Flood forecasting: lessons in uncertainty

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Myth of flow forecasting

"Model output = forecast"

- European approach
- Extremely dangerous in Canada:
  - Complex hydrology (cold region processes)
  - Complex hydrography
  - Enormous areas, few people to do modelling
  - Very low densities of precipitation and streamflow gauges

What can go wrong?

- Things can break when they are under stress
  - Equipment
  - Software
  - Algorithms
  - Procedures
  - People
- Floods are an excellent source of stress!

Nature

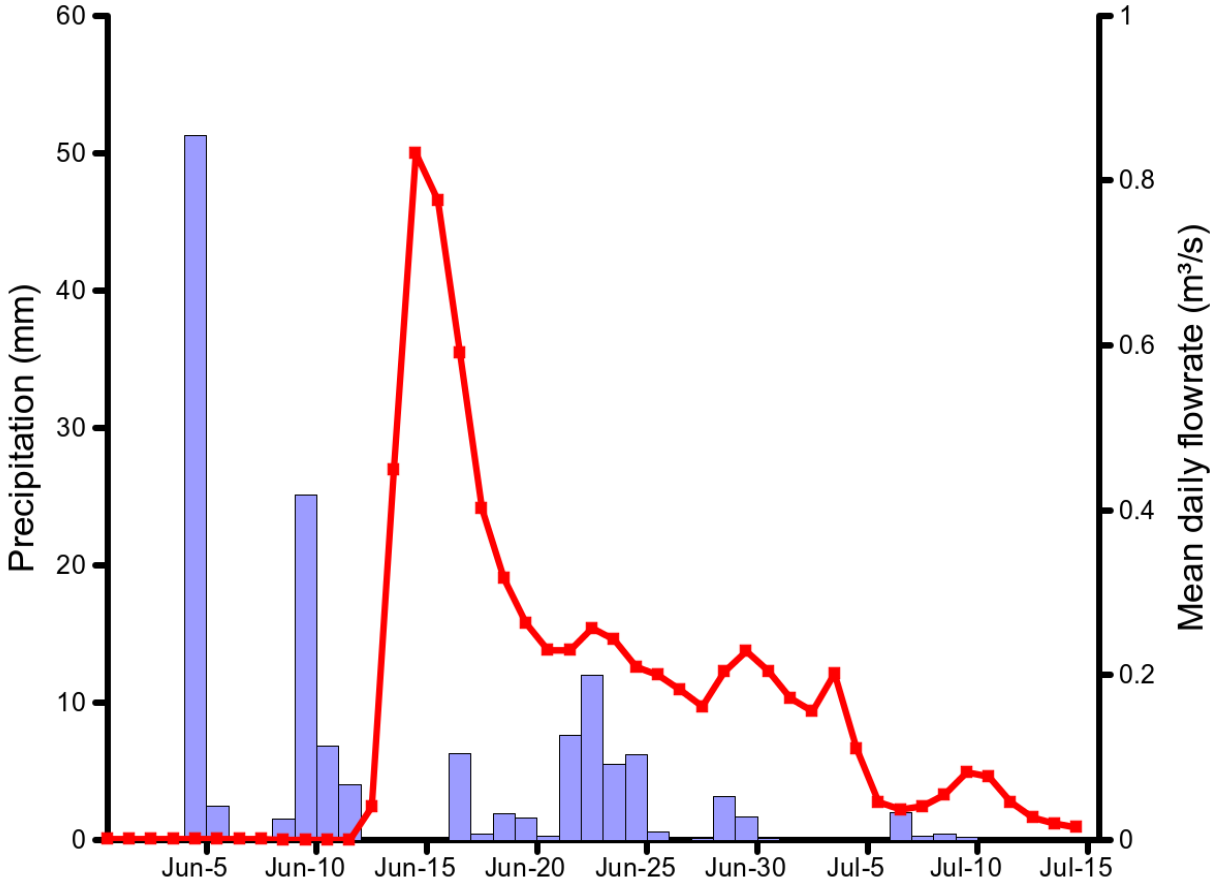
- All floods are different
  - May happen in places you did not expect
  - May have causes that you have not seen before
  - May have processes that you have not prepared for
- The chances of these happening will increase with climate change

