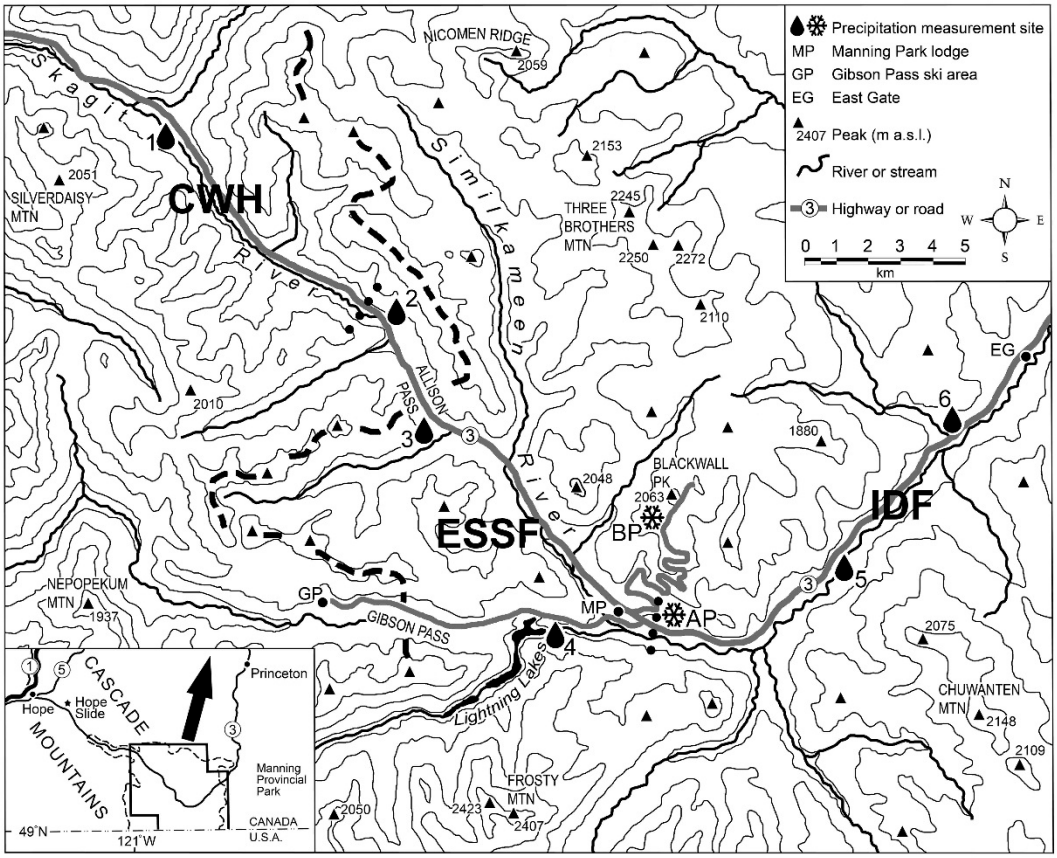
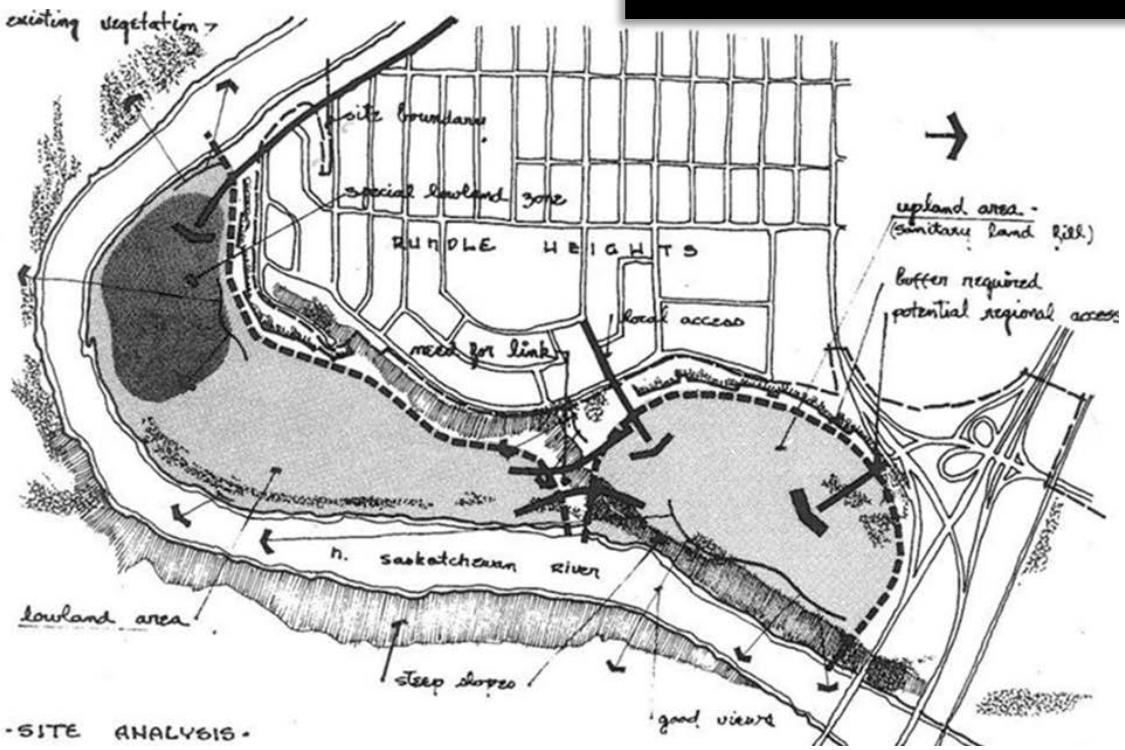
Volume 22 | 2016



Western Geography



Western Geography – Editors' Note

Volume 22 – 2016

Another year has passed and another edition of Western Geography was produced. The majority of the articles presented in this volume represent student research presented at the Western Division, Canadian Association of Geographers (WDCAG) Conference in Prince George, BC (2016).

The Editors would like to thank all the students and professors for submitting their work for consideration in this issue. Without the submissions, there would be no journal. Without the reviewers – quality suffers. Through the process of overseeing the development of the manuscripts, the editors can see the development of young scholars and feel the growth of the spirit of Western Geography.

We look forward to many submissions for Volume 23.

The Editors,

Craig Coburn, University of Lethbridge

Tom Waldichuk, Thompson Rivers University

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Assessing walkability: Comparison of street segment indices for the James Kennedy Elementary School catchment, Township of Langley, BC

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Abstract: *Walkability, a measure of how well-suited an area is to walking, has often been quantified through walkability index audits. This study aims to compare the indices of Pedestrian Environment Data Scan (PEDS), Pedestrian Environmental Quality Index (PEQI), and Walk Score in the study area of the James Kennedy Elementary School catchment zone in the Township of Langley, BC. Our objectives were to better understand how well these indices are correlated, how they differ in their factors and results, and in what ways they could be improved. Our results indicated that in the James Kennedy Elementary School catchment (Langley, BC), the PEDS and PEQI scores, which both place an emphasis on physical surroundings, were highly correlated (r = 0.601; p = 0.000). In comparison, Walk Score, which focuses on accessibility to services, showed some degree of correlation with PEQI (r = 0.333; p = 0.003), but was not significantly correlated with PEDS (r = 0.148; p = 0.189). To create a holistic walkability index, we recommend that the index should incorporate qualities of the built environment, accessibility to services, as well as resident perceptions.*

Keywords: walkability, built environment, urban design, accessibility

Background

Walkability refers to "the extent to which the built environment facilitates or hinders walking for purposes of daily living" (Andrews et al. 2012, p. 1926). Many studies on the topic of health geography have found that walkability is an important factor in promoting physical activity in a population (Berke et al. 2007, Frank et al. 2005, Frank et al. 2007, James et al. 2013, King et al. 2011). For example, in a study by Sundquist et al. (2011), residents living in highly walkable neighbourhoods were compared to those living in less walkable neighbourhoods and were found to be 77% more likely to walk for active transportation and 28% more likely to walk for leisure. Individuals in highly walkable neighbourhoods also completed 50 minutes more walking per week for active transportation compared to those in less walkable neighbourhoods. Furthermore, increased physical activity is correlated with improved population health, including increased longevity and decreased risk of cardiovascular disease, diabetes mellitus type 2, and some types of cancer. Although it might seem simplistic that merely creating a physical environment with high walkability

would directly correlate with an increase in physical activity, even those residents wholly willing to participate in walking in their neighbourhood may be hindered from doing so by obstructions to walkability (Hajna et al. 2013). Redevelopment of neighbourhoods with poor levels of walkability is time-consuming and expensive, so it is important to study neighbourhood walkability carefully and in the proper contexts (Sundquist et al. 2011) in order to plan for walkability in new developments.

Empirical evidence for walkability presents a variety of methodological challenges. A number of commonly used indices have been created to aid in measuring walkability by quantifying a particular combination of neighbourhood characteristics such as land use mix, sidewalk buffer zone width, and pedestrian amenities. Some indices attempt to quantify perceived walkability through survey questions about how safe the pedestrian feels or how likely the pedestrian is to walk a given street segment again (Clifton et al. 2007; Leslie et al. 2005; Nickelson et al. 2013; Program on Health, Equity and Sustainability 2008). The applicability of these indices is dependent on several factors, including the availability of specific spatial data, time and budgetary constraints, and the logistical complexity involved in collecting data on perceived walkability (Boarnet et al. 2006; Brownson et al. 2004). Consequently, walkability indices are often chosen and modified to suit a given study area, as there are large differences in the types of built environments between different regions, countries, and continents (Sundquist et al. 2011). Furthermore, few studies use more than one index on the same study sample (Clifton et al. 2007; Nickelson et al. 2013). However, recognizing inherent differences in approach, methodology, and output of each index, informs our understanding of the indices' conclusions based on the strengths and limitations of the particular index being used.

Many walkability indices exist, such as Pedestrian Environment Data Scan (PEDS) (Clifton et al. 2007) and Pedestrian Environmental Quality Index (PEQI) (Program on Health, Equity and Sustainability 2008) which are street-level audit instruments. These instruments evaluate factors of street segments such as sidewalk width, path lighting, and slope. Walk Score (Walk Score 2015) is an online tool which evaluates any address in the Unites States, Canada, Australia, and New Zealand for proximity to amenities so that users can be more informed of how car-independent a location is. Examples of other walkability indices include the PIN3 Neighbourhood Audit Instrument (Evenson et al. 2009; originally designed for use in urban and rural North Carolina), the Irvine-Minnesota Inventory (Boarnet et al. 2006; originally designed for use in southern California and Minnesota), the St. Louis Audit Tool (Brownson et al. 2004; originally designed for use in St. Louis, Missouri), St. Michael's Neighbourhood Observation Data Collection Tool (Parsons et al. 2010; originally designed for use in Toronto, Ontario), and the Systematic Pedestrian And

Cycling Environmental Scan Instrument (SPACES) (Pikora et al. 2002; originally designed for use in Western Australia).

Purpose

This study aims to address these issues using several different walkability indices, namely Pedestrian Environment Data Scan (PEDS) (Clifton et al. 2007), Pedestrian Environmental Quality Index (PEQI) (Program on Health, Equity and Sustainability 2008), and Walk Score (Walk Score 2015) to assess walkability in the school catchment area of James Kennedy Elementary School in the Township of Langley, BC. Both PEDS and PEQI are short street-level audits of one and four pages in length, respectively, and do not include a resident survey section. This contributed to the choice of their usage for this study, as we had four months to complete the research and desired to use our time as efficiently as possible. PEDS and PEQI are also not specifically tailored to a particular study area, which we chose because there is no audit optimized for use in this region of Canada. Walk Score is a commonly used standard for assessing walking access to goods and services, and is often featured on real estate websites (e.g., zillow.com, estately.com, and trulia.com) so that prospective buyers and renters have a means with which to understand what their daily commutes, trips, and recreation would entail. The juxtaposition of this index with the street-level audits was intended to demonstrate how accessibility to services would correlate with environmental walkability. Our research questions included: (a) how similar are these walkability indices? (b) How do they differ in their factors and results? And (c) how can these existing indices be improved upon?

Hypothesis

We hypothesized that both PEDS and PEQI would result in similar walkability scores, as these indices use many of the same audit measures (e.g., path obstructions and path buffers). We hypothesized that Walk Score, which uses a significantly different focus of measurement (parcel-based instead of segment-based; emphasis on proximity to services instead of pedestrian environment friendliness), would have a dissimilar output. However, we anticipated seeing some positive correlation between well-serviced geographic areas (measured with Walk Score) and pedestrian-friendly locations (measured with PEDS and PEQI audits).

Study Area

The study area for this project was the catchment area of James Kennedy Elementary School in the Walnut Grove community of the Township of Langley, British Columbia (Figures 1-2). We chose a school catchment as our study area because schools are important amenities for neighbourhoods and walkability to them is of paramount importance for schoolchildren to choose active transportation. A catchment also provides a useful geographic boundary to the study area. The geographic context of the James Kennedy Elementary

School catchment, that is, the Township of Langley, is a quickly urbanizing community in a rural setting in British Columbia's Lower Mainland. The Township comprises many urban neighbourhoods as well as large tracts of land that are designated as part of the Agricultural Land Reserve. The James Kennedy Elementary School catchment area is approximately 1 km2, and includes 87 street segments and 1,671 single-family residences. The area also includes several multi-family residential communities, a secondary school, a community centre, and a commercial centre.

FIGURE 1. WALNUT GROVE AND THE COMMUNITIES OF THE TOWNSHIP OF LANGLEY, BRITISH COLUMBIA.

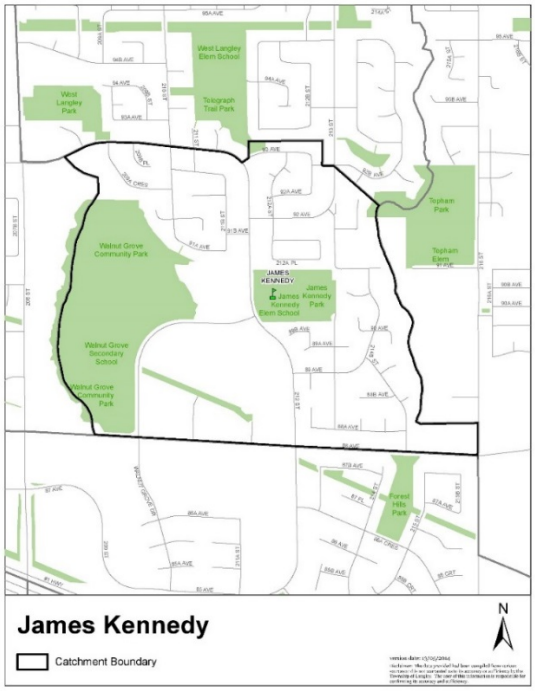

FIGURE 2. THE JAMES KENNEDY ELEMENTARY SCHOOL CATCHMENT.

Methods

Our methods included data collection of geospatial data of street segments and parcels in the catchment areas and the comparison of these indices using statistical analysis.

Data Collection

Geospatial data

We acquired geospatial data from the Township of Langley Open Data Portal (Township of Langley 2014), from which the municipal boundary, elementary catchment area, roads, and parcels shapefiles were retrieved. ArcGIS 10.2.2 (ESRI 2015) was used as the platform for computer mapping and analysis.

In order to create the base map layers of street segments and parcels within the James Kennedy Elementary School catchment, the catchment polygon was intersected with the Township of Langley roads and parcels shapefile layers to create street segments and parcels that were constrained by the James Kennedy catchment.

Walkability data

We used two street-segment audit instruments (PEDS and PEQI) and one address/parcel-based tool (Walk Score). The street-level audit instruments from both PEDS and PEQI were used simultaneously in a paper-based format in a walking survey of the James Kennedy catchment. The instruments are up to four pages for each street segment, and each segment evaluation includes a list of several factors which affect walkability. (See Clifton et al. (2007) for a full PEDS audit and the Program on Health, Equity and Sustainability (2008) for a full PEQI audit.) Examples of some factors include sidewalk width, path lighting, and slope. One PEDS audit and one PEQI audit were used for each street segment (a street length bookended by intersecting streets, or ending in a cul-de-sac) by one of us as street auditor (Heineman). The street segments were then given scores in each walkability factor, according to the particular scoring mechanism outlined in the audit instructions. This process was repeated for each of the 87 street segments in the catchment. The attributes of one street segment could be recorded on each audit instrument in about five minutes, so the auditor spent approximately ten minutes auditing each street segment and recording scores on the paper audits.

The data from the audit instruments were entered into a spreadsheet and each score was weighted according to its relative effect on walkability (e.g., sidewalk completion would receive a higher weighted score than the presence of bike racks). The PEQI index has a standardized weighting scale, but the PEDS index does not, so using our informed understanding of factors in walkability, we created a weighting scale that expressed some similarities to that of the PEQI index, but differed in its inclusion of several divergent factors from those in the PEQI index. The weighted scores were then standardized on a scale of 0 to 100 in SPSS 22.0 (IBM Corporation 2015) using Z-scores. These scores were mapped for each street segment using ArcGIS 10.2.2 (ESRI 2015) and classified by quartile intervals.

In order to obtain Walk Score data, we used the attribute table for the parcel shapefiles and generated a list of 1671 single-family residence parcels located on the audited street segments. We entered each of these addresses into the Walk Score dialog box on WalkScore.com (Walk Score 2015) in order to find the Walk Score for each address. Because Walk Score is an address-based measure, the score is spatially represented as polygons for parcels along street segments. Parcel-based walkability data are therefore not readily comparable to street-based PEDS and PEQI data. To overcome this, we buffered each street segment by 20 metres so that the

buffered area overlapped with the parcel polygons. We then intersected this new street buffer shapefile with the address parcels. The attribute table of the resulting buffer intersect file was sorted by street segment ID and an average parcel Walk Score was derived for each street segment. Walk Scores were not evaluated for strata complexes and non-residential parcels due to their large parcel size, homogenous Walk Scores, and/or lack of residential address, so the total number of street segments for which we derived Walk Score values was 80.

The data from the Walk Score website were already standardized on a scale of 0 to 100. The data were mapped for each street segment using ArcGIS 10.2.2 (ESRI 2015) and classified by quartile intervals.

Statistical Analysis

All three walkability scores were compared with each other for each of the 87 street segments using Pearson's correlation (2-tailed, $p<0.01$).

Results

Our results include maps of all three walkability indices as well as results from the statistical analysis which compared the walkability indices for correlations.

Maps

An examination of the mapped results of the audit scores appear to show similarities between PEDS and PEQI, but not necessarily Walk Score (Figures 3-5).

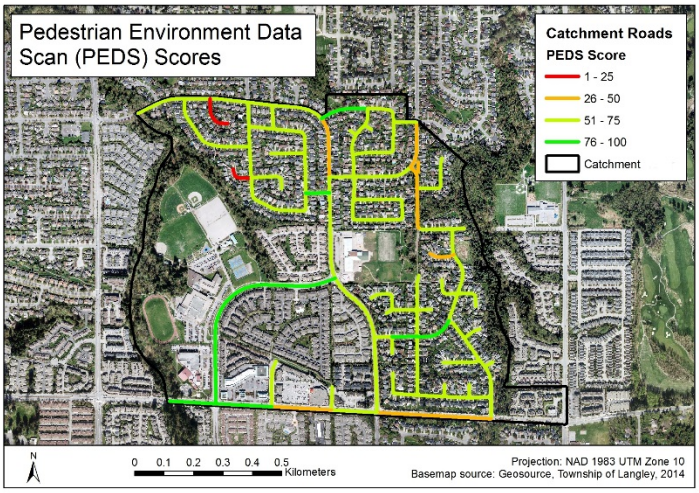

FIGURE 3. PEDS STREET SCORES FOR THE JAMES KENNEDY ELEMENTARY SCHOOL CATCHMENT.

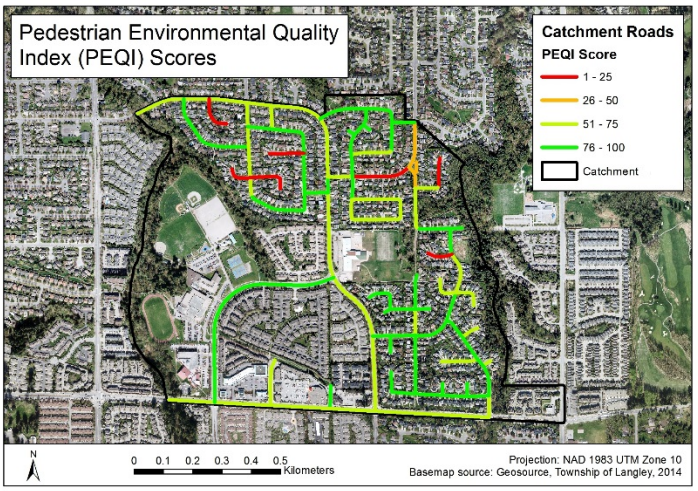

FIGURE 4. PEQI STREET SCORES FOR THE JAMES KENNEDY ELEMENTARY SCHOOL CATCHMENT.

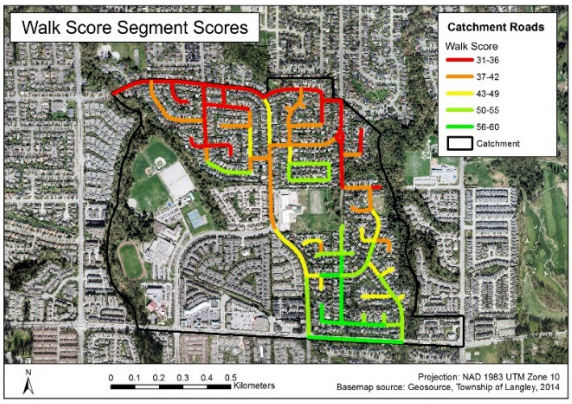

FIGURE 5. WALK SCORE STREET SEGMENT SCORES FOR THE JAMES KENNEDY ELEMENTARY SCHOOL CATCHMENT.

Statistical Analysis

The results of the statistical analysis (Table 1) showed the following: the correlation between PEDS- and PEQI-derived scores of walkability was high (r = 0.601; p = 0.000); the correlation between PEDS and Walk Score was low and not statistically significant (r = 0.148; p = 0.189); the correlation between PEQI and Walk Score was higher and statistically significant (r = 0.333; p = 0.003).

TABLE 1. WALKABILITY INDICES SCORE CORRELATIONS BETWEEN PEDS, PEQI, AND WALK SCORE.

		PEQI	Walk Score
PEDS	Pearson's *r*	.601*	.148
	Sig. (2-tailed)	.000	.189
	N	87	80
PEQI	Pearson's *r*		.333*
	Sig. (2-tailed)		.003
	N		80

* Correlation is significant at the 0.01 level.

Discussion

Comparison of Walkability Indices

As is evidenced in the PEQI score map and especially the PEDS score map, the audits showed similarity in areas where many of the street segments tend to have similar physical environments, such as the streets surrounding the shopping area in the southwest region of the study area. In some areas, street segments could be nearly indistinguishable from one another while walking, and this was apparent in the near uniformity of the scores, which would result in difficulty discerning which segments might need more attention than others from a planning and policy perspective. In comparison, the Walk Score map shows that street segments around the shopping area were not evaluated, because there was no residential address. However, Walk Score is noticeably different from PEQI and PEDS in the area to the north of the study area, where Walk Score values are low because residents are further from the amenities of the shopping area.

An apparent difference in the PEDS and PEQI score maps was the disproportionate low walkability scores of certain cul-de-sac segments as compared to their immediate surroundings. This was due to the major focus of both of the audit instruments on "sidewalk completion," which refers to the extent to which both sides of the street segment are serviced by a sidewalk. Not all cul-de-sacs had sidewalks on both sides of the street (Figure 6); indeed, some cul-de-sacs had no sidewalk at all, and this resulted

in a substantial loss of walkability "points" contributing toward the total walkability score. For example, the inability to score how walkable a sidewalk is results a score of zero on all physical domains such as path material, path condition, path obstructions, path distance from curb, sidewalk width, and curb cuts on the PEDS audit, and width of sidewalk, width of throughway, sidewalk impediments, and driveway cuts on the PEQI audit. This was detrimental to a true walkability score, as cul-de-sacs have such low-volume traffic that the lack of one or even two sidewalks did not necessarily denote an impossibility of walking or a lack of safety in walking, so long as there was a well-maintained, wide surface that was walkable, such as a flat, smooth asphalt road.

FIGURE 6. LACK OF SIDEWALK COMPLETION IN A JAMES KENNEDY CATCHMENT CUL-DE-SAC. SOURCE: GOOGLE MAPS (2014).

In terms of statistical correlation, the PEDS and PEQI audits were found to be highly correlated. This high correlation results most likely from the similarity of the audit format and the factors of the physical environment used in both audits. Walk Score, with its emphasis on area serviceability, was found to have quite different results, but was slightly correlated with PEQI. This slight correlation of PEQI with Walk Score may be because PEQI includes more domains of the physical environment that might correlate with better access to services. A closer examination of PEDS and PEQI revealed that the PEQI audit reduces the street segment score if there are empty spaces along the street segment (such as vacant lots, abandoned buildings, and construction sites) as well as if the street segment lacks planters, gardens, public art, or historical sites. Both PEDS and PEQI include domains such as retail use, public seating, and pedestrian-scale lighting, but PEQI provides greater consideration of lack of services as well as domains of beautification (such as planters) that may go hand-in-hand with areas high in services and therefore flow and movement of people.

PEDS presented problems in its lack of a standardized weighting scale, its overemphasis on sidewalk completion, and its apparent struggle to distinguish clearly between street segments within the same suburban neighbourhood. PEQI was better in distinguishing these nuances, but had an overemphasis on sidewalk completion. Both audits, though classified as measures of objective rather than perceived walkability, were subject to the perceptions of the auditor. Measuring perceptions of walkability might be better undertaken by local residents familiar with the attributes of the walking environment that affect their

decision to walk or not to walk, as this choice is quite possibly the ultimate factor in whether a neighbourhood is "walkable" for its residents.

Walk Score is a very simple, time-efficient way to discern how accessible amenities are from a certain area, but is severely lacking in its inclusion of pedestrian environment characteristics. It is unhelpful to live near amenities and services but not be able to get there, especially for those for whom accessibility is already an issue (e.g., people with disabilities and people without automobiles). However, research has shown that Walk Score is significantly correlated with certain physical environment domains, such as street connectivity, residential density, and access to public transit (Carr et al. 2010). Moreover, Walk Score uses data from Google API, which is regularly updated, a luxury not always afforded to GIS databases, ostensibly making Walk Score a more accurate measurement for certain physical environment domains than GIS-derived analyses. Nevertheless, it is important to remember that Walk Score is not a complete walkability measure in itself, and needs to be supplemented by other methods of measurement that take into account domains of the pedestrian environment. In fact, in a study by Manaugh and El-Geneidy (2011), it was found that even in locations within the highest decile of Walk Score or connectivity measures, only 33% of school trips are made by foot. It is suggested that this low statistic could be affected by unmeasured factors such as safety concerns, traffic levels, and parental preferences (Manaugh & El-Geneidy 2011).

PEDS and PEQI are both street segment audits that can each be completed on one street segment in approximately five minutes. This lends to their relatively time-efficient usage at the street-level scale, but this scale presents an issue in itself as a particularly effort-intensive location for undertaking research. Research projects over a city-wide area, for example, might benefit more from a GIS-derived audit unless there existed sufficient funding, human capital, and time to complete the study. However, for small areas such as an elementary school catchment zone, PEDS and PEQI are both valuable instruments to measure the nuances in walkability in the area. For individual address locations, Walk Score is a convenient and readily available measure of access to amenities for pedestrians.

Limitations

Confounding factors

Research undertaken by Manaugh and El-Geneidy (2011) showed that, when studying walkability's effects on an individual's walking activity, control variables such as household income, vehicle availability, and age of individual must be taken into account. For example, individuals from households with lower incomes were more likely to walk despite poor neighbourhood walkability because of less access to other methods of transportation such as automobiles or public transit. Concomitantly, individuals with ownership of vehicles were less likely to walk

than those with no vehicle. Hence, the measurement of levels of walking activity in a given neighbourhood must consider these confounding factors.

Furthermore, a study by Christiansen et al. (2014) found that the willingness of students to walk to schools in medium to highly walkable locations was increased by other factors as well, such as a distance to school of less than two kilometres, no speeding traffic, and many walking paths in the surrounding neighbourhood. This suggests that areas that have a popular destination such as a school may see higher numbers of people walking within close proximity of the school, and lesser numbers farther away. This does not necessarily mean that the areas nearer to the school are more walkable, but simply that it is convenient for a large number of students to walk because of the proximity of the school to them.

Time, efficiency and walkability

Street-level neighbourhood auditing has a reputation for being labour-intensive, and is usually conducted in research groups when covering entire neighbourhoods (Hajna et al. 2013). However, group auditing entails a much higher level of coordination and planning, as multiple auditors need to be trained in order to to ensure congruence across the study area. For example, the PEQI audit includes a question about how walkable the auditor finds the street segment. If one auditor were to be consistently more stringent than the other auditors in terms of walkability standards, this would result in a skewing of the auditor's results and a lower score of walkability for the street segments that he or she audited. The size of the catchment which we studied along with the resources available (one auditor) resulted in lengthy, though consistent, data collection.

There were some street segments in this study area that, as a direct result of their lack of walkability, limited the speed and efficiency at which data could be collected. Because it was necessary for our sole auditor (Heineman) to carry a backpack filled with textbooks for several hours at a time during our research, amenities such as shelters and seating were sorely missed. Also problematic was the complete lack of pedestrian-scale lighting, which made for a general sense of uneasiness when conducting audits in the evenings under low natural lighting conditions. Of further concern was the lack of satisfactory public transportation available in the area, as most of the research was conducted without the use of a vehicle, but rather by relying on public transit. Furthermore, many of the strata complexes are built as gated communities, which means that they are generally closed to the public and are surrounded by a fence. However, as large communities near the commercial zone, this means that in order to walk to the commercial centre, where most of the amenities and services are, one must walk around the gated communities. This is not efficient as there is no convenient path to the commercial centre. Thus lack of walkability of many street segments, especially those that conveyed a lack of safety or aesthetics for walking (see Figure 7), required more energy to audit, although

this did not affect the accuracy of the data collection.

FIGURE 7. EXTENSIVE FENCE AROUND GATED COMMUNITIES IN THE JAMES KENNEDY CATCHMENT. SOURCE: GOOGLE MAPS (2014).

PEDS weights

It was challenging that the PEDS audit did not have a standardized weighting system for the street-level data. Although we did create a weighting system that mirrored the effects of particular factors on walkability, other researchers might not use the same version of PEDS and therefore could be led to results that cannot be compared across studies.

