Aspects of Wildfire and Flood: Modeling Hazard Frequency & Severity

Prepared by Steven Jakubowski of Impact Forecasting
2017 CAS Spring Meeting, May 24th 2017

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Agenda

Section 1: Wildfire

- Wildfire Model
- Historical Loss Recap

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Wildfire Considerations

- Wildfire peril: On-going, costly, and on the increase
- Wildfire hazard is dependent upon:
  - Weather
  - Fuel
  - Exposure
- “Fire Siege” defined as multiple fires that burn simultaneously
- Property exposure increasing in the Wildland Urban Interface (WUI)
- Insurance contract language: Is it sensitive to fire duration and distance?

Extreme Fire Conditions Driven by Fire Weather

- Most large wildfires are driven by extreme winds
  - Foehn winds
  - a.k.a. Santa Ana, El Diablo, or Sundowner Winds
  - a.k.a. Chinook winds East of the interior west of North America
- Fire weather:
  - Strong winds (> 30mph)
  - Wind gusts can approach hurricane-force level
  - Low humidity (< 20%)
  - Low fuel moisture conditions

Source: IF

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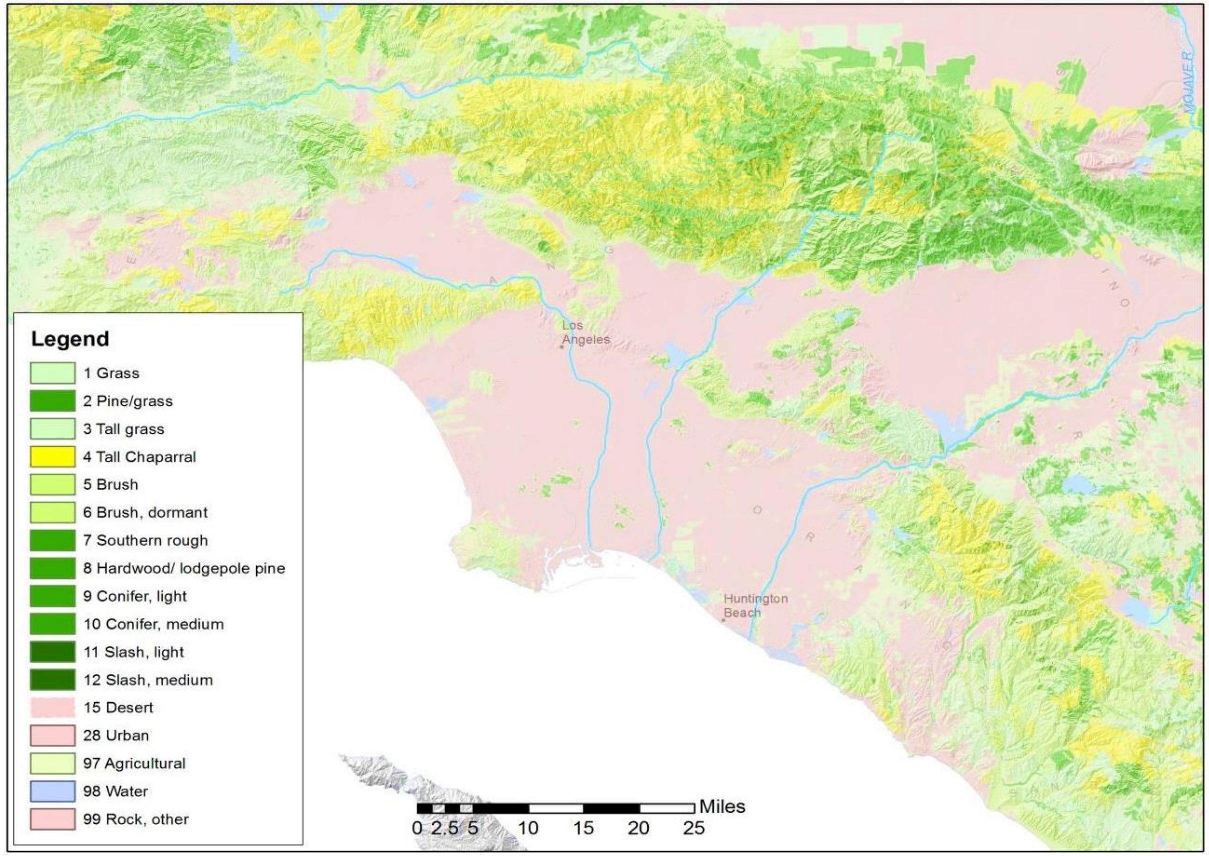
Los Angeles Region Dominated by Chaparral/Brush

- Surface Fuel examples
  - Brush
  - Chaparral
  - Timber/Conifers
  - Agricultural land use
  - Urban land use



Source: IF, Cal Fire

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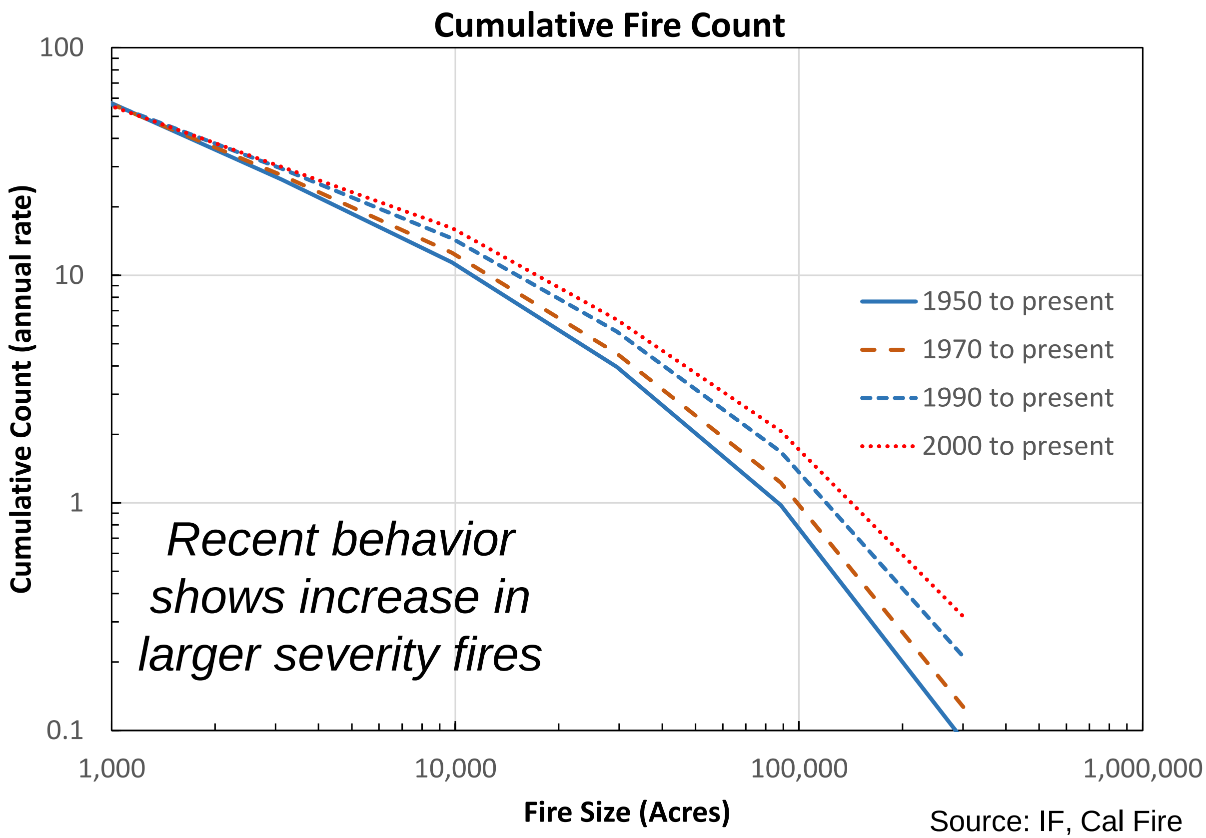
California's Recent Fires: Greater Size & Intensity

- Annualized wildfire frequency vs. severity (wildfire acreage)
  – Plot: 1950 to present, 1970 to present, 1990 to present, and 2000 to present



Source: IF, Cal Fire

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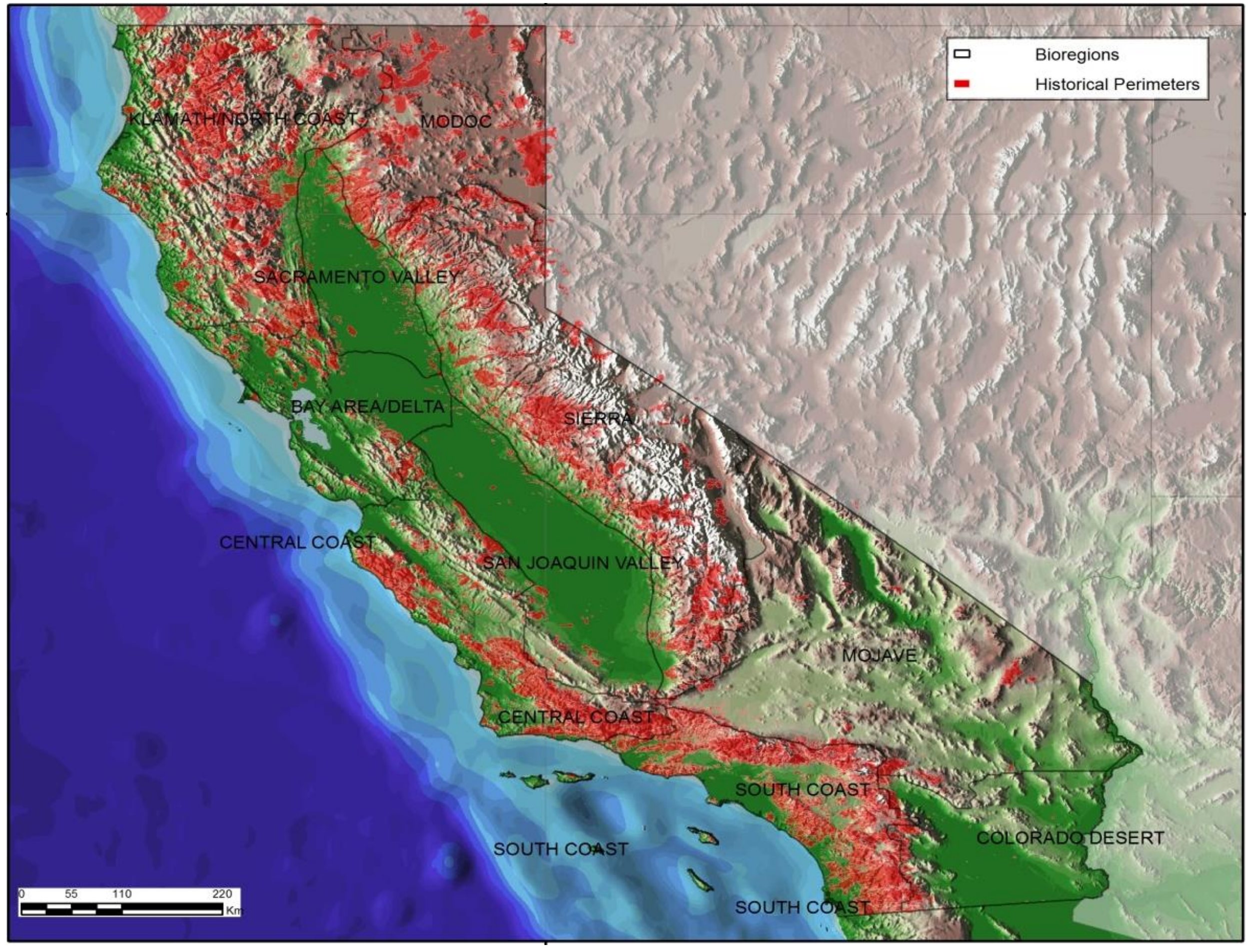
California's Historical Wildfire Experience

- Historical Wildfire Perimeters
  - – Estimates of about 130 wildfire occurrences per year (100+ acres)
- Wildfire occurrence is related to biological regimes that depend on elevation, vegetation, and fuel moisture levels



Source: IF, Cal Fire

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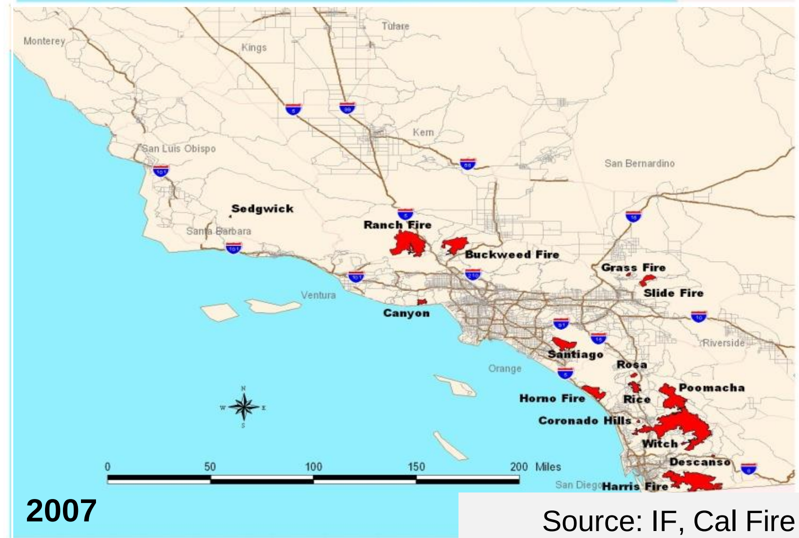
California's Fire Conflagrations & Sieges

Wildfire Conflagration Examples

San Diego & Ventura	1970
Oakland Hills	1991
Los Angeles & Ventura	1993
Los Angeles & San Diego	2003
Los Angeles & San Diego	2007
Valley & Butte Fires	2015

Fire Sieges: Multiple Outbreaks / Brief Timeframe Examples

1993	17 fires	in	11 days
2003	14 fires	in	15 days
2007	12 fires	in	23 days
2015	2 fires	in	22 days



Source: IF, Cal Fire

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Urban Interface Property Growth – Trending Now

- Property changes by wildfire region
- California property stock (housing units)
  - Fire regions (exposure within all historical wildfire perimeters)
  - Unaffected regions (exposure outside wildfire perimeters)

Source: IF, U.S. Census, Cal Fire

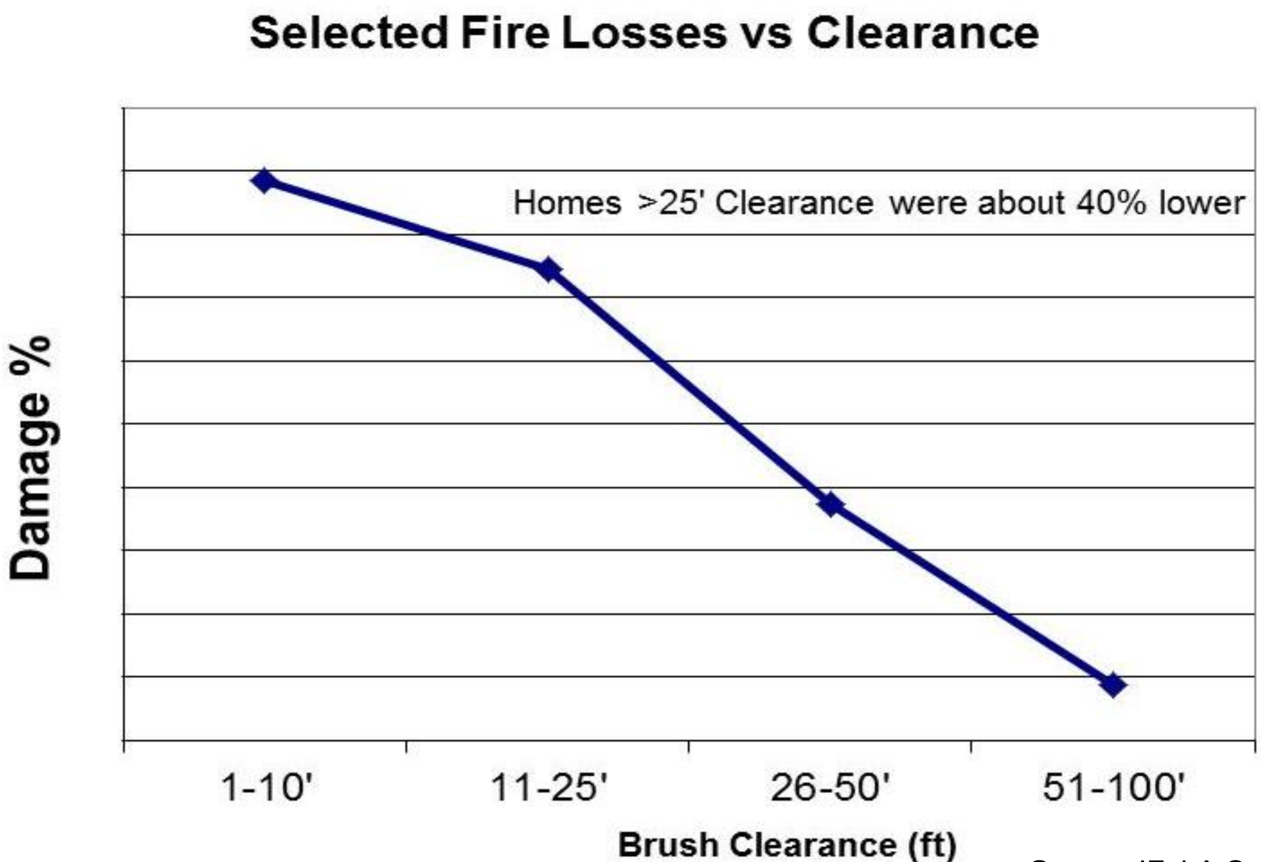
Exposure	Annual Growth
Wildfire Regions	3.6%
Non Wildfire-Affected Regions	1.8%
Result	**Growth in the fire affected regions is *2x greater* than unaffected regions**

Wildfire Reconnaissance: Lake Tahoe (June 2007)

Complete Structure Loss and Surrounding Timber Fuels

Firewise: Clearance = Loss Reduction

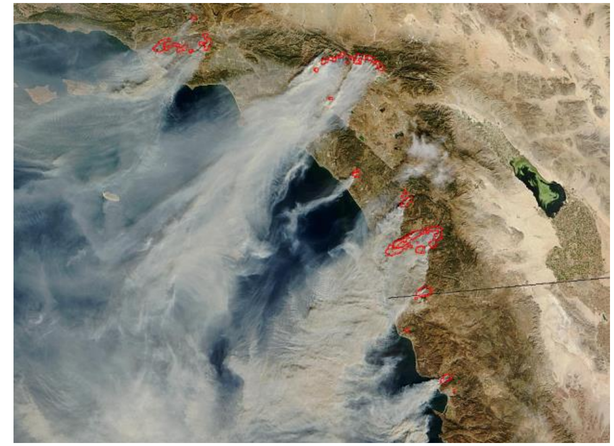
- Review of historical damage vs. brush clearance illustrates the expected reduction with clearance



Source: IF, LA County Fire

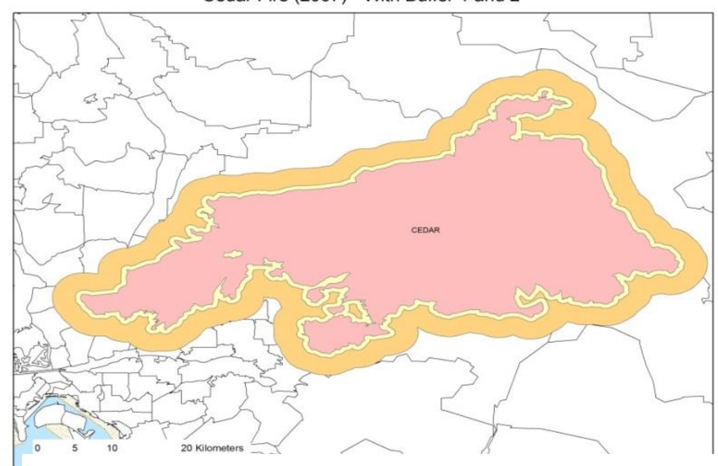
Secondary Effects

- ISSUE: Claims occur inside ***and*** outside of the fire perimeter
  - – Primary losses (structural loss) in perimeter
  - – Secondary losses within buffer region
    - Additional losses from smoke, ember transport, time element (evacuation)
    - Damage ratio considerably lower vs. higher exposure
    - Non-structural secondary losses may occur within the fire perimeter



