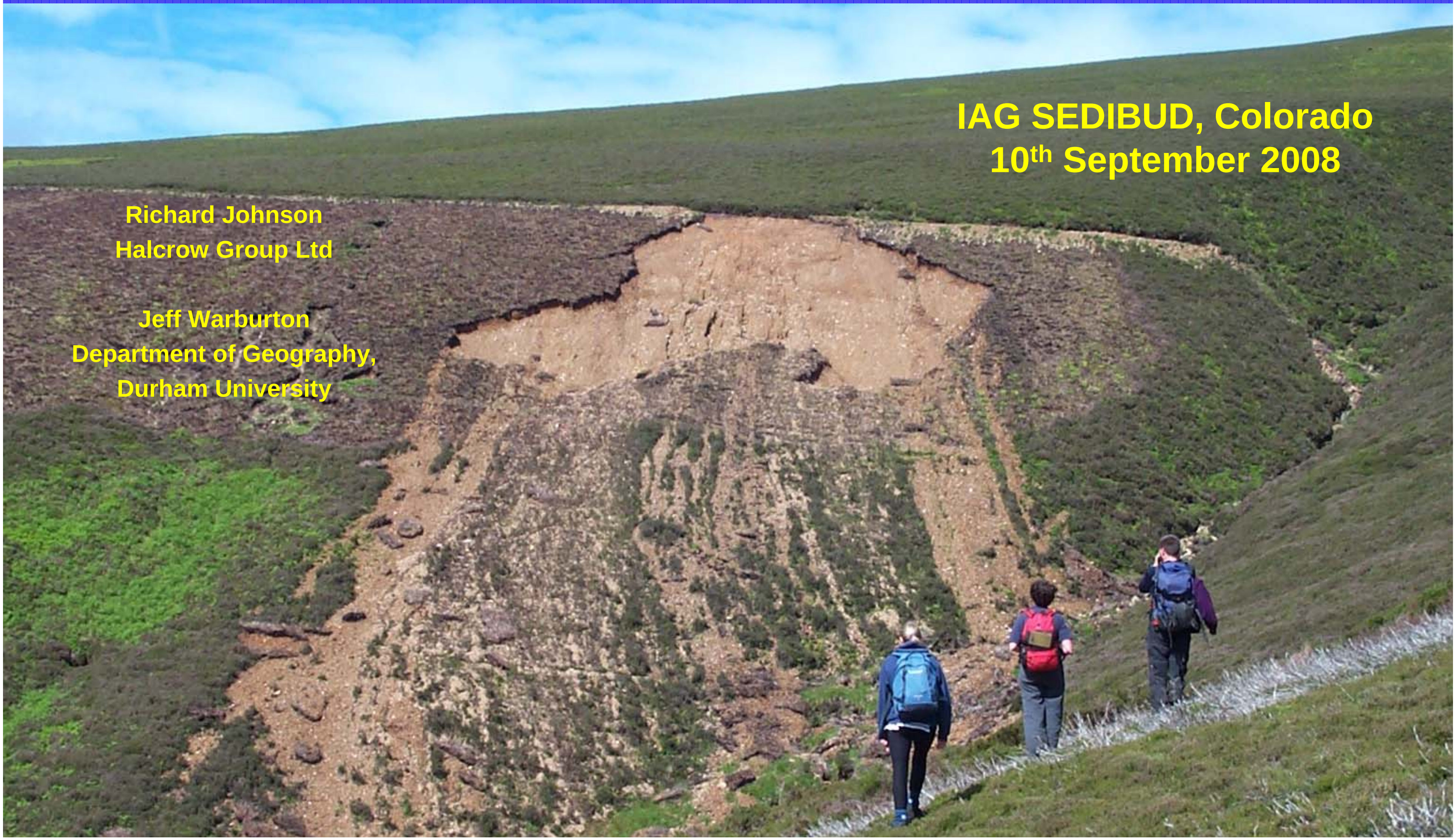
Event versus Post- Event Sediment Transfer Processes in a UK Upland System



IAG SEDIBUD, Colorado
10th September 2008

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Upland Catchment Sediment Budget Research Issues

- Detailed data of sediment dynamics in mountainous catchments are limited, more is required given hazard, risk, & climate change scenarios

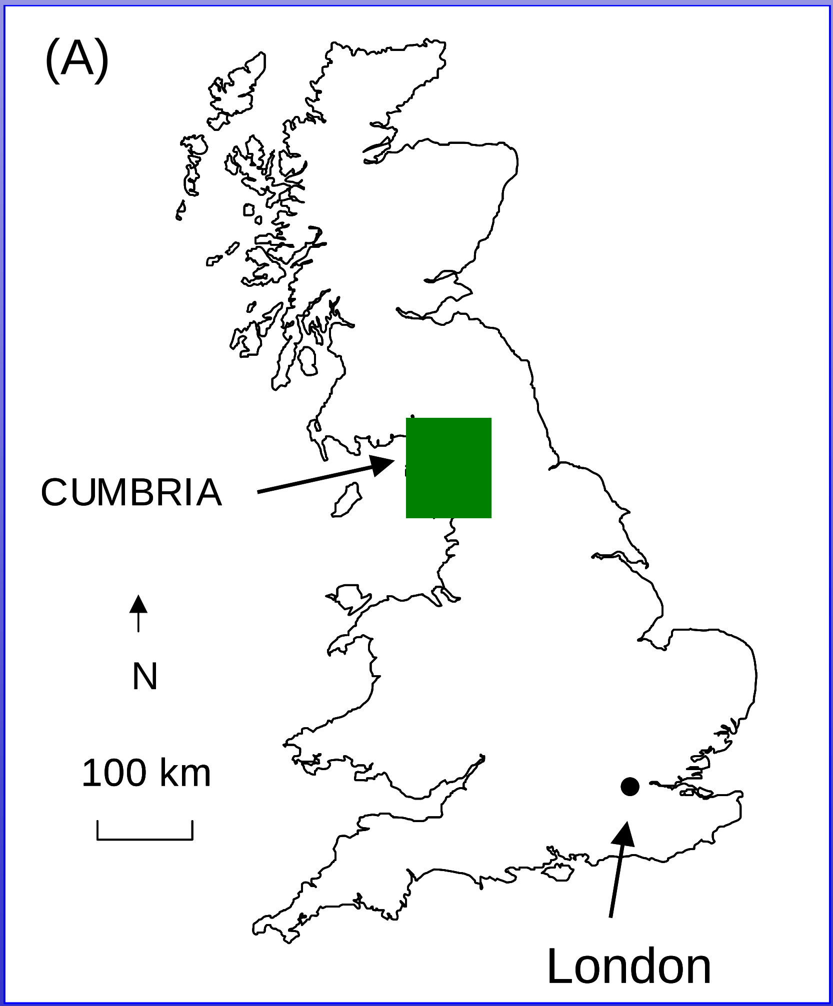
- **Sediment Budgets** are KEY to furthering understanding of mountain/ upland catchment sediment dynamics
- Significant questions include:

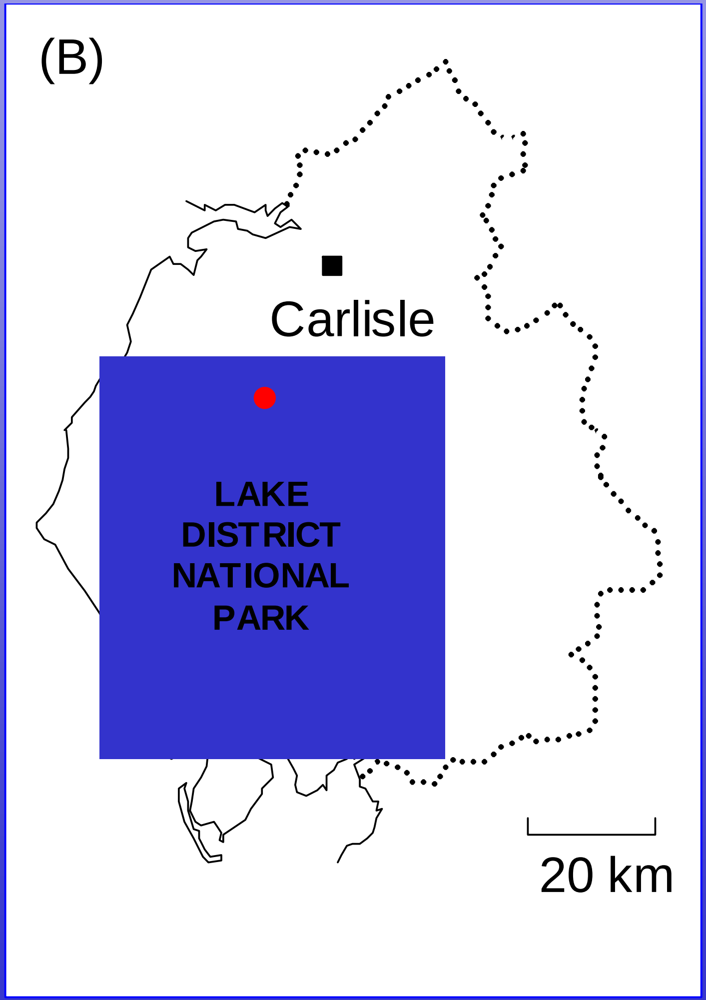
(1) Relative importance of event and post-event geomorphic processes in the sediment transfer cascade;

(2) Change of channel sinks into sediment supply hotspots;