Model limitations

- All models (and modelling programs) contain a variety of algorithms
  - Vary from purely conceptual to quite physically-based
  - It is very easy to encounter situations where a model simply won't work
    - May be due to problems with data
    - May be due to important processes being ignored or represented badly
    - May also be due to assumptions made in the development of the model
- Case studies can show how and why models have failed

Case study 1: Vermilion river basin, summer 2007

- Rainfall runoff events
- I completely failed to build a functioning model

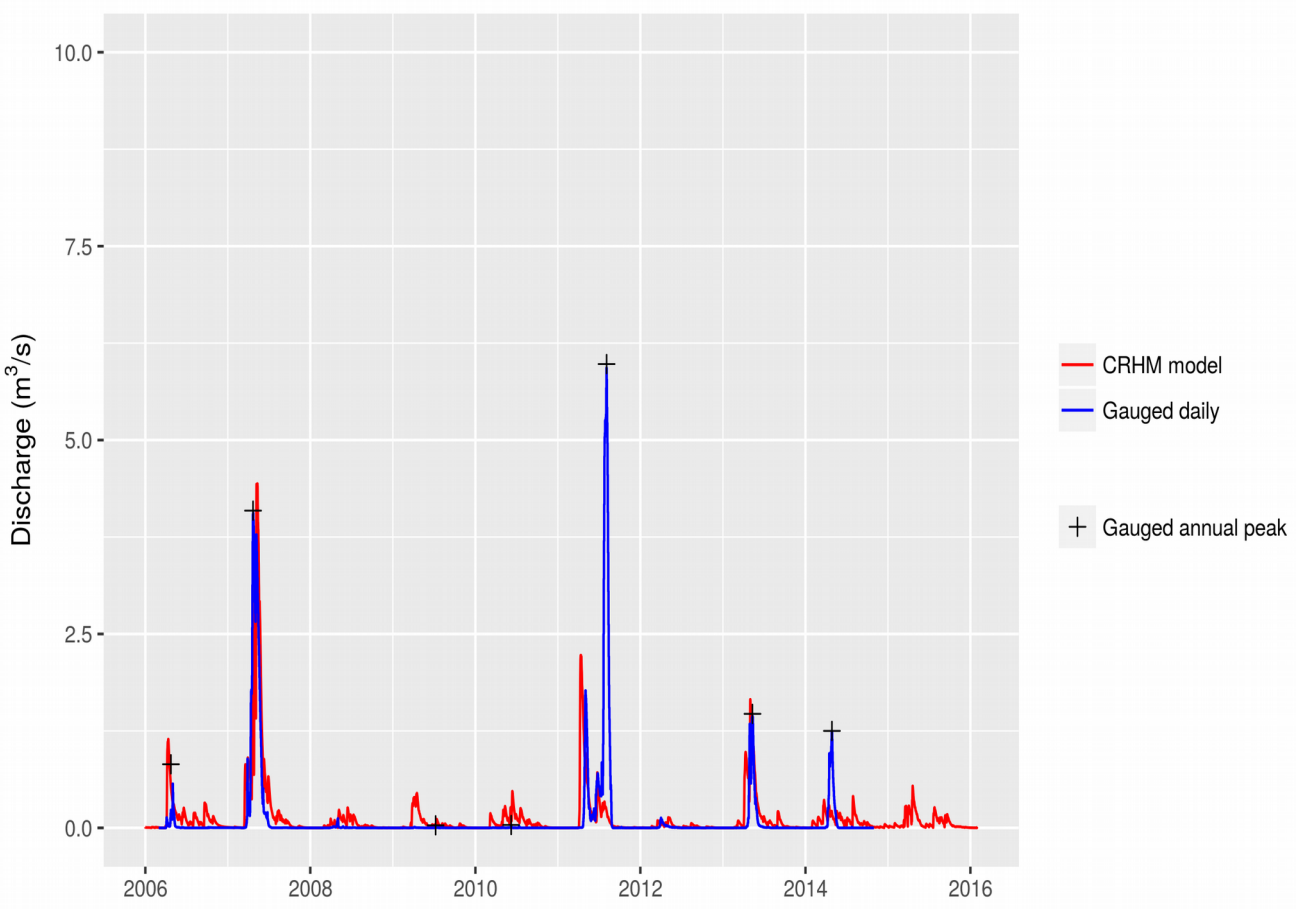


Reason for failure, case 1

- Model (like *all* hydrological models of the time) was unable to reproduce the fill-and-spill of water among Prairie ponds
  - Contributing areas of Prairie basins are dynamic
- Modelling programs developed for anywhere else *cannot* simulate Prairie hydrography
- We have been working on the problem and have developed some algorithms to address this issue

Case 2: Camrose Creek, summer 2011

- Uncalibrated CRHM simulation of flows in Camrose Creek, central Alberta
- Model worked well for most years
- Completely failed in summer of 2011