Smoke from 2003 fire siege

Cedar Fire (2007) - With Buffer 1 and 2



Buffer regions (Cedar Fire)

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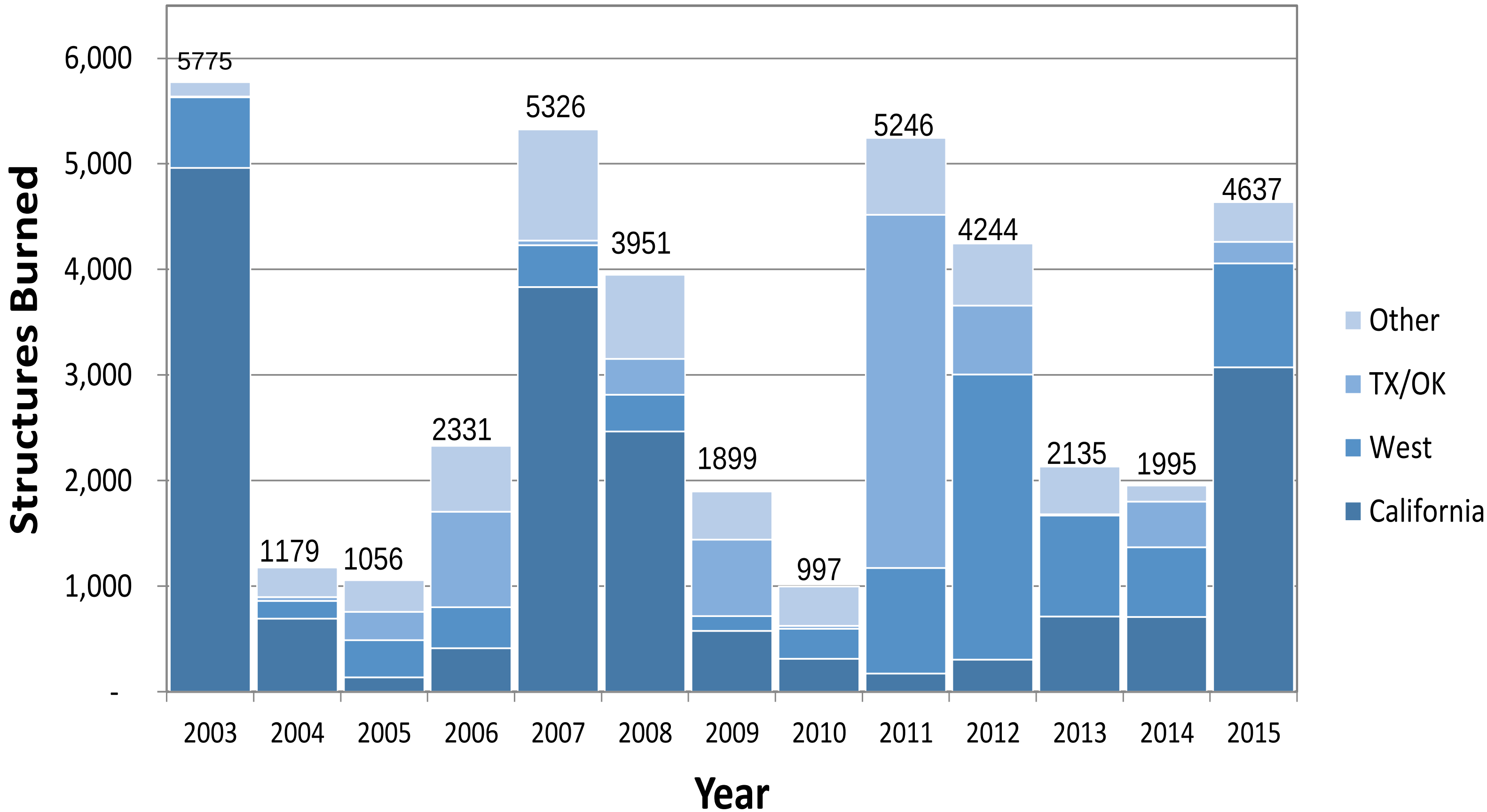
US Average Annual Loss of 3133 Structures



Source: IF, Cal Fire, USFS, ICS-209

Significant Loss Events in California: 2003 to 2015

Year	Incident	Loss (2015 USD)*
2003	Paradise, Cedar Old, Grand Prix, Padua	$2,853 M
2007	Rice, Witch, Poomacha, Harris, Slide, Angora	$2,213 M
2008	Freeway, Sayre	$566 M
2015	Valley, Butte	$1,231 M
	Total	**$6,863 M**

* Adjusted to 2015 using CPI, some losses are estimated

Source: IF, ISO-PCS, LA Times

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Section 2: Fort McMurray Recap

- Fort McMurray, Canada Wildfire of May 2016

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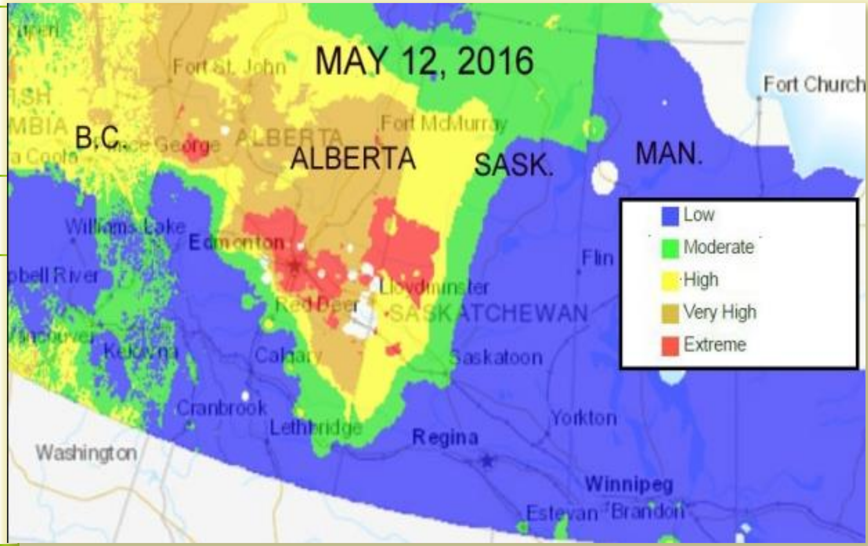
Fort McMurray Wildfire Timeline

May 1	10:30 am MDT	Fire reported, mandatory evacuation ordered for some neighborhoods
May 2		Fire moves away from Fort McMurray
May 3	Late AM	Local weather conditions change dramatically: Temps rise to 30ºC (86ºF), dropping humidity, shifting winds cause the localized fire to grow
Summer conditions in April: April 2016 snow extent for the month was the smallest on record		
May 3	14:25 MDT	Flames and smoke head toward the city. Authorities and residents scramble
	15:45 MDT	Residents are advised to head north or south of the city



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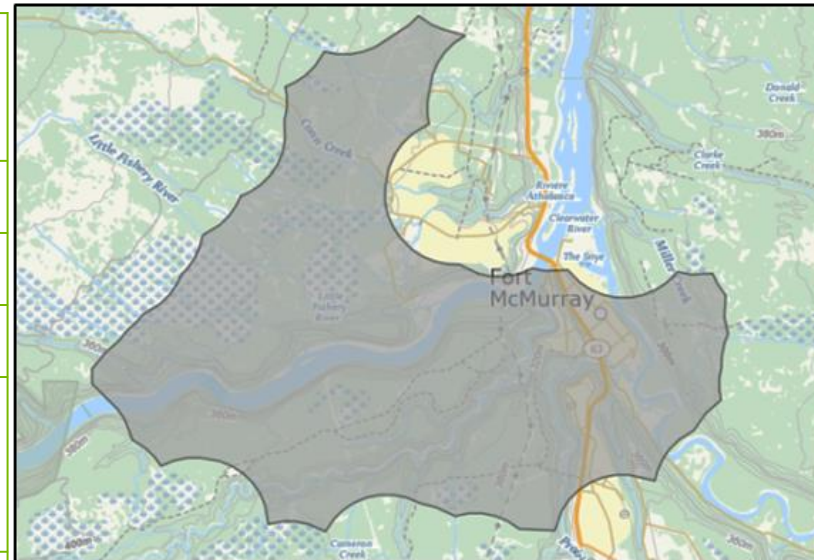
Fort McMurray Wildfire Timeline - Evacuation

