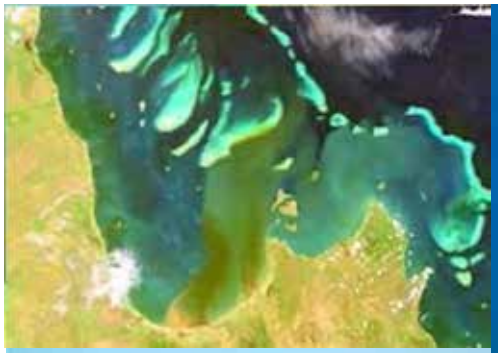
Australian Rivers Institute

Sustainable solutions for rivers, coasts and catchments

Protecting the Great Barrier Reef from sediment pollution



Andrew Brooks, Jeff Shellberg, John Spencer, Jon Olley, Tim Pietsch, Daniel Borombovits, Christina Howley, Graeme Curwen, Fabio Iwashita

South Cape York Catchments

Reef & Rainforest RESEARCH CENTRE

Cape York Sustainable Futures

Queensland Government

Griffith UNIVERSITY

Reef Rescue Research & Development

Smart Futures

Caring for our Country

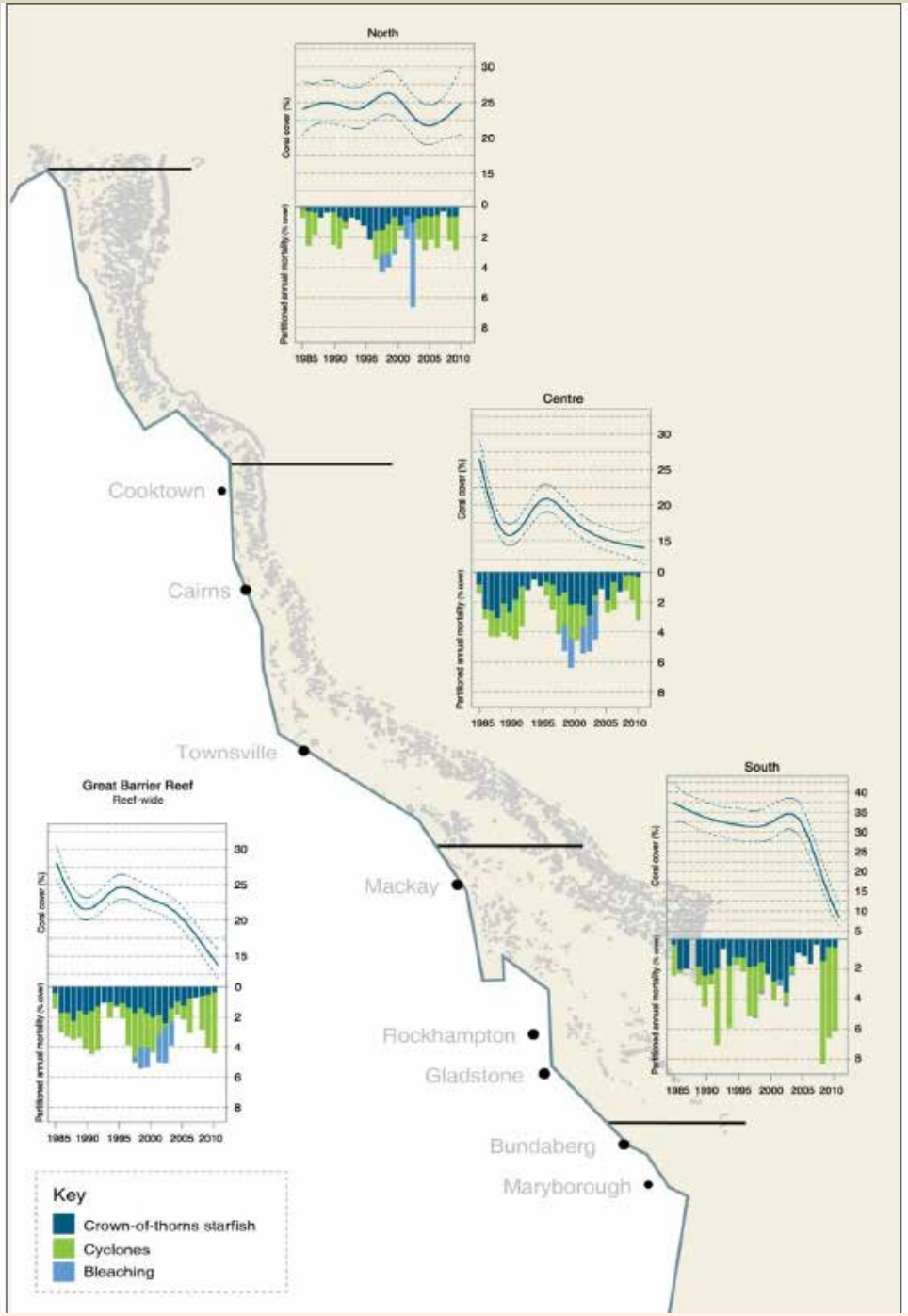
Major drivers of coral cover decline in the GBR

- Climate change:
  - Ocean acidification
  - Bleaching
  - Cyclone (magnitude and frequency)
- Catchment runoff (water quality)

- **Of these it is only really catchment runoff that we can do anything about in the short term**

Crown of thorns (COTs) outbreaks are known to be driven by poor water quality (fine sediment & nutrients)

Even in the Northern GBR - off Cape York – which hasn't seen the same level of coral cover decline as the rest of the reef - it is likely there is a link between COTs outbreaks and catchment runoff