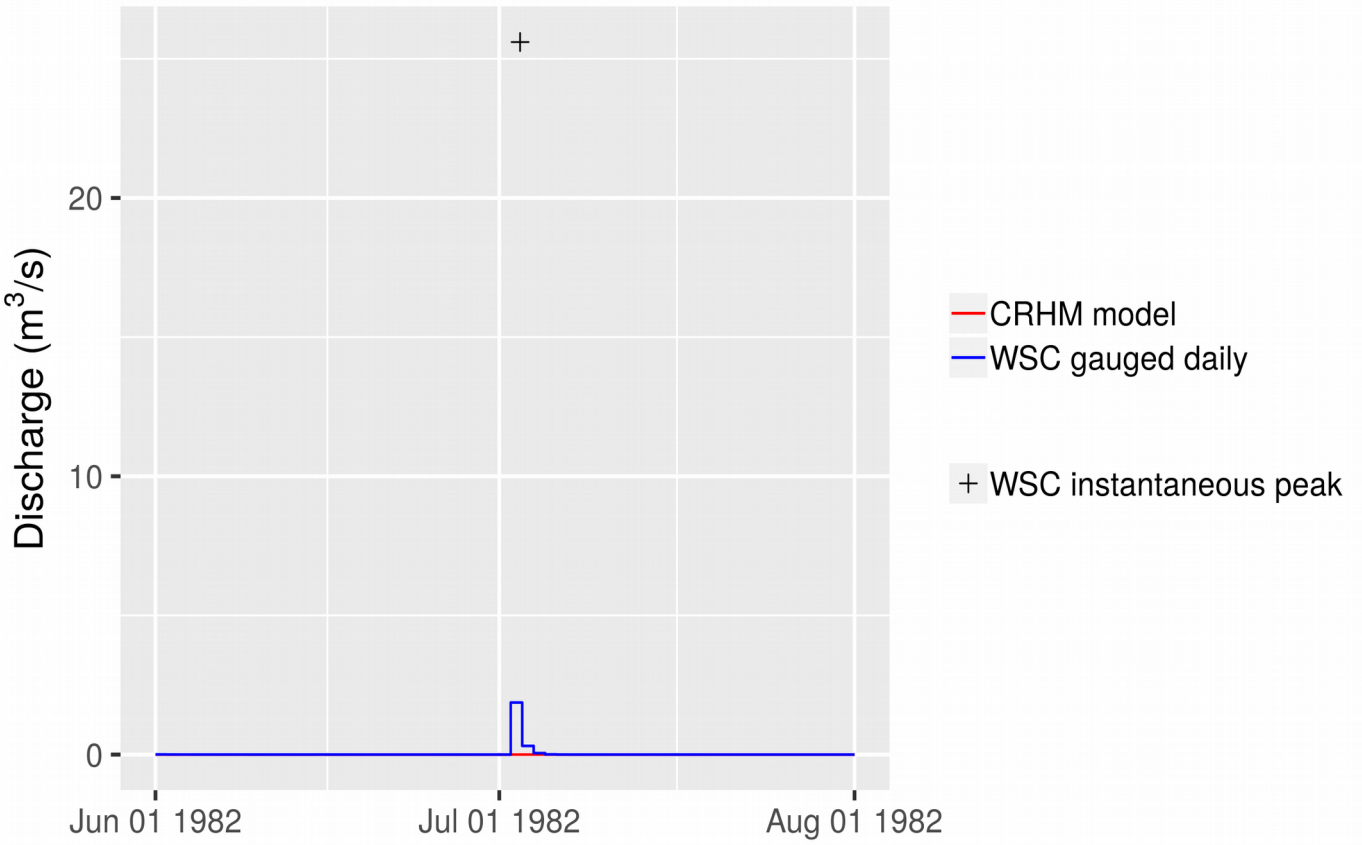


Reason for failure, case 2

- CRHM does not allow rainfall runoff until soil is saturated
  - Modelled snowmelt runoff can occur when soils are not saturated
- Causes problems when small numbers of HRUs are used
