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Vulnerable Vancouver

Finding Residents at Risk in
Vancouver, Canada

by

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Definitions

- **AJAX**: A method for a web page to communicate with a server side program without having the browser refresh. AJAX is particularly useful in mapping web pages because the user may pan or zoom the map and does not lose these settings when an AJAX transaction occurs
- **Dynatree**: a library of code that sits on top of JavaScript and simplifies the creation of a tree control for making the layers on a map visible or invisible
- **Feature**: An object in the real world, for example, a fire hydrant, road, or park
- **Google Maps**: A library of code that sits on top of JavaScript and simplifies the creation of a map on a web page
- **Indicator** or **vulnerability indicator**: Some measure that would make a person vulnerable in the event of an earthquake, such as not being able to speak English or being very young or very old
- **jQuery**: A library of code that sits on top of JavaScript and simplifies the creation of objects on a web page such as tabs, sliders, and dialogs
- **KML**: An XML-formatted text file that contains geographic data and attributes on features that Google Maps can interpret and draw on the map
- **Open Source**: Software that is free for all to use and that usually has its source code available for all to modify
- **PHP**: An Open Source programming language that is particularly proficient in making dynamically generated web pages
- **PostGIS**: An extension to PostgreSQL that allows sophisticated spatial operations on a geographic-based database
- **PostgreSQL**: An Open Source database with many third party modules that is particularly well-suited to connections with dynamically-generated web pages
- **Principal Component Analysis** or **PCA**: A set of mathematical calculations that shows relationships in a group of data. For example, in demographic data of a given area, PCA might show that where there are high levels of unemployment, there are also high levels of social dependence.
- **Python**: An Open Source programming language that is known for its elegant syntax, powerful features, and wealth of third party modules
- **SoVI**: *Social Vulnerability Index*, a method to measure social vulnerability by combining vulnerability indicators and then grouping them by their relationship to the standard deviation

- **Standard Deviation**: The spread of differences between a group of numbers from their average. For example, for the set of numbers:

  2, 4, 4, 4, 5, 5, 7, 9

  The average is 5. The average difference that each number has between itself and 5 is 2.

Contents

Index of Figures

Index of Tables

Abstract

Governments have a responsibility to prepare residents for natural disasters such as earthquake, flood, and hurricane. In areas of the world where likelihood of a certain disaster is high, governments have a particular responsibility to assess vulnerability of residents so that they can take steps to prepare for the disaster.

But assessment of vulnerability is not a straightforward process. Many factors enter into the determination of vulnerability, and these factors may differ from city to city, from culture to culture, and from disaster to disaster. Thus there may never be a “one size fits all” vulnerability index that governments can use to find out which residents are vulnerable in which ways.

The purpose of this thesis is to test the use of an interactive web map for assessing vulnerability for a particular city, Vancouver, Canada, using demographic data from the 2011 census data from Statistics Canada. Using this web map, staff members at City of Vancouver can create custom queries of their residents for particular vulnerabilities such as age, language, and economic status, and display the results on a map. Upon performing visual analysis of the results, staff members can take appropriate action such as scheduling seminars and soliciting volunteers to help the vulnerable residents that the map identifies.

To compare the effectiveness of the interactive web map, Principal Component Analysis (PCA) was also performed. Planners at City of Vancouver were then given the results of the PCA analysis. After several months of usage, the effectiveness of both the web map and the PCA was assessed.

Introduction

The Challenge of Defining Vulnerability

What is the definition of "vulnerability" in the context of natural disaster? Many researchers have attempted to define vulnerability, but there is not an overall definition that has gained wide acceptance (Barnett et al., 2008). In recognition of the difficulty of defining this term, Rasheed and Weeks (2003, p. 547) state, "Assessing urban vulnerability to natural hazards such as earthquakes can be regarded as an ill-structured problem (i.e. a problem for which there is no unique, identifiable, objectively optimal solution)". Tate (2012, p. 326) asserts, "Although there is broad interest in the need to quantitatively model social vulnerability, there is far less consensus regarding the ideal set of methods used for the production of indices" and "If methodologically fragile indices are applied to hazard mitigation planning, decisions resulting from their use may be flawed". Barnet et al. (2008, p. 103) begin their study with the succinct "Vulnerability is an imprecise term with intuitive resonance, if no single definition", while Yoon (2013, p. 840) finds that "Social vulnerability is often hidden and complex, nested in various human aspects, and place sensitive" and concludes that "the outcomes of social vulnerability assessment are mainly decided by the selected variable, regardless of assessment techniques".

Most researchers agree that vulnerability has to do with exposure to physical hazard, such as living near a volcano or being on a coastline that is subject to hurricane. However, defining "social vulnerability" is more elusive. This is because not all people react the same way to a given hazard event (Wu et al., 2002).

Rygel et al. refer to the *coping ability* of individuals and groups as a criterion for defining vulnerability (Rygel et al., 2005). Coping ability as they define it is composed to two attributes:

- Resistance: the ability to absorb the effects of a hazard event and continue to function
- Resilience: the ability to recover quickly from a hazard event

By this definition we may define *social vulnerability* as the study of people whose physical structures and social structures are not robust to begin with, and whose structures may fail in the event of extra stress such as disaster. For example, poor people may not have funds to rebuild their structures, and single mothers may not have social structures to help them with their children while they work. Their *resistance* to disaster is weak, and their *resilience* in recovering from disaster is also weak.

But while there is agreement that certain groups are vulnerable in theory, when an actual disaster happens it can be surprising which groups demonstrate the most vulnerability. For example, a study of recovery rates in New Orleans following Hurricane Katrina found that it is the neighbourhoods in the medium social vulnerability range that are recovering the most slowly. This is because neighbourhoods that are the poorest receive the focus of government assistance and charitable donations, while middle class neighbourhoods comprised of school teachers and health care professionals do not receive such assistance or donations (Finch et al., 2010). And the elderly, who would normally be in the vulnerable category, were particularly resilient during the North American Ice Storm of 1998, due to their experience with power loss in times of war (Jones and Andrey, 2007). As another example of the difficulty in pinning down the definition of vulnerability, a planner at City of Vancouver told the author that people who are well off financially have less coping skills that those that are poor. In her experience, the poor are better at adapting to hardship, whereas the well-off expect government to maintain their life-style after an emergency.

Vulnerability Indexes

In recent years researchers have attempted to define vulnerability in terms of indexes. Indexes are a common facet of modern life. The Dow Jones Index tells us the state of finance, the Consumer Price Index tells us the cost of living, the Human Development Index tells us about social well-being (Barnett et al., 2008). Indexes are an attempt to group raw data together in order to discern patterns.

One of the most influential indexes in the area of social vulnerability is the Social Vulnerability Index (SoVI) (Cutter et al., 2003). This method starts by obtaining raw data such as income, education, and language from the US Census Bureau for a given study area, broken down by counties. The data are normalized and standard deviation is calculated, which are then processed using Principal Component Analysis (PCA). This process identifies significant factors in vulnerability for a given county.

SoVI was a major development in the goal of vulnerability assessment. However, SoVI and subsequent attempts to create a vulnerability index that is applicable across domains of culture and physical infrastructure are not without limitations. Further analysis of such indexes reveals the following weaknesses:

- **Assumption of normality:** One of the assumptions of SoVI is that the average for a given factor in a given county is considered to be normal, and thus residents who fall within one standard deviation of that average are not vulnerable for the given factor. However, consider the highest and lowest GDPs in the world for 2012 (Table 1):

  Table 1: GDP per Capita, 2012

Country	GDP per Capita in 2012 (USD)
Liechtenstein	$141,000
Congo, Democratic Republic of	$400

  (indexmundi.com, 2012)

  We need not calculate the standard deviation for these figures to determine that a figure of one standard deviation above the Congo average of $400 would probably still leave an individual vulnerable in the event of an earthquake. Conversely, the individual in Liechtenstein who falls beneath the one standard deviation would quite possibly have the resources to rebound from the earthquake quickly. As well, the infrastructure in Liechtenstein is likely more robust than the infrastructure of Congo, which decreases vulnerability.

  An example specific to Vancouver is in the area of language. Vancouver has a large number of immigrants from the Pacific Rim countries. According to the 2011 Statistics Canada census, 31% of Vancouver residents do not speak English in the home. Regardless of the spread of the standard deviation, it is likely that this percentage of the population will have difficulties in the event of an earthquake. Thus what SoVI reports as “normal” is not always an acceptable level for a given index.

- **Type of hazard:** Indicators of vulnerability vary between hazards. For example, an index that measures height of building first floor is significant for flood, but not for rockfall (Kappes et al., 2012)

- **Priority of user:** The priority of the user may influence the value of the factor. For example, the height of a building may be of high priority for emergency management because it allows access to the building for purposes of evacuation. However, when the priority is economic loss, a more important factor is the percentage of the building that is damaged, as opposed to the height of the building (Kappes et al., 2012). Barnett et al. (2008, p. 104) state “Determining what is an unacceptable loss is an inherently subjective process, as it is about determining what matters to an exposed group”.

- **Conflicting risk reduction:** Reducing risk for one type of hazard may increase risk for another type of hazard. For example, structures made of wood reduce the risk for earthquake, but increase the risk for hurricane (Kappes et al., 2012).

- **Multiple hazard events:** The effect of multiple hazard events creates an exponential number of factors that may not be measureable. For example, an earthquake of a given magnitude may stress a given building to a degree that researchers deem acceptable. However, if the earthquake happens near the time of a heavy snowfall, the extra pressure on the roof of the building may cause it to collapse (Kappes et al., 2012).

- **Composite indexes:** A composite index by its nature averages out vulnerabilities for a given area and may mask one critical vulnerability (Rygel et al., 2005). For example, an area where residents have high income and good infrastructure may be vulnerable because many residents are seniors who are not mobile in the event of an earthquake.

- **Surrounding environments:** The effect of surrounding environments on structures such as buildings and bridges is not accounted for in assessing the vulnerability of these structures (Kappes et al., 2012). For example, a forest may serve as protection for a building that is deemed to be vulnerable (Holub and Fuchs, 2009), while land cover in general in general mitigates the effect of landslide (Meusburger and Alewell, 2008).

- **Scale:** What is valued may depend on the size of the study region (Barnet et al., 2008). For example, effect on the military in the event of disaster would be a concern of the national government, not the municipal government.

Researchers into social vulnerability have developed many indexes in recent years. Paris and Kates found over 500 attempts to develop indicators of environmental change (Parris and Kates, 2003). As the number and influence of these indexes has grown, other researchers have examined the indexes themselves. Barnett et al. examined the Environmental Vulnerability Index, which incorporates data from 243 nations worldwide. They found (2008, p. 105) that “constructing a country-scale index to appeal to national decision makers and to facilitate intercountry comparisons creates levels of abstraction that dilute the meaningfulness of the index as a reflection of reality”. Rather, they state that (p. 105) “a place-based approach delivers a more accurate assessment of vulnerability than approaches that aggregate, and therefore homogenize, places for the purposes of comparison”.

Yoon examined vulnerability literature and found that researchers have used two main methods to assess social vulnerability: (1) a deductive approach based on the researcher’s understanding of significant variables and (2) an inductive approach based on statistical relationships (Yoon, 2012). The deductive method proceeds from known facts while the inductive method uses probabilities computed from statistical algorithms. SoVI is an example the inductive approach because it uses Principal

Component Analysis to reduce the number of variables, rather than use variables that the researcher deems most significant.

Yoon found that there is no significant difference in quality between deductive and inductive methods, but that (2012, p. 840) "the outcomes of a social vulnerability assessment are mainly decided by the selected variable regardless of assessment techniques". Thus emergency management is best done at the local level where analysts can utilize knowledge of their communities to assess vulnerability and prepare for disaster. Yoon's findings are in agreement with the findings of Barnet et al., cited above.

Aims and Objectives

Defining social vulnerability is a process that benefits from local input and suffers when evaluated with a globally standardized index. The author therefore suggests a new approach. The aim of this thesis is to test the hypothesis that a more adequate assessment of vulnerability can be obtained by examining individual demographics in a given geographic location, rather than by applying vulnerability indexes. The objectives of this thesis are to:

- Develop an interactive tool that a group of planners can use to search their region of interest by numerous criteria to answer questions about specific vulnerabilities in their community
- Assess results of the use of the tool
- Perform Principal Component Analysis on the census data as a parallel process
- Compare the usefulness of Principal Component Analysis with the usefulness of the interactive tool

Evaluation of the hypothesis is by these measures:

- Does the tool highlight geographic areas of the region of interest that have not received emergency planning services commensurate to the region of interest as a whole?
- Does the tool make the demographics more granular, such that new areas of vulnerability become apparent?
- Does combining vulnerability totals aid in assessing overall vulnerability?
- Are initiatives by the planners for the coming year markedly different in location and theme from previous years?
- Are there new initiatives created by the stimulus of the tool?
- How many initiatives are created based on identification of patterns through a vulnerability index as opposed to initiatives created through the tool?

Genesis of the Study

The motivation for this study flowed from the requirement of a Master's thesis in the Geographic Information Science and Systems (UNIGIS MSc) program with University of Salzburg. Because the author is an employee in the GIS department with City of Vancouver, he began by asking colleagues for potential ideas for such a thesis.

In the summer of 2012 the author met with the Director of the Office of Emergency Management with City of Vancouver. The director expressed the wish that they would be able to examine the demographics of the city more closely. Gradually the idea of an interactive web map was formed. This map would allow planners to investigate particular areas for particular vulnerabilities and then plan emergency preparedness seminars, generate training materials, and solicit volunteers accordingly. The planners were especially interested in having the visual feedback that a map provides.

Fortuitously at this time, Statistics Canada began release of the results of the 2011 census. The census results contain data on 1,432 demographic “characteristics”[1] of Canadians. This is the first census since 2006, so it was timely to use this dataset for the project.

The map provided the “tool” for the project, but not the question or hypothesis for the thesis itself. However, as the author began to research the subject of vulnerability assessment by reading studies that other researchers had done, questions began to arise as to the suitability of SoVI and other vulnerability indexes for the purpose of helping planners in the City of Vancouver.

Particularly striking were the demographics for City of Vancouver in the area of language. The 2011 census reports that 31% of Vancouver residents do not speak English in the home. The standard deviation of this statistic is 33.06. The SoVI method divides vulnerability into categories based on the standard deviation to the mean (Figure 1).

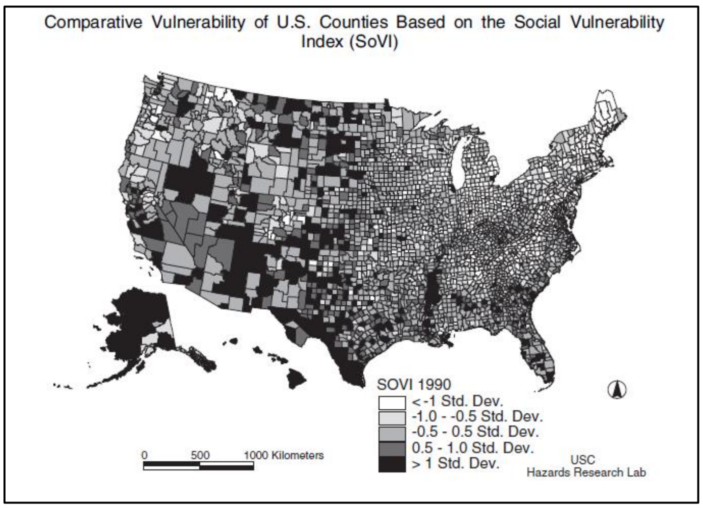


Figure 1: SoVI classification based on standard deviation

(Cutter et al., 2003)

Based on this classification, census tracts in City of Vancouver would not enter the most vulnerable classification until the average exceeded 64.06%. It seems obvious, however, that even an average of 31% should be of concern to planners.

Thus the hypothesis of this study came as a quest to find an alternative to vulnerability indexes.

Methodology

Based on discussions with members of the Office of Emergency Management (OEM) at City of Vancouver the author developed a web map application using Google Maps. Over a period of months in the summer and fall of 2013 the author met with planners at the OEM, took their feedback, and modified the web map accordingly. After several months of use, further meetings with the planners served to assess their usage of the map.

[1] Technically Statistics Canada released two census reports, the 2011 Census and the 2011 National Household Survey. However, the author was able to combine both of these reports into one database for the purpose of this thesis.

A statistical index using Principal Component Analysis (PCA) on the 2011 census data was also generated and made available to planners at City of Vancouver. The final part of the study was a comparison between the usage of PCA and the web map to draw conclusions about the usefulness of the web map.

Scenario: Earthquake in Vancouver

This section describes an imaginary scenario of an earthquake in City of Vancouver, and its effects on four residents. Although they all live in the same building and suffer the loss of their possessions and dwelling places, their ability to cope is markedly different from each other.

On _______, 20__ an M7.3 rupture occurs along an E-W trending shallow crustal fault in the Strait of Georgia, a body of water between Vancouver Island and the mainland cost of British Columbia [2]. The earthquake causes major damage to Vancouver and surrounding municipalities, but we will focus on one small apartment building at ____Pacific Blvd in Vancouver.

This building sustains damage similar to other buildings but assessment by City engineers determines that the building is habitable. However, the building must undergo certain repairs to its structure, which in the aftermath of the earthquake may take up to six months to take place. Until then all residents must not enter the building and must live elsewhere.

Consider the four residents of this building:

John is a computer programmer in the gaming industry. As with the other residents, John had to leave his belongings behind. However, John earns a good salary and has been able to find an apartment in Mission, some 80 kilometers away.

Although John's laptop is back in his residence on Pacific, he previously had the data from his laptop backed up in Internet storage. After the earthquake he purchased a new laptop and quickly retrieved his data. The company that John worked for also had their data backed up and were able to quickly get back online. John is able to continue working at his job by connecting remotely to his network at work. The earthquake was a disaster for others, but for John it has been an inconvenience.

Montana is a First Nations woman who works in an office building in the Downtown Eastside, which due to its aging infrastructure has been hit particularly hard by the earthquake. Her employer has informed her that their systems will out of operation for up to a month, and until that time there is no employment for her.

Montana is a member of Lil'wat First Nations people group in Mount Currie, 150 km to the northwest of Vancouver, and out of the earthquake zone. Montana went back to Mount Currie after the earthquake and plans to remain there until her employer calls her to come back to work. Montana did not really like living in the city, and she may stay in Mount Currie, where she can work in the Band office.

Peter is a retired teacher. The government has set him up in temporary quarters in a small housekeeping unit which he shares with three other retirees. Peter regrets the loss of his apartment, but his days are busy helping his children and grandchildren get back on their feet.

[2] Specifications for this scenario come from dirplan.com, 2013.

Maria is a refugee from Columbia. She arrived in Vancouver the previous fall with her five children. Her husband had been killed by the FARC in their ongoing battle with the Republic of Columbia.

Maria had hoped for a new life in Canada. Her children have been going to school in the West End elementary school, learning English and adapting to their environment, but that school was an old structure made of brick and completely collapsed in the earthquake. Now Maria finds herself housed in temporary shelters in the local hockey rink. Her children are a particular concern to her as they are naturally energetic and go into areas outside of the hockey rink which are not safe.

Maria does not speak English but she had a support group when she arrived in Vancouver to help her. However, she does not know where any of her support group is right now. She cannot understand when the government officials come to her in the hockey rink and give her instructions or tell her news. Maria does not know what to do.

City of Vancouver

Topography

Vancouver, British Columbia, Canada is certainly a blessed city. Flanked by water on three sides that form a natural harbour, and with mountains to the north, it is regarded as one of the jewels of earth settlements (Figure 2).

Figure 2: City of Vancouver

Yet the topology of Vancouver that makes it so attractive also makes it vulnerable to the natural disasters of earthquake and flood. The North Shore Mountains that provide Vancouver with its scenic view are evidence of past geological activity.

Only a few kilometers to the west, numerous tectonic plates of various sizes meet (Figure 3). These include:

- Pacific Plate
- North American Plate
- Juan de Fuca Plate
- Explorer Plate
- Gorda Plate

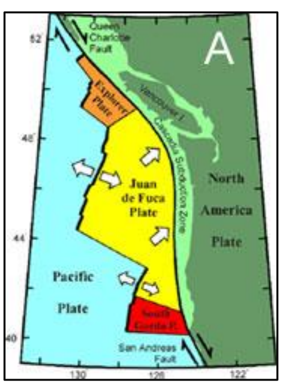


Figure 3: Tectonic plates near Vancouver

(ubc.ca, year unknown)

These plates are constantly in motion, and as they interact with each other, earthquakes happen. The last major earthquake in the Vancouver area occurred on January 26, 1700, with the recurrence rate of such earthquakes being roughly every 500 years (Pipkin et al., 2010, p. 111).

There are three types of earthquakes to which Vancouver is susceptible (Natural Resources Canada, 2011) (Table 2):

Table 2: Earthquake types to which Vancouver is susceptible

Earthquake Type	Earthquake Action	Example	Expected frequency
Megathrust (a.k.a. Subduction)	Oceanic plate slips under North American plate	• 1700 Cascadia earthquake • 2004 Indian Ocean tsunami	300 - 800 years?
Intraplate (a.k.a. - Intraslab - Deep)	Fault in subducting Juan de Fuca plate ruptures	• 1949 Olympia earthquake • 2001 Nisqually (Washington) earthquake	30 years?
Crustal	Fault in North American plate ruptures	• 1946 Vancouver Island earth-quake • Great Hanshin earthquake (Japan, 1995)	100s of years?

(Pacific Northwest Seismic Network, 2011)

Vancouver is also vulnerable to flood. The Fraser River forms the southern boundary of the city, while the Strait of Juan de Fuca, with waters from the Pacific Ocean defines the border to the west. To the north, the natural harbour formed by Burrard Inlet forms the shoreline. Vancouver also possesses the inlet of False Creek, which earlier civic governments dredged to make even larger. This soil is particularly vulnerable to flood and earthquake.