(3) Hydro-meteorological triggers as controlling variables

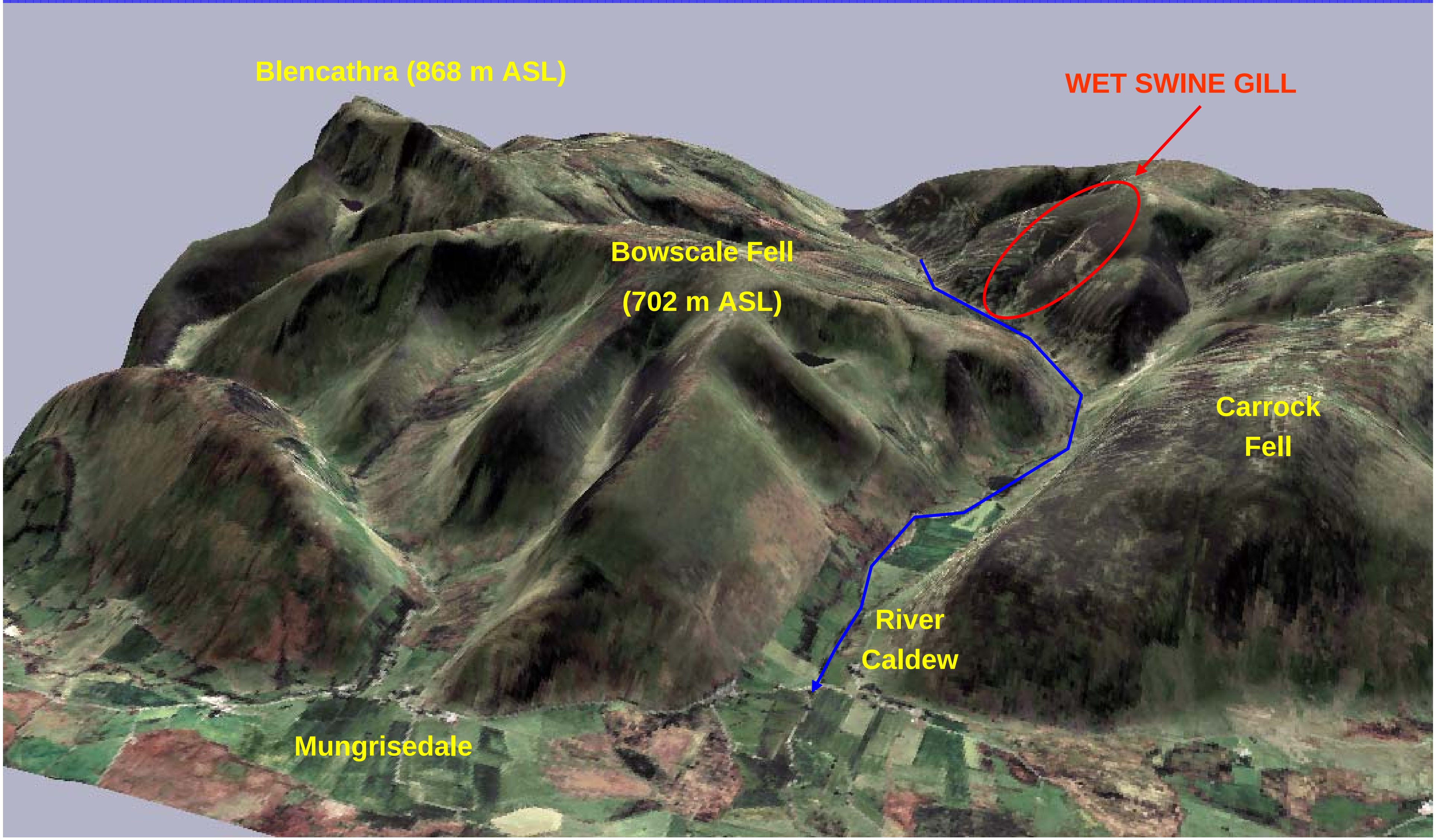
Study Area



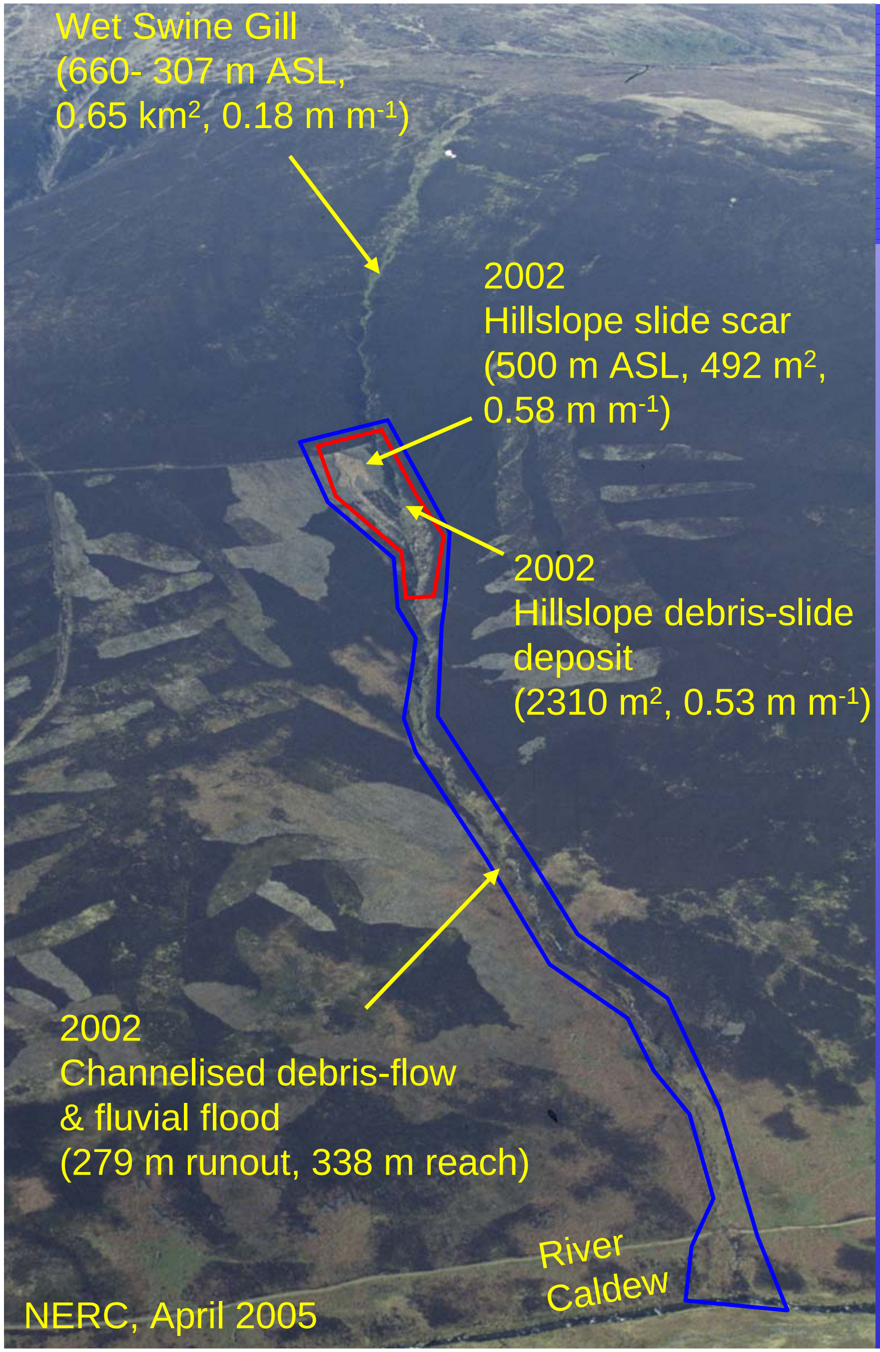


Lake District Northern Fells

Study Area



Blencathra (868 m ASL)
WET SWINE GILL
Bowscale Fell
(702 m ASL)
Carrock
Fell
River
Caldew
Mungrisedale



Wet Swine Gill Investigations

- **Sediment Budget 1 Failure Event**
  2002
  Earth Surface Processes & Landforms (2008)
- **Sediment Budget 2 Post- event**
  June 2003 - Jan. 2004
- **Sediment Budget 3 Post- event**
  April 2008
- **Scar repeat photography & cross-section measurement** 2002- 2008

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2002 Hillslope- Channel Failure Event

- Failure trigger: 1 Feb. 2002
  (54 mm in 8h, 1h rain max. = 9.7 mm)
- Land use preparatory conditions:
  - Heather burn 4 Jan. 2002
  - Excess water supply
- Translational slide in mineral substrate, underlying organic soils (*181* m^3, 203 ± 36 t erosion;
  c. *4* m^3 deposition)
- Blocky debris slide deposit (c. *91* m^3 deposition)
- Channelised debris flow (*142* m^3 deposition)
- Fluvial flood (trace deposition)

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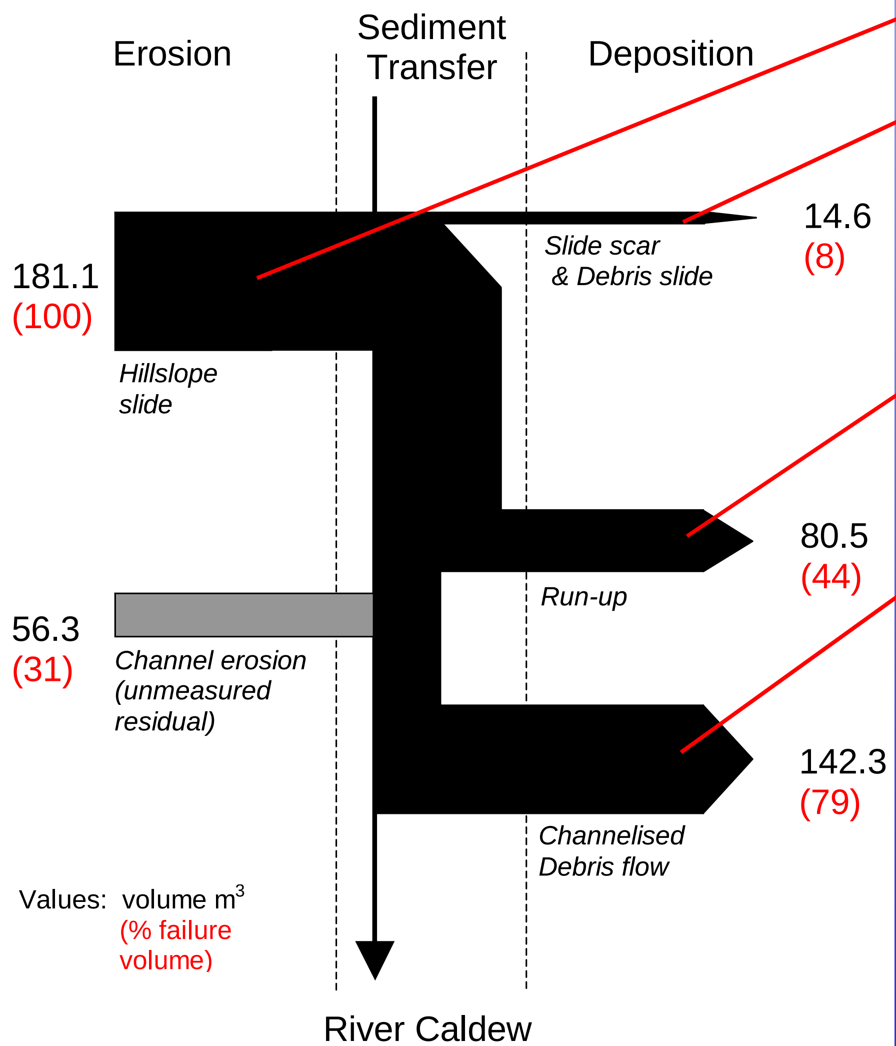
