Gully erosion – the use of computer based landscape evolution models to predict initiation, growth and stabilisation

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What are gullies?

- Incisions in the earths surface that develop from concentrated flow

- Initiation is expected to occur above a threshold flow shear stress

- Gullying considered to be a threshold function dependent on catchment area and slope

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What do we know?

- Enormous amount of studies conducted
- Mapping, material properties, surface and subsurface materials, vegetation, landscape management, climate, topography…………
- We don't really understand initiation, development, rehabilitation despite the huge effort

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How can we advance our understanding?

Landscape evolution models can provide insights

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Landscape evolution models

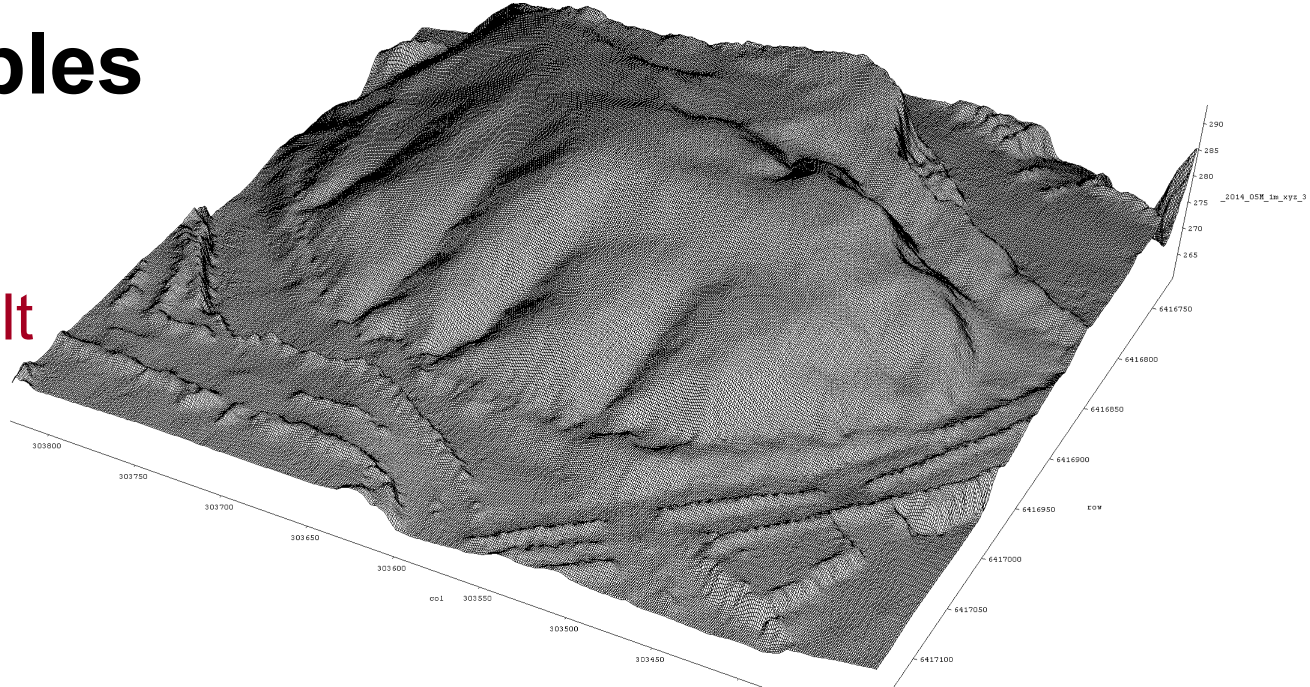
Model inputs and capabilities

- Digital elevation model
- Hydrology and sediment transport data for calibration
- Rainfall data
- Soil information (particle size, erodibility)

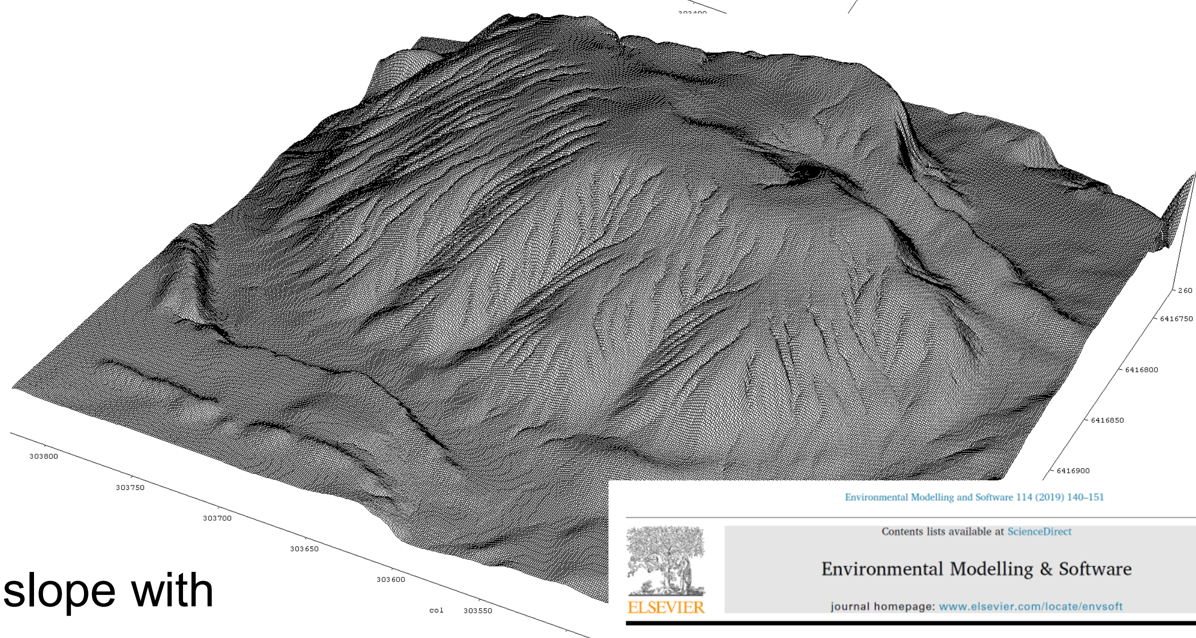
- Latest models have armouring, vegetation growth and pedogenesis functions