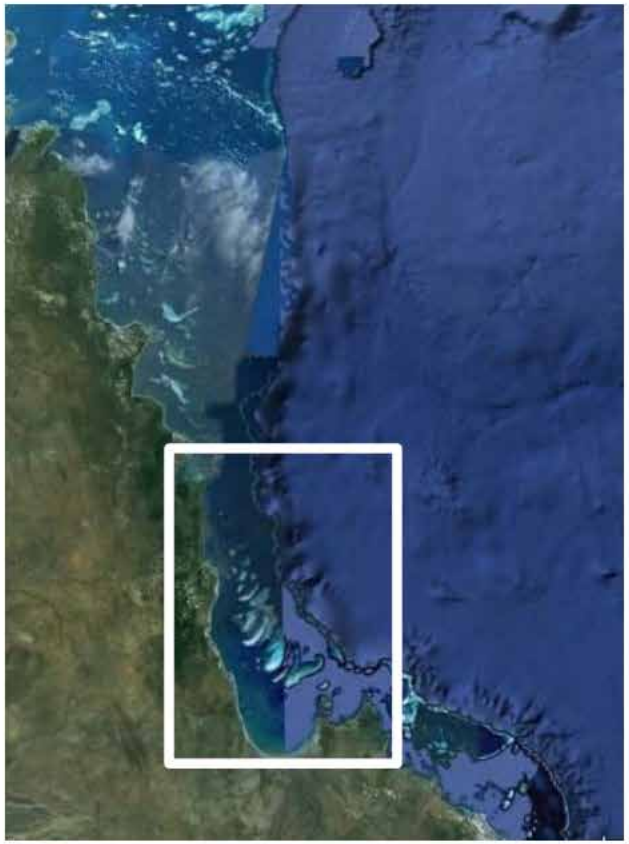


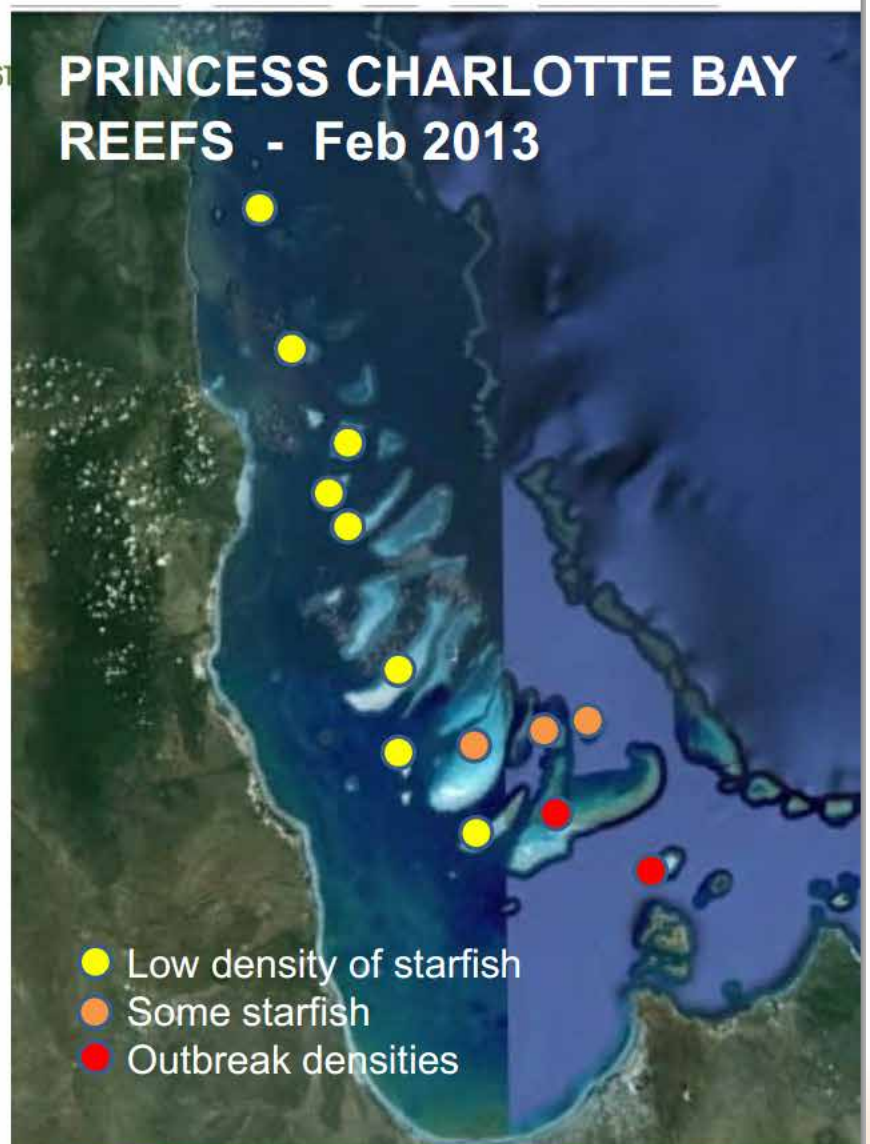
Griffith UNIVERSITY

National Environmental Research Program

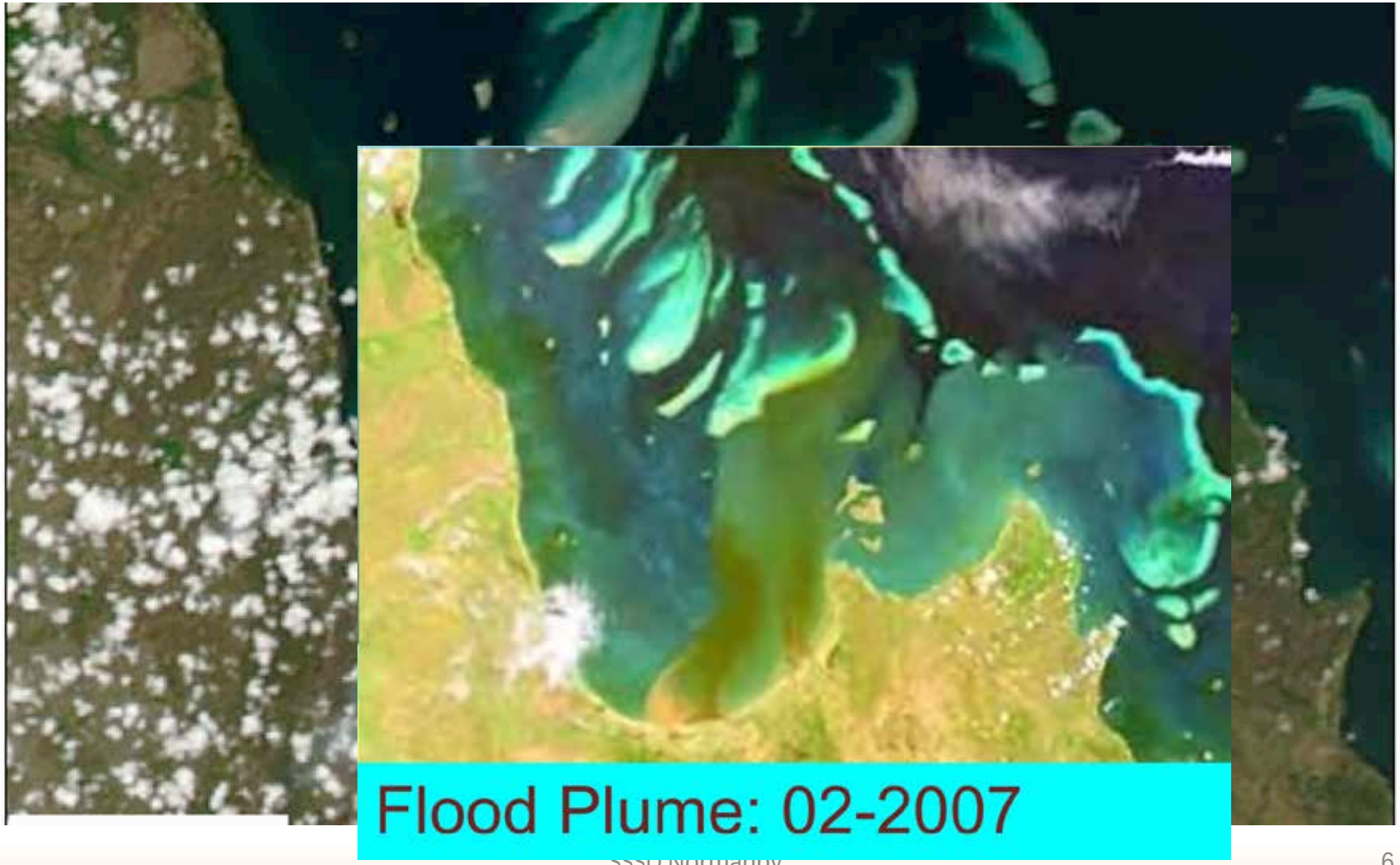
TROPICAL ECOSYST

N. GBR SURVEYS - 1





PCB Flood Plume, Jan 2013

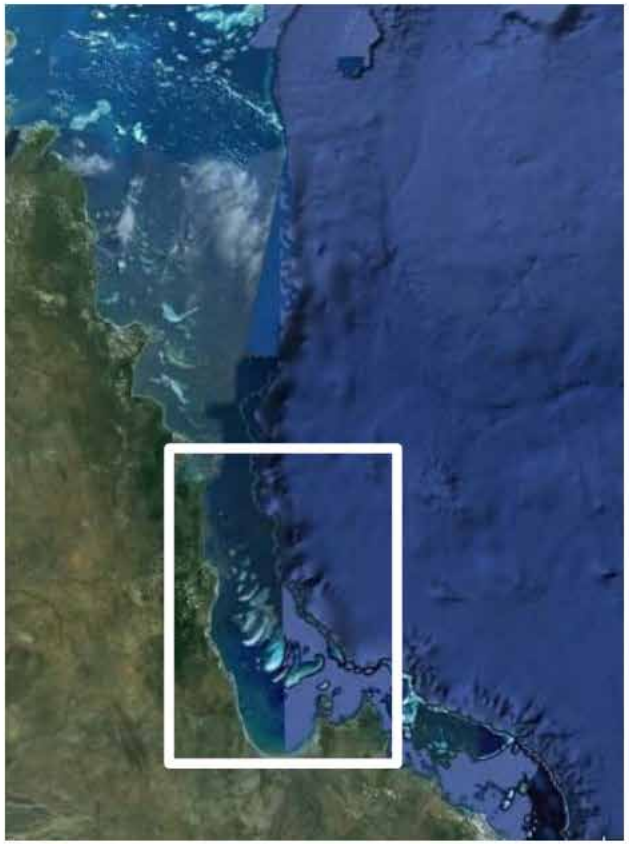


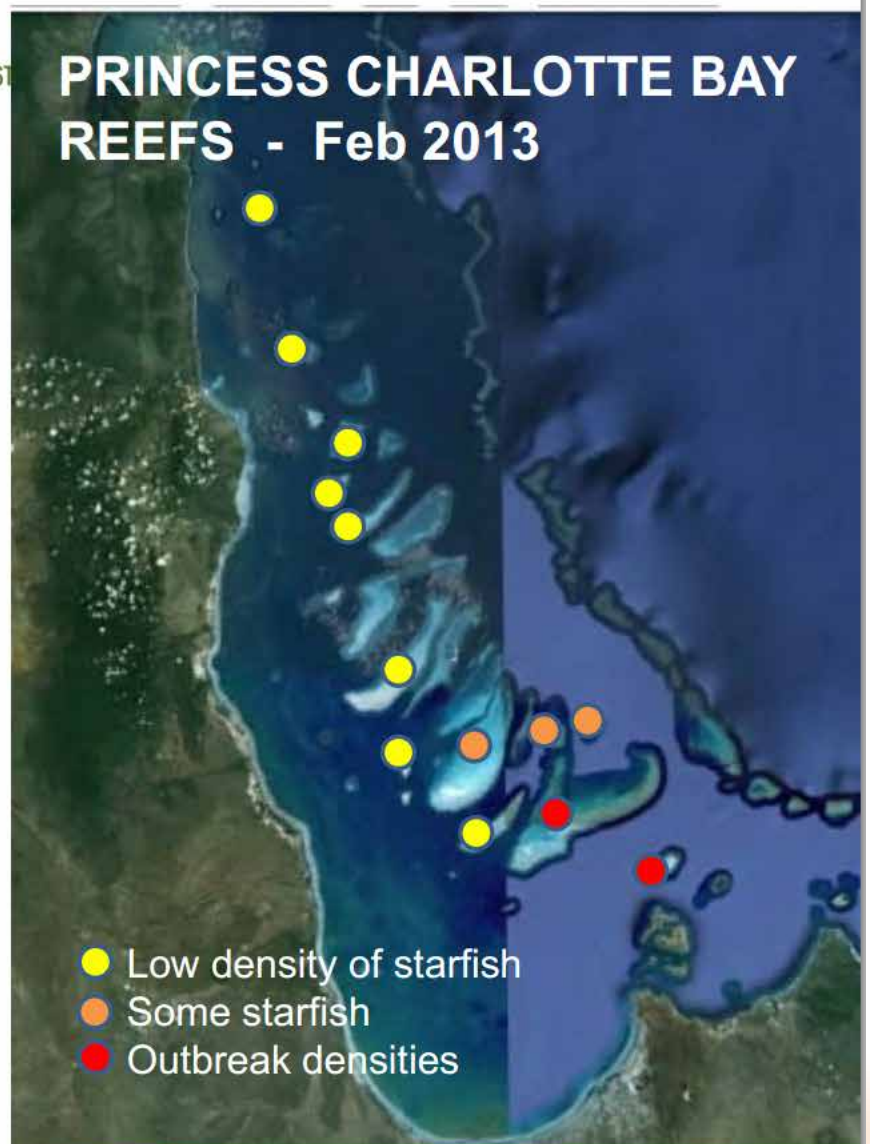
Griffith UNIVERSITY

National Environmental Research Program

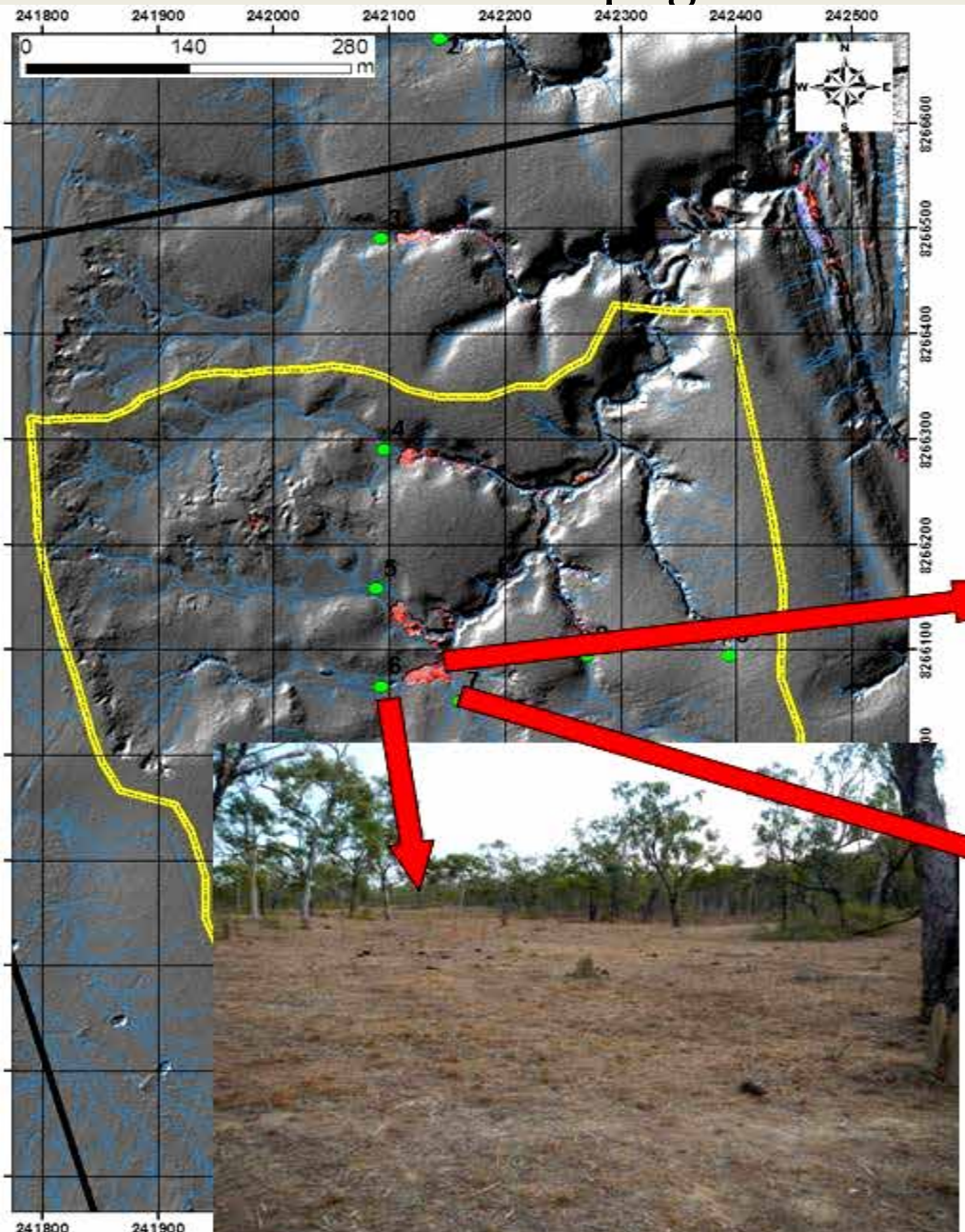
TROPICAL ECOSYST

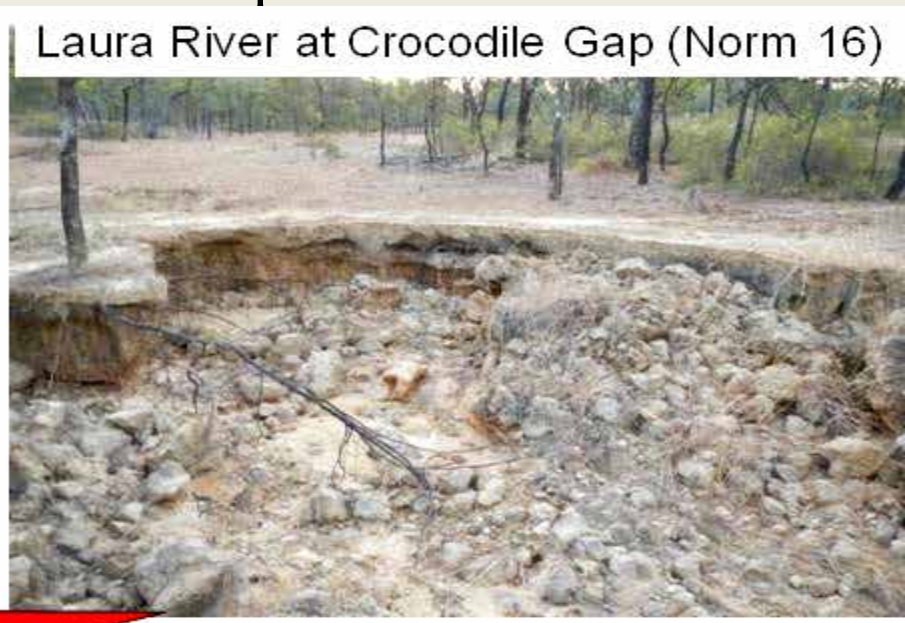
N. GBR SURVEYS - 1





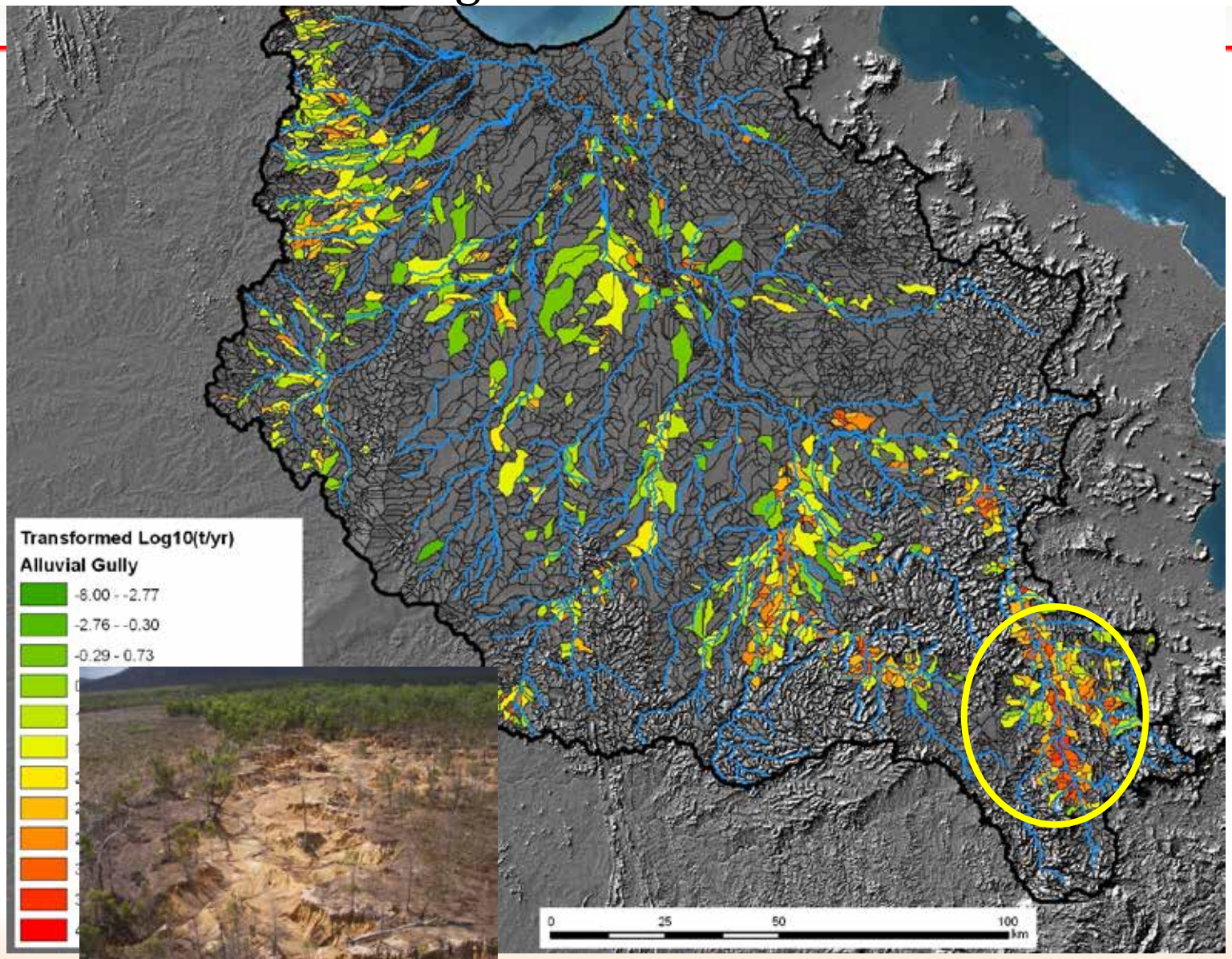
Alluvial gully erosion like this is the major source of anthropogenic Sediment in Cape York

