Seismic Risk Analysis For The City Of Vancouver

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ESSE 4600: Geographic Information Systems (GIS) and Data Integration
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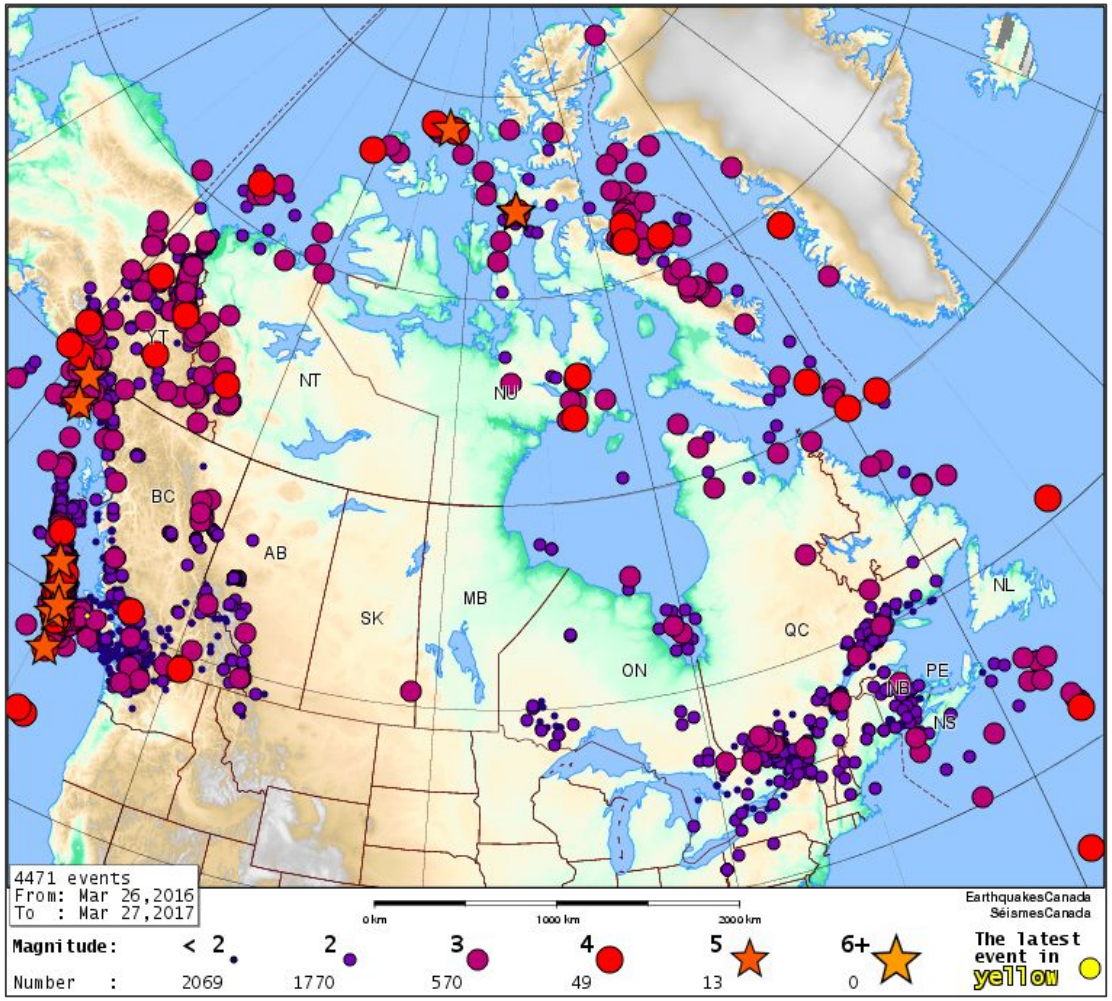
INTRODUCTION

- Earthquakes account for a large amount of human casualties

- Have abrupt and unpredictable nature
  - An in-depth understanding of an area's seismic risk is necessary in order to mitigate damage beforehand

Earthquakes in Canada (March 2016-2017)



http://www.earthquakescanada.nrcan.gc.ca/recent/maps-cartes/index-en.php?maptype=1y&tpl_region=canada

INTRODUCTION

Our Task:

Model the seismic risk of Vancouver City in British Columbia, to gain a better understanding of which sub-regions would suffer the greatest from the event of a nearby earthquake

INTRODUCTION

Why Vancouver City?

- High population density
- Close proximity to the convergent Pacific-North American tectonic boundary

The challenge:

Seismic information is acquired by different agencies during different time periods

- Requires data integration

RISK

Risk was modelled as a product of three factors:

1. **Seismic Hazard**
    - Historical geophysical data
    - Up-to-date structural geological information

2. **Socioeconomic Vulnerability**
    - Infrastructure quality
    - Effectiveness of local emergency services

3. **Exposure**
    - Population distribution
    - Building density

FACTORS OF INTEREST

- Several factors can contribute to the risk of seismic activity in the city of Vancouver

- Those which were studied included:
  - Roads and bridges
  - Buildings
  - Land use
  - Soil type
  - Population density
  - Seismic hazard

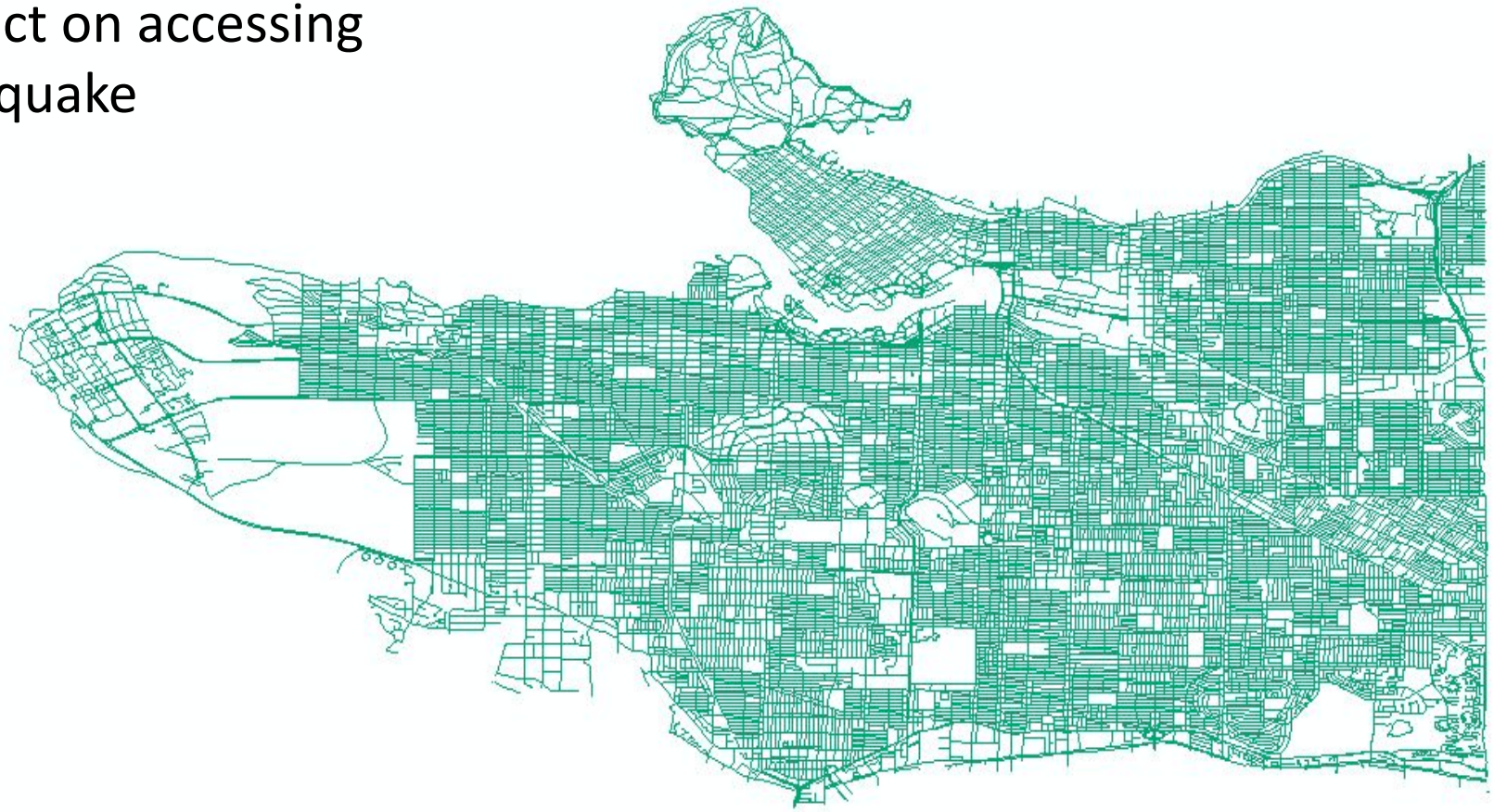
DATABASE

Roads

- Provide escape routes and guide towards low risk regions
- Can have significant impact on accessing regions affected by earthquake

- Dataset used:

  DMTI's 2015 RoadsLine

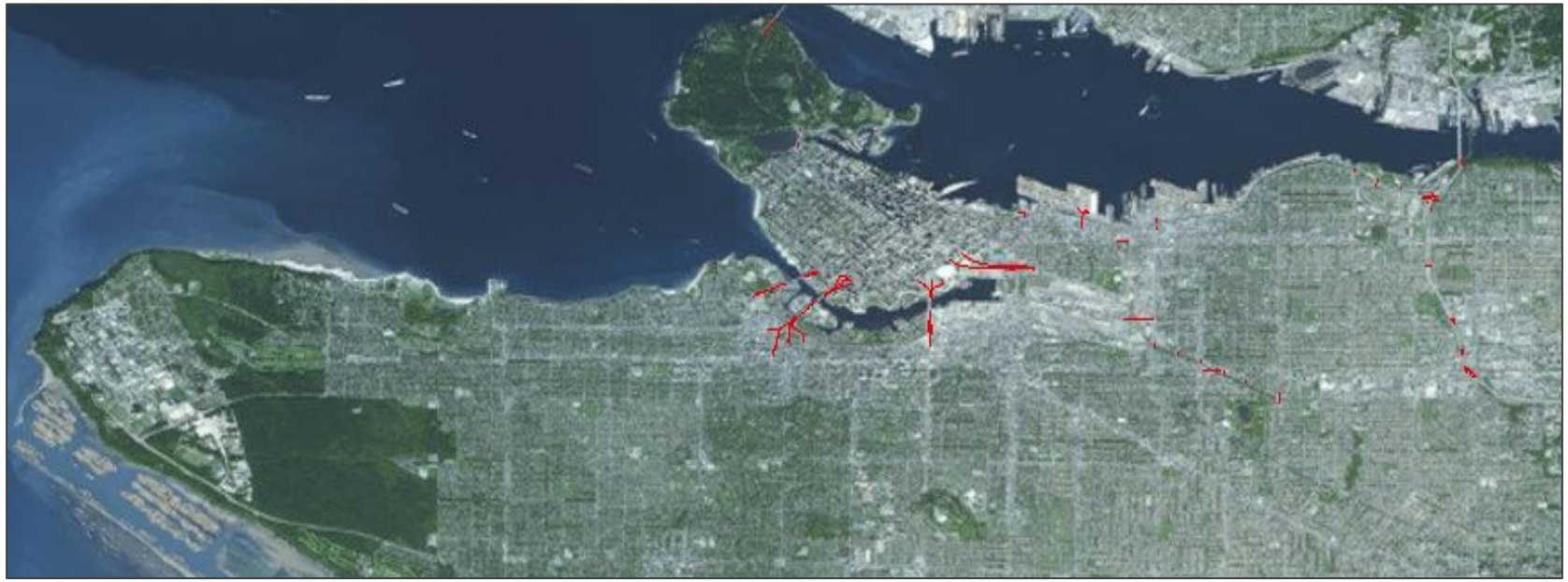


DATABASE

Bridges

- If they collapse, they could isolate regions in the city and make them inaccessible
- Included because of possible omission in roads dataset

- Dataset used: DMTI's 2015 BridgesLine



DATABASE

Buildings

- Earthquakes are threats to the structure of buildings
- Necessary to consider:
  - Heights of buildings
  - Areas of building bases
  - Building age

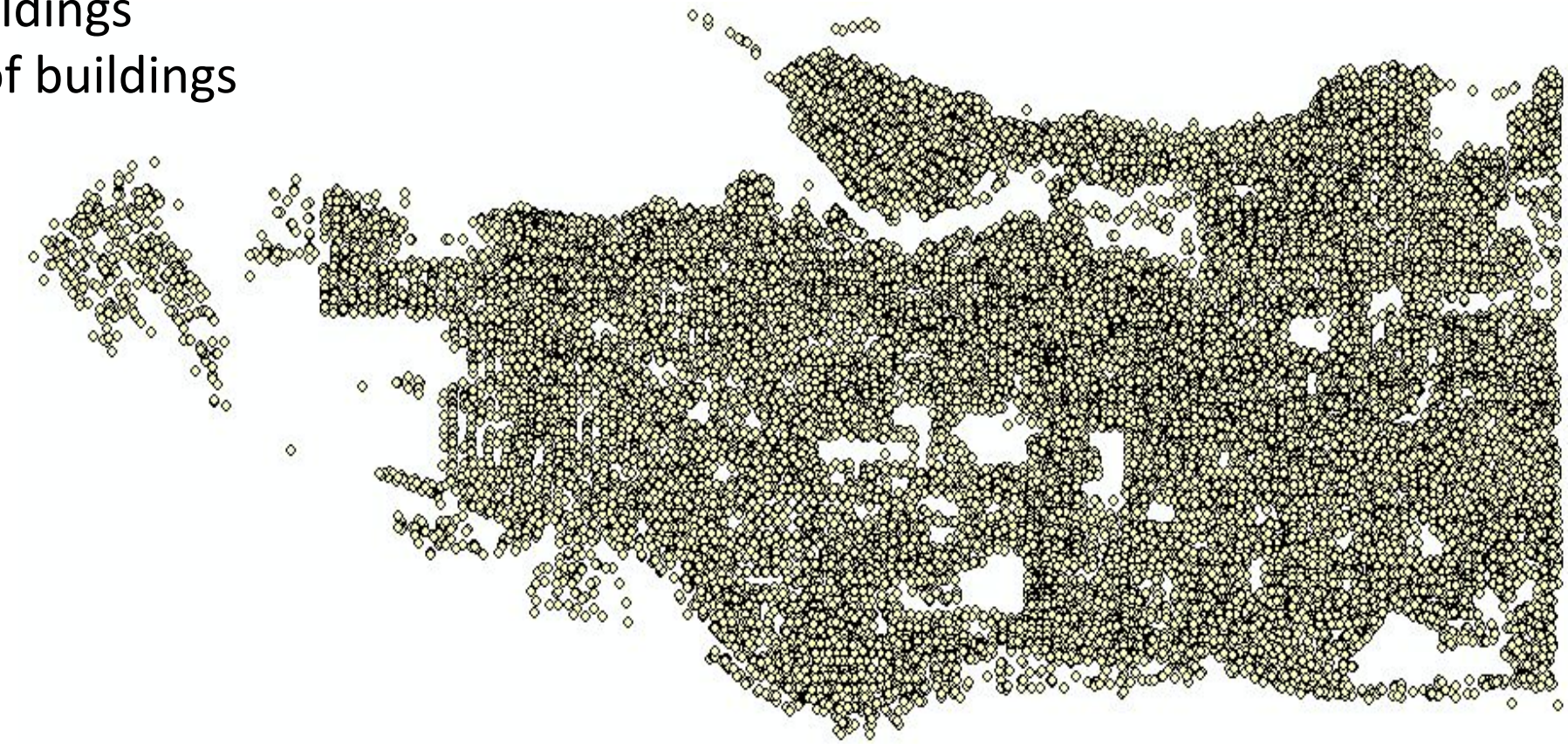
- Datasets used: DMTI's 2015 Enhanced Postal Point
  DMTI's 2015 Building Footprints

DATABASE

Buildings (Continued)

Enhanced Postal Point

- Represented locations of the centroid of buildings
- Provided age of buildings



DATABASE

Buildings (Continued)

Building Footprints

- Represented footprint of building rooftops
- Provided area and height of each building

DATABASE

Schools

- Children have lower capacity when dealing with exigent circumstances
- Schools are most probable location where younger community members would be present

- Dataset used: DMTI's 2014 Education (EDU)

DATABASE

Shelters

- Homeless population also likely to have lower capacity when dealing with exigent circumstances
- Shelters provide services such as temporary housing and food distribution
  - Beneficial after earthquake because can offer aid to others affected

- Dataset used:

Homeless Shelters
From City of Vancouver's Open Data Source

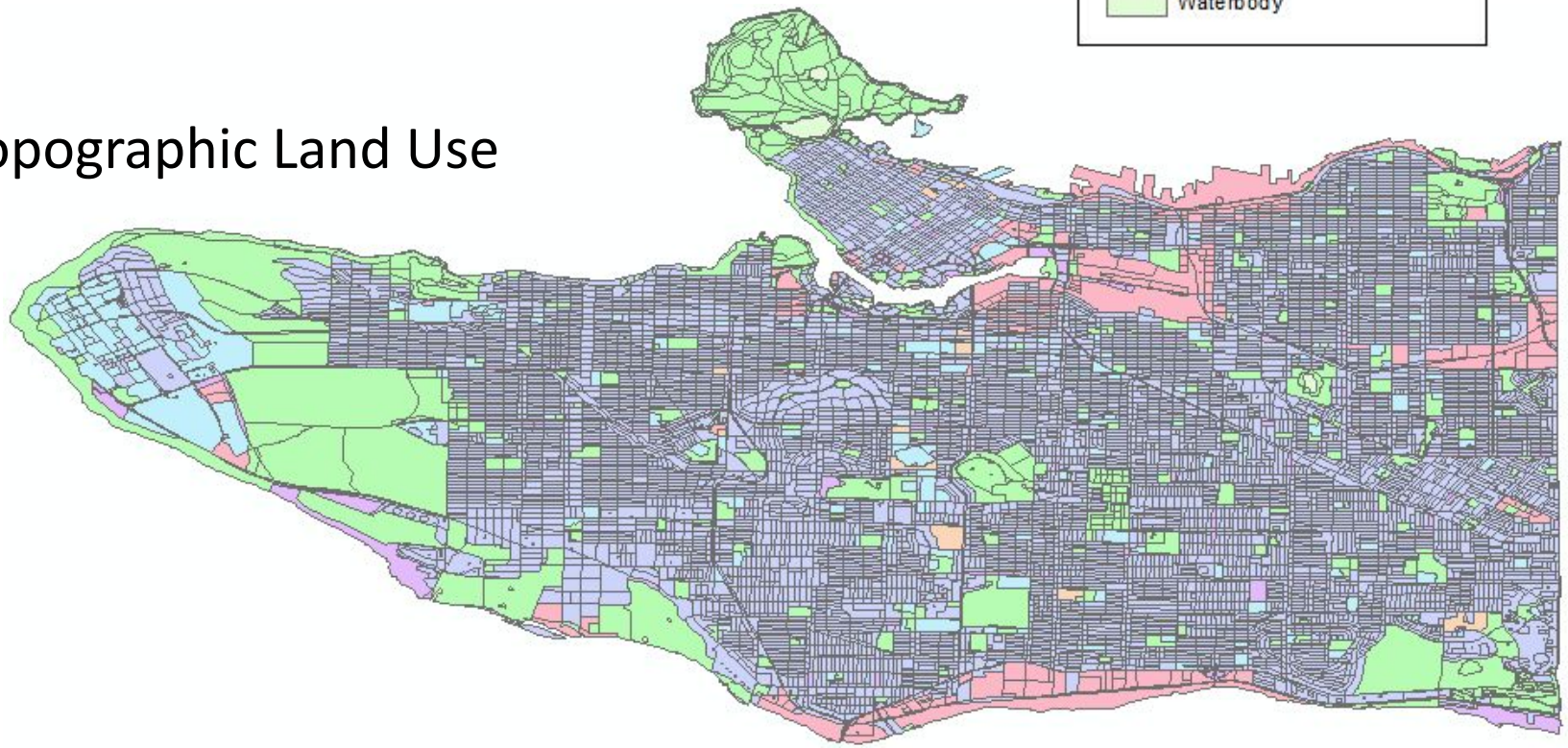
DATABASE

Land Use

- Necessary to classify sub-regions according to their use
  - Land uses can determine magnitude of risk in region

- Dataset used:

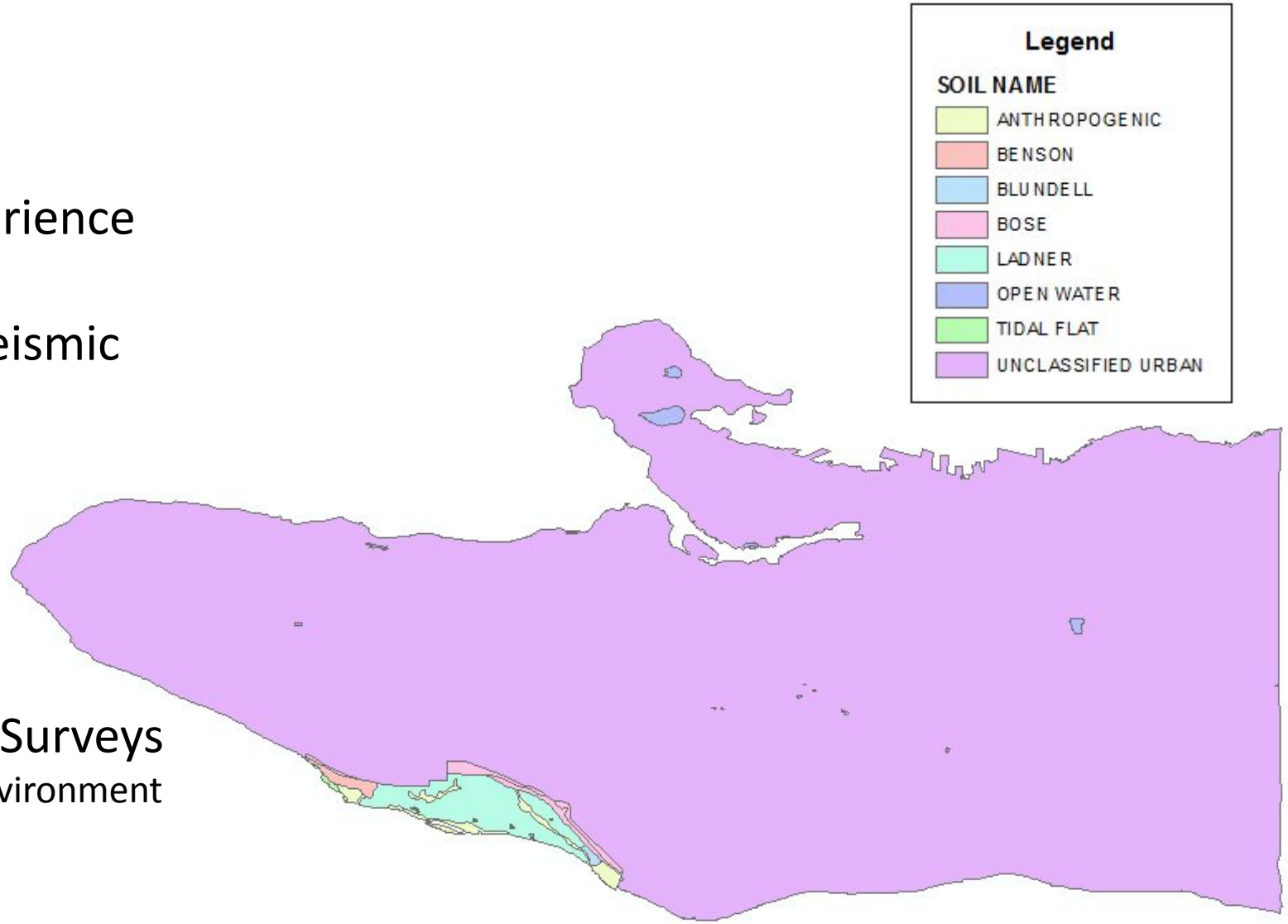
  DMTI's 2014 CanMap Topographic Land Use



DATABASE

Soil Type

- Regions composed of soft (water-saturated) soils experience liquefaction
  - Amplify magnitude of seismic event



- Dataset used:

  2016 British Columbia Soil Surveys
  By British Columbia's Ministry of Environment

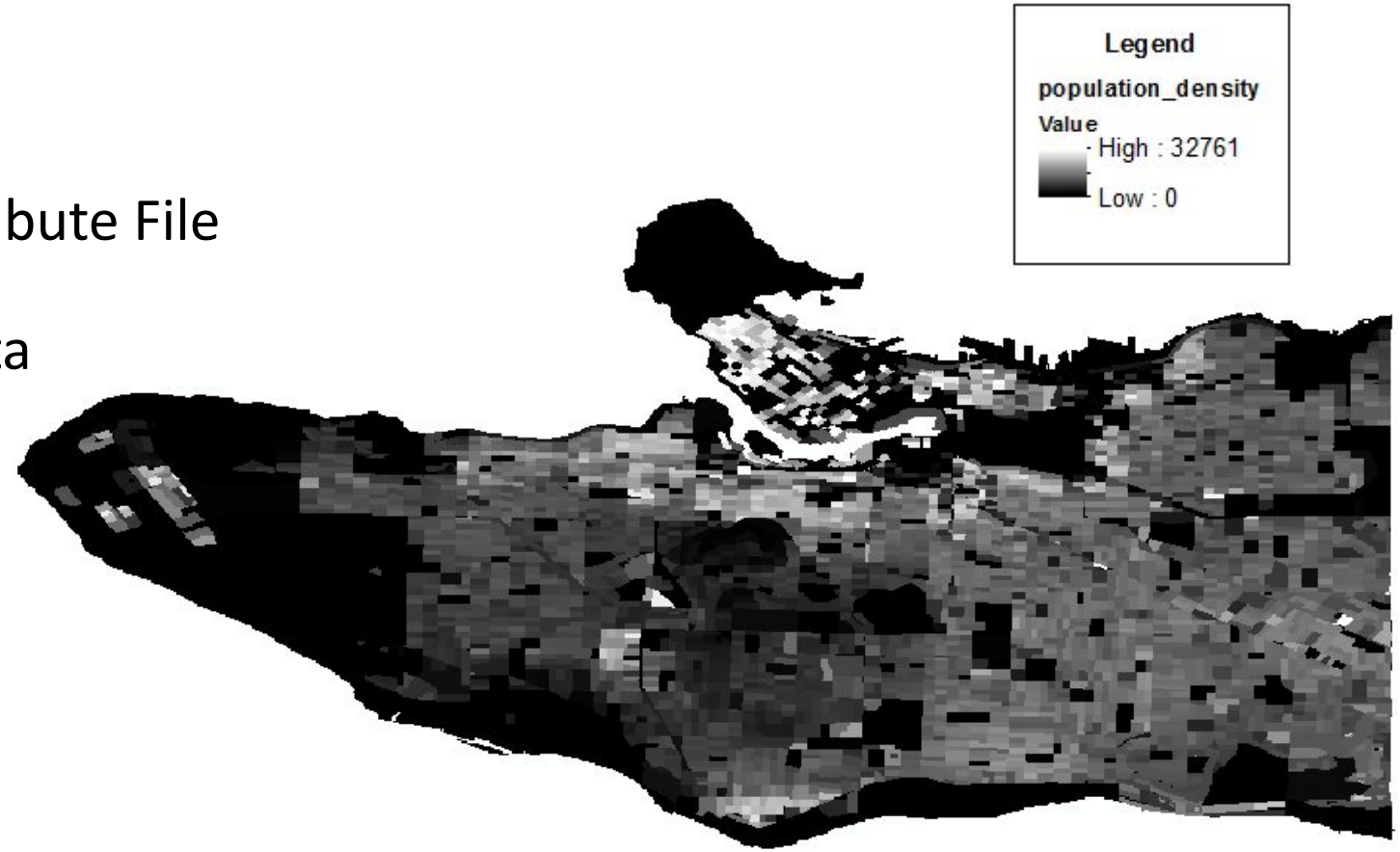
DATABASE

Population Density

- Regions with high population density were likely to have more people injured

- Dataset was created using:

  Canada's 2011 Geographic Attribute File
  (2011 Census Data)
  Defining Regions Of Census Data
  (2011 Dissemination Block)



DATABASE

Seismic Hazard

- Necessary to have hazard values of seismic activity ranging from low to extreme
- Contrary to initial assumption, Vancouver City was composed of only low and moderate hazard regions

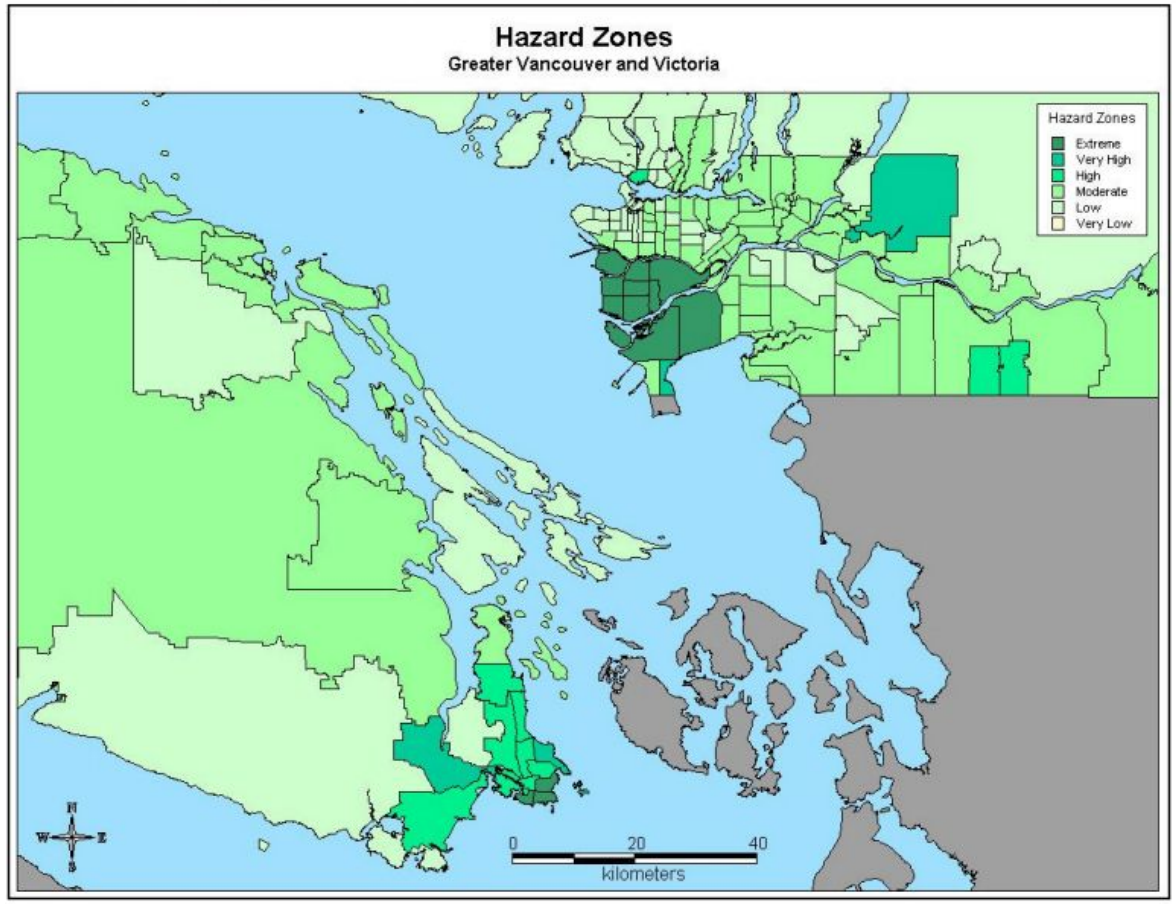
Dataset was created/digitized using:

PDF maps from 2004 study

By Institute for Catastrophic Loss Reduction

DATABASE

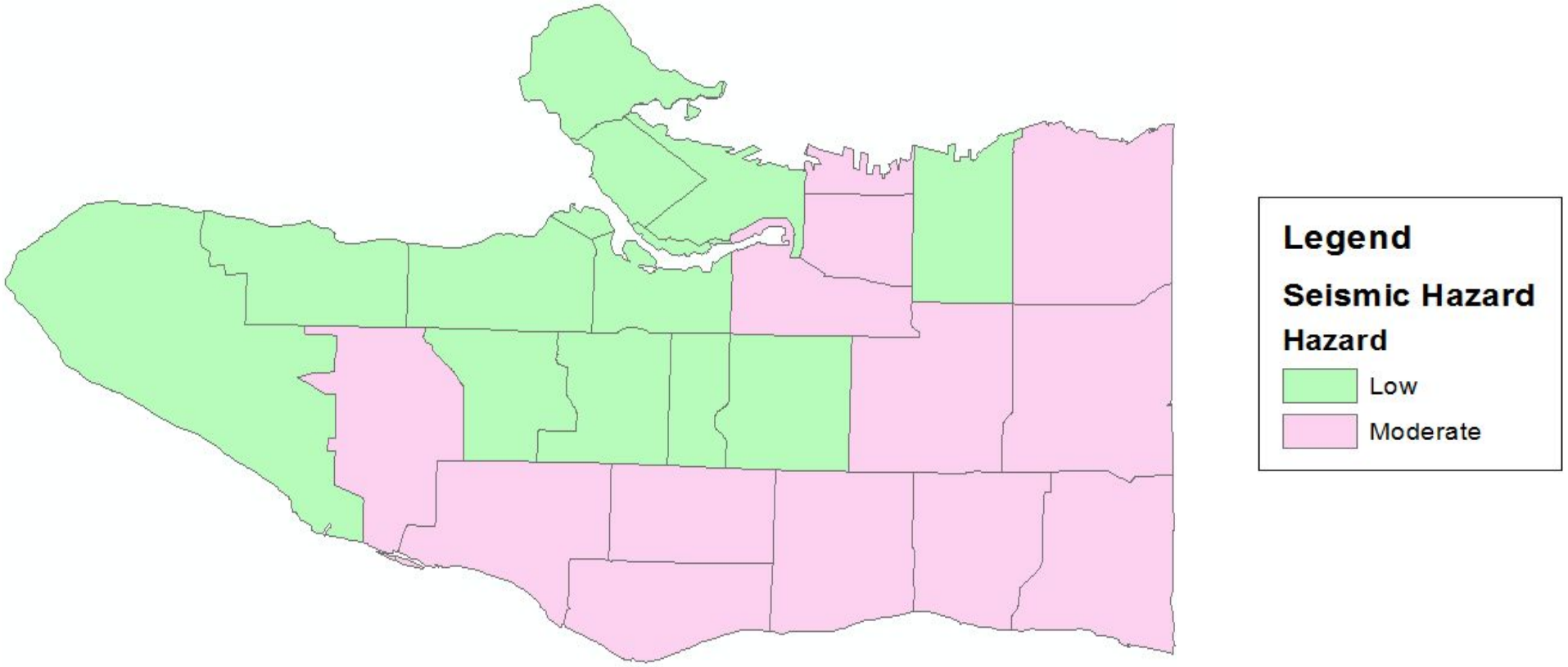
Seismic Hazard (Continued)



PDF maps from 2004 study
By Institute for Catastrophic Loss Reduction

DATABASE

Seismic Hazard (Continued)



DATA PROCESSING

$$\boldsymbol{Risk = Vulnerability\ x\ Hazard\ x\ Exposure}$$

DATA PROCESSING

Vulnerability of Region

Contributing factors:

- Age of buildings
- Height to area of base ratio of buildings
- Land Use
- Soil Type
- Distance to schools
- Distance to roads and bridges
- Distance to shelters

Seismic Hazard of Region

Contributing factors:

- Defined seismic hazard

Exposure of Region

Contributing Factors:

- Population density
- Building density

DATA PROCESSING

- Risk computed in reference to other regions
  - If necessary:
    - Data of layers reclassified
    - Complement values of layers considered
  - Each layer scaled relative to its own maximum value

- Each layer for the vulnerability map was weighed using AHP and their relative importance was found

