Metro Vancouver

Seismic Microzonation Mapping

What Planners Need to Know

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Institute for Catastrophic Loss Reduction
British Columbia Ministry of Emergency Management and Climate Readiness
Pinna Sustainability

Welcome and Introductions

Agenda

- Introduction to the project
- Introduction to the hazards and maps
- Q and A
- Microzonation maps in planning
- Planning Questions/ Q and A
- Wrap up

Important Concepts

Exceedance Probability
(% in 50 years)

Susceptibility

Return Period

Risk

Hazard

Metro Vancouver

Seismic Microzonation Mapping Project

Introducing the Project

Metro Vancouver Seismic Microzonation Mapping Project (MVSMMP)

The MVSMMP is a multi-year research project to generate a suite of **region-specific seismic hazard maps.**

Seismic microzonation maps display predicted variation in earthquake hazards due to local site conditions

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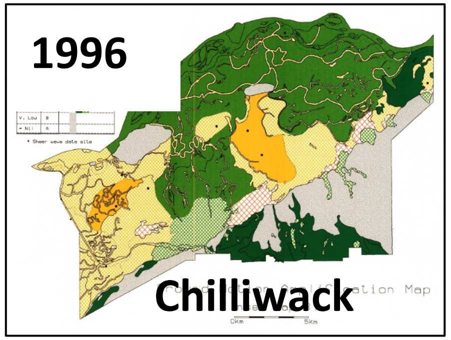
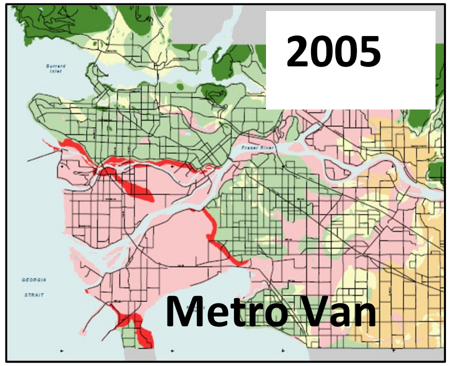
What are Seismic Microzonation Maps (SMM)?

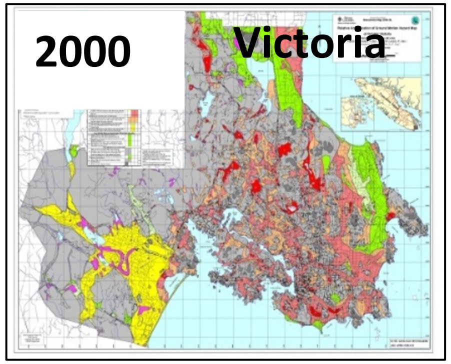
Variation in subsurface ground conditions leads to variation in earthquake shaking across an area. Typically mapped at the urban and regional scale

Seismic microzonation maps display predicted variation in earthquake hazards due to local site (ground) conditions.

Map Inputs:
geological, geophysical, geotechnical information combined with numerical modelling



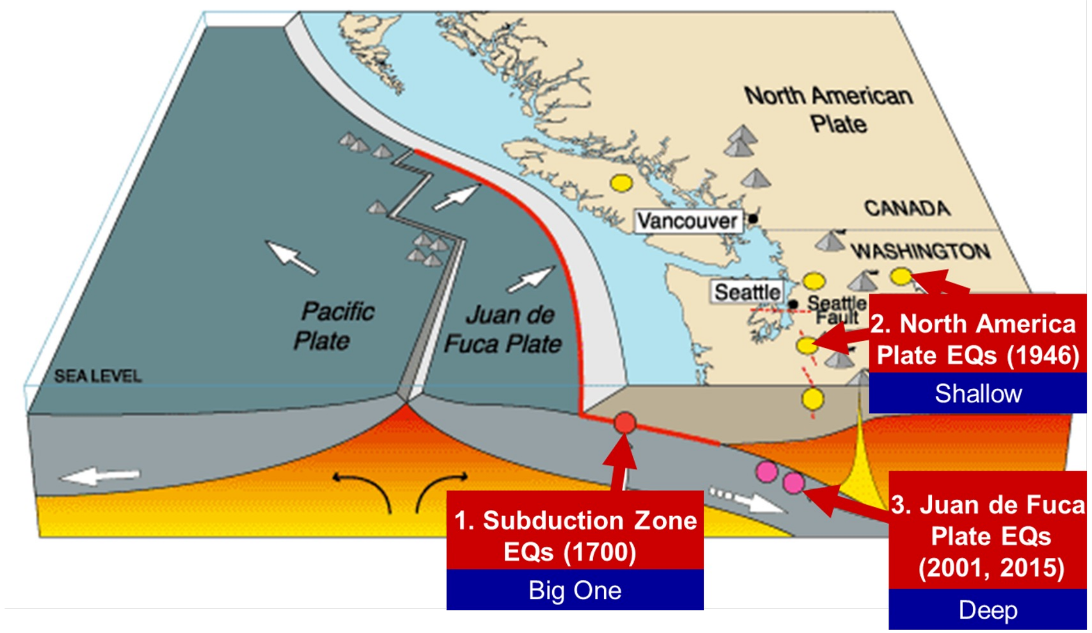


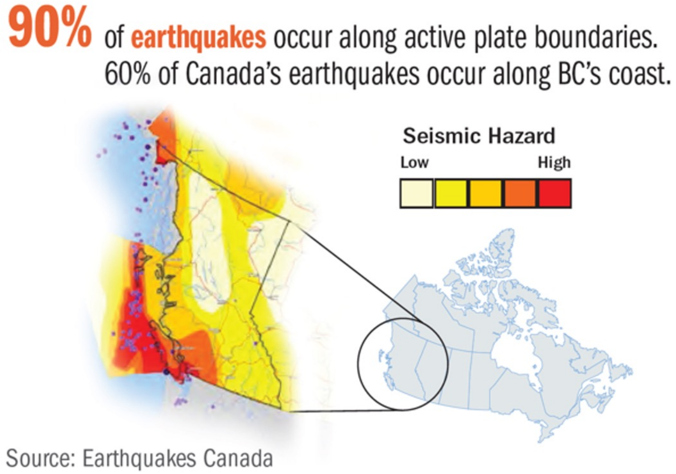


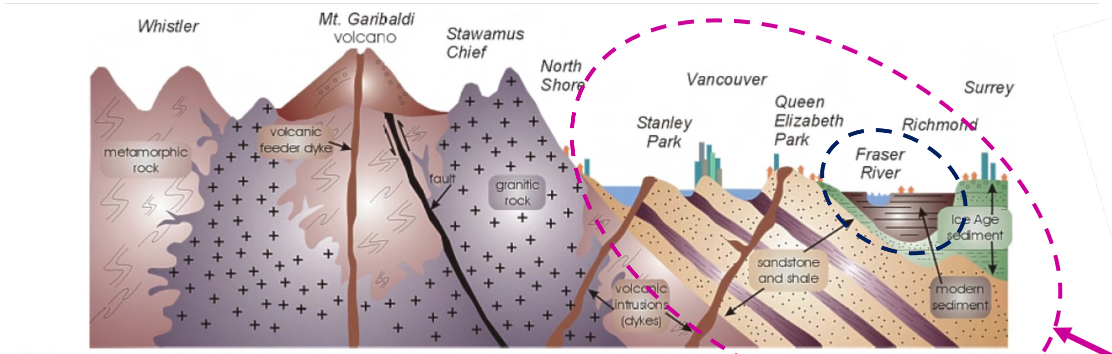
Previous SMM in southwest BC led by Vic Levson (BCGS) and Pat Monahan

Why are SMMs important in MV?

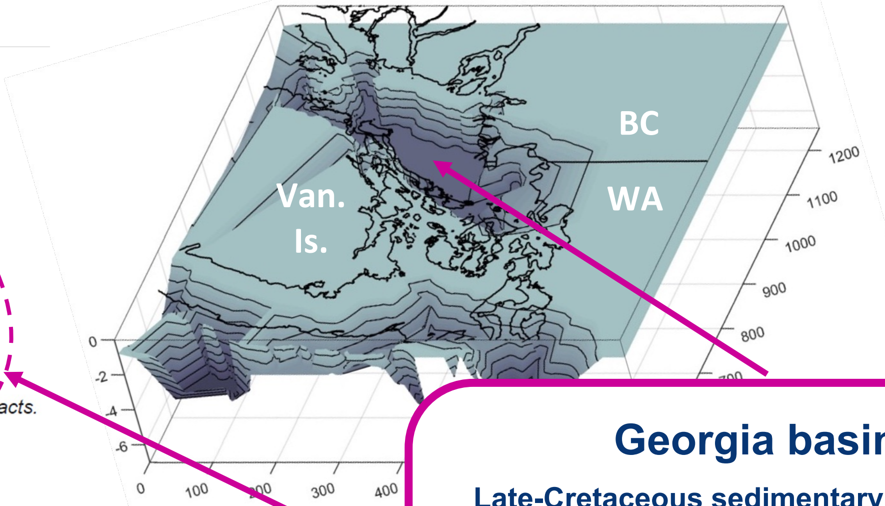
Metro Vancouver is situated in one of the **most complicated seismic hazard regions** in Canada







