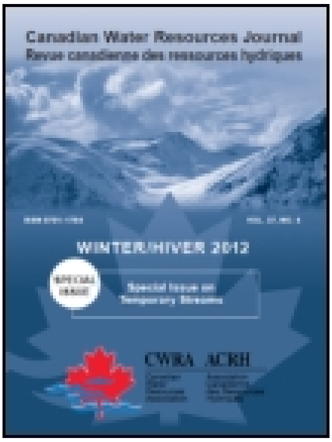

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The Vulnerability of Lower Englishman River to Modelled Climate Change

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The Vulnerability of Lower Englishman River to Modelled Climate Change

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ABSTRACT

It is generally accepted in scientific circles that the earth's atmosphere is warming, and that this warming trend is projected to increase as a result of atmospheric carbon dioxide doubling, by the end of this century. Such warming will affect regional precipitation patterns and thus river hydrology. This study focuses on the effects of modelled regional climate change on the frequency and magnitude of flooding along the floodplain of the Englishman River on the east coast of central Vancouver Island, British Columbia. Using the results of a regional climate model (Reynolds, 2002), we found that there will be changes to the flood regime of the river. Peak annual flows may be 8% larger by 2020, 14% larger by 2050 and 17% larger by 2080. This means that an increase in the frequency and magnitude of flows is likely in the future. For example by 2020, the 15–year flood is expected to have a slightly greater magnitude than the current 20–year flood, and by 2080, the 10–year flood is expected have the same magnitude as the current 20–year flood. The changes in flood magnitudes will have significant impacts on people living on the floodplain. Large areas of the floodplain are currently occupied by houses, and much of the remaining area is zoned for further subdivisions. The current bankfull flood is predicted to increase, and for this to occur there will be a change in the morphology of the channel.

RÉSUMÉ

Dans les milieux scientifiques, on s'entend en général pour admettre que l'atmosphère de la planète se réchauffe et que cette tendance au réchauffement devrait aller s'accentuant du fait que le gaz carbonique atmosphérique sera deux fois plus élevé d'ici la fin du siècle. Un tel réchauffement influera sur les modèles de précipitation régionale et par conséquent sur l'hydrologie fluviale. La présente étude met l'accent sur les effets du changement climatique régional modélisé sur la fréquence et l'ampleur des inondations le long de la plaine d'inondation de la rivière Englishman sur la côte est du centre de l'île de Vancouver, en Colombie-Britannique. À l'aide des résultats du modèle

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climatique régional (Reynolds, 2002), nous avons constaté que le régime d'inondation de la rivière subira des modifications. Les débits de pointe annuels peuvent augmenter de 8 % d'ici 2020, de 14 % d'ici 2050 et de 17 % d'ici 2080. Cela signifie qu'on assistera probablement à une hausse de la fréquence et de l'importance des débits à l'avenir. Par exemple, d'ici 2020, on s'attend à ce que l'inondation avec période de retour de 15 ans soit d'une ampleur légèrement plus élevée que l'inondation actuelle avec période de retour de 20 ans et, d'ici 2080, l'inondation de 10 ans devrait atteindre la même ampleur que l'inondation actuelle avec période de retour de 20 ans. Les changements dans l'ampleur des inondations auront des retombées considérables pour les gens qui habitent la plaine d'inondation. De vastes étendues de la plaine d'inondation sont actuellement habitées et une bonne partie des zones qui restent sont prévues pour des lotissements futurs. On prédit une augmentation de l'inondation de la rive actuelle et, pour que cela se produise, il y aura modification de la morphologie du chenal.

INTRODUCTION

The climate is constantly changing. Some of these changes are of short–term duration (months to years), while others are long term (years to decades). Some changes are seemingly random, while others are cyclical. Some have clearly defined natural causes, and are referred to as 'variations' around a long–term mean, while others lead to 'records', often associated with conditions that are not 'normal'. However, a new type of change appears to be occurring. It is long term and uni–directional (IPCC, 2001) leading to a shift in the climatic means 'global climate change'. This 'global climate change' is a long–term trend (decades to centuries) which, including natural variations, has been triggered by human activity. The United Nations Intergovernmental Panel on Climate Change has concluded that the global atmosphere is warming, and that observed warming over the past 50 years can be attributed to human activities that release greenhouse gases into the atmosphere (IPCC, 1996; 2001).

