Phase 2 Development of a Hydrologic Condition Index for the Puget Sound Basin

Colin Hume

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Phase 2 Development of a Hydrologic Condition Index for the Puget Sound Basin

Salish Sea Ecosystem Conference

April 27th, 2022

Colin Hume
Puget Sound Recovery Lead
Shorelands and Environmental Assistance Program
Topics we’ll cover today

• Phase 1 Hydrologic Condition Index (HCI) outcomes (Volume 4)
• Phase 2 HCI approach
• How HCI fits into existing and emerging decision-support frameworks

Project supported by:

Environmental Science Associates

Clear Creek Solutions
Hydrologic Condition Index (HCI)

Background

• Conceptualized initially by Lucchetti et al. 2014 to assess CAO effectiveness
  • Building on concept that High-pulse-counts ("flashiness") correlate with stream biology

• Stanley et al. 2019 (Volume 4 of the PSWC):
  • Evaluated different methods for calculating HCI
  • Validated HCI with stream gage data
  • Initial proof of concept for “alternative futures” applications
  • Initial concepts on how to integrate HCI with existing PSWC indices and other stream data
  • Recommendations for phase 2 development
Hydrologic Condition Index (HCI)

**Calculate the Index:**
- Overlay grid on a watershed
- Each grid cell – shortest distance to stream ($d_{Og}$), distance from stream intersection to outlet ($d_{Sg}$)
- Land cover and surficial geology combination for each grid cell has a $HPC_{coefficient}$ derived from HSPF hydrologic modeling
- Assess current condition relative to worst possible (all paved)

$\rightarrow$ 0-1 index where **higher values are correlated with relatively more High-Pulse Counts** at the outlet

### Calculation of Hydrologic Condition Index for a Watershed

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Calculate the High Pulse Count value for each grid cell ($HPC_g$).</td>
<td>$HPC_g = HPC_{coeff} \left( \frac{1}{d_{Og} + d_{Sg}} \right)$</td>
</tr>
<tr>
<td>2</td>
<td>Calculate the Hydrologic Condition Value ($HCV_s$) for the watershed.</td>
<td>$HCV_s = \sum_{g=1}^{n} HPC_g$</td>
</tr>
<tr>
<td>3</td>
<td>Calculate the Hydrologic Condition Index (HCI) for the watershed. Divide the hydrologic condition value by the worst case HCV when the watershed is 100% paved.</td>
<td>$HCI = \left( \frac{HCV_s}{HCVs\ worst} \right)$</td>
</tr>
</tbody>
</table>
HCI & High Pulse Counts

Index validation and methods comparison-
- HCI correlates well with **gage measured High-Pulse-Counts** or “stream flashiness” in 8 test basins
- Better than % impervious
Hydrologic Condition Index Phase 2

Major tasks:

• **Calibrate HPC** coefficients for areas outside of Central Puget Sound → Ultimately allow for Puget Sound-wide application

• **Refine HCI Condition Categories** → validating with stream gage data and response variables such as B-IBI
  • Describe “uncertainty”

• **Local Application Use Case Pilots**
HCI Phase 2 - Calibrate HPC coefficients

Watershed selection criteria:
1. Existing calibrated HSPF model available
2. Geographic spread North-Sound Puget Sound
3. Level of development (low – moderate)

Ultimately generate a library of HPC coefficients to draw from for local applications depending on scenario

Table – Phase 1 High-Pulse-Count coefficients for Till surficial geology derived from five King County Watersheds (Lucchetti et al. 2014) with HSPF models which ran 61-years of climate data to generate average yearly HPCs for given combinations of land cover on surficial geology. Outwash values not displayed.