Cartoon cross-section of the Earth below the Vancouver area showing the major rock types and the nature of their contacts.
https://www.cgenarchive.org/vancouver-rocks.html



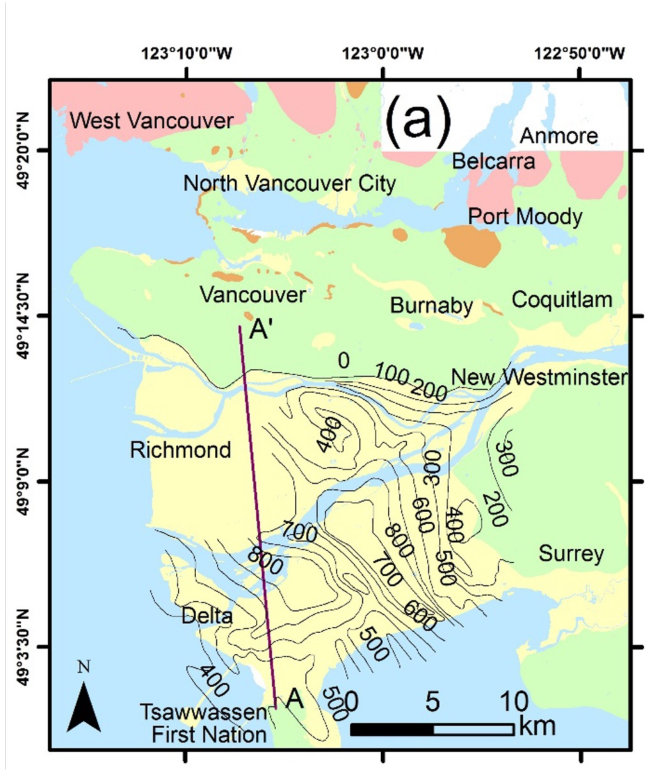
Georgia basin

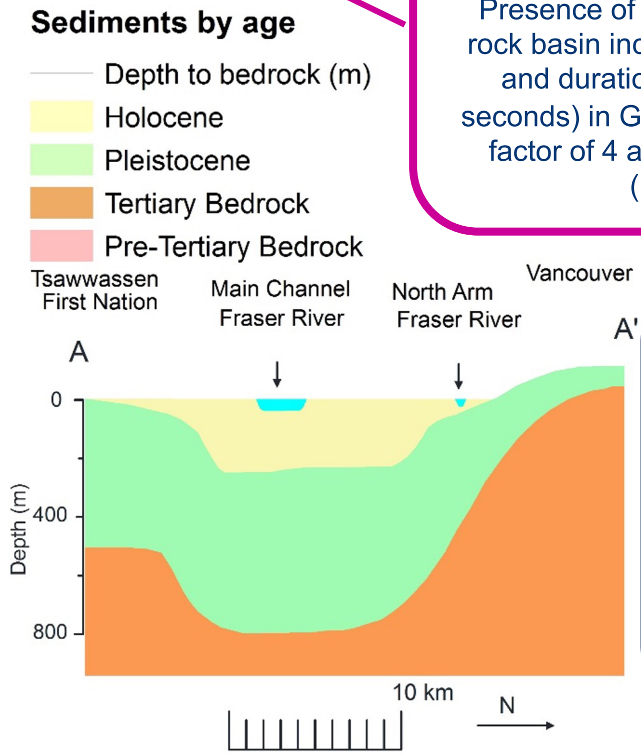
Late-Cretaceous sedimentary rock basin

Presence of the Georgia basin sedimentary rock basin increases the amplitude (intensity) and duration of long-period shaking (> 2 seconds) in Greater Vancouver by an average factor of 4 and 22 seconds longer shaking (Molnar et al. 2014).

Highly Variable Ground Conditions

- Unconsolidated to glaciated sediments, Two rock types
- Elevations from 0 to over 1000 meters
- Max. depth to rock = 800 meters
- **Basin within a Basin**





Fraser River delta

Holocene deltaic basin

Soft sediments amplify earthquake shaking. Nonlinear soil response during strong shaking will lead to deamplification. Saturated sands may liquefy during strong shaking.

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Map Levels

Level 1	Level 2 — 12 Maps!	Level 3 — 18 Maps!
Susceptibility maps Surficial Geology Limited use of subsurface data	**Susceptibility or Hazard Maps** Subsurface geological data and area-specific data on physical properties.	**Advanced analyses of Hazard** Extensive seismological and subsurface geological, geophysical and geotechnical data and simulations. Detailed subsurface maps and models

Increase in seismic hazard analyses

Increase in quality and quantity of geodata

Increase in cost

The Best Information Available

Key Facts

1. There is no Canadian standard for SMMs

   Now EGBC guidelines for BC!

2. No existing SMMs in Canada are accessible in digital (GIS layer) form until now

3. Very few regional SMMs in Canada are Level 3 until now

Key Deliverables

- EGBC Professional Practice Guidelines for Development and Use of SMM in BC (April 2024)
  - EGBC Webinar coming
- Regional Geodatabase(s)
- Regional Velocity Model(s)
- Suite of Region-Specific Seismic Hazard Maps (approx. 30 maps)

  12 Seismic Susceptibility (Level 2)

  18 Seismic Hazard (Level 3; mean return period of 475 and 2,475 years)

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Introduction to the Hazards and Maps

Seismic Hazard

Primary Seismic Hazard is Ground Shaking

Secondary seismic hazards result from source (fault) rupture and ground shaking

"Only" 3 seismic hazards are commonly addressed by Microzonation Mapping

1. Shaking(amplification/deamplification)
2. Seismic-induced Liquefaction Hazard
3. Seismic-induced Landslide Hazard

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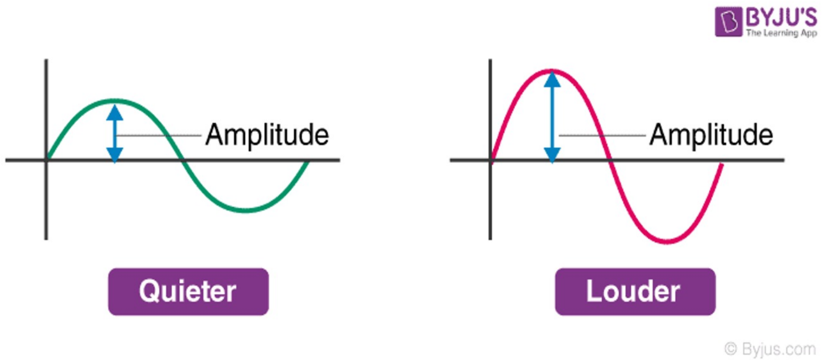
Seismic Hazard: Shaking Amplification/De-amplification

What is it?

Seismic waves travel through the Earth's crust. Soil conditions (loose sediment, soft clay, etc.) slow the waves down and they become amplified.

Why do we care?

Amplification can increase the intensity of shaking experienced. Even if located far from the source, areas of high amplification hazard can still experience strong shaking and damage.



Important Concepts

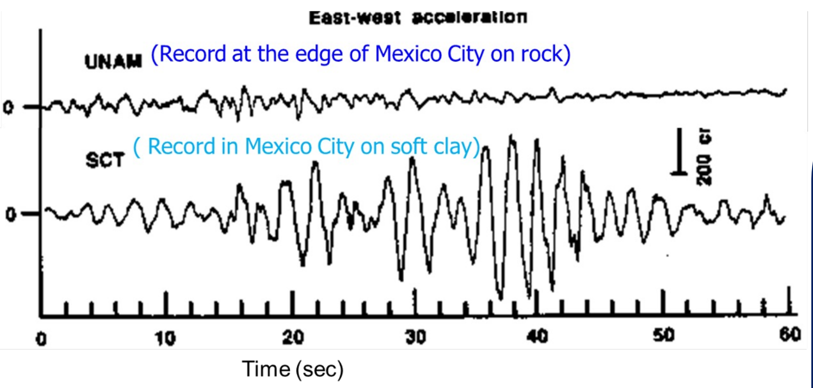
Vs – Shear Wave Velocity, **Vs_{30}** – average Vs in top 30 m

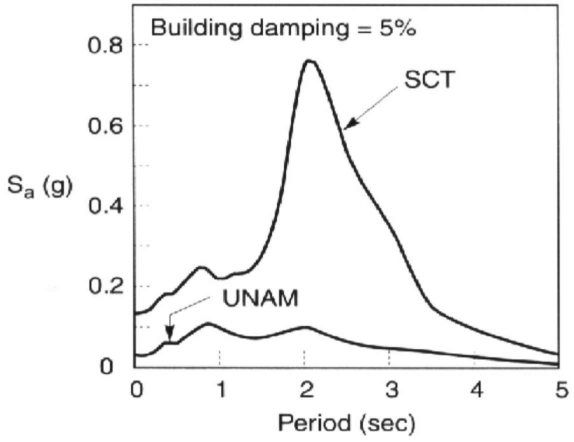
- How waves move (velocity) given ground conditions
- Wave propagation through soil can result in amplification.
- Amplification ⟶ greater acceleration of the ground at a particular site ⟶ intense shaking.