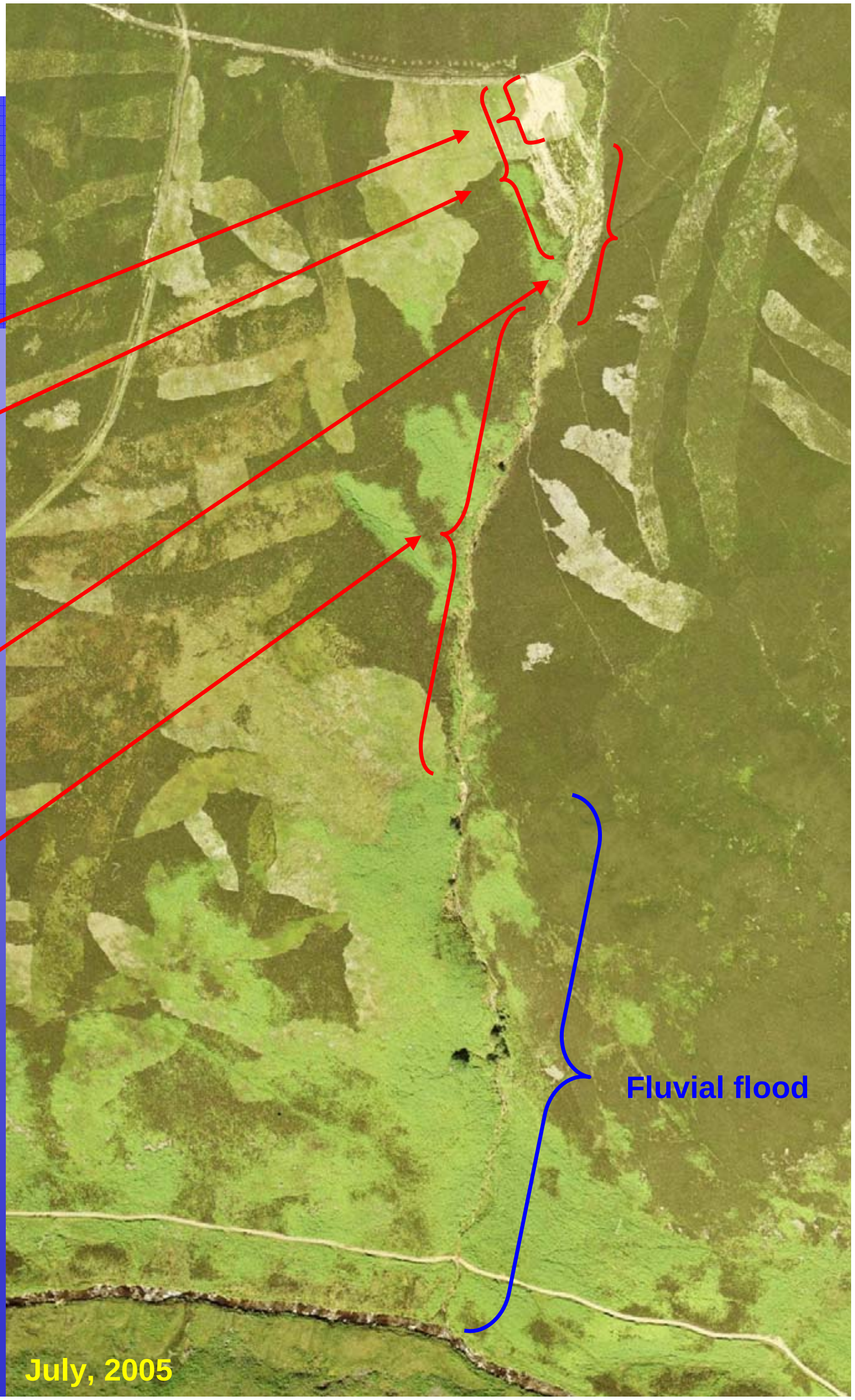
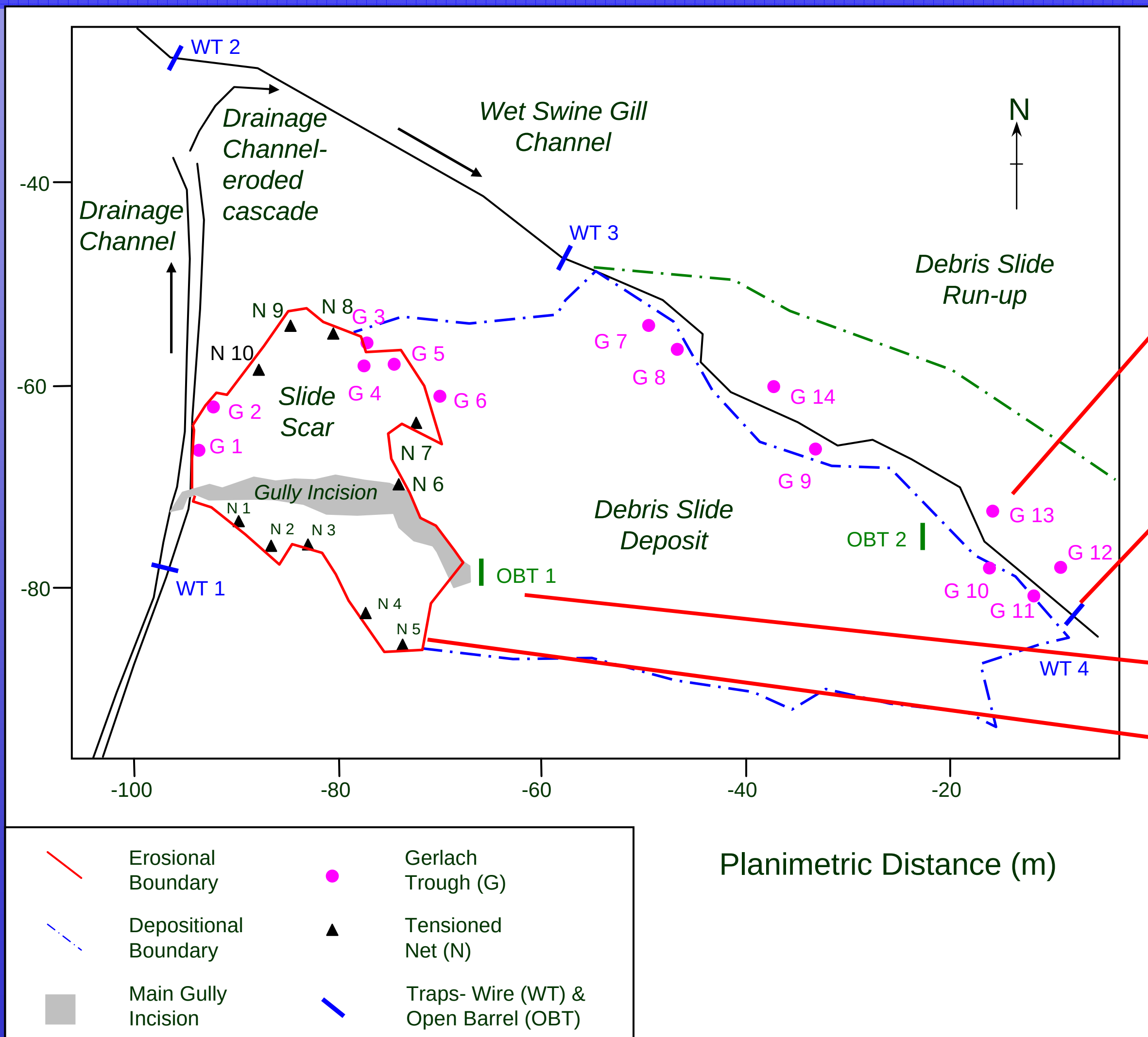
Sediment Budget 1: 2002