While none of these areas is subject to regular flood, recent flood disasters in the Canadian cities of Calgary and Toronto (Wikipedia, 2013; Ctvnews.ca, 2013) raise concerns that the conjunction of multiple environmental conditions such as high tide, melting snowpack, and severe storm could cause a flood event.

Office of Emergency Management

Recognizing the potential for these and other disasters, the City of Vancouver established the Office of Emergency Management in 1994 to assess the City's vulnerability and to take steps to mitigate the effects of these events should they happen.

An important task of this committee is to provide seminars and training materials throughout the city in order to help residents prepare for earthquake. But a "one size fits all" seminar does not recognize the diversity of social conditions which exist within the City, and may not provide the best preparation when the actual earthquake happens. The challenge that Vancouver and all cities face is to find the vulnerabilities that a particular resident or group of residents possess, and to tailor earthquake preparations for them.

Demographics

Vancouver is a city of some 600,000 residents (Table 3), set in a greater metropolitan area of some 2.3 million people. The most striking feature of its demographics is the high level of non-English speakers. This is a result of decades of high immigration from the Pacific Rim countries. Vancouver hosted the Expo '86 world's fair in 1986 and this fair is generally credited with raising the profile of the city as a desirable destination for tourism and immigration. Immigration has continued at a high level since this time.

Table 3: Vancouver demographics

Demographic	Value
Population	603,502
Percent that do not speak English in the home	31%
Average annual income per household	$68,970
Percent with high school or less education	34%
Average age	40
Percentage 65 years or older	13.42%

(Statcan.gc.ca, 2013)

Another figure of note in Vancouver demographics is the age of the population. As with many countries in the West, the percentage of population 65 years and older in Canada is growing (vancouversun.com, 2012). In Vancouver this figure grew from 12.8% in 2006 to 13.42% in 2011 (statcan.gc.ca, 2006) (statcan.gc.ca, 2011). Evans et al. conclude that there will be minimum economic impact from population aging (Evans et al., 2001). However, governments should be concerned about the mobility of seniors in the event of an earthquake.

Principal Component Analysis

Introduction

Principal Component Analysis (PCA) is a methodology for revealing patterns between *indicators* in a given area of study. An indicator is simply a measure of vulnerability in some category. For the study of vulnerability to earthquake in the City of Vancouver, those indicators include such categories as:

- Social dependence
- Education – high school or less
- Family - single parent

As the name suggests, PCA finds the "principal" or important patterns in a group of indicators in a way that filters out unimportant patterns, thus making the important indicators stand out. By seeing these patterns, planners can then take action to address vulnerability.

Note: For the purposes of clarity, the author uses "indicator" rather than "variable" in this section. A "variable" is a broad term; an " indicator" clearly refers to a measure of vulnerability.

Testing PCA Methods

Because of the complexity of PCA, two methods were tested on a dataset with known PCA outcomes. The dataset is the pca_riskprep.xlsx dataset that resides on riskprep.com, as shown (Table 4).

Table 4: pca_riskprep.xslx, Observations tab

symbol	quantity	entry_ price	profit_ dollar	market_cap	cash_and_ marketable	tev	revenues	ebitda
HIT	77	62.66	-121.14	28052.72	7069.036	49917.77	25579.99	616.1314
BKD	185	26.97	75.3	3380.167	163.385	5787.078	497.946	79.928
CGV	132	37.65	-200.67	5596.635	450.6266	7139.015	836.5909	215.5657
SHS	125	39.88	410.8	1916.967	44.039	2154.414	349.695	15.262
CVI	244	20.5	-225.11	1783.58	200.049	2060.499	609.395	112.05
OVTI	149	33.4	-273.17	1902.366	498.895	1450.367	89.056	-14.463
GLF	109	45.6	96.69	1193.216	97.195	1422.449	108.795	55.535
WLL	73	67.7	-127.67	8006.025	18.952	8787.073	146.175	54.089
JOYG	53	95.42	-176.49	10198.91	819.546	9780.362	923.5	200.883
GSM	213	23.55	-291.24	1714.359	159.314	1605.159	76.146	7.313
DEP	124	41	-207.59	2341.151	32.4	3097.051	256.8	59.8
EXEL	434	11.44	-77.39	1264.452	162.664	1310.246	25.302	-31.691
GPOR	174	29	-441.21	1268.823	2.468	1318.272	17.784	9.634
MENT	323	15.78	-88.7	1722.135	133.113	1813.914	193.775	15.984
HS	131	36	254.05	2126.013	191.459	2561.429	646.115	44.265
TBL	134	35.7	407.45	1837.263	272.221	1565.042	296.648	26.145
FTO	177	28.58	-500.01	2852.157	559.836	2643.032	846.248	138.054
WTW	76	64.63	-362.87	4748.507	40.534	6073.058	390.578	103.724

SIRI	2762	1.83	-90.81	7099.417	586.691	10509.39	586.979	197.11
HUGH	83	59.52	10.31	1307.249	182.663	1871.447	240.215	31.156
ALU	1020	4.9	420.45	11323.52	7632.078	10906.3	4641.564	-92.8829
SATS	154	32.46	604.97	2708.643	1130.9	1990.628	479.547	61.949
GMCR	107	45.7	-228.37	6162.526	62.924	7184.619	193.351	28.164
ILMN	67	73.36	-513.8	9100.603	894.289	8517.923	165.757	41.782
IPGP	107	46.55	678.99	2527.985	147.86	2403.943	45.408	7.92

Methods

Method 1 uses the R stats program with these commands, where "pca.dat" represents a tab-delimited text file with the riskprep data in it:

```
# Load the data table in a variable named, aptly, "pca"
pca = read.table("C:/pca.dat",header=TRUE)
# Get the eigenvectors through the prcomp command and load the
# result into a property of pca named, aptly, "eigen"
pca.eigen <- prcomp(pca,retx=TRUE,center=TRUE,scale=TRUE)
# Display the eigenvalues by calculating the squares of the
# standard deviations of the eigenvectors
pca.eigen$sdev^2
```

(stat.ethz.ch, year unknown)

Method 2 uses the numpy module of Python to perform the same calculations.

In both cases, the results matched those in riskprep.com, as shown (Table 5):

Table 5: Eigenvalues and eigenvectors (6 of 8 shown)

Eigen values	4.288071989	1.682677382	1.046190039	0.500233929	0.386802101	0.062075122
	eigen vector1	eigen vector2	eigen vector3	eigen vector4	eigen vector5	eigen vector6
quantity	-0.020695347	0.606421829	-0.442574179	-0.510522766	0.329251973	-0.03033947
entry_ price	-0.148218822	-0.639115342	0.166868909	-0.417522599	0.504133152	0.085254342
profit_ dollar	0.044127233	0.335816835	0.81688388	-0.437841975	-0.140552152	-0.026111626
market_ cap	-0.470311178	0.004576786	-0.009461521	-0.032508464	0.301493691	-0.217037263
cash_ and_ market able	-0.374559442	0.307944214	0.233026777	0.449996406	0.397788441	0.553461492
tev	-0.478739006	0.011219048	-0.030335725	-0.04468646	-0.044268241	-0.4563879

revenues	-0.463084667	0.04846046	0.087859772	0.164494006	-0.305475649	-0.302300733
ebitda	-0.412952595	-0.116988581	-0.214366497	-0.375136064	-0.522760803	0.581402573

Principal Component Analysis for Vancouver Census Statistics

As part of this project PCA was performed using data drawn from the Statistics Canada 2011 census. The census has 1,432 “characteristics” for each tract. A characteristic is a single fact about the population, for example:

- Detailed other language spoken regularly at home, Serbian
- Detailed other language spoken regularly at home, Serbo-Croatian

The immediate purpose of doing PCA on the census was to give planners at City of Vancouver another tool in order to evaluate vulnerability. However, creation of PCA also allows a comparison of usage between PCA and the web map.

Selection of Indicators

From the plethora of characteristics provided by the census, the following 13 vulnerability indicators were constructed:

- Population - 65 years and older
- Family - Single parent
- Income - Low
- Education - High school or less
- Unemployment
- Renter
- English - Not spoken in the home
- Occupation - Arts or service
- Social dependence
- Population growth
- Family - Average size
- Population - 14 years and under
- Aboriginal identity

Vulnerability Indicators Chosen

Indicators were chosen based on work that other researchers have done in the past decades. This section explains the reasoning behind the selection of each indicator.

Population - 65 years and older

The elderly have special challenges in the event of disaster (Dwyer et al., 2004; Cutter et al., 2003; Rygel et al., 2006). Older residents are less likely to have the physical or economic resources necessary to prepare for or recover from disaster (Morrow, 1999). They may also have health-related repercussions from disaster that limit their ability to recover (Rygel et al., 2006).

Indicator

To measure this indicator, **Total population by age groups** was summed where population was 65 and older, and then divided by **Population in 2011**.

Family - Single parent

Single parent families are likely to be living on the economic margin during normal times (Morrow, 1999; Cutter et al., 2003). When disaster strikes the additional demands on a single income may slow recovery (Fox, 2008).

Indicator

To measure this indicator, **Total lone-parent families by sex of parent and number of children** was divided by **Total number of census families in private households**.

Income - Low

Income is a major factor in determining vulnerability (Dwyer et al., 2004; Rygel et al., 2006; Fox, 2008). Poor residents have limited finances with which to buy supplies or prepare dwellings ahead of disaster or to replace and repair these resources after a disaster (Morrow, 1999). The poor also typically live in poorly constructed dwellings that sustain more damage in a disaster than more expensive dwellings (Morrow, 1999). For example, only 9 of 6,600 mobile homes survived in the area where Hurricane Andrew hit in August 1992 (Metro Dade Planning Department, 1992).

Indicator

To measure this indicator, **Prevalence of low income in 2010 based on after-tax low-income measure** was used.

Education - High school or less

Those with lower education have fewer finances to deal with disaster, as well as less understanding of government initiatives to prepare for disaster (Cutter et al., 2003).

Indicator

To measure this indicator, the percentage of those with post-secondary education over the total population was calculated, and then that percentage was subtracted from the number 1. This gives the percentage of the population that do NOT have post-secondary education. The calculation is thus:

1 - (**Postsecondary certificate; diploma or degree** / **Total population aged 25 to 64 years by highest certificate; diploma or degree**).

Unemployment

Employment both before and after a disaster play an important role in limiting vulnerability (Dwyer et al., 2004; Cutter et al., 2003; Fox, 2008). Those who are employed can afford to prepare for disaster and can recover more readily post-disaster than those who are unemployed.

Indicator

To measure this indicator, **Unemployment rate** was used.

Renter

Those who rent their homes are vulnerable because of the transient nature of their residency (Dwyer et al., 2004; Cutter et al., 2003). Renters have little say over the condition of their dwelling places and often cannot prepare for disaster or make repairs after disaster to their homes (Morrow, 1999). For example, none of the public housing units in the path of Hurricane Andrew had window protection infrastructure, with the result that thousands of families had to be sheltered in tent cities following the event (Morrow, 1999).

Indicator

To measure this indicator, **Renter** was divided by **Total number of private households by tenure**.

English - Not spoken in the home

Those with limited English skills are vulnerable in the immediate aftermath of a disaster (Dwyer et al., 2004; Cutter et al., 2003; Rygel et al., 2006). They may not be able to understand government directives in a rapidly-changing situation. As well, prior to a disaster they may not understand the need to make preparations for disaster. Even filling out applications forms can be a challenge for those without proficiency in English (Morrow, 1999). As well, newcomers may be reluctant to trust authorities due to abuse by authority in their native land (Morrow, 1999).

Indicator

The census has several characteristics that could be used to measure vulnerability because of language, including:

- Detailed mother tongue
- Knowledge of official languages
- Detailed language spoken most often at home

The author chose the latter characteristic based on the assumption that if people do not speak English at home, they will have trouble communicating in the event of a disaster. The percentage of citizens that DO speak English at home was then calculated and then that number was subtracted by 1 to obtain the percentage of citizens that do NOT speak English at home. The calculation is thus:

1 - (**Detailed language spoken most often at home, English** / **Total population**)

Occupation - Arts or service

The type of occupation that a person has can affect their ability to recover. Low paying jobs such as found in the arts or service sectors are more likely to be lost because those who normally use these services have to use their disposal income to repair and replace their possessions (Fox, 2008). Also, businesses in the service sector such as restaurants may simply cease to exist after disaster, or move elsewhere (Morrow, 1999).

Indicator

To measure this indicator, **Occupations in art, culture, recreation and sport** and **Sales and service occupations** were summed, and then divided by **Total labour force population aged 15 years and over by occupation**.

Social dependence

In the event of disaster, most residents need additional income to replace and repair. Those dependent on social services do not have this additional income and may not receive this income post-disaster as governments spread out their resources to benefit all of society (Morrow, 1999; Cutter et al., 2003).

Indicator

To measure this indicator, **Percentage of government transfer payments per tract** was used.

Population growth

Fast-growing communities with many new residents are more likely to contain isolated individuals or families who cannot rely on local networks for assistance after a disaster (Morrow, 1999). As well, areas experiencing rapid growth may lack quality housing, sufficient infrastructure, or social services (Cutter et al., 2003; Fox, 2008).

Indicator

To measure this indicator, **Population in 2006** was divided by **Population in 2011**.

Family - Average size

Families with large numbers often have limited finances to prepare for disaster or repair after disaster (Cutter et al., 2003). Larger families may also include the young and elderly, thus increasing vulnerability (Morrow, 1999).

Indicator

To measure this indicator, **Average number of persons per census family** was used.

Population - 14 years and under

Children need special services following a disaster (Dwyer et al., 2004; Cutter et al., 2003; Rygel et al., 2006). For example, in the immediate aftermath of Hurricane Andrew, many mothers had to scramble to obtain baby food, napkins and other necessities needed for infants, and children had to wait in long lineups with their parents, unable to play, or forced to play in areas that were not safe (Morrow, 1999).

Indicator

To measure this indicator, **Percent of the population aged 15 and over** was subtracted from 100.

Aboriginal identity

In general there is a reluctance of ethnic groups to reach out to the larger community for assistance in the event of disaster (Morrow, 1999). Aboriginal residents in particular may not trust government because of past trauma (Government of Western Australia, 2013). Therefore they may not take advantage of government resources such as seminars in order to prepare for disaster or to seek assistance following disaster.

Indicator

To measure this indicator, **Aboriginal identity** was divided by **Total population in private households by Aboriginal identity**.

Vulnerability Indicators Not Chosen

There were two important indicators that the author chose not to include in PCA.

Female - Low income

Many researchers acknowledge that females are more likely to hold low-paying jobs or are part of the underground economy, and that these jobs often disappear after disaster (Morrow, 1999; Rygel et al., 2006; Fox, 2008). They also may have extra responsibilities to family (Cutter et al., 2003). All of these factors increase females' vulnerability to disaster.

However, it is a challenge to identify those females who are vulnerable through the data provided by Statistics Canada. Fox argues that using the percentage of females in a census tract is not an appropriate indicator because all females are not vulnerable; rather, some females are vulnerable because their roles in society sometimes place them in positions where their vulnerability increases (Fox, 2008).

A key indicator of this vulnerability, Fox argues, is low income. The calculation for this indicator is thus the number of females in a tract that are 19 and older who are earning less than $20,000 per year divided by the total number of females in the tract (Fox, 2008).

However, this calculation does not account for females that have financial support through marriage or a common-law relationship, or through other funds such as pension, government transfer payments, family support, etc. Using Fox's calculation, the average of females in Vancouver who have this vulnerability (**Female - Low income**) would be 40.4%.

Looking at census tract 9330024.00 in on the west side of Vancouver, we see that the percentage of **Income - Low** is 12.7%, 8 points less than the city average of 20.9% (Figure 4). This 20.9% figure represents income of all residents in Vancouver. The 8 point difference thus indicates that this tract is relatively affluent.

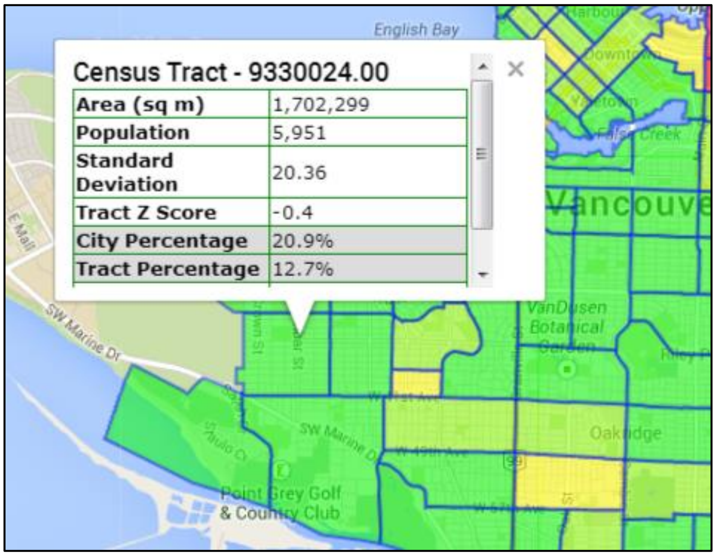


Figure 4: Census tract 9330024.00 has 12.7% Income - Low

However, the percentage of **Female - Low income** using Fox's calculation in the same tract is 39.05% (Figure 5). This high percentage in an affluent neighbourhood raises questions about the validity of the calculation.

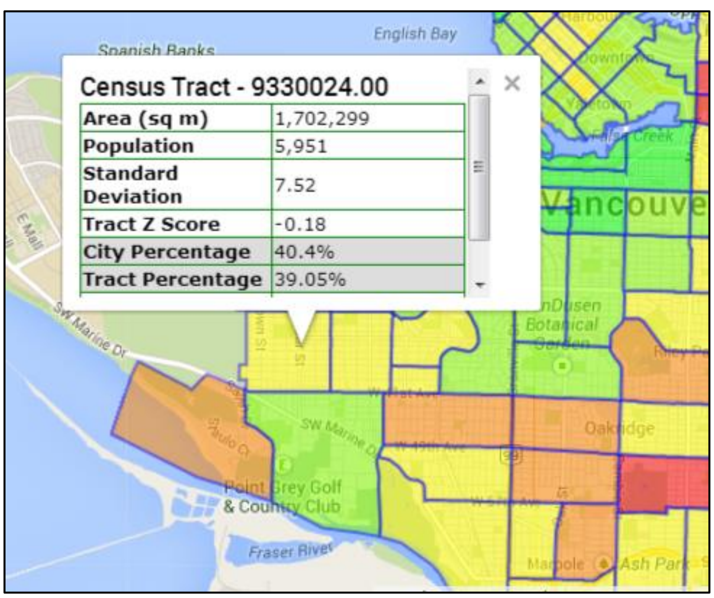


Figure 5: Census tract 9330024.00 has Female - Low income of 39.05%

We also note that the standard deviation for **Income - Low** is much higher than for **Female - Low income**, 20.36% as compared to 7.52% city-wide. The larger deviation makes sense in terms of representing the disparity of incomes throughout the city. The smaller deviation for **Female - Low**

income suggests that the calculation is a broad generalization that does not take into account the factors that reduce female vulnerability as noted above.

Because of concerns about the validity of the calculation, the author has omitted this indicator from the PCA calculation. There is certainly a segment of females that are vulnerable in the way described above, but the data does not support identification of this segment.

Building Construction

There is concern in Vancouver as in many cities about the ability of older buildings made of unreinforced masonry, concrete and other obsolete materials to withstand ground motion. Residents in these types of buildings are certainly vulnerable to earthquake.

The city is now employing HAZUS, a program that FEMA developed, to identify areas of the city that would be vulnerable to disasters such as earthquake and flood. However, there are currently no outputs from HAZUS and there is no guarantee that such outputs would be made publically available when they do exist. For this reason, the author has excluded any indicator representing building construction in this analysis.

Planning Progress

High population growth is often flagged as a vulnerability indicator by researchers making vulnerability indexes. At first glance, three tracts in the Downtown South area would seem to be perfect candidates. Their population growth from 2006 to 2011 is 36%, 44%, and 96% (Figure 6).

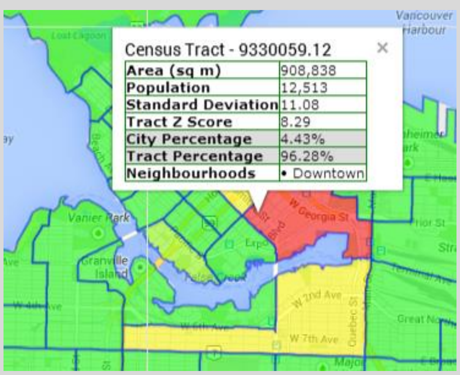


Figure 6: Three tracts with high population growth (red and yellow)

Population grew in these tracts because of changes in zoning that allowed construction of multi-unit dwellings that in some cases were previously industrial and had low population. However, these dwellings and infrastructure were developed using the latest technologies by planners who have studied the latest methodologies for their field.

To get a perspective from someone who was involved with the planning of these areas, the author contacted a senior planner with City of Vancouver. His comments are instructive:

"*I'd note the following:*

1. *Almost all of the new housing in Downtown South has been built under the seismic codes put in place after the SFO 1989 earthquake so I do not believe Dr. Morrow's assertion would apply to Downtown South as having housing that is not of good quality. The West End which is a low growth area has*

older housing and the towers were not built to the seismic codes of today (and therefore would be more vulnerable).

2. *There is a high concentration of publicly owned buildings and services in the downtown peninsula.*
3. *I cannot gauge the 'informal networks' as my experience living in Downtown South was that I was highly 'networked'… not clear how others were as I have not studied it. Interesting to note that the strata (condo) buildings have strata councils so there is a level of government that would be in action after a disaster. My experience of living in a building that had a serious fire is that the strata council was immediately engaged and took care of things.*

So in conclusion…I think Dr. Morrow's assertion is not completely applicable to Downtown South as a high growth area. There are so many different types of high growth areas".

Planners who work at City of Vancouver come out of universities where the latest methodologies are taught and where new methodologies are developed, based on studies by Dr. Morrow and others. Much progress has been made by planners since Dr. Morrow did her study in 1999. Cities *are* learning to do things better.