Perceived walkability

The largest limitation of this study was the lack of measurement of perceived walkability on the part of residents. Unfortunately, perceptions of walkability are some of the most demanding measures to collect, as they generally entail surveying residents via the telephone or the mail (Brownson et al. 2004; Leslie et al. 2005). The street segment audits such as PEDS and PEQI include self-administered questions on perceived walkability for the auditor, and parcel scores such as Walk Score do not include measures of perceived walkability. Although these audits are arguably less time-consuming than sending out resident surveys, they lack the perspective of the residents who actually live in the area and are conceivably more experienced with and cognizant of the issues of walkability in their neighbourhood.

Extensions

Future Directions

A study conducted by Hajna et al. (2013) showed that walkability scores resulting from a modified PEDS audit and GIS-derived walkability scores were highly correlated, suggesting that it may be possible to use GIS instead of the more labour-intensive street-level audits to measure walkability. This could save time and energy in terms of data collection and also translate into time saved converting the collected data into a format that can be easily analyzed. Although each approach has its weaknesses, the researchers found that GIS-derived walkability was not limited to factors that were only at the street-level, but could also include factors such as land-use mix that would be better served with a bird's-eye view afforded by GIS capabilities (Hajna et al. 2013). However, this same study found that both GIS-derived and audit-derived walkability were poorly correlated with perceptions of walkability (Hajna et al. 2013).

To evaluate the consistency in correlations, it would be interesting to conduct the same

study in areas described as urban neighbourhoods, as these areas may be more heterogeneous from street to street than its suburbs may be. Moreover, some of these urban areas may tend to be more walkable in general if they enjoy higher densities and more mixed usage, or better development of pedestrian-friendly amenities such as lower traffic speed limits, increased pedestrian lighting, and buffers such as parallel parking and bike lanes. It would, likewise, be interesting to conduct this study in rural areas, as this would highlight the problems of walkability prevalent and arguably inherent to remote, sparsely populated rural communities with relatively low levels of services and amenities. More research should be undertaken to better understand issues of walkability in rural communities and workable policy initiatives to increase walkability and accessibility.

Planning and Policy Implications

Planning the built environment in such a way that promotes neighbourhood accessibility helps increase physical activity in the residential population, as evidenced by a study by Krizek (2003) which showed that individuals who relocated to an area with better options for transit, walking, and cycling were then less likely to use their automobiles to travel. Indeed, the importance and economic benefits of better population health has made walking the main focus of environmental and policy initiatives in public health recently, especially as development in industrialized countries finds itself consistently catering to automobile dependence (Leslie et al. 2007). Modern policy initiatives can include long-term investments in the amelioration of the physical walking environment as well as simple street design interventions for walking and cycling (Christiansen et al. 2014). Policy-directed research should focus on detecting and targeting places that are either compact and mixed-use but lacking in sidewalk connectivity, or well-connected but not mixed-use. Dense areas should be approached by investing in transportation, connecting cul-de-sacs, and completing sidewalk systems, whereas places with good connectivity should be targeted for denser residential development or mixed-use development (Leslie et al. 2007).

It is also important when planning policies to not only be focused on how many residents walk in a neighbourhood, as this is not necessarily a true measurement of walkability. Individuals with low incomes and with no access to a vehicle may walk but not by choice and instead by necessity, even if their surroundings are not conducive to walking due to crime, traffic, or obstructions such as construction or disrepair. Planners should see both the need for amelioration of the physical environment and the opportunity to alleviate the ramifications of what can be dire financial circumstances for certain residents.

Although being able to quantify and statistically analyze such a complex and seemingly subjective issue as walkability is encouraging and helpful to guide policy and development, it should be noted that consultation with residents is plausibly the

best way to ensure that investment, development, and redevelopment is met with success and approval. Even our own experience spending an extensive amount of time in the study area helped us gain insight into what residents would experience on a daily basis if they were to walk and which developments hinder (e.g., gated communities) or would help increase (e.g., pedestrian lighting) walkability the most, and as experience garners insight, so then those with experience should help guide development.

Conclusion

The subjective nature of walkability means that our ability to quantify the friendliness of a neighbourhood or street to pedestrians is a complex task. We evaluated the indices derived from two street-based audits (PEDS and PEQI) and one online address-based tool (Walk Score) and found that when the factors that are part of the walkability assessment are similar, the derived scores are more likely to be similar for any given street segment. Thus, understanding the factors that control the results from the survey tool is of paramount importance in evaluating the walkability of a neighbourhood. To create a holistic walkability index, we recommend that the index should incorporate qualities of the built environment, accessibility to services, as well as resident perceptions.

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Travel Mode and School Catchment Area: A Case Study in Langley, BC

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Abstract**:** *Solving Canada's childhood obesity epidemic requires a rethinking of children's diets and levels of physical activity. Active transportation, such as walking or bicycling, is an excellent way for elementary schoolchildren to engage in regular physical activity. This study examines the factors affecting transportation mode choice decisions for the journey between home and school in general, and compares the results for two elementary schools with differently-sized catchment areas. Survey instruments were used to collect objective and subjective information from parents of schoolchildren (K-Grade 7) at two elementary schools located in Langley, BC, Canada. Results indicate similar active commuting rates for both schools and similar concerns regarding barriers to walking and bicycling to and from school. Therefore, community planners should carefully reflect on site selection and surrounding neighbourhood design to enhance safety and, thus, encourage active travel between home and school.*

Keywords: school travel, active travel, built environment, mode choice, community design

Introduction

The journey between home and school provides the most common opportunity for children to engage in regular physical activity (Binns et al., 2009) and is the most regular travel activity for Canadian children (Stefan and Hunt, 2006). However, a growing body of evidence over the past few decades reveals there has been a significant decline in rates of active commuting (i.e., walking or bicycling) between home and school among the current generation of North American schoolchildren (Roberts, 1996; McDonald, 2007; Davison et al., 2008; Grow et al., 2008; Buliung et al., 2009; Wendel and Dannenberg, 2009; Babey et al., 2009; Spinney and Millward, 2011; Loitz and Spencer-Cavaliere, 2013). More specifically, in Canada, over half of Canadian schoolchildren (5 to 17 years) use passive travel modes (i.e., riding in a car or bus) for trips between their home and school (Faulkner et al., 2009). Many interrelated factors have contributed to this decline in rates of active commuting

between home and school, such as increased *automobility* (Urry, 2004), automobile-oriented design of urban environments (Frank et al., 2004; Yu and Zhu, 2016), and school siting policies that appear disconnected from current policy directions and academic discourse in community planning and design (McDonald, 2010). For example, Canada's transportation planning practices also tend to undervalue walking (Litman, 2003). The primary concern with this decline in rates of active commuting is the decreased opportunities for children to engage in recommended levels of physical activity (Strong et al., 2005), which is especially troubling given that today's generation of Canadian schoolchildren are less physically active and increasingly prone to obesity (Davison et al., 2008; Janssen et al., 2004; Tremblay and Willms, 2003; Janssen et al., 2006).

There is convincing evidence that suggests children who walk or bicycle to school have higher levels of overall physical activity and cardiovascular fitness (Cooper et al., 2003, 2005, 2010; Davison et al., 2008; Faulkner et al., 2009; Tudor-Locke et al., 2010; Voss and Sandercock, 2010), which is associated with improved physical and mental health, as well as reduced risk for chronic disease (Humphreys et al., 2013; Martin et al., 2014). Moreover, actively commuting to school provides important opportunities for children to explore their neighbourhood, develop a sense of responsibility, and foster independence (Hillman, 1993; Adams and Hillman 1995; Joshi, Maclean and Carter 1999; Bean et al., 2008). Further, it creates a foundation for future travel behaviour (Faulkner et al., 2009) while, at the same time, minimizes environmental impacts by reducing automobile use (Stewart, 2011).

Due to the growing interest in the journey between home and school among academic researchers, public health officials, and urban planners, several programs and policies have begun promoting active commuting for home-school travel, such as "Safe Routes to School" (Boarnet et al., 2005; McMillan, 2005; Osborne, 2005; Jensen, 2008; Binns et al., 2009), the Centers for Disease Control and Prevention's "KidsWalk" (McDonald, 2007), and "Walking School Buses" (for a recent review see Smith et al., 2015). Many of these programs assume that the built environment influences travel mode choice decisions for schoolchildren's journey between home and school (Schlossberg et al., 2006; Boarnet et al., 2005; Kerr et al., 2006, 2007; Larsen et al., 2009). In fact, the research is sufficiently compelling that the relationship between the built environment and health has "entered the mainstream of public health practice" (Mowat, 2015: es3). However, McMillan (2005), Larsen et al. (2009), and McMillan (2007) argue that the nature of the relationships between travel mode choice and built environment remain largely unknown. Several other authors have noted the lack of research on the built

environment correlates of transport-related physical activity (DiGuiseppi et al., 1998; Evenson et al., 2003; Ewing et al., 2004, 2005; Merom et al., 2006; Buliung et al., 2009). Thus, if the goal of community planning policy and neighbourhood design practice is to encourage people to choose active travel modes, then it is first necessary to better understand the neighbourhood-specific factors, and parental attitudes, affecting travel mode decisions for schoolchildren.

This study uses data from a region-wide Safe Routes to School research project conducted in Langley, BC, during the spring of 2013 and fall of 2014 (Jordan and Spinney, 2017). This study summarised and compared differences in questionnaire data collected from parents of schoolchildren of two elementary (K-Grade 7) schools in Langley, BC, Canada. More specifically, this study summarised and compared the (a) modal split for schoolchildren's commute to and from school, (b) socio-demographic and built environment factors that most significantly impact travel mode-choice decisions, and (c) parental attitudes toward perceived barriers to active commuting for two elementary schools; one with a large catchment area and the other with a substantially smaller catchment. The purpose of this study was to investigate whether the size of a school's catchment area impacts modal split for home-school trips and to discuss the results within the context of structured observations of neighbourhood design. The consequences have important implications for public health and safety, environment health, and urban design.

Study Area

The Township of Langley (TOL) is located in southern British Columbia, Canada. It is situated at the center of the Fraser Valley's 'Lower Mainland' (TOL, 2014a). The Trans-Canada Highway runs through the TOL, separating the northern part of the municipality from the southern part (TOL, 2014a). North Langley consists of several distinct communities such as Fort Langley (a National Historic Site) and Walnut Grove (TOL, 2014b). The total population of Langley is approximately 113,240 (TOL, 2014b). The two schools selected for this study are Dorothy Peacock Elementary School (DPES) and Gordon Greenwood Elementary School (GGES). DPES's catchment area is comparatively large (10.8 km^2) and located in the northwest corner of TOL. It is also bordered by the Fraser River and City of Surrey, and contains large zones of industrial and rural areas. On the other hand, GGES is adjacent to DPES's catchment area, but has a comparatively small catchment area (1.3 km^2) and is mostly residential land (Figure 1). DPES and GGES each have 410 registered students, who belong to 278 families at DPES and 302 at GGES.

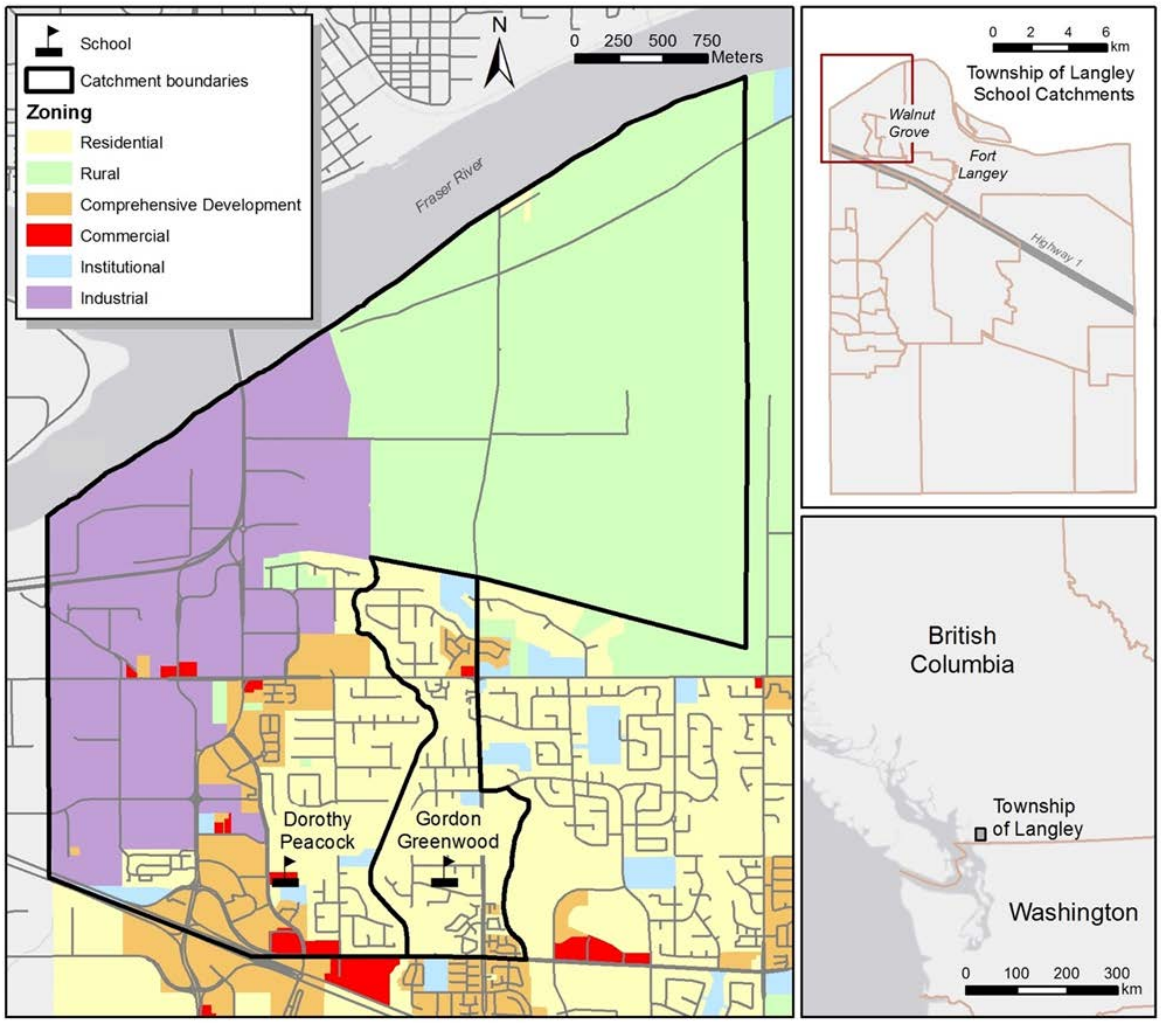

FIGURE 1. STUDY AREA SHOWING DPES AND GGES CATCHMENTS, AS WELL AS LAND USES AND CONTEXT (BASEMAP DATA SOURCES OBTAINED THROUGH ARCGIS 10.3.1. BASEMAP DATA 2017, TOL GEOSOURCE 2015/2016).

Methods

Since parents/guardians are largely responsible for making travel mode decisions, survey instruments were delivered to parents of schoolchildren (K-Grade 7) at both DPES and GGES schools. The "Parent Survey on Walking and Biking to School" questionnaire captured (a) socio-demographic information, (b) parental attitudes toward active transportation barriers, and (c) home locations. If the parent/guardian had more than one child at that school, the parent/guardian was asked to complete the survey for "the child who has the next birthday from today's date" (Jordan and Spinney, 2017: 21). A total of 579 surveys were delivered to the two schools (278 at DPES and 302 at GGES) and distributed to students who were either the only child or who were the oldest sibling in the family

(i.e., one per household) to take home to their parents/guardians (Jordan et al., 2015a and Jordan et al., 2015b). In an envelope provided, parent/guardians returned the completed surveys to the school and these surveys were subsequently collected by the project team. Data collected from each school were then transcribed into digital format and processed, which included quality control validation (Jordan and Spinney, 2017). Processing of respondents' home address, or nearest cross-streets, employed Google Earth 7.17 (Google Inc. 2015) and ArcGIS v10.0 (Esri, 2010) to convert the address information into geographic coordinates for analysis. To protect the respondents' privacy and the confidentiality of their responses, all map illustrations presented herein reflect locations with random noise added to the geographic coordinates (i.e., jittering with +/- 100 metres in both x and y directions). Data for the statistical tests included respondents' answers where multiple responses were given (e.g., if both walking and family vehicle were indicated for most frequent travel mode to/from school); however, only the first response was included in the analyses. When mapping active and passive commuting, only respondents' answers where one response was given were included. Structured observations around the schools were captured, both physically in person and virtually using Google Maps (2015), to provide greater insight into the natural and built environment surrounding each elementary school. Frequency distributions were used to describe and compare the neighbourhood-specific variables, and are illustrated using tables, graphs, and maps. The statistical significance of any differences between dichotomous DPES and GGES variables and active commuting proportions were tested using Chi-square.

Results

The response rate for DPES was 36.7% (102 of 278 surveys were completed) and 46.4% for GGES (140 of 302 surveys were completed). Table 1 illustrates frequency distributions of respondents by grade, sex, highest education, household income, and estimated travel time to school. Expectedly, there were some refusals for highest education (4% of pooled samples) and for household income (31% of pooled samples) survey items, which are omitted from Table 1; meaning the values in Table 1 represent valid percentages.

TABLE 1. PERCENT FREQUENCIES OF SOCIO-DEMOGRAPHIC ATTRIBUTES AT DPES AND GGES.

	Dorothy Peacock	**Gordon Greenwood**	**Absolute Difference**
n	102	140	38.0
Grade			
K-1	26.4	10.7	15.7

2-3	15.7	20.7	5.0
4-5	30.4	26.4	4.0
6-7	27.5	42.1	14.6
Chi (significance)			16.1 (0.024)
Sex			
Boy	46.5	47.5	1.0
Girl	53.5	52.5	1.0
Chi (significance)			0.021 (0.885)
Highest Education			
Secondary or less	11.3	10.4	0.9
Diploma/some college	53.1	40.3	12.8
Bachelor Degree	24.5	35.1	10.6
Graduate Degree	11.2	14.2	3.0
Chi (significance)			8.9 (0.111)
Household Income			
Less than $40K	7.0	10.5	3.5
40 to $79,999	33.3	23.1	10.2
80 to $99,999	12.5	14.7	2.2
$100K +	47.2	51.6	4.4
Chi (significance)			3.8 (0.576)
Estimated Travel Time			
Less than 5 mins	49.5	40.3	9.2
5 to 10 mins	35.6	45.3	9.7
11 to 20 mins	14.9	13.7	1.2
More than 20 mins	0.0	0.7	0.7
Chi (significance)			3.2 (0.356)

The grade level distributions are well spread at DPES, apart from grades 2 and 3, which are underrepresented, but much more skewed for GGES, with Kindergarten and Grade 1 most underrepresented, and a clearly pronounced mode for grade 6 and 7 students. This underrepresentation of lower grades is likely due to the schools' home correspondence distribution systems (e.g., questionnaires were distributed to only children or the oldest sibling in a family, thus, on a one-per-household basis). Both level of educational attainment and household income exhibit strong similarities among

respondents from the two school catchment areas. The modal household incomes in both school catchment areas are over $100,000. The distributions of boys and girls were remarkably similar from the two schools and appear representative of the population. Most families (around 85%), from both schools, live within 10 minutes of their school (Figures 2, 3 and 4). Overall the frequency distributions do not indicate significant bias, apart from grade level, which is biased toward opposite ends of the spectrum.

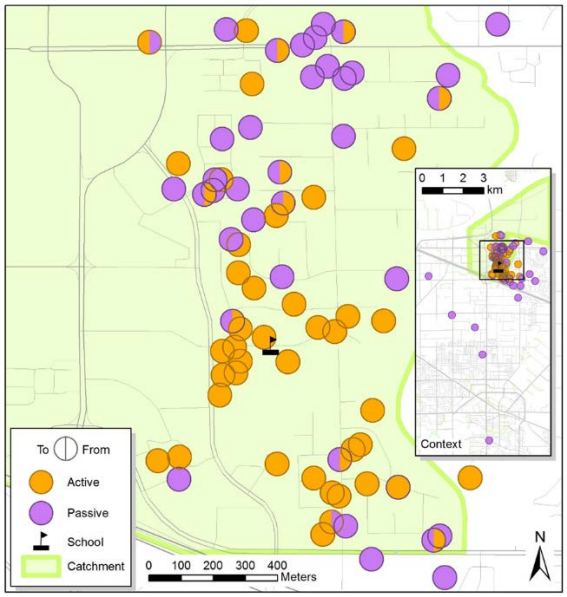

FIGURE 2. HOME LOCATIONS AND TRAVEL MODES FOR DPES (BASEMAP DATA: TOL GEOSOURCE 2015).

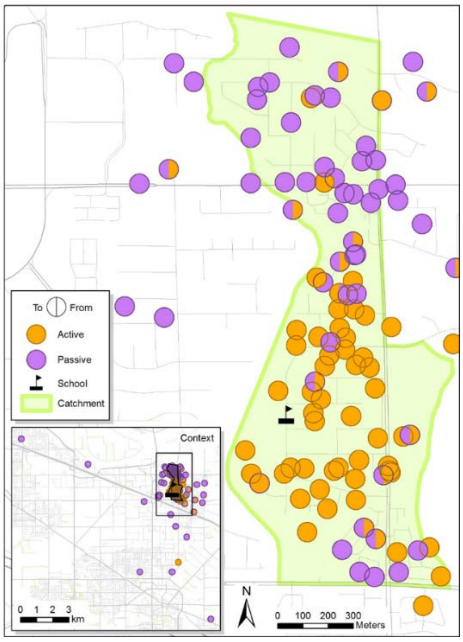

FIGURE 3. HOME LOCATIONS AND TRAVEL MODES FOR GGES (BASEMAP DATA: TOL GEOSOURCE 2015).

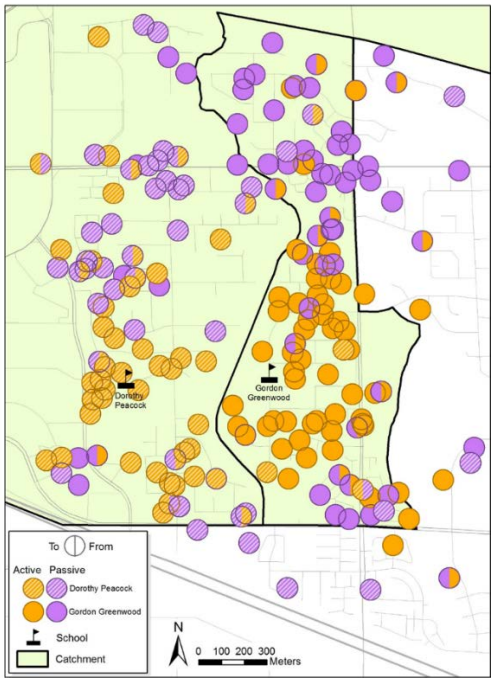

FIGURE 4. HOME LOCATIONS AND TRAVEL MODES FOR DPES AND GGES. MAP IS CLIPPED TO WITHIN THE CATCHMENT AREAS TO EXCLUDE SEVERAL OBSERVATIONS BEYOND THE

BOUNDARY (BASEMAP DATA: TOL GEOSOURCE 2015/016).

The "Parent Survey" also collected information about the issues (*viz*. perceived barriers) affecting parental decisions to either allow or deny their child to walk or bicycle to and/or from school. A comparison of parental attitudes toward active transportation barriers is illustrated in Figure 5, showing the most frequently cited issues affecting a parents' decision to either allow or deny their child to walk or bicycle to/from school. The results highlight distance and intersection safety as the most frequently reported issues for both DPES and GGES (Figure 5). Time commitments, weather and traffic (both speed and volume) round out to the main issues affecting travel mode choice decisions in the two school catchment areas.

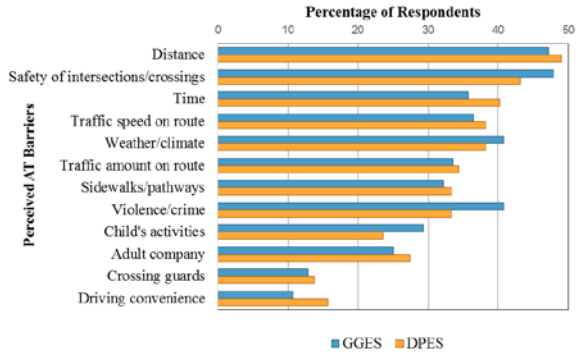

FIGURE 5. PERCENT FREQUENCIES OF PERCEIVED ACTIVE TRANSPORTATION (AT) BARRIERS AT GGES AND DPES.

Though time is more a subjective function of our hurried lifestyles (Spinney and Millward, 2010), distance can also have a subjective dimension (e.g., two kilometers seems farther if you are walking compared to driving). Insufficient traffic calming (e.g., speedbumps), high traffic volumes through the catchment area, a lack of bicycle lanes specifically, and poor bicycling infrastructure in general help explain the complete lack of bicycling reported among the DPES sample. Despite the similarities among the two schools, at least three notable issues appear in the differences between DPES and GGES samples. For example, both intersection safety and community violence/crime appear to be perceived as more important issues among parents in the GGES catchment area, while the related issues of time and convenience appear to be more prominent among the DPES parents. Anecdotal evidence collected through free-response survey items tend to corroborate the results from the closed-response questions regarding perceived active transportation barriers, but a more thorough analysis of the text is beyond the scope of this study.

The key differences for this study's purposes, however, are the distributions of modal split for the two differently-sized school catchment areas. It is noteworthy, although not illustrated in Table 2, that 6.4% of students (through proxy reporting) at GGES regularly chose to ride their bicycle both to and from school. However, the "Parent Survey" data indicated that no DPES student regularly rode their bicycle to or from school. Consequently, both walk and bicycle

modes have been combined into a single category called "active travel." Similarly, since only a single student from DPES regularly rode the bus home, it seemed reasonable to merge bus and car into "passive travel" for both samples (Table 2). Chi-square analyses were used to compare the significance of any differences in the distributions of active and passive travel mode choices for DPES and GGES schools.

TABLE 2. PERCENT FREQUENCIES OF TRAVEL MODES TO AND FROM DPES AND GGES.

	Dorothy Peacock	Gordon Greenwood	Absolute Difference
n	102	140	38.0
Mode to School			
Active	45.1	44.3	0.8
Passive	54.9	55.7	0.8
Chi (significance)			0.016 (0.900)
Mode from School			
Active	52.9	56.4	3.5
Passive	47.1	43.6	2.5
Chi (significance)			0.290 (0.590)

Results in Table 2 clearly indicate that active travel exhibits a relatively large share of the trips made between home and school for both DPES and GGES. In fact, the differences are remarkably similar, despite the difference in the size of the two school's respective catchment areas. Results also reveal similar rates of active commuting in both the morning trip to school and the afternoon trip home (more than half of respondents; Table 2). Consequently, results indicate weak and statistically insignificant differences between DPES's and GGES's active and passive commuting choices both to and from school (Table 2).

Discussion

The stated purpose of this study was to investigate whether the size of a school's catchment area impacts modal split for home-school trips. The results indicate that no significant difference in mode choices exists between two differently-sized school catchment areas; meaning we must fail to reject the null hypothesis of no difference. However, it is important to note that the results from this study may be due to, at least in part, the use of catchment area as a proxy for travel distance. Depending on the distribution of residential land uses relative to the school's location, may be an appropriate measure, but this is simply not the case for DPES. As illustrated in

Figure 1, most of DPES's catchment area includes large zones of industrial and rural areas. Perhaps due in part to an apparent under-representation from rural students attending DPES, the distribution of reporting households in Figure 4 indicates a possibly more compact distribution for DPES, certainly more compact than anticipated solely on the basis of catchment area. Future research should carefully consider whether to rely on catchment area, or to consider an alternative measure such as using GIS to calculate actual travel distance for each respondent and then compare differences in travel mode choices based on total or mean distance for each school.

Davison et al. (2008), using data from the US National Household Transportation Survey, reported as of 2001, less than 16% of schoolchildren aged 5-15 actively commuted to/from school, in contrast to the 48% of schoolchildren within the same age range doing so in 1969. Results from this research run contrary to those reported by Davison et al. (2008) and indicate a comparatively large share of students, from both elementary schools, engaged in active modes of transportation for their commute between their home and school. Table 2 illustrates rates of active commuting of around 40 to 50% which compares to schools of similar vintage, neighbourhood density, and infrastructure design in the region, but differ from other jurisdictions in Canada and across the world. For example, a recent Australian review indicates a range from 13% active commuting in the USA, 48% in Great Britain, and 86% among primary school students in the Netherlands (Gerrard, 2009). In many of these areas, such as the Netherlands, a large share of students bicycle to and from school. However, it is notable that very few students reported bicycling to and from school in this study (only 9 students at GGES) compared to bicycling rates of 49% in the Netherlands and 39% in Denmark (Gerrard, 2009).

Results from this study suggest there are many interrelated factors affecting travel mode choice decisions for the home-school commute. The most frequently-reported perceived barriers to active commuting at both schools were distance and intersection safety, followed by time, weather, and traffic. These perceived barriers were also reported in open-response answers that explained why parents did not allow their children to actively commute between home and school. Structured observations of each school's catchment area also supported these issues. In addition to the quality and design of the built environment and parental attitudes about the barriers to active transportation, it is also important to consider students' attitudes toward active commuting. While this avenue was not explored in this study, there is information about students' desire to actively commute, which may provide interesting opportunities for future research.

Due to the cross-sectional nature of the self-reported survey data employed in this study, and their attendant biases (e.g., social desirability bias), this research is not without its limitations. For example, given the overrepresentation of the older students (higher grades) at GGES, there is an expectation that a greater proportion of students would be permitted by their parents/guardians to walk or bicycle to and from school. The literature confirms a strong positive relationship between age and propensity to actively commute, but only to a certain age (about 10 years) at which point the propensity begins to decrease (Pabayo et al., 2011). However, despite the higher propensity of the older students, within the smaller school catchment area, one would certainly expect significantly higher rates of active commuting within GGES, but the data failed to support that hypothesis, and thus, should not significantly affect the main objective of investigating the impact of school catchment area on travel mode choice decisions.

Another limitation is that the results could have been impacted by using the child's next birthday as a tool to randomly choose a single child in each household. While statistically preferable, we suspect there may be important age, and perhaps sex, differences in travel mode choice decisions for different children within the same household. Furthermore, the adapted survey instrument was not well harmonized with the household incomes in the two school catchment areas. The limited categories for incomes greater than $100,000 preclude a more nuanced analysis of possible associations between travel mode choice and income. We also recognize geographic limitations such as the modifiable area unit problem (MAUP), which is described by Clark and Scott (2013) as well as the potential issue of spatial bias introduced by the nature of the built environment and sample distribution within the study (i.e., school catchment) area. Finally, a spatial regression model would enable comparison of travel mode choices against the catchment area size while holding the other factors constant. A well-specified model would also enable a better understanding of the relative importance of the main factors affecting travel mode choice decisions within this study area.