Site Period (T in seconds)

- Natural frequency at which ground oscillates or vibrates
- Long period, low frequency like rocking/swaying of a boat - deep or soft ground
- Short period, high frequency feels like rapid vibration or rattling – stiff or shallow ground

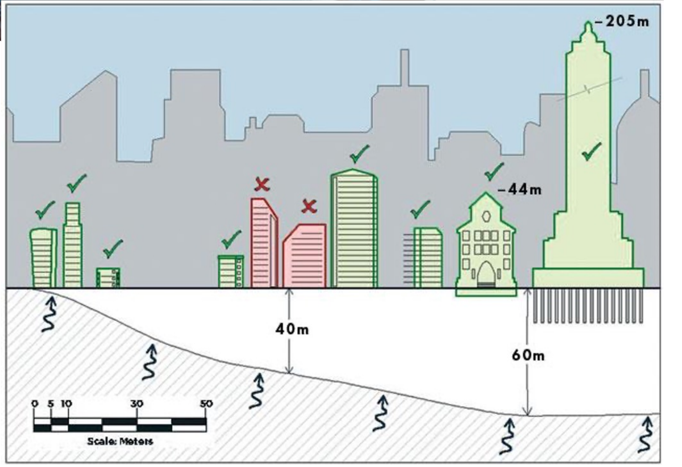
Shaking Amplification Hazard

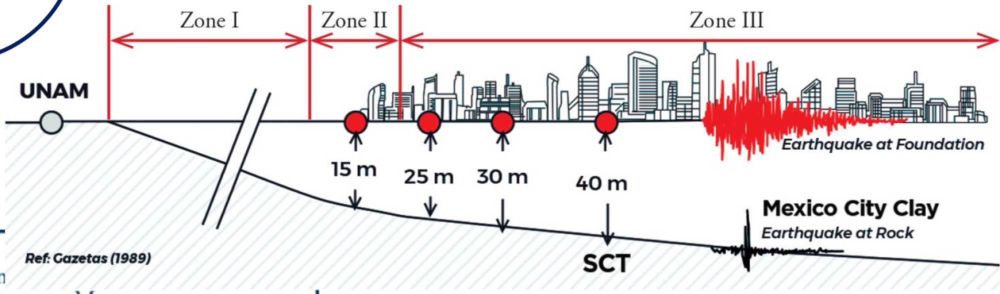




Ground shaking of the 1985 magnitude 8.0 Michoacan earthquake was amplified by soft clays under Mexico City.

Shaking amplitude was **5 times higher** on soft clay sites than rock sites at **2 second period** □ collapse of 412 mid-height buildings (8-18 storeys) with corresponding 2 second period.





Potential Impacts - Shaking

Shaking Potential Impacts

- Cracks in Foundations
- Building Collapse
- Damage to non-structural elements
- Underground utility damage
- Infrastructure no longer stable
- Impact on lifelines and critical facilities
- Buildings twist and sway - damage

Source: Terra Encyclopedia from New Zealand

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Ground Shaking/ Amplification Hazard Mapping

- Vs_{30} most common measure of **seismic ground conditions**
  - Metro Van: Fraser River Delta is 300 m of post glacial sediment over another 300-500 m of glaciated sediments (up to 1 km deep) within the Georgia sedimentary rock basin (up to 6 km deep)

- The most common measures used to produce **Shaking Susceptibility Maps** include :
  - Soil Thickness
  - Shear Wave Velocity
  - Site Period

- The most common measures used to produce **Shaking Hazard Maps** include:
  - Surface ground motion intensity
  - Amplification (> 1) or deamplification (< 1) relative to (dense soil or rock) site condition

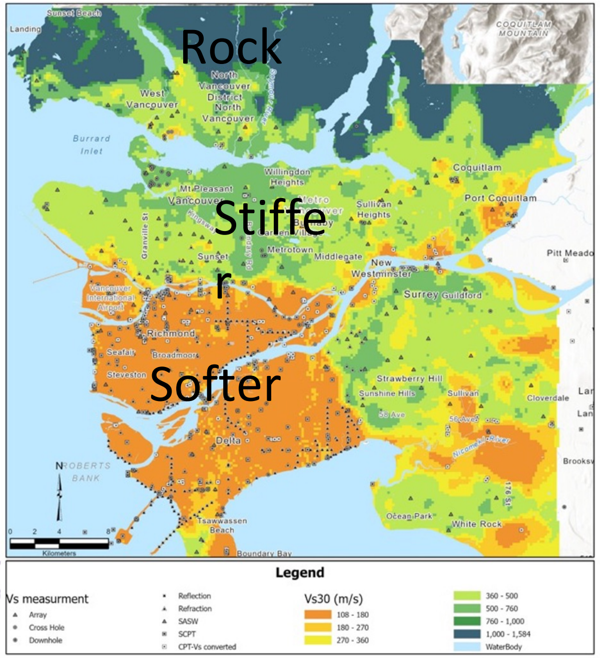
Levels of Shaking Hazard Mapping

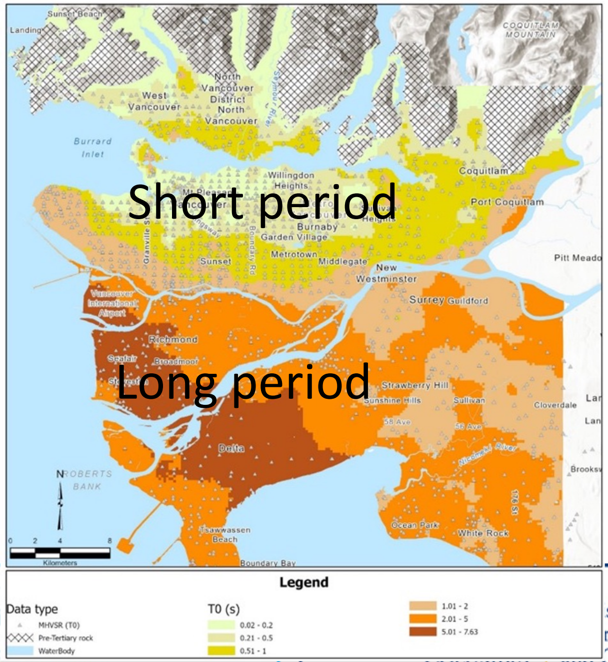
Level 1	Level 2	Level 3
Susceptibility maps	**Susceptibility or Hazard Maps**	**Advanced analyses of Hazard**
General correlations of hazar with site condition maps (surficial geology) Limited use of subsurface da		

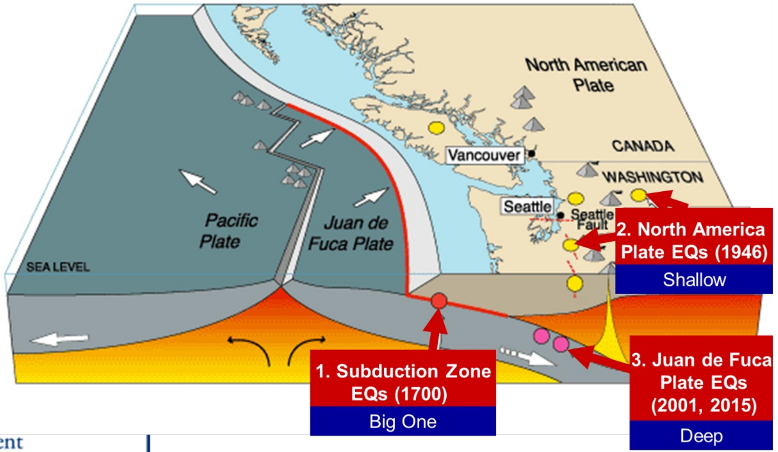
Identify where ground is susceptible to shaking amplification

How much will the ground amplify earthquake shaking?

