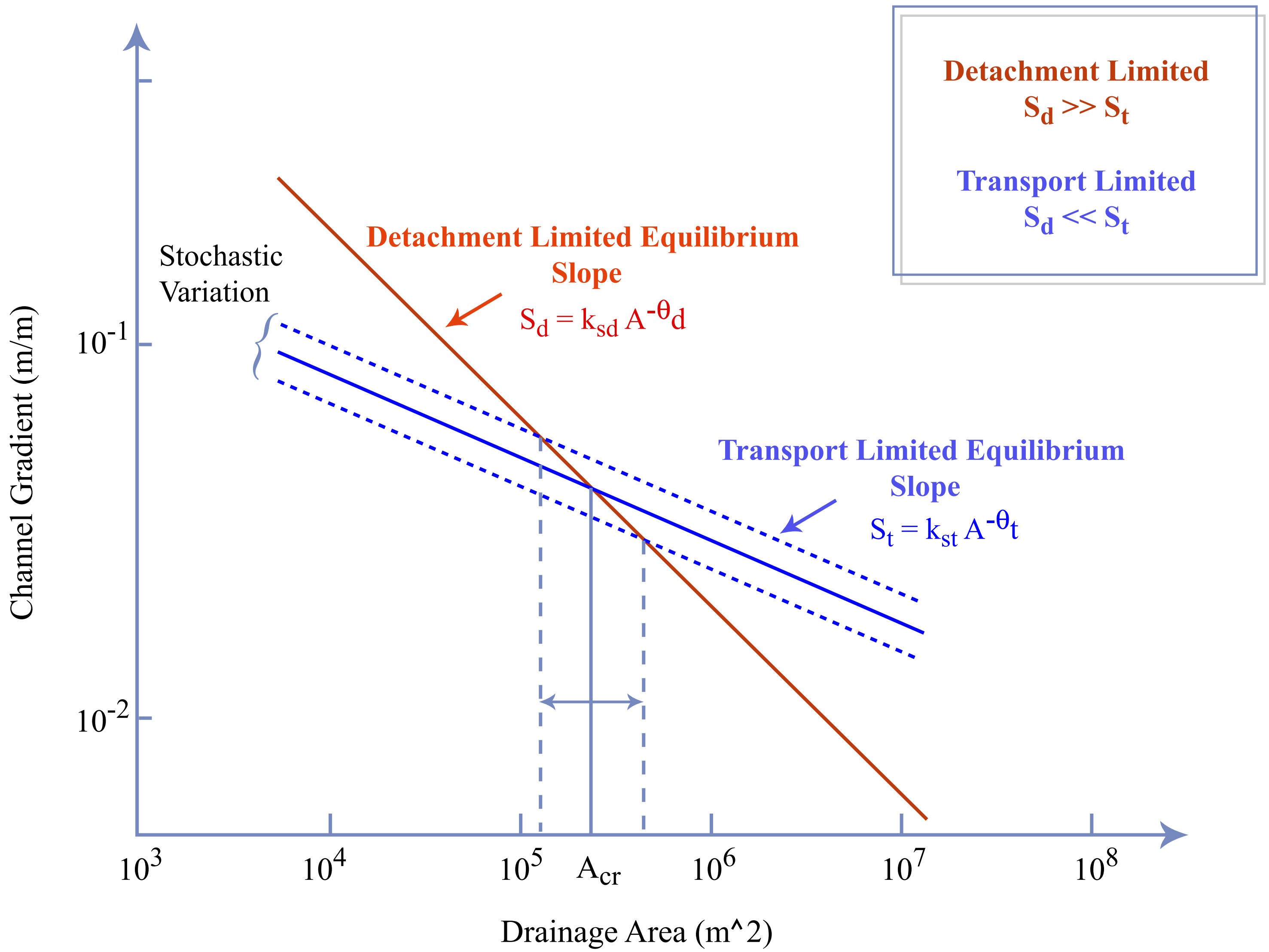
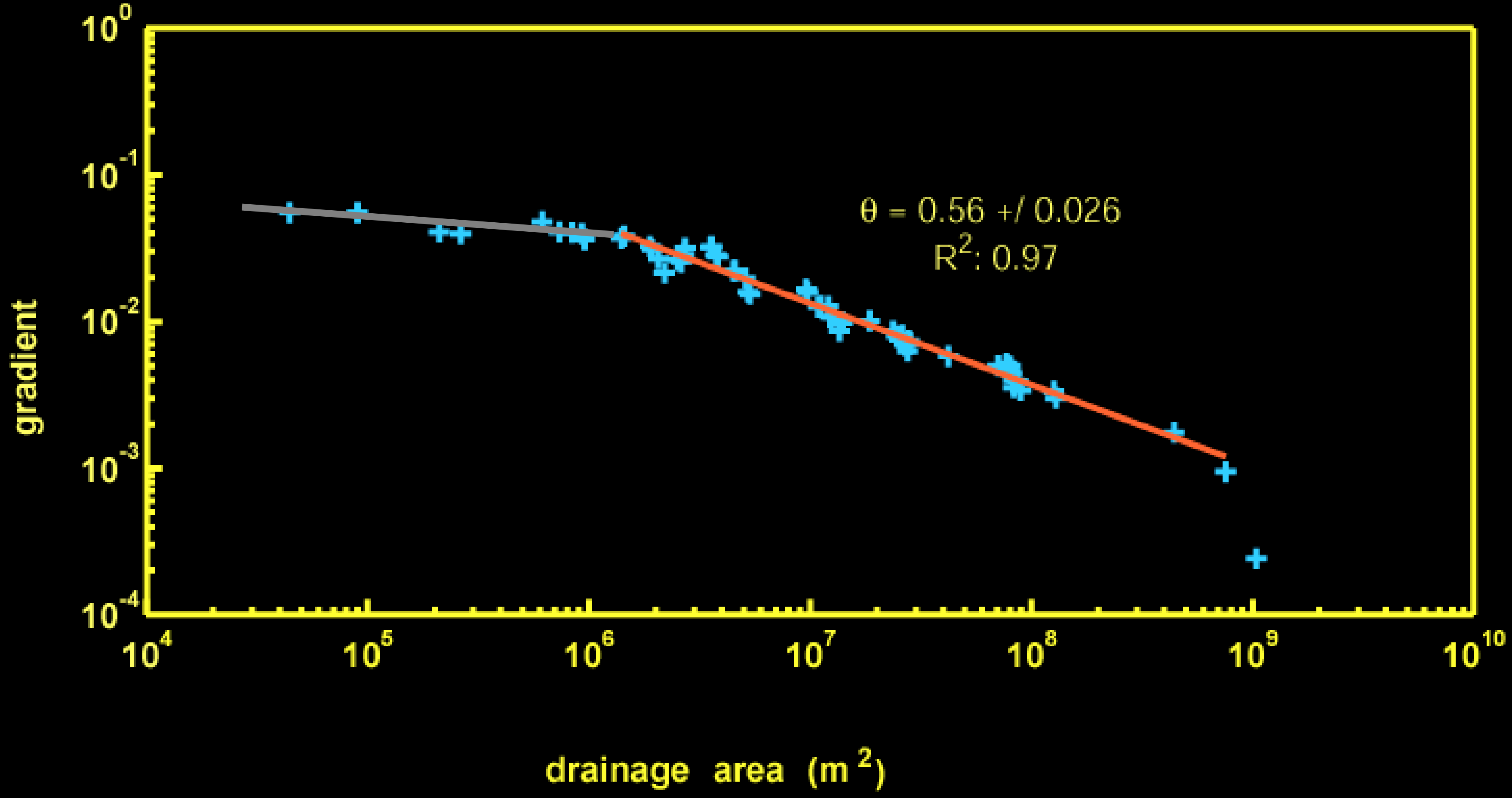
Down-stream process transition (f (q_s) = 1)



Mixed Bedrock-Alluvial Stream (Appalachians, VA)



Concavity Index indistinguishable from detachment-limited bedrock channels

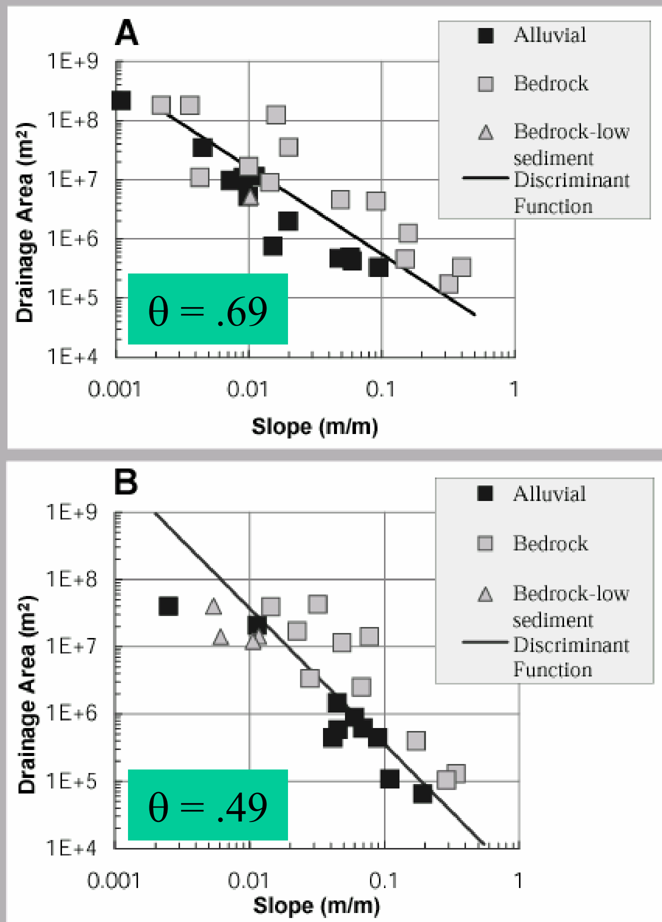


Figure 5. Bedrock and alluvial channel data from the Willapa River watershed. (A) Siltstone. (B) Basalt. All these data were used to define the location of the bedrock–alluvial channel thr old (discriminant function).

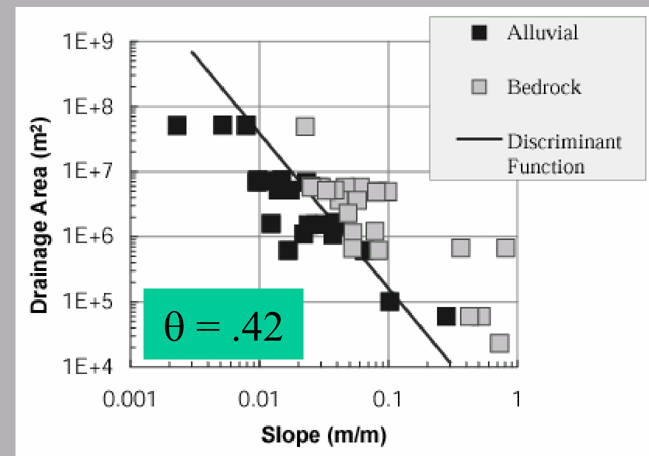


Figure 6. Bedrock and alluvial channel data from the Satsop River watershed (modified from Montgomery et al., 1996).

