INTEGRATION ACROSS DISCIPLINES
TRENDS AND CHALLENGES IN ANALYSIS
OF HIGH RESOLUTION TOPOGRAPHY

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A²HRT Workshop
Boulder, CO
August 21-23, 2018
WHAT CAPTURED OUR IMAGINATION IN HRT?

- For first time, the data, looked just like what we saw in field
- Raw data was every bit as complicated as the real world!

Brasington et al., 2012; Rychkov et al., 2012
PURPOSE OF TALK

• Share with you my perspectives & impressions of high resolution topography (w/o many pictures of HRT) & how to transcend disciplines with it

Convince you its time we moved past the pretty pictures & past the methods...
OVER-FOCUS ON ‘DO IT BECAUSE WE CAN’

- Why?
- Because we can see in data, what we see on the ground.
- Is method driving our science or are we?
- Let’s not fool ourselves... We are not advancing these technologies...
WHAT ARE THE TRENDS?

- Explosion of topographic survey methods
- Cheer-leading for certain technologies
- Same mistakes keep being made!
- Appreciation of role of uncertainty... yet continued use of unsophisticated methods for coping with it
- Wow... look at my point cloud
- Hey, I’ve got two surveys. That should be publishable...
WHAT ARE THE RECENT DEVELOPMENTS?

- Consolidation of topographic survey methods
- Emergence of ‘hybrid’ data collection techniques
- Better error models
- Emergence of more standardized methods for raster-based change detection
- Point-cloud processing (ironically -> decimation focused)
- Cloud-to-Cloud change detection
- Large scale applications
- Novel monitoring applications
CONCLUSIONS

• We focus too much on methodological tangents
  – Too often these include things that *are known*:
    • How to acquire topographic data for surfaces of interest
    • Lost in signal to noise: uncertainty and error modelling

• We are not driving the technology... we’re following it – Oh... look ... something shiny

• Is more always better? What do I really need?
  – While HRT acquisition and processing is getting quicker
    – we quickly find black holes of processing

• What are the questions I really care about?

• What can HRT tell me that I didn’t already know?
GCD... SO WHAT?

- What can we do with that repeat topography?
- Develop a direct measure of fluvial erosion and deposition
- Estimate change in storage terms of sediment budgets
BRIDGE CREEK....

Little incision problem...
Using Beaver Dams to Restore Incised Stream Ecosystems

Micheal N. Pollock, Timothy J. Beehre, Joseph N. Awad, Chris E. Jordan, Vicki Bower, Nicholas Weber, and Carol Vlax

Using Beaver Dams to Restore Incised Stream Ecosystems

Throughout many regions of the world, incised streams have environmental problems that have caused extensive degradation and dysfunction. Incised streams can be defined as streams with a deep channel and a low water table. In incised streams, the water table is low enough to allow for the growth of vegetation. This can lead to a number of problems, including reduced water quality, increased erosion, and decreased biodiversity. Beaver dams can be used to restore incised streams by creating impoundments and increasing water levels. This can help to improve water quality, increase biodiversity, and reduce erosion. Additionally, the presence of beavers can help to create a more diverse and dynamic ecosystem, as they are known to create complex stream networks with a variety of habitats. In conclusion, using beavers to restore incised streams is an effective and sustainable method for improving water quality, reducing erosion, and increasing biodiversity.
Installed September 2009, Occupied by November 2009
WHAT DID WE LEARN?

• Can’t aggrade without eroding!!!
• Speeding up morphodynamic evolution builds both more habitat and more complex fish habitat!

Erosion: 342 m³ +/- 83
Deposition: 846 m³ +/- 228
NET: + 504 m³ (+/- 243)
HRT MAKING A SPLASH....

- Restoration using beaver as restoration agent actually produced a population level increase in density, survival and production of ESA listed salmon.
• How important are braiding mechanisms at explaining change in storage?
BRAIDING MECHANISMS

• Four ‘presumed’ key mechanisms from flume studies
• No empirical field tests of their importance
• Under appreciation of importance of bank erosion
ABOUT THOSE BRAIDING MECHANISMS

• Bar building environment not just about deposition!

• Critical importance of erosion to produce local supply!

• How important are braiding mechanisms at explaining change in storage?
What can HRT tell us about habitat conditions for fish across a huge diversity of river styles?
A TYPICAL CHaMP TOPO SURVEY

Water Depth
- 0.35 - 0.4
- 0.4 - 0.45
- 0.45 - 0.5
- 0.5 - 0.55
- 0.55 - 0.6
- 0.6 - 0.65
- 0.65 - 0.7
- 0.7 - 0.75

Depth (m)
- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.15
- 0.15 - 0.2
- 0.2 - 0.25
- 0.25 - 0.3
- 0.3 - 0.35

Detrended DEM (m)
- High: 102.34
- Low: 99.28

Water Extent

10 cm Contours
CHaMP TOPO SANDBOX

Pilot Phase

• 11 Watersheds throughout the Columbia Basin

• Roughly 45-55 sites in each basin (10-15 annual): 950 Total

• 5500 individual surveys

Map by Martha Jensen
See [http://champmonitoring.org](http://champmonitoring.org)
WHAT WILL GCD x 5000 TELL US WE DID NOT KNOW?