Consider the ground's properties WITH the earthquake shaking that would occur over a mean return period of 475 or 2475 years







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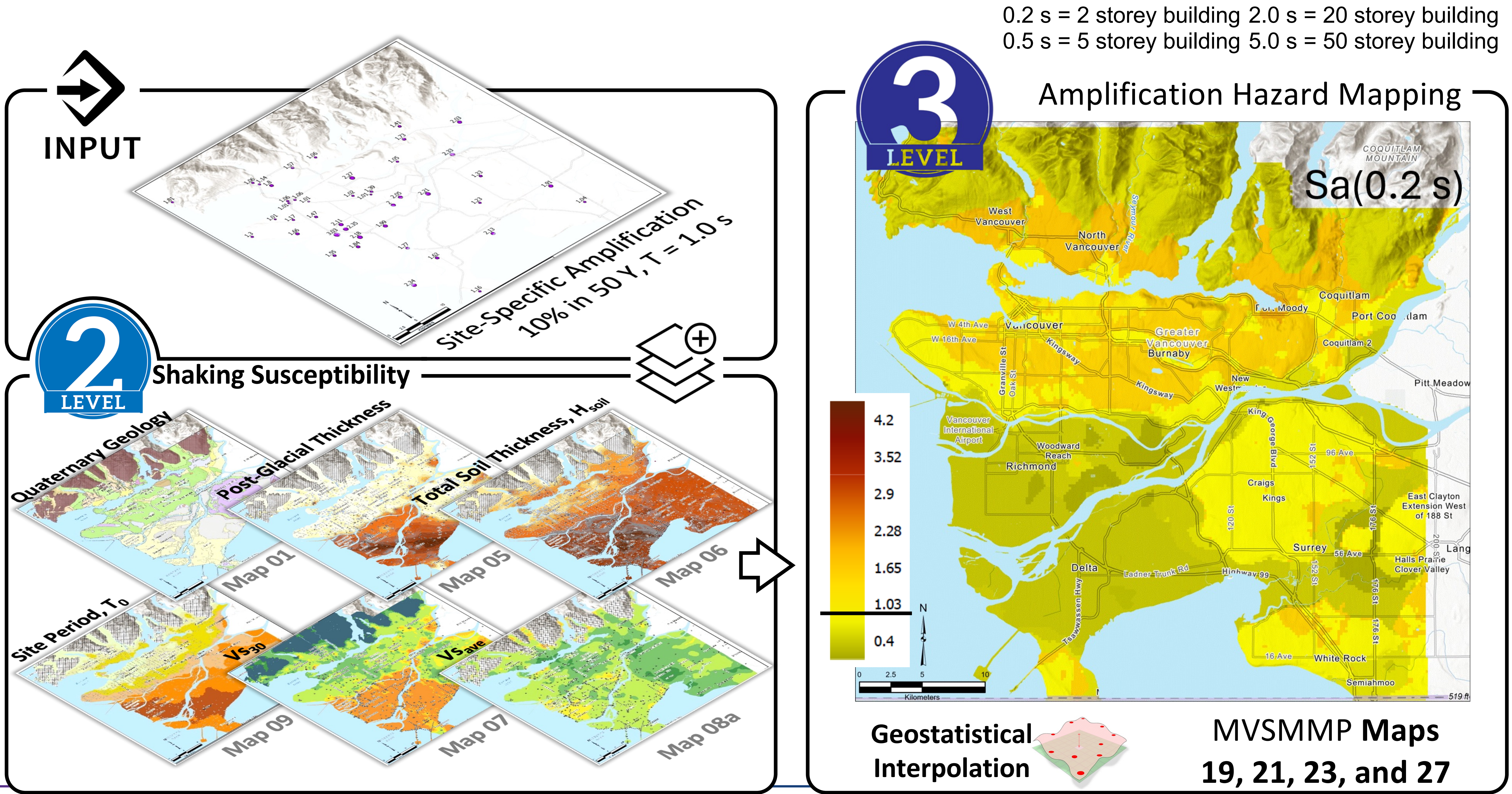

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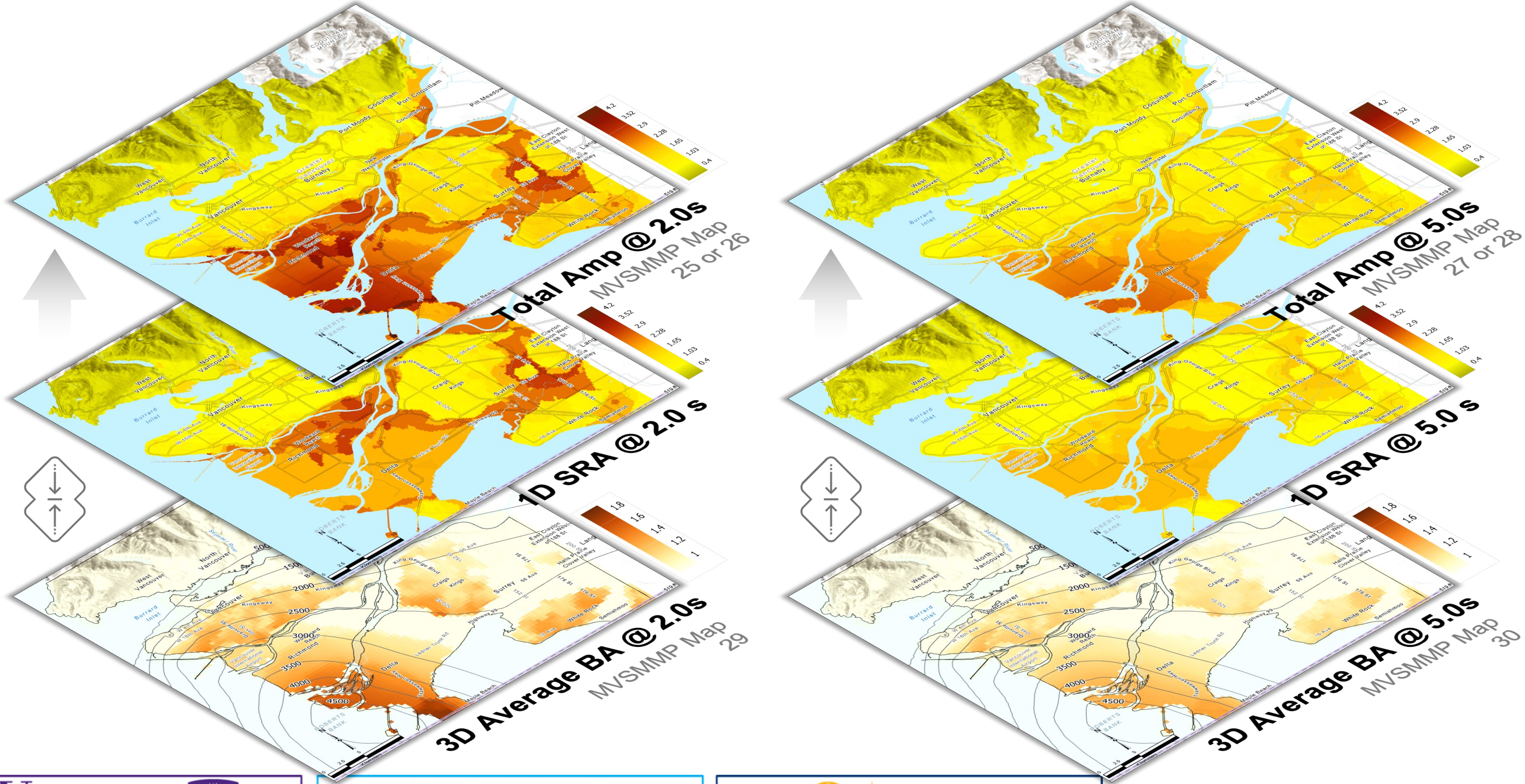

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Seismic Hazard: Liquefaction

What is it?

Liquefaction occurs when soil particles lose contact with each other, lose shear strength, resulting in the soil behaving

like a liquid

- Sand boiling
- Lateral spreading
- Ground settlement
- Ground cracking
- Flow slides