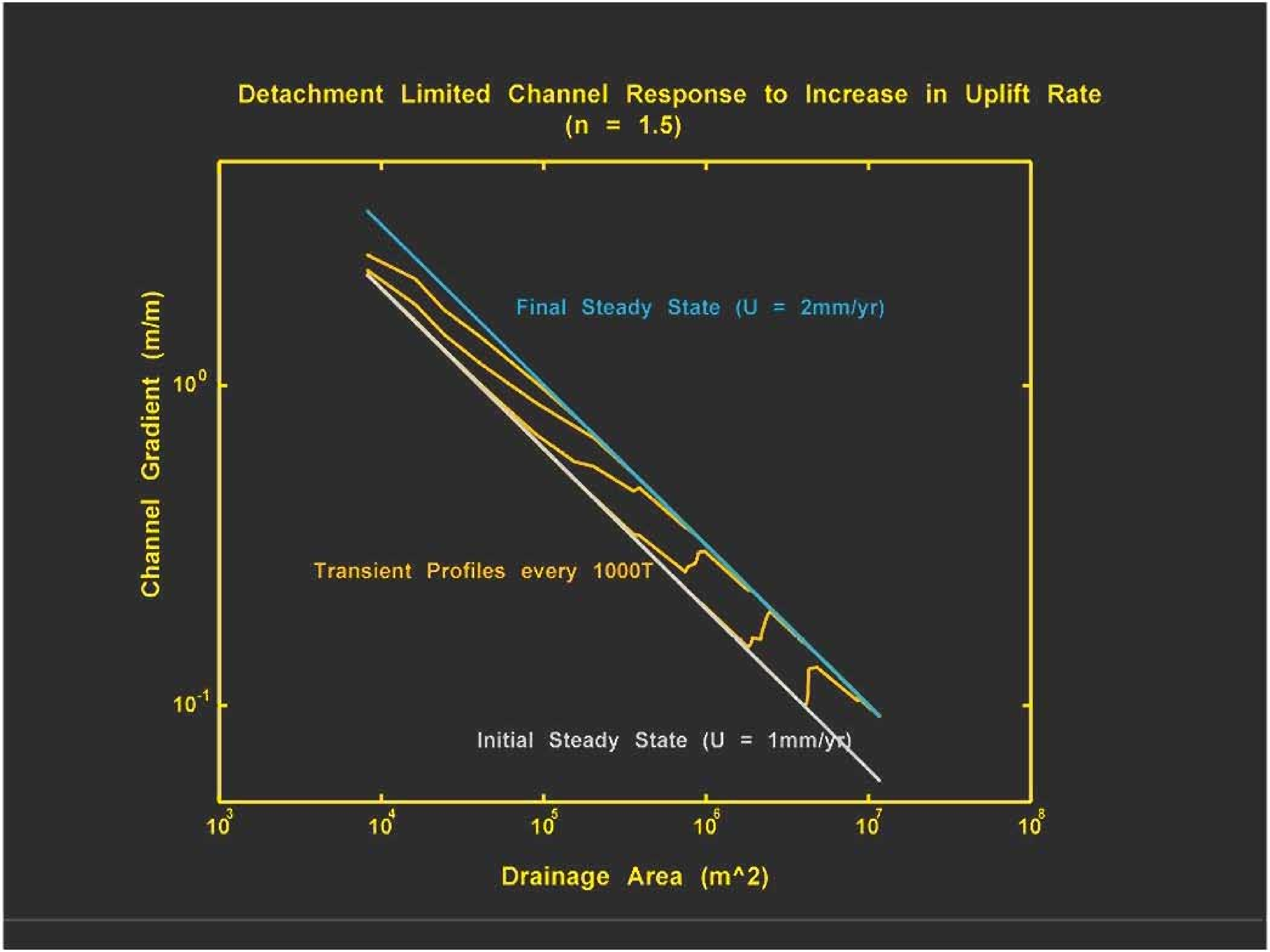
TABLE 1. SUMMARY OF DISCRIMINANT ANALYSIS RESULTS OF THE WILLAPA RIVER AND SATSOP RIVER DATA

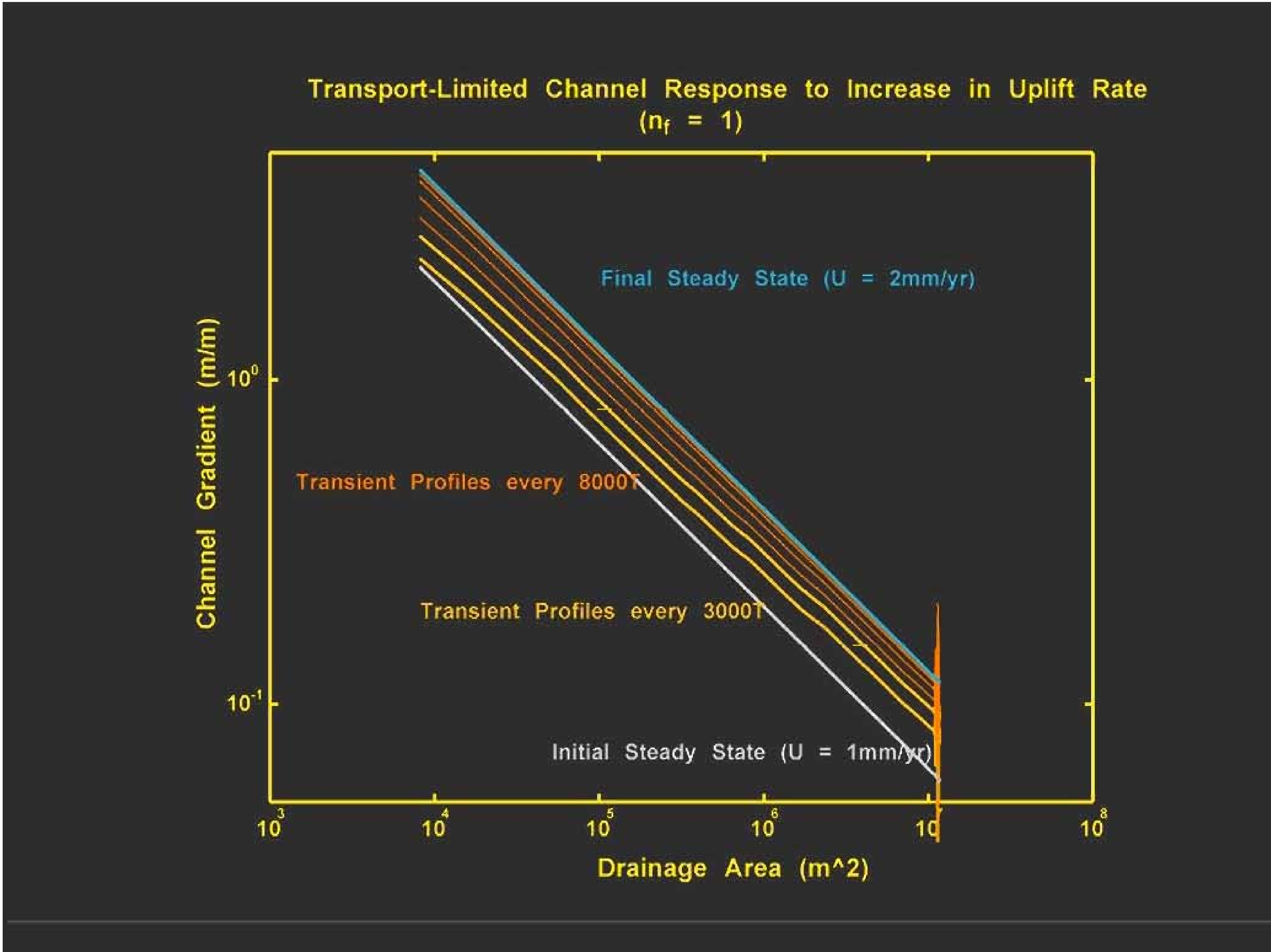
	n	Wilk's lambda*	Discriminant function	Datum correctly classified (%)
Siltstone	33	0.47	$S = 802^{*} A^{-0.69}$	94
Basalt	33	0.68	$S = 56.4^{*} A^{-0.49}$	82
Satsop River	60	0.44	$S = 15.4^{*} A^{-0.42}$	94

Notes: S—slope; *A*—area.
*Lower Lambda values indicate better discrimination possible between data.

MASSONG AND MONTGOMERY
Geological Society of America Bulletin, April 2000

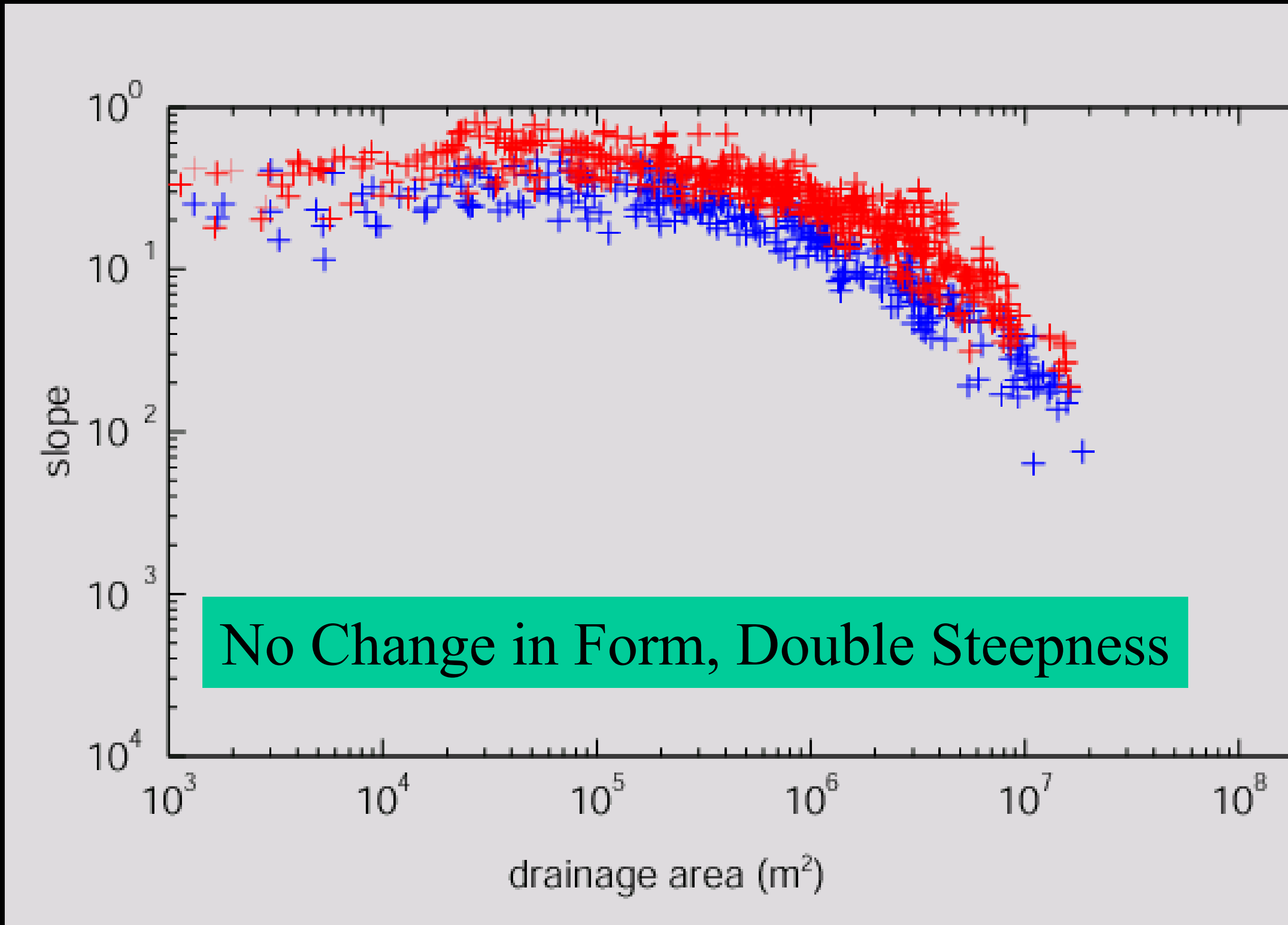
Available data suggests DL and TL streams have similar concavities


