**GEOG 314 (Winter 2023/2024)**

**University of British Columbia**

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## INTRODUCTION

The Vancouver region in British Columbia is known for its coastal landscapes. Therefore, alongside this natural splendor, it faces more challenges of flooding, which poses significant risks to communities, infrastructure and the environment. Due to Vancouver's geographical location, factors such as heavy rainfall, snow-melt, storm surge and seawater rising are the major attributions to previous flood events. Urban development, land-use-land-cover change and alteration of drainage systems could influence flood severity, thus causing different levels of damage to property, disrupting transportation/ social networks and even public safety threats.

Vancouver is the traditional, ancestral and unceded territory of the three Coast Salish Nations, and the land and ocean hold special significance for the original stewards of the land. This report is conducted using settler science and techniques of data collection, flood analysis, etc., and it is the settler neoliberal system in Canada and globally primarily responsible for the impacts of climate change, yet as discussed in this report, it is often the case that disproportionate impacts are felt by those least responsible.

This report aims to inform SLR projections in Vancouver. It uses flood frequency calculation to analyze return periods and probability for different water levels in the Vancouver region under different scenarios of sea level rise. This report uses data from 1918 as well as synthetic time series data to yield results. This report includes an explanation of SLR trends in Vancouver's past, present and future, as well as impacts, recommendations and limitations.

## RESULTS

The mean sea level rise in today's predicted values is higher than expected values due to climate change, rising temperatures, and multiple other factors. We conducted our results by taking the predicted water levels given to us in the analysis and plugging them into the calculator in the annual max height column. Then looking at the weighted skewness (Cw), we can determine our Cw upper bounds and our Cw lower bounds. Once we had the bounds, we looked at the table Frequency Factors K for log-Pearson Type III Distributions to get the values to plug into k lower and k upper, in order with lower and upper bounds. Finally, we can take our results in the column (zp, in m) and compare them to our original values in the analysis. Fig 1 and 2 are graphs looking at the difference. In our results, in Fig 1, there is a definite increase.

We see red bars as predicted values, which are drastically more than the blue bars, which are the expected results. Each return period, as noted by the x-axis, is increasing by roughly 0.3 m. Therefore, we can expect that in each return period, there will be greater amounts of water, causing more severe damage to areas that will see a high likelihood of flood risk. The other dataset that we used is the 2100 + 1m data because since Vancouver is preparing for that type of sea level rise it would make sense for us to analyze that data. Fig 2 shows the return periods of 2100 data, and it has a similar pattern to today's data. The predicted data is way more than expected, which leads to increased amounts of flooding risk for each return period. There is a rough 0.4m increase from expected to predicted levels. Looking at our observed water levels mean (Fig 3), we see the equation $y = 0.0011x + 3.04$. This tells us that water level has been steadily increasing throughout the years. Although there are drops in the data, like in 1988, the trend is still increasing. However, the R^2 value is 0.30, which tells us that the fit of the trendline isn't perfect and there are other factors affecting the trend, like climate change. The mean annual sea level change from 1919-2018 is 1.066 mm/year. The last 20 years (1998-2018), on the other hand, changed by 3.17 mm/year. In the past 20 years, climate change has drastically sped up the amount of sea level rise by over 2x what is expected. It is growing more and more important to look at future probabilities, as we can expect that our analysis will always be a bit less than predicted. We will see more and more increased rates of sea level rise, and preparation for that sea level rise will increase costs and leave a lot of people without homes.