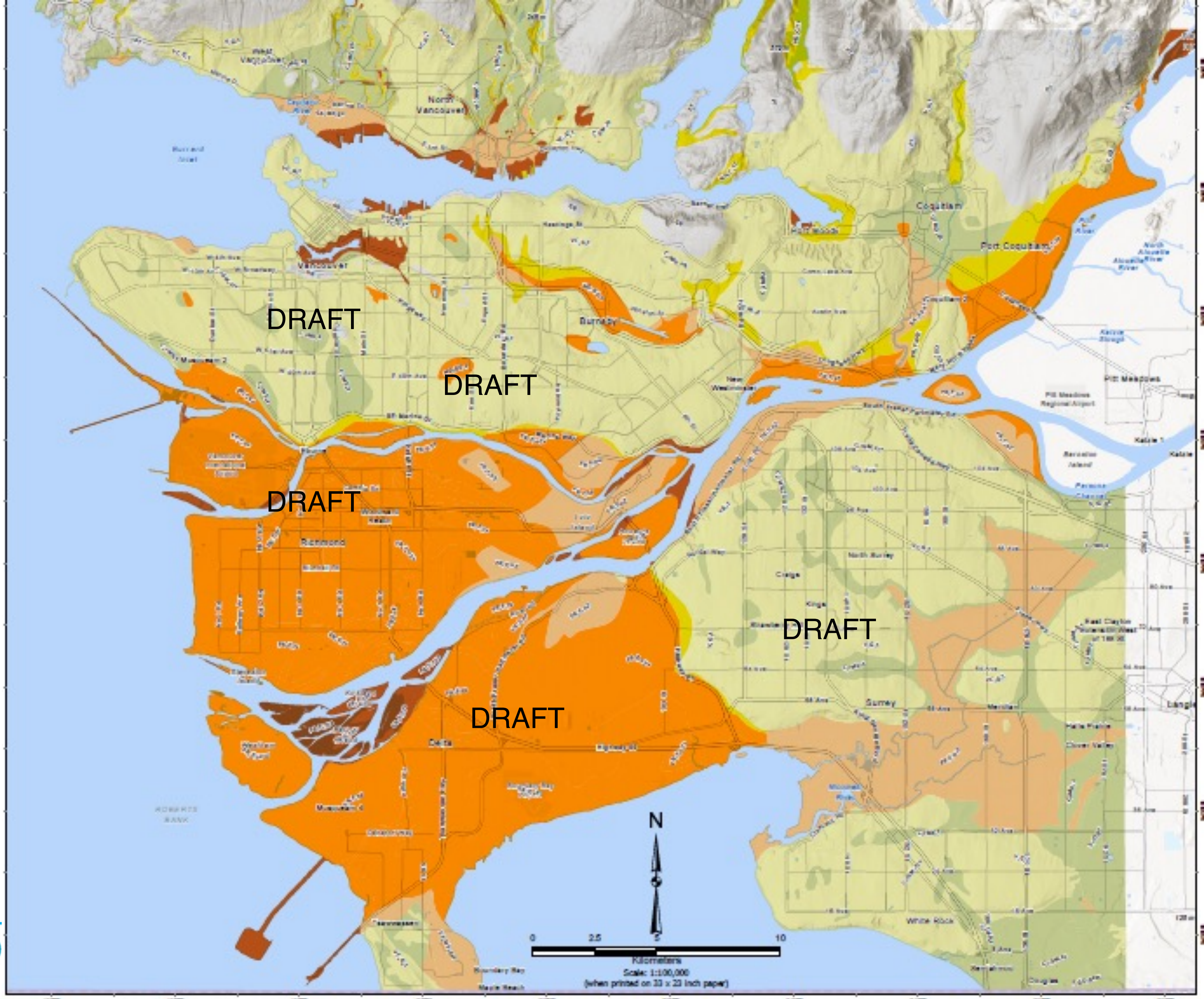
Potential Impacts - Liquefaction

Liquefaction Potential Impacts

- Building settlement and tilting
- Foundation failure (sink or shift)
- Dealing with sand that boils up
- Underground utility damage
- Roads and bridges sink, crack or collapse
- Impact on lifelines and critical facilities
- Long term structural instability

Liquefaction Susceptibility Map

Liquefaction Susceptibility
- None
- Very Low
- Low
- Moderate
- Moderate-High
- High
- Very High



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For example: Levels of Liquefaction Hazard Mapping

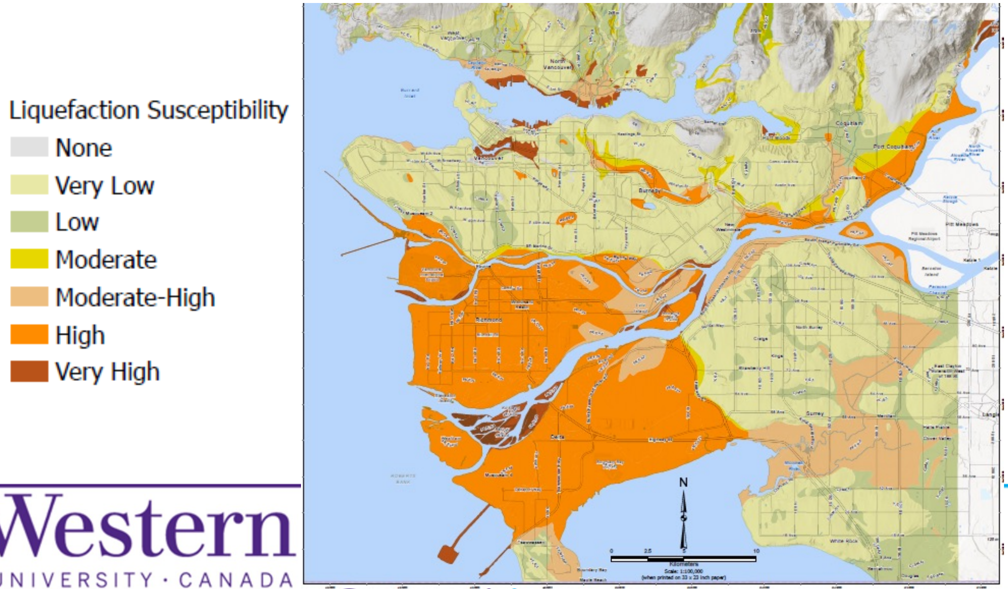
Level 1	Level 2	Level 3
Susceptibility maps	**Susceptibility or Hazard Maps**	**Advanced analyses of Hazard**

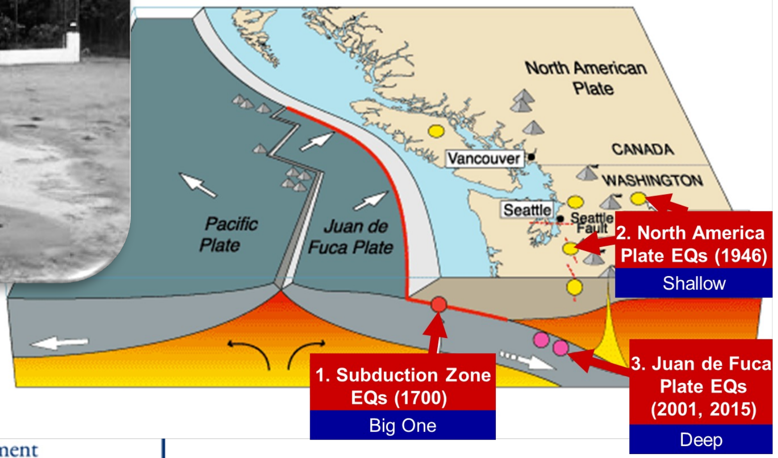
Identify if ground is susceptible to liquefaction

Considers the local soil resistance (how sandy, how saturated)

But will the ground liquefy given the regional seismic hazard?

Consider both the local soil resistance WITH the earthquake shaking that would occur over a mean return period of 475 or 2475 years