Some examples

Landscape as built



100 years



Gullying occurs on the hillslope with deposition in channels

Environmental Modelling and Software 114 (2019) 140–151

Contents lists available at ScienceDirect

ELSEVIER

Environmental Modelling & Software

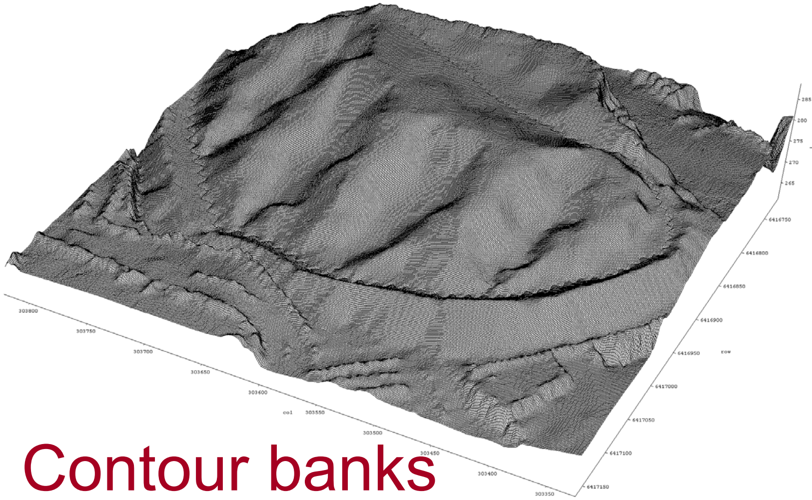
journal homepage: www.elsevier.com/locate/envsoft

Position Paper

Geomorphic design and modelling at catchment scale for best mine rehabilitation – The Drayton mine example (New South Wales, Australia)

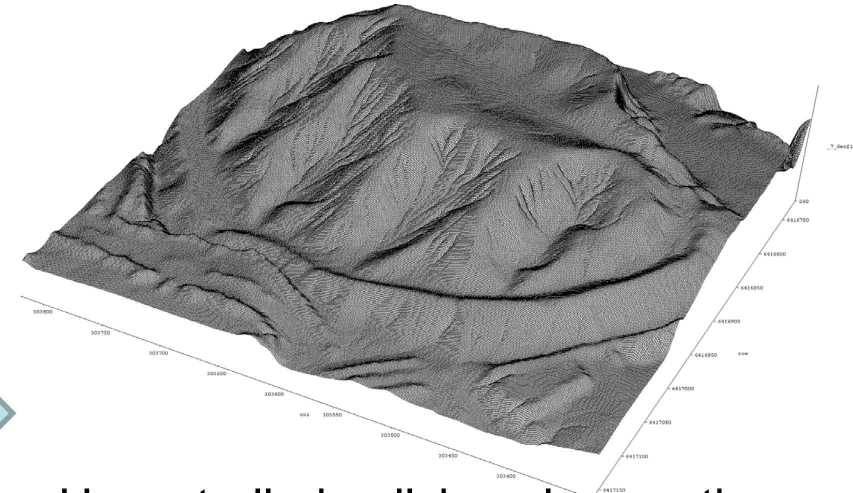
G.R. Hancock[a,*], JF Martín Duque[a,b,c], G.R. Willgoose[d]

