Regional Curves of Hydraulic Geometry for Wadeable Streams in Marin and Sonoma Counties
San Francisco Bay Area

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Background

• Funded in 2009 under EPA 2100 Grant for $30k and managed by SFEP

• Project Goals:
  • Update original Leopold curve for SF Bay Area for Marin and Sonoma for area/width/depth
  • Assess major factors (i.e. precip, geology, % urbanization) impact channels
  • Collected and analyzed 58 data points
  • Phase I report analyzes for several variables
  • [Hopefully] a Phase II to further stratify and analyze data
In the 1950’s a group of U.S. Geological Survey researchers led by Luna Leopold ushered in modern process geomorphology with an aggressive campaign to measure and explain the physics underlying these processes. Leopold’s approach involved coupling field observations and measurements with theoretical models to explain geomorphological processes.

The Virtual Luna Leopold Project

On February 23, 2005, Luna Leopold died at the age of 90. Luna was a vital force, a man of extraordinary creativity and originality, whose passion about science and the natural world permeated all he did. He wrote with a clarity, simplicity, and insightfulness that inspired generations of researchers. Nearly all of Luna’s papers precede the time when publishing houses made pdf’s available. In order to avoid Luna’s seminal papers becoming “classics” (papers often cited but never read), we have created a web page where the majority of Luna’s papers have been scanned and made available online as pdf’s. Luna assisted with this work, reviewing the publication list and helping us find originals of papers.

GEOLOGICAL SURVEY PROFESSIONAL PAPER 252

Quantitative measurement of some of the hydraulic factors that help to determine the shape of natural stream channels: depth, width, velocity, and suspended load, and how they vary with discharge as simple power functions. Their interrelations are described by the term “hydraulic geometry.”

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. 20402
Price 40 cents (paper cover)
Major Downstream Trends

- discharge ↑
- width ↑
- depth ↑
- velocity ↑
- gradient ↓
- grain size ↓
Bankfull or Effective Flow

- For alluvial rivers - “author of their own geometry”
- “The flow that over time forms the equilibrium channel dimensions”
- ~ 1.5 yr RI flow
- Must be found from bankfull indicators in field
Hydraulic Geometry and Creek Restoration

- Channel parameters described with power functions using $Q$ as the sole independent variable: $BFw = aQ^b$  $BFd = cQ^f$  $BFv = kQ^m$

- An important design tool used in many restoration project designs – regional curves are plots of “stable” or “equilibrium” sites

- Plots of field sites are “regional curves”
1978 - One curve for SF Bay Region at 30” MAP (curve A)

Data points not plotted

Assumed 1.5 RI and plotted A, W and D from gaging records at USGS gage sites

Best done as local dataset (our project)
Finding bankfull elevation is not always easy

- A depositional feature not always present
- Most Bay Area streams are incising
Finding bankfull in the real world...
Adjustments in the Fluvial System
Hydraulic Geometry: A Geomorphic Design Tool for Tidal Marsh Channel Evolution in Wetland Restoration Projects

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Introduction

Since at least the 17th century observers have noted how the depth and width of tidal marsh channels are affected by anthropogenic alterations in the upstream tidal prism or volume of water exchanged upstream of a point during a tidal cycle. This understanding was stated perceptively in 1637 by ship owners in the town of Cley in Norfolk, England, who were petitioning to have newly installed dikes on tidal marshes upstream of the shipping channel in their harbor removed.

The banke of earth ... taketh away ... the indraught of water 80 rods and upwards in breadth and one myle at least in length [an area larger than 65 ha] ... so that what silt or mud the flood tide bringeth in both settle and remaine in the navigable channel ... through want of the ebb tide which formerly overflowed the aforesaid 80 rods of ground in breadth and one myle in length (Cozens-Hardy 1927).

Intrinsic in this description is a concept that there is an equilibrium form of a tidal channel for a given-sized marsh with a particular tidal range within an estuary that is relatively stable over long periods of time. This form is the expression of a dynamic equilibrium between erosional and depositional processes.