Conclusion

Students at both DPES and GGES exhibit relatively high rates of active commuting between home and school, but many students who live in close proximity to school continue to be chauffeured. Therefore, additional strategies are clearly required to mitigate perceived barriers to active transportation as a means of increasing schoolchildren's health and well-being. In addition, improving pedestrian safety for schoolchildren also improves the quality of the pedestrian environment for the

rest of the community. Moreover, children play a critical and valuable role in society, thus it is important they are provided with the means to live safe and healthy lives. In addition to pedestrian safety (e.g., crossing guards and traffic calming), it is important that schools, especially elementary schools, are sited and situated as a central component of the community they serve.

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Research Note:

The changing cultural differences between Japanese and Canadian inner rural-urban fringe residential landscapes: the rural idyll and estate homes.

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Abstract: *There are a variety of residential combinations on the edge of cities owing in part to non-farm residences being mixed in with rural landscapes, including those of farm residences. In Canada, where there is a strong cultural connection with Europe, the large non-farm estate has been a characteristic type of housing in the rural-urban fringe. In Japan, on the other hand, large lot estate homes are absent. Instead, high density tract housing is usually found on the edge of cities along with randomly dispersed apartment buildings and non-farm houses among farmland. The purpose of this paper is to examine selected cultural differences between the Japanese and Canadian rural-urban fringe with a focus on residential landscapes, through a review of the literature, which is supplemented with landscape observations. The results are that in Japan rural landscapes on the edge of cities are increasingly being valued for their recreational, i.e., gardening, and natural qualities, and this can be related to a changing rural idyll, which has been based on agrarianism. In Canada we see the estate home – even close to the city -- due to an enduring rural idyll that originated in the European countryside, combined with larger lots, and a desire to preserve natural landscapes. The principal conclusion is that the rural idylls of Japan and Canada differ, and these differences are expressed in the inner rural-urban fringe landscape. However, the Japanese rural idyll appears to be merging with the Canadian rural idyll in terms of a desire to preserve nature in the inner rural-urban fringe.*

Introduction: Defining the residential rural-urban fringe in Japan and Canada:

Sorensen's (2000) impressions of landscapes in the Japanese rural-urban fringe (fringe for short) are that power lines are criss-crossing everywhere, and that the landscape seems to have no order. Generally, there is a higher density of land uses in the Japanese fringe (Figure 1), and some land uses just do not exist in Canada, specifically rice paddies, which dominate the landscape. Moreover, religious spaces differ: Shinto shrines and Buddhist temples appear instead of Christian churches and monasteries. In addition, unlike in Canada (Figure 2), one does not find estate homes in the inner Japanese fringe, and there does

not seem to be the same idyllic view toward these landscapes.

FIGURE 1. RURAL-URBAN FRINGE OF USHIKU CITY NEAR TOKYO WITH THE TRADITION FARM HAMLET IN THE BACKGROUND (11 JUNE 2013). (SOURCE: T. WALDICHUK).

FIGURE 2. ESTATE HOME OUTSIDE OF VANCOUVER, BC (JULY 2016). (SOURCE: H. MARKANO)

This paper focuses on the differences in culture between the Canadian and Japanese fringes[i]. In particular, I focus on the inner fringe, which has a mixture of urban and rural landscapes, and is on the immediate edge of the built-up city, where it conceptually forms a ring around it. Whereas the adjacent outer fringe forms the outer ring and tends to have fewer rural to urban land conversions (see Bryant et al., 1982, p.12; Qvistrom, 2007). Landscapes in the fringe are dynamic (Cadieux et al., 2013); the process of change is complex, and is based on the actions of the many actors involved (Bryant and Mitchell, 2006, figure 13.1). Researchers have focused on the culture of these landscapes (e.g., Bunce, 1994; Cadieux et al., 2013; Taylor, 2010). For the purpose of this paper, culture is defined as non-material, e.g., the people who live in the rural-urban fringe and their attitudes, and as material, e.g., a farm house (Martinez, 1998, p.3). This material culture refers to the built or material landscape (Cadieux et al., 2013). In this paper I argue that that the rural idyll is conceived differently in Japanese culture, compared to Canada, and that the different conceptualization of this idyll helps to explain morphological differences between the inner fringes of Japan and Canada. I also suggest that the Japanese rural idyll is becoming similar to the Canadian one.

Non-material cultural differences:

The inner rural-urban fringe is made up of old-time residents, some of them full and part-time farmers. There are also newcomers, many of whom are from cities and are known as exurbanites (Bryant et al., 1982), and many who commute to jobs in

the city core or to the larger metropolitan area (Woods, 2005). In both Japan (e.g., Waldichuk and Whitney, 1997) and Canada (e.g., Walker, 1987), the attitudes of these newcomers often differ dramatically from those of the old-timers and may lead to conflict (Bryant et al., 1982; Bunce, 1994; Woods, 2005). Many are motivated to move to the fringe because of affordable housing (Heimlich and Anderson, 2001; Sorensen, 2002). In Canada, other newcomers may move to live in more expensive housing, e.g., the rural estate home. Many of these are the people who are searching for the rural idyll (Woods, 2005).

The rural idyll has been written about extensively (e.g., Bell, 2006; Bunce, 1994; Bunce, 1981; Short, 2006; Woods, 2005). It refers to a peaceful, quiet and moral image of rural areas (Woods, 2011, p.21), and was also an attitude expressed in ancient poetry about rural landscapes in China, Greece, and Rome (Tuan, 1974, pp.102-109; Williams, 1973), and in more contemporary literature (e.g., Williams, 1973). It is also related to nostalgia for the past (Bunce, 1994; Short, 2006; Woods, 2005). In the 1800s in Europe, e.g., England, the rural idyll referred to – in part -- wealthy people living in relative luxury in rural estates (Bunce, 1994; see Williams, 1973). This notion has contributed to the North American rural idyll, which is based more on valuing nature than is the English idyll (Bunce, 1994, p.4). Cadieux (2011), for example, focuses on the importance of nature when discussing the rural idyll in the context of large lot subdivisions in the rural-urban fringe of Toronto. Taylor (2010) also talks about the importance of the "ideology of nature" when discussing opposition to planning proposals in the Oakville area near Toronto. The North American idyll also embodies old lifestyles and the evolution of agriculture more than the English idyll does (Bunce 1994, p.36), so agricultural history is important in the North American rural idyll.

But Japan has a different cultural history and thus a different conceptualization of the rural idyll. Francks (2006, p.279) states that Japanese people do not "aspire to the rural idyll of life in the real countryside" unlike people in Britain (or in Canada, which is the focus here). Thus, one aspect of the Japanese rural idyll – being nostalgic about one's rural hometown or furusato -- has not led to the landscape expressions in the inner fringe such as estate homes that one sees in Britain or North America[ii]. However, the Japanese have a strong desire to visit remote rural areas, and rural tourism has capitalized on this (McMorran, 2014).

Meanwhile, similar to the North American idyll, which embodies nature preservation, people in Japan have become interested in protecting natural landscapes, in particular, wooded areas of the inner fringe (e.g., Ichikawa et al., 2006; Yokohari and Bolthouse, 2011a; Yokohari and Bolthouse, 2011b). Thus, more environmentally friendly attitudes are becoming common in the Japanese inner fringe.

The other aspect of the Japanese rural idyll that is expressed in inner fringe landscapes is agrarianism, which in Japanese is called nohon shugi ("agriculture-is-the-base-ism") (Ogura, 1982, p.1). It is similar to the pastoral ideal (Marx, 1964) and agrarian fundamentalism, which is a belief that agriculture is a fundamental economic and virtuous activity (see Tuan, 1974; Ogura, 1982). Thomas Jefferson promoted

agriculture as a virtuous activity in the US, and the government continued to support agriculture and rural areas from that point on (Tuan, 1974). The ideas of agrarianism in Japan have existed since the 1600s, and during the Meiji period (1868-1912) when Japan was opening up to the West agrarianism became part of agricultural policies. There was concern that the development of manufacturing would have a negative impact on the farming class (Ogura, 1982, p.2). Penelope Francks (1992) mentions that agrarianism was used to oppose industrialization. She has also stated that farm interest groups have obtained public backing for protecting agricultural crops from imports due to the public's support for traditional farm landscapes and what they produce (Francks, 2006). The idea that agriculture – even small-scale – is in the nation's interest is exemplified by the Emperor's annual planting of a small rice paddy at the Imperial Palace (See Francks, 2006).

Material cultural differences between the inner rural-urban fringe of Canada and Japan:

Japanese farm houses form, in general, nucleated settlements, with the fields located outside of the hamlet (Trewartha, 1965). Whereas in most of Canada, especially the western provinces where the Dominion Land Survey system was used (McGillivray, 2006, pp.278-280), land was surveyed into square-shaped townships, so farm houses are dispersed (see Warkentin, 1997, pp.99-101). Moving closer to the city core, there is a higher density and variety of land uses in the Japanese inner fringe. In Canada, there can be a mixture of tract housing and estate homes. In Japan, tract housing also dominates. Adjoining these housing developments can be apartment buildings, often owned by local farmers (see Yamamoto and Tabayashi, 1989), and unorganized newcomer housing built on upland fields outside farm hamlets (see, e.g., Hebbert, 1986; Sorensen, 2001). Also, there are often new homes nearby that are for the offspring of the farm households. These are known as branch families or bunke (Brown, 1968), whereas the main farm household (or stem household), which is taken over by the eldest son, is known as the honke (Brown, 1966). The spread of these branch families mixed in with newcomer housing can lead to farmland fragmentation (Figure 3).

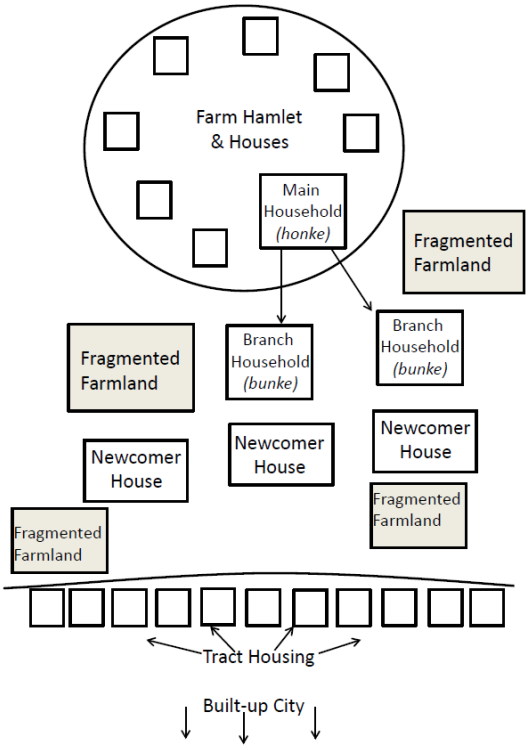

Figure 3. Japanese inner rural-urban fringe.
Source: T. Waldichuk

I would argue that, with reference to the inner fringe, the ideas of agrarianism are expressed more widely in the Japanese landscape. This is evident by observing the

extent to which gardening and farming go on in the inner fringe. In the morning, evening and on weekends I have commonly seen people – most of them retired non-farmers – working in their garden plots at the edges of Ushiku city, a commuter city of Tokyo. Moreover, these garden plots can be seen as one rides the commuter trains, such as the Joban or Takasaki lines, from central Tokyo out through the inner and outer fringe toward the rural periphery. Rice paddies also continue to be cultivated with full-time farmers increasingly managing the paddies on contracts with farmland owners.

Canada and Japan – impacts and changing attitudes in the inner rural-urban fringe:

Landscape management issues are different in the Canadian and Japanese inner fringe due to different rural idylls. In Canada locating estate homes on farmland can lead to reduced agricultural production (e.g., City of Pitt Meadows, 2008) as the owners are generally non-farming urbanites. These estate homes tend to be on large lots, and large lot housing developments use up more land per home than do suburban developments (Heimlich and Anderson, 2001). Furthermore, as alluded to previously, newcomers moving to the inner fringe who are seeking the rural idyll often become disturbed by agricultural smells and noises or urban development (Woods, 2005), which leads to conflict and a shattering of the rural idyll. Although these conflicts do periodically occur in the inner fringe of Japan, they are less of a problem because newcomers are not seeking the same rural idyll that Canadians are.

Gardening and small-scale farming are increasingly becoming more popular in the Japanese inner fringe (Yokohari et al., 2010a), which reaffirms the influence of agrarianism. These plots are known as shimin noen (citizens' food gardens), and the German-modelled kleingarten (small garden) with chalets, where users stay on weekends (Wiltshire and Azuma, 2000). A change in land-use regulations has allowed farmers to rent their land to non-farmers to use as community garden plots (Ijima & Edahiro, 2013; Wiltshire and Azuma, 2000). This has become popular with aging farmers who no longer want to farm or cannot do so. These farmers gladly rent out or let people use their idle farmland for free (Yokohari et al., 2010b). I have noticed that most of these plots are small, roughly 3 by 6 metres, and are usually called katei saien or kitchen gardens, but some people are farming larger plots that are the size of tennis courts. Some retired urbanite non-farmers have even becoming involved in the operations of aging farm households (Yokohari and Bolthouse, 2011a).

People are interested in growing their own produce due to food accessibility (Yokohari and Bolthouse, 2011a) and safety issues in Japan (Mok et al., 2013; Yokohari et al., 2010b; Yokohari and Bolthouse, 2011a). It is also a hobby, especially for retired people. In American and Canadian cities community gardens have also increased in number (see Guitart et al., 2012); however, I would argue that they are more common in the inner fringe of Japan, particularly gardens that are informally arranged between local farmers and non-farming residents.

As mentioned above, there has been a movement to preserve woodland ecosystems in the inner fringe of Japan with residents and volunteer groups undertaking

the work. This has culminated with the satoyama movement (see Kobori and Primack, 2003; Chatoroboky & Chatoroboky, 2013; Yokohari and Bolthouse, 2011b). A satoyama is a traditional farm landscape with farm houses, vegetable fields, woods and rice paddies (Figure 4). These are old human-modified landscapes that have formed traditional, sustainable farm communities, and managing the growth of trees has been integral to keeping the modified ecosystem in balance.

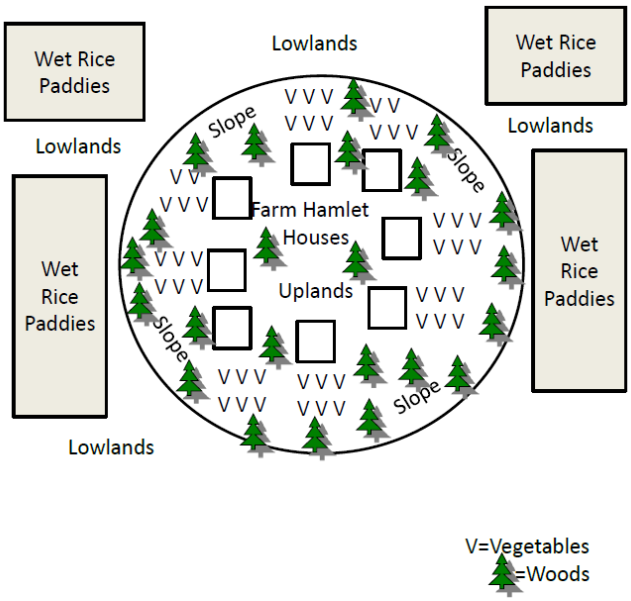

Figure 4. Satoyama landscape.

Source: T. Waldichuk
Bing image for woods licensed under the Creative Commons license system.

Discussion and Conclusion:

In Canada, inner fringe residential landscapes are viewed as places of inexpensive housing but also as landscape expressions of the rural idyll – specifically the estate home. Whereas in Japan these landscapes have just been viewed as the location of inexpensive housing and a better living environment than the cores of large cities (Sorensen, 2002), but that situation is changing.

Agrarianism – an ideology that has perpetuated the virtues of farming and growing food -- is expressed more in the inner fringe of Japan where there is an abundance of garden plots, which are leased or borrowed from aging farmers. The growers are mostly retired urbanites, who grow produce as a hobby, to socialize, or perhaps because everyone seems to have a plot. It is hard to say whether these gardeners are motivated by the Emperor planting a rice paddy (Francks, 2006), but inner fringe residents are surrounded by farm fields and vegetable plots, which may encourage them to obtain a garden plot. Recently though, people have been wanting to grow their own food due to concerns about the safety of imported food (Mok et al., 2013; Yokohari et al., 2010b; Yokohari and Bolthouse, 2011a).

Meanwhile, there is an increased interest in preserving the natural environment of the Japanese inner fringe, specifically satoyama landscapes (e.g., Yokohari and Bolthouse, 2011a), and this aligns well with the Canadian rural idyll

which, similar to the American idyll, emphasizes nature (Bunce, 1994). But satoyama landscapes are also agricultural (Yokohari and Bolthouse, 2011b), and thus the preservation of this landscape can also be related to agrarianism. Moreover, Yokohari and Bolthouse (2011b, p. 207) go on to say that these satoyama landscapes have also become idyllic due to their representation in Miyazaki, Hayao's 1988 children's animation Tonari no Totoro ("My Neighbour Totoro").

In sum, I have argued that due to differences in cultural history the rural idyll in the inner fringe of Japan is different from that of Canada, which accounts for many of the morphological differences in their respective inner fringes. In Japan ideas related to agrarianism have helped to perpetuate agriculture and the expansion of vegetable plots. The Canadian rural idyll, which comes from Europe and embodies the estate home and nature (Bunce, 1994), has led to a different pattern of residential, farm and natural landscapes in the inner fringe. But the Japanese rural idyll is becoming more like the Canadian one in terms of a desire to preserve nature – the evidence for which is the preservation of satoyama landscapes in the inner fringe (e.g., Yokohari and Bolthouse, 2011a).

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[i]Although this is a comparative study, the paper focuses most on the Japanese rural-urban fringe.

[ii]Rapid urbanization (e.g., see McDonald, 1985; and Sorensen, 2002, ch.3) in the 20th century led to city dwellers longing for their rural hometown or *furusato*, which is an idyllic place (Creighton, 1997; Rea, 2000). This rural nostalgia in Japan (see Clammer, 1997; Creighton, 1997; McMorran, 2014) is different from the Anglo-North American version (see Bunce, 1994) and shows no landscape expression in the inner fringe.

Research Note:

The GBCs Glacier Image Alphabet: A new climate change learning tool using Google Earth

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Abstract: *An important part of climate change education is an understandable and memorable presentation of components within the climate system. Here, we present the development of a learning tool clarifying glaciers with a focus on their association with climate. Images of glaciers and glacial features that resemble lower case letters were obtained by examining the range of satellite image types displayed on Google Earth's virtual globe. Each letter-image of the alphabet was matched with a glaciological term starting with that letter, and describing the glacial feature or process in the corresponding image. The ensemble of images, terms and their definitions, was portrayed as a classroom educational poster. This Glacier Image Alphabet is a visually attractive and informative glossary of terms representing glacier processes, such as accumulation, ablation, and ice flow, as well as ice age and ice core records, and common glacier features and names. The poster contains a glacier distribution map, and is accompanied by an online component in Google Tour Builder to provide a more interactive geographical learning tool with expanded content. The Glacier Image Alphabet is aimed at senior high school and first year undergraduate students.*

Introduction

This paper presents a method of reinforcing learning about glaciers and climate change, and serves to foster geographic literacy as endorsement and support for the *St. John's Declaration* (Boxall *et al*., 2013). It is the product of an undergraduate research project by the first author supervised by the second author. Our objective was to convey basic physical processes relating glaciers to climate change by creating an educational classroom poster depicting the alphabet as glacier images that look like letters, paired with glaciological terms starting with the corresponding letter. We combine this poster with a map showing the depicted glaciers' geographical distribution, and an online component using the experimental Google Tour Builder platform.

Worldwide, satellite and ground data have shown a reduction in glacier size, at sometimes staggering rates. Melting glaciers and ice sheets have resulted in significant changes in downstream hydrology and sea level (IPCC, 2013), and have become an icon of anthropogenic climate change (Marzeion

et al., 2014). Even with this clear picture, climate change is still much contested amongst the general public, with each nation conceptualizing it differently (Lorenzoni and Pidgeon, 2006). It can be difficult to teach climate change from a factual and scientific perspective given that school values towards science and environmental education differ (Barma *et al*., 2015). However, it is alarming when 75% of 1500 teachers in the USA are teaching climate change without a clear understanding of the processes (Plutzer *et al*., 2016). Present and future generations of students need to be exposed to scientific facts and concepts that will help them understand climate change and its effects without the influence of potentially biased media or ignorant public opinion (McNeill and Vaughn, 2012). Since glaciers are considered key indicators of climate change (Haeberli *et al*., 2007), and elicit both awe and curiosity (NSIDC, 2015), they provide excellent examples of climate change impacts that speak to our continued impact on the global environment.

The virtual globe of Google Earth, with its range of medium- to high-resolution satellite imagery, has become very popular for sharing 3D spatial geographical information (Sheppard and Cizek, 2009) and has the capability to be used in education (e.g. Patterson, 2007). Correctly identifying various types of landscapes and landforms is vital to information extraction from satellite imagery. Visual analysis of remote sensing images has traditionally used image interpretation elements, or "selective keys", for feature identification (e.g. Lillesand *et al*., 2014; Bianchetti and MacEachren, 2015). Selective keys generally consist of pairing annotated images, illustrating a select landscape feature, with a description that explains the feature in a systematic manner using key elements such as tone, texture, size, shape, etc. We adjust this selective keys concept by selecting glacial features that resemble letters of the alphabet on satellite images in Google Earth. We loosely base this on two recent satellite image alphabets using buildings and clouds shaped like letters (De Bruin, 2009; Voiland, 2012). Our aim is not to identify glacier outlines in detail, which remains challenging even for specialists (Paul *et al*., 2013), but for students to learn about common and clearly identifiable glacier features as well as concepts that are not visually identifiable on satellite images, which are all important for understanding the significance of glaciers in the climate system.

Methodology

In order to find glaciers and glacial features that resemble lower case letters, we visually examined the range of satellite images that make up Google Earth's virtual globe in areas with known glacial cover. An effort was made to select glacier images from each continent to capture the global glacier distribution (e.g. Pfeffer *et al*., 2014). Images of letter shapes at a range of scales were extracted and cropped to squares of uniform size. In order to show the letter shape in an upright position several of the glacier images were rotated relative to North. Of these image-letters, a complete glacier image

alphabet was selected, where each image-letter was used as the starting letter for a glacier term represented on the image. These terms were either representative of the relation between glaciers and climate, or common glaciological terms, and were selected from literature and online scientific sources (Singh *et al*., 2011; Benn and Evans, 2010; the *National Snow and Ice Data Center Cryosphere Glossary*), while taking into account the glacier geography and climate curriculum requirements within Canadian High School grades 10-12 and University introductory-level physical geography courses (e.g. Alberta Education, 2002; Ministry of Education, Province of BC 2006; Christopherson, 2013).

The entire alphabet was collected, with several duplicate letters, and a preliminary *Glacier Image Alphabet* was formatted as image-term pairs fitted into columns on a conference poster. Each image-letter was also annotated with the glacier name, geographical coordinates, and location. This poster was presented at the 57th Annual Meeting of the *Western Division of the Canadian Association of Geographers* (WDCAG-KRAM 2015), and in first, second, and third-year geography classes at the University of Lethbridge. In all geography classes the project was supplemented by an oral introduction, survey sheets, and slide examples of a range of duplicate letters and colour schemes. Surveys were used to collect feedback about image-letter clarity, poster layout and colour scheme, and understanding of the terms from the students' perspectives. Additionally, general comments were collected on the feedback forms and during the WDCAG-KRAM 2015 conference.

All image-letter locations on Google Earth were saved as a KML placemark file with geographic location and glacier name information. This file was used to construct a world map with glacier-letter locations which was included on the poster, and was also used in a digitized version of the *Glacier Image Alphabet* in the experimental platform of Google Tour Builder (Google, 2015). This digitized version links the glacier-letter images directly to their virtual globe locations in Google Earth, but also includes all terms and other information on the poster, supplemented by web links to peer-reviewed scientific/governmental websites describing either the process in the glacier image or the glacier itself.

Results

Feedback from 154 undergraduate geography students on the project in general, the initial poster layout and glacier letter-image shapes and their terms was transcribed and numerically analyzed. On the basis of the cumulative feedback, twelve problematic letter-images were replaced, some requiring new terms, and the poster layout and colour scheme were improved.. Additionally, the wording of the majority of term definitions was updated. The most significant layout improvement was to start all term headers with a lower case letter to match the glacier image-letters, which are all in lower case. Most student comments

about the project in general and final poster were very positive, commenting on how the poster is an "Excellent visual aid for learning" and "Good layout, easy to read and understand"; and that Google Tours was an "effective", "fun" online tool, and "everyone loves to explore google maps/earth". Critical comments tended to focus on the fact that it was not entirely clear that the ultimate educational goal was to explain the link between glaciers and climate change. Other critiques included the possibly too difficult content for high school students more junior than grade 12, and specific layout issues (e.g. "put a north arrow on the rotated image pictures").

The updated final *Glacier Image Alphabet* includes 26 letters and accompanying terms and definitions covering glacier mass balance processes (incl. accumulation and ablation); climate response (e.g. retreat and ice flow); glacier hydrology (incl. runoff and lakes), climate records (ice cores), general glacier features (e.g. moraines, crevasses); and glacier names (e.g. jökull and breen). Each image-letter and term pair also includes the name of the glacier depicted, the geographical coordinates, mountain range, and continent. Examples of four image-letters and their terms are depicted in Figure 1. Additionally, a world map is included on the poster, showing all letter locations, and illustrating the global distribution of glaciers.

FIGURE 1. EXAMPLES OF FOUR LOWER-CASE IMAGE-LETTERS (I-C-E-Z) IN THE GLACIER IMAGE ALPHABET, PAIRED WITH THEIR CORRESPONDING TERMS AND GLACIER INFORMATION. THE LAYOUT IS EQUIVALENT TO THE CLASSROOM POSTER.

The Google Tour Builder aspect of the *Glacier Image Alphabet* contains a page introducing the project, and pages for each image-letter paired with the term explanations. This is roughly equivalent to the classroom poster display. Additionally, Google Tour Builder includes a Google Earth map panel zoomed into the location of the glacier letter-image. In this map the letters may appear in a rotated position (e.g. Figure 2), as the map panel is oriented with North

facing up. Supplementary features in Google Tour Builder include one or two web links to online information about the glacier terms, or a link to an online video explaining the term or showing the glacier. However, the main strength of Google Tour Builder lies in the flight-like navigation through the Google Earth worldmap, through which the viewer can tour all letter locations on a virtual globe, exploring glaciers on the full mosaic of satellite images with the possibility of adjusting the viewing scale from global to local. This aids in understanding the spatial relationships between glaciers and the surrounding terrain, displays the global distribution of glaciers, and illustrates the spatial distribution of glacier types and features. Figure 2 shows an example of the Google Tour Builder page for the image-letter *p* and its accompanying term *proglacial lake*. The URL for the complete Google Tour Builder project page is: https://goo.gl/aTXISU. Note that Google Tours Builder is only fully functional after the user has installed Google Earth freeware (https://www.google.com/earth/) on their computer or mobile device.

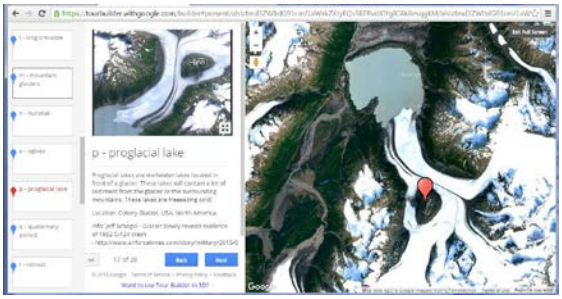

FIGURE 2. SCREEN CAPTURE OF THE ONLINE GOOGLE TOURS BUILDER PAGE FOR THE LETTER-IMAGE P. THIS INCLUDES THE TERM PROGLACIAL LAKE AND ITS DEFINITION, THE GLACIER NAME AND LOCATION, A WEB LINK TO FURTHER INFORMATION ABOUT THE GLACIER, AND THE GOOGLE EARTH MAP PANEL.

Summary and future directions

In this paper we presented the development of: i) a classroom educational poster pairing glacier letter-shape images with their explanatory glaciological terms; ii) a global map of the glacier letter-image locations, and; iii) an online learning component using Google Tour Builder to show additional geographical relationships. The resulting *Glacier Image Alphabet* was created as a learning tool to engage students to explore glaciers and their importance in responding to and recording climate change. The feedback that we received from university students and WDCAG-KRAM 2015 conference participants suggests we succeeded in creating a visually attractive and engaging poster, and an interesting and informative digitized interactive alphabet in Google Tour Builder.

Based on a general review of educational resources and literature, we believe our project is unique in the field of geographical education. We therefore aim to test the implementation in a pilot study within high school and university settings in southern Alberta. The further development of the *Glacier Image Alphabet* into a successful educational tool will require design and content refinement of the online component, a lesson plan, and an enhanced active learning aspect (Scheyvens *et al.*,

2008). This may be implemented by creating a game with self-regulated learning purposes (Hwang *et al*., 2013) within our Google Tour Builder component. These improvements could not only help with increasing the educational value, but also help with further development of the project's main message about the connection between climate change and glacier response.

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Sustainable Suburban Development in British Columbia: How the Master Planned Communities *Westhills* and *Partington Creek* follow sustainable development practices

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Abstract: *For the past few decades, the principles of sustainable development have become a crucial part in the planning and managing of development projects in the globally built environment. Today, nearly every new development project declares some sense of "sustainability", but what does it truly mean to be sustainable? Westhills, in the City of Langford, and Partington Creek, in the City of Coquitlam, are two primary examples of development projects in British Columbia that are truly sustainable; these Master Planned Communities follow New Urbanist principles, and have been designed to reduce sprawl, produced compact and socially diverse homes, and are pedestrian-orientated settlements.*

Keywords: Development; Sustainability; Community; New-Urbanism; British Columbia

Introduction

Since the early 1970s, the developed world has begun to experience exponential growth in environmentally-friendly sustainable development. After the 1972 Stockholm Conference on the Human Environment, and the 1980 World Conservation Strategy of the International Union for the Conservation of Nature, world leaders realized that we needed to create an organization whose sole purpose was to raise awareness of the need for sustainable development. In 1987, the World Commission on Environment and Development or "Brundtland Commission" was established; it defined sustainable development as "the development that meets the needs for the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). The purpose of this article is to overview, the master planned communities Westhills and Partington Creek, and to discuss how these development projects are truly sustainable. In this article, I will discuss how Westhills and Partington Creek in British Columbia are two examples of "true" sustainable developments because of how they follow New Urbanist principles through their proposed land-use developments, neighbourhood plans and environmental protection.

New Urbanism: New Urbanism (NU) is a specific movement that aims to reduce sprawl and improve societal well-being through changes to the built environment

that produce compact, socially diverse and pedestrian-oriented settlements (Trudeau, 2013, p. 435). Proponents of the urbanist movement have suggested that it offers a model of sustainable development. In his article, New Urbanism as Sustainable Development, Dan Trudeau investigates new urbanist principles and how they can be sustainable in development through discussing how the practices of new urbanism relate to a variety of sustainable development goals (Trudeau, 2013, p. 435).

