Predicting post-fire erosion under variable fire regimes

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The risks are real!

PHOTO: John Knocks, Local Farmer

The risks are real!

The risks are real!

PHOTO: Adrian Murphy, Melbourne Water

The risks are real!

PHOTO: Wayne Tennant, GBCMA

The risks are real!

The risks are real!

Wildfire	Erosion events	Catchment	Management response (water supply system)
2003	Debris flow	Ovens, Victoria	• Boil water notices • Increased water restrictions (level 4 of 4)
	Flood/debris flow	Cotter, ACT (Canberra)	• Switched supply (1 yr); • Water restrictions; • New treatment plant ($38 Mil)
2006-07	Debris flow	Ovens, Victoria	• Boil water (6 months), • New treatment plant
	Debris flow & flood	Macalister, Victoria	• Increased water restriction level; • Water carting (Feb - Sep 07)

Management questions…

Sources of water quality impacts?

How much? How often? Where?

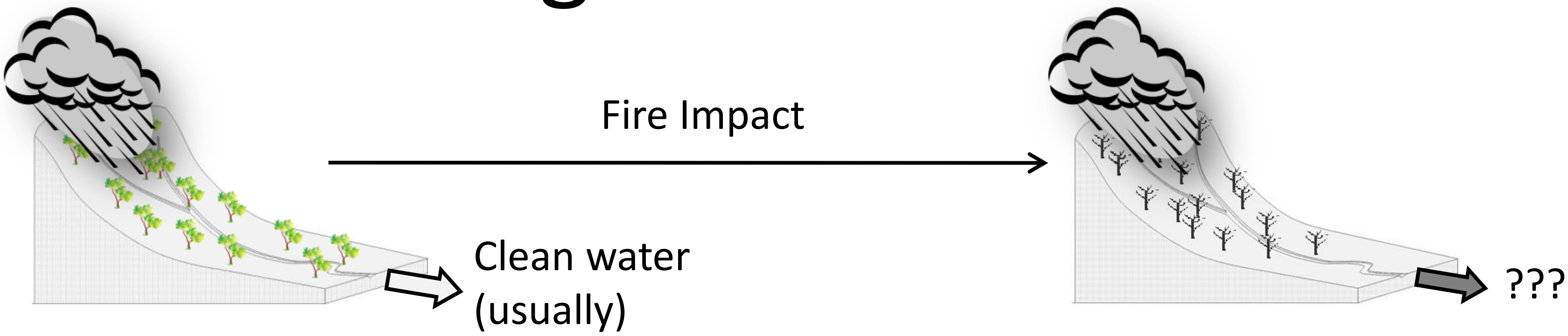
Effects of different fire regimes?

Outline

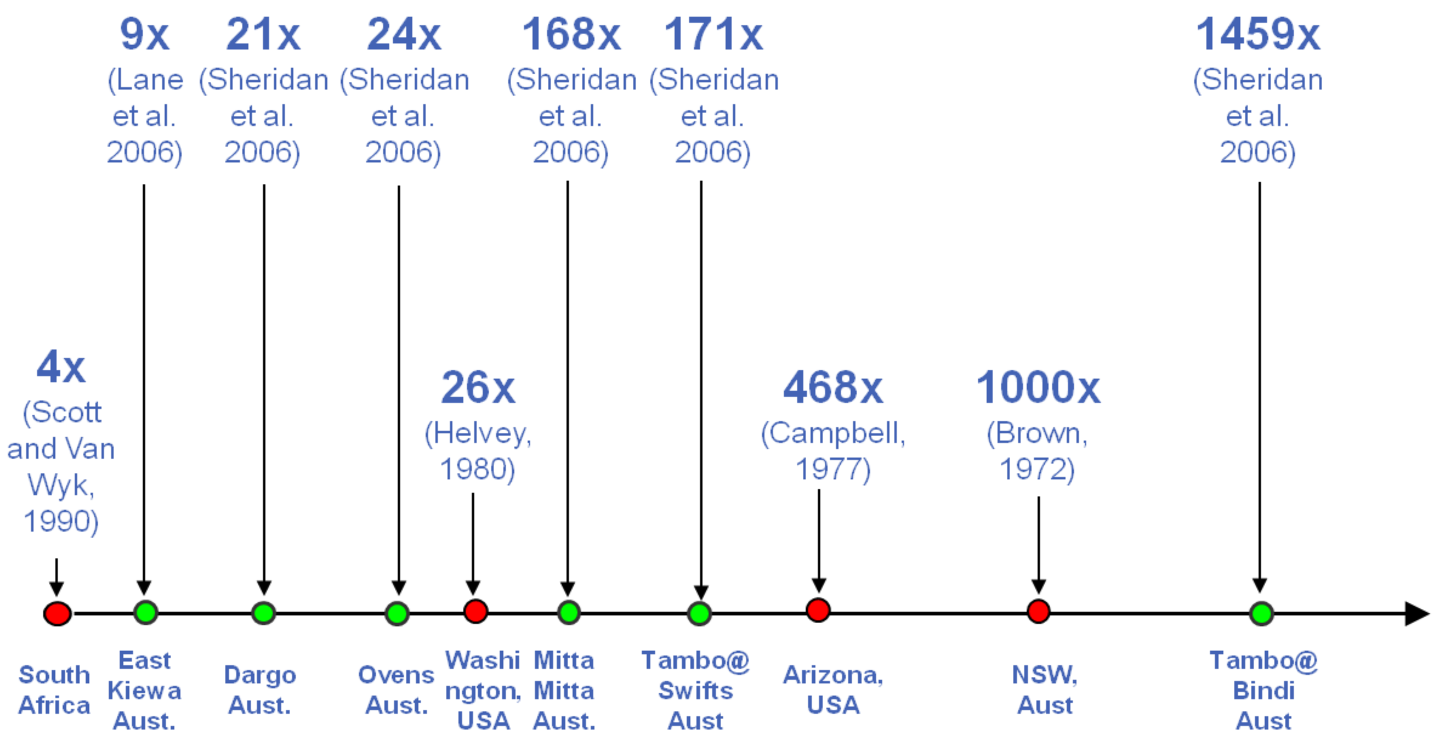
- Prediction – challenges and existing tools.
- High magnitude events and risk→ Debris flows
- Shift in focus: magnitude → frequency
- Predicting and measuring frequency
- Conclusions

Predicting erosion after fire

Predicting erosion after fire

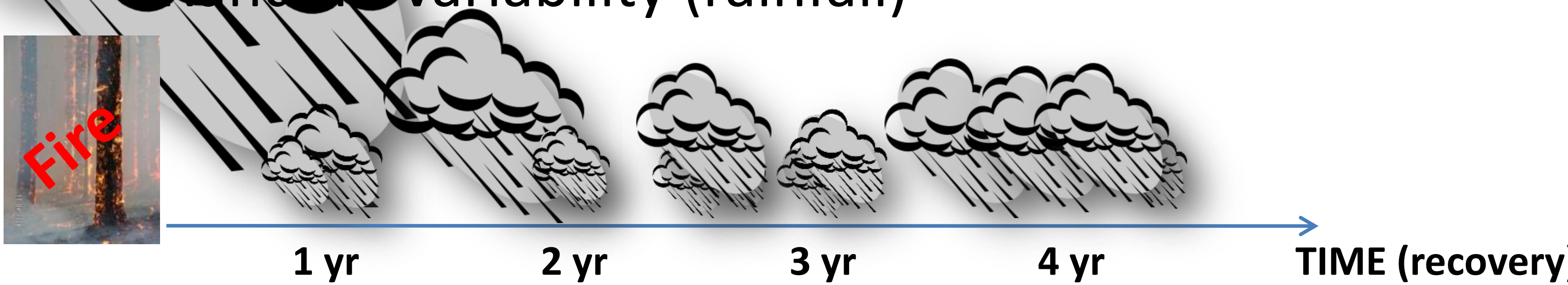


Large variability in measured impacts:



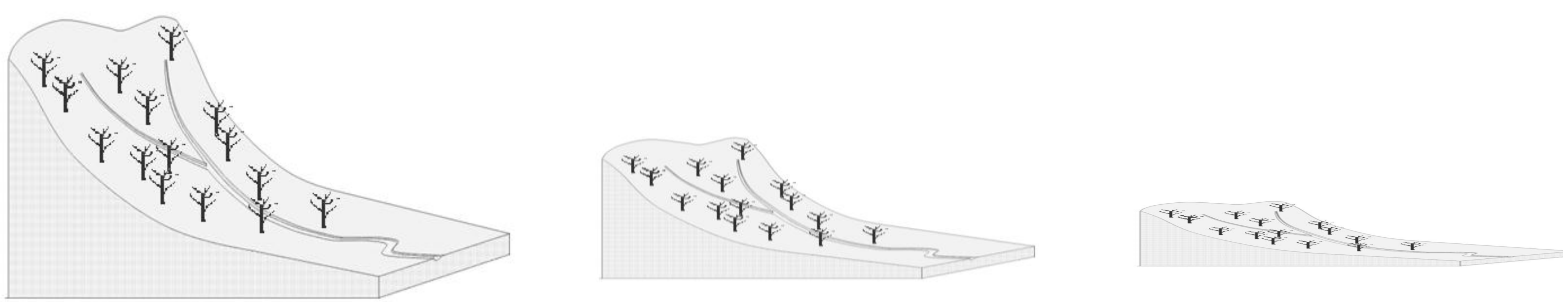
Predicting erosion after fire

- Sources of variability in erosion
  - Random variability (rainfall)



  - Deterministic variability (landscape properties)

    e.g. Slope



Predicting erosion after fire

USLE (Universal Soil Loss Equation)

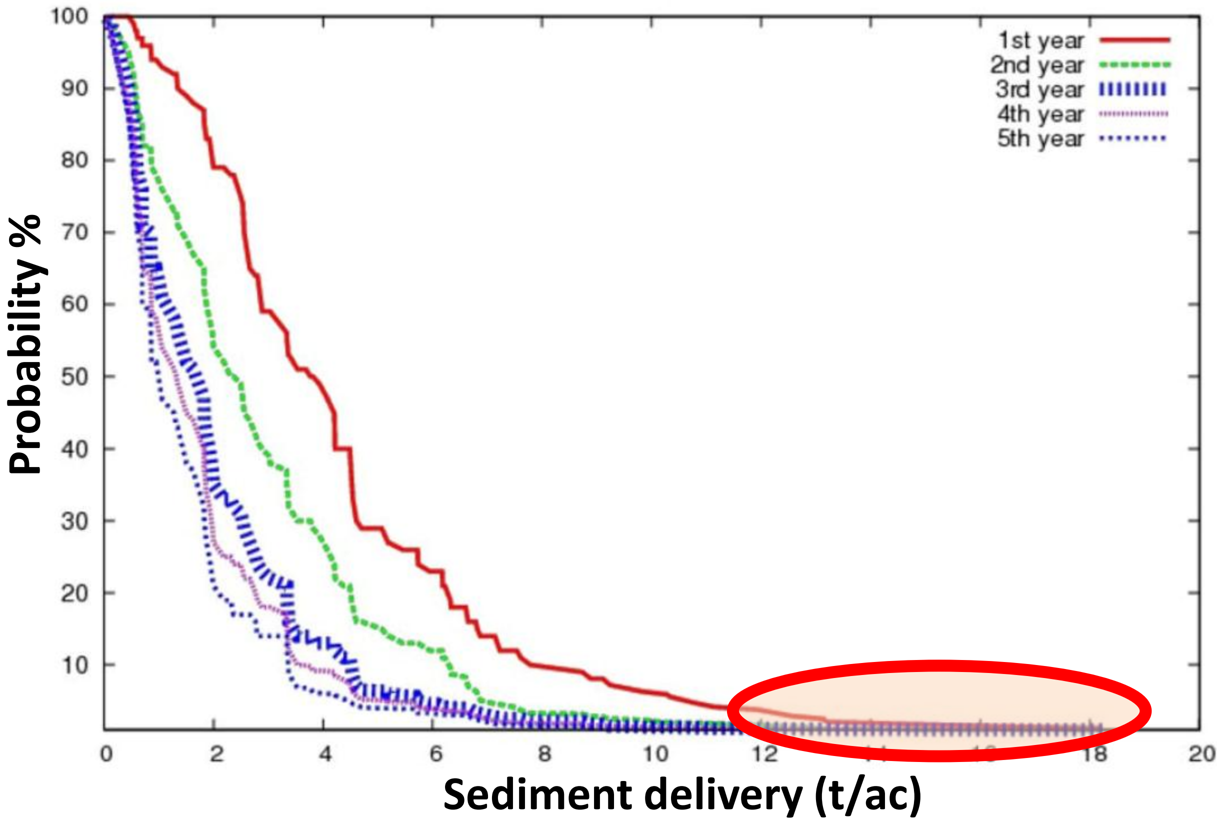
- Predicts average annual hillslope erosion
- Using data from long term erosion monitoring

Annual soil loss (t/ha/year) = R x K x L......

Predicting erosion after fire

ERMiT (Erosion Risk Management Tool)

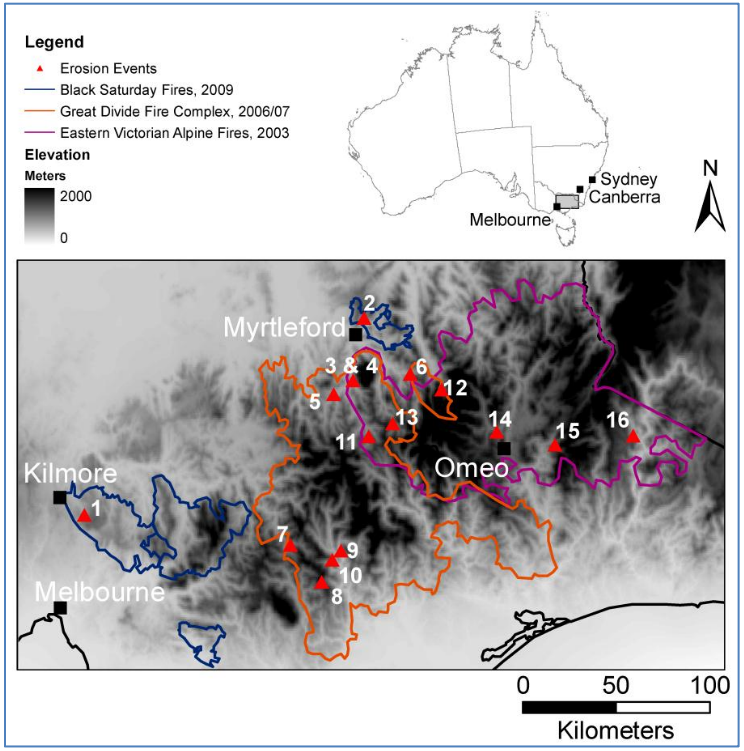
- Predicts sediment delivery from hillslopes in post-fire period
- Rainfall is a random variable

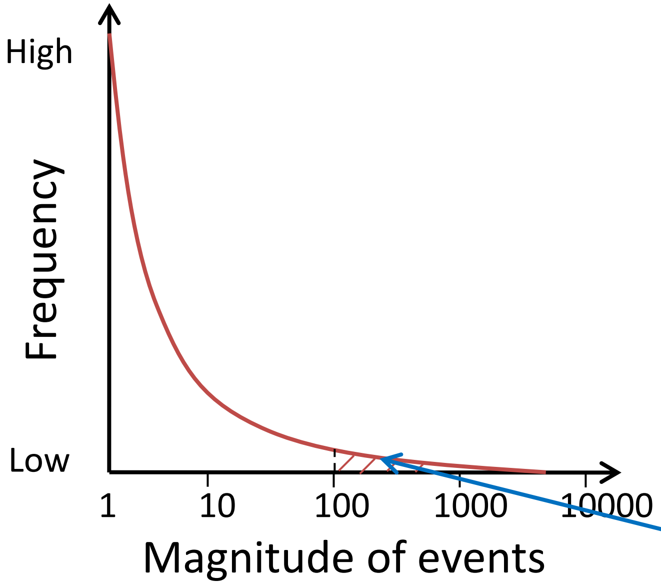


Main source of risk…

Most risk embedded in high magnitude events…

….where water quality thresholds are exceeded





Debris flows, mud flows, flash floods…big problem…but how often?