Proposed landscapes

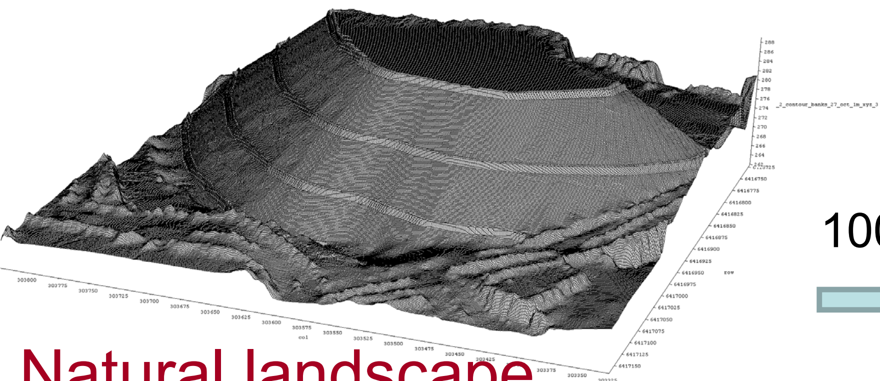


100 years

Less and smaller gullying on hillslopes

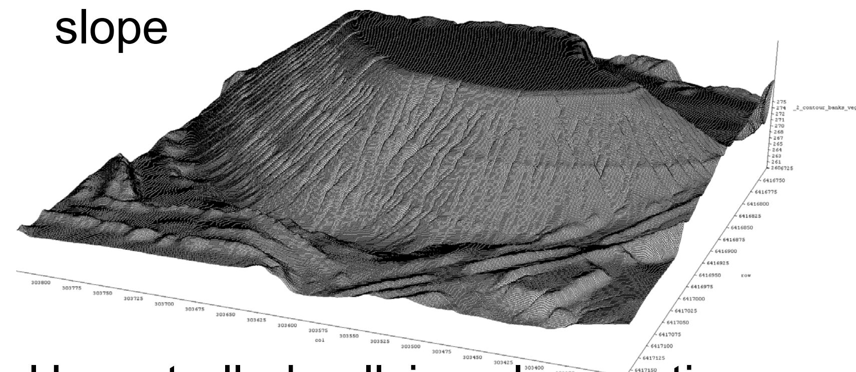


Contour banks

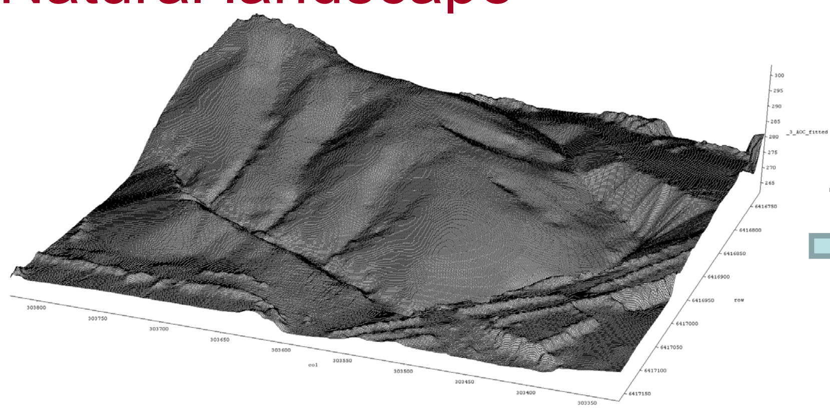


100 years

Uncontrolled gullying along entire slope

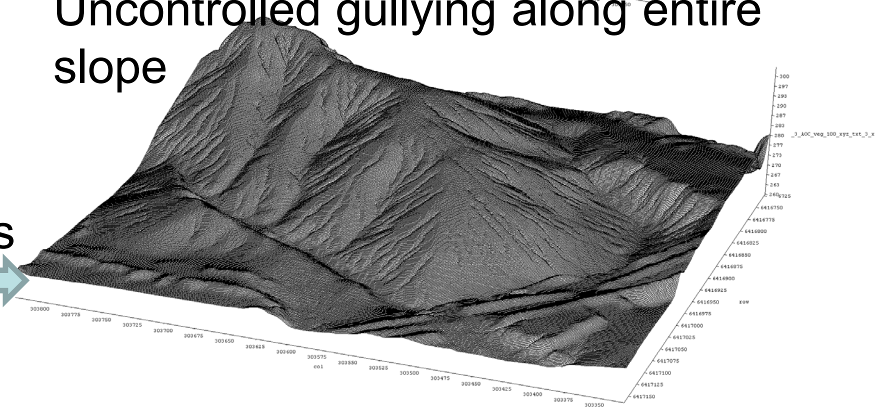


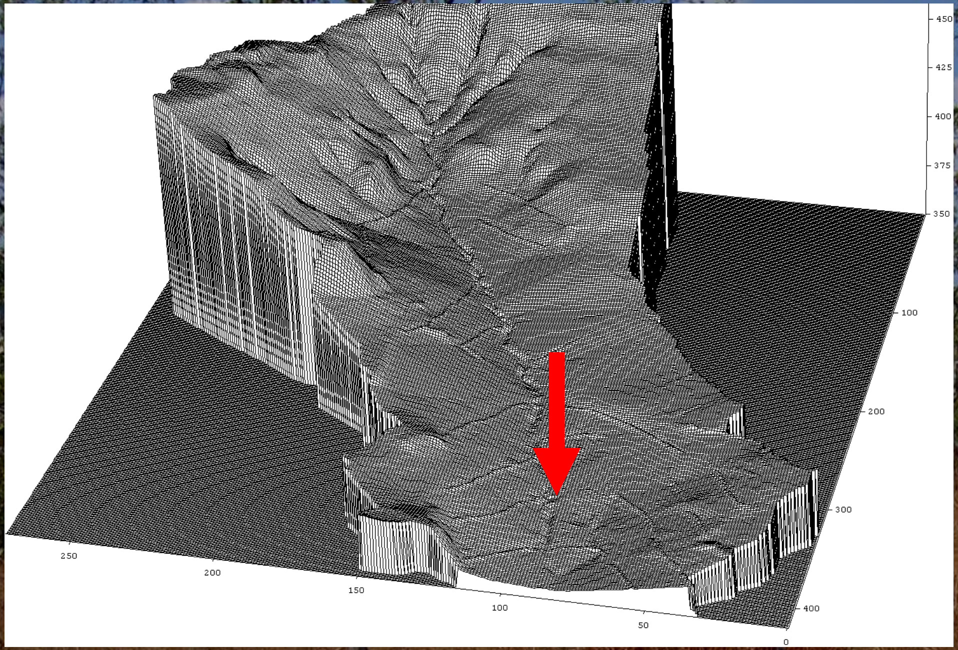
Natural landscape

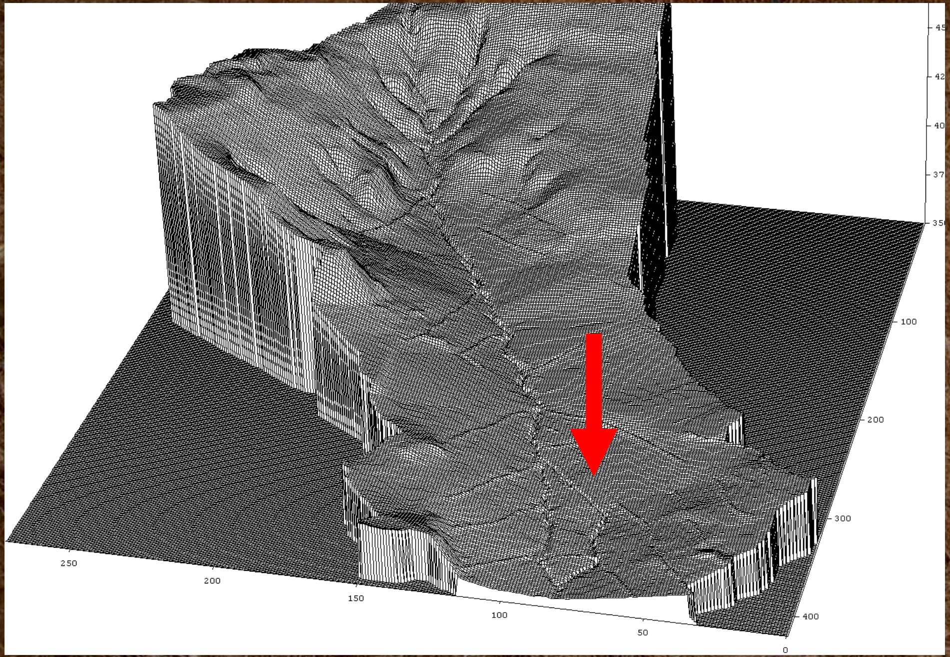


100 years

Uncontrolled gullying along entire slope





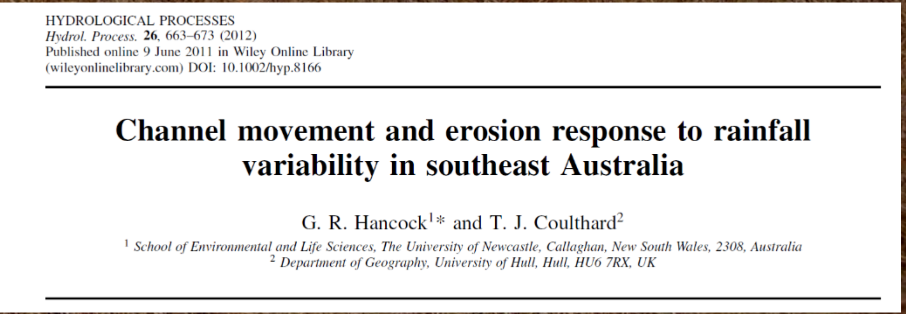


Stanley catchment, NSW