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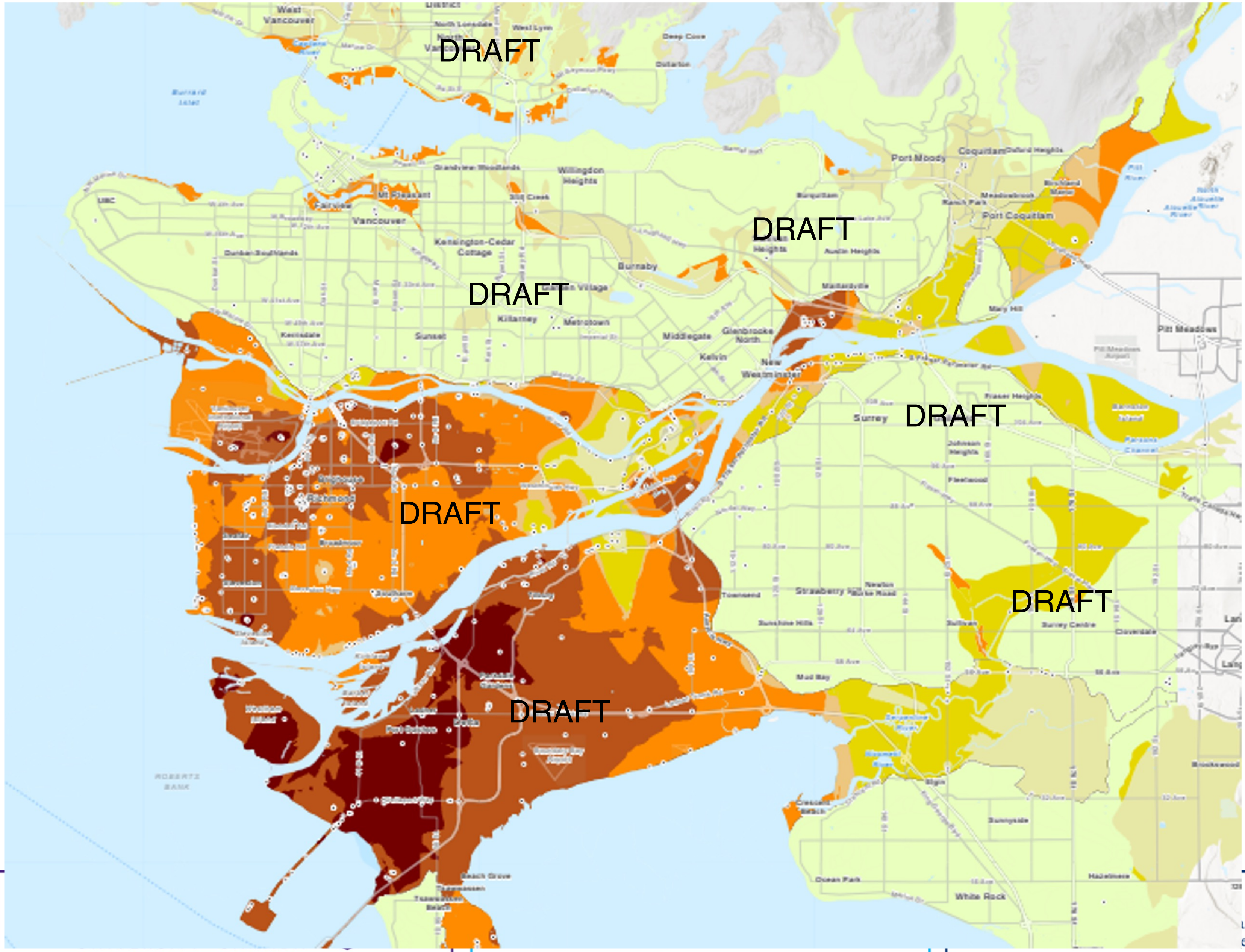
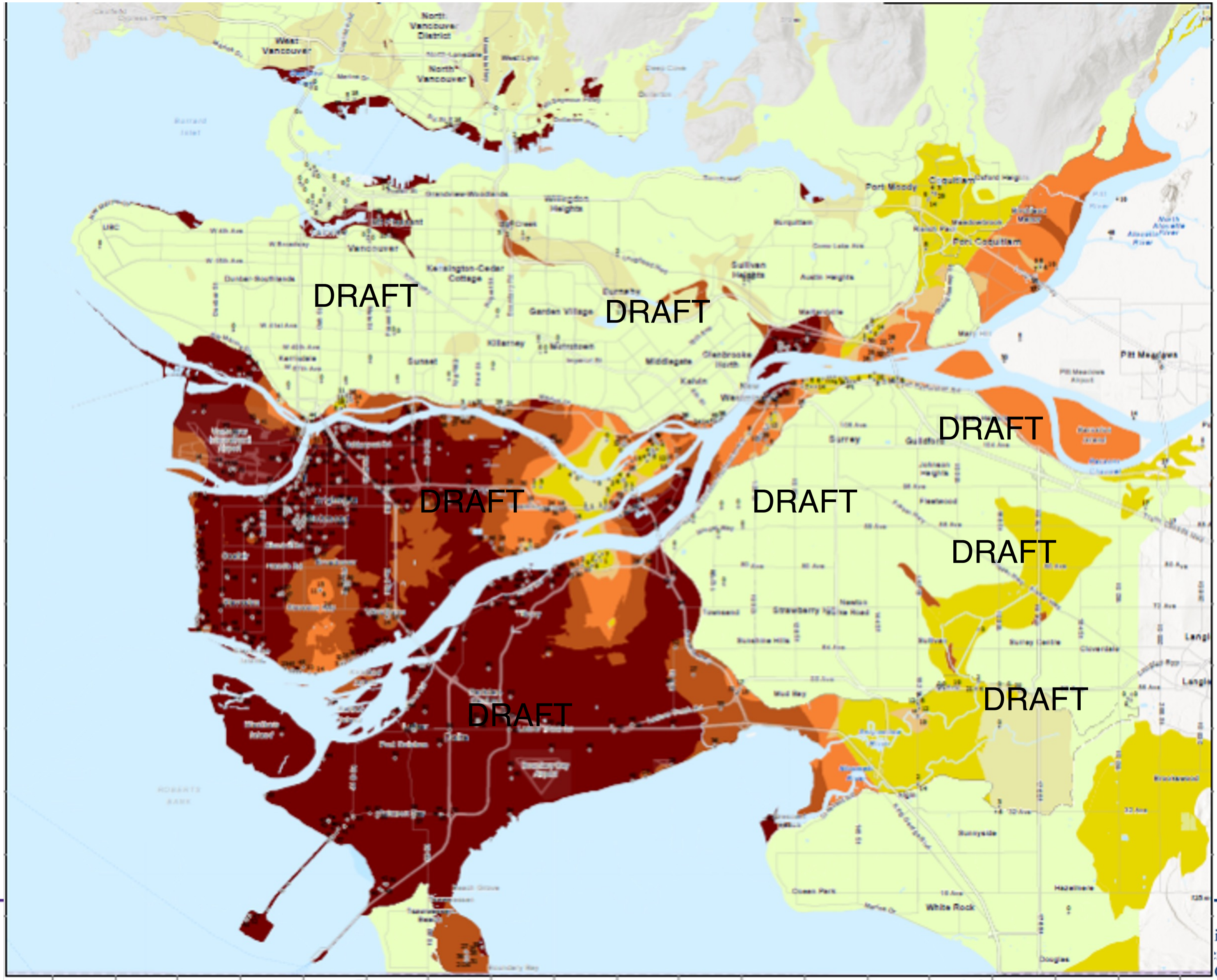
10% Probability of exceedance in 50 years/ 475 Return Period



Seismic-Induced Liquefaction Hazard

LPI	Hazard Category
0	Very low hazard
1-5	Low hazard
5-10 10-15	High hazard – sand boils and ground cracking may develop
15-25 25-35 > 35	Very high hazard – sand boils and ground cracking are likely. Lateral spreading may develop.

2% Probability of Exceedance in 50 years, 2475 Year Return Period



Seismic-Induced Liquefaction Hazard

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15-25 25-35 > 35	Very high hazard – sand boils and ground cracking are likely. Lateral spreading may develop.

Seismic Hazard: Landslide

3. Seismic-induced **landslide**

What is it?

- **Landslide** is the movement of a mass of rock, debris, or earth down a slope.
- Susceptibility to rainfall induced landslides can also be interpreted from the landslide susceptibility map