DATA PROCESSING

Vulnerability Map

Analytical Hierarchal Process (AHP)

Layers weighed based on level of importance

- Pairwise comparison
- Scaled from 1 to 9
  - 1 □ Least
  - 9 □ Most

Criteria	Age of Building	Land Use	Shelter Distance	School Distance	Height - Base Ratio	Bridges	Soil Types	Roads
Age of Building	1.00	3.00	9.00	5.00	2.00	3.00	4.00	4.00
Land Use	0.33	1.00	3.00	1.67	0.67	1.00	1.33	1.33
Shelter Distance	0.11	0.33	1.00	0.56	0.22	0.33	0.44	0.44
School Distance	0.20	0.60	1.80	1.00	0.40	0.60	0.80	0.80
Height -Base Ratio	0.50	1.50	4.50	2.50	1.00	1.50	2.00	2.00
Bridges	0.33	1.00	3.00	1.67	0.67	1.00	1.33	1.33
Soil Types	0.25	0.75	2.25	1.25	0.50	0.75	1.00	1.00
Roads	0.25	0.75	2.25	1.25	0.50	0.75	1.00	1.00

Regional Vulnerability Weighting

DATA PROCESSING

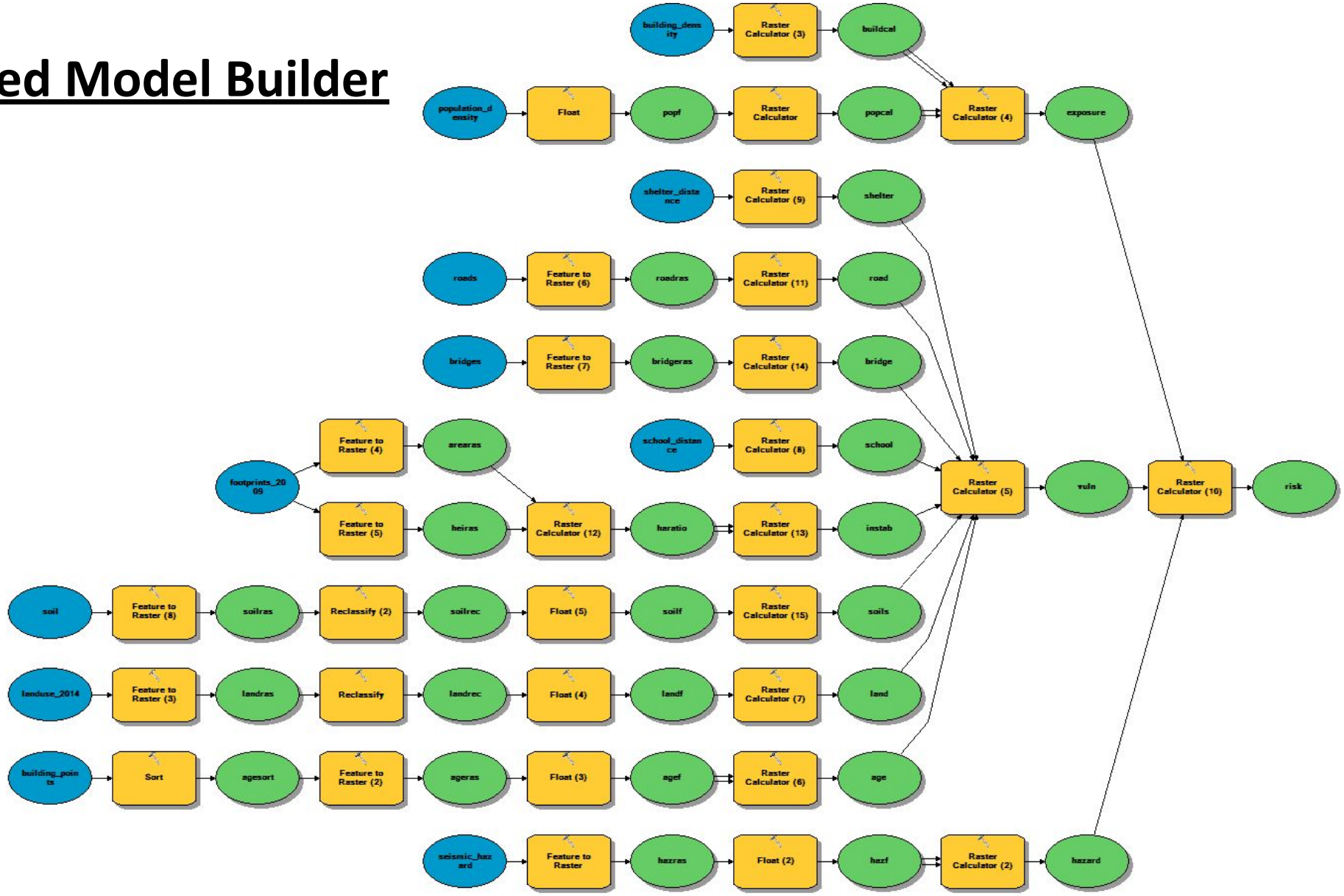
Relative Importance of Features

Criterion	Weight (%)
Age of Building	33.6
Land Use	11.2
Shelter Distance	3.7
School Distance	6.7
Height/Base Ratio	16.8
Bridges	11.2
Soil Types	8.4
Roads	8.4