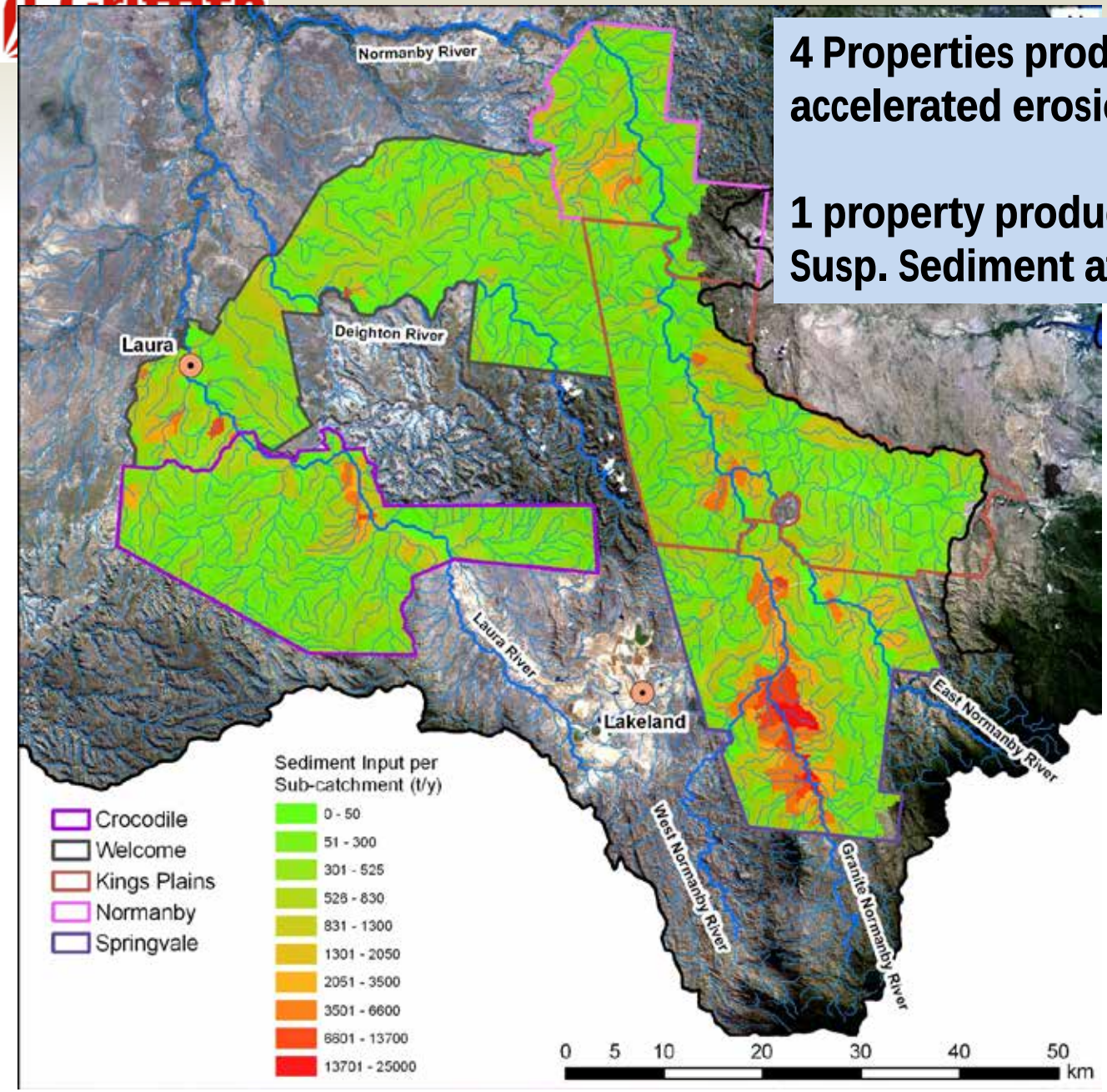




Photos Jeff Shellberg

We can now identify erosion hotspots and better prioritise management effort

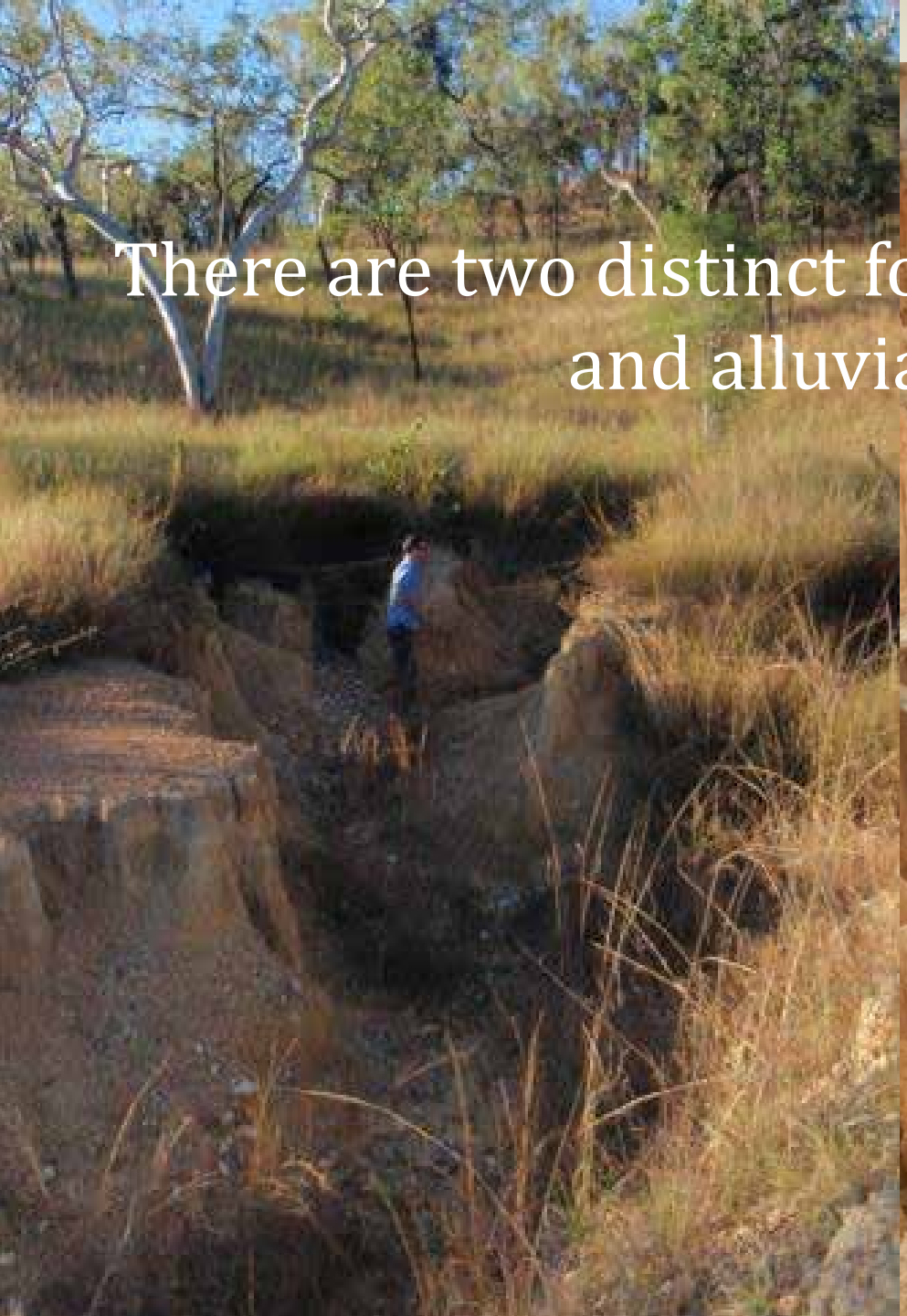


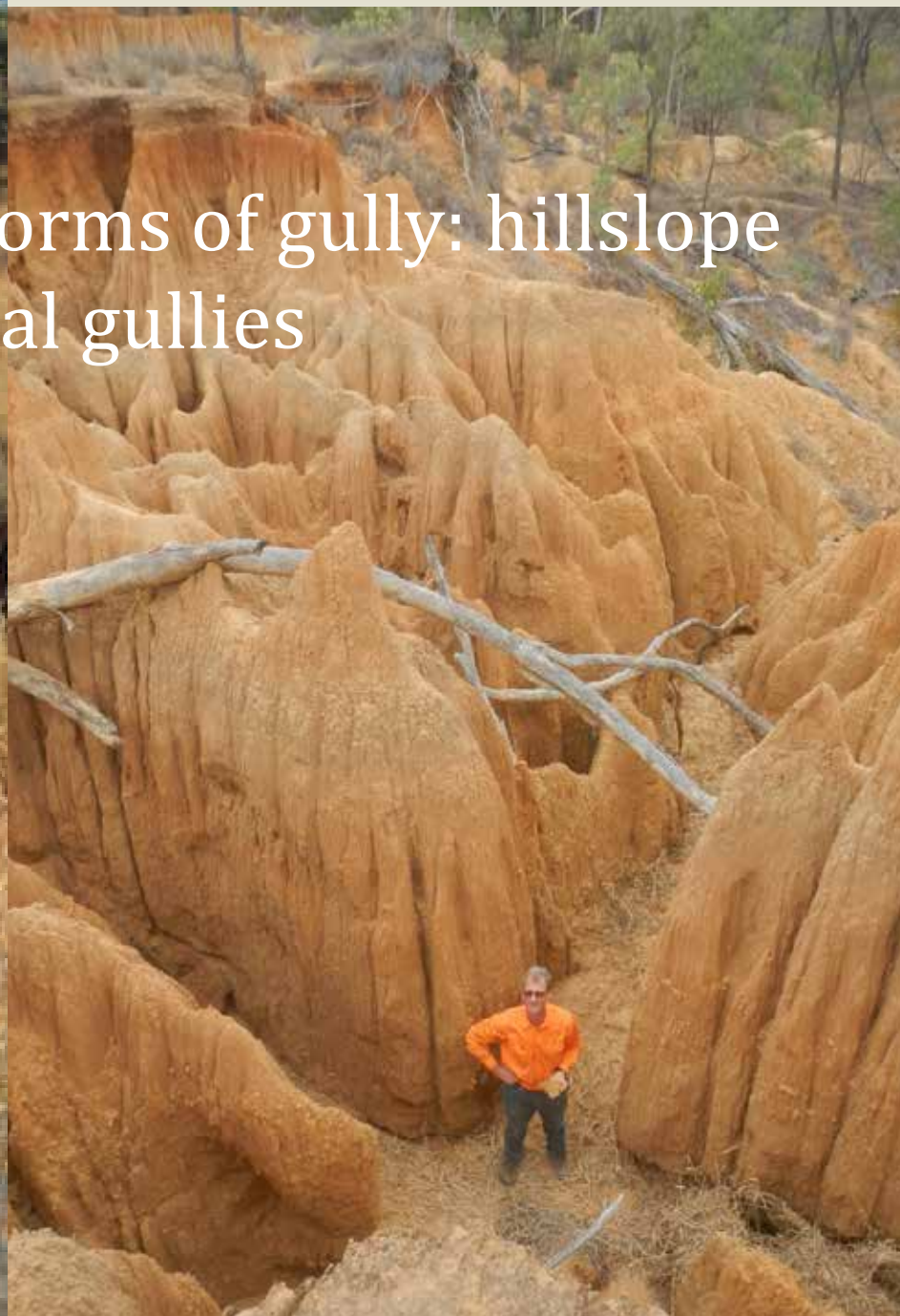


4 Properties producing ~ 60% of all accelerated erosion;

1 property producing ~ 40% of all Susp. Sediment at catchment scale

There are two distinct forms of gully: hillslope and alluvial gullies





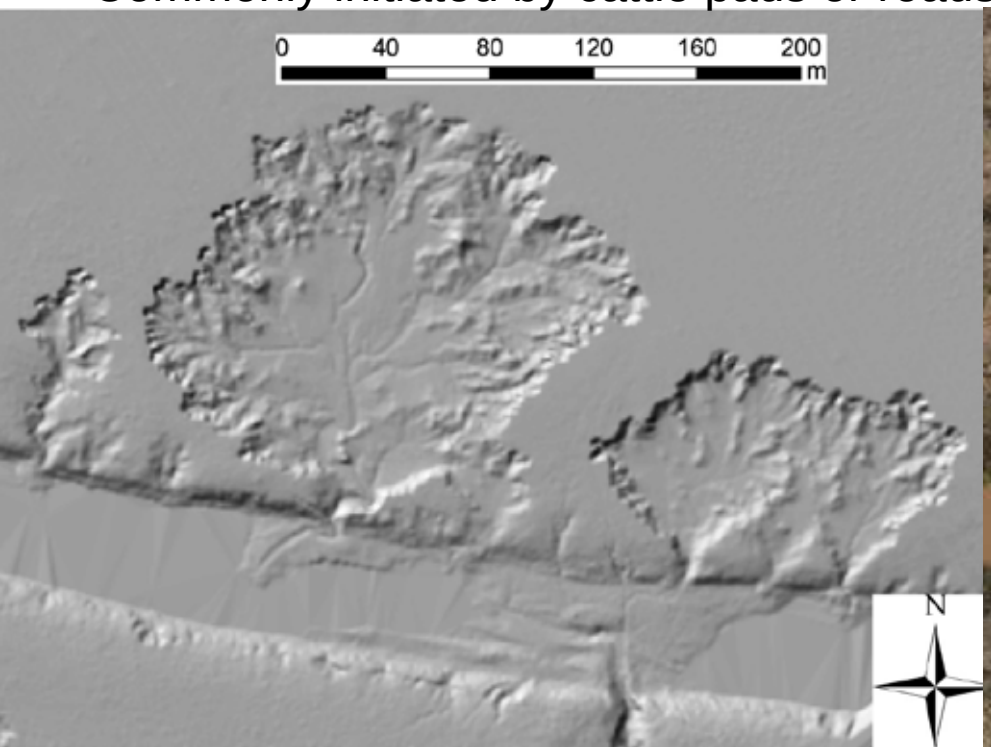
Hillslope Gullies

(e.g., upper catchments, typical of granitic upland areas)

- Generally found in steeper headwater and low order valleys
  in a mix of colluvium & alluvium (significant coarse sediment component)
- Length >> width (due to lateral confinement / topographic control)
- Driven by concentrated overland flow and excess shear stress
- Accelerated by loss of vegetation cover / grazing pressure (direct disturbance + indirect alteration of rainfall/runoff relationship)
- Tend to be self-limiting according to slope/area threshold (+ available sediment on slopes)

Alluvial Gullies

- Gullies that occur exclusively in alluvial sediments (e.g., often > 80% silts and clays)
- Typically along flat floodplains / terraces of main stem channels of large rivers in tropical savannah landscapes
- Typically have well developed deep soil profiles (highly weathered since deposition)
- Highly connected source of suspended sediment
- Width = or > Length…….lack of lateral confinement
- Commonly initiated by cattle pads or roads/tracks across channel banks

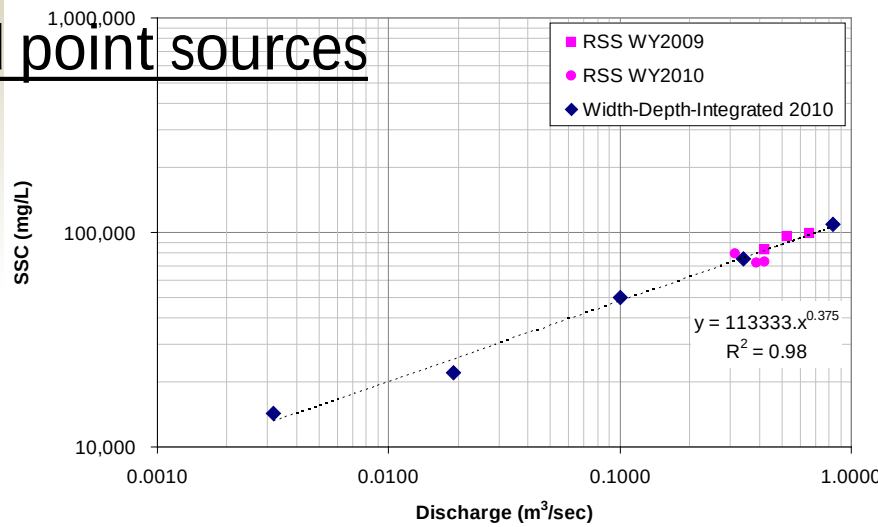


Gully Management to date in the GBR

- To date the focus in catchments like the Burdekin has been on small scale management of relatively inactive hillslope gullies
- To date the major problem associated with alluvial gullies has yet to be addressed

Researchers in the Burdekin implementing gully rehabilitation trials in a hillslope gully

Alluvial Gullies are highly concentrated point sources



Alluvial gullies tend to be transport limited sources (no hysteresis)

