The Local Effects of Global Climate Change in the City of Vancouver: A Community Toolkit and Atlas

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Introduction

As the world struggles to comprehend and address the consequences of global climate change, global trends inevitably have local impacts. Sea level rise is one particular manifestation of climate change that has far reaching implications for all coastal cities in the world, including the City of Vancouver.

BTAworks has created a toolkit to illustrate the effects of global climate change at a neighbourhood level in Vancouver. Our goal is to make climate change impacts more tangible to the average citizen.

This project is inspired by the sea level rise work being conducted in places like San Francisco, New York City, Florida, and the Netherlands.[1,2,3,4,5,6] By using popular education via art, sculpture, and social media, these initiatives have grounded abstract concepts of global climate change via sea level rise at a local level.

Locally, Stephen Sheppard at the University of British Columbia and its Collaborative for Advanced Landscape Planning have developed compelling 3D visualization techniques and participatory processes to explore visions of the future under climate change.[7] The recent May 2011 publication of *Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use* by the BC Ministry of Environment illustrates the consequences and challenges of sea level rise for communities along the Province's extensive coastline.[8]

Our starting point was an acknowledgement of the almost constant change that Vancouver's coastline has undergone over the course of the City's history. Early maps and illustrations from 1898 show a city coastline that is barely recognizable to today's citizen, and our history has been one of adaptation to change brought about by our own

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[1] San Francisco Bay Conservation and Development Commission. (2011). *San Francisco Bay Scenarios for Sea Level Rise Index Map*. Accessed from http://www.bcdc.ca.gov/planning/climate_change/index_map.shtml

[2] City of New York. (2011). *Climate Change*. Accessed from http://www.nyc.gov/html/planyc2030/html/theplan/climate-change.shtml

[3] Jim O'Grady. (2011, Feb 9). *Sea Level Rise Could Turn New York Into Venice, Experts Warn*. Accessed from http://www.wnyc.org/articles/wnyc-news/2011/feb/09/climate-change/

[4] Stanton, E.A.and Ackerman, F. (2007). *Florida and Climate Change: The Costs of Inaction*. Accessed from http://sei-international.org/publications?pid=886

[5] Deltacommittee. (2008). Working together with water: A living land builds for its future. Accessed from http://www.deltacommissie.com/en/advies

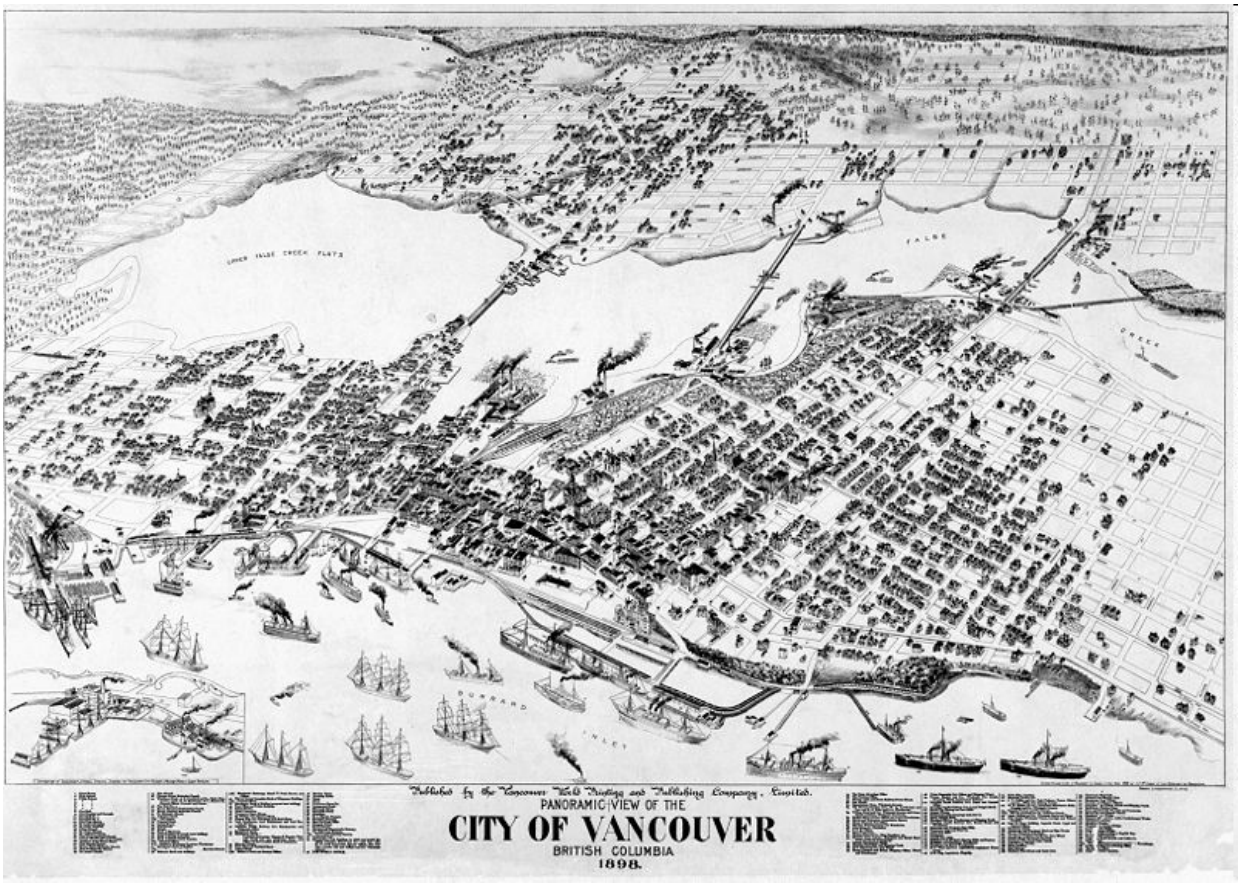
[6] AFP. (2008, Sept 3). Dutch government warned against rising sea levels. Accessed from http://afp.google.com/article/ALeqM5gu1GqZQ_HCXpdu8kK3ZTzNGDZ3RA

[7] Kristi Tatebe, MSc.P, Dr. Alison Shaw, and Dr. Stephen Sheppard (2010). *Technical Report on Local Climate Change Visioning for Delta: Findings and Recommendations*. Accessed from http://www.calp.forestry.ubc.ca/wp-content/uploads/2010/02/Delta-Technical-Report_V1-0.pdf

[8] BC Ministry of Environment (2011). *Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use Draft Policy Discussion Paper*. http://www.env.gov.bc.ca/cas/adaptation/sea_level.html

hand. In the late 1890s, False Creek extended to Clark Drive, and there was once a bridge on Main Street. As time passed, False Creek was filled in to its existing boundaries. This sets an appropriate context in which to consider future city adaptation to changing conditions over which we may have less control.

Figure One – Panoramic View of the City of Vancouver, British Columbia, 1898



Source: Vancouver Archives

Figure Two – A Map of the 1898 False Creek shoreline superimposed onto a contemporary Vancouver aerial photograph with reference streets

Source: City of Vancouver

Figure Three – 1898 False Creek Shoreline superimposed on a contemporary Vancouver aerial photograph

Source: City of Vancouver

Our first stop was the mapping and land use data made available under the City of Vancouver's new Open Data Catalogue, which enabled us to generate maps indicative of various sea level rise scenarios for the City. By linking this data to City zoning information, we were also able to analyze the use of the land we stand to lose.