  - Large areas never become completely saturated in the model, so there was zero calculated runoff
- In reality, portions of the basin were saturated, causing runoff
- Now working on incorporating variable moisture capacity in CRHM

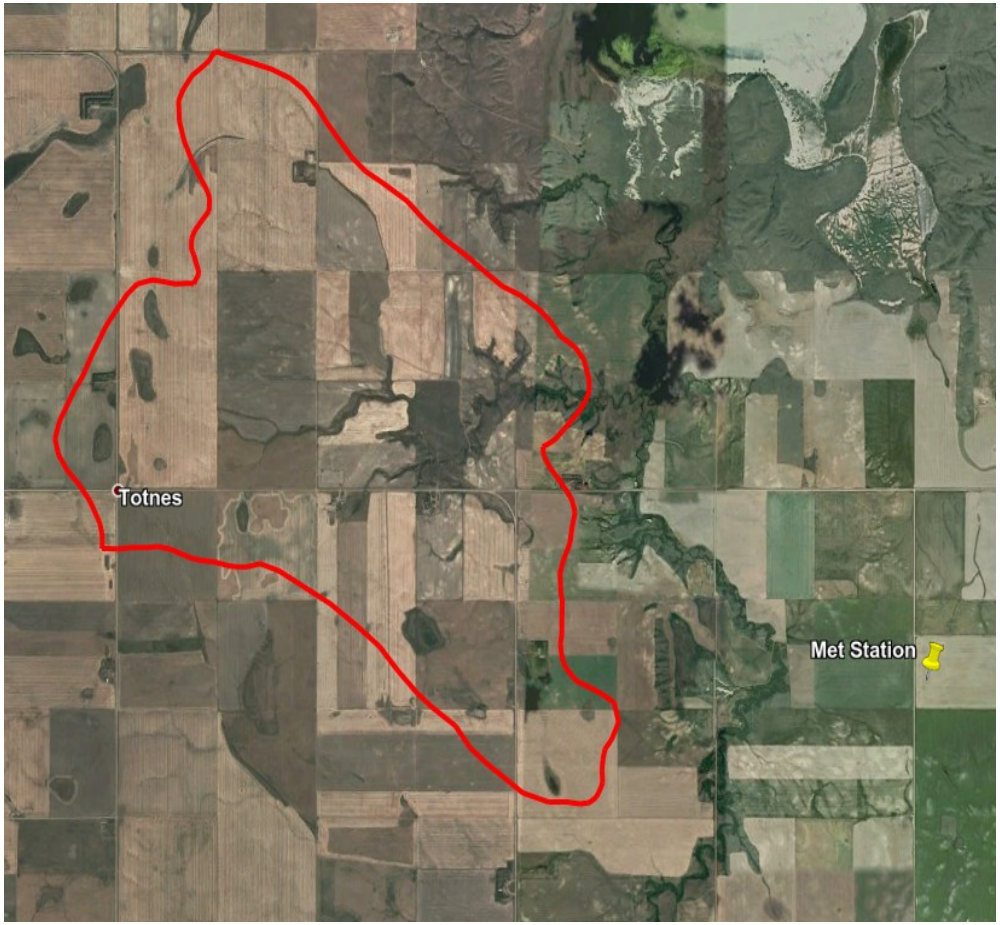
Case 3: Creighton Tributary, Bad Lake, SK, 1982