Geomorphology 125 (2011) 383–401

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Evidence of debris flow occurrence after wildfire in upland catchments of south-east Australia

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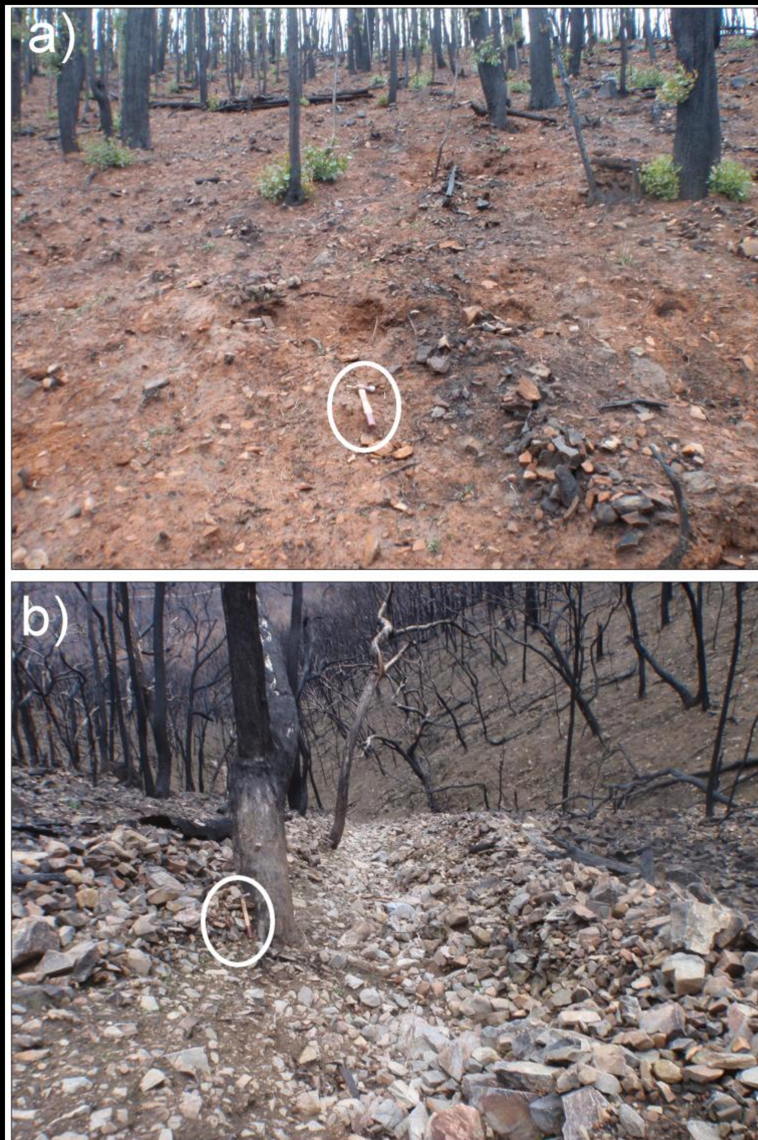
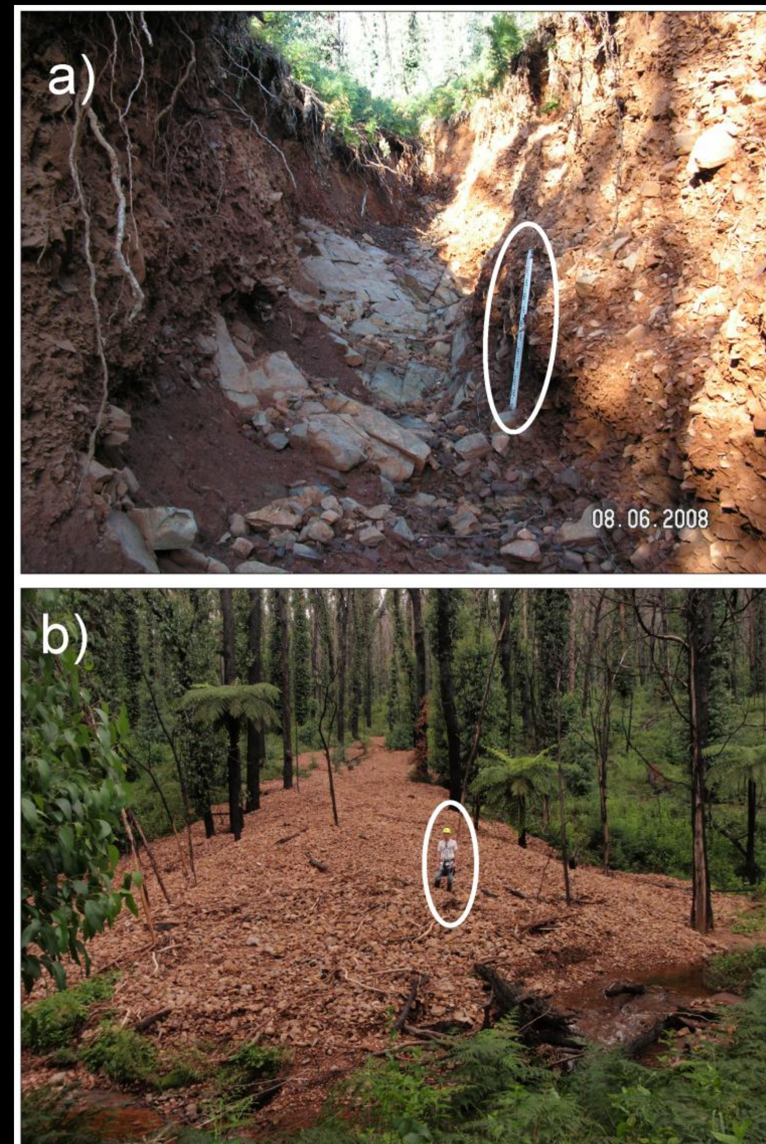
#	Site and Event Date	Location	Catchment size (ha)	Elevation (m)	Slope (degrees)	Fire Severity [b]	Annual Rainfall (mm)	Geology	Ecological vegetation class (EVC)	Event type	Run-out length (L/H)
1	Sunday Ck, March 2009	N 5861774 E 334100	8-18	400-600	30% ≥ 25° 9% ≥ 30°	100% ≥ 2	800-1000	-Sedimentary (marine) mudstone & sandstone -Metamorphic derivatives	Grassy dry	Runoff generated debris flow	3.4
2	Myrtle Ck, March, 2009	N 5963909 E 479045	10-25	450-800	55% ≥ 25° 25% ≥ 30°	100% ≥ 2	1000-1200	-Sedimentary (marine) mudstone & siltstone -Metamorphic derivatives -Igneous granite & grandiorite	Heathy dry forest	Runoff generated debris flow	2.8
3	Yarrarabula 1 Oct, 2007	N 5931411 E 473200	10-90	300-800	54% ≥ 25° 25% ≥ 30°	95% ≥ 2[c]	1000-1200	-Sedimentary (marine) mudstone & siltstone -Metamorphic derivatives	Heathy dry forest	Runoff generated debris flow	3.4
4	Yarrarabula 2 Oct, 2007	N 5931411 E 473200	90-200	300-1400	41% ≥ 25° 24% ≥ 30°	98% ≥ 2[c]	1000-2000	-Igneous granite	Heathy dry forest [a]	Flash flood	n/a
5	Dec, 2007	N 5925691 E 464878	30-90	350-650	48% ≥ 25° 24% ≥ 30°	95% ≥ 2	1000-1200	-Sedimentary (marine) mudstone & siltstone	Heathy dry forest	Runoff generated debris flow	3.9
6	Oct, 2007	N 5935095. E 502684	30-100	450-1000	74% ≥ 25° 45% ≥ 30°	73% ≥ 2	1000-1200	-Sedimentary (marine) mudstone & siltstone	Heathy dry forest	Runoff generated debris flow	3.4
7	Unknown, 2007	N 5846104 E 440702	10-140	500-900	64% ≥ 25° 37% ≥ 30°	100% ≥ 2	1200-1500	-Sedimentary (marine) mudstone & siltstone	Shrubby dry forest	Runoff generated debris flow	-
8	Abberfeldy Unknown, 2007	N 5826790 E456970	-	1300	13% ≥ 25° 3% ≥ 30°	99% ≥ 2	1200-1600	-Sedimentary (marine) mudstone & siltstone	Montane wet forest	Mass-failure	-
9	, Feb, 2007	N 5843139 E 467165	70-350	250-1000	52% ≥ 25° 29% ≥ 30°	100% ≥ 2	800-1000	-Sedimentary (marine and fluvial) mudstone & sandstone	Heathy dry forest	Runoff generated debris flow	3.0
10	Feb, 2007	N 5838539 E 462910	100-350	350-850	36% ≥ 25° 10% ≥ 30°	100% ≥ 2	800-1000	-Sedimentary (marine) mudstone & siltstone	Shrubby dry forest	Runoff generated debris flow	3.3
11	Abbeyard, June, 2007	N 5902168 E 481366	-	500-900	62% ≥ 25° 25% ≥ 30°	99% ≥ 2	1000-1200	-Sedimentary (marine) mudstone & siltstone	Heathy dry forest	Runoff generated debris flow	-
12	January 2004	N 5926579 S 519300	130 - 250	650-1400	31% ≥ 25° 11% ≥ 30°	60% ≥ 2	1600-1800	- Metamorphic derivatives of sedimentary rocks -Igneous grandiorite	Montane wet forest	Flood event	n/a
13	Dingo Ck , Feb, 2003	N 5909223 E 493698	350-400	600-1200	76% ≥ 25° 48% ≥ 30°	96% ≥ 2	1200-1400	-Sedimentary (marine) mudstone & siltstone	Heathy dry forest	Runoff generated debris flow	3.8
14	Big River (Omeo), 2003	N 5904544 E 548026	~60	700-1000	42% ≥ 25° 15% ≥ 30°	100% ≥ 2	800-1000	- Sedimentary (fluvial) sandstone & siltstone - Igneous granite & grandiorite	Heathy dry forest	Runoff generated debris flow	-
15[d]	Blueys Ck, 2003	N 5898006 E 577947	20-50	700-1000	70% ≥ 25° 37% ≥ 30°	96% ≥ 2	800-1000	- Sedimentary (marine) siltstone	Shrubby dry forest	Runoff generated debris flow	-
16[d]	Suggan Buggan, 2003	N 5903000 E 618653	80-110	600-900	39% ≥ 25° 25% ≥ 30°	43% ≥ 2	600-800	- Sedimentary (marine) mudstone & sandstone - Igneous granite	Shrubby dry forest	Runoff generated debris flow	-