It was not until the 1960s that scientists (Myrick & Leopold 1963) attempted to systematize an understanding of the relationship between tidal flows and channel geometry of tidal marsh channels using equations of hydraulic geometry, as had been done for alluvial rivers and canals 30 years before. These equations relate channel cross-sectional geometry to discharge according to the power functions: $W = aQ^b$, $D = cQ^f$, and $v = kQ^m$, where $W$ is the width, $Q$ is the characteristic discharge, $D$ is the average depth, and $v$ is the characteristic velocity. By continuity of flow the sum of the constants $a$, $c$, and $k$ and the sum of the exponents $b$, $f$, and $m$ are both equal to 1. Various researchers have measured flow and channel cross-sectional parameters and then calculated the exponential parameters for downstream changes in hydraulic geometry. (See Allen 2000 for a succinct de-
Sonoma County Sites

Figure 2: Location of Sonoma County Survey Sites
Data Collection and Analysis

Multiple Field Parameters

- BF Width and Elevation
- Pebble Counts
- Profile and Cross-Section Surveys
- Many more GIS Analysis
- Drainage area
- % imp and channelized network
- Precipitation

Calculated Parameters
- BF flow, area, velocity, W/D ratio, SS many more
Results...

- Over 20 different graphs and tables in the report
- Showing only a few today
- New analysis of the required floodplain width and chanelized network length
Slope and DA Frequency Plots

- 14 sites > 3% slope – fills in data gap for steeper streams
- Fills in data gap for smaller streams
Dominant Geomorphic Setting

Types
1. Wide alluvial valley
2. Narrow predominantly alluvial valley
3. Moderately wide alluvial valley
4. Alluvial fan*
5. Narrow, predominantly colluvial valley or canyon
6. Steep, mostly bedrock confined canyon
7. Plain, often uplands transitional to tidelands
Rosgen Classification

Frequency Distribution of Field Sites by Rosgen Stream Class (with some modification for Bay Area)
## USGS Gage Sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Bankfull Discharge (cfs)</th>
<th>Reservoir Upstream</th>
<th>Approximate Recurrence Interval (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corte Madera Creek at Ross Gage Site 11460000</td>
<td>953</td>
<td>Yes</td>
<td>1.3</td>
</tr>
<tr>
<td>Lagunitas Creek at Samuel P. Taylor Park, Gage Site 1146400</td>
<td>842</td>
<td>Yes</td>
<td>1.1</td>
</tr>
<tr>
<td>Novato Creek at Novato, Gage Site 11459500</td>
<td>303</td>
<td>Yes</td>
<td>1.2</td>
</tr>
<tr>
<td>Sonoma Creek at Agua Caliente, Gage Site 11458500</td>
<td>3139</td>
<td>No</td>
<td>1.2</td>
</tr>
<tr>
<td>Walker Creek near Marshall, Gage Site 11460750</td>
<td>1065</td>
<td>Yes</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Note: Recurrence intervals were determined from a flood frequency analysis of Peak Annual flows from USGS data.
Regional Curve – X-Sectional Area

Bankfull Cross-Sectional Area versus Drainage Area

\[ \gamma = 13.292 \chi^{0.8335} \]

\[ R^2 = 0.95793 \]
Regional Curve – Bankfull Width

Bankfull Width Versus Drainage Area

\[ y = 12.893x^{0.4662} \]

\[ R^2 = 0.89833 \]
Regional Curve – Bankfull Depth

Bankfull Depth versus Drainage Area

$y = 1.0195x^{0.5687}$

$R^2 = 0.92607$
Regional Curve – Flood-Prone Width

Floodprone Width Versus Drainage Area for All Data including Unstable Rosgen Stream Classes F and G

\[ y = 23.69x^{0.4315} \]

\[ R^2 = 0.80379 \]
Regional Curve – Flood-Prone Width

Floodprone Width Versus Drainage Area for Relatively Stable Channels with Rosgen Stream Classes F and G Channels Removed from Plot

\( y = 26.084x^{0.5413} \)

\( R^2 = 0.87057 \)
Degree of Channelization

![Graph showing the relationship between upstream drainage network length and bankfull discharge. The equation is $y = 4.6503x^{1.0265}$ with $R^2 = 0.94433$.](image)
Manning's $n$ by Rosgen Stream Type

- **Max**
- **Min**
- **Average**
Next Steps

Looking for Phase II funding to:

• Perform more field survey at focus sites
• Statistical data analysis and segregation
• Look for riparian signature on floodplain (part of SFEI team) – focus on required floodplain width
• Assess water quality impacts of sediment production from channel erosion
• Prepare a formal methods and procedures guidance document
• Publish findings and prepare presentations of findings and use regional curves for creek restoration design and watershed analyses
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