Detachment Limited Channel Response to Increase in Uplift Rate
(n = 1.5)
Final Steady State (U = 2mm/yr)
Transient Profiles every 1000T
Initial Steady State (U = 1mm/yr)
Channel Gradient (m/m)
Drainage Area (m^2)
10^0
10^-1
10^3
10^4
10^5
10^6
10^7
10^8

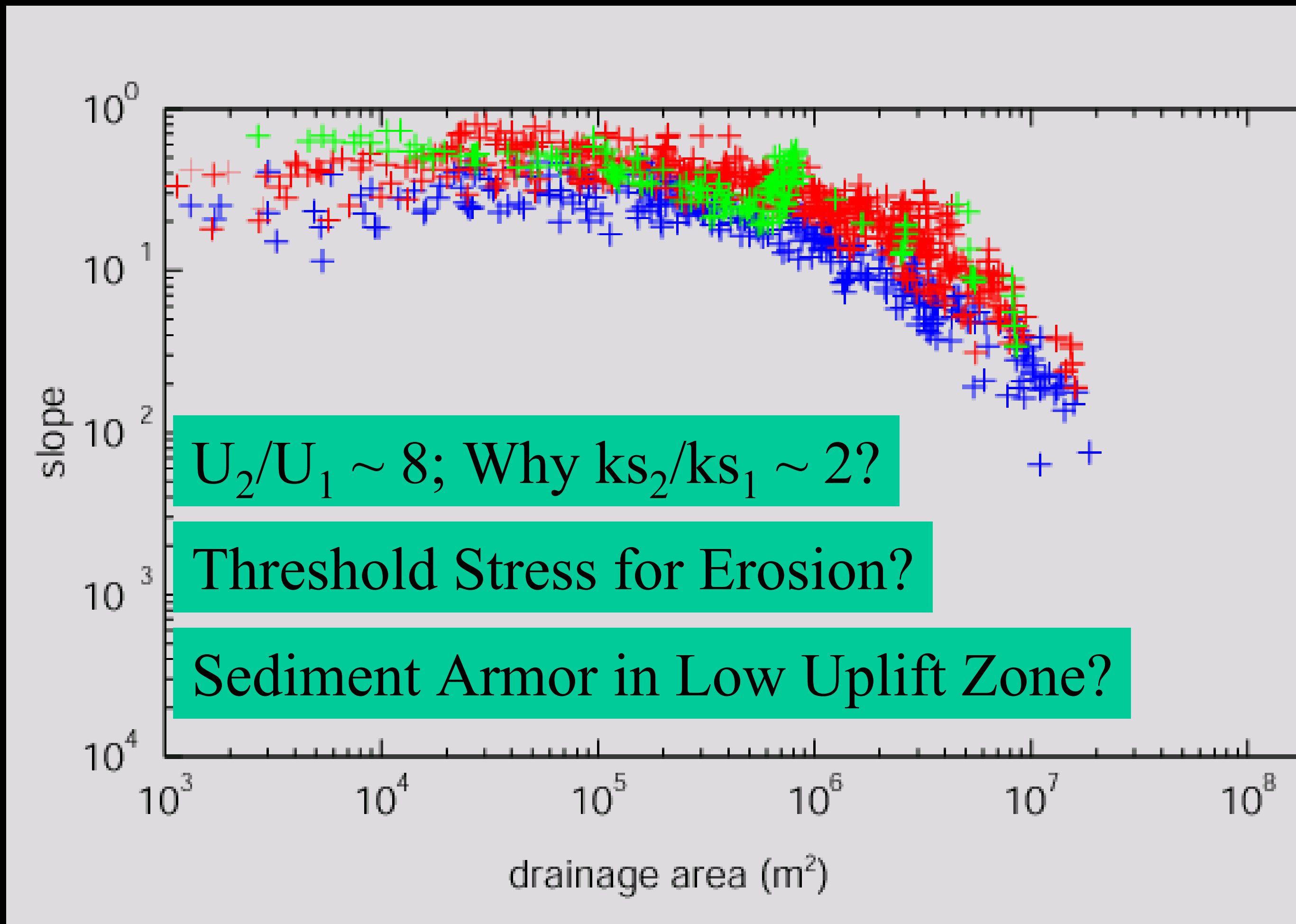


Transport-Limited Channel Response to Increase in Uplift Rate
(n_f = 1)
Final Steady State (U = 2mm/yr)
Transient Profiles every 8000T
Transient Profiles every 3000T
Initial Steady State (U = 1mm/yr)
Channel Gradient (m/m)
Drainage Area (m^2)

King Range Trunk Streams



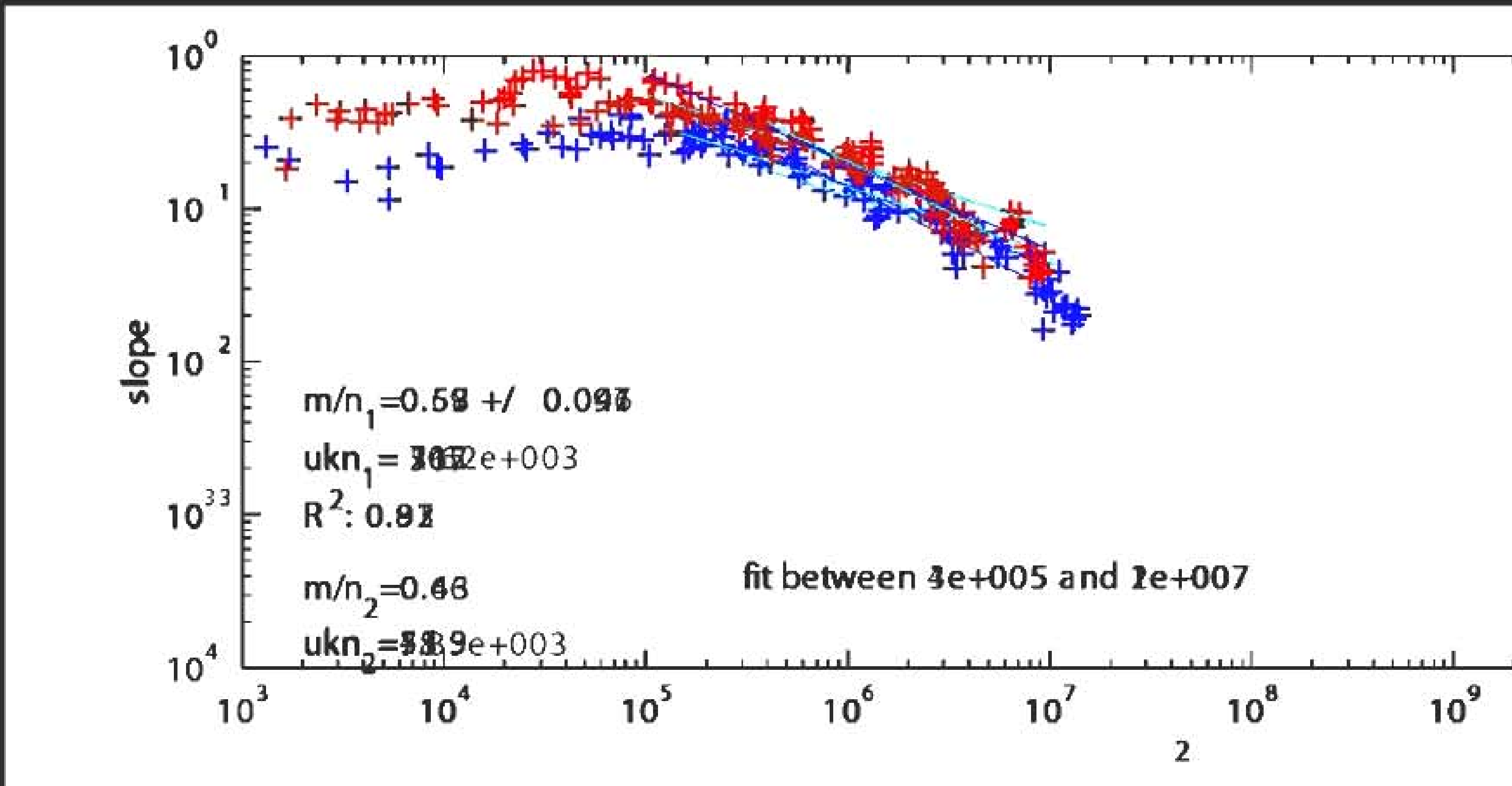
Tributary Response: Kinematic Wave



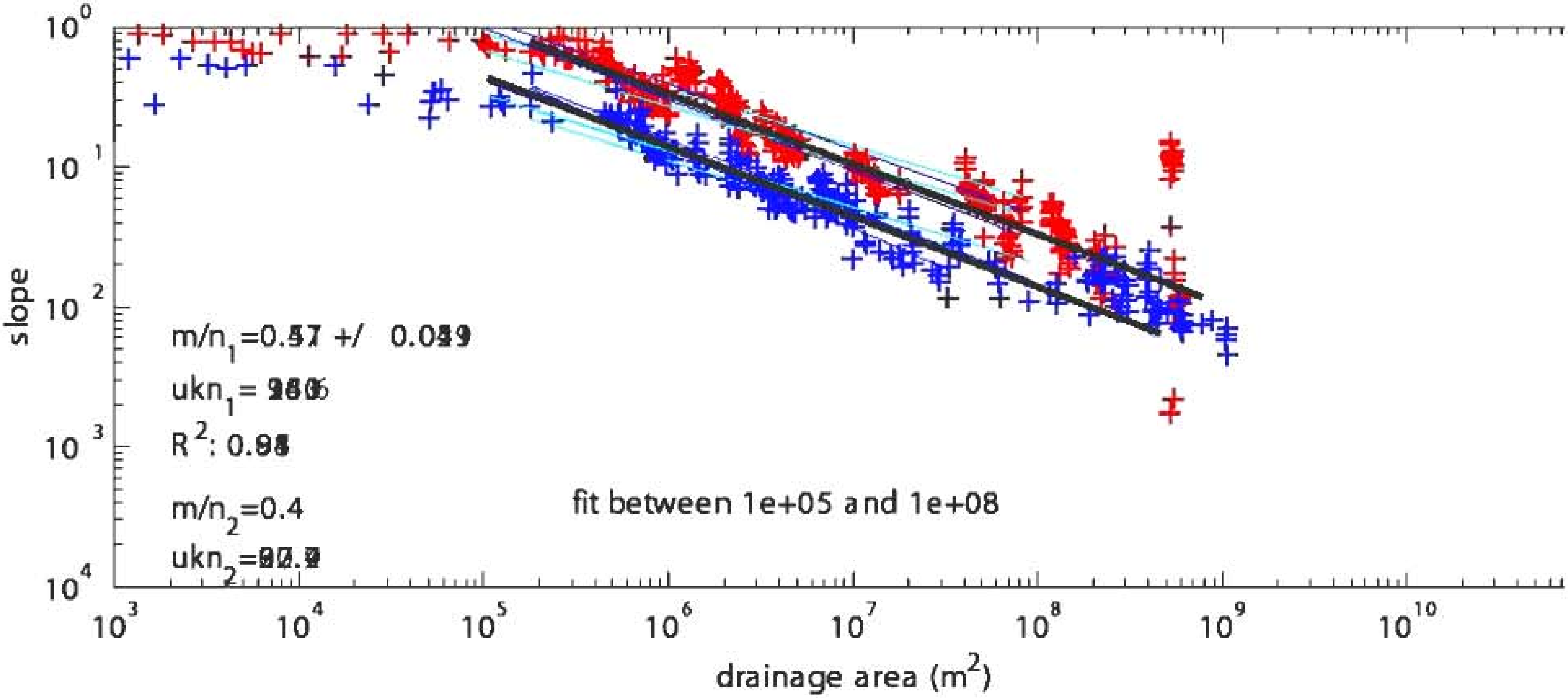
$U_2/U_1 \sim 8$; Why $ks_2/ks_1 \sim 2$?

