

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

by

Ben Ethier

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Royal Roads University  
Victoria, British Columbia, Canada

Supervisor: Rick Robinson  
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COMMITTEE APPROVAL

The members of Ben Ethier's Thesis Committee certify that they have read the thesis titled *Climate Change: Current and Future Impacts on Erosive Rainfall in Calgary, Alberta* and recommend that it be accepted as fulfilling the thesis requirements for the Degree of Master of Science in Environment and Management:

Audrey Dallimore [signature on file]

Nicole Sparks [signature on file]

Final approval and acceptance of this thesis is contingent upon submission of the final copy of the thesis to Royal Roads University. The thesis supervisor confirms to have read this thesis and recommends that it be accepted as fulfilling the thesis requirements:

Rick Robinson [signature on file]

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### **Abstract**

Rainfall data collected every five minutes between 1988 and 2017 at the Huntington Hills rainfall gauge in Calgary Alberta and downscaled CanRCM4 climate change data for RCP 4.5 and RCP 8.5 IPCC scenarios are used to calculate current erosive rainfall value (R-value) for use in RUSLE calculations and estimate future change in R-value respectively.

R-values have increased by 2.14 times since 1990. R-values are expected to increase by 28% (RCP-4.5) and 31% (RCP8.5). This increase is slightly lower than values reported by other literature, though show a predicted increase over time.

Further studies should focus on 3 areas, expand scope by including more stations, investigate regression-based formulae, and estimate R-values based on daily rainfall. The potential for increased negative effects on all stakeholders warrants a careful but expedited expansion of this study to ensure the certainty of the magnitude of R-value change for the City of Calgary as a whole.

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*This thesis is dedicated to Daina Ethier.*

*Thank you for instilling in me a lifelong passion for scientific discovery and learning*

### **Introduction**

Climate change has become a widely discussed topic since the beginning of the millennium and is now an accepted global reality (IPCC, 2013). In the prairie region of Canada, climate models have predicted that weather extremes will become even more extreme as a result of the impacts of global climate change (Lemmen, Warren, Lacroix, & Bush, 2008). Climate change may have changed rates of average annual sediment loss from construction sites in Calgary, Alberta over the past 20 years, and could continue to impact rates of average annual sediment loss into the future.

This widening of extremes means, for example, droughts will be more prolonged and drier, while rainstorms will be more powerful and intense. Of most significant concern is how climate change will impact life as we know it today. Of significant concern is the impact of climate change on today's economic, agricultural and industrial sectors as well as on infrastructure (Lemmen, et al. , 2008 and Warren & Lemmen, 2014). There are some estimated benefits to the agricultural industry such as increased crop production due to longer warmer growing seasons, or the introduction of novel food crops in previously untenable northern climates due to more extended growing seasons. However, the benefits are estimated to be surpassed by the damaging impacts of extreme weather events and the introduction of invasive warm climate species further north. Similarly, resource extraction and industry may see some benefits from climate change such as increases in extraction or production efficiency due to longer warmer working seasons or increased access to northern locations. Again, though these benefits are likely to be exceeded by the loss of winter access from melting permafrost loss to

destructive natural events such as wind, precipitation, or fire. The insurance and tourism industries are already reporting significant changes in revenues, most notably in the insurance industry due to increased catastrophic natural events (Warren & Lemmen, 2014). Volume and intensity of rainfall are expected to increase as global temperatures rise. Some hypothesize this increase could be amplified in high altitudes or regions near mountainous terrain (Clark, Allison, & Sitler, 2009). Rainfall intensity and volume and duration are significant factors in the calculation of rainfall erosivity construction site sediment loss (Wall, Coote, Pringle, & Shelton, 2002).

The City of Calgary manages stormwater runoff with the use of a separate sewer system, meaning stormwater and sanitary wastewater are collected, conveyed, and treated separately before being released back to the local surface watershed (City of Calgary, 2009). Rainwater, snow, or ice melt (stormwater) is collected by inlets found within the curbs and gutters of streets and directed to the river through underground pipes. Stormwater collected in the urban environment can contain sediment and contaminants from hard and soft urban surfaces such as roofs, streets, sidewalks, parking lots, and lawns (Makepeace, Smith, & Stanley, 2009). In some cases, stormwater is managed and treated with the use of stormwater retention ponds that slow the velocity of entering stormwater allowing fine sediments to settle out and be collected at the bottom of the pond before the water is released to the river system (Figure 1). One study has shown that stormwater retention ponds in Calgary are effective at retaining sediments and associated contaminants from stormwater; the study identified contaminants such as salt, hydrocarbons, cadmium, chromium, copper, lead, selenium, and zinc as contaminants of concern (Westerbeek-Vopicka, 2009). The City of Calgary notes that sites with exposed soils and

subsoils have the potential to contribute significant volumes of sediment to these stormwater management ponds (City of Calgary, 2011).



Figure 1. What is a Stormpond? Reprinted from Storm Drainage System FAQ, In [www.Calgary.ca](http://www.Calgary.ca), n.d., Retrieved August 24, 2018, from <http://www.calgary.ca/UEP>. Copyright 2018 by The City of Calgary. Reproduced with permission.

Currently, the City of Calgary governs and controls construction site sediment management practices through a process of erosion and sediment control (ESC) plan submission by project owners or proponents and approval by the water resources branch of the City of Calgary. This approval is granted as part the Drainage Bylaw (City of Calgary, 2017) and

Section 7 of the Alberta Environmental Protection and Enhancement Act, which outlines the regulatory authority of the City of Calgary to not permit the discharge of a substance that will impair the quality of stormwater (Province of Alberta, 1993). Approval is based on an equation that estimates annual soil loss of a site with exposed soil, by inputting site-specific and constant factors into the Revised Universal Soil Loss Equation (RUSLE). This calculation is performed by the applicant and submitted to the City of Calgary for review and approval before the applicant can start any soil disturbing activities (City of Calgary, 2011). RUSLE and the associated calculation is used in a somewhat similar permitting process by the United States Environmental Protection Agency (United States Environmental Protection Agency, 2012). The original RUSLE formula and process have been adapted for Application in Canada (FAC) by including winter erosion conditions, a rainfall erosivity isoerodent map for all Canadian provinces, seasonally variable soil erodibility, and an irregular slope calculation (Wall et al., 2002).

This adapted version of the equation is called RUSLEFAC and is published by Agriculture and Agri-Food Canada (Wall et al., 2002). The RUSLEFAC publication outlines the relationship between rainfall volume, intensity, and duration and its erosive power (R-value) to the rate of sediment loss from a specific slope. R-values are a measure of the energy of rainfall and can be reported in either imperial or metric units. For the purposes of the study all R-values will be reported in metric units as  $\text{Mj} \cdot \text{mm} / \text{ha} \cdot \text{hr} \cdot \text{yr}$  (Foster, McCool, Renard, & Moldenhauer, 1981). For readability and conciseness, R-value units will not be noted. In an ESC plan, all slopes for a parcel of exposed land are reviewed for compliance with City of Calgary requirements. The R-value isoerodent maps used in the RUSLEFAC handbook for the prairie

region were taken from Stolte and Wigam (1988) and updated with data through 1990 (Stolte and Owoputi, 1994). The authors of RUSLEFAC note that the accuracy of the calculation or data used for a specific location is unknown and the isoerodent R-value maps should only be used as an estimate for geographically specific locations where more accurate data does not exist. Finally, Given the reliance upon RUSLEFAC in managing urban and rural soil and water resources, its accuracy is critical. Of concern, then, is the issue of whether changes in rainfall volume, duration, and intensity that are suspected to have occurred in the past 20 years are accounted for in the latest version based on pre-1990 data.

RUSLEFAC (2001) is by no means the most up-to-date or technologically advanced method of determining annual soil loss from a site. Table 1 describes the various models available for calculating annual soil loss from a site. Although there are more efficient and up-to-date models available, RUSLEFAC is the only model that has direct applicability in Canada. This study therefore uses this 2001 model with Canadian data to allow for direct comparison of results calculated in similar ways. The use of an older model (RUSLEFAC, 2001) with Canadian data allows for direct comparison of historic results calculated in similar ways.

Table 1.

Various models available for calculating soil loss from a site, availability of a digital interface and the applicability in Canada.

Model Name	Author	Year	Major findings	Computerized Model	Available Canada Wide
Universal Soil Loss Equation	Wischmeier, and Smith	1965 and 1978	Mathematical equation to estimate the amount of soil erosion from an agricultural field and the impacts alternative crop management has on soil loss. Updates in 1978 added new isoerodent maps, and extended land uses	No	No
Revised Universal Soil Loss Equation	Renard et al.	1997	Updates to the USLE rainfall calculation formula using a maximum intensity of rainfall First computerized model based on DOS programming	Yes	No
Revised Universal Soil Loss Equation For Application in Canada	Wall et al.	2001	Rainfall calculations based on original USLE formula. Updated isoerodent maps for Canada	No	Yes
Water Erosion Prediction Project	Lafren et al.	1991	Windows-based Erosion calculator grounded on USLE formulas. Updated as recently as 2009	Yes	No
Revised Universal Soil Loss Equation Version 2	USDA	2013	Introduced the new concept of erosivity density and allowed for the calculation of erosivity across a specific period	Yes	No

The City of Calgary has invested substantial effort in understanding how climate change may impact both less frequent catastrophic weather events in the form of floods, fires, and damaging winds, as well as frequent less consequential impacts such as heatwaves, multi-year droughts, or increased rainfall intensity in the City (City of Calgary, 2018b & Calgary, 2018c Figure 2).

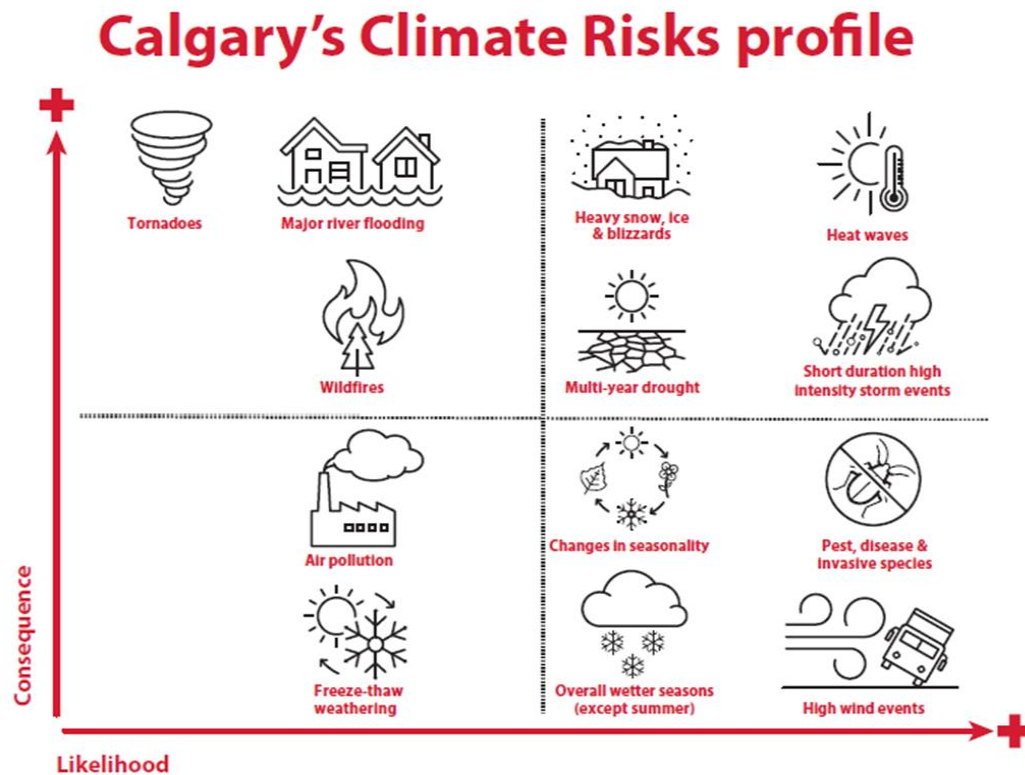


Figure 2. Calgary's Risk Profile. Reprinted from Calgary's Climate Program, In [www.Calgary.ca](http://www.Calgary.ca), n.d., Retrieved August 24, 2018, from <http://www.calgary.ca/UEP>. Copyright 2018 by The City of Calgary. Reproduced with permission.

Currently, the City of Calgary is focusing on eight main climate resiliency programs: flood plan, water efficiency plan, waste diversion and reduction, urban biodiversity, increasing urban tree canopy cover, increasing naturalized park area, water saving tips for citizens, green municipal buildings, and wastewater treatment plant retrofits and upgrades (City of Calgary 2018a). These programs focus on the direct impacts of climate change on citizens and the City of Calgary's operations. There appears to be less understanding of how climate change may indirectly impact current policies and operations. Indirect impacts of climate change on the City of Calgary might include increased grass maintenance, pest control, and irrigation costs for

playing fields and maintained parks. Infestations or disease or fungus such as Dutch Elm Disease may also spread easier through drought-stressed trees owned and maintained by the City of Calgary (Solla & Gil, 2005).

Forsee and Ahmad (2011) showed that climate change impacted rainfall in Nevada would potentially exceed the design requirements of storm infrastructure in the Las Vegas Valley. The City of Calgary (2018b) *Climate Resiliency Strategy* has identified increased storm intensity duration and frequency due to climate change as part of future planning, and The City of Calgary is making efforts to ensure new infrastructure can meet future climate needs and old infrastructure is upgraded. It is possible that climate change and increased rainfall intensity duration and frequency could, in the future, and may have already directly impacted the amount of sediment being eroded from sites with exposed soils within the City of Calgary. Indirectly, if this eroded soil is deposited in stormwater management ponds or underground pipes, the efficiency of these of these systems may be reduced (City of Calgary, 2011). Though the cost of removing sediment from stormwater management ponds and underground pipes is not documented publicly, one study does give insight into the difficulties associated with this type of maintenance. Hoyt and Brown (2005) note eight common problems associated with the long-term maintenance and operation of stormwater management ponds, as well as important considerations for the pre-construction, construction, and post-construction phases. Ongoing maintenance falls under the post-construction phase, and one of the primary considerations is the prevention of excess debris and sediment from entering the pond. Prevention could include upstream protections such as low impact stormwater design, street sweeping, and erosion control or prevention.

**Research Objective**

The proposed research has three objectives. First, the current R-value for the City of Calgary will be calculated with the most recent data available. Second, the expected changes in R-value will be calculated based on a City of Calgary climate change model. Finally, current and future changes to R-values will be assessed and sediment loading to the City of Calgary storm infrastructure impacts assessed and quantified.

To accomplish these objectives, the research questions to be addressed are: What is the R-value specifically for the City of Calgary, and how has it changed over the past 20 years? Will it change in the future as a consequence of climate change, and if so, what will the consequences be to stormwater infrastructure management in the City of Calgary?

This research will also estimate how climate change might affect the R-value in the future. The research will also compare three values: 1) the City of Calgary construction site sediment losses for 2017 calculated using the current R-value, 2) sediment losses for 2017 calculated using the updated R-value, and 3) future sediment loss estimates calculated using R-values adjusted for climate change. The scope of the research question will be limited to the last 29 years of rainfall data to update the R-values, and the future 100 years to estimate climate change impacts. The study area is confined to the City of Calgary corporate limits due to the volume of data and calculations required, and limited time available.

**Estimating sediment run-off**

Average annual soil loss in tonnes per hectare per year (A) can be modeled if local rainfall erosivity (R), soil erodibility (K), slope length (LS), and protection (P) and cover (C)

factors are known for a particular site. These factors are represented in equation 1 (Wall et al., 2002).

$$A=R * K * LS * C * P.....(1)$$

This model is known as the Revised Universal Soil Loss Equation or RUSLE and has been updated for more specified use in the prairie provinces of Canada (Wall et al., 2002). Although the RUSLE model was initially developed to help farmers conserve topsoil on agricultural land, it has been accepted by both the USEPA and the City of Calgary for modeling and predicting the effectiveness of site management practices used to control erosion of sediment from a slope (City of Calgary, 2011; United States Environmental Protection Agency, 2012 ).

Generally, in the City of Calgary, rainfall (R-value), and soil erodibility (K-value) are accepted as constant, and conservative factors are applied (City of Calgary, 2011). The remaining factors; Slope, erosion protection, and sediment protection can vary from site to site and can be easily measured from plans or in the field. The determination of R values currently comes from isoerodent maps which are provided in RUSLEFAC (Wall et al., 2002), while K-values can be determined through soil sampling and comparison to the nomograph provided by RUSLEFAC (Wall et al., 2002). The City of Calgary requires landowners and project proponents to calculate annual estimated soil loss for all construction sites or to provide the City with the information necessary to calculate annual estimated soil loss for any construction activity where topsoil will be removed (City of Calgary, 2011)

**Current R-value**

The current R-value provided by RUSLEFAC was calculated with data up to 1990 (Wall et al., 2002). Additionally, calculations were made for all of Canada, and the accuracy and relevance are unknown for locations as specific as the City of Calgary corporate limits. Wall et al. (2002) note that the isoerodent maps are only meant to provide estimates for regions within Canada and provide three alternatives to calculating more accurate R values. The alternatives used in this study are based on preference provided in the literature (Wall et al., 2002).

**Calculate R-Value using historical measured EI values (Wischmeier & Smith, 1978)**

The most appropriate equation based on available historical data as suggested by Wall, Coote, Pringle, and Shelton (2002) in RUSLEFAC is the method suggested by Wischmeier and Smith (1978). More recent versions of this calculation have been suggested and implemented in the United States; but the calculation used and suggested in the RUSLEFAC handbook was utilized to ensure comparability to R-values provided by the handbook. This method relies on the relationship between a rainstorm's energy and intensity, and calculation is based on the impact energy of a raindrop on exposed soil. Wischmeier and Smith (1978) show that an accurate estimation of a local R-value must include the cumulative effects of moderate storms as well as the occasional severe storm. The R-value for a specific location is calculated by summing all erosive rainfall for a year and averaging it over 22 years to account for the cyclical nature of rain events. Individual storms are identified by a period of 6 hours where less than 12.7 mm of rain falls unless at least 6 mm of rain falls in a 15-minute period. This classification system was used to limit the amount of time and energy spent on calculating data for over 4000 sites and 22 years of data. The energy per unit of rainfall within a storm can be represented by equation 2.

Originally, Wischmeier and Smith (1978) provided a calculation for US customary units or a conversion that used rain in centimetres. To better align with standard international units Foster et al. (1981) provided a direct conversion from the original US customary unit to standard international units. This converted equation is noted below.

$$e=0.119 + 0.0873 \log_{10} i \dots\dots\dots(2)$$

where e (MJ/ha/mm) is the energy of rainfall at each increment, and i is the rainfall intensity in mm/hr.

The erosive energy (E) for a storm is the energy per unit multiplied by the volume of rainfall in that unit. Each increment is then summed to produce erosive energy for a storm. This relationship is represented by equation 3.

$$E=\sum_k^p e_k \Delta V_k \dots\dots\dots(3)$$

where e<sub>k</sub> is the energy per unit of rainfall calculated in equation 2, p is the number of units or segments, and V<sub>k</sub> is the volume of rain collected in each segment.

R-value for an individual storm is calculated as the product of total storm energy (E) calculated in equation 3 and the maximum 30-minute intensity (I) and is represented in equation 4.

$$R=EI \dots\dots\dots(4)$$

The R-value for each calculated storm in a year is averaged to provide an annual average erosive rainfall. Finally, this method requires that the R-value for each year be averaged for the minimum 22-year monitoring period specified.

This equation required large volumes of very accurate rainfall data and a minimum of 30-minute rainfall intensity data. Though the volume of data and computational work was high, this

was still the preferred method of calculation suggested by a paper comparing methods (M. A. Nearing, Yin, Borrelli, & Polyakov, 2017). This and other methods described do not account for winter conditions (M. A. Nearing et al., 2017). Though these calculations could be completed, they were outside the time constraints of this project. As such, only data from April 15<sup>th</sup> to November 15<sup>th</sup> was be included. This range is based on the Erosion and Sediment Control Guidelines published by the City of Calgary (2011).

**Calculate based on the relationship between R and the one-in-two-year, 6-hour storm, (Ateshian & ASCE, 1974)**

This method relied on the empirical relationship between R values and the one-in-two-year 6-hour storm. In an attempt to simplify the original equation outlined above, Ateshian (1974) proposed a relationship that built on the finding of Wischmeier & Smith (1978). Two thousand locations were analyzed and combined into two separate calculations describing the relationship between the R-value and the 2-year, 6-hour rainfall depth. One described rainfall east of the Rockies (Type I) and the second described rainfall west of the Rockies (Type II). The equation which represents the individual storm index for rainfall east of the Rockies is represented below in equation 5, where p equals the 2-year, 6-hour rainfall depth in inches.

$$R=16.55 p^{2.2} \dots\dots\dots(5)$$

This method builds on the original work of Wischmeier & Smith (1978) but appears to overestimate the R-values in some situations (Kachanoski, 1985; Wall, Coote, Pringle, & Shelton, 2002). This method does not take into account winter conditions, but other similar equations do (Hayhoe, Pelletier, & Coote, 1995). This calculation is widely used in some

provincial and federal guidelines as an alternative in the absence of the required rainfall data required by the Wischmeier & Smith (1978) equation.

**Calculate R-value using the relationship between R and annual or monthly rainfall amounts (Renard and Freimund, 1994)**

The current state of the art in climate change modelling only allows daily rainfall volumes to be predicted. This limited precision means that hourly or 15-minute data required to run the calculation noted above cannot be reliably or accurately provided. Limited data precision is a common problem noted by Nearing (2001), in a similar study for the United States. A method was developed to predict R-values based on the relationship between monthly and annual rainfall volumes, both of which are available in the datasets provided. This method relies on the statistical relationship between the modified Fournier coefficient (F; Fournier, 1960; Arndoldus, 1980), total annual or monthly rainfall amounts and the R-value. The authors evaluated erosivity of rainfall at 155 locations in the United States. They propose an equation relating the Fournier coefficient to monthly rainfall volumes. This relation is represented in equation 6, where  $p_i$  is monthly rainfall in mm and P is the annual precipitation.

$$F = (\sum_{i=1}^{12} p_i^2) / P \dots\dots\dots(6)$$

The relationship between the Fournier coefficient and the R-value as calculated by the authors is represented in equation 7 for monthly rainfall volumes less than 50mm and in equation 8 for monthly rainfall volumes higher than 50mm.

$$R\text{-value} = 0.7397F^{1.847} \dots\dots\dots(7)$$

$$R\text{-value} = 95.77 - 6.081 + 0.04770F^2 \dots\dots\dots(8)$$

This method is based on statistical relationships between a comparatively smaller sample size than Wischmeier and Smith (1978). Though the statistical relationships were significant ( $r^2=0.81$  for equation 7 and  $r^2=0.75$  for equation 8), there may be some doubt about the accuracy of this method compared to others. Alternatively, this method provides a relatively simple relationship between easily collectible monthly or annual rainfall data and the R-value. This method was utilized in a study assessing potential changes in erosivity due to climate change in the 21<sup>st</sup> century (M. Nearing, 2001). It is also worth noting that the author determined there to be no advantage to using either annual or monthly rainfall data to calculate R values in this way. A separate study comparing this method to historical data collected across the United States noted that for the majority of the continental United States this method was suitable, but for some areas West of the Rockies and mountainous or near mountainous areas this method did not always correlate well (Biasutti & Seager, 2015).

### **Current guidelines and policies**

Currently, The USEPA uses RUSLE (United States Environmental Protection Agency, 2012), and The City of Calgary uses RUSLEFAC (City of Calgary, 2011) to predict and estimate construction site sediment release rates. The US EPA allows individual States to set specific standards of runoff for all construction activities over 1 acre (0.40 hectares), which is regulated by a permit issued by state or federal agencies. Most state requirements are related to the management of specific volumes of stormwater on site and not sediment release rates. The City of Calgary has set a limit of 2 tonnes/hectare/year for all slopes with in any site or project where landowners or proponents applying to remove vegetation during construction (City of Calgary, 2011). This requirement is regulated through the development permitting process and is

administered directly by the City of Calgary (City of Calgary, 2018a). In Canada, there are no federal level guidelines setting standards for sediment run-off from construction sites, though the Fisheries Act does classify sediment releases to fish-bearing waters as harmful to fish.

### **Climate change impacts on R-value**

Researchers in many regions of the world are exploring the relationships between climate change and rainfall erosivity. A review of the literature reveals an increase in rainfall erosivity of between 9% and 52%, and most models identify that geography and local climatic conditions play a large part in the variability (Panagos et al., 2017; Mondal, Khare & Kundu, 2016, Hoomehr, Schwartz, & Yoder, 2016).

#### **Europe**

Panagos et al. (2017) used Gaussian Process Regression to estimate the effect changing climate and vegetation cover would have on soil erosion at 1,541 locations across Europe. The authors used WROLDCLIM data and Rainfall Erosivity Data at European Scale (REDES). Estimates for three climate change scenarios through 2050 were compared to current estimates from 2010. Increases in erosive rainfall ranged from 16% for the least aggressive scenario to 27% for the most aggressive. On average, the authors estimated an 18% increase in rainfall erosivity over the next 40 years. The authors also noted a wide variation of estimated change in erosive rainfall across Europe from a decrease of 200 MJ\*mm/ha\*h\*yr to an increase of over 1050 MJ\*mm/ha\*h\*yr. The authors speculate that it is related to the current erosive rainfall in the areas.

**India**

Mondal, Khare, and Kundu (2016) used a Statistical DownScaling Model to project Global Circulation Climate modelled rainfall into monthly precipitation averages. These averages were compared to 9 existing rainfall stations to calibrate the predictive model. The authors predicted a gradual increase in rainfall, which was contrary to historical rainfall data which had shown a decline. Four different climate models were tested based on the aggressiveness of climate change. The authors predicted a change in rainfall erosivity 24% to 32% in the first ten years, 18% to 75% in the 2050's and 20% to 202% in the 2080s. The authors note that the wide variation was due to the different climate change scenarios; the authors also suggest that changes in rainfall erosivity are susceptible to changes in rainfall. In their case, 30-minute interval data was not available and was a limitation to the study.

**USA**

Hoomehr, Schwartz, and Yoder (2016) investigated how three future climate change scenarios would affect erosive rainfall from 2010-2099. The authors used Global Circulation Climate Models and Statistical DownScaling to estimate both monthly rainfall and daily weather series data for the study site (Appalachian region). This data were calibrated and compared to existing historical data for the area from 1959 to 2000. Future rainfall was modelled from 2010 to 2099. The authors predict a change in erosive rainfall at 7% for the least aggressive model, 28% for the moderate model and 49% for the most aggressive climate change model.

**Representative concentration pathways (RCP)**

Representative concentration pathways (RCP) are a combination of plausible assumptions about future carbon emissions based on socio-economic development, technological

advancement, policy development, changes in energy intensity and source, economic growth, and population changes from current numbers (IPCC, 2013). There are four recognized representative concentration pathways that have been named based on the target radiative forcing in the year 2100. In order of least reduction in global climate temperature to greatest, these pathways are RCP 8.5, RCP 6.0, RCP 4.5, and RCP 2.6. Radiative forcing is essentially the difference between energy entering the earth's atmosphere and the energy leaving, and is affected by changes in greenhouse gas concentrations in the atmosphere. A positive forcing value would relate to increases in global temperatures also known as the greenhouse effect. A decrease in values would result in cooling temperatures, and stabilization would result in negligible temperature changes (IPCC, 2013).

Representative concentration pathways serve as an input into climate models, and resultant climate predictions are influenced by changes in greenhouse gas emissions predicted by changes in concentration pathways. The use of multiple concentration pathways in studies allows for a useful comparison of how anthropological changes might impact climate study outcomes for both long-term and near-term modelling experiments (van Vurren, 2011)

#### **Business-as-usual (RCP 8.5)**

The first concentration pathway, RCP 8.5, is known as business-as-usual. This pathway is based on the assumptions that global populations remain high, population growth remains high, income growth remains slow. There is also the assumption that moderate technological improvements and energy intensity improvements, combined with an absence of climate change policy, lead to an increase in energy demand and greenhouse gas emissions (Riahi et al., 2011). This representative concentration pathway corresponds to continuing down the current path of

greenhouse gas emissions, or business-as-usual. This emissions pathway also represents the concentration pathway with the highest greenhouse gas emissions (IPCC, 2013).

#### **Climate stabilization by 2100 (RCP 4.5)**

The second concentration pathway, RCP 4.5, is known as the stabilized radiative forcing pathway. This emissions scenario assumes that by the year 2100 radiative forcing has stabilized. Similar, to RCP 8.5, this pathway assumes no diversion from current population growth or income growth. The assumption is that these global greenhouse gas pricing policies drive conversions to electric power and technological innovations in carbon capture and storage as well as bioenergy production. Finally, RCP 4.5 assumes an increase in forested landcover as part of a global emissions mitigation strategy (Thompson, 2011). RCP 4.5 is the lower of the two intermediate emissions scenarios. The specific use of RECP 4.5 and RCP 8.5 are discussed further as part of the Downscaled Climate Change Rainfall Predictions section.

#### **Methodology**

Methodologies for the study were based on comparable studies with similar intent (Hoomehr, Schwartz, & Yoder, 2016, Nearing, 2001). Calculations and formulas were taken directly from peer-reviewed scientific papers and are referenced as such in the thesis, while the data used was taken from City of Calgary data sources. To provide the most accurate assessments, two separate data sets and calculations, a historical dataset and a future predictions dataset, were used for the study due to the difference in detail and precision in each for available historical and climate change data.

**Historical dataset**

The dataset was created by accessing rainfall data collected at the City of Calgary precipitation monitoring station for Huntington Hills. This station was chosen for its proximity to the Environment and Climate Change Canada rainfall monitoring station located at the Calgary International Airport. Although the Environment Canada site at the Calgary International Airport is the official weather station for the area, the data is not recorded in 15-min increments or less past 2008. City of Calgary data from Huntington is recorded in smaller time increments of 5-minutes and for more recent period (current to 2017) making it more applicable to the study's precision and timescale requirements while still allowing for historical comparability.

This monitoring station uses a weighing bucket type rain gauge that is accurate to 0.2mm of rainfall and reports volumes every five minutes. The dataset consisted of annual five-minute rainfall volumes from April to November for the years 1988 to 2017 inclusive. Some of the annual data sets provided data for the months before April and after November. Data outside of the April through November window were removed to ensure year-to-year comparability and applicability to calculation requirements. Standard monitoring, maintenance, quality assurance, and quality control methods are implemented at the City of Calgary rainfall monitoring stations.

**Downscaled climate change rainfall predictions**

Downscaled climate change rainfall predictions used by the City of Calgary for climate change adaptation, flood mitigation, and infrastructure planning were used. The dataset was produced by Risk Science International (RSI) under contract to the City of Calgary. This climate change data is based on the Canadian Regional Climate Model (CANRCM4) and was produced from a single run of a single model from a single pathway. Though there are indeed more robust

climate change datasets available, this dataset has been specified for the 25-km-by-25-km grid point most closely associated to the Calgary International Airport. The use of the CANRCM4 data provides relevancy for the local climate change expected for a single grid point that is most useful for City of Calgary administration. This dataset was selected over other data sets for its relevance to other City of Calgary climate change projects and studies. Using a single climate change data set ensures that the outcomes of this study are both comparable and relevant to City of Calgary administration.

Two RCPs were used in the creation of the data set, RCP 4.5 and 8.5. Emissions scenarios 4.5 and 8.5 were chosen as they represent both the business-as-usual scenario and the climate stabilization driven by global climate policy scenario. The use of two scenarios allows the city administration to prepare for the business as usual scenario while comparing to a scenario of a stabilized climate.

A dataset and calculation for future predictions based on climate change required the use of downscaled climate change rainfall predictions for two climate change scenarios, low emission (RCP 4.5) and high emission, or business as usual (RCP 8.5). These predictions are not yet able to provide detail finer than daily rainfall volumes, necessitating the use of a separate formula based on less detailed data.

The data provided was based on a single model run for both the low emission climate change scenario (RCP4.5) and the business as usual high emission scenario (RCP8.5), of the CanRCM4 climate change model which was bias corrected to fit historical data from 1981-2010. The data provided was estimated from daily precipitation volumes from 2018-2100. Precipitation

for winter months was not included to ensure alignment with the historical data and requirements of the calculation.

### **Data Analysis**

#### **Calculate R-Value using historical measured EI values (Wischmeier & Smith, 1978)**

Following the methods suggested by Wischmeier and Smith (1978), original datasets for all years were first classified into erosive storms based on the following criteria: 1) A storm where more than 12.7 mm of rainfall occurred in a 6-hour period, or 2) 6 mm of rain falls in a 15-minute period. Each storm was assigned a storm event number unique to that year. Moreover, data that fell outside of the classification criteria were excluded. Any data that fell outside of the April 15th to November 15th time window was then excluded. The remaining rainfall data was considered ready for the Wischmeier and Smith calculation and accumulated by year. For each individual storm within a year, equation 2 was first applied to determine the 5-minute incremental energy. Equation 3 was applied by first multiplying the incremental energies by the corresponding incremental volumes and summing the outcomes for the all increments for the total duration of the erosive storm. The product of equation 3 represented the total storm energy. Equation 4 was applied by multiplying the total energy of a storm by the storm's maximum 30-minute intensity. The product of equation 4 represents the storm's total erosive energy or storm R-value. The annual erosive energy was acquired by summing the individual storm erosive energy for the entire year. The annual 22-year mean R-Value was produced by averaging the previous 22 annual R values.

### **Sources of uncertainty and levels confidence**

There are three major sources of possible uncertainty related to the update of the current R-value with historical data. First, there is a concern that the data collect may be inaccurate or incomplete. To mitigate this concern, only quality managed and controlled data was used. The data set is QA/QC by City of Calgary staff at the time of collection. Additionally, once the data sets were received, they were reviewed and data outside of the required parameters set out by the study was removed.

The second concern is the accuracy of the calculations conducted for this study. To mitigate this concern, two random sets of annual data, one from the southern USA and one from Calgary were blindly analyzed by two researchers using the same methodology. Both researchers calculated R-values were within 1% of each other confirming the accuracy of the calculations.

Third there is the issue of human error introduced when running large volumes of complex data. This concern was mitigated by the use and development of excel spread sheets that utilize macros to automatically calculate R-values on large standardized data sets. Ten percent of these macros were cross referenced with hand calculations to confirm accuracy.

The final source of uncertainty comes from the variation of rainfall across large geographic areas. Ideally, a study would characterize different rainfall regimes within the study area and run separate calculations for each. The work involved with a study of this type exceeds the timelines available. This is the major source of uncertainty and can only be mitigated by expanding the scope of this study from one station to multiple stations across the city.

Certainty in the data, calculation and methods are high, but certainty outside of the geographic area of the Huntington Hills rainfall station is unknown. For the specific location there is a conservative estimated certainty of plus or minus 50 R-value units.

**Calculate R-value using downscaled climate change data based on the relationship between R and annual or monthly rainfall amounts (Renard and Freimund, 1994)**

Daily downscaled rainfall volumes for 2018-2100 were summed into monthly and annual rainfall volumes. Daily values are too precise for the required formula to utilize; monthly and annual rainfall volumes are required. Following the methods outlined by Renard and Freimund (1994), equation 6 was applied by first squaring the rainfall volume for each month of data. The outcomes for all months in a year were summed and divided by the annual rainfall volume. Equation 7 or 8 were then applied depending on whether the F value was above or below 50. The outcome of this represents the estimated R-value for the year.

**Results and Discussion**

Results have been separated into two parts based on both the methodology used for each dataset and the type of information being assessed. The first section focuses on the use of historical measured rainfall data to suggest a more up-to-date R-value than that suggested by Wall et al., (2002) in RUSLEFAC, last updated with rainfall data current to 1990. The second section explores how climate change could potentially effect changes in R-values based on future climate change scenarios.

### Current local R-value and its change

Erosivity results calculated from data collected from the City of Calgary rainfall gauge at Huntington Hills (Figure 3) from 1988-2017 showed an increase in the R-value from 300 to 642.

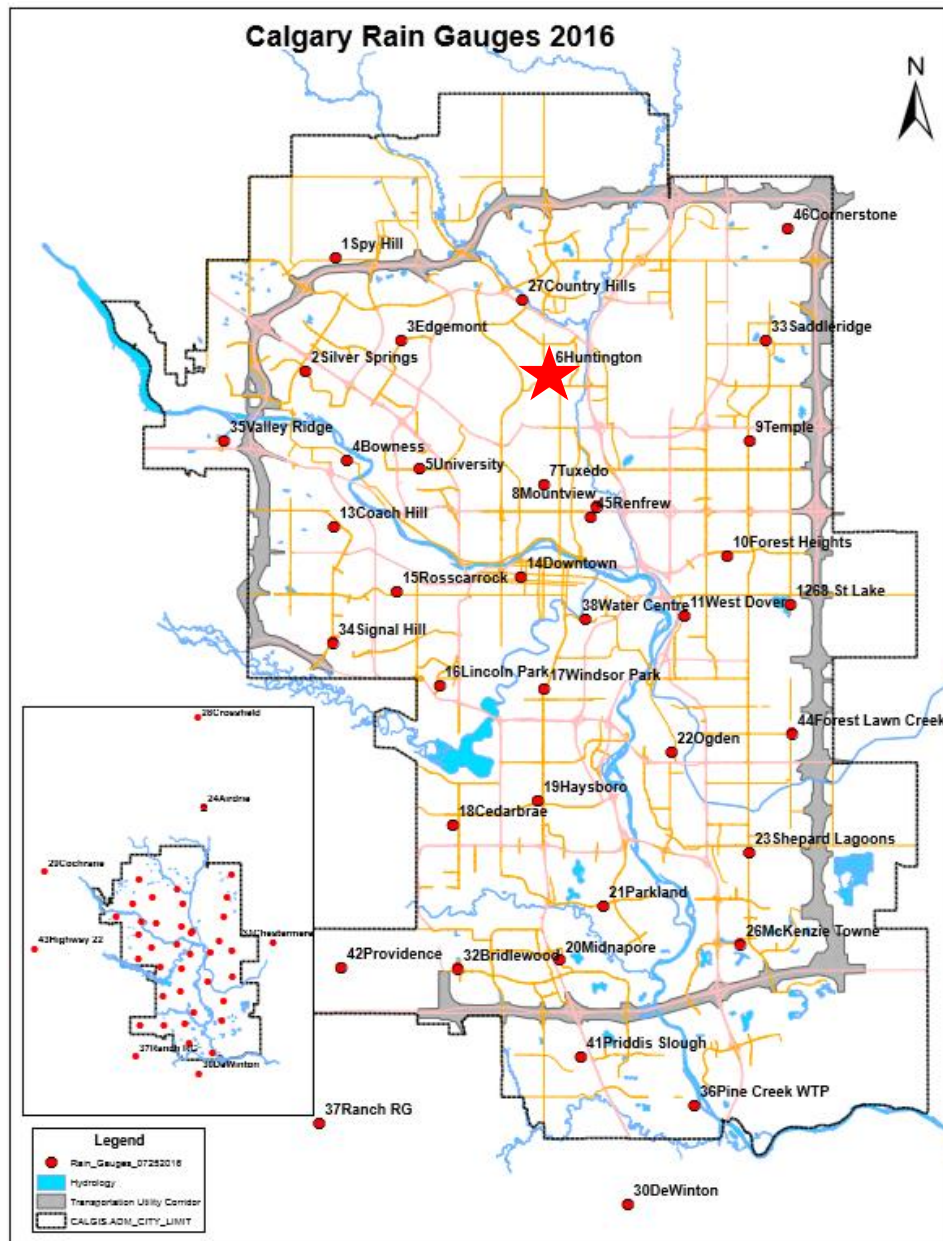


Figure 3. Huntington Hill rain gauge. Calgary, Alberta, Canada. Reprinted from Storm Drainage System FAQ, In [www.Calgary.ca](http://www.Calgary.ca), n.d., Retrieved August 24, 2018, from <http://www.calgary.ca/UEP/Water/Documents/Water-Documents/What-is-a-stormpond-infographic.pdf>. Copyright 2018 by The City of Calgary. Reproduced with permission.

The change in R-value represents an increase of 2.14 times or a change of 114 % from the original value reported by Wall et al. in 2001 with data current to 1990. Additionally, when the mean 22-year rainfall erosivity is calculated with data from 1988 through 2017, there is a generally positive trend with an average increase of 5.7 % per year across the nine years with available data (Figure 4).

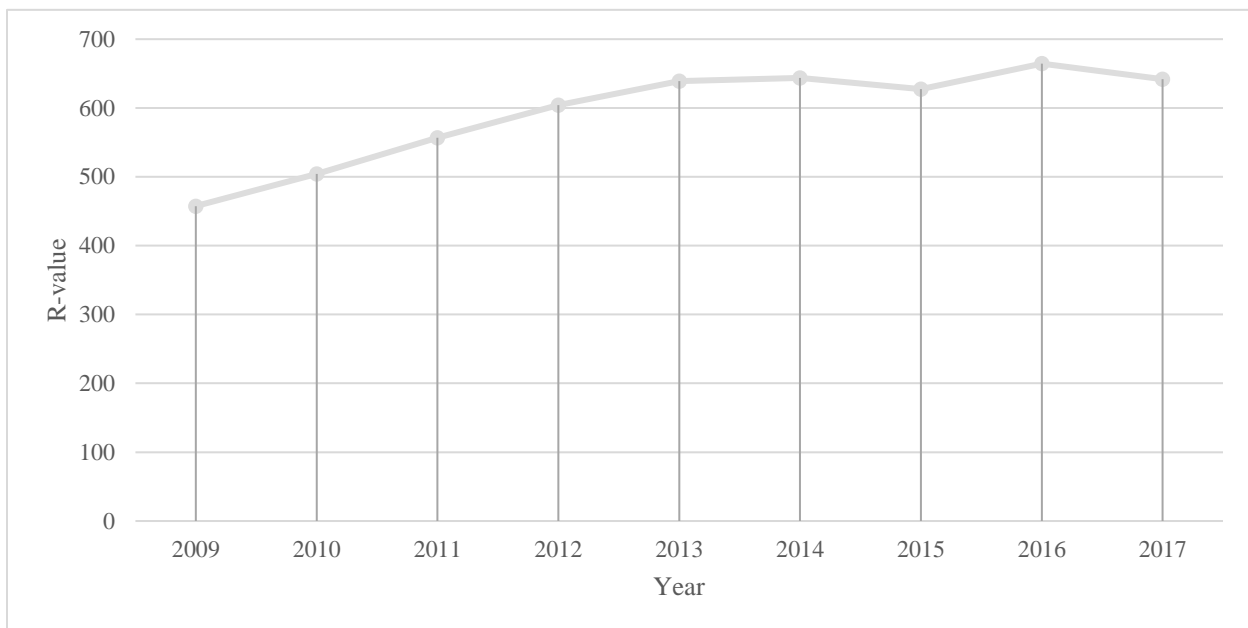
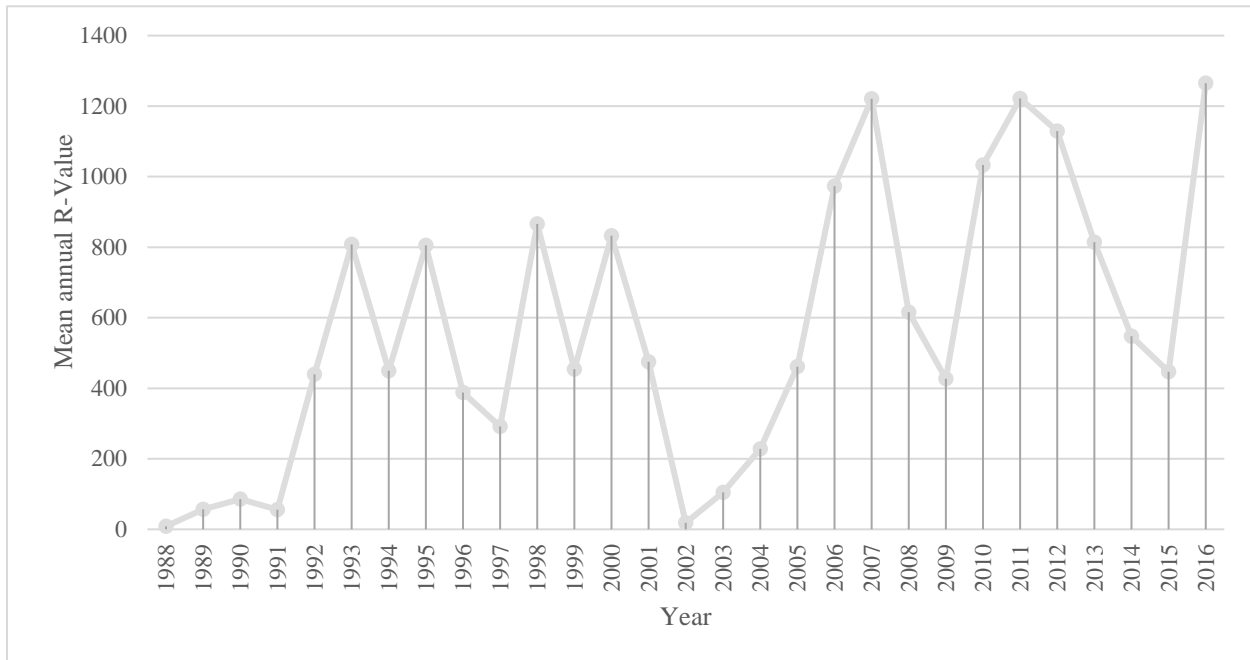


Figure 4. Moving 22-year mean R-value for Huntington Hills Station, City of Calgary

When rainfall erosivity was calculated year to year, without averaging across 22 years, significant fluctuations in annual average R-values were noted between years (Figure 5). The minimum annual rainfall erosivity value calculated was 9 in 1988, and the maximum rainfall erosivity value calculated was 1264 in 2016 representing a difference of 1256 between the minimum and maximum annual R-value. The most significant change from year to year occurred between 1991 and 1992. The R value calculated for the year 1991 was 56. The following year

the R-value was calculated as 449, this represents the most significant year-to-year change in R-value of 393 between those years. The year-over-year changes range from an increase of 22.3% from 2009 to 2010 to a decrease of 3.2% from 2016 to 2017, representing a difference of 19.1%



between the maximum and minimum.

Figure 5. Mean annual R-value for Huntington Hills Station, City of Calgary

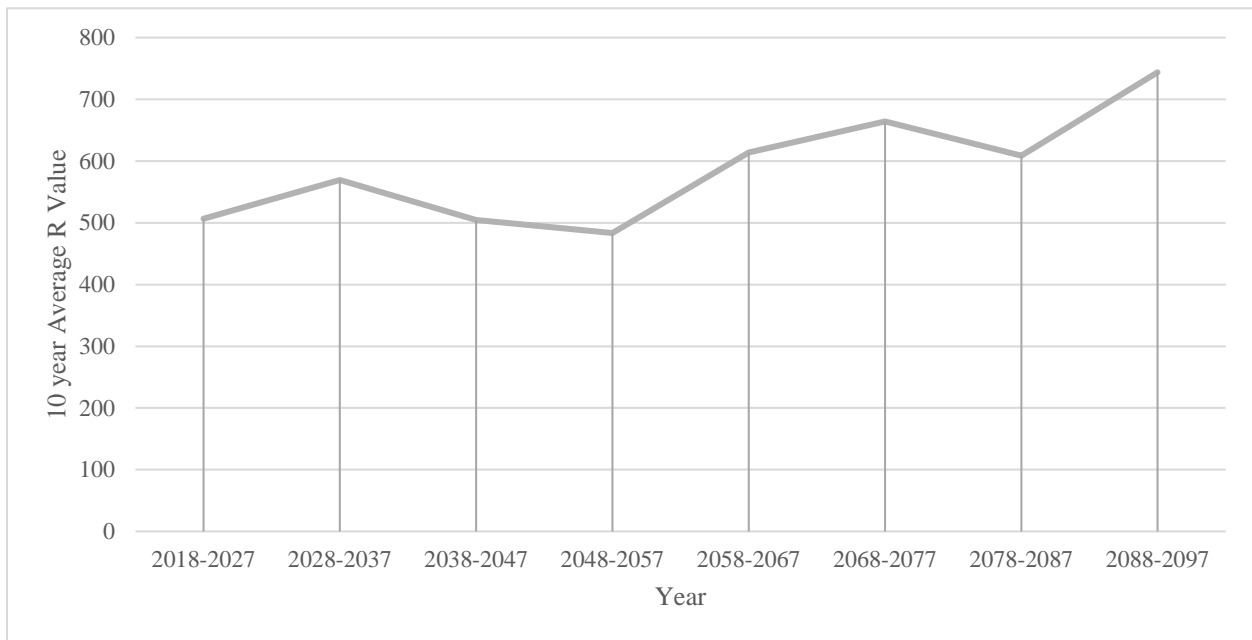
**Impact on R-values based on climate change predictions**

R-values estimated from climate change predictions fall into two categories based on the climate change scenario they are predicting. The first is the business as usual (RCP 8.5), the second is the low carbon emission future (RCP 4.5).

**Business as usual (RCP 8.5)**

In the business-as-usual scenario, RCP 8.5, the estimated percent change in R-values from 2018 to 2100 was 31.2 percent. When the estimated annual R-value was averaged over 10 years, the mean 10-year R-value initially decreases through the middle of the century to a low of

483 (Figure 6). Following the mid-century low, the R-value then steadily increases to a high of 744 in the last decade of the century. This represents a difference in R-value of 261 between minimum and maximum. The minimum mean percent change in the ten years average R-value is -11.3% from the second and third decade. The maximum change was 27.0% between the fourth and fifth decade; this represents a difference of 38.3%. The annual R-value for each individual year shows large fluctuations from year to year. The mean annual percent change in R-Value varied from a minimum of -81.2% in 2098 to a maximum of 513.9% in 2068; this represents a



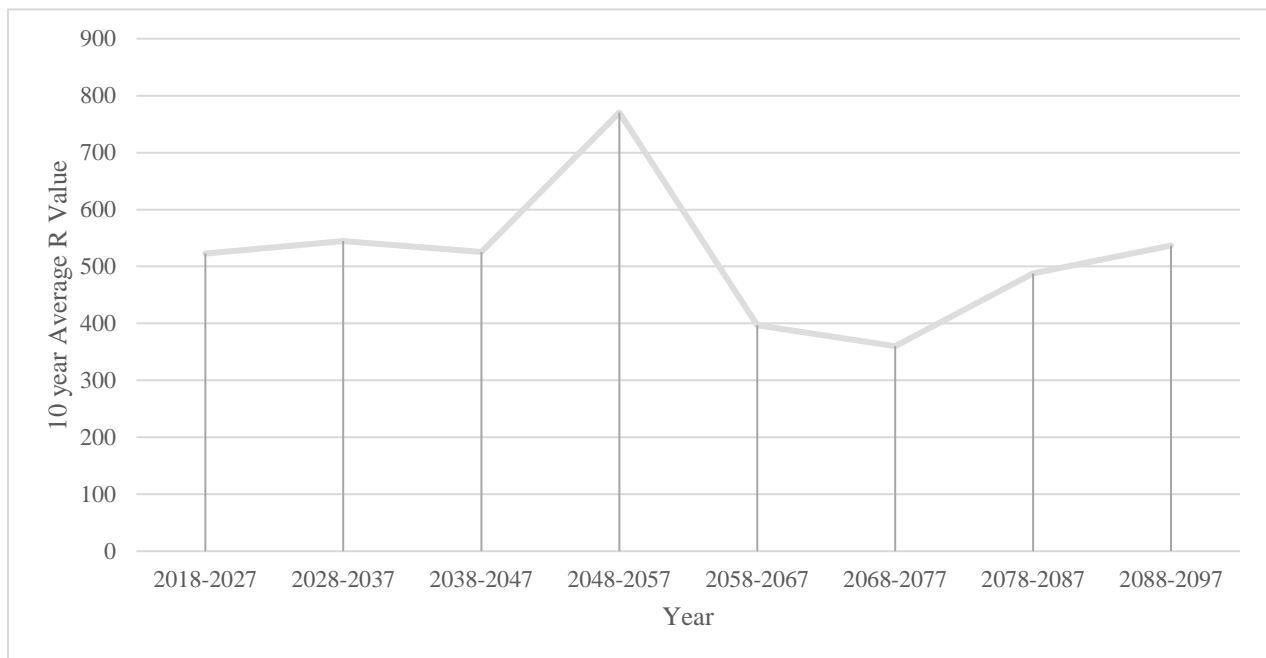
difference in mean annual percent change in R-value of 595.1% between the minimum and maximum.

Figure 6. Mean 10-year R-value for Huntington Hills Station, City of Calgary using the business as usual climate change model (RCP 8.5)

**Climate stabilization by 2100 (RCP 4.5)**

In the climate stabilization scenario, RCP 8.5, the estimated percent change in R-values from 2018 to 2100 was 27.8 percent. When the annual R-value for each year was averaged over

10-years; the mean 10-year R-value initially remains stable before sharply increasing for the period between 2047 and 2058 to a maximum of 770 (Figure 7). Following this spike, there is a sharp decrease through 2077 to a minimum of 360. For the remainder of the century, the R-value steadily increases to 536. This represents a difference in R-value of 410 between minimum and maximum. The minimum mean percent change in the ten years average R-value is -48.5% from the fourth to fifth decade. The maximum change was 46.5% between the third and fourth decade, representing a difference of 95%. The annual R-value for each year shows large fluctuations from year to year. The mean annual percent change in R-Value varied from a minimum of -73.4% in 2029 to a maximum of 265.9% in 2053, which represents a difference in mean annual percent change in R-value of 339.3% between the minimum and maximum.



*Figure 7.* Mean ten-year R-value for Huntington Hills Station, City of Calgary using the low carbon future climate change model (RCP 4.5)

**The Current R-value for the City of Calgary has changed significantly from the accepted value**

The R-value calculated with up-to-date historical data from 1988-2017 shows a significant change from the generally accepted value reported by both Wall et al. (2002) and Kachanoski R.G. (1985). Though these articles are relatively dated and use data that is 28 years old, they are still cited and referenced regularly, presumably since there has been no subsequent research to update the R-values in Canada. The current study used one rainfall monitoring station and temporally used 29 years of data which is substantially smaller than the sample size used by Wall et al. (2002). However, it is essential that local municipalities use available local data since climate change impacts are regarded as occurring in local site-specific ways (Lemmen et al. 2008). That said, larger-scale spatial and temporal datasets and analyses, perhaps province-wide, would give context to the relevance of these findings specific to City of Calgary data of the past three decades.

Importantly, the calculated variance of the R-values estimated for Calgary using the isoerodent maps and associated R-value estimates in literature may no longer be applicable for the City of Calgary. It is also possible that if the isoerodent maps are no longer applicable for Calgary, they may no longer apply to large parts of Alberta, the prairie region, or Canada. The RUSLEFAC handbook (2001) is the most recent and up-to-date publication that suggests R-values not only for Calgary but all of Canada. The fact that this handbook is published by the Canadian Federal Government only lends further credibility. It is likely that the use of the RUSLEFAC handbook is ubiquitous across Canada and possibly other countries.

The implications of this widespread utilization depend on how wide-ranging the “inaccuracies” and the recent impacts of climate change are, in Calgary, Alberta and Canada. Locally, an inaccurate R-value could mean that average annual soil loss from slopes in surrounding agricultural areas could be underestimated, impacting soil conservation, fertilizer use, and surface and groundwater quality. Within City limits, the difference in R-values could mean that average annual soil loss from slopes within soil disturbing sites have been underestimated. Depending on how widely these average annual soil loss estimates are used within the City of Calgary for planning and maintenance, there could also be implications to cost estimates and budgets as well as regional, provincial and federal approvals or commitments. Finally, there is also a potential that water quality of the watershed for local and downstream users could be impacted.

Future studies should focus on a cautious stepwise expansion and assessment of this study, to determine the applicability of the original RUSLEFAC handbook. Such studies of this nature should expand the focus and scope provided initially here temporally and geographically. Geographic expansion first to other rain gauges within the City of Calgary, then to other cities in Alberta and prairie provinces, will allow a better understanding of how changes in R-values may be impacted regionally if at all. The temporal expansion will help provide a better understanding of how R-values have changed over time. This temporal expansion may allow for a better understanding of how climate change may have affected R-values in the past. A stepwise assessment is advised to avoid bias and allow for the confirming or refuting of the original RUSLEFAC findings at each step. Starting at a small geographic scale such as other municipalities with 15-min rainfall volume data for the last 22-years, and expanding to a larger

scale, such as municipalities in other prairie provinces, allows for the validation or invalidation of this study's findings at each step, preventing the excessive expenditure of time and funds on large-scale projects that may not be required.

First, the R-value for all of Calgary's rain gauges as a whole geographically should be investigated using all available rainfall gauges and rainfall data. There is a possibility that the R-value for the Huntington Hills rainfall monitoring station is not representative of the R-value for Calgary as a whole. It is also possible that due to the varied topography within the City limits of Calgary, different R-values for different areas of the City may exist and may be more appropriate than a single average of all stations. The next steps should be to expand the scope of this study both regionally to Central and Southern Alberta to determine if R-values still align with the accepted literature on a broader scale. If locally and provincially calculated R-values do not align with accepted literature, a nationwide revision of the RUSLEFAC handbook may then be appropriate.

It would also be useful to conduct a comparative study using the same City of Calgary data with different R-value calculations from both the Universal Soil Loss Equation and the more recent RUSLE2 or other more current methods and formulae, to determine if there is a significant difference in calculated R-values. Though the formula used in this study was based on the formula used in the original RUSLEFAC to ensure comparability, it by no means represents the current state of the art in the calculation of rainfall erosivity such as the digitized models used by the United States Department of Agriculture and United States Environmental Protection Agency (Lafren et al., 1991; USDA, 2013). A comparison study of RUSLEFAC (2001) with

WEPP (2009) and RUSLE2 (2013) may refute or corroborate the reliability of the methodology used both here and in existing literature.

Finally, based on the findings of this study, the City of Calgary should endeavor to update the rolling 22-year average R-value annually for the rainfall gauge used in this study and any others utilized in future studies, since the research shows that there is a variation in real City of Calgary data from literature expectations. Annually updating the R-value will provide City administration with a better understanding of the possible differences in estimated sediment yield to rivers and infrastructure. Though it is not suggested that this R-value is immediately implemented and enforced, city administration should track the implications of updated R-value on future approvals. Continual update and tracking will help in planning and risk assessment and will prevent future shock should the findings be validated and implemented. This represents a cost-effective and efficient way to keep abreast of and capture possible increasing climate change impacts on stormwater management and infrastructure in the City of Calgary, rather than relying on decadal or longer updates.

Annual R values in Calgary are heavily influenced by severe, intense short-duration storms. Calculations in this study show that annual R-values, and subsequently average R-values at the Huntington Hills rainfall monitoring station, are often heavily influenced by a small number of rainstorms. In years with more than five erosive rainfall events, the most erosive storm contributed an average of 43% to the total R-value. The second most erosive storm contributed 19%. Though there is a possibility these highly erosive rainstorms may occur seasonally, both findings are limited by the small scope of the study and the fact that it was not the specific objective of the study. This finding is nonetheless interesting as it aligns with the

author's anecdotal observations. For Calgary, the finding of seasonally highly erosive rain storms provides further evidence that rainfall in the region can be volatile and presents its own set of planning and prediction problems. Evidence of volatile rainfall is consistent with the predicted increasing extremes under global climate change (IPCC, 2013; Lemmen, Warren, Lacroix, & Bush, 2008 and Warren & Lemmen, 2014). Rainfall volume is only one factor in calculating R-values, so a wet year may not necessarily mean a highly erosive year. Volume intensity and duration must all be factored to determine annual erosivity. No evidence of these specific findings was available in scientific literature for the local area.

There are a number of consequences to this finding. First the averaging of 22 years of climate data may limit the effects of rainfall extremes on both the high and low side, but this may not be the best option for areas where annual R-values are heavily impacted by short duration high-intensity rainfall or where annual R-values are disproportionately impacted by a small number of storms. There is a possibility that by averaging 22 years of annual erosive rainfall, the potential to predict and limit the impacts of the most damaging and erosive storms and erosive years is excessively limited. The use of 22-year averages provides a good guideline, but may not be representative of actual erosive rainfall in conditions influenced by high-intensity short duration storms. This finding also advocates for caution on the part of the City of Calgary in the use of average and 22-year average R-values in the estimation of soil loss from sites with exposed soils.

There is a possibility that this phenomenon could be explored further through the implementation of a weighting system whereby storms or years with higher than usual intensity are given a more significant impact on the average R-value, which would be consistent with the

expected increasing extremes under global climate change. It would also be interesting to study further this phenomenon and why or how it may be occurring. Further understanding of the reasoning behind these preliminary findings could better help in the future planning for not only erosion management and prediction, but possibly other industries like insurance or disaster management (Lemmen, Warren, Lacroix, & Bush, 2008; Warren & Lemmen, 2014).

### **Change in Estimated R-values impacts the estimated annual average soil loss in the City of Calgary**

The R-value published by the City of Calgary is based on the values published by Wall et al. (2002) and varies substantially from those calculated in this study. The linear nature of the relationship between factors that affect average annual soil loss in the RUSLEFAC calculation means that any change in one factor means there will be a direct impact on the total estimated annual average soil loss calculated. Of all the factors in the RUSLEFAC calculation only two, soil erodibility (K-value) and rainfall erosivity (R-values), are considered constant and constrained by site conditions. Provided all conditions on site remain the same and only the R-value is changed, the change in R-value will have a direct and linear impact on the estimated annual average soil loss and annual average site soil loss.

Therefore, a correction factor of 2.14 can be applied to a calculated estimated annual average soil loss in the City of Calgary to determine the potential estimated annual average soil loss with the new R-value. Though these calculations are conducted as part of an approval process, they are limited by the fact that they are theoretical calculations based on information provided by applicants requiring approval prior to the commencement of work. The actual impact of a change in rainfall erosivity on actual annual average site soil loss or actual site

sediment yield depends on site conditions, the installation of sediment management and control practices, and the adherence to approved plans.

More sites than expected will not meet the average annual soil loss approval limit set by the City of Calgary. The number of sites that do not pass under the newly calculated R-value can be calculated based on the City of Calgary limit of no more than 2 tonnes per hectare per year of average annual soil loss from any given slope on a site with exposed soils, and approvals data collected by the City of Calgary. Table 2 shows a comparison of the number of sites that meet the approval requirements based on the current R-value of 300 versus the newly calculated value of 642.

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*

Variable	R-Value	
	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

An increased volume of sediment than previously estimated may have entered the City of Calgary storm infrastructure. Once the R-value correction factor has been applied to all sites approved in 2017, the difference in total estimated mass of sediment approved to enter the City of Calgary storm infrastructure can be calculated. Table 3 outlines the calculated difference in estimated sediment entering the storm system based on the newly calculated R-value of 642.

Table 3

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

Variable	R-value		Difference
	Accepted (300)	Calculated (642)	
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

This will help track the potential impact that the difference in published and calculated R-values might have on approvals. The difference underlines the importance of ensuring that approvals are followed and adhered to on site, limiting the risks of actual sediment runoff from sites.

It will also be advantageous to begin working with stakeholders and applicants to educate them on the risk associated with using the published number, which may no longer be applicable and may not be the most conservative value. Education of this nature will need to be completed by the agency or entity that decides to implement this number. This responsibility would likely fall to the City of Calgary as the study and results are most applicable to the geographic area. The City of Calgary could also lean on the expertise and reach of other agencies or associations that represent watershed stakeholders, for example, the Bow River Basin Council made up of stakeholders and users of the Bow River or the Bow River Working Group. By leveraging the reach and expertise of these groups, the City of Calgary may be able to more efficiently disseminate results and implications of the findings of this study. This education should be the first step in implementing the calculated R-value if it is accepted as factual. Engagement will also be an essential step in ensuring that the impacts of this change are limited. Due to the

substantial difference in accepted and proposed R-values, there is a potential that some protection and prevention measures that have been relied upon in the past may not be adequate under the proposed R-value. Engagement and risk education will also help to gain wider acceptance of the reasoning for changing a number that has been assumed to be constant for nearly 16 years.

### **Climate change is likely to impact future R-values in the City of Calgary**

The R-value in the City of Calgary is expected to increase on average between 28 and 31 percent over the next 82 years, depending on future carbon emissions scenarios. The overall changes in R-value calculated by this study are reasonably similar to the estimated changes calculated by other studies conducted in Europe (Panagos et al., 2017), India (Mondal, Khare, & Kundu, 2016) over similar time frames. Most notably, the future R-values estimated in this research for the City of Calgary reasonably match the future R-values estimated by Hoomer, Schwartz, & Yoder (2016) for the Appalachian region of the United States. Table 4 shows the estimated future changes in R-values between both studies and the percent difference. The low carbon future scenario estimates were nearly identical (0.71 percent lower) while the business as usual scenario showed a substantially lower change (-36.32 percent lower).

Table 4

*Future Changes in R-values estimated by two studies*

Estimated percent change	Hoomer, Schwartz, & Yoder (2016)	Current Study	Percent difference
RCP 4.5	28	27.8	0.71
RCP 8.5	49	31.2	36.32

Generally, the estimated change in R-values over the years covered by this study are lower. It is interesting to note that the business-as-usual (RCP8.5) case is substantially lower for the City of Calgary.

The estimated R-values provided by this study are just that, estimates. Care should be taken in the use and application of the estimated impacted of climate change on future R-values in the City of Calgary as there are still a number of uncertainties. Although the climate change models used here have been accepted and utilized in other climate change studies, some uncertainty is introduced the further rainfall estimate data is downscaled. Additionally, the estimated R-values based on climate change are essentially estimates based on estimated rainfall. This means that any uncertainties or biases introduced by the downscaling of climate change data are combined with the uncertainty and applicability of the R-value estimate calculations to Calgary's local unique climate regime. Though caution is advised in the application of this information due to uncertainty, the data is nonetheless valuable in providing insight into possible future erosive rainfall conditions.

The implication of substantial changes in future erosive rainfall must be carefully considered and monitored. Substantial changes in erosive rainfall could affect soil conservation and erosion in both the rural and urban environments. In rural areas surrounding Calgary, unexpected increases in erosive rainfall could contribute to degradation, loss and subsequent artificial amendment or remediation of soil and soil nutrients. Risks are even higher within the municipal corporate limits of the City of Calgary, where unexpected changes in erosive rainfall could impact the subsoil loss from exposed land. If this soil is intercepted by stormwater retention ponds, there is a possibility that maintenance and sediment removal costs will increase

over time. Eroded soil that is not intercepted by storm ponds will likely be released into the Bow or Elbow River. This sediment could impact the ability of citizens to recreate or enjoy the river. Fine sediments released to the river systems may also impact the ability of fish and other aquatic vertebrates and invertebrates to reproduce.

Going forward it would be useful to create a national level estimate of future changes in erosive rainfall based on various climate change scenarios. The primary responsibility in coordinating a national strategy will require Environment and Climate Change Canada to drive a national level assessment but will require collaboration and cooperation with Agriculture and Agri-food Canada, who published the initial version of RUSLEFAC and can provide expertise in soil erosion sciences. National level erosion estimation has been conducted in Europe where detailed rainfall monitoring is readily available (Panagos, 2017). A similar project, though ambitious, would provide a starting point for residents and businesses to begin planning and implementing adaptations and resiliency plans to mitigate the impacts of changes in erosive rainfall across rural and urban areas of Canada. A national strategy is a good starting point, but as was illustrated in this study, unique climate regimes may mean local impacts could vary significantly from national or regional estimates. Municipalities, both urban and rural, that are concerned about the implications of changes in erosive rainfall should endeavour to create local estimates to better understand local impacts. Finally, The City of Calgary should investigate the possibility of a more appropriate, more accurate way of predicting R-values based on daily monthly and annual rainfall volumes for Calgary climate region.

**The Modified Fournier Index may not be appropriate for use in Calgary's climatic regime**

Previous literature notes that this index applies to the continental United States. When the R-values calculated with the Wischmeier and Smith (1978) formula were compared to those calculated using the Modified Fournier Index, there was only a 21% correlation. Though this correlation does not prove or disprove the validity of the Modified Fournier Index for local conditions, it does warrant further investigations.

A surficial assessment of the two formulas shows a possibility that the difference in calculated values is a product of the rainfall inputs. The Modified Fournier Index relies on monthly and annual rainfall volumes, whereas the Wischmeier and Smith formula includes the use of maximum 30-minute intensity. Though a difference is expected between the two formulas, the substantial difference may be due to the lack of intensity in the Modified Fournier Index, coupled with the finding that annual rainfall erosivity is heavily influenced by short duration high-intensity storms. The Modified Fournier Index was developed as a means of estimating R-values in the absence of readily available 15-minute rainfall data.

Though the Modified Fournier Index was the most appropriate formula for estimating R-values based on the available data, it does suggest that climate change estimates in this study may be inaccurate. This finding also suggests there may be inaccuracy involved in the calculation of other similar studies investigating the impact climate change may have on erosive rainfall on a regional or local scale.

Further study into the applicability of the Modified Fournier Index at a local and regional scale is warranted. It is possible that the Modified Fournier Index may not be accurate at a local or regional scale, it may still be accurate when used at a larger scale. If further investigation

shows that the Modified Fournier Index is not appropriate for use locally, regionally, or nationally, there is potential value in investigating the ability of statistical regression analysis to create a local variant of the Modified Fournier Index that may be more applicable. This study would likely involve the use of a number of rainfall monitoring stations with short duration monitoring records for at least 22 years. R values calculated using the Wischmeier and Smith formula could be compared with daily monthly and annual rainfall volumes for the same station. Best fit analysis may provide a more appropriate formula.

**There are potentially more appropriate methods for estimating R-values with daily, monthly, and annual rainfall volumes in Calgary's climatic regime**

Based on the findings of Biasutti and Seager (2015), more appropriate and accurate R-values estimates could be obtained for some locations in the United States by applying regression analysis to known daily and monthly rainfall volumes, and R-values calculated using the Wischmeier and Smith formulas. They found that generally in the continental United States the Best Fit was provided by a linear regression model.

Following these findings, a similar preliminary assessment was conducted for the City of Calgary using known daily rainfall volumes and daily R-values calculated using the Wischmeier and Smith formula. Due to the scope of work required and time limitations only the last five years of data were used and no rainfall was excluded from the data set. Daily rainfall volumes and calculated R-values were compared using linear regression, polynomial regression, and power regression (Figure 5). Table 5 compares the  $r^2$  values for the different regressions performed on the data set.

Table 5

*Comparison of  $r^2$  for 3 different regression analyses of 5 years of rainfall and R-value data*

Regression-type	Formula	R2
Linear	$y=0.0954x + 3.0226$	0.73
Exponential	$y=0.9214x^{0.6436}$	0.93
Polynomial	$y=-0.0001x^2 + 0.1639x + 1.9277$	0.84

The preliminary investigation of a locally appropriate formula seems promising based on the  $r^2$  values achieved by all regression analysis conducted on the most recent five years of data available. It should be noted that because the data was not organized or categorized based on volumes, there is a substantial bias to low volume storms. Figure 8 shows a comparison of regression curves, formulas, and R-values. The lack of high volume rainfall data and the bias to low volume data means that the formulas provided are still very preliminary.

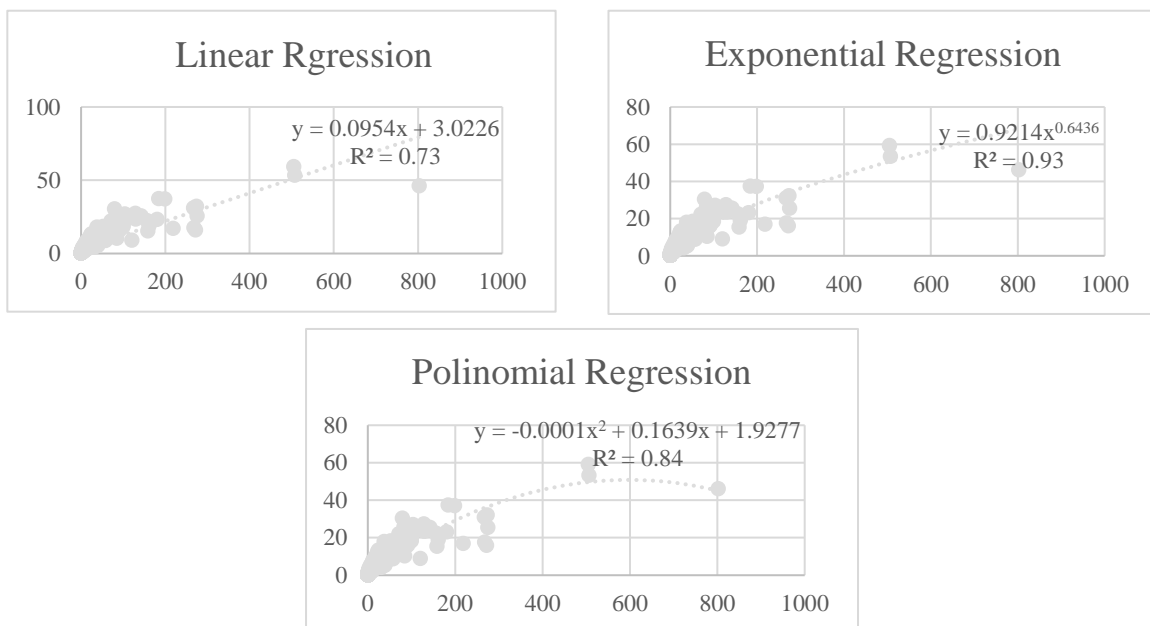


Figure 8. Regression analysis of the most recent five years of rainfall data for Huntington Hills Station Calgary Alberta, Canada

It appears based on the preliminary investigation, that there is a possibility that a more appropriate and accurate formula may be possible for the local climatic regime present in the City of Calgary, though further investigation will be required to ensure that the most appropriate formula is found. Future studies should focus on using more data points from more stations across the City of Calgary. Additionally, to account for and limit the bias of low volume rainfalls, future studies should endeavour to categorize and separate formulas based on different rainfall volumes. A first attempt could exclude rainfall that is outside of the 12.7mm of rainfall in 6 hours and include all rainfall greater than 6mm in 15 min depending on the data available. A second attempt could include the categorize rainfall greater than or less than 50mm per day. There is a potential that this categorization could make the formula more accurate at higher volumes that cause more erosion.

### **Conclusions**

Based on calculations using precise data from 1988 to 2017 from the Huntington Hills rainfall monitoring station in Calgary, Alberta, Canada, erosive rainfall has increased from 300 to 642 which is 2.14 times greater than the value reported by Wall et.al (2002) and utilized by the City of Calgary for approval purposes (City of Calgary 2011). The magnitude of change in other communities across Calgary is uncertain though it is likely to have also increased. To ensure that these impacts can be tracked and monitored, it is imperative that the City of Calgary administration continues to update 22-year mean R-values for the City on an annual basis. It will also be advantageous to expand on this study by including more rainfall monitoring stations. In addition, administration should immediately begin consulting with the larger development

community on how this change will impact both ESC approvals and the potential cost increase of soil disturbing development within the City of Calgary.

Further, estimated R-values are expected to increase by 28% (low carbon future) or 31% (business as usual), which is equal to or less than the estimated increases for the Appalachian region of the United States reported by Hooper, Schwartz and Yoder (2016), which were 28% and 49%, respectively. This information should be used carefully as the applicability of formulas to local conditions and uncertainties introduced through downscaling and estimations mean the actual changes in R-values could be greater or less than those reported. The findings of this study will nonetheless provide a stepping stone to further understanding of the role climate change will play in erosive rainfall locally, regionally, and nationally.

The change in the current R-value for the City of Calgary is likely to increase the estimated sediment loads from construction sites to the storm system by approximately 2.14 times, or between 1876 tonnes with full implementation of site sediment and erosion control measures in compliance with approvals and 34856 tonnes with no implementation of site sediment and erosion control measures in compliance with approvals. This vast difference in average annual site soil loss highlights the reliance on site level controls and the onsite compliance with approvals based on theoretical calculations. Because this change represents a substantial change from what stakeholders currently utilize, care must be taken in implementing the change as the increased R-value will require increased spending by stakeholders to ensure they can meet approval requirements. The certainty of the change in R-value is very high for the Huntington Hills community, but the magnitude of change for other communities and the City of Calgary as a whole is less certain. The potential for increased sediment discharges, pond cleaning

costs, and development costs warrants a careful but expedited expansion of this study to ensure the certainty of the magnitude of R-value change for the City of Calgary as a whole.

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Appendix A  
*R-values calculated with historical data  
from 1988 to 2017, Huntington Hills  
Station, Calgary Alberta, Canada*

	<u>R-value</u>
1988	8.69
1989	56.83
1990	86.06
1991	55.57
1992	439.80
1993	807.76
1994	449.17
1995	805.18
1996	387.39
1997	291.49
1998	865.78
1999	454.38
2000	832.84
2001	474.64
2002	18.79
2003	104.97
2004	228.43
2005	461.54
2006	973.42
2007	1220.63
2008	615.26
2009	426.97
2010	1032.63
2011	1221.53
2012	1129.00
2013	814.08
2014	547.35
2015	446.51
2016	1264.91
2017	<u>303.47</u>

Appendix B

*Average 22-year R-value calculated with historical data from 1988 to 2017, Huntington Hills Station, Calgary Alberta, Canada*

	Average 22 year R value	Percent change
2009	457.53	
2010	504.07	10.17
2011	557.01	10.50
2012	604.42	8.51
2013	638.89	5.70
2014	643.78	0.77
2015	627.36	-2.55
2016	664.44	5.91
2017	641.64	-3.43
average	610.20	4.45

Appendix C

R-values calculated with climate change data from 2018 to 2100, Calgary Alberta, Canada

Year	Month	RCP-4.5					RCP-8.5				
		Rainfall		F Index		R factor	Rainfall		F Index		R factor
		Monthly	Annual	Monthly	Annual		Monthly	Annual	Monthly	Annual	
2018	1	4.09		0.04			13.27		0.41		
	2	1.55		0.01			10.28		0.25		
	3	6.12		0.10			31.29		2.29		
	4	14.07		0.53			29.15		1.99		
	5	131.97		46.79			35.90		3.01		
	6	27.57		2.04			63.46		9.41		
	7	49.18		6.50			159.71		59.59		
	8	60.29		9.76			52.60		6.46		
	9	63.06		10.68			6.98		0.11		
	10	5.65		0.09			15.85		0.59		
	11	6.22		0.10			3.36		0.03		
	12	2.45	372.23	0.02	76.67	370.08	6.19	428.05	0.09	84.22	428.03
2019	1	3.36		0.03			8.06		0.11		
	2	21.90		1.44			0.93		0.00		
	3	1.56		0.01			12.57		0.28		
	4	49.27		7.27			53.94		5.09		
	5	30.59		2.80			85.23		12.71		
	6	32.63		3.19			65.36		7.48		
	7	80.19		19.25			143.58		36.07		
	8	37.66		4.25			72.56		9.21		
	9	21.72		1.41			85.30		12.73		
	10	3.31		0.03			6.30		0.07		
	11	46.57		6.49			11.10		0.22		
	12	5.29	334.05	0.08	46.25	879.97	26.55	571.49	1.23	85.21	435.99
2020	1	6.34		0.09			1.20		0.00		
	2	6.34		0.09			34.41		1.72		
	3	0.00		0.00			13.42		0.26		
	4	33.80		2.69			12.27		0.22		
	5	73.62		12.78			77.45		8.69		
	6	86.39		17.60			230.35		76.88		
	7	71.57		12.08			66.30		6.37		
	8	70.84		11.83			65.49		6.21		
	9	54.53		7.01			150.70		32.90		
	10	7.99		0.15			19.04		0.53		
	11	4.00		0.04			5.51		0.04		
	12	8.71	424.13	0.18	64.55	288.43	14.09	690.23	0.29	134.10	947.51
2021	1	27.54		2.46			11.49		0.23		
	2	5.00		0.08			2.86		0.01		
	3	16.27		0.86			6.13		0.07		
	4	13.97		0.63			73.61		9.54		
	5	29.61		2.84			85.86		12.97		
	6	63.57		13.11			110.94		21.66		
	7	46.85		7.12			169.44		50.53		
	8	35.75		4.14			33.47		1.97		
	9	10.87		0.38			15.93		0.45		
	10	43.90		6.25			24.19		1.03		
	11	2.96		0.03			14.50		0.37		
	12	12.01	308.29	0.47	38.38	623.58	19.82	568.23	0.69	99.52	562.09
2022	1	15.56		0.58			1.00		0.00		
	2	11.77		0.33			1.17		0.00		
	3	24.37		1.41			11.42		0.39		
	4	37.93		3.42			18.25		1.01		
	5	30.52		2.22			97.12		28.53		
	6	146.11		50.80			40.16		4.88		
	7	78.55		14.68			68.84		14.33		
	8	26.15		1.63			24.33		1.79		
	9	6.85		0.11			56.85		9.77		

	10	15.44		0.57			3.99		0.05		
	11	8.85		0.19			1.63		0.01		
	12	18.17	420.27	0.79	76.72	370.42	5.91	330.66	0.11	60.87	266.42
2023	1	2.95		0.02			0.91		0.00		
	2	0.85		0.00			3.71		0.04		
	3	28.83		2.00			23.09		1.72		
	4	32.81		2.59			14.25		0.66		
	5	39.14		3.69			22.90		1.69		
	6	45.27		4.93			49.69		7.97		
	7	162.56		63.64			66.59		14.31		
	8	48.82		5.74			22.41		1.62		
	9	36.00		3.12			35.98		4.18		
	10	3.78		0.03			44.93		6.52		
	11	5.22		0.07			10.94		0.39		
	12	9.04	415.27	0.20	86.04	442.77	14.45	309.85	0.67	39.77	665.85
2024	1	11.91		0.48			4.66		0.06		
	2	11.01		0.41			10.16		0.27		
	3	22.21		1.66			2.50		0.02		
	4	20.48		1.41			21.02		1.14		
	5	23.02		1.78			50.86		6.67		
	6	68.97		16.01			93.14		22.36		
	7	49.51		8.25			50.58		6.59		
	8	22.90		1.77			43.35		4.84		
	9	12.50		0.53			39.01		3.92		
	10	27.26		2.50			52.12		7.00		
	11	9.73		0.32			13.53		0.47		
	12	17.68	297.16	1.05	36.16	558.47	7.07	387.99	0.13	53.46	226.02
2025	1	1.61		0.01			0.98		0.00		
	2	1.08		0.01			3.69		0.04		
	3	2.27		0.02			11.49		0.36		
	4	18.39		1.50			4.05		0.04		
	5	55.83		13.78			64.08		11.21		
	6	22.20		2.18			90.54		22.38		
	7	60.15		16.00			105.18		30.21		
	8	14.63		0.95			48.32		6.38		
	9	5.77		0.15			15.82		0.68		
	10	20.33		1.83			12.52		0.43		
	11	7.75		0.27			5.86		0.09		
	12	16.11	226.12	1.15	37.84	607.36	3.68	366.22	0.04	71.87	336.08
2026	1	20.73		0.83			12.79		0.29		
	2	13.18		0.34			5.18		0.05		
	3	20.36		0.80			24.43		1.07		
	4	26.08		1.32			24.09		1.04		
	5	72.06		10.04			17.68		0.56		
	6	141.09		38.49			160.46		46.18		
	7	139.56		37.66			130.55		30.57		
	8	31.95		1.97			39.51		2.80		
	9	24.35		1.15			52.80		5.00		
	10	10.36		0.21			35.02		2.20		
	11	1.61		0.01			40.37		2.92		
	12	15.91	517.25	0.49	93.29	504.79	14.63	557.51	0.38	93.07	502.88
2027	1	2.02		0.01			18.02		0.46		
	2	10.16		0.17			5.05		0.04		
	3	46.66		3.50			26.64		1.00		
	4	53.14		4.54			116.17		19.07		
	5	113.89		20.87			183.52		47.59		
	6	162.46		42.46			105.73		15.80		
	7	115.61		21.50			86.68		10.62		
	8	65.07		6.81			106.76		16.11		
	9	28.22		1.28			33.09		1.55		
	10	11.31		0.21			6.06		0.05		
	11	6.41		0.07			4.95		0.03		

2028	12	6.61	621.56	0.07	101.49	580.99	15.04	707.72	0.32	112.63	694.77
	1	15.69		0.34			0.46		0.00		
	2	1.01		0.00			13.83		0.63		
	3	5.33		0.04			20.57		1.40		
	4	96.89		13.10			2.79		0.03		
	5	52.98		3.92			23.07		1.76		
	6	143.63		28.79			67.48		15.03		
	7	263.76		97.10			39.02		5.02		
	8	49.41		3.41			43.20		6.16		
	9	29.59		1.22			36.02		4.28		
	10	33.51		1.57			21.56		1.53		
	2029	11	17.30		0.42			23.39		1.81	
12		7.32	716.43	0.07	149.99	1162.85	11.63	303.01	0.45	38.09	614.83
1		5.59		0.08			9.41		0.19		
2		4.53		0.05			35.96		2.73		
3		13.29		0.44			6.41		0.09		
4		19.76		0.98			14.02		0.42		
5		59.90		8.97			82.27		14.31		
6		104.14		27.12			58.57		7.26		
7		85.79		18.41			103.99		22.87		
8		65.33		10.68			41.62		3.66		
9		8.85		0.20			93.16		18.35		
10		8.29		0.17			5.63		0.07		
2030	11	13.27		0.44			11.44		0.28		
	12	11.08	399.83	0.31	67.84	309.24	10.40	472.89	0.23	70.45	326.41
	1	13.75		0.51			5.22		0.12		
	2	11.76		0.37			0.00		0.00		
	3	8.16		0.18			1.91		0.02		
	4	51.01		6.96			38.30		6.26		
	5	60.67		9.84			30.08		3.86		
	6	50.32		6.77			52.65		11.83		
	7	52.49		7.36			42.12		7.58		
	8	41.66		4.64			32.96		4.64		
	9	21.88		1.28			11.14		0.53		
	10	20.92		1.17			0.93		0.00		
2031	11	15.08		0.61			5.62		0.13		
	12	26.36	374.06	1.86	41.54	721.71	13.32	234.23	0.76	35.73	546.37
	1	9.62		0.24			10.15		0.15		
	2	7.89		0.16			13.20		0.26		
	3	9.30		0.22			40.81		2.50		
	4	22.57		1.31			49.76		3.71		
	5	68.20		11.97			134.96		27.32		
	6	79.58		16.29			175.14		46.01		
	7	97.33		24.37			73.46		8.09		
	8	22.98		1.36			66.47		6.63		
	9	30.21		2.35			86.24		11.16		
	10	21.61		1.20			2.02		0.01		
2032	11	12.56		0.41			11.93		0.21		
	12	6.81	388.65	0.12	60.00	261.41	2.54	666.68	0.01	106.07	626.32
	1	12.42		0.33			13.64		0.47		
	2	18.31		0.73			14.61		0.54		
	3	13.85		0.42			6.49		0.11		
	4	27.15		1.60			7.87		0.16		
	5	25.44		1.40			65.23		10.86		
	6	163.68		58.08			131.26		43.96		
	7	61.72		8.26			44.94		5.15		
	8	48.05		5.00			48.02		5.88		
	9	61.71		8.25			45.08		5.18		
	10	10.80		0.25			4.32		0.05		
2033	11	7.78		0.13			8.26		0.17		
	12	10.40	461.31	0.23	84.69	431.82	2.21	391.92	0.01	72.56	340.83
	1	4.72		0.06			3.14		0.01		

	2	0.00		0.00				14.23		0.25		
	3	25.79		1.89				16.65		0.35		
	4	22.99		1.50				16.40		0.34		
	5	77.76		17.20				18.10		0.41		
	6	81.98		19.12				137.87		23.89		
	7	50.71		7.31				232.28		67.81		
	8	30.48		2.64				189.66		45.21		
	9	27.65		2.17				88.42		9.83		
	10	5.89		0.10				54.54		3.74		
	11	10.33		0.30				11.88		0.18		
	12	13.30	351.59	0.50	52.80	222.69		12.50	795.67	0.20	152.21	1194.83
2034	1	12.71		0.28				21.75		0.80		
	2	4.47		0.03				3.51		0.02		
	3	2.80		0.01				1.22		0.00		
	4	9.75		0.17				42.39		3.05		
	5	102.75		18.35				36.91		2.31		
	6	93.41		15.17				267.55		121.59		
	7	113.88		22.54				66.98		7.62		
	8	130.60		29.65				26.47		1.19		
	9	31.72		1.75				69.71		8.25		
	10	32.19		1.80				10.50		0.19		
	11	26.32		1.20				17.49		0.52		
	12	14.67	575.26	0.37	91.34	487.62		24.23	588.69	1.00	146.55	1114.20
2035	1	6.53		0.07				1.12		0.00		
	2	11.35		0.21				4.31		0.04		
	3	3.33		0.02				17.86		0.67		
	4	51.11		4.26				7.28		0.11		
	5	105.81		18.24				71.77		10.86		
	6	232.93		88.40				120.04		30.39		
	7	62.33		6.33				105.85		23.63		
	8	46.89		3.58				56.58		6.75		
	9	59.71		5.81				32.15		2.18		
	10	0.00		0.00				9.56		0.19		
	11	11.36		0.21				40.73		3.50		
	12	22.43	613.78	0.82	127.94	870.50		6.99	474.25	0.10	78.42	383.06
2036	1	7.19		0.09				6.55		0.09		
	2	14.86		0.38				1.48		0.00		
	3	15.11		0.40				13.88		0.40		
	4	11.58		0.23				31.00		1.99		
	5	175.84		53.60				56.98		6.73		
	6	123.57		26.47				124.16		31.95		
	7	36.67		2.33				84.00		14.63		
	8	124.48		26.87				51.58		5.51		
	9	29.20		1.48				27.66		1.59		
	10	26.30		1.20				54.82		6.23		
	11	5.41		0.05				12.16		0.31		
	12	6.56	576.79	0.07	113.18	700.72		18.21	482.48	0.69	70.11	324.17
2037	1	16.26		0.58				4.48		0.06		
	2	2.37		0.01				5.36		0.08		
	3	36.19		2.88				28.00		2.15		
	4	20.20		0.90				66.13		12.01		
	5	84.05		15.51				60.74		10.13		
	6	68.64		10.35				67.03		12.34		
	7	83.03		15.14				56.77		8.85		
	8	24.46		1.31				49.60		6.76		
	9	81.98		14.76				8.17		0.18		
	10	14.21		0.44				8.03		0.18		
	11	10.75		0.25				4.28		0.05		
	12	13.19	455.34	0.38	62.52	276.15		5.55	364.14	0.08	52.87	223.01
2038	1	2.05		0.01				18.25		0.89		
	2	10.64		0.21				2.32		0.01		
	3	24.38		1.08				16.19		0.70		

	4	28.76		1.50		36.91		3.65			
	5	182.57		60.52		35.79		3.44			
	6	126.40		29.01		95.20		24.30			
	7	54.32		5.36		91.73		22.56			
	8	72.15		9.45		38.88		4.05			
	9	24.26		1.07		8.24		0.18			
	10	7.98		0.12		8.41		0.19			
	11	2.94		0.02		20.50		1.13			
	12	14.31	550.76	0.37	108.70	653.33	0.48	0.00	61.12	267.88	
2039	1	10.42		0.25		6.46		0.14			
	2	8.11		0.15		11.77		0.46			
	3	13.52		0.42		4.01		0.05			
	4	10.46		0.25		9.37		0.29			
	5	132.62		40.51		33.15		3.62			
	6	63.07		9.16		67.11		14.81			
	7	72.79		12.20		46.33		7.06			
	8	46.80		5.04		30.80		3.12			
	9	23.44		1.27		43.63		6.26			
	10	38.76		3.46		30.48		3.06			
	11	5.42		0.07		17.84		1.05			
	12	8.74	434.15	0.18	72.97	343.67	3.06	304.00	0.03	39.94	671.16
2040	1	12.53		0.35		6.48		0.09			
	2	19.67		0.86		13.08		0.37			
	3	10.06		0.23		13.37		0.38			
	4	40.39		3.63		52.78		5.97			
	5	56.81		7.18		44.04		4.16			
	6	106.09		25.05		95.35		19.49			
	7	75.09		12.55		56.72		6.90			
	8	67.62		10.18		11.92		0.30			
	9	32.78		2.39		111.10		26.46			
	10	10.05		0.22		44.79		4.30			
	11	12.27		0.34		7.36		0.12			
	12	5.91	449.27	0.08	63.06	279.37	9.50	466.48	0.19	68.73	315.03
2041	1	26.92		2.07		10.53		0.20			
	2	0.00		0.00		7.49		0.10			
	3	11.36		0.37		36.73		2.46			
	4	22.07		1.39		35.38		2.29			
	5	62.62		11.23		66.91		8.18			
	6	64.90		12.06		119.65		26.16			
	7	64.46		11.89		86.96		13.82			
	8	32.07		2.94		51.83		4.91			
	9	21.67		1.34		86.90		13.80			
	10	35.52		3.61		20.50		0.77			
	11	5.03		0.07		21.10		0.81			
	12	2.74	349.35	0.02	47.00	906.77	3.33	547.30	0.02	73.52	347.50
2042	1	10.54		0.19		8.22		0.09			
	2	5.93		0.06		13.18		0.24			
	3	4.72		0.04		24.78		0.85			
	4	80.49		10.79		128.87		23.04			
	5	179.11		53.46		68.24		6.46			
	6	105.21		18.45		189.00		49.55			
	7	75.64		9.54		89.60		11.14			
	8	59.13		5.83		131.53		24.00			
	9	34.77		2.01		16.35		0.37			
	10	23.78		0.94		3.84		0.02			
	11	8.24		0.11		45.33		2.85			
	12	12.52	600.09	0.26	101.68	582.82	1.96	720.91	0.01	118.62	760.82
2043	1	6.37		0.08		0.00		0.00			
	2	2.23		0.01		4.68		0.04			
	3	7.49		0.11		8.91		0.15			
	4	7.80		0.12		6.53		0.08			
	5	160.86		51.17		80.92		12.19			

	6	101.44		20.35		91.61		15.62			
	7	128.87		32.84		199.86		74.34			
	8	23.44		1.09		40.37		3.03			
	9	22.70		1.02		49.23		4.51			
	10	22.96		1.04		46.26		3.98			
	11	12.76		0.32		2.57		0.01			
2044	12	8.73	505.64	0.15	108.31	649.25	6.34	537.29	0.07	114.03	709.97
	1	6.31		0.09		0.45		0.00			
	2	11.53		0.30		1.89		0.01			
	3	17.59		0.71		26.37		1.04			
	4	33.07		2.50		37.44		2.10			
	5	103.89		24.73		80.69		9.78			
	6	106.29		25.88		151.27		34.36			
	7	59.89		8.22		187.87		53.00			
	8	33.05		2.50		21.94		0.72			
	9	29.11		1.94		113.54		19.36			
	10	9.01		0.19		22.10		0.73			
	11	5.66		0.07		5.13		0.04			
2045	12	21.10	436.48	1.02	68.16	311.30	17.27	665.95	0.45	121.59	794.93
	1	2.90		0.03		1.33		0.00			
	2	2.64		0.03		13.72		0.33			
	3	3.62		0.05		29.20		1.50			
	4	27.47		2.75		54.04		5.15			
	5	22.93		1.91		57.28		5.79			
	6	56.08		11.45		124.45		27.33			
	7	72.59		19.18		107.07		20.23			
	8	27.07		2.67		77.68		10.65			
	9	8.08		0.24		59.53		6.25			
	10	34.19		4.26		20.95		0.77			
	11	13.41		0.65		6.99		0.09			
2046	12	3.77	274.76	0.05	43.25	777.59	14.55	566.79	0.37	78.47	383.38
	1	0.77		0.00		4.27		0.04			
	2	3.37		0.02		18.86		0.80			
	3	32.84		2.05		15.41		0.54			
	4	10.22		0.20		20.34		0.94			
	5	86.59		14.29		51.40		5.98			
	6	83.46		13.27		79.30		14.23			
	7	131.16		32.77		70.10		11.12			
	8	51.03		4.96		105.05		24.97			
	9	76.47		11.14		39.95		3.61			
	10	30.82		1.81		21.57		1.05			
	11	12.03		0.28		2.41		0.01			
2047	12	6.15	524.93	0.07	80.86	401.60	13.31	441.95	0.40	63.69	283.19
	1	21.42		0.87		9.99		0.17			
	2	11.86		0.27		9.52		0.15			
	3	18.45		0.65		13.16		0.29			
	4	44.96		3.84		40.11		2.67			
	5	65.48		8.16		122.11		24.74			
	6	113.27		24.40		110.49		20.25			
	7	104.55		20.79		125.09		25.96			
	8	59.16		6.66		94.34		14.77			
	9	64.19		7.84		54.35		4.90			
	10	8.29		0.13		12.91		0.28			
	11	3.03		0.02		3.17		0.02			
2048	12	11.07	525.72	0.23	73.86	349.90	7.47	602.71	0.09	94.28	513.70
	1	0.75		0.00		2.29		0.01			
	2	4.41		0.05		5.02		0.05			
	3	14.76		0.51		47.29		4.08			
	4	27.22		1.73		14.17		0.37			
	5	28.50		1.89		94.74		16.38			
	6	77.00		13.81		68.05		8.45			
	7	89.47		18.65		97.43		17.33			

	8	76.03		13.47		108.02		21.30			
	9	72.20		12.14		52.11		4.96			
	10	20.40		0.97		31.35		1.79			
	11	10.13		0.24		20.52		0.77			
	12	8.37	429.24	0.16	63.62	282.75	6.85	547.83	0.09	75.57	362.10
2049	1	4.20		0.05			2.07		0.01		
	2	0.52		0.00			1.89		0.01		
	3	19.90		1.05			18.63		0.63		
	4	23.11		1.42			62.44		7.11		
	5	52.33		7.28			34.62		2.19		
	6	90.31		21.69			160.62		47.04		
	7	103.81		28.66			132.59		32.05		
	8	52.17		7.24			81.06		11.98		
	9	16.66		0.74			18.90		0.65		
	10	1.53		0.01			6.21		0.07		
	11	11.42		0.35			21.12		0.81		
	12	0.00	375.95	0.00	68.49	313.44	8.34	548.50	0.13	102.67	592.52
2050	1	26.06		0.91			4.59		0.03		
	2	3.55		0.02			5.26		0.04		
	3	6.30		0.05			31.38		1.56		
	4	80.94		8.74			27.37		1.19		
	5	50.77		3.44			119.12		22.47		
	6	246.97		81.41			194.59		59.96		
	7	79.17		8.37			119.71		22.69		
	8	88.37		10.42			37.71		2.25		
	9	109.58		16.03			71.85		8.17		
	10	38.82		2.01			18.89		0.56		
	11	6.44		0.06			1.06		0.00		
	12	12.23	749.20	0.20	131.66	916.50	0.00	631.52	0.00	118.93	764.41
2051	1	3.25		0.01			5.69		0.07		
	2	10.35		0.09			6.79		0.10		
	3	42.66		1.57			33.60		2.56		
	4	83.32		6.00			68.26		10.56		
	5	110.68		10.59			68.13		10.52		
	6	422.36		154.24			54.37		6.70		
	7	172.15		25.62			100.46		22.87		
	8	179.89		27.98			45.30		4.65		
	9	105.86		9.69			19.52		0.86		
	10	15.59		0.21			24.90		1.40		
	11	5.22		0.02			4.22		0.04		
	12	5.19	1156.52	0.02	236.07	2747.88	10.14	441.38	0.23	60.56	264.65
2052	1	5.86		0.08			1.85		0.01		
	2	39.72		3.84			10.54		0.31		
	3	6.33		0.10			47.82		6.31		
	4	76.48		14.22			13.96		0.54		
	5	16.90		0.69			42.40		4.96		
	6	81.30		16.08			43.34		5.19		
	7	55.92		7.60			65.18		11.73		
	8	66.89		10.88			20.51		1.16		
	9	23.01		1.29			46.44		5.95		
	10	22.76		1.26			8.46		0.20		
	11	6.92		0.12			50.00		6.90		
	12	9.12	411.20	0.20	56.36	241.21	11.68	362.18	0.38	43.64	790.60
2053	1	4.19		0.05			21.53		1.10		
	2	6.05		0.10			7.71		0.14		
	3	24.52		1.58			1.18		0.00		
	4	33.94		3.04			48.06		5.48		
	5	40.49		4.32			73.18		12.71		
	6	53.46		7.53			92.97		20.52		
	7	46.52		5.70			76.31		13.83		
	8	53.59		7.57			33.13		2.61		
	9	72.66		13.92			20.65		1.01		



2059	12	17.17	499.59	0.59	81.85	409.26	18.99	657.37	0.55	111.52	682.91
	1	6.29		0.07			10.93		0.13		
	2	2.01		0.01			3.70		0.02		
	3	6.94		0.09			42.46		2.00		
	4	94.00		16.31			33.34		1.24		
	5	111.91		23.12			61.72		4.23		
	6	61.75		7.04			243.94		66.11		
	7	75.37		10.48			193.50		41.60		
	8	77.25		11.02			219.19		53.38		
	9	68.35		8.62			30.48		1.03		
	10	27.42		1.39			38.56		1.65		
	2060	11	4.22		0.03			9.98		0.11	
12		6.25	541.77	0.07	78.25	381.77	12.32	900.11	0.17	171.66	1495.31
1		4.50		0.04			7.28		0.11		
2		4.63		0.04			13.02		0.35		
3		19.59		0.74			27.47		1.55		
4		64.13		7.94			27.12		1.51		
5		87.54		14.80			28.13		1.62		
6		62.26		7.49			161.75		53.61		
7		104.16		20.96			60.46		7.49		
8		73.36		10.40			73.13		10.96		
9		34.50		2.30			29.58		1.79		
10		27.30		1.44			16.42		0.55		
2061	11	11.20		0.24			36.16		2.68		
	12	24.52	517.68	1.16	67.55	307.35	7.48	488.01	0.11	82.33	413.02
	1	13.66		0.52			10.02		0.13		
	2	1.18		0.00			10.42		0.14		
	3	27.77		2.14			25.81		0.84		
	4	6.10		0.10			6.37		0.05		
	5	53.62		7.97			191.77		46.31		
	6	73.34		14.91			254.78		81.73		
	7	56.07		8.72			73.37		6.78		
	8	35.35		3.46			72.87		6.69		
	9	25.38		1.79			89.98		10.19		
	10	16.92		0.79			48.06		2.91		
2062	11	21.70		1.30			5.52		0.04		
	12	29.67	360.76	2.44	44.14	807.49	5.22	794.19	0.03	155.83	1248.02
	1	6.24		0.10			9.33		0.23		
	2	17.82		0.82			20.81		1.15		
	3	6.73		0.12			13.86		0.51		
	4	52.99		7.25			18.92		0.95		
	5	27.29		1.92			36.56		3.54		
	6	36.01		3.35			84.00		18.69		
	7	101.85		26.80			106.84		30.24		
	8	46.14		5.50			38.19		3.86		
	9	32.34		2.70			9.60		0.24		
	10	30.25		2.36			19.84		1.04		
2063	11	21.44		1.19			13.61		0.49		
	12	8.06	387.15	0.17	52.28	220.05	5.88	377.43	0.09	61.05	267.45
	1	10.51		0.27			32.64		2.01		
	2	5.57		0.08			5.91		0.07		
	3	3.75		0.03			31.92		1.92		
	4	21.41		1.12			62.27		7.31		
	5	33.78		2.79			120.19		27.22		
	6	63.47		9.85			118.88		26.63		
	7	109.30		29.22			66.37		8.30		
	8	38.57		3.64			37.56		2.66		
	9	51.18		6.41			23.09		1.00		
	10	39.23		3.76			3.91		0.03		
2064	11	13.78		0.46			11.50		0.25		
	12	18.27	408.81	0.82	58.46	252.70	16.47	530.71	0.51	77.90	379.15
	1	10.47		0.19			12.75		0.26		

	2	22.99		0.92			32.80		1.70		
	3	44.65		3.46			16.03		0.41		
	4	64.45		7.21			91.38		13.18		
	5	100.81		17.63			115.00		20.88		
	6	110.56		21.21			118.81		22.28		
	7	89.40		13.87			47.53		3.57		
	8	54.27		5.11			50.25		3.99		
	9	51.06		4.52			15.51		0.38		
	10	5.23		0.05			78.56		9.74		
	11	12.68		0.28			33.53		1.77		
	12	9.86	576.44	0.17	74.60	355.15	21.39	633.55	0.72	78.87	386.38
2065	1	16.95		0.61			12.41		0.35		
	2	0.00		0.00			0.00		0.00		
	3	51.87		5.72			60.37		8.31		
	4	59.00		7.40			33.40		2.54		
	5	52.18		5.79			17.90		0.73		
	6	65.14		9.02			137.16		42.92		
	7	69.92		10.39			87.04		17.28		
	8	61.40		8.01			41.97		4.02		
	9	38.76		3.19			10.54		0.25		
	10	29.00		1.79			10.67		0.26		
	11	17.64		0.66			19.71		0.89		
	12	8.54	470.40	0.16	52.74	222.39	7.18	438.34	0.12	77.68	377.49
2066	1	6.07		0.07			10.03		0.31		
	2	0.72		0.00			9.37		0.27		
	3	11.32		0.24			9.90		0.30		
	4	36.90		2.52			34.13		3.56		
	5	191.82		68.15			35.50		3.85		
	6	74.78		10.36			52.55		8.44		
	7	96.83		17.36			67.30		13.84		
	8	47.73		4.22			19.76		1.19		
	9	44.40		3.65			46.86		6.71		
	10	23.98		1.07			14.06		0.60		
	11	3.19		0.02			15.42		0.73		
	12	2.20	539.94	0.01	107.66	642.57	12.48	327.35	0.48	40.26	681.23
2067	1	2.17		0.01			4.53		0.05		
	2	11.57		0.22			19.66		0.99		
	3	19.07		0.61			19.04		0.93		
	4	87.18		12.73			59.88		9.22		
	5	82.79		11.48			19.15		0.94		
	6	129.01		27.87			96.51		23.96		
	7	68.29		7.81			33.84		2.95		
	8	59.38		5.91			38.70		3.85		
	9	47.14		3.72			19.96		1.02		
	10	54.44		4.96			22.04		1.25		
	11	10.05		0.17			14.01		0.50		
	12	26.05	597.14	1.14	76.62	369.74	41.37	388.68	4.40	50.09	209.38
2068	1	4.07		0.03			10.49		0.16		
	2	14.87		0.38			10.02		0.15		
	3	36.89		2.32			20.76		0.63		
	4	14.98		0.38			44.06		2.84		
	5	123.29		25.87			201.83		59.63		
	6	152.48		39.58			242.40		86.02		
	7	98.48		16.51			57.26		4.80		
	8	66.38		7.50			40.45		2.40		
	9	27.49		1.29			30.98		1.40		
	10	13.25		0.30			9.95		0.14		
	11	33.09		1.86			6.69		0.07		
	12	2.18	587.45	0.01	96.02	529.50	8.20	683.09	0.10	158.34	1285.59
2069	1	4.49		0.06			8.07		0.12		
	2	21.36		1.29			20.79		0.82		
	3	1.42		0.01			23.73		1.07		

	4	16.01		0.73			26.72		1.36		
	5	46.59		6.15			81.21		12.53		
	6	95.68		25.93			100.02		19.00		
	7	67.43		12.88			111.67		23.69		
	8	34.28		3.33			64.54		7.91		
	9	30.25		2.59			22.98		1.00		
	10	6.58		0.12			19.17		0.70		
	11	12.94		0.47			13.43		0.34		
	12	16.00	353.03	0.73	54.29	230.26	34.07	526.39	2.20	70.75	328.48
2070	1	10.55		0.24			13.46		0.32		
	2	23.73		1.20			1.51		0.00		
	3	17.66		0.67			2.70		0.01		
	4	87.04		16.20			8.18		0.12		
	5	71.49		10.93			23.92		1.02		
	6	73.20		11.46			70.14		8.80		
	7	71.17		10.83			165.23		48.80		
	8	59.70		7.62			196.66		69.14		
	9	17.63		0.66			4.93		0.04		
	10	4.00		0.03			42.75		3.27		
	11	14.54		0.45			19.99		0.71		
	12	17.00	467.71	0.62	60.91	266.66	9.95	559.42	0.18	132.42	926.11
2071	1	9.94		0.23			6.65		0.05		
	2	5.39		0.07			10.89		0.15		
	3	1.89		0.01			16.39		0.33		
	4	40.90		3.89			87.74		9.51		
	5	115.50		30.98			209.10		53.99		
	6	96.15		21.47			292.64		105.74		
	7	58.89		8.05			64.06		5.07		
	8	73.16		12.43			35.74		1.58		
	9	12.13		0.34			21.89		0.59		
	10	8.07		0.15			28.59		1.01		
	11	1.17		0.00			20.50		0.52		
	12	7.41	430.61	0.13	77.74	378.00	15.70	809.89	0.30	178.83	1615.21
2072	1	2.30		0.01			13.43		0.23		
	2	1.89		0.01			13.56		0.24		
	3	17.75		0.65			13.82		0.25		
	4	19.24		0.76			86.45		9.66		
	5	68.41		9.63			211.12		57.58		
	6	113.40		26.46			121.54		19.08		
	7	86.61		15.43			100.28		12.99		
	8	69.42		9.92			85.88		9.53		
	9	55.74		6.39			39.42		2.01		
	10	21.07		0.91			28.29		1.03		
	11	27.65		1.57			33.87		1.48		
	12	2.59	486.06	0.01	71.75	335.26	26.43	774.09	0.90	114.98	720.29
2073	1	4.91		0.05			7.22		0.11		
	2	6.83		0.10			14.16		0.42		
	3	12.01		0.30			2.69		0.02		
	4	34.81		2.50			8.16		0.14		
	5	75.07		11.61			35.19		2.59		
	6	84.32		14.65			79.99		13.40		
	7	159.33		52.32			120.24		30.27		
	8	46.71		4.50			117.72		29.01		
	9	23.17		1.11			32.07		2.15		
	10	10.50		0.23			16.27		0.55		
	11	11.33		0.26			27.59		1.59		
	12	16.22	485.19	0.54	88.16	460.46	16.34	477.65	0.56	80.81	401.21
2074	1	4.46		0.05			14.55		0.34		
	2	2.98		0.02			6.97		0.08		
	3	17.28		0.81			46.85		3.57		
	4	37.53		3.80			47.34		3.64		
	5	59.03		9.41			65.11		6.89		

	6	90.83		22.28		148.91		36.05			
	7	26.16		1.85		94.08		14.39			
	8	21.78		1.28		63.32		6.52			
	9	46.07		5.73		75.83		9.35			
	10	27.11		1.98		26.76		1.16			
	11	4.58		0.06		14.88		0.36			
	12	32.51	370.32	2.85	50.13	209.57	10.55	615.16	0.18	82.53	414.60
2075	1	12.74		0.33			2.11		0.01		
	2	8.11		0.13			12.43		0.33		
	3	18.74		0.72			15.42		0.51		
	4	13.69		0.38			11.83		0.30		
	5	49.50		5.00			33.37		2.41		
	6	147.97		44.65			132.87		38.18		
	7	94.57		18.24			127.32		35.05		
	8	44.14		3.97			45.81		4.54		
	9	48.27		4.75			25.15		1.37		
	10	17.84		0.65			17.13		0.63		
	11	13.10		0.35			26.76		1.55		
	12	21.70	490.36	0.96	80.13	395.97	12.22	462.42	0.32	85.21	436.04
2076	1	19.42		0.85			11.52		0.27		
	2	5.01		0.06			14.57		0.43		
	3	12.00		0.33			21.60		0.95		
	4	3.31		0.02			28.86		1.70		
	5	74.97		12.69			73.96		11.14		
	6	118.90		31.91			68.05		9.43		
	7	60.81		8.35			93.52		17.81		
	8	51.08		5.89			42.49		3.68		
	9	53.79		6.53			61.93		7.81		
	10	22.32		1.12			30.00		1.83		
	11	9.85		0.22			21.11		0.91		
	12	11.51	442.97	0.30	68.27	312.01	23.41	490.99	1.12	57.08	245.08
2077	1	1.10		0.00			10.17		0.27		
	2	13.16		0.28			11.25		0.33		
	3	59.34		5.67			17.45		0.80		
	4	112.62		20.42			21.15		1.18		
	5	54.82		4.84			37.78		3.76		
	6	68.83		7.62			119.36		37.52		
	7	134.89		29.29			61.46		9.95		
	8	112.95		20.54			44.86		5.30		
	9	24.93		1.00			8.91		0.21		
	10	25.57		1.05			14.30		0.54		
	11	6.64		0.07			8.31		0.18		
	12	6.40	621.25	0.07	90.84	483.30	24.73	379.72	1.61	61.65	270.96
2078	1	5.54		0.05			12.02		0.36		
	2	25.43		0.98			10.82		0.29		
	3	7.42		0.08			9.44		0.22		
	4	52.49		4.16			27.53		1.87		
	5	55.60		4.66			110.66		30.20		
	6	267.21		107.68			99.31		24.32		
	7	72.86		8.01			67.92		11.38		
	8	49.08		3.63			18.81		0.87		
	9	42.80		2.76			7.97		0.16		
	10	16.74		0.42			4.44		0.05		
	11	39.26		2.32			19.35		0.92		
	12	28.66	663.09	1.24	135.99	971.77	17.26	405.52	0.73	71.36	332.59
2079	1	21.25		1.61			5.26		0.05		
	2	4.85		0.08			33.69		1.97		
	3	31.30		3.50			39.43		2.70		
	4	14.64		0.77			87.12		13.16		
	5	14.50		0.75			81.98		11.65		
	6	55.80		11.14			116.96		23.72		
	7	34.68		4.30			69.94		8.48		

	8	39.11		5.47			39.92		2.76		
	9	22.00		1.73			30.04		1.56		
	10	15.62		0.87			35.59		2.20		
	11	18.40		1.21			24.10		1.01		
	12	7.51	279.66	0.20	31.64	436.54	12.74	576.78	0.28	69.53	320.32
2080	1	8.63		0.13			16.47		0.38		
	2	18.55		0.60			9.93		0.14		
	3	35.28		2.17			22.92		0.74		
	4	17.65		0.54			53.80		4.08		
	5	107.34		20.09			76.42		8.23		
	6	131.00		29.93			241.75		82.35		
	7	114.28		22.78			85.88		10.39		
	8	67.69		7.99			51.77		3.78		
	9	25.39		1.12			97.32		13.35		
	10	11.27		0.22			34.56		1.68		
	11	15.57		0.42			13.65		0.26		
	12	20.72	573.39	0.75	86.76	448.71	5.22	709.69	0.04	125.42	839.97
2081	1	23.42		0.96			4.38		0.04		
	2	11.04		0.21			4.17		0.04		
	3	45.16		3.57			17.93		0.70		
	4	44.40		3.45			2.76		0.02		
	5	71.75		9.01			141.96		44.07		
	6	159.42		44.45			35.76		2.80		
	7	90.85		14.44			129.61		36.73		
	8	45.56		3.63			82.24		14.79		
	9	53.23		4.96			11.45		0.29		
	10	8.60		0.13			9.43		0.19		
	11	12.37		0.27			15.40		0.52		
	12	5.91	571.72	0.06	85.13	435.36	2.27	457.36	0.01	100.19	568.52
2082	1	4.28		0.06			13.57		0.27		
	2	8.32		0.22			13.73		0.27		
	3	15.16		0.71			12.13		0.21		
	4	5.45		0.09			39.75		2.29		
	5	31.01		2.99			159.82		37.04		
	6	28.62		2.55			77.94		8.81		
	7	109.81		37.47			269.71		105.47		
	8	88.49		24.34			30.50		1.35		
	9	16.47		0.84			45.76		3.04		
	10	8.39		0.22			6.13		0.05		
	11	0.53		0.00			11.79		0.20		
	12	5.23	321.76	0.09	69.57	320.55	8.85	689.68	0.11	159.12	1297.35
2083	1	13.43		0.35			9.75		0.18		
	2	12.19		0.28			1.70		0.01		
	3	24.24		1.12			53.48		5.38		
	4	32.02		1.96			58.41		6.42		
	5	101.70		19.79			134.32		33.95		
	6	70.36		9.47			57.13		6.14		
	7	110.22		23.25			77.46		11.29		
	8	61.12		7.15			66.42		8.30		
	9	49.52		4.69			32.24		1.96		
	10	28.12		1.51			23.58		1.05		
	11	17.89		0.61			13.61		0.35		
	12	1.71	522.53	0.01	70.21	324.82	3.40	531.49	0.02	75.03	358.24
2084	1	8.15		0.11			16.43		0.47		
	2	21.03		0.76			23.89		0.99		
	3	11.12		0.21			25.47		1.12		
	4	138.67		33.13			14.91		0.38		
	5	83.83		12.11			124.48		26.74		
	6	129.02		28.68			89.47		13.82		
	7	74.02		9.44			61.65		6.56		
	8	56.73		5.54			106.73		19.66		
	9	15.37		0.41			65.77		7.47		

	10	17.31		0.52			11.62		0.23		
	11	13.00		0.29			18.12		0.57		
2085	12	12.16	580.43	0.25	91.46	488.71	20.85	579.40	0.75	78.75	385.51
	1	20.54		0.79			12.29		0.31		
	2	11.20		0.24			9.21		0.17		
	3	4.93		0.05			37.22		2.80		
	4	28.08		1.49			46.88		4.44		
	5	24.67		1.15			83.12		13.96		
	6	129.18		31.42			74.48		11.21		
	7	74.15		10.35			46.62		4.39		
	8	88.17		14.64			48.31		4.72		
	9	100.53		19.03			56.65		6.48		
	10	31.16		1.83			15.47		0.48		
	11	11.08		0.23			48.38		4.73		
2086	12	7.31	530.99	0.10	81.32	405.12	16.38	495.00	0.54	54.22	229.92
	1	8.99		0.13			9.94		0.19		
	2	0.74		0.00			26.90		1.39		
	3	13.02		0.27			14.75		0.42		
	4	22.40		0.81			18.71		0.67		
	5	136.46		30.21			116.90		26.34		
	6	185.81		56.02			66.70		8.57		
	7	127.32		26.30			93.71		16.93		
	8	28.24		1.29			40.31		3.13		
	9	35.20		2.01			33.09		2.11		
	10	31.55		1.62			66.71		8.58		
	11	7.08		0.08			15.80		0.48		
2087	12	19.48	616.29	0.62	119.38	769.45	15.33	518.85	0.45	69.27	318.57
	1	18.53		0.74			6.76		0.06		
	2	3.56		0.03			15.14		0.30		
	3	22.33		1.08			16.50		0.36		
	4	108.43		25.40			58.76		4.56		
	5	36.26		2.84			103.44		14.14		
	6	85.07		15.63			312.34		128.96		
	7	64.33		8.94			67.42		6.01		
	8	44.74		4.32			92.59		11.33		
	9	21.22		0.97			24.33		0.78		
	10	16.62		0.60			26.33		0.92		
	11	24.95		1.34			18.75		0.46		
2088	12	16.92	462.94	0.62	62.51	276.06	14.14	756.50	0.26	168.16	1438.54
	1	16.58		0.49			8.39		0.11		
	2	17.68		0.56			0.48		0.00		
	3	25.75		1.18			16.04		0.41		
	4	50.31		4.51			16.63		0.44		
	5	99.64		17.71			293.15		135.74		
	6	43.44		3.37			64.70		6.61		
	7	116.00		24.00			53.91		4.59		
	8	56.73		5.74			21.82		0.75		
	9	69.82		8.69			74.27		8.71		
	10	24.15		1.04			48.88		3.77		
	11	10.77		0.21			9.64		0.15		
2089	12	29.88	560.76	1.59	69.08	317.34	25.22	633.13	1.00	162.28	1345.89
	1	0.75		0.00			31.95		1.63		
	2	23.69		0.75			8.86		0.13		
	3	48.34		3.11			29.57		1.40		
	4	53.79		3.85			23.23		0.86		
	5	254.11		85.96			106.52		18.16		
	6	96.57		12.42			121.47		23.61		
	7	122.53		19.99			67.01		7.19		
	8	44.20		2.60			32.84		1.73		
	9	64.71		5.57			46.00		3.39		
	10	11.53		0.18			93.61		14.02		
	11	15.63		0.33			55.33		4.90		

2090	12	15.31	751.15	0.31	135.07	959.88	8.49	624.89	0.12	77.13	373.45
	1	4.54		0.05			10.13		0.16		
	2	8.25		0.15			22.44		0.80		
	3	8.70		0.17			14.53		0.34		
	4	23.28		1.20			28.94		1.33		
	5	11.88		0.31			85.65		11.67		
	6	125.13		34.80			238.32		90.33		
	7	59.61		7.90			76.16		9.23		
	8	86.92		16.79			35.48		2.00		
	9	61.72		8.47			70.14		7.82		
	10	35.45		2.79			28.19		1.26		
	11	12.98		0.37			13.27		0.28		
2091	12	11.44	449.89	0.29	73.30	346.00	5.53	628.79	0.05	125.27	838.25
	1	10.01		0.20			7.89		0.11		
	2	2.16		0.01			14.22		0.35		
	3	5.66		0.06			17.69		0.55		
	4	20.31		0.81			31.50		1.73		
	5	68.80		9.35			73.80		9.52		
	6	180.50		64.32			121.20		25.68		
	7	68.79		9.34			85.52		12.78		
	8	48.00		4.55			52.92		4.89		
	9	36.29		2.60			59.02		6.09		
	10	19.32		0.74			65.94		7.60		
	11	41.85		3.46			26.69		1.24		
2092	12	4.84	506.55	0.05	95.48	524.58	15.72	572.10	0.43	70.98	330.04
	1	6.93		0.14			9.92		0.15		
	2	11.89		0.42			19.43		0.59		
	3	7.63		0.17			28.41		1.27		
	4	23.16		1.58			32.48		1.66		
	5	10.62		0.33			142.15		31.82		
	6	66.12		12.85			120.68		22.94		
	7	61.33		11.06			108.20		18.44		
	8	28.54		2.39			35.94		2.03		
	9	71.65		15.09			50.79		4.06		
	10	4.55		0.06			63.70		6.39		
	11	36.89		4.00			19.09		0.57		
2093	12	10.94	340.26	0.35	48.44	958.51	4.12	634.90	0.03	89.97	475.82
	1	22.19		0.89			9.09		0.11		
	2	12.04		0.26			14.34		0.27		
	3	14.82		0.40			15.09		0.30		
	4	56.57		5.78			76.06		7.65		
	5	77.83		10.94			192.12		48.81		
	6	109.81		21.78			147.07		28.60		
	7	86.70		13.58			118.84		18.68		
	8	47.13		4.01			68.25		6.16		
	9	88.72		14.22			22.91		0.69		
	10	25.70		1.19			13.79		0.25		
	11	6.59		0.08			39.95		2.11		
2094	12	5.49	553.59	0.05	73.19	345.20	38.68	756.19	1.98	115.62	727.33
	1	4.60		0.03			32.07		1.99		
	2	19.53		0.57			11.49		0.26		
	3	26.49		1.05			18.41		0.66		
	4	135.33		27.41			3.82		0.03		
	5	112.76		19.03			153.19		45.43		
	6	132.57		26.31			74.54		10.76		
	7	85.49		10.94			85.73		14.23		
	8	68.64		7.05			31.06		1.87		
	9	42.14		2.66			29.89		1.73		
	10	19.89		0.59			38.27		2.83		
	11	12.49		0.23			21.94		0.93		
2095	12	8.12	668.04	0.10	95.98	529.14	16.13	516.53	0.50	81.22	404.32
	1	1.07		0.00			7.89		0.11		

	2	15.88		0.52			19.23		0.66		
	3	8.05		0.13			22.35		0.89		
	4	38.20		3.03			39.83		2.81		
	5	35.96		2.68			176.78		55.42		
	6	105.05		22.91			54.81		5.33		
	7	136.27		38.55			71.96		9.18		
	8	67.88		9.57			49.78		4.39		
	9	26.78		1.49			49.97		4.43		
	10	14.69		0.45			43.20		3.31		
	11	24.23		1.22			20.63		0.75		
	12	7.56	481.64	0.12	80.69	400.23	7.43	563.86	0.10	87.39	453.94
2096	1	8.46		0.18			14.89		0.67		
	2	9.08		0.21			10.75		0.35		
	3	31.64		2.58			12.48		0.47		
	4	18.80		0.91			37.54		4.23		
	5	5.90		0.09			24.40		1.79		
	6	70.20		12.72			30.43		2.78		
	7	110.75		31.66			38.85		4.53		
	8	47.06		5.72			45.10		6.11		
	9	47.51		5.83			10.35		0.32		
	10	16.16		0.67			56.38		9.55		
	11	13.82		0.49			15.56		0.73		
	12	8.03	387.43	0.17	61.24	268.60	36.24	332.97	3.94	35.46	538.86
2097	1	9.82		0.15			9.93		0.15		
	2	3.46		0.02			8.99		0.12		
	3	11.36		0.20			46.90		3.33		
	4	21.36		0.70			32.43		1.59		
	5	143.01		31.55			86.35		11.29		
	6	135.01		28.12			339.97		175.04		
	7	155.85		37.47			24.94		0.94		
	8	35.60		1.95			21.67		0.71		
	9	94.85		13.88			25.69		1.00		
	10	16.25		0.41			40.60		2.50		
	11	6.20		0.06			22.29		0.75		
	12	15.44	648.20	0.37	114.88	719.25	0.53	660.32	0.00	197.43	1949.02
2098	1	4.49		0.03			12.62		0.32		
	2	28.84		1.43			20.05		0.81		
	3	17.48		0.52			3.23		0.02		
	4	39.10		2.63			97.08		19.04		
	5	97.48		16.33			134.63		36.61		
	6	133.71		30.72			45.09		4.11		
	7	146.78		37.02			30.02		1.82		
	8	35.27		2.14			14.90		0.45		
	9	42.91		3.16			59.68		7.19		
	10	9.07		0.14			19.71		0.78		
	11	4.45		0.03			9.20		0.17		
	12	22.46	582.04	0.87	95.02	520.32	48.82	495.03	4.81	76.15	366.27
2099	1	8.85		0.14			35.18		2.52		
	2	7.17		0.09			19.09		0.74		
	3	4.11		0.03			85.62		14.91		
	4	11.65		0.25			17.71		0.64		
	5	66.90		8.16			61.39		7.67		
	6	156.43		44.60			55.43		6.25		
	7	155.50		44.07			60.56		7.46		
	8	49.29		4.43			40.19		3.29		
	9	34.11		2.12			28.81		1.69		
	10	35.09		2.24			64.74		8.53		
	11	8.12		0.12			7.63		0.12		
	12	11.51	548.72	0.24	106.49	630.61	15.20	491.55	0.47	54.28	230.22
2100	1	20.54		0.74			12.08		0.38		
	2	14.00		0.35			2.88		0.02		
	3	4.15		0.03			1.08		0.00		

4	18.27		0.59			51.52		6.91		
5	31.93		1.80			66.23		11.42		
6	264.88		123.59			72.33		13.63		
7	111.25		21.80			47.48		5.87		
8	77.06		10.46			64.80		10.94		
9	14.74		0.38			13.80		0.50		
10	2.23		0.01			15.20		0.60		
11	0.00		0.00			16.19		0.68		
12	8.66	567.71	0.13	159.87	1308.85	20.33	383.90	1.08	52.04	218.85

Appendix D

*R-values calculated with climate change data from 2018 to 2100, Calgary Alberta, Canada*

Year	Rvalues		Percent Change	
	Climate Scenario		Climate Scenario	
	RCP-4.5	RCP-8.5	RCP-4.5	RCP-8.5
2018	370.08	428.03		
2019	879.97	435.99	137.78	1.86
2020	288.43	947.51	-67.22	117.32
2021	623.58	562.09	116.20	-40.68
2022	370.42	266.42	-40.60	-52.60
2023	442.77	665.85	19.53	149.92
2024	558.47	226.02	26.13	-66.06
2025	607.36	336.08	8.75	48.70
2026	504.79	502.88	-16.89	49.63
2027	580.99	694.77	15.10	38.16
2028	1162.85	614.83	100.15	-11.51
2029	309.24	326.41	-73.41	-46.91
2030	721.71	546.37	133.38	67.38
2031	261.41	626.32	-63.78	14.63
2032	431.82	340.83	65.19	-45.58
2033	222.69	1194.83	-48.43	250.56
2034	487.62	1114.20	118.97	-6.75
2035	870.50	383.06	78.52	-65.62
2036	700.72	324.17	-19.50	-15.37
2037	276.15	223.01	-60.59	-31.21
2038	653.33	267.88	136.59	20.12
2039	343.67	671.16	-47.40	150.55
2040	279.37	315.03	-18.71	-53.06
2041	906.77	347.50	224.57	10.31
2042	582.82	760.82	-35.73	118.94
2043	649.25	709.97	11.40	-6.68
2044	311.30	794.93	-52.05	11.97
2045	777.59	383.38	149.79	-51.77
2046	401.60	283.19	-48.35	-26.13
2047	349.90	513.70	-12.87	81.40
2048	282.75	362.10	-19.19	-29.51
2049	313.44	592.52	10.86	63.63
2050	916.50	764.41	192.40	29.01
2051	2747.88	264.65	199.82	-65.38
2052	241.21	790.60	-91.22	198.73
2053	882.65	257.49	265.92	-67.43

2054	708.40	224.37	-19.74	-12.86
2055	544.37	510.63	-23.15	127.59
2056	267.29	790.60	-50.90	54.83
2057	798.59	276.37	198.77	-65.04
2058	409.26	682.91	-48.75	147.10
2059	381.77	1495.31	-6.72	118.96
2060	307.35	413.02	-19.49	-72.38
2061	807.49	1248.02	162.72	202.17
2062	220.05	267.45	-72.75	-78.57
2063	252.70	379.15	14.84	41.76
2064	355.15	386.38	40.54	1.91
2065	222.39	377.49	-37.38	-2.30
2066	642.57	681.23	188.94	80.46
2067	369.74	209.38	-42.46	-69.26
2068	529.50	1285.59	43.21	514.00
2069	230.26	328.48	-56.51	-74.45
2070	266.66	926.11	15.81	181.93
2071	378.00	1615.21	41.75	74.41
2072	335.26	720.29	-11.31	-55.41
2073	460.46	401.21	37.35	-44.30
2074	209.57	414.60	-54.49	3.34
2075	395.97	436.04	88.95	5.17
2076	312.01	245.08	-21.20	-43.79
2077	483.30	270.96	54.90	10.56
2078	971.77	332.59	101.07	22.74
2079	436.54	320.32	-55.08	-3.69
2080	448.71	839.97	2.79	162.23
2081	435.36	568.52	-2.97	-32.32
2082	320.55	1297.35	-26.37	128.20
2083	324.82	358.24	1.33	-72.39
2084	488.71	385.51	50.46	7.61
2085	405.12	229.92	-17.10	-40.36
2086	769.45	318.57	89.93	38.56
2087	276.06	1438.54	-64.12	351.56
2088	317.34	1345.89	14.95	-6.44
2089	959.88	373.45	202.48	-72.25
2090	346.00	838.25	-63.95	124.46
2091	524.58	330.04	51.61	-60.63
2092	958.51	475.82	82.72	44.17
2093	345.20	727.33	-63.99	52.86
2094	529.14	404.32	53.28	-44.41
2095	400.23	453.94	-24.36	12.27

CLIMATE CHANGE IMPACTS ON EROSIVE RAINFALL

2096	268.60	538.86	-32.89	18.71
2097	719.25	1949.02	167.78	261.69
2098	520.32	366.27	-27.66	-81.21
2099	630.61	230.22	21.20	-37.14
2100	1308.85	218.85	107.55	-4.94
average			27.89	31.17

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Appendix E  
*Average 10 year R-values calculated with climate change data from 2018 to 2100, Calgary Alberta, Canada*

Year	Rvalues		Percent Change	
	Climate Scenario		Climate Scenario	
	RCP-4.5	RCP-8.5	RCP-4.5	RCP-8.5
2018-2027	522.69	506.56		
2028-2037	544.47	569.40	4.17	12.40
2038-2047	525.56	504.76	-3.47	-11.35
2048-2057	770.31	483.37	46.57	-4.24
2058-2067	396.85	614.03	-48.48	27.03
2068-2077	360.10	664.36	-9.26	8.20
2078-2087	487.71	608.95	35.44	-8.34
2088-2097	536.87	743.69	10.08	22.13
average			5.01	6.55

## Appendix F

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

site #	R-value of 300		R-value of 642	
	sediment yield (t/ha/yr)	pass	sediment yield (t/ha/yr)	pass
1	0.93	yes	1.98	yes
2	0.12	yes	0.26	yes
3	0.02	yes	0.05	yes
4	0.11	yes	0.23	yes
5	0.52	yes	1.12	yes
6	1.08	yes	2.31	
7	0.87	yes	1.87	yes
8	0.04	yes	0.09	yes
9	0.47	yes	1.00	yes
10	0.94	yes	2.02	
11	0.16	yes	0.35	yes
12	0.07	yes	0.14	yes
13	0.18	yes	0.39	yes
14	0.73	yes	1.56	yes
15	0.14	yes	0.30	yes
16	0.58	yes	1.25	yes
17	1.08	yes	2.31	
18	1.88	yes	4.02	
19	2.35		5.03	
20	0.10	yes	0.21	yes
21	0.09	yes	0.18	yes
22	1.57	yes	3.36	
23	0.14	yes	0.30	yes
24	0.95	yes	2.03	
25	3.20		6.85	
26	0.86	yes	1.83	yes
27	1.24	yes	2.65	
28	1.14	yes	2.44	
29	1.08	yes	2.32	
30	0.08	yes	0.16	yes
31	0.05	yes	0.11	yes
32	1.06	yes	2.26	
33	2.11		4.51	
34	0.56	yes	1.21	yes
35	0.64	yes	1.37	yes
36	0.21	yes	0.45	yes

37	0.67	yes	1.43	yes
38	0.11	yes	0.23	yes
39	0.42	yes	0.90	yes
40	0.09	yes	0.19	yes
41	1.98	yes	4.24	
42	1.13	yes	2.42	
43	0.40	yes	0.86	yes
44	0.57	yes	1.22	yes
45	0.36	yes	0.77	yes
46	0.80	yes	1.70	yes
47	0.07	yes	0.15	yes
48	0.93	yes	1.98	yes
49	0.71	yes	1.51	yes
50	0.08	yes	0.18	yes
51	0.46	yes	0.99	yes
52	0.15	yes	0.32	yes
53	2.05		4.39	
54	0.00	yes	0.01	yes
55	0.69	yes	1.47	yes
56	0.62	yes	1.33	yes
57	1.35	yes	2.89	
58	0.77	yes	1.65	yes
59	0.04	yes	0.08	yes
60	2.42		5.18	
61	0.29	yes	0.62	yes
62	1.57	yes	3.37	
63	1.23	yes	2.63	
64	0.32	yes	0.69	yes
65	0.05	yes	0.11	yes
66	1.07	yes	2.30	
67	0.00	yes	0.01	yes
68	1.50	yes	3.21	
69	1.29	yes	2.76	
70	4.66		9.98	
71	1.92	yes	4.10	
72	0.24	yes	0.51	yes
73	0.34	yes	0.73	yes
74	0.98	yes	2.10	
75	0.06	yes	0.13	yes
76	0.05	yes	0.10	yes
77	0.00	yes	0.00	yes
78	1.13	yes	2.41	