Post-fire debris flows





Post-fire debris flows

Lake Buffalo, Victoria
29th Oct 2007

Post-fire debris flows

Tawonga Gap, Victoria
28th Oct 2007

Post-fire debris flows

Licola, Victoria
21th Feb 2007

Post-fire debris flows

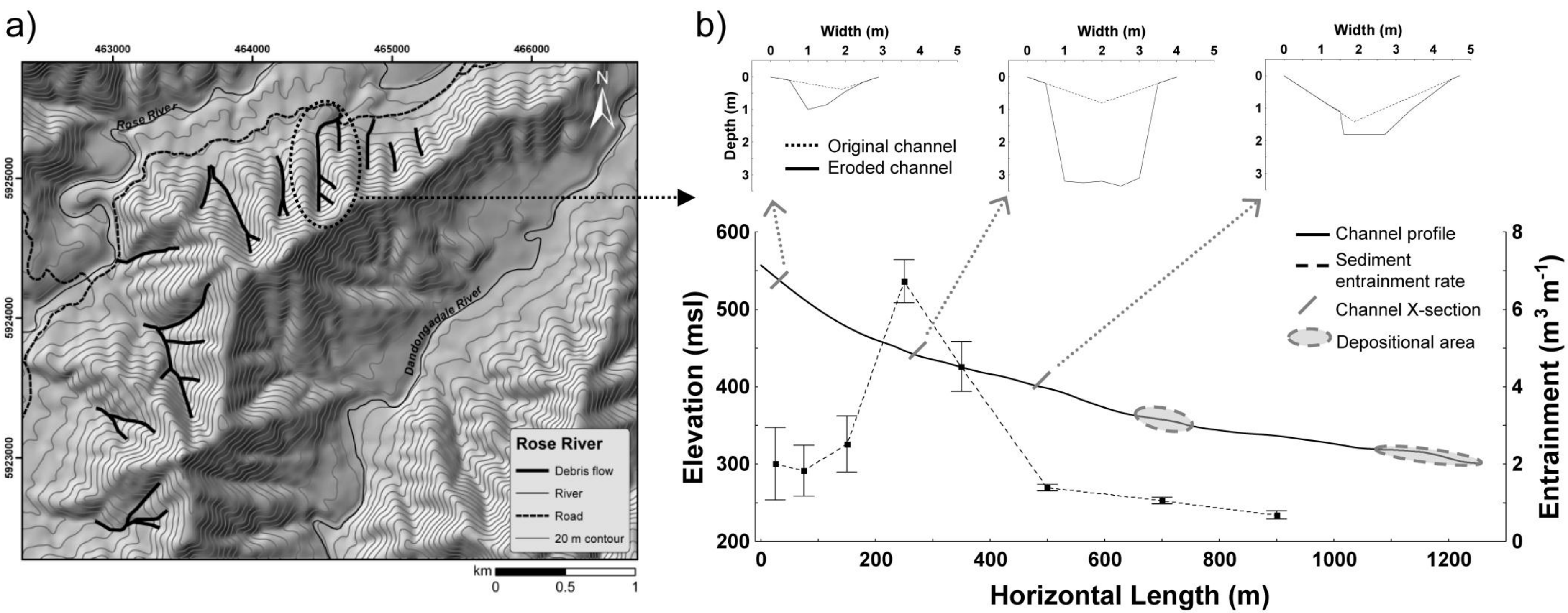
Buckland River Catchment, Victoria
26th Feb 2003