The author kept the **Population growth** indicator despite it being not applicable to Downtown South. It gives planners an opportunity to find smaller areas where either social services or social networks have not kept pace with development.

Web site: vulnerablevancouver.ca

This section describes the interactive web map for this thesis, http://vulnerablevancouver.ca.

Architecture

One guiding principle of this web map is that the software should be Open Source or otherwise free. This is for two reasons:

- Others can recreate the architecture at minimal cost
- It is a test of whether Open Source software can match the best of proprietary software

The architecture of vulnerablevancouver.ca involves a web map, a client-side language, a server-side language, and a spatial database (Figure 7).

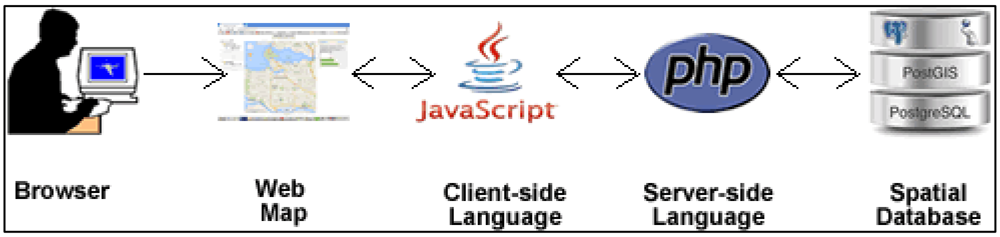


Figure 7: Architecture of vulnerablevancouver.ca

These roles are fulfilled by Google Maps, JavaScript, PHP, and a PostgreSQL database with the spatial extension PostGIS. Of all these software programs, only Google Maps does not qualify as Open Source. However, Google does allow up to 25,000 calls for the Google Maps API per day. This number far exceeds the expected demand for vulnerablevancouver.ca.

When the browser connects to vulnerablevancouver.ca, it receives a web page with a Google Map embedded in it. As the browser user searches the map using the tools on the right pane of the web page, JavaScript in the web page sends requests to server-side programs to fulfill the request.

The server-side programs are written in the PHP web language. PHP in turn formats the requests into SQL statements and fires them off to PostGIS. PostGIS is the spatial extension that sits on top of PostgreSQL. PHP receives the result set from the query to PostGIS, and formats it in the way that the JavaScript is expecting it, and sends it back to the browser. Sometimes this is a JSON-encoded string, and sometimes it is a dynamically-generated KML document. In either case, the JavaScript that made the request to the PHP program now renders the result onto the web page.

In the case of a KML file, the Google Maps API handles much of the formatting (Figure 8). In the figure below, the API has read a dynamically generated KML document and rendered the map with appropriate colours for each tract based on the request that the user made, which was for **Family - Single Parent**. However, the determination of which colour each tract gets was done in the PHP program, as was the table in the InfoWindow.

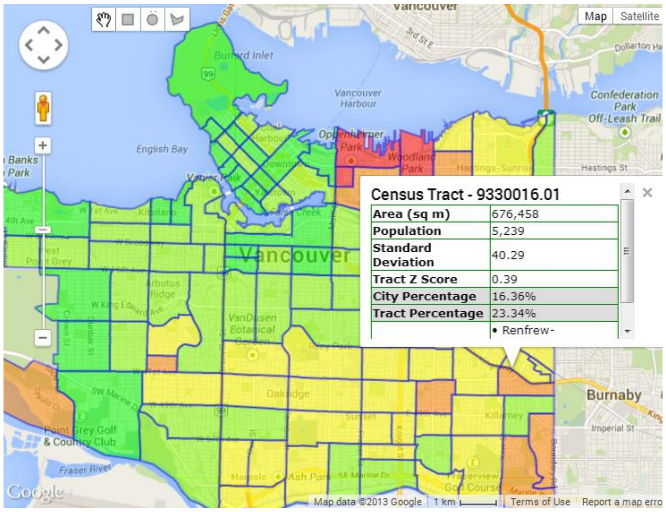


Figure 8: Result of user request for Family - Single Parent indicator

The following section discusses the various components of vulnerablevancouver.ca

Web Map

There are several choices for web map for this web site, including:

- Google Maps
- Bing Maps
- Yahoo! Maps
- OpenStreetMap

Google Maps was chosen because it has the richest API and because it is most familiar to users. According to one web statistics page, Google Maps currently has over 89% of maps on the World Wide Web (trends.builtwith.com, 2013).

Client-Side Language

JavaScript is the most widely-used client-side languages for web pages today (Figure 9).

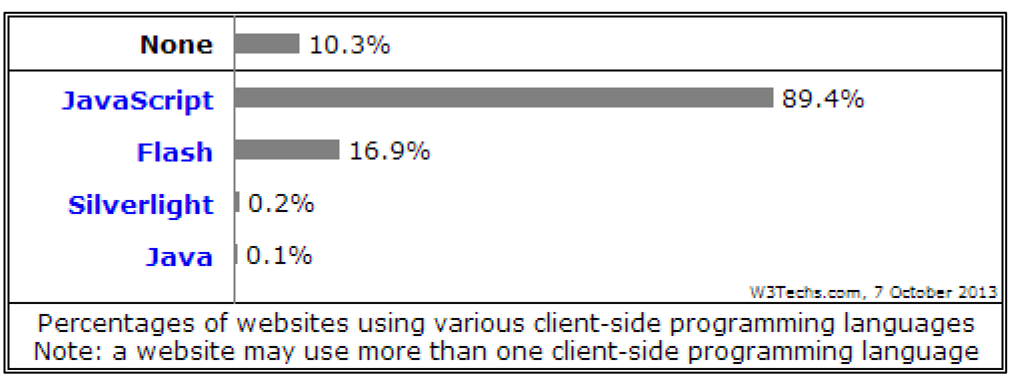


Figure 9: Client-side language usage for October 2013

(W3techs.com, 2013)

JavaScript allows interaction between the user and the web page without refreshing the page, and also allows for server-side interaction via AJAX. This last facility is critical for a web map application because it allows the user to zoom and pan to a given location, and then request more data from the server side without losing their settings.

The introduction of JavaScript frameworks in recent years makes JavaScript easier to use. Frameworks provide a simplified API that a developer can call, rather than having to write all code directly in JavaScript. The vulnerablevancouver.ca web site uses the following JavaScript APIs:

- Google Maps API
- jQuery library API
- Dynatree treeview control API

The following section discusses these APIs.

Google Maps API

Google developed the Google Maps API to allow user interaction with the map without having to refresh the web page. The API is implemented as an object-oriented architecture where each object has its own methods and properties. For example, the *map* object represents the map itself and has a method called *getCenter()* that returns the coordinates at the center of the map. Having an object-oriented architecture simplifies operations on the map for the developer.

jQuery Library API

The jQuery library creates the tabs in the right pane and the sliders in the Indicators tab (Figure 10), and the dialog box that appears when the user draws a shape on the map and then clicks the Draw Report button. The AJAX transactions also use jQuery, which simplifies the AJAX process.

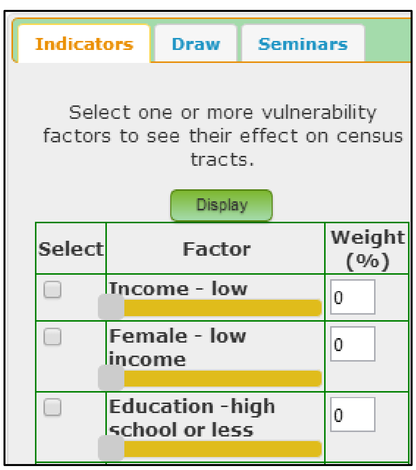


Figure 10: jQuery tabs and sliders

Dynatree Treeview Control API

The Dynatree control creates the layers panel on the left of the web page (Figure 11). Some of the layers are enabled when the web page loads because they are *static* layers, that is, they do not change based on the user's actions. Other layers are disabled when the web page loads because they *dynamic*, that is, they change according to the user's selections. It does not make sense to show these layers until the user makes their selections.

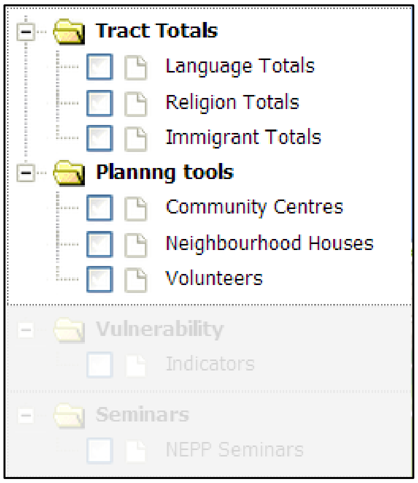


Figure 11: Dynatree control

Server-Side Language

The server-side language handles incoming requests from the web map for data, sends those requests to the spatial database, formats the results, and returns them to the web map.

There are several choices for server-side language, including:

- Asp.net
- PHP
- Python framework such as Django

The author chose PHP, a loosely-typed, simplified version of the C language with a vast array of functions and strong support from the Open Source community. PHP is highly regarded on the World Wide Web; a recent survey of server-side language usage shows that over 81% of web sites that use a server-side language prefer PHP, as opposed to 18% for asp.net (w3techs.com, 2013) (Figure 12).

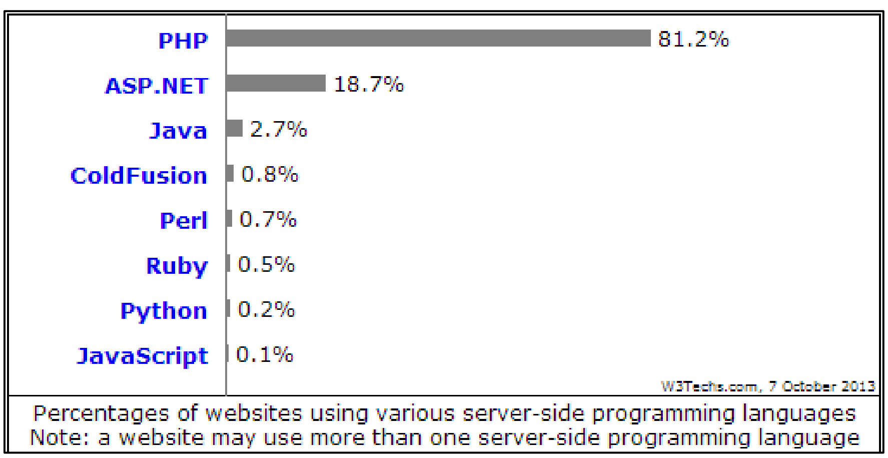


Figure 12: Server-side language usage for October 2013

(W3techs.com, 2013)

Spatial Database

The spatial database plays a critical role in a Google Maps application because the map does not store data, but rather presents data that the server-side program feeds to it. The spatial database must be capable of:

- Storing geographic data
- Performing spatial queries on the data
- Retrieving the data in a timely manner
- Returning the data in a format that the server-side program understands

There are several choices for Open Source or inexpensive spatial databases, including:

- Spatialite
- MySQL
- PostgreSQL with PostGIS extension

Spatialite is a spatial library that extends the file-based SQLite library. SQLite is referred to as a "light" database because it has a small footprint and does not need the complex maintenance of larger systems such as Oracle and SQL Server. However, SQLite is a fully functioning database and Spatialite provides complex spatial processing capabilities. Unfortunately, there is currently no PHP library for Spatialite.

MySQL is widely available, both through the free Community Edition, and also through many web hosting packages. It does have a spatial extension, but is limited in that it can only perform a bounding-box spatial query.

PostgreSQL began as a project at University of California, Berkeley in the 1980's and has since become an Open Source project with many contributors. Refractions Research added the PostGIS extension in 2001 to provide spatial functionality to the PostgreSQL core engine.

PostGIS outperformed Oracle in a recent study by the Indian Institute of Technology (cleverelephant.ca, 2012). It is also capable of performing spatial queries using irregular polygons and circles, unlike MySQL. Also, it has a large number of built-in tools that accelerate database operations. For example, the shp2pgsql and shp2pgsql-gui tools allow for direct import and export between ESRI shapefiles and a PostGIS database. See "Using PostGIS Built-In Tools" in the Appendix for examples of usage of PostGIS built-in tools.

For these reasons the author selected PostgreSQL with the PostGIS extension as the database for this application.

Data for vulnerablevancouver.ca

Sourcing the Data

Data for vulnerablevancouver.ca came from the following sources (Table 6):

Table 6: Data sources for vulnerablevancouver.ca

Data Type	Description	URL
Boundary files	Shapefile of polygons representing census tracts within Canada	http://www12.statcan.gc.ca/census-recensement/2011/geo/bound-limit/bound-limit-eng.cfm
Census profiles	Data on residents at census tract level including topics: • Population • Age • Single parent • Language	http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/index.cfm?Lang=E
National Household profiles	Data on residents at census tract level including topics: • Religion • Aboriginal population • Language • Education • Employment • Renter • Income	http://www12.statcan.gc.ca/nhs-enm/2011/dp-pd/prof/index.cfm?Lang=E
Open Data	Vancouver Open Data with shapefiles for city boundary and neighbourhoods	http://data.vancouver.ca/datacatalogue/index.htm

Getting the Data

Getting the 2011 census data and the National Household Survey (NHS) data from the Statistics Canada web site proved to be a challenge. The web site provides download of its census and NHS data, but for Greater Vancouver, not for Vancouver itself. The user must manually download each census tract for the city in a two-step process. However, an automated process using Python provided a programmatic solution to this problem. See "Using Python to Get Census Data from Statistics Canada" in the Appendix for details.

Processing the Data

QGIS, Python, and PostgreSQL were used to process the data.

QGIS

QGIS was used to derive the Vancouver polygons from the Canada-wide shapefile of census tracts that Statistics Canada provided. QGIS is an Open Source application that provides the much of the same functionality as ArcMap. See "Using QGIS for Spatial Operations" for more information on QGIS.

Python

Python is an Open Source program language that has simple syntax, powerful features, and a wealth of 3rd party modules. Python had several important roles in this project (Figure 13).

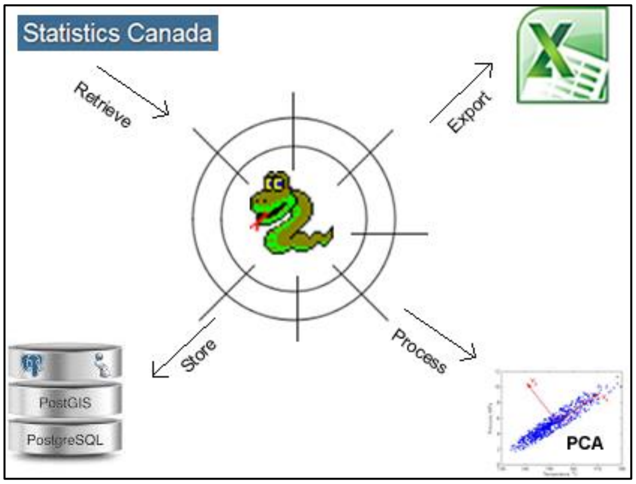


Figure 13: Python's roles in vulnerablevancouver.ca

The following table provides details on Python's roles and the modules that it provided for these roles (Table 7).

Table 7: Python's roles and modules provided

Role	Module
Retrieve census tract CSV files from Statistics Canada web site	requests/urllib
Store in Postgres and query database	psycopg2
Process census tract data into Principal Component Analysis (PCA)	numpy
Export PCA results to Excel	xlwt

Displaying the Data

"There are three types of lies:

- *Lies*
- *Damn lies*
- *Statistics"*

(Mark Twain, year unknown)

People do not fall neatly into categories of data. The researcher has to make choices about how to present a view of the data, inevitably at the cost of some other, equally valid view of the data. The view involves generating statistics on the data.

Vulnerability indexes such as SoVI generate statistics on vulnerability indexes by taking the mean of a sample, and then calculating the standard deviation of the mean (Cutter et al., 2003). If the value for a given tract is greater than one standard deviation, it is deemed significant.

This may work for some indicators, but for others it is not effective. For example, the city-wide figure for residents in Vancouver who do not speak English in the home is 31%. The standard deviation for this indicator is 33.06. This means that to be significant under the method above, a census tract would have to have an average of 64.06% to be deemed significant.

After consideration of these issues, the author decided to put both standard deviation and average percentage on the map, with the grouping on the average (Figure 14).

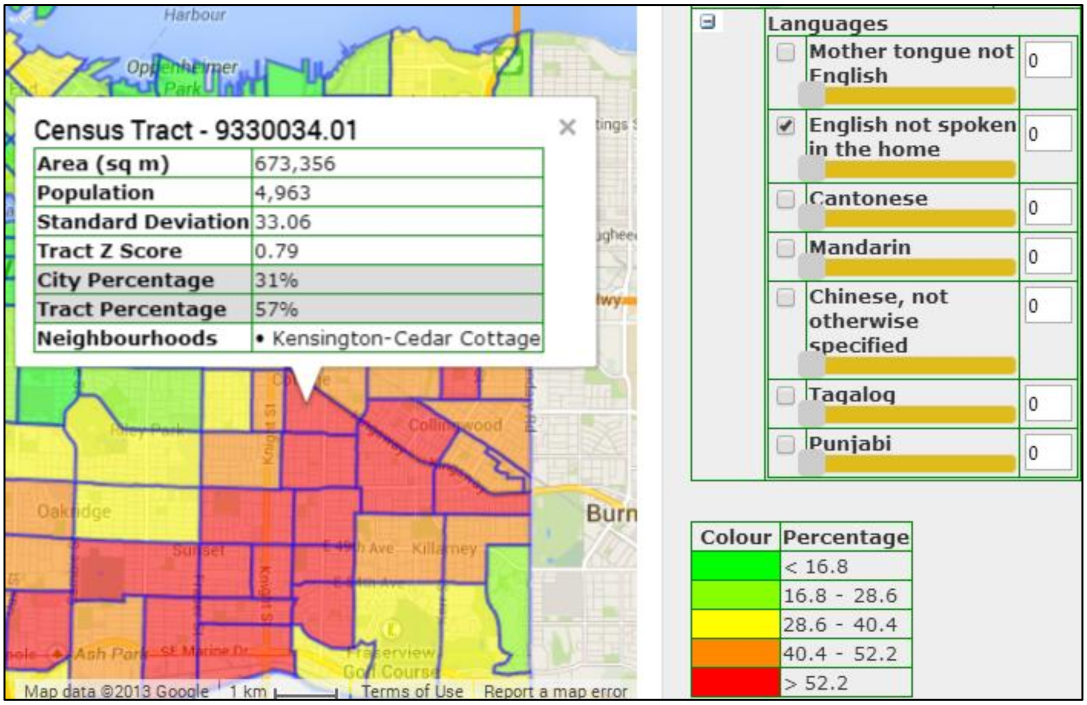


Figure 14: Indicator grouped by Tract Percentage

In contrast to the concept that a given standard deviation can be significant for all indicators, this method allows the planner to make decisions on each indicator in isolation. Thus for **English - not spoken in the home**, the planner may feel that the 31% citywide percentage by itself is significant, whereas for **Family - Single parent**, a tract figure of 22% may be significant (Figure 15).

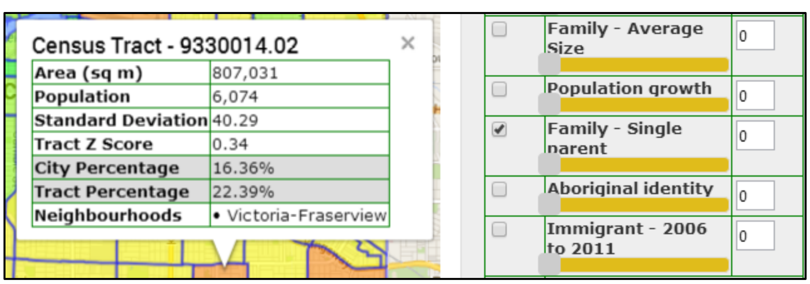


Figure 15: Family - Single Parent

There is also a decision to make on the *classification* method for the percentages. There are numerous ways to group data. The author took the lowest and highest values for a given indicator and divided them into five even groups.

This is the *equal interval* method. While it works adequately for some indicators, for other indicators it gives misleading results. For example, in the case of **Aboriginal identity**, it appears that only one census tract is significant (Figure 16).

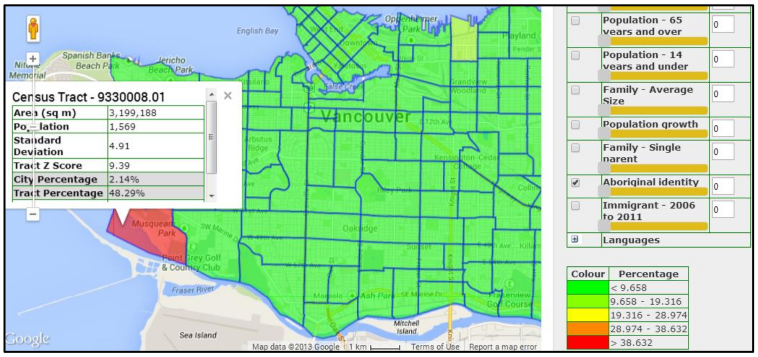


Figure 16: Aboriginal identity

However, this is because this tract encompasses the Musqueam Indian Reserve and has an anomalous figure of 48%, and there are no other census tracts that are over 20%. Other tracts that have relatively high percentages are masked by this percentage (Figure 17).

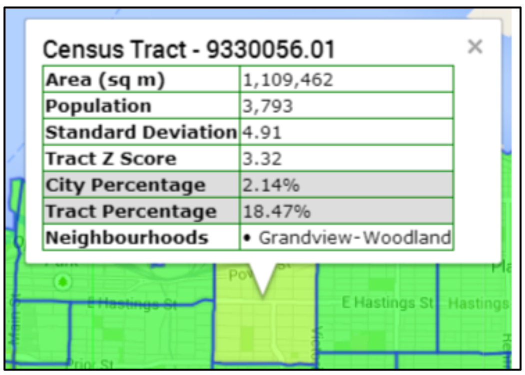


Figure 17: Census tract with Aboriginal identity of 18%

However, any other grouping method would also have drawbacks in certain indicators. For example, the *quantile* method makes an even number of tracts in each group. This method would always show the same number of census tracts as green, yellow, and red, thus homogenizing their differences. In the end, it is up to the planner to understand the statistics, and with a nod to Mark Twain, do their job the best they can.

Workflows

There are three workflows that the user goes through in vulnerablevancouver.ca:

- View Vulnerability Indicators
- View NEPP Seminars
- View Draw Report

The following section describes both the client actions and the server actions for these workflows.

View Vulnerability Indicators

Overview

A primary purpose of vulnerablevancouver.ca is to display vulnerability indicators on the map at the census tract level. The user can click on any census tract to view details of the indicator for the tract.

Client Actions

To view the distribution of a vulnerability indicator, the user clicks the **Indicators** tab, selects the given indicator, and then clicks **Display**. The map refreshes and shows the distribution of the selected indicator on the map (Figure 18).

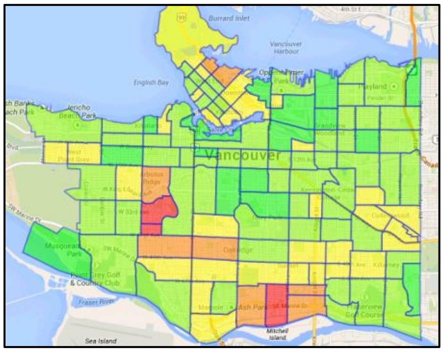


Figure 18: Immigrant - 2006 to 2011 layer

A table appears at the bottom of the right pane to explain the significance of the colours (Figure 19).

Colour	Percentage
	< 3.772
	3.772 - 7.544
	7.544 - 11.316
	11.316 - 15.088
	> 15.088

Figure 19: Table at bottom of right pane for Immigrant - 2006 to 2011 layer

Selecting a tract invokes a Google Maps InfoWindow (Figure 20).

Census Tract - 9330067.02

Area (sq m)	235,297
Population	4,501
Standard Deviation	3.18
Tract Z Score	1.53
City Percentage	7.15%
Tract Percentage	12.01%
Neighbourhoods	• Downtown • West End

Figure 20: InfoWindow for census tract for Immigrant - 2006 to 2011 layer

The InfoWindow contains attributes for the tract that the user may find useful in understanding the data.

Server Actions

When the user clicks **Display**, JavaScript in the web page determines the indicators that the user has checked and creates a URL with a custom query string. For example, the query string in this URL refers to the Renters layer with a weight of 1 and the **Social dependence** layer with a weight of 100:

```
http://vulnerablevancouver.ca/indicatorKML.php?rand=123&indicator=11xx1::16xx
100
```

The browser then creates a new KML layer with the URL as the source. The rand=123 parameter is necessary to prevent the KML from being cached along the route from the server (Google, 2008).

When the URL is called, PHP code breaks down the query string, generates a query to the PostgreSQL database, retrieves the results, and dynamically creates a KML layer based on the query string. Back on the client side, the browser renders the KML onto the map, not knowing that it was generated by a server side program.

In the case of the **Immigrant Totals** and **Language Totals** layers, the user can also select a layer from the Tract Totals folder in the layer controls pane (Figure 21).

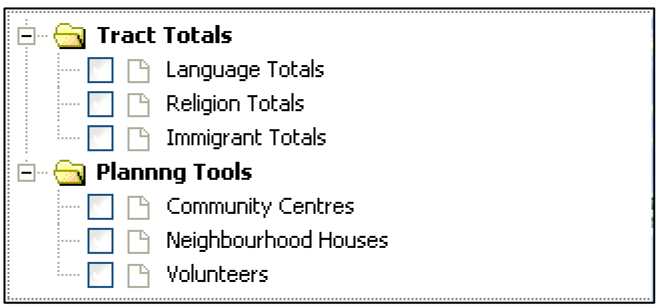
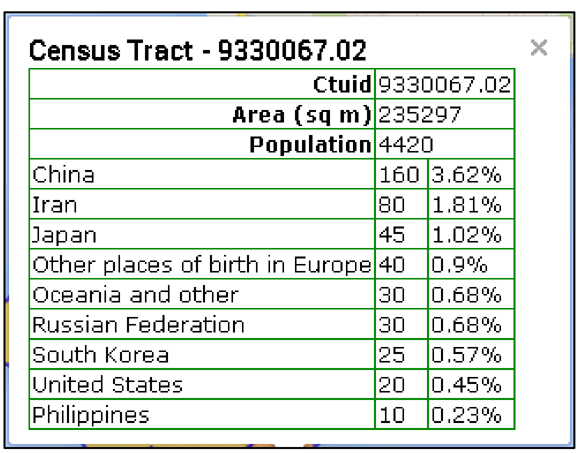


Figure 21: Tract Totals and Planning Totals layer groups

Selecting one of these checkboxes draws another layer on top of the map. The user can then select a tract to invoke an InfoWindow that displays the totals for the selected tract (Figure 22).



Census Tract - 9330067.02

Ctuid	9330067.02	
Area (sq m)	235297	
Population	4420	
China	160	3.62%
Iran	80	1.81%
Japan	45	1.02%
Other places of birth in Europe	40	0.9%
Oceania and other	30	0.68%
Russian Federation	30	0.68%
South Korea	25	0.57%
United States	20	0.45%
Philippines	10	0.23%

Figure 22: InfoWindow for Immigrant Totals

These layers do not have parameters as the indicator layers do and thus do not have to be generated dynamically on the server side. They reside on the server as static KML files.

View NEPP Seminars

Overview

The Neighbourhood Emergency Planning Program (NEPP) provides seminars and other training resources in order for groups and individuals to prepare for an emergency (vancouver.ca 2013). The user of vulnerablevancouver.ca is able to view the seminars that NEPP has hosted from 2011 onward.

Client Actions

To view the NEPP seminars, the user first selects the **Seminars** tab and then selects one or more years to display (Figure 23).

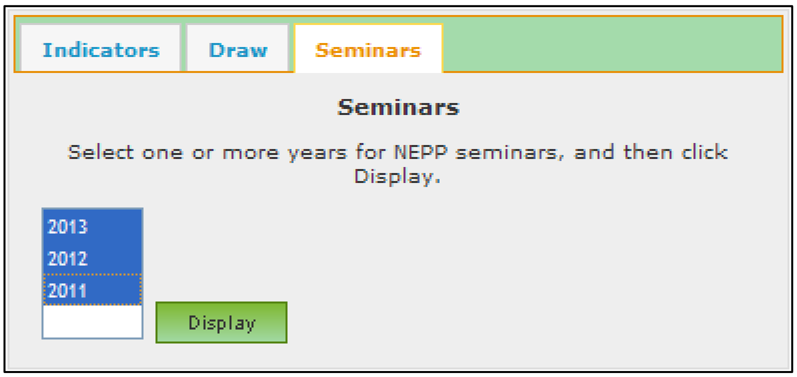


Figure 23: NEPP Seminars tab

The result is a layer that displays the seminar locations as a Google Visualisation Heat Map (Figure 24).

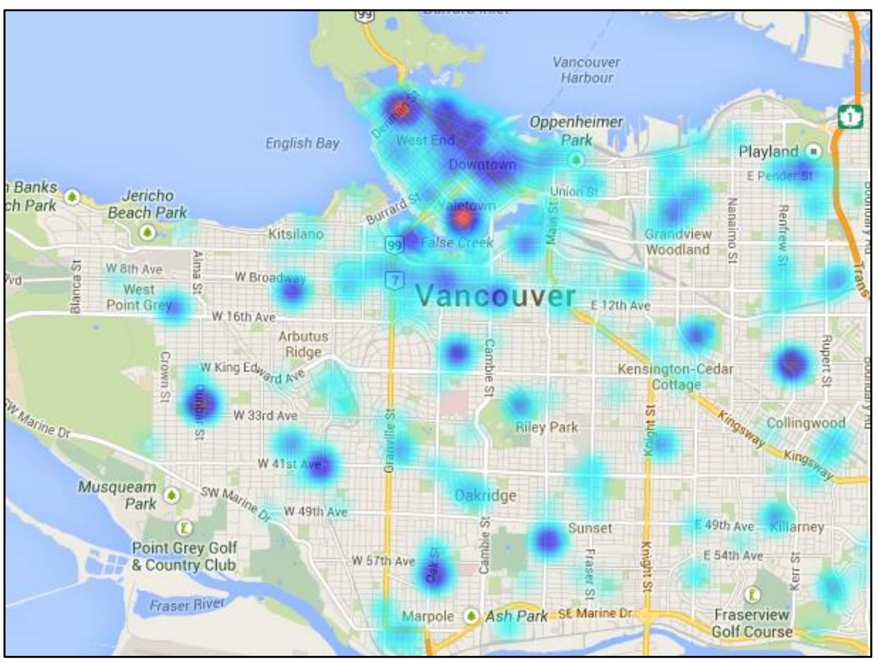


Figure 24: Seminar locations as Google Visualisation Heat Map

The heat map shows concentrations of seminars. This is preferable to showing markers for each seminar. Because many of the seminars are in the same location, the markers would be on top of each other, and the user would only see one marker per location.

As the user zooms in, the heat map degrades into individual areas on the map. Still, it is apparent to see that in the West End, the West End Community Centre has hosted many seminars (Figure 25).

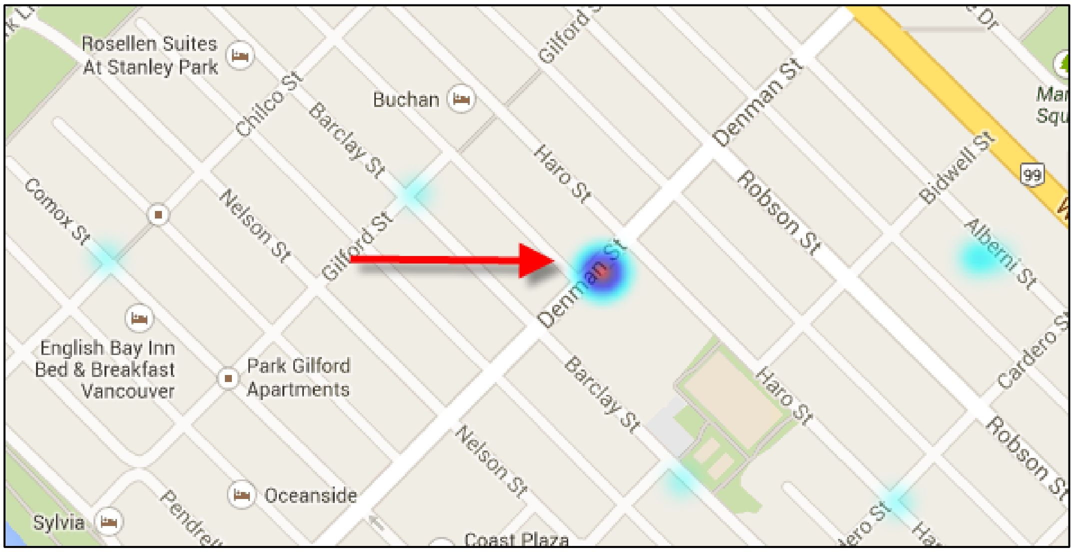


Figure 25: Heat map shows that the West End Community Center has hosted many seminars

Server Actions

When the user clicks **Display**, JavaScript code in the browser fashions a URL containing the years that the user has chosen and sends an AJAX request to a PHP program on the server side. The PHP program queries the PostgreSQL database for seminars for the given year, formats a JSON string with data from the query, and sends it back to the browser. The browser in turn iterates through the JSON string and creates an array that is suitable to pass to the constructor for the heat map. The line below creates the heatmap layer for the map.

```
lyrNeppSeminar = new google.maps.visualization.HeatmapLayer;
```

View Draw Report

Overview

The Draw Report tool allows the user to draw a shape on the map and then retrieve information about features that are within the shape.

Client Actions

The Drawing Manager produces the familiar strip of tools on the map (Figure 26).

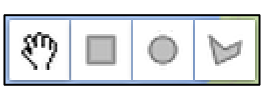


Figure 26: Google Maps Drawing Manager control

The user clicks the Google Drawing Manager control and then draws either a rectangle, circle, or polygon on the map (Figure 27).

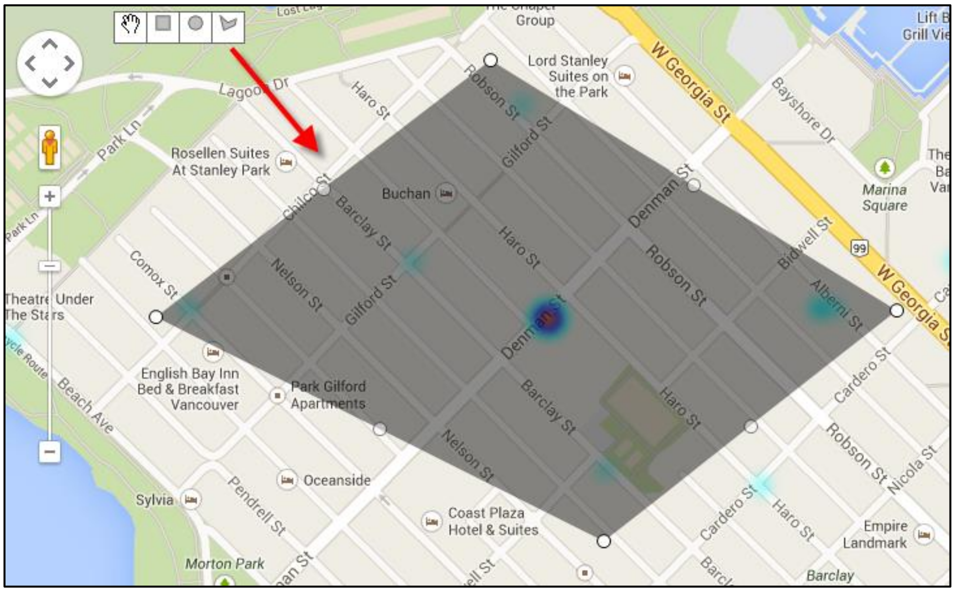


Figure 27: Drawing Manager control and polygon on map that the user drew

To view a Draw Report, the user clicks the **Draw** tab, selects a Draw report and then clicks **Get Draw Report**. The report displays in a dialog (Figure 28). Currently there is only one Draw report, but the architecture of the Draw tab allows for any number of Draw Reports.

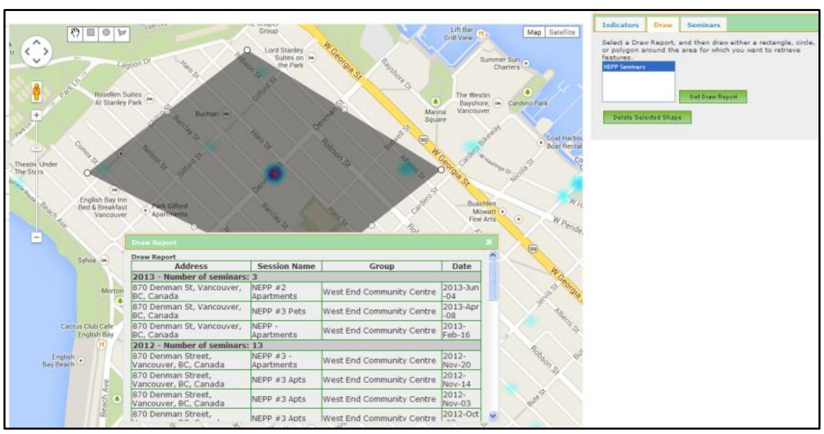


Figure 28: Draw Report for NEPP Seminars within polygon shape

Server Actions

When the user clicks **Get Draw Report**, JavaScript in the browser determines what kind of shape the user has drawn, and sends items of data for each shape to a server side PHP program. For a rectangle, the browser sends the south-west and north-east coordinates of the rectangle. For a circle, the browser sends four points at degrees of 0 (zero), 90, 180, and 270 at the radius of the circle. For a polygon, the browser sends a list of the points in the polygon.

On the server side, the PHP program fashions a spatial query to send to the PostgreSQL database. The PostGIS extension handles the query, and sends back only those features that are within the shape.

PostGIS is capable of complex spatial queries. See “Google Circles and PostGIS Circles” in the Appendix for more information.

Persian Puzzle

Two census tracts in the West End show unusually large percentages in the **Immigrant - 2006 to 2011** layer (Figure 29).

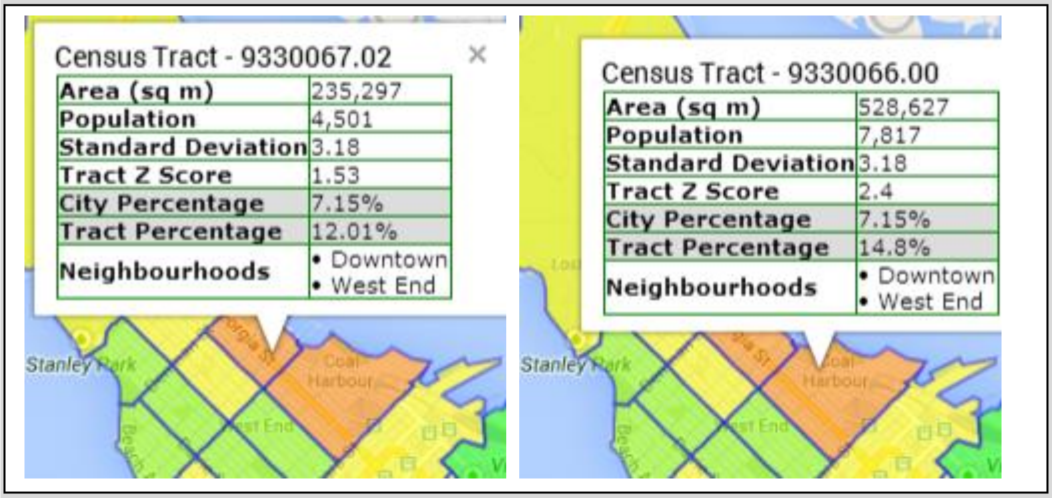


Figure 29: Immigrant - 2006 to 2011 layer for two census tracts in West End

Furthermore, both tracts show high levels of immigrants from both China and Iran (Figure 30).

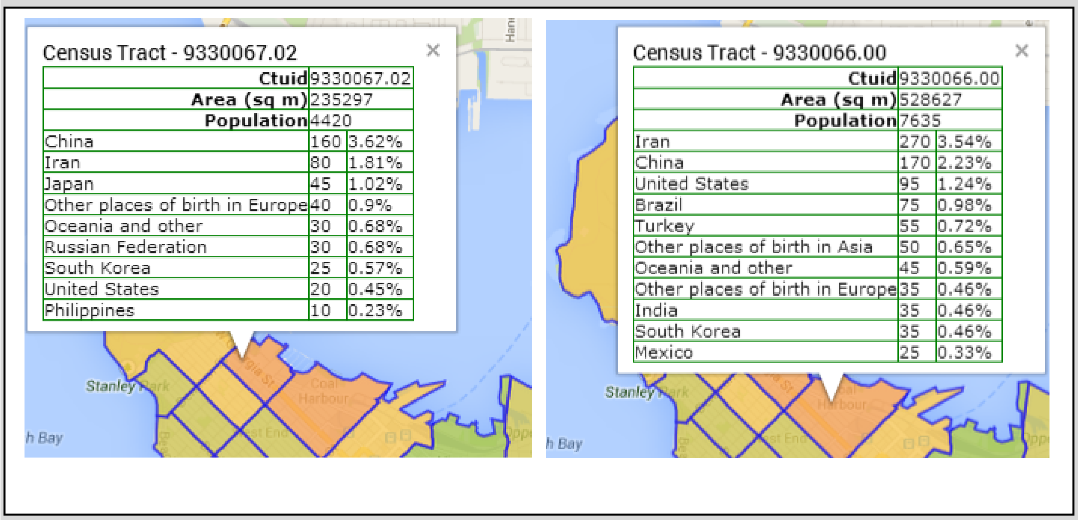


Figure 30: Immigrant Totals for two census tracts in West End

It is obvious that some pattern is happening here. Immigrants from China are high in numerous parts of the city, but from Iran only in these two tracts.

A recent Iranian immigrant unravels the Persian puzzle:

"The majority of Iranian people coming to Canada fall under two different categories:

- *Skilled worker category*
- *Business category*

The first group are educated people with very good working experience and with enough money to handle their life at the beginning without having a job in Canada.

The second group has an enormous amount of cash as they have to put thousands of dollars into Canadian banks in order get a permanent visa. In some cases they bring millions of dollars.

With that background in mind, understand that having a home instead of renting is important in our culture, so these types of people have the desire and funds to buy their own home. There are three different areas in Vancouver that have appeal to Iranians:

1. *West Vancouver (this is for the most wealthy)*
2. *North Vancouver, which already has a large Persian community*
3. *The West End, which is close to North Vancouver and West Vancouver and thus gives the sense of home*

Added to this is the fact that Iranians are usually coming from big cities and these cities are like the West End: crowded, with only a few steps to grocery stores, shopping, and restaurants. As well they are only a few paces from a pleasant stroll along the ocean at English Bay, Stanley Park, or Coal Harbour.

Finally, why the north side of Robson Street has a higher rate of Iranian immigrants than the south side is because the north side is Coal Harbor, where the new condos are, whereas the south side of Robson Street is where there are older, rental properties.

Please remember that I just talked about the wealthy. Persian people also buy homes or rent in different areas of Metro Vancouver (Coquitlam, Burnaby, etc.)"

This detailed analysis sheds light on a pattern that only a recent immigrant from Iran would be aware of, and highlights the uncertainty of analysis by planners and researchers. We know what we know, but how much is there out there that we don't know?

Results

This section describes the results of the study. Principal Component Analysis and the web map were evaluated in terms of usefulness to planners at City of Vancouver.

Principal Component Analysis Results

The results of the PCA process show that four groups of indicators, or *factors* explain 80% of the patterns between the indicators. The higher the number within a column, the more influence the indicator has (Table 8).