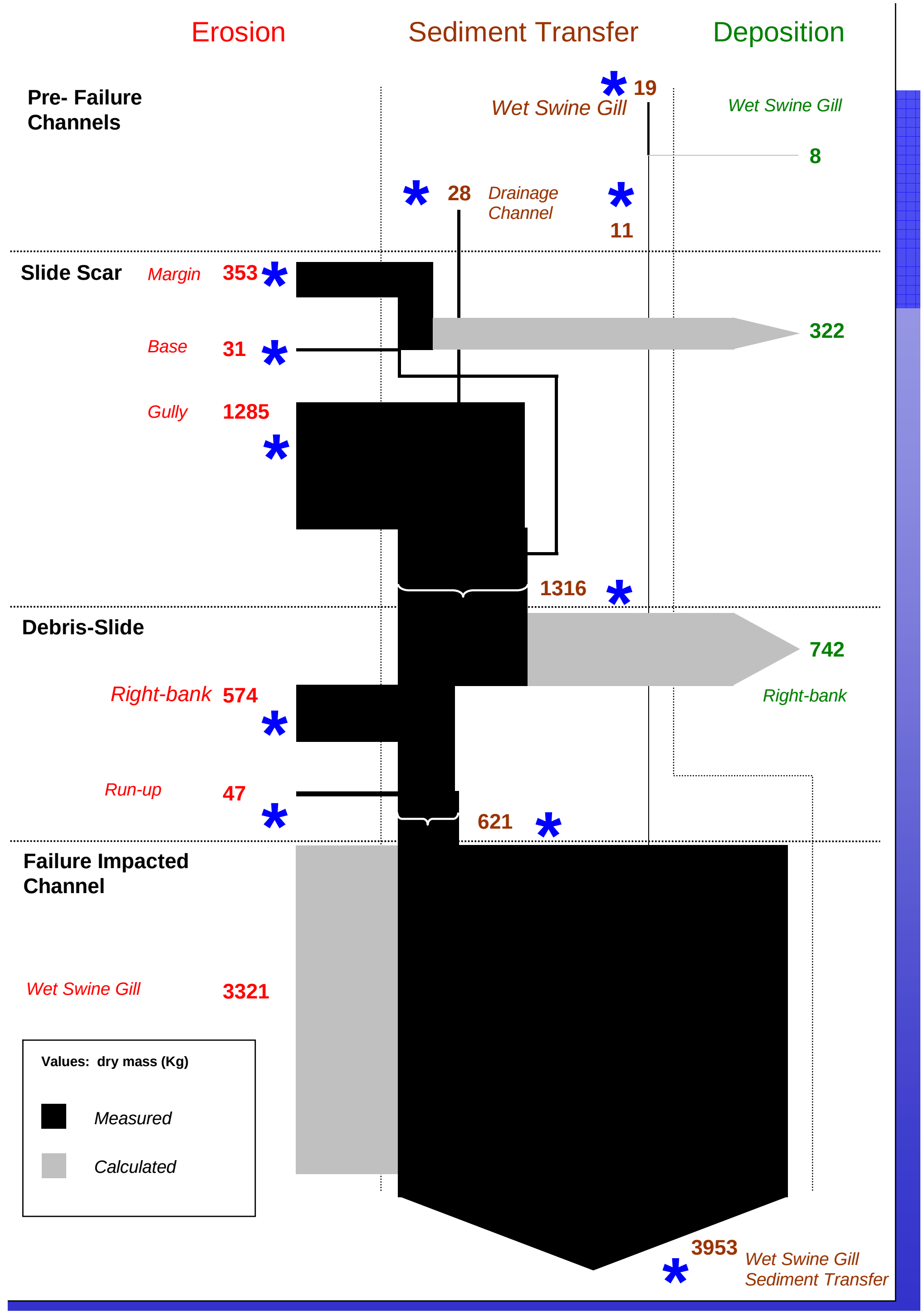




Sediment Budget 2:
June 2003- January 2004



- Elevated channel sediment yield downstream of debris- slide deposits (3.95 t versus 0.01- 0.02 t)
- Channel sediment: store (event) to supply (post-event) switch. Accounts for 3.3 t
- Hillslope erosion (0.62- 1.32 t) is less than channel activity (3.95 t)
- Gully erosion is the dominant hillslope sediment production and transfer process (1.29 t)
- Un-vegetated hillslopes (1.32 t) yield greater sediment than vegetated hillslopes (0.05- 0.57 t)



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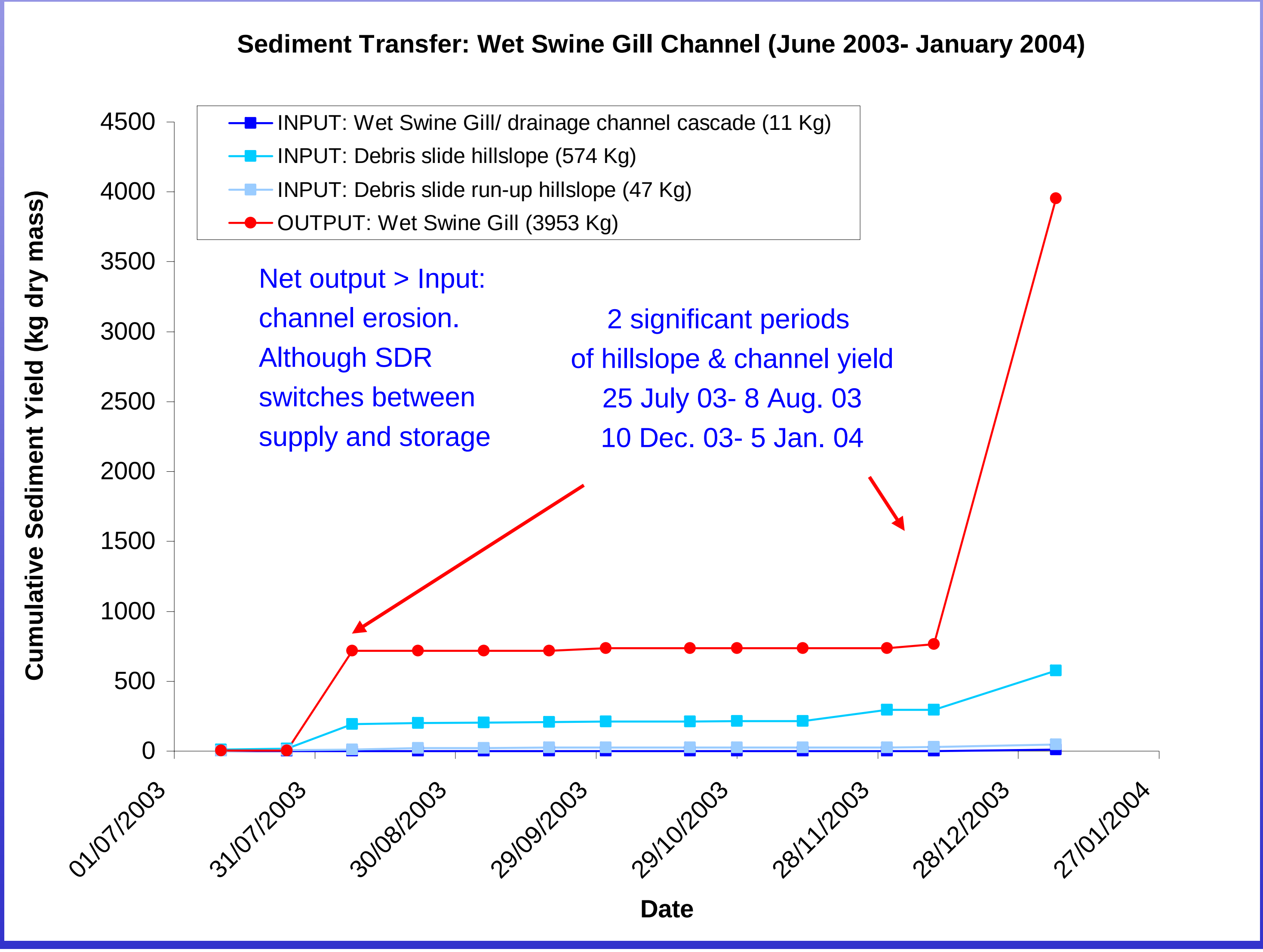
Hillslope- Channel Interactions



