Robust impact patterns: an approach to account for uncertainties in local sea-level rise vulnerability assessments

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Presentation overview

Part I

Develop a new approach

Robust Impact Patterns (RIPs) Method

- SLR impacts over wide range of futures
- Basis for developing robust adaptation options

Part II

Apply RIPs method to City of Vancouver (CoV)

- Demonstrate applicability

Part III

Host expert workshop with CoV experts

- Assess usability and limitation
Presentation overview

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Sea-level rise (SLR) uncertainties

• Increasing flood risk

• SLR – one of the most certain effect of climate change

• How much and when is deeply uncertain
Diverse projections for global mean sea levels

- Broad range of sea-level rise (SLR) projections just in recent years
- From 0.98m to 6m

![Graph showing upper limits of global mean SLR projections for 2100 (m)]

- a) Church et al. (2013) (IPCC 5th Assessment Report)
- b) Kopp et al. (2014)
- c) Horton et al. (2014)
- d) Jevrejeva et al. (2014)
- e) Dutton et al. (2015)
- f) Hansen et al. (2016)
- g) Jackson and Jevrejeva (2016)
Compounding uncertainties in SLR impact assessment
SLR planning with deep uncertainties

**Optimal adaptation options**
*(Traditional approach)*
- Lowest cost and highest benefit
- Single or handful of “best” prediction(s)
- Eliminate uncertainties

**Robust adaptation options**
*(Recommended approach)*
- Acceptable performance across multiple futures
- Large number of plausible futures
- Account for uncertainties
New approach to assess impacts for SLR adaptation planning

Future flood scenarios → GIS & Socio-economic models → Flood impact maps → Self organizing maps (SOMs) → Robust impact patterns

Economic
Social
Environmental
Pattern recognition (e.g. facial recognition)

Example: satellite imageries of tropical storms in Indian Ocean

Spatial variations are preserved
Applying the RIPs Method at the City of Vancouver

**STAGE I**
Develop future flood scenarios

**STAGE II**
Geospatially model flood impacts

**STAGE III**
Identify robust impact patterns

- **336** Future flood scenarios
- **14** Impact types for each scenario
- **16** Robust impact patterns for 14 impact types
336 future coastal flood scenarios

- Storm return period
- Sea-level rise
- Population and land-use distribution
- Power outage extent
- Stage damage functions

Flood event with no adaptation action

- 1:50
- 1:500
- 1:10000

Sea-level rise:
- 0m
- 1m
- 2m
- 3m
- 4m
- 5m
- 6m

Population and land-use distribution:
- Current land-use
- Status Quo
- Compact
- Sprawl

Power outage extent:
- Optimistic
- Pessimistic

Stage damage functions:
- HAZUS default
- MCM
336 future coastal flood scenarios

- Storm return period
- Sea-level rise

Flood event with no adaptation action

1:500

0m

Current land-use

Optimistic HAZUS default

Pessimistic Status Quo

Compact Sprawl

1m

2m

3m

4m

5m

6m

1:1000

1:500

Worst-case outage scenario of B2 flood scenario

Pessimistic outage scenario for 1:500 year storm with 2m SLR

Flood depth (m) - 1:500 yr storm and 2m SLR

0 - 0.77

0.78 - 1.3

1.3 - 1.9

1.9 - 2.5

2.5 - 3.1

3.1 - 3.7

3.7 - 4.3

4.3 - 4.9

4.9 - 5.5

5.5 - 6.1

6.1 - 6.7
14 Flood Impacts Modelled

**ECONOMIC**

Business disruptions:
1. Primary sectors
2. Secondary sectors
3. Tertiary sectors

Direct building damage:
4. Residential
5. Commercial
6. Governmental

**SOCIAL**

Potentially affected:
7. Vulnerable population
8. Schools
9. Health care facilities

10. Social services
11. Transportation points
12. Emergency services

**ENVIRONMENTAL**

13. Debris generated
14. Sewage backup damage potential
Business Disruption (Tertiary sectors)

- Temporary closures due to disruptions induced by flood event
- Disruptions from building damage and power outage
- Based on business disruption model in Chang (2008)
16 Patterns of Business Disruption (Tertiary sectors)
Grouping Robust Impact Patterns

16 robust patterns of business disruption (tertiary sectors)

Groups by sea-level rise ranges
A: 4-6m
B: 2-4m
C: 0-2m

Type of SLR scenarios represented by each pattern
Business Disruption (Tertiary sectors) – Group A, B, C