Table 8: Principal Component Analysis for Statistics Canada data

	Economic Factor	Household Factor	Aboriginal Identity Factor	Population Patterns Factor	
Eigenvalues	**4.967514739**	**3.217387364**	**1.273605016**	**1.163170453**	**City-wide Average**
% of Influence	0.38	0.25	0.1	0.09	
Population - 65 years and older	-0.186656092	0.150799633	-0.29307349	0.477208467	13.42%
Family - Single parent	-0.37707293	-0.055617301	-0.253141493	-0.128793058	16.36%
Income - Low	-0.203495251	-0.385866351	-0.068946656	0.08279368	20.9%
Education - High school or less	-0.402249402	-0.057844989	0.199224728	-0.036856785	27%
Unemployment	-0.317820427	-0.218579446	-0.102228485	-0.19232879	7.2%
Renter	0.055127069	-0.517039016	0.044804218	0.158340872	51.4%
English - Not spoken in the home	-0.333185528	0.204608869	0.351518505	0.000692162	31%
Occupation - Arts or service	-0.30478869	-0.242320211	0.33630454	0.071862861	30.88%
Social dependence	-0.411914836	-0.147162482	0.043638391	0.096351187	10.3%
Population growth	0.085460165	-0.047615417	0.376001179	-0.655817425	4.43%
Family - Average size	-0.269324462	0.421954814	-0.028221896	-0.064621574	2.8%
Population - 14 years and under	-0.239209374	0.409067414	-0.143338194	-0.170100993	12.6%
Aboriginal identity	-0.07119683	-0.192174588	-0.62596772	-0.455800312	2.14%

Indicators that have minus signs indicate an *inverse* relationship between indicators. For example, there is an inverse relationship between the amount of water that I drink and how thirsty I am. The more I drink, the less thirsty I am, not the thirstier. The relationship is the important thing, not whether the sign is positive or negative.

The columns have labels that help to identify the underlying meaning of the factor. However, the actual meaning of a factor may be more complex than a single label can state. All that the results of PCA give are numbers; it is up to humans to make sense of the numbers. The city wide percent of the indicators display in the rightmost column. This is not something that PCA does.

Analysis of Factors

This section provides analysis of the four most important factors in the PCA result.

Economic Factor

The first factor we may label as the "Economic Factor" (Table 9).

Table 9: Economic Factor

Social dependence	-0.411914836
Education - High school or less	-0.402249402
Family - Single parent	-0.37707293
English - Not spoken in the home	-0.333185528
Unemployment	-0.317820427
Occupation - Arts or service	-0.30478869
Family - Average size	-0.269324462
Population - 14 years and under	-0.239209374
Income - Low	-0.203495251
Population - 65 years and older	-0.186656092
Aboriginal identity	-0.07119683
Renter	0.055127069
Population growth	0.085460165

This factor includes a number of fairly evenly matched indicators, at the top of which are social dependence and education of high school or less. We might state the story of this factor as: "Where there is social dependence and low education, there is also employment in the service or arts sectors, or unemployment. As well, those who do not speak English in the home, who are a single parent, or whose income is low are found here".

Household Factor

The second factor we may label as the "Household Factor" (Table 10).

Table 10: Household Factor

Renter	-0.517039016
Family - Average size	0.421954814
Population - 14 years and under	0.409067414
Income - Low	-0.385866351
Occupation - Arts or service	-0.242320211
Unemployment	-0.218579446
Aboriginal identity	-0.192174588
Social dependence	-0.147162482
Education - High school or less	-0.057844989
Family - Single parent	-0.055617301
Population growth	-0.047615417
Population - 65 years and older	0.150799633
English - Not spoken in the home	0.204608869

There are two distinct patterns in this factor. The first is **Renter**, the second is **Family - Average Size** and **Population - 14 years and under**. Looking at these indicators on the map makes these patterns more clear (Figure 31, Figure 32, and Figure 33).

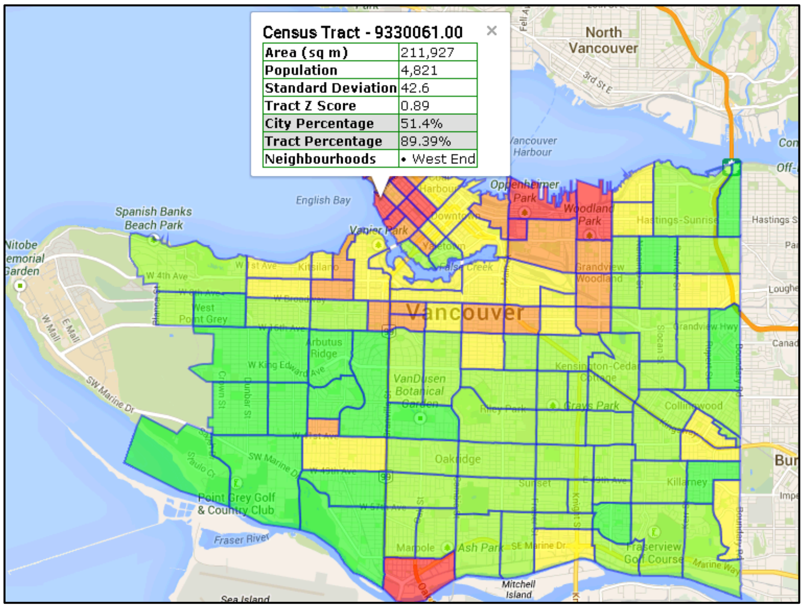


Figure 31: Renters layer

The West End (top left area of the map in red) has many renters, with one tract percentage exceeding 89%. Looking at the **Family - Average size** layer, we see that the West End does not have large families (Figure 32), but that areas to the south in the city do have large families (Figure 33).

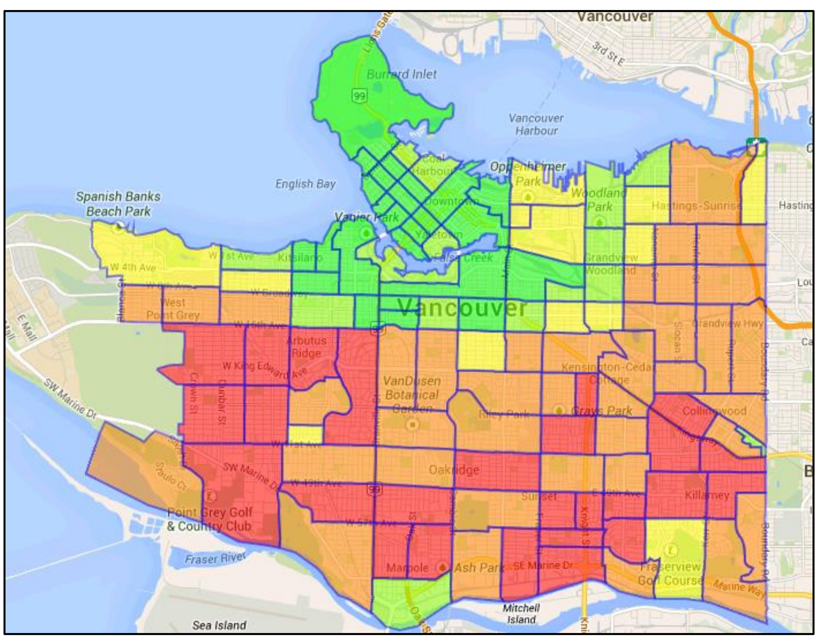


Figure 32: Families - Average size layer

Looking at the **Population - 14 years and under** layer, we see the same story - the West End does not have a large population of 14 years and under, but areas to the south in the city do (Figure 33).

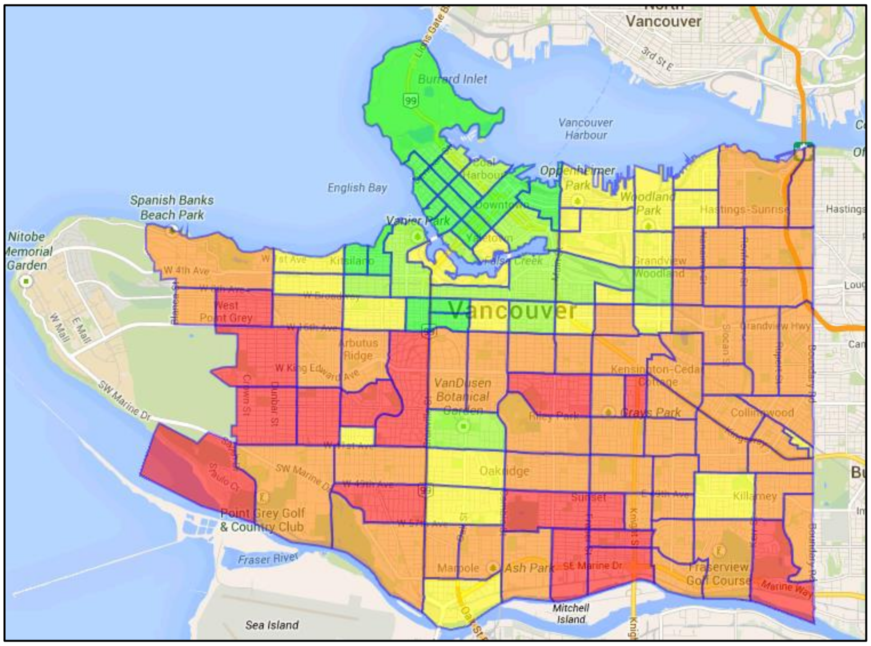


Figure 33: Population - 14 years and under layer

Thus we can state the story of this pattern as "Where there are renters, families are not large and population 14 years and under is low. As well, renters tend to have low income. Conversely, where families are large there is also a large population 14 years under, but with a smaller number of renters".

Aboriginal Identity Factor

The third factor we may label as the "Aboriginal Identity Factor" (Table 11).

Table 11: Aboriginal Identity Factor

Aboriginal identity	-0.62596772
Population growth	0.376001179
English - Not spoken in the home	0.351518505
Population - 65 years and older	-0.29307349
Family - Single parent	-0.253141493
Population - 14 years and under	-0.143338194
Unemployment	-0.102228485
Income - Low	-0.068946656
Family - Average size	-0.028221896
Social dependence	0.043638391
Renter	0.044804218
Education - High school or less	0.199224728
Occupation - Arts or service	0.33630454

The one dominant indicator in this factor is **Aboriginal identity**. This pattern is most apparent in one particular tract in Vancouver's south west. This tract encompasses the Musqueam Indian Reserve, where 48% of residents claim Aboriginal identity (Figure 34).

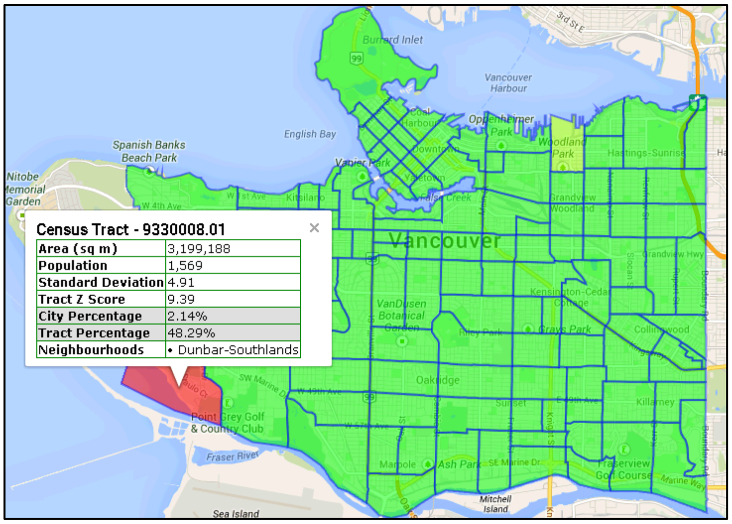


Figure 34: Aboriginal identity layer

Secondary indicators here are **Population growth**, **English - Not spoken in the home**, **Population - 65 years and older**, and **Family - Single parent**. We might state the story of this factor as: "Where there is high Aboriginal identity, there tends to be little population growth and fewer people that do not speak English in the home. As well, there tends to be a higher population of 65 years and over, as well as single parents."

Population Patterns Factor

The fourth factor we may label as the "Population Patterns Factor" (Table 12).

Table 12: Population Patterns Factor

Population growth	-0.655817425
Population - 65 years and older	0.477208467
Aboriginal identity	-0.455800312
Unemployment	-0.19232879
Population - 14 years and under	-0.170100993
Family - Single parent	-0.128793058
Family - Average size	-0.064621574
Education - High school or less	-0.036856785
English - Not spoken in the home	0.000692162
Occupation - Arts or service	0.071862861
Income - Low	0.08279368
Social dependence	0.096351187
Renter	0.158340872

The fourth factor is difficult to explain because it shows a pattern where **Population growth** and **Aboriginal identity** have an inverse relationship with **Population - 65 years and older**. There are no census tracts in the city that model this pattern in particular, and in fact the pattern seems to contradict the pattern in the third factor, **Aboriginal Identity Factor**, which shows an inverse relationship between **Population growth** and **Aboriginal identity**.

One cause for this pattern might be three tracts in the Downtown South neighbourhood of Vancouver, which have shown growth rates of 36%, 44%, and 96% between 2006 and 2011 (Figure 35). This growth was stimulated by changes in zoning that allowed the creation of many new multi-unit dwellings. Because the population in 2006 was small, the percentage of growth between 2006 and 2011 is high. These percentages are anomalies in terms of the overall growth of population in the city between 2006 and 2011, which is 4.4%.

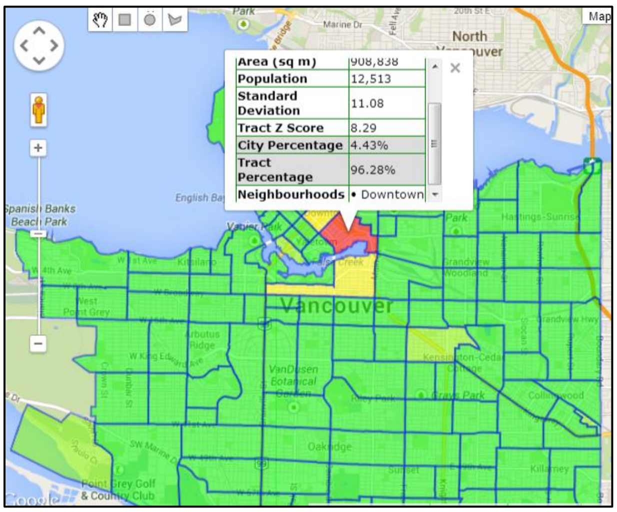


Figure 35: Population growth layer

To find out if these high percentages are responsible for the fourth factor, an exercise in *sensitivity analysis* on the data was also performed. Sensitivity analysis tests the effects of changing or omitting an independent variable on a dependent variable. In this case, the **Population growth** indicator was removed from the analysis. Running PCA again using this technique created a more understandable set of eigenvectors (Table 13).

Table 13: Fourth factor without Population growth

Population - 65 years and older	-0.85552
Income - Low	-0.26181
Occupation - Arts or service	0.253673
Population - 14 years and under	0.211498
Social dependence	-0.12264
Renter	-0.01421
Family - Single parent	0.004803
English - Not spoken in the home	0.026542
Unemployment	0.075333
Family - Average size	0.075577
Education - High school or less	0.152821
Aboriginal identity	0.199357

Leaving out **Population growth** makes this pattern clearly centered on **Population - 65 years and older**, with a correlation to **Income - Low** and an inverse correlation to **Occupation - Arts or service** and **Population - 14 years and under**. If we accept this pattern as valid, we might state the story of this pattern as: “Where there is a large population 65 years and older there tends to be low income. Also there is low percentage of people employed in the arts or service sectors, and low percentage of population 14 years and under”.

It is also noteworthy that this is the fourth set of eigenvectors, and accounts for only 9% of the overall patterns in the data.

Limitations of PCA

The PCA results above shed light on patterns of vulnerability, but they also show limitations of PCA. For example, the indicator **English - Not spoken in the home** is not a major influence in any of the top four factors, yet it is a major concern to planners at City of Vancouver. The City-wide percentage of such residents is 31%, with a given tract having 55% or greater (Figure 36). PCA does not reveal this vulnerability.

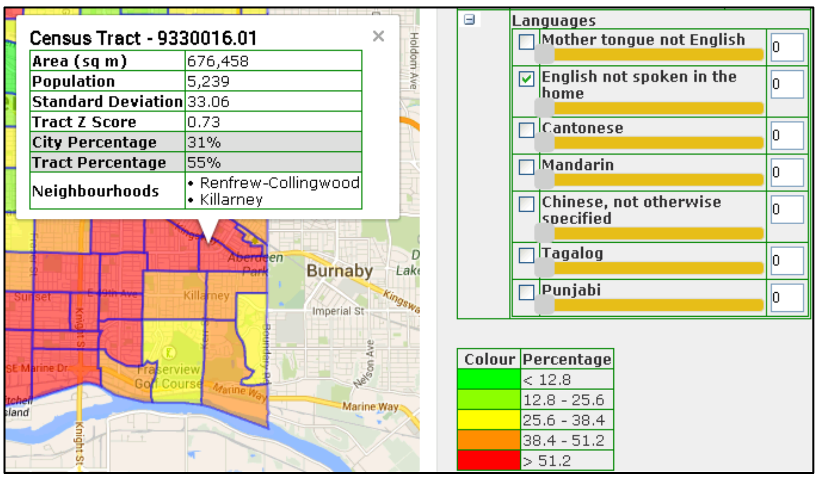


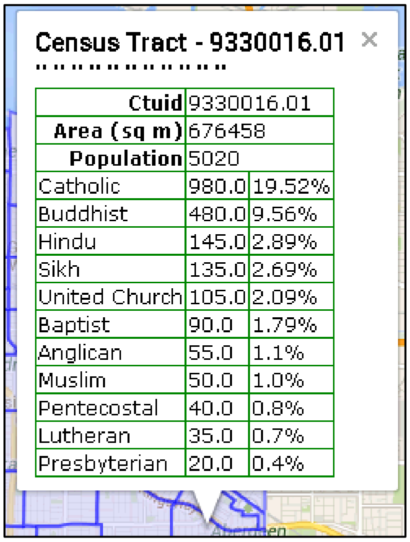
Figure 36: English not spoken in the home layer

As well, as our analysis above demonstrates, it is usually not enough to have a set of eigenvectors to understand the data. The map explains the patterns, but the patterns, once understood, may refer to anomalies in the data such as concentrations of an indicator in a certain location. Planners may not be interested in pursuing such anomalies.

In the case of the large population growth in three census tracts in the Downtown South district, planners do not see vulnerability issues here; the buildings have been designed with the latest advances in seismic technology, the infrastructure has been thoughtfully laid out, and community centers exist to foster a sense of community in these areas. As well, the new occupants of these units are generally gainfully employed citizens, who would have financial resources to help themselves in the event of an earthquake. PCA does not communicate these details, but rather outputs a pattern that is not valid to planners at City of Vancouver.

Another limitation of PCA is that it calculates metric data, not nominal or categorical data. But planners may be interested in these types of data. For example, one area of interest for City of Vancouver planners is the religion of citizens. This is because in the event of an earthquake, members of a religion often go their house of worship, that is, a church, synagogue, mosque, or temple. But how can PCA model that population? Residents are not vulnerable simply because they go to church. Rather, they go to the church in the event of an earthquake, and thus religious leaders should prepare their building for such an event.

City planners used the **Religion Totals** layer on vulnerablevancouver.ca to identify which religions have high members in given tracts (Figure 37). This allows them to plan earthquake preparedness seminars in local houses of worship.


Census Tract - 9330016.01

Ctuid	9330016.01	
Area (sq m)	676458	
Population	5020	
Catholic	980.0	19.52%
Buddhist	480.0	9.56%
Hindu	145.0	2.89%
Sikh	135.0	2.69%
United Church	105.0	2.09%
Baptist	90.0	1.79%
Anglican	55.0	1.1%
Muslim	50.0	1.0%
Pentecostal	40.0	0.8%
Lutheran	35.0	0.7%
Presbyterian	20.0	0.4%

Figure 37: Religion Totals layer

Web Map Results

Summary

In several measures, the web map did provide a useful tool for planners at City of Vancouver. The following table provides a summary of the evaluation of each measure (Table 14).

Table 14: Summary of measurement results

Measure	**Evaluation**
Does the tool highlight geographic areas of the region of interest that have not received emergency planning services commensurate to the region of interest as a whole?	Yes. The web map reveals that the West End in particular has received many seminars, while the Downtown Eastside, a poor area of town has received relatively fewer seminars.
Does the tool make the demographics more granular, such that new areas of vulnerability become apparent?	Yes. Language and immigrant patterns are particularly apparent on the web map.
Does combining vulnerability totals aid in assessing overall vulnerability?	Limited.
Are initiatives for the coming year markedly different in location and theme from previous years?	Too early to tell. Based on results of the other criteria, the author surmises that planners will schedule seminars in locations and themes that have not been addressed so far.

Are there new initiatives created by the stimulus of the tool?	Yes. These initiatives in particular are planned: • Seminars in churches / synagogues / mosques / temples • Focus on soliciting volunteers in areas where number of volunteers is low • Layer for past and future seminars • Response planning
How many initiatives are created based on identification of patterns through a vulnerability index as opposed to initiatives created through the tool?	It does not appear that planners will schedule any new seminars because of the Principal Component Analysis that was performed on the data.

Discussion

Measure: Does the tool highlight geographic areas of the region of interest that have not received emergency planning services commensurate to the region of interest as a whole?

The Neighbourhood Emergency Planning Program (NEPP) takes requests for seminars on planning for emergencies (vancouver.ca, 2013). The Office of Emergency Management has done over 600 seminars since 2011.

While this is an impressive number, the NEPP Seminar layer shows that the distribution favours the West End (Figure 38). This a concentrated area of population, with 40,000 people living in 200 square blocks.

