Potential Effects of Climate Change on Hydrology and Geomorphology in BC

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Talk Overview

Part I
1. Background
   • Acknowledgments
   • Water-related values
   • Forest Management Concerns
   • Projected Climate Changes
2. Hydrologic Changes and Implications

Part II
1. Geomorphic Changes and Implications
2. Overall Forest Management Implications of Projected Climate Changes

Acknowledgements

Content partially drawn from:


- Project stems from Chief Forester’s FFEI.

FFEI – “to adapt British Columbia’s forest and range management framework so that it continues to maintain and enhance the resilience and productivity of B.C.’s ecosystems as our climate changes.”

- Provincial Vulnerability Assessment

R.G. Pike  Mayo Lake, near Duncan BC.
Water-related Values

Images: R.G. Pike
Where water supply is limited, conflicts may result between and among the various uses.
Forest Management Concerns
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Hydrologic Systems in BC

1. Rain-dominated regimes

2. Snowmelt-dominated systems

3. Mixed/hybrid regimes

4. Glacier-augmented systems

Images: Eaton and Moore 2007
What are the project changes in BC Climate?

- Increased winter and summer temperatures
- Greater warming in the north vs. southern BC.
- Wetter winters throughout.
- Dryer summers in Southern BC
- Wetter summers in northern British Columbia
- Increased intensity and amount of precipitation.
- Reduction in return periods of extreme events.

Source: Pike et al. 2008: pg 5
What are the projected hydrologic changes for BC?

1) Increased atmospheric evaporative demand and vegetation changes
2) Increased water temperatures
3) Decreased snow accumulation and accelerated melt
4) Glacier mass balance adjustments
5) Altered timing and magnitude of streamflow
6) Increased levels of storm events and disturbances
7) Accelerated melting of ice

Source: Pike 1998
Atmospheric evaporative demand and vegetation changes

- The atmosphere’s ability to evaporate water will increase.
- Vegetation changes (e.g., interception/evap characteristics) will alter water balance.
Atmospheric evaporative demand and vegetation changes

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Hydrologic Implications:

- Increased evaporative losses from water bodies
- Increased water demands
- Reduced vegetation growth and survival
- Increased wildfire risk
Increased Stream and Lake Temperatures

- Altered growth, egg & juvenile development
- Thermal barriers to both adult and juvenile migrations
- Delayed autumn spawning and reduced survival
- Increased frequencies of disease
- Altered species abundance and distribution (e.g., bull trout)

Continental Freshwater Effects: complex changes to thermal regimes, hydrological cycles & ecosystems likely to promote range expansions of warm-water fish & contractions by coldwater species in North America (Minns et al.)
Anticipated changes -
Where will they most likely occur?

- Fish responses will vary: impacts to some... benefits for others
- Cold-water “guild” species the most vulnerable (tolerate max. temps. up to ~24°C); e.g., bull trout
  - Affected most strongly where current conditions are near the maximum levels of thermal tolerance
  - Smaller, more southerly streams and lakes at lower elevations
- Cool-water (e.g., rainbow trout) and warm-water guilds may benefit
  - Faster growth and range/habitat expansions, esp. in the north
Decreased snow accumulation and accelerated snowmelt

- Average snowlines will migrate north in latitude and higher in elevation in response to increasing temperatures.
- Changes to snow depths may affect ground temperatures and subsequently infiltration rates / runoff.

P. Teti  Snow Measurement near Williams Lake
Decreased snow accumulation and accelerated snowmelt

- Average snowlines will migrate north in latitude and higher in elevation in response to increasing temperatures.
- Changes to snow depths may affect ground temperatures and subsequently infiltration rates / runoff.

Hydrologic Implications:
- Accelerated timing of snowmelt peaks
- Exacerbated summer low-flows.
- Water supply changes affecting hydroelectric power, fish, aquatic habitat, and winter recreation.
Precipitation as Snow: 1961-90 and Change by 2050 for CGCM2-A2

Source: ClimateBC- A. Walton; Wang et al., 2006
Glacier mass balance adjustments (advance/recession)

Glaciers will continue to recede, except those at the coldest locations.

Hydrologic Implications:

• Short-term: less severe low flows (number of days)
• Long-term increases number of low flow days
Altered timing and volume of streamflow (peak flows, low flows)

Preface...
• Storage and release mechanisms (groundwater, wetlands, lakes) importantly control streamflow in many watersheds.