Channel movement

Different rainfall events can produce channel movement

Position, pattern and timing unique to rainfall used


HYDROLOGICAL PROCESSES
Hydrol. Process. **26**, 663–673 (2012)
Published online 9 June 2011 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/hyp.8166

Channel movement and erosion response to rainfall variability in southeast Australia

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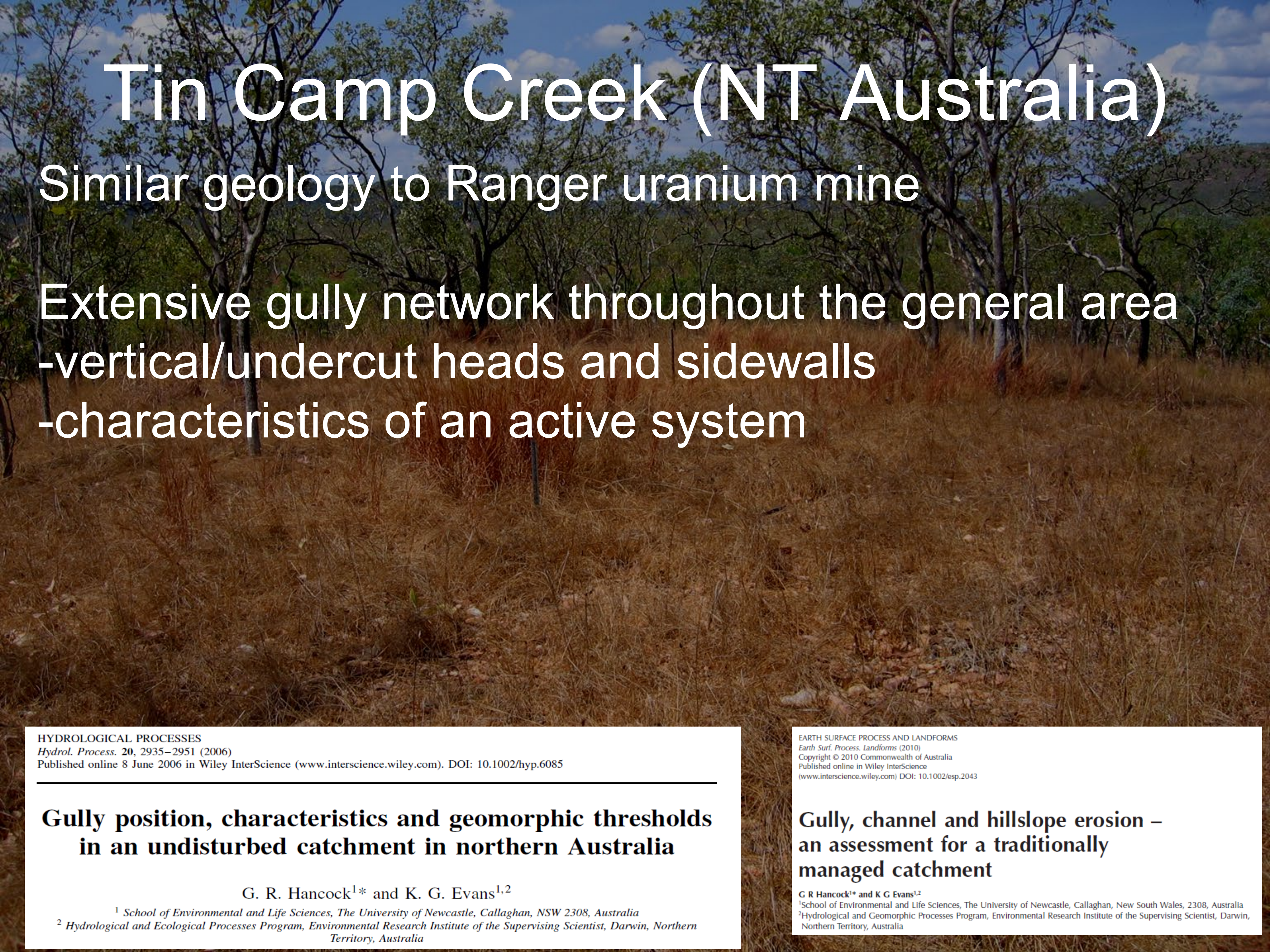
[2] *Department of Geography, University of Hull, Hull, HU6 7RX, UK*



