Flood Protection Challenges and Innovative Solutions in Urban Areas:

Sea Island Dike Design Case Study

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1. Urban Flood Challenges – Infrastructure and Development

2. Urban Flood Challenges – Sea Level Rise

3. Flood Management at Vancouver Airport

4. Dike Design Case Study

5. Conclusions and Q&A
“Urban areas are particularly vulnerable to the expected increase in extreme weather conditions due to their high population densities and concentration of industry and infrastructure.”

- CWRA 2015 Theme
Urban Flood Management Case Study

Vancouver International Airport (YVR)

- Regional & National transportation hub
- Concentration of infrastructure
- Commercial development interests
Flood Management and Sea Level Rise Adaptation - “Protect” Strategy

15 km perimeter dike system + 6 drainage pump and flood boxes

Average Ground El. 1 - 2m

Historic Dike El. 3.6m

Current Design El. 4.7m

Dyke System Centreline Elevation (m, Geodetic)

- Lower than 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 3.9
- 4 (+/- 0.1)
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 8.0
Urban Challenges - Sea Level Rise Adaptation

BC MoE 2011
Case Study: Grauer Road Dike Replacement

Location and History

Dike Design Crest Elevation: 4.7 m Geodetic
- Incorporates 1 m of Sea Level Rise
- Approx. 500-year return period Fraser River flood level in year 2100
- Existing setback dike alignment (red) no longer viable due to development
Space Limitations

Development and Infrastructure

Arthur Laing Bridge (Vancouver)
Canada Line
Rapid Transit Bridge
Outlet Designer Centre
Grauer Road
Terminal
Options Analysis and Selected Alignment

Balancing Space Between Development and Flood Protection

Selected Alignment Below Bridge Opening
- ~ 3 m raise above existing ground
- Provide 50 km/hr road (1 lane each way)

~ 36 m
Arthur Laing Bridge Foundation
Design Challenges

- Bridge foundation bearing capacity and settlement under typical dike fill load

- Bridge structural response during earthquake – “flexibility of piers”

- 800 Stone Columns installed along either side of bridge in 1990’s for ground improvement = ideal seepage path!

Design Your Way Out of the Problem
Dike Fill Considerations: Lightweight vs. Buoyancy vs. Seepage

Expanded Polystyrene (EPS)
Unit Weight = 0.1 – 0.4 kN/m$^3$

*Would float away without anchor!*

Pumice
Unit Weight = ~7 kN/m$^3$

*Won’t float away, but porous! Stability and seepage concerns*
How to keep a pumice dike stable?

**Steel Sheetpile Design**

- Thick & deep steel sheet pile down the middle
- Weld sheet pile joints to reduce seepage
Bringing the concept together…
The “Lightweight Dike” Solution
From Concept to Detailed Design to Construction

- **11 m Buried Steel Sheet Pile**
- **EPS layer to mitigate road cracking due to differential settlement**
- **Road gravel base layers above**
- **Bridge Foundation**
- **Pumice Fill Around Sheetpile**
- **Building the wall to be buried**
- **Ready for road base layers**
Sub-excavate for pumice and Trench for installing sheetpile
Construction Methodology

Drive piles in sections

Then pull up whole wall to final elevation
Construction Methodology

Pumice placement in 300 mm lifts, light compaction (vibratory plate)
Construction Methodology

Burying the sheet pile and transition to standard dike away from bridge loading zone
Retaining walls maintain original “flexible” response of piers under seismic event
• Sheetpiles installed in one piece sections with special smaller driving head
• Twice daily monitoring/survey for settlement and movement during driving
Construction Challenges – Archaeology, Utilities

- Musqueam First Nation Marpole Midden Material
- Keeping utilities out of dike
Project Summary – Grauer Road Dike

Completed in 2014 on schedule for opening of Outlet Designer Centre.

- **Owner**: Vancouver Airport Authority
- **Lead Consultant**: Kerr Wood Leidal
- **Geotechnical Sub-consultant**: Golder Associates
- **Bridge Structural Sub-consultant**: Ausenco
- **General Contractor**: Jacob Bros. Construction

*First lightweight flood dike application we are aware of in Canada.*
Lessons for Urban Flood Management

1. Assess & Communicate **Flood Risk** to all stakeholders.

2. Adapt through integrated flood **land use planning** – consider future development

3. Some development & infrastructure will **always** need to be protected – incorporate resilience and innovation into design!
Thank you! Questions?

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