In many respects these maps are overly simplistic as they assume that there are no proactive interventions implemented such as diking or the introduction of sea gates. As we have already noted, history has shown that we were quite prepared to modify our coastlines to suit our needs in the past and we have no doubt that we will continue to do that in the future. We believe, however, that these maps are very useful non-the-less as they graphically illustrate the impact of sea level change and start to raise questions about how we might approach an adaptation strategy for Vancouver. For example, while population numbers for any number of local and regional planning initiatives in Metro Vancouver are often projected as ever increasing, our underlying assumption has been that the land base we have to work with will remain constant. As sea levels rise, this

assumption should be questioned. Furthermore, while many might see sea level rise in our city as an issue that will largely impact the owners of expensive waterfront homes, an analysis of the data paints a different picture. In reality the areas that are disproportionally impacted are our industrial lands, our historic areas and our public realm - the seawall, waterfront parks and public spaces -- in fact, much of what defines us as a city.

Our initial modeling shows how sea level rise might affect the City of Vancouver by following simple contour lines for the City available on the City's Open Data website. For areas being identified as affected by sea level rise, these effects will range from outright flooding to soil saturation. It is important to note that buildings are rarely located right at the high tidal line, but rather, it is common practice to build about 2 meters or more above the high tide line to buffer any effects such as wave spray, overtopping, or abnormally high tides (Table One). The citywide maps do not account for the effects of specific site variations such as soil composition, exposure to the Fraser River, or existing dike infrastructure.

From an overall Citywide perspective, areas that are severely affected by sea level initially seem to be modest, but when this 2 meter zone of affect is accounted for, the total amount of land mass that is affected quickly becomes substantial.

Table One – Sea Level Rise and its Effects on Overall City of Vancouver Land Mass

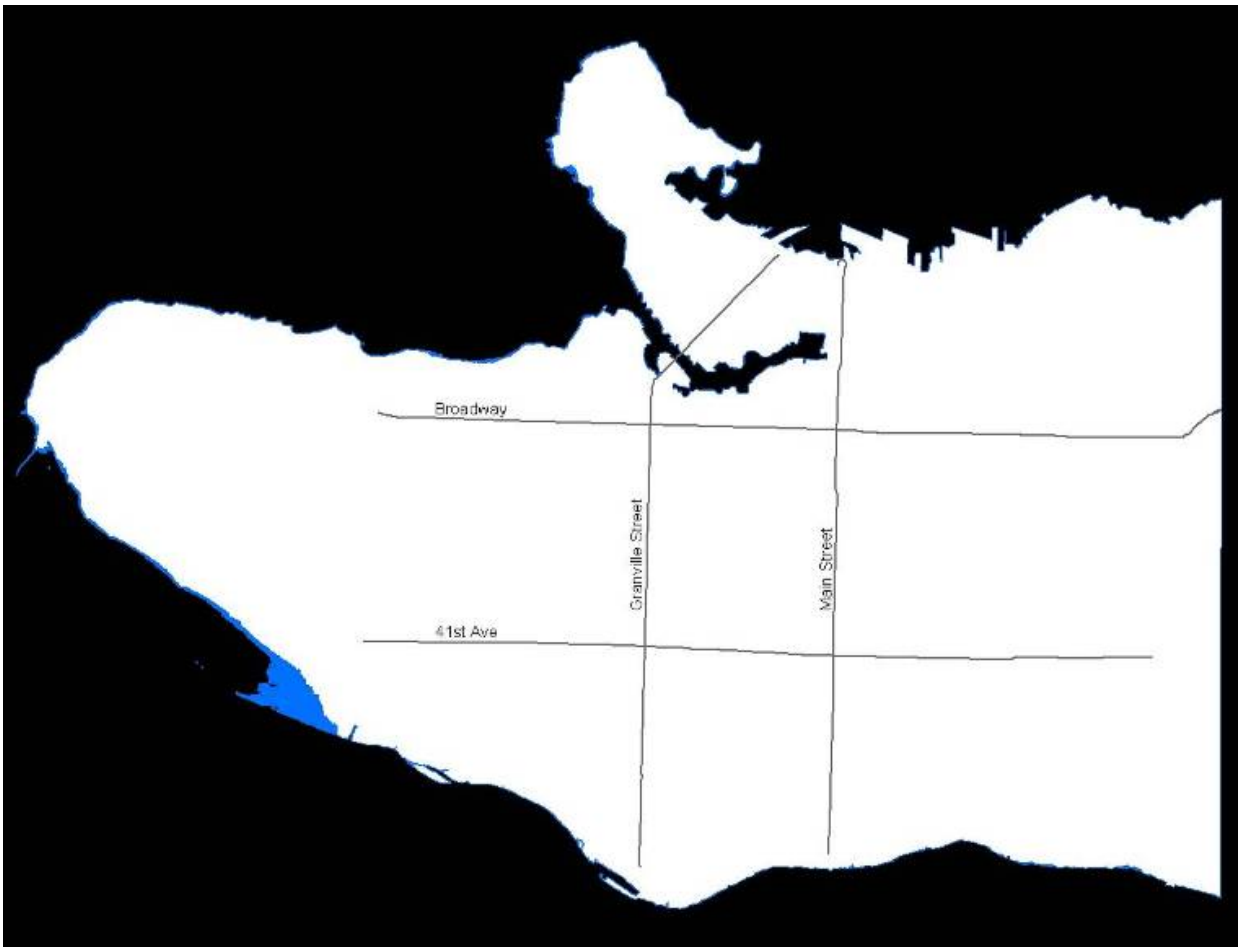
Elevation of Sea Level Rise	% of Total Land Mass Severely Affected	% of Total Land Mass With Additional 2 meter Zone of Affect
0 metres	1%	5%
1 metres	3%	8%
2 metres	5%	11%
3 metres	8%	12%
4 metres	11%	13%
5 metres	12%	N/A
6 metres	13%	N/A

Note: The total land mass of the City of Vancouver is 114 square kilometers or 44 square miles.