One Event

16.6 mm rainfall

0.11 km^2 area

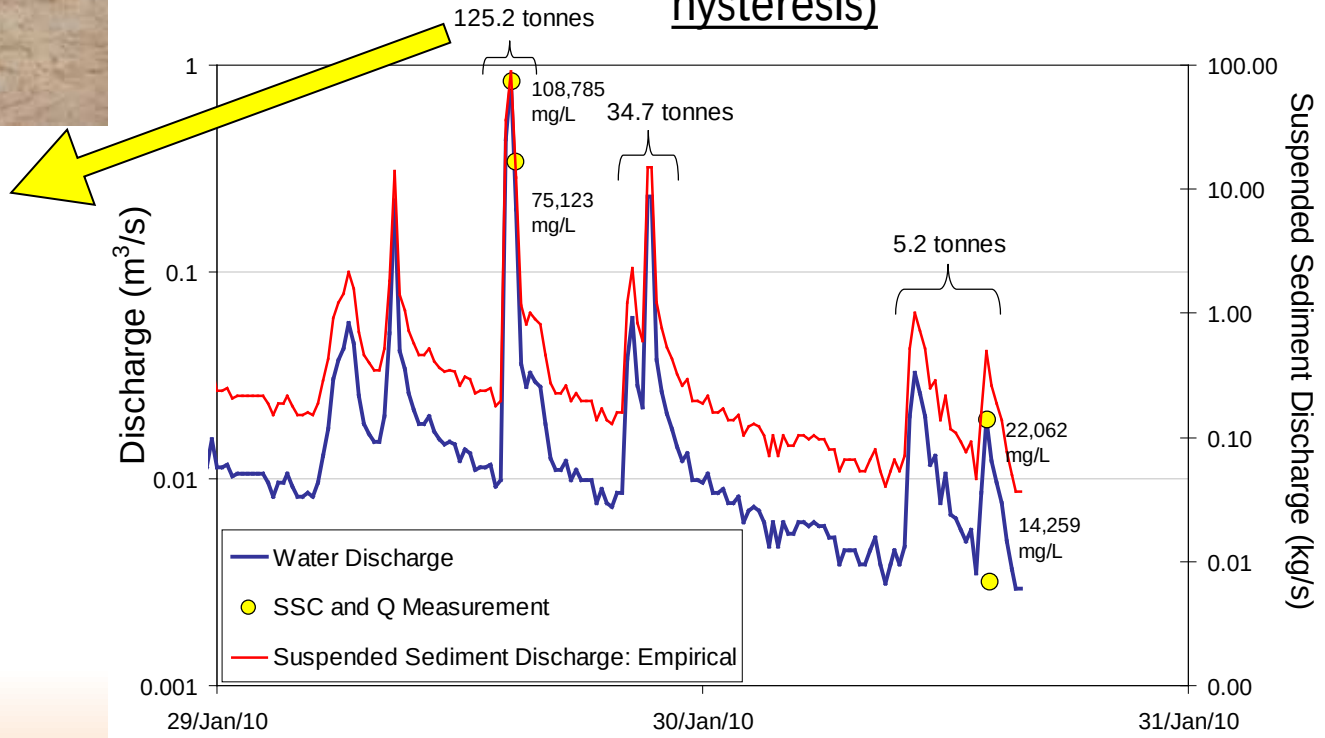
2490 m^3 rainfall

1383 m^3 runoff

Runoff C= 0.40

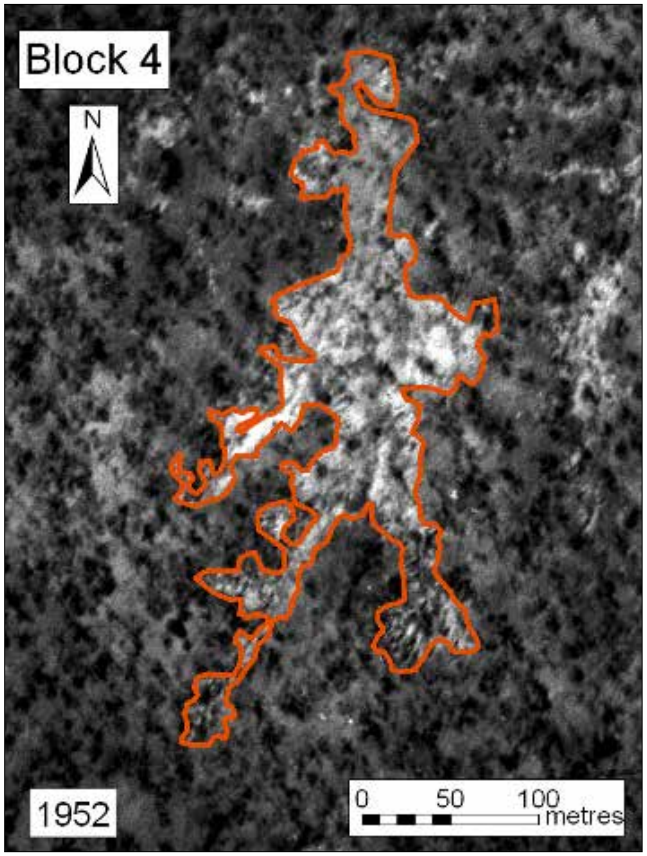
Peak SSC = 108,786 mg/L

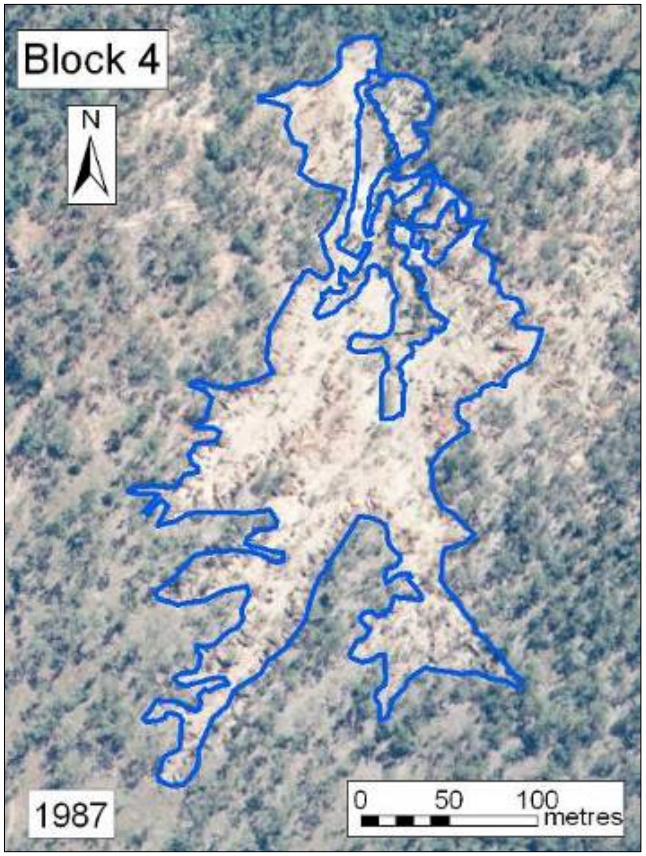
SS Load = 125.2 tonnes



(Jeff Shellberg)

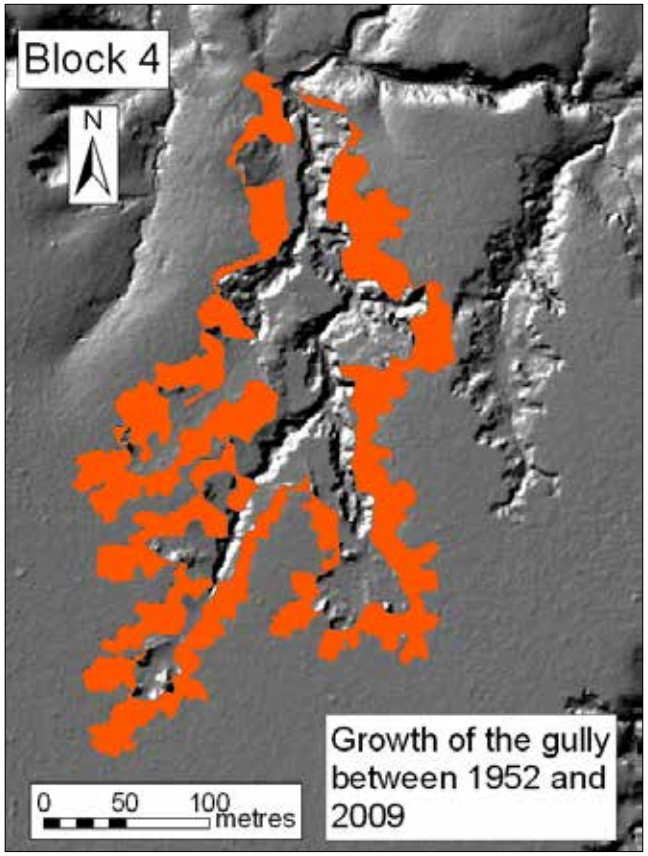
Gully expansion rates and initiation dates can be reconstructed from airphoto analysis