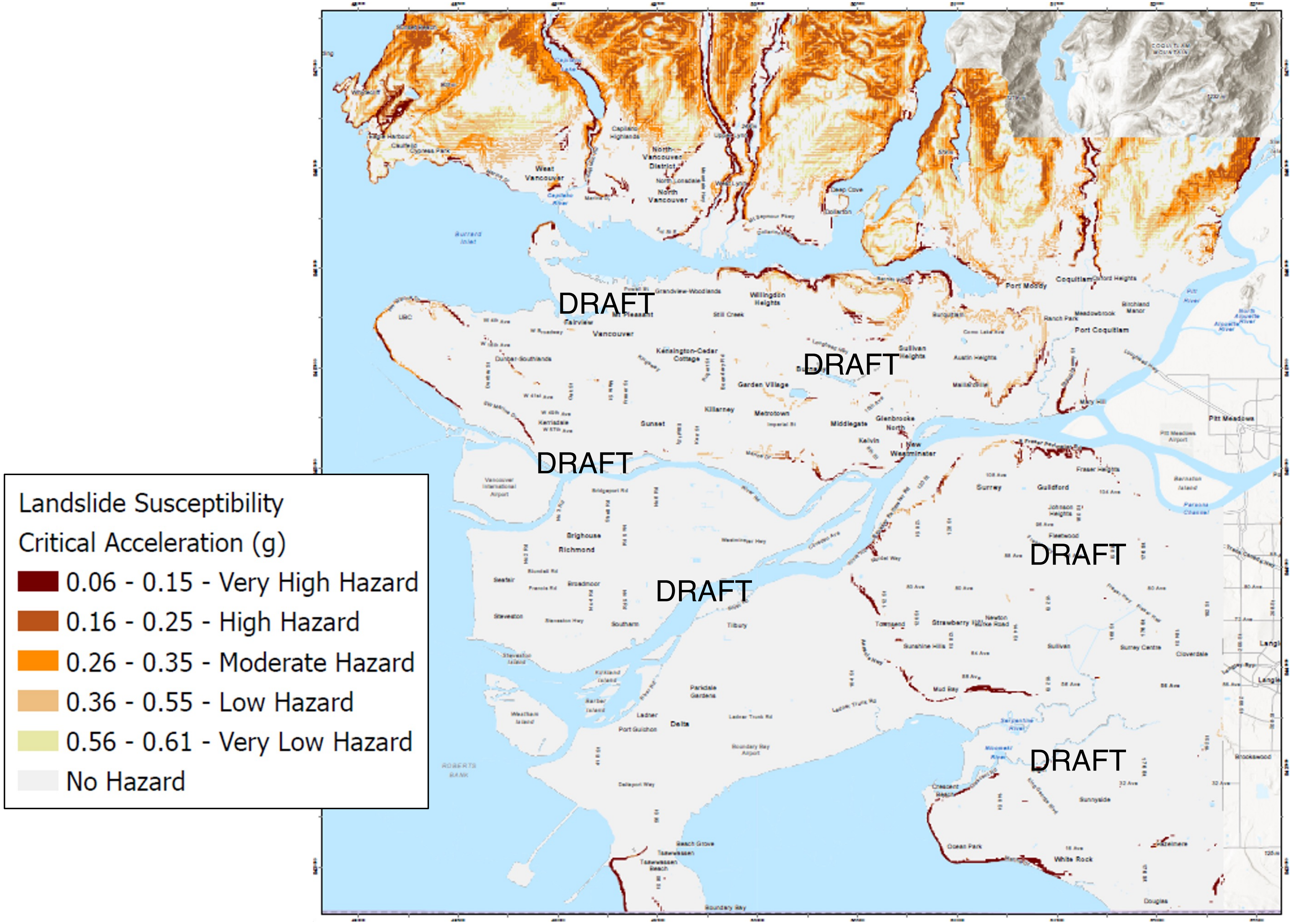
Potential Impacts - Landslide

Landslide Potential Impacts

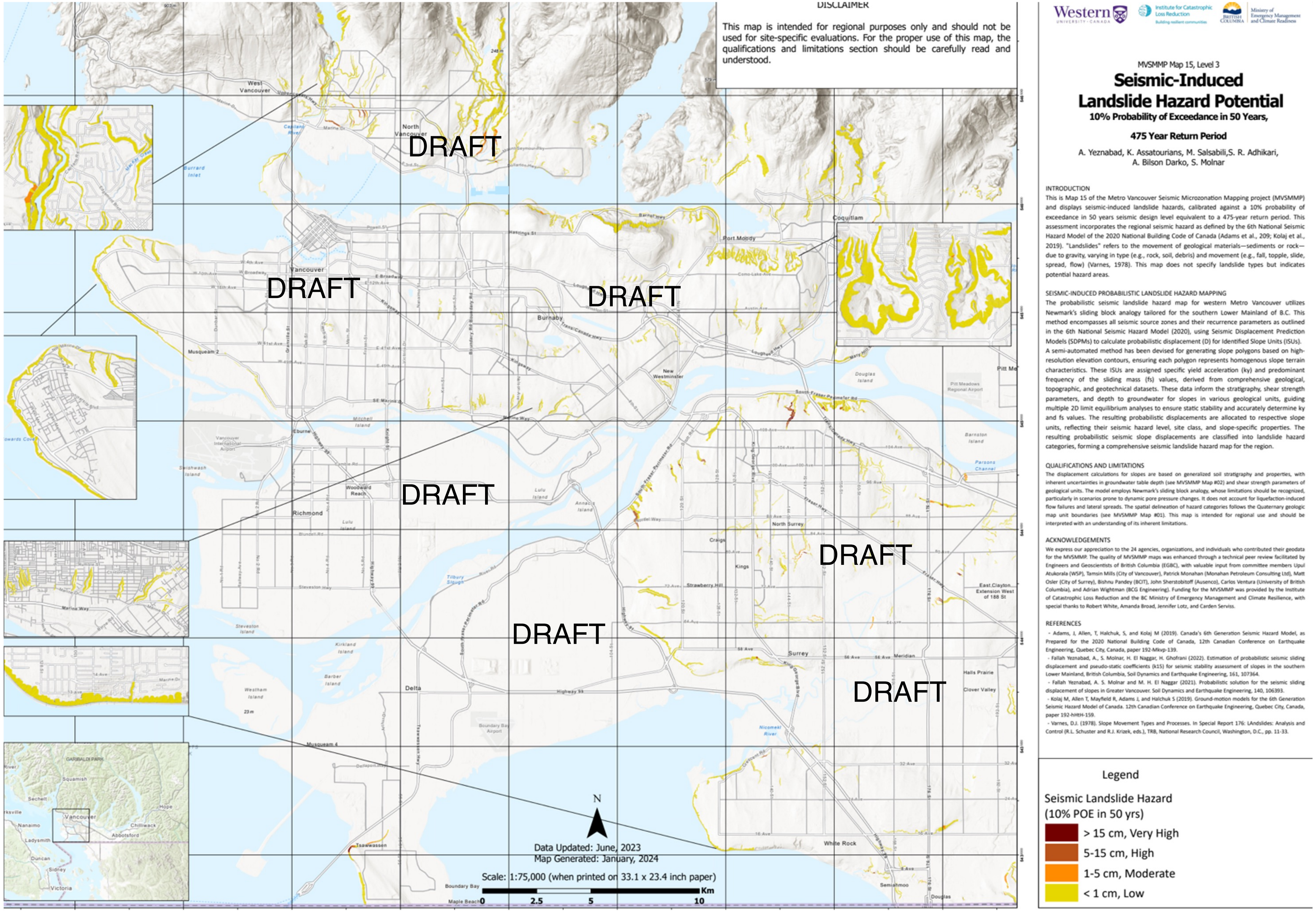
- Direct impacts to buildings / infrastructure
- Transportation disruption
- Utility service interruptions
- Loss of life and property
- Environmental impacts such as sediment and debris in waterways, habitat disruption

Source: PhysOrg - Japan

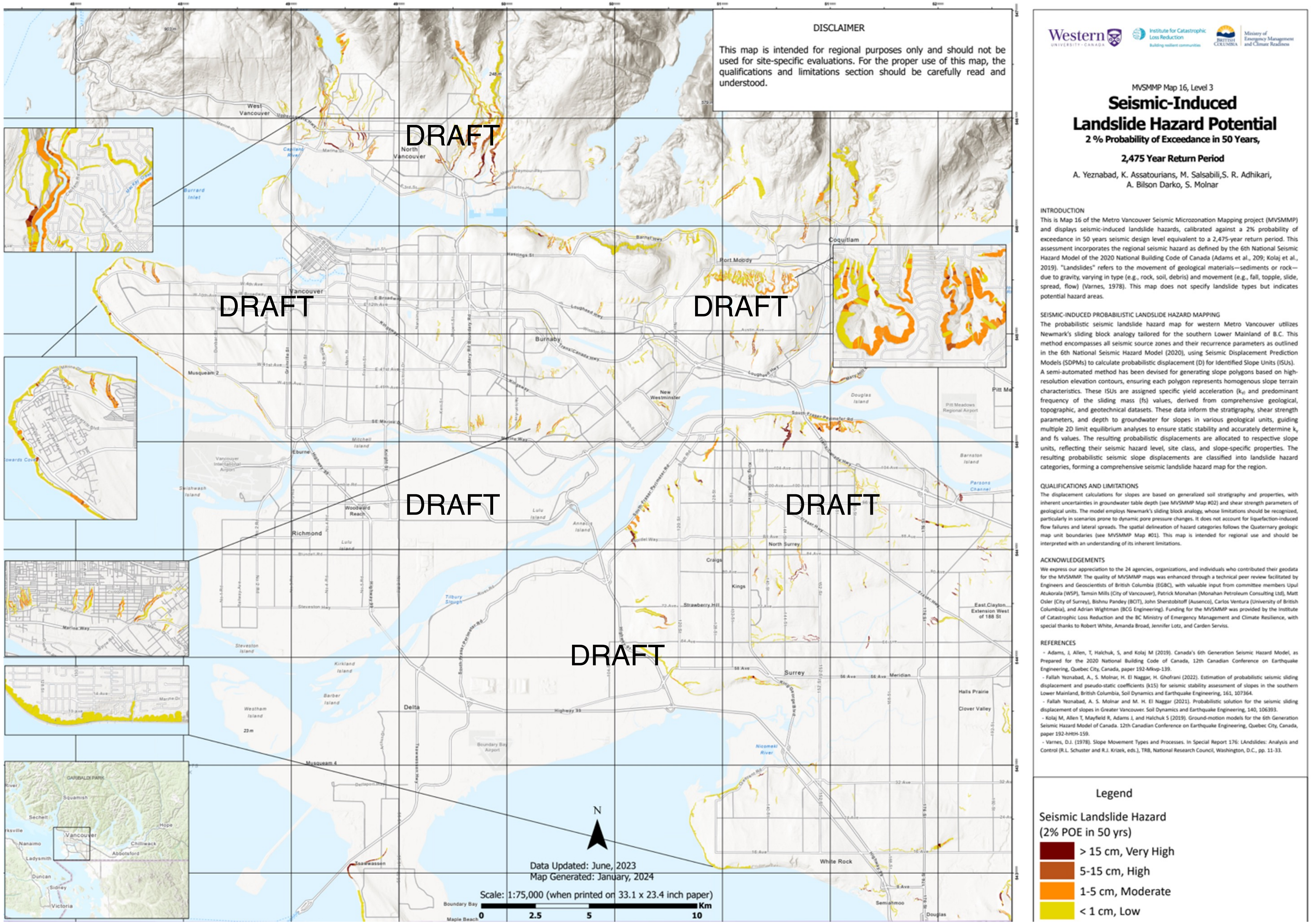
Landslide Susceptibility



Landslide Hazard: 475 Year Return Period



Landslide Hazard 2,475 Year Return Period



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Question and Answer

Why Should Planners Care?

Limitations

The SMM Maps do not replace the need for site specific seismic or geotechnical field investigation for a building permit or detailed design for construction drawings.

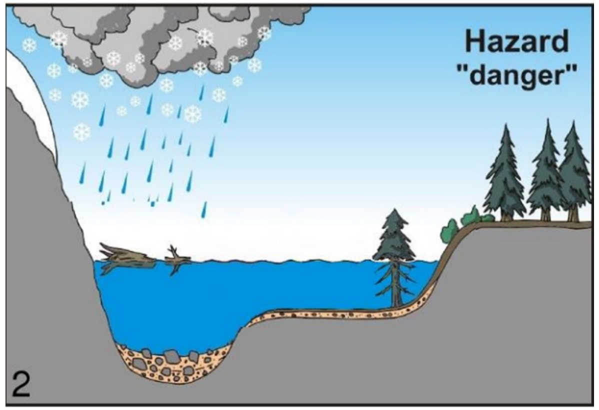
The SMM Maps do not depict seismic risk or seismic stability of major infrastructure

The maps do not fully capture human-made alterations to ground conditions (fill, ground improvement etc.)