The New Urbanism movement is having a profound influence over how people today view their homes, and their communities. In turn, New Urbanism is shaping stronger, healthier, more intuitive and appreciative geographical places. At its heart, the New Urbanism movement represents "a paradigm shifts for land development, and is guided by an interest in creating places that minimize the environmental impacts of growth and also foster a place-based sense of community among residents" (Trudeau, 2013, p. 436). In its entirety, this movement is rightfully committed to addressing environmental problems when it comes to development and living sustainably, but is also invested in seeing that people ultimately enjoy the places they live in.

New Urbanism in Canadian Cities:

For the past few decades, New Urbanism principles have become increasingly popular in Canadian planning theory and practice. Most municipal plans include new urbanist principles like mixed-use, mixed-income housing, identifiable community centres, quality urban design and walkable and connected street systems (Grant and Bohdanow, 2008, p. 109). Major Canadian cities such as Vancouver, Victoria, Edmonton, Calgary, Regina, Winnipeg, Toronto, Ottawa, Montreal, Halifax etc. all follow New Urbanist principles as a modern approach to their planning and development. These cities have all extensively adopted New Urbanist principles as standard planning practice in a variety of development projects across Canada, and as such, they have all adjusted their development standards to encourage or demand features such as mixed-use land, street connectivity, walkability, an increase in public spaces, and more transportation options. It is through this positive influencer in developing Canada's major cities that our country is able to accommodate and be accepting of all lifestyles, as our urban cities continue to grow rapidly.

Master Planned Communities:

Master Planned Communities are designed to give residents a "complete living experience." While the term "master planning" is fairly generic and refers to the design and construction of a large scale project according to an overall development concept, a "master planned community" is a residential development project usually managed by a single company (Rosenblatt et al, 2009, p. 123). Beyond the provisions of housing, master planned communities include infrastructure, streetscapes, landscaping, parks and open spaces, as well as recreational and other facilities for community use and overall community development.

In her article, Master Planned Communities and the Reformation of Cities for Health and Wellbeing: Cecily J. Maller writes on how:

this trend of developing master planned communities is perhaps partially explained by the influence of "New Urbanism", a North American planning tradition which emphasizes place-based communities, and the role of the physical environment in creating community (2012, p. 3).

The creation of a "Master Planned Community" is becoming an increasingly common form of development in terms of residential landscape around the world, and for many places, these are also the newest forms of suburban development. There is no more developing of homes side by side, row by row, with no parks or grocery stores near by. Now, Master Planned Communities are focusing on public spaces and retail shops, and developing the homes around these places.

Case Study 1 - Westhills in the City of Langford

Welcome to Westhills; a master planned community of "new homes, townhomes and condos, celebrating the values of environmental stewardship, sustainability and active living in a beautiful West Coast setting" (Westhills, 2012, p. 1). The Westhills lands encompass approximately 209 hectares of rolling sloped lands, knolls, and rocky outcroppings located in the City of Langford on Vancouver Island (Westhills, 2012, p. 1). This particular development embodies the City of Langford and the Westhills Land Corporation's goal of "creating a unique, large-scale master planned community based on the principles of social and environmental sustainability" (Westhills, 2012, p. 1).

The official Westhills Land Corporation website states that:

> *Major guiding factors of the design and implementation are considerations of location, alternative transportation modes, environmental preservation, community agriculture, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality (2012, p. 1).*

These characteristics are demonstrated in the creation of approximately 6000 new residential units, with supporting commercial, civic and educational facilities as well as approximately 84 hectares designated as park and open space, equivalent to 40% of the total land area (2012, p. 1).

District Energy and Westhills "CES" Program:

District Energy is the centralized production of heating and/or for a wider community. These systems have traditionally used fossil fuels e.g. natural gas as a central energy source. An important feature of Westhills is their Community Energy System (CES) program, which is one of North America's most innovative district heating and cooling networks that provides clean energy to more than 1,000 residents (SSL, 2014, p. 1). This particular system - designed, built, owned and operated by local parties - represents the next generation of

sustainability by making renewable, local energy accessible to new homeowners in the community (SSL, 2014, p. 1). By offering quality homes with efficient building envelopes and tapping into a local, renewable energy source, the award-winning Westhills is one of North America's greenest communities! Westhills truly is a beautiful corner of the Earth to call home. Their prices are affordable, the homes are well made, environmentally conscious, and the people are warm and welcoming to the neighbourhood. As a master planned community, Westhills aims to offer sustainable development for people who come from all class ranges, different ethnicities, and it is available for all ages to own. Situated between Langford and Glen Lake, this development truly is a great place for anyone to call their home.

Case Study 2 - Partington Creek in the City of Coquitlam

Greater Vancouver's population is projected to grow from 2.2 million to 3.4 million by 2041 (Campbell and Soong, 2012, pp. 1) which puts incredible pressure on all of the local municipalities to meet development needs while maintaining livability of their communities and also protecting the environment. Designed to be developed at the foot of Burke Mountain in Coquitlam on the Lower Mainland of B.C., the Partington Creek watershed is an underdeveloped and ecologically rich watershed covered by diverse second growth forest and is one of the last ecologically healthy streams in the Metro Vancouver region (Campbell and Soong, 2012, p. 1). Figure 1 and 2 are two aerial images depicting the geographical location and design plan for the Partington Creek development project on Burke Mountain in the city of Coquitlam.

FIGURE 1. AN AERIAL IMAGE OF THE PARTINGTON CREEK DEVELOPMENT SITE. (IMAGE COURTESY OF KERR WOOD LEIDAL ASSOCIATES LTD.).

FIGURE 2. AN AERIAL IMAGE OF THE PARTINGTON CREEK DEVELOPMENT PROPOSAL. (IMAGE COURTESY OF KERR WOOD LEIDAL ASSOCIATES LTD.).

In their article, Crystal Campbell and Dana Soong write:

> *To address environmental concerns, planners moved the village core to the east and modified land use densities. Collaborating with*

> *engineers, planners increased the proposed building heights and forms, and the scale and intensity of the development, so that more space could be set aside for environmental protection and sustainable infrastructure (2012, p. 1).*

A 1.5 billion Greenfield development, Partington Creek will be the future home to some 12,000 people. By using a progressive approach of iterative collaboration among planning, engineering, environmental, financial professionals, and stakeholders, it is possible to create a more sustainable community (Campbell and Soong, 2012, p. 2). The City of Coquitlam has developed a Neighbourhood Plan for Partington Creek to provide land use direction and detailed policies to guide development over the next 25 years (Partington Creek Neighbourhood Plan, 2013).

The Plan details a vision for the area that was developed through extensive consultation with the community. It defines the type and location of housing and commercial buildings in the neighbourhood, outlines transportation networks, identifies natural and recreational areas, and outlines pedestrian and cycling networks (Partington Creek Neighbourhood Plan, 2013). As a true sustainable development project, the lead Engineering Firm, Kerr Wood Leidal Associates received an Award of Excellence from the Association of Consulting Engineering Companies in British Columbia in 2012 for this project's Integrated Watershed Management Plan; making it one of the leading sustainable suburban developments on the Lower Mainland in B.C.

Is Sustainable Development for Everyone?

Although the facts strong favour new urbanist principles for sustainable development as being one of the best ways to address many of the world's current environmental and social issues, however, it does have some strong drawbacks. On a global scale, sustainable development is only available for a fraction of the world's population. Those who live in underdeveloped countries will never be exposed to sustainable development the ways that those who live in developed countries are. Another factor behind whether sustainable development is for everyone is that being "sustainable" in today's world comes at a high cost, and it is not affordable for all income earners. So even in developed countries, living sustainable is only available for a fraction of the people who can afford to spend the extra money on the expensive ecofriendly products etc.

Conclusion

At the start of this article, I presented the question: what does it mean to be sustainable? Today, nearly every new development project declares some sense of "sustainability," and in my opinion, Westhills and Partington Creek are examples of developments that are truly sustainable. As Master Planned Communities, they are both prime examples of development projects that follow New Urbanist principles. Through their proposed land-use developments,

neighbourhood plans and environmental protection efforts they aim to reduce sprawl, have produced compact, socially diverse homes and are pedestrian-oriented settlements. As previously noted at the beginning of this article, the Brundtland Commission defined sustainable development as "the development that meets the needs for the present without compromising the ability of future generations to meet their own needs". That is precisely what today's modern sustainable development projects seek to achieve; and in my opinion the two case studies have demonstrated how this outcome has been achieved.

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Landscapes of Illth: Applying Ruskin to Contemporary Cultural Landscape Geography

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Abstract: *John Ruskin, the first great art critic and historian to devote his attention primarily to landscape art, is named in virtually every textbook on cultural landscape geography. Ruskin's exposure of social injustice and his critique of the moral contradictions of capitalism started many of the founders of the English Labour Party on the road to socialism. Ruskin's statement 'there is no wealth but life,' and his critique of illth as an appropriation of wealth that ignores human and environmental flourishing, are founding ideas in many disciplines. Cultural Landscape Geography has been a core subfield of Human Geography for nearly a century, and yet to this point no scholar has utilized Ruskin's concept of illth to describe landscape. This article argues that the phrase 'landscape of illth' could be a helpful description of the cultural landscapes created in contemporary society and traces the concept from Ruskin to various North American landscapes.*

Keywords: Wealth, illth, cultural landscape, Ruskin

Introduction

John Ruskin (1819 – 1900) was one of the leading intellectuals and activists of the Victorian era. His writing is multidisciplinary with themes ranging from landscape art to geology, architecture to ornithology, and botany to political economy. He is a conceptual father of many disciplines ranging from the first ecologist to being the inspiration for the arts and crafts movement (Sawyer 2012). In some circles he is most widely known as the Victorian whose marriage ended due to non-consummation (Prodger 2015). The story of Effie leaving John for a pre-Raphelite artist has inspired numerous books as well as an opera, a silent film and assorted plays. For Geographers, however, Ruskin is best known for his contribution to the landscape tradition.

Ruskin is described by Stephen Daniels and Dennis Cosgrove (1988, p. 5) as the first great art critic and historian to devote his attention primarily to landscape art. They demonstrated how "landscape became in Ruskin's eyes a suitable subject for examining the deepest moral and artistic truths." Proclaimed by Peter Fuller (1985, p. 283) as the "first true prophet of the post-modern and post-industrial era," Ruskin and the landscape tradition has been the subject of an increasing corpus of study that has reached beyond the disciplinary boundaries of art history for at least the last forty years. At the height of his reputation as an art critic, Ruskin shifted his emphasis from art to the relationship between art and society, and then directly to social and economic questions. Spear (1976, p. 12) notes how he

attacked laissez faire capitalism "with a savagery that made his comments on painters and architects seem mild by comparison."

Ruskin's impact has been substantial and multidisciplinary. His disclosure of social injustice and his critique of the moral contradictions of capitalism started many of the founders of the English Labour Party on the road to socialism (Spear, 1976). Mahatma Gandhi was so impacted by his writings that he translated Ruskin's *Unto His Last* into his native Gujarati. Ruskin's (1862) statement that 'there is no wealth but life' and his critique of 'illth' (the poverty, ill-health, pollution and despair that were the attendant downside of economic wealth) are cited as founding ideas for understanding the dynamics of capitalism today (Koo, 2013).

Ruskin's Concept of Illth

"THERE IS NO WEALTH BUT LIFE" (Ruskin, 1862) is the most quoted of Ruskin's sentences, and he himself wrote it in capitals. The phrase is the central tenant of his political economy, as for Ruskin economics remained a branch of ethics – it could not be separated from moral philosophy. "Wealth for Ruskin was qualitative not quantitative. Wealth did not simply mean the acquirement and accumulation of material goods commanding an exchange value. Rather, wealth were things that 'availed to life'" (Spear, 1976, p. 13).

The term Illth first appears in an 1860 article in Cornhill Magazine, which was later compiled into a single volume in 1862 titled *Unto this last*, a reference to Christ's Parable of the Workers in the Vineyard from Matthew 20:1-16. Ruskin re-appropriates the parable into a political ethic regarding the distribution of a living wage. In so doing, the text aroused the ire of many readers who felt the ethic at very least bordered on a socialist stance that was largely disdained. In the text Ruskin critiques a growing political science which fails to precisely define wealth, citing an author who claims, "Everyone has a notion, sufficiently correct for common purpose, of what is meant by wealth…It is no part of the design of this treatise to aim at metaphysical nicety of definition" (1862, p. 6). Ruskin then embarks on a project of illustrating a rich conception of wealth, concluding that wealth is necessarily intertwined with justice:

The whole question, therefore, respecting not only the advantage, but even the quantity, of national wealth, resolves itself finally into one of abstract justice. It is impossible to conclude, of any given mass of acquired wealth, merely by the fact of its existence, whether it signifies good or evil to the nation in the midst of which it exists. Its real value depends on the moral sign attached to it, just as sternly as that of a mathematical quantity depends on the algebraical sign attached to it. Any given accumulation of commercial wealth may be indicative, on the one hand, of faithful industries, progressive energies, and productive ingenuities: or, on the other, it may be indicative of mortal luxury, merciless tyranny, ruinous chicane. Some treasures are heavy with human tears, as an ill-stored

harvest with untimely rain; and some gold is brighter in sunshine than it is in substance (p. 23).

Later Ruskin sums up emphatically: "Wealth, therefore, is 'THE POSSESSION OF THE VALUABLE BY THE VALIANT'" (p. 41).

So Ruskin views wealth not simply as a mass of amoral possessions, but as resources fairly acquired and subsequently deployed for the benefit of society. In Ruskin's view, when these tools are ill-gotten and/or deployed to the detriment of society they fail to be wealth – they rather become illth:

Whence it appears that many of the persons commonly considered wealthy, are in reality no more wealthy than the locks of their own strong boxes are, they being inherently and eternally incapable of wealth; and operating for the nation, in an economical point of view, either as pools of dead water, and eddies in a stream…or else, as dams in a river, of which the ultimate service depends not on the dam, but the miller; or else, as mere accidental stays and impediments, acting not as wealth, but (for we ought to have a correspondent term) as "illth," causing various devastation and trouble around them in all directions (p. 78-79).

George Bernard Shaw, in his 1889 essay, *The Economic Basis of Socialism*, pays homage to Ruskin in his section titled "Illth" (p. 22-29). Shaw bitterly critiques England's social policies and uses the concept of illth to illustrate the juxtaposition between luxury in the face of poverty:

The moment a price is to be had for a luxury, it acquires exchange value, and labor is employed to produce it. A New York lady, for instance, having a nature of exquisite sensibility, orders an elegant rosewood and silver coffin, upholstered in pink satin, for her dead dog. It is made; and meanwhile a live child is prowling barefooted and hunger-stunted in the frozen gutter outside. The exchange-value of the coffin is counted as part of the national wealth; but a nation which cannot afford food and clothing for its children cannot be allowed to pass as wealthy because it has provided a pretty coffin for a dead dog (p. 22).

Illth, then, is an appropriation of wealth that ignores human and environmental flourishing. It is wealth turned toward a project's secondary or even tertiary importance. Or, as we see in Mumford, wealth actively used for destruction. Lewis Mumford's *Technics and Civilization* (1934) is a classic in the fields of technology studies, media studies, and communication theory. Mumford began probing questions that later intellectuals would extensively build on as the academy began to think seriously about technology as a force worth serious contemplation. Mumford ranges in topics in his 1934 work, and in the book's later stages he turns to a critique of industrial society, particularly the military-industrial complex-–a concept anticipated by Mumford, but not coined for some three decades after the

book's publication. In this manuscript, Mumford cites Ruskin's influence saying:

An army is a body of pure consumers. As the army grew in size it threw a heavier and heavier burden upon productive enterprise: for the army must be fed and housed and equipped, and it does not, like the other trades, supply any service in return except that of "protection" in times of war. In war, moreover, the army is not merely a pure consumer but a negative producer: that is to say, it produces illth, to use Ruskin's excellent phrase, instead of wealth-misery, mutilation, physical destruction, terror, starvation and death characterize the process of war and form a principal part of the product (p. 93).

In Mumford's work, illth moves from referring to the immoral, selfish, or questionable uses of wealth to the production of devastation – that which uses resources in order to produce destruction, misery, terror and death. This is a perceptive re-appropriation of the term to characterize the intention of the modern military-industrial complex to produce that which actively destroys. This is not too distant from the thoughts of Ruskin. "If wealth consists of things that avail life, illth consist of death-dealing things – the manufacture of things that cannot be consumed, whose consumption is harmful, or whose manufacture causes more damage than its consumption gives benefit" (Spear 1976, p. 13). Ruskin asserted that all land owners had a responsibility to contribute to the common wealth of society, and not the common illth.

Cultural Landscapes of Illth

Cultural Landscape Geography has been a core subfield of Human Geography for nearly a century, and yet to this point no scholar we have found has utilized Ruskin's concept of illth to describe a landscape. The phrase 'landscape of illth' is used only one time by Fellows (1981, p. 287), a biographer of Ruskin, who describes "the nature of the maddened postcircumferential dream landscape of Illth," defined as "a landscape of ruined surplus or excessive meaning become refuse that tends to dispose of itself almost as if in the vortical syntax of self-cannibalization."

We argue that the phrase 'landscape of illth' could be a helpful way to describe many of the cultural landscapes socially created in contemporary society. In order to make this point we review cultural landscape literature with an eye toward illth. Dennis Cosgrove described landscape as a "suitable subject for examining the deepest moral and artistic truths" (Cosgove and Daniels, 1984, p. 5). Landscape is defined in the *Dictionary of Human Geography* as "a polysemic term referring to the appearance of an area, the assemblage of objects used to produce that appearance, and the area itself" (Johnston, 2000, p. 316). The root of the word derives from the Old English *landscipe,* referring to a "district owned by a particular lord or inhabited by a particular group of people" (Mikesell, 1969, p. 576). By the early seventeenth century this meaning had been influenced by the Dutch *landschap* painters and "came to refer to the appearance of an area, more particularly to the representation

of scenery" (Johnston, 2000, p. 316). Philip Hamerton, an author on landscape appreciation in the late nineteenth century, discussed landscape in two senses – as "the visible world" and as a "piece of the earth's surface that can be seen at once" (Mikesell, 1969, p. 576). This is the basis of the contemporary definition which, according to Johnston, is "a portion of land or territory which the eye can comprehend in a single view, including all the objects so seen, especially in its pictoral aspect" (Johnston, 2000, p. 316).

The idea of landscape was brought full force into the discipline of geography in 1925 through an article titled "The morphology of landscape" by Carl Sauer. Sauer, in an assault upon the environmental determinism of his day, described the task of geography as "the establishment of a critical system which embraces the phenomenology of landscape, in order to grasp in all of its meaning and color the varied terrestrial scene" (Sauer, 1925, p. 320). He defined a landscape generally as an area or region, but went on to define the usage among the German geographers as "a land shape, in which the process of shaping is by no means thought of as simply physical. It may be defined, therefore, as an area made up of a distinct association of forms, both physical and cultural" (Sauer, 1925, p. 321). He goes on to state "the cultural landscape is fashioned from a natural landscape by a culture group. Culture is the agent, the natural area is the medium, and the cultural landscape is the result" (Sauer, 1925, p. 343).

Possibly the most influential book on landscape since Sauer is *The Interpretation of Ordinary Landscapes* edited by D.W. Meinig in 1979. Though this volume contained very little new material, it acts as a powerful summary of the work of the period, with chapters by Jackson, Lowenthal, Lewis, Meinig, Samuels, Sopher, and Yi-Fu Tuan. Two chapters are relevant to our discussion of illth. Pierce Lewis's contribution to the work, "Axioms for reading the landscape," is undergirded by two basic premises. The first is that "all human landscape has cultural meaning" and that we can "read the landscape as we might read a book" (Lewis, 1979, p. 12). The second is that most people are unaccustomed to reading the landscape. Lewis then provides seven axioms to act as guides in interpreting landscape. The first, the Axiom of landscape as clue to culture states that "the man-made landscape… provides strong evidence of the kind of people we are, and were, and are in the process of becoming" (Lewis, 1979, p. 15). This may be the most frightening of the axioms when considering landscapes of illth. Similarly, the Axiom of cultural unity and landscape equality states that, "nearly all items in human landscapes reflect culture in some way," (Lewis, 1979, p. 18) asserting that a change in the architecture of a McDonalds is reflective of a change in culture. The remaining Axioms relate less to our study of illth but are interesting nonetheless: the Axiom of common things, the Historic Axiom, the Geographic Axiom, the Axiom of Environmental control, and the Axiom of landscape obscurity.

Meinig, in his groundbreaking

chapter "The beholding eye: ten versions of the same scene," confronts the problem that "any landscape is composed not only of what lies before our eyes but what lies within our heads," (Meining, 1979, p. 34) by providing ten ways a group of people could view a common scene. The ways include: landscape as nature, landscape as habitat, landscape as artifact, landscape as system, landscape as problem, landscape as wealth, landscape as ideology, landscape as history, landscape as place, and landscape as aesthetic. A few of these viewpoints reflect in various ways what we will describe as a landscape of illth. Landscape as problem is described as seeing "a condition needing correction," which is certainly (one would hope) indicative of illth. Landscape as wealth could have a corollary as illth if it were spelled out more clearly, but Meinig uses it only to quantify landscape as an appraiser in a market economy – in this sense an impoverished view of wealth relative to Ruskin's philosophy. Landscape as ideology may come closer, as a landscape can provide, "a symbol of the values, the governing ideas, the underlying philosophies of a culture" (Meining, 1979, p. 42). As such, a landscape of illth transcends one particular landscape scene and reveals truths about a broader society. Landscape of aesthetic might be contrasted by a landscape of illth, which could perhaps be considered anti-aesthetic, though a landscape of illth is not simply a (potentially subjective) aesthetic matter. That is to say, a landscape of illth is not simply ugly. Yet, a significant aspect of Ruskin's critique of industrialization involved the aesthetic. "Ruskin's passionate opposition to industrialism had aesthetic as well as moral origins. The ugliness it spawned was a constant offense to his extraordinary visual sensitivity, a mockery of his devotion both as a critic and a considerable artist in his own right to landscape and landscape painting" (Spear, 1976, p. 13). However, illth is intended not only to be a matter of aesthetic but of qualitative experience and systemic production.

In the 1980s and 1990s a number of new directions for interpreting landscapes were suggested. One of these, phenomenology, is summarized well by Christopher Tilley in *Places, Paths, and Monuments: A Phenomenology of Landscape.* Tilley (1994, p. 12) defines phenomenology as, "the understanding and description of things as they are experienced by a subject." In phenomenology, "subjectivity and objectivity connect in a dialectic producing a place for being in which the topography and physiography of the land and thought remain distinct but play into each other as an 'intelligible landscape', a spatialization of being" (Tilley, 1994, p. 14). He states,

numerous authors, a massive environmental lobby, and a 'green movement' have consistently remarked on the manner in which landscapes, buildings, places and localities in contemporary society seem to have lost, or be in the process of losing, their value and significance… Once stripped of sedimented human meanings, considered to be purely epiphenomenal and irrelevant, the landscape becomes a surface or volume like any other, open for exploitation and

everywhere homogeneous in its potential exchange value for any particular project. It becomes desanctified, set apart from people, myth, and history, something to be controlled and used. (Tilley, 1994, p. 21).

Such a landscape could easily be described as a landscape of illth. If "the spirit of a place may be held to reside in a landscape" (Tilley, 1994, p.26), then the spirit of destruction, exploitation, neglect and control can come to characterize particular landscapes.

Another significant conceptual basis for interpreting landscapes is hermeneutics, demonstrated through authors such as Duncan and Duncan or Schein. Hermeneutics seeks to get beyond the description of "landscapes in and of themselves" in order to show "how their meanings are always buried beneath layers of… ideological sediment" (Duncan and Duncan, 1988, p. 117). A hermeneutical practitioner combines literary theory with social theory in order to examine the text-like quality of landscapes. Duncan and Duncan use three examples to illustrate how texts can be transformed into the landscape. Schein builds upon this foundation by applying hermeneutical methods to Ashland Park, a suburb of Lexington, KY. Schein (1997, p. 663) describes America as "a particular challenge to the landscape interpreter," due to its piecemeal creation, rugged individualism, laissez-faire capitalism, and political democracy. "Each seemingly individual decision behind any particular U.S. landscape is embedded within a discourse. When the action results in a tangible landscape element… the cultural landscape becomes the discourse materialized." Considering Ruskin's concept of illth in this vein, a landscape of illth reveals a culture of illth – a discourse of death-dealing things.

A final conceptual framework for landscape interpretation that nicely captures Ruskin's concept of illth stems from Marxism and is illustrated in the works of Cosgrove and Mitchell. Cosgrove (1984, xiv) redefines landscape, stating that the "landscape idea represents a way of seeing." He argues that "landscape constitutes a discourse through which identifiable social groups historically have framed themselves and their relations with both the land and with other human groups, and that this discourse is closely related epistemically and technically to ways of seeing." In *Social Formation and Symbolic Landscape,* Cosgrove argues that before a capitalistic economy the relationship between human beings and the land was unalienated. With a capitalistic economy came "a relationship between owner and economy, an alienated relationship wherein man stands as an outsider and interprets nature causally" (Cosgrove, 1984, p. 64). Mitchell (2000, p. 88) builds upon these ideas by arguing that, "the 'work of culture' is to advance social reproduction (or societal integration) through the making and marking of differences that do a lot to obfuscate connectedness." In his chapter, "The Work of Landscape" he traces a history of labor in Johnstown, Vancouver, and Sacre-Coeur to illustrate Cosgrove's assertion that "landscape, along with cartography, and the

development of modern theatre, was an important tool for the 'practical appropriation of space'" (Mitchell, 2000, p. 116). Hence, landscapes justified to owners of property their status and the rightness of their rule over the land. Seen in this way, the landscape itself becomes an "imposition of power: power made concrete in the bricks, mortar, stones, tar, and lumber of a city, town, village, or rural setting" (Mitchell, 2000, p. 123).

Thus, in summary, a landscape of illth is a landscape that does not contribute to the betterment of society – that does not avail to life. A landscape of illth reveals the immoral, selfish, or questionable uses of wealth for the production of devastation. Such landscapes are simultaneous ecological and social sceneries of destruction, misery, terror and death. A landscape of illth consists of death-dealing things deployed to the detriment of society and nature. Landscapes of illth see the intentional production of waste supersede human and/or environmental flourishing. A landscape of illth possesses deep cultural meaning and reveals moral truths about the imposition of power and the spirit of destruction, exploitation, neglect and control within the culture laying waste to natural and human ecosystems.

Contemporary Landscapes of Illth

Landscapes of illth exist in countless settings across the globe and are generated by multifaceted factors such as capitalism, resource extraction and warfare. The history of deforestation in West Virginia provides a compelling example of how landscapes of natural beauty and vitality can be transformed into illth within a single generation. In 1880 two-thirds of the state was covered by ancient growth hardwood forests. By 1920 of every 10 acres of previously hardwood forest, four had been converted into farms, four were "just" cutover, and two remained woodlands. Historian Ronald Lewis (1998, p. 7) describes how "West Virginia officials promoted the exploitation of these resources as the surest road to economic development and the railroad as the most efficient engine for delivering economic growth." Coupled with "cutout and get out" exploitive practices of the lumber and mining industries and accommodationist legislative actions aimed at enhancing capitalist development, these forces decimated the environment upon which the economic base was dependent. By the 1920s the scale of environmental destruction was mammoth, resulting in acute social ramifications. It removed the foundation of backcountry family-based agriculture and changed the economic mode of production from agrarian to wage-based laborers. Bio-physically it wreaked tremendous environmental havoc upon the entire state with forest fires, floods, stream pollution, and soil erosion (Lewis, 1998).

Once the mountains had been skinned of their forest, the lumber companies closed their operations and moved to greener country in the south and west. Without lumber the railroads soon pulled up their track and withdrew from the mountains as well. Again the countryside fell silent, once booming mill towns declined, and

propertyless wage earners were left to drift away to become members of the new marginalized poor. In this condition, West Virginia confronted the Great Depression and its modern paradox as a state whose robust expansion had saddled it with an anemic economy. (Lewis, 1998, p. 9)

Horace Kephart lived in the heart of what he described as a "superb primeval forest" for most of his life. In 1925 he described the same geographic location as, "wrecked, ruined, desecrated, turned into a thousand rubbish heaps, utterly vile and mean." He then asks the question, "Did anyone ever thank God for a lumberman's slashing?" (Lewis, 1998, p. 12) Emory Wriston, a pioneer conservationist in West Virginia, summed up the landscape of illth even more poetically: "If trees could talk and cuss, West Virginia would be a poor place for a preacher to go on a picnic" (Lewis, 1998, p. 264).

A contemporary example may be seen in Edmonton, Alberta's city centre, where a geographic phenomenon exists that locals call "the 97 St. Divide." From Jasper Ave looking north up 97 St. one side of the street looks profoundly different than the other. On the west side lies Canada Place and the downtown core filled with skyscrapers, city hall and bystanders rushing on busy streets wearing ties and pantsuits. On the east side lie older dilapidating buildings advertising pawn shops, massage parlors, pubs and short term loans. Bystanders on this side of the road are frequently pushing shopping carts or idly chatting on street corners. One side of 97 St. represents the so called wealth of the city (though not wealth as Ruskin defines it) and the other side its illth. This is not to say each side is reduced to either wealth or illth in some kind of a dualistic polarity. The east side of 97 St. is not a landscape of illth because it is ugly. It embodies illth because, in the spirit of Meinig, illth can be used a landscape lens to view the intentional waste and destruction of people, property, and resources that serves to empower and enrich the wealth holders/havers who are literally and metaphorically represented on the west side of the divide. The landscape looking up 97 St. is not difficult to interpret: resources are taken from one side in order to enhance the other.

East Hastings Street in Vancouver provides another contrast between this city's structures and status symbols of power and its own landscape of illth where the powerless congregate. It is infamous for being the most poverty stricken postal code in Canada and one of the only places where drug laws are not enforced. The landscape is replete with homeless individuals lying on sidewalks, addicts shooting up, and agents of social services working to alleviate the conditions of illth almost to no avail. Last summer one of the authors was on a field trip along East Hastings with a class and witnessed a homeless man trying to cross a side street to West Hastings near the city centre. As soon as he touched the curb a security guard escorted him back to the part of the portrait in which society has deemed he belonged. Again, the discourse in this landscape is clear for all to see – one side is for the powerless, the other for the

powerful. One side for wealth; the other for illth.

Conclusion

John Ruskin's writings have contributed to countless academic disciplines and have impacted scholarship throughout the natural and social sciences. One of Ruskin's biographers, Raymond Fitch (1982, p. 42) described him as,

"the great Victorian prophet of what we would now call the apparent deterioration of life. Stylist, aesthete, economist, moralist, glaciologist, naturalist, or nympholept he may also have been, but the compulsive current of his many works is his rising nausea at the prospect of a global slum, a depleted planet… that our culture has been blighted, that the world's body has been infected by its mind…[and by] life's struggle with wealth."

