# Testing for Variance in Mean Annual Storm Water Discharge for the Assiniboine River at Headingley, Winnipeg

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## Introduction

This statistical analysis was prompted by a report on the "Cockburn-Calrossie combined sewer relief works project" which proposes the "Parker storm retention basin" as an equally efficient integration into the existing storm sewer network in Winnipeg (WWWD, 2017). As such, it was examined whether there was a significant difference in the mean annual discharge observed near the Cockburn-Calrossie site during Winnipeg's peak rain month over the past decade, enough to warrant the project or any other change in their methods of storm water management. The null hypothesis suggests there is no significant difference between mean annual discharge for each June day in the past decade: implying a change in the methods of storm water management as a non-necessity. The alternative hypothesis suggests that at least one June day has a mean discharge that differs significantly from other years in the past decade: implying a change in storm water management methods as a necessity and potentially warrants the Calrossie-Cockburn project. By testing for the variation of mean discharge for each June day from 2007 to 2016, the alternative hypothesis is the claim for this two-tailed test. It is important to investigate the necessity of the methods and infrastructure used for handling a locality's storm water to preserve the highest potential standard of storm water management, planning, and policy. Achieving the most suitable system for storm water management will more likely ensure a competent level of working efficiency, economic viability, environmental sustainability and human safety for the project by reducing the likelihood of risks that result from extreme discharge fluxes, and is especially important in areas that rely on a consistent water input.

## Data Analysis

The data was collected from an all-year operating hydrometric station that measured the Assiniboine river flow at Headingley, which is within ten km. of the Calrossie-Cockburn site

(Bodnaruk et al, 2010): assuming the discharge measured at this gauge was representative of the discharge experienced by the Calrossie-Cockburn neighborhood. Anova was used to investigate the change in average discharge for each June day relative to the same June day for following years in the past decade. This is because it provides evidence of extreme and null discharge events, a narrowed time frame for the occurrence of these events, and measures of between and within group variance. Anova compared the average discharge for each June day to that of the same June day for other years: assuming the peak rain month was always June. Given that the observed discharge was less or greater than, or had a balanced frequency of drought and flooding compared to other years indicated a relative drought, flood, or null period that occurred during the early, middle, or later days of June for that year. The between and within group variance is evident from the variation of discharge between different June days in a month and between the same June day in different years. It was assumed that the daily June discharges for each year were independent of one another, that the variance in discharge including all months of the year was equal, and that the average discharge for each June day per year was approximately normally distributed. Normalcy and standard error overlap were verified in a frequency distribution graph (Fig. 1) and a standard error graph (Fig. 2), and tested at the 0.05 level of significance.

## Results

The Anova provided enough evidence to reject the null hypothesis and support the claim that at least one of the June days had a mean annual discharge that differed significantly from other years in the past decade. Evidence supports the occurrence of a relative drought period in June 2008, a relative flood period in June 2011, a null period in June 2015, as well as an overall inconsistent discharge flux between the same June days in different years within the past decade.

## Discussion

The Anova gave an F test value (F = 349.12) greater than the critical F value ($F_{crit}$ = 1.91), which allows the rejection of the null hypothesis (Table 1). This decision is further supported by the large difference of the between group (MS = 14.166) from the within group variance (MS = 0.041) which is illustrated in how the mean discharge for each June day varied more in relation to the same June day in different years than they would compared to other June days within the same year (Table 1). This provides enough evidence to support the claim that at least one of the June days experienced a mean discharge that differed significantly from other years. Some examples of this were found in June 2008, 2011, and 2015 where a drought, a flood period, and a null event likely occurred respectively. First in June 2008, the Assiniboine river experienced the minimum mean annual discharge in the past decade, but had the second highest degree of variance compared to other years (Table 1 & Fig 2). This suggests a drought period took place, and the comparatively high standard deviation indicates a large variation in the daily June discharge for that year, in that there were likely inconsistent drought and flooding periods throughout that month (Fig. 1). Second, in June 2011, the Assiniboine river at Headingley recorded the maximum mean discharge in the past decade and likely experienced a flood period. Its minimum standard deviation suggests there was little variation in the daily June discharge for that year, in that there were likely consistent flooding periods throughout that month (Table 1 & Fig. 2). Finally, in June 2015 Fig. 1 depicts the largest frequency of discharge values clustered around the mean in what could be considered a null event. Although, Table 1 suggests a high degree of variance in that drought and flood periods likely occurred at roughly the same frequency for that month. Overall, the study indicates a significant difference in mean annual discharge between the same June days of different years and between different June days of the same year in the past decade, and this is depicted by the inconsistent

occurrences of drought, flood, and null periods. This supports the necessity of a change in the methods of managing storm water, and potentially the Calrossie-Cockburn project, that will eventually normalize the inconsistent fluxes of extreme discharge events produced by the Assiniboine river at Headingley.