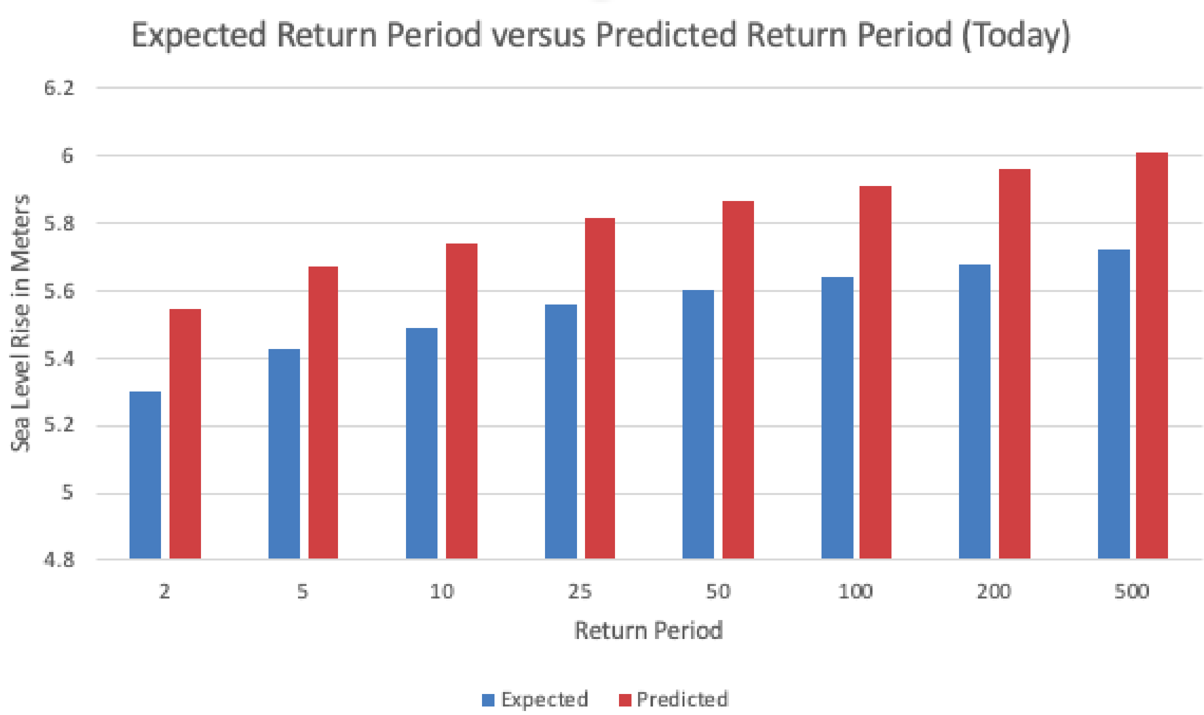


Fig 1. Return Periods of Today's values, red is predicted values (what we calculated), and blue is expected values (what we were given in analysis)