This article has traced Ruskin's concept of illth as an antonym to his definition of wealth as life through the literature of cultural landscape geography and has suggested that the nomenclature 'landscape of illth' could be a valuable descriptor for interpreting many of the degraded or destroyed landscapes of our world today. One only needs to pay attention to the first few links in any news feed to grasp the extent to which landscapes of illth are becoming more prominent. Yet, Ruskin does not leave us to suffer and die in an illth saturated world. Instead, his desire for the future lay in the hope that humanity would find a way on the path toward wealth as life. Spear says of Ruskin that behind his,

"distinction between wealth and illth, and the occasional programmatic suggestion that anticipate those of modern environmentalists, lay the belief – only now being re-established on a scientific rather than a moral basis – that man must consider himself part of the natural order; that he must reject the dangerous illusion that he can or should conquer nature, and remember that human societies are not only systems in themselves, but part of larger ecosystems upon which man as much as any other species depends upon for survival" (Spear, 1976, p. 13).

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Trash Talk in Edmonton: The Implications of Converting Garbage to Greenery along the Edmonton River Valley

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Abstract: *Edmonton possesses the largest interconnected parkland in North America. Unlike other popular North American parks, there is little scholarly research on the history of this environmental asset. This paper highlights preliminary research towards a module in a historical digital atlas about Edmonton's River Valley – a module that provides insight into waste mitigation and the management of local natural resources, where an urban problem can result in desirable amenities: such as, an urban green space. During the City of Edmonton's formative years, locations for dumping garbage were chosen solely for inexpensive cost and convenience; impacts on the environment and human health were not concerns. Throughout the twentieth century, environmental regulations evolved to account for a myriad of issues that occur from accumulating waste – for instance, leachate and methane containment. By the 1960s, the broader environmental movement coalesced into a reaction against unnecessary pollution, but most importantly, it emphasized human health and strengthening our relationship with our environment. Through interviews with City of Edmonton Waste Management employees and an analysis of historical documents, various scholarly works, and contemporary local, and provincial, legislation, this article discusses the challenges and implications of transitioning landfills to parks in Edmonton within different eras.*

Keywords: Reclamation; Landfills; History; Parks; Edmonton

Introduction

Imagine the smell of smouldering refuse, the air thick with flies, piles of rotten debris, ashes, and half-burnt household products covering what was once a patch of greenery. During the City of Edmonton's formative years, refuse was dumped everywhere, and more specifically near the river valley and ravines. Locations for dumping garbage were chosen solely for inexpensive cost and convenience; impacts on the environment and human health were not concerns. Over time, dumping grounds required capping and reclamation—processes that differ depending on environmental regulations in a specific timeframe. Despite varying regulations, past landfills have become important environmental and human health features in parks along the Edmonton

River Valley. Landfill and industrial systems such as the Grierson and Beverly Dumps, and the Frontier Farms Landfill marred the river valley. However, these garbage disposal systems were later closed and made part of Louise McKinney, Rundle, and Strathcona Science Park, helping to create Edmonton's now famously aesthetic river valley. An analysis of historical documents and contemporary, local and provincial legislation, as well as interviews with waste management employees, reveals that the differing restrictions and challenges of transforming landfills into these specific river valley parks led to minimal negative environmental implications.

The history of landfills in Edmonton is short. Nineteenth century Alberta had a sparse, rural- based population, and because of the absence of consumer products, many materials had to be reused (Murray, 1994). Edmonton's garbage disposal – usually done by open burning or dumping near the river – continued to be the responsibility of the individual homeowner. However, near the end of the nineteenth century, the need for garbage collection became apparent (Environmental Waste Management, 1979). Thus, Edmonton's first municipal landfill – or nuisance grounds – was opened in 1894 (Environmental Waste Management, 1979).

Rat Creek Dump and Incinerator

Herzog (2010) outlines a brief history of Edmonton's waste management and its first nuisance grounds (called Rat Creek Dump) and the Decarie Incinerator. The Rat Creek Dump[2] was constructed where Commonwealth Stadium now stands. When a large volume of garbage built up at the dumping grounds, the city constructed the Decarie Incinerator and began its operations in 1908. While Edmonton's residential neighbourhoods became populated, citizens began to complain about the incinerator. Several citizens attended a public meeting in which Herzog quotes an edition of the Edmonton Bulletin that states: "Residents of Norwood demand removal of a vile smelling monster" (Edmonton Bulletin, 1910; Herzog, 2010). However, the public protests had little effect, and the incinerator operated into the early 1930s, and the dump was used until 1939.

Clover Dale Flats Incinerator

The volume of trash began to pile up in the early twentieth century, with most garbage going to Rat Creek or Grierson Hill Dumps (Environmental Waste Management, 1979). By the 1930s the city decided that burning was a better, more inexpensive option for dealing with garbage, and in 1932 it constructed the Clover Dale Flats Incinerator near what is now the Muttart Conservatory (Herzog, 2010). The incinerator was seen as a way to eliminate the small, and smelly, nuisance grounds throughout the city (Environmental Waste Management,

1979). Despite further complaints from residents, the incinerator was expanded in 1954 (Herzog, 2010). However, usage of it waned until it closed in 1974 (Environmental Waste Management, 1979). Remnants of the incinerator can be found beside Connors Road, where a Doves of Peace sculpture sits on buried mounds of ash left over from the incinerator (Herzog, 2010).

Grierson Dump

The Grierson Dump and its nuisance grounds began before the turn of the twentieth century and it eventually contained ash from the above-mentioned incinerators and other refuse, such as cans and metal items that were not easily reused or burnt (Godfrey, 1993). The Grierson Dump was centrally located at the foot of Grierson Hill (near where the Shaw Conference Centre now stands) and was subject to many complaints. Grierson Dump achieved notoriety during the Depression as the location of a shantytown (with approximately fifty bachelors living in shacks built at the openings of old coal mines) in 1935 (Edmonton Journal, 1935). The inhabitants survived by selling items they scavenged from the dump, including paint cans and car parts. The site appears to have gone out of operation, with the shacks presumably destroyed by the late 1940s (City of Edmonton, 1943). By this time, only "clean fill" was used in the river valley for stabilizing the river bank from future sliding.

From the 1940s to the 1970s waste management went through many changes (Environmental Waste Management, 1979). In the 1940s the increasing amount of waste and air pollution led to the City of Edmonton abandoning incinerators in favour of solid waste landfill sites. The 1950s was a period of consolidation of the solid waste collection and disposal methods that were previously adopted (the construction of the new incinerator, a reduction of small open dumps, curtailment of back-yard burning, and full motorized garbage collection). However, from the 1960s to 70s many changes occurred in solid waste management. Incineration was completely terminated and the collection system of sanitary landfilling was introduced. As was inevitable with increasing environmental concerns, the above-mentioned Cloverdale incinerator could not be revamped due to anti-pollution regulations. By the late-1960s, the City of Edmonton maintained two landfill sites that were operated in cooperation with Provincial regulations passed in 1961.[3]

Beverly Dump and Rundle Park

In 1956, the City of Edmonton purchased dumping grounds near the town of Beverly to supplement their incinerator and various other landfills. The site for the landfill began as a farm owned by the Prins family, and was later used unsuccessfully as a strip mine in the 1950s (Herzog, 2000). During an interview, an

engineer working for Edmonton Waste Management stated that dumping of liquid and solid wastes began in the abandoned strip coal mines in 1960 (Yee, 2014, personal communication).

From 1956 to the beginnings of dumping refuse in 1960, government regulations had changed and the city began distancing urban development and fencing portions of the refuse grounds to allow for safe residential development — the term dump changed to sanitary landfill, and accordingly, the city was attempting to ensure those living around the landfill had safe living conditions. Establishing distance and fencing, however, did not alleviate concerns: fires broke out many times in the rubbish of the Beverly Sanitary Landfill (an issue now prevented by layering soil on top of refuse according to provincial legislation), and the residents from the area (now known as Rundle Heights) around the dump complained of health concerns related to smouldering garbage (City of Edmonton Archives, 1970; Alberta Environment, 2010; Yee, 2014, personal communication).

Godfrey, through his guide to the geology of Edmonton, provides insight on the Beverly landfill site where roughly twenty-five meters of solid waste was deposited at the Beverly site from the mid-1950s to the early 1970s (1993). In addition to accepting Edmonton's refuse and industrial waste, the landfill was also a disposal site for old cars: approximately ten meters of compressed cars underlie the landfill. One particular landfill fire is noted to have produced such intense heat that it lasted a week and melted the steel of the underlying cars, solidifying it into an impermeable layer at the landfill's bottom. This event resulted in a liner for the refuse at a time when the placement of thick clay liners and other impermeable membranes were not enforced by the provincial government.

In order to minimize the nuisance to the homes of Rundle Heights, a part of the dump was contoured, following specifications outlined in the city park plan (Rundle Park Grading Plan, 1970). However, in 1969 residents expressed their displeasure with the actions undertaken by the city to eliminate the burden of the landfill by sending many complaint letters. A Report to the City Commissioner from the City Planner lists a complaint by a resident who described the Beverly Landfill site as an "unsightly eye sore and health and safety hazard in this modern day and age" (1969). Under the 1961 Regulations for the Control of Refuse Disposal Systems, it was understood that a sanitary landfill that would operate for a number of years would improve the area or buffer arrangements would distance the landfill site from residential development by 1500 feet (Provincial Board of Health, 1961). Citizens believed that satisfactory buffer arrangements were not made. They noted that the City of Edmonton constructed a waste disposal site knowing

that immediate residential development would take place within 1500 feet of it. These complaints highlight the issues that are brought forward when a landfill site is in close proximity to urban development: people do not want to live near heaps of garbage. Nonetheless, despite the effective complaints from the citizens of the Rundle Heights division, it was not complaints that brought the closure to the landfill site.

The lifespan of Beverly dump was estimated at ten to fifteen years, and the original plans state that the dump would be converted to parkland once the site had been filled with refuse (Yee, 2014. Personal communication). Thus, a specific grading plan was implemented in the early 1970s to convert the landfill into parkland.

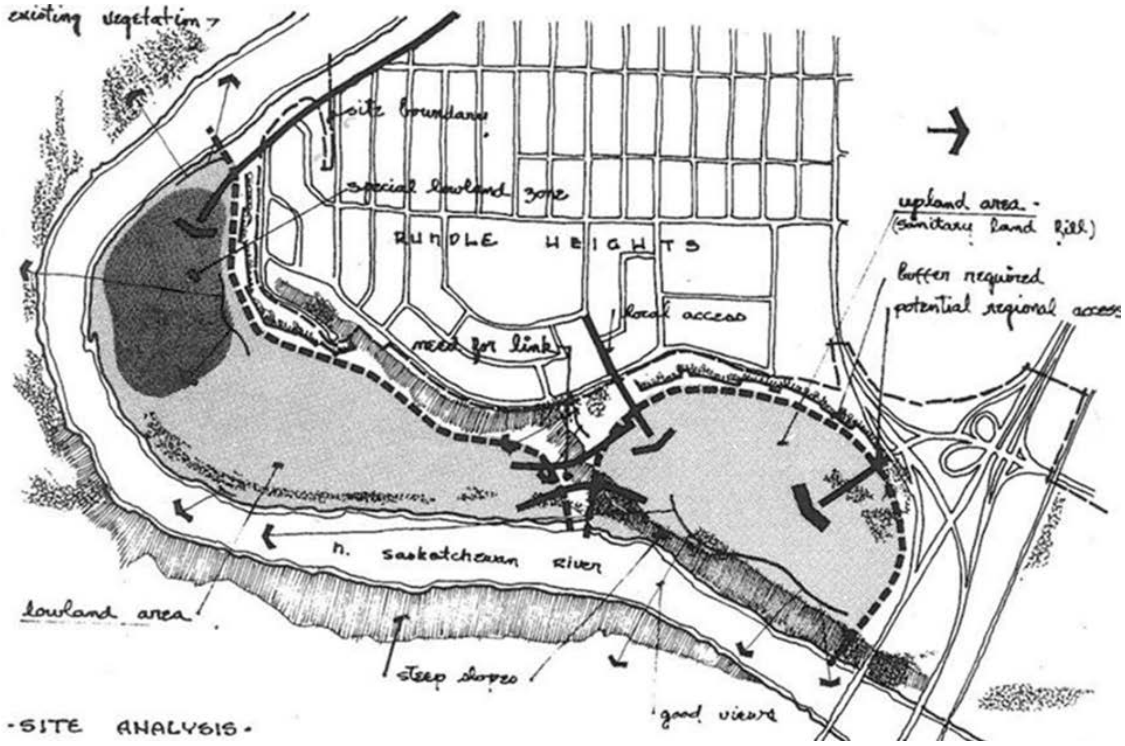

Figure 1. The picture shown above is taken from the Beverly Dump grading plan in 1970, indicating the areas of the site used for transitioning into parkland. (Source: Reproduced with permission from the City of Edmonton Archives)

The grading process to convert landfill to parkland went smoothly and by 1972 the city finished covering the landfill and completed the nine-hole Rundle Park Golf Course where most of the landfill was located; however, when the golf course

clubhouse was constructed a year later hazards of building over a landfill site became apparent. According to a 1979 Environmental Protection Services report about *Landfill Gas Migration to the Rundle Park Golf Course,* a subsurface investigation revealed that combustible gases generated by decomposing garbage were present below the golf course – an area considered to be free of buried garbage. Up to a maximum of 83% volume of methane gas was measured in the subsurface adjacent to the golf course. Thus, some methane was detected in the clubhouse, and to reduce the possibility of explosion, the Parks and Recreation department and City of Edmonton installed a ventilation system below the clubhouse. They also installed a monitoring system to warn when methane beneath exceeded 20%. Lastly, a flare station was also set in place to prevent any migration of landfill gas that could cross the street and enter people's homes.

After all the proper renovations were complete, Rundle Park officially opened as a Capital City Recreation Park in 1978. Beverly Dump was transformed into a popular river valley park, recreation centre, and golf course. The fairways and greens of the Rundle Golf Course, along with other diversions, signify a different time with little landscape evidence of the past landfill – a flare burning off combustible methane, less aesthetically pleasing trees, rolling hills, and the occasional tire that emerges to the surface (Yee, 2014, personal communication). The present effects of less strict environmental regulations from the past in Rundle Park are seemingly aesthetic, and they do not detract from this popular park destination.[5]

Many reports claim that "clean waste" was used to fill the Beverly Dump site for conversion. Interestingly, whereas clean waste is mentioned in many records, it was not clearly defined at the time. There were no controls on hazardous waste in Alberta.[4] If one drives through the golf course they may notice that the trees do not grow well. During a 2014 interview with Yee, he speculated that a thin capping layer and hazardous waste used to contour the site might be the cause of improper growth. Yee also noted that at the time of grading there were slower methods of compaction and less strict regulations. Now many small hills caused by less intensive compaction and grading are noticeable, especially near the Rundle Park golf course.

FIGURE 2. THE PICTURE SHOWN ABOVE IS RUNDLE PARK IN 1970. A VIEW FROM 107 AVE IN WHICH TRANSITION FROM A LANDFILL SPACE TO PARK HAD BEGUN. (SOURCE: REPRODUCED WITH PERMISSION FROM THE CITY OF EDMONTON ARCHIVES).

FIGURE 3. THE PICTURE SHOWN ON THE TOP RIGHT IS A TAKEN FROM 107 AVE IN 2013. TAKE NOTE OF THE SIGNAGE CAUTIONING CITIZENS OF THE ROUGH ROAD – INFLUENCED BY DIFFERENTIAL SETTLEMENT DUE TO GARBAGE DECOMPOSING BENEATH. (SOURCE: VALIQUETTE, MARIE-JOSÉE).

Beverly Dump received its last refuse in 1972 (John S. Graham Architects & Engineers, 1973). During the time that the Beverly landfill site was active, another landfill site also accepted waste on 75th street (Herzog, 2010). This landfill was in

operation from the mid-1950s to 1975, when it was capped and transformed into the Millwood's Golf Course (Herzog, 2010). Due to old standards of compaction, this site also resulted in rolling hills and "differential settlement" (Yee, 2014, personal communication). Yee also mentions that when the 75th street and Beverly dumps were near closure the Edmonton city officials had trouble finding a replacement landfill, but they found an interim solution through the Frontier Farms Landfill, which was eventually replaced with Edmonton's first engineered sanitary landfill at Clover Bar.

Frontier Farms Landfill and Strathcona Science Park[6]

Yee (2014, personal communication) outlined the history of the Frontier Farms Landfill. In 1971 the City of Edmonton made an agreement with the County of Strathcona to use a site at the Frontier Farms Landfill with the objective of infilling gravel pits to restore the land's original contours. Yee states that Frontier Farms was an interim solution to move garbage away from the two landfills that were undergoing closure: the Beverly landfill, which later became Rundle Park, and the landfill on 75th St. which later became Millwood's Golf course. Thus, a short lifespan for Frontier Farms was anticipated, and when it was closed it held approximately two million tonnes of garbage). The South Frontier Farms Landfill operated from 1972 to 1975, and the North Frontier Farms Landfill operated from 1975 to 1977 (Das, et. al. 1996).

Upon closure of the Frontier Farms Landfills, a clay cap was installed to prevent moisture from entering the waste, thereby hindering the production of leachate[7] and methane gas as well as its leakage. However, the compaction of this solid waste "wasn't great so there was a lot of deferential settlement at that site" (Yee, 2014, personal communication). In which case, a representative from the City of Edmonton Waste Management staff noted that the standards of compaction were not what they are today. In 1976, ownership of Frontier Farms was transferred to the Province of Alberta from the County of Strathcona, and in 1979 the City of Edmonton constructed a final clay cover and completed site reclamation (Das et. al., 1996).

Since 1979, the site has been known as the Strathcona Science Park (EBA Engineering Consultants Ltd, 1996). The six buildings and roads present in the park were complete by 1980 (Das, et. al., 1996). These buildings held interactive educational displays, and the park maintained gravel trails as well as educational signage. But the Strathcona Science Park was not a popular destination due to its location. Thus, in 1993 the buildings in the Strathcona Science Park were closed, although the trails in the park remain open.

The previous landfill operations at the Strathcona Science Park were initially

unnoticeable other than the "differential settlement" contributing to the park's rolling landscape (Yee, 2014, personal communication). However, in 1992 leachate was discovered at the base of the first landfill, and solutions to the leakage became a challenge within this site. Initially the Province of Alberta installed a leachate recovery system in which affected groundwater was collected and pumped from a trench to be stored in a holding tank, then filtered, and stored in a second tank before it was shipped for disposal (Daset. al., 1996). Shortly thereafter the Province of Alberta sought a permanent solution for the leachate. In 1995 Alberta Environmental Protection approached the City of Edmonton to collect, store, treat, and dispose the affected groundwater (Daset. al., 1996). The City of Edmonton then commissioned a hydrogeological investigation that recommended improvements on the clay cap and vegetated cover to prevent infiltration from water that was penetrating the top of the landfill and contributing to leachate production and seepage.

While the City of Edmonton was installing pumping wells to divert leachate, they noticed evidence of landslides and decided not to add further weight in a clay cap (Yee, 2014, personal communication). They hired a consultant to investigate the landfill site, and created a plan involving the expansion of an existing swale[8] on top of the landfill to improve drainage, along with the addition of a geomembrane[9] to prevent water infiltration in the swale area (Das et. al., 1996). The geomembrane was key in controlling precipitation without experiencing additional instability in the landfill, thereby allowing the city to dig up waste, rebury it, and recap it in a safe location with a new soil covering in 1997 (Yee,2014, personal communication). The monitoring of leachate production still occasionally occurs, and the leachate collection ceased in the early 2000s when it was no longer perceived as a threat.

Originally, Strathcona Science Park was part of a Capital City Recreational Park Plan implemented in the 1970's. This plan created the modern day look -- through parks such as Gold Bar and Rundle-- with its intricate trail system (Edmonton Parks and Recreation, 1974).[10] Currently the park has been left as a natural area, and infrastructure repair is seemingly neglected by the Province of Alberta, although the grass and trails are occasionally maintained. Strathcona Science Park remains as a low level day use park: Sunridge Ski Hill occupies a northern building in the park and manages the ski hill; benches and trails remain open to citizens throughout the year (Environment and Sustainable Resource Development, 2014).

Most early landfills in the Edmonton area were located in pre-existing depressions, including natural features such as river banks and ravines, or man-made excavated gravel and sand sites in which

the filling of these sites was inexpensive, thereby allowing for certain areas to be reclaimed over time (Godfrey, 1993). By the 1960s, engineers took into account factors such as methane leakage and proper capping for reclamation, and by the early 1970s professionally engineered landfills accounted for geological, hydrogeological, and other environmental constraints.

Clover Bar Landfill

In 1972 the Clover Bar Sanitary Landfill site had a clay liner, perimeter beams, and a groundwater interceptor system in its original design (Yee, 2014, personal communication). The groundwater diversion and leachate collection system pumped leachate to a treatment plant). These regulations brought more environmental and human health safety to the original conception of a sanitary landfill than ever before. The Clover Bar Landfill, situated on a lower terrace of the North Saskatchewan River, was a safer long-term solution to a landfill within city limits; replacing the 75th street dump, Beverly Dump, and the Frontier Farms Landfills.

In the early 1990s, the Clover Bar Landfill implemented landfill methane gas collection (Public Works, 1992). A landfill should be monitored for decades for gas emissions caused by decomposing garbage, even after closure. The odorless gas, methane, is particularly a problem because it has twenty-one times the greenhouse effect of carbon dioxide. Technological innovations help alleviate this cause. Technology allows landfills, such as Clover Bar landfill, to make money from their gas emissions by converting them into electricity and feeding the electricity into the power grid; Clover Bar generates enough electricity for 4,600 Edmonton homes annually (Yee, 2014, personal communication).

Clover Bar's standards worked well during its time, and stand as a fine technological example of the improvements made by the 1990s. However, the Provincial Standards for Landfills in Alberta changed in 2010. For example, the capping of the Clover Bar Landfill was not as thick as modern regulations call for in 1992 (Yee, 2014, personal communication). Upon closure of a section in the Clover Bar Landfill, a capping and vegetation plan was implemented in which waste management planted one hundred trees that died shortly thereafter. Currently, a re-vegetation plan based on native-species usage is underway; the practitioners hope to create safe ecological succession, conforming the site's appearance to the rest of the river valley. They are not finished capping the rest of Clover Bar to today's environmental standards, but this process should finish within the next few years (Yee, 2014, personal communication; Spotowski, 2014, personal communication).

Louise McKinney Park

By the 1990s, there were few evident environmental concerns with transforming the long-closed Grierson Dump area into a park area (City of Edmonton, 1943). In 1943 infilling land with refuse material proved satisfactory in retaining erosion and bank movements of the Grierson area. Grierson was noted as stabilized and having the potential to be developed as a park area whenever funds were available. And any future development was also said to include the necessary drainage, construction of pathways, and tree and shrub planting. Notably, no other concerns stemmed from the garbage at this site and its future reclamation options: these plans were primarily focused on park developments, and not reclamation based on environmental and human health concerns.

In 1975, crews excavated the site of Commonwealth Stadium where a large portion of the Grierson Dump was uncovered in order to perform construction of the building. In the late-1990s, talk of park development on top of a buried portion of Grierson Dump began. A park vision booklet created in 1997 states that Louise McKinney could be a potential hallmark park that demonstrated an intimate relationship to the River Valley and the metropolitan area: a great asset to Edmonton's urban society (Gibbs and Brown Landscape Architect, 1997).

In 2005 the City of Edmonton examined Phase II of its park plan for the Louise McKinney Park. The Riverfront Promenade, Plaza, and emergency road access were planned to be constructed on a terrace and bank of the North Saskatchewan River in which slope stability remained a potential issue, as it has been in the past century (Spencer Environmental Management Services Ltd, 2005). Another concern from the report lists the construction of the Riverfront Plaza in the vicinity of the former landfill (Grierson Dump). The report lists construction in the area as having the potential to introduce leachate that may migrate into the river and impact human health. While the Riverfront Plaza and Promenade sites were in an active landslide area on Grierson Hill and underlain by dry waste landfill materials, geotechnical assessments were undertaken and leachate was monitored through additional investigations. The studies reported no issues, and a dump from the early twentieth century developed (in its second phase) into the Louise McKinney Park by the early twenty-first century. An article noted that Louise McKinney joined "the ranks of such Edmonton parks as Rundle and Mill Woods golf course […] [in which it] proudly takes its place atop a former garbage dump." (Herzog, 2008, A3).

FIGURE 4. PICTURED ABOVE IS A SHACK OF SHANTYTOWN AT THE GRIERSON DUMP IN 1938. (SOURCE: REPRODUCED WITH PERMISSION FROM THE CITY OF EDMONTON ARCHIVES).

Conclusion

The idea of a park system has existed in Edmonton throughout the twentieth century, just as landfill systems have. For instance, an *Interim Report on Land Use and Land Reservation for Public Recreation in the North Saskatchewan River Valley* states that since 1905 it set aside land to accommodate "parks and recreational needs" (Edmonton Parks and Recreation, 1961, p. 3). Eventually, specific plans for the river valley parks system began to develop in the 1960s. In 1961, the Parks and Recreation Department General History of Parks listed a mandate "to advance the well-being, both physical and mental of inhabitants in today's crowded cities" (1961, p. 1). Because the Parks and Recreation and Waste Management Departments followed this mandate, Edmonton's parks system today

contributes to urban wellness and provides numerous fun and healthy recreational activities.

Due to the quick urbanization of Edmonton, the need for recreational space became evident after residential developments were established; concomitantly, the allocation of waste became a visible environmental problem (McDowell, 2012). Human activities generate waste, and the amount of waste increases as the demand for a higher quality of life increases: increasing population, consumption, urbanization, industrialization, and economic development result in the increased generation of diversified solid waste. This solid waste should not be dumped without research, because it is not only unsightly, unhygienic, and environmentally harmful, but it also requires the allocation of space. Modern landfills are now well-engineered facilities that are located, designed, operated, and monitored to ensure compliance with environmental regulations.

The mitigation of effects from dump closure has evolved from being unconcerned to preventing dangerous human and environmental risks. The changes throughout the decades reflect not only the problems that accompanied visible waste management issues through rapid urbanization in the West, but a broader environmental movement that reacted to these changes. By the 1960s, a countercultural movement called environmentalism evolved to deal with complex issues related to long-term effects of human impact and environmental degradation (McDowell, 2012). Ever-expanding scientific evidence of humanity's negative impact on the environment, and the discomfort of living in close proximity to landfill systems became evident in Edmonton. Before the Beverly Dump, a sanitary landfill in Edmonton had not existed. After the Beverly Dump, clay liners, compaction, and capping developments were used in newer landfills. In the 1960s, the city did not address methane concerns, but by the 1970s a methane monitoring system was installed in the Rundle Park golf course. Shortly after, by the 1990s, leachate and groundwater contamination became a concern in the instance of the Frontier Farms landfill. Clover Bar Landfill was built with the knowledge of previous landfill sites and followed regulations, although it is not currently up to date. The 2010 Standards for Landfills in Alberta have been discerned through trial and error, years of experience, and put together by an expert panel of sanitation engineers. These regulations alleviate long-term hazards and the need to fix future any risks.

The main purpose of landfill restoration is to meet public health standards and environmental regulation, but aesthetic and landscape features are also important when a landfill is capped after its final sealing. In many instances, restoration occurs through succession and

manipulating the environment to create meadows, forests, and parks above old dumping grounds. However, there are challenges to landfill remediation. After remediation of a site is complete, there are risks that developers are often concerned about. Issues emerge due to, for instance, improved environmental regulations and insufficient remediation. While the need for parks in Edmonton has been great, at times the conversion to parkland has lacked proper research and later environmental and human health problems required remedy – for instance, the need for the above-mentioned leachate system at the historic Frontier Farms site. However, the lack of research has ultimately been unimportant since the waste produced in Edmonton's history has not had observable negative effects. Transitioning three landfills into Rundle, Strathcona Science, and Louise McKinney Park throughout different eras of environmental regulations has been successful.

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Notes

1. Parks such as William Hawerlak (Mayfair) Park were not reclaimed from a city landfill; nonetheless, garbage was used in conversion to Parkland as infill for abandoned gravel pits.

2. Rat Creek Dump was the first nuisance grounds in use, but shortly thereafter the town of Edmonton bought, or leased, many small sites to use as dumping grounds.

3. By 1961 cities and towns over 10,000 required to have 'sanitary landfills,' according to Regulations Respecting the Control of Refuse Disposal Systems (Division 12).

4. Despite provincial legislation requiring sanitary landfills, the definition of hazardous waste at this time was not listed.
5. At the time, a consultant for the City of Edmonton determined that the upward hydraulic action of ground water present made it difficult for liquid materials to be carried away from the landfill (Yee, 2014., personal communication). Annual reports (sent into the Edmonton Board of Health) of groundwater monitoring at Rundle Park from 1994 to 2007 indicate that no health or environmental concerns occurred from groundwater at the Beverly site.
6. Prior to 1900, and thereafter, the site was used as a coal mine. In 1952 the site was taken over by Glacier Sand & Gravel Ltd and gravels were extracted until 1972. From June 1961, a company called East Side Disposal Ltd. began to use the site (one of the former gravel pits) for waste disposal (Das et. al., 1996).
7. Leachate: liquid that has been in contact with waste in the landfill and has undergone chemical or physical changes (Spotowski, 2014, personal communication).
8. Swale: A depression in land and a marsh-like natural feature of the landscape.
9. Geomembrane: a containment liner made of various materials (Daset. al., 1996).
10. In the 1974 Capital City Recreational Park Plan they note a concept to create trail system linking various parks within the total park system, which provided the impetus to create the current ribbon of green that links various trails throughout the parks in the Edmonton River Valley.

Precipitation gradients at the crest of a British Columbia coastal mountain range

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Abstract: *The mesoscale (25 km) precipitation gradient across the crest of the Cascade Mountains BC was investigated by measuring May-October precipitation over five years at six sites. Results show that 56% of the regional west-to-east decrease in precipitation across the Cascade Mountains occurs within 15 km east of the crest. This suggests that the leeward rain shadow effect develops quickly even when the frequency and intensity of cyclonic disturbances crossing the range is lower compared to the November-April period. West of the crest, the mesoscale precipitation gradient is nested inside a more complex regional gradient, especially in November-April. The vertical precipitation gradient was calculated using data from valley-bottom and high-elevation climate stations near the Cascade crest, and the results show this gradient is much steeper in November-April than in May-October. This study indicates that mesoscale precipitation gradients may not be apparent from regional-scale gradients across a mountain range.*

Introduction

Orographic enhancement of precipitation in mid-latitude mountains, with consequent windward-leeward differences in precipitation, is well understood at synoptic scales. Much less is understood about this phenomenon at spatial scales of less than about 20 km (Roe, 2005), despite some attempts to understand topography-precipitation relationships at these scales (e.g. Anders et al., 2007). An understanding of orographic enhancement of precipitation at this mesoscale is important for evaluating precipitation patterns at or near a topographic divide. For example, a shift of only a few kilometers in the zone of heavier precipitation near a divide can have important implications for evaluating spillover rainfall and resulting flooding on the rain-shadow side of a range (Wratt et al., 2000). In fact, the distinctiveness of mountain hydrology is best developed at such small spatial scales where great heterogeneity occurs in meteorological forcings (Gerrard, 1990; Bach and Price, 2013). In the mountains of western North America, knowledge of hydrology is particularly limited by problems of spatial scaling in complex topographic settings with steep climatic gradients, notably precipitation (Bales et al., 2006). This imposes major limitations on simulations and predictions of hydrological processes for water management purposes, especially

in the context of changing climate and a movement toward more physically-based models with greater data needs (Bales et al., 2006). Singh and Woolhiser (2002) review errors in runoff simulations produced by spatial variations in precipitation, noting that an effective resolution of precipitation data is around 2.5 km2. In the absence of a dense network of gauges, the only way such a fine resolution can be achieved is through better understanding of mesoscale precipitation variations, especially in mountainous watersheds. This issue is of particular importance in the Skagit and Similkameen River basins in whose headwaters our study takes place, because these rivers provide important downstream water resources.

