“It is hard to imagine that a transport estimate made in the absence of a sound understanding of watershed history and dynamics would be of much use at all.”
Great diversity in channels and watersheds...

G. Parker. Fly River, Papua New Guinea.

J. Imran. Brahmaputra River, Bangladesh.

A. Alabyan and A. Sidorchuk. Siberia
...emerging from complex interactions

Wheaton et al., 2011
How much and what type of sediment is being delivered to this channel?

What information do you need to answer those questions?

Is sediment supply a BIG number or SMALL number?
Hydrology matters...
Land use matters...
Soils, surficial and bedrock geology matter...
Storage matters...

Natural and human-caused ‘legacy effects’

Sediment transport through watersheds is complicated
Grain size matters

Figure 7.1. Categories of transported materials in a stream
Grain size matters...
Coarse and fine load often have different sources/transport paths

Floodplains preserve old channel deposits + overbank

Banks and levees made of suspended load

Bed and lower point bars made of bed material load
Grain size matters...
Coarse and fine load often have different sources/transport paths

All else held constant, aggradation on the bed causes...
All else held constant, aggradation on the floodplain…

So while the sources may be independent, effects on channel morphology and hydraulics are linked

Big implications for habitat: Rachelly et al., 2020
How can we stop erosion?

This is not always the right question to ask.
The simple, key questions…

How much and what type of sediment is supplied?

How do flow and supply change over time and with distance downstream?

How many distinct ‘reaches’ are there along my stream?

In what ways might each reach adjust to changes in flow or sediment supply?
A few key messages up front…

In many cases, all that is needed/feasible is to know if supply is a big # or small #

Measuring channel behavior, morphology and bed characteristics will inform your understanding of supply and ‘sensitivity’

Sometimes you need numbers, but good numbers don’t come easy
   Spatial and temporal variability over wide range of scales, Interactions of many non-linear processes

   Develop conceptual model of reach types, sources, sinks, connectivity…
   …then measure/model key rates

   Multiple independent and semi-redundant estimates often needed

May need to know locations, mechanisms, and rates of erosion and deposition
   Size matters…boulders, cobbles, gravel, sand, mud play distinct roles
   Models can be useful and/or misleading
   Examine and consider implications of hydrologic non-stationarity
   Many new tools available, none are comprehensive or bullet-proof
Insightful books for watershed analysis and stream restoration

Methods in Stream Ecology
Roadmap

**TODAY**

- Basic Reconnaissance
  - With a tight budget, what do you really need to know?
- Case studies in sediment supply, transport, and morphodynamics
- Hydrologic analysis and non-stationarity
  - Targeted modeling and metrics. Stationarity Assumption?
- Push-button Geomorphology
  - The geek approach. What computer models can and can’t tell you.

**TOMMORROW**

- Basin-average erosion rates: The cosmo method
  - Millennial-scale landscape rates of erosion.
- Reservoir and pond sedimentation rates
  - Time- and space-integrated measurements that may be useful.
- Watershed Sediment Budget
  - Tools and techniques for robust constraints on sources and sinks.
How would you describe these channels?
Stages of a Watershed Assessment

Stage 1  **Data Compilation (description and mapping)**
- Evaluate watershed context
- Determine landscape units
- Assess river character

Stage 2  **Data Analysis**
- Define and interpret River Styles
- Explain contemporary character/behavior
- Assess river history

Stage 3  **Predict future river structure**

Stage 4  **Prioritize watershed management issues**

Stage 5  **Identify target conditions for river**
River Styles Hierarchy

- **Watershed**: Watershed area determined by drainage divide. Determines the boundary conditions within which rivers operate.
- **Landscape Unit**: Topographic unit determined on the basis of local relief, valley slope and morphology. Defines the valley-setting.
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- **Geomorphic Unit**: Instream and floodplain landforms (pools, bars, levees, backwaters, etc.) that reflect distinct form-process associations.
- **Hydraulic Unit**: Uniform patches of flow and substrate material within a geomorphic unit.
- **Microhabitat**: Individual elements (e.g., logs, rocks, gravel patches) within a stream.
Many other classification schemes out there