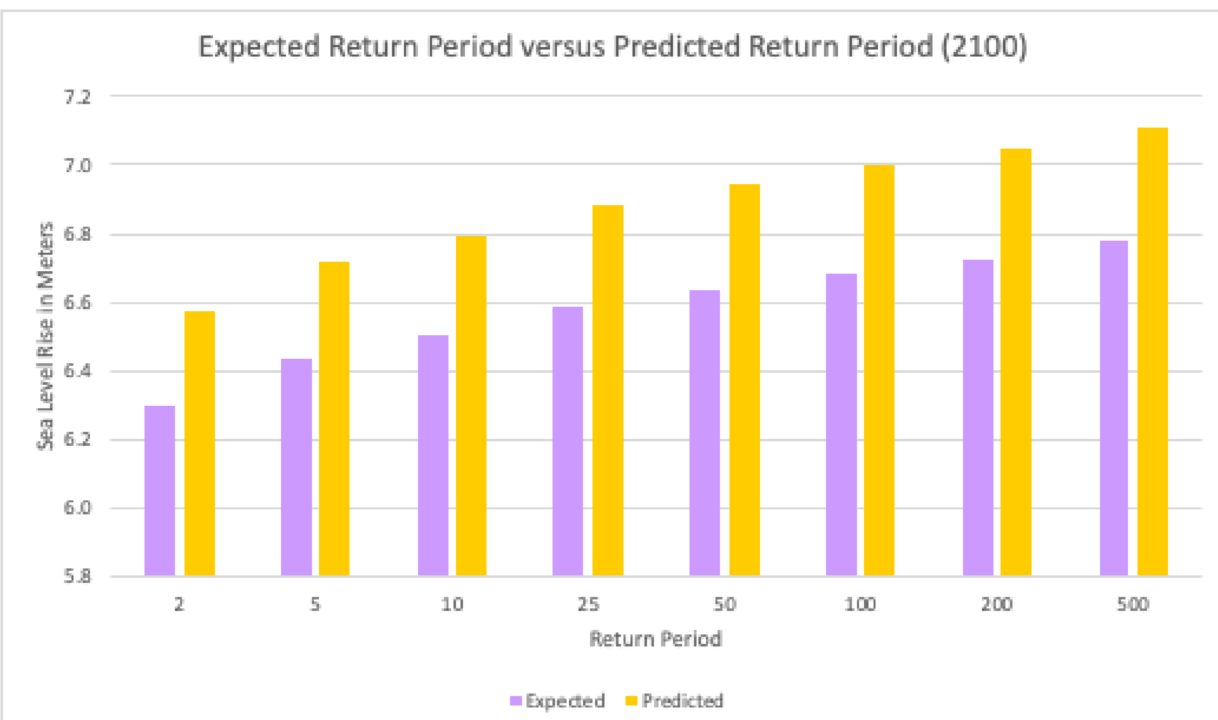


Fig 2. Return Periods of 2100 + 1m sea rise values, yellow is predicted values (what we calculated), purple is expected values (what is given in analysis)