<table>
<thead>
<tr>
<th>Land Cover on Till</th>
<th>Hamm Creek (set 1)</th>
<th>Miller Creek (set 2)</th>
<th>Des Moines Creek (set 3)</th>
<th>Newaukum Creek (set 4)</th>
<th>Duwamish Creek (set 5)</th>
<th>HPC AVG</th>
</tr>
</thead>
<tbody>
<tr>
<td>forest</td>
<td>2.393443</td>
<td>2.672131</td>
<td>3.655738</td>
<td>4.606557</td>
<td>7.04918</td>
<td>4.07541</td>
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<tr>
<td>shrub</td>
<td>2.639344</td>
<td>3.311475</td>
<td>4.47541</td>
<td>6.016393</td>
<td>7.081967</td>
<td>4.704918</td>
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<tr>
<td>pasture</td>
<td>2.803279</td>
<td>4.032787</td>
<td>4.622951</td>
<td>6.590164</td>
<td>7.606557</td>
<td>5.131148</td>
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<tr>
<td>wetland</td>
<td>2.901639</td>
<td>4.868852</td>
<td>4.540984</td>
<td>7.52459</td>
<td>8.245902</td>
<td>5.616393</td>
</tr>
<tr>
<td>clear cut</td>
<td>3.819672</td>
<td>5.032787</td>
<td>5.360656</td>
<td>8.606557</td>
<td>8.803279</td>
<td>6.32459</td>
</tr>
<tr>
<td>grass</td>
<td>5.672131</td>
<td>5.213115</td>
<td>6.032787</td>
<td>9.983607</td>
<td>8.47541</td>
<td>7.07541</td>
</tr>
<tr>
<td>bare</td>
<td>5.114754</td>
<td>8.52459</td>
<td>7.901639</td>
<td>10.508197</td>
<td>11.459016</td>
<td>8.701639</td>
</tr>
<tr>
<td>building</td>
<td>30.508197</td>
<td>34.803279</td>
<td>33.491803</td>
<td>29.622951</td>
<td>31.836066</td>
<td>32.052459</td>
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<tr>
<td>pavement</td>
<td>26.540984</td>
<td>36.885246</td>
<td>36.508197</td>
<td>34.032787</td>
<td>35.737705</td>
<td>33.940984</td>
</tr>
<tr>
<td>open water</td>
<td>27.934426</td>
<td>38.163934</td>
<td>38.131148</td>
<td>36.655738</td>
<td>37.786885</td>
<td>35.734426</td>
</tr>
<tr>
<td>unpaved road</td>
<td>33.983607</td>
<td>37.180328</td>
<td>36.901639</td>
<td>34.754098</td>
<td>36.672131</td>
<td>35.898361</td>
</tr>
<tr>
<td>paved road</td>
<td>34.360656</td>
<td>37.655738</td>
<td>37.344262</td>
<td>35.180328</td>
<td>37.213115</td>
<td>36.35082</td>
</tr>
</tbody>
</table>
HCI Phase 2 – **Refine HCI Condition Categories**

Phase 1 Extrapolates the relationship between HPC and B-IBI to the HCI to establish thresholds of likely stream condition → **Phase 2 expand sample of watersheds to higher HCI range.**

Plot of measured high pulse counts and Benthic Index of Biotic Integrity (B-IBI) survey points. A high pulse count of approximately 14 to 15 provides an approximate, useful discrimination between good (60-80), fair (40-60), and poor (<40) B-IBI scores. B-IBI data from DeGasperi & Gregersen (2015).
HCI Phase 2 – Local Application Use Cases

• HCI provides a metric (“ruler”) by which to evaluate current condition relative to potential “worst” – status and trends application

• HCI may be useful in evaluating hydrologic implications of future land cover changes and decisions related to:
  • Land use designations and zoning under GMA
    • CAO evaluations
    • Buildable Lands Programs
  • Stormwater planning (e.g. Stormwater Management Action Plans)
    • Condition Assessment
    • Retrofit or stormwater mitigation planning

A planning-Level tool for rapid assessment and scenario evaluation
Local Applications – Buildout Scenarios
Coarse-Scale