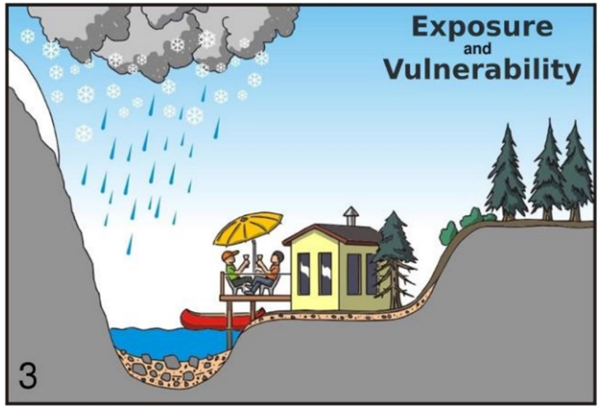
Hazard to Land Use Continuum

Define desired outcomes:
i.e. RGS, OCP, Hazard Policies

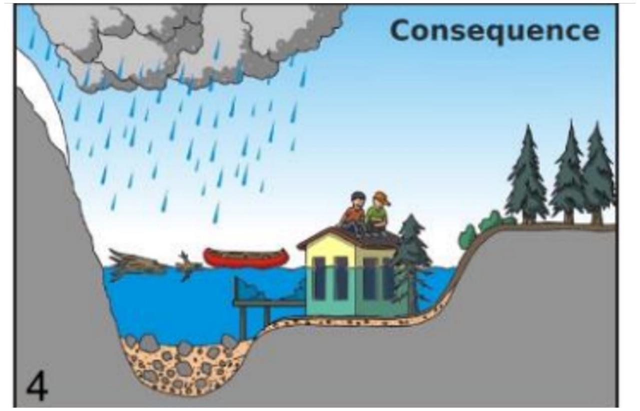
Monitor Performance and build community resilience



Define susceptibility and hazard threat



Identify who and what could be harmed



What is the severity of consequences?

Develop strategies, policies and regulations to reduce potential consequences to an acceptable level

SMM Uses in Planning - Risk and Vulnerability Assessment

Deaths, Disruption, Dollars and Downtime

SMMs provide spatial information on susceptibility and hazard threat:

- where is it likely to be more intense due to site characteristics & basin effects, under specific seismic conditions (type and location of earthquake)?

Combine with parcel level building dataset and damage/loss curves to understand damage which is then used to help calculate casualties, recovery time and disrupted occupants.

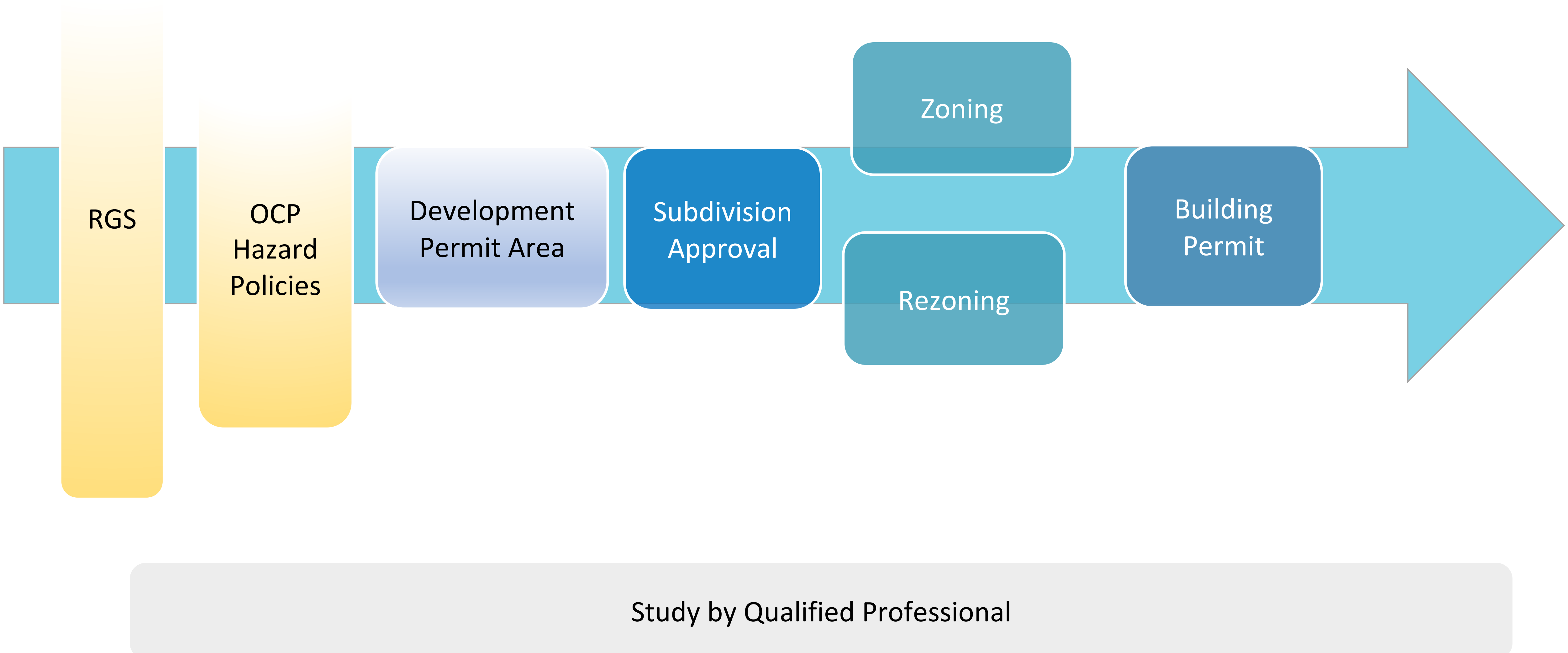
SMM Uses in Planning: Risk and Vulnerability Assessment

Set risk reduction goals that define success in terms of how building types will function after a quake

Policy options consider realistic upgrades and the performance change of the upgrades

considerations of affordability, occupant displacement for retrofits, climate adaptation to other hazards, etc.

Hazard Related Planning Tools



SMM Uses in Planning – Land Use

RGS and OCP

- Avoid **NEW** risks, reduce **EXISTING** risk
  - Reduce Exposure – don't put things in harms way
  - Reduce Vulnerability – Retrofit or new builds that are less susceptible to damage
- Avoid high hazard areas for higher risk activities and critical infrastructure

Development Permit Area

- Example: for Landslide we have Steep Slope Hazard Areas and DPAs (North Van.)

Subdivision Approval

Zoning

- Short buildings are more susceptible to damage from short periods and taller buildings are more susceptible to damage from long periods.
- Opportunitv to ask for further studv and earthquake performance of the building

SMM Uses in Planning – Land Use

Zoning and Project Meetings

- Maps can provide a high level sense of the cost of site amelioration and the need for more in depth site study and geotechnical and structural effort

Terms of Reference for site specific investigation (QP study)

- Requirements for site-specific information to be obtained and used by Engineering Professionals where Ground Shaking susceptibility is high.
- Peer review requirement if very different from SMMs

RFP Requirements

- RFP requirements for these maps to be integrated/considered

Alternative alignments and prescriptive design requirements for linear infrastructure.

Restrictive Covenants

SMM and Building Code

SMM is the most detailed communication of expected earthquake shaking effects due to local site conditions.

- SMM use a site specific approach. Better local information
- NBCC: local site effects are 'grouped' or 'binned' to ensure the design ground motions are conservative
- The building code recommends that "site-specific" seismic hazard analysis be performed in special cases (e.g., high importance buildings)
- Maps may help persuade clients to complete performance based design above and beyond the building code

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SMM further uses

Engineering Standards

Incorporate in Asset Management risk assessments and planning for renewal

- Understand where failures may most likely occur (when combined with asset vulnerability information)

Improve planning for Emergency Response

- Debris management
- Interruption of critical infrastructure
- Concentration of casualties
- Where to put response supplies, prioritize rapid building assessment

Take Home Messages

- Seismic Hazard includes a variety of hazards that impact buildings and infrastructure in different and compounding ways
- SMMs provide the best local information available
- We rely on regional systems (from Translink to water to district energy) and land use
- Planners have included flood hazard mapping across policy frameworks, how best to incorporate seismic hazard?
- Can help us take risk-based approaches to land use and development and help us identify where retrofits are most needed.
- Economy of scale with energy efficiency and climate risk – resilient neighbourhoods and buildings

For More Information

- https://metrovanmicromap.ca
  - Developing open data portal (geodata, maps), accessed at the above website
  - Developing online map viewer experience, accessed at the above website
  - Maps for western Metro Vancouver (Phase I) available in summer 2024
  - Maps for eastern Metro Vancouver (Phase II) available in late 2026
- Sheri Molnar, smolnar8@uwo.ca
- For the published EGBC Guidelines and Webinar - stay tuned via the EGBC Continuing Education emails and/or the EGBC Website Events (egbc.ca)

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