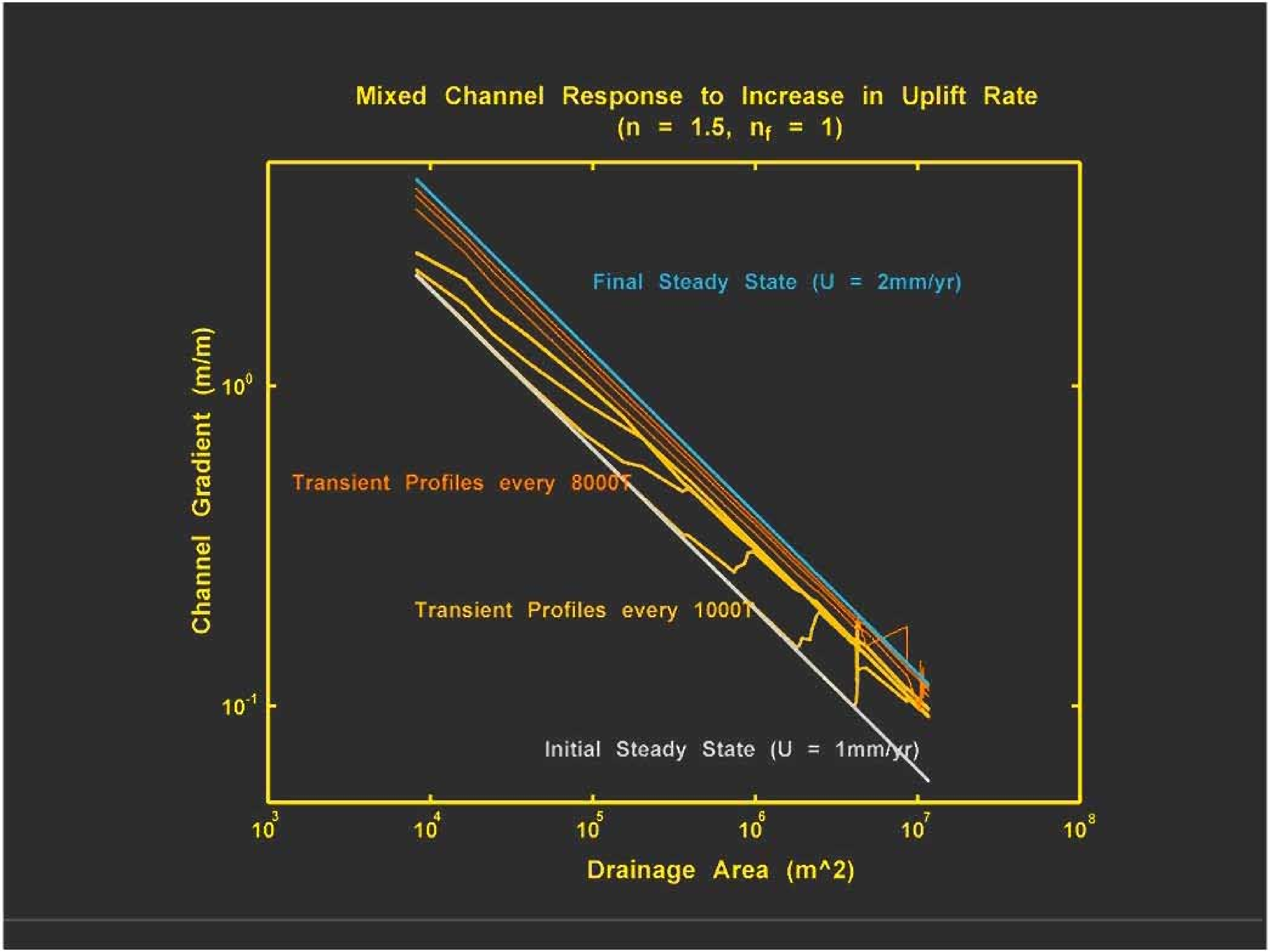
Threshold Stress for Erosion?

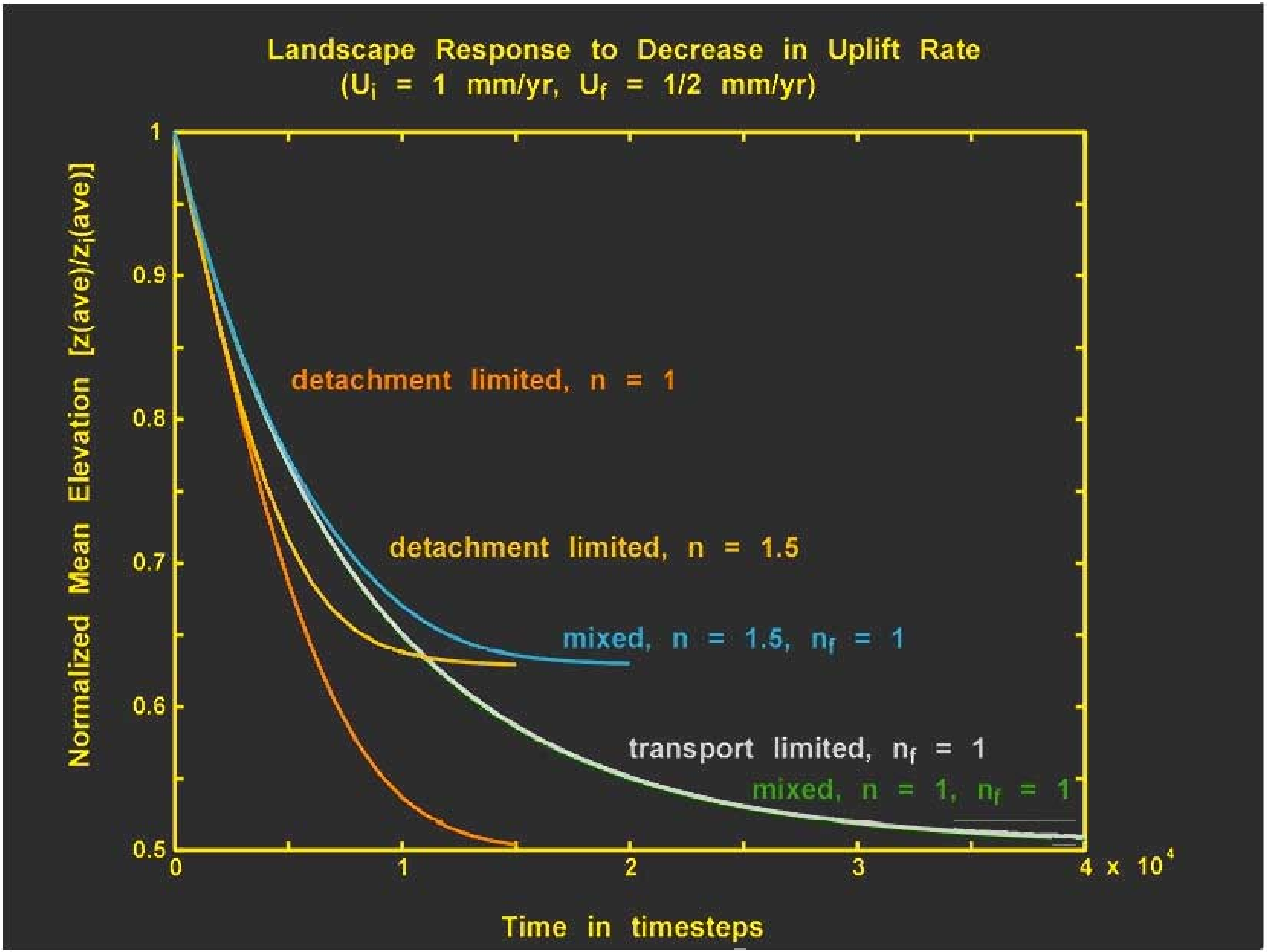
Sediment Armor in Low Uplift Zone?



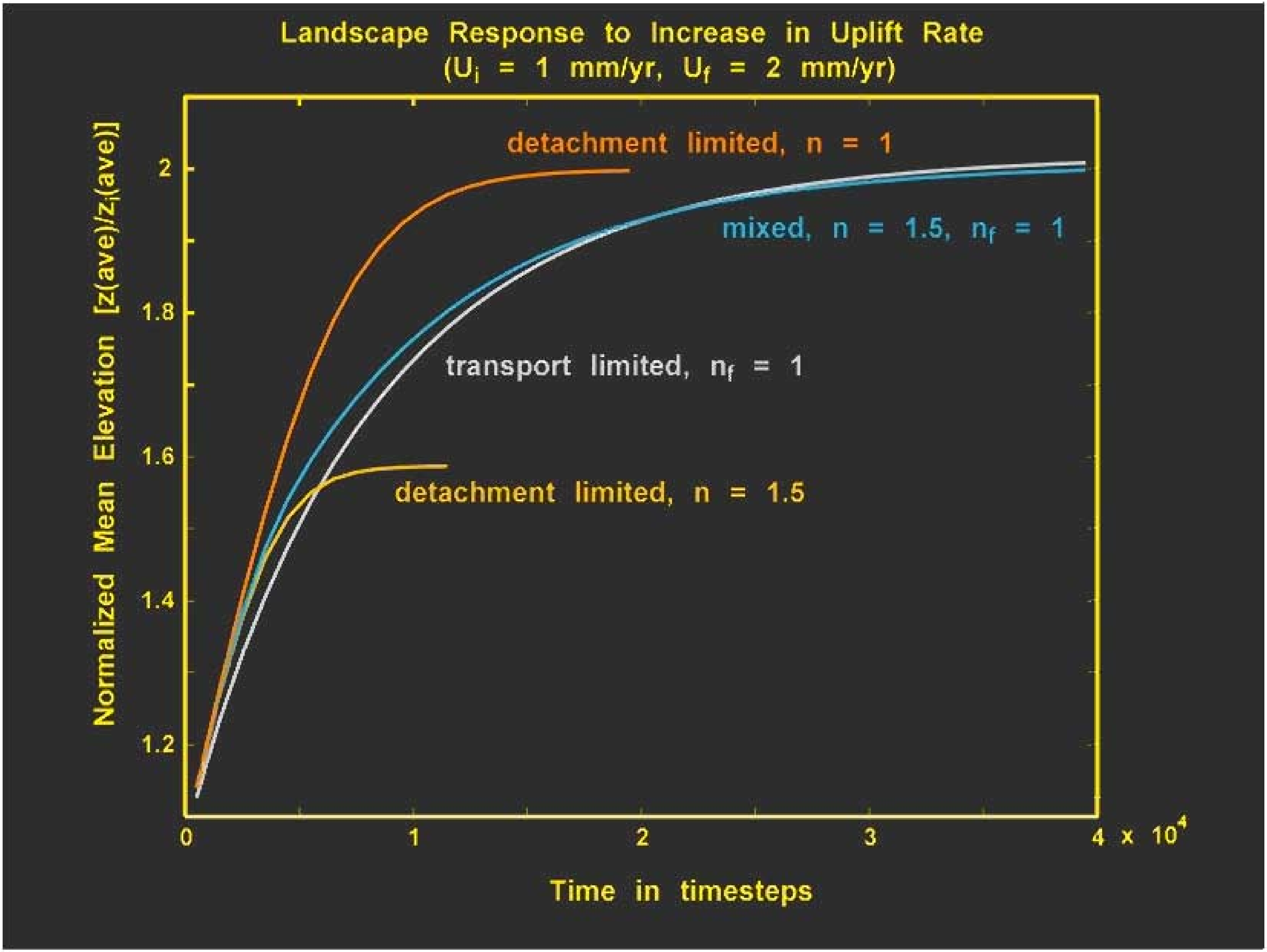
slope
m/n1=0.58 +/ 0.097
ukn1= 3.61e+003
R2: 0.92
m/n2=0.46
ukn2=5.89e+003
fit between 3e+005 and 1e+007


