Dams and Hydrologic Regime in the Penobscot River: A reappraisal based on historical records and hydrologic modeling

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Introduction: The Penobscot River Watershed has a long history of hydrologic alteration by humans. Dams, and the logging/mill industries that built them, have caused large changes to both surface and ground water regimes throughout the watershed. These alterations can influence many hydrologic processes, changing the timing and magnitude of downstream flows. The Penobscot also has a large variety of dam types (i.e. storage, run-of-the-river) for different purposes (i.e. flood control, hydropower), by different stakeholders (i.e. timber industry, utilities), which we hypothesize will have different influences on downstream flow regime.

As part of the larger Future of Dams project and in concert with our collaborators throughout the New England Sustainability Consortium, we focus our research on providing stakeholders with tools to facilitate better informed decisions about dams. Towards this ultimate goal, the research we present here is targeted at quantifying changes to hydrologic regime in the context of varied dam management, and to help stakeholders better understand the interactions between dam management decisions and downstream surface water flows. We ask three main dam management decisions altered hydrologic regime throughout the history of this watershed. We also examine the historical variation in downstream water discharge, calculated Using the HEC-RAS model.

Study Area: Penobscot River Watershed
- 22,300 km²
- 30 USGS gauge rivers
- 130 dams (46 Run of River & 79 Storage)
- 19 of which have hydraulically adjacent downstream gauges
- 5 of which have records before & after dam construction

Kingsbury Stream Watershed
- Tributary to the Picnicwater, ME
- 1 gauge (At outlet in Abbot, ME)
- 1 dam (storage)

Objectives & Applications: Identify periods of change in watershed characteristics, caused by dams, landuse change, or climate.

Apply discharge to downstream flow regime related to known periods of change in watershed characteristics

- power generation, via stream power
- channel habitat, via hydraulic geometry for channel width, depth, and velocity
- using relationships developed by Dudley, 2004

Estimate flow regime for the Penobscot in an un-dammed scenario

Approach 1, Hydrology History: Identifying periods of change in the Kingsbury Stream based on hydrologic model performance.

Methods: Use model to identify
- surface water
- observed differences in cumulative probability
- characterize flow regime using

Approach 2, Hydrology: Quantifying changes to downstream flow patterns before and after changes to dam management.

Methods: Compile spatial and historical data relating to dams and their stakeholders
- quantity the change in flow regime relative to known changes in watershed history
- Characterize flow regime using Flow Duration Curves (cumulative probability distributions)

Table 3: Sites with a dam upstream, and overlapping the record of a USGS gauge

<table>
<thead>
<tr>
<th>Dam Name</th>
<th>Gauge Site</th>
<th>Distance Downstream (km)</th>
<th>Added Contributing Area (km²)</th>
<th>Tributary and Other Influences</th>
<th>Available Flow Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada Dams</td>
<td>South Branch at Canada</td>
<td>0.22</td>
<td>c</td>
<td>None</td>
<td>After</td>
</tr>
<tr>
<td>Dol Pond</td>
<td>North Branch at Pittsfield</td>
<td>23.94</td>
<td>466.657</td>
<td>Many tributaries</td>
<td>After</td>
</tr>
<tr>
<td>Metacomet</td>
<td>Pleasantville</td>
<td>5.76</td>
<td></td>
<td>None</td>
<td>Before &amp; After</td>
</tr>
<tr>
<td>Metacomet</td>
<td>North Branch at Starks</td>
<td>6.528</td>
<td>3,127.40</td>
<td>Many tributaries</td>
<td>Before &amp; After</td>
</tr>
<tr>
<td>Sebec</td>
<td>Sebec at Sebec</td>
<td>0.27</td>
<td>0.96</td>
<td>None</td>
<td>Before &amp; After</td>
</tr>
<tr>
<td>Medway</td>
<td>West Medway at Medway</td>
<td>0.26</td>
<td>19.21</td>
<td>One small tributary</td>
<td>Before &amp; After</td>
</tr>
<tr>
<td>Howard Branch</td>
<td>North Branch at Starks</td>
<td>0.33</td>
<td>0.96</td>
<td>None</td>
<td>Before &amp; After</td>
</tr>
<tr>
<td>Peribay &amp; West North</td>
<td>West North</td>
<td>1.87</td>
<td>0.96</td>
<td>Two large river flows on two merging channels</td>
<td>B&amp;B Howard, After-W</td>
</tr>
<tr>
<td>West Branch at Medway</td>
<td>Sebec at Sebec</td>
<td>1.93</td>
<td>0.96</td>
<td>None</td>
<td>Before &amp; After</td>
</tr>
<tr>
<td>Pleasant at Nqr</td>
<td>Pleasant at Nqr</td>
<td>1.93</td>
<td>0.96</td>
<td>None</td>
<td>Before &amp; After</td>
</tr>
<tr>
<td>Picquet at Dover-Foss</td>
<td>Picquet at Dover-Foss</td>
<td>1.93</td>
<td>0.96</td>
<td>None</td>
<td>Before &amp; After</td>
</tr>
<tr>
<td>Penobscot at West Enfield</td>
<td>Penobscot at Passadumkeag</td>
<td>1.93</td>
<td>0.96</td>
<td>None</td>
<td>Before &amp; After</td>
</tr>
<tr>
<td>Penobscot at Mattawawesk</td>
<td>Penobscot at Eddington</td>
<td>1.93</td>
<td>0.96</td>
<td>None</td>
<td>Before &amp; After</td>
</tr>
<tr>
<td>North Branch at Pittston</td>
<td>North Branch at Pittston</td>
<td>1.93</td>
<td>0.96</td>
<td>None</td>
<td>Before &amp; After</td>
</tr>
<tr>
<td>Mattawawesk at Mattawawesk</td>
<td>Mattawawesk at Mattawawesk</td>
<td>1.93</td>
<td>0.96</td>
<td>None</td>
<td>Before &amp; After</td>
</tr>
<tr>
<td>Kingsbury at Abbot</td>
<td>Kingsbury at Abbot</td>
<td>1.93</td>
<td>0.96</td>
<td>None</td>
<td>Before &amp; After</td>
</tr>
</tbody>
</table>

Discussion & Future Work:
- Approach 3: Changes in model performance before and after the 2000-2003 interval may indicate change in runoff or storage within the Kingsbury Watershed.
- Consistently low model performance indicates large uncertainty in model parameters.
- Connecting variation in model performance with changes to a watershed requires this be repeated for a known change, such as dam construction.

Approach 2: Storage and Run-of-River dams do not change different flows in flow regime before after their construction.
- The same changes are not seen in precipitation and temperature.
- Uncertainty in discharge measurements needs to be taken into account to verify differences in flow regime.
- Differences in controlling probability distributions cannot be attributed to dams alone.

Future Work:
- Further investigation into historical changes in the watershed is necessary to attribute these changes in flow regime to dams, land use, climate, etc.
- Model use to identify changes elsewhere in Penobscot where the record is longer.
- Use Composite flow regime in time (CFRT) of the Penobscot River in an un-dammed scenario.

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- Data: USGS, NASA, NOAA, EROS, and others.

References: