Flood Forecasting in British Columbia

Flood Forecasting Methods and Models Workshop
Calgary, Alberta
February 19th, 2014
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Overview

• British Columbia – Flood and Emergency Management Policy and Framework
• Rivers and Hydrology in BC
• Seasonal Flood Risk Assessment
• Flood Forecasting in BC – techniques and products
• Recent Flood Events
BC Flood Response Plan (2012)

- Joint plan between various ministries
- Outlines provincial flood response roles and responsibilities
- Emergency Management BC takes lead role in stakeholder co-ordination and emergency response/management
- Large role for local communities in planning, response, and recovery
River Forecast Centre

- interpret snow, meteorological and stream flow data to provide warnings and forecasts of stream and lake runoff conditions around the province
- Lead agency in BC for
  - Flood Advisories and Warnings
  - Water Supply and Low Stream flow Advisories
  - Analysis of provincial snow data province
- Act as Subject Matter Experts to support the provincial Emergency Management model
River Forecast Centre

- Relatively small team consisting of Manager (+Dam Safety), Section Head, 2 Forecast Hydrologists (1 new in 2013), 1 technician
- Hydraulic Modelling part of Flood Hazard group (1-2 staff)
- Regional staff “on-the-ground”
British Columbia
Source: ClimateBC
Daily Discharge for Lillooet River near Pemberton (08MG005)

Date

Bella Coola

Source: ClimateBC
Seasonal Flood Risk
Snow Monitoring

- Snow program coordinated by the BC Ministry of Environment
- Manual Snow Surveys completed up to 8 times per year
- Snow depth and snow water equivalent
- Up to 155 surveys per period
Snow Monitoring

- 53 Automated sites around the province
- Provide “real-time” observations of snow depth, snow water equivalent, temperature and total precipitation
- Sent via GOES satellite
- Useful for accumulation (particularly “in-between” snow survey periods), invaluable for snow melt
Snow Bulletin

• 8 per year - coincides with manual survey schedule

• Includes
  – Snow basin indices
  – Seasonal volume runoff forecasts
  – Summary of snow conditions
  – Assessment of outlook for seasonal flood risk and seasonal water supply
Seasonal Volume Forecasts

- Currently forecast for 16 rivers (based on a Principle Component Analysis)
- Assist with government dam/reservoir operations (Nicola, Okanagan)
- Useful for seasonal flood risk assessment and water supply outlooks
08MF005 - Fraser River at Hope

\[ y = 5943.3x + 2689.1 \]
\[ R^2 = 0.4121 \]

Maximum Instantaneous Discharge (cms)

April 1st Fraser River SWE Index

1948 = 15300 cms

1955
1957
1964
1972
1976
1978
1999
2012 = 1.31

2 yr RP
Snowpack and Probability

Flood Frequency (Fraser-Hope) and Snowpack

- **Return Period (years)**
- **Peak flow at Hope (m³/s)**

Legend:
- **HIGH**
- **NORMAL**
- **LOW**
Flood Forecast System
• Weather Forecasts
  – Environment Canada
  – Pacific NW (Washington)
  – European Modelling
  – short, medium, long term
- Observed Weather (precipitation, temperature, snow melt)
- Environment Canada Weather Stations, Ministry of Highway Stations, Provincial Fire Weather Stations, Snow Pillows
• Real-time river levels from Water Survey of Canada
• Examine rates of rise in river (in response to weather conditions)
• Compare with historical range of extreme flows
Data Management Systems

- Data acquisition through
  - GOES (RFC Domsat and/or EDDN) – primarily snow pillows, some WSC
  - FTP (WSC, EC Wx, Fire Wx, Transportation Wx)
  - Emailed csv/txt files (Precip forecasts, WSC summary data for modelling)
Data Management Systems

- Data Management
  - Snow data stored in Min. of Environment Database
  - GOES data stored in temporary database
  - CSV files stored on primary and back up servers
  - No effective database for data used in modelling/analysis
  - Data analysis primarily done through Excel files/scripts
  - Improving data management systems a high priority (integrating data acquisition, analysis and reporting)
  - Also focusing on data acquisition and back-up/business continuity (e.g. network failure, changes in satellite network feeds)
WARNS Hydrologic Model

- Developed in 1976 as a combination of the UBC Watershed Model and the WSC Routing Model (SIMPAK)
- Fraser Watershed divided into 16 sub-basins, and each basin divided into elevation bands. Separate routine for Skeena River
- Basin parameterization not adjusted during operation
- Snowmelt/runoff modelled in each sub-basin, then routed downstream
• April 1\textsuperscript{st} snowpack set as initial condition (interpreted from snow surveys)

• Weather observations (Daily Max and Min Temp, Precip) from 12 Environment Canada stations and 5 snow pillows