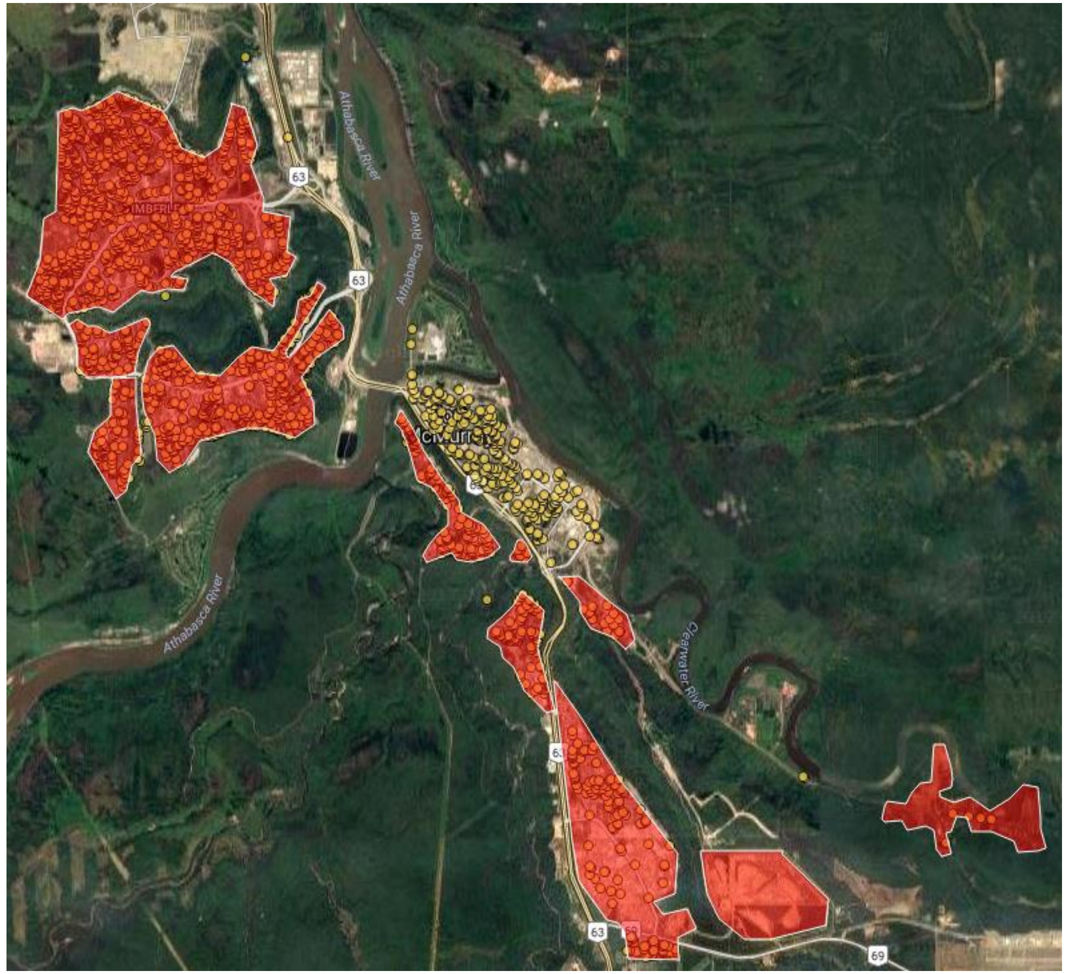
May 3	**18:31 MDT**	**Fort McMurray** is placed under **mandatory evacuation** order
May 5		Fire estimated at 850 km^2
May 6		Fire estimated at 1,560 km^2
May 7		Fire estimated at >2,000 km^2
May 16		**Air Quality Index (AQI) is at Level 38**. AQI usually ranked 1 to 10, with 10 being the worst
May 16		Fire estimated at > 2,850 km^2
May 18		Government declares June 1st resident return day. Fire burn area is estimated at > 3,500 km^2
May 19		Fire continues traveling east, has consumed an est. > 5,000 km^2 equaling the total area of all fires in 2015
June 1		**Evacuees return**



Fire Perimeter on May 4 (Source: CWFIS)

Exposure Response

- Property exposure analyzed with GIS methods to compare exposure with fire perimeter
  - Fire complex has multiple fire perimeters
- Clients saw fire perimeters with real-time exposure
  – Accumulation reports were generated relative to the suite of fire perimeters



Source: Aon Benfield

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Fort McMurray Loss Scenario vs. Other Events

Year	Quarter	Trended Rank	Date	Location	Province	Event/Perils	Estimated Loss in 2016 CDN000's
2016	2	1	May	Fort McMurray	Alberta	Wildfire	$4,000,000
1998	1	2	Jan	Ontario/ Quebec	Ontario/ Quebec	Ice Storm	$2,288,083
2013	2	3	June	S Alberta	Alberta	Flood	$1,974,469
2013	3	4	July	GTA	Ontario	Rainstorm	$1,080,176
2011	2	5	May	Slave Lake Alberta	Alberta	Wildfire	$821,287
2005	3	6	Aug	Ontario	Ontario	Hailstorm/Sewer Backup	$775,683
2010	3	9	Jul	SE Alberta	Alberta	Hail/ Wind	$630,234
2012	3	7	Aug	Calgary	Alberta	Flood, Hail and Wind	$612,853
2014	3	8	Aug	Central Alberta	Alberta	Hail/ Wind	$603,034
1991	3	10	Sep	Calgary	Alberta	Hailstorm	$549,352


(Source: @ CBCEyeopener)

Damage in Fort McMurray

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Fort McMurray Loss Scenario vs. Other Events

- Fort McMurray - costliest event on record for Canada (est. CDN 4 Billion insured loss)
  - Ice Storm of 1998 and Calgary Floods of 2013 (trended for inflation only) approx. same insured loss as Fort McMurray event

Question: Where can the next Fort McMurray arise in Canada?
High concentration of population and exposed values in remote areas

Section 3: FLOOD

- US Coastal Flood Modeling

Storm Surge Model Characteristics

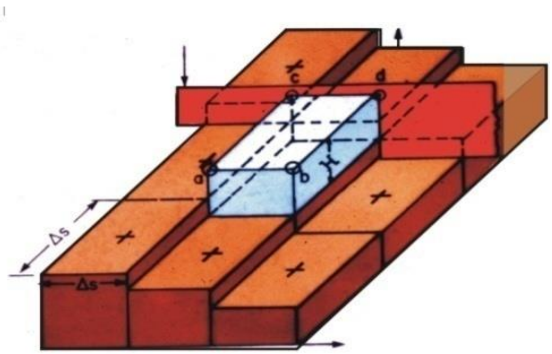
Hurricane Storm Surge

- Surge modeling should address:
  - Entire tropical storm lifecycle
  - Bathymetry offshore / topographical onshore
  - Consider all land-falling storms in the stochastic suite
  - Encompass all land-falls for a given storm (first, second, third strike)
  - Use the same stochastic event set as the wind set
- Common storm surge models
  - SLOSH (National Hurricane Center)
  - ADCIRC (Academic communities)

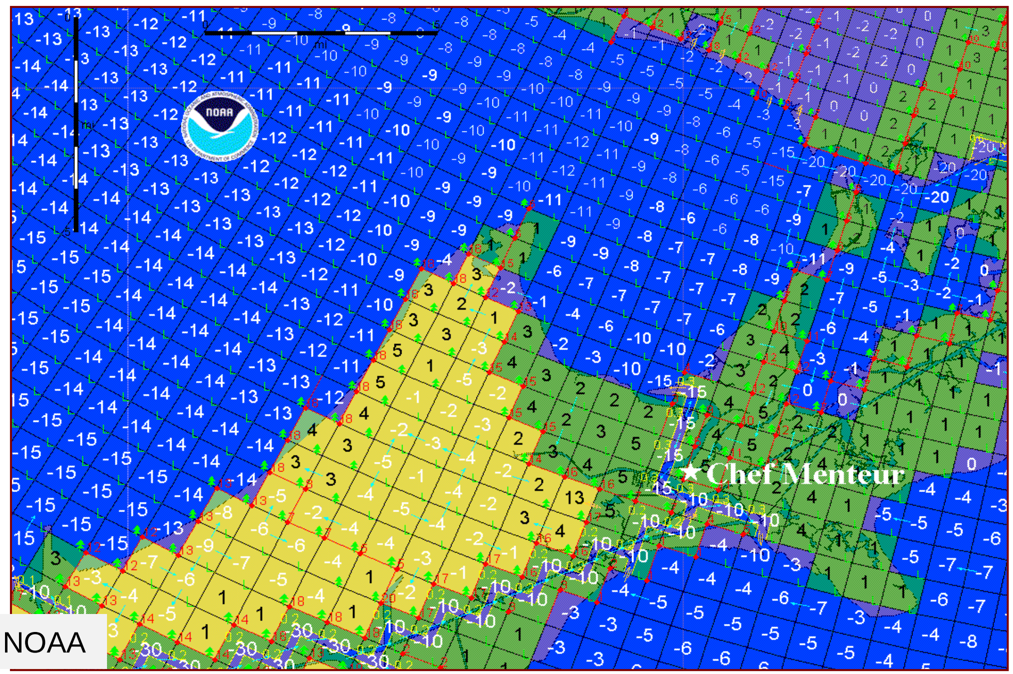
Deep Coastal Bathymetry Hazard

Shallow Coastal Bathymetry Hazard

Storm Surge Modeling



- Analysis applied to gridded mesh
- Resulting output provides surge heights relative to vertical datum



Source: NOAA

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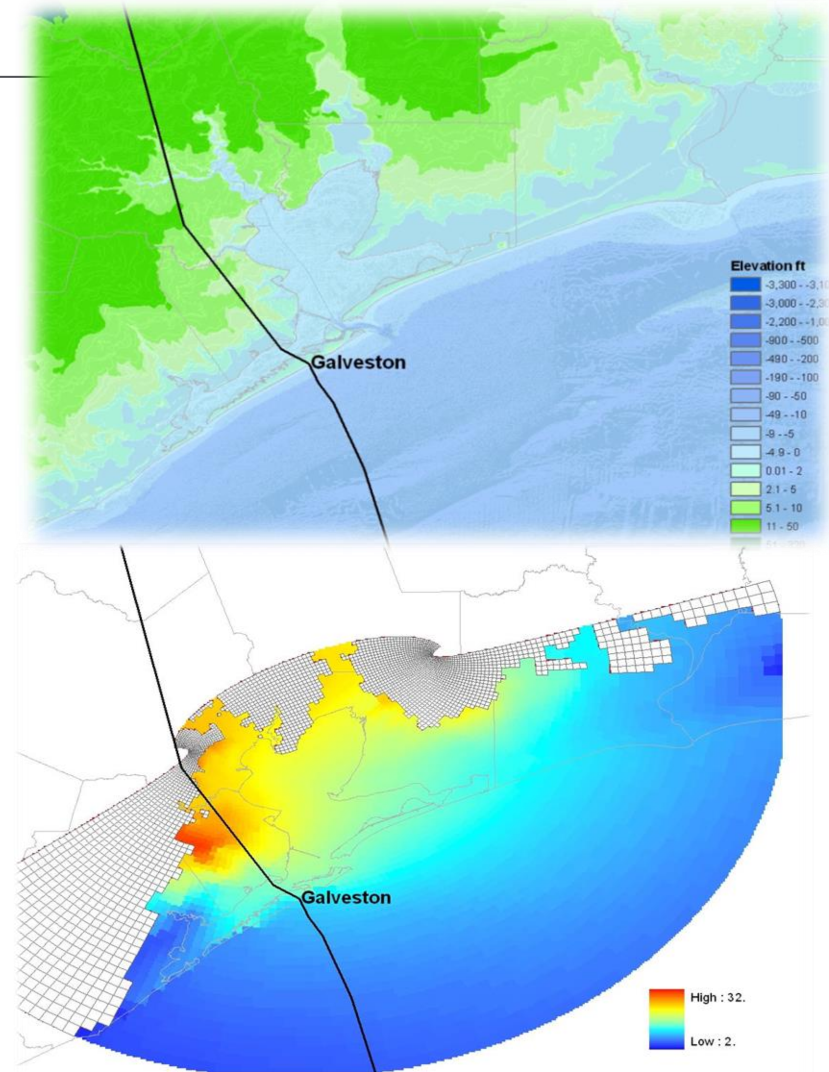
Surge Height Generation

