Application of HEFR at Brazos River at Richmond

Implementation and Suggested Improvements

Presented to the Trinity and San Jacinto Rivers and Galveston Bay Basin and Bay Expert Science Team

April 8, 2009
Overview

• BRA system
• Development of instream flow regime statistics for the Brazos
• Application of HEFR
  – Qualifying high flow pulse events
  – Interaction of HFP events and water diversions
  – Frequency criteria
• Summary and recommendations
Flow Regime Statistics

- Statistics jointly developed by TPWD, TCEQ and BRA
- Consistent with flow regime approach of the TIFP
- Intended as a interim criteria until instream flow studies completed
## HEFR Flow Regime Statistics
### Brazos River at Richmond 1923-1959

**Hydrologic Conditions**

<table>
<thead>
<tr>
<th>Wet</th>
<th>Average</th>
<th>Dry</th>
<th>Subsistence</th>
</tr>
</thead>
</table>

### High Flow Pulse Characteristics

<table>
<thead>
<tr>
<th>F = Frequency (per season)</th>
<th>D = Duration (days)</th>
<th>Q = Peak Flows (cfs)</th>
<th>V = Volume (ac-ft)</th>
</tr>
</thead>
</table>

### Overbank Flows

<table>
<thead>
<tr>
<th>Return Period (R) : 0.7 (years)</th>
<th>Duration (D) : 36 (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (V) : 1,622,698 (ac-ft)</td>
<td>Peak Flow (Q) : 61,600 (cfs)</td>
</tr>
</tbody>
</table>

#### High Flow Pulses

<table>
<thead>
<tr>
<th>F</th>
<th>D</th>
<th>Q</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>19,500</td>
<td>297,551</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
<td>19,150</td>
<td>270,154</td>
</tr>
<tr>
<td>1</td>
<td>12</td>
<td>15,300</td>
<td>166,116</td>
</tr>
<tr>
<td>1</td>
<td>11</td>
<td>13,175</td>
<td>146,867</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>19,500</td>
<td>297,551</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>19,150</td>
<td>270,154</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>15,300</td>
<td>166,116</td>
</tr>
<tr>
<td>1</td>
<td>7</td>
<td>13,175</td>
<td>146,867</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>9670</td>
<td>90,288</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>10,200</td>
<td>101,405</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>8830</td>
<td>77,177</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>7730</td>
<td>56,162</td>
</tr>
</tbody>
</table>

### Base Flows (cfs)

<table>
<thead>
<tr>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,955</td>
<td>3,670</td>
<td>2,635</td>
<td>2,038</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,630</td>
<td>2,030</td>
<td>1,450</td>
<td>1,150</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>885</td>
<td>1,170</td>
<td>930</td>
<td>760</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Subsistence Flows (cfs)

<table>
<thead>
<tr>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>460 (7Q2 743 cfs)</td>
<td>408 (7Q2 743 cfs)</td>
<td>359 (7Q2 743 cfs)</td>
<td>403 (7Q2 743 cfs)</td>
</tr>
</tbody>
</table>
Qualifying High Flow Pulse Event

Conceptual Description

Qualifying HFP simultaneously meets
the pulse peak,
duration and volume
flow recommendations
WAM Modeling
Brazos River at Richmond 1940 -1997

• Brazos WAM Run 3 modified to include
  – Return flows from BRA sources
  – System diversions at Richmond
    • 111,574 af/yr firm
    • 670,000 af/yr interruptible

• Daily flows
  – Regulated flows before system diversion
  – Distributed to daily using historical percentage of monthly flow
  – Appropriated flow reserved for senior rights
Regulated Flows at Brazos River at Richmond
Calendar Year 1968

- Mean Daily Flow (cfs)
- Daily Regulated Flow
- Monthly WAM Regulated Flow
- Monthly WAM Instream Flows
- Monthly WAM Diversion

Regulated Flows at Brazos River at Richmond Calendar Year 1968

- Mean Daily Flow (cfs)
- Daily Regulated Flow
- Monthly WAM Regulated Flow
- Monthly WAM Instream Flows
- Monthly WAM Diversion
Average Annual Diversion of Run-of-River Streamflow
Brazos River at Richmond 1940 - 1997

Average Annual Regulated Streamflow
4,771,228 AF

- Undiverted Base Instream Flow
  15%
  734,846 AF

- Undiverted HFP
  33%
  1,558,198 AF

- Undiverted Flood
  40%
  1,896,706 AF

- Diversions
  12%
  581,478 AF

Average Annual Run-of-river Diversion
581,478 AF

- HFP
  53.1%
  308,671 AF

- Base
  24.9%
  144,877 AF

- Flood
  22.0%
  127,930 AF
Average Annual Impacts of Diversions on HFP Volume
Brazos River at Richmond 1940 – 1997

- Undiverted HFP 1,558,198 AF (83.5%)
- Curtailed Diversion 102,580 AF (5.5%)
- Diversion 204,303 AF (11.0%)

Continued diversion during HFP events impact pulse volume 5.5%.