Tables and Figures

Table 1. Results of Analysis of Variance for the discharge observed at the hydrometric station at the Assiniboine river at Headingley, Winnipeg for each day in June for the past decade

Anova: Single Factor (10 Years)

SUMMARY

| *June Year* | *Count* | *Sum* | *Average* | *Variance* | *Standard Deviation* |
|---|---|---|---|---|---|
| 2007 | 30 | 142.3128496 | 4.743761653 | 0.023652235 | 0.153792832 |
| 2008 | 30 | 117.6482317 | 3.921607722 | 0.027681734 | 0.166378286 |
| 2009 | 30 | 133.9713325 | 4.465711083 | 0.11642755 | 0.341214815 |
| 2010 | 30 | 130.6327346 | 4.354424485 | 0.173747435 | 0.416830224 |
| 2011 | 30 | 187.159143 | 6.2386381 | 0.000158842 | 0.012603235 |
| 2012 | 30 | 148.5809651 | 4.952698836 | 0.01641768 | 0.128131496 |
| 2013 | 30 | 162.58137 | 5.419379001 | 0.013551047 | 0.116408966 |
| 2014 | 30 | 170.9554032 | 5.698513438 | 0.003605488 | 0.060045713 |
| 2015 | 30 | 155.2284122 | 5.174280407 | 0.027212961 | 0.164963515 |
| 2016 | 30 | 140.4914012 | 4.683046706 | 0.003306928 | 0.057505898 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 127.4942648 | 9 | 14.16602942 | 349.1217235 | 6.038E-150 | 1.91224 |
| Within Groups | 11.76709513 | 290 | 0.04057619 | | | |
| Total | 139.2613599 | 299 | | | | |

Figure 1. Frequency distribution graph verifying the approximate normalcy of discharge for each June day for the past decade: class 1 includes the base discharge values and class 5 the maximum discharge values.