This research focuses on the hydrologic impacts of modelled regional climate change on the floodplain of Englishman River, a 7th order river on the east coast of central Vancouver Island. The research attempts to answer the question "what is the vulnerability of the Lower Englishman River Floodplain to modelled climate change?"

BACKGROUND

On the BC south coast, climate change is expected to lead to warmer temperatures, more precipitation, a decreased snow pack at lower elevations, and changes to the timing and magnitude of river discharge. In general, over the next century, climate change is expected to result in several key changes. Temperatures are expected to increase 1–4°C (Coulson, 1997; Hengeveld, 1997; Whitfield *et al.*, 2002; BC Ministry of Water, Land and Air Protection, 2002), and precipitation is expected to increase 10–20% (Coulson, 1997; BC Ministry of Water, Land and Air Protection, 2002).

Variations in temperature and precipitation exert tremendous influences on the amount and form of water that reaches the land surface. Higher temperatures are expected to increase the ratio of rain to snow. For example, Loukas *et al.,* (2002) predicted 35% increase in rainfall and 65% decrease in snowfall by 2080–2100 in the Upper Campbell watershed on central Vancouver Island based on a climate change model (CGCM1). Compared to baseline data for the Englishman River, Reynolds (2002) predicted a 75–85% decrease in snow water equivalent and snow cover by 2080 using future climate change simulations.

Climate change may influence the timing and magnitude of discharge in rivers on the BC coast. Unlike much of Canada where flooding occurs during the spring freshet, floods on coastal BC occur in the fall and winter months during large rain storms or rain–on–snow events. Changes in fall and winter temperature may affect snow accumulation and hence the magnitude and occurrence of rain–on–snow events. Loukas and Quick (1999) found that higher temperatures in the Upper Campbell watershed may produce more rainfall during the wet fall and winter months, may lead to a transient, ripe snowpack, and the combined effects may result in prolonged flood events during this time. Coulson (1997) suggested that in southern BC and on the BC Coast, the spring freshet will occur up to one month earlier. Increased precipitation is typically amplified in runoff by a factor of about 1.5–2 (Karl and Riebsame, 1989). Thus, annual discharge for such rivers on the BC coast is expected to increase 10–40% (Coulson, 1997; Reynolds, 2002). These increases are projected to be primarily in the fall, and there will be lower summer flows.

Reynolds (2002) considered the hydrologic and climatic impacts of a changed climate on six watersheds (including Englishman River) representing the dominant runoff forms of Georgia Basin. Through the use of the UBC Watershed Model (Quick, 1995), it is possible to provide a forecast of the possible changes in the hydrology of the Georgia Basin in this future climate. The climatic input for the modelling came from the Canadian Global Coupled Model (CGCM1). Twenty–one year time slices (1973–1993, 2013–2033, 2043–2063, 2073–2093) were chosen from the CGCM1 to simulate the climatic and hydrologic changes over the next hundred years within the basin. Under a changed climate, the hydrological response varies significantly depending on the basin's dominant form of winter precipitation. The simulation results indicate that rain–driven systems will have higher winter streamflow driven by greater winter rains. Watersheds that are now snow–driven will experience a shift toward a hybrid–type flow regime, while hybrid watersheds, currently controlled by winter rainfall and summer snowmelt, will experience the most significant annual changes showing a strong transition towards winter rainfall driven runoff.

STUDY AREA

Englishman River is a part of the Georgia Basin drainage network located on the eastern side of the Vancouver Island Ranges of the Insular Mountains on south–central Vancouver Island (Holland, 1976), and drains a 324 km^2 watershed into Georgia Strait at Parksville on the east coast of Vancouver Island (Figure 1). Elevations in the Englishman River watershed range from Mt. Arrowsmith at 1817 masl and Mt. Moriaty at 1610 masl to sea level with a mean watershed elevation of 695 masl.