BEST EXPERIMENTAL OPPORTUNITY FOR HYPOTHESIS TESTING ACROSS SCALES YET....

http://champmonitoring.org

TS topographic & habitat surveys...
GCD to describe behavior... in a poor condition variant.
GCD TO DESCRIBE BEHAVIOR... IN A GOOD CONDITION VARIANT

DYNAMIC RIVER BEHAVIOR CHANGES CAPTURED WITH CHaMP

Changes with less than a 95% probability of being real

Erosion
Deposition

Volume

Changes with less than a 95% probability of being real

Erosion
Deposition

Elevation Change (m)

Champ Site: Tucannon River, WA ID: CBWG5583-481459
WHAT CAN HRT TELL US ABOUT BUILDING BLOCKS OF RIVERS?

What characteristic assemblages of geomorphic units exist?

What gives rise to heterogeneity versus homogeneity in the building blocks of a riverscape?

**POINT BAR**
- Tier 1: (c or > bankfull)
- Tier 2: Convectives
- Tier 3: Bank Attached
- Tier 4: Point Bar

**GEOMORPHIC FORM**
- Point bars are convex, bank attached bars that form on the inside banks of meander bends. Gravel beds tend to fine downstream and lateral distance from the bank. Bar surface roughness toward the channel.

**PROCESS INTERPRETATION**
- Point bars evolve as a result of the process of lateral channel migration, i.e., the change in lateral channel position caused by deposition of sediment on the convex bank and erosion along the outside, concave bank. Sand and gravel are moved by traction toward the inside bank by helical flow.

**ASSOCIATED GEOMORPHIC UNITS AND STRUCTURAL ELEMENTS**
- Point bars are closely associated with riffles, runs, Bar-Forced Pools, and various types of scars, namely, Channel Banks.

**TYPICAL SALMONID FISH HABITAT ASSOCIATIONS**
- Anadromous fish habitats are found at pool sites at the tops of riffles, especially at Point Bar Forced Pools, where pools occur, and pool heads at the base of Bar-Forced Pools, etc. Point Bars, where fish can forage on food items being washed down from the steepened ramp above.

**RIFFLE**
- Tier 1: (c or > bankfull)
- Tier 2: Convectives
- Tier 3: Channel Spanning
- Tier 4: Riffle

**GEOMORPHIC FORM**
- Riffles form as topographic highs along an uneven longitudinal profile, between bends in sinuous alluvial channels. Riffles are shallow, steep, planar, channel-spanning features.

**PROCESS INTERPRETATION**
- Riffles are areas of sediment accumulation that increase channel roughness during high-flow stages, and are maintained or built at various flow stages by the consequent increased turbulence and reduced velocity over the steepened surface. Riffles are often dissected at low-flow stages, and re-washed or reworked at stages higher than bankfull.

**TYPICAL SALMONID FISH HABITAT ASSOCIATIONS**
- Riffles are commonly associated with fish habitats such as the upper and downstream bar-attached pools, etc., where fish forage on food items being washed down from the steepened ramp above.
TAXONOMY FOR MAPPING FLUVIAL LANDFORMS

- Four Tiers
  - Stage Height
  - Shape / Form
  - Morphology
  - Roughness/Vegetation
- Over 100 fluvial geomorphic units found in literature, of which 68 are distinctive (3b)
- Clearer, topographically based definitions

GUT: Geomorphic Unit Toolkit: https://riverscapes.github.io/pyGUT/

From: https://riverscapes.github.io/pyGUT/
Wheaton et al. (2015) – Geomorphology; DOI: 10.1016/j.geomorph.2015.07.018
Differentiating shape longitudinally (i.e. stream-wise), vs. laterally (i.e. cross sectional)

<table>
<thead>
<tr>
<th>Convexity</th>
<th>Mound</th>
<th>Saddle</th>
<th>Wall</th>
<th>Plane</th>
<th>Trough</th>
<th>Bowl</th>
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</thead>
<tbody>
<tr>
<td>XS</td>
<td>Convex</td>
<td>Concave</td>
<td>NA</td>
<td>Planar</td>
<td>Concave</td>
<td>Concave</td>
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<tr>
<td>LP</td>
<td>Convex</td>
<td>Convex</td>
<td>NA</td>
<td>Planar</td>
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TIER 2 - FORM

- Key for the riffle... is the thalweg...
- Flow goes up and over (convex), through the thalweg (concave)