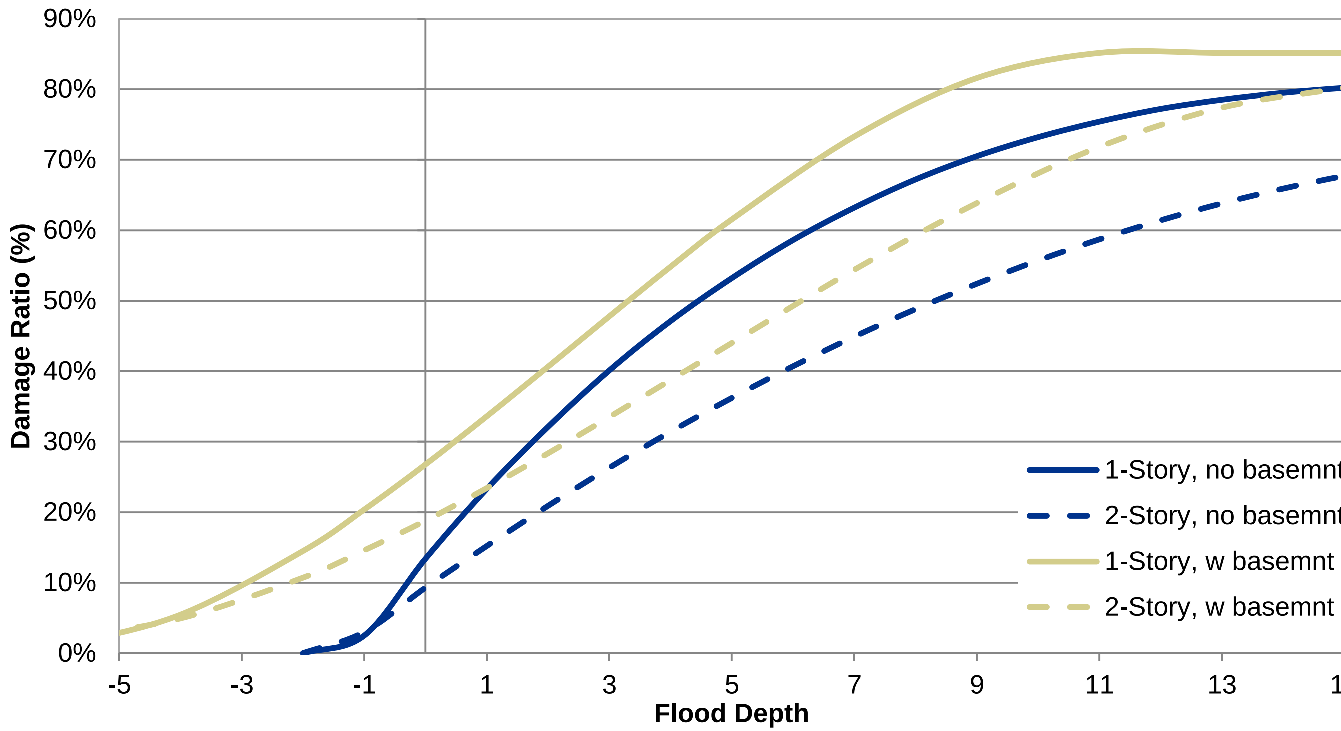
- Model surge height generation for a selected storm track. Model incorporates:
  - Storm strength, direction, and radius of maximum winds
  - Physical characteristics to transport surge throughout the lifecycle for each step
  - Output retained across grid mesh, stored in a data warehouse



Source: IF

Vulnerability Example – Depth Damage Functions

- Correlates inundation with expected mean damage ratio
- Uncertainty around mean can be large (CV of 50% or more)
- Inundation is measured relative to first floor
- USACE functions may be based on limited data sets

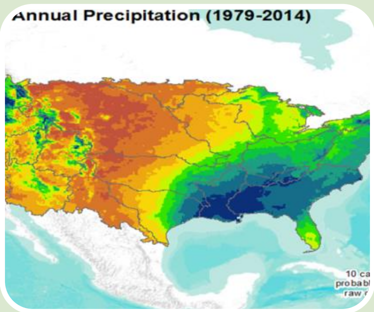


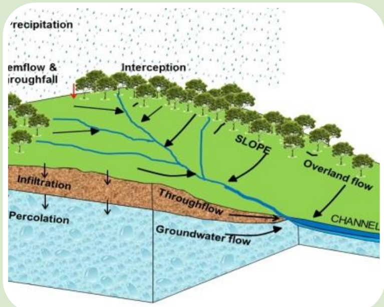
Source: US Army Corp of Engineers (USACE)

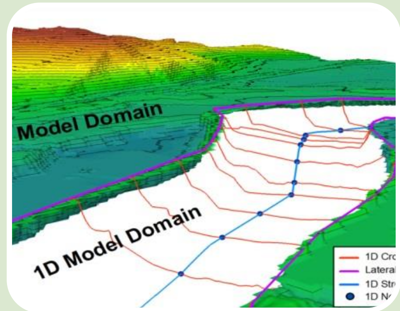
Section 4: Inland Flooding

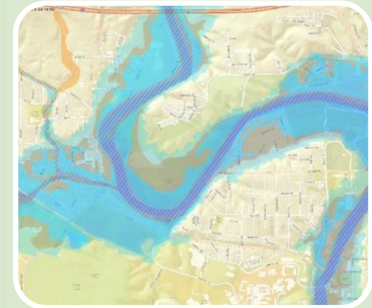
- Inland Flood Modeling

Inland Flood Hazard Simulation Approach









Precipitation:
The main source of flooding

Rainfall-runoff:
Rainfall behavior in stream network

Routing:

The technique of determining the **flood** hydrograph at a section of river

Defense:

Flood risk mitigation

Inundation:

Flood depth and footprint in affected areas

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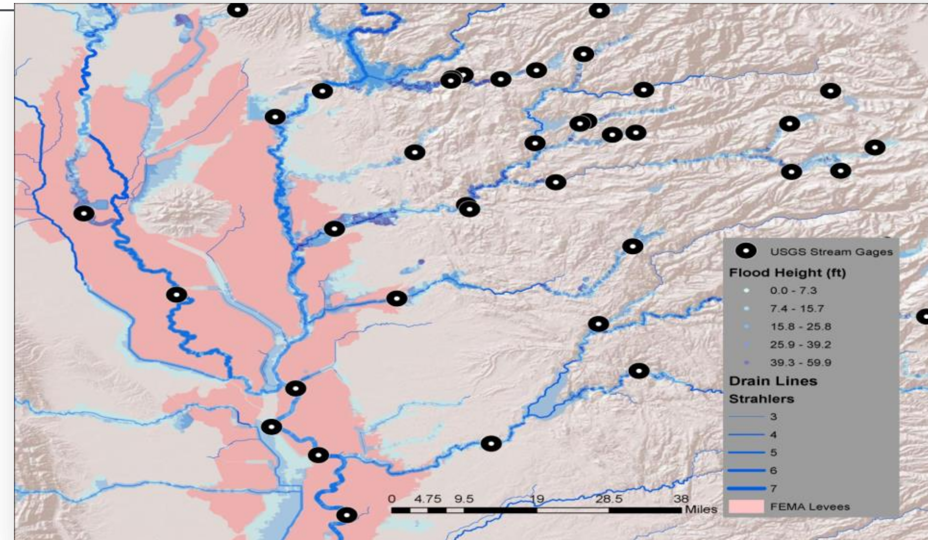
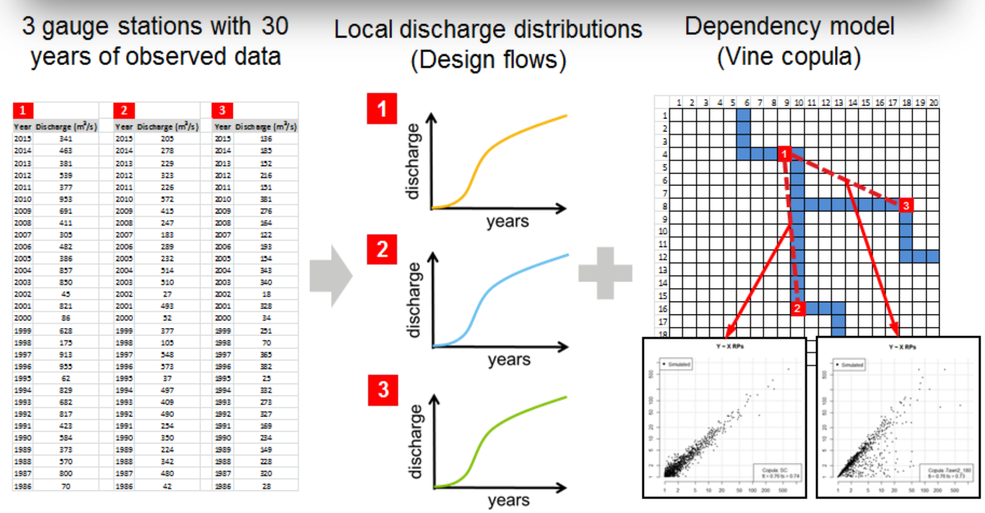
Probabilistic Flood Model – Key Aspects

- **Flood maps** for a range of return periods are model hazard core
  - Modelled by 2D hydrodynamic model at high resolution
- **Stochastic event set** provides realistic flood scenario views in given territory
  - Simulated from a dependency model based on hydrological observations and state-of-art multivariate statistical methods
- **Vulnerability module** provides link between hazard and damage