Data Source: City of Vancouver Open Data Catalogue
Analysis by BTAWorks

High Tide 2011

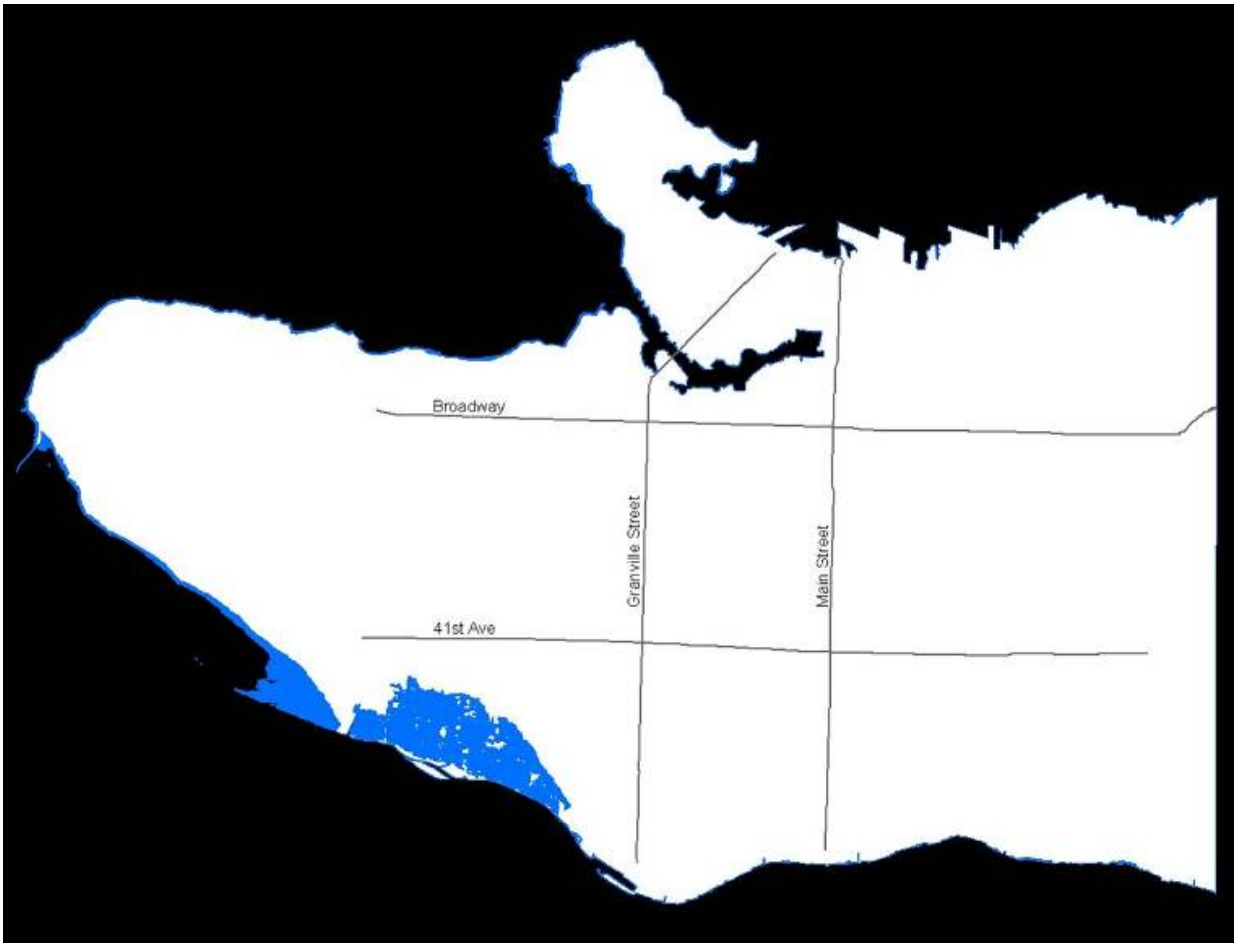
At High Tide 2011, the City of Vancouver remains intact. The area indicated in blue currently consists of tidal mud flats.



Data Source: City of Vancouver Open Data Catalogue
Map by BTAWorks

+1 Meter Affected Area (Severe Storm 2011)

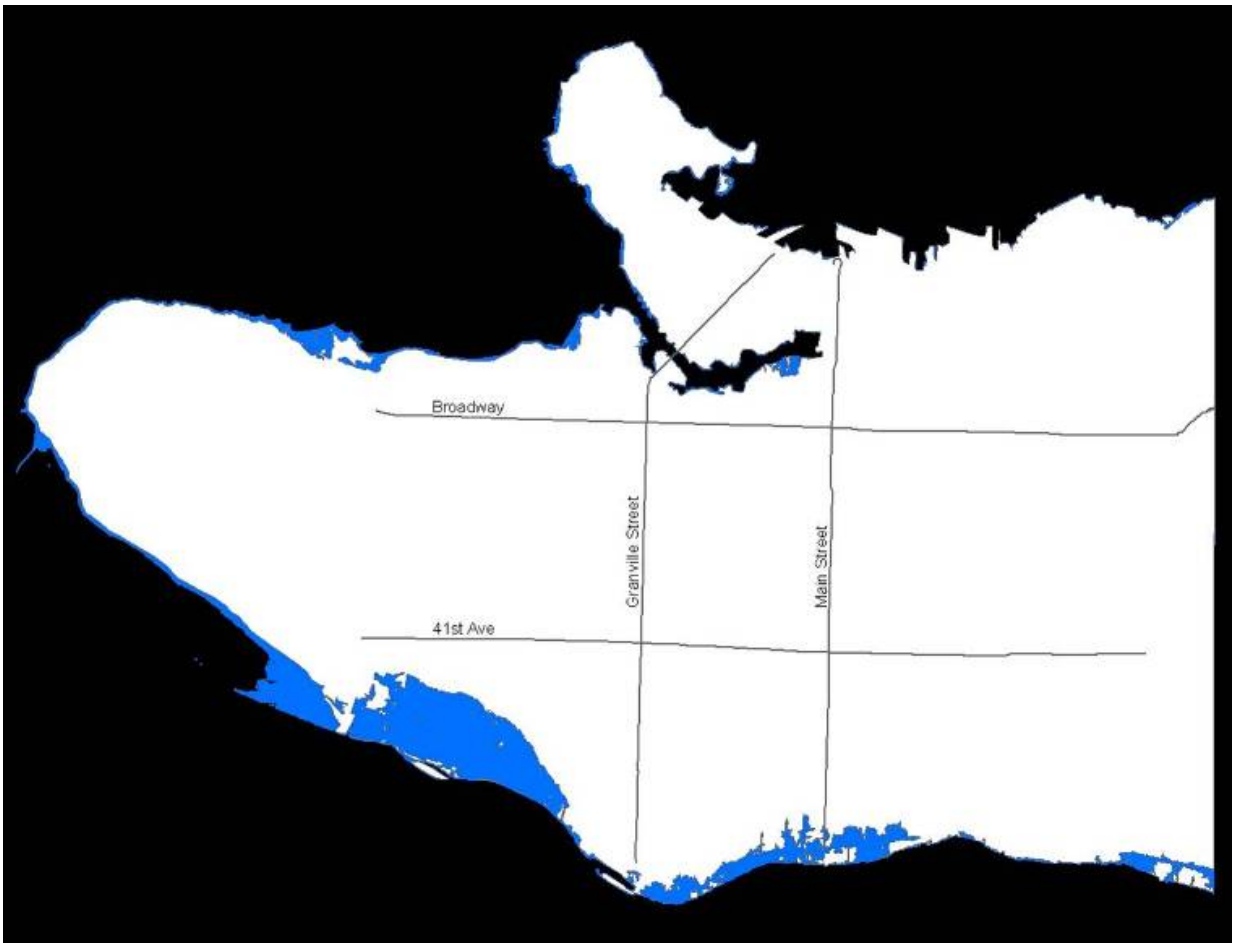
Faced with a severe storm and factors such as a “Proxigean Spring” (a rare, unusually high Spring tide), areas around Vancouver’s Southlands would be affected. Indeed, there are currently areas that would face flooding issues during a severe storm, especially if magnified by a high tide. Based upon current projections in *Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use*, this +1 meter scenario is an illustration of the areas of Vancouver that would be heavily affected by sea level rise in the year 2100. For the most part these areas are already protected from flooding by a dike.