- Uncalibrated CRHM model accurately simulated snow accumulation and snowmelt runoff
- Model failed to simulate the peak streamflow event



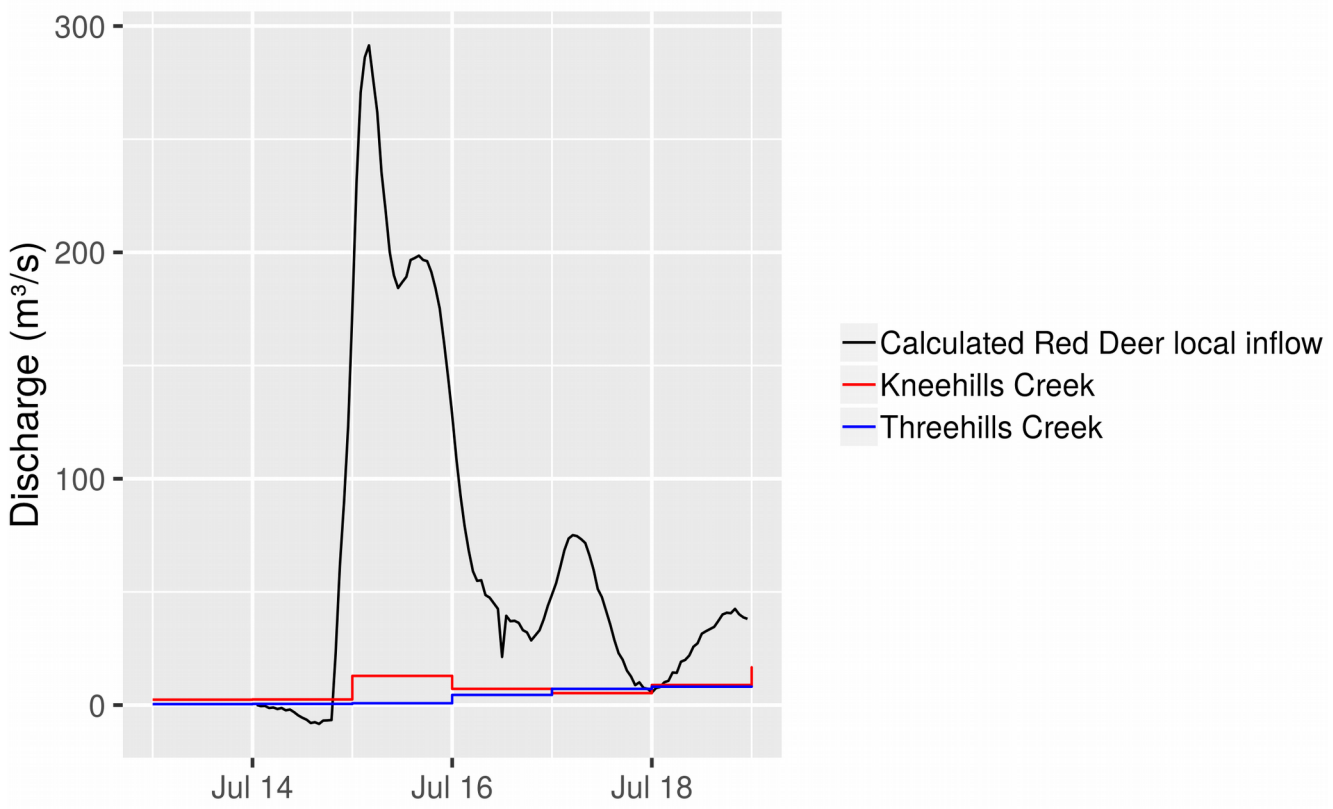
Reason for failure, case 3

- No rainfall was recorded at the gauge, which was only ~3 km from the stream gauge
- Rainfall was very intense and localized
- Resulted in a very peaky hydrograph with very little volume
- Very hard to model!



Case 4: Red Deer River at Drumheller, summer 1999

- Could not model the event
- No rainfall in any gauges
- Flows in tributaries do NOT add up to the estimated local inflows



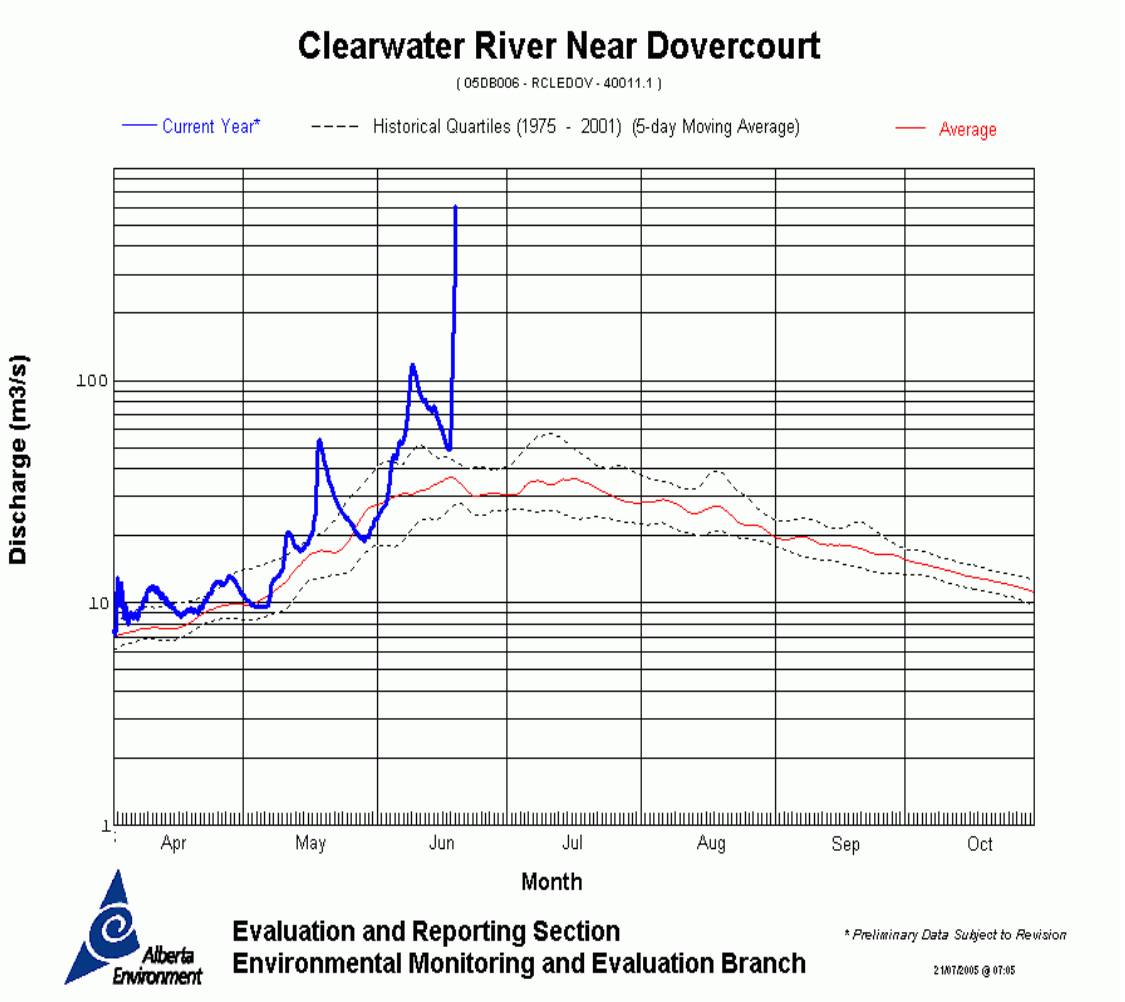
Reason for failure, case 4

- Rainfall was very small and intense – radar showed *one* red pixel for *one* - 20 minute sweep
- Badlands are clay, and steep
- Resulted in large ungauged flows and overland flows *between* the gauges



Case 5: North Saskatchewan River basin, June 2005

- Stream gauges in North Saskatchewan abruptly stopped giving values during a flood
- Need gauge flows to verify models
- Made forecasting flows for City of Edmonton very difficult



Reason for failure, case 5

- Gauging stations were destroyed by high flows
- Last transmitted stage = height of instruments in shelter



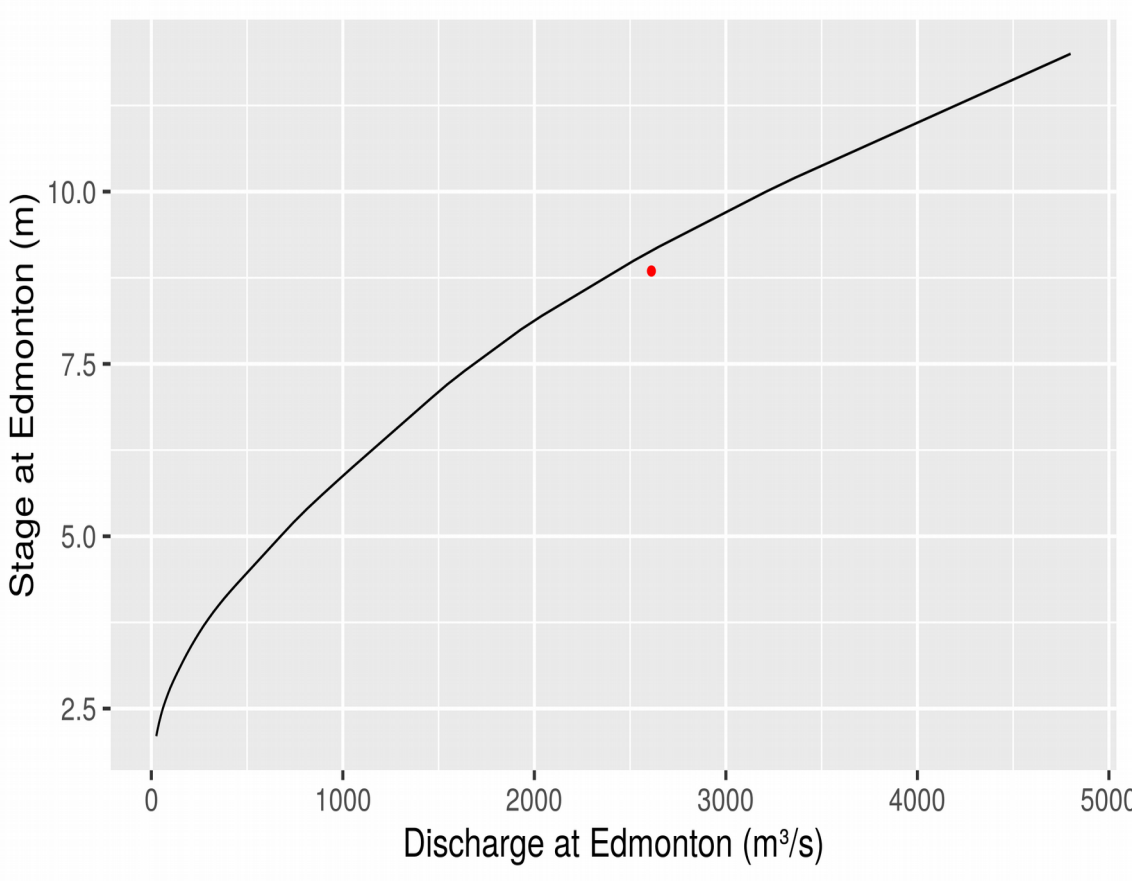
Case 6: North Saskatchewan River at Edmonton, June 2005

- Forecast flows for the City of Edmonton were fairly accurate, but the stage forecasts were not
- Resulted in complaints, esp. from the media (who were disappointed that Edmonton wasn't going to flood)



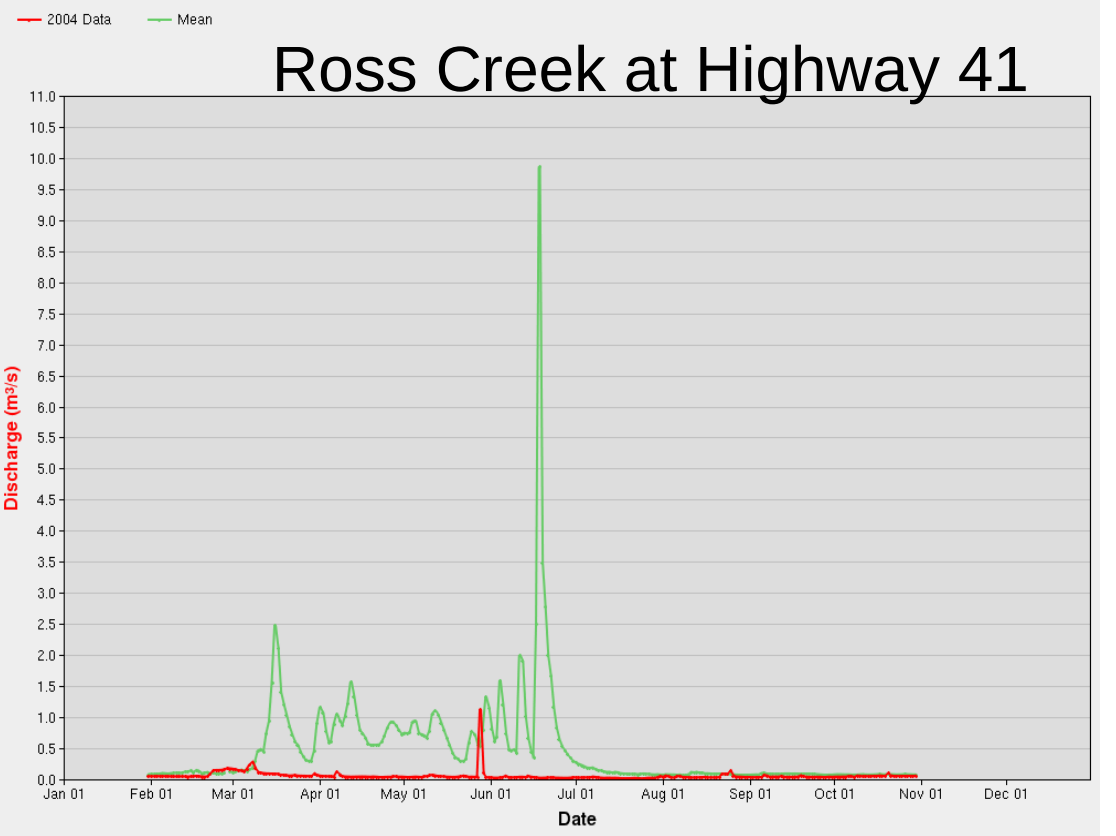
Reason for failure, case 6

- The rating curve in use at the time resulted in a forecast stage that was about 0.3 m too high
- Occurred despite many flow measurements and curve adjustments



Case 7: Cypress Hills, Feb. 2004

- Heavy snowpack in the Cypress Hills
- Rising temperatures due to a Chinook
- Resulted in almost no gauged streamflow; model predicted large flows



Reason for failure, case 7

- Photos taken just afterwards show no snow on the north side of the Cypress Hills, but a deep pack on the south side
- Consistent with sublimation due to Chinook
- Not simulated by existing models



North side of Cypress Hills, Feb. 25, 2004



South side of Cypress Hills, Feb. 25, 2004

Summary

- All models will give bad results, depending on the type of event being simulated
- Climate change increases the vulnerability of models
  - Calibrations become less valid
  - Made worse by changes due to people (drainage, urbanisation)
  - New types of events occur which do not exist in the historical record

Example: Southeastern Sask./Southwestern Man. flooding, July 2014

- A new type of event for the Prairies
  - Heavy rains in June, over very large area
  - Followed by very heavy rainfall beginning June 30
  - Caused widespread flooding
- Hard to model
  - Unprecedented in the historical record
    - Large-scale rain events appear to be increasing
  - Prairie “fill-and-spill” hydrography
    - Flooding due to overland flow
    - Heavily drained



Alida, Sk

http://news.nationalpost.com/2014/07/02/why-exactly-are-floods-soaking-saskatchewan-and-manitoba-and-are-they-here-to-stay/