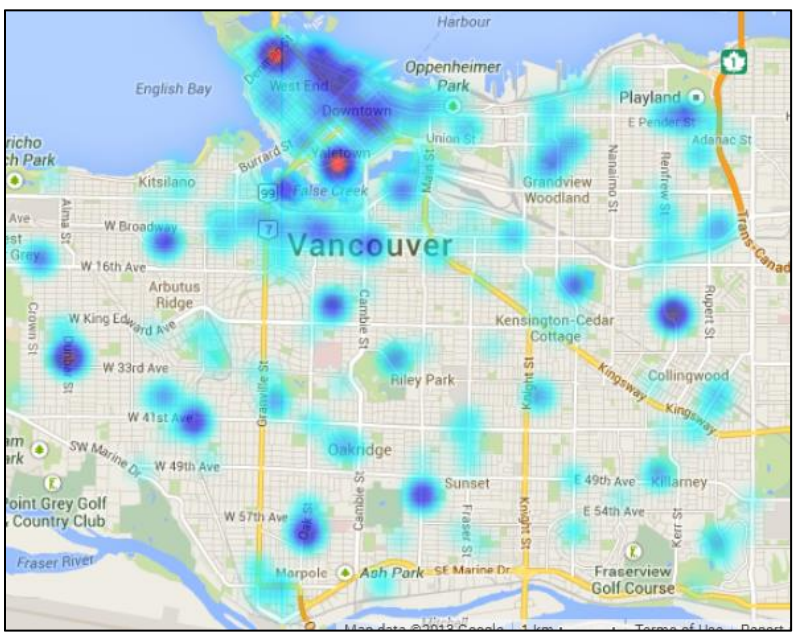
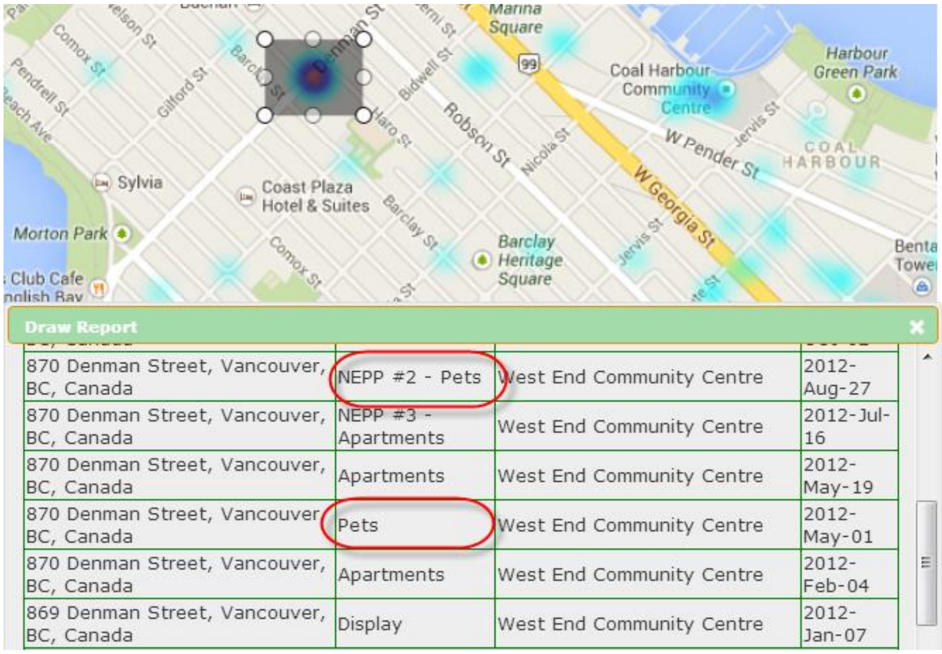


Figure 38: NEPP Seminars layer. West End is top and left.

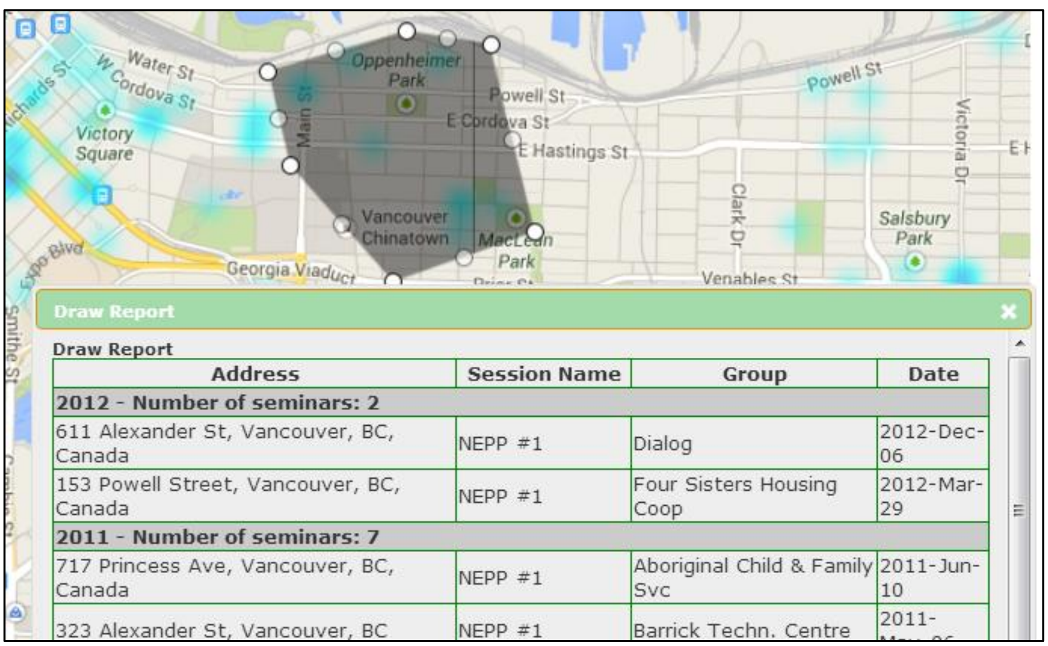
The Draw Report shows that the West End Community Centre alone has been host to 23 seminars since 2011, including three seminars on pets (Figure 39).



870 Denman Street, Vancouver, BC, Canada	NEPP #2 - Pets	West End Community Centre	2012-Aug-27
870 Denman Street, Vancouver, BC, Canada	NEPP #3 - Apartments	West End Community Centre	2012-Jul-16
870 Denman Street, Vancouver, BC, Canada	Apartments	West End Community Centre	2012-May-19
870 Denman Street, Vancouver BC, Canada	Pets	West End Community Centre	2012-May-01
870 Denman Street, Vancouver, BC, Canada	Apartments	West End Community Centre	2012-Feb-04
869 Denman Street, Vancouver, BC, Canada	Display	West End Community Centre	2012-Jan-07

Figure 39: Draw Report for West End Community Centre

The Draw Report also shows that the Strathcona neighbourhood, which contains about 12,000 residents, has been host to nine seminars since 2011 (Figure 40).



Draw Report

Address	Session Name	Group	Date
2012 - Number of seminars: 2			
611 Alexander St, Vancouver, BC, Canada	NEPP #1	Dialog	2012-Dec-06
153 Powell Street, Vancouver, BC, Canada	NEPP #1	Four Sisters Housing Coop	2012-Mar-29
2011 - Number of seminars: 7			
717 Princess Ave, Vancouver, BC, Canada	NEPP #1	Aboriginal Child & Family Svc	2011-Jun-10
323 Alexander St, Vancouver, BC	NEPP #1	Barrick Techn. Centre	2011-

Figure 40: Draw Report for Downtown Eastside and Strathcona

This neighbourhood contains the Downtown Eastside, where percentages of vulnerability indicators such as low income, single parent families, and social dependence are high (Figure 41).

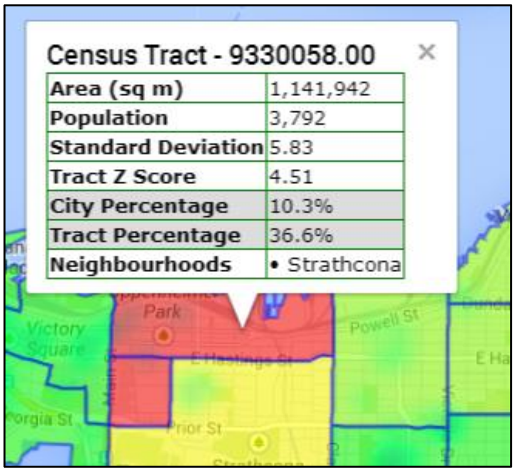


Figure 41: Social dependence layer for Downtown Eastside

A key method that planners use to schedule preparedness seminars is by a group approaching the City either through the NEPP web site or by phone and requesting a seminar. This is a reactive, not a proactive method. A challenge for planners at City of Vancouver to grapple with is how to provide emergency preparedness for an area of the City where people do not request help. These people may be equally or more vulnerable than people that do request help.

Measure: Does the tool make the demographics more granular, such that new areas of vulnerability become apparent?

Planners were interested in particular to see patterns of language and immigration.

Planners for City of Vancouver are aware of the diversity of languages in the city, and in past years have tried to target areas where known language populations exist. For example, the area of 49th and Main is referred to as the Punjab Market and even has its own entry on Wikipedia (Wikipedia.org, 2013). This is a natural area in which to schedule seminars in the Punjabi language.

However, planners now have a tool that shows at the census tract level residents who do not speak English in the home, and then identifies which languages are strongest in these areas.

For example, 55% of residents in a tract on the south east side of Vancouver do not speak English in the home (Figure 42).

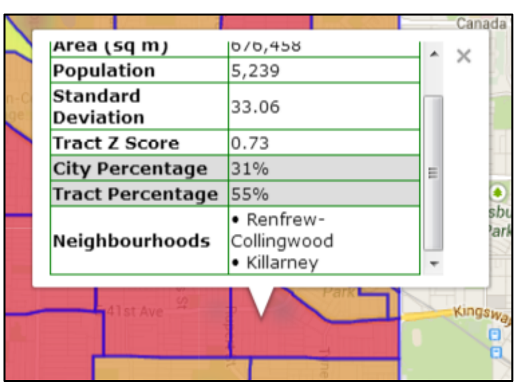


Figure 42: 55% of residents in tract do not speak English in the home

The **Language Totals** layer then shows which languages are strongest in this census tract (Figure 43).

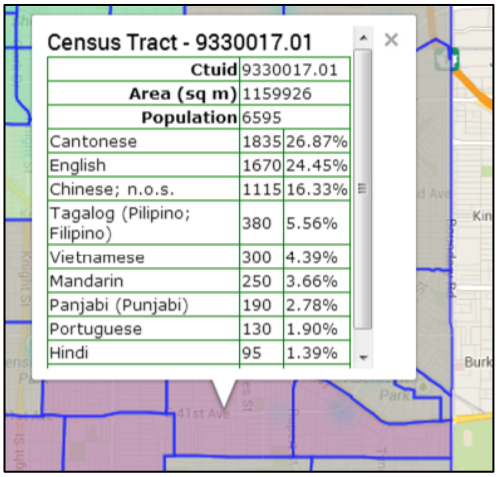


Figure 43: Languages Totals for census tract 9330017.01

Planners at City of Vancouver also were interested to see immigrant patterns. For example, two tracts on the west side of Vancouver (not the “West End”), typically thought of as a more stable area, show surprisingly large totals for immigrants who have arrived between 2006 and 2011 (Figure 44).

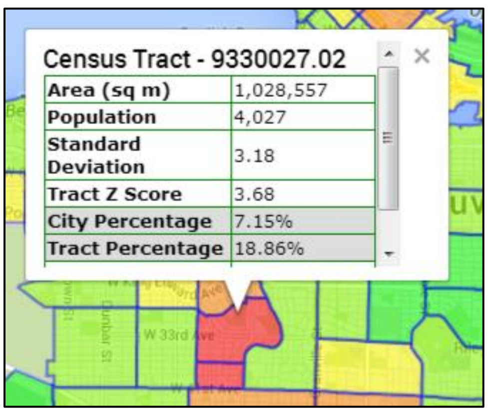


Figure 44: Immigrant - 2006 to 2011 layer

The **Immigrant Totals** layer shows that many of these immigrants are from China (Figure 45).

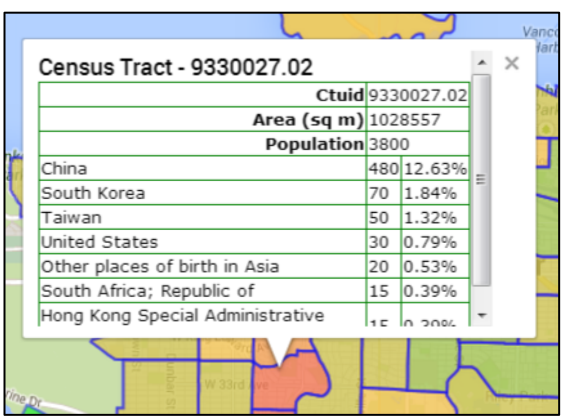


Figure 45: Immigrant Totals layer

Adding the **English not spoken in the home** layer shows that 48% of residents in one of these tracts do not speak English in their home (Figure 46). This should be an area of concern for Vancouver planners.

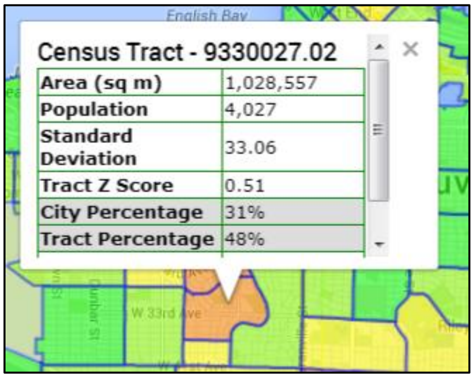


Figure 46: English not spoken in the home layer

Measure: Does combining vulnerability totals aid in assessing overall vulnerability?
One of the features of SoVI is that once vulnerability indicators are produced, the researcher adds them together to generate an overall vulnerability for the area of interest (Cutter et al., 2003).

As noted above, one of the weaknesses of vulnerability indexes is that adding vulnerability indicators together can mask an indicator (Rygel et al., 2005). For example, an area that has high income may also have a high number of seniors. The seniors may be responsible for the high income indicator, but are vulnerable because they are not mobile.

Another weakness of this method is that it assumes that all vulnerability indicators are equal. Cutter et al. acknowledge this challenge in their statements (2003, p. 254) "We selected an additive model, thereby making no a priori assumption about the importance of each factor in the overall sum. In this way, each factor was viewed as having an equal contribution to the county's overall vulnerability. In the absence of a defensible method for assigning weights, we felt this was the best option."

Using an interactive map enables the planner both to combine vulnerabilities and to assign weights to each indicator. Combining vulnerabilities is a simple matter of checking multiple indicators in the Indicators tab (Figure 47).

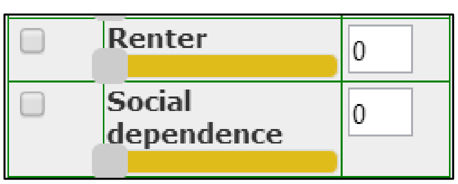


Figure 47: Combining vulnerabilities

To add weight to an indicator, the planner drags the slider to the right or manually enters a number from 1 to 200 (Figure 48). Having a weight of 100 means that if a percentage in a tract is 18%, it now becomes 36%.

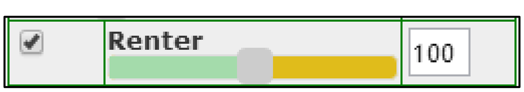


Figure 48: Adding a weight of 100 to an indicator.

As a test of the usefulness of this functionality, the author created various combinations of the vulnerabilities of **Renter** and **Social dependence**. The **Renter** layer by itself clearly shows that residents in the West End and surrounding areas have high percentages of renters (Figure 49).

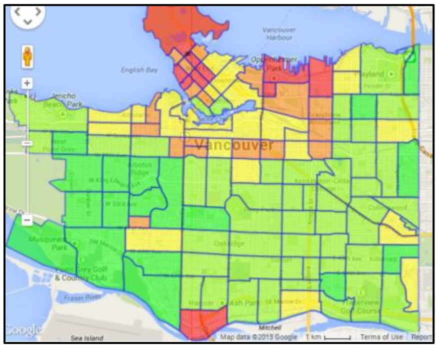


Figure 49: Renter layer

The **Social dependence** layer by itself shows us that the Downtown Eastside and other areas in the east area of Vancouver have high social dependence (Figure 50).

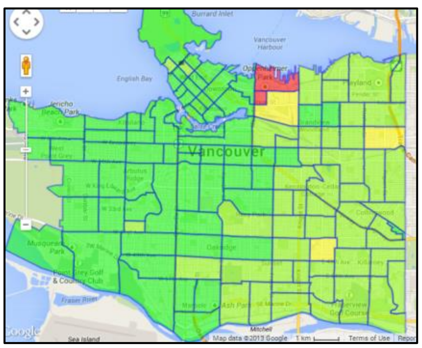


Figure 50: Social dependence layer

What does combining **Renter** and **Social dependence** tell us? It seems to smooth out the percentages rather than point to any new areas (Figure 51).

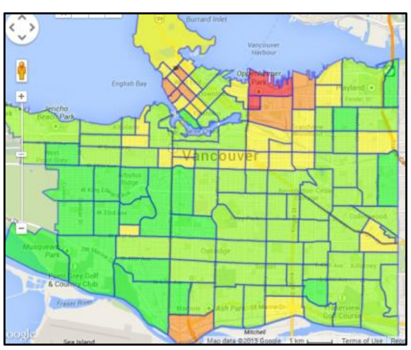


Figure 51: Renter and Social dependence layers, no weighting

What does combining **Renter** at a weight of 100 and **Social dependence** tell us? Again, it does not seem to produce any new revelation about these vulnerabilities in combination with each other (Figure 52).

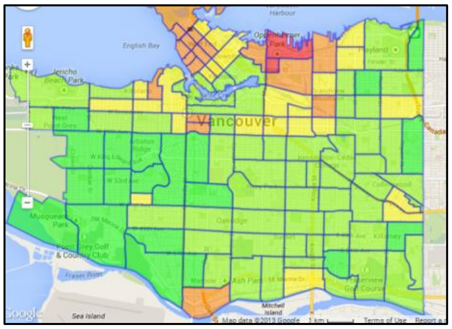


Figure 52: Renter layer at 100 weight and Social dependence layer

What does combining **Renter** and **Social dependence** at a weight of 100 tell us? Again, it is hard to see any new pattern here (Figure 53).

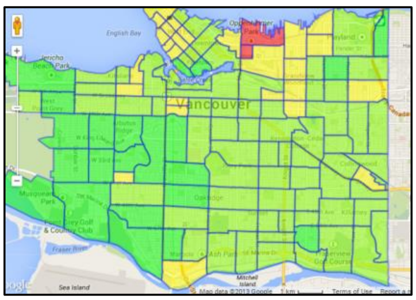


Figure 53: Renter layer and Social dependence at 100 weight

These tests do not show any particular benefit to combining vulnerabilities. Likewise, City of Vancouver planners found these tools of limited use. There might be cases where a planner is looking for a particular combination of vulnerabilities and could find it with these tools. However, most often the planner finds useful patterns by examining one indicator at a time. The Tract Totals layers (**Language Totals**, **Religion Totals**, and **Immigrant Totals**) exist to help explain the indicator further, not to act as combinations of indicators.

Measure: Are initiatives for the coming year markedly different in location and theme from previous years?

The answer to this question is outside the time scope of this project. City of Vancouver planners were just beginning to plan for the year 2014 when the author completed the interactive web map. Based on the enthusiasm that planners showed for the tool, the author surmises that a number of seminars in 2014 would be in new locations and in different themes than previous years.

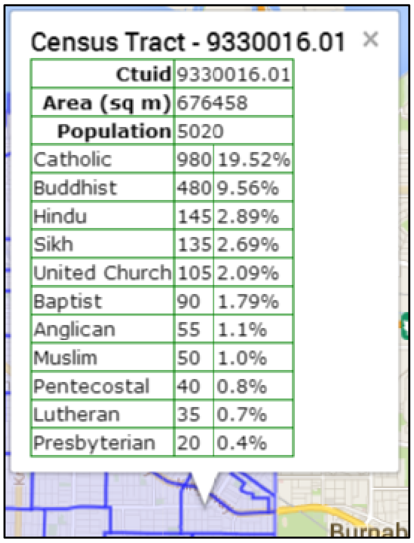
Measure: Are there new initiatives created by the stimulus of the tool?

After looking at the map, planners had ideas for these new initiatives:

Religions

Planners told the author that in the event of a disaster, residents who are adherents to a religion often go their church / synagogue / mosque / temple. Therefore planners are interested in identifying which religions have large numbers in given tracts and then doing seminars in these buildings. The seminars would not only focus on earthquake preparedness for individuals but also on what the religious leaders can do to prepare their buildings.

In response, the author created the **Religion Totals** layer (Figure 54). This layer shows the religions in a given tract sorted by number of adherents to the religion.



Ctuid	9330016.01	
Area (sq m)	676458	
Population	5020	
Catholic	980	19.52%
Buddhist	480	9.56%
Hindu	145	2.89%
Sikh	135	2.69%
United Church	105	2.09%
Baptist	90	1.79%
Anglican	55	1.1%
Muslim	50	1.0%
Pentecostal	40	0.8%
Lutheran	35	0.7%
Presbyterian	20	0.4%

Figure 54: Religion Totals layer

Volunteers

Planners wanted to know where their volunteers live. This will help them to assign volunteers to given areas and also to identify areas that have few volunteers so that they can expend effort to get more volunteers in those areas.

Planners provided a spreadsheet with volunteer addresses on it. Using this data source, the addresses of the volunteers were geocoded at the postal code level (Figure 55). Planners requested this generalized level of display rather than at the address or address hundred block level for reasons of privacy.