Post-fire debris flows

Licola, Victoria
21th Feb 2007

Post-fire debris flows

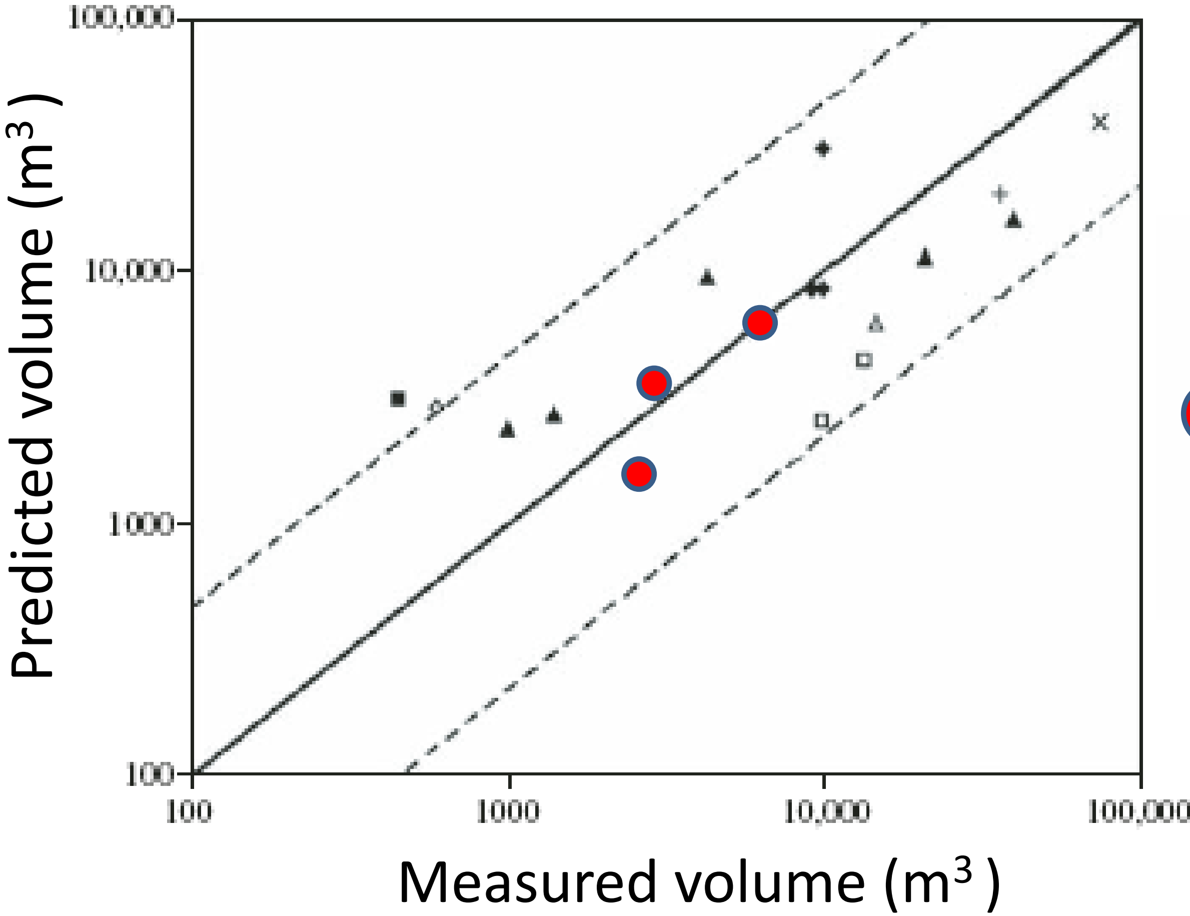
- Occur in steep headwater catchments
  - 30-minute rainfall intensity > 35 mm/h
- Single event >100t/ha
  - Extreme response = 100s of years of background erosion



Predicting debris flow magnitude

…Volume = …+…slope +…burn area +…rainfall

$$\ln V = 7.2 + 0.6(\ln A) + 0.7(B)^{0.5} + 0.2(T)^{0.5} + 0.3$$



Debris flows in Western US
From Cannon, 2010

North-east Victoria

What about frequency???

From:

Magnitude…

=

Is it big or small?

To:

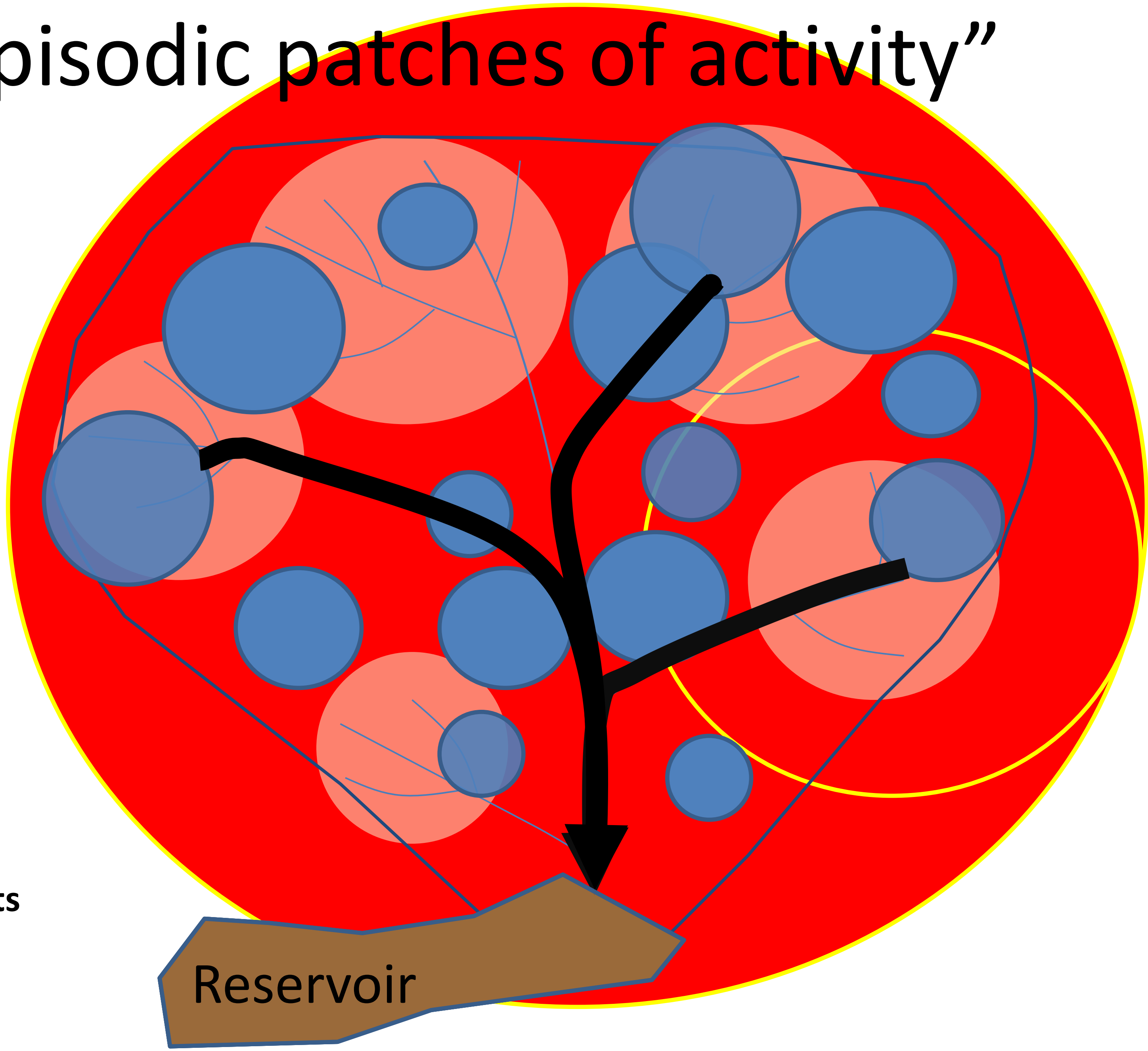
Frequency…

=

How often?