slope
drainage area (m2)
fit between 1e+05 and 1e+08
m/n2=0.4

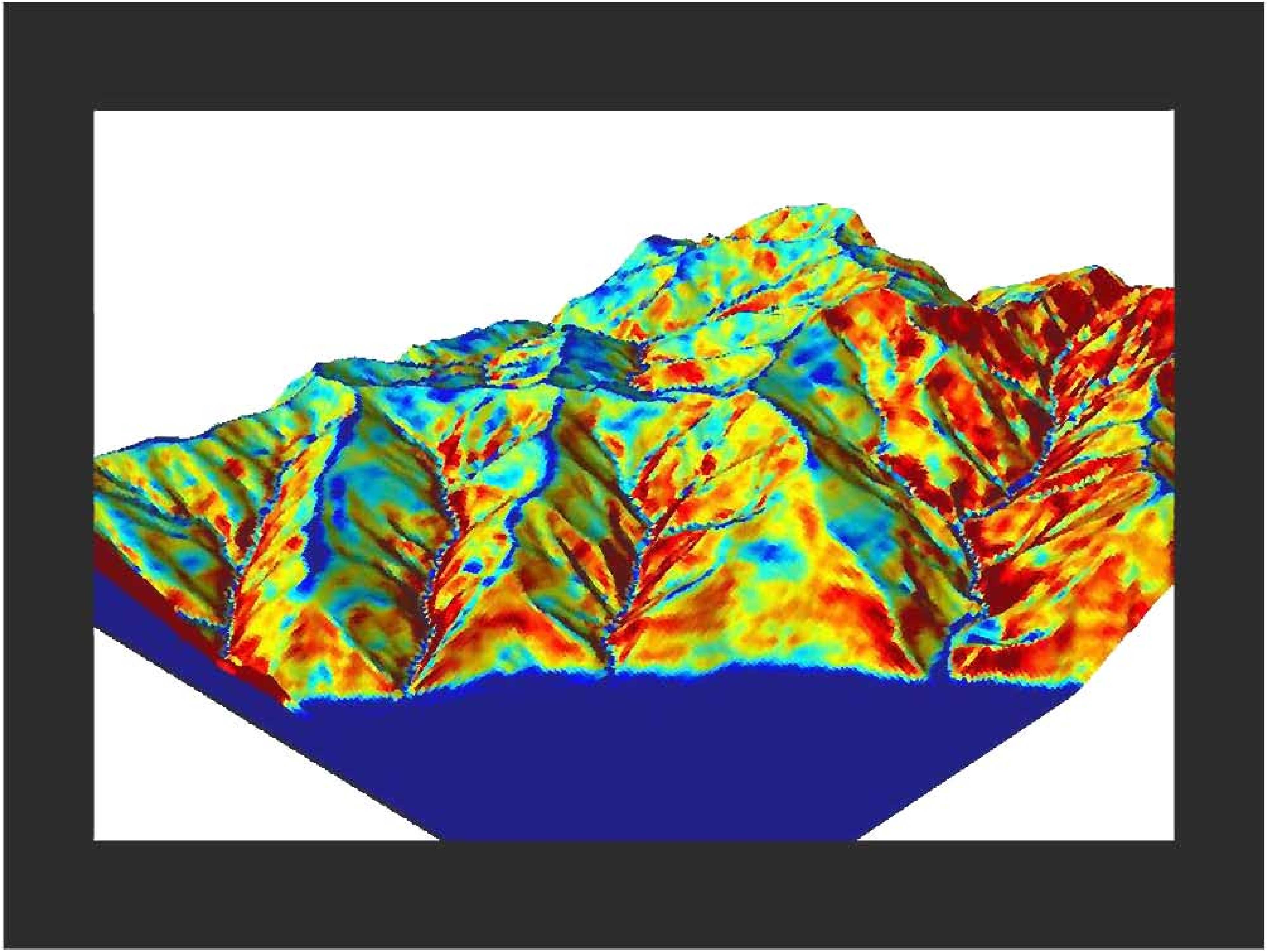

Mixed Channel Response to Increase in Uplift Rate
(n = 1.5, n_f = 1)
Final Steady State (U = 2mm/yr)
Transient Profiles every 8000T
Transient Profiles every 1000T
Initial Steady State (U = 1mm/yr)
Channel Gradient (m/m)
10^0
10^{-1}
10^3
10^4
10^5
10^6
10^7
10^8
Drainage Area (m^2)



Landscape Response to Decrease in Uplift Rate
(U_i = 1 mm/yr, U_f = 1/2 mm/yr)
Normalized Mean Elevation [z(ave)/z_i(ave)]
1
0.9
0.8
0.7
0.6
0.5
0
1
2
3
4 x 10^4
Time in timesteps
detachment limited, n = 1
detachment limited, n = 1.5
mixed, n = 1.5, n_f = 1
transport limited, n_f = 1
mixed, n = 1, n_f = 1



Landscape Response to Increase in Uplift Rate
(U$_i$ = 1 mm/yr, U$_f$ = 2 mm/yr)
detachment limited, n = 1
mixed, n = 1.5, n$_f$ = 1
transport limited, n$_f$ = 1
detachment limited, n = 1.5
Normalized Mean Elevation [z(ave)/z$_i$(ave)]
1.2
1.4
1.6
1.8
2
0
1
2
3
4 x 10^4
Time in timesteps



Tectonic Geomorphology

- Intermediate Timescale Patterns and Rates of Deformation
  - Bridge between Geodetic and Geologic
  - 1e3 – 1e6 years
  - Spatial and Temporal Resolution
- Paleoseismicity / Tsunami Records
- Interaction of Climate and Tectonics

Intermediate Timescale Deformation

Approaches

- Static Landforms as Strain Gauges
  - Terraces (fill/strath, fans, marine platforms, coral reefs, moraines, etc)
- Dynamic Topography – Invert for Rock Uplift
  - Bedrock and Alluvial Channel Networks
  - Colluvial Channels
  - Hillslopes
  - Glacial Cirques and Valleys

Intermediate Timescale Deformation

Problems

- Local/Regional Patterns and Rates of Rock Uplift
- Fault Behavior and Slip Rates
  - Kinematics and temporal evolution
- Interaction of Structures
  - Linkage, rupture across segment boundaries
- Off-Fault Deformation and Distributed Strain
- Slip Rates and Paleoseismicity of Blind Thrusts
- Role of Lower Crustal and/or Mantle Flow
  - Little / no record in upper crustal structures

Interaction of Climate and Tectonics

Problems

- Does Erosion Dictate Rock Uplift Rate / Pattern?
- Nature and Strength of Feedbacks
    - Uplift – Topography – Climate – Erosion - Uplift
- Do Details of the Erosion Mechanism Matter?
    - Bedrock Channels; Sediment flux; Debris Flows; Glaciers
- Steady State Orogens
    - Plausible? Probable? Time to Steady State?
- Impact of Late Cenozoic Climate Change
- Controls on Topographic Relief

Research Needs

Erosion Processes and Climate Linkages

- Bedrock Channel Erosion Laws (role lithology, sediment flux, sediment size, debris flows, storms)
- Glacial Erosion Mechanics (glacier flux, ice dynamics, hydrology)
- Landslide Initiation and Inventory (storms, seismic acceleration)
- Extreme Events and Orography (storms, glacier outburst floods, landslide dam-bream floods)
- Controls on River and Terrace Gradient (climate vs. tectonics; channel width)
- Chemical and Physical Weathering Relationship

Research Needs

Chronology

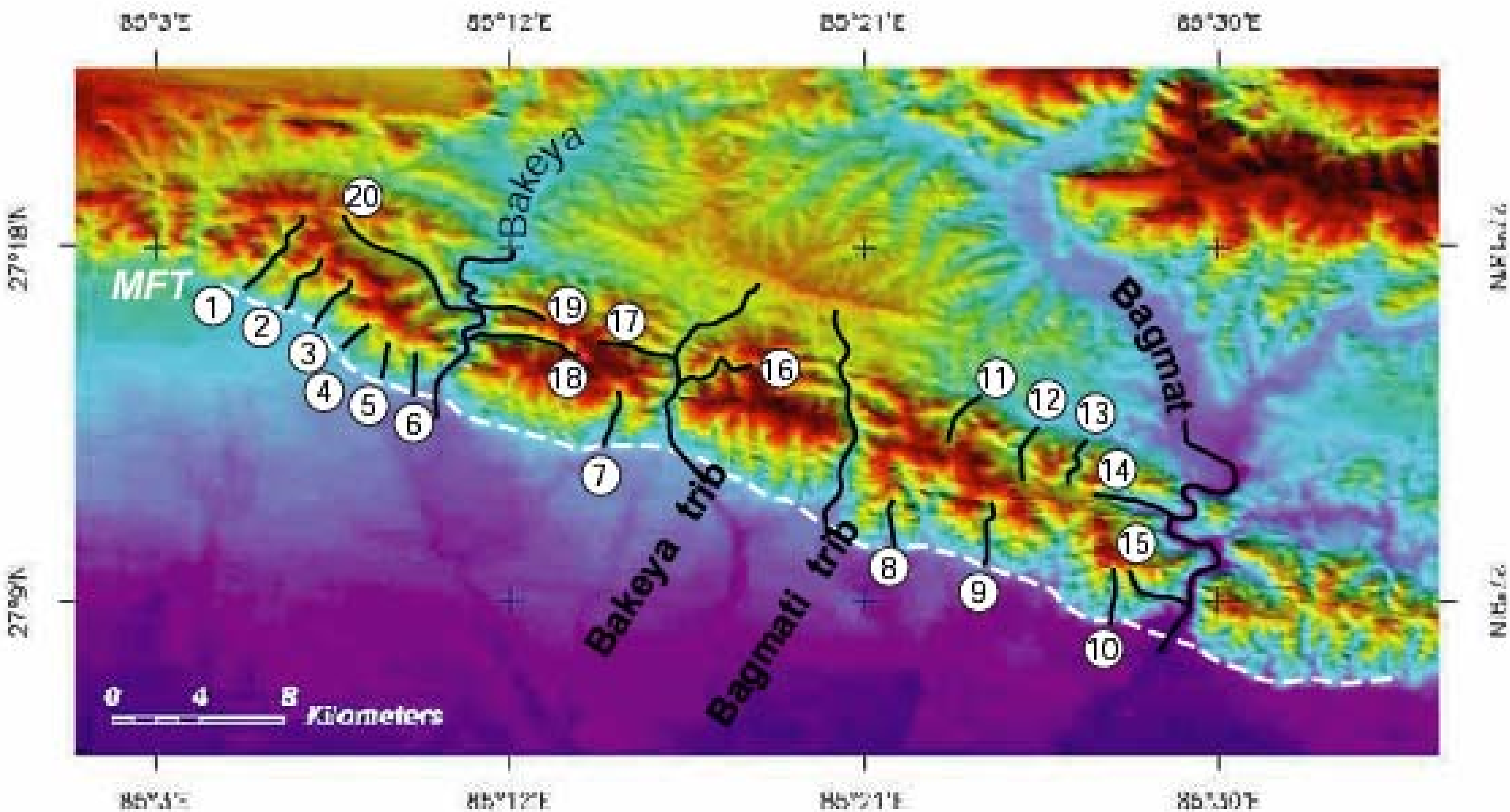
- Cosmogenic Isotope Methodologies
  - » Inheritance, Production Rates, Multiple Systems
- In-Situ / Detrital Thermochronology
- U-Th/He Dating of Young Volcanics
- Relief Evolution
  - » Topography, Denudation Rate, Isotherm Structure and their Temporal Evolution
  - » Near Surface Thermal Advection