• Climatic changes, therefore, will vary by region depending on the watershed’s current sensitivity to regional temperature and precipitation changes AND storage and release mechanisms.
Altered timing and volume of streamflow (peak flows, low flows)

Rain-dominated regimes
• Increased frequency and magnitude of winter storm-driven peak flows
• Drier summers with increased number and magnitude of low-flow days.
• Changes in hybrid snowpacks … potential early indicator?

Source: Eaton and Moore 2007
Altered timing and volume of streamflow (peak flows, low flows)

Rain-dominated regimes
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Snowmelt-dominated systems
• Shorter snow accumulation season
• Earlier start to the spring freshet.
• Shift in period of low flows.
• Plateau SMDR mostly in one elevation band therefore more likely sensitive to changes in snow (abrupt changes).

Source: Eaton and Moore 2007
Altered timing and volume of streamflow (peak flows, low flows)

Mixed/hybrid regimes
- Reduced spring peak flows that occur earlier
- Reduced winter low flows (i.e., more water) if precipitation falls as rain instead of snow.

Source: Eaton and Moore 2007
Altered timing and volume of streamflow (peak flows, low flows)

**Mixed/hybrid regimes**
- Reduced spring peak flows that occur earlier
- Reduced winter low flows (i.e., more water) if precipitation falls as rain instead of snow.

**Glacier-augmented systems**
- Decrease peak flows occurring earlier, similar to snowmelt-dominated regimes.
- Increased frequency and duration of low-flow days

Source: Eaton and Moore 2007
Forest Management Implications - Hydrology

Hydrologic Implications:

• More $$ to deal with winter storm-related damage (roads, floods, etc.)
• Increased aquatic concerns in re: fish (temperatures, migration)
• Decreased summer water availability
• Hydro-power concerns… IPP vs. BC hydro
• Water restrictions and brown lawn
• Changes in Forest Planning and Operations (covered in part II)
Part II

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“Stationarity is Dead” (Milly et al., 2008—Science, 319, 573-574)

- Climate change undermines a basic assumption—that natural systems fluctuate within an unchanging envelope of variability

(Cohen, 2008; Graphics from by T. Peterson)
Storm Frequency-Magnitude

- Increased magnitude for a given frequency (e.g. 5-25% increase in 10-year event observed in Washington from 1948-1976 vs. 1976-2006) (Salathe, 2008)

- November 12-17, 2006 Event ~20 year event (Miles, 2008) vs. ~100 yr event (pre-1998 data) (Chapman, 2007; IWL 2006)
Landslides

• Precipitation Intensity-Duration-Frequency correlates with MAP (e.g. Miles, 2001)

• Combine with landslide initiation thresholds (e.g. Cain, 1980)

• Landslide initiating storm events approx twice as frequent with 10% increase in MAP
Landslides

- Landslide frequency is correlated to mean annual precipitation (e.g. Van. Isl./Coast)

- Estimate changes based on shifting MAP

- E.g., Guthrie and Brown (2008) ~15-20% increase in landslide rates through shift to “wet” conditions
Landslides

• In Northern BC recent climate shifts have been associated with increased landslide frequency (Geertsema et al. 2007)

• 20th century changes of ~+0.6-1.3C; MAP~+10.2-18.6% (Eggington, 2005)

• Both short-term (storm) and long-term (seasonal/annual precip and temp) responses are important

• ~2-3x increase in landslide rates associated with recent change
Fluvial Processes

- Cumulative watershed effects
- Increased sediment supply
- Increased peak-flow regimes
- Altered LWD supply
- Decreased channel and fan stability
Glaciers

- Glacial recession and thinning
- Changes to hydrologic processes
- Decreased slope stability (e.g., de-buttressing)
- Increased sediment production
- Outburst flooding (moraine-dam; jökulhlaups)-site specific

Photo: Geertsema et al. 2006
Permafrost & Snow-Ice Processes

- Warmer temp (winter/annual)
- Changes to snow and avalanche processes
- Permafrost melting (North & high elevation)
- River ice and ice jams

Implications

- Altered forest harvest scheduling (operable ground, timing),
- Transportation (reduced use of ice bridges),
- Increased rates of slope failures.
- Increased soil water levels influencing runoff timing and amounts.
- Altered recreation (fishing opportunities).
Sea-level Rise & Coastal Erosion

- Projected sea-level rise varies with GCM Model, and varies with location on the Coast
- ~0.1 to 0.5m rise based on mean projects (Bornhold, 2008)
- Some areas more sensitive than others (e.g. Lower Mainland, NW Haida Gwaii)

Implications
- Increased erosion, infrastructure impacts (log sorts, docking areas)
Fire