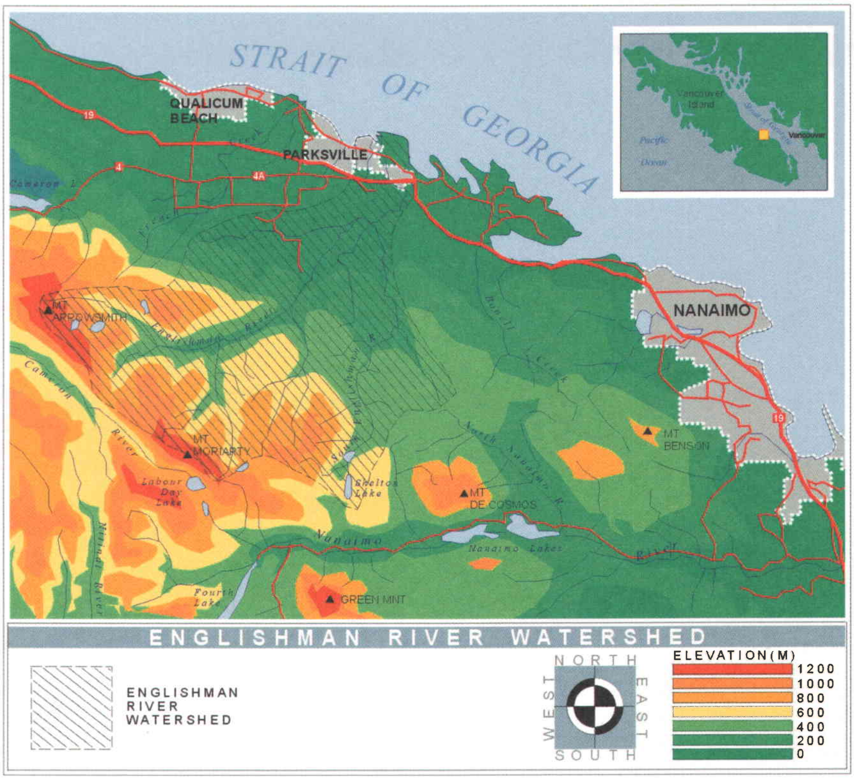

Figure 1. Englishman River Watershed.

Studies on the south coast of BC have shown that the rain–dominated zone corresponds to the 0–300 masl elevation band, the rain–on–snow zone corresponds to the 300–800 masl elevation band and the snow zone corresponds to the area above 800 masl (BC Ministry of Forests, 1999; Hudson, 2001; Hudson, personal communication, 2003).

Approximately 30% of the watershed area lies within the 0–300 masl rainfall dominated elevation band. Above that, approximately 60% lies within the 300–800 masl rain–on–snow elevation band, and approximately 10% of the watershed is within the snow fall elevation band, higher than 800 masl.

The Englishman River is primarily a rain–driven hydrologic system (Wade and Whitfield, 2001), which is influenced by heavy fall and winter rain and rain on snow. The majority of flow occurs during the fall and winter months with the summer period characterized by low discharges. Figure 2 shows the modelled average daily discharge of the river between 1973 and 1993 (Reynolds, 2002) in 5–day time slices. Observed flow data do not exist for Englishman River during this entire time period. However, from existing real data, the hydrograph is considered to be relatively accurate. Heavy fall and winter rainfall starting about October (time slice 60) and lasting until about April (time slice 20) causes peak annual flows, lower spring precipitation coupled with melting of snow from April to May (time slices 21–29) result in decreasing discharges, and dry summers from June to September (time slices 30–60) result in low discharges.

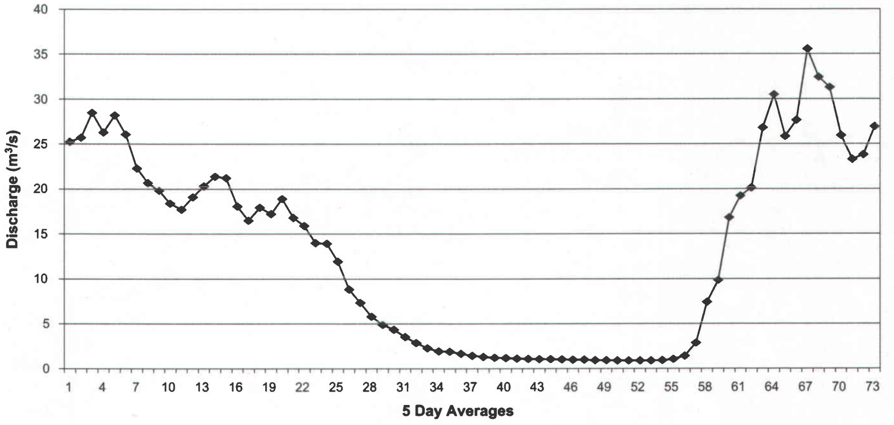

Figure 2. Hydrograph of the Englishman River for the period 1973–1993 (x axis period #1 January 01, end of period #73 December 31). From Reynolds (2002).