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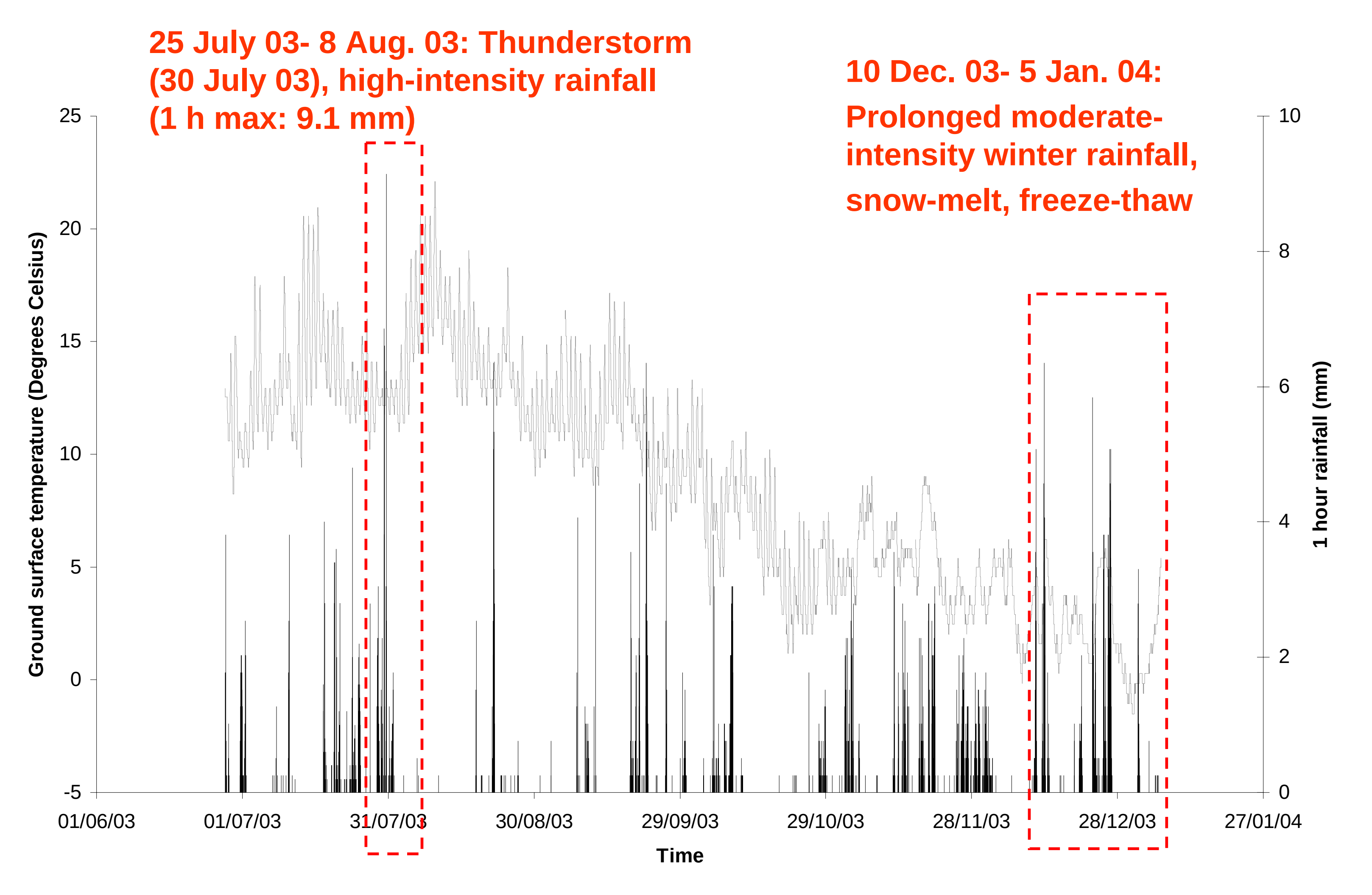
Sediment Budget 2: Meteorological Conditions



Long-term Slide Scar Change

- **Evaluated using**:

  - Repeat fixed point photography

    (13 times, 5.75 years: June 02- March 08)

  - Scar cross sections
    (4 times, August 02- March 08)

  - Gully cross sections linked to meteorological data
    (Sediment Budget 2)