<table>
<thead>
<tr>
<th>Spatial Scale</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment</td>
<td>Land cover/land use (LCLU)</td>
</tr>
<tr>
<td></td>
<td>Land topography</td>
</tr>
<tr>
<td>Landscape unit</td>
<td>LCLU and sediment production</td>
</tr>
<tr>
<td></td>
<td>Land topography and sediment production</td>
</tr>
<tr>
<td></td>
<td>Rainfall and groundwater</td>
</tr>
<tr>
<td>Segment</td>
<td>Valley setting</td>
</tr>
<tr>
<td></td>
<td>Channel gradient</td>
</tr>
<tr>
<td></td>
<td>River flows and levels</td>
</tr>
<tr>
<td></td>
<td>Sediment delivery</td>
</tr>
<tr>
<td>Reach</td>
<td>Riparian corridor and wood production</td>
</tr>
<tr>
<td></td>
<td>Channel planform, migration, and features</td>
</tr>
<tr>
<td></td>
<td>Channel geometry</td>
</tr>
<tr>
<td></td>
<td>Sediment transport</td>
</tr>
<tr>
<td></td>
<td>Riparian vegetation, aquatic vegetation, wood</td>
</tr>
</tbody>
</table>

Grabowski et al. 2014
Many other classification schemes out there

Montgomery and Buffington, 1997

Why are we going to spend the next 30 min + most of the afternoon talking about this?

This is the first step in:
- Understanding why different parts of your river behave differently
- Designing a rapid assessment protocol
- Determining what to pursue for contextual analysis
- Deciding what/where to measure for a sediment budget

<table>
<thead>
<tr>
<th>CHANNEL TYPE</th>
<th>Sediment storage elements</th>
<th>Typical bed material</th>
<th>Bedform pattern</th>
<th>Dominant roughness elements</th>
<th>Dominant sediment sources</th>
<th>Typical confinement</th>
<th>Typical pool spacing (channel widths)</th>
<th>CHANNEL TYPE</th>
<th>Sediment storage elements</th>
<th>Typical bed material</th>
<th>Bedform pattern</th>
<th>Dominant roughness elements</th>
<th>Dominant sediment sources</th>
<th>Typical confinement</th>
<th>Typical pool spacing (channel widths)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step pool</td>
<td>Overbank, bedforms</td>
<td>Fluvial, bank failure</td>
<td>Multiple</td>
<td>Sinuosity (dunes), braids,</td>
<td>Fluvial, bank failure</td>
<td>Unconfined</td>
<td>5 to 7</td>
<td>Cascade</td>
<td>Overbank, bedforms</td>
<td>Fluvial, bank failure</td>
<td>Fluvial, bank failure, debris flows</td>
<td>Fluvial, hill slope, debris flows</td>
<td>Confined</td>
<td>1 to 4</td>
<td></td>
</tr>
<tr>
<td>Cascade</td>
<td>Overbank, bedforms</td>
<td>Fluvial, bank failure</td>
<td>Featureless</td>
<td>Grains, banks</td>
<td>Fluvial, bank failure</td>
<td>Confined</td>
<td>1 to 4</td>
<td>Bedrock</td>
<td>Overbank</td>
<td>Fluvial, bank failure</td>
<td>Fluvial, bank failure, debris flows</td>
<td>Fluvial, hill slope, debris flows</td>
<td>Confined</td>
<td>&lt;1</td>
<td></td>
</tr>
<tr>
<td>Bedrock</td>
<td></td>
<td>Cobble-boulder</td>
<td>Random</td>
<td>Grains, banks</td>
<td>Boulder</td>
<td>Confined</td>
<td>1 to 4</td>
<td>Colluvial</td>
<td></td>
<td>Cobble-boulder</td>
<td>Boulder</td>
<td></td>
<td>Confined</td>
<td>Unknown</td>
<td></td>
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<tr>
<td>Colluvial</td>
<td></td>
<td></td>
<td>Irregular</td>
<td>Boundaries (bed and banks)</td>
<td>Pockets</td>
<td></td>
<td></td>
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</tr>
</tbody>
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**River Styles Hierarchy**

- **Watershed**: Watershed area determined by drainage divide. Determines the boundary conditions within which rivers operate.

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What are the different parts of the watershed?

Which detachment, transport, deposition processes are occurring where?
How well connected is the system?
Where are complete or partial barriers?
How has/might connectivity change?

see Fryirs et al., 2007
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What are the different parts of the river network?

River Styles™ tree developed for NSW, Australia

YOU decide how to divide up the river network!

Brierley et al., 2002
Visual representation of NSW River Styles

Which river styles are you working on?

These are each different ‘process domains’

Different ecological functions
hydro-geomorphic processes
sensitivities to change
potential for recovery
What’s in a name?