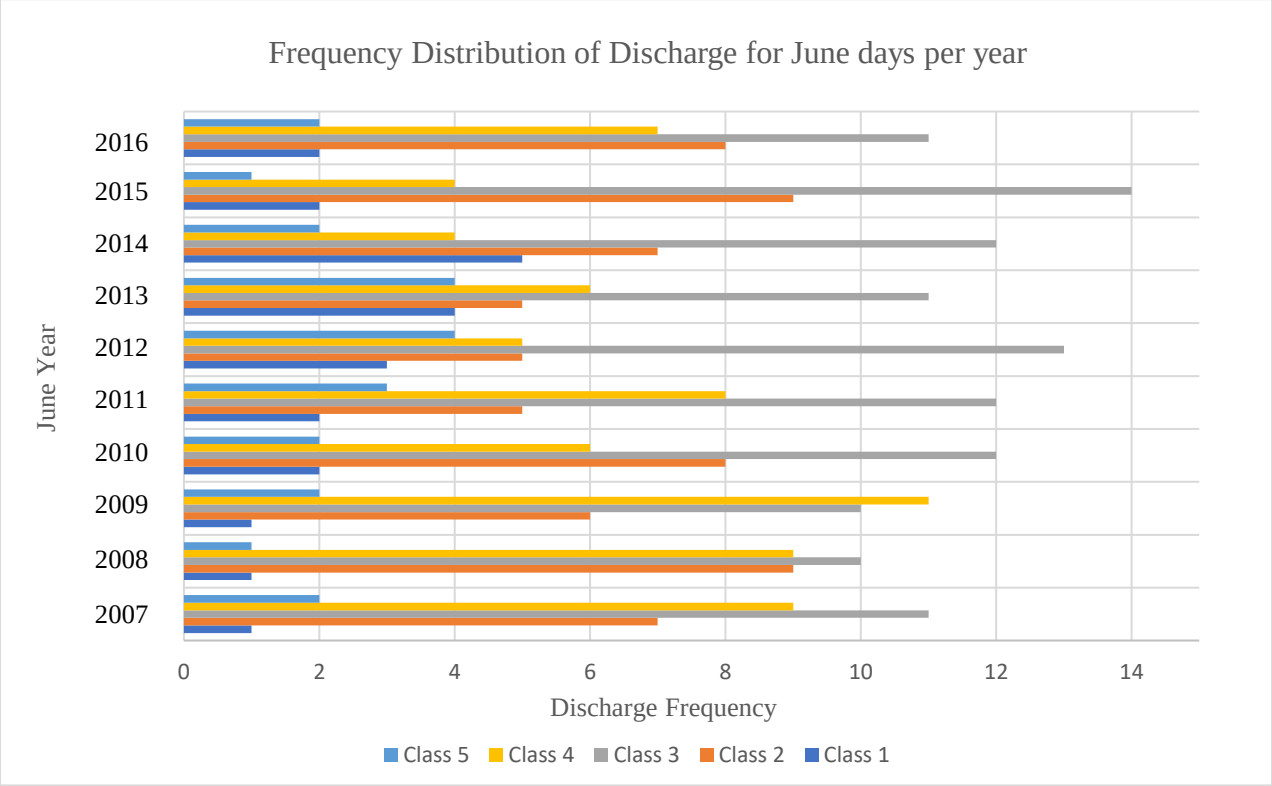


Figure 2. Standard error of mean annual discharge for the expected peak rain month (June) in the Assiniboine River at Headingley, Winnipeg