Tin Camp Creek (NT Australia)

Similar geology to Ranger uranium mine

Extensive gully network throughout the general area
-vertical/undercut heads and sidewalls
-characteristics of an active system

HYDROLOGICAL PROCESSES
Hydrol. Process. **20**, 2935–2951 (2006)
Published online 8 June 2006 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hyp.6085

Gully position, characteristics and geomorphic thresholds in an undisturbed catchment in northern Australia

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[2] *Hydrological and Ecological Processes Program, Environmental Research Institute of the Supervising Scientist, Darwin, Northern Territory, Australia*

EARTH SURFACE PROCESS AND LANDFORMS
Earth Surf. Process. Landforms (2010)

Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/esp.2043

Gully, channel and hillslope erosion – an assessment for a traditionally managed catchment

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[2]Hydrological and Geomorphic Processes Program, Environmental Research Institute of the Supervising Scientist, Darwin, Northern Territory, Australia

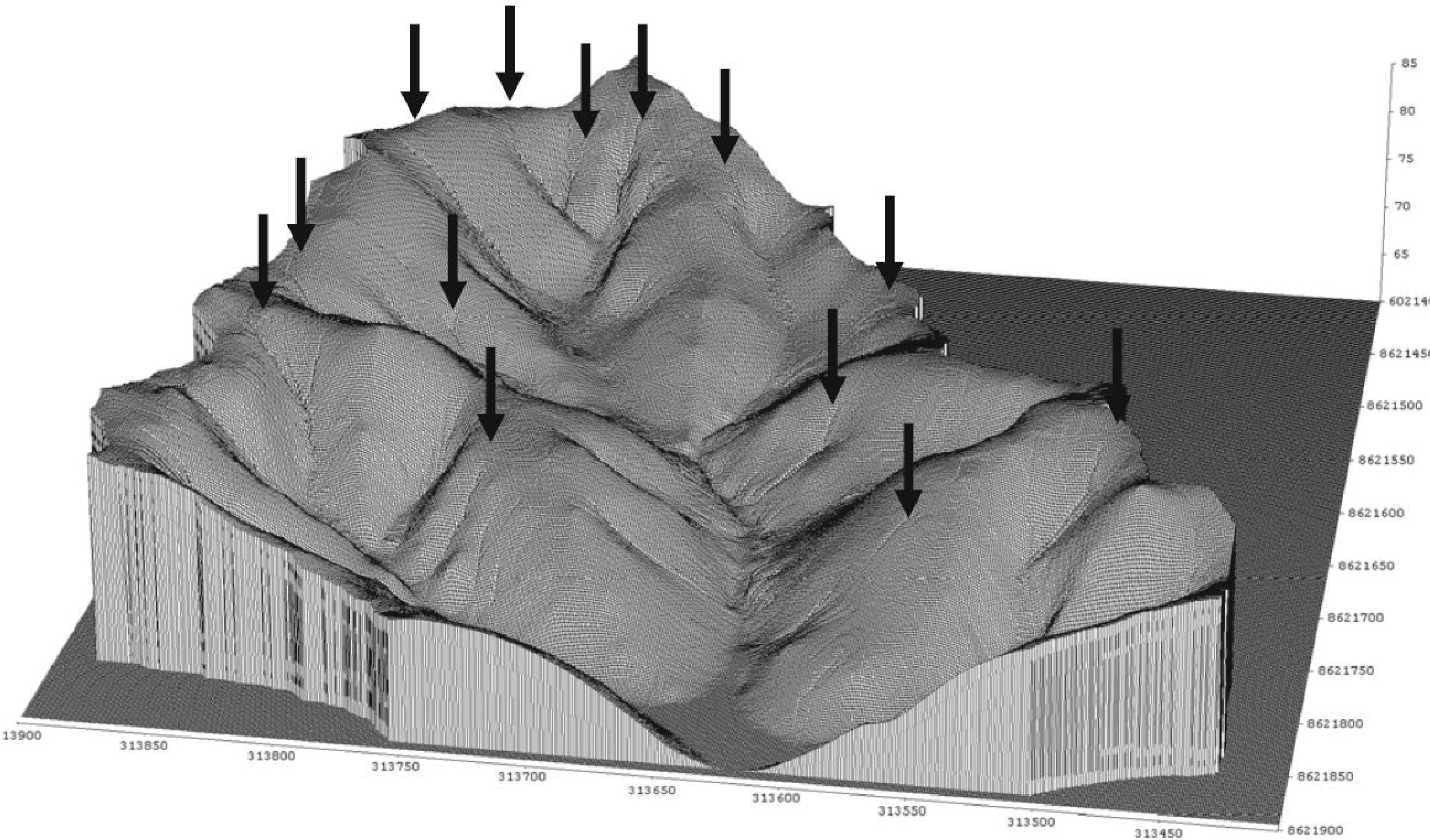


Fig. 5 Entire modelled domain of the Tin Camp Creek catchment after 50 years of erosion using C1 parameters. *Arrows* indicate the position of

Stoch Environ Res Risk Assess
DOI 10.1007/s00477-013-0741-y

ORIGINAL PAPER

Transient landscapes: gully development and evolution using a landscape evolution model