Data Source: City of Vancouver Open Data Catalogue
Map by BTAWorks

+2 Meter Affected Area

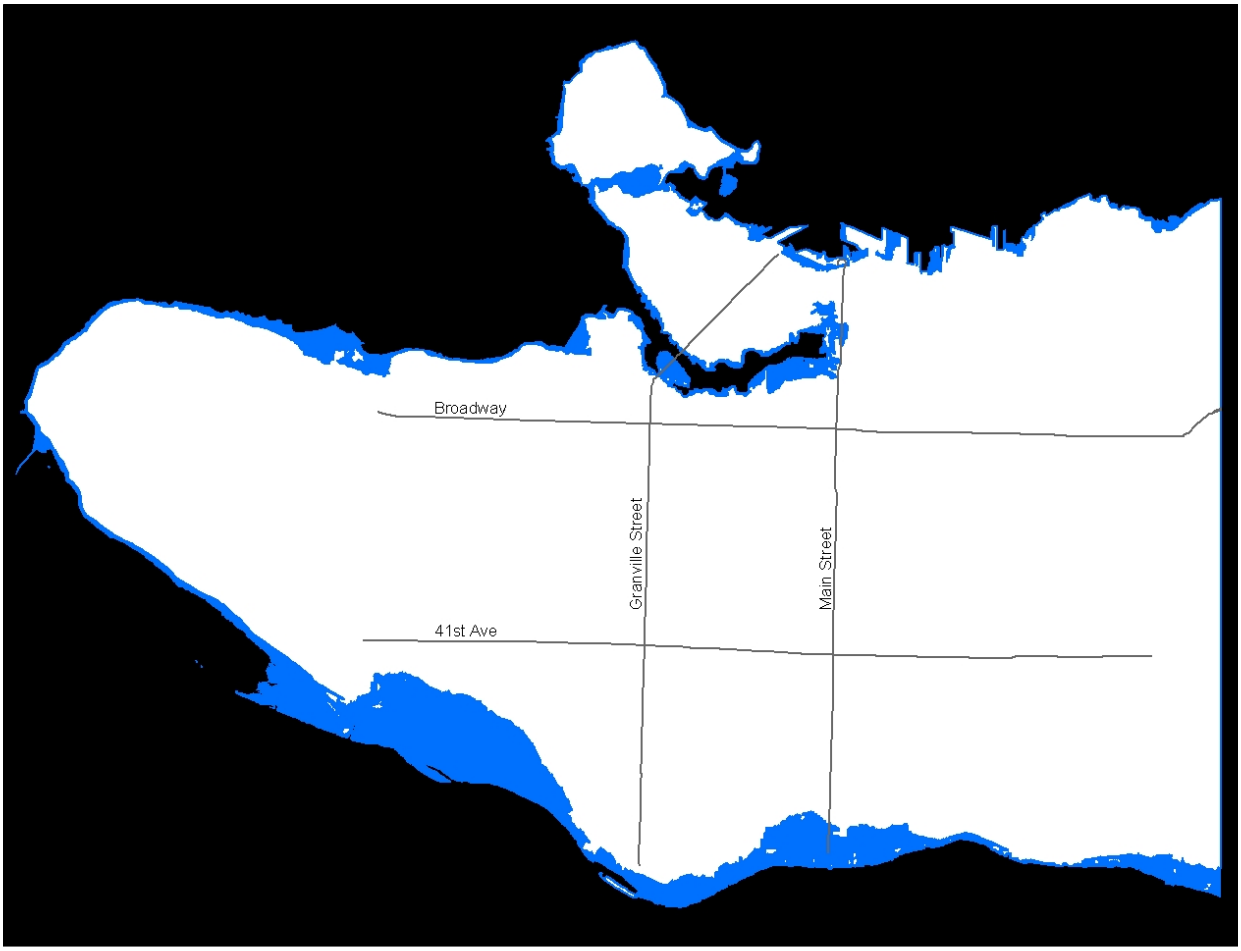
At a 2 Meter Affected Area, much of southern portion of Vancouver, Point Grey, and Kitsilano as well as the southern end of False Creek would be affected.



Data Source: City of Vancouver Open Data Catalogue
Map by BTAWorks

+3 Meter Affected Area (Severe Storm 2100)

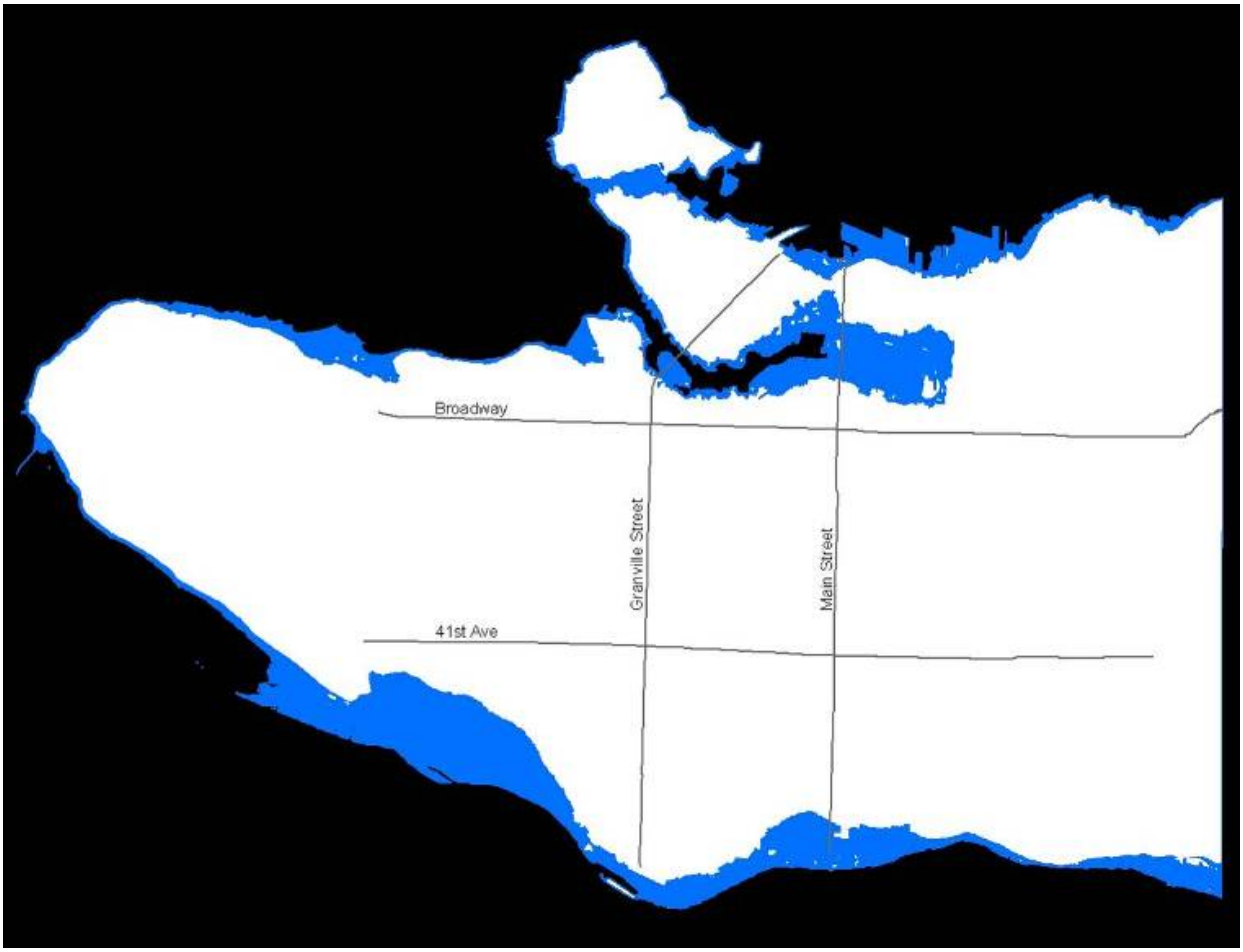
The 3 meter affected area illustrates the areas around the City of Vancouver that may be affected when projected sea level rise is combined with a severe storm in 2100. Most of the shoreline around the City of Vancouver including areas like the Harbour, and the southern edge of the City and Granville Island would be heavily affected.



Data Source: City of Vancouver Open Data Catalogue
Map by BTAWorks

+4 Meter Affected Area

With the 4 meter interval, False Creek would revert back to its 19th century boundaries. The southern edge of the city, Gastown, and Chinatown and the Harbour would be heavily affected.