“Episodic patches of activity”

Year 1

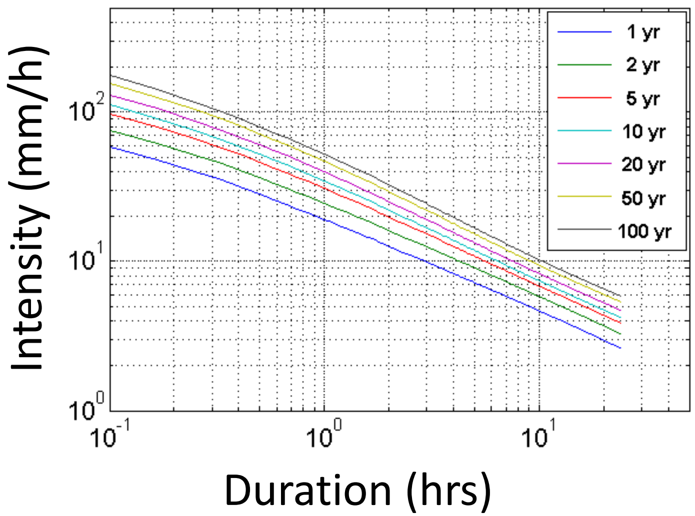


Rainfall

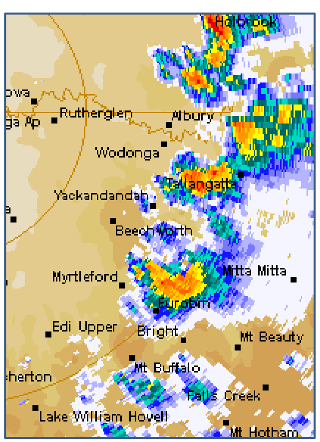
Frequency, Intensity, Storm Size

DATA

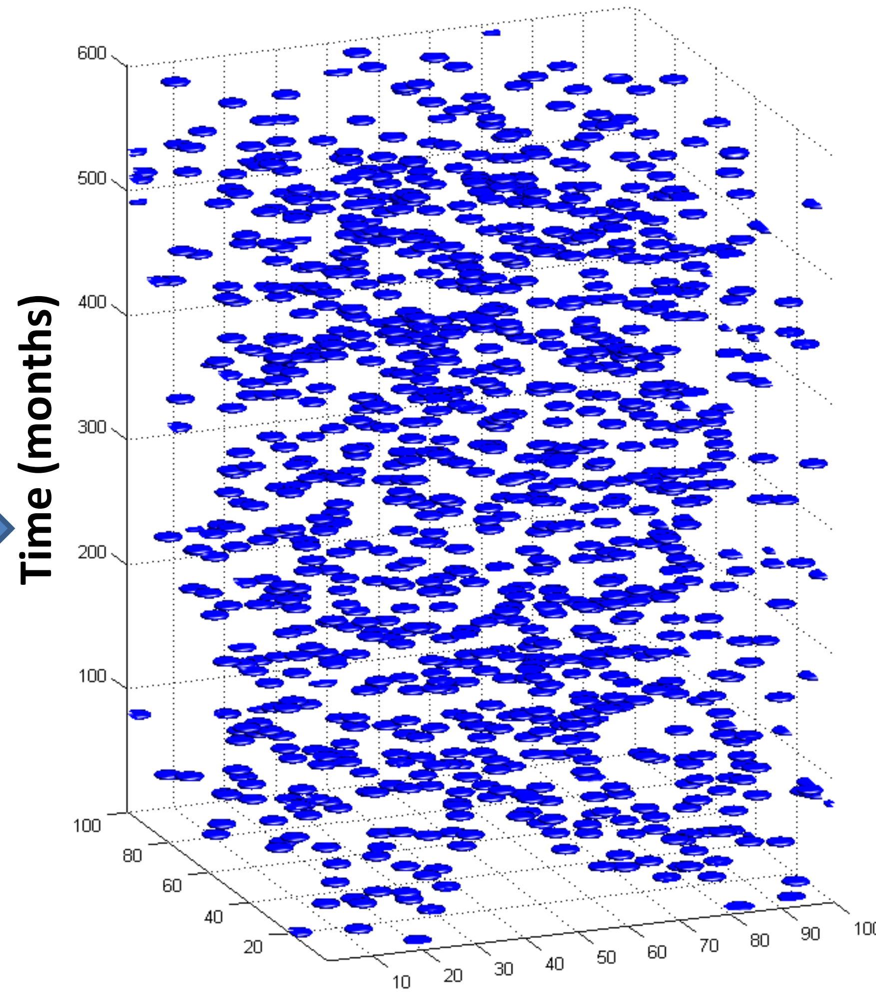
Intensity, frequency, duration



Radar Data



MODEL

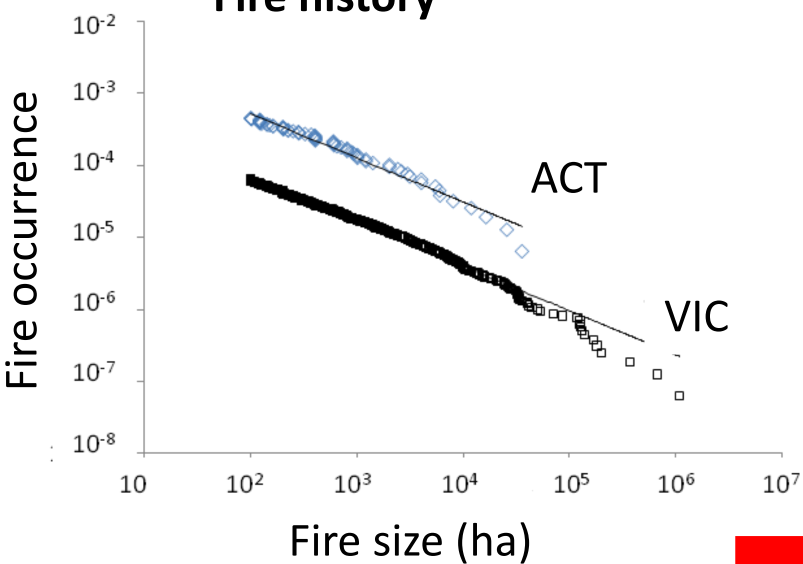


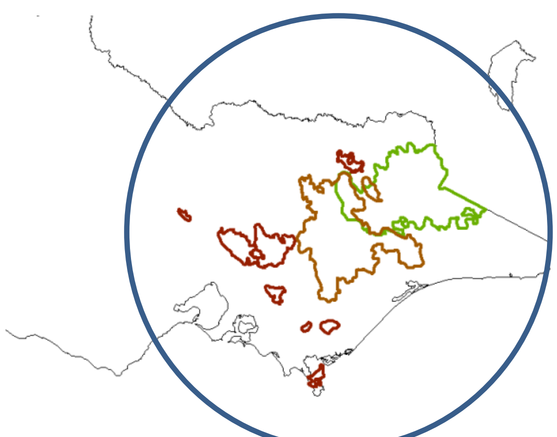
Fire

Frequency, Severity, Extent

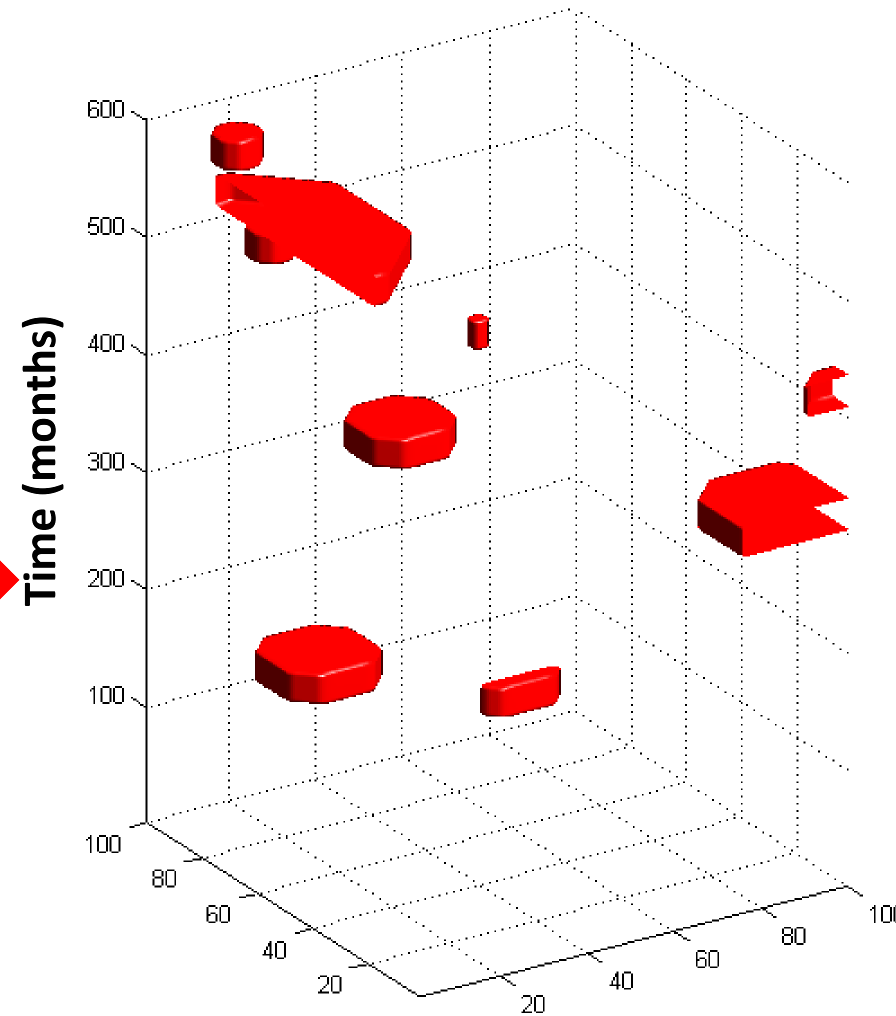
DATA

Fire history