Layer Weights for Elements of the Vulnerability Layer

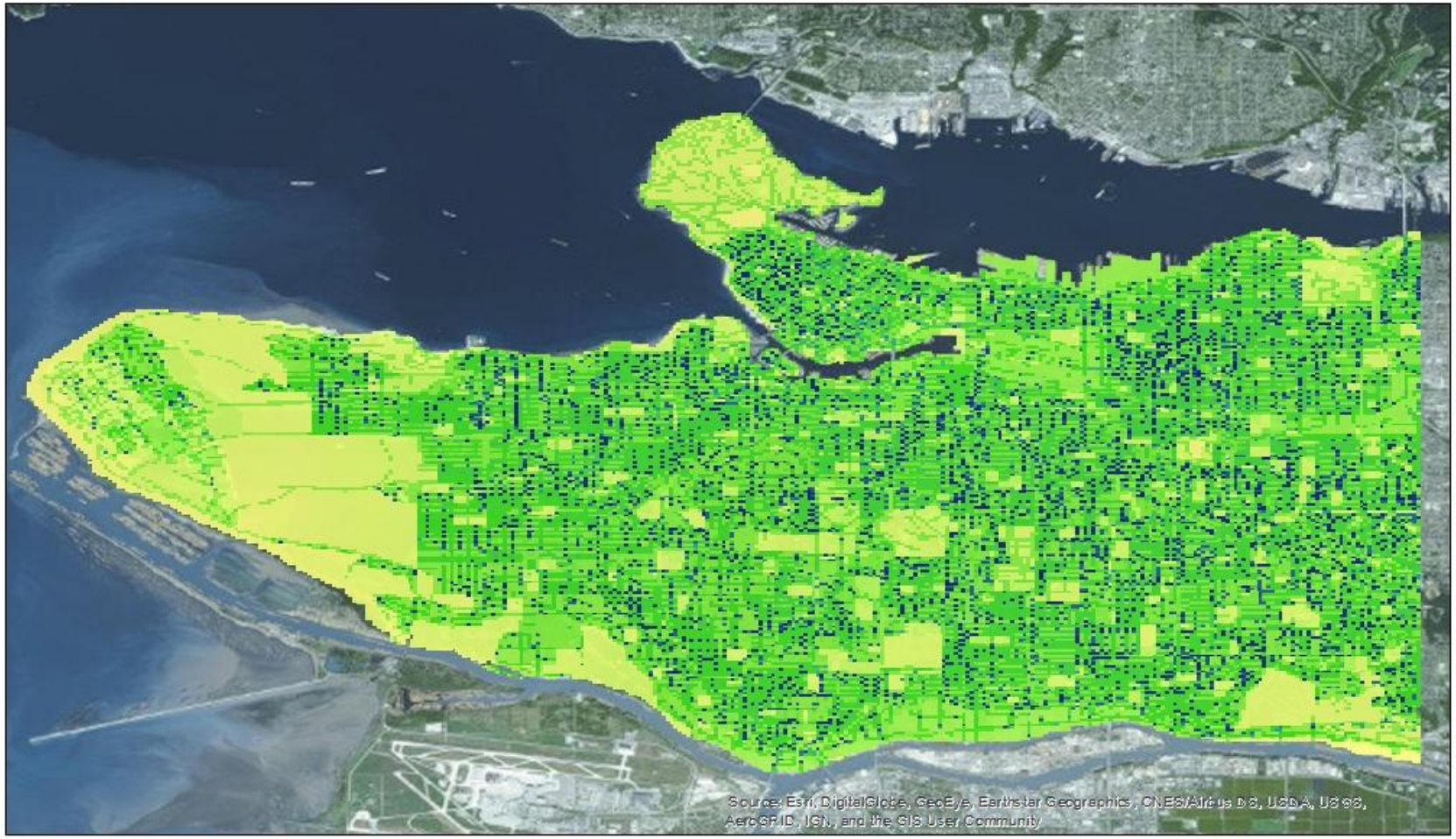
DATA PROCESSING

Generated Model Builder



RESULTS

Seismic Vulnerability Map of Vancouver City



Legend

vuln

Value

High : 0.894677

Low : 0.0751099

0 1.75 3.5 7 Kilometers

1:105,000

N

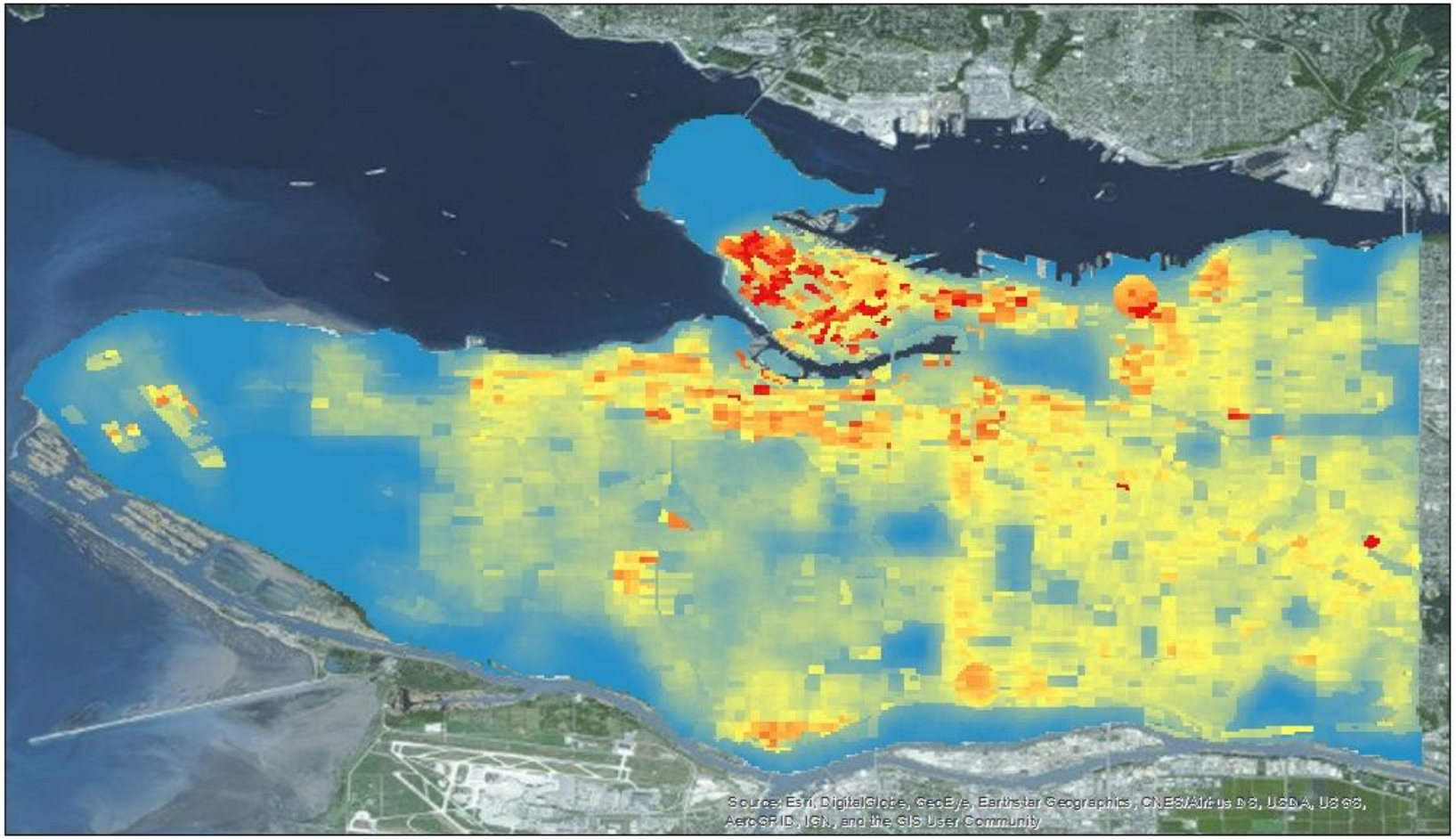
W E

S

Produced by Dawid, Agata and Dmitriy on March 28, 2017

RESULTS

Seismic Exposure Map of Vancouver City



Legend

exposure

Value

High : 0.874255

Low : 0

0 1.75 3.5 7 Kilometers

1:105,000

N

W E

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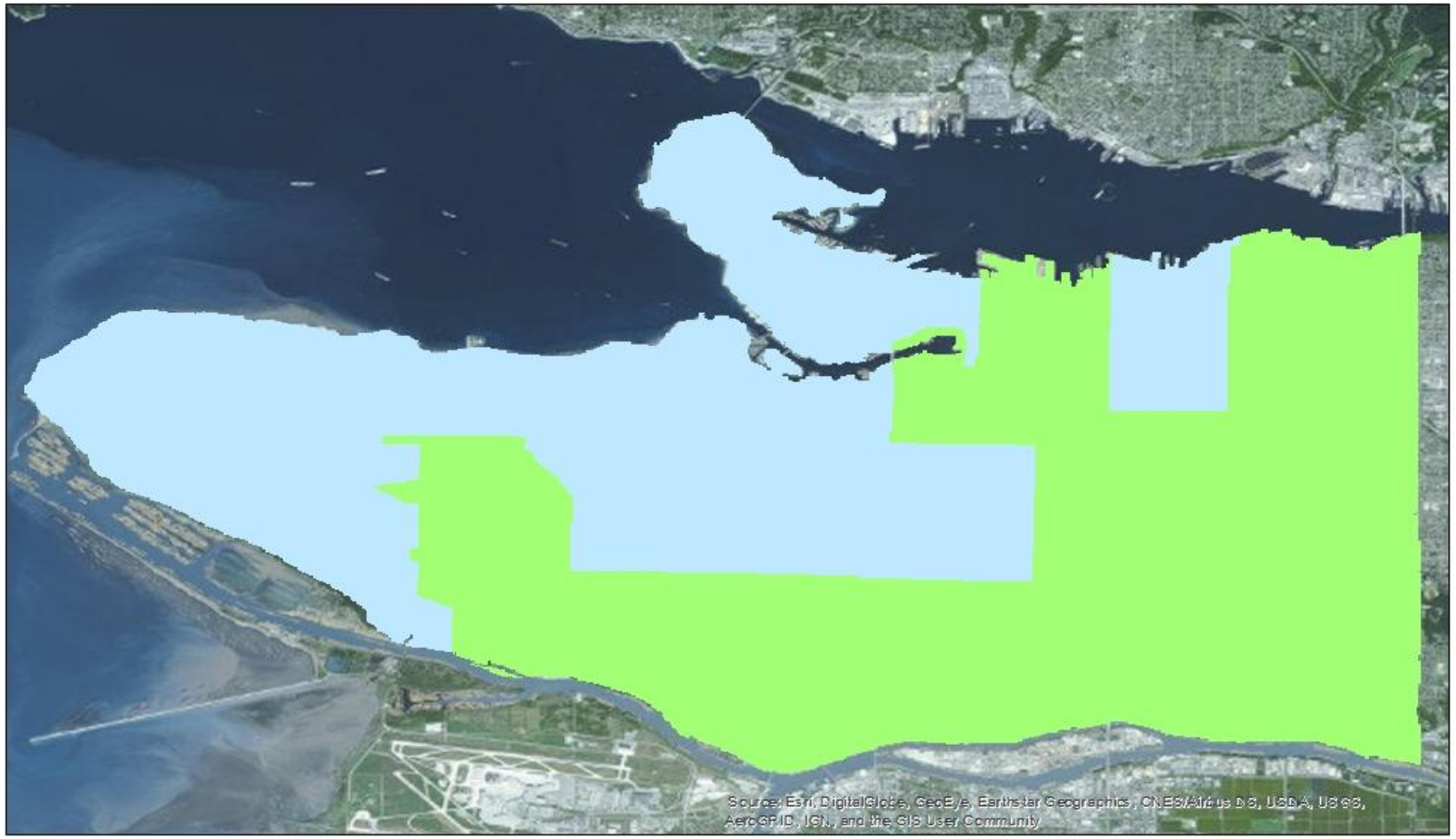
Produced by Dawid, Agata and Dmitriy on March 28, 2017

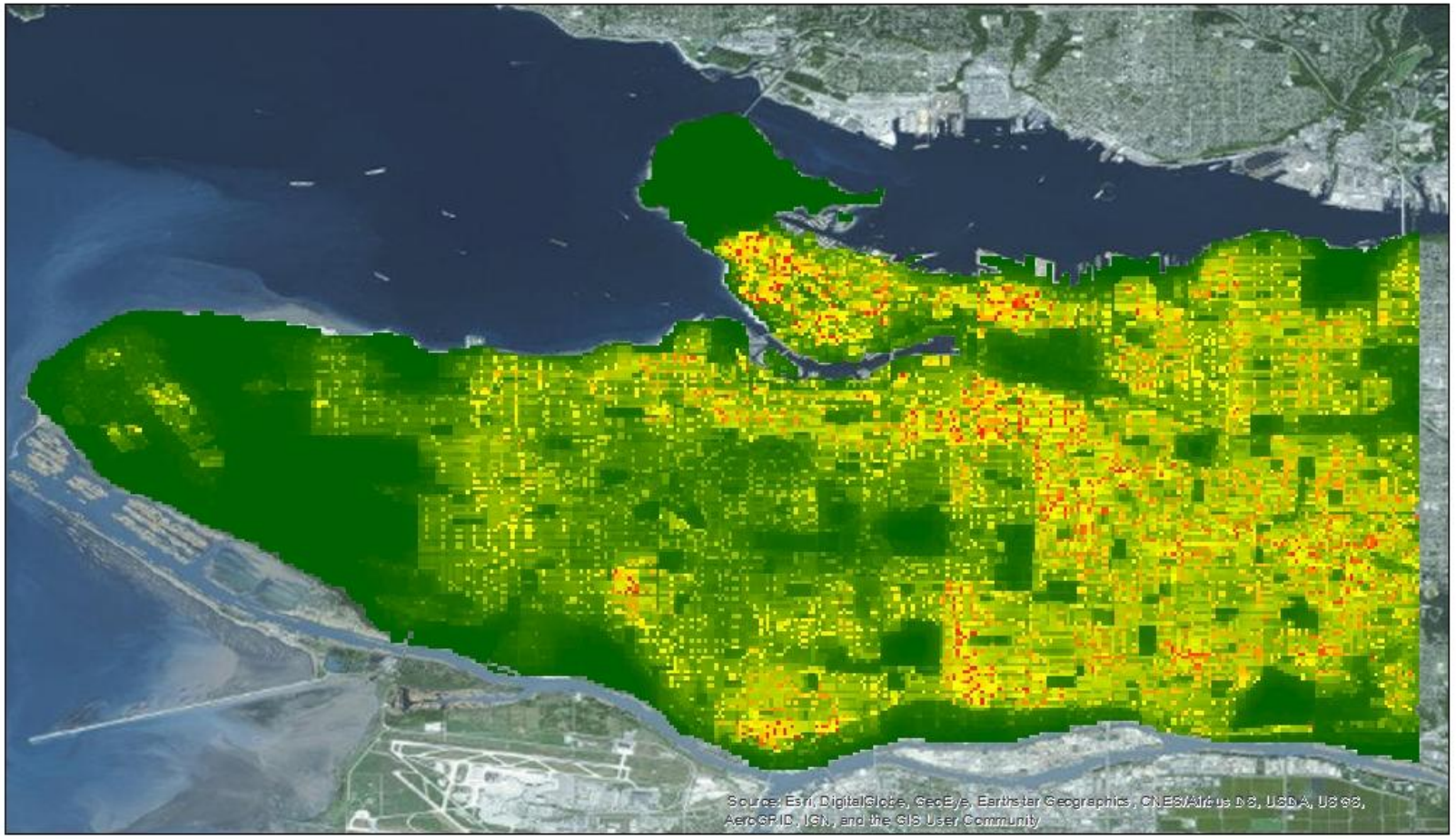
RESULTS

Seismic Hazard Map of Vancouver City



RESULTS

Seismic Risk Assessment Map of Vancouver City



Produced by Dawid, Agata and Dmitriy on March 28, 2017

LIMITATIONS OF MODEL

- Earthquakes are unpredictable and not well defined to regions
  - Historical data may not represent reality
- Risk of any region is dependant on magnitude of the seismic activity
  - Factors of risk may vary depending on strength of earthquake
- Vancouver City is dynamic
  - Model does not consider constantly changing conditions of city (Ex. changing materials utilized in structures)

FUTURE IMPROVEMENTS

Model can be improved to better represent seismic risk by:

1. Considering traffic along roads
   - Ex. Are roads one-way? How does this increase the danger of its users?

2. Considering distances to fire halls and hospitals and adjusting results to account for emergency response times

3. Further refining population density to be dynamic
   - We studied where people resided, not where they currently where