As the river system is of moderate size with no lakes of significant size that moderate peak flows through storage, the river exhibits a very 'flashy' hydrologic response to rainfall events. (In other words, the river rises quickly in response to rainfall and rapid snowmelt, and falls quickly after the rain event ends.) On March 13, 2003 for example, a flood occurred during which the river rose approximately 2 m in 24 hours. This represents an increase in discharge from 20–313 m^3/s.

The study area is the floodplain of the Englishman River downstream of the Highway 19 bridge to the 4.1 masl point on the floodplain where there is tidal influence from Georgia Strait. The floodplain is defined by BC Ministry of Environment, Lands and Parks (1985) 200–year floodplain mapping (see Figure 3). The study area is located partially within the jurisdiction of the City of Parksville and partially within the jurisdiction of the Regional District of Nanaimo. It is approximately 1.82 km^2, and comprises the low elevation floodplain with elevations that range from 3–15 masl.

METHODS

This project builds on research conducted by Reynolds (2002). In his study, models were customised and used to simulate hydrologic conditions for three future climate change scenarios (2013–2033, 2043–2063 and 2073–2093) and were compared to a model–simulated background period (1973–1993). In this study these time

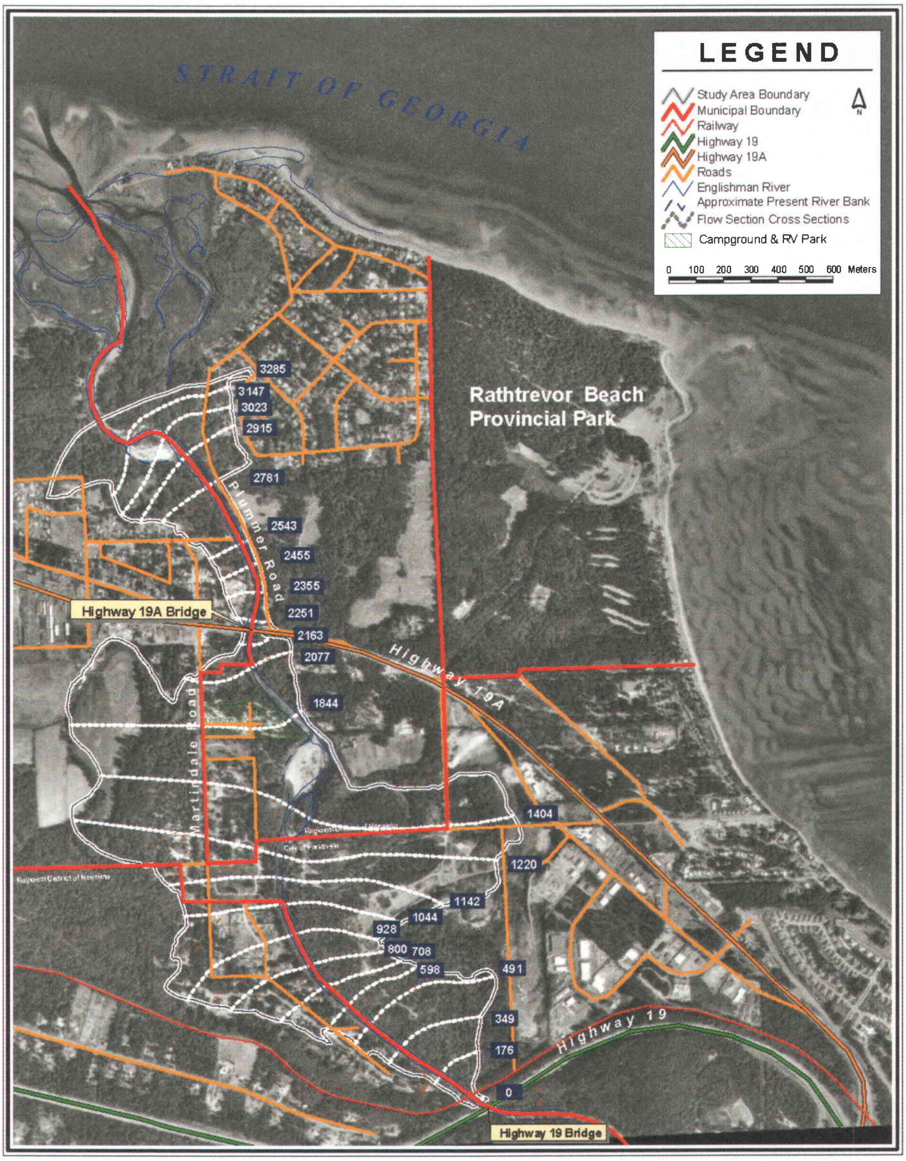

Figure 3. Study Area.

scenarios are referred to as 2020, 2050 and 2080, respectively. The 1973–1993 period is referred to as the background period. The methodology for these models are discussed in Reynolds (2002) and Whitfield *et al.* (2002).

To answer the research question, present discharge trends were determined. Methods used are described in detail in Weston (2003), and included a flood frequency analysis, the generation, extension, and analysis of the river rating curve, the generation of floodplain cross–sections and a longitudinal profile, and the estimation of the bankfull flood.

An analysis or the Englishman River hydrology was then conducted to determine the present bankfull, 2, 5, 10, 15 and 20–year flood elevations along the floodplain. Modelled estimates were calibrated by a flood in March 2002, equivalent to the 3.1–year flood event. This event is referred to as the observed discharge scenario.