The sharp decrease in precipitation immediately leeward of a mountain range is also responsible for the abrupt transition in vegetation communities across many of British Columbia's ranges (Cannings and Cannings, 2004): the short horizontal distances over which this transition occurs are evident from maps of the province's biogeoclimatic zones (BC Ministry of Forests, Lands and Natural Resource Operations, 2014). In most mountain regions, local differences in species composition and the positioning of vegetation communities are the result of steep environmental gradients including that of precipitation (Hadley et al., 2013).

Mesoscale precipitation patterns at a topographic divide can also have a major influence on mountain geomorphic processes (Gerrard, 1990; Willett, 1999; Janke and Price, 2013). For example, many hazardous geomorphic processes of mountains involve cascades of moisture and sediment including glaciers, snow avalanches, debris avalanches, debris flows and floods, which are intimately connected to small-scale horizontal and vertical gradients of precipitation (Hewitt, 2004). In our study area, there has to our knowledge not been any attempt to link geomorphic processes and mesoscale precipitation gradients.

Orographic enhancement of precipitation occurs in three ways. The simplest mechanism is the lifting and adiabatic cooling of an air mass below the dew point, resulting in condensation and precipitation (Price, 1981; Smith et al., 2003). Terrain can also lift an air mass to the level of free convection above which the air continues to rise freely until below the dew point (Roe, 2005). Terrain also plays a role in the seeder-feeder mechanism first proposed by Bergeron (1968), where precipitation generated by cyclonic lifting in a higher atmospheric layer falls into clouds formed by the influence of topography in a lower layer, augmenting precipitation by the processes of riming and coalescence (Browning and Hill, 1981; Carruthers and Choularton, 1983; Choularton and Perry, 1986; Robichaud and Austin, 1988; Loukas and Quick, 1994, 1996). In reality, orographic enhancement of precipitation usually involves some combination of these three mechanisms.

A phenomenon closely related to orographic enhancement of precipitation is

spillover, in which a portion of the precipitation generated windward of a range falls on the leeward side during individual storms. Spillover precipitation is usually a small-scale phenomenon occurring within 6-29 km of a range's crest (Sinclair et al., 1997). Cloud delay time, the time required from condensation to cloud priming or precipitation, is a key variable influencing the presence and extent of spillover precipitation (Smith et al., 2005), with longer delay times resulting in greater spillover. The geometry of storm winds in relation to a topographic barrier, relative humidity and stability of the approaching air mass, and synoptically induced upward motion are also important controlling factors in spillover (Sinclair et al., 1997; Wratt et al., 2000).

Horizontal precipitation gradients (hereinafter abbreviated HPG) that result from orographic enhancement are some of the most pronounced climatic gradients on Earth, with a predictable pattern even at scales of a few kilometers (Roe, 2005). They are typically characterized by a major increase of precipitation as one approaches the windward side of a range and then a sharp decrease away from the crest on the leeward side (Houze, 2012). Such patterns have been noted around the world, particularly in maritime mountain ranges (Price, 1981; Whiteman, 2000; Bach and Price, 2013) where an order-of-magnitude decrease in precipitation can occur from the windward to leeward side (Price, 1981; Wratt et al., 2000). Vertical relief plays an important role in determining the precise location of maximum precipitation: small hills and islands are generally associated with a maximum at the topographic crest, while larger topographic obstacles are more likely to exhibit a maximum windward of the crest (Carruthers and Choularton, 1983; Roe, 2005).

Topographic barriers also create vertical precipitation gradients (hereinafter abbreviated VPG), with precipitation generally increasing with elevation (e.g., Salter, 1919; Lauscher, 1976; Barry, 2008). However, the relation between elevation and precipitation is frequently more complex than this (Frere et al., 1975). For example, in Sri Lanka it is complicated by monsoonal winds and associated heavy precipitation (Puvaneswaran and Smithson, 1991). Furthermore, an altitudinal belt of maximum precipitation usually exists above which precipitation levels off or even decreases (Puvaneswaran and Smithson, 1991; Loukas and Quick, 1996; Barry, 2008). The elevation of this precipitation maximum varies by geographic location as well as season.

Investigations into orographic enhancement of precipitation have generally pursued three tracks of enquiry: theory, observations, and modeling (Roe, 2005). In order for models to provide useful insights, their results must be verifiable with observational studies. This paper reports on an observational study of the mesoscale HPG and VPG at the crest of the Cascade Mountains in southern British Columbia. The focus of the study is on May-October precipitation, when the precipitation

gradient is expected to be complicated by thermodynamically constrained convective processes. The specific objectives are to (1) investigate the HPG at the Cascade crest at a horizontal scale of about 25 km and relate this to the regional (~102 km) HPG, (2) evaluate the location of maximum precipitation with respect to the Cascade crest and determine how quickly the rain shadow effect develops leeward of the crest, and (3) evaluate the VPG at the Cascade crest. The importance of this study lies in its investigation of the HPG at a spatial scale that is too small to investigate using precipitation records from long-term climate stations, a problem emphasized by several authors (Schermerhorn, 1967; Rasmussen and Tangborn, 1976; Kyriakidis et al., 2001; Scherrer et al., 2010).

Study Area

The Cascade Mountains of southern British Columbia, hereinafter called the Cascades, are situated about 200 km inland from the Pacific Ocean and therefore subjected to a major maritime influence. The range's orientation parallel to the coast and roughly perpendicular to storm tracks has important implications for the efficiency of orographic lifting (Whiteman, 2000). The study area is situated immediately north of the Canada-US border in the Hozameen Range of the Cascades, where the mountains form a major divide between westward-flowing rivers such as the Skagit and eastward-flowing rivers such as the Similkameen (Figure 1). The Skagit River is an important hydroelectric river in Washington State and the Similkameen River provides an important water supply in both BC and Washington; thus knowledge of precipitation gradients at the Cascade crest is especially important.

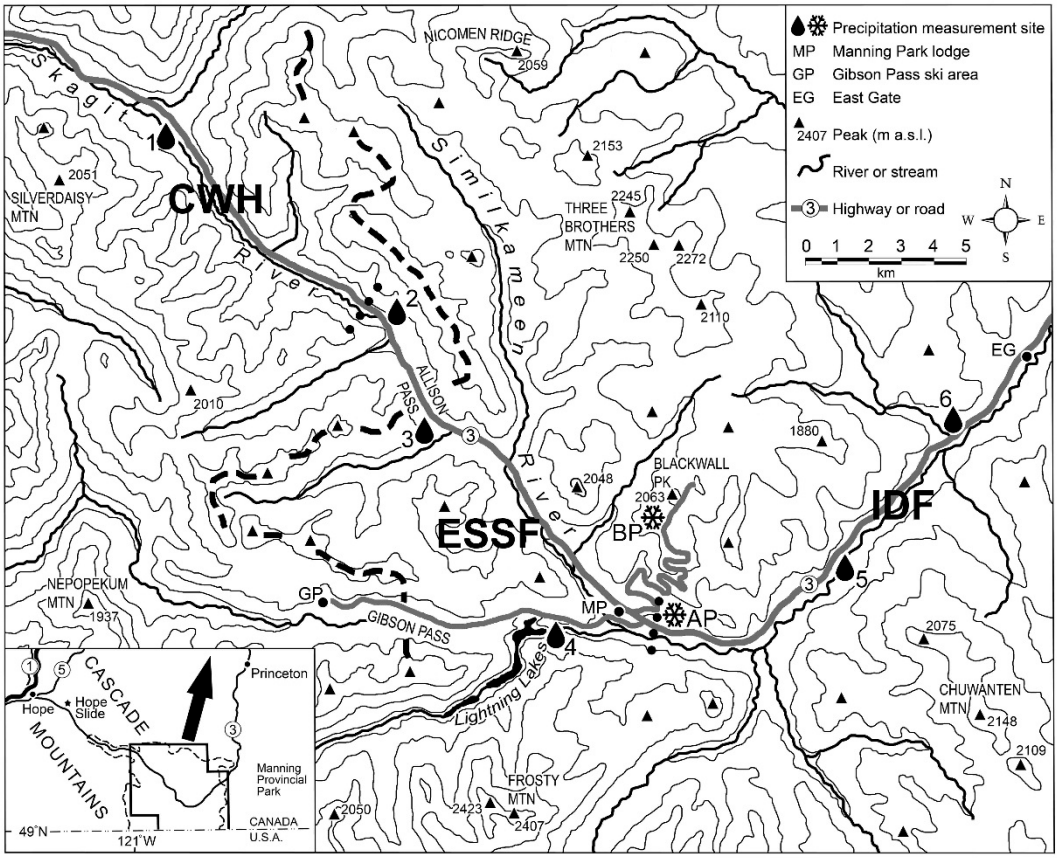

FIGURE 1. STUDY AREA. THE BOLD DASHED LINE IS THE CASCADE CREST AS DEFINED BY THE SKAGIT-SIMILKAMEEN RIVER WATERSHED DIVIDE; THE BOLD DOTTED LINES INDICATE THE BOUNDARIES OF THE CWH, ESSF AND IDF VALLEY-BOTTOM BIOGEOCLIMATIC ZONES (SEE TEXT). MANUAL RAIN GAUGES.

Maximum elevations in the study area are 2100-2400 m asl while local relief is on the order of 500-800 m. Most peaks in the study area are rounded and below timberline but the degree of glacial dissection, although not elevation, increases markedly west of the study area (Figure 2). The Cascades receive most of their precipitation from mid-latitude cyclones originating over the Pacific Ocean and embedded in the westerly circulation. Precipitation is highly seasonal on the west side of the range owing to the wintertime dominance of the Aleutian Low in the Gulf of Alaska where most cyclones are spawned, and the protective influence of the offshore Pacific High in summer (Hare and Thomas, 1974; Phillips, 1990; Oke and Hay, 1994; Whiteman, 2000). The resulting prominent winter peak in precipitation, falling almost entirely as snow in the study area, is illustrated in Figure 3a. This winter peak is much less prominent on the east side of the range (Figure 3b).

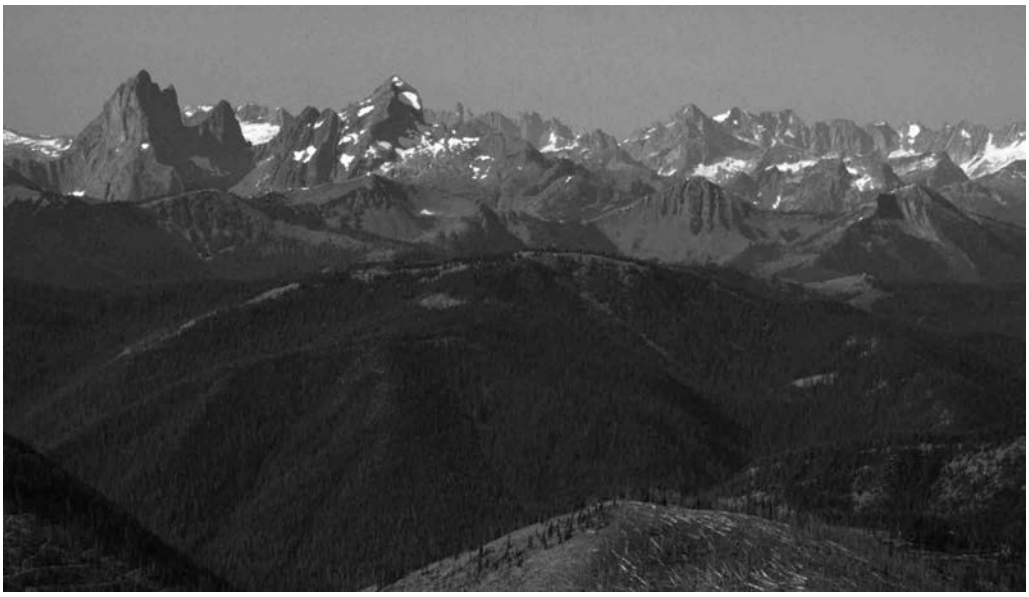

FIGURE 2. VIEW SOUTHWEST FROM THREE BROTHERS MOUNTAIN (FIGURE 1) OVER ROUNDED SUMMITS OF THE STUDY AREA TOWARD THE GLACIALLY DISSECTED SUMMITS OF THE WESTERN CASCADES.

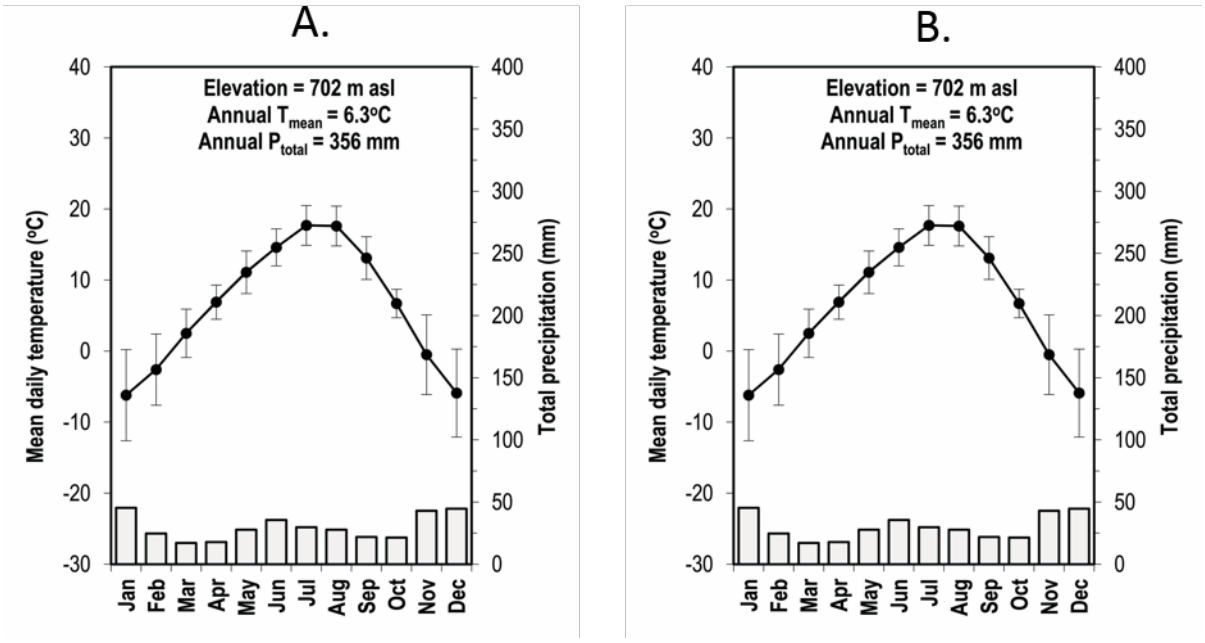

FIGURE 3. CLIMOGRAPHS FOR (A) HS STATION ON THE WEST SIDE OF THE CASCADES, AND (B) PA STATION ON THE EAST SIDE OF THE RANGE. SEE FIGURE 1 FOR THE LOCATIONS. THE SOLID LINE INDICATES MEAN MONTHLY TEMPERATURE AND THE BARS MEAN MONTHLY PRECIPITATION. DATA FROM METE

Although in summer the strongest westerly circulation is situated at the

latitude of the study area, it is still much weaker than in other seasons with a corresponding decrease in the intensity of cyclonic storms (Hare, 1997). Most summer precipitation is either convective rainfall (Whiteman, 2000) or cyclonic rainfall generated during periodic weakening of the Pacific High (Loukas and Quick, 1996). Convective rainfall is more common on the east side of the Cascades as illustrated by the minor springtime peak in precipitation in Figure 3(b). The more continental climate regime on the east side of the range is illustrated by the greater range of temperature at 'Princeton A' compared to 'Hope Slide' (Figure 3).

The rapid transition from a maritime to more continental climate regime in the study area is also evident from the biogeoclimatic zones in the valley bottoms (BC Ministry of Forests, Range and Natural Resource Operations, 2014). West of Allison Pass (Figure 1), the coastal western hemlock (CWH) zone is dominated by stands of western hemlock (Tsuga heterophylla), coastal Douglas-fir (Pseudotsuga menziesii var. menziesii), western red cedar (Thuja plicata) and amabilis fir (Abies amabilis) (Green and Klinka, 1994). East of Manning Park Lodge (Figure 1), the interior Douglas-fir (IDF) zone is dominated by stands of interior Douglas-fir (P. Menziesii var. glauca), lodgepole pine (Pinus contorta) and hybrid white spruce (Picea engelmannii × glauca) (Hope et al., 1991). Between these two zones, the Engelmann spruce-subalpine fir (ESSF) zone, which owes its presence to the slightly higher valley-bottom elevations here (Figure 1), is dominated by stands of subalpine fir (Abies lasiocarpa), Engelmann spruce (Picea Engelmannii), lodgepole pine and amabilis fir (Green and Kilinka, 1994).

Data and Methods

Data Collection

Data from manual rain gauges were employed to examine the mesoscale HPG at the Cascade crest. The gauges employed are unshielded plastic gauges with an orifice diameter of 10.5 cm, mounted with the orifice level and 80-85 cm above the ground (Figure 4). Six gauges were placed along Hwy. 3 west and east of the Cascade crest at Allison Pass, with a spacing of 2-9 km between gauges (Figures 1 & 5). An effort was made to minimize elevation differences but a total vertical range of 470 m was unavoidable given the highway gradient over Allison Pass (Figure 5). The effect of the highway's dog-leg shape across the Cascade crest (Figure 1) on valley-bottom precipitation is unknown, but assumed to be negligible given the light winds in summer (Hare and Thomas, 1974; Hare, 1997). All of the gauges were placed in the middle of forest openings with a minimum diameter 1-2 times the height of surrounding coniferous trees, in order to minimize wind-generated under-catch. Measurements were carried out at intervals of 2-6 weeks (average 27 d) during May-October from 1992 to 1996, with the exact measurement period each year being dictated by snow-free conditions (Table 1). Given the time of year, virtually all of the precipitation measured was rainfall. The

design of the gauges and the addition of a small amount of kerosene oil after every reading ensured that evaporation losses were negligible. The kerosene oil had no discernible effect on measurement accuracy because its lower density prevented any mixing with rainfall in the gauge. November-April precipitation data were not possible to obtain with these gauges because they are not designed to measure snowfall and at any rate would have been buried by the winter snowpack in the study area.

FIGURE 4. MANUAL RAIN GAUGE AT SITE 4, ILLUSTRATING THE GAUGES EMPLOYED FOR MAY-OCTOBER PRECIPITATION MEASUREMENTS AT THE SIX SITES IN FIGURE 1. A 19×12 CM FIELD BOOK AT THE BASE OF THE POST PROVIDES SCALE.

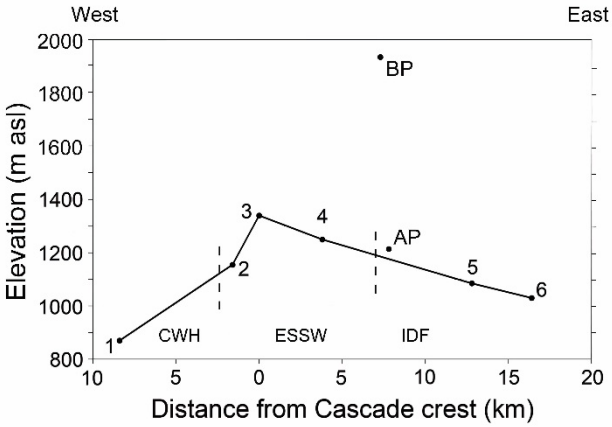

FIGURE 5. RAIN GAUGE SITE ELEVATION AGAINST DISTANCE FROM THE CASCADE CREST AT ALLISON PASS. RAIN GAUGE NUMBERS AND CLIMATE STATION ABBREVIATIONS CORRESPOND TO THOSE IN FIGURE 1. DASHED LINES INDICATE THE BOUNDARIES OF THE CWH, ESSF AND IDF BIOGEOCLIMATIC ZONES.

TABLE 1. DIVISION OF THE MAY-OCTOBER MANUAL RAIN GAUGE DATA INTO MAY-JULY (EARLY-SUMMER) AND AUGUST-OCTOBER (LATE-SUMMER) PERIODS.

Year	Start of data collection	Latest date included in May-July period	End of data collection	Number of collection periods: May-July	Number of collection periods: August-October

1992	19 April	29 July	14 November	6	4
1993	10 April	17 July	08 October	3	3
1994	29 April	21 July	15 October	3	3
1995	1 May	20 July	09 October	3	3
1996	26 May	25 July	19 October	2	4

Data from the 'Hope Slide' (HS: 49.275°N, 121.237°W) and 'Princeton A' (PA: 49.468°N, 120.513°W) climate stations (Figures 1 & 3), located at similar elevations, were employed to examine the regional HPG (Meteorological Service of Canada, 2013a,b). These stations are situated 40 km west and 25 km east of Allison Pass respectively. Precipitation is measured employing a Nipher-shielded gauge with an orifice diameter of 12.7 cm and height of 150 cm above the ground or snow surface. Precipitation data from the 'Blackwall Peak' automated snow pillow station (BP: 49.095°N, 120.772°W, 1940 m asl) operated by the BC River Forecast Centre (River Forecast Centre, 2013) and the 'Allison Pass' climate station (AP: 49.063°N, 120.772°W, 1215 m asl) operated by the BC Ministry of Forests (J. Sweeten and R. Kimmerly, 2013, pers. comm..) were employed to examine the VPG near the Cascade crest. Precipitation at these stations is measured using a 38 cm diameter PVC standpipe with a single Alter shield to reduce wind-generated under-catch, and mounted on a 3 m tower to maintain the gauge above the snowpack. The BP station provides the highest-elevation climate data for this region, while the valley-bottom AP station is situated about 7 km east of Allison Pass (Figure 1).

Measurement Error

Errors resulting from under-catch of precipitation due mainly to improper gauge siting and wind need to be considered in this study, especially in relation to snowfall measurements (Larson and Peck, 1974). The manual rain gauges employed for the May-October precipitation measurements are identical to the Canadian Type B gauge with an average catch efficiency of 99.4% (Devine and Mekis, 2007). These unshielded gauges' rainfall catch efficiency drops to about 90% in 4.5 m s-1 winds (Larson and Peck, 1974). However, summer winds of this velocity were almost never observed in the small valley-bottom forest openings where the gauges were situated, so the under-catch resulting from wind is assumed to be negligible.

Errors in rainfall measurements with Nipher- and Alter-shielded gauges are very small (Larson and Peck, 1974; Adam and Lettenmaier, 2003) and therefore unlikely to have any impacts on the analysis. For snowfall measurements, a Nipher-shielded gauge has a catch efficiency of 80% and 57% in 5 m s-1 and 8 m s-1 winds, respectively (Goodison et al., 1998). An Alter-shielded

gauge performs less well with a catch efficiency of 60-75% in 5 m s-1 winds and only 15-45% in 8 m s-1 winds (Hansen and Davies, 2002; Duchon et al., 2008). The Nipher- and Alter-shielded gauges' location in small forest openings (except at the 'PA' station) means such wind velocities are likely rare, mitigating the under-catch error. Given the monthly to annual precipitation totals employed in this study, the overall error of the precipitation measurements is assumed to be in the range of 5-15% (Winter, 1981).

The analyses of meso- and regional-scale HPG and VPG of May-October precipitation are probably affected very little by the gauge biases described above, because either the same gauge type was employed at all sites or the under-catch of rainfall by the three gauge types is negligible. However, analysis of the November-April regional HPG is affected by the difference in snowfall catch efficiency between the Nipher- and Alter-shielded gauges. The exact magnitude of the error is impossible to calculate without wind speed data from the stations. The VPG in November-April should be affected less by this because the same gauge type is employed at the AP and BP stations.

Data Analysis

The manual rainfall measurements were first summed to find the total May-October precipitation for each year. The individual years' totals and the five-year mean May-October precipitation at each site were then plotted against straight-line distance west or east of the Cascade crest. The rainfall data were also divided into approximately May-July (early-summer) and August-October (late-summer) periods (Table 1) and plotted against distance from the Cascade crest. The mesoscale HPG west and east of the Cascade crest was then calculated.

The annual, May-October and November-April regional HPG across the Cascades was examined using 1990-2006 data from the HS and PA climate stations. In addition, the May-October regional HPG between these stations for 1992-6 was compared to the mesoscale HPG derived from the manual rainfall data. The HS and PA data were also compared to 1990-2006 data from the AP station near the Cascade crest to evaluate whether the regional HPG changes between the west and east sides of the range. The comparisons of annual and November-April precipitation in this case had to rely on smaller (10-year) periods of overlap because of significant gaps in the winter precipitation record from the AP station.

The May-October and November-April VPG was investigated using 1991-2001 data from the AP and BP climate stations. These stations are ideally located for this purpose because they are equidistant east of the Cascade crest, only 5 km apart in a north-south direction, and with a reasonably large elevation difference (725 m; Figure 1). Only years with complete precipitation records were used for this analysis.

The HPG and VPG were calculated from the differences of total precipitation

between pairs of rain gauges or climate stations. Positive and negative gradients indicate a precipitation increase and decrease, respectively, from west to east or from low to high elevation. The HPG and VPG are expressed in % km-1 in order to be independent of absolute precipitation amounts. However, they are also expressed in mm km-1 to facilitate comparison with other studies and application in other fields such as watershed modelling.

Results

Weather During 1992-6

May-October precipitation at the HS station was close to normal for each year during 1992-6, with on average only 5% more precipitation (Table 2). The PA station, on the other hand, received more precipitation than normal in every year, especially 1993 and 1995, with on average 25% more precipitation (Table 2). Consequently, the difference in May-October precipitation between the HS and PA stations was 10% smaller than normal during 1992-6. The May-October mean daily temperature at both stations was slightly higher than normal in every year except 1996, and on average was very close to normal (Table 3).

TABLE 2. MAY-OCTOBER PRECIPITATION FOR 1992-6 IN RELATION TO THE 1971-2000 CLIMATIC NORMAL AT THE 'HOPE SLIDE' (HS) AND 'PRINCETON A' (PA) STATIONS.

May-October precipitation (mm)						
	1971-2000 Normal	1992	1993	1994	1995	1996
HS	408.5	397.4	459.9	369.0	431.1	477.8
PA	164.0	175.2	258.7	173.5	239.4	181.7
Difference	244.5	222.2	201.2	195.5	191.7	296.1

Departure from 1971-2000 normal (%)						
	1992	1993	1994	1995	1996	Mean
HS	-3%	+13%	-10%	+6%	+17%	+5%
PA	+7%	+58%	+6%	+46%	+11%	+25%
Difference	-9%	-17%	-20%	-22%	+21%	-10%

TABLE 3. MAY-OCTOBER MEAN DAILY TEMPERATURE (°C) FOR 1992-6 IN RELATION TO THE 1971-2000 CLIMATIC NORMAL AT THE 'HOPE SLIDE' (HS) AND 'PRINCETON A' (PA) STATIONS.

May-October mean daily temperature (°C)

	1971-2000 Normal	1992	1993	1994	1995	1996
HS	11.5	12.7	12.2	12.1	12.0	10.6
PA	13.5	14.2	13.7	14.5	13.7	12.8
Difference	2.0	1.5	1.5	2.4	1.7	2.2

Departure from 1971-2000 normal (°C)

	1992	1993	1994	1995	1996	Mean
HS	+1.2	+0.7	+0.6	+0.5	-0.9	+0.4
PA	+0.7	+0.2	+1.0	+0.2	-0.7	+0.3
Difference	-0.5	-0.5	+0.4	-0.3	+0.2	-0.1

Mesoscale Gradient (HPG)

A box plot of the May-October manual rainfall data collected during 1992-6 shows that in addition to precipitation increasing toward the Cascade crest (site 3), the data at each site are approximately normally distributed (Figure 6). This was confirmed by a normal quantile plot which shows the data to be normally distributed at p = 0.05. The HPG east of the Cascade crest is steeper than the gradient west of the crest (-2.1 and 1.7 % km-1, or -6.7 and 4.5 mm km-1, respectively), with an overall west-to-east gradient across the crest of -1.1 % km-1 or -2.9 mm km-1 (Figure 7). When the HPG is separated into individual years (Figure 8) it is clear that near the Cascade crest 1992 and 1993 were much wetter than the other years, which is not really apparent from the climate records west and east of the study area (Table 2). Three of the years (1993, 1995-6) show a precipitation maximum at the Cascade crest (site 3) while two (1992, 1994) show a maximum either windward (site 1) or leeward (site 4) of the crest.

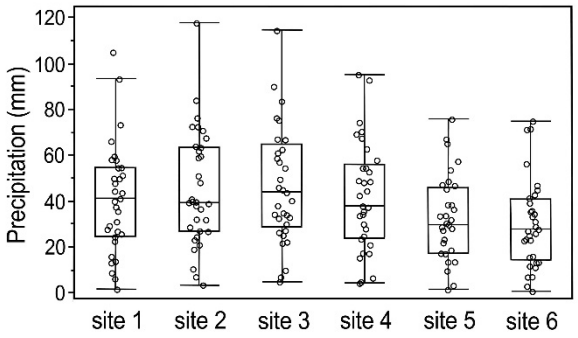

FIGURE 6. BOX PLOT OF MAY-OCTOBER PRECIPITATION VALUES FOR 1992-6. MEASUREMENT PERIOD LENGTH IS 2-6 WEEKS (AVERAGE = 27 D). RAIN GAUGE NUMBERS CORRESPOND TO THOSE IN FIGURE 1. THE

HORIZONTAL LINE THROUGH BOXES INDICATES THE MEDIAN AND THE WHISKERS THE RANGE OF VALUES AT EACH SITE.

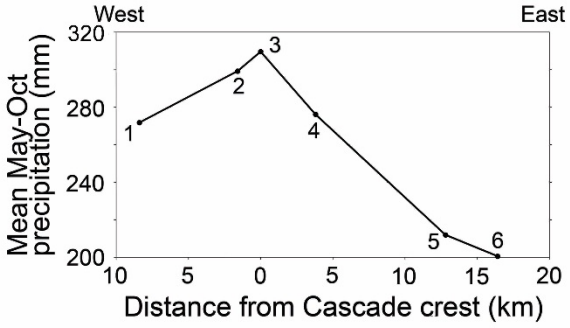

FIGURE 7. MEAN MAY-OCTOBER PRECIPITATION FOR 1992-6 AGAINST DISTANCE FROM THE CASCADE CREST. RAIN GAUGE NUMBERS CORRESPOND TO THOSE IN FIGURE 1.