- Large scale forest fires have the potential to have the largest impact on watershed geomorphology (and hydrology)

Implications
- Increased surface erosion, slope instability, loss of bank root strength, increased flow
- Increased watershed sensitivity/decreased resilience
Windthrow

- With increased storm severity, increased windthrow likely

**Implications**
- Influence on landslide initiation
- Riparian areas (LWD supply rates, channel stability)
- Increased sediment production
Insect/Disease

• Most vulnerable to Watershed-Landscape scale disturbances

Implications
• Increased frequency of “channel forming” flows -> stability
• Altered LWD supply regime
Forest Management Implications

- Impacts to FRPA values (water, fish, timber, soils)
- Water/Community water supply
- Fish habitat
- Loss of productive timber and soil
Forest Management Implications

- Public and worker safety (~5 deaths/year from landslides in Canada) (Schuster, 1996)
- Risk to infrastructure, property
- Design and maintenance costs
- Liability issues
- Public perception
Overall Forest Management Implications

What can we do? Can we do anything?

1. **Focus on the most effective responses**
2. **Identify Watershed Vulnerabilities**
3. **Assess current practices / operations**
4. **Define time period of interest** (e.g., 20 years, 50 or 100 years from now). *Since different processes respond at different rates, the identified vulnerabilities will change with time period of interest.*
5. **Modify operations/ practices as required.**
Hydro/Geo Watershed Vulnerabilities

1. Fish Passage – Culvert / Stream crossings
2. Terrain Stability
3. Planning/Assessment: WAP, RoC/ECA – concepts of “hydrologic recovery”
4. Riparian Management Areas
5. Roads
6. Restoration – past and future
7. Operations: (e.g., wet weather shutdown guidelines, altered harvest scheduling, practices?)
8. Site loss / degradation
9. Permanence of Watershed features – Wetlands, Lakes, Riparian areas, etc.
Vulnerabilities-Terrain

- Have had modest success with terrain management
- Pre-code vs. Post-code (drop from ~10-30x to ~3-5x) (FPB, 2005; Guthrie 2008; Horel 2007)
- FRPA and landslides?
- Landslide rates likely to increase ~1-3x with projected changes (approx. return to landslide rates of Pre-Code)
- Shifts in unstable terrain (Class IV->V; III->IV)
Vulnerabilities-Planning

- Incorporate risk/loss to down-slope resources in planning
- Long-term infrastructure (roads, bridge, drainage) designed to account for changing climate
- Use alternate harvesting techniques on sensitive terrain (requires research to identify the effectiveness of techniques) or avoid terrain for high risk areas (down-slope consequences)
- Landscape level planning- Examine ROC/ECA and cut-block placement
**Vulnerabilities-Operations**

- Increased wet weather shutdown days; decreased winter operability
- Design for future (upfront capital costs) vs. maintenance
- Alternate practices...

<table>
<thead>
<tr>
<th>FM Implication or issue</th>
<th>Why occurring or concern?</th>
<th>Where?</th>
<th>How address? Can it be addressed?</th>
<th>Barriers</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stream Crossings - Culverts</td>
<td>Increased failure rates via increased in predicted fall-winter storm magnitude/ freq; increased flow via MPB and Wildfire.</td>
<td>All of BC</td>
<td>Practice: assess current structures re: CC / areas – risk based approach Practice: Upgrade highest priority to accommodate climate changes, re-evaluate annually Policy: review size guidelines. Increase size or modify acceptable risk</td>
<td>Cost- upfront Time Unwillingness to believe will be an issue</td>
<td>Lives Salmonid Habitat Connectivity Reduced mitigation/ restoration costs over long-term Lower $ spent on fixing problems</td>
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Vulnerabilities-Cumulative Effects

- Multiple stressors (temperature, fish harvest, habitat, etc.)
- Shifts in management of timber to multiple resource values from land-base (e.g., water, flood risk)?
- Mitigation vs. Restoration
- Restoration often externalized
- Watershed Restoration Program~ $75M/year (Sutherland, 1998); Fish Passage issues (FPB, 2009); Chase Creek Flood Risk and MPB salvage
- Define time period of interest and value(s) to be managed

Stoltz Bluff Photo: KWL
Summary

• Effects of Climate change on watershed processes will be complex.

• Will be many important implications beyond forestry….

• All hydrologic regimes will see changes in how much and when water is delivered… not just snow regimes!

• Need for greater focus on managing/mitigating cumulative effects across multiple forest and range values and interests.

Photo: R.G. Pike