River Styles procedural tree

Partly-confined valley setting
(10-85% of channel abuts valley bottom margin)

Partly confined

Degree of lateral confinement
(planform-controlled 10-50% confined)

Planform-controlled

River planform
(# channels, sinuosity, lateral constraint)

Planform descriptor

Geomorphic units
(instream and floodplain)

Geomorphic units descriptor

Bed material texture

Bed descriptor

Resultant verbose and abbreviated names

Partly confined
PC

Partly confined, planform-controlled
PC_PC

Partly confined, planform-controlled,
low sinuosity, terrace constrained
PC_PC_LSIn_TrCS

Partly confined, planform-controlled,
low sinuosity, terrace constrained,
discontinuous floodplain
PC_PC_LSIn_TrCS_DcFp

Partly confined, planform-controlled,
low sinuosity, terrace constrained,
discontinuous floodplain,
gravel bed
PC_PC_LSIn_TrCS_DcFp_Gbed

Key:

- add existing or new term
- compulsory must have
- not compulsory - use if splitting or more detail needed
A common taxonomy for describing rivers

<table>
<thead>
<tr>
<th>TYPES OF MARGIN CONTROL OR CONSTRAINTS</th>
<th>PLANIFORM TYPES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedrock</td>
<td>Headwater</td>
</tr>
<tr>
<td>Terrace</td>
<td>Gorge</td>
</tr>
<tr>
<td>Fan</td>
<td>Canyon</td>
</tr>
<tr>
<td>Dune</td>
<td>Braided</td>
</tr>
<tr>
<td>TYPES OF ANTHROPOGENIC MARGIN</td>
<td>Meandering</td>
</tr>
<tr>
<td>Stopbank</td>
<td>Wandering</td>
</tr>
<tr>
<td>Constructed levee</td>
<td>Low sinuosity</td>
</tr>
<tr>
<td>Embankment</td>
<td>Anastomosing</td>
</tr>
<tr>
<td>Bank revetment</td>
<td>Anabranching</td>
</tr>
<tr>
<td>Railroad</td>
<td>Chain of ponds</td>
</tr>
<tr>
<td>Road</td>
<td>Valley fill</td>
</tr>
<tr>
<td>Pipe</td>
<td>Swamp</td>
</tr>
<tr>
<td>Concrete</td>
<td>Floodout</td>
</tr>
<tr>
<td>Earth</td>
<td>Canal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INSTREAM GEOMORPHIC UNITS</th>
<th>Mid-channel geomorphic units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank-attached geomorphic units</td>
<td></td>
</tr>
<tr>
<td>Lateral bar (alternate or side bar)</td>
<td>BrSt Alluvial riffle</td>
</tr>
<tr>
<td>Scree bar</td>
<td>SpPo Alluvial pool</td>
</tr>
<tr>
<td>Point bar</td>
<td>CrSt Longitudinal bar (medial bar)</td>
</tr>
<tr>
<td>Point bar</td>
<td>RpSt Transverse bar (linguoid bar)</td>
</tr>
<tr>
<td>Tributary confluence bar (channel junction bar, eddy bar)</td>
<td>TChBa Alluvial riffle</td>
</tr>
<tr>
<td>Ridge</td>
<td>ChSt Alluvial pool</td>
</tr>
<tr>
<td>Chute channel</td>
<td></td>
</tr>
<tr>
<td>Ramp (chute channel fill)</td>
<td>Rphoon Boulder mound</td>
</tr>
<tr>
<td>Bench</td>
<td></td>
</tr>
<tr>
<td>Point bench</td>
<td></td>
</tr>
<tr>
<td>Stationary bar</td>
<td></td>
</tr>
<tr>
<td>Point eddy</td>
<td></td>
</tr>
<tr>
<td>Boulder berm</td>
<td></td>
</tr>
<tr>
<td>Concave bank bench</td>
<td></td>
</tr>
<tr>
<td>Compound bank-attached bar</td>
<td></td>
</tr>
<tr>
<td>Floodplain geomorphic units</td>
<td></td>
</tr>
<tr>
<td>Occasional floodplain</td>
<td></td>
</tr>
<tr>
<td>Discontinuous floodplain</td>
<td></td>
</tr>
<tr>
<td>Floodplain (alluvial flat)</td>
<td></td>
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<tr>
<td>Levee</td>
<td></td>
</tr>
<tr>
<td>Creasele edge</td>
<td></td>
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<tr>
<td>Flood channel (back channel)</td>
<td></td>
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<tr>
<td>Flood runner</td>
<td></td>
</tr>
<tr>
<td>Backswamp (distal floodplain, floodplain wetland, floodplain lake)</td>
<td>Bsw Floodplain channel anabranch (secondary or flood channel)</td>
</tr>
<tr>
<td>Floodplain sand sheet</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BED MATERIAL TEXTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedrock</td>
</tr>
<tr>
<td>Boulder</td>
</tr>
<tr>
<td>Cobble</td>
</tr>
</tbody>
</table>
Begin to classify channel network with these primary gradients...