A (4-6m SLR) | B (2-4m SLR) | C (0-2m SLR)
---|---|---
~4100 closures | ~2100 closures | ~900 closures

Hotspots:
- Downtown: 44%
- Strathcona: 9%
- West End: 8%
- Grandview: 8%
- Marpole: 6%

Hotspots:
- Downtown: 38%
- Marpole: 13%
- Strathcona: 9%
- Kerrisdale: 8%
- Oakridge: 6%

Hotspots:
- Downtown: 33%
- Fairview: 13%
- Marpole: 12%
- Sunset: 12%
- Kitslano: 7%
Business Disruption (Tertiary sectors) – Hotspots

<table>
<thead>
<tr>
<th>Column A</th>
<th>4-6m SLR</th>
<th>Column B</th>
<th>2-4m SLR</th>
<th>Column C</th>
<th>0-2m SLR</th>
</tr>
</thead>
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<td>~4100 closures</td>
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**Hotspots:**

- Downtown: 44%
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**Hotspots (Downtown):**

- 38% Downtown
- 13% Marpole
- 9% Strathcona
- 8% Kerrisdale
- 6% Oakridge

**Hotspots (Strathcona):**

- 33% Downtown
- 12% Fairview
- 12% Sunset
- 7% Kitslano

**Hotspots (Marpole):**

- 13% Downtown
- 12% Fairview
- 12% Sunset
- 7% Kitslano
Business Disruption (Tertiary sectors) – Group A (4-6m SLR)

Total: 3676.85
Total: 4250.63
Total: 4355.68
Total: 4516.08

Total: 3868.79
Total: 4092.4
Total: 3461.52

Total: 3113.65

SLR
Business Disruption (Tertiary sectors) – Group C (0-2m SLR)

- Total: 1808.92
- Total: 1142.85
- Total: 511.11
- Total: 1069.34

SLR

Land-use
Potentially Affected Social Service Facilities

- Disruption due to inundation and/or power outage

- Homeless shelters
- Free-meal locations
- Non-market housing
- Childcare and pre-school centres
- Community centres
- Senior centres
Social Services Disruption – Group A, B, C

<table>
<thead>
<tr>
<th>A (4-6m SLR)</th>
<th>B (2-4m SLR)</th>
<th>C (0-1m)</th>
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<tr>
<td>~ 380</td>
<td>~ 150</td>
<td>~ 110</td>
</tr>
</tbody>
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Hotspots:
- **Downtown**: 29%
- **Grandview**: 18%
- **Strathcona**: 18%
- **West End**: 9%
- **Marpole**: 8%

Hotspots:
- **Downtown**: 39%
- **Marpole**: 20%
- **Fairview**: 9%
- **Mt Pleasant**: 7%
- **Oakridge**: 6%

Hotspots:
- **Downtown**: 26%
- **Fairview**: 23%
- **West Point Grey**: 21%
- **Mt Pleasant**: 12%
- **Marpole**: 8%
Social Services Disruption – Change in hotspots

### Diagrams

- **6m SLR**
- **2-3m SLR**
- **0-1m SLR**

### Table

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<td></td>
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</tr>
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#### Hotspots:

- **Downtown**
  - 6m SLR: 29%
  - 2-3m SLR: 39%
  - 0-1m: 26%
- **Grandview**
  - 6m SLR: 18%
  - 2-3m SLR: 20%
  - 0-1m: 23%
- **Strathcona**
  - 6m SLR: 18%
  - 2-3m SLR: 9%
  - 0-1m: 21%
- **West End**
  - 6m SLR: 9%
  - 2-3m SLR: 7%
  - 0-1m: 12%
- **Marpole**
  - 6m SLR: 8%
  - 2-3m SLR: 6%
  - 0-1m: 8%
Sewage Backup Damage Potential Index

- Common flood hazard with potentially severe impacts
- First attempt index to account for risk factors inside and outside homes
- Relative level of damage expected from sewage backup in ground related homes at the city block level

**Diagram:**

- **Type of drainage system connected**
- **Number of pre-70s homes**
- **Number of ground related homes**
- **Power outage**
- **Sewage pump installed**
- **Flood depth and distance**
Figure 5.24 The 16 RIPs of sewage backup damage potential index (SBDPI). The shading shows the damage potential per hectare, while the total damage potential in each RIP is labeled above it.