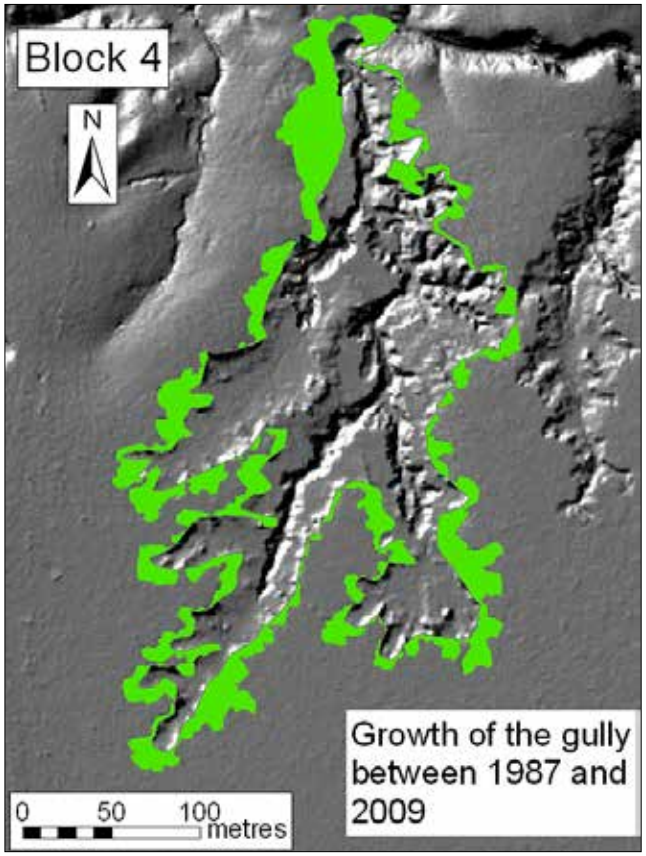




- Example from the West Normanby

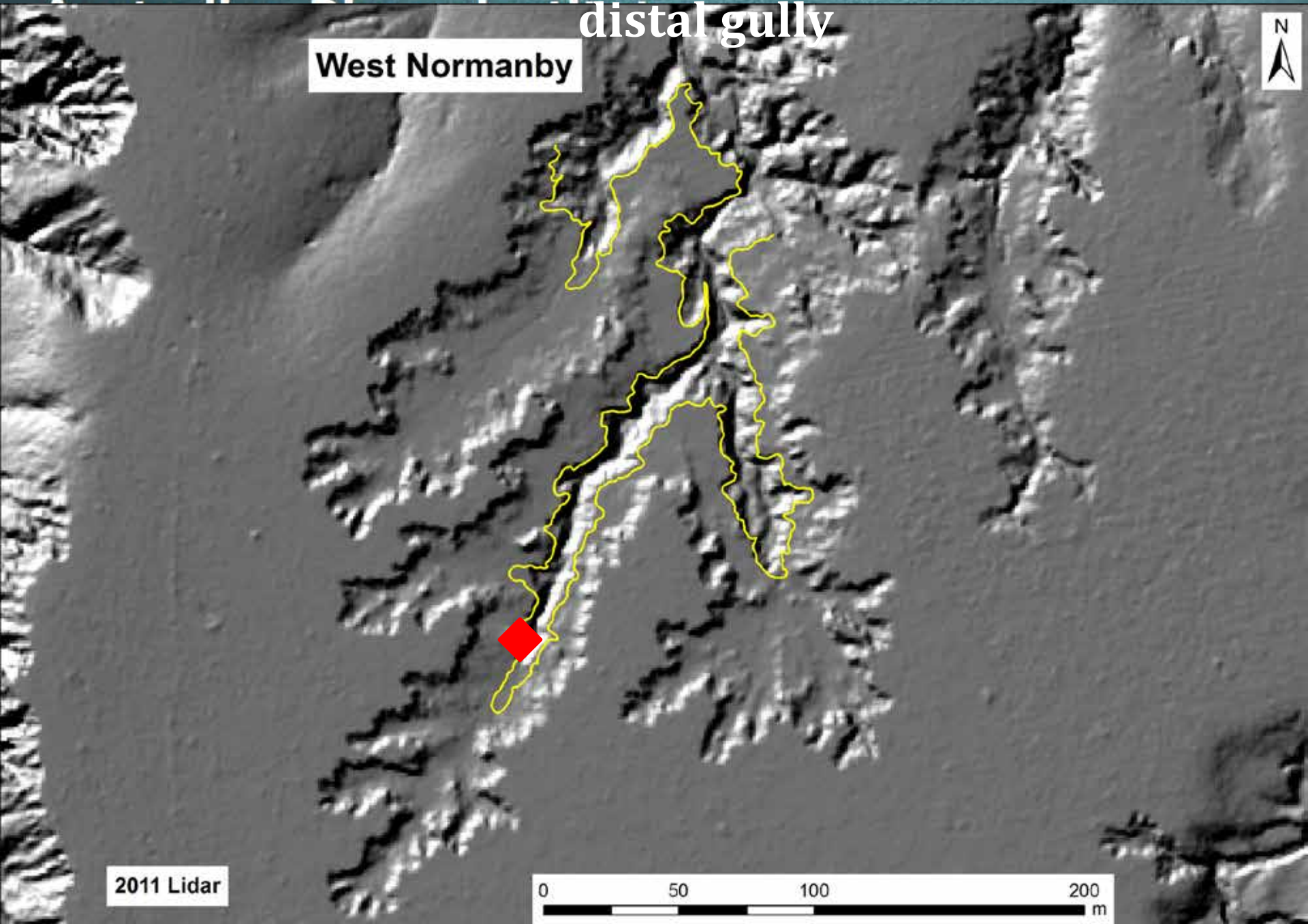
West Normanby Alluvial Gully

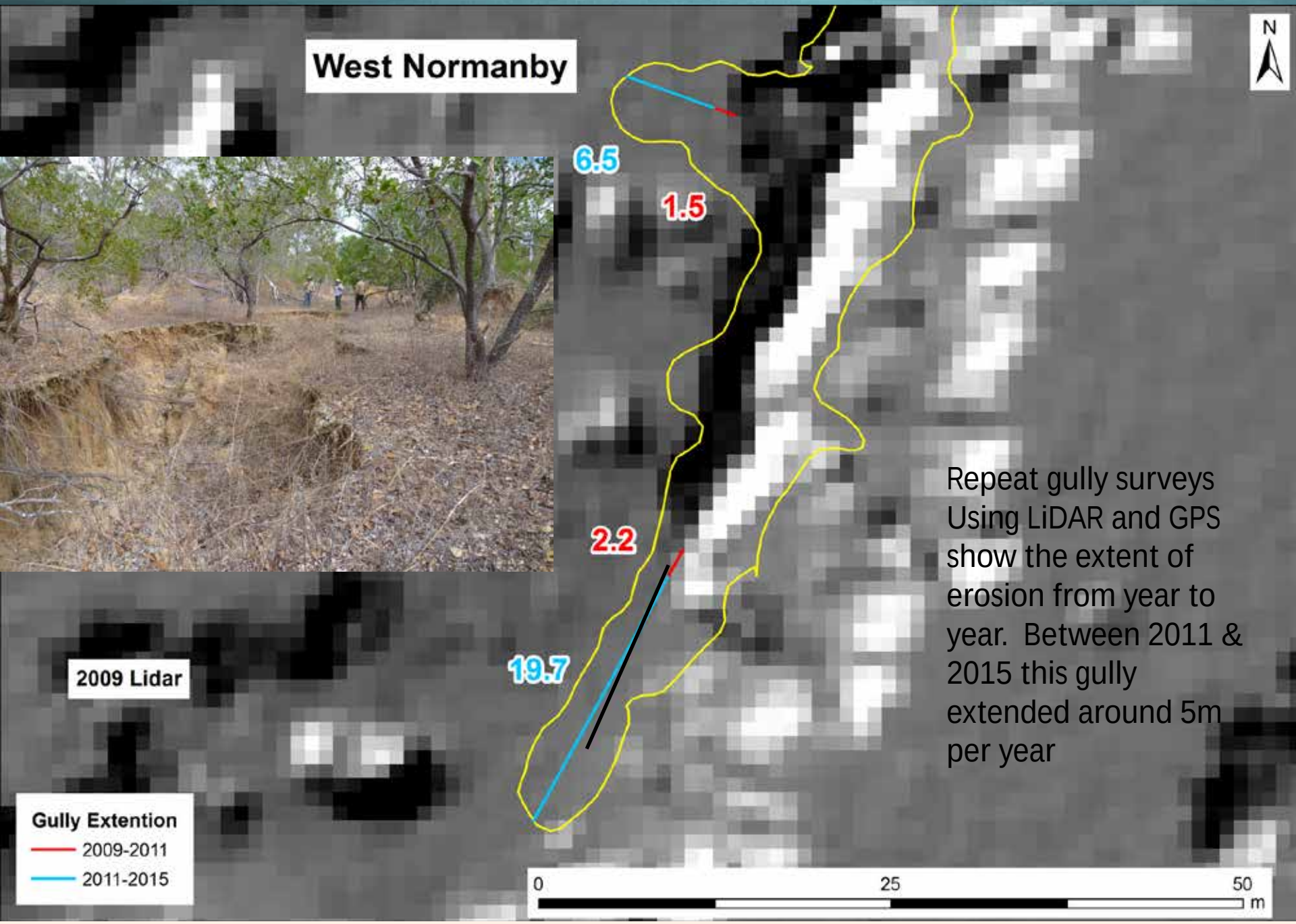




Note the second phase of incision into the main gully (see next slide)

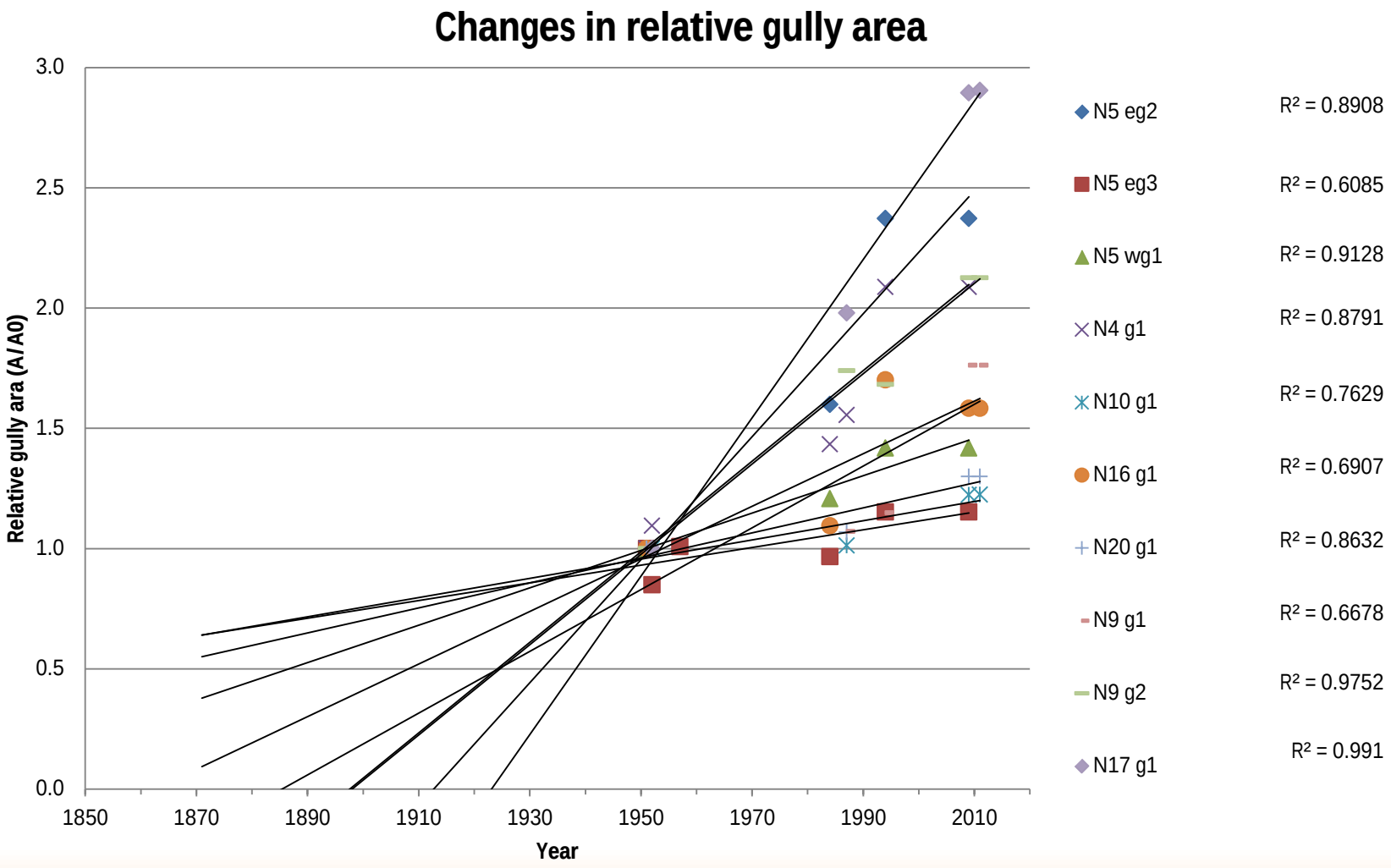
Secondary gully incision West Normanby distal gully





Repeat gully surveys Using LiDAR and GPS show the extent of erosion from year to year. Between 2011 & 2015 this gully extended around 5m per year

Gully erosion acceleration/initiation can be linked to the arrival of cattle into the landscape



How do we reduce sediment from alluvial gullies?

- A characteristic of alluvial gullies is that they are triggered by cattle tracks or other disturbances like farm tracks – but once triggered they can't be stopped by simply removing the cattle or the original disturbance.
- We have to treat the soil to stabilise it.
- It is a process more akin to mine site rehabilitation rather than farm management

Managing highly active incipient (early stage) alluvial gullies is a cost effective way to avoid extensive future erosion – as well as halting current erosion

- This gully producing ~ 400t/yr
- Should be able to treat such a site for ~ $20K ($50/t – current erosion + >> future erosion avoided)

Intensive Active Gully Rehabilitation Trials – gully regrading

Before: Nov 2011

After: Dec 2011

(Jeff Shellberg)

Erosion Control Treatment Plots to test how best to stabilise the soils and address the root cause of the problem

1) Reduce Water Runoff Into Gullies
2) Stabilize Gully Head
3) Reduce Slope of Gully Channel

1. No Treatment
2. Gypsum, Compost, Native Grass
3. Gypsum, Compost, Exotic Grass
4. Gypsum, Hydromulch, Exotic Grass
5. Gypsum Only
6. Compost, Native Grass
7. Straw, Exotic Grass

Before Dec 2011 (Jeff Shellberg)

After April 2012

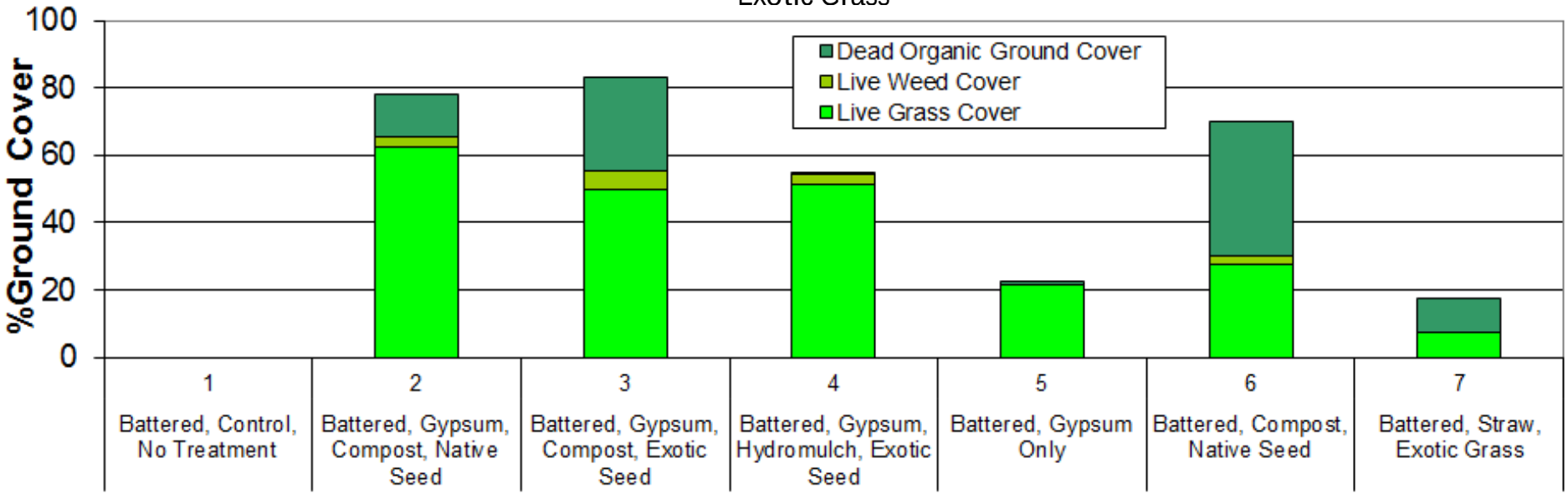
Gully treatments - Crocodile Station alluvial gully experimental plots

Gully	Plot #	Treatment	Gypsum	Mulch	Grass
CRGC1-29	1	Regrade Only	None	None	None
CRGC1-29	2	Regrade, Gypsum, Compost, Native Grass	80t/ha	25mm surface compost	Native grass: Kangaroo (Themeda triandra), Black spear (Heteropogon contortus), Queensland bluegrass (Dichanthium sericeum) (180 kg/ha or 3.8 kg/210 m^2)
CRGC1-29	3	Regrade, Gypsum, Compost, Exotic Grass	80t/ha	25mm surface compost	Exotic grass: Indian bluegrass (Bothriochloa pertusa), Saraji Sabi grass (Urochloa mosambicensis), Jap millet (Echinochloa esculenta) (180 kg/ha or 3.8 kg/210 m^2)
CRGC1-29	4	Regrade, Gypsum, Hydromulch, Exotic Grass	90t/ha	10mm surface hydromulch	Exotic grass: Indian bluegrass (Bothriochloa pertusa), Saraji Sabi grass (Urochloa mosambicensis), Jap millet (Echinochloa esculenta), verano stylo (Stylosanthes hamata) (100 kg/ha or 2.1 kg/210 m^2)
CRGC1-29	5	Regrade, Gypsum	80t/ha	None	None
CRGC1-29	6	Regrade, Compost, Native Grass	None	25mm surface compost	Native grass: Kangaroo (Themeda triandra), Black spear (Heteropogon contortus), Queensland bluegrass (Dichanthium sericeum) (180 kg/ha or 3.8 kg/210 m^2)
CRGC1-29	7	Regrade, Straw, Exotic Grass	None	25mm surface straw	Exotic grass: Indian bluegrass (Bothriochloa pertusa), Saraji Sabi grass (Urochloa mosambicensis), Jap millet (Echinochloa esculenta) (180 kg/ha or 3.8 kg/210 m^2)
CRGC60/61	8	Regrade Only	None	None	None
CRGC60/61	9	Regrade, Straw, Exotic Grass	None	25mm surface straw	Exotic grass: Indian bluegrass (Bothriochloa pertusa), Saraji Sabi grass (Urochloa mosambicensis), Jap millet (Echinochloa esculenta) (180 kg/ha or 1.4 kg/75 m^2)
CRGC60/61	10	Regrade, Gypsum	80t/ha	None	None
CRGC60/61	11	Regrade, Gypsum, Compost, Exotic Grass	80t/ha	25mm surface straw	Exotic grass: Indian bluegrass (Bothriochloa pertusa), Saraji Sabi grass (Urochloa mosambicensis), Jap millet (Echinochloa esculenta) (180 kg/ha or 1.4 kg/75 m^2)
CRGC60/61	12	Regrade, Gypsum, Compost, Native Grass	80t/ha	25mm surface compost	Native grass: Kangaroo (Themeda triandra), Black spear (Heteropogon contortus), Queensland bluegrass (Dichanthium sericeum) (180 kg/ha or 1.4 kg/75 m^2)
CRGC1-40	CRGC1-40	Regrade Headcut, Gypsum, Hydromulch, Exotic Grass, Wood Grade Control	80t/ha	10mm surface hydromulch	Exotic grass: Indian bluegrass (Bothriochloa pertusa), Saraji Sabi grass (Urochloa mosambicensis), Jap millet (Echinochloa esculenta), verano stylo (Stylosanthes hamata) (100 kg/ha or 2.1 kg/210 m^2)
CRGC1-32	CRGC1-32	No Treatment Control Headcut	None	None	None
CRGC1-28	CRGC1-28	No Treatment Control Side-Wall	None	None	None