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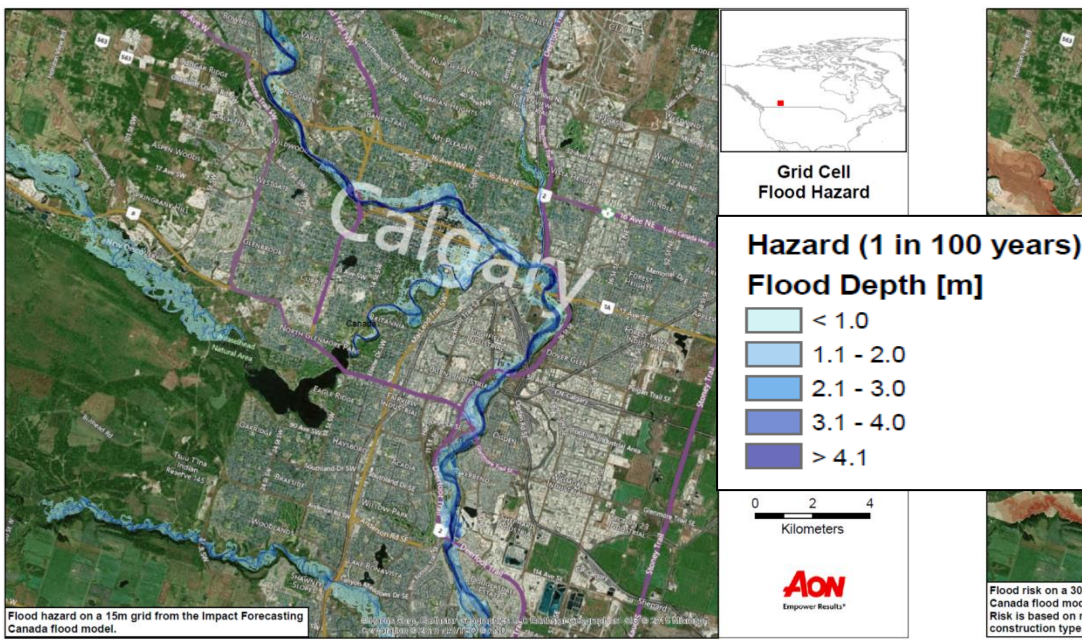
Flood Hazard Map vs. Probabilistic AAL Map

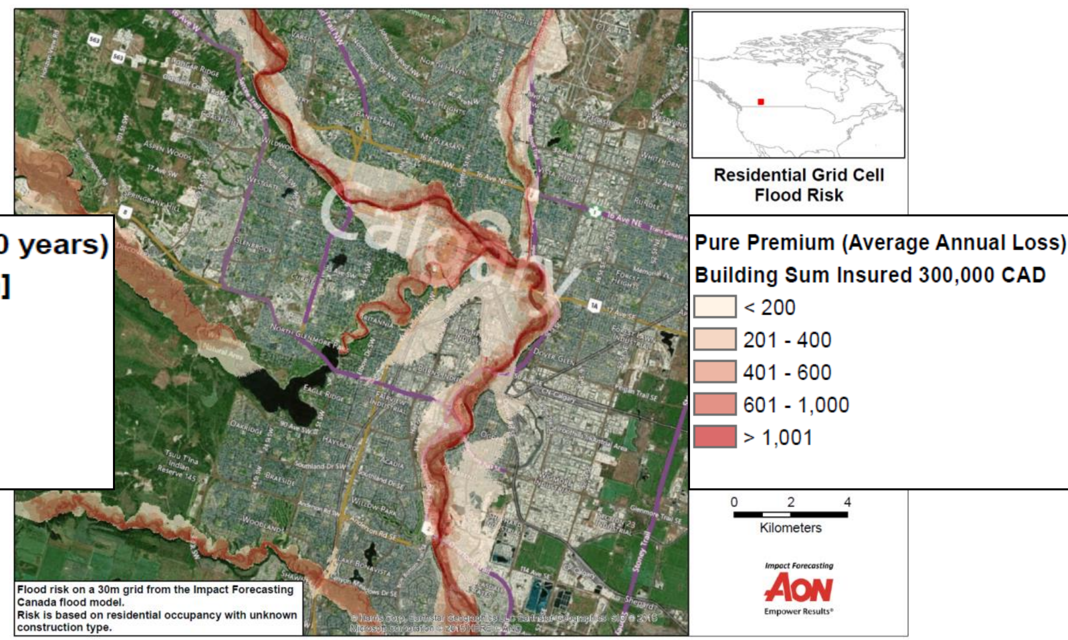
Flood map

– Available for a range of return periods
– In / out flood zone, inundation depth
– Does not reflect realistic flood events
– Does not give any rate indication

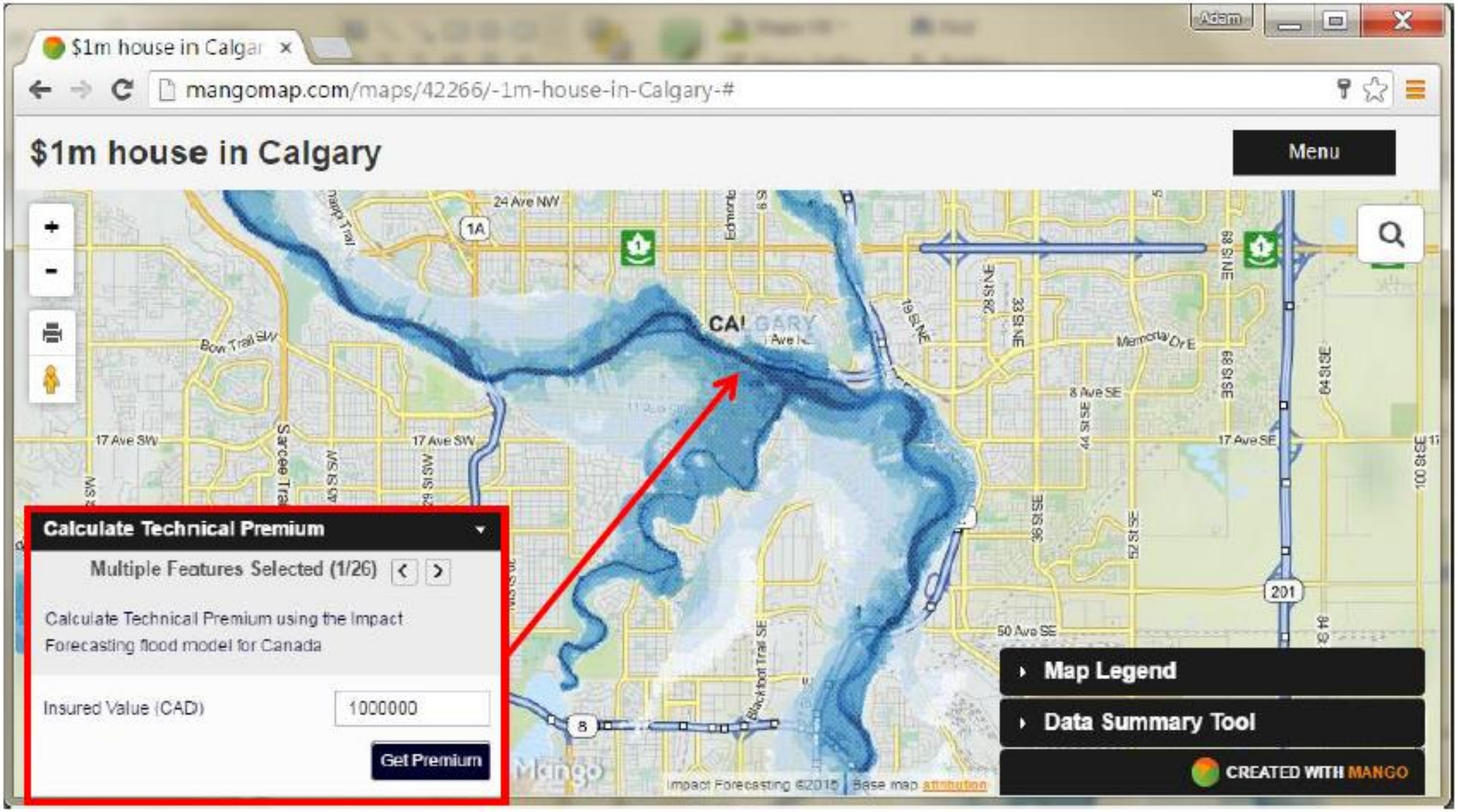
Probabilistic model (risk map)

– Depends on property parameters
– Pure premium as % of insured value
– Based on realistic events catalogue
– Gives rate indication





Underwriting Rate Calculation - Selected Site



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Underwriting Rate Calculation

- **Probabilistic** models based on high resolution hazard maps can be used for location-level flood loss (pure premium) assessment
  – Differentiated by risk type – property parameters
  – Possible inclusion of multiple sub-perils (flood plain, off-flood plain)
- **Risk data for rating** – by high resolution grid, postal code, or zones

geolat	geolon	Pure Premium
33.932	-117.974	0.00843
33.921	-117.976	0.01726
33.927	-117.976	0.00851
33.915	-117.975	0.01612
33.937	-117.975	0.00750
33.935	-117.975	0.00578
33.93	-117.974	0.00876
33.944	-117.973	0.00490
33.934	-117.975	0.00250
33.921	-117.975	0.01161
33.942	-117.974	0.01144
33.932	-117.976	0.00390
33.935	-117.974	0.00767