28 July 02

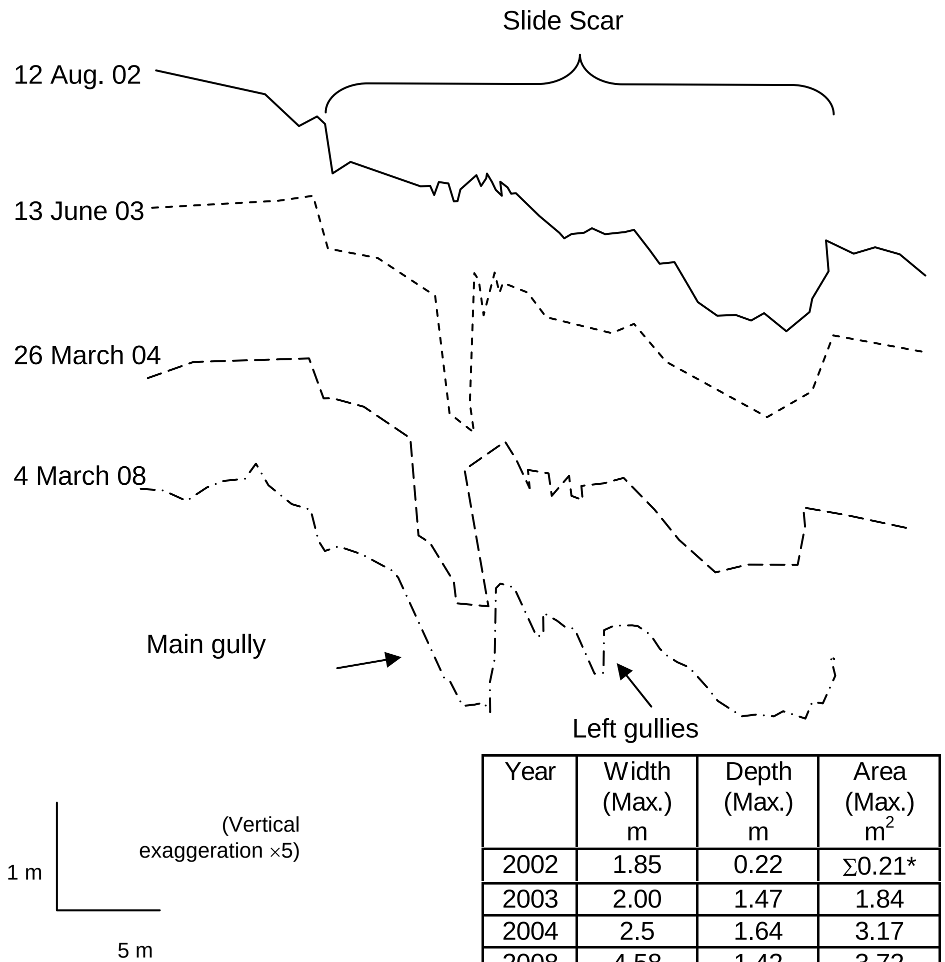
4 March 08

Long-term Slide Scar Change

- **Evaluated using**:
  - Repeat fixed point photography

    (13 times, 5.75 years: June 02- March 08)
  - Scar cross sections

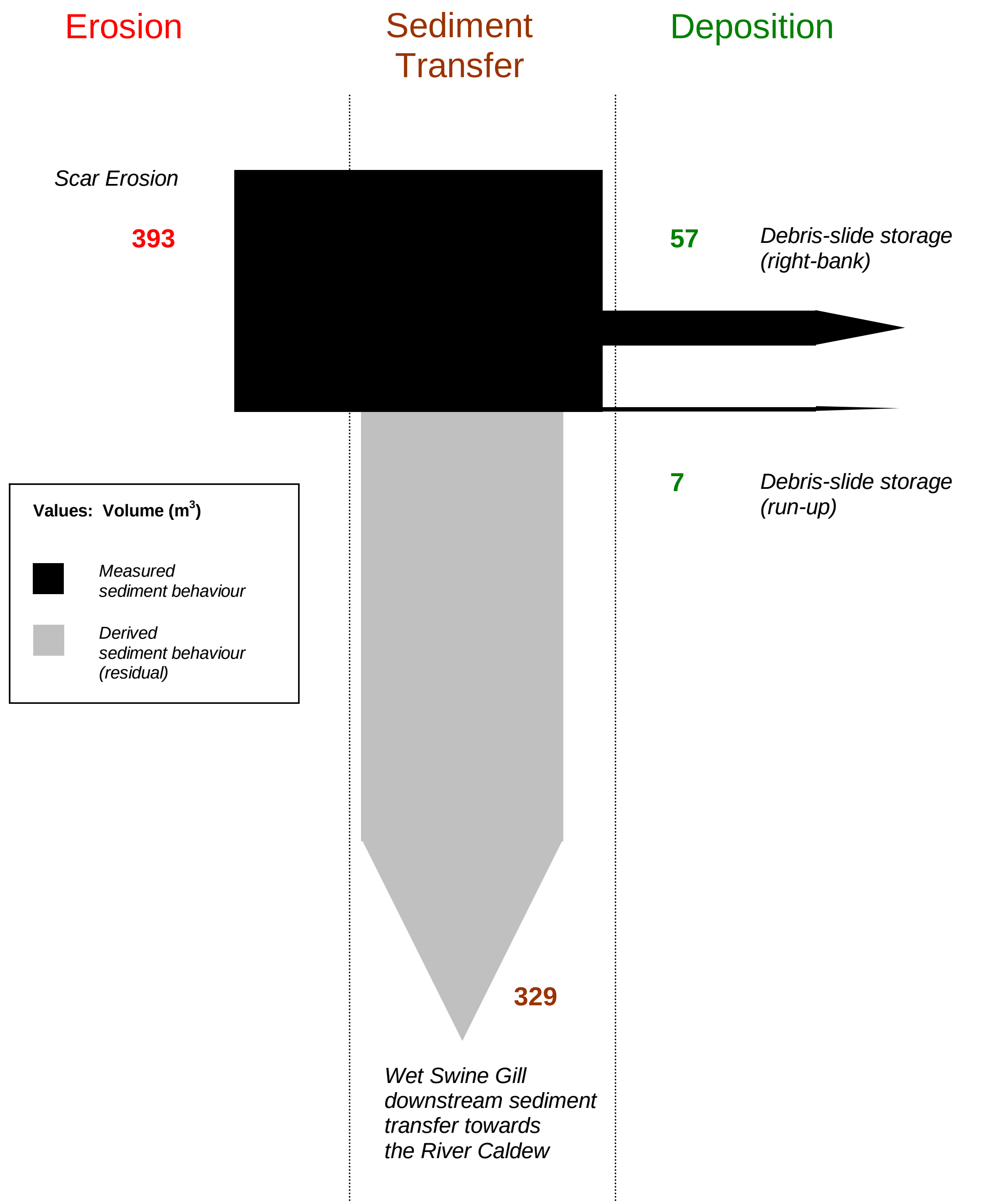
    (4 times, August 02- March 08)
  - Gully cross sections *(Sediment Budget 2)*



Year	Width (Max.) m	Depth (Max.) m	Area (Max.) m^2
2002	1.85	0.22	Σ0.21*
2003	2.00	1.47	1.84
2004	2.5	1.64	3.17
2008	4.58	1.42	3.72

Sediment Budget 3: April 2008

- Reconstructive sed. budget
- Quantify impacts of post-event processes
- Period: c. 2250 days (6.15 a)
- Measurements:
  - Scar XS
  - Debris slide areas, % un-vegetated (exposed sediment), and deposit depths
- Over longer-term hillslope erosion also important source. Most probably pre 2003- 2004



Sediment Budget Comparison (2002 & 2008)

System zone	2002 (m^3)	2008 (m^3)
Slide Scar	181.1	393.4
Debris Slide (RB)	10.4	57.2
Debris Slide (Runup)	80.5	7.5
Channel	142.3	328.7

- **Scar:**
  - 212 m^3 post-event erosion (c. 117% of failure volume)
  - Feb 02: 181.1 m^3 d^{-1}
  - Feb 02- April 08: Mean 0.09 m^3 d^{-1}, but rapid gullying up to 2004 (rate variable)

- **Debris Slide:**
  - Net storage reduction (90.9 m^3 to 64.7 m^3)- vegetation re-growth & channel erosion
  - Storage gain on right bank (c. + 47 m^3), Storage loss on run-up (c. - 73 m^3)

- **Channel:**
  - Net increase in channel sediments (2008 residual), so new influx from hillslope activity, c. 166 m^3
  - SB 2 shows sensitive to erosion. Absence of new deposit so downstream transfer
  - c. 247 ± 35 t (or 40 t p.a.), a plausible value?

Summary- Sediment Dynamics

- Timing & length of sediment budget investigation is important, as different rates and phases of geomorphic activity:
  - 2002 event — Large one day transfer (181 m^3) (SB1)
  - 2002-2004 — Rapid scar gully development (pre and during SB2)
  - 2003-2004 — (1) Evacuation of event and post-event channel sediments (5.3$\times$ > hillslope activity: 6 months) (SB2)
    (2) Channel yield much greater downstream of event impacts (4 t v 0.02 t) (SB2)
    (3) Sensitivity to thunderstorms & winter storms
  - 2002-2008 — Hillslope scar erosion greater than 2002 event (212 m^3). Much more significant than evident during SB2

Conclusions

- 6 years after the failure, post-event hillslope erosion is greater than the event sediment yield. Over time gully erosion succeeded by channel reworking
- Need long-term monitoring of sediment dynamics, to determine the significance of large events in sensitive localities
(nested sediment budgets)
- Direct measurements of all key processes to avoid errors inherent in residual components
- Need to better integrate hydro-meteorological and sediment yield data
(i.e. a higher frequency of sediment yield records)
- Need to consider alternative techniques to improve accuracy & precision of measurements, e.g. terrestrial laser scanning of scar