Tectonic Geomorphology

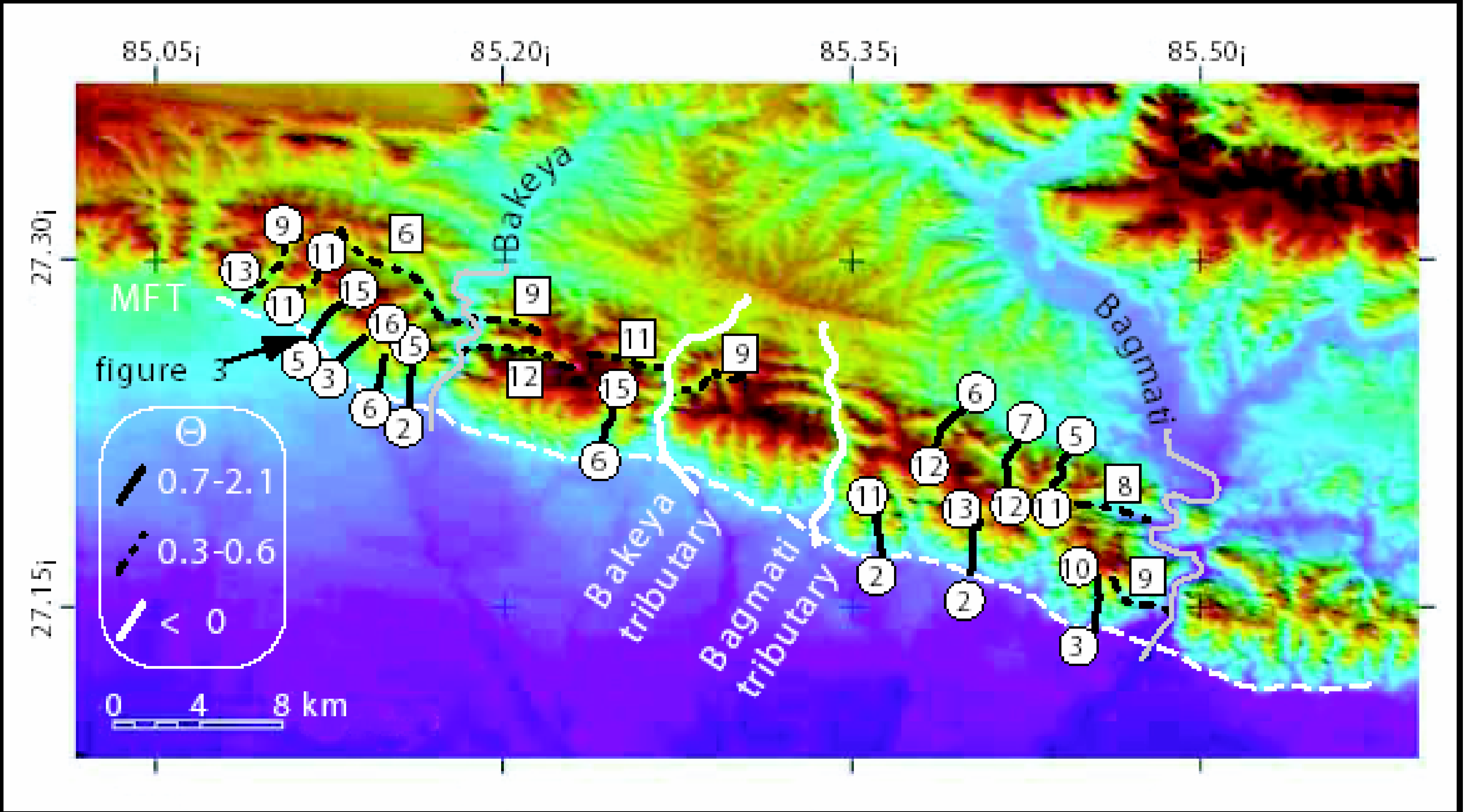
Data Needs

- Development of Chronometers and Centers for Analyses, Digital Compilation/Distribution of Data
- Affordable High-Resolution Satellite Data (ASTER, INSAR)
- High-Resolution DEMs (LIDAR, SRTM, ASTER)
- Digital Geologic Maps
- Dense Arrays Climate Data (Orography)
- Digital Mapping Technologies (e.g., PDA, Laser Range Finder, GPS Total Station)
- GPR – Shallow Structures

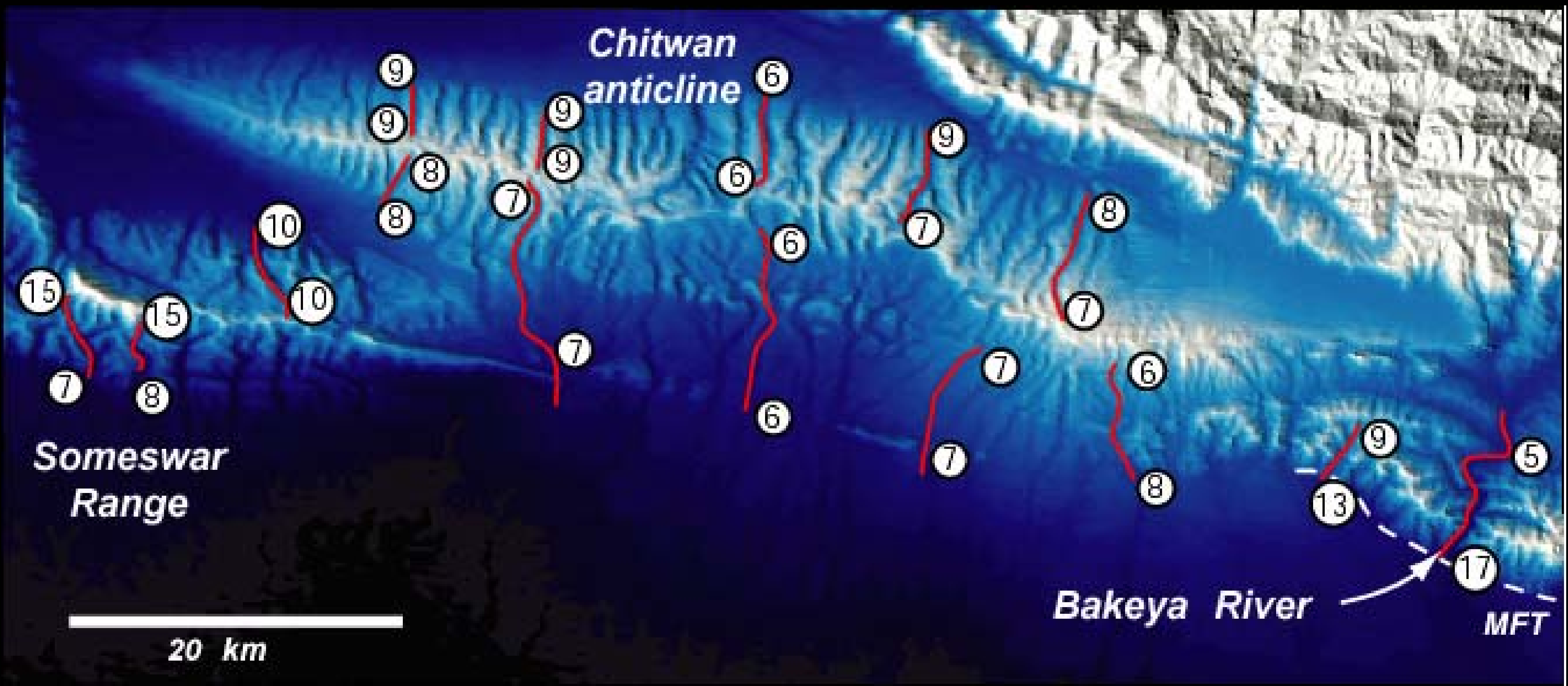
Siwalik Hills Anticline
Himalaya Foreland, Nepal