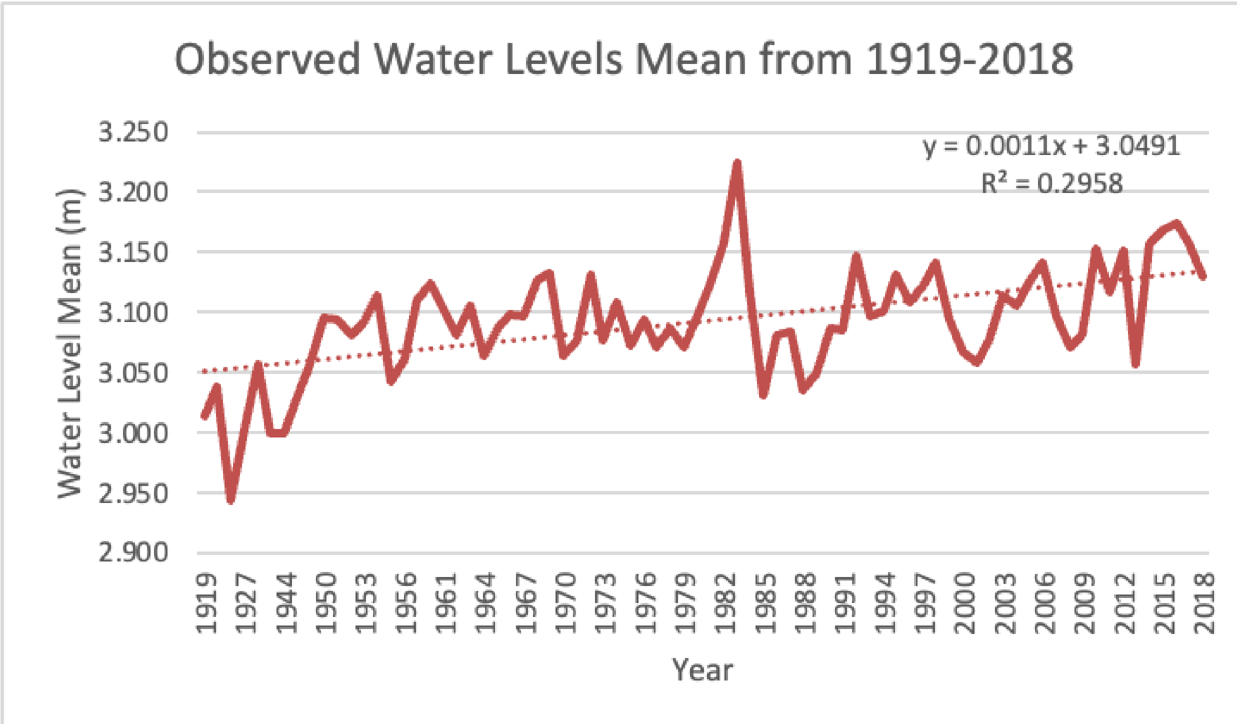


Fig 3. Observed Water Levels Means from 1919-2018 with trendline and an equation of 0.0011x + 3.0491 and an R^2 value of 0.2958.

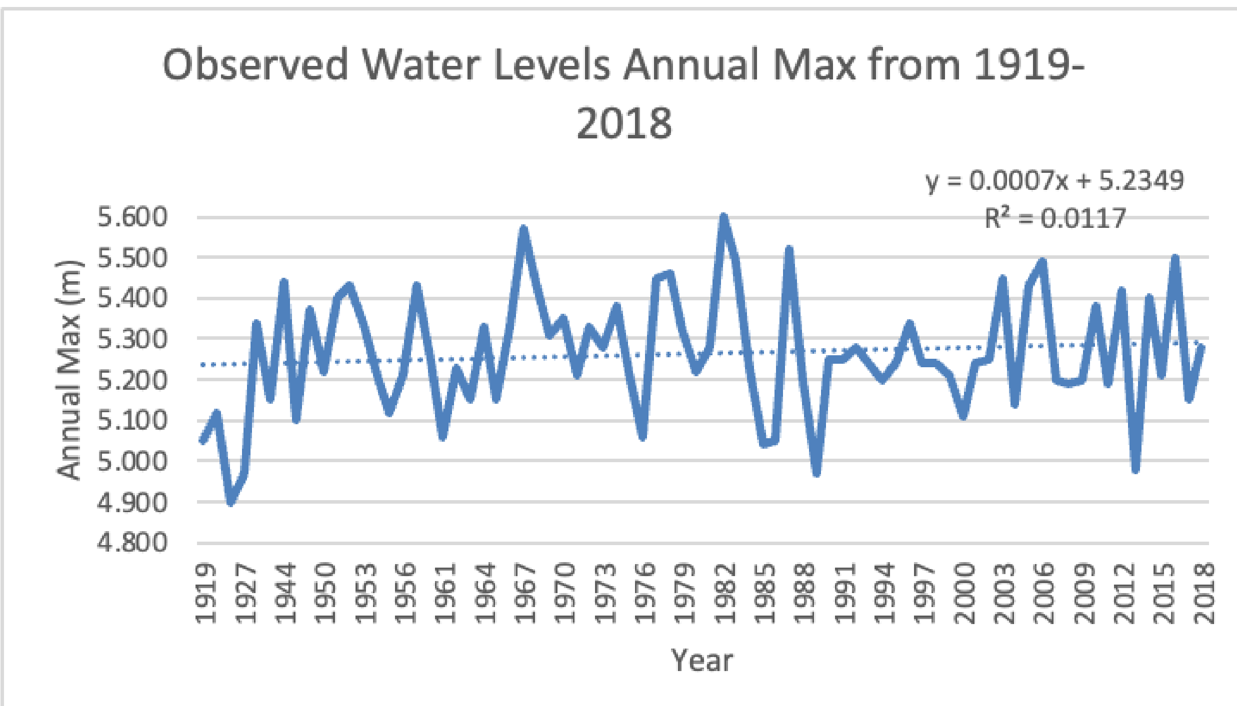


Fig 4. Observed Water Levels Annual Max from 1919-2018 with trendline and an equation of 0.0007x + 5.2349 and an R^2 value of 0.0117.