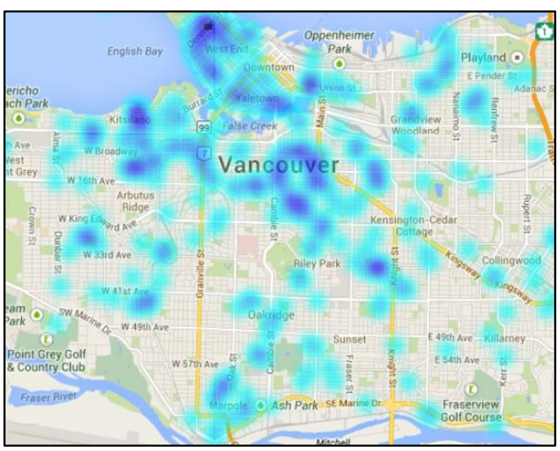


Figure 55: Volunteers layer

An interesting suggestion that one planner made was that an administrator could log into the site, draw a circle / rectangle / polygon on the map and retrieve volunteer information within the shape in a similar fashion to the Draw Report for Seminars. However, this would have to wait for a further iteration of the web map.

Future Seminars
Planners thought that having two layers for seminars, one for seminars completed and one for seminars planned would be a good motivational tool. Volunteers could see the effect of their work as the colour for the planned layer turns into the colour for the completed layer.

Response Planning
Planners suggested some uses for the web map to plan responses after a disaster occurs. For example, planners at a Provincial level have mapped out disaster routes (Figure 56). Laying these routes on the web map in conjunction with layers of elderly and low income residents could show City of Vancouver planners where potential bottlenecks could occur in getting into affected areas or in evacuating vulnerable residents.

Figure 56: Disaster routes for Vancouver and surrounding municipalities

(Gov.bc.ca, year unknown)
How many initiatives are created based on identification of patterns through a vulnerability index as opposed to initiatives created through the tool?

The author performed Principal Component Analysis (PCA) on the census data, then interpreted and documented the results of the first four groups of eigenvectors and gave the results to the planners. The planners read the author's documentation but were not inspired to create any new seminars or initiatives based on the patterns.

The lack of effectiveness of the analysis patterns echoes the same response that another researcher received from a neighbouring municipality. In this case the researcher performed PCA on a demographic dataset and gave the results to the municipal planners. Their response was "Don't tell us what the patterns are, tell us where the people that don't speak English are". Thus while academics may receive insights from examining patterns, it seems clear that planners "on the ground" want numbers for a given vulnerability in a given area.

Conclusions

This section discusses challenges that the project had and ends with some concluding thoughts.

Challenges

There were three challenges to this project:

- Creating a web map
- Getting planners to use the web map tool
- Defining vulnerability

Creating a Web Map

The first challenge was to create the web map. The author is proficient at all of the technologies involved, and thus did not undergo a learning curve for any of these technologies. Nonetheless, the author spent much of his project time creating the web map, and then changing the web map as he made decisions about the focus of the web map. For anyone else to create such a tool, they must these technologies at their fingertips so that they can change the web map without difficulty.

Having said that, it must also be said that the tools – all free and Open Source, performed marvellously well. QGIS was able to select and export the desired census tracts; Python was able to download the census tract data, store them, and then perform Principal Component Analysis and other processing on the data; PostgresSQL was able to store and efficiently query the spatial data in its database.

Most impressive was the map itself, which was a product of complex JavaScript frameworks. Google has done an amazing job to create their map and to provide an API that is easy to understand and use. The jQuery library allowed the author to easily create tabs, slides, and dialogs, and to perform AJAX lookups. Dynatree provided an excellent looking layers control that had the functionality to allow the browser to respond to checkbox clicks and to programmatically enable or disable folders. In all of these tasks, the browsers of Chrome, FireFox, and Internet Explorer 9 and greater did not falter. Considering that JavaScript is a technology that is two decades old and that its authors had never heard of Google Maps, AJAX, or tree controls when they created it, JavaScript continues to show its worth as a well-designed program language.

Getting Planners to Use the Web Map

The second challenge of this project was to get the planners at City of Vancouver to use the web map. The author was fortunate to be an employee of City of Vancouver, and thus had a direct connection to the planners. Nonetheless, planners at City of Vancouver, like other employees everywhere are already busy doing their job the way that they already know how to do it.

The inability to stop what one is doing and take time to learn to do something new that might improve what one is doing has been called "The Tyranny of the Urgent" (Hummel, 1994). The best tool in the world is of no use unless the people for whom it is intended use it. Fortunately the author had full support from staff members at City of Vancouver. An outsider bringing such a tool to an organization, however, might not have such success.

Defining Vulnerability

This thesis ends where it began, with the challenge of defining the chameleon-like nature of vulnerability.

The author was struck by the statement of an emergency planner at City of Vancouver that poor people fare better after a disaster than wealthy people. “Wealthy people expect the government to put them up in the best hotels”, she said. “Poor people have better coping skills. They are used to getting by on the margins. A disaster is just one more challenge for their lives”. And in the case of Hurricane Katrina, poor people actually did fare better than middle class people. This is because government aid flowed to the poor areas, leaving middle class areas to fend for themselves (Finch et al., 2010).

The statement by the City of Vancouver planner, made by a staff member who has experienced people’s response to disaster, and the situation in Hurricane Katrina run contrary to the conclusions of most studies on vulnerability, i.e., that poor people do not fare as well as more wealthy people during and after a disaster. What are we to do then? Toss out forty years of study on disasters and start over? Give up?

All participants in vulnerability assessment, from academics to planners to students writing a thesis have the same goal in mind: to identify those members of society who are vulnerable in the event of a disaster, to determine in which ways they are vulnerable, and to give them tools to prepare for such an event, both before and after the disaster. Yet despite the best efforts of all these participants, the definition of vulnerability still seems sometimes like a bar of slippery soap that jumps out of your hands just when you think you’ve got it contained.

Summary

Decades of research have gone into the defining and refining of concepts and measures to assess vulnerability to disaster. SoVI and subsequent vulnerability indexes allowed researchers to unveil patterns and to help planners prepare their constituency for disaster.

But planners need more than patterns. They need tools to help them in their job, which is to take practical steps to prepare for disaster. The planners that the author met with at City of Vancouver are not starting from the beginning. They already have a good sense of where the vulnerable people are. And they already know what they don’t know, that is, what vulnerable people they are missing. They can do their job best by having tools that help them find what they are looking for, so that they can make the preparations that they need to make, for the vulnerable people that are out there somewhere.

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Appendix

Using Python to Get Census Data from Statistics Canada

Getting the 2011 census data and the National Household Survey (NHS) data from the Statistics Canada web site proved to be a challenge. The web site provides download of its census and NHS data, but not for Vancouver in particular. The user must manually download each census tract for the city.

The process is made more complicated because the user must navigate to two URLs. First the user navigates to the URL of the given census tract, for example,
http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CT&Code1=4903&Geo2=CMA&Code2=933&Data=Count&SearchText=9330001.01&SearchType=Begins&SearchPR=01&B1=All&Custom=&TABID=1

Once on this page, the user must navigate again to the URL for the census tract as a CSV file, for example,
http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/details/download-telecharger/CSV.cfm?Lang=E&Geo1=CT&Code1=4903&Geo2=CMA&Code2=933&Data=Count&SearchText=9330001.01&SearchType=Begins&SearchPR=01&B1=All&Custom=&TABID=1

The author developed a Python to provide a programmatic solution to this problem. Python takes the following steps (Figure 57):

1. **Query** the PostgreSQL database to retrieve the list of census tract ids, for example, 9330001.01
2. **Fetch** the web page that refers to this census tract from Statistics Canada
3. **Parse** the URL for the CSV file that is on this web page
4. **Fetch** the CSV file for this census tract
5. **Store** the CSV file on the hard drive

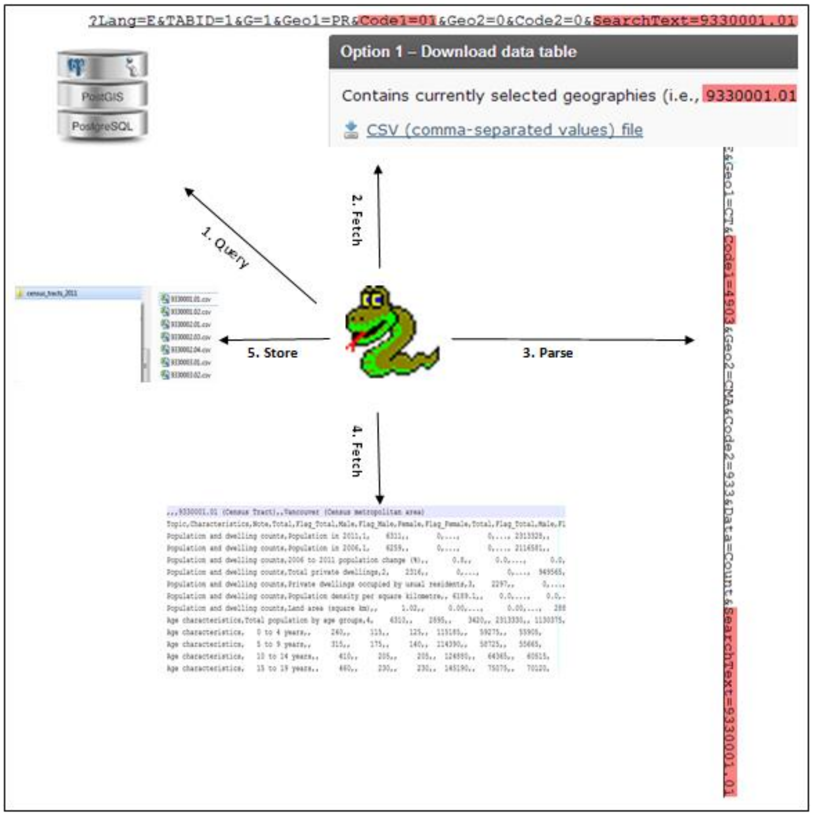


Figure 57: Getting data from Statistics Canada web site

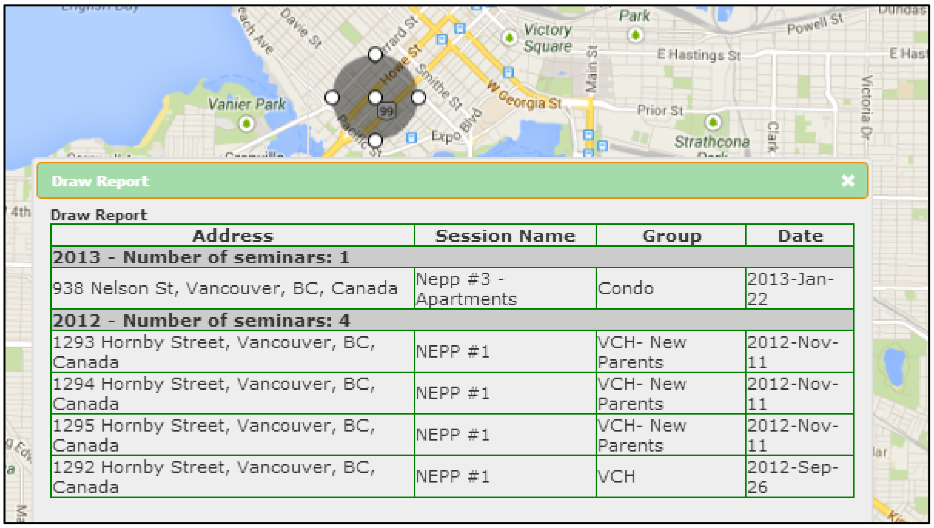
The following Python code shows how to do this. It serves as an example of the power and elegance of the Python programming language.

```
# Assumes the user has the psycopg2 extension and a PostgreSQL
# database with table of census tract data in it
import psycopg2
import urllib
from common import * # common has the database credentials
connectionString = "dbname='%s' user='%s' host='%s' password='%s'" %
(dbname,user,host,password) # these come from common.py
try: # Try to connect to the PostgreSQL database
    conn = psycopg2.connect(connectionString)
except:
    print "I am unable to connect to the database"
    sys.exit()
'''
The first url below is the one that displays the census tract page. On
that page is the code1 value, which the second url needs. Extracting
that code1 value, the program then makes the url that returns the csv
file. The %s is the placeholder for the census tract and code1 value
for each census tract.
'''
urlTemplate = "http://www12.statcan.ca/census-recensement/2011/dp-
pd/prof/search-
recherche/frm_res_geocode.cfm?Lang=E&TABID=3&SearchText=%s"
```

```
urlCSVTemplate = "http://www12.statcan.ca/census-recensement/2011/dp-
pd/prof/details/download-
telecharger/CSV.cfm?Lang=E&Geo1=CT&Code1=%s&Geo2=CMA&Code2=933&Data=Co
unt&SearchText=%s&SearchType=Begins&SearchPR=01&B1=All&Custom=&TABID=3
"
query = \
'''
SELECT ctuid
FROM census_tract
'''
cursor = conn.cursor()
cursor.execute(query)
lstResult = cursor.fetchall() # get all the results
counter = 0 #Make a counter to tell me how many files processed
for ctuid, in lstResult:
    counter += 1
    url = urlTemplate % ctuid # interpolate the census id into the url
    fp = urllib.urlopen(url) # open the url as if it is a file
    content = fp.read() # read the contents of the 'file'
    fp.close()
    begin = content.find("Code1")+ 6 # find where Code1 begins
    end = content.find("&",begin) # find where Code1 value ends
    code1 = content[begin:end] # Slice out the Code1 value
    urlCSV = urlCSVTemplate % (code1,ctuid) # interpolate again
    fpCSV = urllib.urlopen(urlCSV) # open the second url
    contentCSV = fpCSV.read()
    fpCSV.close()
    # There is a crlf plus a cr in the returned file, so...
    contentCSV = contentCSV.replace("\r\n","\n") #replace characters
    # Make the file name from the ctuid itself
    pathToFile = "census_tracts_2011/%s.csv" % ctuid
    outFileHandle = open(pathToFile,"w") # open a file for write
    outFileHandle.write(contentCSV) # write the csv content
    outFileHandle.close() # close the file
    if counter % 2 == 0: # tell me what's been done
        print "Number of files written:",counter
print "number of census tracts",counter
```

Google Circles and PostGIS Circles

When the user draws a circle on the map and then clicks **Get Draw Report**, a report appears in a dialog that shows the NEPP seminars that have taken place within the area of the circle (Figure 58). How does this magic happen?



Address	Session Name	Group	Date
2013 - Number of seminars: 1			
938 Nelson St, Vancouver, BC, Canada	Nepp #3 - Apartments	Condo	2013-Jan-22
2012 - Number of seminars: 4			
1293 Hornby Street, Vancouver, BC, Canada	NEPP #1	VCH- New Parents	2012-Nov-11
1294 Hornby Street, Vancouver, BC, Canada	NEPP #1	VCH- New Parents	2012-Nov-11
1295 Hornby Street, Vancouver, BC, Canada	NEPP #1	VCH- New Parents	2012-Nov-11
1292 Hornby Street, Vancouver, BC, Canada	NEPP #1	VCH	2012-Sep-26

Figure 58: Google circle and Draw Report

The first thing to understand is that there are two software programs combining with each other here, Google Maps and the PostGIS extension of the PostgreSQL database, and that they don't automatically know about each other. Google Maps must expose enough information about its circle so that PostGIS can recreate the circle and query the database for those seminars that fall within the circle.

Google Maps exposes two facts about its circle, the radius of the circle and the center point. Having those two facts, the browser uses the Google geometry library to also find the four points to the north, south, east, and west of the radius of the circle:

```
spherical = google.maps.geometry.spherical;
center = selectedShape.getCenter();
radius = selectedShape.getRadius();
north = spherical.computeOffset(center, radius, 0);
east = spherical.computeOffset(center, radius, 90);
south = spherical.computeOffset(center, radius, 180);
west = spherical.computeOffset(center,radius,270);
```

The browser now performs an AJAX query, sending these four points to the server side PHP program. The PHP uses these four points to construct a spatial query to the database. The WHERE clause of the query illustrates the complex spatial operations of which PostGIS is capable:

```
WHERE
ST_WITHIN
(
  geometry,
  ST_MAKEPOLYGON
  (
    ST_CURVETOLINE
    (
      ST_GEOMFROMTEXT
      (
        'SRID=4326;
         CIRCULARSTRING
```

```
        (
          -123.1199 49.2662,
          -123.1098 49.2727,
          -123.0998 49.2662,
          -123.1098 49.2596,
          -123.1199 49.2662
        ) -- end CIRCULARSTRING
    ') -- end ST_GEOMFROMTEXT
     ) -- end ST_GEOMFROMTEXT
  ) -- end ST_CURVETOLINE
) -- end ST_WITHIN
```

This query first creates a CIRCULARSTRING, which is a curved string that begins and ends on the same point. The CIRCULARSTRING acts as input to ST_GEOMFROMTEXT, which makes a valid geometry object, using the spatial reference id (SRID) for WGS84, which is what Google Maps uses.

The geometry object then acts as input to ST_CURVETOLINE. This function converts a CIRCULARSTRING to a valid polygon, with a default value of 128 segments. This is because PostGIS does not actually do a spatial query with a circle, but rather with an approximation of a circle.

Finally the polygon acts as input to ST_WITHIN, which PostGIS uses to retrieve features within the polygon.

PHP retrieves the results of the spatial query, formats it as an HTML table and sends it back to the browser. The browser invokes a jQuery dialog and outputs the HTML table to the dialog.

Using PostGIS Built-In Tools

The PostGIS spatial extension in PostgreSQL comes with a large array of built-in tools. This section describes some of the tools that the author used in this study. They demonstrate the spatial capabilities of PostgreSQL and the PostGIS extension.

Loading a Shapefile into PostgreSQL

PostGIS has several methods for importing shapefiles directly into PostgreSQL and for exporting PostgreSQL spatial tables directly as shapefiles. One way to import is to use the Shapefile Import/Export Manager (shp2pgsql-gui.exe) (Figure 59).

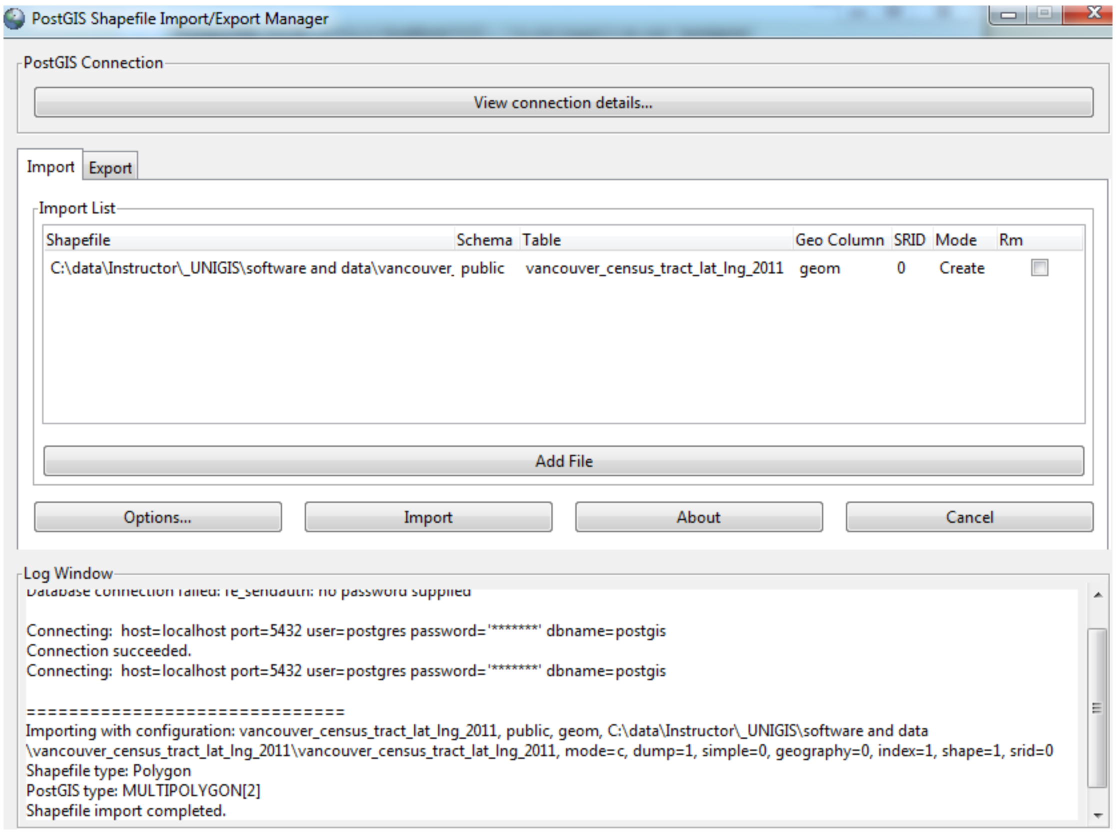


Figure 59: Loading a shapefile directly into PostgreSQL using shp2pgsql-gui.exe

It is also possible to load a shapefile directly into a PostgreSQL spatial table using the **shp2pgsql** and **psql** tools. There is copious documentation on these tools on the World Wide Web; for here I will give the command line syntax.

1. Invoke a command line window. On Windows 7,you must right-click the **Command Prompt** icon in the **Accessories** program group and select **Run as administrator** in order to run these commands.
2. Navigate to the **bin** folder of the PostgreSQL distribution folder.
3. Invoke shp2pgsql to create an SQL file suitable for insert into PostgreSQL with this syntax:

```
shp2pgsql "path_to_shapefile"  schemaname.tablename  >
filename.sql
```

For example:

```
Shp2pgsql
"C:\VulnerableVancouver\vancouver_neighbourhood\csg_neighbourhood
_areas" public.vancouver_neighbourhood_utm10  >
vancouver_neighbourhood_utm10.sql
```

This command creates the vancouver_neighbourhood_utm10.sql file with instructions to create the public.vancouver_neighbourhood_utm10 table.

4. Invoke psql with arguments of username, database, and file to load:

```
psql -U myUserName -d postgis -f
vancouver_neighbourhood_utm10.sql
```

This command causes psql to open the postgis database and execute the statements in vancouver_neighbourhood_utm10.sql, thus creating the vancouver_neighbourhood_utm10 table in PostgreSQL.