Valley confinement

River longitudinal profile

Flow accumulation
Valley confinement

Confined
>90% interacting with confining margins

Partly Confined
90-50%: margin controlled
10-40%: planform controlled

Unconfined
<10% interacting with cm
Confinement tells you more than any other metric about channel constraints and adjustment capacity.
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All have the same channel/valley ratio!
Confinement tells you more than any other metric about channel constraints and adjustment capacity.
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Second tier characteristics for classification
Indicators of channel behavior

- Assemblage of geomorphic units that make up a reach
- Channel planform
- Bed material texture
Metrics of channel planform

(a) Number of channels
- Single
- Up to 3 (wandering)
- > 3 (braided)
- > 3 (anastomosing/anabranching)
- Discontinuous or absent

(b) Sinuosity
- Degrees of sinuosity:
  - Modified from Schumm, 1985
  - 1.00–1.05 (straight)
  - 1.06–1.30 (low sinuosity)
  - 1.31–3.0 (sinuous/meandering)

- Types of sinuosity:
  (from Church, 1992)
  - Sinuous
  - Irregular meanders (passive)
  - Regular meanders
  - Tortuous meanders
  - Confined pattern

(c) Lateral stability
- Meander growth and shift:
  - Extension/increasing amplitude
  - Translation/downstream progression
  - Rotation
  - Neck cutoffs

- Degree of braiding:
  (from Schumm, 1985)
  - < 5%
  - 5–34%
  - 35–65%
  - > 65%

- Character of braiding:
  - Mostly bars
  - Bars and islands
  - Mostly islands diverse shape
  - Mostly islands long and narrow

- Avulsive behavior:
  - 1st order avulsion (wholesale shift)
  - 2nd order avulsion (reoccupation)
  - 3rd order avulsion (thalweg shift)
Interpretations from channel planform

Kleinhans, 2010
Modes of adjustment vary considerably for different river types

| Channel type   | Grain size | Width & depth | Bedforms | Stream gradient (sinuosity/elevation) 
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Colluvial</td>
<td>p</td>
<td>p</td>
<td>-</td>
<td>-/p(^c)</td>
</tr>
<tr>
<td>Bedrock</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-/-</td>
</tr>
<tr>
<td>Cascade</td>
<td>p</td>
<td>-</td>
<td>-</td>
<td>-/-</td>
</tr>
<tr>
<td>Step-pool</td>
<td>p</td>
<td>-/p(^d)</td>
<td>p</td>
<td>-/p</td>
</tr>
<tr>
<td>Plane-bed</td>
<td>+</td>
<td>p/+</td>
<td>-</td>
<td>-/p</td>
</tr>
<tr>
<td>Braided</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>++/+</td>
</tr>
<tr>
<td>Pool-riffle</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>++/+</td>
</tr>
<tr>
<td>Dune-ripple</td>
<td>p</td>
<td>+</td>
<td>+</td>
<td>++/+</td>
</tr>
</tbody>
</table>

\(^{\text{a}}\) Modified from Montgomery and Buffington (1997). Response potential for each channel type is discussed elsewhere (Montgomery and Buffington, 1997; 1998; Buffington et al., 2003).

\(^{\text{b}}\) Changes in stream gradient may occur via altered sinuosity or incision/aggradation that alter the absolute elevation change across a reach. Slashes in the table distinguish these two responses.

\(^{\text{c}}\) Fluvial incision/deposition is possible, depending on the degree of colluvial fill.

