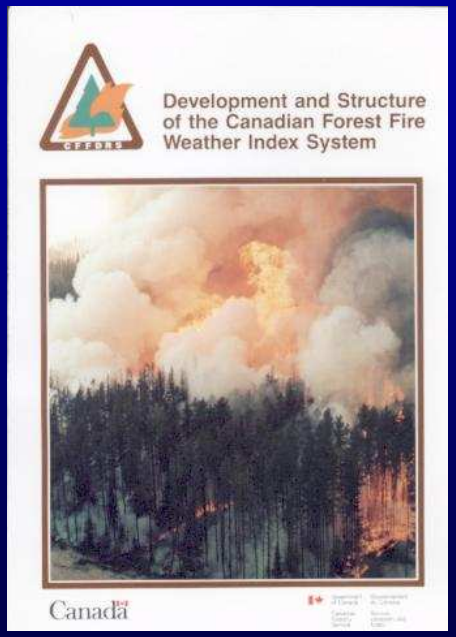
The Canadian Fire Danger Rating System: its use and interpretation



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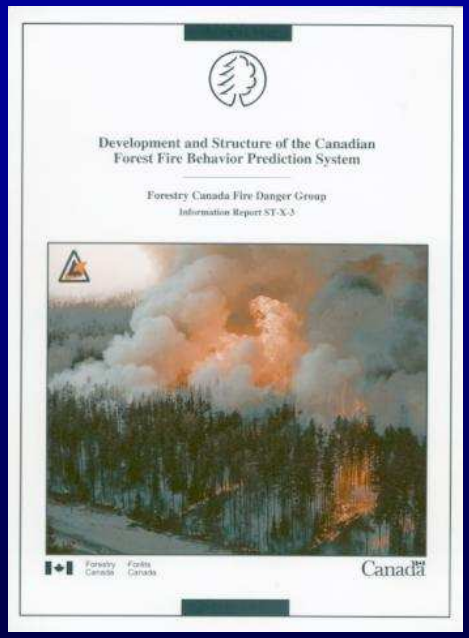


CFFDRS

- The Fire Weather Index System (FWI)
  - Fuel moisture in a standard stand
  - Relative fire behaviour over a region
- The Fire Behaviour Prediction System (FBP)
  - Stand specific, quantitative fire behaviour

CFFDRS – basic use

- FWI
  - Used to assess fire potential for daily operational planning
    - Estimating fire occurrence, preparedness planning, detection planning, prevention (e.g., restricted fire zones)
- FBP
  - Used to make location specific predictions of fire behaviour in a range of situations
    - e.g., fire suppression activities, fire monitoring, PB planning and execution, fire line safety

The FWI System: a short history

- The system is based on models built from field experimentation
- Field research began in the early 1930's in Ontario
  - In stand measurements (focus on pine stands)
    - Moisture content
    - Ignition sustainability

The FWI System: a short history

- Tracer Index
  - Moisture of the top layer of fine surface fuels (needles, small twigs, leaves)
  - Initially based on direct measure of evaporation (late in the day)
  - then based on noon weather
    - Similar accuracy, earlier obs.

The FWI System: a short history

- Hazard Index tables were developed
  - Indicated ease of ignition and vigor of spread on a common scale 0 to 16
- initially developed for
  - pine, hardwood and grass
- then expanded to Eastern Canada
  - Slash

The FWI System: a short history

- In 1939 through 1961 test fire program expanded across the country
  - Range of important forest types
    - Aspen, mixedwood, pine, spruce, fir, grassland
  - Range of stand closures

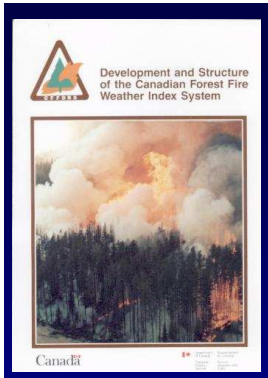
The FWI System: a short history

- Test fires
  - Ignited point fires in-stand with matches
    - occasionally small campfires used
  - Over 2 minutes vigor of ignition, flame length, etc were measured
  - Over 20,000 observations

The FWI System: a short history

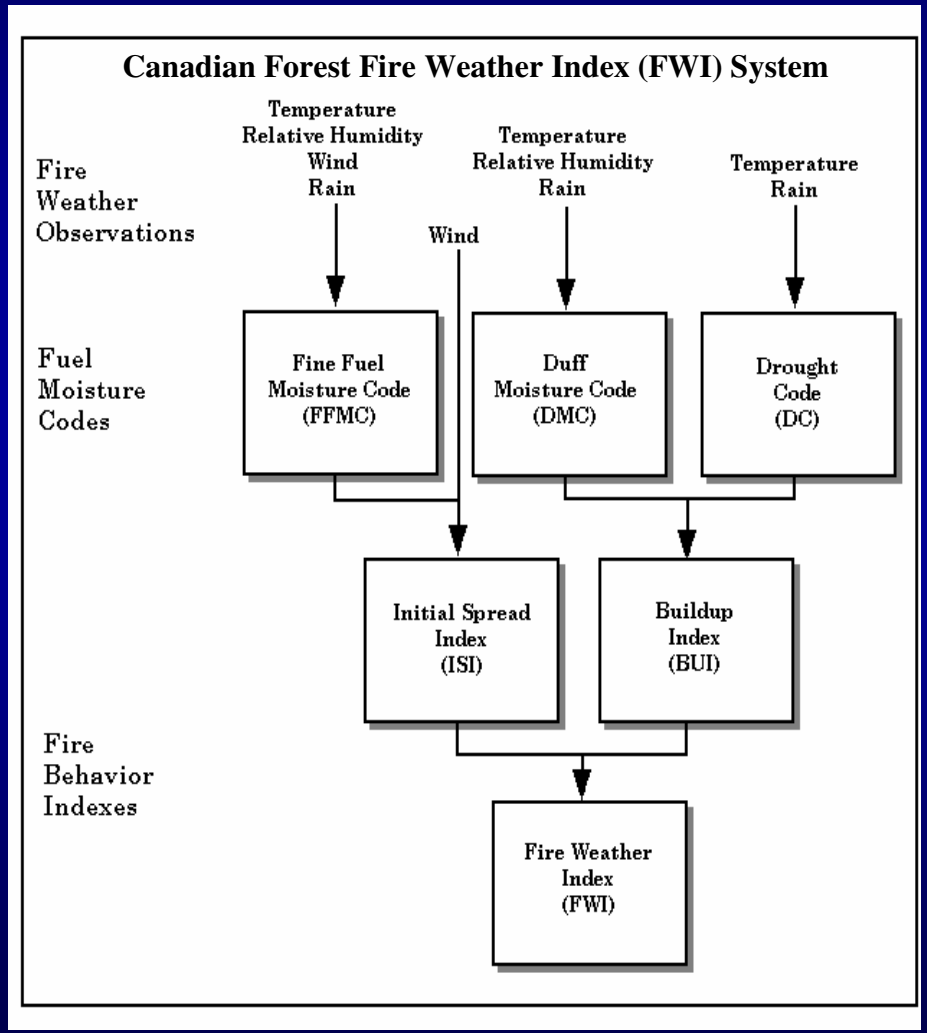
- Regional research lead to numerous fire hazard and danger systems across the country
  - All relied on a Tracer Index and a drought factor and reported on the same 0 to 16 scale
- In late 60's a "universal system" was proposed
  - All agencies across would use the same common base system
    - but interpret output regionally