## DISCUSSION

### Sea Level Rise in Vancouver

Since 1919, there has been an observed rise in the mean water levels in Vancouver. Despite outstanding years such as 1982, where the mean water level shown seems to be an outlier, sea levels in Vancouver have been consistently trending upwards. Though the provided equation may point to a linear sea level rise, the previous 20 years have seen an accelerated rate of sea level rise. While the mean annual sea level change from 1919-2018 was 1.066 mm/year, in the last 20 years, this rate increased to 3.17 mm/year.

In the future, it is unlikely that sea levels will continue to rise at a steady rate, as current values show substantial increases in comparison to the projected values of the present day. This trend is likely to be true for projected future values as well. With a variety of complex factors that influence sea level rise, climate change being a big player in changes in sea level, it can be difficult to predict and plan exactly how severe sea level rise in Vancouver will be in the future.

Preparations for sea level rise are more often designed for high-water extreme events rather than mean sea-level rise, but coastal cities such as Vancouver should begin to plan around the possibility of continued mean sea-level rise. Spring tides, moon cycles, and storm surges can all increase the probability of high-water events, but with mean sea levels increasing, coastal planners may need to start treating high-water event infrastructure as the norm to avoid injuries and damage. New developments must be made with flood construction levels in mind, not only taking into consideration current flood levels but future flood levels as well.

Though coastal planners may be able to prevent danger in new developments, they should also account for the potential displacement that may occur with rising mean sea levels. Preparations for sea-level rise should include policies that safeguard affected and vulnerable communities, as well as looking into solutions that minimize socio-economic risk.

## Impacts of Sea Level Rise in Vancouver

Due to the location of Vancouver as a coastal city, and the high cost of living and value of land, coupled with the settler history, the human, economic, and environmental impacts of SLR have the potential to be quite severe. Three main areas will be at an increased flood risk: Fraser River foreshore, Jericho Spanish banks, False Creek, and the port lands. (p. 6 City of Vancouver n.d.). The Fraser River foreshore is the largest area impacted and holds additional cultural impacts due to the location of the Musqueam reserve territory (p. 6 City of Vancouver, n.d.).

Human impacts are not limited to those living in the food areas but rather to all residents of Vancouver. Loss of land, livelihoods and belongings, along with potential forced relocation, are among the primary impacts that hold repercussions for the social, emotional, and financial well-being of citizens. At the same time, decreased access to natural public spaces is also a forecasted outcome due to the projections of flood events on pubic and parkland, especially in areas such as Jericho foreshore and Kitsilano (p.6, City of Vancouver n.d., City of Vancouver n.d.). Additional human impacts include cultural impacts; as mentioned previously, the main area affected by SLR in the Fraser River Foreshore is the Musqueam reserve territory. The cultural importance of coastal spaces in the city of Vancouver for all residents cannot be overstated, however especially in the context of the settler history of the city and the country, the loss of what little territory is left for first nations such as the Musqueam and impacts of this, such as loss of cultural spaces, decreased access to traditional foods, archaeological sites, all hold severe implications for health and wellbeing of the nation (Chubb 2024, p. 1,6 City of Vancouver n.d.)

SLR impacts in Vancouver hold large economic implications, both for the city and individuals living there. The costs of relocating and/or updating critical infrastructure, as well as increased drainage issues in low-lying areas, resulting in a raised groundwater table and increased sewer backups and localized flooding, are among the key impacts that will cost the city (p.6, City of Vancouver n.d.). In a city such as Vancouver, where the average home price is over 1m, the high value and small amounts of land will result in large economic impacts for both the city and individuals. Increased costs will also include increased costs of flood insurance and the decreasing availability of insurance. (p. 1, 6 & 15, City of Vancouver n.d.). An example of this happening already is in the Stanley Park seawall, which has been damaged due to the increasing extreme water events, notably record king tides in 2022, and a replacement could cost the city 250 million (Saunders 2023).

Environmental impacts for the city include coastal inundation and reduced drainage capacity, coastal erosion, increased salinization of groundwater, and changes and loss of coastal habitat resulting from coastal squeeze: the phenomenon in which space for coastal habitats is reduced by a combination of sea level rise and human interventions such as dykes, sea walls, etc. (Chubb 2024). In a city such as Vancouver that has extreme rainfall, which will be further increased from climate change, we will see increased flooding from a coupling of impacts of climate change.