IF Variable resolution lat/long grid

IF Orange County AAL Grid

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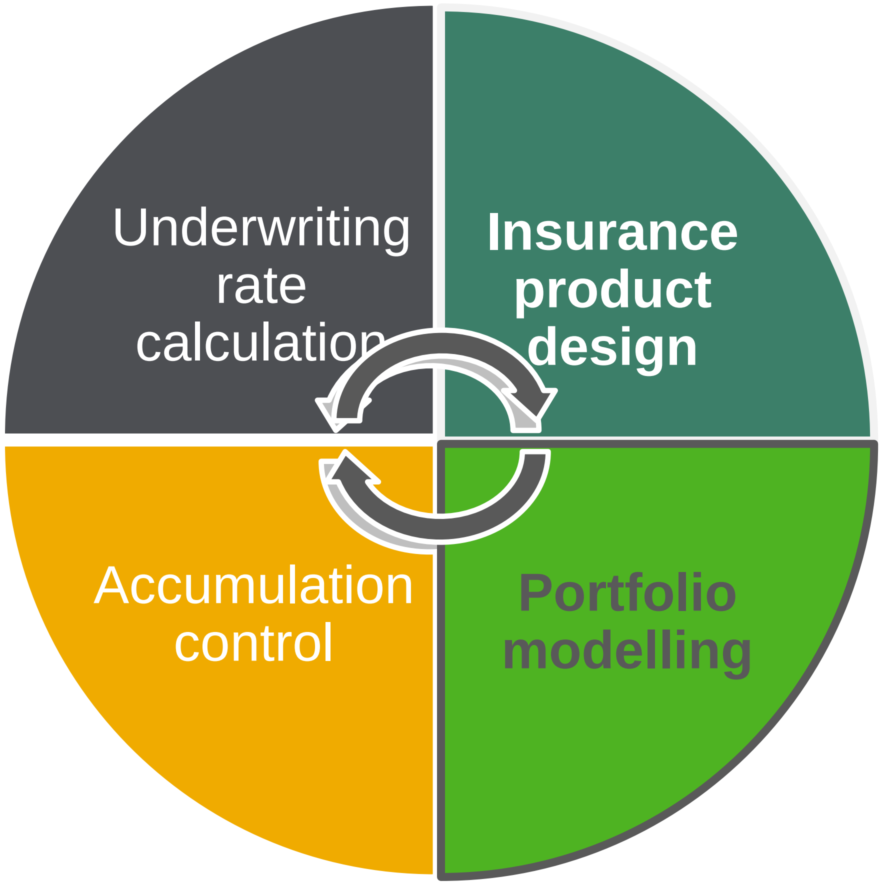
Probabilistic Flood Model – Use Cases

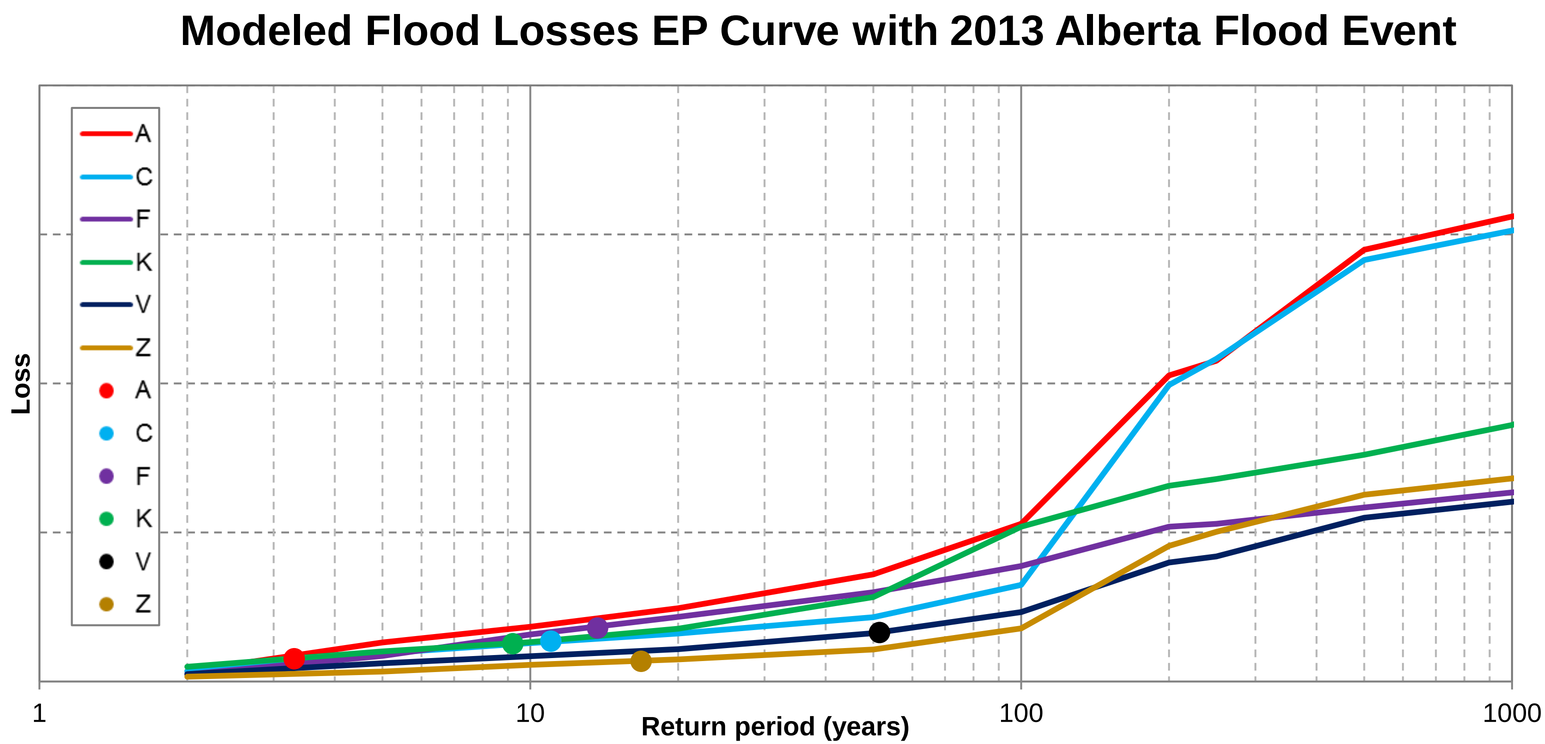


Different market evolutions – different starting points

- **United States**
  - Highly regulated, established market
- **Canada**
  - Fresh market looking for technical solutions to flood design products

Portfolio Modeling

- Traditional use and primary purpose of probabilistic models
- Provides aggregate view on the portfolio losses
- Assessment of solvency capital requirement or reinsurance capacity



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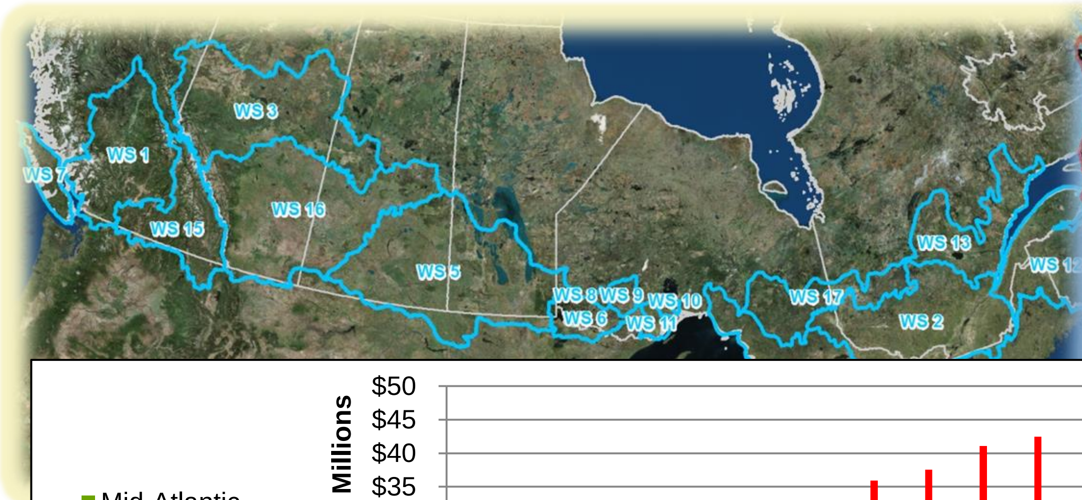
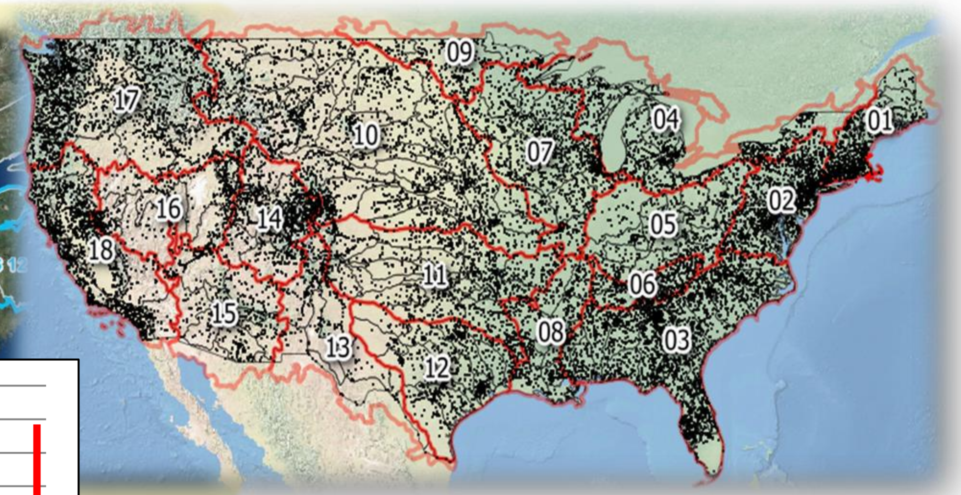
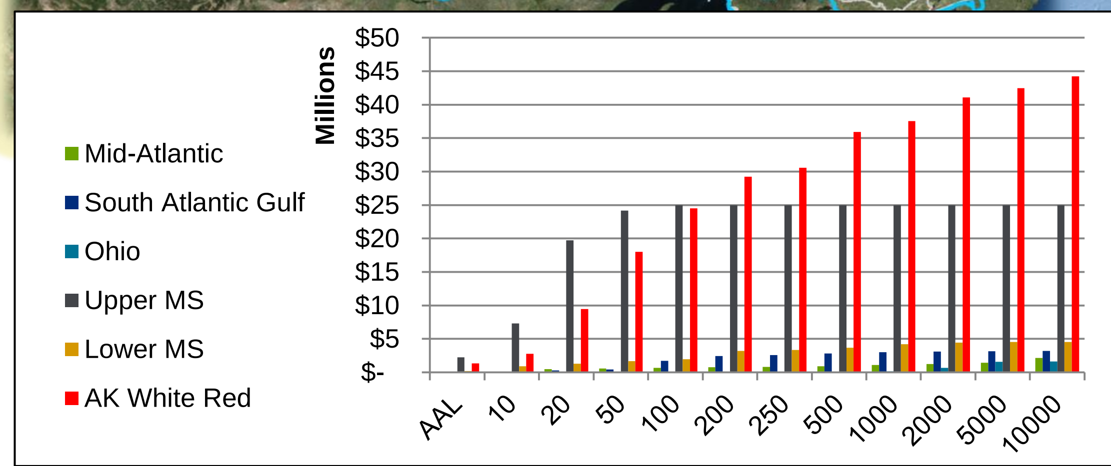
Accumulation Control