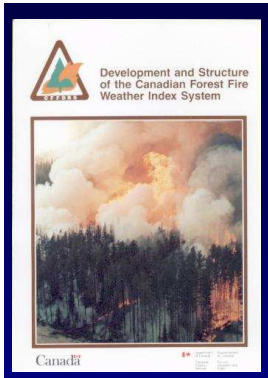
This is basically the national system we use today



The FWI System

- Tracks moisture (in three layers) and fire behaviour potential in a 'standard' closed pine stand
  - Based on solar noon observation of Temperature, RH, Wind speed and rainfall

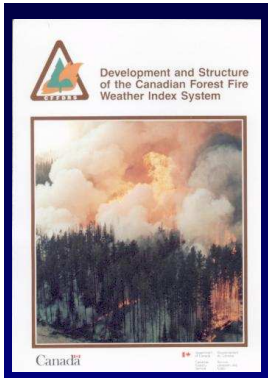




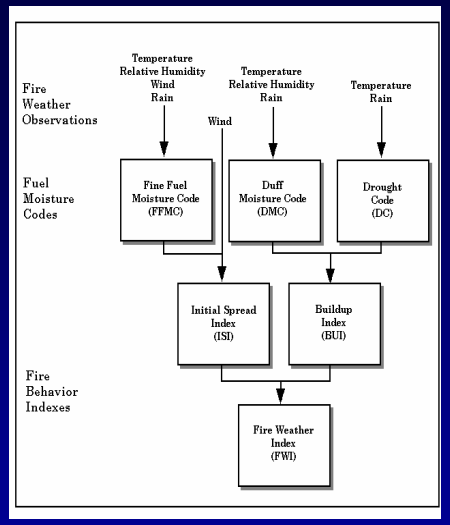
The FWI System

- Moisture Code values are transformed such that high values indicate high fire danger
  - However each is a basic moisture exchange model that follows the form

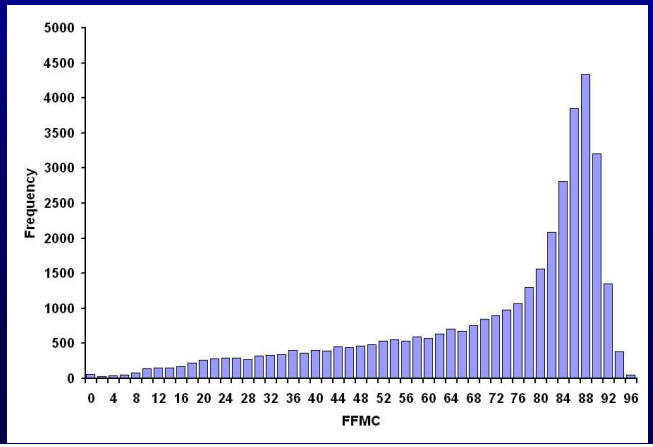
$$\frac{MC_N - EMC}{MC_{N-1} - EMC} = e^{-k \cdot t}$$

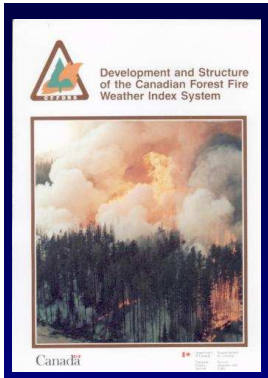


The FWI System



- The Fine Fuel Moisture Code (FFMC)
  - Moisture content of the layer of surface litter (fuels that carry surface spread) on top of a decaying organic layer
  - Response time of layer is about 2/3 day





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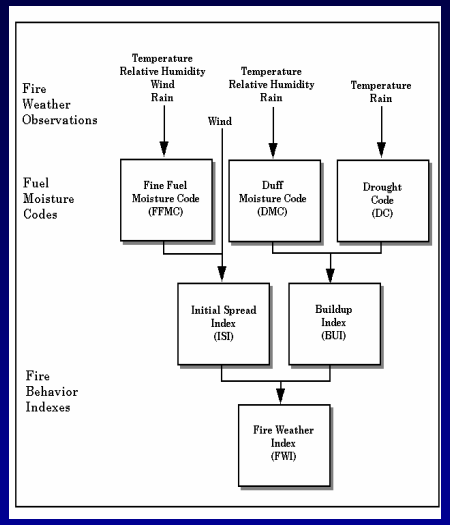
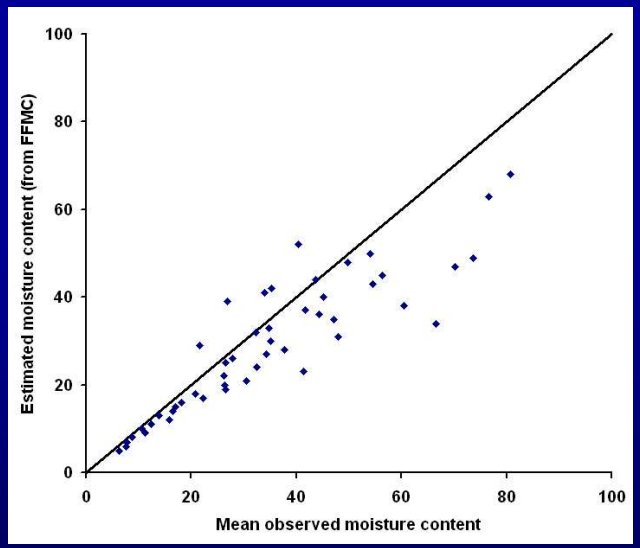
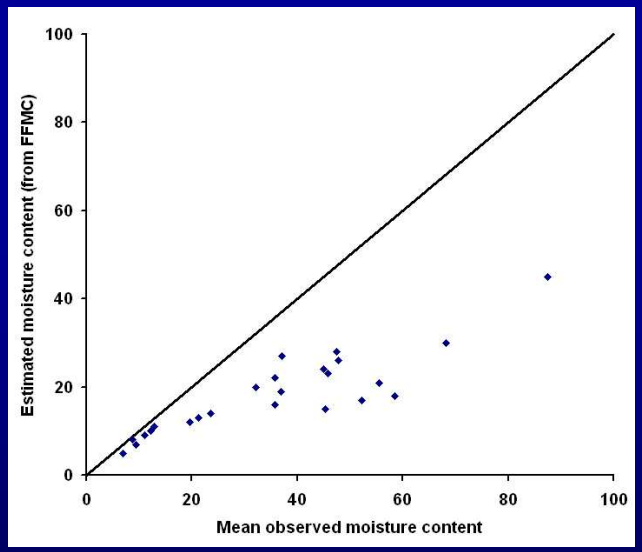


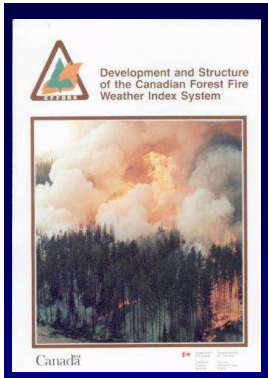
- FFMC versus observed moisture



Pine



Aspen



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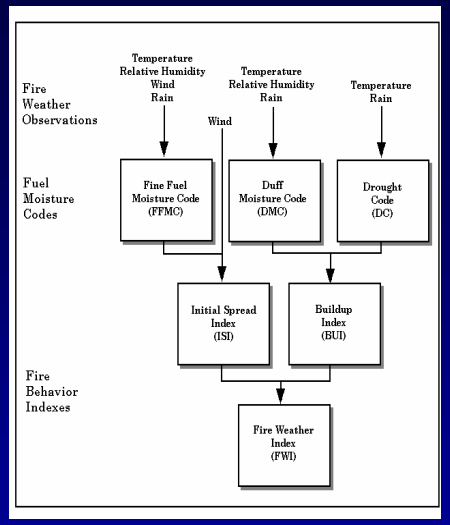
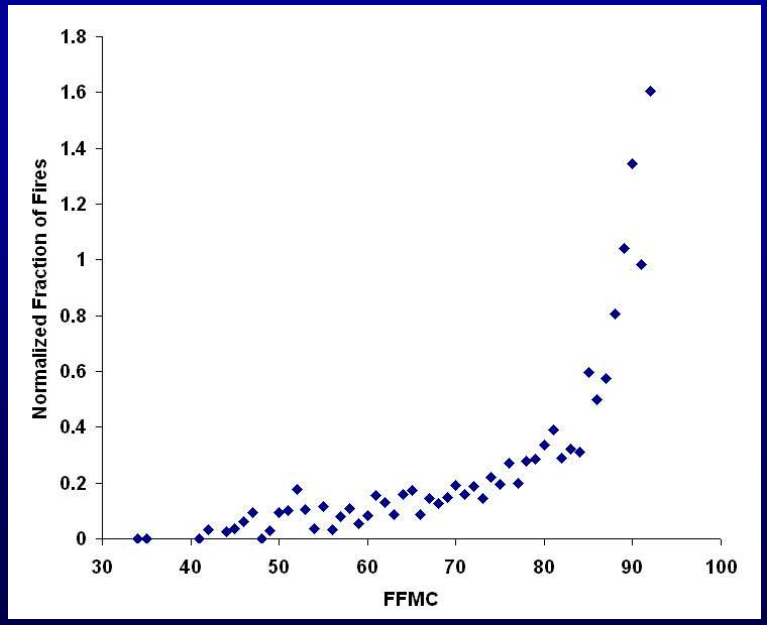
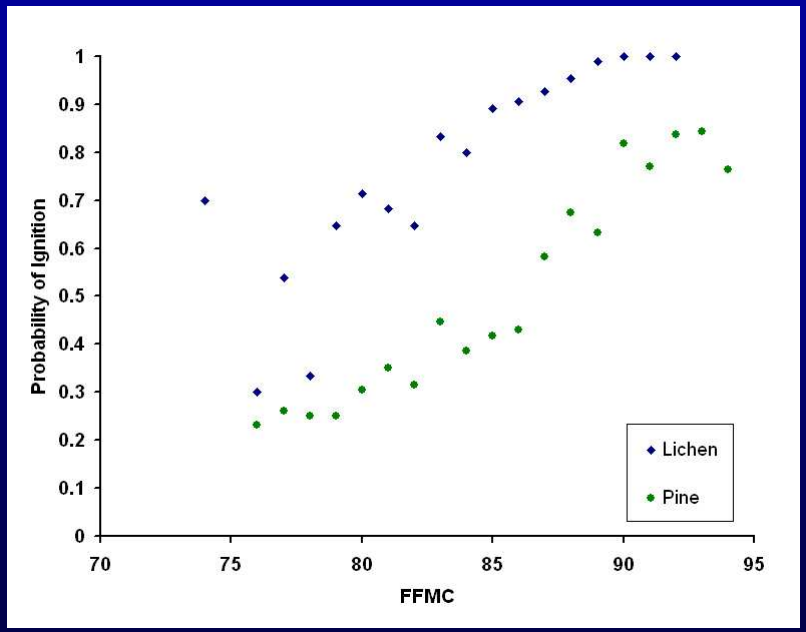
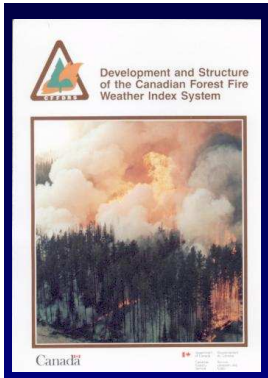


- FFMC
  - Used as an indicator of ease of ignition and spread of a fire







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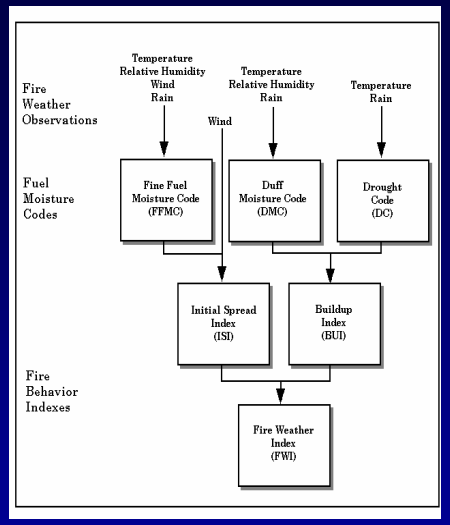
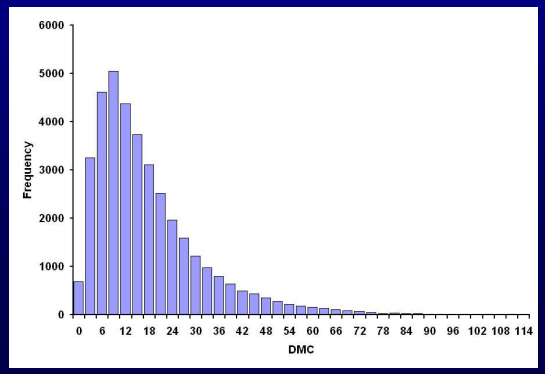
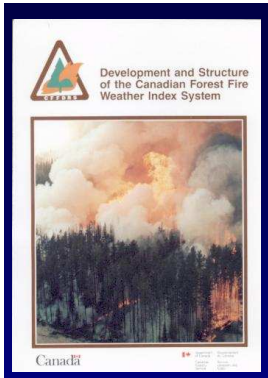


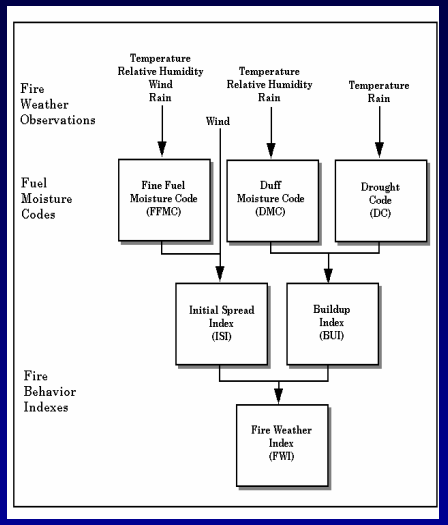
- The Duff Moisture Code (DMC)
  - Moisture content of top of the organic layer (top 7 cm)
  - Bulk density 5 kg/m^2
  - Response time ≈15 days

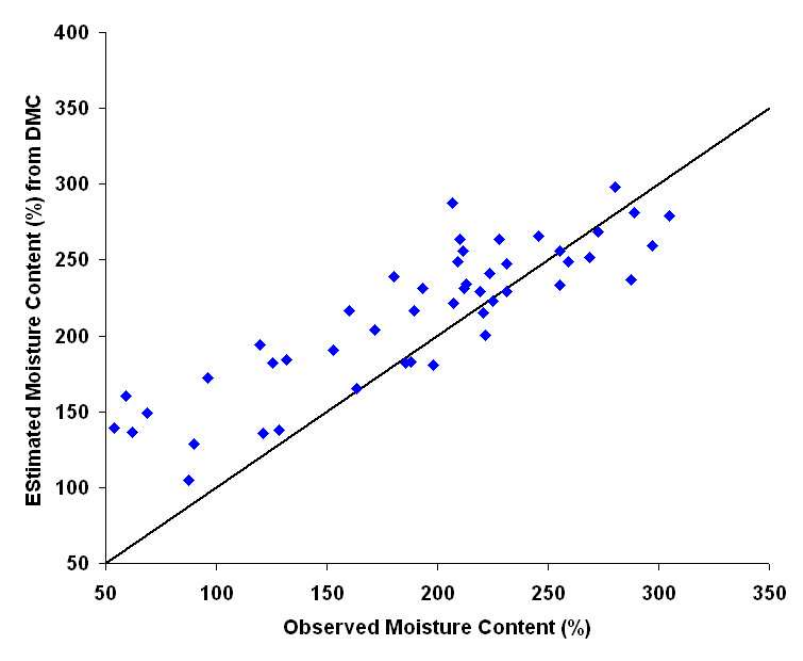


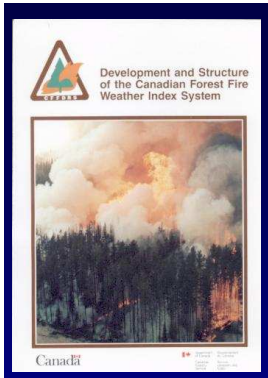


The FWI System

- DMC verses observed moisture







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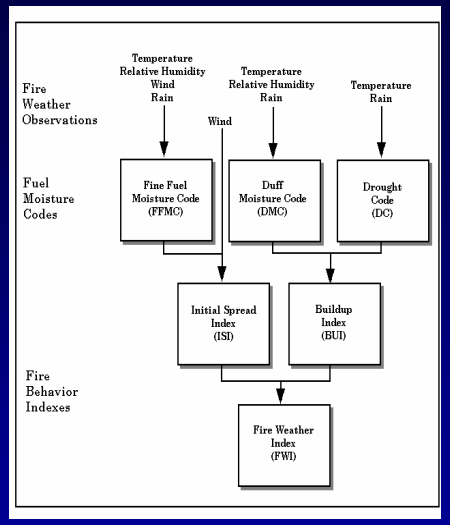
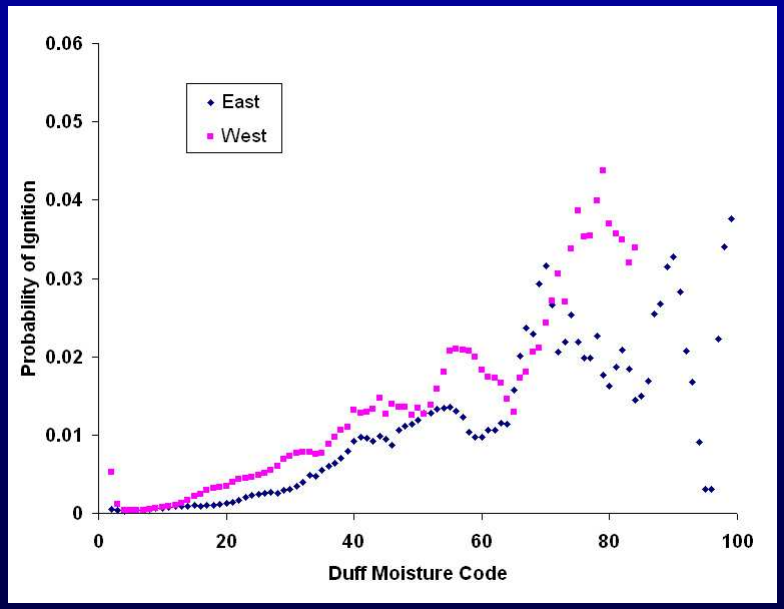
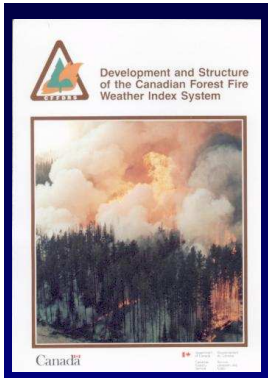


- DMC
  - Used as an indicator of receptivity of the forest floor to ignition from lightning





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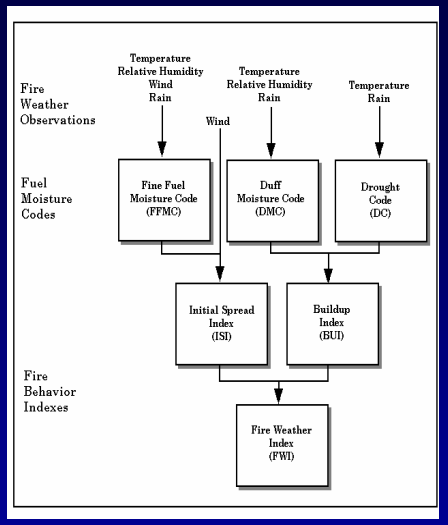
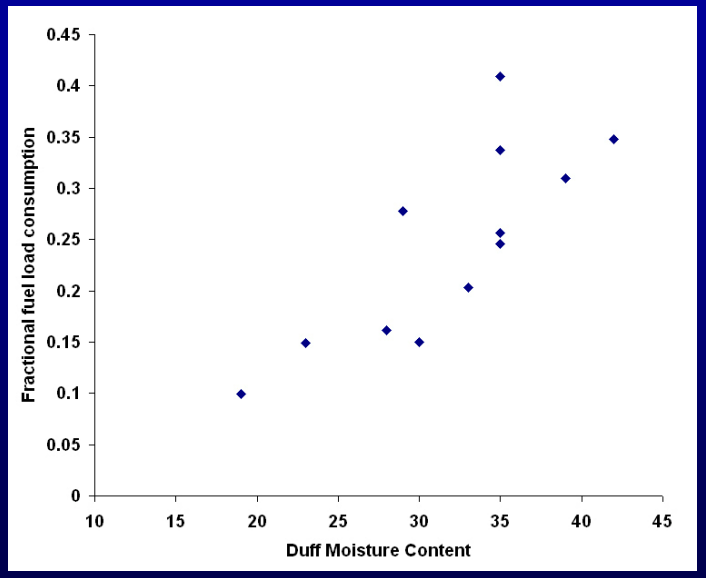
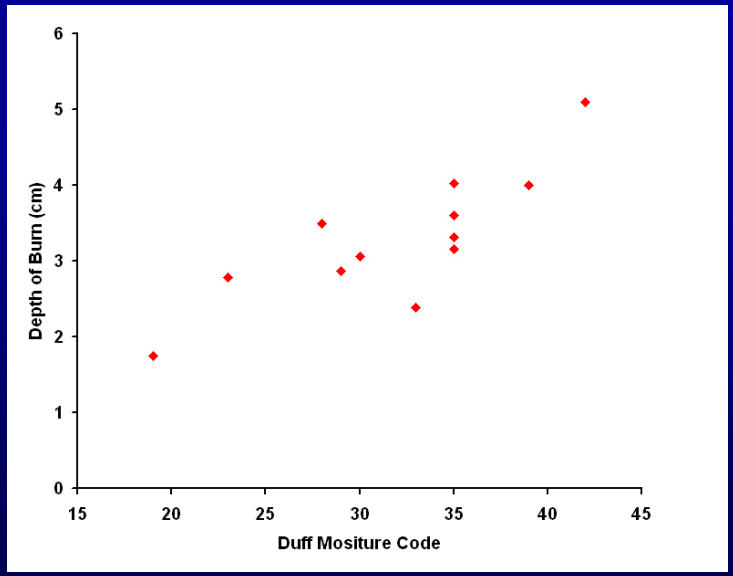
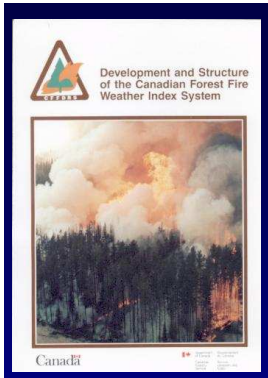


- DMC
  - Is sometimes used by modellers as a predictor of fuel consumption in specific stands as well







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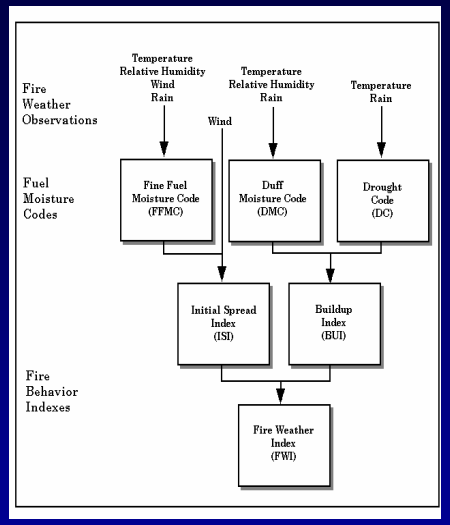
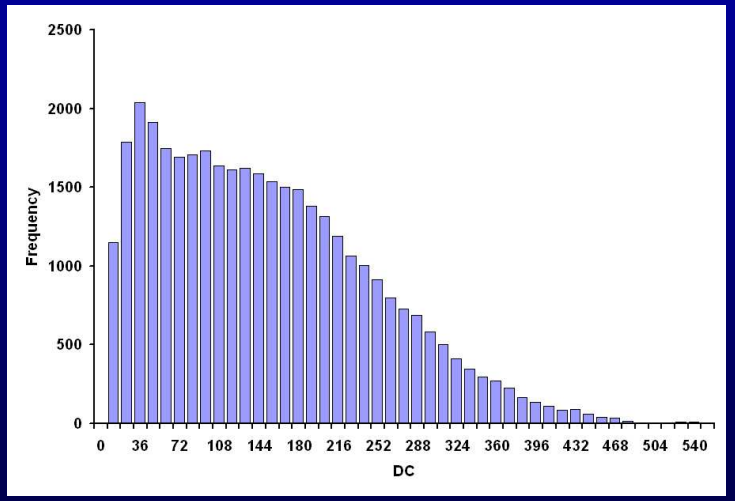
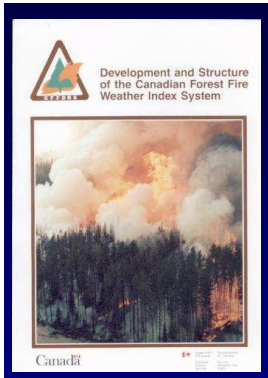


- The Drought Code (DC)
  - Moisture content of large woody fuels and deep organic layer (approximately 7 to 17 cm depth)
  - Bulk density if 25 kg/m^2
  - Response time ≈53 days
  - Used as an indicator of difficulty of suppression
    - Sustained deep smouldering





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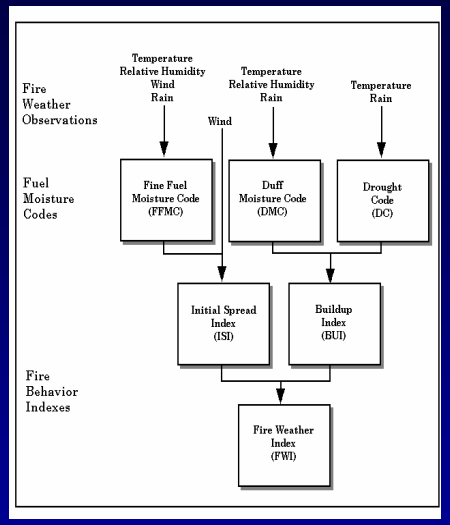
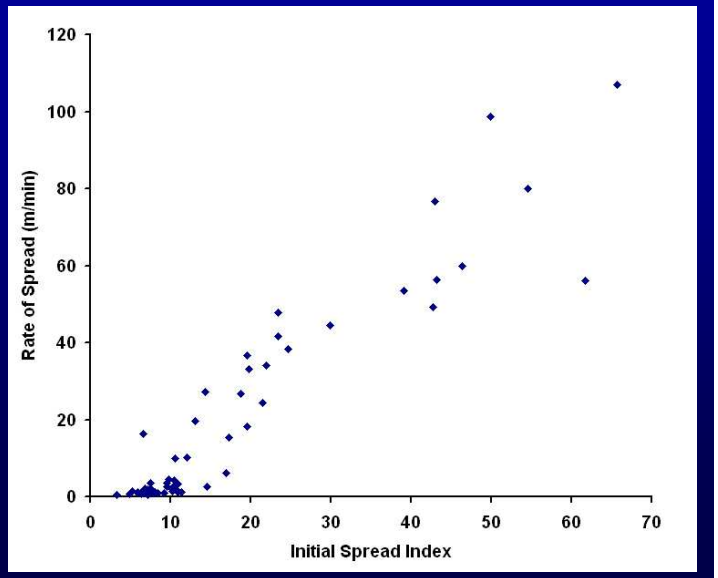
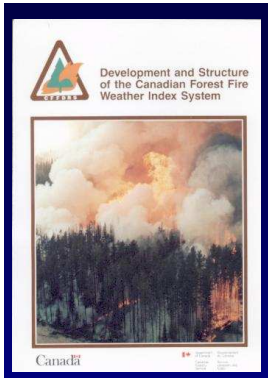


- The Initial Spread Index (ISI)
  - Combines FFMC and wind speed to create a unitless index of potential Rate of Spread (ROS)
  - Used as a general indicator of rate of spread potential across a region.
    - Explicitly correlated with ROS for multiple forest types in the FBP System





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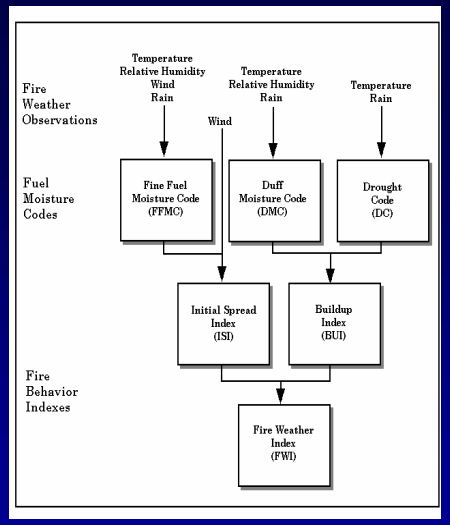
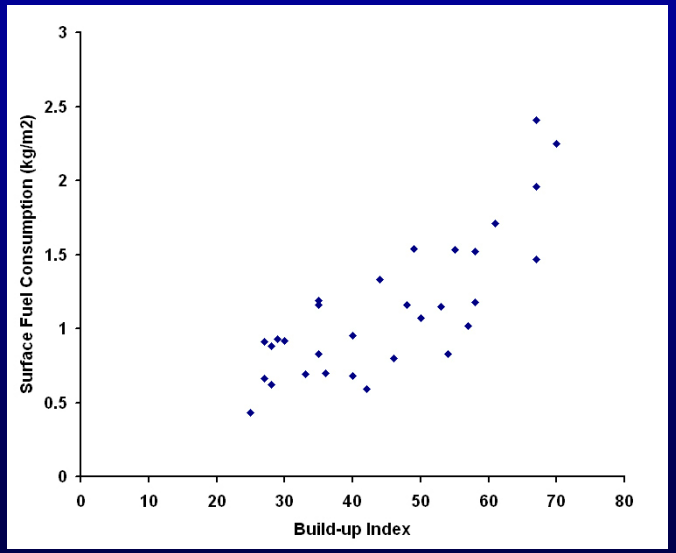
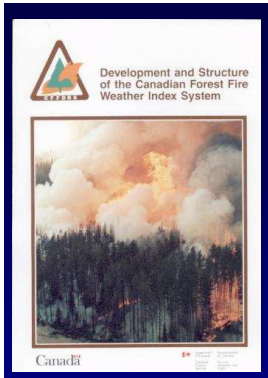


- The Build-up Index (BUI)
  - a simple combination of the DMC and DC
  - used as a unitless indicator of potential fuel consumption





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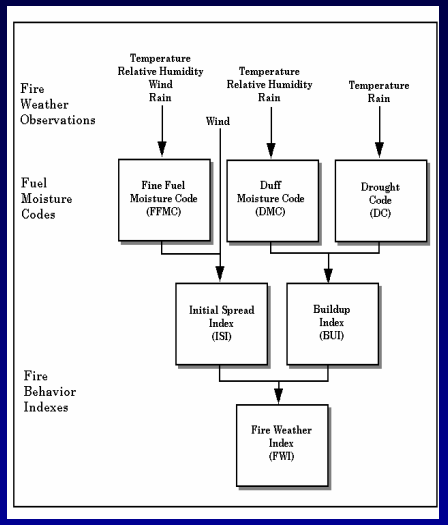
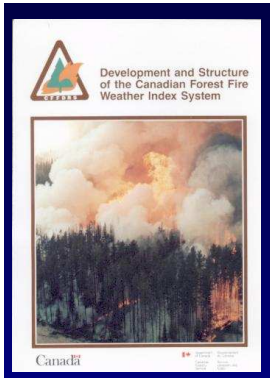
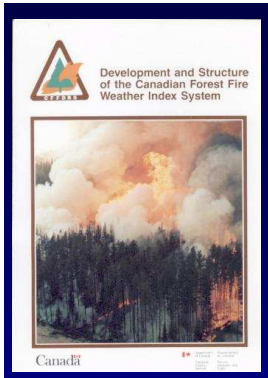


- The Fire Weather Index (FWI)
  - Combines the ISI and the BUI
    (integrating potential spread and potential consumption)
  - A unitless index of the potential intensity of a spreading fire.



The FWI System

- Codes and indices are generally assigned qualitative ranges by each province (and sometime within regions in a province)
  - Based on regional climate, fuels and fire activity



The FWI System

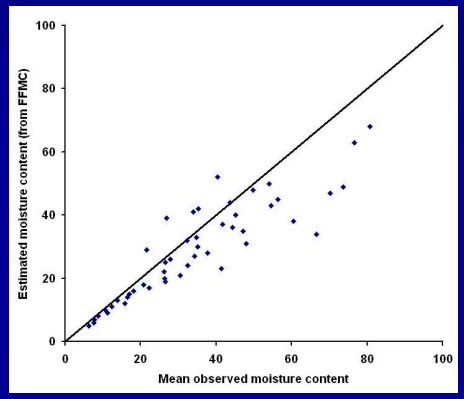
Usage notes

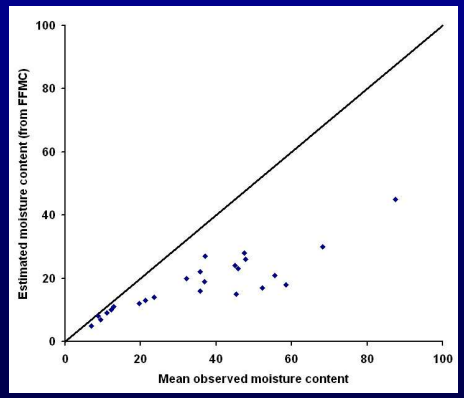
- FWI system outputs have been found to be well correlated with fuel moisture and fire activity over a wide range of forest types, however….

  In terms of their absolute values, they are meant to be interpreted locally.

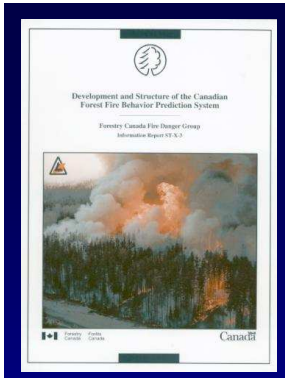
  - e.g., A FFMC of 90 in Pine in northwest Alberta is not the same as a FFMC of 90 in Aspen eastern Ontario

Pine



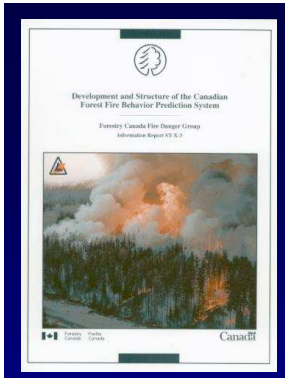


Aspen



The FBP System

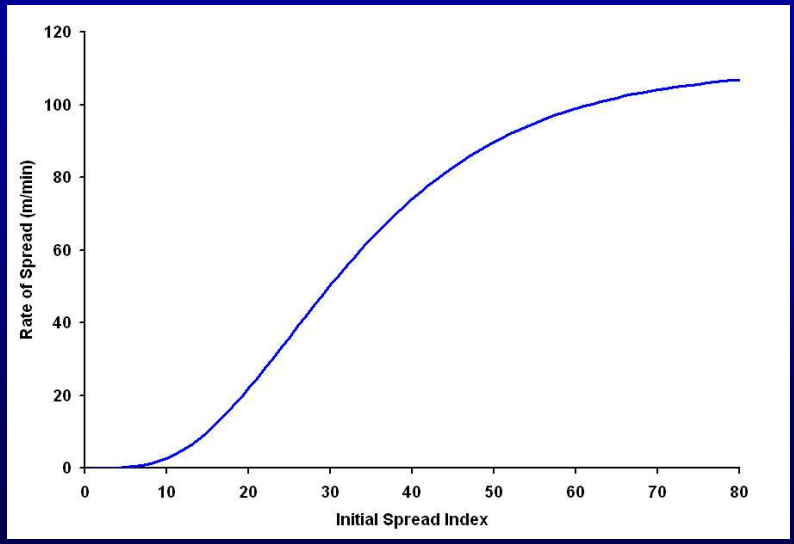
- Provides quantitative predictions of fire behaviour for 16 major forest fuel types across Canada
  - Pine (red, white, jack (immature and mature), lodgepole, ponderosa)
  - Spruce (upland and lowland)
  - Deciduous
  - Mixedwood (spring and summer, with and without spruce budworm damage)
  - Grass (standing and matted)
  - Slash

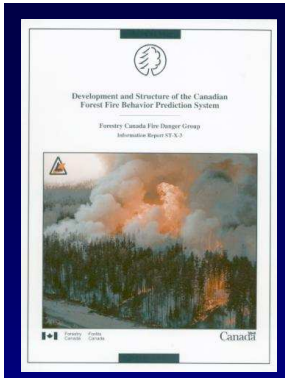


The FBP System

- Basic physical reasoning is used to develop the form of empirical models
  - e.g. the rate of spread/ ISI models are built using a single S-shaped function that incorporates the concept of dual equilibrium rate of spread (surface and crown)

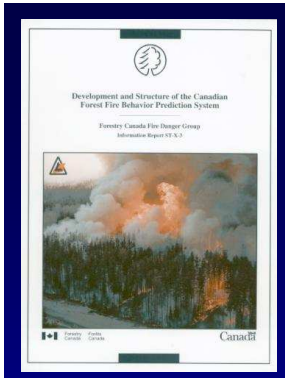
$$ROS = a \cdot (1 - e^{-b \cdot ISI})^{c}$$





The FBP System

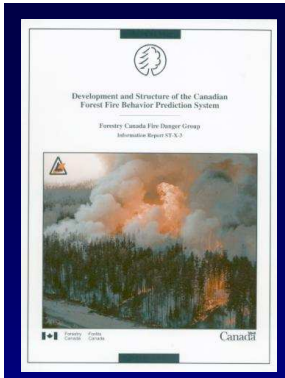
- …Stand specific models are then built from experimental burning projects carried out in the field
  - Blocks cut out of a forest stand
  - Intensively sampled fuels (load , stand density)
  - Ignitions under a range of moisture and wind conditions
  - Stand average rate of spread estimated from coarse scale behaviour
  - average fuel consumption calculated post-burn based on point measurements within the stand



The FBP System

- Experimental burning projects have been carried out across Canada since the late 1960's
  - over 400 experimental fires

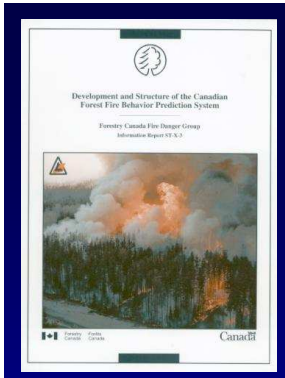
- Experimental measurements are supplemented with observations from well documented wildfires



The FBP System

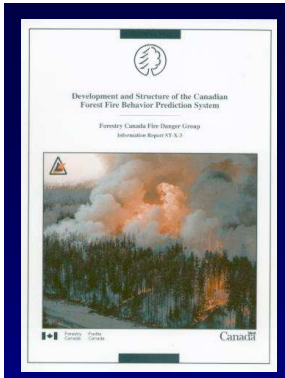
- System Inputs
  - Fuel Type, Date, Latitude, Longitude
  - FFMC, BUI, wind speed, wind direction

  - Slope, slope azimuth, elevation
  - Line or point ignition
  - Duration of fire growth estimate



The FBP System

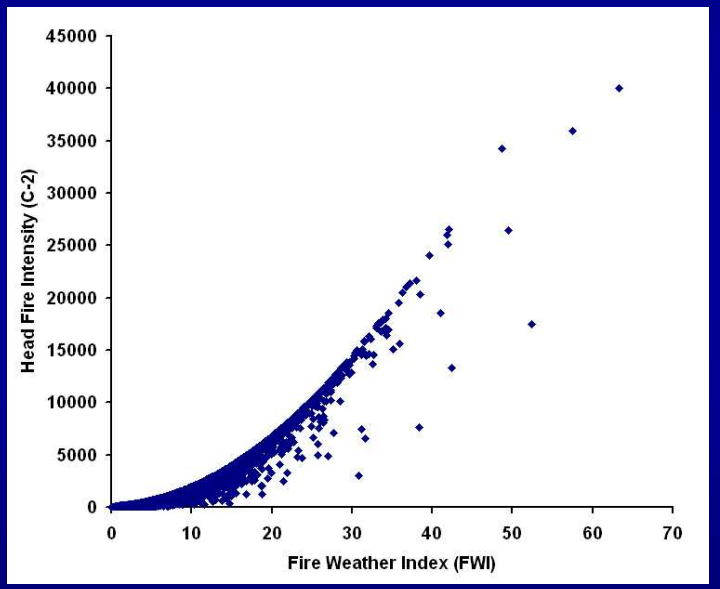
- Major outputs for each forest type
  - Surface and crown fuel consumption (SFC and CFC)
  - Rate of spread (ROS)
  - Head Fire Intensity (HFI)
  - Fire type
    - Surface, Intermittent Crown, Crown

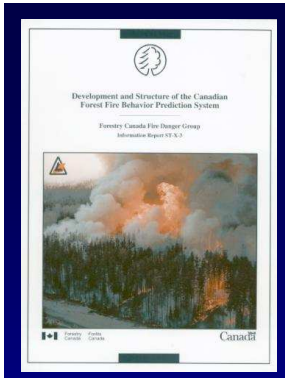


The FBP System

Analogues to the FWI System

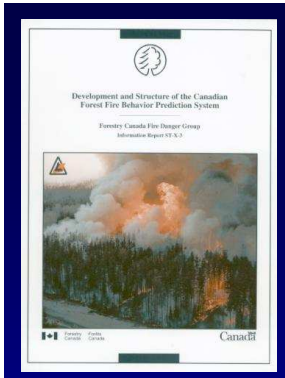
- BUI ∠ SFC
- ISI ∠ ROS
- FWI ∠ HFI





The FBP System

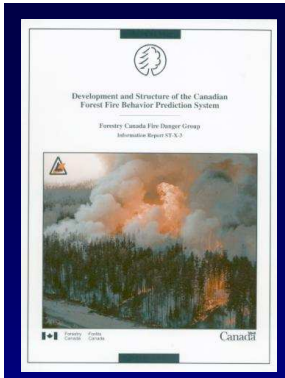
- Other outputs
  - Crown Fraction Burned
  - Length-to-breadth ratio for elliptical growth
  - Back and flank fire rates of spread (and intensity)
  - Elliptical area, perimeter and perimeter growth rate



The FBP System

Issues around the field experimentation and empirical model building approach

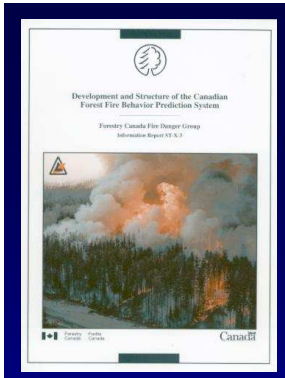
- Advantages
  - Predicted fire behaviour is realistic and does not need to be scaled
- Disadvantages
  - Adapting the system to new forest types is difficult
    - Must measure spread and build a new empirical model



The FBP System

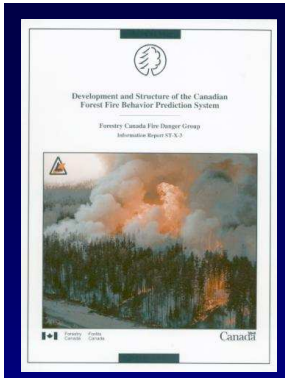
Usage notes

- The FBP System
  - Uses standard fuel loads (surface and crown) for most fuel types
  - Bases predictions on modelled fuel moisture (FFMC, BUI, foliar moisture) not observed moisture in any particular fuel element
  - Predicts average fire behaviour
    - There is in reality a lot of fine scale variability in fuel consumption, rate of spread and fire intensity



The FBP System

- Usage notes cont'd
  - The FBP System was designed to provide guidance to fire managers who would use its output to supplement their experience and judgment, based on their knowledge of each situation.
    - e.g., a fire in a forest type that differs from a standard FBP fuel type significantly



Fire Growth

- The FBP System's spread equations are used as the basic driver of fire growth models, using an elliptical growth model along with spatial forest fuels information
  - e.g. PROMETHEUS: the Canadian Wildland Fire Growth Model

    (http://www.firegrowthmodel.com/)

Accessory Fuel Moisture System

- A system of moisture content models that fit within the framework of the CFFDRS
  - Hourly FFMC
  - Diurnal FFMC
  - Stand specific DMC adjustments (BC)

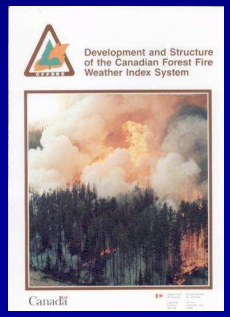
  - Sheltered Duff Moisture Code (SDMC)

CFFDRS

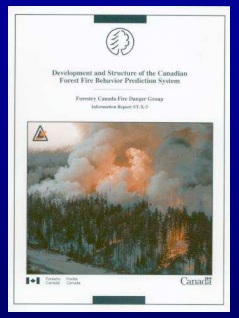
Some ongoing projects and future development

- Improved crown fire behaviour models (ICFME)
- Rate of spread models in MPB killed forest
- Refinement of mixedwood fire behaviour models
- Development of stand specific moisture content calibrations with FFMC
- Open/exposed grass moisture model (and refined ROS models)
- Development of fuel load specific fuel consumption models
- Probability of ignition models for a range of forest floor types
-

CFFDRS
Primary Documentation



- FWI
  - C.E. Van Wagner (1987) **The Development and Structure of the Canadian Forest Fire Weather Index System**. Canadian Forest SERvice, Forestry Technical Report 35.



- FBP
  - Forestry Canada Fire Danger Group (1992) **Development and Structure of the Canadian Forest Fire Prediction System**. Forestry Canada, Information Report ST-X-3

CFFDRS
Primary Documentation

- Interactive training courses (CD)
  - Understanding the FWI System
  - Canadian Fire Behaviour Prediction System
  - Principles of Fire Behaviour

http://www.ubcpress.ubc.ca/

The Canadian Fire Danger Rating System: its use and interpretation

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