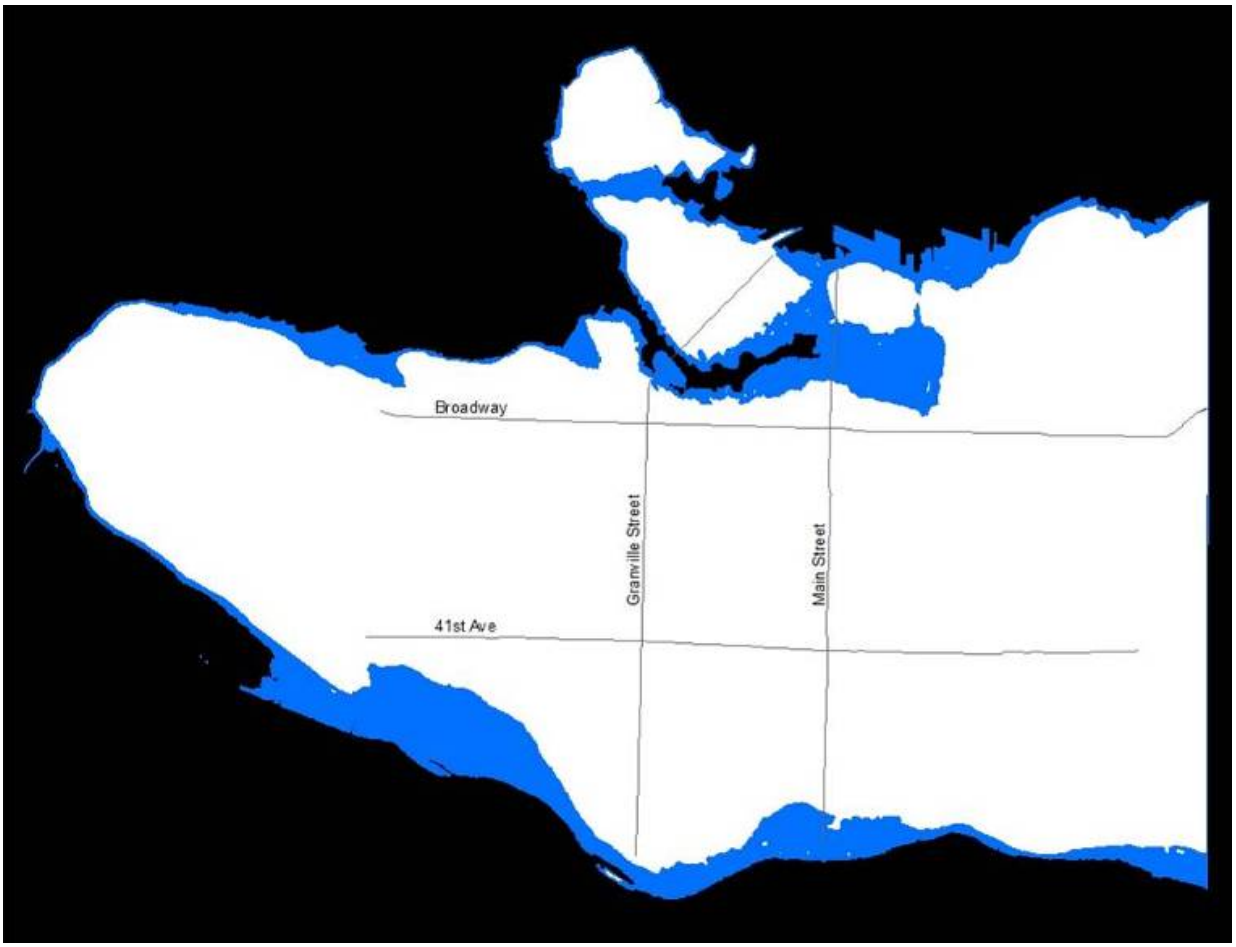


Data Source: City of Vancouver Open Data Catalogue
Map by BTAWorks

+5 Meter Affected Area and +6 Meter Affected Area

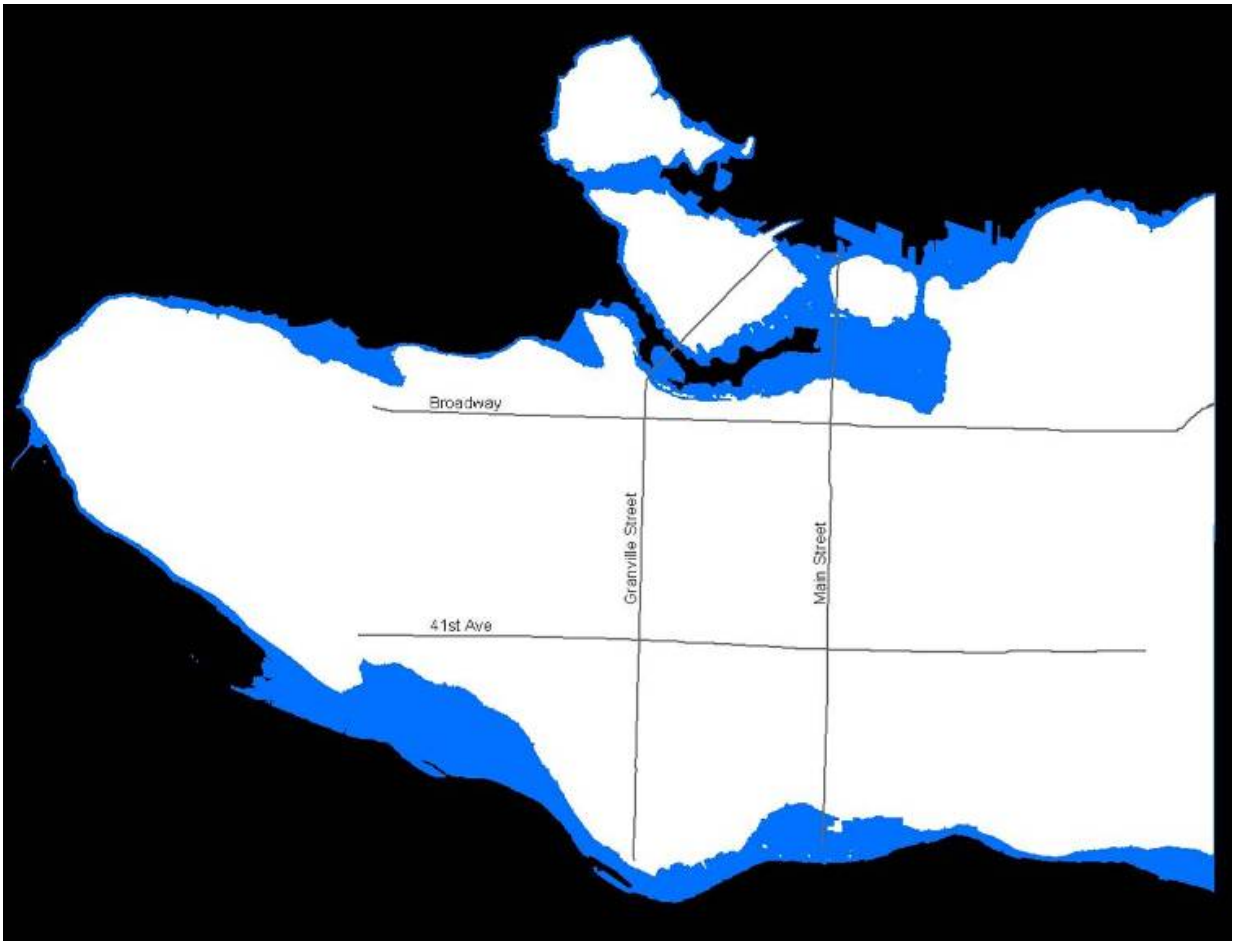
At the 5 and 6 Meter intervals, the maps illustrate scenarios that are extremes based upon existing projections and data on sea level rise. Downtown Vancouver effectively becomes an archipelago and the coastline of the City of Vancouver comes unrecognizable from its original form.