G. R. Hancock · G. R. Willgoose · John Lowry

The UNIVERSITY of NEWCASTLE AUSTRALIA

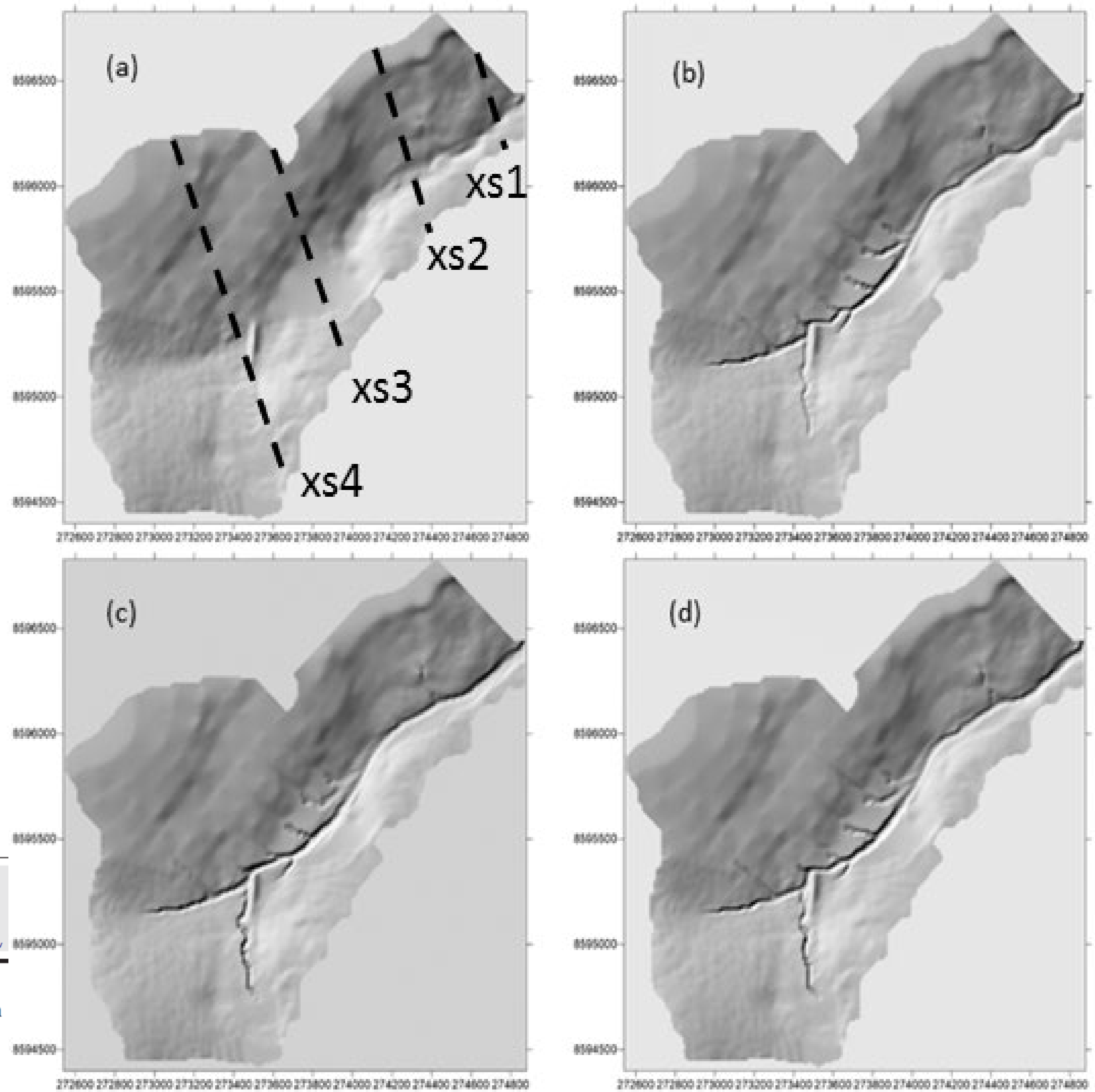
LOOK AHEAD

Results 100 years – Corridor Creek

Landscape rapidly gullies

Different rainfall scenarios produce different gully patterns

Gully position and form looks plausible