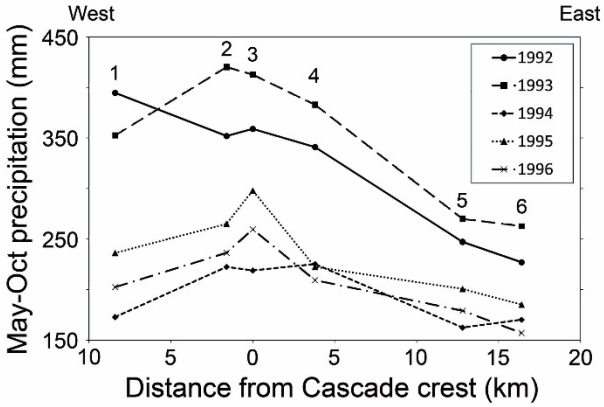

FIGURE 8. MAY-OCTOBER PRECIPITATION IN INDIVIDUAL YEARS AGAINST DISTANCE FROM THE CASCADE CREST. RAIN GAUGE NUMBERS CORRESPOND TO THOSE IN FIGURE 1.

Except at site 1, the May-July (early-summer) period is wetter than the August-October (late-summer) period (Table 1) along the entire transect across the Cascade crest (Figure 9). The HPG east of the Cascade crest is also less uniform in May-July, with an increase from site 5 to 6 (Figure 9). The opposite is true west of the crest, with the May-July HPG from site 1 to 2 disappearing in the late period. As a result, the HPG in May-July is steeper west of the crest (+2.5 % km-1 or +3.4 mm km-1) compared to east of the crest (-1.7 % km-1 or -2.8 mm km-1) with an overall gradient of -0.5 % km-1 or -0.7 mm km-1. In contrast, the HPG in August-October is steeper east of the crest (-2.6 % km-1 or -3.9 mm km-1) compared to west of the crest (+0.8 % km-1 or +1.1 mm km-1) with an overall gradient of -1.6 % km-1 or -2.2 mm km-1.

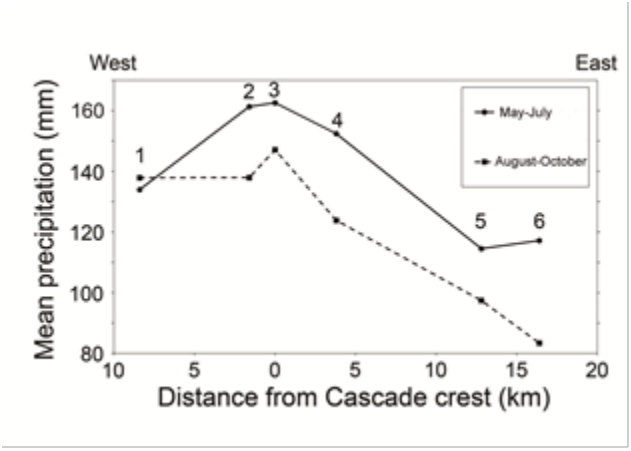

FIGURE 9. MEAN MAY-JULY (EARLY SUMMER) AND AUGUST-OCTOBER (LATE SUMMER) PRECIPITATION (SEE TABLE 1) FOR 1992-6 AGAINST DISTANCE FROM THE CASCADE CREST. RAIN GAUGE NUMBERS CORRESPOND TO THOSE IN FIGURE 1.

Regional Gradient (HPG)

Table 4 shows the annual, May-October and November-April regional HPG across the Cascades for 1991-2006 calculated from the HS, AP and PA station data. The regional HPG was also calculated for May-October precipitation during 1992-6, for which data

on the mesoscale HPG are available, and found to differ by only 0.1 % km-1 (0.2 mm km-1) from the 1991-2006 gradient (Table 4). Therefore the five-year mesoscale HPG derived from the manual rainfall data is more than likely reflective of the longer-term May-October mesoscale HPG. The regional HPG across the Cascades was found to vary by season (Table 4): the November-April gradient (-1.5 % km-1 or -11.9 mm km-1) is steeper than the May-October gradient (-1.1 % km-1 or -4.5 mm km-1). The total decrease from the west to east side of the Cascades is also greater in November-April (78% or 619 mm) than in May-October (58% or 235 mm) (Table 4).

TABLE 4. REGIONAL HPG BETWEEN THE 'HOPE SLIDE' (HS), 'ALLISON PASS' (AP) AND 'PRINCETON A' (PA) STATIONS.

		Mean annual precipitation	Mean May-Oct. precipitation	Mean Nov.-Apr. precipitation	Mean May-Oct. precipitation, 1992-6
HS-AP	Precipitation (mm)	1162 → 534[a]	402 → 240[b]	757 → 283[a]	
	Change[d] (mm)	-627	-162	-474	
	(%)	-54	-40	-63	
	HPG[d] (mm km^{-1})	-18.5	-4.7	-13.9	
	(% km^{-1})	-1.6	-1.2	-1.8	
AP-PA	Precipitation (mm)	534 → 330[a]	246 → 171[c]	283 → 166[a]	
	Change[d] (mm)	-204	-75	-117	
	(%)	-38	-31	-41	
	HPG[d] (mm km^{-1})	-11.3	-4.2	-6.5	
	(% km^{-1})	-2.1	-1.7	-2.3	
HS-PA	Precipitation (mm)	1195 → 341[b]	402 → 167[b]	793 → 174[b]	427 → 206
	Change[d] (mm)	-854	-235	-619	-221
	(%)	-71	-58	-78	-52
	HPG[d] (mm km^{-1})	-16.4	-4.5	-11.9	-4.3
	(% km^{-1})	-1.4	-1.1	-1.5	-1.0

a1993-5, 2000-6.
b1991-2006.
c1990-2006.
dNegative values indicate a decrease from west to east.

Table 4 also shows the regional HPG on the west and east side of the Cascades separately. The years employed for calculating the annual, May-October and November-April HPG vary according to the temporal overlap in the data available from the two stations. Notwithstanding the small errors this would create, the results show that annual precipitation decreases rather than increases toward the Cascade crest on the west side of the range (HS-AP stations), although this HPG (-1.6 % km-1 or -18.5 mm km-1) is not as steep as on the east side (-2.1 % km-1 or -11.3 mm km-1; Table 4). The HPG is 0.5 % km-1 steeper both in May-October and November-April on the east side compared to the west side, although when expressed in absolute terms this gradient is 0.5-7.4 mm km-1 steeper on the west side because of the higher precipitation totals there (Table 4). The difference between the May-October and November-April HPG is the same on both sides of the Cascades (0.6 % km-1 greater in November-April). However, when expressed in absolute terms this difference is much greater on the west side (9.2 mm km-1) compared to the east (2.3 mm km-1). It is also much greater on the west side (23% or 312 mm) compared to the east (10% or 42 mm) when expressed as a total change, reflecting again the higher precipitation totals on the west side of the range.

When mean May-October precipitation during 1992-6 at both manual rain gauge sites and regional climate stations is plotted as a function of distance across the Cascades (Figure 10), it is clear that on the east side of the range the steepest precipitation decline occurs within about 15 km of the crest; this accounts for approximately 50% of the precipitation decrease from the HS to PA stations. Figure 10 also shows that on the west side of the Cascades, May-October precipitation at the HS station is much greater than at the numbered higher-elevation sites closer to the crest. The result is a negative HPG from the HS station to rain gauge site 1, with a secondary precipitation peak at the crest (Figure 10).

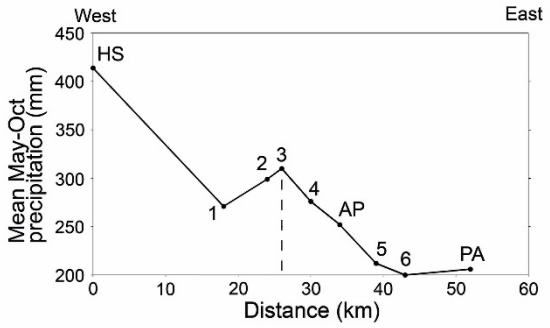

FIGURE 10. MEAN MAY-OCTOBER PRECIPITATION FOR 1992-6 ACROSS THE CASCADE MOUNTAINS. NUMBERED SITES CORRESPOND TO THE RAIN GAUGE SITES IN FIGURE 1. THE VERTICAL DASHED LINE INDICATES THE CASCADE CREST AT ALLISON PASS.

Vertical Gradient (VPG)

Table 5 shows the VPG in May-October and November- April. Even considering that gaps in the winter record result in only three years of overlap in the two seasons' precipitation data, it is clear that the VPG in November-April is much steeper (+218 % km-1 or +527 mm km-1) compared to the

May-October gradient (+53% km-1 or +128 mm km-1). The total increase between the AP and BP stations is also much greater in November-April compared to May-October (+158% or +382 mm and +38% or +93 mm, respectively; Table 5). This reflects the fact that the BP station receives almost twice as much precipitation in November-April compared to May-October precipitation, whereas the AP station receives the same amount of precipitation in both seasons.

TABLE 5. VPG BETWEEN THE 'ALLISON PASS' (AP) AND 'BLACKWALL PEAK' (BP) STATIONS.

	Elevation (m asl)	Mean May-Oct. precipitation[a] (mm)	Mean Nov.-Apr. precipitation[b] (mm)
AP	1215	244	242
BP	1940	337	624
Change[c] (mm)		93	382
(%)		38	158
VPG[c] (mm km^{-1})		128	527
(% km^{-1})		53	218

a1991-4, 1996-7, 1999-2001.

b1994-5, 2000-1.

cPositive values indicate an increase from low to high elevation.

May-October precipitation at the rain gauge sites was found to be very strongly and negatively correlated with distance from the Cascade crest (Figure 11a) but only weakly correlated with elevation (Figure 11b). The low R2 value in the latter case is caused primarily by site 1 west of the Cascade crest which despite its low elevation (870 m asl) receives a large amount of May-October precipitation. However, when the rain gauge sites are divided into those west and east of the Cascade crest, a clearer relationship becomes evident between May-October precipitation and elevation (Figure 12).

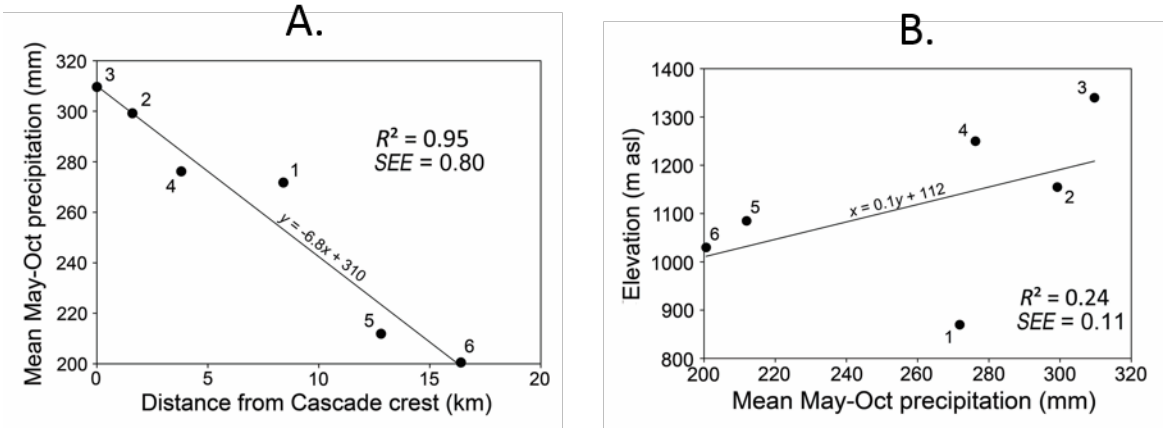

FIGURE 11. REGRESSION OF MEAN MAY-OCTOBER PRECIPITATION FOR 1992-6 AGAINST (A) DISTANCE WEST OR EAST FROM THE CASCADE CREST AND (B) ELEVATION. RAIN GAUGE NUMBERS CORRESPOND TO THOSE IN FIGURE 1.

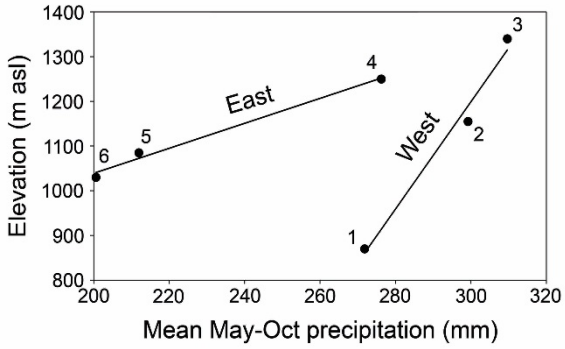

FIGURE 12. MEAN MAY-OCTOBER PRECIPITATION FOR 1992-6 AGAINST ELEVATION WITH RAIN GAUGE SITES DIVIDED INTO THOSE WEST AND EAST OF THE CASCADE CREST. RAIN GAUGE NUMBERS CORRESPOND TO THOSE IN FIGURE 1.

Discussion

Weather - 1992-6

The weak correspondence in May-October precipitation between the HS and PA stations (Table 2) probably reflects the diminished effect of maritime cyclonic systems and the much greater role of spring and early-summer convective precipitation on the east side of the Cascades (Figure 3b). The 10% smaller-than-normal difference in precipitation between the HS and PA stations in 1992-6 means that the regional HPG (Table 4), and possibly also the mesoscale HPG at the Cascade crest, is underestimated in this study.

The annual variations in precipitation and temperature in 1992-6 (Tables 2 & 3) appear to be related at least in part to warm (El Niño) and cold (La Niña) phases of the El Niño-Southern Oscillation cycle (National Oceanic and Atmospheric Administration, 2015). El Niño phases typically produce drier and warmer conditions in southern British Columbia during winter, and sometimes extending into spring and early summer, while La Niña phases typically produce wetter and cooler winters (Moore et al., 2010). The El Niño

phases of 1991-2 and 1994-5 (National Oceanic and Atmospheric Administration, 2015) appear to be reflected in below-normal precipitation at the HS station in 1992 and 1994 (Table 2), and above-normal temperatures at the HS station in 1992 and PA station in 1994 (Table 3). Curiously, the PA station did not show a decrease in precipitation during either of these El Niño phases (Table 2). The La Niña phase of 1995-6 (National Oceanic and Atmospheric Administration, 2015) appears to be reflected at both stations in above-normal precipitation in 1995 and 1996 (table 2) and below-normal temperatures in 1996 (Table 3). The departures from normal in Table 2 also suggest that precipitation differences between the west and east sides of the Cascades may be smaller during El Niño phases and larger during La Niña phases, but more investigation is needed to confirm this.

Mesoscale Gradient (HPG)

The results show a much greater difference in mean May-October precipitation during 1992-6 on the east side of the Cascade crest compared to the west side as a result of the steeper HPG on the east side and the greater distance between sites 3 and 6 (Figure 7). It is clear from Figure 10 that the mesoscale HPG west of the Cascade crest is also complicated by the large decrease in precipitation from the HS station to site 1 as discussed in the next section. In individual years the pattern is even more complicated, and the differences between rain gauge sites are smaller probably because the spatial heterogeneity is greater than the distance between rain gauge sites. One reflection of this heterogeneity is the shift of the precipitation peak with reference to the Cascade crest (Figure 8). Wratt et al. (2000) discuss several factors including relative humidity, wind velocity and direction relative to the topographic barrier, and air mass stability that can cause the precipitation peak at the crest to be shifted east or west in this way, but there is no way to tell whether the eastward shift in 1994 (Figure 8) results from more spillover that year. There is also no clear relationship between this shift and the precipitation departures in Table 2.

The larger difference between sites 3 and 6 in August-October compared to May-July (Figure 9) as well as in the calculated gradient suggest that the mesoscale HPG is more uniform later in the summer on the east side of the Cascade crest. This may be due to the much greater prevalence of convective precipitation east of the crest in spring and early summer (Phillips, 1990; Whiteman, 2000) which would produce a more heterogeneous spatial pattern of precipitation. The lack of a HPG west of the crest in August-October (Figure 9) may indicate that weak cyclonic systems at this time of year are not associated with much orographic enhancement (Loukas and Quick, 1994).

Regional Gradient (HPG)

The seasonal difference in the regional HPG across the Cascades (Table 4) is almost certainly attributable to seasonal differences in the frequency, intensity, and type of precipitation generating

mechanisms. In November-April effectively all of the precipitation in the range is associated with cyclonic disturbances (Hare and Thomas, 1974; Phillips, 1990; Oke and Hay, 1994; Loukas and Quick, 1996). This frontally-generated precipitation has a relatively uniform spatial pattern and therefore its orographic enhancement on the west slopes of the Cascades is also relatively uniform, producing a steeper HPG. In contrast, the much more random spatial distribution of summertime convective lifting and its ability to propagate at any distance east of the Cascade crest results in a decrease in the HPG.

In addition to being steeper in November-April, the regional HPG is also much steeper on the east side of the Cascades (Table 4). The fact that precipitation decreases rather than increases on the west side toward the Cascade crest (Figure 10, Table 4) suggests that the generally lower mountains west of the study area are more efficient at orographic enhancement than higher mountains further east. In fact, the mean annual precipitation at the 'Hope A' climate station in the town of Hope (49.368°N, 121.498°W; Meteorological Service of Canada, 2013a), located near sea level (39 m asl) at the east end of the coastal Fraser Lowland (Figure 1), is 1.7 times greater than at the HS station in Table 4. Therefore it appears that the Cascades exert an influence on precipitation formation already at their westernmost edge, an effect which is probably enhanced at the narrow eastern end of the coastal Fraser Lowland by convergence of incoming air masses as noted in other mountains (Loukas and Quick, 1994, 1996; Sinclair et al., 1997; Barry, 2008; Mass, 2008). The peak in precipitation at the Cascade crest shown in Figure 10 is therefore a secondary maximum after a much larger peak near the western edge of the range, with the HS station itself being in a small rain shadow created by topographic barriers located west of it in the manner described by Griffiths and McSaveney (1983), Saunders et al. (1997), Garreaud (1999) and Anders et al. (2007). Such 'mini' rain shadows on the west slopes of the Cascades are not reflected in the biogeoclimatic sub-zones (Green and Klinka, 1994), either because the precipitation decrease is insufficient to produce marked vegetation differences or because the rain shadows are too small in size to be shown on 1:250,000 scale mapping of biogeoclimatic zones.

Few studies have addressed the distance over which a rain shadow develops immediately leeward of the crest of a coastal mountain range. Wratt et al. (2000) show that the rain shadow in the Southern Alps develops over a distance of about 20 km. The results of our study indicate that the Cascades' rain shadow develops within 15 km east of the crest (Figures 7 & 10) and that the mesoscale HPG is strongly controlled by distance from the crest (Figure 11a). On the basis of qualitative observations of snowpack depth in the study area over many winters, it appears that the rain shadow in winter may develop over a similar short distance.

The meso- and regional-scale HPGs in this study have important implications for understanding the biophysical environment of the Cascades. For example, they provide an insight into the rapid change in valley-bottom biogeoclimatic zones across the Cascade crest. In the study area the transition from a coastal western hemlock zone to an interior Douglas-fir zone occurs over a road distance of only 13 km (Figure 1), which agrees closely with the mesoscale HPG east of Allison Pass (+2 to -7 km in Figures 7 & 9). This also supports the conclusion that the 1992-6 mesoscale HPG examined in this study is representative of the long-term mesoscale HPG. Without the intervening Engelmann spruce-subalpine fir zone occupying the slightly higher-elevation valley bottom between Allison Pass and Manning Park Lodge (Figure 1), the transition from coastal to interior vegetation communities would be even more abrupt.

The results of this study also have implications for watershed modelling and water management in mountain basins, in that a regional HPG obtained by analysis of data from long-term climate stations cannot capture mesoscale HPGs that are nested inside it. Watershed models developed for mountain regions, such as the UBC watershed model widely used in British Columbia, extrapolate point precipitation values from climate stations over the entire basin (Quick, 1995). More accurate knowledge about the mesoscale HPG can improve the accuracy of such models, especially for rivers such as the Skagit and Similkameen with flow sources in a coastal mountain range with sharp windward-leeward precipitation contrasts. The results of this study also indicate that watershed modelling may need to employ different values of the HPG in summer and winter seasons.

Vertical Gradient (VPG)

The much steeper VPG in November-April compared to May-October (Table 5) suggests that winter cyclonic precipitation is more amenable to orographic enhancement than summer convective precipitation. This indicates that watershed models may also need to employ different values of the VPG in summer and winter seasons. At the mesoscale, May-October precipitation exhibits a strong correlation with elevation only when locations west and east of the Cascade crest are considered separately (Figures 11b & 12) because of the different HPG on the west and east slopes of the Cascades (Table 4). At the regional scale, the relationship between elevation and precipitation on the west side of the Cascades would be further confounded by the much greater precipitation at low elevations along the western edge of the range. For example, Loukas and Quick (1994) have shown that along the western edge of the Coast Mountains about 140 km west of our study area, annual and seasonal precipitation reaches a maximum at only 400-800 m elevation. A similarly low elevation for the precipitation maximum has been found in the Cascades of Washington State (Schermerhorn, 1967; Rasmussen and Tangborn, 1976).

Conclusion

The results of this study indicate that a major mesoscale HPG exists at the Cascade crest in summer, even though this is a time of year when cyclonic storms are less frequent and weaker and orographic forcing is complicated by convective effects. The results also indicate that the precipitation peak at the crest may be secondary to a much larger windward peak that occurs as a result of initial uplift of air masses near or at the western margin of the Cascades and convergence of air masses at the head of the coastal Fraser Lowland. The rain shadow effect develops very quickly leeward of the crest and appears to be fully developed within about 15 km. The results also show that the VPG near the Cascade crest is much steeper in winter than in summer, probably because of the dominance of cyclonic precipitation in winter. The results of this study have important implications for understanding other biophysical gradients in the Cascades and coastal mountain ranges in general.

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Simulating Land Use Change in a Southern Interior Watershed in British Columbia

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Abstract: *British Columbia is a mountainous Canadian province with a limited supply of high quality agricultural land. Climate change and ongoing development are putting significant pressures on land and water resources throughout the Okanagan Valley, in the southern interior of the province. We use the CLUE-S (Conversion of Land Use and its Effects at Small regional extent) system to forecast land use change for the Deep Creek watershed, in the northern Okanagan Valley. Understanding what factors are contributing to land use change and where that change is likely to occur can help local and regional governments to better manage these changes. The calibration process highlighted the important factors affecting land use change. Model forecasts show that there will be continuing development pressure on agricultural land, an important food sovereignty issue for a mountainous province with a small area suitable for agriculture.*

Keywords*:* CLUE-S, Deep Creek watershed, land use change, simulation, water district

Introduction

Approximately 150,935 of British Columbia's 925,186 km^2 land mass is assessed as having at least some agricultural capacity, such as being able to sustain occasional grazing of native species (Standing Committee on Agriculture, 1978). However, prime agricultural land accounts for only 1.1% of this total, and most of that is located in valley bottoms, or near major urban centers (Smith, 1998). The Okanagan valley is one of the areas with prime agricultural land, and it is facing tremendous development pressures. Land use change has important implications for food sovereignty, agribusiness viability and landscape scale environmental processes, implications which local and regional governments, who are largely responsible for directing land use change, attempt to manage. By combining land use classification data with a range of other spatial variables that we collected or calculated, we are able to identify several factors that are correlated with land use in the Deep Creek watershed in the northern Okanagan valley. We then use these correlations to develop a forecast of land use change. Our results highlight the continuing pressure to develop agriculture, an important issue in a province where the population is strongly supportive of protecting agricultural land and promoting food sovereignty (McAllister Opinion Research, 2014).

The Okanagan Valley extends from the US border in British Columbia some two hundred kilometers north (see Figure 1). In the rain shadow of the Coast and Cascade mountains, the valley bottom receives between 330 and 450 mm / year of precipitation, and faces an annual moisture deficit in the 300 to 400 mm range (Neilson et al., 2010; Duke et al., 2008). Mean annual temperature and the potential evapo-transpiration are 8˚ C and 890 mm respectively (Ping et al., 2010). Climate change is expected to result in a larger moisture deficit (Neilson et al., 2010). The dry, relatively warm climate makes the Okanagan Valley an attractive destination for tourists and retirees. The valley has among the highest rates of population growth of any region in Canada (Statistics Canada, 2012 a, b). This growth is placing pressure on natural resources, particularly water and agricultural land.

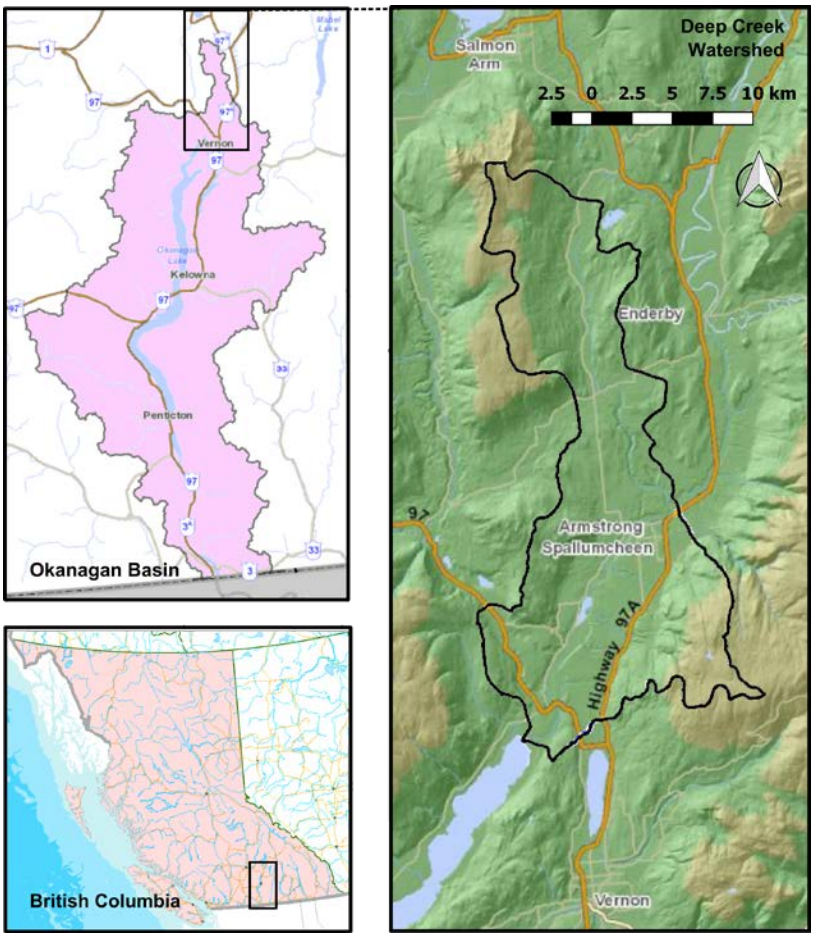

FIGURE 8.LOCATION OF DEEP CREEK WATERSHED IN OKANAGAN BASIN IN BRITISH COLOMBIA, CANADA. IMAGES GENERATED USING IMAP BC (2014).

Climate change is likely to intensify the resource pressures already being experienced in the Okanagan valley, including the Deep Creek area. To date, annual precipitation, particularly winter snowfall, has increased (Ping et al., 2010) along with daily minimum temperatures (Cohen and Kulkarni, 2001). The frost free period has been increasing by more than three days per decade, now ranging from 120 to 150 days (Zbeetnoff, 2006). Warmer winter temperatures are likely to result in an earlier freshet with higher peak flows and significant reductions in late season flows (Merritt, et al., 2006).There is some suggestion that total annual flows will also decline (Cohen and Kulkarni, 2001).

Milder winters will increase the land area suitable for many crops, particularly perennials such as tree fruits and wine grapes (Neilsen et al. 2001). There is some evidence that such changes are taking place (Rayne et al., 2009; Cohen et al., 2006). The precise pattern of these changes depends, to a large degree, on the microclimates created by the complex topography of the region (Cohen et al., 2006) and a policy environment that isn't necessarily concerned with protecting the ability of agriculture to expand. The longer growing season and warmer temperatures will increase water demand, precisely at the time when surface flows and groundwater recharge is reduced (Neilsen et al., 2001). Reservoir storage is an important part of water management systems in many parts of the Okanagan; earlier peak flows and lower late season flows will increase the need for water storage (Merritt, et al., 2006). Overall, climate change is likely to exacerbate the environmental impacts of current water use patterns.

Surface-groundwater interactions are also strong in the study area, with groundwater contributing significantly to the lower reaches of Deep Creek and as an important source of water for Okanagan Lake (Ping et al., 2010). Flow rates at peak freshet are 1 – 2 m^3 / sec while non-freshet flow is 0.1 to 0.3 m^3 / sec (Nichol et al., 2011). Withdrawals of groundwater from aquifers feeding Deep Creek can therefore have significant effects on flow rates, and on habitat conditions within the creek (Ping et al., 2010). These withdrawals can be significant. For example, almost 2,346 ha in the Township of Spallumcheen is currently irrigated, predominantly with groundwater (British Columbia Ministry of Agriculture and Lands [BCMAL], 2008). Surface withdrawals from Deep Creek are also significant, with documented annual withdrawals of 2.13 million m^3 for domestic and commercial use and almost 3 million m^3 for irrigation purposes (Ping et al., 2010), the large majority of which is used in July and August (Pike et al., 2010). Extractions therefore account for about a third of annual discharge, accounting for a larger share after the freshet, the prime irrigating season. New water licences are not being issued for Deep Creek (British Columbia Ministry of Environment [BCME], 2013). However, climate change is expected to cause an earlier freshet and a longer low flow period,

the period when peak demands occur (Pike et al., 2010; Langsdale et al., 2007).

Land use change is a dynamic process driven by a combination of economic, social, environmental and technological forces (Turner et al., 1990). Different land uses provide different land use or ecosystem functions (de Groot, 2006; Millennium ecosystem assessment [MEA], 2005). Many land uses are multi-functional, for example, farmland may produce aesthetic and biodiversity values along with food production (MEA, 2005). Changing land use effects not just the primary purpose, but a range of functions. Changing land use patterns can also effect the vulnerability of places and people to climatic, economic or socio-political perturbations (Kasperson, et al., 1995; Kasperson and Kasperson, 2001). Forecasting land use change can support planners and decision makers with protecting important environmental resources and addressing social and economic vulnerabilities.

A variety of approaches to modeling land use/cover change (LUCC) have been developed, reflecting differing research objectives and data availability. They can be loosely divided into those that seek to model the process of land use change and those that project from observed patterns of land use. Agent-based models (ABM) belong to the former category (Parker and Filatova, 2008; Polhill et al., 2008; Alexandridis et al.2007; Robinson et al., 2007; Parker et al., 2003) while many spatially explicit simulation models belong to the latter (Pijanowski et al. 2005; Verburg and Veldkamp 2004; Verburg et al. 2002; Kok and Veldkamp 2001; Schotten et al., 2001; Hilferink and Rietveld 1999; Berry et al., 1996). Model selection depends on the purpose of the simulation exercise.

