COLUMBIA RIVER WATER USE PLAN
5-YEAR REVIEW OF ARROW LAKES RESERVOIR

OPERATIONS

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OPERATIONS AGENDA

- Description of Columbia System
- Historical Reservoir Levels
- Arrow Lakes Reservoir Operational Influences
- Operational Trends:
  - 2001-2007 (Pre Water Use Plan period from start of the process)
  - 2008-2012 (First 5 years operating under the Water Use Plan)
- Expected Future Operational Trends
COLUMBIA RIVER SYSTEM

BC Hydro’s main stem Columbia System Projects including Mica, Revelstoke & Keenleyside Dams.
COLUMBIA RIVER SYSTEM

Mica Dam/Kinbasket Reservoir:
- Columbia River Treaty Project with Treaty/Non-Treaty storage.
- Flexible operations.
- Discharges into Revelstoke

Revelstoke Dam/Reservoir:
- Not a Columbia River Treaty Project
- Very limited available storage.
- Generally inflows pass through.
- Discharges into Arrow.

Small Tributary Projects:
- Whatshan (small storage).
- Walter Hardman (no storage).
- Both discharge into Arrow.

Arrow Lakes Dam/Reservoir:
- Columbia River Treaty Project with Treaty/Non-Treaty storage.
- Limited flexibility in operations.
- Discharges into Columbia River and into the US.
ARROW OPERATIONAL INFLUENCES

Factors that BC Hydro has limited control over Arrow Lakes Reservoir operation:

- Reservoir discharges are prescribed by the Columbia River Treaty: (limited flexibility over discharges and impacts Arrow reservoir levels)
  - Based on water supply in the entire Columbia basin (not just the Canadian portion of the basin).
  - Calculated twice a month considering change in precipitation, snowpack and inflow since the previous calculation and current weather forecast information.

- Weather related: (contributes to Arrow inflow and impacts Arrow reservoir levels)
  - Snowpack (amount of snowpack in the entire Columbia River basin helps determine flood control points during freshet).
  - Inflow (local inflow into Revelstoke and Arrow Lakes Reservoirs).
  - Discharge from Mica Dam when Kinbasket Reservoir is full (must pass inflows).
AREAS THAT BC HYDRO HAS SOME ARROW OPERATIONAL FLEXIBILITY:

- Adjusting maintenance schedules at Mica and Revelstoke Dams.
- Discharges from the upstream Mica Dam: (contributes to Arrow inflow and impacts Arrow reservoir levels)
  - Generation optimized to best meet province needs (domestic load and exports).
  - Limited or no flexibility if Kinbasket Reservoir is projected to be or is full.
- Columbia River Treaty Supplemental Operating Agreements: (uses limited Treaty flexibility to impact Arrow reservoir discharges and levels)
  - Seasonal storage agreements (typically fall or summer) up to 2010.
  - Non-power uses agreements.
  - Libby co-ordination agreements.
- Columbia River Treaty Non-Treaty Storage: (uses limited Treaty flexibility to impact Arrow reservoir discharges and levels)
  - Non-Treaty Storage required to be filled between 2004 and 2011.
  - Provisional Draft bridged a period with no Non-Treaty Storage agreement.
  - New agreement signed April 10, 2012 (replaces seasonal storage agreements).
ARROW OPERATIONAL INFLUENCES

BC Hydro used mutually agreed upon Non-Treaty Storage & Supplemental Operating Agreements with the US from 2008-2012 to benefit operations:

<table>
<thead>
<tr>
<th>AGREEMENT</th>
<th>YEAR ACTIVE</th>
<th>OPERATIONAL BENEFIT</th>
<th>OPERATIONAL OUTCOME</th>
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</thead>
<tbody>
<tr>
<td>Libby Coordination</td>
<td>2008-2012</td>
<td>Mostly Power</td>
<td>Adjusts Arrow releases in two release/storage cycles (usually summer to fall/fall to winter) to compensate for US impact on Kootenay River operation (resulted in minor Arrow level changes &lt; ~4 ft). In 2013, a new agreement was signed to provide greater year round flexibility.</td>
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<tr>
<td>Non-Power Uses</td>
<td>2008-2012</td>
<td>Mostly Non-Power with some Power</td>
<td>Arrow releases are adjusted to protect Canadian Mountain Whitefish (January-March) and Rainbow Trout (April-June). In January, water is stored in Arrow (up to ~10 ft) with the water released by the end of July for the benefit of US fish and Arrow power.</td>
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<tr>
<td>Summer Storage</td>
<td>2009-2010 replaced by Provisional Draft in 2011</td>
<td>Mix of Power &amp; Non-Power</td>
<td>Arrow releases typically adjusted with storage of water in early summer and releases completed by late summer (minor Arrow level increases of &lt; ~3 ft).</td>
</tr>
<tr>
<td>Fall Storage</td>
<td>2008-2010 replaced by Provisional Draft in 2011</td>
<td>Mostly Power &amp; some Non-Power</td>
<td>Arrow releases typically adjusted with storage of water in the fall and releases completed by late winter (Arrow level increases of &lt; ~10 ft).</td>
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<tr>
<td>Provisional Draft</td>
<td>2011 once Non-Treaty Storage filled Jan 7 and replaced in 2012 by Non-Treaty Storage</td>
<td>Mix of Power &amp; Non-Power</td>
<td>Non-Treaty Storage was 100% filled in Jan 2011 and this agreement was a bridge until a new Non-Treaty Storage agreement was in place. It replaces Summer/Fall Storage plus has additional flexibility. It reduced Non-Treaty Storage volume to help manage an unusal maintenance outage at Mica Dam. Signed Apr 10, 2012 and in effect until Sep 15, 2024 to maximize power generation and enhance soft constraint target performance with year-round flexibility (same benefits as Summer/Fall Storage &amp; Provisional Draft plus additional benefits). In 2012 it was used for flood management to limit discharge/damage downstream of Arrow Reservoir during the large freshet.</td>
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<tr>
<td>Non-Treaty Storage (NTS)</td>
<td>2012 after signing of Non-Treaty Storage</td>
<td>Mix of Power &amp; Non-Power</td>
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</tbody>
</table>
2001 was a record dry year in the entire Columbia basin resulting in low levels. BCH had a summer storage agreement to help increase summer levels.

2004 & 2005 were also both dry years in the entire Columbia basin resulting in low summer levels. BCH had summer storage agreements for 2006 & 2007 and a Fall storage agreement for 2007/08.
2009 was a dry year but levels were propped up by filling Non-Treaty Storage and other operating agreements.

2012 was an extremely wet year on the Canadian side of the basin until July resulting in very high summer reservoir levels and then very dry into the fall.

2013 started very wet but suddenly turned very dry in July for several months.
Arrow Reservoir levels in the Pre-WUP period (2001-2007) are generally lower than the WUP period to date (2008-2012) due to:

- Below normal inflows of ~80% from 2001-2007 vs. ~107% for 2008-2012.
- Non-Treaty storage was emptied in 2004 as the old agreement expired and it was full again in 2011 before a new agreement was signed in 2012.
- Operating agreements with the US were regularly mutually agreed upon from 2006-2012 that resulted in increased fall/winter and summer reservoir levels.
- Canadian Columbia system operating changes.
ARROW LEVELS: PRE-WUP vs. WUP (extra)

WUP Period: Mean Level 2008-2012

Pre-WUP Period: Mean Level 2001-2007

Consultative Committee Evaluation Period: Mean Level 1984-1999
Arrow levels were generally adjusted using operational flexibility allowed under the Columbia River Treaty as follows:

- Supplemental Operating Agreements (Seasonal Storage & LCA) increased levels from January to July and in the fall.
- If Non-Treaty Storage was always full and Columbia system flexibility was eliminated, winter/spring levels would be lower and summer levels would close to full for ~2 months and fall levels would also be higher.
2010 ARROW OPERATIONS SUMMARY
EXPECTED FUTURE OPERATION TRENDS

Based on what we know now:

- Arrow Lakes Reservoir levels are generally expected to follow the same pattern in the future as the 2008-2012 period (subject to variability with inflows and weather).

- Winter reservoir levels are generally expected to reach a minimum of between 1400 and 1414 ft (426.7 and 431.0 m) in March to April.

- Summer reservoir levels are generally expected to peak in late June or early July between 1435 and 1444 ft (437.4 m and 440.1 m) before drafting through the rest of the summer.

- Supplemental operating agreements are expected to continue to mutually provide operational power and non-power benefits:
  - Agreements are used to maximize power generation, improve soft constraint target performance, and provide downstream benefits (Canadian fish and flood control).
  - Non-Treaty Storage Agreement.
  - Non-Power Uses and Libby Coordination agreements.