+5 Meter Affected Scenario



Data Source: City of Vancouver Open Data Catalogue
Map by BTAWorks

+6 Meter Affected Scenario



Data Source: City of Vancouver Open Data Catalogue
Map by BTAWorks

Sea Level Rise and Land Use

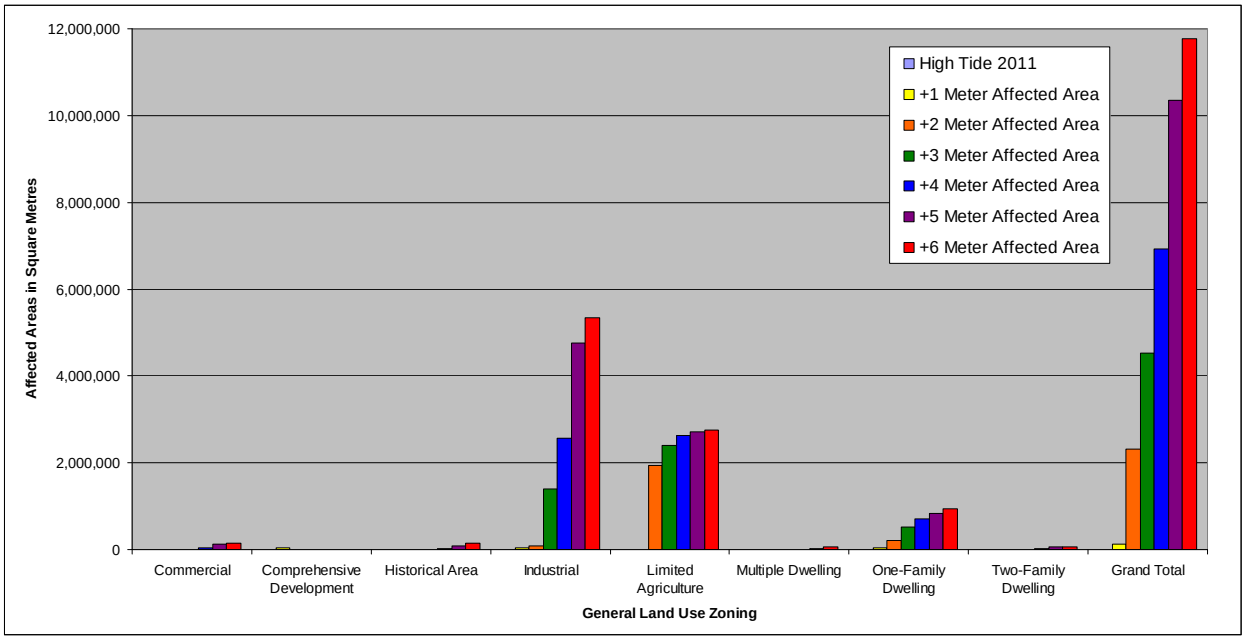
Not all land in a city is of equal strategic value, From the initial inquiry into how much land mass might be affected by various scenarios of sea level rise, BTAworks began to look in more depth at what kinds of land uses would be affected. Using land use data and building upon our initial scenarios, certain land uses in the City of Vancouver are more deeply affected than other land uses depending on scenario. Limited Agriculture and Industrial Lands are heavily affected by sea level rise in both land mass and percentage of land mass,

Table Two – Sea Level Rise and Affected Land Use by Percentage

	Baseline Land Area (in sq m)	High Tide 2010	+1m Affected Area	+2m Affected Area	+3m Affected Area	+4m Affected Area	+5m Affected Area	+6m Affected Area
Commercial	4,976,163	0%	0%	0%	1%	2%	3%	4%
Comprehensive Development	13,420,081	0%	1%	2%	7%	13%	17%	19%
Historical Area	399,479	0%	0%	0%	3%	21%	39%	50%
Industrial	8,559,830	1%	1%	16%	30%	55%	63%	67%
Limited Agriculture	2,852,769	0%	68%	84%	92%	95%	96%	97%
Multiple Dwelling	683,549	0%	0%	0%	0%	1%	2%	3%
One-Family Dwelling	57,027,176	0%	0%	1%	1%	1%	2%	2%
Two-Family Dwelling	6,950,464	0%	0%	0%	0%	1%	1%	1%
Grand Total	114,016,511	0%	2%	4%	7%	10%	12%	13%

Data Source: City of Vancouver Open Data Catalogue
Analysis by BTAWorks

Chart One – Sea Level Rise and Affected Land Use by Land Mass



Data Source: City of Vancouver Open Data Catalogue
Analysis by BTAWorks

In the context of sea level rise, the vulnerability of the stock of limited agricultural and industrial lands highlights the urgency of long term planning for these particular land uses at a city and regional level. The importance of these types of land may indeed increase as increasing fuel costs stimulate local manufacturing, distribution, and repair industries as well as food production and processing.

Which Scenario?

While this paper has presented a number of sea level rise scenarios and their impacts on existing land use, there remains a question as to which one should be used to guide the public, policymakers, and urban planners. If more current and accurate localized data could be obtained, how does one narrow the focus to address a specific anticipated sea level rise over a defined time period as well as provide understanding of the consequences and challenges of decision and indecision over sea level rise?

One possible starting point is a 3 volume report entitled *Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use* published by the Province of British Columbia and written by Ausenco Sandwell Engineering. With 127 kilometres of coastal dikes in B.C. protecting 220,000 people in their communities, the BC Government is preparing new guidelines for coastal flood plain mapping, sea dike design and flood construction levels that account for the impacts of sea level rise as part of the BC Regional Adaptation Collaborative (RAC). As part of this process, the Provincial government commissioned Ausenco Sandwell Engineering to develop a 3 volume technical backgrounder for the RAC's recommended new standards for sea dike design and management of coastal flood hazards.

While the content of the report is for information and does not represent official Provincial policy, it does provide a localized reference point from which future policies for sea level rise in BC coastal communities like the City of Vancouver can be explored. This work has involved reviewing both historical data and current climate change and sea level models and research to determine appropriate sea level rise estimates for the target year of 2100.

Based upon their extensive current literature and technical survey, the paper pursued a global sea level rise allowance of 1 metre by the Year 2100. While this sea level rise could be lower or higher, this is the best estimate that current research suggests by that timeframe.

In the context of our scenario maps, a 1 metre sea level rise sounds innocuous. Indeed, other studies have suggested much higher sea level rises by 2100.[9] For certain parts of the British Columbia coast, sea level rise may be slightly lower when regional variations in gravity and plate tectonics are accounted for (See Table Three). However, to build and engineer for a sea level rise of 1 metre, one needs to account for phenomenon such as high tide, surge allowance, wave effect, and freeboard. When this is all accounted for, the report suggests that the preliminary Flood Construction Reference Plane for Vancouver Harbour should be 5.6 metres above current levels for the year 2100.