A: 4-6m  
B: 2-4m  
C: 0-2m
Sewage Backup Damage Potential Index – Group A, B, C

A (4-6m SLR)
- Total: 130.0
- ~160
- Hotspots:
  - Hastings Sunrise 18%
  - Kerrisdale 12%
  - West Point Grey 7%
  - Marpole 7%
  - Dunbar Southlands 7%

B (2-4m)
- Total: 166.05
- ~110
- Hotspots:
  - Hastings Sunrise 19%
  - Kerrisdale 11%
  - Dunbar Southlands 11%
  - Kitsilano 11%
  - West Point Grey 8%

C (0-1m)
- Total: 185.01
- ~90
- Hotspots:
  - Hastings Sunrise 17%
  - Kitsilano 11%
  - Dunbar Southland 8%
  - Grandview 8%
  - West Point Grey 7%
Sewage Backup Damage Potential RIP of 2-3m SLR
Part III: Evaluating the utility of the RIPs method from potential users’ perspective – how?

**EXPERT WORKSHOP**
- 15 experts
- Involved in SLR planning OR Problem expert

The robustness of the impact patterns can:

A. Support development of adaptation options that are more uncertainty-tolerant.
Part III: Evaluating the utility of the RIPs method from potential users’ perspective – how?

**EXPERT WORKSHOP**
- 15 experts
- Involved in SLR planning OR Problem expert

**SURVEY**
- 10 specific ways to use RIPs to support SLR adaptation planning

**GROUP DISCUSSIONS**
- Why
- Examples
Expert workshop: survey results (10 ways to use the RIPv)

### Options development

- **Generate new ideas of SLR adaptation option**
  - Strongly disagree: 1
  - Disagree: 11
  - Neutral: 3
  - Agree: 3
  - Strongly agree: 2
  - No answer: 1

- **Refine adaptation options**
  - Strongly disagree: 1
  - Disagree: 4
  - Neutral: 8
  - Agree: 3
  - Strongly agree: 2
  - No answer: 1

- **Develop wider range of adaptation types (e.g. soft, hard, combination)**
  - Strongly disagree: 1
  - Disagree: 10
  - Neutral: 2
  - Agree: 3
  - Strongly agree: 2
  - No answer: 1

- **Develop more uncertainty-tolerant adaptation options**
  - Strongly disagree: 3
  - Disagree: 10
  - Neutral: 2
  - Agree: 3
  - Strongly agree: 2
  - No answer: 1

- **Support long range planning of modifications**
  - Strongly disagree: 1
  - Disagree: 3
  - Neutral: 7
  - Agree: 4
  - Strongly agree: 2
  - No answer: 1

### Access to resources and stakeholder

- **Prioritize SLR adaptation efforts and resources**
  - Strongly disagree: 2
  - Disagree: 9
  - Neutral: 4
  - Agree: 3
  - Strongly agree: 1
  - No answer: 1

- **Communicate sea-level rise risk**
  - Strongly disagree: 3
  - Disagree: 8
  - Neutral: 2
  - Agree: 3
  - Strongly agree: 1
  - No answer: 1

- **Highlight new types of stakeholders to engage**
  - Strongly disagree: 2
  - Disagree: 5
  - Neutral: 3
  - Agree: 3
  - Strongly agree: 1
  - No answer: 1

- **Support justification for planning for a worse scenario**
  - Strongly disagree: 2
  - Disagree: 5
  - Neutral: 3
  - Agree: 3
  - Strongly agree: 1
  - No answer: 1

- **Provide better leverage to request for resources**
  - Strongly disagree: 2
  - Disagree: 13
  - Neutral: 1
  - Agree: 3
  - Strongly agree: 1
  - No answer: 1
**Expert workshop: group discussion results**

Communicate SLR risk to stakeholders

UNANIMOUSLY AGREED

**Why?**

- Relevant and understandable to multiple types of stakeholders
- Raise awareness with neighborhood-specific impacts
- Educate about cascading effects
- Communicate compounding impacts
- Easier way to convey the worse case scenario

“Helps to diversify the risk. Not just people that live near water that are affected. Helps to put it on people’s radar.”

[Participant #2, CoV Planning]

“Practically, the worse case scenario is something we don't want to make even more terrible and this tool could support this“

[Participant #7, Consultant]
SUMMARY

• Impact assessment approach
  Efficient way to consider SLR impacts across wide range of futures. Consider uncertainties in early stages

• City of Vancouver application
  Demonstrated applicability and value of including indirect impacts

• Useful communication tool
  Multiple ways to support adaptation planning – most useful for risk communication

• Future modifications
  Needs modifications to further support developing adaptation options
THANK YOU

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