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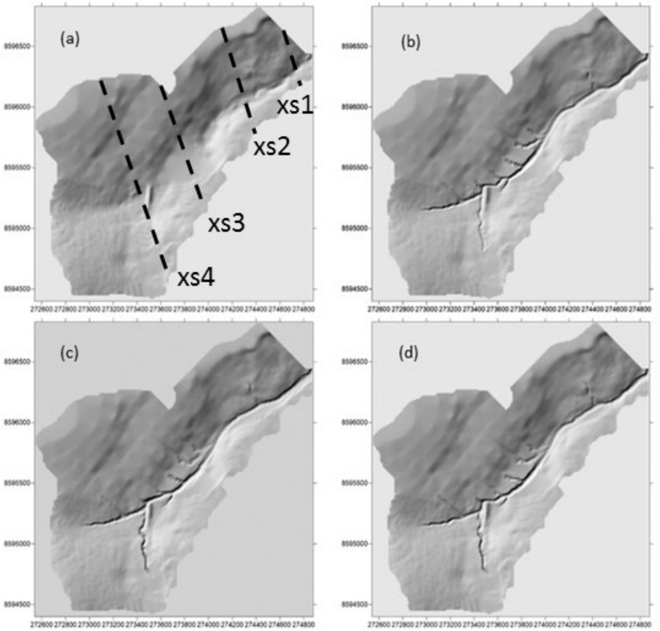
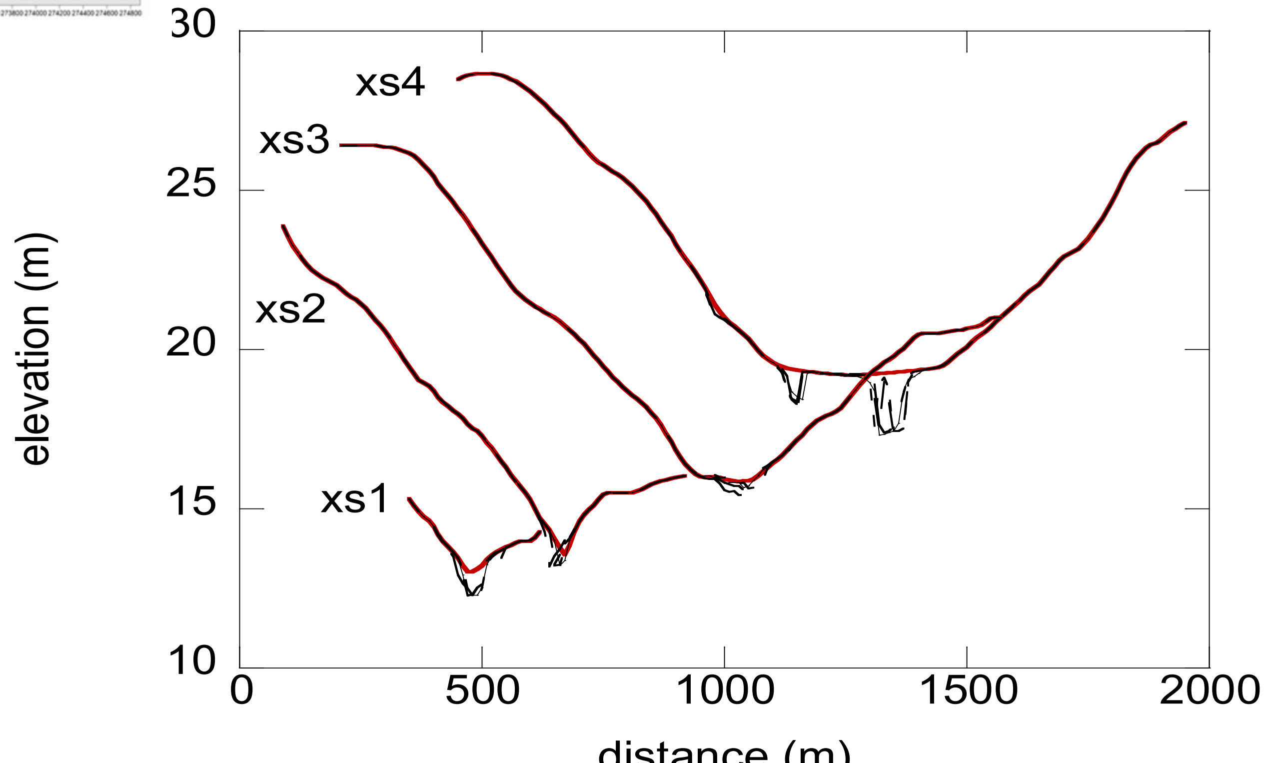
journal homepage: www.elsevier.com/locate/scitotenv

Soil erosion predictions from a landscape evolution model – An assessment of a post-mining landform using spatial climate change analogues

G.R. Hancock [a,*], Verdon-KiddD. [a], LowryJ.B.C. [b]