[9] Ballard, Aron and Lidster, Ryan. (2006, Nov 7). *Denial as Projections Place BC Cities Under Water*. Accessed from http://thetyee.ca/News/2006/11/07/Immersed/

Table Three - Preliminary Flood Construction Reference Plane (FCRP) and FCL for 2100 for Specific Areas in Coastal British Columbia (Elevations relative to Canadian Geodetic Datum)

	Fraser River Delta	Vancouver Harbour	Squamish River Delta	East Vancouver Island	West Vancouver Island	Central and North Coast
Global SLR Allowance	1.0 m					
Regional Adjustment [1]	+0.21 m	0 m	0 m	-0.17 m	-0.27 m	-0.22 m
High Tide [2] (HHWLT m CGD)	2.0 m	1.9 m	2.05 m	1.6 m	2.0 m	3.8 m
Surge Allowance [3]	1.7 m	1.4 m	1.3 m	1.3 m	1.3 m	1.7 m
Wave Effect Allowance [4]	0.65 m	0.65 m	0.65 m	0.65 m	0.65 m	0.65 m
Flood Construction Reference Plane (FCRP)	**5.6 m**	**5.0 m**	**5.0 m**	**4.4 m**	**4.7 m**	**6.9 m**
Freeboard [5]	0.6 m	0.6 m	0.6 m	0.6 m	0.6 m	0.6 m
Flood Construction Level (FCL)	**6.2 m**	**5.6 m**	**5.6 m**	**5.0 m**	**5.3 m**	**7.5 m**

[1] Based on current values for areas (Vancouver and Squamish taken to be neutral due to regional variations or present lack of site specific data)

[2] Varies by site and location in BC, as defined by CHS Tide Tables for areas, – Cowichan Bay used for East Vancouver Island – Tofino used for West Vancouver Island - Queen Charlotte City used for Central and North Coast.

[3] Recommended value for AEP based on "Policy Discussion Paper 2010" – includes allowances for local wind setup.

[4] Based on wave runup on natural gravel – pebble beach shoreline.

[5] Assumes no Flood Proofing, specific Building Foundation type, or Tsunami.

Source: Ausenco Sandwell and BC Ministry of Environment, 2011, *Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use Guidelines for Management of Coastal Flood Hazard Land Use*.

We believe that this data is currently the best technical estimate on the effects of sea level change for the City of Vancouver. Based on this data, we have developed a series of scenarios on the prospective costs and challenges of sea level rise for the City of Vancouver. Due to technical limitations of the available data, we have used a 5 metre interval for our estimates on the effect of sea level rise for the City of Vancouver.[10]

[10] The contour interval data layer on the City of Vancouver's Open Data Catalogue is only available in 1 metre increments.

The Stakes

By using these estimates we can develop an understanding of the potential impacts of sea level rise and we can begin to understand some of the possible costs of sea level rise to the City of Vancouver.[11]

Based upon the 2011 Total BC Assessment values, the City of Vancouver was assessed to be worth about $212 billion, which can be broken down to $154 billion for land and $58 billion for buildings.[12] It is important to note that these assessment values do not include the significant portions of land required for city infrastructure, let alone the cost of utilities, roads, sewers, and other expensive and critical civic infrastructure.

With a land mass of 114 square kilometers or 44 square miles, this 2011 assessment value for the City of Vancouver breaks down to an average of $1,859 per square metre or $172 per square foot. Based upon a possible 5 meter sea level rise affected area level which will affect upwards to 12 percent of the City's land mass, over $25 billion worth of Vancouver real estate could be heavily impacted in this scenario.

What are some of the mitigation costs?

The City of Vancouver has a shoreline of approximately 51 kilometres (51,000 m) with the University Endowment Lands having an additional 8.5 kilometres (8,500 m). With a general engineering estimate of defensive coastal infrastructure for soft and hard (design and build) costing ranging from $5,000 per linear metre for an earth dike to $10,000 per metre for a seawall, the order of magnitude for construction costs for mitigating the effects of sea level rise ranges from $255 million to $510 million. This estimate is based upon current 2011 costs and does not include any land acquisition costs which could be quite substantial.

To place these mitigation costs in the context of recent public infrastructure projects, the Canada Line cost $2 billion for 23.2 kilometres of track and stations (including the Vancouver airport spur) or $82,200 per metre[13], the Dunsmuir Bike Lane cost $3.2

[11] We also attempted to use a Geographic Information Systems based estimation methodology to provide a secondary estimate. The methodology selected all property parcels below the 5 meter interval and assigned total values from the 2011 BC Property Assessment to these affected properties and summarized these values to produce an estimate. Unfortunately, due to current data limitations, we could not produce a reliable estimate. However, we expect that as the property GIS data quality file improves over time, this methodology may produce another metric of the property value that may be closer to real world costs.

[12] BC Assessment. (2011) *City of Vancouver Assessment Roll Report*. Accessed from http://vancouver.ca/ctyclerk/cclerk/20110120/documents/csbu1.pdf

[13] Transport Canada. (2007, Dec 17). Canada Line Unveils First Train in Richmond. Accessed from http://www.tc.gc.ca/eng/mediaroom/releases-nat-2007-07-h241e-1405.htm

million for 2 kilometres or $1,600 per metre.[14] The Vancouver Convention Centre Expansion cost $885 million.[15]

Beyond the hard financial costs of mitigation and impact on private property, sea level rise threatens to transform much of the natural capital that has defined the City of Vancouver in terms of livability and identity. The costs of this transformation are impossible to quantify.

Using simple cross sections of the northeastern corner of the Granville Island Public Market as an example,, sea level rise and the actions required to adapt to its challenges will not only require a significant amount of infrastructure construction in terms of coastal defense, but will alter the current relationship between Vancouverites and the water (Figure Four to Six).

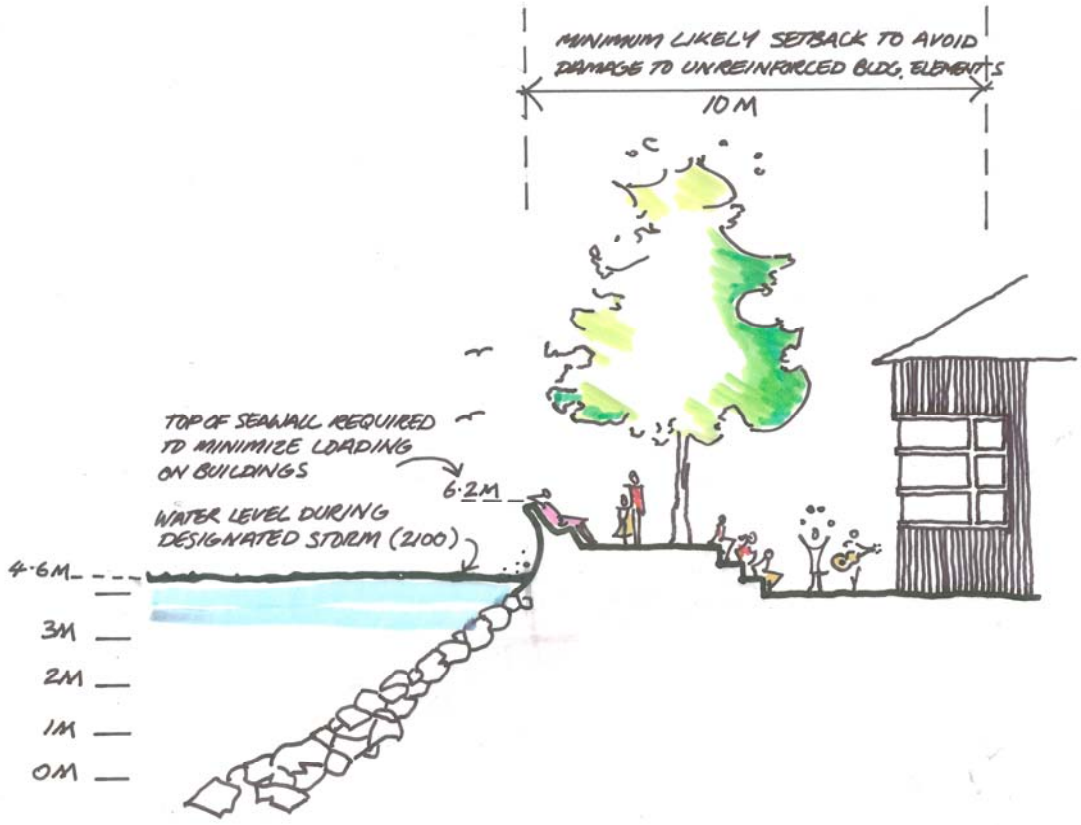
Figure Four – Photograph of Northeastern Corner of the Granville Island Public Market