**Recommendations for SLR adaptation and mitigation in Vancouver**

In the context of SLR in city planning, plans must include extreme events: the culmination of high tide / king tide on a spring tide or storm surge. As evidenced by the results, Vancouver will experience an increase in high-water events. The BC government has set a precedent of planning for 1m SLR for 2100 when building, zoning, and subdivisions, and 2200 for land use adaptation, with a minimum 1:200 return period (Chubb 2024, City of Vancouver n.d. ). After reviewing the results of this report, SLR adaptation strategies are recommended; adaptation is defined as strategies that can be modified in the future: this is key due to the variability in severity of impacts depending on the emissions scenario we end up on (Chubb 2024, City of Vancouver n.d.).

Combination measures are recommended, in alignment with the City of Vancouver reports as the most likely measures used (City of Vancouver n.d.). Combination measures include both protection and resistance measures. Retreat measures, also known as avoid measures, plan for the eventual relocation of people and infrastructure in high-risk areas, as well as restricting new developments (Chubb 2024). Though expensive, these are suitable for high emissions scenarios (Chubb 2024). Protect measures, also known as resist measures, aim to build structures to keep flood waters out of areas dry as opposed to keeping out floodwaters; these can include both soft measures, such as wetland restoration, and hard measures, such as dyke constructions (Chubb 2024).

After conducting community engagement with residents of Fraser River floodplains, results showed that after early-stage conversations, the strongest interest was portrayed in a resist approach, with many putting avoid approaches and relocation as a last resort. The priority expressed was to design for adaptability, co-benefits, nature, safe-to-fail infrastructure, and others (City of Vancouver, 2018, n.d.)

With the results in mind, showing an increased probability of extreme events and the likelihood of SLR, it will be essential to encourage flood resilient design standards via bylaws to ensure the lowest possible lifetime risk of infrastructure and to adhere to floodplain maps and assessments in construction of new critical infrastructure. Additionally, it will be essential to fund up-to-date floodplain mapping and risk assessments, especially due to the variability in SLR depending on different emissions scenarios (Chubb 2024 ).

## Conclusion

The main finding of our report is that sea level rise is not stopping. Climate change, rising temperatures, rain intensity, and more urbanization are just some factors that are aggravating sea level rise. Each return period from 10 years to 500 years will be more damaging to structures, homes, and overall health due to the increase in sea rise. Historic sea level rise cannot be used to predict future increases, given the accelerating pace of climate change. (City of Van 2018) The human, cultural, economical, and environmental impacts that arise from sea level rise will be important to keep in mind as we find ways to adapt or mitigate for change. In the past 20 years, there has been an expedited rate of sea level rise from climate change. Overall, we are seeing a 1-2 mm/year increase with a predicted 5.8m rise for a 100-year return period. The City of Vancouver is now preparing for this change by either using adaptation or mitigation methods. Some of the adaptation methods listed by the city include building structures like seawalls and dikes, accommodation like raising structures, relocation of assets, and a combination of methods. However, with adaptation comes a cost. Resources will be needed for most projects, which allocates an economical impact. Some of the human and cultural impacts of adaptation include loss and homes, loss of land and the loss of property if relocation or any of the other methods is needed. Some of the mitigation methods include raising land through development, making flood-proof housing and nature-based design to stop water from reaching homes. Mitigation techniques also require major resources. There is no silver bullet that solves sea level rise but mitigation and adaptation methods can slow down the effects.

## Contribution statement

**Ashley Cheng:** Helped with the introduction and impact part, and did the calculations and conducted the charts in the result section.

**Tala Zhang:** Helped with discussion segment of SLR in Vancouver.

**Jeffery Liao:** Helped with results and finished the conclusion.

**Ayesha Andrews:** Helped with the impact part and recommendations

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