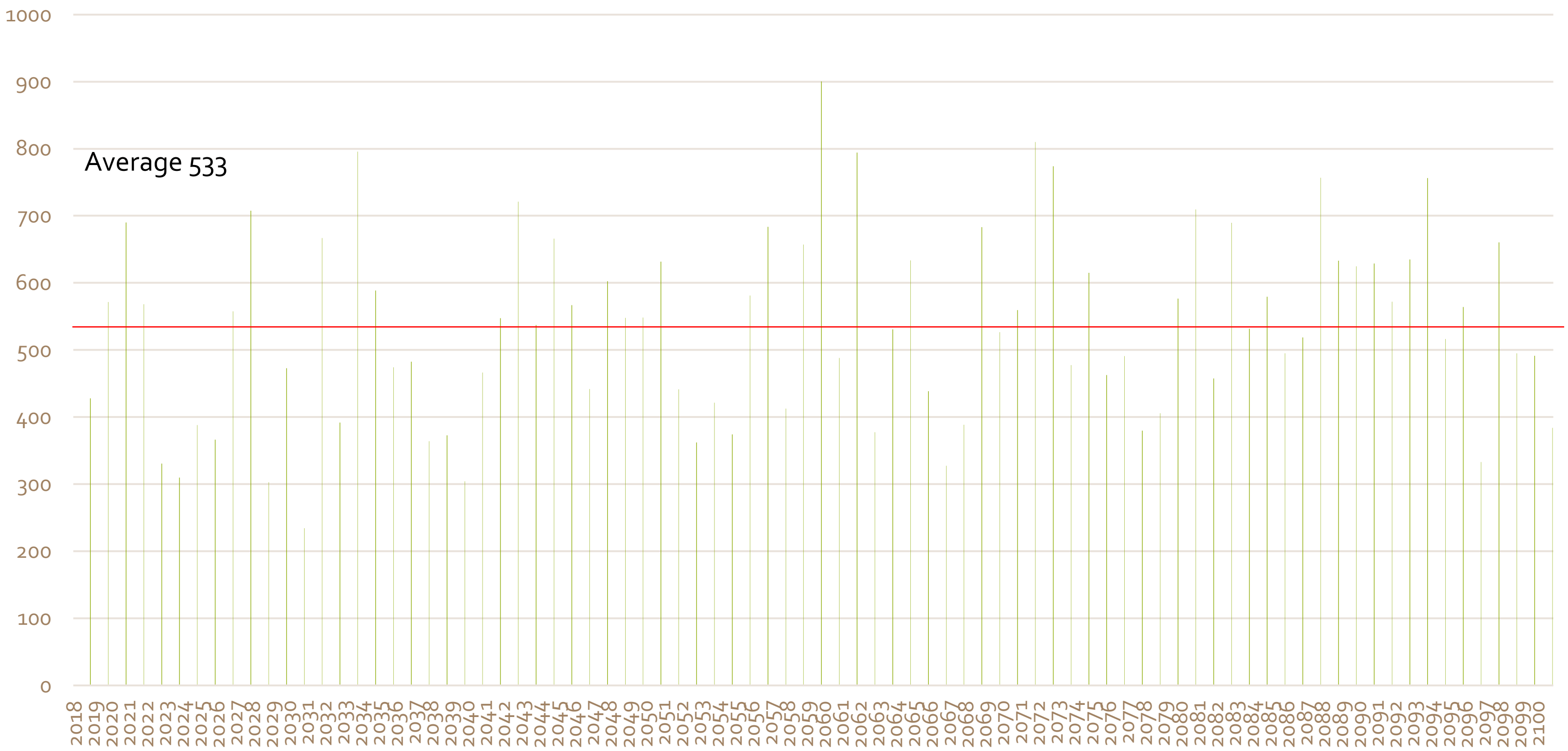
Contact Info

Ben Ethier
403-268-2082
Ben.ethier@Calgary.ca

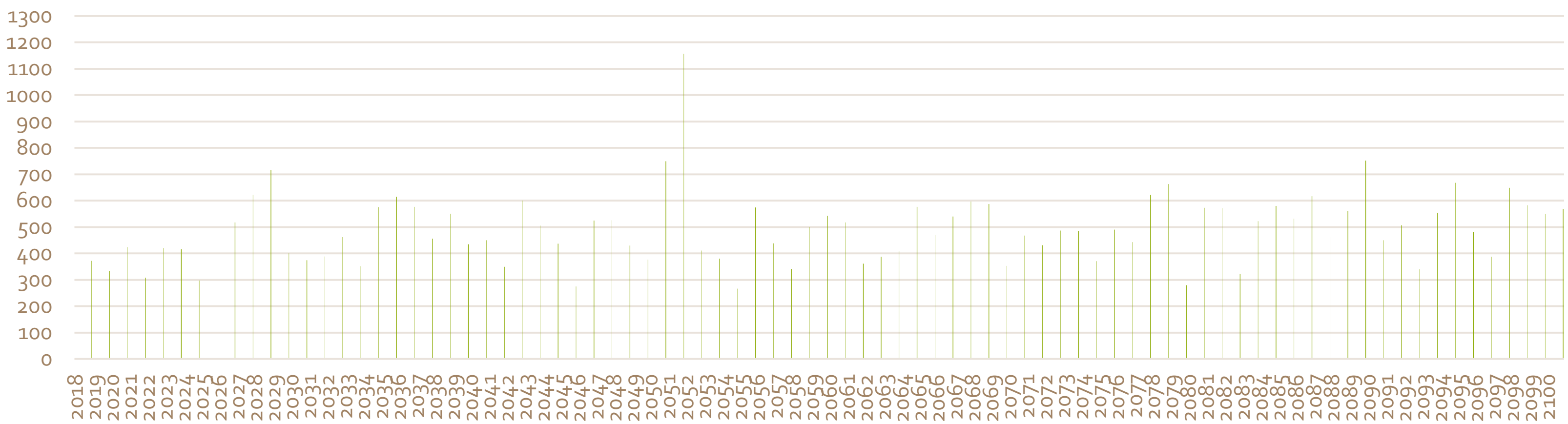
Annualized rainfall RCP4.5

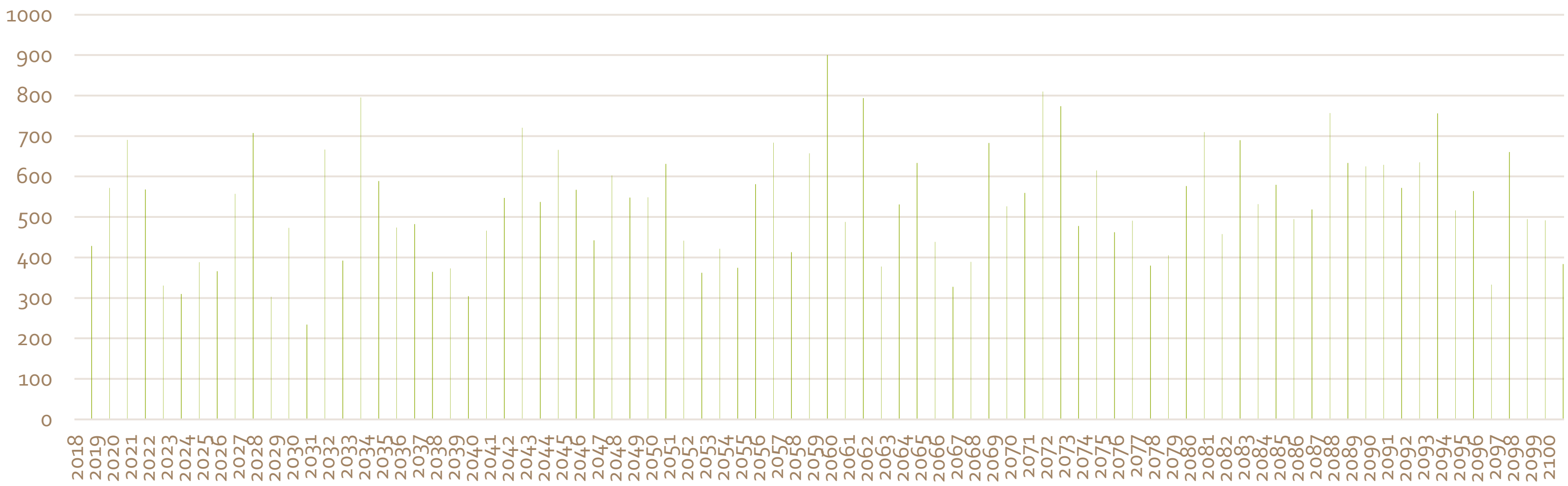


Annualized Rainfall RCP 8.5

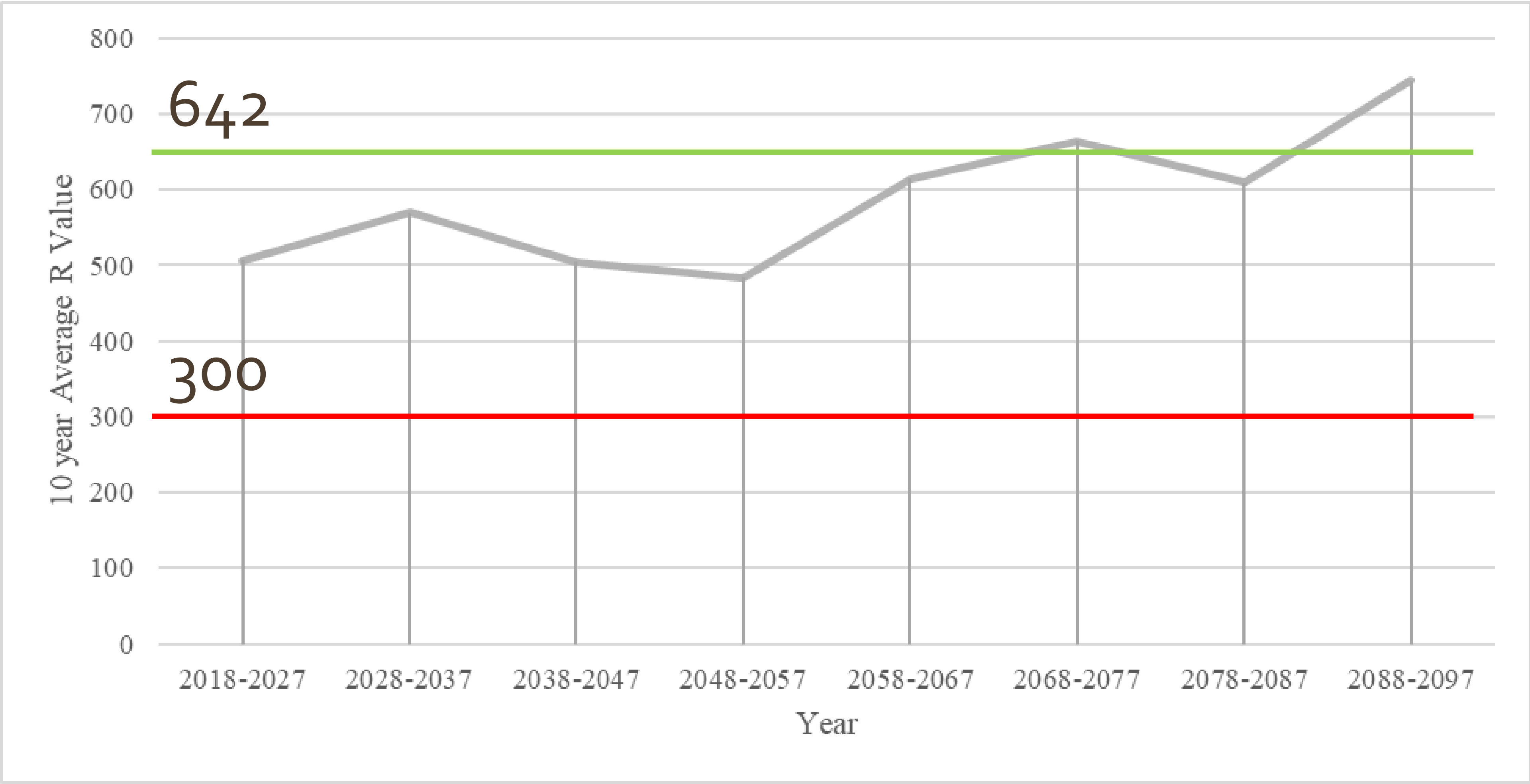


Comparative annualized 4.5 to 8.5





Findings- Climate Change – RCP 8.5 (Business as usual)



Findings - Climate Change – RCP 4.5 (Climate Stabilization by 2100)