Future annual peak discharges for the three time periods were then calculated using the future annual average five–day discharge values produced by Reynolds (2002) (Table 1). The percent change over the baseline was then applied to each of the present bankfull 2–year, 3.1–year, 5–year, 10–year, 15–year and 20–year annual peak instantaneous discharge values to provide future bankfull 2–year, 3.1–year, 5–year, 10–year, 15–year, and 20–year peak instantaneous discharge values for each time period.

In order to determine the vulnerability of the Englishman River to climate change, future modelled discharge values were obtained by making use of the results derived from precipitation data generated by a numerical climate model discussed in Reynolds (2002) and Whitfield *et al.* (2002).

The maximum annual average 5–day daily discharge values for the Englishman River, modelled by Reynolds (2002) are shown in Table 1.

Table 1. Maximum annual average 5–day daily discharges for the baseline (1973–1993) and future (2020, 2050 and 2080) time periods (from Reynolds, 2002).

Return Interval	Current Q	Q2020–8%	Q2050–14%	Q2080–17%
1.4–1.5 (bankfull)	233–240	252–259	266–274	273–281
2	269	291	307	315
3.1 (observed)	313	338	357	366
5	362	391	413	424
10	432	467	492	505
15	473	510	539	553
20	502	542	572	587

The changes in maximum annual average 5–day discharge from the baseline period for each of the three future scenarios were calculated. For example, if there is 10% difference between baseline flow and 2080 flow, and the 2–year baseline flow is 100 m^3/s, then the 2080 2–year flow will be 110 m^3/s.

Increases in annual maximum peak flow are often proportionally greater than those of flows averaged over a period of days (Ashmore and Church, 2001; Coulson, 1997; U.S. National Research Council, 1999). For example, in the Cordillera, the increases in mean annual flood from 1947–1979, over pre–1947 levels are about 30% and about 35% for the 10–year flood, compared to about 20% for the mean annual flow (Ashmore and Church, 2001). Coulson (1997) states that an increase in the maximum monthly runoff would indicate a potential for an increase in peak daily flow in British Columbia. The U.S. National Research Council (1999) has developed a relationship between three day average flows and instantaneous peak flows:

$$Q_3 = 0.394^* Q_P^{1.027} \qquad [1]$$

Where Q_3 is average 3–day flow and Q_P is instantaneous peak flow.

Using their formula, an average 3–day flow of 200 m^3/s would be proportional to an instantaneous peak flow of 431 m^3/s.