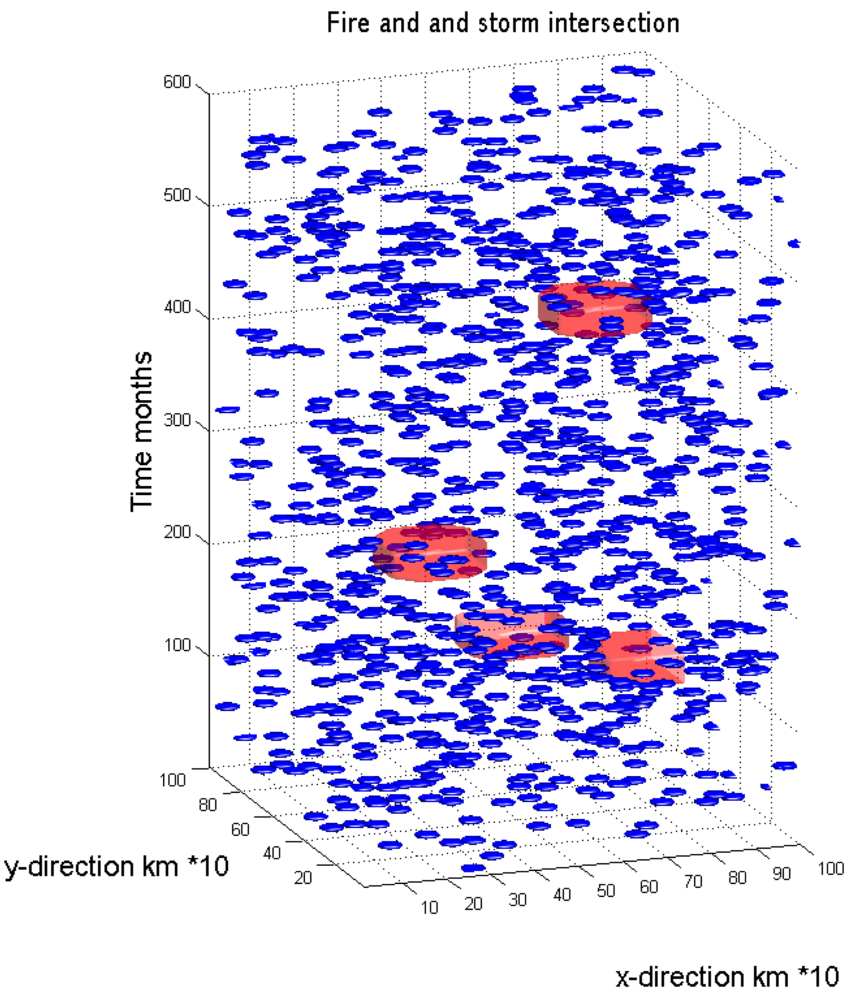


MODEL



Coverage Model…

Debris flows occur where high intensity fires and storms intersect with susceptible catchments



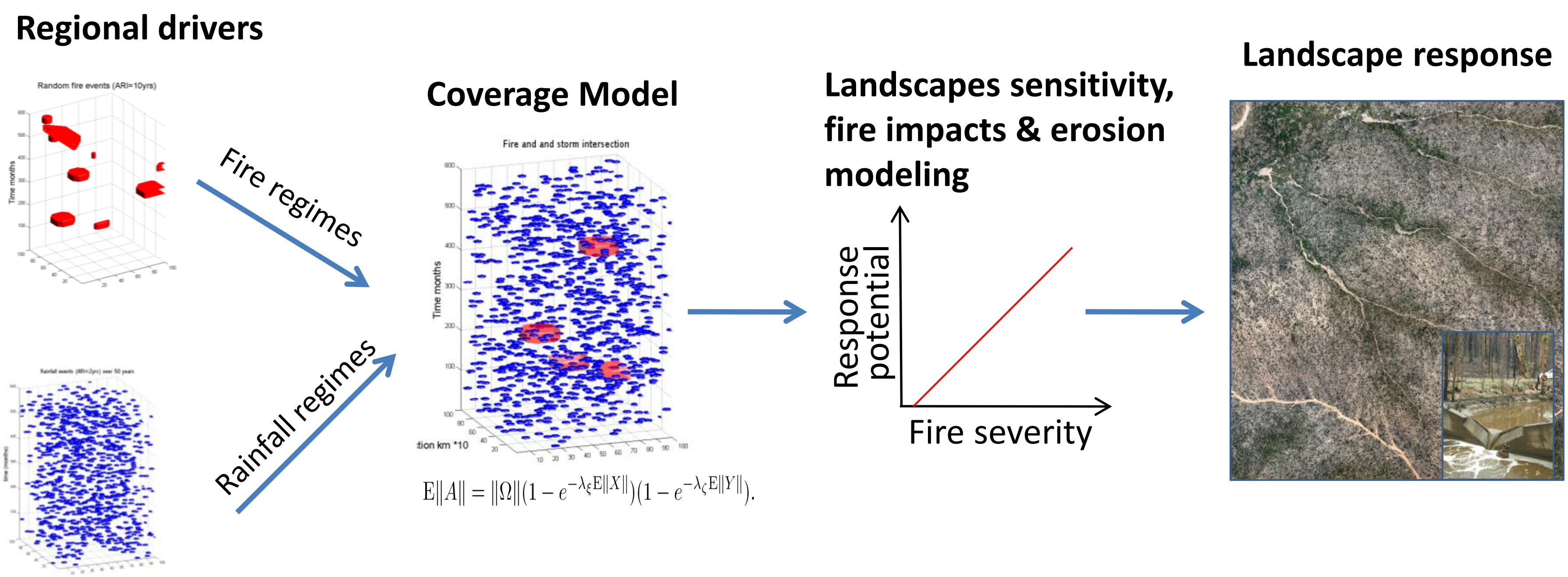
$$E\|A\| = \|\Omega\|(1 - e^{-\lambda_\xi E\|X\|})(1 - e^{-\lambda_\zeta E\|Y\|}).$$

In order to use this model, need to know…

1. Rainfall thresholds
2. The frequency of rainfall > thresholds
3. The frequency of fires
4. The size of storms and fires