79	1.10	yes	2.35	
80	3.11		6.65	
81	0.01	yes	0.03	yes
82	0.11	yes	0.23	yes
83	1.91	yes	4.09	
84	0.01	yes	0.01	yes
85	1.40	yes	2.99	
86	1.19	yes	2.54	
87	0.10	yes	0.22	yes
88	0.31	yes	0.67	yes
89	0.81	yes	1.73	yes
90	2.07		4.42	
91	1.93	yes	4.13	
92	2.87		6.15	
93	0.12	yes	0.25	yes
94	0.02	yes	0.04	yes
95	0.11	yes	0.23	yes
96	0.09	yes	0.20	yes
97	0.23	yes	0.50	yes
98	2.55		5.46	
99	1.63	yes	3.48	
100	0.05	yes	0.11	yes
101	0.63	yes	1.35	yes
102	0.21	yes	0.44	yes
103	2.17		4.65	
104	1.40	yes	2.99	
105	0.22	yes	0.47	yes
106	0.15	yes	0.32	yes
107	0.17	yes	0.37	yes
108	1.58	yes	3.38	
109	0.94	yes	2.02	
110	0.80	yes	1.70	yes
111	0.09	yes	0.20	yes
112	0.02	yes	0.04	yes
113	0.31	yes	0.67	yes
114	1.76	yes	3.78	
115	0.10	yes	0.21	yes
116	1.90	yes	4.06	
117	0.08	yes	0.18	yes
118	1.78	yes	3.80	
119	0.74	yes	1.59	yes
120	1.63	yes	3.49	

121	1.57	yes	3.36	
122	0.62	yes	1.32	yes
123	0.92	yes	1.97	yes
124	1.32	yes	2.82	
125	0.31	yes	0.66	yes
126	0.82	yes	1.75	yes
127	0.03	yes	0.07	yes
128	0.37	yes	0.80	yes
129	0.15	yes	0.33	yes
130	0.94	yes	2.00	yes
131	1.13	yes	2.41	
132	0.01	yes	0.03	yes
133	0.02	yes	0.04	yes
134	0.11	yes	0.23	yes
135	0.96	yes	2.06	
136	0.14	yes	0.30	yes
137	0.14	yes	0.29	yes
138	1.57	yes	3.36	
139	0.14	yes	0.30	yes
140	0.03	yes	0.07	yes
141	0.06	yes	0.13	yes
142	0.68	yes	1.46	yes
143	0.41	yes	0.88	yes
144	1.70	yes	3.65	
145	0.07	yes	0.15	yes
146	0.24	yes	0.51	yes
147	2.14	yes	4.58	
148	0.23	yes	0.48	yes
149	0.00	yes	0.01	yes
150	0.80	yes	1.71	yes
151	1.32	yes	2.82	
152	0.15	yes	0.32	yes
153	0.21	yes	0.44	yes
154	1.03	yes	2.21	
155	0.16	yes	0.34	yes
156	1.01	yes	2.15	
157	1.33	yes	2.85	
158	2.42	yes	5.17	
159	0.01	yes	0.03	yes
160	0.05	yes	0.11	yes
161	1.16	yes	2.48	
162	0.91	yes	1.95	yes

163	1.17	yes	2.49	
164	1.57	yes	3.36	
165	0.83	yes	1.78	yes
166	1.63	yes	3.49	
167	1.04	yes	2.22	
168	0.42	yes	0.90	yes
169	2.00	yes	4.28	
170	1.47	yes	3.15	
171	0.95	yes	2.04	
172	0.01	yes	0.02	yes
173	0.09	yes	0.18	yes
174	0.18	yes	0.38	yes
175	1.40	yes	2.99	
176	1.49	yes	3.18	
177	0.36	yes	0.76	yes
178	0.14	yes	0.31	yes
179	1.80	yes	3.85	
180	0.73	yes	1.56	yes
181	0.40	yes	0.85	yes
	181	170	181	113

## Appendix G

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

site #	R value of 300			R value of 642		
	Estimated tonnes of sediment (Tonnes/site/year)			Estimated tonnes of sediment (Tonnes/site/year)		
	Yield with controls	Yield without controls	Yield difference	Yield with controls	Yield without controls	Yield difference
1	0.25	5.08	4.83	0.54	10.87	10.34
2	2.10	3.50	1.40	4.49	7.49	3.00
3	0.81	8.00	7.19	1.73	17.12	15.39
4	11.00	30.00	29.00	23.54	64.20	62.06
5	0.04	4.00	3.96	0.09	8.56	8.47
6	0.50	24.00	23.50	1.07	51.36	50.29
7	4.03	44.79	40.76	8.63	95.85	87.23
8	2.30	12.40	10.10	4.92	26.54	21.61
9	1.45	29.00	27.55	3.10	62.06	58.96
10	1.18	5.91	4.73	2.53	12.65	10.12
11	0.28	1.90	1.62	0.60	4.07	3.47
12	1.30	30.20	0.30	2.78	64.63	0.64
13	1.19	239.40	238.21	2.55	512.32	509.77
14	0.56	11.30	10.74	1.20	24.18	22.98
15	0.50	467.00	466.50	1.07	999.38	998.31
16	0.22	2.94	2.72	0.47	6.29	5.82
17	0.73	80.64	79.91	1.56	172.57	171.01
18	0.56	5.64	5.08	1.20	12.07	10.87
19	15.85	158.53	142.68	33.92	339.25	305.34
20	0.35	14.19	13.84	0.75	30.37	29.62
21	0.60	11.96	11.36	1.28	25.59	24.31
22	1.06	5.44	4.38	2.27	11.64	9.37
23	0.53	1.78	1.25	1.13	3.81	2.68
24	2.76	27.66	24.90	5.91	59.19	53.29
25	14.80	296.70	281.90	31.67	634.94	603.27
26	1.94	32.39	30.45	4.15	69.31	65.16
27	0.16	35.58	35.42	0.34	76.14	75.80
28	0.94	187.00	186.06	2.00	400.18	398.18
29	1.13	11.31	10.18	2.42	24.20	21.79
30	2.16	430.20	428.04	4.62	920.63	916.01
31	0.08	28.00	27.92	0.18	59.92	59.74
32	4.96	80.69	75.73	10.61	172.68	162.06
33	2.20	2.60	0.40	4.71	5.56	0.86
34	5.40	59.57	54.17	11.56	127.48	115.92
35	14.60	219.60	205.00	31.24	469.94	438.70
36	0.92	92.44	91.52	1.97	197.82	195.85
37	1.30	26.00	24.70	2.78	55.64	52.86
38	21.30	118.40	97.10	45.58	253.38	207.79
39	1.30	15.40	14.10	2.78	32.96	30.17
40	0.04	1.40	1.36	0.09	3.00	2.91
41	0.22	2.49	2.27	0.47	5.33	4.86
42	10.20	57.60	47.40	21.83	123.26	101.44
43	2.19	12.16	9.97	4.69	26.02	21.34
44	3.40	57.00	53.60	7.28	121.98	114.70
45	0.13	12.80	12.67	0.27	27.39	27.12
46	9.30	34.00	24.70	19.90	72.76	52.86
47	0.36	18.00	17.64	0.77	38.52	37.75
48	0.12	2.41	2.29	0.26	5.16	4.90
49	0.34	6.80	6.46	0.73	14.55	13.82
50	0.24	2.40	2.16	0.51	5.14	4.62
51	0.72	145.44	144.72	1.54	311.24	309.70
52	3.84	41.06	37.22	8.22	87.87	79.65
53	1.10	4.00	2.90	2.35	8.56	6.21
54	0.06	0.20	0.14	0.13	0.43	0.30
55	0.59	20.49	19.90	1.26	43.85	42.59

56	2.89	137.49	134.60	6.18	294.23	288.04
57	5.91	123.14	117.23	12.65	263.52	250.87
58	0.07	13.77	13.70	0.15	29.47	29.32
59	1.72	57.00	55.28	3.68	121.98	118.30
60	2.60	513.80	511.20	5.56	1099.53	1093.97
61	0.25	5.08	4.83	0.54	10.87	10.34
62	0.46	6.10	5.64	0.98	13.05	12.07
63	0.89	173.70	173.70	1.90	371.72	371.72
64	4.08	30.00	25.92	8.73	64.20	55.47
65	0.36	4.80	4.44	0.77	10.27	9.50
66	11.06	34.13	23.07	23.67	73.04	49.37
67	0.05	0.98	0.93	0.11	2.10	1.99
68	18.91	210.00	191.09	40.47	449.40	408.93
69	8.36	83.59	75.23	17.89	178.88	160.99
70	2.40	6.12	3.72	5.14	13.10	7.96
71	1.98	19.80	17.82	4.24	42.37	38.13
72	7.70	77.00	69.30	16.48	164.78	148.30
73	0.23	46.40	46.17	0.49	99.30	98.80
74	12.05	133.92	121.87	25.79	286.59	260.80
75	1.30	45.00	43.70	2.78	96.30	93.52
76	0.23	3.14	2.91	0.49	6.72	6.23
77	1.51	50.32	48.81	3.23	107.68	104.45
78	31.84	131.00	99.16	68.14	280.34	212.20
79	2.09	23.30	21.20	4.47	49.86	45.37
80	5.67	23.25	17.58	12.13	49.76	37.62
81	0.30	30.90	30.60	0.64	66.13	65.48
82	1.87	2.68	0.80	4.00	5.74	1.71
83	0.00	2.90	2.90	0.00	6.21	6.20
84	0.20	4.00	3.80	0.43	8.56	8.13
85	9.04	125.61	116.57	19.35	268.81	249.46
86	28.78	479.00	450.22	61.59	1025.06	963.47
87	9.80	149.30	139.50	20.97	319.50	298.53
88	44.62	446.00	401.38	95.49	954.44	858.95
89	0.15	4.91	4.76	0.32	10.51	10.19
90	0.53	9.39	8.86	1.14	20.09	18.95
91	1.40	5.00	3.60	3.00	10.70	7.70
92	0.17	33.70	33.53	0.36	72.12	71.75
93	0.55	109.47	108.92	1.18	234.27	233.09
94	0.10	21.00	20.90	0.21	44.94	44.73
95	1.58	411.30	409.12	3.38	880.18	875.52
96	28.00	132.00	104.00	59.92	282.48	222.56
97	22.60	113.13	90.53	48.36	242.10	193.73
98	13.40	26.10	12.70	28.68	55.85	27.18
99	0.01	29.00	28.99	0.03	62.06	62.03
100	4.23	47.00	42.77	9.05	100.58	91.53
101	8.10	1627.00	1618.90	17.33	3481.78	3464.45
102	0.50	109.00	108.50	1.07	233.26	232.19
103	4.45	9.65	5.20	9.52	20.65	11.13
104	0.13	25.98	25.85	0.28	55.60	55.32
105	0.01	9.30	9.29	0.02	19.90	19.88
106	1.13	1.88	0.75	2.42	4.02	1.61
107	1.68	332.00	330.32	3.60	710.48	706.88
108	0.37	73.20	72.84	0.78	156.65	155.87
109	0.02	5.61	5.59	0.04	12.01	11.96
110	4.78	64.50	59.72	10.23	138.03	127.80
111	0.60	119.56	118.96	1.28	255.86	254.57
112	0.79	39.70	38.91	1.69	84.96	83.27
113	5.51	54.00	48.49	11.79	115.56	103.77
114	33.40	92.80	59.40	71.48	198.59	127.12
115	141.00	1152.00	1011.00	301.74	2465.28	2163.54
116	2.20	7.30	5.10	4.71	15.62	10.91

117	2.70	9.47	6.77	5.78	20.27	14.49
118	15.54	63.81	48.27	33.26	136.55	103.30
119	1.14	5.70	4.56	2.44	12.20	9.76
120	2.10	2344.00	2343.90	4.49	5016.16	5015.95
121	0.03	6.23	6.20	0.06	13.33	13.27
122	0.64	128.00	127.46	1.37	273.92	272.76
123	0.08	1.91	1.83	0.17	4.09	3.92
124	3.00	6.75	3.75	6.42	14.45	8.03
125	20.00	397.00	377.00	42.80	849.58	806.78
126	1.30	4.60	3.30	2.78	9.84	7.06
127	0.35	70.00	69.65	0.75	149.80	149.05
128	1.33	533.00	531.67	2.85	1140.62	1137.77
129	13.30	266.00	252.70	28.46	569.24	540.78
130	2.67	988.41	985.74	5.71	2115.20	2109.48
131	5.00	18.00	13.00	10.70	38.52	27.82
132	10.50	210.00	99.50	22.47	449.40	212.93
133	1.00	46.00	45.00	2.14	98.44	96.30
134	5.09	42.47	37.38	10.89	90.89	79.99
135	1.61	538.02	536.41	3.45	1151.36	1147.92
136	32.10	0.16	31.94	68.69	0.34	68.35
137	0.87	173.60	172.73	1.86	371.50	369.64
138	4.03	895.10	891.70	8.62	1915.51	1908.24
139	93.22	397.66	304.44	199.49	850.99	651.50
140	4.20	193.60	189.40	8.99	414.30	405.32
141	3.40	70.00	66.60	7.28	149.80	142.52
142	1.19	5.31	4.12	2.55	11.36	8.82
143	0.48	62.50	62.02	1.03	133.75	132.72
144	0.35	258.88	258.53	0.75	554.00	553.25
145	0.75	150.50	149.75	1.61	322.07	320.47
146	2.30	459.00	456.70	4.92	982.26	977.34
147	1.80	20.00	18.20	3.85	42.80	38.95
148	0.80	159.00	158.21	1.70	340.26	338.56
149	11.00	138.00	127.00	23.54	295.32	271.78
150	13.50	270.00	256.50	28.89	577.80	548.91
151	0.89	173.70	173.70	1.90	371.72	371.72
152	5.95	33.03	27.08	12.73	70.68	57.95
153	1.21	10.40	9.19	2.59	22.26	19.67
154	2.28	60.00	57.82	4.88	128.40	123.73
155	5.24	15.00	9.86	11.21	32.10	21.10
156	0.74	53.54	52.80	1.58	114.58	112.99
157	11.78	32.70	20.92	25.21	69.98	44.77
158	1.91	6.02	4.11	4.09	12.88	8.80
159	11.98	488.81	476.83	25.64	1046.05	1020.42
160	7.70	154.00	146.30	16.48	329.56	313.08
161	0.02	3.69	3.67	0.04	7.90	7.85
162	1.75	124.76	123.01	3.75	266.99	263.24
163	0.61	6.82	6.21	1.31	14.59	13.29
164	1.89	364.00	362.00	4.04	778.96	774.68
165	28.00	132.00	104.00	59.92	282.48	222.56
166	0.01	0.81	0.80	0.02	1.73	1.72
167	0.15	29.70	29.55	0.32	63.56	63.24
168	0.12	1.60	1.48	0.26	3.42	3.17
169	6.59	185.95	179.36	14.10	397.93	383.83
170	0.52	25.10	24.58	1.11	53.71	52.60
171	4.80	969.50	964.70	10.27	2074.73	2064.46
172	2.70	270.00	267.30	5.78	577.80	572.02
173	28.30	157.00	128.70	60.56	335.98	275.42
174	0.54	107.60	107.06	1.16	230.26	229.11
175	186.30	518.00	331.70	398.68	1108.52	709.84
176	0.08	160.00	159.92	0.17	342.40	342.23
177	2.70	27.00	20.00	5.78	57.78	42.80

178	3.00	36.00	33.00	6.42	77.04	70.62
179	1.09	647.07	645.98	2.33	1384.73	1382.40
180	0.07	7.23	7.16	0.15	15.47	15.32
181	0.47	1.76	1.29	1.01	3.77	2.76
182	0.25	5.14	4.89	0.54	11.00	10.46
183	26.60	98.40	71.80	56.92	210.58	153.65
184	1.38	3.85	2.47	2.95	8.24	5.29
185	2.60	26.00	23.60	5.56	55.64	50.50
186	7.60	28.00	20.40	16.26	59.92	43.66
187	3.00	618.00	615.00	6.42	1322.52	1316.10
188	7.73	162.05	154.32	16.54	346.79	330.24
189	16.36	324.00	307.60	35.01	693.36	658.26
190	0.00	6.07	6.07	0.01	12.99	12.98
191	0.26	259.00	258.74	0.56	554.26	553.70
192	28.40	316.00	287.60	60.78	676.24	615.46
193	2.00	5.50	3.50	4.28	11.77	7.49
194	4.48	14.90	10.42	9.59	31.89	22.30
195	0.19	2.70	2.51	0.41	5.78	5.37
196	1.29	129.00	127.71	2.76	276.06	273.30
197	8.34	18.50	10.16	17.85	39.59	21.74
198	0.26	52.70	52.44	0.56	112.78	112.22
199	1.10	207.00	205.90	2.35	442.98	440.63
200	1.59	31.90	30.31	3.40	68.27	64.86
201	0.54	46.90	46.36	1.16	100.37	99.21
202	4.90	97.90	93.00	10.49	209.51	199.02
203	2.80	14.40	11.60	5.99	30.82	24.82
204	0.23	260.00	259.77	0.50	556.40	555.90
205	2.90	58.40	55.50	6.21	124.98	118.77
206	4.54	45.36	40.82	9.72	97.07	87.35
207	0.06	11.90	11.84	0.13	25.47	25.34
208	2.74	25.68	22.94	5.86	54.96	49.09
209	2.09	21.03	18.94	4.47	45.00	40.53
210	0.42	7.20	6.78	0.90	15.41	14.51
211	8.44	23.44	15.00	18.06	50.16	32.10
212	1.32	2.43	1.11	2.82	5.20	2.38
213	0.40	4.45	4.05	0.86	9.52	8.67
214	2.58	3.69	1.11	5.52	7.90	2.38
215	1.97	6.59	4.62	4.22	14.10	9.89
216	15.28	442.47	427.19	32.70	946.89	914.19
217	1.58	6.20	4.62	3.38	13.27	9.89
218	3.45	697.70	694.30	7.38	1493.08	1485.80
219	1.76	3.25	1.49	3.77	6.96	3.19
220	8.34	18.50	10.16	17.85	39.59	21.74
221	1.38	15.40	14.02	2.95	32.96	30.00
222	11.00	138.00	127.00	23.54	295.32	271.78
223	3.70	13.60	9.90	7.92	29.10	21.19
224	0.80	2.60	1.80	1.71	5.56	3.85
225	0.07	1.30	1.23	0.15	2.78	2.63
226	0.06	21.30	21.24	0.13	45.58	45.45
227	0.10	0.20	0.10	0.21	0.43	0.21
228	170.98	16.71	154.27	365.90	35.76	330.14
229	8.90	59.80	50.90	19.05	127.97	108.93
230	1.84	36.70	34.86	3.94	78.54	74.60
231	7.60	21.10	20.92	16.26	45.15	44.77
232	0.18	53.61	53.43	0.39	114.73	114.34
233	10.50	210.00	99.50	22.47	449.40	212.93
234	3.50	710.00	706.50	7.49	1519.40	1511.91
235	0.19	36.43	36.24	0.41	77.96	77.55
236	5.30	177.00	171.70	11.34	378.78	367.44
237	1.10	1.10	0.00	2.35	2.35	0.00
238	0.42	4.67	4.25	0.90	9.99	9.10

239	3.15	3.50	0.35	6.74	7.49	0.75
240	1.53	29.00	27.47	3.27	62.06	58.79
241	3.00	30.00	27.00	6.42	64.20	57.78
242	0.56	5.64	5.08	1.20	12.07	10.87
243	0.34	7.62	7.28	0.73	16.31	15.58
Totals	1645.53	30575.04	29090.64	3521.44	65430.59	62253.97