Vegetation Changes……
After Two (2) Wet Seasons

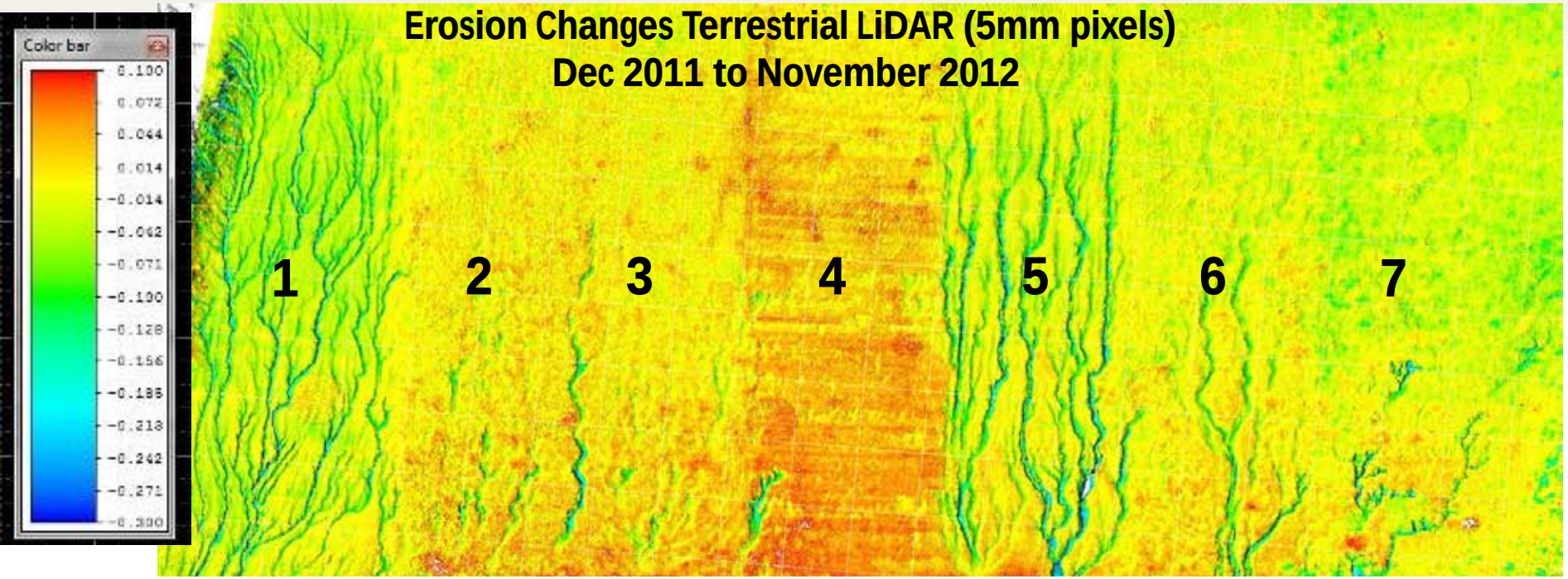
1) Reduce Water Runoff Into Gullies
2) Stabilize Gully Head
3) Reduce Slope of Gully Channel

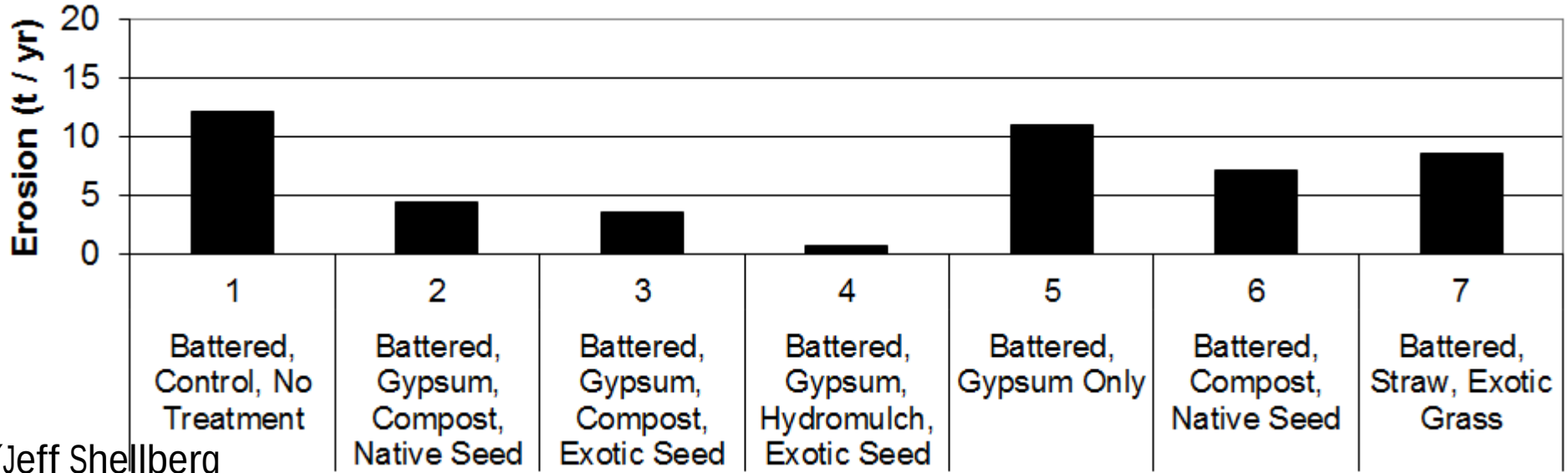
1	2	3	4	5	6	7
Control No Treatment	Gypsum Compost Native Grass	Gypsum Compost Exotic Grass	Gypsum Hydromulch Fertilizer Exotic Grass	Gypsum Only	Compost Native Grass	Straw Exotic Grass



Erosion Changes……
After One (1) Wet Season

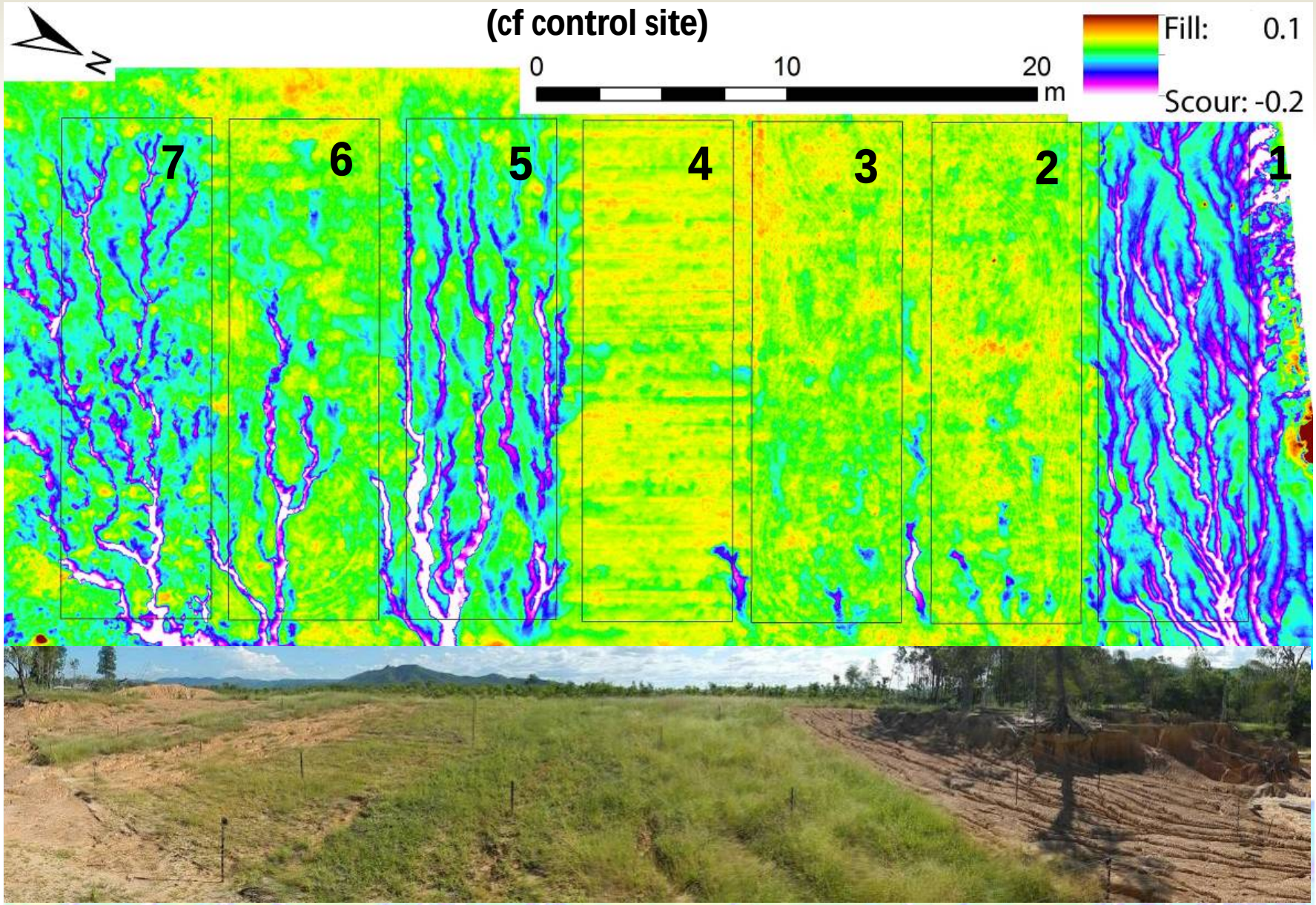
1) Reduce Water Runoff Into Gullies
2) Stabilize Gully Head
3) Reduce Slope of Gully Channel





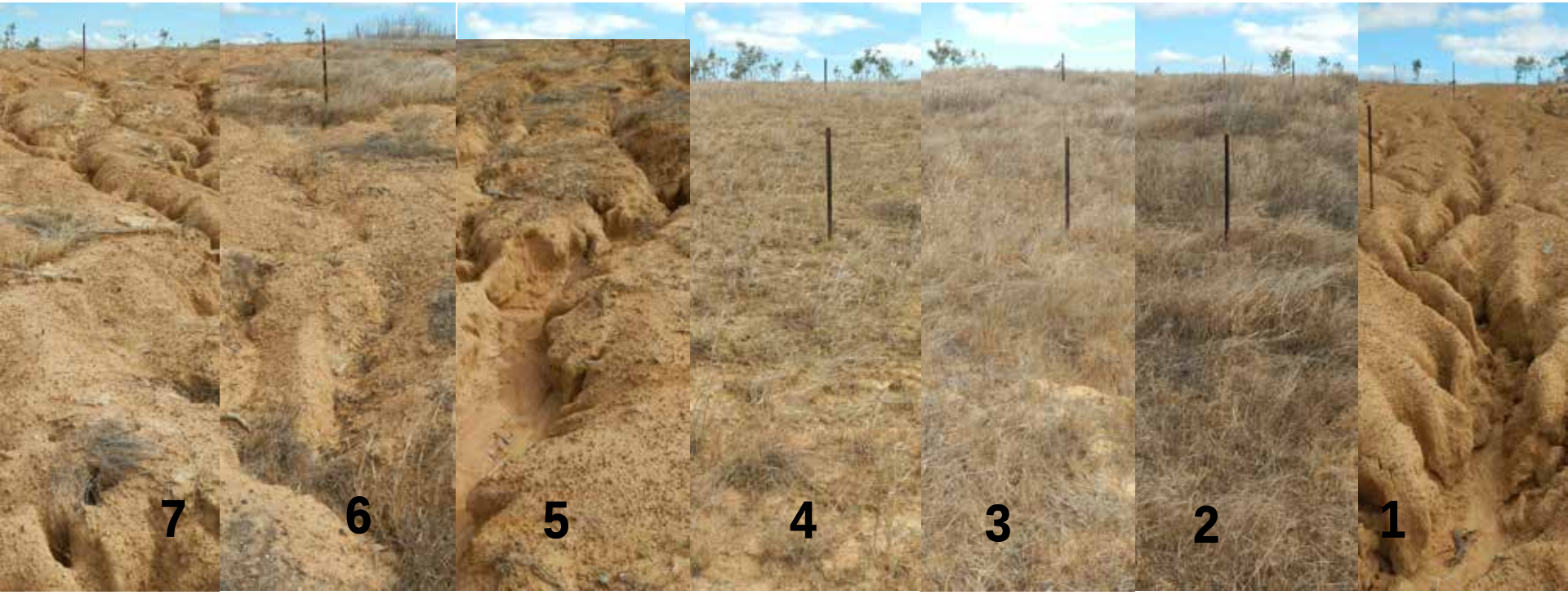
(Jeff Shellberg

After two wet seasons erosion rates reduced by 75% in optimal treatment (cf control site)



(Jeff Shellberg)

Trial plots - July 2015 dry season (4 years post implementation)



Optimal treatment next to the regraded only treatment – CRGC29 July 2015.
Regrade only site erosion rates (LHS) were higher than the control (do nothing).
Plot on RHS of image has achieved a 75% reduction in sediment yield

Trial Cattle Exclusion Sites
at River Frontage Gullies

1) Reduce Water Runoff Into Gullies
2) Stabilize Gully Head
3) Reduce Slope of Gully Channel

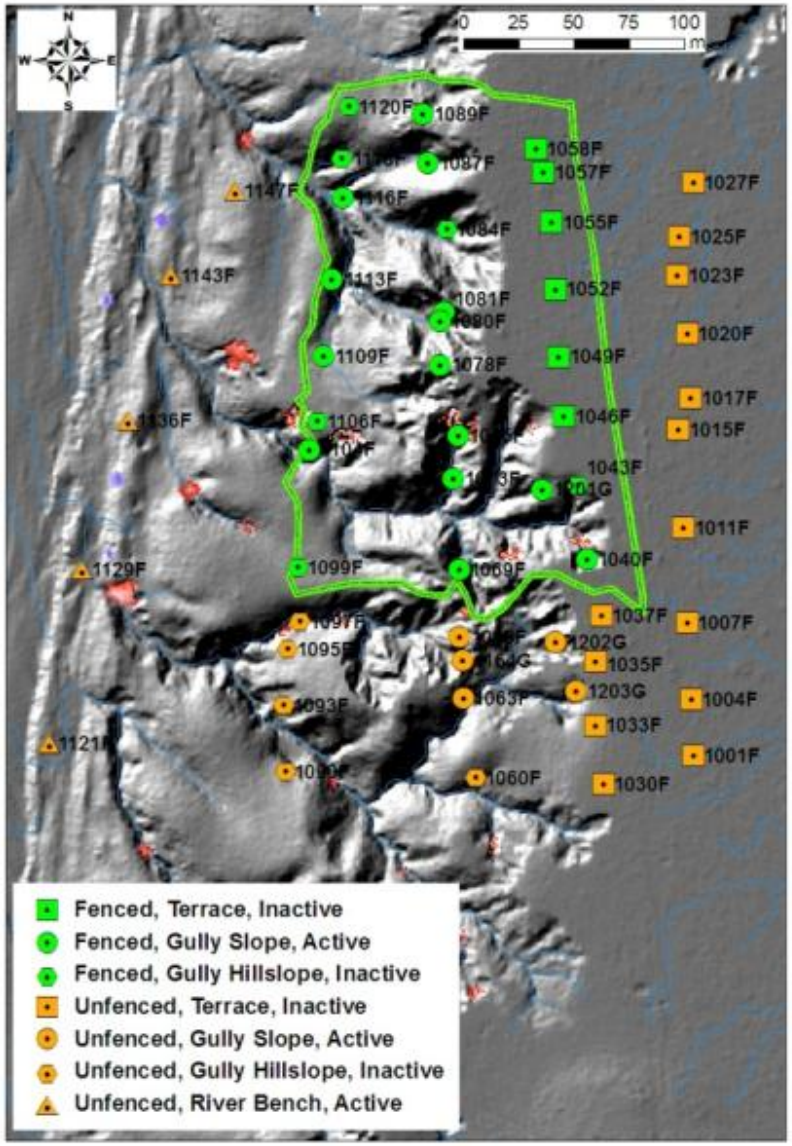
- **Three (3) cattle exclusion sites (~5 ha each)**
  - West Normanby (frontage)
  - Granite Normanby (frontage)
  - Laura River (paddock)

- **Vegetation Monitoring**
  - 50 plots (4 m^2) at each exclusion area
  - Control plots outside, treatment inside
  - % cover, species, biomass, tussocks, weeds

- **Erosion Monitoring**
  - LiDAR Topography 2009, 2011…2020?
  - Plot scale erosion depth
  - Plot soil condition

- **Timeline**
  - Before Fence: Nov 2011, April 2012
  - After Fence: Nov 2012, April 2013
  - Repeat yearly or in 2020

West Normanby River Frontage



(Jeff Shellberg)

Alluvial gully management: passive approach – cattle exclusion: How long will it take to see a significant sediment reduction (return on investment)?