Repairing Invalid Geometry

Open Source data may have invalid geometries in it. In this project, the neighbourhoods shapefile in data.vancouver.ca had two invalid polygons in it, resulting in the error message: "TopologyException: side location conflict".

Executing the ST_IsValidReason() function identified the polygons (Figure 60):

```
select name, ST_IsValidReason(geom)
from vancouver_neighbourhood_utm10
```

name	st_isvalidreason
Arbutus-Ridge	Valid Geometry
Shaughnessy	Valid Geometry
Riley Park	Valid Geometry
South Cambie	Valid Geometry
Kensington-Cedar Cottage	Valid Geometry
Renfrew-Collingwood	Valid Geometry
Oakridge	Valid Geometry
Killarney	Self-intersection[498295.443804653 5450129.85183047
Victoria-Fraserview	Valid Geometry
Sunset	Valid Geometry
Marpole	Valid Geometry
Kerrisdale	Valid Geometry
Dunbar-Southlands	Valid Geometry
West Point Grey	Valid Geometry
Kitsilano	Valid Geometry
Fairview	Valid Geometry
Mount Pleasant	Valid Geometry
Downtown	Valid Geometry
West End	Valid Geometry
Strathcona	Self-intersection[492755.745427214 5459386.12774228
Grandview-Woodland	Valid Geometry
Hastings-Sunrise	Valid Geometry

Figure 60: Invalid geometries in Vancouver Open Data neighbourhoods

Using QGIS, the invalid geometries can be easily seen (Figure 61).

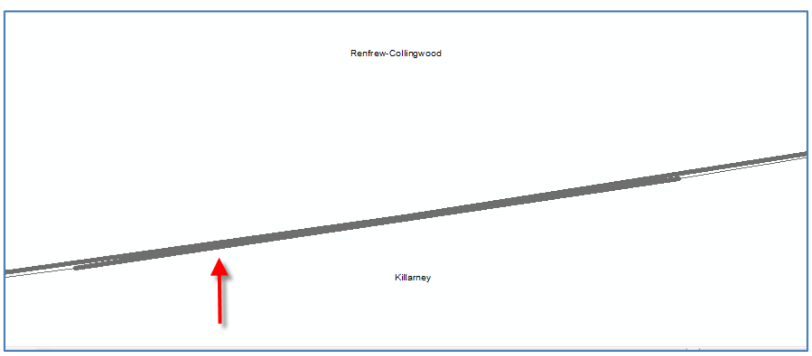


Figure 61: Invalid geometry in Killarney polygon

Using ST_Buffer with a buffer length of 0.0 creates an identical geometry that is valid because it uses OGC topology rules (opengeo.org, date unknown). It is also necessary to wrap the buffered polygon in the ST_Multi function because the column type of vancouver_neighbourhood_utm10 is multipolygon and ST_Buffer returns a polygon.

```
UPDATE vancouver_neighbourhood_utm10
SET geom = ST_Multi(ST_Buffer(geom,0.0))
where ST_IsValid(geom) = false
```

Converting from MultiPolygon to Polygon

Polygons from Statistics Canada are sometimes multipolygons; that is, they are composed of one major polygon and smaller polygons. These smaller polygons are usually extraneous to the main polygon.

Importing into PostgreSQL using shp2pgsql-gui.exe creates these multipolygons in PostgreSQL. However, to work with PHP, which can only parse a string representation of the multipolygons, it is necessary to convert the multipolygons to polygons. To do this, first create an additional geometry column named geom2:

```
SELECT
AddGeometryColumn('mySchemaName','myTableName','myGeometryColumnName',
'4326','POLYGON',2);
```

Then populate the column with the first polygon in the multipolygons. The `ST_GeometryN` function extracts the polygon specified by the second argument of the function call, in this case the first polygon.

```
UPDATE myTableName
set myGeometryColumnName = ST_GeometryN(geom,1)
```

Next, remove the geom column and rename the `myGeometryColumnName` column to geom. Now you have a PostgreSQL table with a geometry column of type polygon.

Using QGIS for Spatial Operations

QGIS is an Open Source GIS desktop program that offers much of the same functionality as ArcGIS. The Vancouver census tract polygons were derived using QGIS. This section describes that process and in doing so demonstrates the potential of QGIS to provide an Open Source alternative to ArcGIS.

To derive Vancouver census tract polygons:

1. Make a new map in QGIS and add the Canada census tracts and the Vancouver boundary file. These polygons are available as shapefiles from the Statistics Canada website at http://www12.statcan.gc.ca/census-recensement/2011/geo/bound-limit/bound-limit-eng.cfm.

2. Create centroids from the census polygons (Figure 62). It is necessary to create centroids because the spatial location query will not select tracts that are on the border of the Vancouver boundary polygon, but rather only tracts that are WITHIN the boundary polygon.

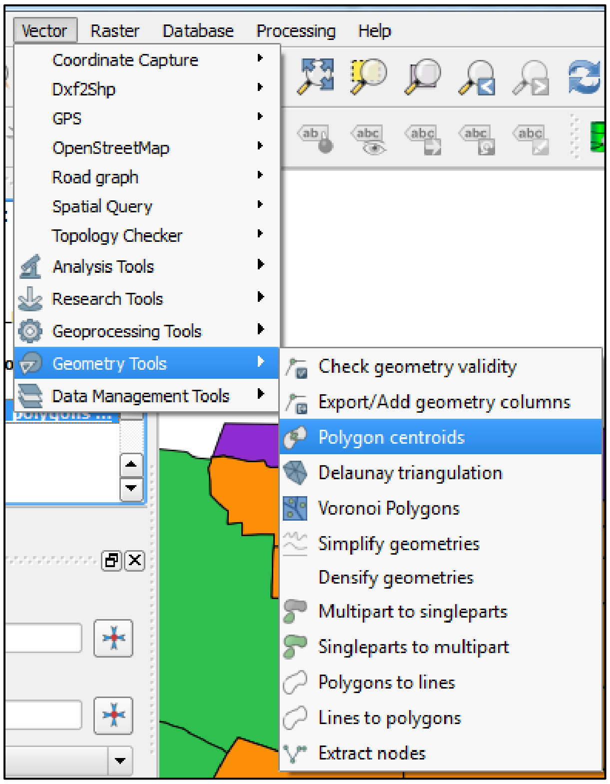


Figure 62: Creating polygon centroids

3. Invoke the Spatial Query tool (Figure 63). This tool is hidden beneath the Coordinate Capture icon (Figure 64).

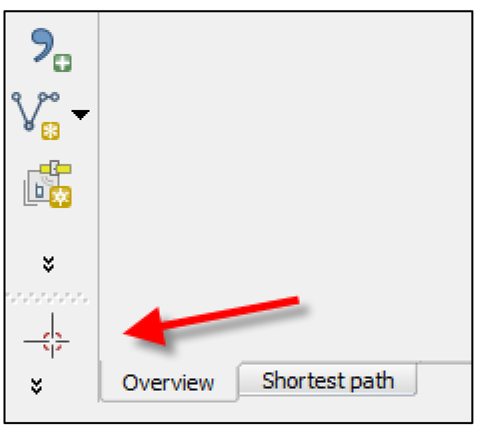


Figure 63: Spatial selection tool is hidden under Coordinate Capture icon

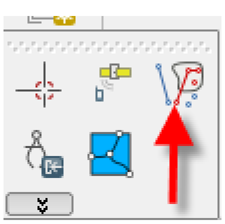


Figure 64: Spatial selection icon

4. Configure the spatial query so that QGIS selects the census tract centroids that are within the Vancouver boundary polygon (Figure 65).

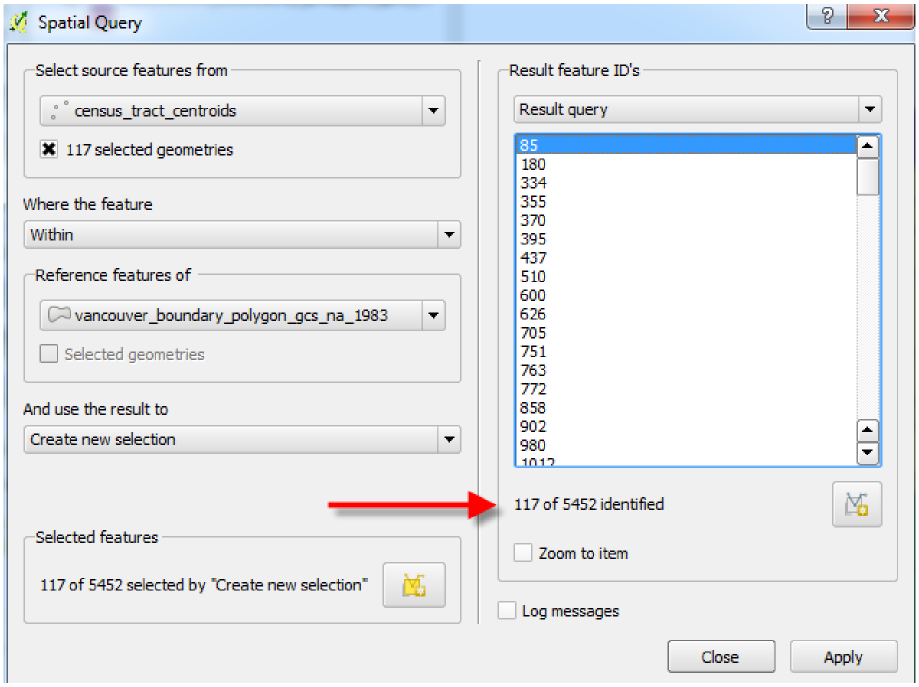


Figure 65: Spatial Query results for Vancouver census tracts

This creates the correct number of 117 census tract centroids.

5. Join the census tract centroids back to the Canada census tract polygons (Figure 66, Figure 67).

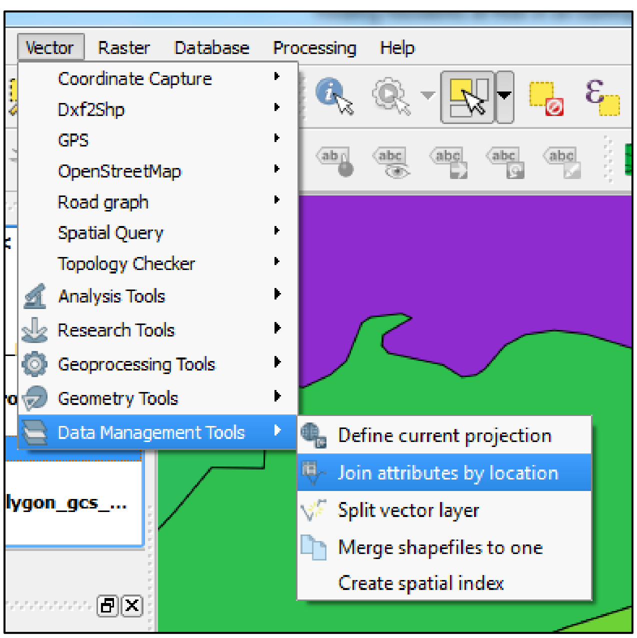


Figure 66: Initiating a spatial join between Vancouver centroids and census tract polygons

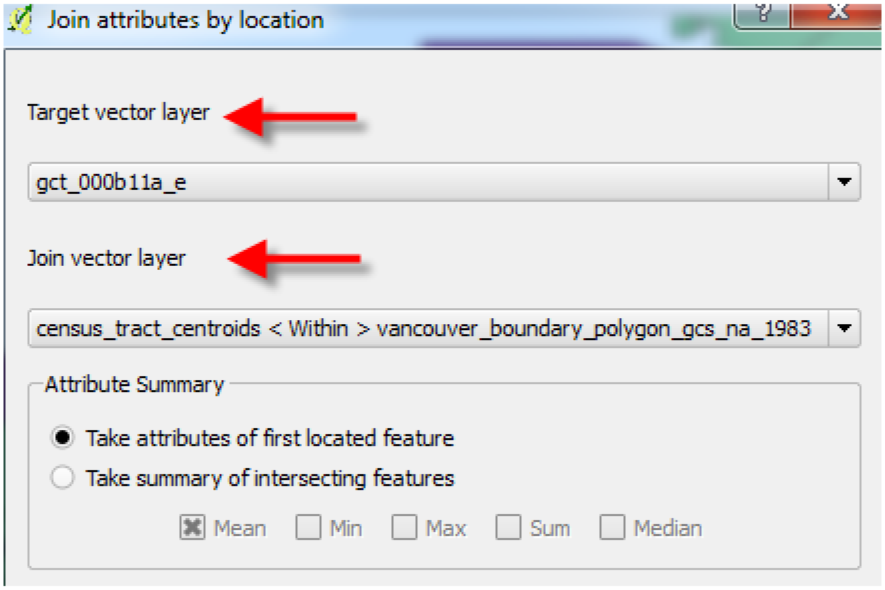


Figure 67: Joining centroids back to polygons

The result of this operation is 116 census tract polygons, not 117. This is because one census tract polygon did not join to the census tract centroids because the centroid for this polygon was actually outside of the polygon (Figure 68).

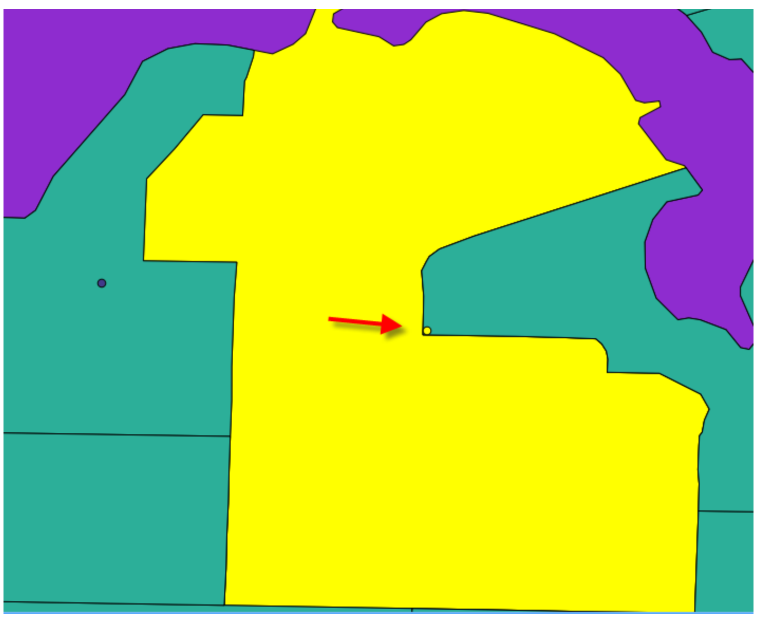


Figure 68: Centroid of polygon is not within polygon

6. To correct this situation, first put the Vancouver census centroids layer into edit mode (Figure 69). This enables editing tools on the Edit toolbar.

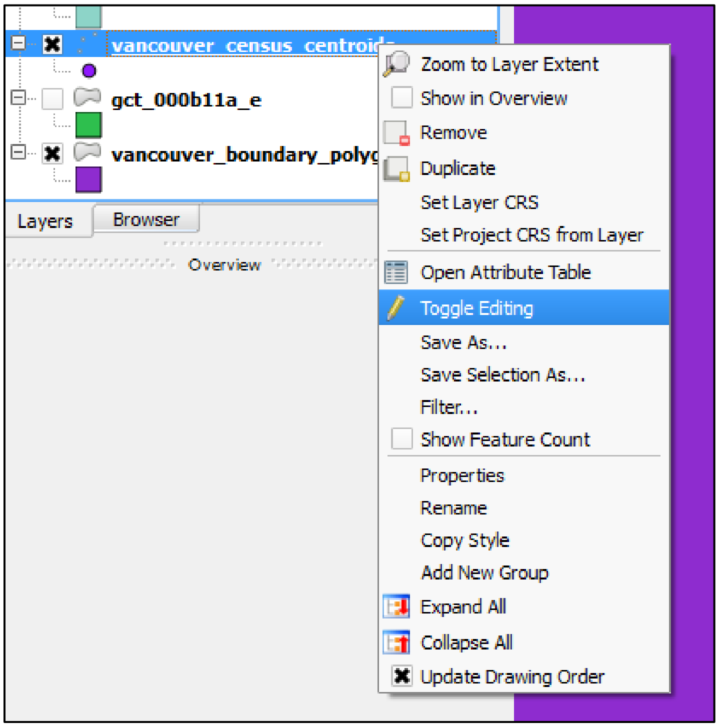


Figure 69: Entering Editing mode

7. Click the Move Feature tool (Figure 70), select the point feature on the map, and drag the point over the area of the missing Vancouver census tract polygon (Figure 71).

Figure 70: Move Feature tool

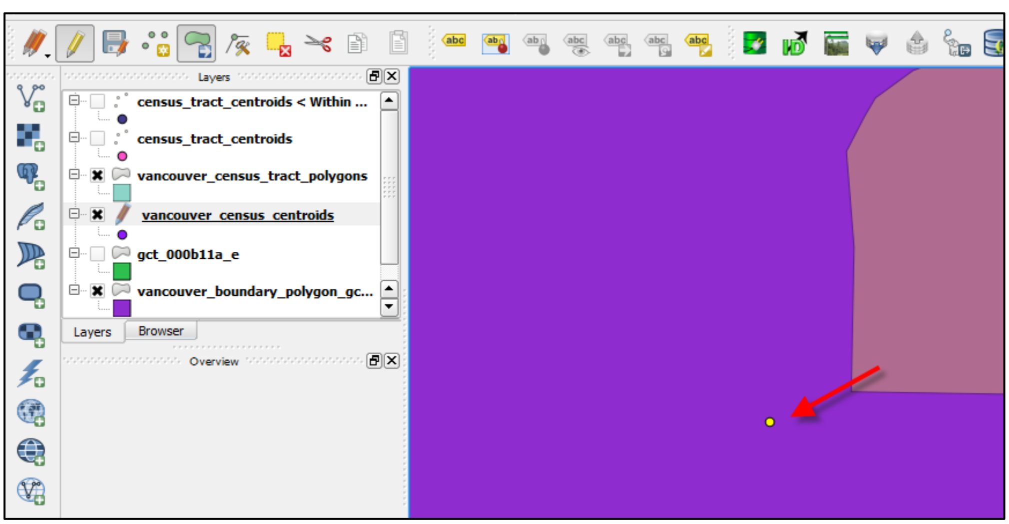


Figure 71: Moving a point feature

QGIS prompts the user to save changes when exiting Edit Mode (Figure 72).

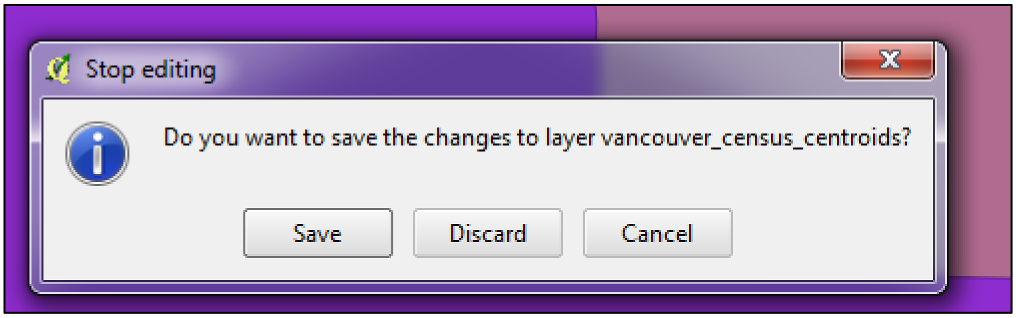


Figure 72: Saving changes to the point features

8. Repeat the spatial join, this time specifying the edited Vancouver census centroids layer as the Join vector layer (Figure 73).

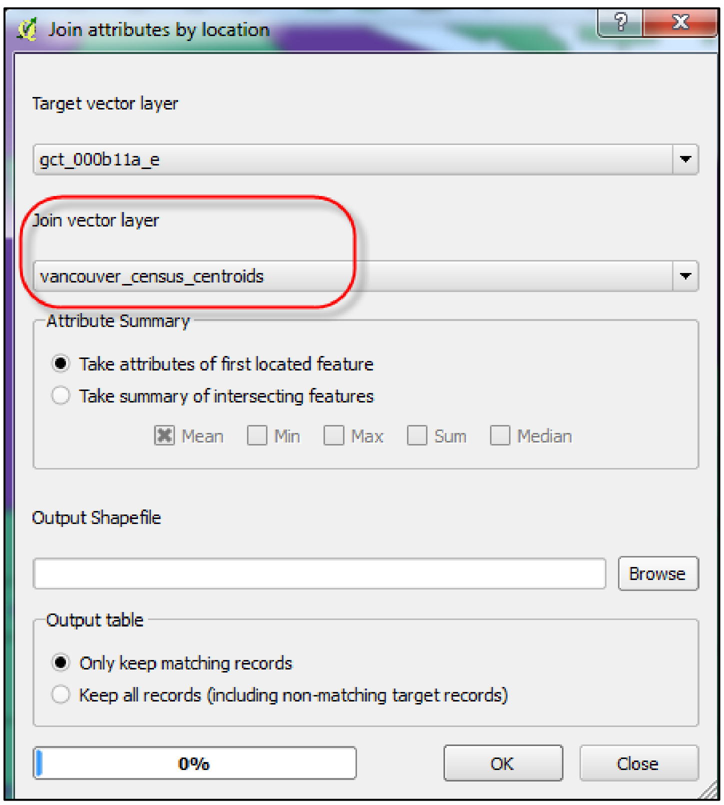


Figure 73: Joining to edited vancouver_census_centroids

The result is the correct 117 tracts (Figure 74).

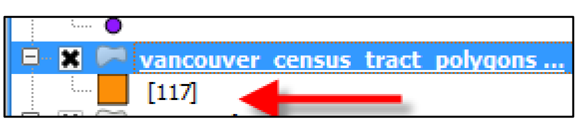


Figure 74: Feature count for Vancouver census tract polygons is 117

9. Save the selected Vancouver polygons as a shapefile, or insert directly into PostgreSQL.