• Observed daily flow conditions (WSC gauges at sub-basin outlets)

• 5-day weather forecasts for weather station points (developed by CMC from GEM model)
WARNS Hydrologic Model

- Output is 5-day forecast of daily average flow for all sub-basins
- Forecasts are run once daily
- Forecasters manually calibrate/adjust snow pack input on daily basis
- Undergo professional review and often adjusted based on judgement
- Posted to website for public access and distributed amongst stakeholders
Ensemble and What-if Scenarios

![Graph showing flow (m3/s) over dates from 3/18/2011 to 7/6/2011]
Fraser River Hydraulic Model – MIKE11

- Operated by Flood Hazard Management group (Surrey)
- Uses 5-day WARNS daily flow forecast (at Hope and inflow from Harrison)
- Tidal influence (important downstream of Mission) taken into consideration
- 5-day forecasts of peak daily water level (and estimated time) for 100+ locations along the Fraser from Hope to the ocean
- Verification using WSC gauges, local real-time gauge network, and municipal/city staff gauges (support from municipalities)
- Model run once daily during peak flow periods
- Model output posted to RFC website
Fraser Routing Model (FRouT)

- Simple mass-balance / flow continuity model
- Uses calibrated travel times (eg. Typically takes 3 days to travel from Upper Fraser to Hope) with lateral tributary flow additions
- Works well for rain events (“pulse” type) and for hourly forecasts at Prince George
CLEVER Model

- “Channel Links Evolution Explicit Routing” Model
- In the development/testing phase
- Divides Fraser into sub-basin and lump-sum process modelled using unit-hydrograph method
- Flow routed using kinematic wave
- Snow melt modelled using temperature index method
- Uses same weather observation, flow, and weather forecast data as WARNS
- Potential to extend forecast to 10 days utilizing the routing, and move from daily average flow to hourly flow
- Expanding provincial coverage (e.g. Columbia river tributaries)
Artificial Neural Network Model

- Developed by Environment Canada (Sean Fleming) and is in test phase
- For Rain and Rain-on-snow Coastal watershed
- “Super-ensemble” with multiple (6) neural network models applied to 42 weather forecast ensembles (ie. 252 ensemble stream flow forecasts)
- Primarily focused on prediction of flood thresholds
Runoff Models

- Simple runoff models developed for ~20 Coastal (rain/ROS driven) watersheds
- Uses 10-day precip point forecasts as input (receive 4x per day)
- Used more as a risk categorization tool rather than a flow forecast
Warnings and Advisories

- **A High Streamflow Advisory** means that river levels are rising or expected to rise rapidly, but that no major flooding is expected. Minor flooding in low-lying areas is possible.

- **A Flood Watch** means that river levels are rising and will approach or may exceed bankfull. Flooding of areas adjacent to affected rivers may occur.

- **A Flood Warning** means that river levels have exceeded bankfull or will exceed bankfull imminently, and that flooding of areas adjacent to the rivers affected will result.
Communications

- Warnings/Advisories posted to RFC web
- Email distribution (EMBC forwards to local governments)
- Conference calls with Emergency Management/Stakeholders to communicate risk
- Media interviews
When will it end?
• Snow Surveys (twice a month through melt season)
• Monitoring Snow Pillows
• Snow line surveys
• MODIS satellite analysis (in conjunction with UNBC, UBC and BC Hydro)
• Runoff monitoring
• Ensemble Forecasts
SNOWL 8-day composite snow cover: BULKLEY 2012-4-23

- Null
- Snow (62.76%)
- Snow Free (31.85%)
- Partial Snow (5.39%)
SNOWL 8-day composite snow cover: BULKLEY 2012-4-29

- Null (58.38%)
- Snow (29.07%)
- Snow Free (12.55%)

Legend:
- Null
- Snow
- Snow Free
- Partial Snow
Case Studies: Bella Coola 2010

- Significant Atmospheric River event over the September 23-24\textsuperscript{th} period
- Precipitation amounts >200mm in 36 hr
- 100-200 year event
- Community isolated for extended period and major infrastructure damage
Case Study – Peace Region 2011

- 2 separate heavy rainfall events over a 2 week period associated with an “upper low” system
- 25-year to 100-year event
- Significant infrastructure damage (roads, rail)
- In excess of $85 million in damages
Case Study – Freshet 2012

• High snowpack and seasonal risk
• Significant spring rainfall (record in Kootenays, several heavy rainfall events in the Monashees)
• 15 registered flooding events affecting over 100 communities in BC
• 20 to 50 year high flows
• Mission Creek, Sicamous, Shuswap, Lower Fraser River, Tulameen, Johnson Landing
THANKS!- QUESTIONS?

http://bcrfc.env.gov.bc.ca/index.htm