Cattle Exclusion Trials

1) Reduce Water Runoff Into Gullies
2) Stabilize Gully Head
3) Reduce Slope of Gully Channel

Will Grass Vegetation Recover and Reduce Erosion if Cattle Are Excluded for 10-20 Years?

- Fence Cattle from River Frontage
- Rely on Natural Resilience of Vegetation
- Monitor Erosion Reduction Over Time ?

West Normanby Exclusion Plots **July 2015**;

Very little visible evidence of reduction in erosion rates after ~ 4 yrs exclusion (tbc with aerial LiDAR)

The Bowen River

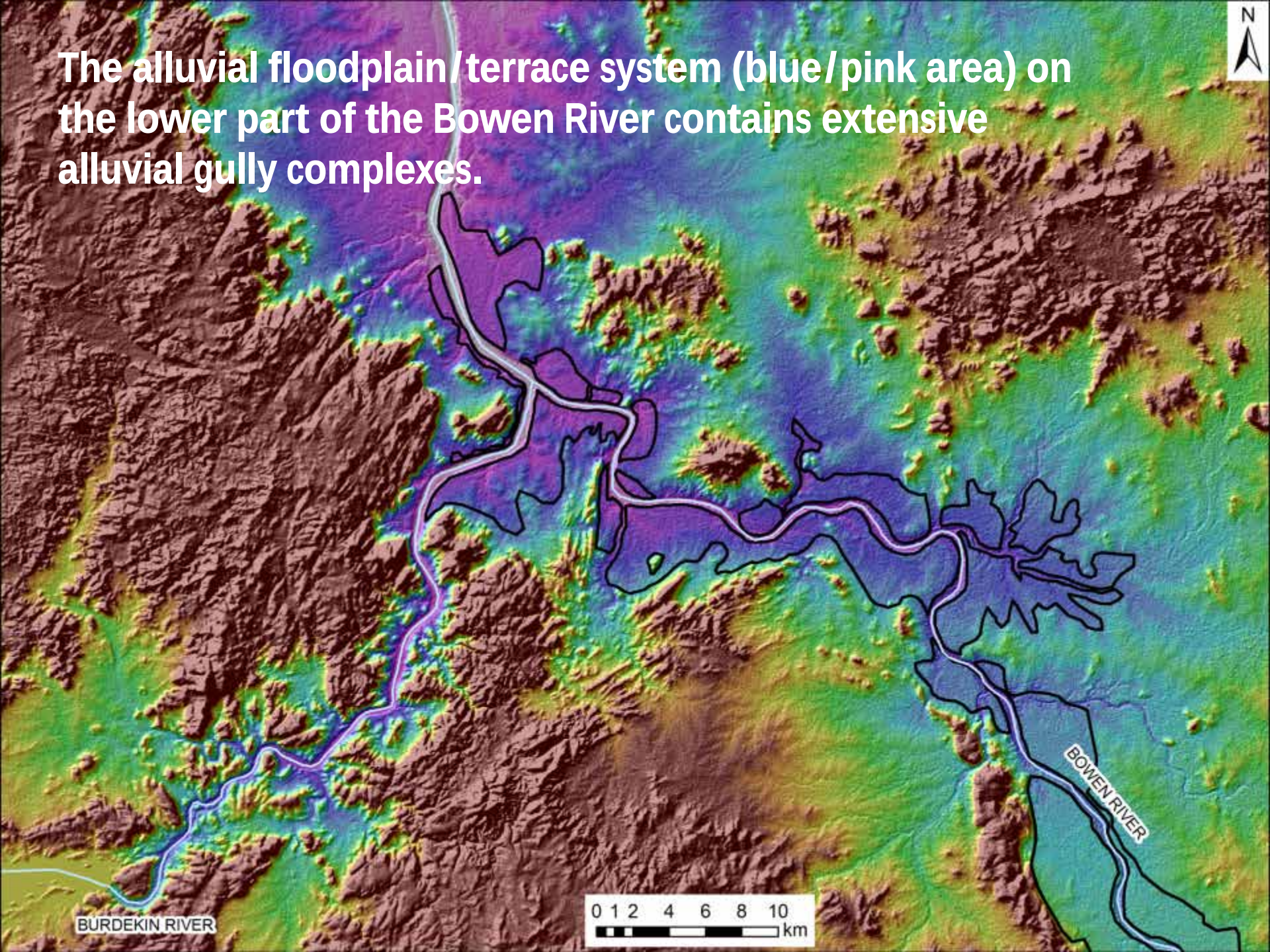
- The Bowen River is a major tributary to the Burdekin River which enters downstream of the Burdekin Falls dam
- It has been identified via sediment tracing and loads monitoring as contributing the greatest sediment load to the GBR.
- The Bowen River is dominated by Alluvial Gullies
- If sediment loads to the GBR are to be reduced sediment yields from alluvial gully erosion have to be significantly reduced

Proportion of the Sediment to the GBR from the Bowen & Bogie Rivers

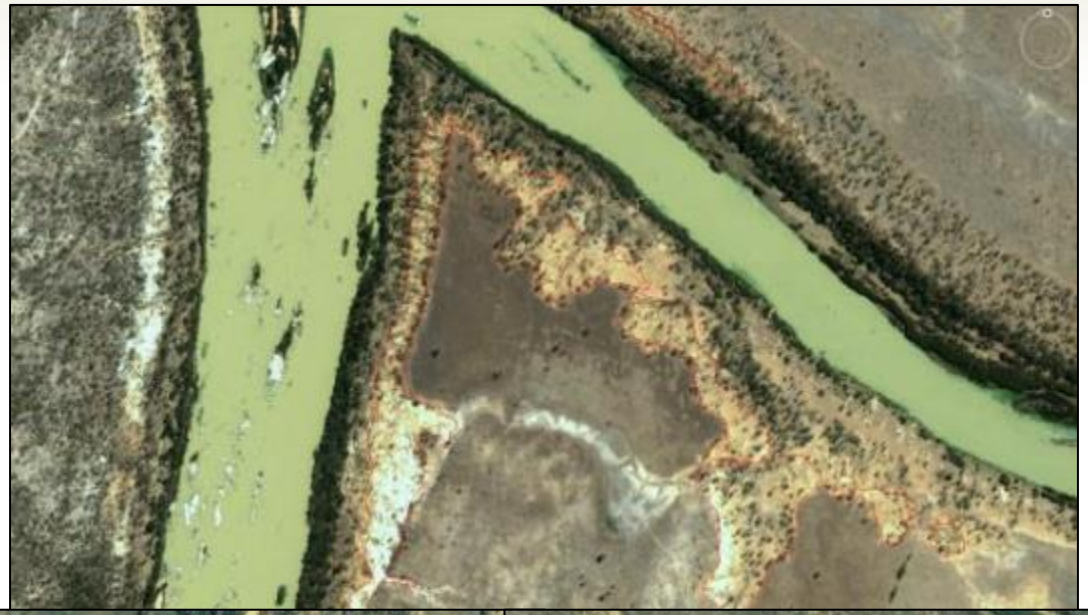
Burdekin Sediment Budget 2005-2009	load % breakdown by particle size				av loads (Mt/yr: 2005-2009)				
	clay	silt	sand	total	clay	silt	sand	total	% of total at outlet
Burdekin R (below dam)	52%	41%	6%	100%	1.32	1.05	0.15	2.52	30%
Bowen R (@ Myuna)	27%	49%	24%	100%	1.02	1.84	0.90	3.76	45%
Lower Bowen/Burdekin ungauged tribs include: Oaky Ck, Pelican Ck, Lower Bowen R; Bogie R)	36%	38%	25%	100%	0.79	0.83	0.55	2.16	26%
Lower Burdekin @ Inkerman (catchment outlet)	**37%**	**44%**	**19%**	**100%**	**3.12**	**3.71**	**1.60**	**8.44**	**100%**
Bowen + Lwr Bowen & tribs +BogieR	***30%***	***45%***	***25%***	***100%***	***1.80***	***2.67***	***1.45***	***5.92***	***70%***
% of total at outlet					*58%*	*72%*	*91%*	***70%***	

Data source: Bainbridge et al., (2014) Water Resources Research

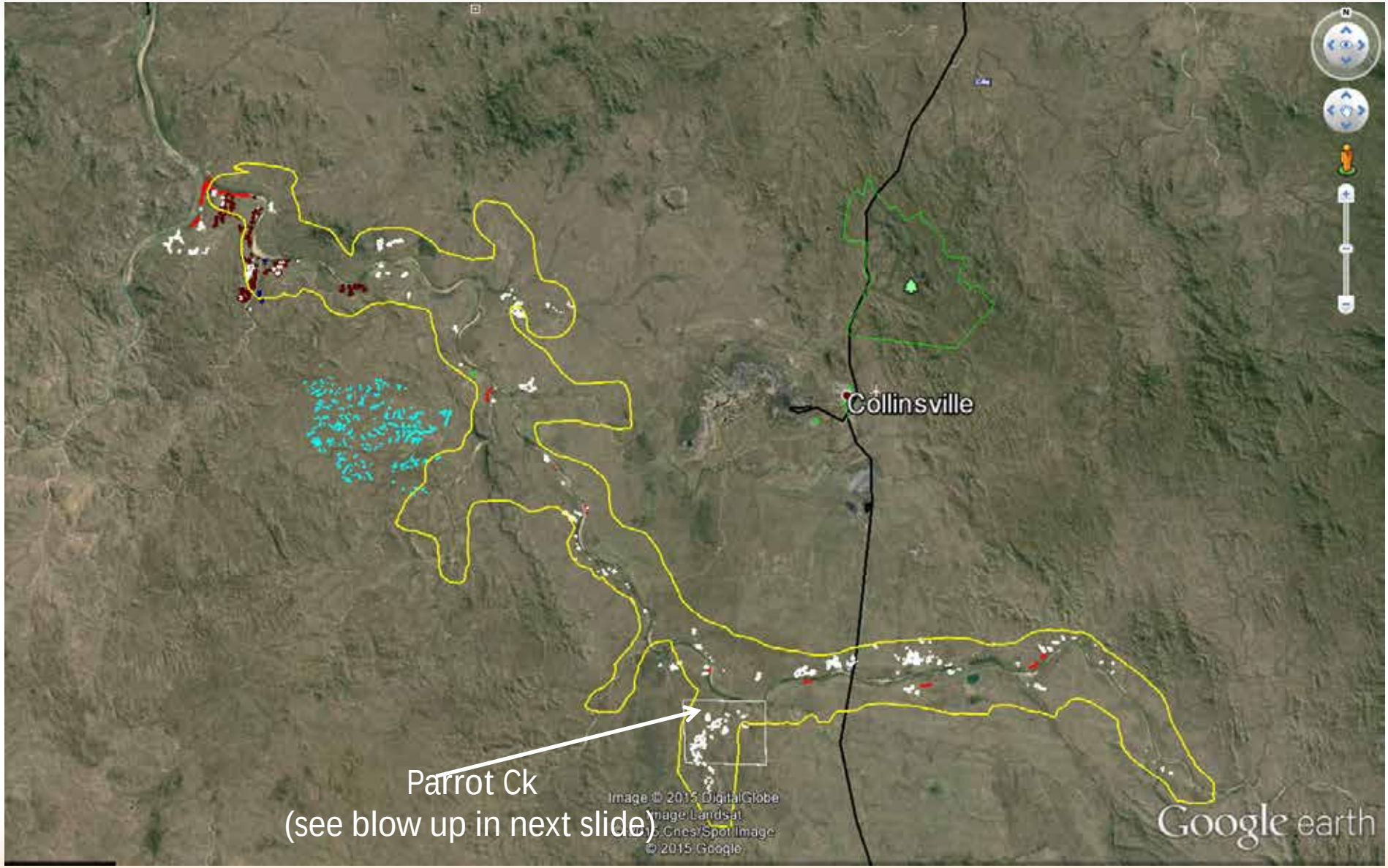
Burdekin River TSS loads is estimated to represent 47% of input to whole GBR (Water et al. 2013) ; hence – **Bowen/Bogie inputs represent ~ 30% of the silt/clay input to the entire GBR**


The alluvial floodplain/terrace system (blue/pink area) on the lower part of the Bowen River contains extensive alluvial gully complexes.
N
BURDEKIN RIVER
BOWEN RIVER
0 1 2 4 6 8 10
km

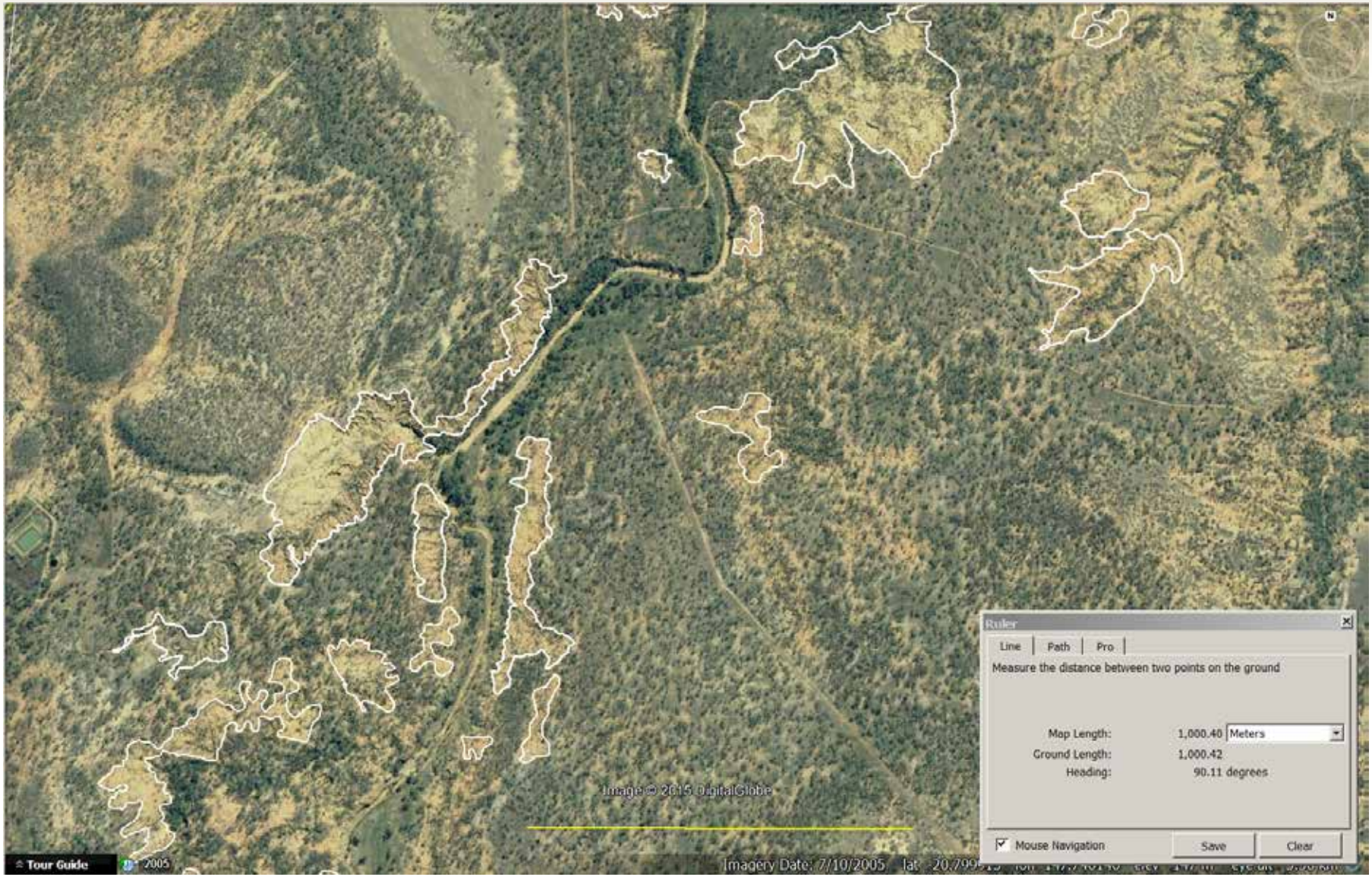
Examples of Bowen River Alluvial Gullies