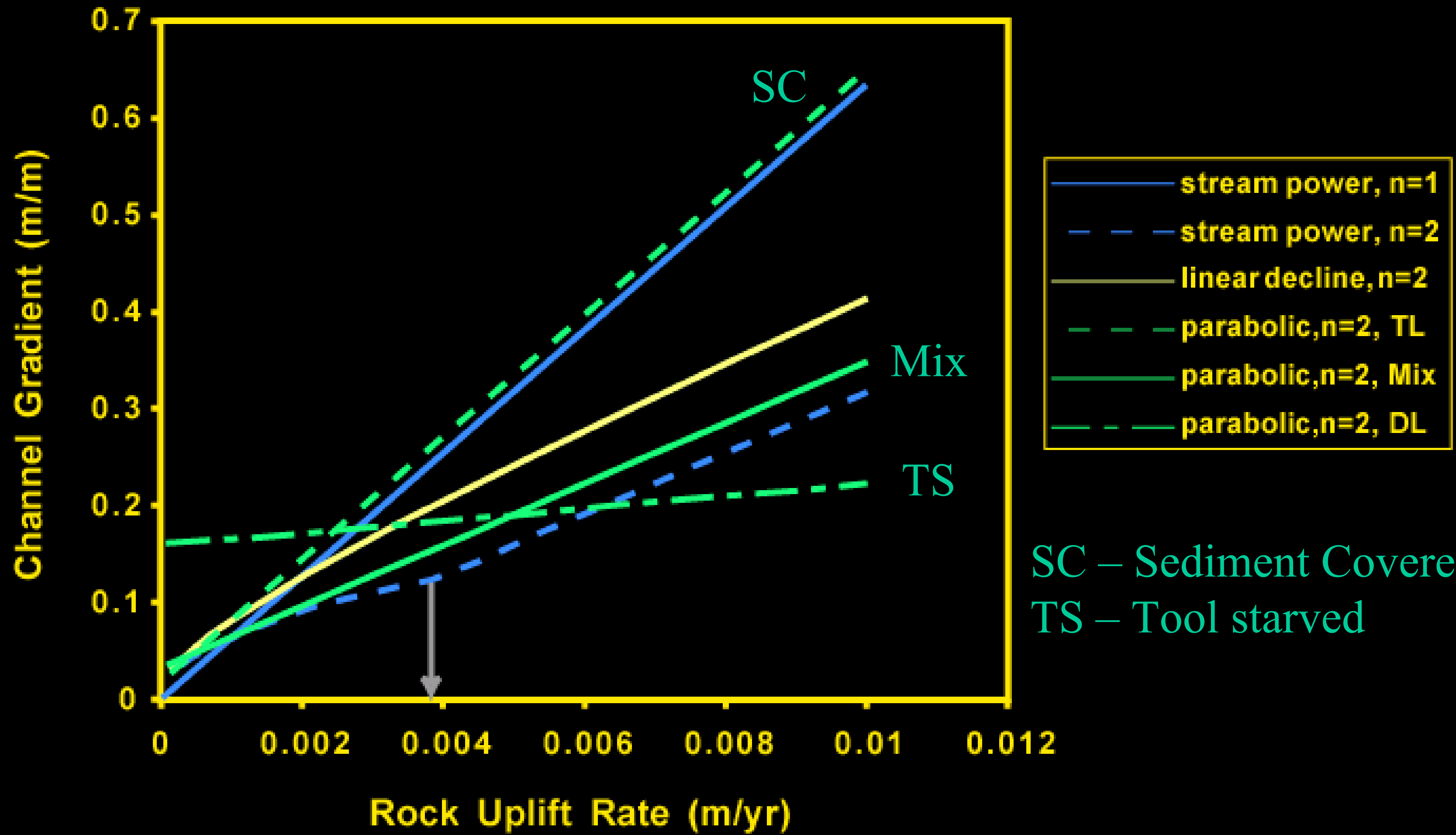
Modeled Erosion Rates



Modeled Erosion Rates

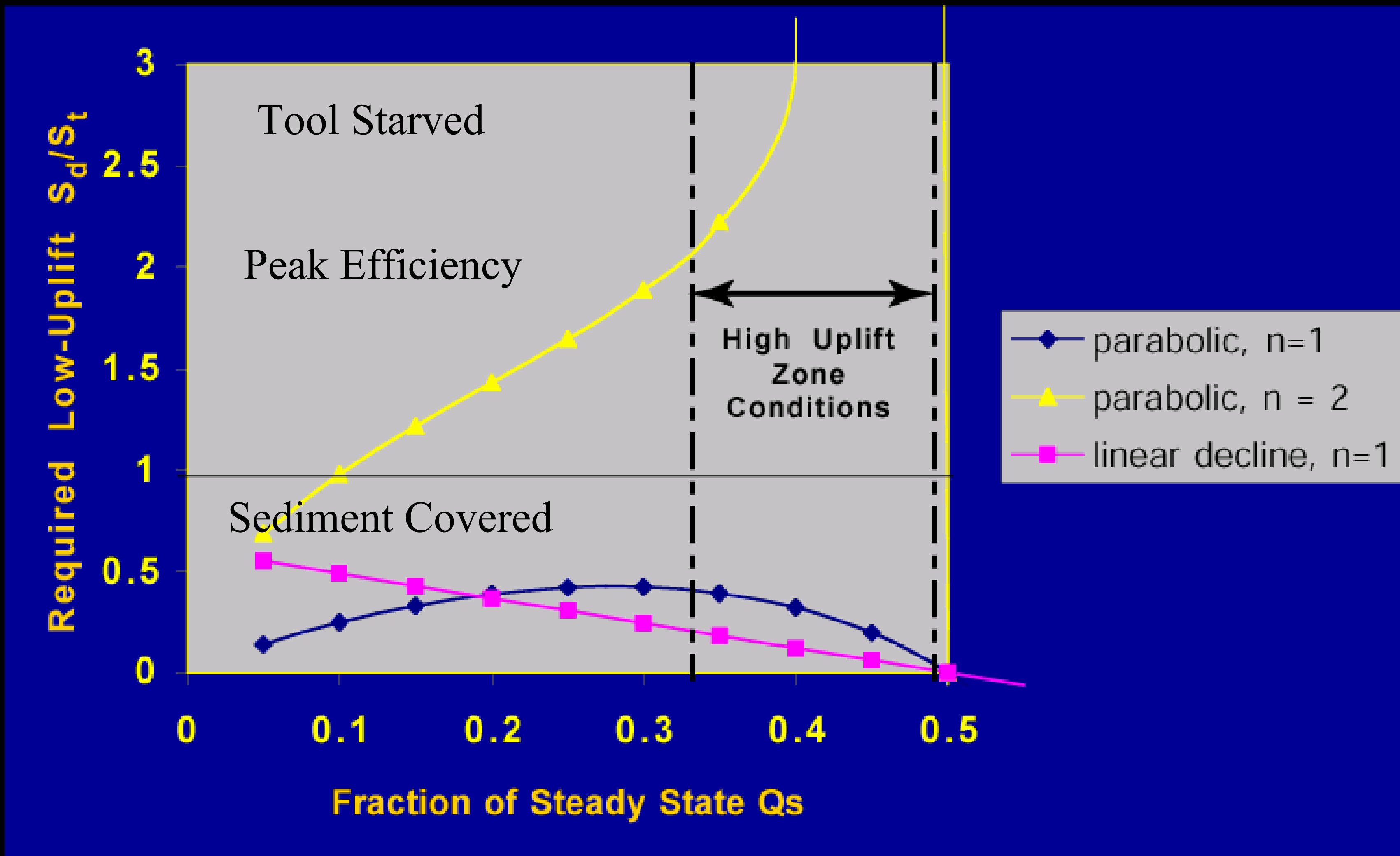


Sediment Flux Lag Complicates Landscape Response – Transient Shifts from Sediment Covered to Tool Starved Likely



SC – Sediment Covered
TS – Tool starved

Sediment-flux Models:
Required Low-Uplift Zone Conditions for $k_{s2}/k_{s1} = 2$



Model Testing Strategies

Steady State Morphology

- Elevation, Relief, Roughness, Network Statistics, etc.

--> generally non-unique

- Exception: Abrupt long-stream changes in U, K

Transient Behavior

- Pattern of Topographic Change
- Magnitude of Topographic Change
- Timescale of Response

--> richest source of information

Exploit Natural Experiments in Transient Landscape Evolution

Conclusions

Steady State Morphology

- Detachment, Transport, Mixed Conditions Indistinguishable
  (if $\theta_d = \theta_t$)
- $F(q_s)$ Models Imply Different Slope-Area Relations
  (if θ_d not = θ_t)

Transient Behavior

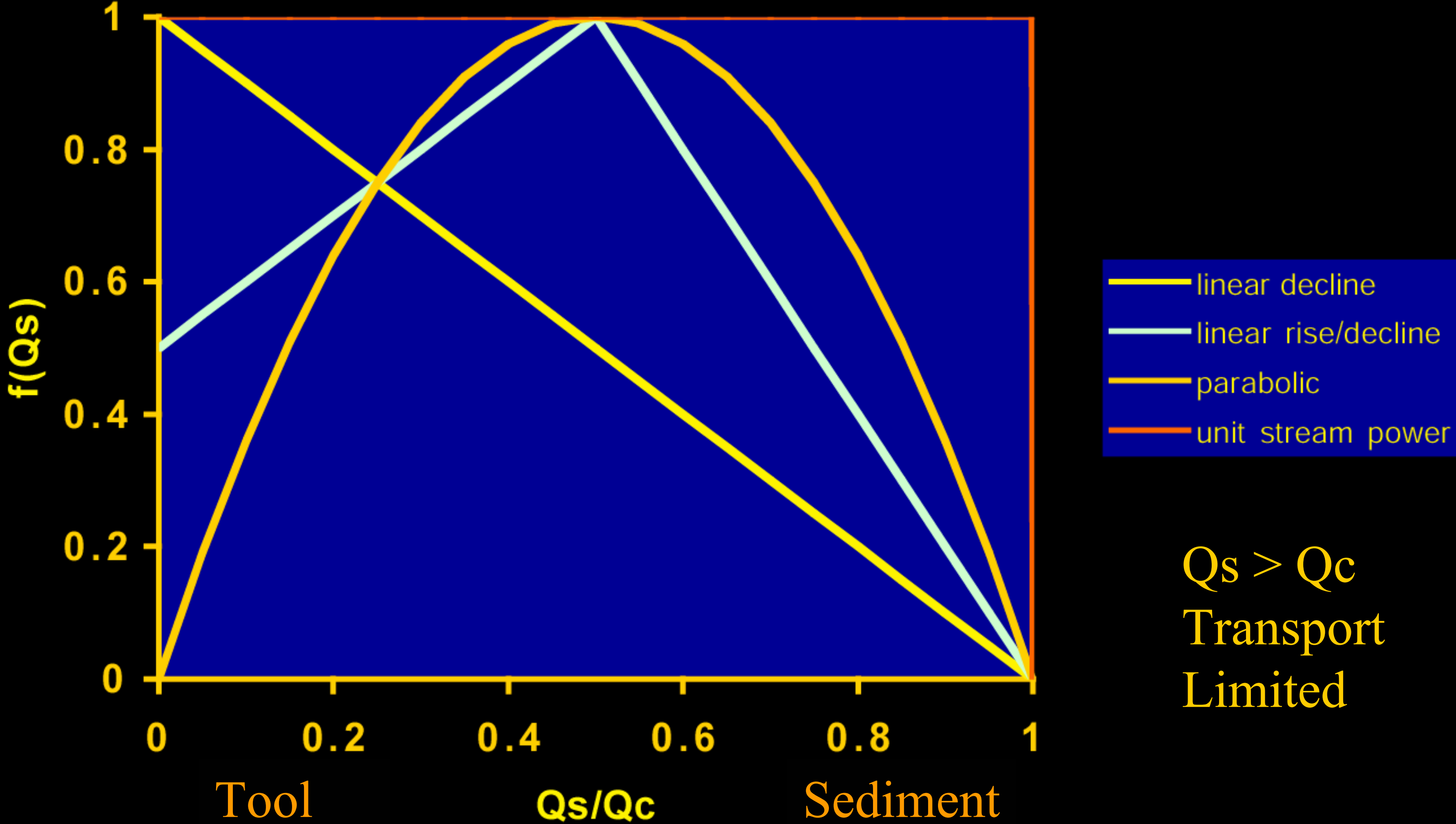
- Pattern: Kinematic vs. Diffusive Wave
- Magnitude: Non-linearity
- Timescale: Kinematic vs. Diffusive, Non-linearity

Occurrence and Behavior of Mixed Channels

- A_{cr} Decreases with Uplift Rate if $n > n_f$
- Channels Near Transition Show Complex Transient Response
  - Initial Kinematic Wave Response to Increasing Uplift if $n > n_f$
  - Initial Diffusive Response to Decreasing Uplift for all n