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South Fork Asotin Creek: Planformed Controlled with Discontinuous Floodplain Condition: Poor

Geomorphic Units - Tier 3
IN-CHANNEL

Concavities (e.g. Pools):
- Chute (Ch)
- Pocket Pool (Pk)
- Pond (Pd)
- Pool (Po)

Convexities (e.g. Bars):
- Margin Attached Bar (Br)
- Mid-Channel Bar (Bc)
- Riffle (Rf)

Planar Features:
- Cascade (Ca)
- Rapid (Ra)
- Run (Gr)
- Transition Zones (Tr)
- Bank (Bk)

Channel Features:
- Thalweg
- Old Thalweg

Structural Elements:
- LWD
• Plane bed dominated (rapids & runs)
• Starved of wood..
• Limited interaction with floodplain
ADDING P.A.L.S. (WOOD)
South Fork Asotin Creek: Planformed Controlled with Discontinuous Floodplain

Condition: Poor

Lat: 46.24869088939191
Long: -117.2892015084726

Geomorphologic Units Pre Restoration

Geomorphologic Units Post Restoration

Concavities
Convexities
Planar

Concavities (e.g. Pools)

Convexities (e.g. Bar)

Planar Features

Channel Features

Structural Elements

IN-CHANNEL

Chute (Ch)
Pocket Pool (Pk)
Pond (Pd)
Pool (Po)
Margin Attached Bar (MAB)
Mid-Channel Bar (MCB)
Riffle (Rf)
Cascades (Ca)
Rapid (Rd)
Run (Gu)
Transition Zones (Tz)
Bank (Bk)

Old Thalweg

New Thalweg

LWD

Condition: Moderate

Elevation

2093 ft (638 m)

2080 ft (634 m)
NETWORK MODEL
OF CARRYING CAPACITY

\[ \sum \text{Capacity} \downarrow \text{Each Reach} \]

Carrying Capacity Estimation:
Reach-scale mechanistic model
- Water depth
- Water velocity
- Water temperature
- Invertebrate prey

Network Extrapolation
Structural equation modeling:
- GPP
- Riparian vegetation
- Geomorphic character
- Water temperature

Juvenile Steelhead Capacity (fashm)
- 10.4 - 19.6
- 1.3 - 2.4
- 4.0 - 10.4
- 0.0 - 1.3
- 2.4 - 4.0

Productivity (survival)
carrying capacity (abundance)

N stage \( i \) + 1

N stage \( i \)
**MAGIC STEP**

- Imputation
- This step is one of our biggest development hurdles...
- Can we predict site level summary from network level output?

From: Wheaton et al. (2017) – ESPL; DOI: [10.1002/esp.4137](https://doi.org/10.1002/esp.4137)
GEOMORPHIC UNIT IS NEXUS & HRT GOT IS THERE

ABANDONED FLOOD PLAIN (TERRACE)

Tier 1 - (< or > bankfull)
Tier 2 - Active Flood plain
Tier 3 - Bank Attached
Tier 4 - Floodplain

Abandoned Floodplain (Terrace)
- coarse grained, older, valley fill

Abandoned Floodplain (Terrace)
- fine-grained, younger inset deposit

Active Flood Plain

GEOMORPHIC FORM

An abandoned Flood Plain (Terrace) is a valley bottom, planar accumulation of stream-deposited alluvium that is no longer directly associated with the active channel. Terraces comprise a tread, the planar upper surface representing the relict floodplain surface; and a riser, the erosional slope or flank of the terrace landform. Terrace sequences can be inset within other terrace deposits forming “fights” of step-like features surrounding the active channel (see above and right).

PROCESS INTERPRETATION

Terraces form as valley-fill floodplain sediments are later eroded (incised) and remnant surfaces are left abandoned along the channel margins. Terraces can form as cut features, by subsequent incision of valley fill alluvium; as fill features that are subsequently eroded into terrace forms; or as purely erosional stroth surfaces, etched into resistant deposits, or even bedrock of the confining canyon walls.

ASSOCIATED GEOMORPHIC UNITS AND STRUCTURAL ELEMENTS

Abandoned floodplains-terraces are closely associated with both floodplain and hillslope geomorphic units. Older, coarse terrace remnants directly overlie bedrock (above); younger, fine-grained and inset terraces underlie the contemporary floodplain and include paleochannels, channel cutoffs and banks (at left). Terraces are generally not in contact with instream geomorphic units, except where the abandoned floodplain acts as the confining boundary—in this case, the terrace riser would exhibit cutbank forms, and would supply sediment to the active channel.
We live in a time where we have rapidly moved from an era of being data poor to data rich...

Even if you had that coveted data... what would you do with it?

Does it really make your life easier?

Don’t let the HRT be a substitute for thinking... instead use HRT to help shed light on your curiosities and big questions