(a)
(b)
(c)
(d)
xs1
xs2
xs3
xs4

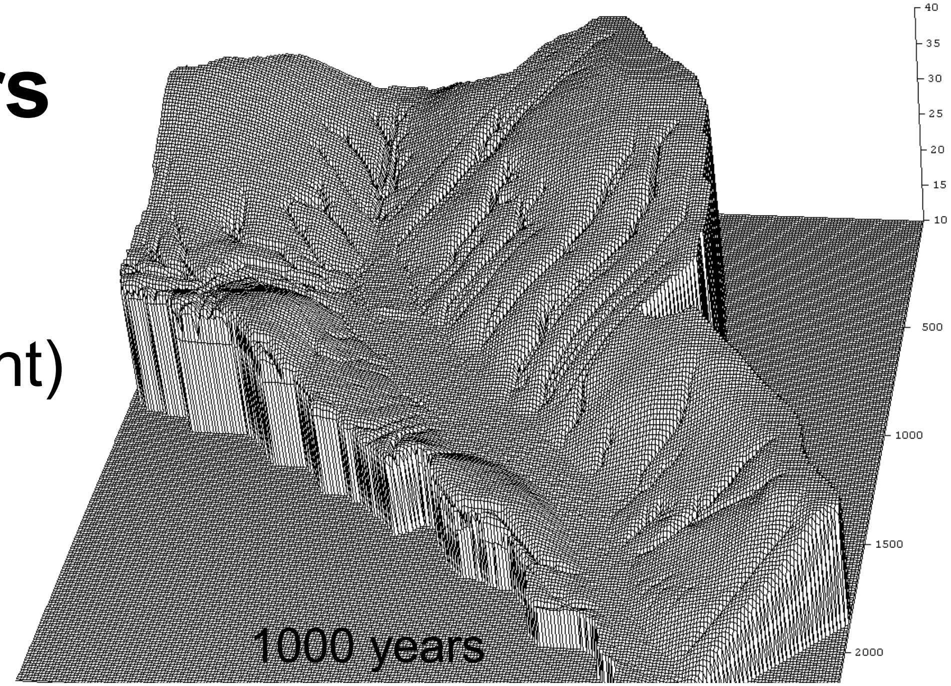

30
25
20
15
10
0
500
1000
1500
2000
elevation (m)
distance (m)
xs4
xs3
xs2
xs1

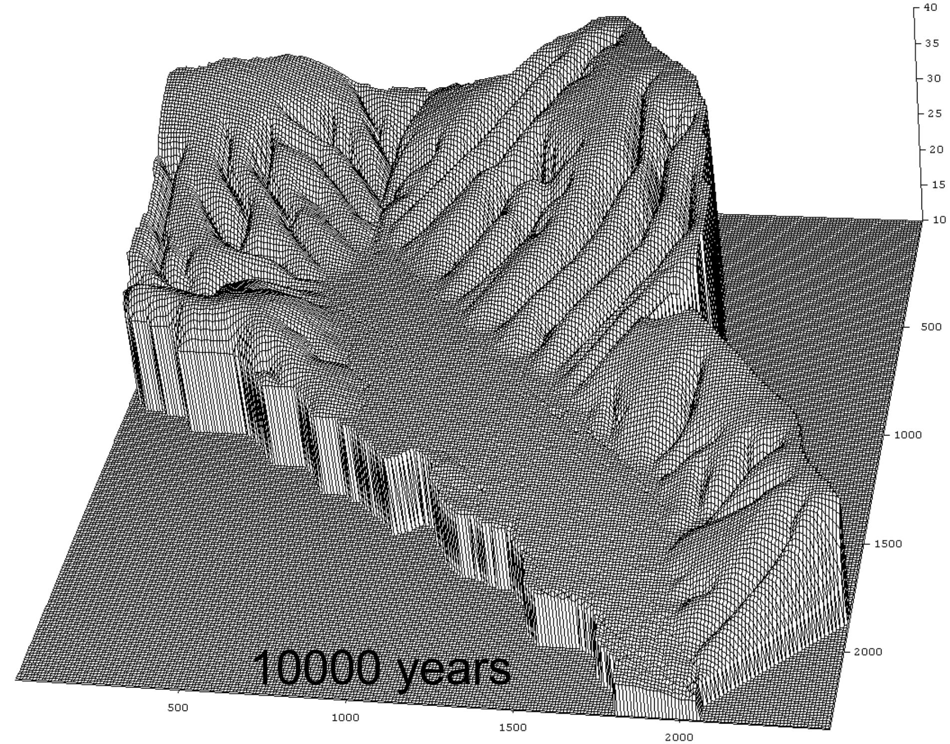
Results 100-10000 years

Predicted landscape looks plausible (qualitative assessment)

Gully position, hillslope shape look plausible

Max. depth of incision ~12 m





What do we know?

1. **Base level controls depth of gully**
   Deposition will control depth

2. **Surface roughness will reduce erosion**
   i.e. loss of connectivity

3. **Surface conditions will change with time and erosion rates will reduce**
   (and we have limited data on this)

Conclusion

- We demonstrate the application and usefulness of landscape evolution models for gully understandings
- Valuable tools which can help understand the environment
- Models are continually evolving with new capabilities

Earth Surf. Dynam., 4, 607–625, 2016
www.earth-surf-dynam.net/4/607/2016/
doi:10.5194/esurf-4-607-2016

Earth Surface Dynamics
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Exploring the sensitivity on a soil area-slope-grading relationship to changes in process parameters using a pedogenesis model

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AGU PUBLICATIONS
JGR
Journal of Geophysical Research: Earth Surface
RESEARCH ARTICLE
10.1002/2014JF003186

The effects of sediment transport, weathering, and aeolian mechanisms on soil evolution

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Key Points:
- Soil evolution in aeolian landscapes differ from bedrock-weathering landscapes
- Armoring plays a major role in soil evolution in bedrock-weathering landscapes
- Aeolian landscapes show considerable spatial variability in soil depth and PSD

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 114, F03001, doi:10.1029/2008JF001214, 2009

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The mARM spatially distributed soil evolution model: A computationally efficient modeling framework and analysis of hillslope soil surface organization

Sagy Cohen,[1,2] Garry Willgoose,[1] and Greg Hancock[2]