Progress On Use of Paleo-Conditioned Streamflow Data On Gunnison River Basin For Aspinall EIS

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Tree Ring Data Related Developments

- **June ’05**
  - Hydrologic Period of Record
  - Tree Ring Data Discussed
  - Single trace / index sequential / stochastic analysis
  - Depletions – staged or up-front

- **September ’05**
  - Committed to iterative trace analysis (at a min)

- **December ’05**
  - Began statistical analysis of unique periods of record including proxy data 1569 to 1997

- **February ’06**
  - Dr Rajagopalan and Dr Ray presented preliminary plan for implementing tree-ring data
Tree Ring Data Developments, continued

• April ’06
  – Developed Forecasting Algorithm for any given hydrology
  – Solved leap-year problem (daily model issues)
  – Decided to use natural flow data (StateMod -> RiverWare)
  – Settled on ’37-’97, with paleo-conditioned data in appendix

• August ’06
  – Continued debate on period of record (!)
  – Jim Prairie presented single trace/ISM/stochastic comparison, and techniques for handling data and interpreting results
Paleo Problems…

• Large extremes are outside scope of study
• Annual volumes applied, but seasonal variability is needed (fixed with transition sequencing)
• May not capture magnitudes of events
• Temporal (year-year) transitions problematic
• Spatial distributions problematic
• “This must be voodoo!” : )
Paleo Positives:

- Establishment of baseline conditions
- Captures system states very well (graphic)
- Length and intensity of prehistoric droughts
- Sequent-peak algorithm
- Long-term basin firm yield
- Return frequency of droughts
- More data to run operations on

“There is nothing sacred about historic sequences of hydrology”

Dr. Balaji Rajagopalan

Udall, 2005
Paleo Game Plan 1/2

1) Stochastic Historic Flow Sequences
   a) Generation of annual flow sequences using KNN
   b) Historic data: 1937-1997 (flow recs)
   c) Compare results to ISM

2) Statistical Support
   a) Compute suite of statistics
      i. Wet and dry period stats
      ii. Run lengths of droughts and floods
      iii. Monthly flow properties
   b) Compare with results from historic data
Paleo Game Plan 2/2

• Baseline Risk Assessment
  – Develop a sequent-peak algorithm
    • Storage required for given yield over various drought deficits
    • Assess system risk (reliability)
    • Provides storage required for various levels of firm yield

• Transition Sequencing of Prehistoric Data
  – Using paleo reconstruction from Woodhouse et al. 2006:
    • Simple block bootstrap of paleo data
    • Determine the state of the system for paleo data
    • For each year use a KNN method to resample the observed data to conditionally generate the flow magnitudes that are consistent with the generated “state” of the (paleo) system
Paleo Reconstructed Streamflow Data

Block Bootstrap Data (30 year blocks)

Compute state information (Assume 3 state system)

Use KNN technique to resample natural flow data consistent with paleo state information

Natural Streamflow Data

Categorize natural flow data (3 state system has 9 categories)
Periods under Consideration

- 1569-1997  Proxy Data Obtained From Recent Dendrochronology (Woodhouse, 2006)
- 1906-1916  Regressed Monthly Gauge Data
- 1917-1936  Recorded Monthly Gauge Data
- 1937-1997  USFWS Flow Recommendations
- 1937-2004  Updated Flow Recs
- 1975-2004  Daily Gauged Data Record
### Comparison of basic statistics on Annual Flow Volumes

<table>
<thead>
<tr>
<th>Period</th>
<th>Mean</th>
<th>Median</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>1569-1997</td>
<td>2,330</td>
<td>2,393</td>
<td>429</td>
</tr>
<tr>
<td><strong>1906-1916</strong></td>
<td><strong>2,630</strong></td>
<td><strong>2,809</strong></td>
<td><strong>11</strong></td>
</tr>
<tr>
<td>1917-1936</td>
<td>2,501</td>
<td>2,454</td>
<td>20</td>
</tr>
<tr>
<td>1937-1997</td>
<td>2,319</td>
<td>2,269</td>
<td>61</td>
</tr>
<tr>
<td><strong>1937-2004</strong></td>
<td><strong>2,247</strong></td>
<td><strong>2,192</strong></td>
<td><strong>68</strong></td>
</tr>
<tr>
<td>1975-2004</td>
<td>2,313</td>
<td>2,276</td>
<td>30</td>
</tr>
</tbody>
</table>
y = 0.2232x + 1932.3
R² = 0.0016

Reclamation
Trend Comparison:
Tree Ring Record by Century

\[
y = 4.636x - 5208.8 \\
R^2 = 0.0029
\]

\[
y = -0.1134x + 2563.1 \\
R^2 = 2E-05
\]

\[
y = 0.591x + 1253.1 \\
R^2 = 0.0006
\]

\[
y = -2.021x + 6089.1 \\
R^2 = 0.0067
\]

\[
y = 1.1294x + 167.68 \\
R^2 = 0.0025
\]
Trend Comparison:
Natural Flow 1906-2004

\[ y = -4.7698x + 11666 \]
\[ R^2 = 0.0335 \]
Trend Comparison:
Natural Flow 1906-2004

1906-1916
\[ y = -19.719x + 40312 \]

1917-1936
\[ y = -60.594x + 119236 \]

1937-1997
\[ y = 7.5825x - 12596 \]

1975-2004
\[ y = -21.831x + 45747 \]
Trend Comparison:
Tree Ring Record 1569-1997

1569-1997

\[ y = 0.2232x + 1932.3 \]
Trend Comparison:
Tree Ring Record 1569-1997 and 1906-2004 Natural Flow Data

1569-1997
\[ y = 0.2232x + 1932.3 \]

1906-2004
\[ y = -4.7698x + 11666 \]

Annual Inflow (kaf)
Trend Comparison:
Tree Ring Record 1569-1997 and 1937-1997

1569-1997
\[ y = 0.2232x + 1932.3 \]

1937-1997
\[ y = 7.5825x - 12596 \]
Trend Comparison:
Tree Ring Record 1569-1997 and 1937-1997

1569-1997: 
\[ y = 0.2232x + 1932.3 \]

1937-1997: 
\[ y = 7.5825x - 12596 \]

1937-2004: 
\[ y = -0.4968x + 3226.1 \]