Preliminary mapping along the lower Bowen R shows there are ~ 2000 ha of highly active gullies



Highly concentrated area of large alluvial gullies along Parrot Creek

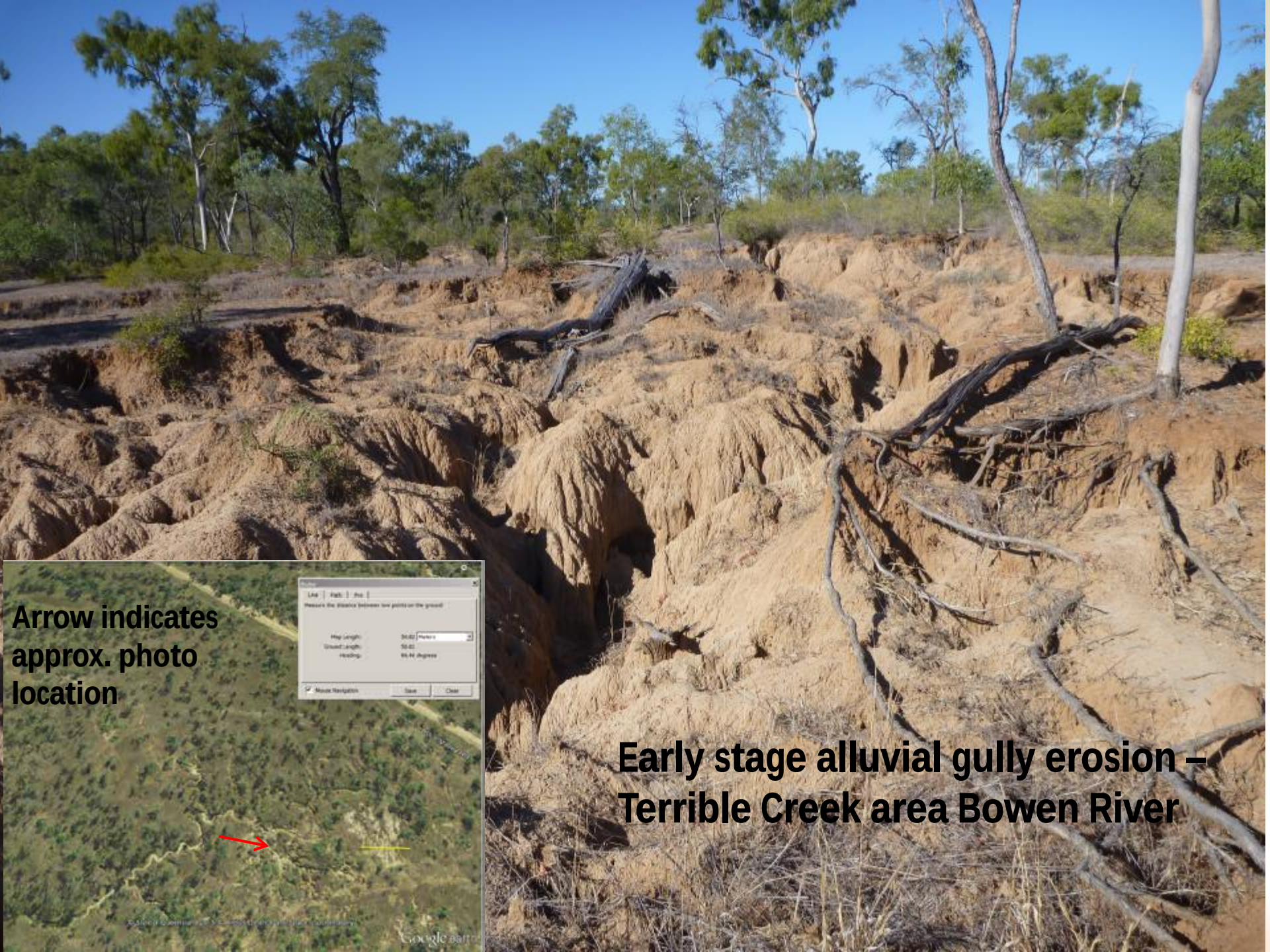


Note yellow scale bar is 1km – mapped gullies in this image range in size from a ~1 to 30 ha

Highly Active Alluvial Gullies in the Bowen Catchment

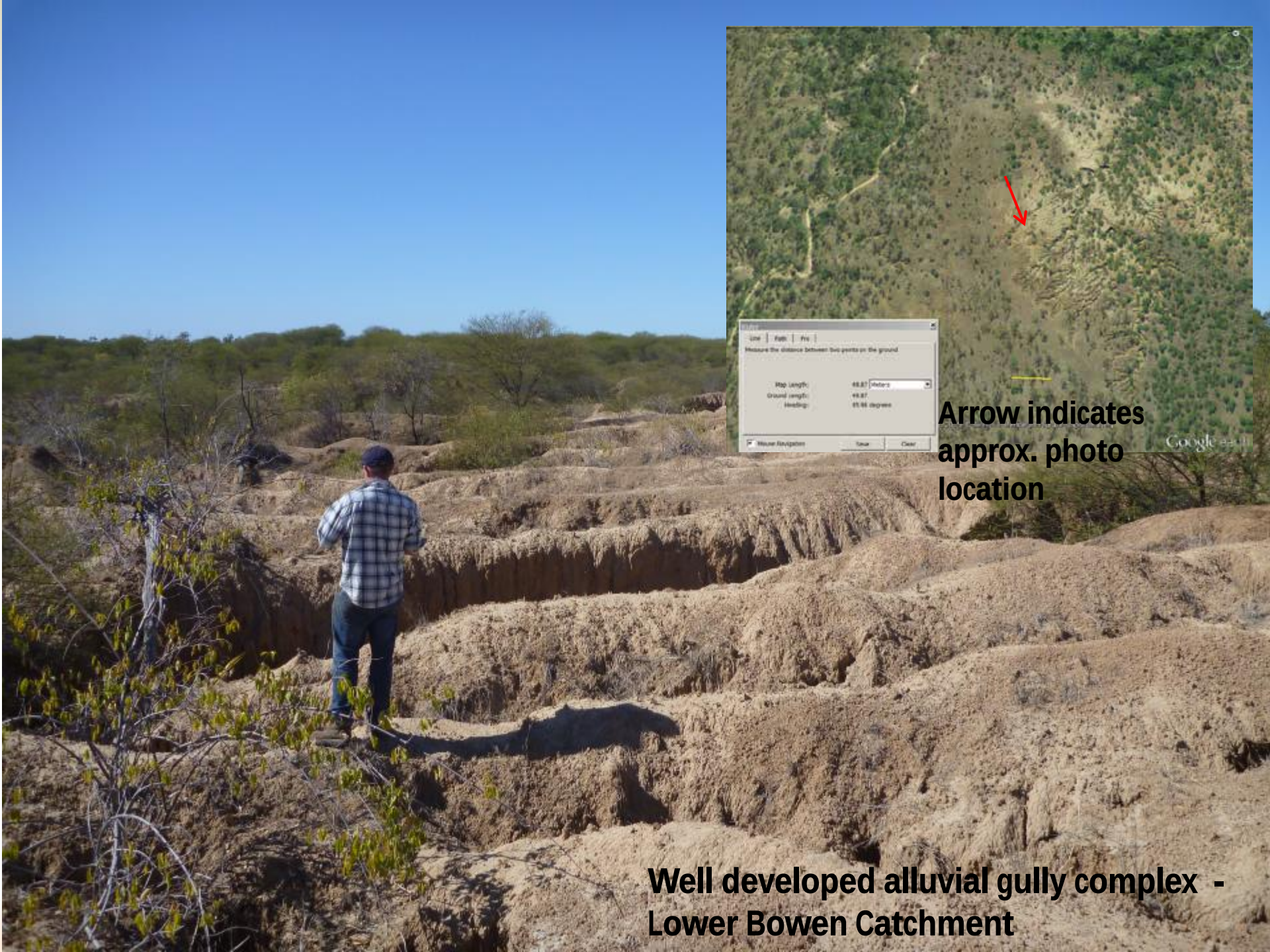

Attempted regrading of gully head without any additional soil treatment; this has been shown to increase erosion rates above background rates in erosion trials

Active alluvial gully complex showing remnant pedestals with trees atop. Gravel like lag on the gully floor are predominantly calcrete nodules which accrete from within the soil profile as part of the gully erosion process


Arrow indicates approx. photo location
Early stage alluvial gully erosion – Terrible Creek area Bowen River

Highly active early stage alluvial gully erosion – Terrible Creek area Bowen River. Depression in foreground is a sink-hole connected to the main gully via tunnel erosion

Highly active early stage alluvial gully erosion – Terrible Creek area Bowen River.



Well developed alluvial gully complex - Lower Bowen Catchment

Well developed alluvial gully complex - Strathmore – note extensive tunnel erosion

Incipient alluvial gully in the adjacent palaeo-swale to the gully shown in the previous slide

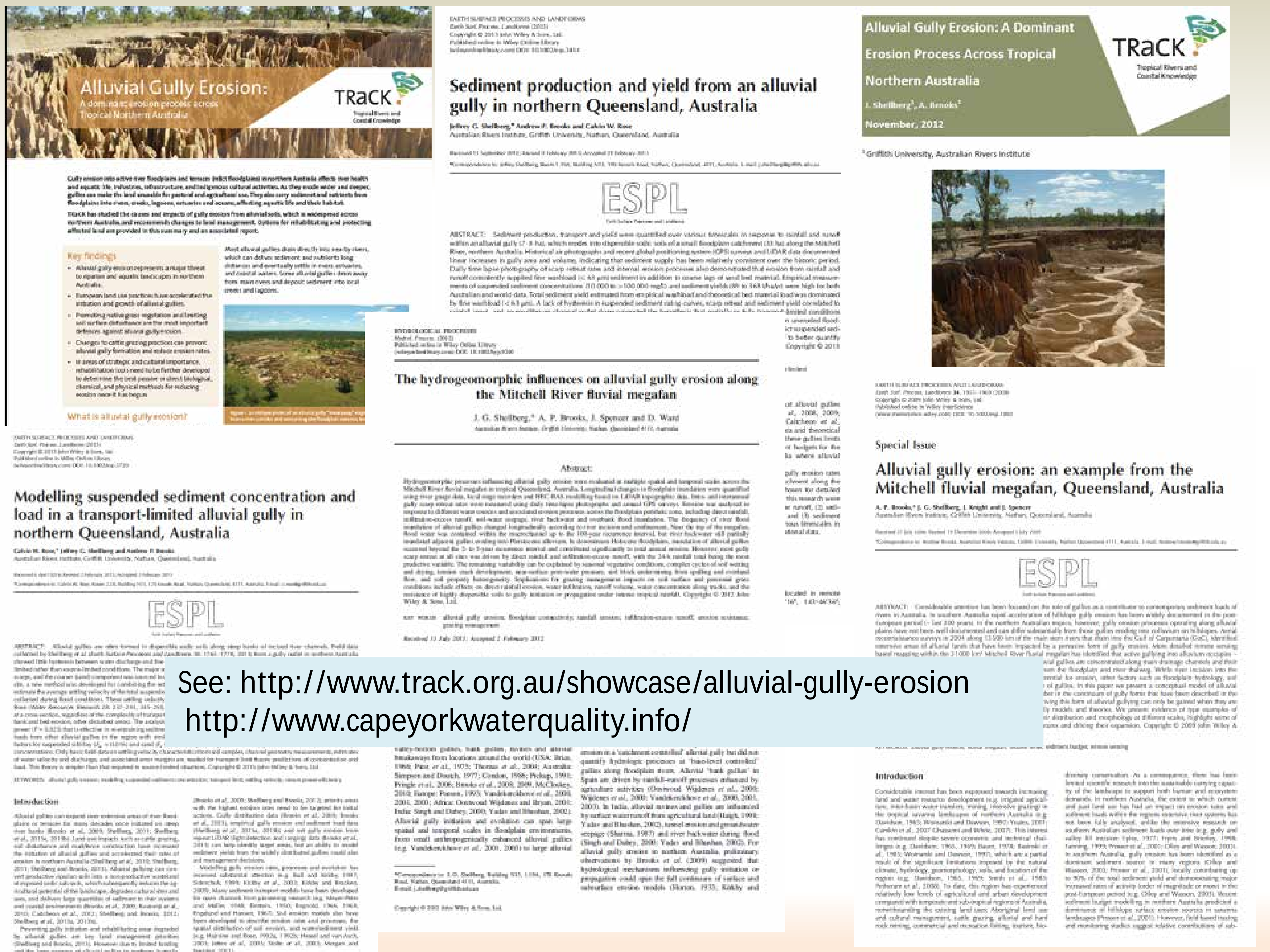
Incipient alluvial gully - Blue Valley area; gully is eroding into the margins of the alluvial terrace (assumed to be Pleistocene age)

The solution for the Reef

- Sediment loads to the reef will only be reduced if there is a major investment in the management of alluvial gullies
- Most other sources pale into insignificance compared to this issue.
- The good news though is that with the appropriate expertise, resources and focused effort – significant results can be achieved on relatively short timeframes (e.g. < 10 years) within the existing resources

Further work

- There is a diversity of alluvial gully forms, and more research is required to identify the key characteristics of the soil chemistry and other drivers which lead to such diversity of form, and hence rehabilitation requirements.
- In the Bowen catchment, the initial evidence is compelling that alluvial gullies are indeed the dominant source of sediment to the Bowen River and the whole GBR lagoon. However, precision mapping along the lines of that undertaken in the Normanby is required in this catchment to confirm this.
- Given this, it should be a priority to collect high resolution LiDAR data in the Burdekin catchment to enable us to quantify the relative distribution of hillslope and alluvial gullies and their respective sediment contribution, and to help prioritize rehabilitation.


Alluvial Gully Erosion:
A dominant erosion process across Tropical Northern Australia
TRaCK
Sediment production and yield from an alluvial gully in northern Queensland, Australia
ESPL
Alluvial Gully Erosion: A Dominant Erosion Process Across Tropical Northern Australia
November, 2012
Griffith University, Australian Rivers Institute
The hydrogeomorphic influences on alluvial gully erosion along the Mitchell River fluvial megafan
Abstract
Special Issue
Alluvial gully erosion: an example from the Mitchell fluvial megafan, Queensland, Australia
Modelling suspended sediment concentration and load in a transport-limited alluvial gully in northern Queensland, Australia
Introduction
See: http://www.track.org.au/showcase/alluvial-gully-erosion
http://www.capeyorkwaterquality.info/