[14] Howell, M. (2010, Sept 28). Hornby bike lane to cost $3.2 million. Accessed from http://communities.canada.com/vannet/blogs/12thandcambie/archive/2010/09/28/hornby-bike-lane-to-cost-3-2-million.aspx

[15] British Columbia Office of the Auditor General. (2007, October). A Review of the Vancouver Convention Centre Expansion Project : Governance and Risk Management. Accessed from http://www.bcauditor.com/pubs/2007/report3/review-vancouver-convention-centre-expansion-project-gove

Figure Five – Cross Section of the Northwestern Corner of the Granville Island Market, 2010

Figure Six – Cross Section of the Northwestern Corner of the Granville Island with Extended Protective Seawall, 2100

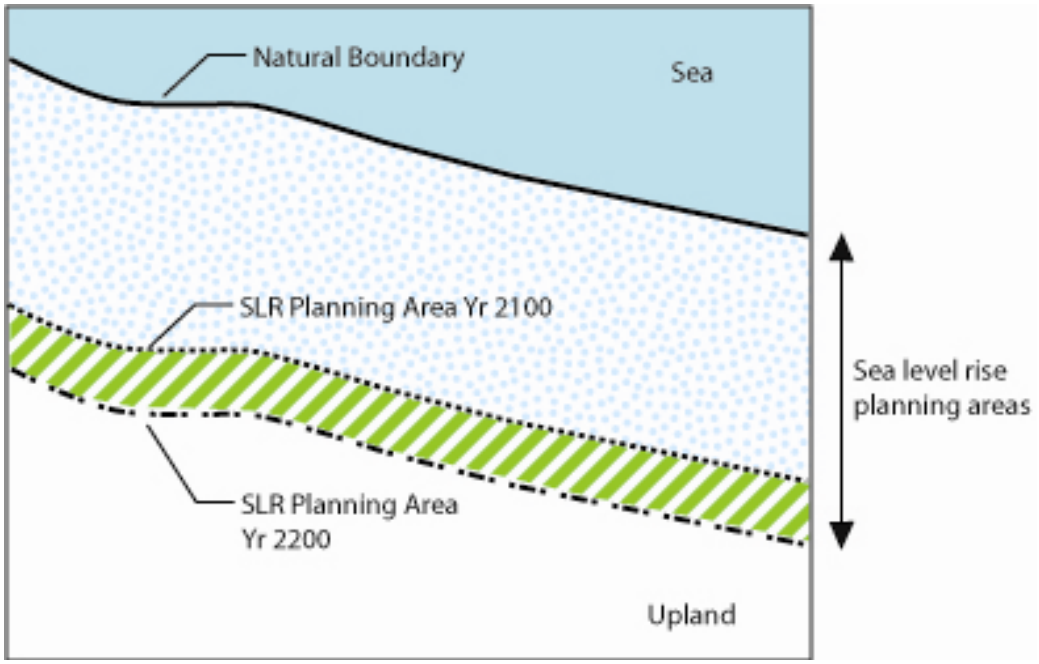


Where to Start? – The Sea Level Rise Planning Area and a Regional Open Data Catalogue

How would we go about planning the adaptation of Vancouver in the face of sea level rise? What factors would need to be considered and how could these be incorporated into planning policies?

The first step could be the use of the information on sea level rise to develop a Sea Level Rise (SLR) Planning Area (See Figure Seven). This is a recommendation from the Provincial Adaptation Guidelines and one that is worth examining. Specific adaptation policy instruments like Sea Level Rise Planning Areas will need to be developed; however, in parallel, a regional level of understanding regarding the impact of sea level rise in the Metro Vancouver area is also critical. No adequate adaptation initiative for sea level rise will succeed if done on a piecemeal municipality by municipality basis. The first step is to have the same basis of understanding throughout the region which means the base information for all of Metro Vancouver needs to be available.

Figure Seven - The Concept of a Sea Level Rise Planning Area



Source: Ausenco Sandwell and BC Ministry of Environment. 2011. *Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use Guidelines for Management of Coastal Flood Hazard Land Use.*

As introduced in the Ausenco Sandwell Report, a Sea Level Rise (SLR) Planning Area could be defined in areas of the City that would be especially sensitive and/or vulnerable to Sea Level Rise based upon current localized science. Like a flood zone designation, special planning and land use measures would be enacted to protect these areas or, in certain cases, discourage certain types of land use and physical and infrastructure development within the zone.

The designation of an SLR Planning area would serve two important functions. First, it would raise awareness amongst land owners, insurers and public agencies of the potential risk. Secondly, extending the designations to subsequent periods of time (eg. 100 year increments) reinforces the reality that sea level rise is not a finite phenomenon - if the current mitigation efforts are unsuccessful, the sea may continue to rise to a greater or lesser extent for many centuries to come. The siting of buildings of a shorter anticipated lifespan (such as single family homes) may be acceptable within the 2100 Planning Area, but it may be determined that infrastructure investments such as industrial facilities and major transportation routes should be located in areas with longer anticipated suitability.

The choices necessary to protect cities from sea level change have profound land use implications. Revetment (earthen) dikes of the type seen in Richmond require the lowest elevation, preserving ocean views, but have a large footprint, increasing land acquisition costs and impacts on adjacent structures. While sea walls have a smaller footprint, depending on the level of protection required they may need to be 8-10 times the height of a revetment to provide effective protection to adjacent structures from the wave spray loads they generate. The reality is that any proposed strategy will incorporate a range of different approaches, and what works for one part of the city's coastline will be unsuitable for another area.

While understanding the consequences of sea level rise may be accomplished through traditional methods of professional studies, access to a region wide Open Data Catalogue is an essential tool to begin this work. This study would have been impossible to develop without the City of Vancouver's Open Data Catalogue. The availability, ease, and quality of data and its acquisition eased the development time and expense of creating this study. Currently, a regional counterpart to the City of Vancouver's Open Catalogue does not exist and consequently, a Metro Vancouver wide level analysis would not be able to duplicated. Most importantly, the mitigation and adaption strategies will need to occur on a Metropolitan level as a municipality by municipality piecemeal approach will likely not be sufficient.

Conclusions

This study is intended to be a toolkit that we hope will facilitate a meaningful dialogue and policy discussions regarding climate change and its effect on our city. This toolkit can be used background for public education and the raising awareness of the impact of climate change in Vancouver. A number if questions immediately come to mind such as: What aspect/ illustrative approach to the data will have the most effective impact. Who are we trying to reach? Planners, policy makers, developers, or the general public? Is a different approach or message necessary to communicate effectively with the various groups?

Like coastal cities around the world, the natural capital of Vancouver's coastline that has defined the social, cultural, and financial value of the City will be affected by sea level rise. There is no doubt that the changes we will have to make will impact how we experience our City. These changes will also be expensive and the mechanism by which we elect to pay for them will have broader implications for the City and region as a whole.

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About BTAworks

BTAworks is an architectural and urban research and development division of Bing Thom Architects committed to promoting innovative and resilient design, dialogue, and good urban living.

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