Based on the above data, it has been conservatively assumed that an increase in the maximum annual average 5–day daily discharge is proportional to an increase in annual instantaneous peak flow. The justification for this assumption is that if there is an increase in average flow there should be an increase in the entire range of flows, including the instantaneous peak. It was assumed that the peak flows observed to date would follow this future predicted pattern.

The change over the baseline was then applied to each of the present calculated 2–year, 5–year, 10–year, 15–year, 20–year and observed discharge annual peak instantaneous discharge values to provide future 2–year, 5–year, 10–year, 15–year, 20–year and observed discharge annual peak instantaneous discharge values for the periods 2020, 2050 and 2080.

RESULTS

Should the Reynolds scenario occur, an 8% increase in annual peak discharge at year 2020, a 14% increase at 2050 and a 17% increase at 2080 should be expected. This means that by the year 2020, the 15–year flood may have a slightly greater magnitude than the current 20–year flood, and the 10–year flood may be similar in size to the current 15–year flood. The 5–year flood may have the same magnitude as the current 6.7–year flood and the 2–year flood may have the same magnitude as the 2.5–year flood. The bankfull flood is not expected to be significantly larger, and still less than the current 2–year flood. However the increased discharge associated with the flood is expected to lead to changes in the channel morphology.

By the year 2080 the 10–year flood is expected to have the same magnitude as the current 20–year flood. The 5–year flood is expected to have the same magnitude as the current 9.2–year flood and the 2–year flood is expected to have nearly the same magnitude as the current 3–year event. The bankfull flood is expected to be larger than the current 2–year flood. This suggests there will continue to be instability in the channel, with bank and channel erosion and corresponding deposition.

The current bankfull flood is estimated to have a discharge of 233–240 m^3/s. By 2080, this discharge is predicted to increase to 273–281 m^3/s. This means that by 2080, on average, the channel forming flow (1.4–1.5 year return) will have flows currently equivalent to discharge that presently occur every 2.2–2.5 years. Channel geomorphology will change by 2080 to compensate for increased discharges. The channel may become deeper and remain within the existing banks, or become wider, leading to erosion of the banks and loss of land along the river. The river may also cut a new channel through lands that have not experienced flows in recent history.

Table 2 outlines the present bankfull (2, 3.1, 5, 10, 15 and 20–year) peak flow discharges, and future annual peak discharge values for the same time periods.

Table 2. Maximum annual average 5–day daily discharges for the baseline (1973–1993) and future (2020, 2050 and 2080) time periods (from Reynolds, 2002).

Maximum Annual Average 5–Day Daily Discharge (m^3/s)	
QBaseline	35.53
Q2020	38.46
Q2050	41.17
Q2080	42.85

CONCLUSION

This study has determined how the Lower Englishmen River floodplain is vulnerable to expected changes in precipitation and temperature likely to be experienced in the next 80 years as a result of global climate change.

The Englishman River, like many other rivers with a similar hydrologic regime in the area, is vulnerable to floods of increased frequency and magnitude if modelled climate change occurs; these floods may be up to 8% higher in magnitude by 2020 and 17% higher in magnitude by 2080. Based on this work a major consequence would be the advancement of return periods of flood events. In the Englishman River, by 2020, the 15–year flood is expected to have a slightly greater magnitude than the current 20–year flood, and the 10–year flood is expected to be similar in size to the current 15–year flood. The 5–year flood is expected to have the same magnitude as the current 6.7–year flood, and the 2–year flood is expected to have the same magnitude as the 2.5–year flood. However, the bankfull flood is not expected to be significantly larger and should still be less than the current 2–year flood. By 2080, the 10–year flood is expected to have the same magnitude as the current 20–

year flood. The 5–year flood is expected to have the same magnitude as the current 9.2–year flood, the 2–year flood is expected to have nearly the same magnitude as the current 3–year event, and the bankfull flood is expected to be larger than the current 2–year flood.

The change in flood magnitudes will have significant impacts on people who live on the floodplain. For example, someone living in an area of the floodplain flooded, on average, once every 20 years (the 20–year floodplain), should expect by 2080 to be flooded, on average, once every 10 years. The 20–year floodplain will become the 10–year floodplain. Every year there is a 5% chance that the 20–year floodplain will flood and every year there is a 10% chance that the 10–year floodplain will flood.