Curtailment during HFP events impact diversions 33.4%.
Impact of Diversions on HFP Peak
Calendar Year 1968

Mean Daily Flow (cfs)

- Streamflow after diversion
- Peak - curtailed diversions
- Peak - continued diversion
- HFP Peak Flow Recommendation
Impact of Diversions to Occurrence of HFP  
Brazos River at Richmond 1940 - 1997

<table>
<thead>
<tr>
<th>Diversion Rate Threshold (cfs)</th>
<th>HFP Events that Meet Peak Criteria</th>
<th>Total HFP Events</th>
<th>Flood Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curtailed HFP Diversion (number of events)</td>
<td>250</td>
<td>584</td>
<td>72</td>
</tr>
<tr>
<td>Continued HFP Diversion (number of events)</td>
<td>230</td>
<td>567</td>
<td>72</td>
</tr>
<tr>
<td>Impact to Occurrence (number of events)</td>
<td>20</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>Impact to Occurrence (%)</td>
<td>8%</td>
<td>2.9%</td>
<td>0%</td>
</tr>
<tr>
<td>Return Period of Impacts (years)</td>
<td>2.9</td>
<td>3.4</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Qualifying HFP By Hydrologic Condition

Brazos River at Richmond 1940 – 1997

HFP Peak Discharge (cfs)

HFP Volume (af)

Non-Qualifying HFP

Wet Qualifying HFP

Avg Qualifying HFP

Dry Qualifying HFP

Small Flood Threshold

Range of Wet Hydrologic Condition

Small Flood Threshold

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Winter Season Qualifying HFP Frequency
Brazos River at Richmond  1940 – 1997 (Regulated Flows)

Winter Season Frequency Criteria 1.0 per season
Modeled Occurring Frequency 0.60 per season

Exceeds Criteria every 4.2 years
Summary

• Methodology is complex – implementation even more so
• Aggregated criteria increase complexity of application with minimal benefit to the environment
• Pulses are a significant source of water
Recommendations

• Methodology is complex – implementation even more so
  – Consider simplifying; are hydrologic conditions (wet, average, dry) needed to characterize HFP criteria?
Recommendations

• Over-constraining criteria increase complexity of implementation with minimal benefit to the environment
  – Consider relaxing criteria, such as meeting one of the three criteria to qualify

• Pulses are a significant source of water
  – Consider a diversion rate threshold, below which the Qualifying HFP criteria do not apply
  – The frequency distribution should incorporate multi-year variability (return period) and the corresponding accounting
Questions?
Duration of Curtailed Diversion During HFP

Brazos River at Richmond 1940 – 1997

Percent of Time Duration of Curtailment is Less Than or Equal (%)
## Qualifying HFP Frequency

Brazos River at Richmond 1940 – 1997 (Regulated Flows)

<table>
<thead>
<tr>
<th></th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Criteria (per season)</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Frequency of Occurrence (per season)</td>
<td>0.60</td>
<td>0.66</td>
<td>0.50</td>
<td>0.71</td>
</tr>
<tr>
<td>Return Period of Occurrence (years)</td>
<td>1.66</td>
<td>1.45</td>
<td>2.00</td>
<td>1.41</td>
</tr>
<tr>
<td>Return Period of Exceeding Criteria (years)</td>
<td>4.46</td>
<td>3.41</td>
<td>6.44</td>
<td>3.22</td>
</tr>
</tbody>
</table>
Winter Season Qualifying HFP Frequency
Brazos River at Richmond 1923 – 1959 (Pre-Dam)

- Winter Season Frequency Criteria: 1.0 per season
- Naturally Occurring Frequency: 0.6 per season

Exceeds Criteria every 4.6 years
## Qualifying HFP Frequency

Brazos River at Richmond 1923 – 1959 (Pre-Dam)

<table>
<thead>
<tr>
<th></th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency Criteria</strong> (per season)</td>
<td>1.00</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Frequency of Occurrence</strong> (per season)</td>
<td>0.6</td>
<td>0.6</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Return Period of Occurrence</strong> (years)</td>
<td>1.6</td>
<td>1.6</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Return Period of Exceeding Criteria</strong> (years)</td>
<td>4.6</td>
<td>5.3</td>
<td>9.3</td>
<td>7.4</td>
</tr>
</tbody>
</table>
Daily Diversion to Capture Monthly Appropriation
Brazos River at Richmond March thru April 1968
Daily Diversion to Capture Monthly Appropriation

Brazos River at Richmond September 1968

- Rate to capture monthly WAM target 5,109 cfs

Mean Daily Flow (cfs)

0 5,000 10,000 15,000

9/1 9/6 9/11 9/16 9/21 9/26

**Base Flow and Senior Rights**

**Diversion Above Base Criteria**

**Diversion During HFP**

**Curtailed Diversion During HFP**
Overview

• Focus on pulse data
• System can be operated so that diversion during pulses has minimal impact on environment
• Curtailment of diversion during pulse flows increases complexity of operation and impacts water supply without significant benefit to environment
• Multi-year variability can be easily incorporated into the frequency recommendations