A LUCC forecast can be used to predict changes in land use and resulting water demand, and to identify areas where the demand for development may lead to irreversible conversion of agricultural land to built forms. We reviewed a range of models, including SAMBA (Boissau and Castella 2003; Castella et al. 2005), cellular automata models (e.g. Clarke et al., 1998; Kirtland et al., 1994), the Mathematical Programming based Multi Agent System – MPMAS (Berger, and Schreinemachers., 2009), GEOMOD (Pontius et al., 2001; Pontius and Malanson 2005; Pontius and Spencer 2005), an econometric (multinomial logit) model (Chomitz and Gray, 1996), a general ecosystem model (Fitz et al., 1996),the Conversion of Land Use and its Effects - CLUE – model (Kok and Veldkamp 2001;Veldkamp and Fresco 1996), and the Conversion of Land Use and its Effects in Smaller scale-CLUE-S – model (Verburg et al. 2002; Verburg and Veldkamp 2004).

The large variety of land use types and the varying objectives of land owners (commercial farmers, hobby farmers, retirees, etc.) meant that any process based model that represented this diversity would be computationally infeasible. Simplifying the model would make it practical to solve, but then be subject to the information losses that result from the simplification. We therefore opt to take a pattern based approach, and use the CLUE-S system.

CLUE-S has proven to be an effective tool for modeling fairly fine scale land use change. It has been used as land use change projection tool in African, Asian, American and European locations (Verburg et al., 2005; Castella et al., 2005; Hurkmans et al., 2009; Neumann et al., 2011). This choice does preclude analysing the direct effect of policies such as changes in taxes which impact on the decisions of land managers. However, a pattern based model can be calibrated using more readily available spatial data, and will likely capture many of the spatial influences that drive activities to particular locations in a landscape.

A comprehensive overview of the CLUE-S system can be found in Verburg (2010). Some important elements are described here. Fundamentally, the CLUE-S system distributes a forecast of aggregate land use change across the landscape. It does not predict how much land use change will occur, but rather where the change will occur. The model evolves a gridded map of the study landscape forward, changing land use of individual grid cells using a probabilistic transition model. The transition probabilities are impacted by driving factors that are measured or calculated for each grid cell. The impact of driving factors on the transition probabilities is assumed constant over the length of the simulation.

In addition to the aggregate land use changes, CLUE-S also requires a method for assigning transition probabilities for each land use type in each cell. The system is built to use the results of logistic regressions relating cell level variables to the probability that a cell will be of a certain land use type. These probabilities are modified by user supplied transition characteristics, such as some land uses having more 'resistance' to change and others being 'terminal' states from which no further change can occur (land is not 'undeveloped'). The transition characteristics – elasticity and iteration probability – reflect certain land use change properties. Readers are referred to Verburg (2010) for additional information.

The regression results are necessary inputs to the CLUE-S system, and also tools to help understand the driving factors that are related to land use change. As with any regression, part of the challenge is identifying all the variables that may be are important drivers. In the semi-arid Okanagan, agricultural land use types will require irrigation, and therefore we include variables related to potential water sources.

Methods

By including distance to surface water and depth to groundwater as driving factors in these regressions, we both empirically estimate the role of these drivers on land use change, and incorporate these influences into the simulation model.

Study Site

The Deep Creek watershed is located in the northern part of the Okanagan Valley, a semi-arid valley in the southern interior of British Columbia (Figure 1). The watershed covers an area of 230 km^2 and includes the communities of Armstrong and Spallumcheen. It cuts across the boundary of Columbia-Shuswap regional district (CSRD) and regional district of North Okanagan (RDNO). The elevation of the southern part

of the creek ranges between 340 – 520 meters in above sea level, while the northern part ranges from 370 – 1575 meters above sea level (GeoBC, 2009).

Forestry, agriculture, manufacturing and tourism are all important economic activities in the watershed. The area included within the boundaries of the Township of Spallumcheen overlaps to a large degree with the boundaries of the Deep Creek watershed. Within the township, the share of employment in agriculture is among the highest in the province (British Columbia Ministry of Agriculture, Food, and Fisheries [BCMAFF], 2002).

The agriculture overview of township of Spallumcheen reports an average farm size of 38.1 ha with cropped area covering more than half (52 %) of the farmed area, with pasture (managed and unmanaged) area occupying 44 %. Among livestock enterprises, there are 11,109 cattle on 155 farms and 44 % of the dairy herd in Okanagan valley is found within the township limits (BCMAL, 2008). Poultry farming has significantly intensified. There were 325,263 birds on 150 farms in 1996, while in 2006 there were 908,632 birds on 99 farms. Irrigated area has also increased, from 8 % of total farm land in 1996 to 14 % in 2006 (BCMAL, 2008). Unless irrigation efficiency has improved by at least 43% over the same period, this increase in irrigated land will have increased total water use.

The North Okanagan basin has an average annual precipitation of 468 mm on the valley floor and 592 mm on the surrounding mountains (Duke et al., 2008). The basin has a semi-arid climate with a bimodal precipitation pattern. A winter peak reflects the migration of Pacific storms across the region, while convective storms result in another peak in the summer (Merritt, et al., 2006). Daily minimum temperature has increased noticeably, as has precipitation, particularly winter snowfall (Cohen and Kulkarni, 2001). The frost free period has increased ~~a~~nd these changes in climate are lengthening the growing season thereby reducing the risk of extreme minimum winter temperatures (Cohen et al., 2006).

Presently, more than half of the Deep Creek watershed is covered by forest and range land. As part of Canada's Montane forest region, dominant species include *Pseudotsuga menziesii* subsp. *glauca* (Douglas-Fir) and *Pinus contorta* (Lodgepole Pine) (Demarchi, 2011). Wildfires and the recent outbreak of mountain pine beetle has caused considerable forest damage (British Columbia Ministry of Forests, Lands and Natural Resources Operations [BCMFLNRO], 2011). Forest and range lands are the undeveloped land use in the watershed. Generally, land use demand is filled by converting forest and range land to other uses. This reduces the extent of forest and range land, thereby decreasing the ecosystem services provided by these lands.

<u>Generation of spatial information.</u>

A pattern based forecasting model predicts changes in the values of one map based on

the patterns of relationships between the values on that map and a set of explanatory maps. The choice of the map resolution and calculation of the explanatory maps is described here. As is typical of such systems, computational burden increases rapidly with the number of cells and number of land use types being modelled. We chose a 500 m × 500 m cell size to balance resolution with computational efficiency, and with the aim of eventually linking our results to downscaled climate data as part of a larger coupled land use and watershed hydrology model. Since average farm size in the Township of Spallumcheen was 36.8 ha in 2001, and 62.5 ha in 2006 for the Regional District of North Okanagan (BCMAFF,n.d.,; BCMAL, 2008). An average farm therefore is represented by 1.4 to 2.5 grid cells. Gridding the landscape also meant representing all polygon based data as grid cells. Generally, this involved rasterizing the polygons at a fine resolution, and then conducting a spatial aggregation to generate a result for the scale of the grid cells used in the simulation. Standard tools in ArcGIS™ (9.3) were used to generate a grid map that overlays the watershed boundary polygon. The resulting grid contains 1112 cells. Remaining data processing consists of scaling data to be consistent with the simulation grid.

CLUE-S models land use change, and a key ingredient is a land use map. To generate the base map, land uses have to be aggregated down to a limited number of land use types, and single land use types have to be assigned to each grid cell. A recently concluded land use survey map for Okanagan basin, obtained from BCMAL, covered much of the study site (Van der Gulik, et al., 2010). A second, slightly older map, also available from BCMAL, was used to patch the missing areas. Most of these missing areas were in the north part of the watershed.

A raster map of the land use data was generated at a 10 m × 10 m resolution. Each 500 m × 500 m grid cell was assigned one land use type, the most common land use among the 2,500 pixels in each grid cell. More than 40% of grid cells had only one land use and 18% had only two. Almost 82% having one land use accounting for at least 50% of pixels in the grid cell. Less than 5% of cells had the dominant land use in the cell accounting for less than one third of the pixels in the cell. The two most dominant land use/cover types were woodland (102.78 km^2) and grassland (17.98 km^2), together accounting for nearly half of the grid cells.

There were 42 different land uses remaining over the 1112 grid cells. Many of these land uses were only represented by one or a few cells. It is not possible to estimate a regression model with fewer observations than independent variables. So, land use types with too few observations were aggregated into other groups. In the end, land use was grouped into three broader categories – undeveloped, agriculture, and urbanized area – with the agriculture category divided into three more, pasture and forage, cultivation land, and livestock farm. Each cell was then assigned the

dominant land use from those of the pixels it contained (Figure 2).

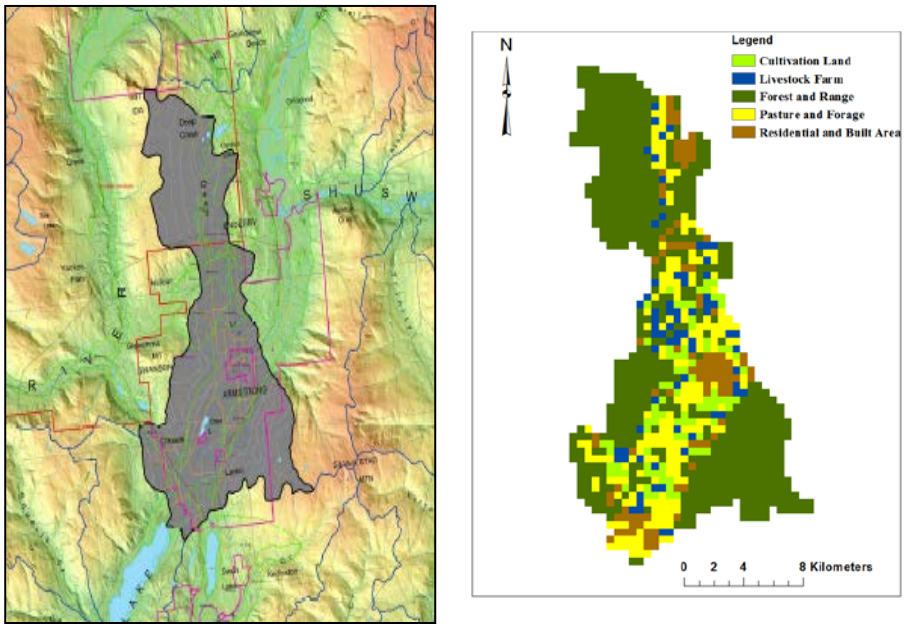

FIGURE 9. MAJOR LAND USES AND THEIR SPATIAL DISTRIBUTION IN THE STUDY AREA FOR YEAR 2010. FOREST AND RANGE, AND PASTURE AND FORAGE LAND DOMINANT LAND USE DISTRIBUTED ACROSS THE WATERSHED. THE TOPOGRAPHY OF WATERSHED IS DISPLAYED IN THE RIGHT HAND SIDE MAP.

The physical variables included as potential LUCC drivers were elevation, slope, aspect, soil depth, percent sand, percent silt, depth to groundwater and distance to surface water. Elevation, slope and aspect are important determinants of the local climate conditions. To calculate average elevation, slope and aspect for each cell, contour map information provided by the provincial government (GeoBC, 2009) was rasterized in ArcGIS™ (ESRI, 2012) to generate a digital elevation model at a 25 m × 25 m resolution. The cell elevation was the average of the elevation for the DEM grid points. A slope was calculated for each grid point (relative to its neighbours) and then this was averaged to generate a slope for the cell. This slope measure would be high for cells that have a significant amount of elevation change, even if the overall elevation change is small. An alternative would have been to have two measures, one for roughness and another for elevation change. For aspect, the direction of the fall line for each DEM grid was calculated, and assigned a compass orientation (North, East, South or West). The most common orientation was then assigned as the orientation for the 500m × 500m cell.

Access to transportation and markets is important for many activities. Farmers need roads to access markets for inputs and to deliver products for sale. Residents use

roads to access employment and retail. Much of the Deep Creek watershed is rural residential, with many jobs located in the cities of Vernon and Salmon Arm, both just outside the watershed. Distance to urban centers and access to transportation are expected to be drivers for land use change. Distances from the centroid of each 25m pixel to the nearest urban center (Vernon or Salmon Arm), nearest highway and nearest paved surface were calculated. A simple arithmetic average of the distance for each pixel in a grid cell was assigned as the grid cell value. In this way, grid cells that have a road running through the middle will not have a value of zero, while a grid cell with a road near each edge will have a value smaller than the distance to the grid cell centroid. An alternative would have been a measure of road density together with a measure of distance from the cell centroid. Such explorations are left for future work.

Soil depth, sand and silt percentages are important components of the agricultural capacity of the land. Soil depth, sand and silt percentages were generated using a soil map available from Soil Landscapes of Canada version 3.2 (Agriculture and Agri-Food Canada, 2012). These maps were rasterized at a 25 m × 25 m grid scale and then an arithmetic average calculated for the 500 m × 500 m grid cells.

Given the semi-arid climate, many agricultural activities cannot occur without irrigation. Irrigators holding water licences – generally long established farmers – are able to draw from surface sources. Those who do not have a licence or are too far away from a source to make conveyance of water practical can use groundwater. For irrigators relying on their own water supply, the cost of access – increasing with distance or depth – are likely to affect the choice of agricultural activities (Mendelsohn, R., and Dinar, 2003; Green et al., 1996). Irrigators can also choose between sources, surface, groundwater, or if available piped water from a water provider. While irrigators may maintain a portfolio of water sources as a way to manage the risk of water shortage, for this analysis we assume that each grid cell is supplied by only one source. That source is piped water if available, groundwater or surface water if a surface source is available within one kilometer, and groundwater otherwise. In this region, surface water that is moved any significant distance is usually done by a water provider. Irrigators that access surface water directly generally pump that water directly into an irrigation system, hence the limited distance. As for other variables, alternative distances and variable combinations could be examined, and doing so is left for future work.

Distance to surface water was calculated in the same way as distance to nearest road and depth to groundwater as for elevation. Within the driving variables data set, dummy variables were used to separate the regions with and without access to piped water and/or access to surface water. Depth to groundwater itself was calculated using an interpolated map of the groundwater elevation (not depth) across the study site. (Ping et al., 2010). The depth to groundwater was calculated as the

difference between the elevation of the land surface and the groundwater elevation, with negative values set to zero. Less than 5 % of the grids (46) had negative values that were set to zero.

There are a number of water utilities in the watershed that provide water for residential and agricultural purposes. Polygons representing the areas serviced by each water provider were obtained from the Okanagan Basin Water Board. Similar to how land use types were assigned, if more than half of the 25 m × 25 m pixels in a grid had access to piped water for agricultural purposes, then the grid cell was labeled as having access to piped water.

In addition to the drivers already described, we also expect that land use types will tend to cluster (e.g. see Verburg et al., 2004). Failure to account for this clustering risks introducing a bias into regression estimates (see Anselin, 2002; Anselin 1995 and work that built thereupon). To capture this effect, we calculate a neighbourhood association that reflects the relative dominance of the cell under consideration within its immediate neighbourhood. This measure is equal to one if all neighbouring cells have the same type, and in the limit approaches zero if none of the neighbouring cells are of the same land use type. For further details see Anputhas et al., (2016).

Aggregate trend variables

Aggregate changes in land use types for the study area were based on forecasting forward past trends. Changes in residential land use area were assumed to follow projected population growth (BCstats, 2006). Changes in the relative composition and absolute amount of agricultural land use types was calculated based on historic trends for these variables using Census of Agriculture information (British Columbia Ministry of Agriculture, 2011; BCMAL, 2009; BCMAL, 2008;). Overall, changes for cultivation land, livestock farm, pasture and forage land, and residential and built area are projected to be, respectively, 0.50, -0.67, 0.95, and 1.12 percent per year, with these changes made up for by a corresponding reduction in forest area (Figure 3).

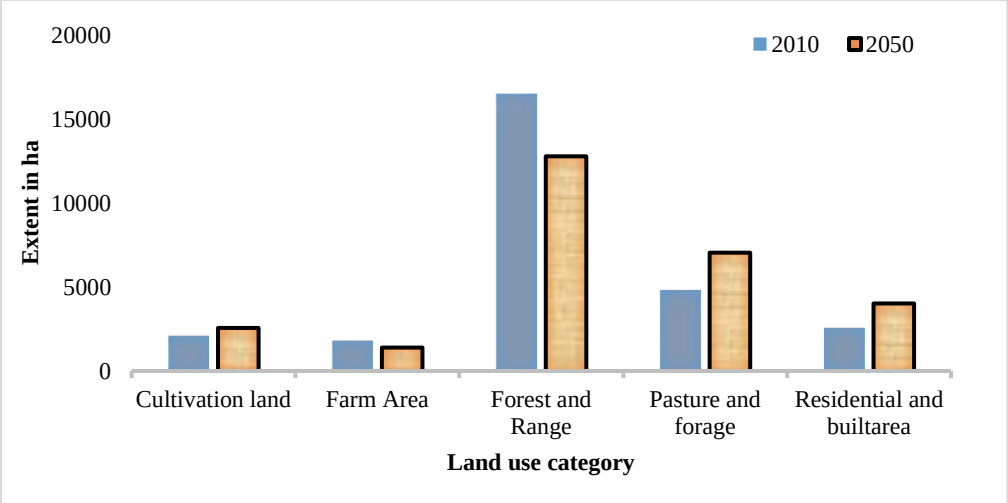

FIGURE 10. AGGREGATED LAND USE DEMAND IN YEARS2010 AND 2050 FOR THE STUDY AREA. CULTIVATION LAND, PASTURE AND FORAGE, AND RESIDENTIAL AND BUILT AREA IS EXPECTED TO EXPAND IN THE FUTURE, WITH MOST OF THIS EXPANSION ACCOUNTED FOR BY A REDUCTION IN THE FOREST AND RANGE AREA.

Conversion elasticities (see Verburg, 2010) measure the 'resistance' of a land use type to change. After reviewing the literature and consulting with local experts, elasticities were set at 0.65, 0.75, 0.80, 0.85 and 0.95 for pasture and forage, cultivation land, forest and range, livestock farm and residential and built respectively. This captures the fact that pasture and forage is relatively easy to convert to a range of other land uses, while residential and built areas are much more difficult to convert. The conversion sequence (also see Verberg, 2010) captures the fact that land use change is typically ordered. For our simulations, conversion in either direction was possible between all land use types except residential and built areas. Once land was converted to residential or built, it could not convert to any other use.

Results and Discussion

We report two levels of results, the logistic regressions which are inputs to the simulation model, and the simulation model results themselves. While most of our driving variables have effects similar to those found elsewhere, the way we include access to water and our use of neighbourhood association are both novel. We therefore devote some space to these regressions prior to describing the simulation results.

Regression results

The fit of the regression models was good. They were fit using a forward conditional stepwise regression (SAS 9.2 and SPSS 19), with the strength of fit assessed using receiver operator curves (ROC) (Pontius and Schneider, 2001). Parameter estimates that were not significant at the 95% level were dropped, except where noted. Table 1 presents the coefficient estimates and

goodness of fit measures (model Chi-square, pseudo R^2, and the area under the ROC curve). Model fit was best for the forest and range land use type, the type with the greatest number of observations, and poorest for the livestock farm land use type. All the models are significant at 0.1 % error level (prob< 0.001). These ROC values are in the range reported for similar models, where they vary within the range of 0.735 to 0.983 (Lin et al., 2007).

Distance to urban centre, spatial association, distance to river (within the buffer zone) and south orientation were positively correlated with the cultivation land use type. Distance to paved surface, population density, slope and depth to groundwater were negatively correlated (Table 1). Cultivation land tended to be located close to urban centers, reflecting proximity to markets. The negative influence of population density and paved surface was consistent with residential and built areas being a higher value use, driving cultivation land to be close to, but not too close to, settled areas. Slope and depth to groundwater had the expected signs, as did spatial association. Steep land is hard to work, and there are benefits of being near other cultivation land cells that are not captured by the driving variables, reflected in the significance of the spatial association variable. The sign on distance to river was opposite to expectations, but may reflect water table or flooding issues not captured by the included variables.

TABLE 2. THE PARAMETER ESTIMATES, LEVEL OF SIGNIFICANCE, CHI – SQUARE VALUES, AND R2 VALUES OF LOGISTIC REGRESSION OUTPUT AND ROC VALUES FOR EACH LAND USE CATEGORY IN THE STUDY AREA.

Variables	Cultivation land	Livestock farm	Residential & built area	Pasture &Forage	Forest &Range
Distance to highway	–	–	-0.0004 (0.00009)	–	0.0002 (0.00005)
Distance to urban center	0.0002 (0.00004)	–	-0.0002 (0.00003)	–	–
Distance to paved surface road	-0.0007 (0.00025)	-0.0009 (0.00026)	–	–	0.0007 (0.00019)
Population density	-0.0035 (0.00184)	–	0.0162 (0.00274)	-0.0105 (0.0031)	-0.0189 (0.00459)
North direction of aspect				0.4893 (0.2295)	–
South direction of aspect	0.7856 (0.28459)	–	–	–	–
East direction of aspect	–	0.6468 (0.27153)	–	–	–
Slope	-0.0750 (0.03561)	-0.1874 (0.04910)	–	-0.1565 (0.0275)	0.2046 (0.02491)
Percentage of sand	–	0.0261 (0.00732)	0.0146 (0.00695)	–	–
Depth of ground water level	-0.0056 (0.00266)	-0.0076 (0.00330)	-0.0094 (0.00245)	-0.0106 (0.0015)	0.0100 (0.00155)
Distance to river in buffer zone	0.0020 (0.00062)	–	–	–	-0.0004 (0.00014)
Distance to lake and reservoir	–	–	-0.0006 (0.00030)	–	0.0004 (0.00020)
Spatial association	0.7852 (0.39938)	0.8911 (0.41908)	–	0.9928 (0.3086)	–
Constant	-5.2086 (0.72637)	-2.5627 (0.43893)	0.4663 (0.56595)	-0.4821 (0.2520)	-3.0141 (0.26166)
Number of grids / cells	84	73	103	193	659
Model Chi-Square value	167	117	241	262	792
Pseudo R^2 (Cox & Snell)	0.14	0.10	0.20	0.21	0.51
ROC value	0.88	0.84	0.93	0.84	0.89

All explanatory variables are significant at 0.05 error level except the population density that is significant for cultivation land at 0.10 error level. Values in the parenthesis are standard errors Distances and depths are measured in metres; slope and amount of sand are in %; population density is in per square kilometres and other variables are unit less .

For the livestock farm land use type, distance to paved surface, depth to groundwater and slope were negatively correlated, while easterly orientation, percentage of sand and spatial association were positive. Livestock operations prefer flat, well drained land with easy access to groundwater – where water is not available from a utility. They also tend to be located with easy access to transportation. They tend to face east, a fact that, like the positive role of spatial association, likely captures other spatial drivers not reflected in the included variables.

Residential and built areas were negatively associated with distance to highway, distance to urban center, distance to lake / reservoir and depth of groundwater table, while population density, and percentage of sand had a positive influence. Spatial association did not have a strong enough effect to be retained in the model. Highways are generally built to connect population centers, and the existence of those highways tends to enable development at the margins of urban centers. The influence of distance to highway and distance to urban center are consistent with these facts. Residents in the town have water supplied by a utility, so distance to lake / reservoir and depth to groundwater likely capture other effects, as is probably the case for percentage of sand. These may reflect suitability of the town site for building. The strong influence of population density and the missing influence of spatial association reflect the fact that built areas are where people live, and thus population density is likely positively correlated with any other factors that contribute to a spatial correlation for built areas.

Pasture and forage land use is the second largest land use found in the study area (Table 1). Population density, slope and depth to groundwater were negatively associated with this land use type, while northerly orientation and spatial association were positive. Where water was not available from a utility, access to water was important, which was consistent with the influence of depth to groundwater. Flatter land is preferred. The influence of northerly orientation may occur because pasture is a superior use on some sites, where microclimates are not suitable for cultivating higher value, heat loving crops. The very high influence of spatial association suggests that there are other spatial drivers that have not been included in the model.

The residual land use class is forest and range, the land use that would occur were land not converted to other uses. Hence, the influence of the driving variables reflects the fact that the land remaining as forest and range is less attractive for those other uses. Distance to highway, to paved surface roads, and depth to groundwater and distance to a lake or reservoir had a positive influence, while population density and distance to a river were negative. Highways and road networks are built to connect settlements and enable conversion of land to other uses, so the negative association with these variables makes sense. The influence of depth to groundwater and distance to lake or reservoir was consistent with the fact that

most of the land development had occurred on the valley bottom, where lakes and reservoirs are located, and where groundwater is easier to access. In an agricultural area like the Deep Creek watershed, settlement patterns are related, at least historically, to agricultural activities, consistent with the influence of population density. The negative influence of distance to flowing surface water, within the one kilometer band of that water, may reflect topographic constraints that limit other land uses in some of those areas.

Overall our regression results are qualitatively consistent with the many other studies that have investigated factors that drive land use change (Hersperger and Bürgi, 2007; Jansen et al., 2007; Haase, 2007; Verburg, and Overmars, 2007; Dendoncker et al., 2007; Brandt et al., 1999). The strong role played by our measure of neighbourhood association highlights the importance of clustering. The importance of including such a measure is described in more detail in Anputhas et al. (2016). While models of discrete land use change have seldom used measures to reflect clustering effects, concern about spatial correlation has been an important issue in spatial statistics (Overmars et al., 2005; Aguiar et al., 2007; and Gellrich and Zimmermann, 2007). Our results highlight how assuming all important spatial effects are captured by the included driving variables can miss important relationships.

Our approach to water access reflects that the choice of water source is generally discrete. Capital and operating costs together generally lead a land owner to only use one source at a time, even if multiple sources are available. The dominant source is generally the lowest cost source, with the choice of crop and irrigation technology reflecting these costs (e.g. reference with Zilberman used earlier). The importance of surface water and groundwater accessibility has been shown to be an important driver of land use change in other work (e.g. Park et al., 2011; Luo et al., 2010; Valbuena et al., 2008; Verburg and Veldkamp 2004; Verburg et al., 2004). However, it has not been integrated into land use change forecasting. For water and other inputs to land use that are discrete choices, similar adjustments to the driving variables should be made.

Simulation Results

The expansion of residential and built areas occurs largely in the far northwest and the south of the watershed, areas close to Salmon Arm and Vernon, and close to a highway corridor (Figure 4). Much of this new build area is converted from forest and range, some comes from livestock land use types, and smaller amounts are converted from other land use types (Figures 2 and 4). The simulation results predict that a large share of the expansion of built areas will occur along the interface between agricultural uses and the forest and range lands. The largest expansion of built areas into agricultural land uses is predicted to occur along the southern part of the watershed, which is close to Vernon, and where there are two important highway corridors. In this area there is less forest land available to convert, and that which there is

has a steep slope, making it less attractive. The livestock land use area declines throughout the watershed. While the area devoted to livestock may decline, this does not mean that livestock numbers will decline by the same amount. If livestock intensity is increasing, then there is a need to dispose of animal waste. Much of this will be spread on land that is classified as cultivation land and in particular pasture and forage land. Likewise, pasture and forage land is intimately connected to livestock operations, as these areas produce the feed consumed by the livestock. The simulation suggests that most of the remaining livestock operations will be concentrated in the central part of the watershed, north of Armstrong. Waste disposal will likely be concentrated in these areas.

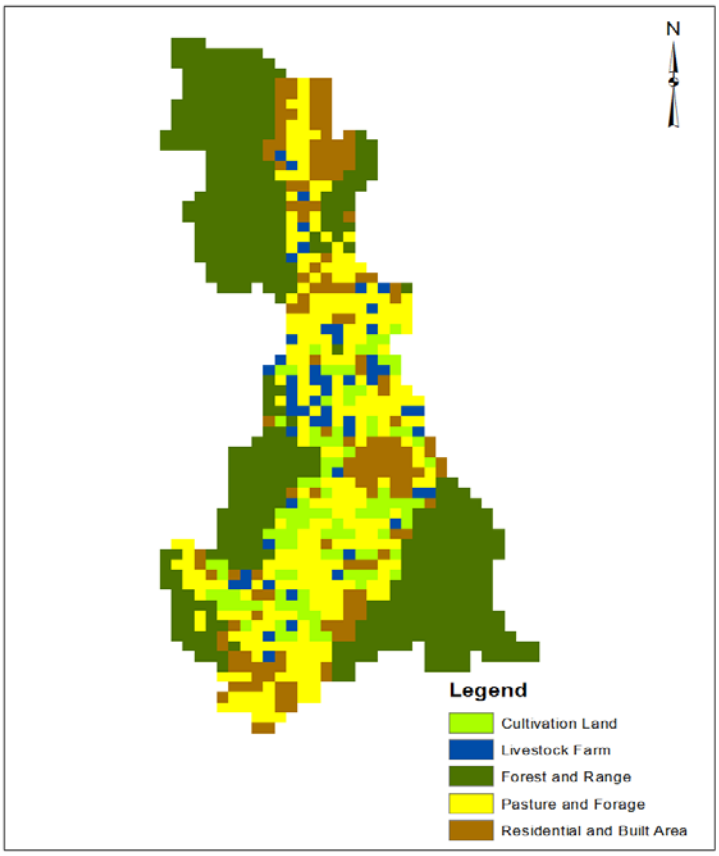

FIGURE 11. LAND USE CHANGES IN DEEP CREEK WATERSHED IN 2050. DEVELOPMENT EXPANSION IS EXPECTED TO TAKE PLACE CLOSER TO SALMON ARM (NORTH) AND VERNON (SOUTH) AREAS WHILE THE LIVESTOCK IS SHRUNK TO MIDDLE PART OF THE WATERSHED.

Our simulation results suggest that land near to Vernon and Salmon Arm will be under the greatest pressure for conversion to the residential and built land use type. If the communities in and around the Deep Creek watershed want to protect the agricultural

land within the watershed, then they should be cautious about investing in infrastructure that facilitates conversion, such as expansion of the road network, in areas that are agricultural. Likewise, if areas that are less valuable agriculturally are made easily accessible for development, pressure on agricultural land will be reduced. Further, policies that directly increase the profitability of farming, from preferential tax treatment through assistance with marketing to payments for ecosystem services can all reduce the incentive to convert land (for a discussion of policy options relevant to British Columbia, refer Curran and Stobbe, 2010).

Climate change impacts, such as changes in forest fire risk and impacts on global food markets, will also impact on the Deep Creek watershed. The model predicts that much residential development will occur on what is currently forest and range land. Some of this will be expansion into the forest interface area. In anticipation of climate change, fire risk management should be considered (Frontline Express, 2012). Likewise, potential increases in food demand may significantly change the value of agricultural land (Calzadilla, 2013). Protecting agricultural land may therefore have a role in climate change adaptation.

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