Modeling overview…

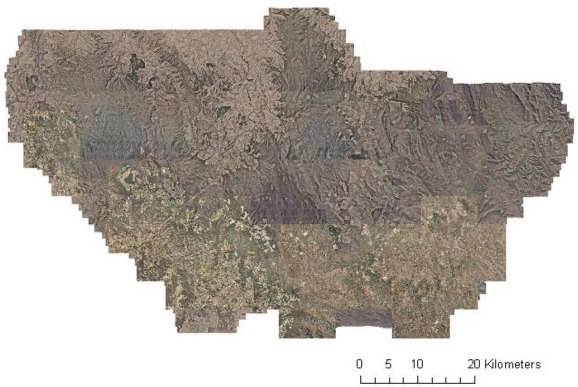
- Aim to develop a model which considers the risk to water quality within the context of variable fire regimes



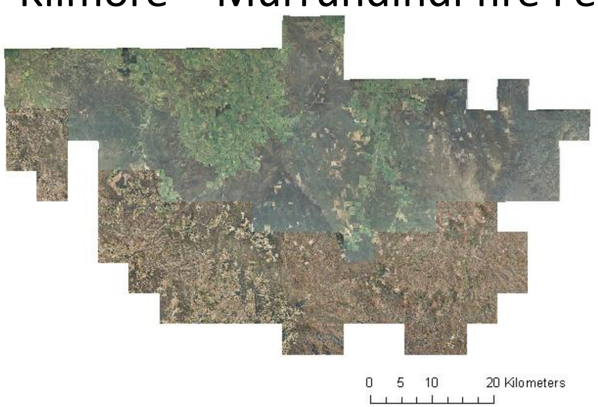
Landscape response (Field study)

…Frequency as a function of landscape attributes…

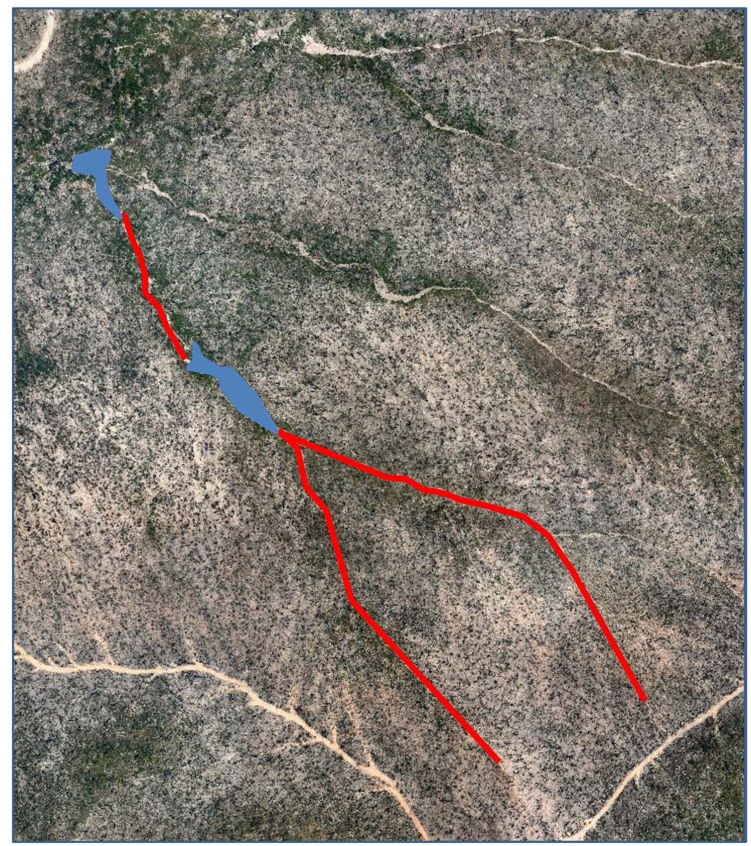
Kilmore – Murrundindi fire March 2009



Kilmore – Murrundindi fire Feb 2010

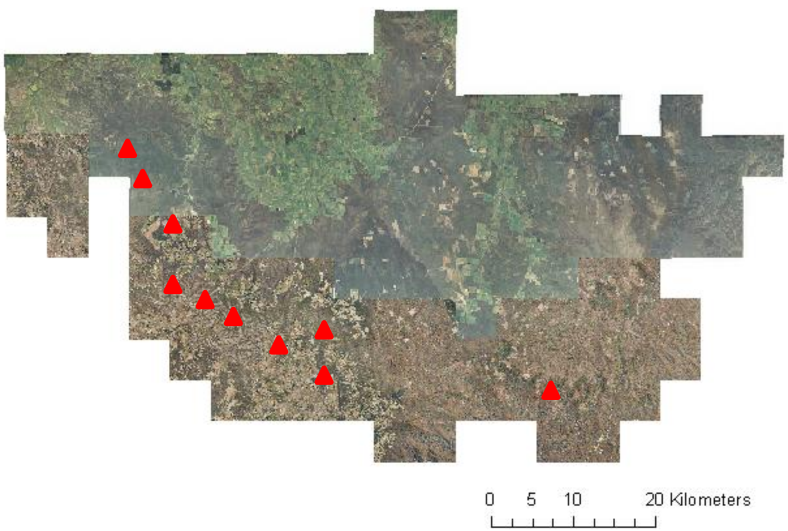


Stanley– March 2009



Landscape response (Field study)

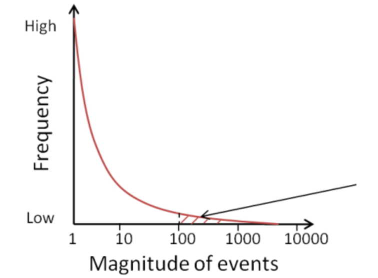
…Frequency in relation to landscape attributes…



Debris flow affected catchments

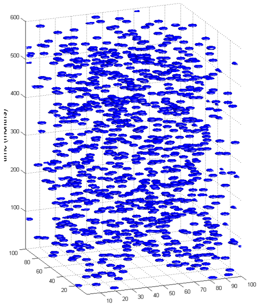
Variable	Attribute	Debris Flows (%)
Topography	Slope>30 deg	90
	Slope<30 deg	10
Forest Type	Dry Forests	80
	Damp Forest	20
	Wet Forest	0
Rainfall	Intensity>30mm/h	100
	Intensity<30mm/h	0
Fire Severity	High	9
	Moderate	1

Summary

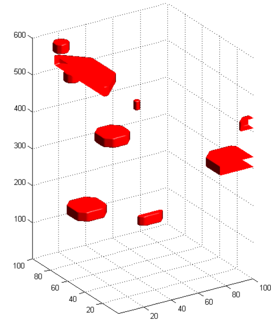


- Majority of risk embedded in a few large events e.g . Debris flows

- The question shifts from *"How Big?"* to *"Where and How Often?"*
  - Focus on rainfall and fire regimes, rather than erosion processes *per se*
  - Erosion occurs when fire and storms overlap



Summary



- Degree of overlap determined by frequency and size of
  1. Fires of different severities
  2. Storms that exceed intensity thresholds

- Model can quantify degree of overlap (Risk)
  - For different fire regimes

- Relating *fire severity* and *rainfall* to *erosion response* at a landscape scale remain an important area for research

Acknowledgements

- **Bushfire CRC** for research funding
- **Victorian Department of Sustainability and Environment** (fire history, aerial photography, and other spatial data sets)
- **Australian Bureau of Meteorology** (radar data)
- **Melbourne Water** and **eWater CRC** (for previous funding research)

"Fire in the Landscape - Water"

END-USER FIELD EXURSION

Beechworth, NE Victoria

Summer 2011/2012

Organisers: T. Turnbull, P. Nyman, T. Bell G. Sheridan

Email: nymanp@unimelb.edu.au

THANK YOU!

References

Nyman P, Sheridan GJ, Smith HG, Lane PNJ (2011) Evidence of debris flow occurrence after wildfire in upland catchments of south-east Australia. *Geomorphology 125(3), 383-401.*

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