Effects of Climate Change on Marine Infrastructure

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Canada’s Coasts

World’s longest, and arguably, most varied.
- Geography and Oceanography
- Ice cover
- Permafrost
- Post-glacial rebound
Sensitivity to Sea Level Rise (Shaw et al.)

Our coasts
Climate change
Adaptation Toolkit
- GIS
- CIAPS
Salt Marsh Trail
Cow Bay
NW Arm
Closing
Infrastructure

1,040 Fishing Harbours, 18 Port Authorities
Waterways, Communities
Climate change

- Increased CO₂ (400 ppm)
- Warmer air and oceans
- Ocean acidification
- Rising seas
- Changing weather patterns
- Less ice, more open water

Source: NOAA
Climate change Scenarios

Global mean sea level rise

Year

Mean over 2081–2100

RCP2.6
RCP4.5
RCP6.0
RCP8.5

Source: IPCC 5th (2013) SPM-9
Marine Infrastructure

**Concerns:**
- Relative sea level rise
- Longer open water seasons
- Increased runoff → increased sedimentation
- Permafrost thaw → large scale erosion

**Primary Impacts of Climate Change:**
- **Function**
  - Resources (e.g. siting of harbours wrt fisheries)
  - Navigation (Ice cover, Arctic navigation)
- **Performance**
  - Wave action
  - Flooding
  - Erosion, Sedimentation, Dredging
  - Serviceability (e.g. wharf elevations, decay)
Nearshore conditions

Waves $H_s = 6m$ to $10m$ offshore
Biggest waves break offshore

Small depth increase offshore – negligible effect

Nearshore:
Waves $= f(\text{waves, bathymetry, water level})$
Wave height often controlled by water depth
Depth increase inshore $\rightarrow$ proportional increase in wave height

Combined effects of storm surge, tides and sea level rise are CRITICAL factors
Nearshore effects

Design conditions:
100 yr offshore wave and the 100 yr water level?
10,000 yr probability (100x100)?
NO - They are inter-related.

AND
The statistics of nearshore conditions are quite different from offshore.
The ‘100 year’ nearshore event is not simply the nearshore conditions during the 100 yr offshore event
The Statistics of the Problem: Joint probabilities of water levels and waves

Joint probability assuming independence...with inter-dependence
Offshore waves (Halifax)

(Relative sea level rise has no real effect)
Nearshore waves at Cow Bay, Halifax now and in 50 years
Marine Infrastructure at Risk

We’ve already seen 100yrs of rising sea levels
Adaptation Measures

1. Hold the Line
2. Managed Realignment
3. No Active Intervention
   - Ongoing, adaptive process.

Adaptation to Climate Change requires:
- Planning
- Development and implementation of codes and standards
- Risk-based analysis and design

The ‘design life’ of a coastal structure is 25-50 years, but the functional life of a site is much longer. Facilities get re-capitalized, re-purposed, or abandoned, and new facilities get constructed.
Toolkit

To be able to adapt to climate change on our coasts, we need to be prepared.

This means:
- Understanding our coast and how it works
- Understanding what the future might look like
- Understanding the consequences of change

Then…
- We can plan and implement adaptation strategies
  - Risk-based framework
  - Rational design procedure
Toolkit: Coastal GIS

Inputs:
- DEMs (LIDAR),
- Air photos
- Bathymetry
- Waves
- Structures

Results:
- Shoreline classification
- Climate change scenarios
- Vulnerability tools
Tides

Legend
HHWLT
- 0.52 - 0.60
- 0.61 - 0.70
- 0.71 - 0.80
- 0.81 - 0.90
- 0.91 - 1.00
- 1.01 - 1.20
- 1.21 - 1.50

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VCF – Vulnerability to Coastal Flooding

Legend
-1.00 - 0.00
0.01 - 0.25
0.26 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 2.00
2.01 - 5.00

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Longshore sediment transport under climate change (less ice)
Changes to net transport

Legend:
- Qn_57yrs (From the 57 years of hindcast)
- Qn_00s (From the 2000s hindcast)

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Closing
Coastal Infrastructure Adaptation Planning System (CIAPS)

- Joint probability approach - full range of possible loading events.
- Conditions vary over time (includes climate change)
- Computes probability of failure over time for a defined process (e.g. overtopping).
- Iterate to find optimum geometry to minimize total costs (combined operating and maintenance / repair costs).

Applications:
- Salt Marsh Trail, Halifax
- Cow Bay Causeway, Halifax
- Northwest Arm Seawalls, Halifax
- Breakwater Park, Kingston
Salt Marsh Trail (Halifax) - built on bed of Musquaduboit Railway
Flood shoals as a result of causeway

Salt Marsh Trail
Cow Bay
NW Arm
Closing

Salt Marsh Trail Causeway Restoration Project

Coldwater Consulting Ltd
Salt Marsh Trail

Frequency flooding and damage.
- Life-cycle optimization of alternatives based on both capital and maintenance costs incl. climate change effects
Understanding the coast: Tidal model
Understanding water levels

COASTL model

Currents ‘funnel’ water into Cole Harbour.

Water levels 0.3 to 0.5m higher than Halifax.
Adaptation Alternatives

Status quo

Partial Abandonment

Increase openings, bridges, culverts

Adapt design to changing conditions
CIAPS - 50-yr planning horizon

Optimized trail elevation under 3 sea level rise scenarios
Cow Bay Causeway

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Cow Bay
Construction
CIAPS

Features:
Systematic evaluation of how forcing and response changes under climate change scenarios
Use of Joint Probabilities
Life cycle costing for capital and maintenance/repairs

Result:
Comprehensive tool to incorporate climate adaptation into the design process
Closing

Climate change will lead to:
- Increased rates of relative sea level rise
- Reduced ice cover
- Changes to storm patterns
- Changes to precipitation
- Changes to resource characteristics

Marina Infrastructure Adaptation requires:
- An understanding of coastal processes
- Planning framework for adaptation
- Adaptive strategies (flexible, adaptable)
- Risk-based design tools that incorporate changing climate scenarios
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