Generalized Stream-Power Incision Model

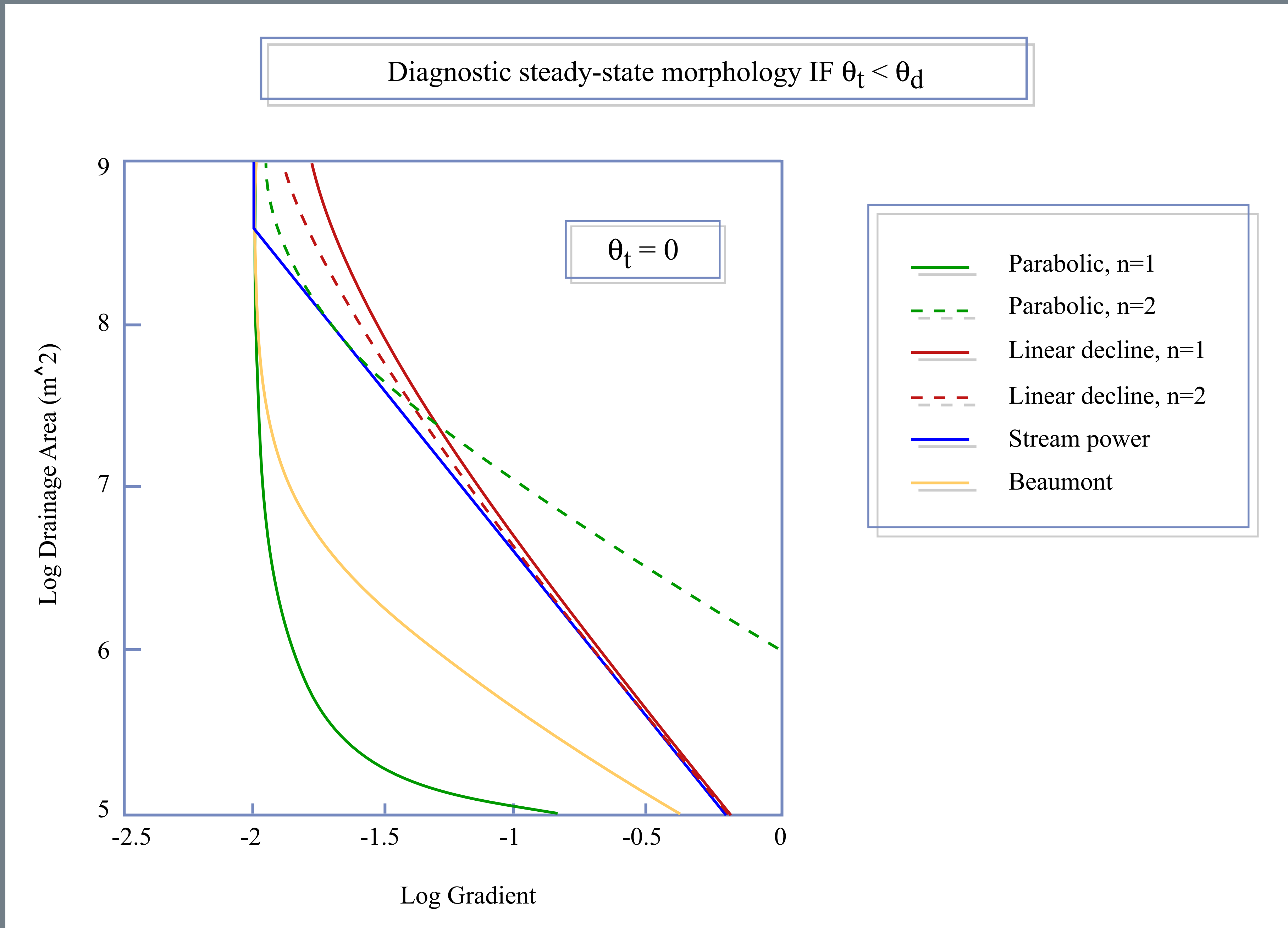
$$E = KA^m S^n \qquad K = K' f(q_s)$$



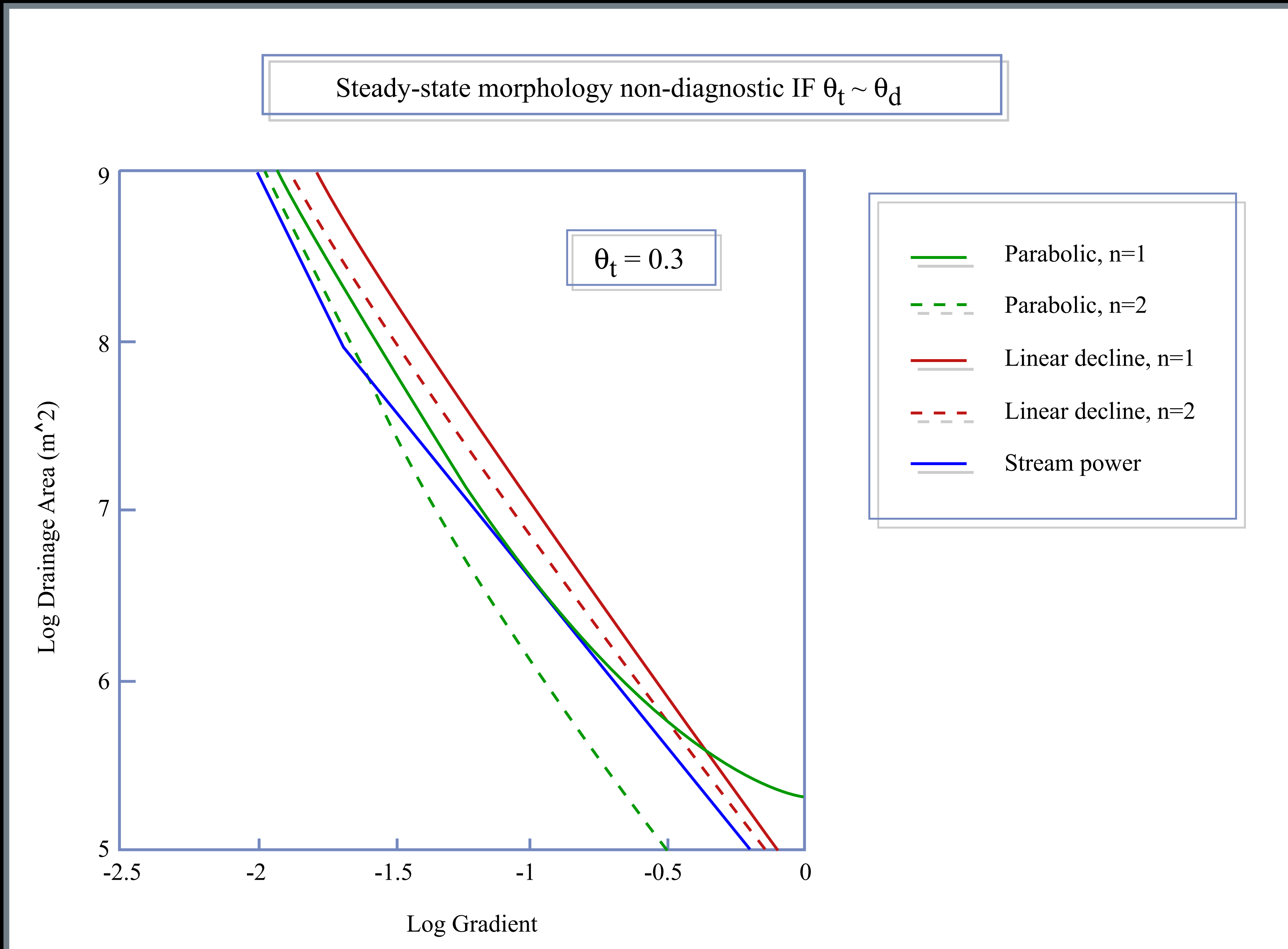
Tool Starved

Sediment Covered

Qs > Qc
Transport Limited

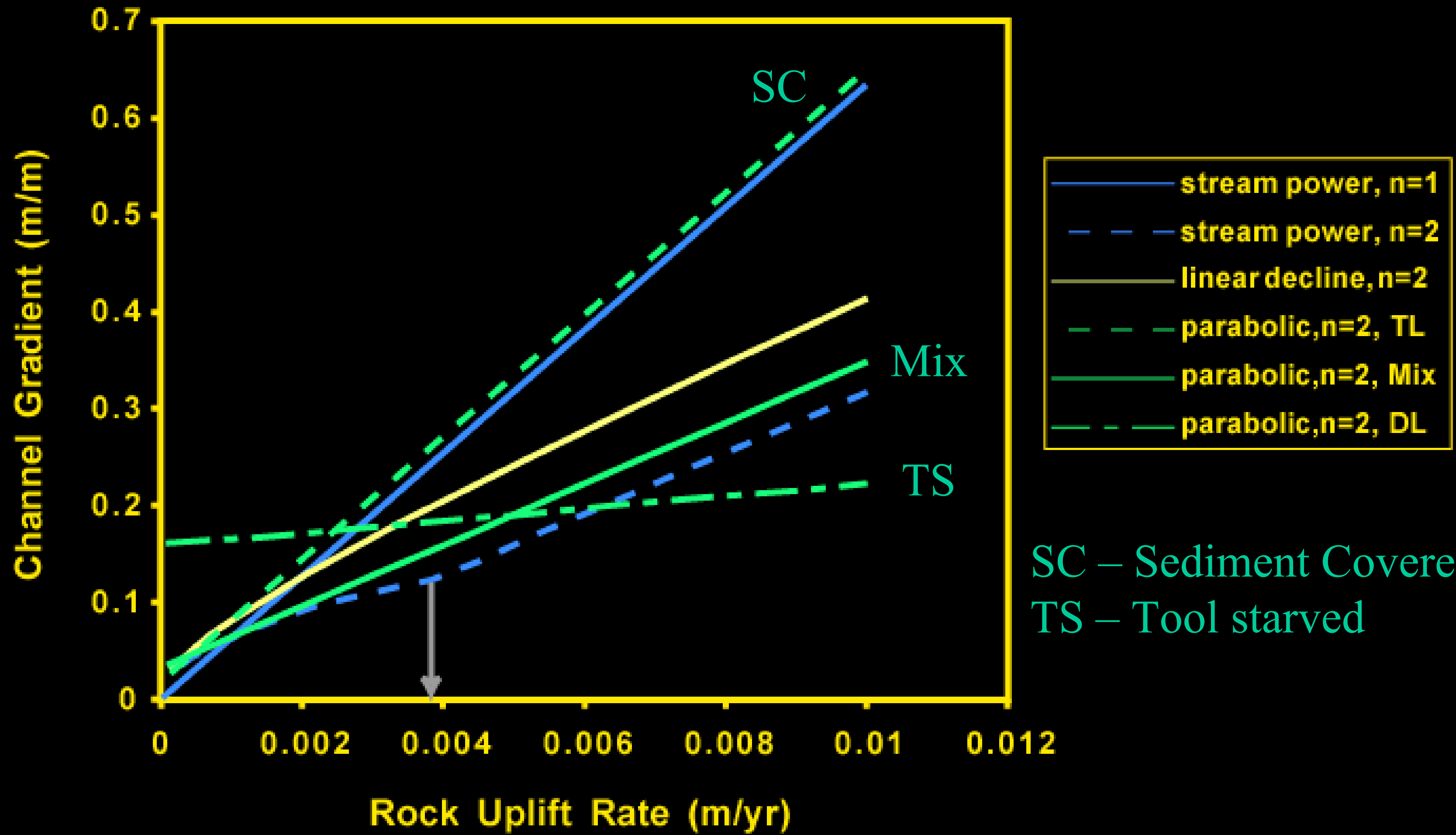


Diagnostic steady-state morphology IF θt < θd
θt = 0
Log Drainage Area (m^2)
Log Gradient
9
8
7
6
5
-2.5
-2
-1.5
-1
-0.5
0
Parabolic, n=1
Parabolic, n=2
Linear decline, n=1
Linear decline, n=2
Stream power
Beaumont



Steady-state morphology non-diagnostic IF θt ~ θd
θt = 0.3
Parabolic, n=1
Parabolic, n=2
Linear decline, n=1
Linear decline, n=2
Stream power
Log Drainage Area (m^2)
Log Gradient
9
8
7
6
5
-2.5
-2
-1.5
-1
-0.5
0

Topographic Sensitivity to Uplift Rate Potentially Diagnostic



SC – Sediment Covered

TS – Tool starved