Large areas of the floodplain are currently occupied by houses, and much of the remaining area is zoned for further subdivisions. By 2080, residents of the west side of the floodplain, south of Highway 19A, could be faced with access interruptions approximately every two years, and the residents of the trailer park and campground would be partially or fully flooded. Similarly, residents in a large subdivision to the northeast of the study area access their houses through the study area. Their access road, currently protected from floods up to the 10–year return period, will become vulnerable to minor flooding by the 5–year flood by 2020 and inundated by the 5–year event by 2080. By 2080, the bankfull flood is predicted to increase from a discharge of approximately 240 m^3/s to approximately 281 m^3/s. For this to occur there will have to be a change in the morphology of the channel.

RECOMMENDATIONS

As a result of global climate change the actual impacts to people who live, work and play on the Englishman River floodplain will depend on the nature of the actions taken by all levels of government over the next few years. Based on the findings of this project, the following recommendations are provided:

- Both the City of Parksville and the Regional District of Nanaimo should consider zoning flood–prone areas for no permanent development, using the land for uses such as parks and recreation.

- If the political will does not exist for this option, future residential lands must be zoned and designed to prevent future infrastructure investments and the loss of human lives from flooding. Development fees should be charged now so money can be invested to provide for the necessary flood protection in the future at no additional charge to the governments of the day. This holds the present rather than future generation responsible for costs, which seems fair, as the present generation receives the immediate benefit while not experiencing the future costs.

- Municipal, regional district and provincial planners should be made aware immediately of the expected changes to the hydrology of Englishman

River and its floodplain as a result of climate change. A summary of the findings of this study should be presented to each of the appropriate governments and be brought before each of their governing councils.

- Provincial and municipal governments responsible for civil engineering, water, waste–water and storm–water works in the Parksville and RDN areas should be made aware that the use of climatological averages based on the past 30 years is not a useful predictor of the future for design, construction and maintenance of such works.

- Instead of using the climatological averages regarding streamflow in the Englishman River, the findings of this thesis should be used; particularly the future instantaneous peak flow discharge return intervals, the changes to bankfull discharge, and the corresponding floodplain mapping.

- Changes in hydrology should be taken into account in designing, repairing, and building civic works such as roads, bridges, dykes and docks.

- Forestry managers on the east coast of Vancouver Island should be aware of the impact of climate change on hydrology and biogeoclimatic zones. Forestry infrastructure such as roads and bridges, and forestry operational procedures such as rainfall shut down guidelines may need to be redesigned, replaced or updated.

- Watersheds similar to the Englishman River on the east coast of Vancouver Island should be investigated to identify where human infrastructure exists. The methods of this study can be used to determine if this infrastructure will be vulnerable to increased flooding due to climate change.

- Regional climate models and the information based on such models should continue to be refined and updated as more knowledge and information becomes available.

In conclusion, it is important to realize that, without a determined effort, the development and implementation of strategies to adapt to increased frequency and magnitude of flooding will not occur before damages occur. To avoid this, policy makers must be prepared to make decisions based on future models rather than on past facts. Decisions must be carefully weighed when considering the social, ecological and economic costs of adaptation in the future. The Englishman River floodplain is vulnerable in many ways to the expected changes in the global climate. Current actions by governments are only leading to significant future costs, liabilities rather than assets for future generations; short–term gain for long–term pain!

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Appendix A

Photo 1. March 13, 2003. Martindale Road is flooded–cutting off access to the entire west floodplain south of Highway 19A.

Photo 2. March 13, 2003. Flooding along Martindale Road. The partially submerged sign warns the area is prone to flooding.

Photo 3. March 14, 2003. Approximately 24 hours after the peak of the flood. The water is receding in a trailer park on the west side of the floodplain. The person is pointing to the water elevation maximum.

Photo 4. March 14, 2003. Approximately 24 hours after the peak of the flood. The water is receding in a trailer park on the west side of the floodplain. Cars still have difficulty driving.

Photo 5. March 14, 2003. Approximately 24 hours after the peak of the flood. Some cars are not driveable.

Photo 6. March 14, 2003. Approximately 24 hours after the peak of the flood. A building in the trailer park is flooded.