\(^{\text{d}}\) Changes in channel depth can occur via pool fill/scour.
Armoring allows gravel bed rivers to adjust transport rates to changes in sediment supply.
Armoring tends to increase under low sediment supply conditions. Vázquez-Tarrío et al., 2020
## Tools for geomorphic assessments

![Image of tools](https://riverscapes.xyz/)

### Table 1: Some of the available automated and semi-automated tools for the geomorphic analysis of rivers

<table>
<thead>
<tr>
<th>Tool</th>
<th>Website or download page</th>
<th>Key related papers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Confinement and valley setting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valley-bottom extraction tool (V-BET)</td>
<td><a href="http://rcat.riverscapes.xyz/Documentation/Version_1.0/VBET.html">http://rcat.riverscapes.xyz/Documentation/Version_1.0/VBET.html</a></td>
<td>Gilbert, Macfarlane, and Wheaton (2016)</td>
</tr>
<tr>
<td>Valley bottom confinement tool (VBCT)</td>
<td><a href="http://confinement.riverscapes.xyz">http://confinement.riverscapes.xyz</a></td>
<td>Fryirs et al. (2016)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>O'Brien et al. (2019)</td>
</tr>
<tr>
<td>TerEx toolbox (terrace and floodplain mapping)</td>
<td><a href="https://qcnr.usu.edu/labs/belmont_lab/resources">https://qcnr.usu.edu/labs/belmont_lab/resources</a></td>
<td>Clubb et al. (2017)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stout and Belmont (2014)</td>
</tr>
<tr>
<td><strong>River planform</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geomorphic network and analysis toolkit (GNAT)</td>
<td><a href="http://gnat.riverscapes.xyz/">http://gnat.riverscapes.xyz/</a></td>
<td>Macfarlane, Gilbert, et al. (2017);</td>
</tr>
<tr>
<td>Beaver restoration assessment tool (BRAT)</td>
<td><a href="http://brat.riverscapes.xyz/">http://brat.riverscapes.xyz/</a></td>
<td></td>
</tr>
<tr>
<td><strong>Geomorphic units</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geomorphic unit tool (GUT)</td>
<td><a href="http://gut.riverscapes.xyz/">http://gut.riverscapes.xyz/</a></td>
<td>Bangen, Wheaton, Bouwes, Bouwes, and Jordan (2014)</td>
</tr>
<tr>
<td>Support vector machine classifier (SVMc)</td>
<td>Remote sensing software for example, eCognition <a href="http://www.ecognition.com/">http://www.ecognition.com/</a>,</td>
<td>Belleti et al. (2017)</td>
</tr>
<tr>
<td></td>
<td>ORFEO <a href="https://www.orfeo-toolbox.org/">https://www.orfeo-toolbox.org/</a></td>
<td>Belleti et al. (2017)</td>
</tr>
<tr>
<td>Hydrodynamic modeling</td>
<td>Variety of software are available for example,</td>
<td>Demarchi, Bizzi, and Piégay (2016, 2017)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wyrick, Senter, and Pastemack (2014)</td>
</tr>
<tr>
<td><strong>Bed material texture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topographic analysis tools (TAT), including</td>
<td><a href="http://tat.riverscapes.xyz/">http://tat.riverscapes.xyz/</a></td>
<td>Brasington, Vericat, and Rychkov (2012)</td>
</tr>
<tr>
<td>ToPCAT</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>River behavior</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morphological change—Geomorphic change</td>
<td><a href="http://gcd.riverscapes.xyz/">http://gcd.riverscapes.xyz/</a></td>
<td>Wheaton, Brasington, Darby, and Sear (2010);</td>
</tr>
<tr>
<td>detection (GCD)</td>
<td></td>
<td>Wheaton et al. (2013)</td>
</tr>
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</table>

Fryirs, et al., 2019
Tools for geomorphic assessments

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</tr>
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<tr>
<td>Planform statistics</td>
<td><a href="https://repository.ucr.edu/buffer.php?current=author&amp;author=37&amp;dataset_id=15">https://repository.ucr.edu/buffer.php?current=author&amp;author=37&amp;dataset_id=15</a></td>
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<tr>
<td>Measures of channel width and centreline</td>
<td>RivWidth: <a href="http://uniglobalhydrology.org/rivwidth/">http://uniglobalhydrology.org/rivwidth/</a></td>
<td>Pavelsky and Smith (2008)</td>
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<td><a href="http://www.mathworks.com/matlabcentral/fileexchange/58264-rivmap-river-">http://www.mathworks.com/matlabcentral/fileexchange/58264-rivmap-river-</a></td>
<td>Schwenk, Khandelwal, Frakkin, Kumar, and</td>
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<td>PyRIS: <a href="https://github.com/linnemaglia/pyris">https://github.com/linnemaglia/pyris</a></td>
<td>Monegaglia, Zolezzi, Guineralp, Henshaw, and</td>
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<td>Tubino (2018)</td>
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<td>SCREAM</td>
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<td>Rowland et al. (2016)</td>
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**Downstream patterns of rivers and controls**