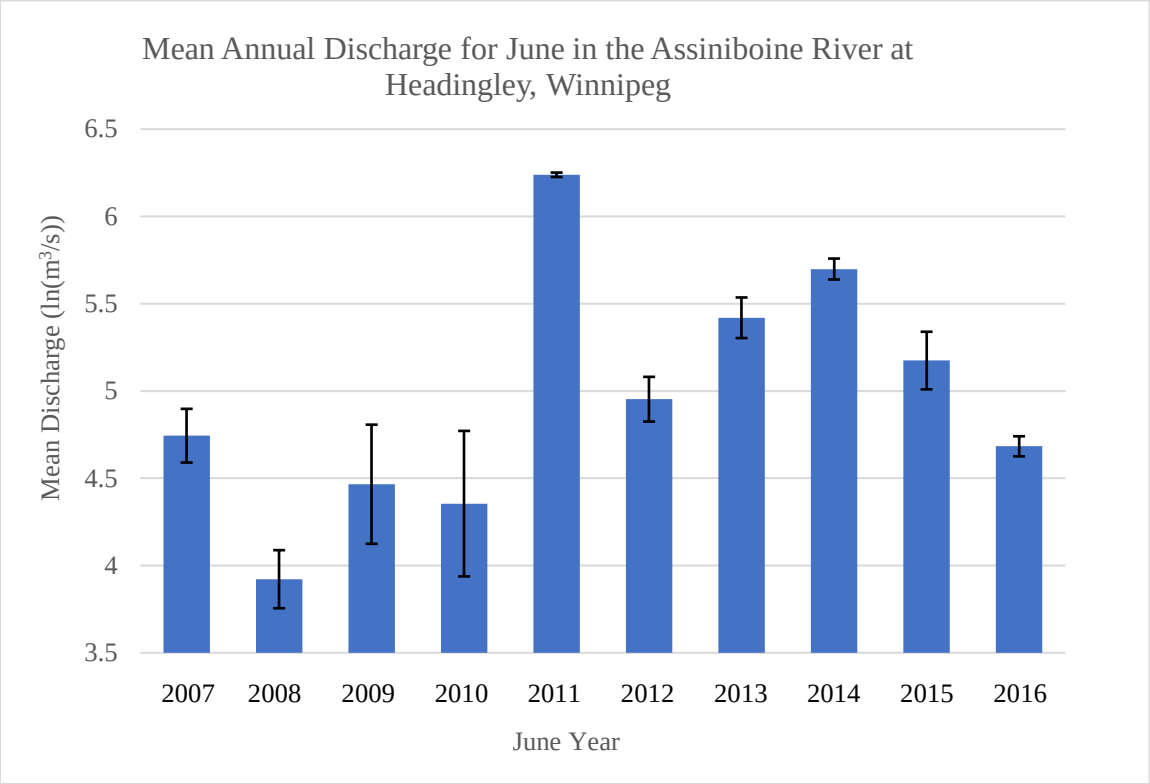
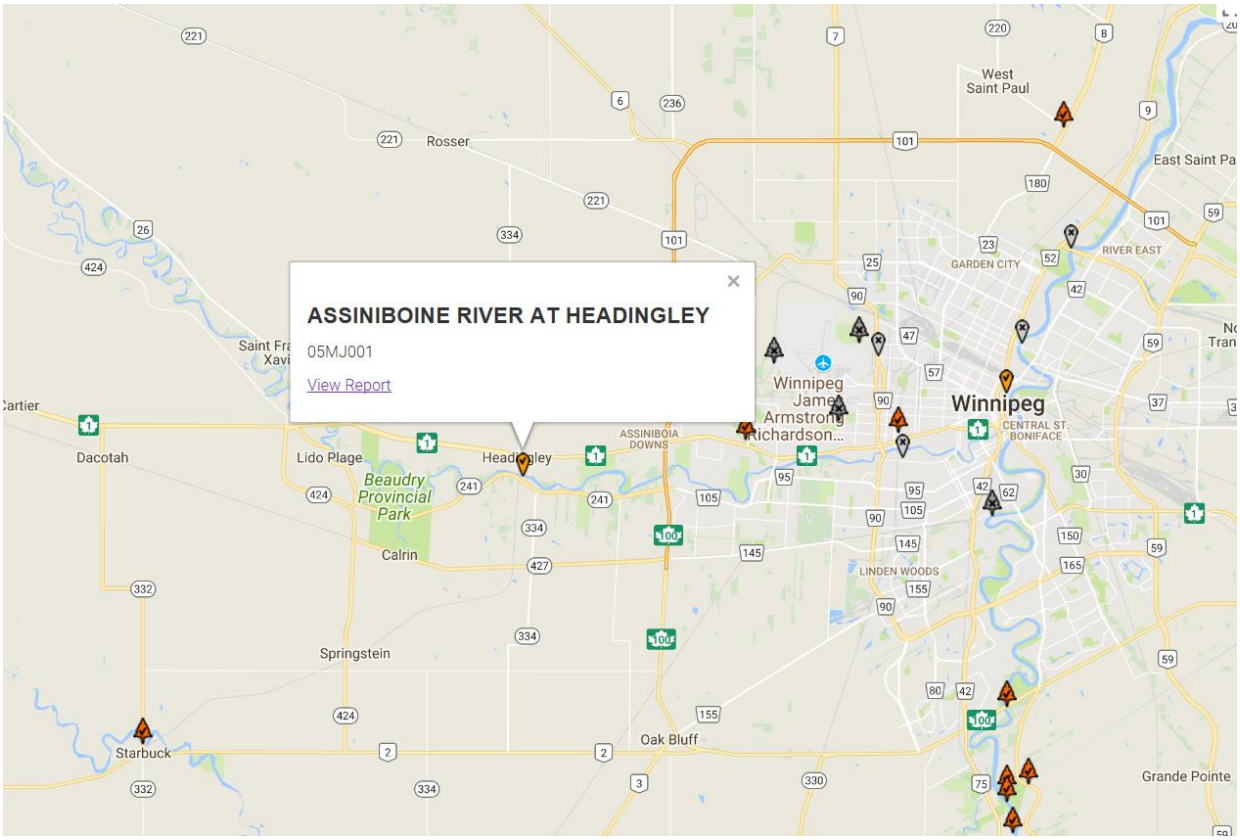


Figure 3. Map of proposed construction site for combined sewer system for the Cockburn and Calrossie combined sewer relief project in Winnipeg, Manitoba: includes closest hydrometric data station for the Assiniboine River at Headingley




Works Cited

Bodnaruk, B., Curi, F., Ewing, J., Houston, R., Huth, A.K., MacMillan, D., Parente, M., Sharp E., Turcotte, D., Volden, R., Wilcox, M, Zhu, J. (May 2010). Cockburn and calrossie combined sewer relief works project final conceptual report. Retrieved from http://winnipeg.ca/waterandwaste/drainageFlooding/pdfs/CockburnCalrossieFinalReport_web.pdf

Water Survey of Canada - WSC. (191-). Historical hydrometric data [Data file]. Available from https://wateroffice.ec.gc.ca/google_map/google_map_e.html?map_type=historical&search_type=province&province=BC

Winnipeg Water and Waste Department - WWWD. (April 10, 2017). Cockburn and calrossie combined sewer relief works project. Retrieved from http://winnipeg.ca/waterandwaste/drainageFlooding/cockburn_calrossie_cso.stm