- Identify **exposure clusters** as potential sources of big catastrophe loss
  - Usual use of administrative zones and sums insured
- Enhanced accumulation using model support loss accumulation
- Effective accumulation control requires zones reflecting the underlying hazard behavior – watersheds







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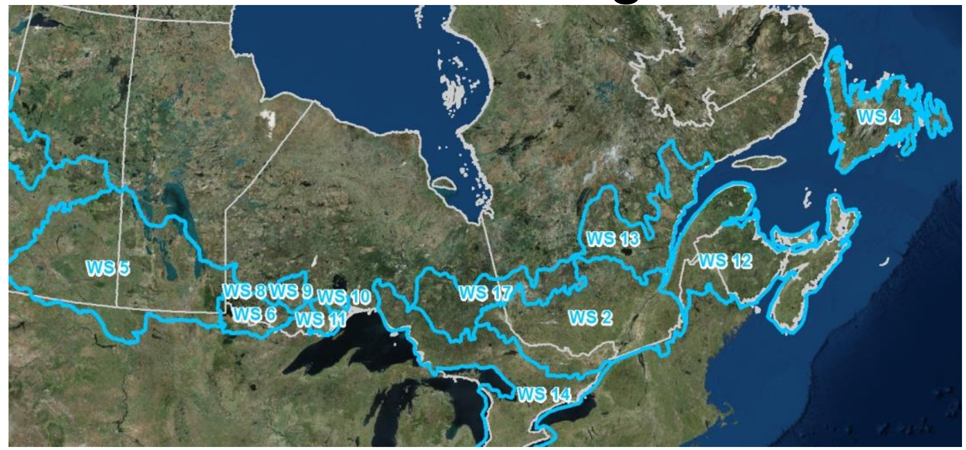
Accumulation Control Workflow

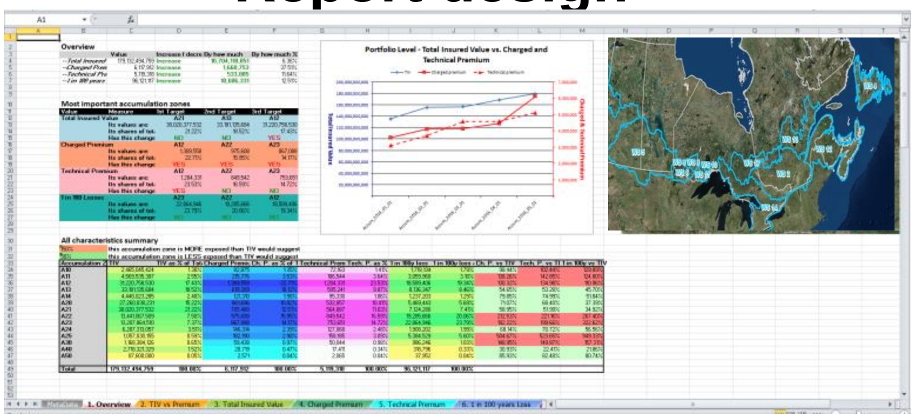
Accumulation values / metrics

Zone Name	Exposed TIV	Exp. TIV as % of total	Pure Premium	PP as % of total	PP vs. ETIV
Newfoundland and Labrador	5,597,784,492	1.49%	239,232	0.35%	23%
Prince Edward Island	296,784,663	0.08%	4,671	0.01%	9%
Nova Scotia	9,046,791,873	2.41%	346,624	0.50%	21%
New Brunswick	5,763,710,234	1.53%	1,723,422	2.51%	164%
Quebec	109,931,790,013	29.24%	31,875,629	46.39%	159%
Ontario	146,964,970,963	39.09%	16,639,604	24.21%	62%
Manitoba	11,745,326,355	3.12%	5,307,024	7.72%	247%
Saskatchewan	1,205,095,988	0.32%	59,593	0.09%	27%
Alberta	51,042,498,272	13.58%	5,268,911	7.67%	56%
British Columbia	34,366,483,865	9.14%	7,252,256	10.55%	115%
Yukon	NA	NA	NA	NA	NA
Northwest Territories	NA	NA	NA	NA	NA
Nunavut	NA	NA	NA	NA	NA
Total	375,961,236,718	100%	68,716,967	100%	

Accumulation regions



Report design

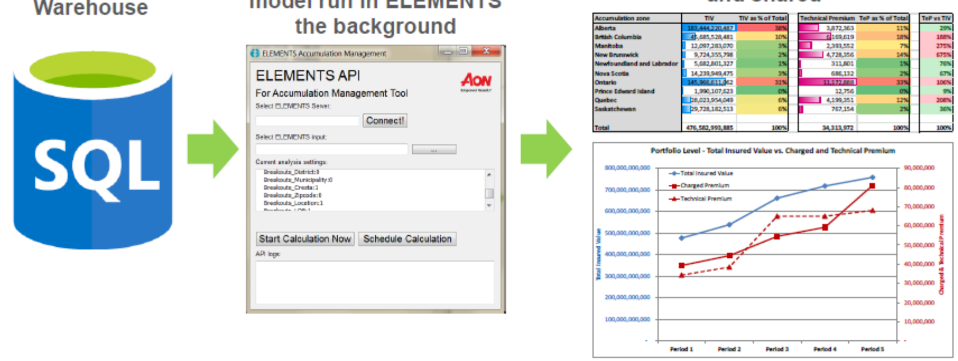


Workflow automation

Your Data Warehouse

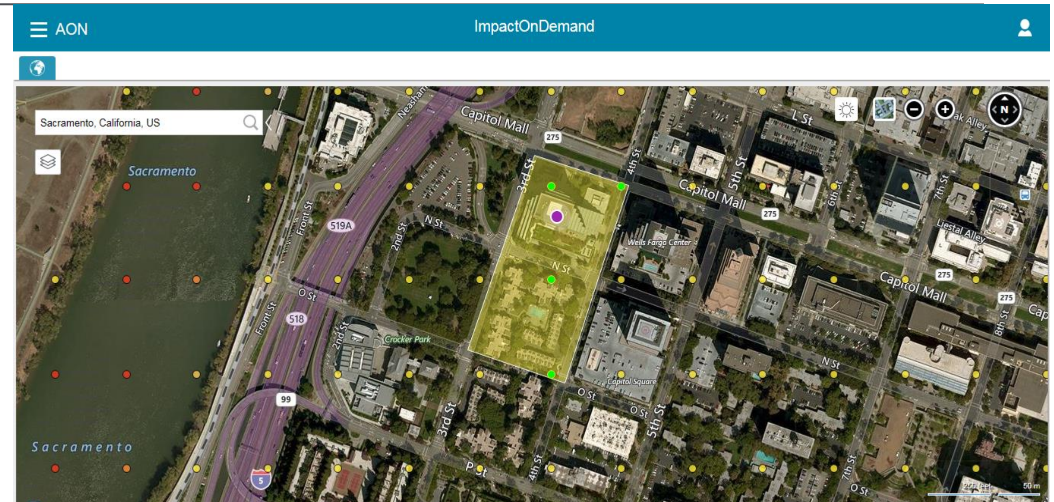
1 or 0 click automated model run in ELEMENTS the background

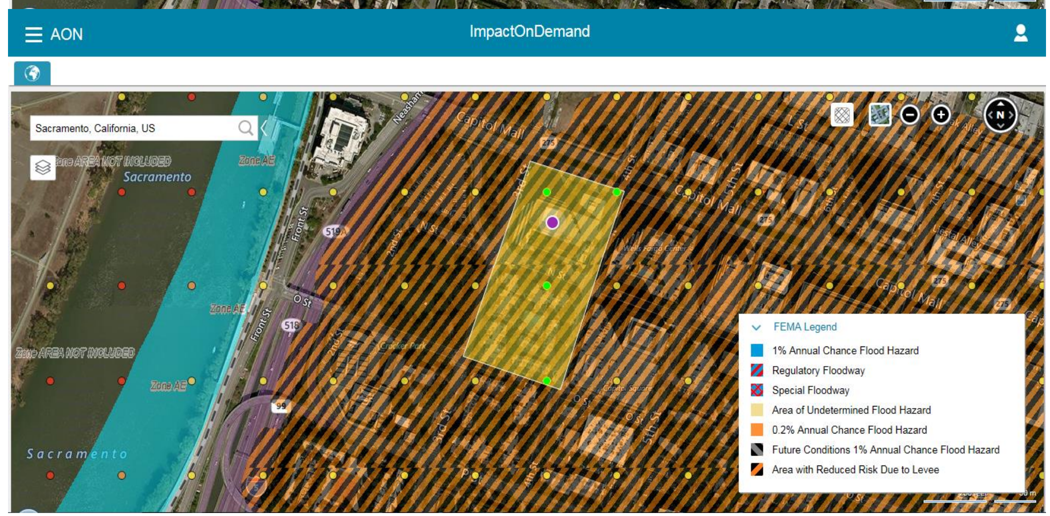
Standard report produced and shared



Notional AAL Grid Precalculated for Underwriting

- Building & contents loss costs at every 100 meter lat/long point across the U.S.
  - Site elevation
  - IF flood plain depths
- Confirm exposure location and geocoding
- Reposition geocode if necessary
- Overlay FEMA flood plains
- Calculate technical premium





No data preparation or ‘modelling-on-the-fly’ required

Key Benefits

- Probabilistic models are effective tools for **rate calculation**, evaluating the **effect of insurance conditions** (limits and deductibles) and **risk accumulations**

- When compared with hazard maps, probabilistic models offer a **true rating recommendation**

- Accumulation using **physically defined zones** allows better utilisation of underwriting limits

- **Unification of tools and data** provides a key to comprehensive and consistent workflow for primary underwriting, portfolio monitoring, and modelling,

Questions?

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1 in 250 years flood plain map for Calgary