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<tr>
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<th>Website or download page</th>
<th>Key related paper/s</th>
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<tr>
<td>Longitudinal profile—ArcMap stacked profile</td>
<td><a href="http://www.arcgis.com/index.html">http://www.arcgis.com/index.html</a></td>
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<td>Network Profiler Tool</td>
<td><a href="https://riverscapes.github.io/NetworkProfiler/">https://riverscapes.github.io/NetworkProfiler/</a></td>
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<tr>
<td>Catchment area—ArcMap flow accumulation</td>
<td><a href="http://www.arcgis.com/index.html">http://www.arcgis.com/index.html</a></td>
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*Note:* This is not intended to be an exhaustive list of all available tools, rather a guide to direct the reader to the tools identified in Figures 2b and 3, and mentioned in the text. All websites were accessed June 17, 2019.
Rapid Assessment vs Contextual Analysis

Rapid Assessments:
Aim to be repeatable, quantitative, and representative
Limited ability to discern cause of problems in complex systems
Often require frequent sampling, large number of sites

Contextual Analysis:
Aim to attain comprehensive, holistic understanding of the system
Often difficult to quantify components
Can guide assessments, monitoring, measurements for sed budget
Roadmap

TODAY

Forget rates. What can we learn from basic form-process relationships?

Basic Reconnaissance
  - With a tight budget, what do you really need to know?

Case studies in sediment supply, transport, and morphodynamics

Hydrologic analysis and non-stationarity
  - Targeted modeling and metrics. Stationarity Assumption?

Push-button Geomorphology
  - The geek approach. What computer models can and can’t tell you.

TOMORROW

Basin-average erosion rates: The cosmo method
  - Millennial-scale landscape rates of erosion.

Reservoir and pond sedimentation rates
  - Time- and space-integrated measurements that may be useful.

Watershed Sediment Budget
  - Tools and techniques for robust constraints on sources and sinks.
Reach 1

Laterally unconfined, low gradient channel
Steep hillslopes deliver sediment to low gradient valley floor
Weak tuff and rhyolite bedrock, recent severe burn

Example: North Fork Cable Creek, Oregon
Reach 2

Partly confined, planform controlled with strong veg influence
Channel incised into a narrow, high-gradient valley
Channel gradient steeper, bed material coarser, less heterogeneity
Reach 3

Laterally unconfined, occasional confining terraces

Valley widens, well developed (and connected) floodplain

Much gravel deposition and heterogeneity in bedforms

Reach 4: Sediment Transport

Reach 3: Sediment Accumulation

Reach 2:

Basalt

Tuff
Reach 4
Partly confined, margin controlled
Channel crosses fault and enters onto hard Columbia River Basalt
Step-pool to pool-riffle morphology
Some history on the landscape we’ll be examining this afternoon.
Long profiles of EF, SF Little Bear and other drainages of the Bear River Range

Longitudinal profiles extracted with Stream Profiler Tool: geomorphtools.org
Figure from Gary O’Brien
Your assignment for this afternoon:

Work in groups of 3-4

The Logan River Watershed is being targeted for a major watershed restoration project with the goal of restoring cutthroat and brown trout habitat.

Utah DNR has requested a map illustrating the different reach types that occur along the river. This info will be used to determine which sites to prioritize for further monitoring and restoration.
Your assignment for this afternoon:

1. Obtain paper maps, GIS and/or Google Earth data

2. Peruse the data for 30 min. Identify points/areas of interest along the channel and throughout the watershed.

3. Spend ~30 min delineating distinct reaches of the mainstem Logan River along our tour route. Delineate distinct River Styles and describe each reach wrt:
   1. valley confinement
   2. number of channels, sinuosity
   3. slope and/or discontinuities in the long profile
   4. notable sediment sources and sinks
   5. other relevant attributes (e.g., D50, slope)

Turn in by 5pm:

1. Paper map showing reach breaks
2. Answers to questions at each stop and brief descriptions of each River Style
Questions we’ll discuss at each stop

(1) Which erosional processes do you see evidence for? What is conveying sediment to the channel? Amount and type of sediment supplied?

(2) Is there a clearly defined bankfull channel? How deep is it?

(3) Which geomorphic units do you see?

(4) Is the bed armored? Does bed material move at channel filling flow? How does $\tau_o$ compare to $\tau_c$?

(5) Is there evidence of coarse suspended load (little in the bed, but deposits of fine gravel or sand in sheltered locations or within bars)?

(6) How sensitive is this reach to changes in flow and/or sediment supply?