<table>
<thead>
<tr>
<th>Future Buildout Scenario</th>
<th>Potential Development Units</th>
<th>Hydrologic Condition Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Scenario</td>
<td>1058 Units</td>
<td>HCl = 0.6 Poor Condition</td>
</tr>
<tr>
<td>Increased Riparian Buffer Scenario</td>
<td>923 Units</td>
<td>HCl = 0.44 Poor Condition</td>
</tr>
<tr>
<td>Green Development Scenario</td>
<td>2122 Units</td>
<td>HCl = 0.23 Moderate to Good Condition</td>
</tr>
</tbody>
</table>

Current Condition

Story Map
Local Applications – Buildout Scenarios
Finer-Scale

- Will generally require higher resolution land cover and flow-path layers
- Account for Critical Areas to some degree
- Account for LID and/or stormwater mitigation requirements
- Generalized templates for typical development or redevelopment in zoning categories

Image from Lucchetti et al. 2014
Pilot Opportunity!

• Looking for **3 pilot use cases** with local governments:
  • Stormwater Planning
  • Land Use Planning (GMA/SMA)
  • Restoration Planning
  • Status and Trends metric
  • Other?

• Consultant team and Ecology will produce a report which illustrates how the HCI can be integrated into an **existing planning framework**.

Contact me at 425-395-5283 OR colin.hume@ecy.wa.gov
Integrating the HCI into the PSWC Framework

- Existing Broad-scale indices (Volumes 1 and 2) compare areas for their contribution and/or level of degradation for:
  - Water Flow Processes
  - Water Quality Processes
  - Terrestrial Habitats
  - Freshwater Habitats
  - Marine Shoreline Habitats
Type of Data & Information:

Application:

What to Use:

Scale:

Broad-Scale – 100’s of sq. miles

Mid-scale – 10’s of sq. miles

Fine-Scale – less than 1 sq. mile

= Integrated result

Land use and stormwater planning - Type, & location of new development, prioritization of restoration and protection actions.

Assessments of watershed processes such as those found in Puget Sound Characterization.

Coarse scale data on land cover/land use, geology, precipitation, topography, & hydrology.

The most important areas contributing to processes such as movement of water, sediment, nutrients & general level of watershed integrity.

Project Design of Restoration and Mitigation

Predictive hydrologic models, water quality, species & habitat monitoring data etc.

Site specific data on biological, physical and chemical conditions

Quantifies: hydrologic flows, limiting water quality factors, habitat structure & functions

Integrating the HCI into the PSWC Framework
Integrating the HCI into PSWC Framework

- HCI can be used as a “mid-scale” part of the integration framework
- Complement the Broad-scale indices
- Narrower indicator of stream function than existing indices
- Allow for alternative future scenarios evaluation to communicate implications of future land cover change

<table>
<thead>
<tr>
<th>Steps</th>
<th>Use Tool</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What is the predominate Watershed Management Category for your watershed?</td>
<td>Broad scale results and local information.</td>
<td>Protection? Restoration? Development?</td>
</tr>
<tr>
<td>2. Determine risk from future buildout. Good, moderate, or poor hydrologic condition?</td>
<td>HCI score for existing and full buildout.</td>
<td>Intact Hydrologic Condition → Moderate Hydrologic Condition → Poor Hydrologic Condition → Degraded Hydrologic Condition</td>
</tr>
</tbody>
</table>
| 3. Integrate results from step 1 and 2. | Solution templates. | • For “Protection” areas and HCI < 0.21, use protection actions  
• For “Restoration” areas and HCI > 0.21 & < 0.44, use restoration actions.  
• For “Development” areas and HCI > 0.44, use LID. |
| 4. Which areas will help maintain a healthy hydrologic condition? | HCI scores, land cover, geology, and proposed actions. | Identify areas that could improve Hydrologic condition through restoration actions or green development actions. |
| 5. Design future development alternatives and rerun HCI. | HCI score for proposed development. | |
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Puget Sound Watershed Characterization
Website

Contact:
Colin Hume
425-395-5283
colin.hume@ecy.wa.gov

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